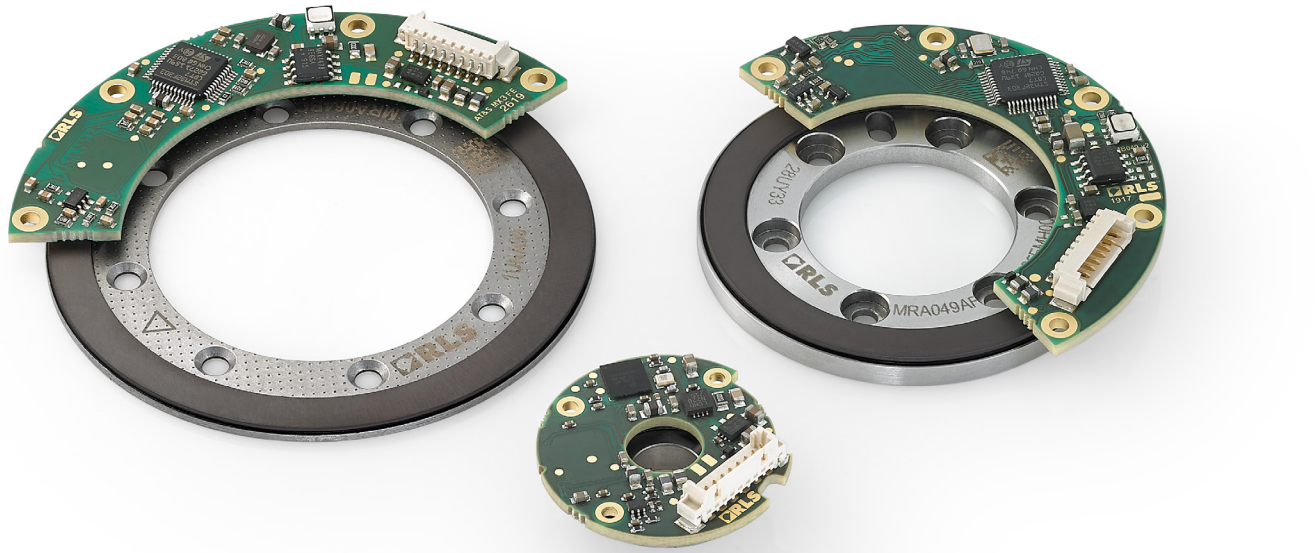
Data sheet
MBD01_05
Issue 5, 15th July 2020

AksIM-2 off-axis rotary absolute encoder



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.

The encoder operates in a temperature range from -40 °C to +105 °C and is highly resistant to shock and vibration.

The AksIM-2 encoder 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 are visualised with the on-board LED.

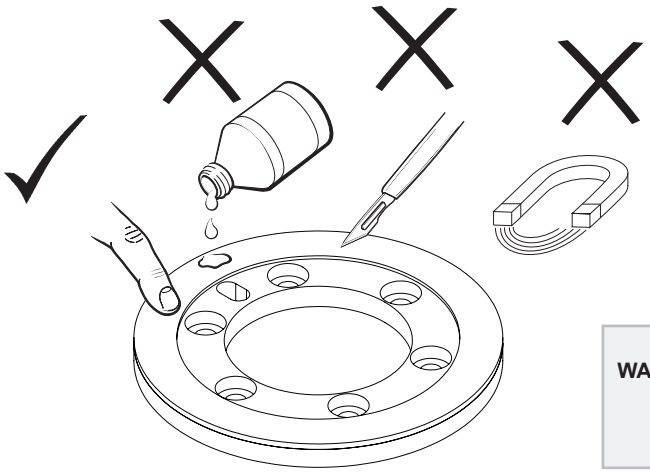
The AksIM-2 encoder system is suitable for use in industrial and medical applications.

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.

- **True absolute system**
- **Custom magnetic sensor ASIC**
- **Self-calibration option**
- **No hysteresis**
- **Resolutions up to 20 bits**
- **Multiturn counter option**
- **High speed operation**
- **9 kHz bandwidth, 44 kHz refresh rate**
- **Low profile, non-contact**
- **Built-in self-monitoring**
- **Integrated status LED**
- **BiSS, Asynchronous serial (UART), SPI, PWM or SSI**
- **High corrosion resistant magnetic ring**
- **Up to 600 bar pressure**

Storage and handling



WARNING: Magnetic rings should not be exposed to magnetic field densities higher than 50 mT on its surface.
Magnetic fields higher than 50 mT can damage the ring.

Chemical resistance

Chemical	Test performed with	Readhead	Ring with CPE rubber	Testing parameters
Hydraulic oil	Panolin Atlantis 15	-	✕	4 weeks at 60 °C (ISO175)
	ISO VG 46 (SAE MS1004)	✓	✕	4 weeks at 60 °C (ISO175) and 70 °C
	Castrol Hyspin AWS 32	-	✕ (✓ at 25°C)	65 °C ✕, 25 °C ✓
Insulating oil	Nytro 10 XN	-	✕	4 weeks at 60 °C (ISO175) and 70 °C
	MIDEL 7131	-	✕	70 °C
	Shell Diala S3 ZX-I	✓	✕	70 °C and 85 °C
Motor oil	SAE 15W-40	✓	✓	4 weeks at 25 °C (ISO175)
Cutting oil	Rezilol SCM BCL	✓	✓	4 weeks at 25 °C (ISO175)
Brake fluid	DOT-4	✓	✓	4 weeks at 25 °C (ISO175)
Coolant	Blasocut 2000 CF, 5%	-	✓	4 weeks at 25 °C (ISO175)
Antifreeze	Wolf VW G12 (100%)	✕	✓	70 °C and 85 °C
Lubricating grease	ISOFLEX TOPAS NB 52	✓	✓	4 weeks at 25 °C (ASTM D4289)
	HD Flexolub-A1 (pink)	✓	✕	Readheads 1 week at 80 °C (ASTM D4289), rings several weeks at 25 °C
	HD 4B No. 2 (yellow)	✓	✕	1 week at 80 °C (ASTM D4289)
	HD SK-2 (green)	✓	✕	1 week at 80 °C (ASTM D4289)
Sea water	Instant Ocean® sea salt, 3.5 %	✕**	✓	4 weeks at 25 °C (ISO175)
Ethanol	Technical, ≥ 95 %	-	✓	4 weeks at 25 °C (ISO175)
Isopropyl alcohol	Technical, ≥ 95 %	O*	(✓ short term cleaning)	12 hours at 25 °C
Acetone	Technical, ≥ 95 %	✕	✕	4 weeks at 25 °C (ISO175)

✓ Resistant
✕ Not resistant (elastoferrite swelling > 0.5 % / adhesive joint failure / readhead failure)
O Noticeable impact, but does not interfere with encoder operation
* Destroys conformal coating (if present). No impact on other components
** Open electronic circuit should not come in contact with conductive fluids
\- Not tested

Test samples were immersed in chemicals in accordance with ISO 175:2010(E) and ASTM D4289 – 13 (2014) standards. During testing, we closely monitored changes in CPE elastoferrite layer's mass and height as well as readhead's functionality. Metal hubs did not corrode.

AksIM-2 dimensions - encoder selection table

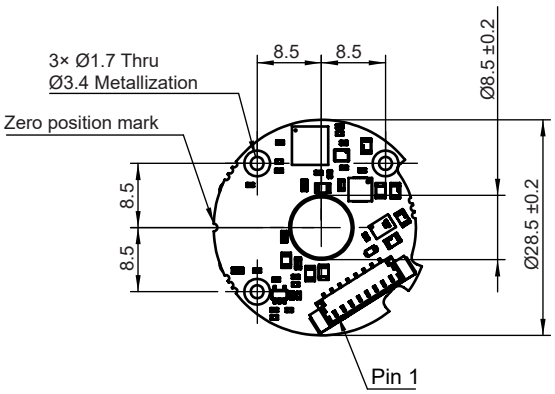
Dimensions in mm.

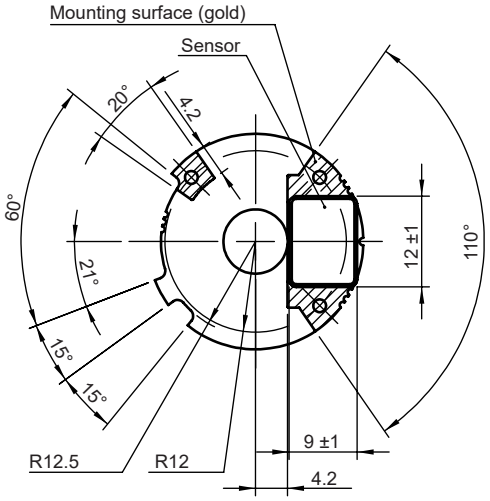
Part number	Ring					Readhead				Max resolution	System thickness (Typ.)	Mass (g)	Page
	Inner diameter	Circle for fasteners	Outer diameter	Thickness	Inertia (kg × mm²)	Inner diameter	Circle for fasteners	Outer diameter	Arc length				
MB022 readhead and MRA022 ring													
MB022-G						8.5	24	28.5	360°	17 bit		2.7	**4**
MRA022HP008DMN00	8	none	21.5	5.4	0.36						12.4	7.0	**5**
MB029 readhead and MRA029 rings													
MB029-F						14	35.4	38	360°	18 bit		4.5	**6**
MRA029BC010DSE00	10	15	29	2.0	0.75						7.8	5.9	**7**
MRA029GP013DMN00	12.7	none	29	7.0	1.0						12.8	9.0	
MB039 readhead and MRA039 ring													
MB039-E						23	49	54	196°	19 bit		4.8	**8**
MRA039BC020DSE00	20	25	39	2.0	2.3						7.8	9.2	**9**
MB049 readheads and MRA049 rings													
MB049-D						34	54	59	190°	19 bit		4.5	**10**
MB049-E						26	54	59	138°	19 bit		4.2	**11**
MRA049BC025DSE00	25	31	49	2.0	5.5						7.8	15	**12**
MRA049AF025EMH00	25	31	49	3.9	13						9.7	32	
MRA049BG034DSN00	34	none	49	2.0	4.8						7.8	11	
MB053 readhead and MRA053 rings													
MB053-E						36	66	74	130°	20 bit		5.3	**13**
MRA053BC030DSE00	30	36	53	2.0	7.4						7.8	16	**14**
MRA053BG040DSN00	40	none	53	2.0	5.9						7.8	11	
MB064 readhead and MRA064 ring													
MB064-D						48	69	74	140°	20 bit		6.9	**15**
MRA064BC040DSE00	40	46	64	2.0	15						7.8	20	**16**
MB080 readhead and MRA080 rings													
MB080-D						64.4	85	90	97°	20 bit		4.0	**17**
MRA080BC055DSE00	55	61.5	80	2.0	32						7.8	26	**18**
MRA080AF055EMH00	55	61.5	80	3.9	74						9.7	64	
MRA080DF068DMH00	68	88	95	4.9	114						10.7	72	

Dimensions and installation drawings

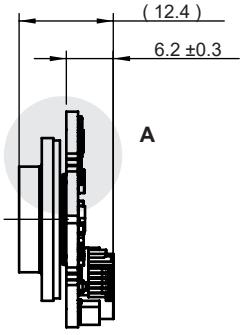
Dimensions and tolerances in mm.

MB022 readhead

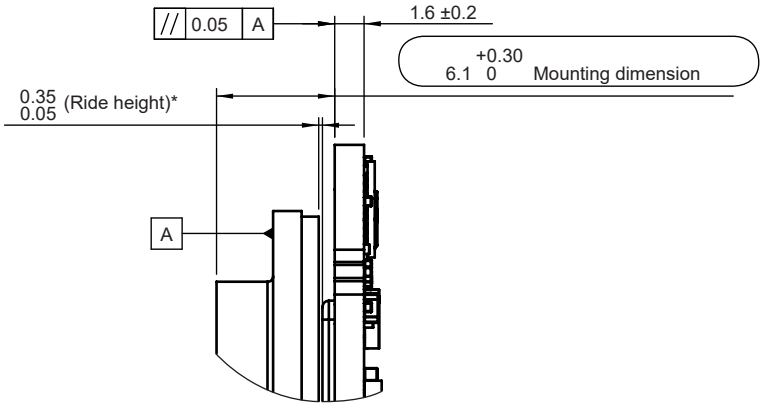




Encoder assembly



Detail A

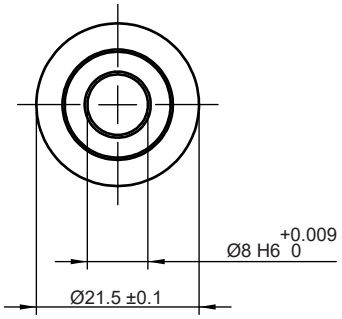


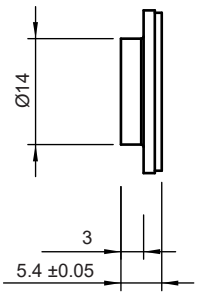
* Note: Ride height influences noise on the output. See page 20 for details.

Dimensions and installation drawings continued

Dimensions and tolerances in mm.

MRA022HP080DMN00 ring

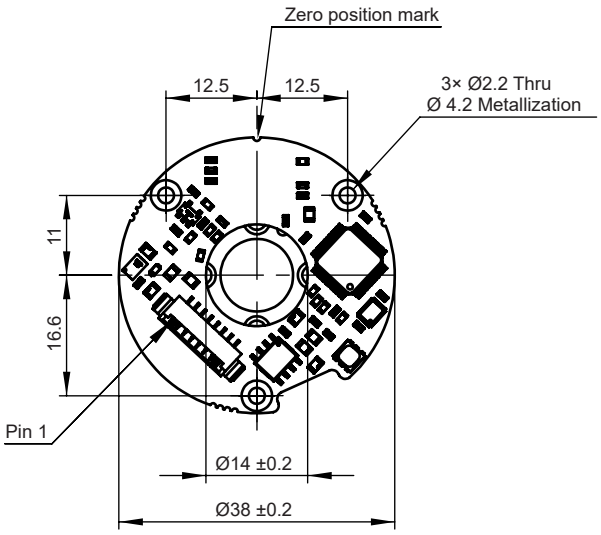


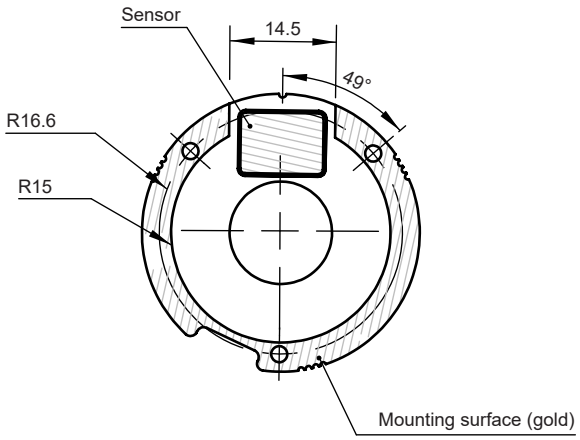


Dimensions and installation drawings continued

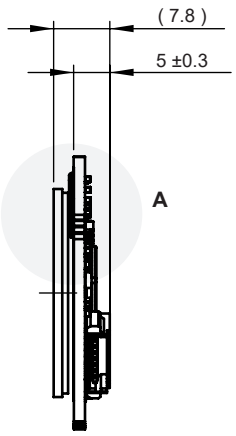
Dimensions and tolerances in mm.

MB029 readhead

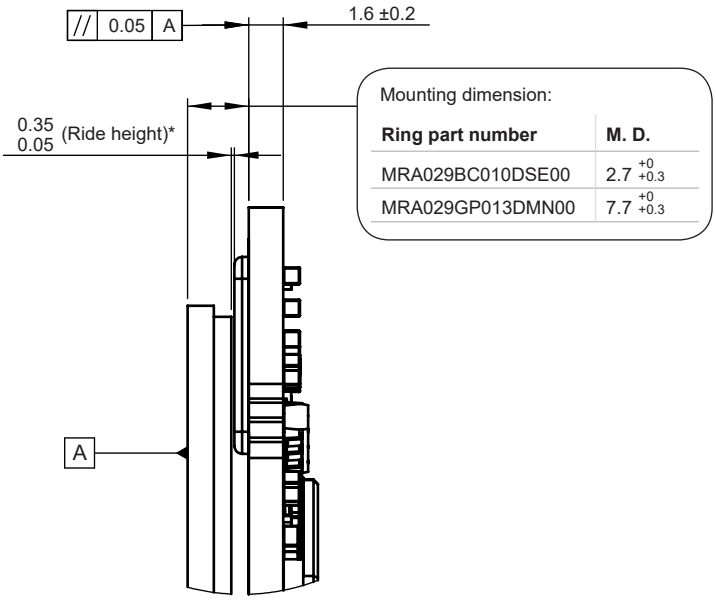




Encoder assembly



Detail A



Mounting dimension:

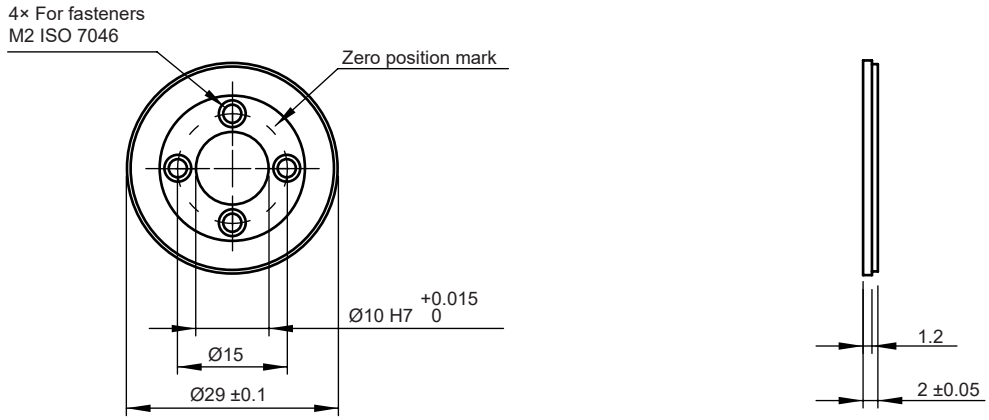
Ring part number	M. D.
MRA029BC010DSE00	$2.7^{+0}_{+0.3}$
MRA029GP013DMN00	$7.7^{+0}_{+0.3}$

* Note: Ride height influences noise on the output. See page 20 for details.

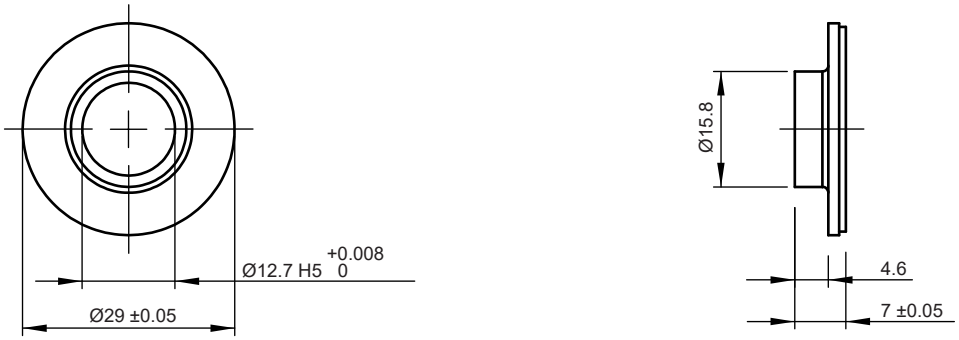
Dimensions and installation drawings continued

Dimensions and tolerances in mm.

MRA029BC010DSE00 ring



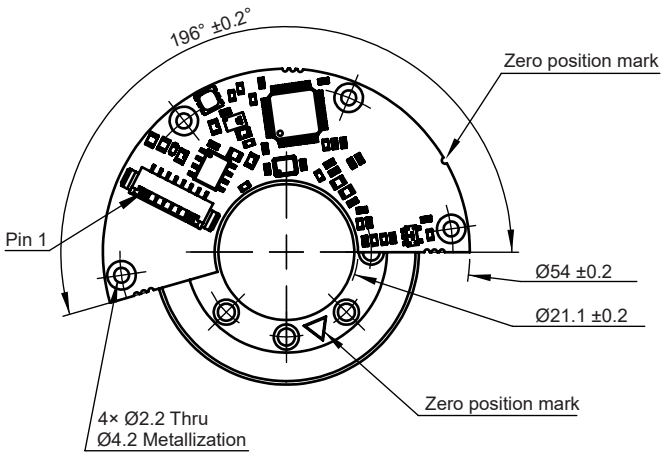
MRA029GP013DMN00 ring

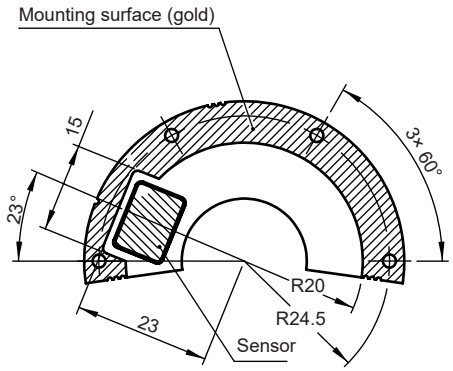


Dimensions and installation drawings continued

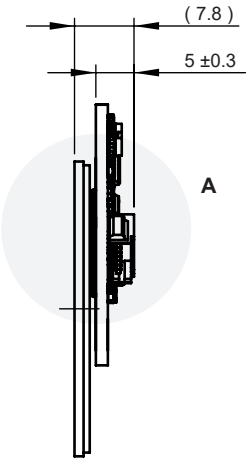
Dimensions and tolerances in mm.

MB039 readhead

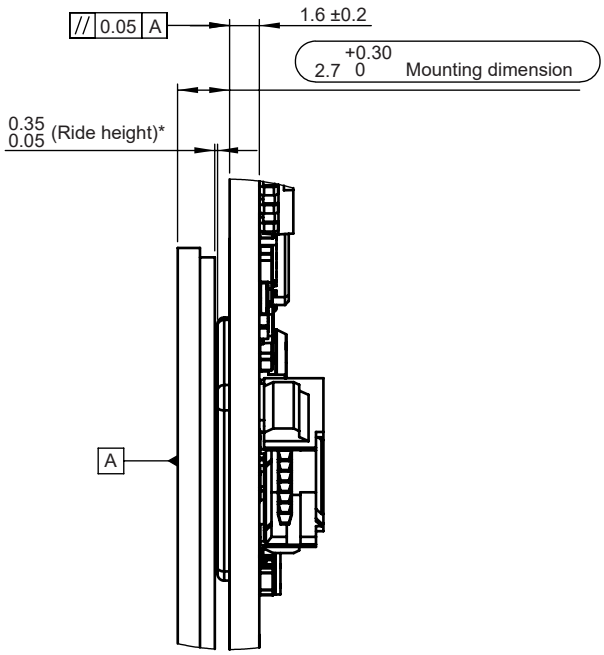




Encoder assembly



Detail A

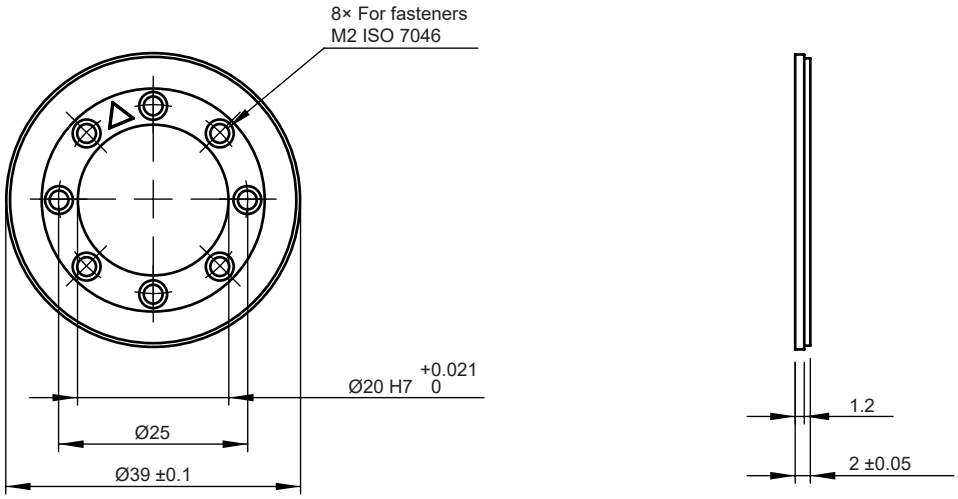


* Note: Ride height influences noise on the output. See page 20 for details.

Dimensions and installation drawings continued

Dimensions and tolerances in mm.

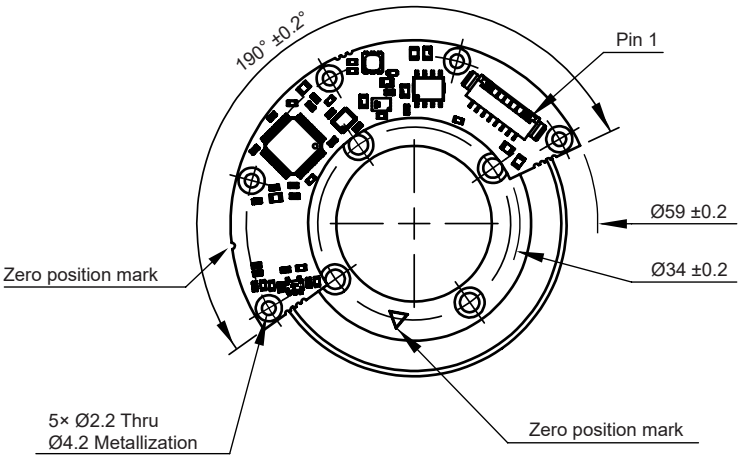
MRA039BC020DSE00 ring

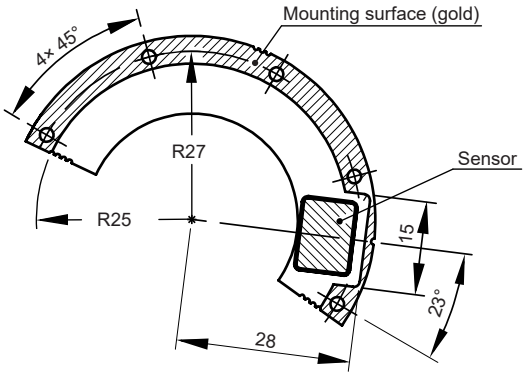


Dimensions and installation drawings continued

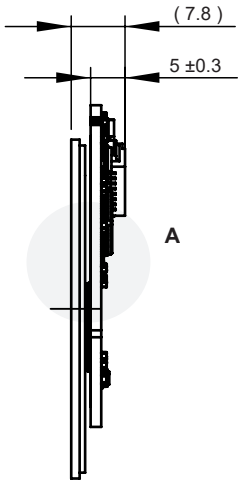
Dimensions and tolerances in mm.

MB049 readhead size D

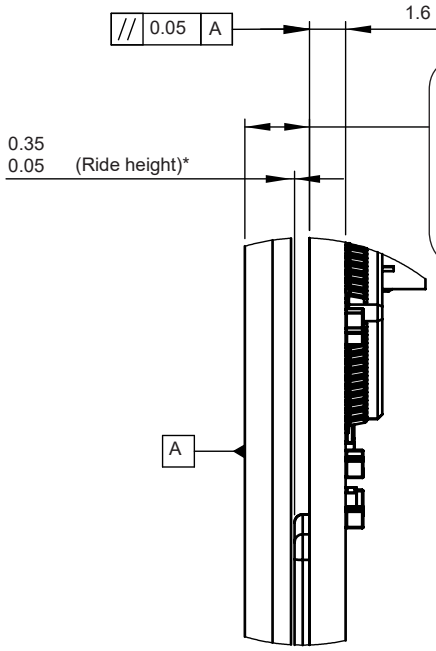




Encoder assembly



Detail A



Mounting dimension:

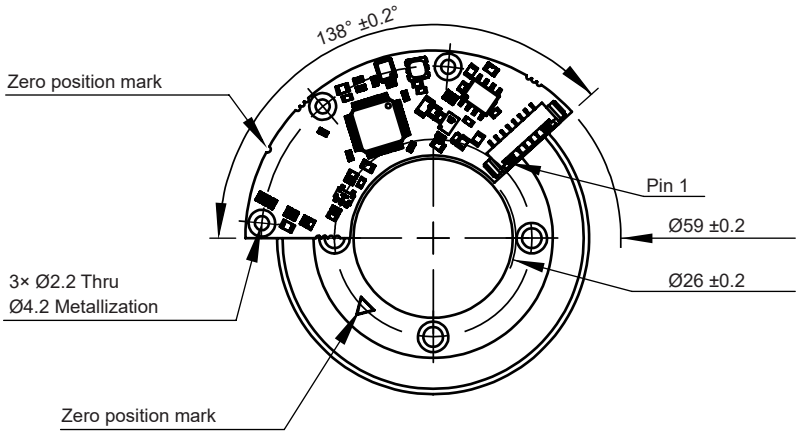
Ring part number	M. D.
MRA049BC025DSE00	$2.7^{+0}_{+0.3}$
MRA049AF025EMH00	$4.6^{+0}_{+0.3}$
MRA049BG034DSN00	$2.7^{+0}_{+0.3}$

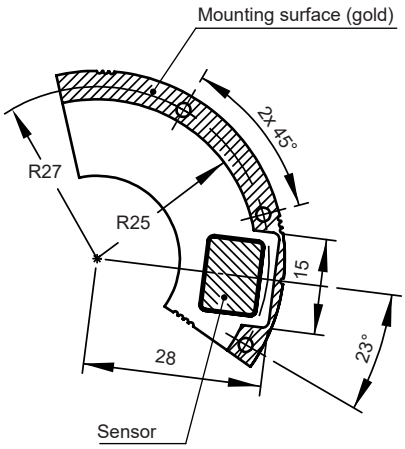
* Note: Ride height influences noise on the output. See page 20 for details.

Dimensions and installation drawings continued

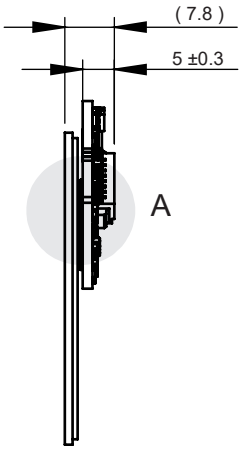
Dimensions and tolerances in mm.

MB049 readhead size E

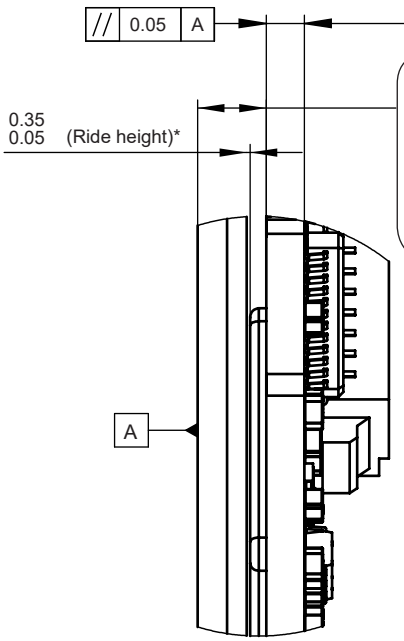




Encoder assembly



Detail A



Mounting dimension:

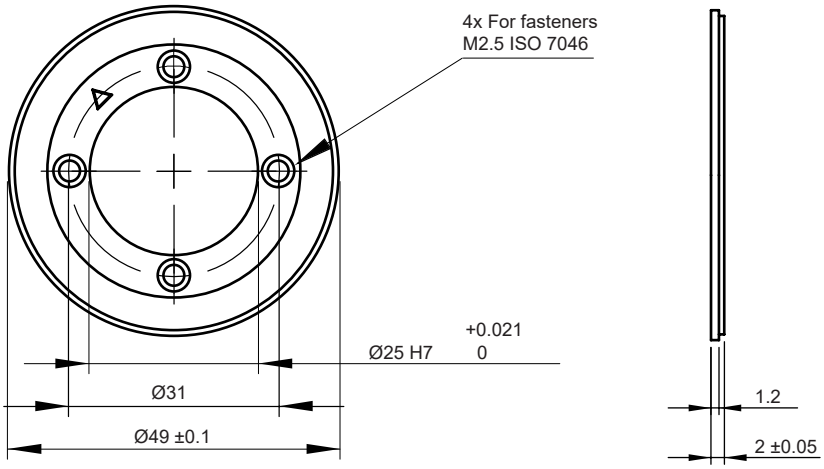
Ring part number	M. D.
MRA049BC025DSE00	$2.7^{+0}_{+0.3}$
MRA049AF025EMH00	$4.6^{+0}_{+0.3}$
MRA049BG034DSN00	$2.7^{+0}_{+0.3}$

* Note: Ride height influences noise on the output. See page 20 for details.

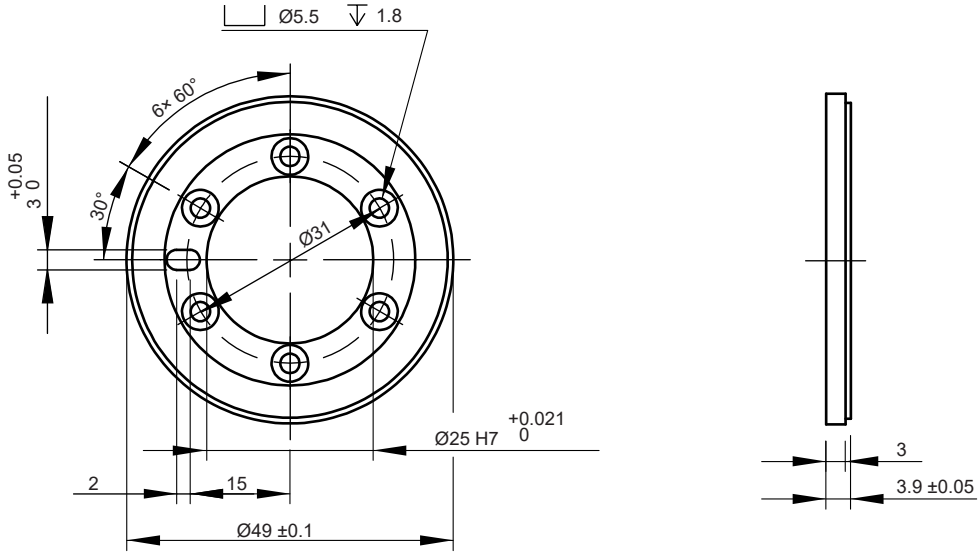
Dimensions and installation drawings continued

Dimensions and tolerances in mm.

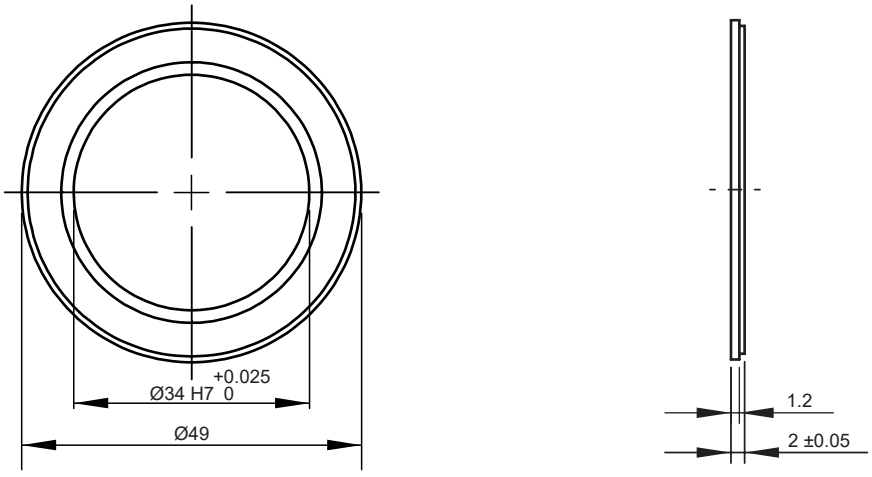
MRA049BC025DSE00 ring



MRA049AF025EMH00 ring



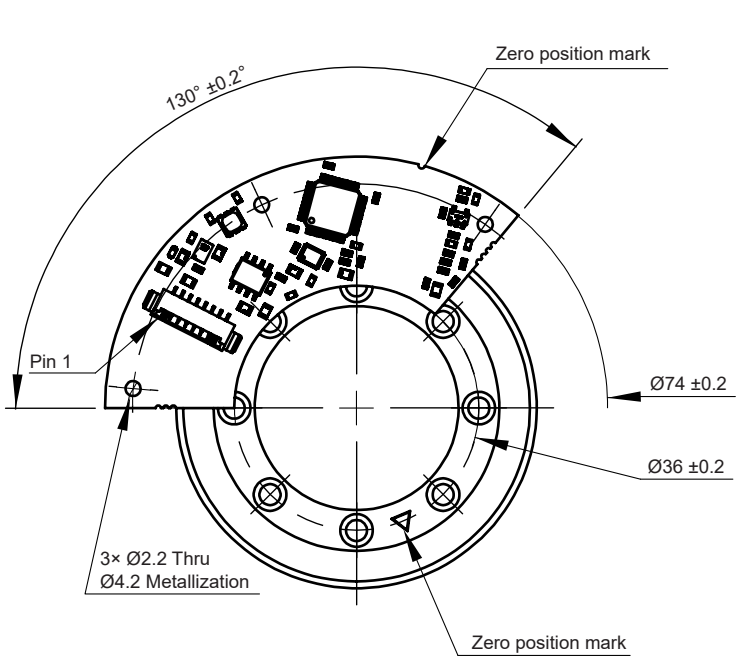
MRA049BG034DSN00 ring

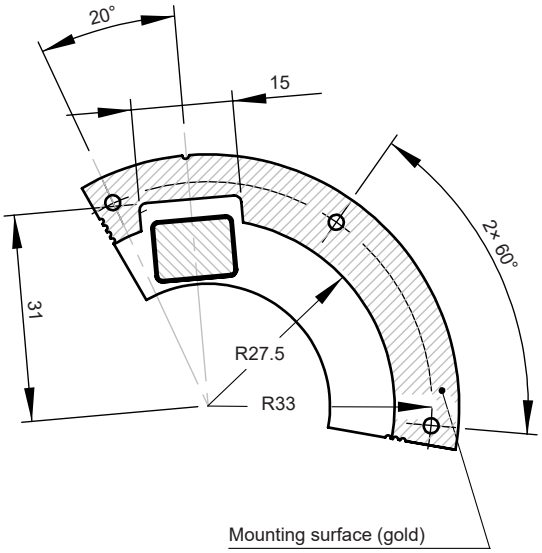


Dimensions and installation drawings continued

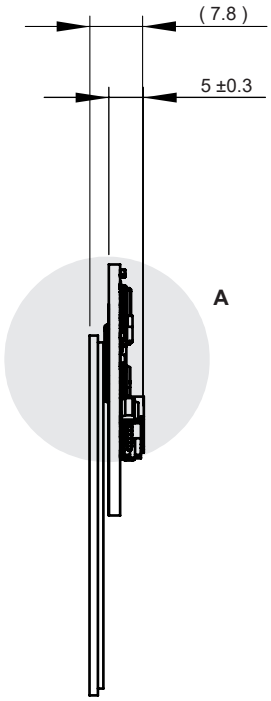
Dimensions and tolerances in mm.

MB053 readhead size E

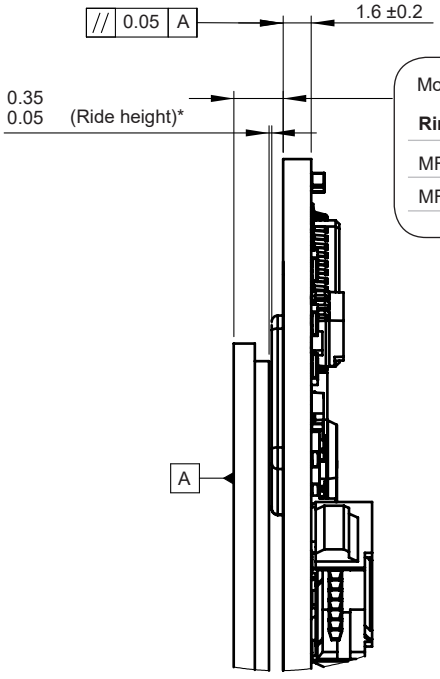




Encoder assembly



Detail A



Mounting dimension:

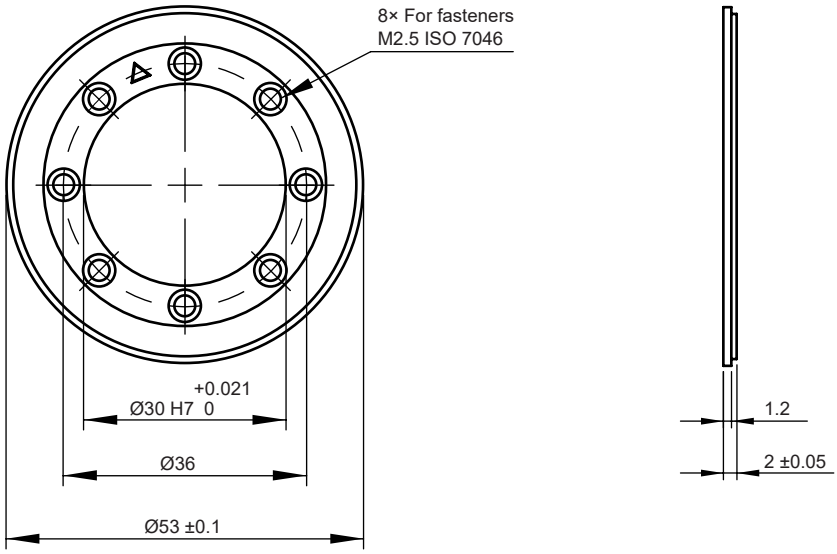
Ring part number	M. D.
MRA053BC030DSE00	$2.7^{+0}_{+0.3}$
MRA053BG040DSN00	$2.7^{+0}_{+0.3}$

* Note: Ride height influences noise on the output. See page 20 for details.

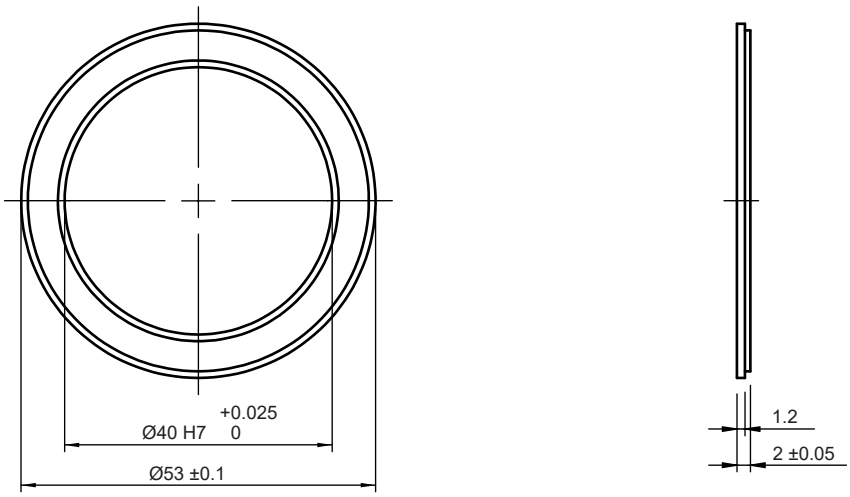
Dimensions and installation drawings continued

Dimensions and tolerances in mm.

MRA053BC030DSE00 ring



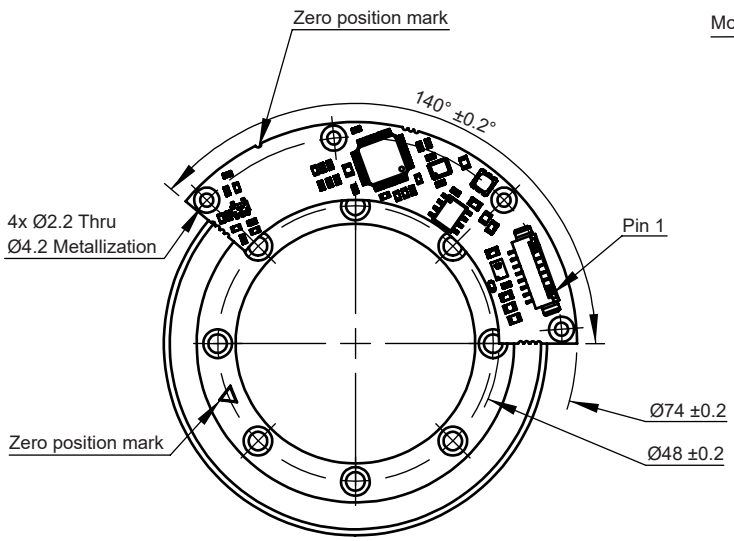
MRA053BG040DSN00 ring

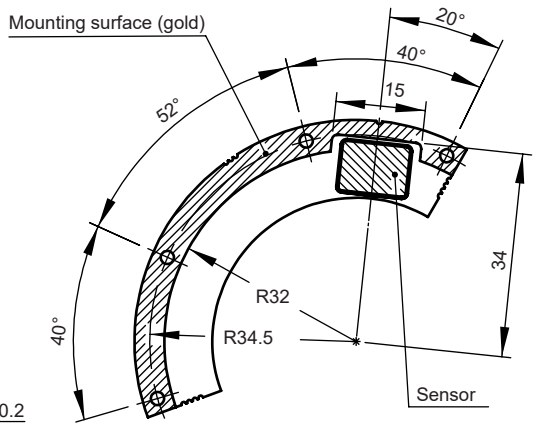


Dimensions and installation drawings continued

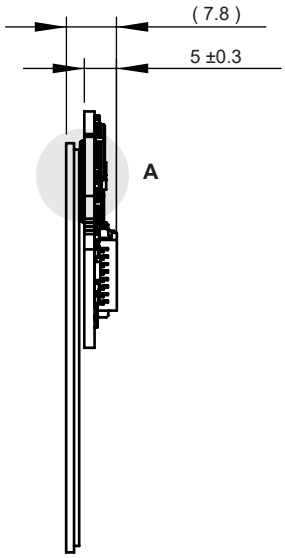
Dimensions and tolerances in mm.

MB064 readhead size D

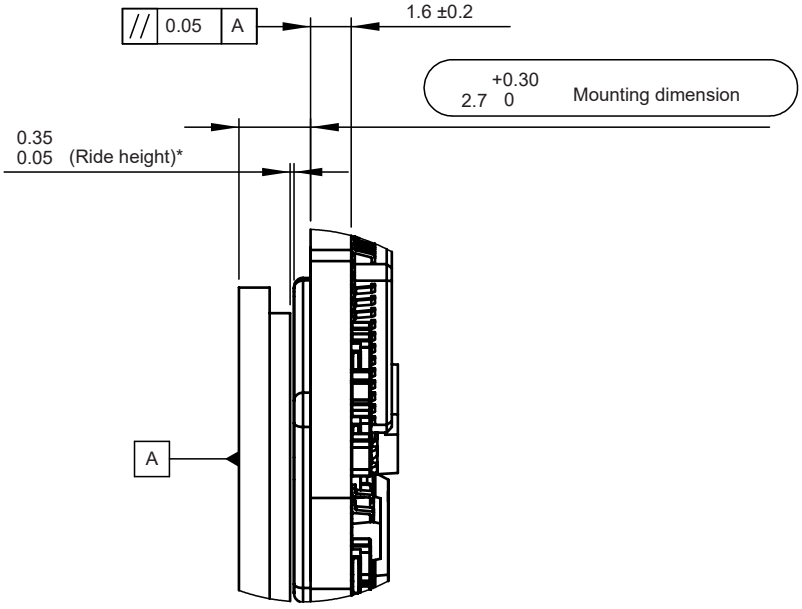




Encoder assembly



Detail A

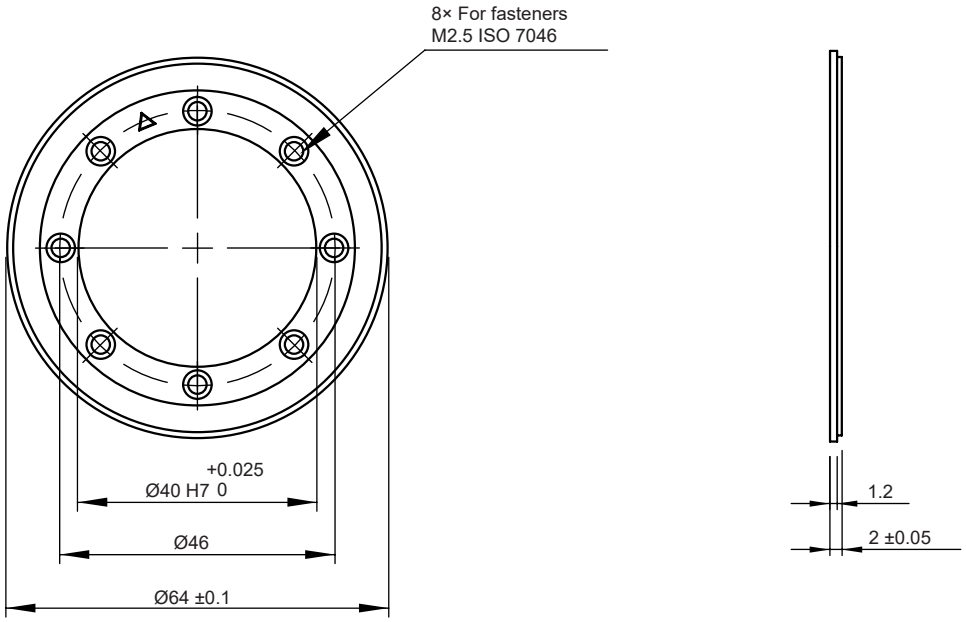


* Note: Ride height influences noise on the output. See page 20 for details.

Dimensions and installation drawings continued

Dimensions and tolerances in mm.

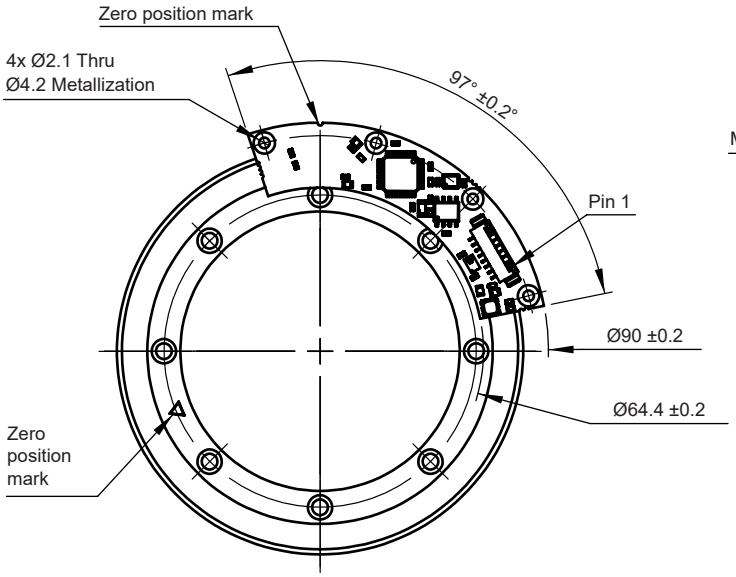
MRA064BC040DSE00 ring

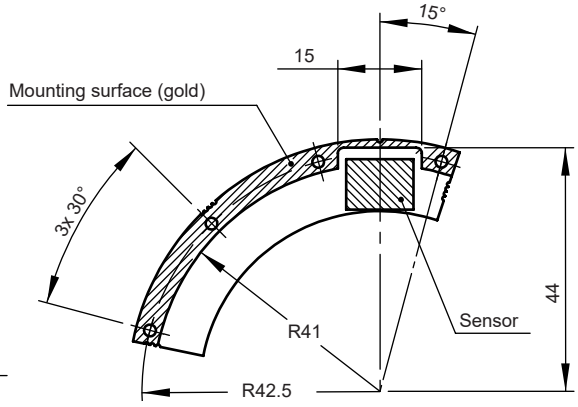


Dimensions and installation drawings continued

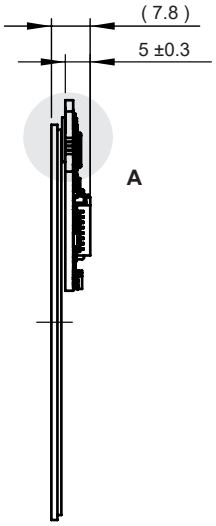
Dimensions and tolerances in mm.

MB080 readhead

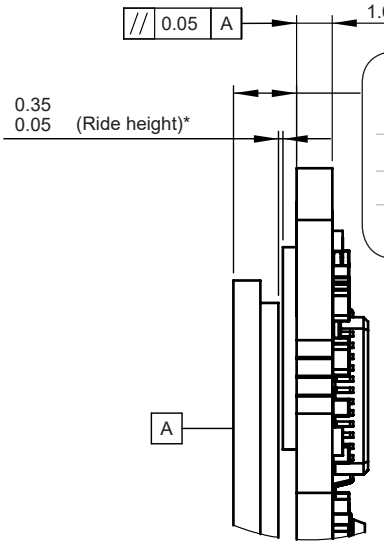




Encoder assembly



Detail A



Mounting dimension:

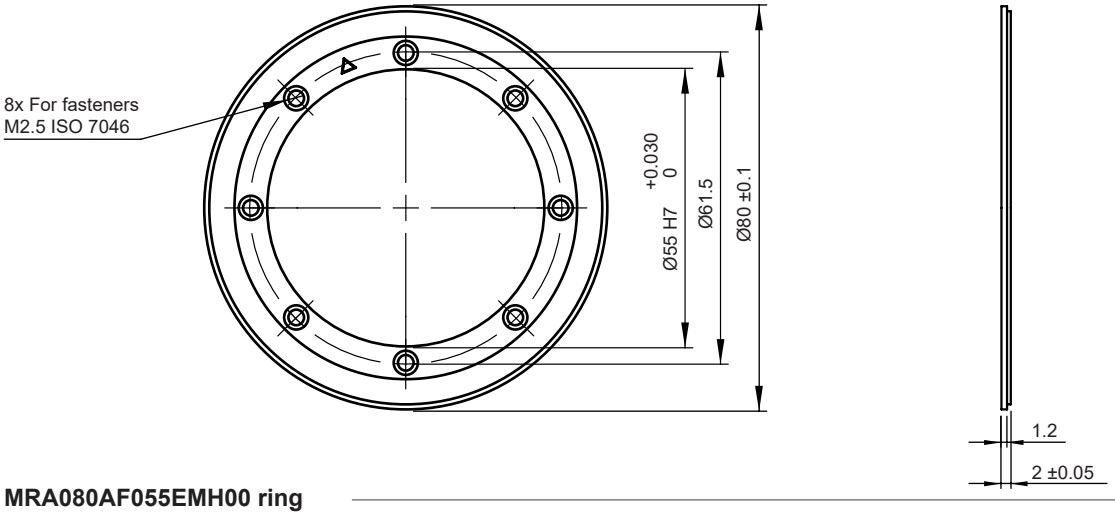
Ring part number	M. D.
MRA080BC055DSE00	$2.7^{+0}_{+0.3}$
MRA080AF055EMH00	$4.6^{+0}_{+0.3}$
MRA080DF068DMH00	$5.6^{+0}_{+0.3}$

* Note: Ride height influences noise on the output. See page 20 for details.

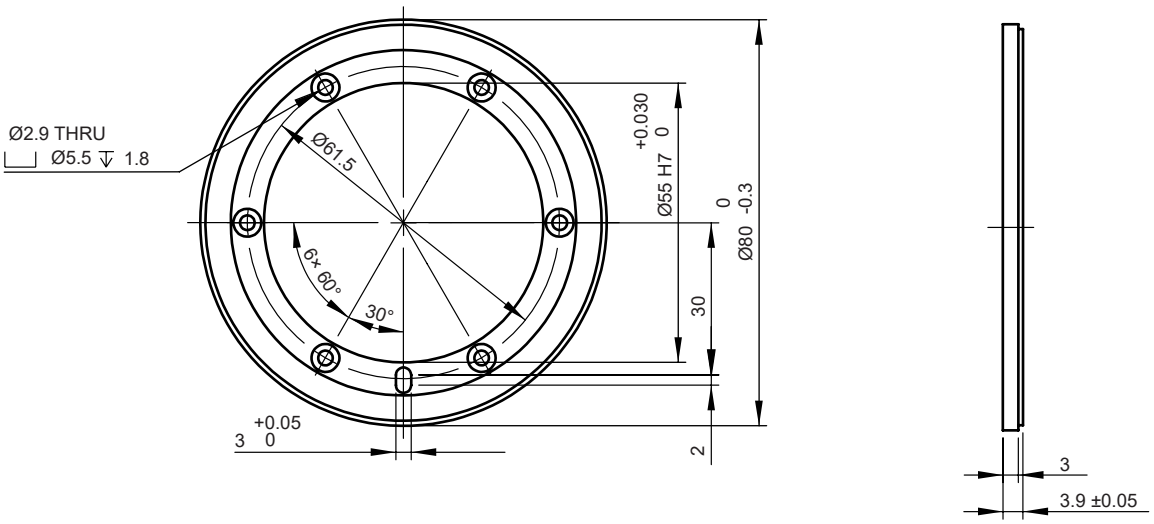
Dimensions and installation drawings continued

Dimensions and tolerances in mm.

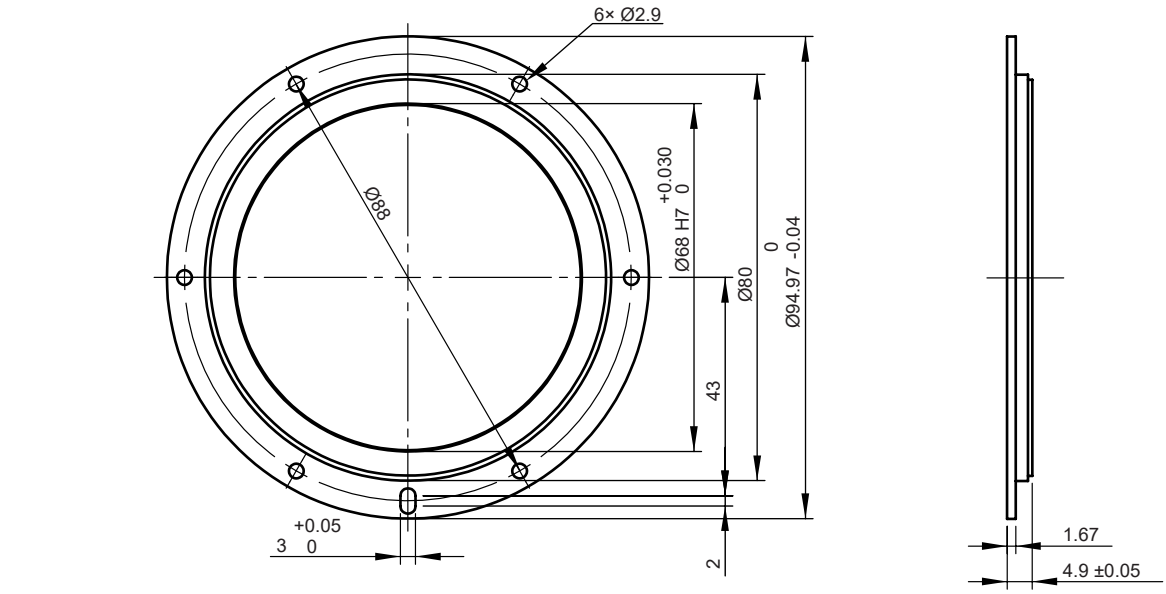
MRA080BC055DSE00 ring



MRA080AF055EMH00 ring



MRA080DF068DMH00 ring



Technical specifications

System data		
Reading type	Axial reading	
Resolution	From 17 bit to 20 bit and 16 bit multiturn counter option (see chapter Available resolutions on page 26)	
Maximum speed	10,000 RPM (for higher speeds contact RLS)	
Encoder accuracy	±0.05° / 180 arcsec (before installation - errors caused by mounting inaccuracy of the readhead, ring and drive shaft are not included)	
Final system accuracy	Typ. ±0.025° / 90 arcsec (after encoder self-calibration - see chapter Installation instructions on page 20). For accuracy up to ±0.005° / 18 arcsec 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 (outer diameter)	22 mm, 29 mm, 39 mm, 49 mm, 53 mm, 64 mm, 80 mm	
Material type	2 mm thick rings	EN 1.4016 / AISI430 with glued CPE rubber filled with ferrite particles
	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 table on page 3	
Environmental data		
Operating and storage temperature	-40 °C to +105 °C (standard) -30 °C to +85 °C (obsolete, available only on request)	
Humidity	Up to 70 % non-condensing (for higher contact RLS)	
External magnetic field	±20 mT	
Pressure	Up to 600 bar with special option - See chapter Operation in high-pressure applications on page 24	
Shock	100 G (6 ms, half-sine, EN 60068-2-27:2009)	
Vibration	80 G (55 Hz - 2000 Hz, EN 60068-2-6:2008)	

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. If communication is running at a rate of at least 5 readings per second, LED will be lit steadily.

LED	Status
Green	Normal operation; position data is valid.
Orange	Warning; position is valid, but the resolution and/or accuracy might be out of specification. Some operating conditions are outside limits.
Red	Error; position data is not valid.
Slow flashing	Communication has not been established.
	Position was not requested within last 200 ms. Color of flashing - see above.
No light	No power supply.
Continuously fast flashing red	System error during start-up or operation.
3 sec. fast flashing	Self-calibration result - see table on page 22.

Installation instructions

Axial position adjustment (ride height)
The nominal distance between the sensor and the ring is between 0.05 mm and 0.35 mm.
We recommend you to use the gold-plated surface on the underside as a reference point for mounting the readhead. If you use the top of the readhead as your reference point, you must carefully adjust the ride height according to the readhead thickness.
The integrated LED can be used as an indicator. When the correct ride height is reached, the LED lights green and does not change color when the ring rotates.

The center point of the ring and the center point of the readhead arc must be coaxial. The permissible tolerances are shown in the table below.

Installation tolerances (readhead to ring)

Axial displacement (ride height)	0.05 mm to 0.35 mm Smaller ride height is desired. Increasing the ride height exponentially increases encoder noise.
Mounting dimension (nominal distance between readhead and ring mounting surfaces)	See installation drawings on pages 4 to 18.
Tangential displacement	±0.3 mm
Radial displacement	MRA022: ±0.1 mm MRA029: ±0.3 mm MRA039: ±0.4 mm MRA049, MRA053, MRA064, MRA080: ±0.5 mm
Non-parallel mounting	Tilt angle < 0.2°

Visual process of the encoder installation can be seen in the AksIM-2 installation video.

Measuring ride height between ring and readhead

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

Value is proportional to the distance between the sensor and ring. To calculate real distance use the following formula:
Ride height = K × (N - Ln (Sqrt (SignalLevel)))

K and N are chosen depending on the encoder size.

Encoder size	K	N
022, 029	188.42	8.37
039, 049	167.24	8.647
053, 064, 080	142.08	9.023

SignalLevel value is available in BiSS register at addresses 0x4E - 0x4F (see document MBD02) and on UART interface with command 'a' (see page 30).

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	±0.03°	±0.03°	±0.025°	±0.025°	±0.02°	±0.02°

WARNING!

ESD protection
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.

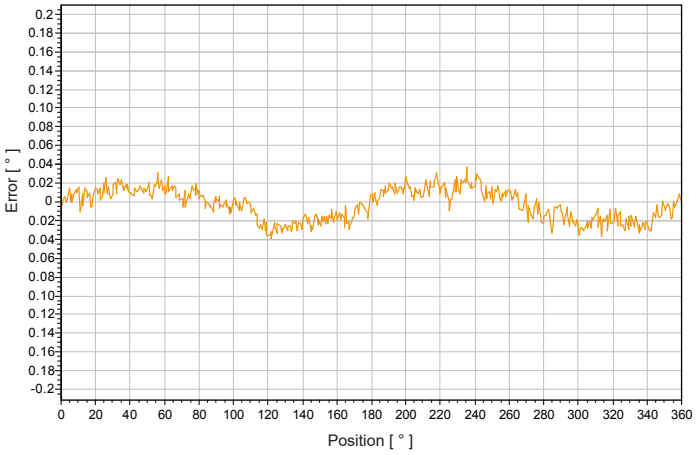
Accuracy of the encoder system

Precise centering of the ring is the key to good overall accuracy.

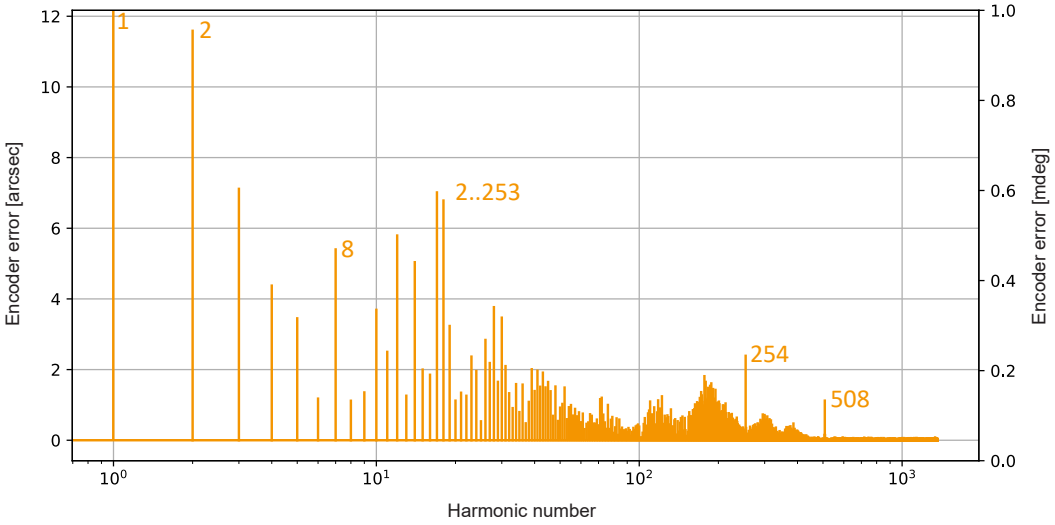
By minimising the eccentricity of the ring assembly (using a gauge) and using a drive shaft with precision bearings, the error can typically be reduced to ±0.05° for MRA080 rings and ±0.06° for MRA049 rings.

A typical accuracy diagram after good installation of MRA080 (without eccentricity) is shown in the diagram on the right.

To improve accuracy after installation, we recommend you 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)

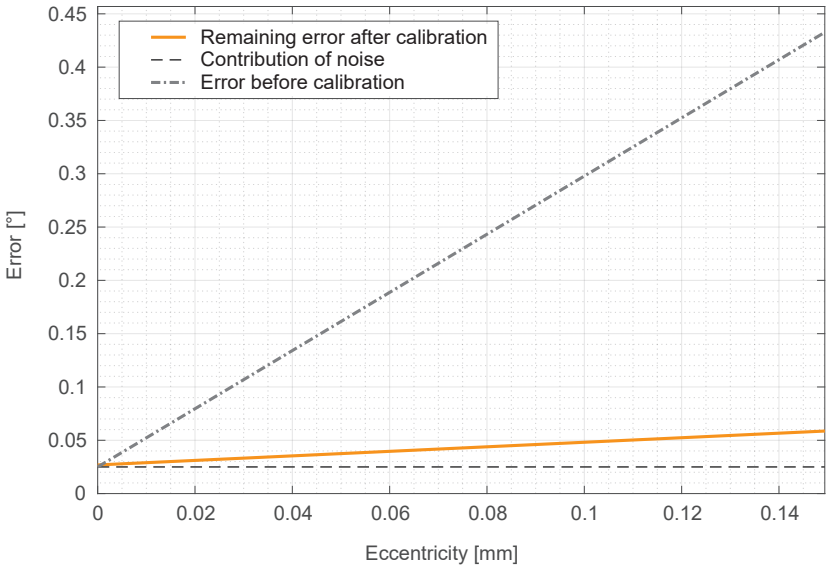
Self-calibration after installation

The self-calibration function eliminates the error cause by eccentricity, which is a dominant part of the encoder accuracy and is caused by the eccentric mounting of the ring. It cannot compensate for the magnetization 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 corresponding USB encoder interface. Not available with PWM and SSI outputs. For details, refer to the description of the selected communication interface. 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. The minimum speed is 6 RPM.
- Suitable communication interface or adapter that enables the function to be triggered.

The graph below shows by how much the encoder accuracy can be improved with the self-calibration function.
The remaining minimum accuracy of ±0.02° is influenced by magnetization variations and noise of the readhead.



After completing the self-calibration procedure, fast-flashing LED reports if procedure was successful.

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

Video on self-calibration function is available here: Explainer video: AksIM-2 self-calibration feature.

Note: Encoder size 022 currently does not support self-calibration.

External magnetic field

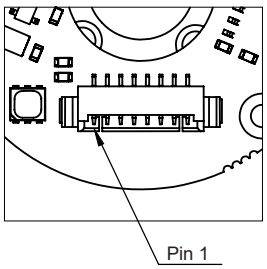
The operating principle of any magnetic encoder is to detect changes in the magnetic field of the magnetised ring. External magnetic fields generated by permanent magnets, electric motors, coils, magnetic brakes, etc. can affect the operation of the encoder. If the homogeneous magnetic field perpendicular to the readhead is between 0 mT and 20 mT, it may affect accuracy. If it is greater than 20 mT, it temporarily causes the encoder to malfunction. Fields stronger than 50 mT can 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 be mounted with the readhead facing away from the source of the escaping magnetic field. Contact RLS for more information.

Electrical connections

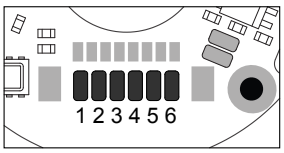
Connector	Soldering pads	BiSS-C	Asynchronous serial	SPI	PWM	SSI
1	1	5 V supply				
2	2	0 V (GND)				
3		Temperature sensor pin 1				
4		Temperature sensor pin 2				
5	3	MA+	RX Command in+	SCK	Status out	Clock+
6	4	MA–	RX Command in–	NCS	-	Clock–
7	5	SLO+	TX Data out+	MISO	PWM out	Data+
8	6	SLO–	TX Data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

Pinout



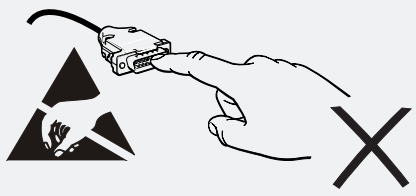
8-pin low profile connector
FCI 10114830-11108LF

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



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

The soldering of the wires to the encoder must be done according to IPC-A-610 class 2 or 3 (or similar).
If incorrect soldering is observed, the warranty will be void.



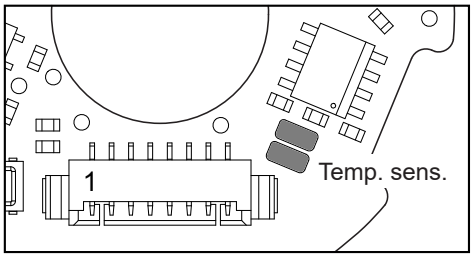
WARNING!

ESD protection
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.

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.



NOTE: Pt1000 sensor can be soldered to the encoder in factory. Contact RLS for availability of this option.

Operation in high-pressure applications

The encoder can be configured for operation at an ambient pressure of up to 600 bar. Typical applications include ROV submarines, where the entire system is immersed in oil. A special version of the encoder must be used with the "P" option. All frequencies must be reduced and the timings must be increased by 12 %. The selected oil bath must be checked for compatibility with the Chemical resistance table on page 2. Silicone-based oil is recommended.

List of available part numbers:
MB029DCC18MFNP00
MB049DCC19MDNP00
MB080DCC17BDNP00
MB080DCC20MDNP00

For more information Contact RLS.

Communication interfaces

BiSS		
	Clock frequency	From 400 kHz to 5 MHz
	Maximum request rate	44 kHz (38 kHz multiturn counter option)
	Mechanical sample rate	18 kHz
	Bandwidth	9 kHz
	Resolution	See table on page 26
	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, 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 table on page 26
	Latency	<10 µs
SPI		
	Clock frequency	Max 4 MHz
	Maximum request rate	54 kHz (48 kHz multiturn counter option)
	Mechanical sample rate	18 kHz
	Bandwidth	9 kHz
	Resolution	See table on page 26
	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	55 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 table on page 26
	Latency	55 µs to 110 µs
	Timeout (monoflop time)	20 µs

* Note: 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.

Available 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 get fine position. Noise margin increases exponentially with increasing ride height between the ring and readhead.

Multiturn counter

Multiturn counter is available on the following communication interfaces: BiSS, Asynchronous serial (UART), SPI or SSI.
Multiturn option is selected with the resolution in part number on page 39. 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 rotation is bigger, encoder will report an error to indicate an invalid multiturn counter value. To reset this state, it is necessary to apply a new multiturn counter value over the communication interface or cycle power to the encoder. If encoder is rotated for ±360° or multiple rotations, this movement is not registered and also multiturn error is not set. If any other error is set during a rotation of 90° or more, the multiturn counter value may become inconsistent with 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 powering-up the encoder
- 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 writting new value into the encoder or by power cycle. On SSI interface only power cycle is available.

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

BiSS and UART use an algorithm that recalculates the new position for each request. This way the request frequency can be higher than the internal cycle frequency of the encoder. Usually 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 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. There is no additional recalculation.
The internal cycle of the encoder is 55 µs. This is the delay between the time when the mechanical position is latched by the sensor and the time when 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.

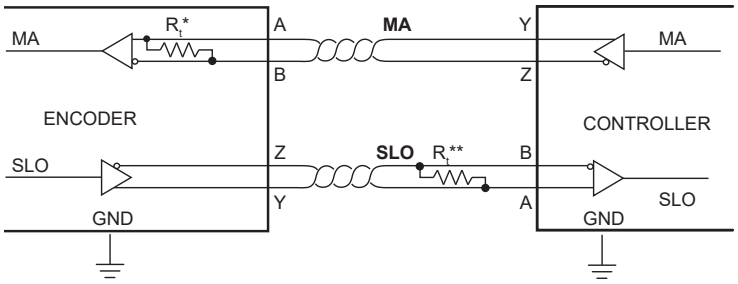
For example:
At t = 0 µs the physical position is latched but position data is not yet calculated. It will be available at 55 µs.
If the request comes at t = 1 µs – 54 µs, the last available data will be sent - the one from previous cycle when position was latched at t = –55 µs.

BiSS-C interface

The encoder position in up to 20 bit natural binary code and the encoder status are available via the BiSS-C protocol. The position data is left aligned. After the position data there are 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 custom parameters can be stored into the readhead and additional data can be read from the readhead.

Electrical connection



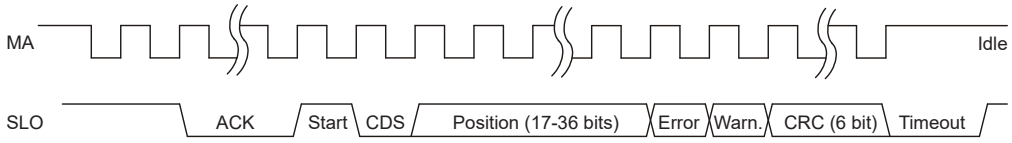
Signals	
MA	Master clock. Max clock frequency is 5 MHz.
SLO	Slave out. Data is output on rising edge on MA.

* 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



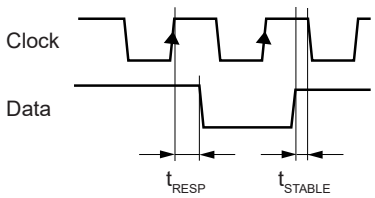
MA is idle high. Communication is initiated with first falling edge.
The encoder responds by setting SLO low on the second rising edge on MA. ACK length is 13 bits.
When the encoder is ready for the next request cycle, it indicates this to the master by setting SLO high.
The absolute position and the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

Cable length compensation

The readhead 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. The total cable length from the encoder to the receiver must be considered.

$t_{DELAY} = t_{RESP} + t_{PROP} \times$ 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	Possible reason for failure
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.

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	Status		CRC (inverted)
			Error	Warning	
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 AksIM-2 website.

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

Encoder programming

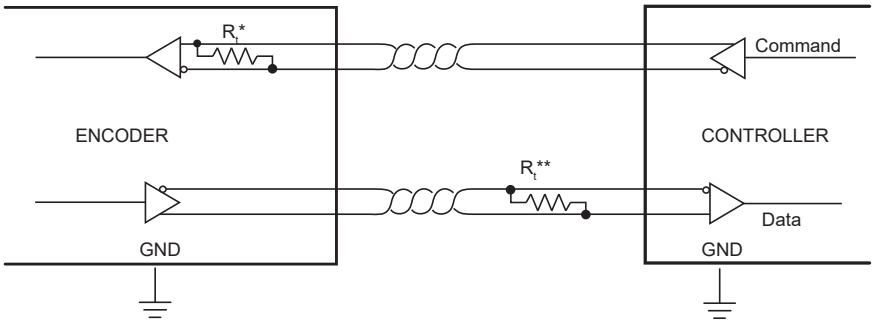
Encoder supports register access which allows setting zero position, running self-calibration function, configuring the encoder, reading signal level indicator, temperature, detailed status bits and electronic datasheet. It also allows storing up to 4 kB of user data into the encoder (eg. motor parameters, 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 AksIM-2 website.

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
Link speed (baud rate)	115.2 kbps	128 kbps	230.4 kbps	256 kbps	500 kbps	1 Mbps

Link speed setting can be changed in the field by following the procedure described in application note. See section Encoder programming on page 32.

NOTE: It is not possible 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 is to 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) (Changed in FW version 2.5)

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 is 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

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 10 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 20.
Command 'i'	
Byte transmitted	**Contents**
B1	ASCII header 'i'
B2	Self calibration status - see document MBD03
B3 - B4	Ring eccentricity (µm)
B5 - B6	2 bytes: eccentricity phase (deg)
B7 - B8	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 revision
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.

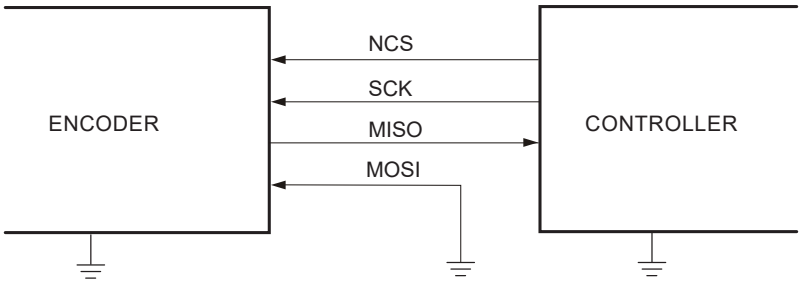
SPI - Serial peripheral interface

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.

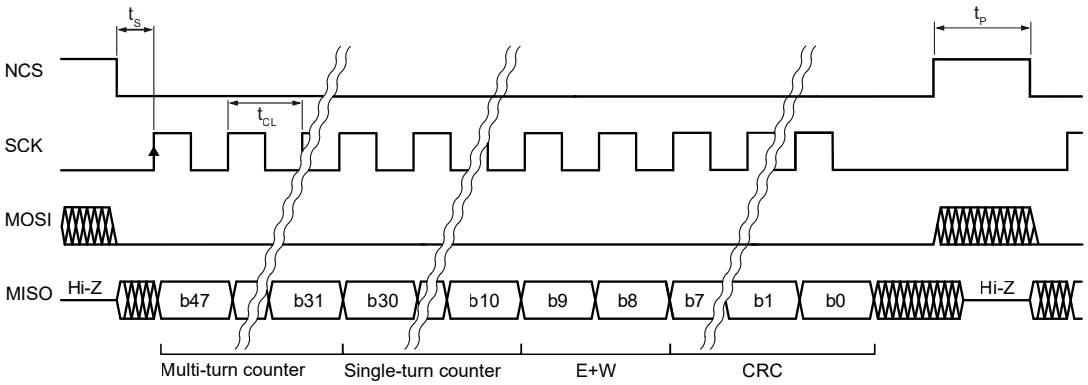
Electrical connection

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 Ohm 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.
SCK	Serial clock. Shifts out the data on rising 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. 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 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 from www.rls.si/aksim-2.

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 www.rls.si/aksim-2

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:

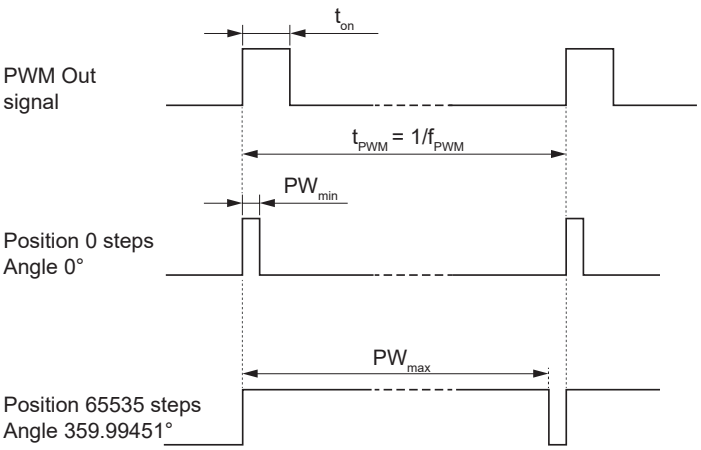
- Operation outside the installation tolerances
- Invalid or damaged magnetization of the ring
- Sensor malfunction
- System error
- No power supply

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 PW_{min} 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}).

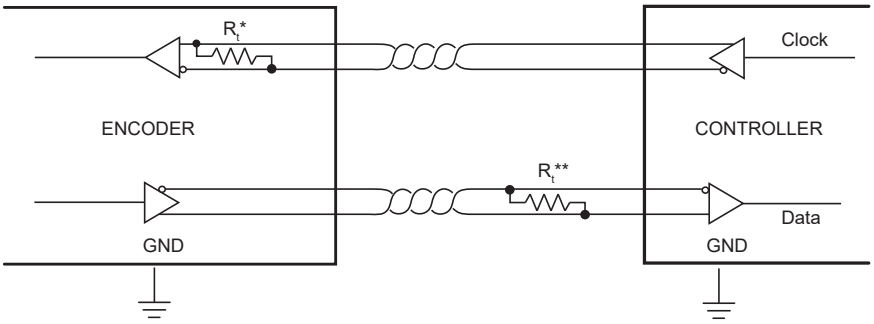
$$\textit{Position}\ [\text{counts}] = \frac{t_{on} \times 65536}{t_{PWM}} - 1 \qquad \textit{Position}\ [°] = \frac{(t_{on} - PW_{min}) \times 360°}{t_{PWM}}$$

SSI - Synchronous serial interface

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

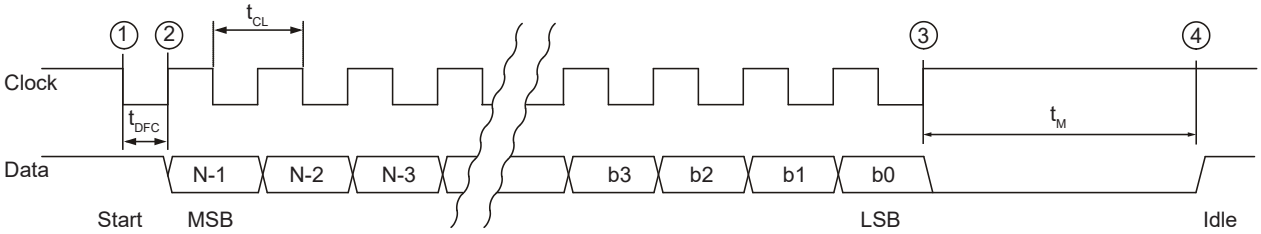


* The Clock and Data signals are 5 V RS422 compatible differential pairs with RC termination inside the readhead.
** Termination at the controller is required if total cable length is longer than 5 m. The nominal impedance of the cable is 120 Ω.

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



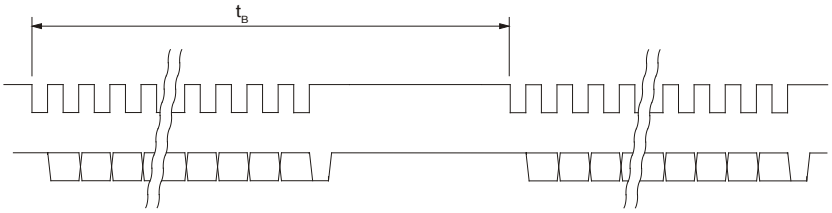
NOTE: See table "Structure of data packet" on the page 27.

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 t_M before the next reading can take place.

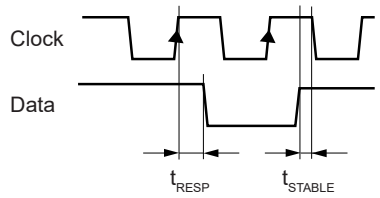
While reading the data the period t_{CL} must always be less than t_M. However, reading the encoder position can be terminated at any time by setting the Clock signal to high for the duration of t_M.

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.

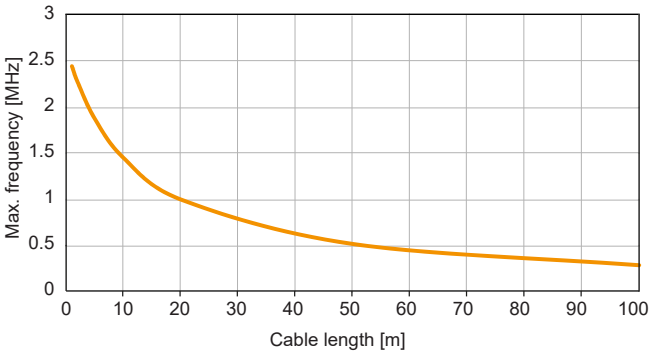
Maximum frequency



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.

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

	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 - 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.

Readhead part numbering

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 *

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 (standard)
For **SP:** **L -** SPI
For **SF**: Link speed in kbps:

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

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

A	B	C	D	E
122	275	366	549	1099

Resolution
16B - 16 bits per revolution (for PW output only)
17B - 17 bits per revolution
18B - 18 bits per revolution (for sizes 029 and up)
19B - 19 bits per revolution (for sizes 039 and up)
20B - 20 bits per revolution (for sizes 053 and up)

Multiturn counter options
17M - 17 bits per revolution + 16 bits multiturn counter
18M - 18 bits per revolution + 16 bits multiturn counter (for sizes 029 and up)
19M - 19 bits per revolution + 16 bits multiturn counter (for sizes 039 and up)
20M - 20 bits per revolution + 16 bits multiturn counter (for sizes 053 and up)

Shape and connector orientation
D - Partial arc, radial connector exit (only for sizes 049, 064, 080)
E - Partial arc, tangential connector exit (only for sizes 039, 049, 053)
F - Full circle, radial connector exit (only for size 029)
G - Full circle, axial connector exit (only for size 022)

Connector option
N - FCI 10114830-11108LF
P - Soldering pads (only for DC, SF and SC communication interface); Not available for MB049-E

Option
T - Extended temperature range (standard)
L - Extended low temperature range, –40 °C to +85 °C (for MB022 only)
P - High pressure (up to 600 bar)***

Special requirements
00 - No special requirements (standard)

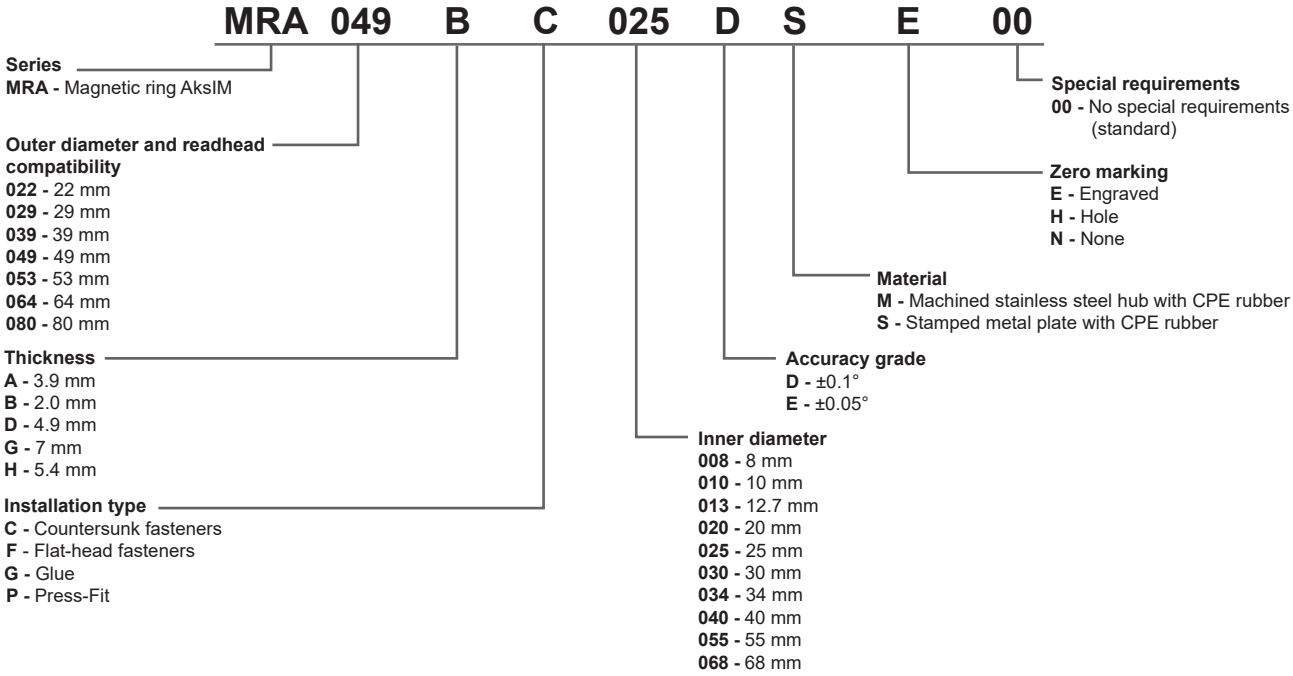
* - Not recommended for new design
** - SPI and PWM are not available on MB022 and MB049-E.
*** - See chapter Operation in high-pressure applications on page 24.

Available combinations for readheads:

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

* - Not recommended for new design
** - SPI and PWM are not available on MB022 and MB049-E.
*** - See chapter Operation in high-pressure applications on page 24.

Ring part numbering



Available combinations for rings:

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				
	064		C				N	
	080	A	F	055	E	M	H	
		B	C		D	S	E	
		D	F	068		M	H	

Available ring part numbers:

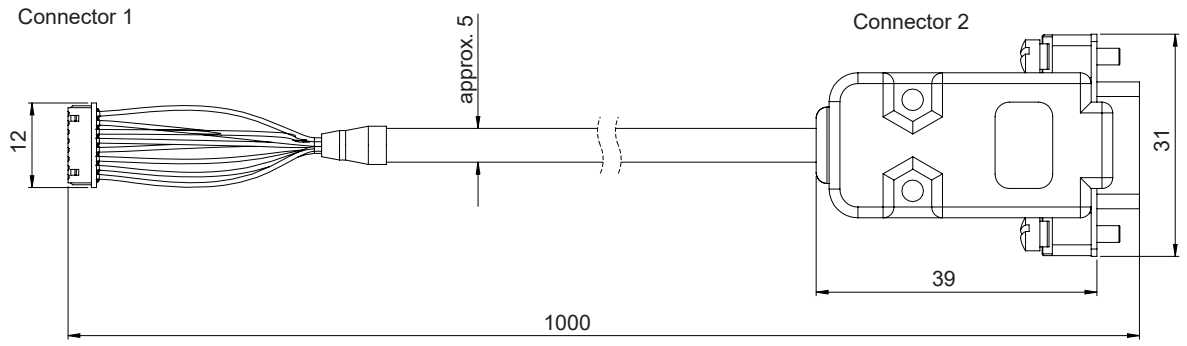
MRA022HP008DMN00
MRA029BC010DSE00
MRA029GP013DMN00
MRA039BC020DSE00
MRA049AF025EMH00
MRA049BC025DSE00
MRA049BG034DSN00
MRA053BC030DSE00
MRA053BG040DSN00
MRA064BC040DSE00
MRA080AF055EMH00
MRA080BC055DSE00
MRA080DF068DMH00

Accessories

Cables with crimped connectors

Compatible readhead	Part number	Length	Connector 1	Connector 2	Notes
MB022-N MB029-N MB039-N MB049-N MB053-N MB064-N MB080-N	**ACC015**	1.0 m	FCI 10114826-00008LF and 10114827-002LF	Flying leads	Single-shielded
	ACC016			DSUB-9 M	

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+	RX data out +	MISO	PWM out	Data+
8	7	Yellow	SLO–	RX data out –	MOSI	-	Data–

Cable specifications

Part numbers	ACC015, ACC016
Cable specifications	LI12YC12Y
Configuration	4 × 2 × 0.14 mm²
Sheath colour	Grey (RAL7032)
Rated voltage	250 V
Temperature range	Moving –30 °C to +125 °C Static –40 °C to +130 °C Not valid for cables with DSUB-9 M connector.
Environmental compliance	RoHS conform 73/23/EWG-Guideline CE conform Halogen free
Chemical resistance	Largely resistant to acids, bases and usual oils. Free from lacquer damaging substances and silicone.

ACC016 can be used for direct connection to E201-9S or E201-9B USB encoder interface.

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Document issues

Issue	Date	Page	Corrections made
3	15. 5. 2020	1	Description amended
		3, 4, 5, 19, 20, 26, 37, 38, 40	MB022 and MRA022 added
		3, 14, 40	MRA053BG040DSN00 added
		18	MRA080DF068DMH00 ring tolerances and dimensions amended
		19	Shock and vibration added
		23, 24	Electrical connections amended
		24	Operation in high-pressure applications chapter added
		26	Multiturn - shaft turn counter limitation table amended
		33	SPI interface and EncoLink added
		39	Option -05 removed from Part numbering
		41	Connector D removed
4	1. 7. 2020	33	SPI electrical connection and timing diagram amended
		34	SPI encoder position data structure amended
5	15. 7. 2020	4, 6, 8, 10, 11, 13, 15, 17	Mounting dimensions amended