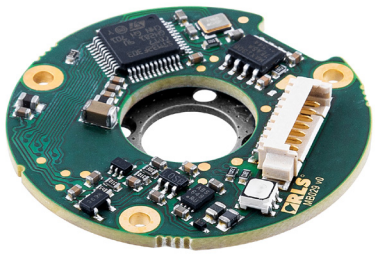
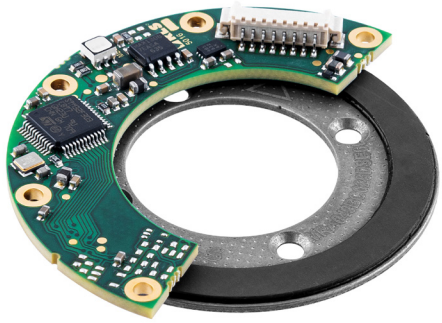
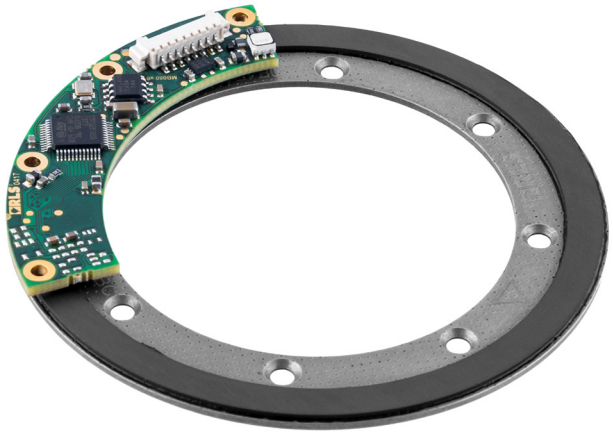
Data sheet
MBD01_01
Issue 1, 18th December 2017

AksIM-2 off-axis rotary absolute encoder







AksIM-2 is a non-contact high performance off-axis absolute rotary encoder designed for integration into space-constrained applications. 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 come with SSI, BiSS and asynchronous serial communication interfaces and offer a range of binary resolutions to 20 bits per revolution.

The encoder operates from -30 °C to +85 °C or -40 °C to +105 °C with extended temperature range option and is resistant to shock and vibrations.

The AksIM-2 encoder has a built-in advanced self-monitoring function, continually checking several internal parameters. Error reporting, warnings and other status signals are available on all communication interfaces and are visualised with the on-board LED.

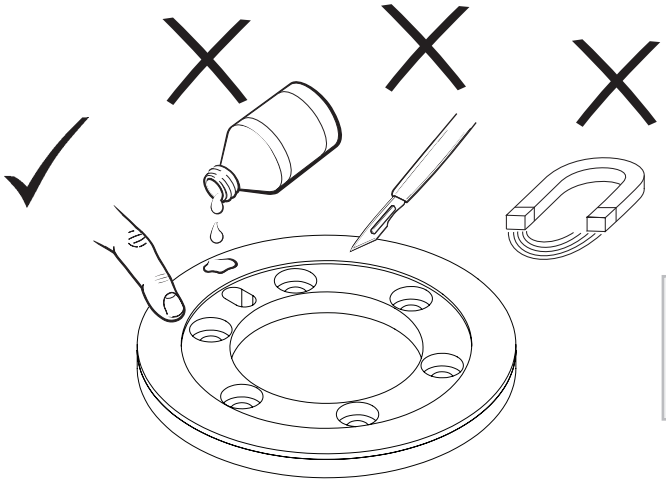
The AksIM-2 encoder system is suitable for use in industrial and medical applications.

A typical application is a robotic arm joint with a cable feed running through the ring or a precision gearbox where the ring is attached onto the main transmission shaft.

Custom design service for OEM integration is also available.

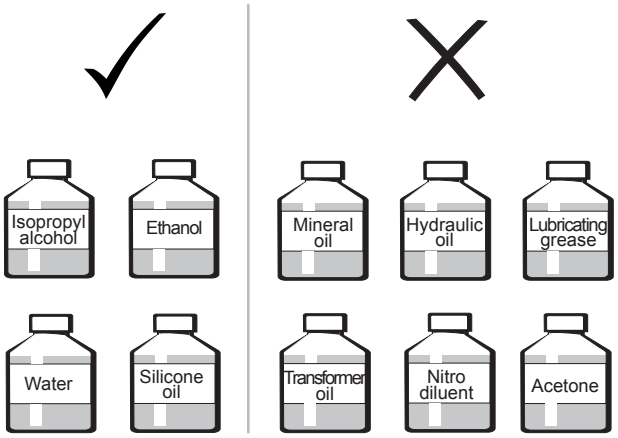
- **True absolute system**
- **Custom magnetic sensor ASIC**
- **Self-calibration option**
- **No hysteresis**
- **Resolutions up to 20 bits**
- **Multiturn counter option**
- **High speed operation**
- **9 kHz bandwidth, 44 kHz refresh rate**
- **Low profile, non-contact**
- **Built-in self-monitoring**
- **Integrated status LED**
- **SSI, BiSS or asynchronous serial communication interface**
- **Corrosion resistant magnetic ring**

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



Readhead

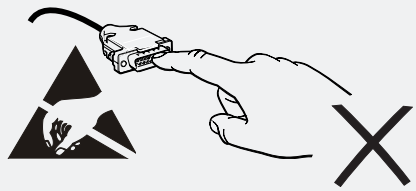
The readhead is resistant to a range of greases and oils commonly found in industry.
If the encoder is to be used in the area without air, it is recommended to use silicone-based oils or demineralised water.
Before any long-term immersion into any liquid or gas, please consult your local sales representative.
Encoder is not vacuum compatible.

Magnetic ring

The magnetized rubber on the ring does not withstand the following chemicals: mineral oils, hydraulic oils, most of transformer oils, lubricating grease, nitro diluent, acetone etc.
The following have been tested and are not recommended:

- ISO VG 46 (SAE MS1004 type HM)
- Nytro 10 XN
- MIDEL 7131
- Shell Diala S3 ZX-I.

The rings are resistant to isopropyl-alcohol, ethanol, water and some silicone-based oils.



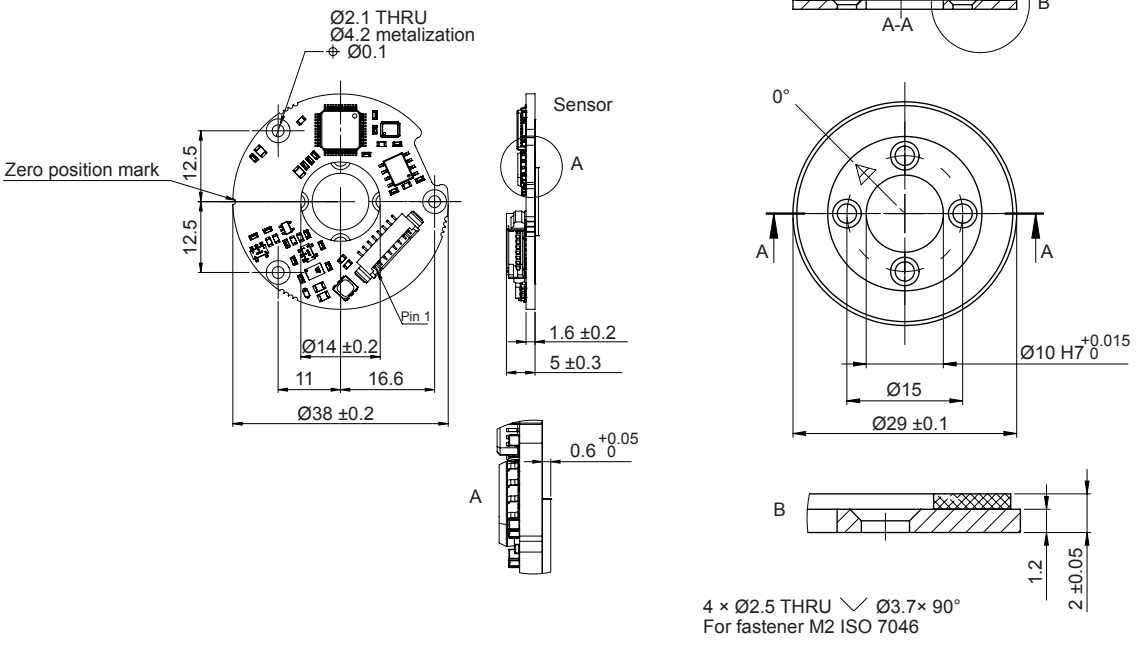
WARNING!

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.

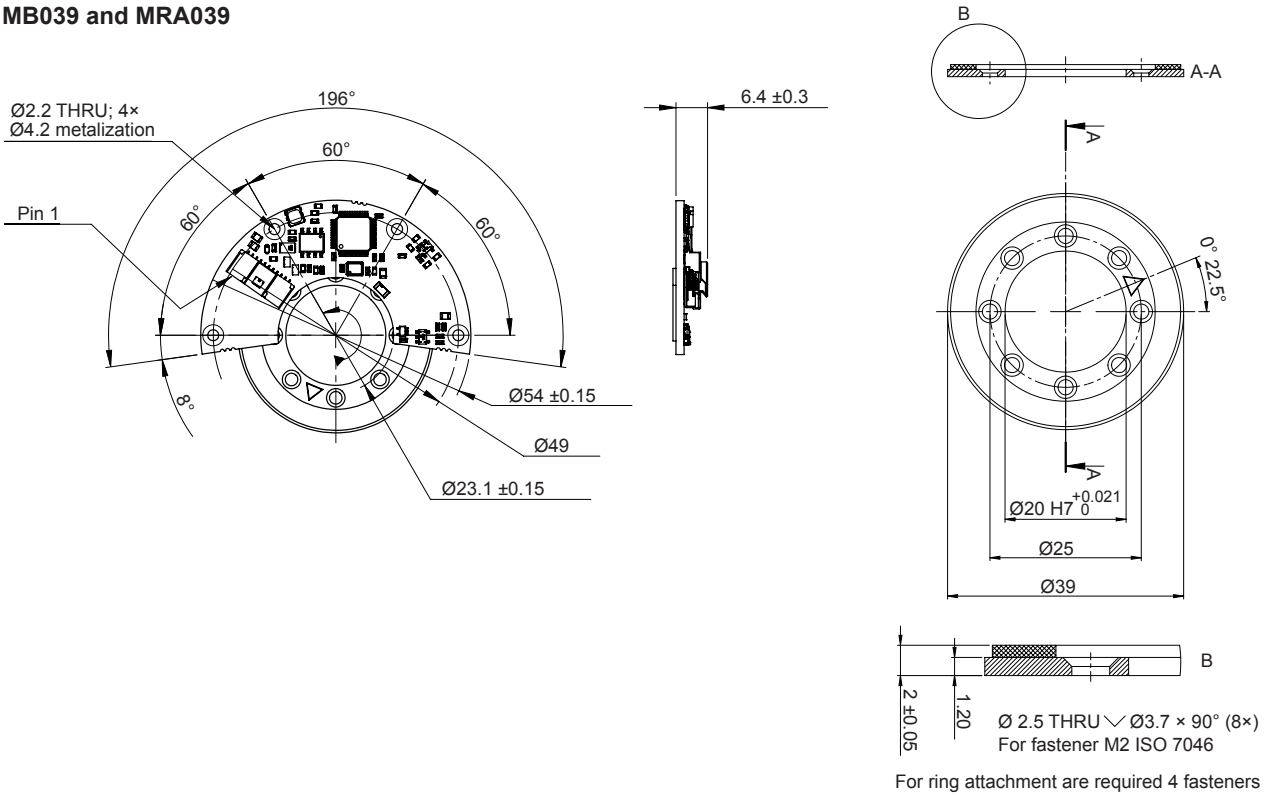
Dimensions

Dimensions and tolerances in mm.

MB029 and MRA029



MB039 and MRA039

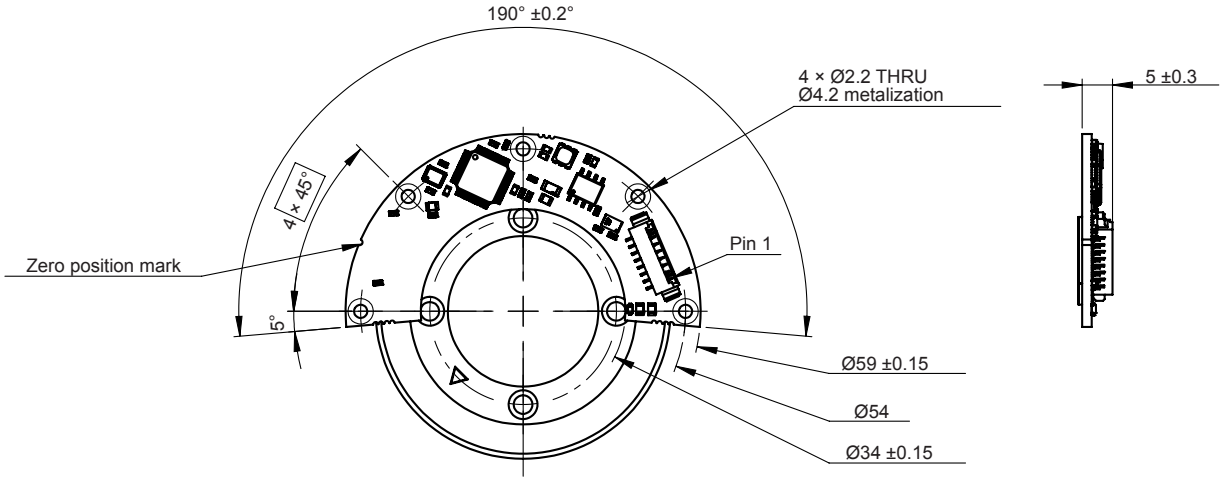


For ring attachment are required 4 fasteners

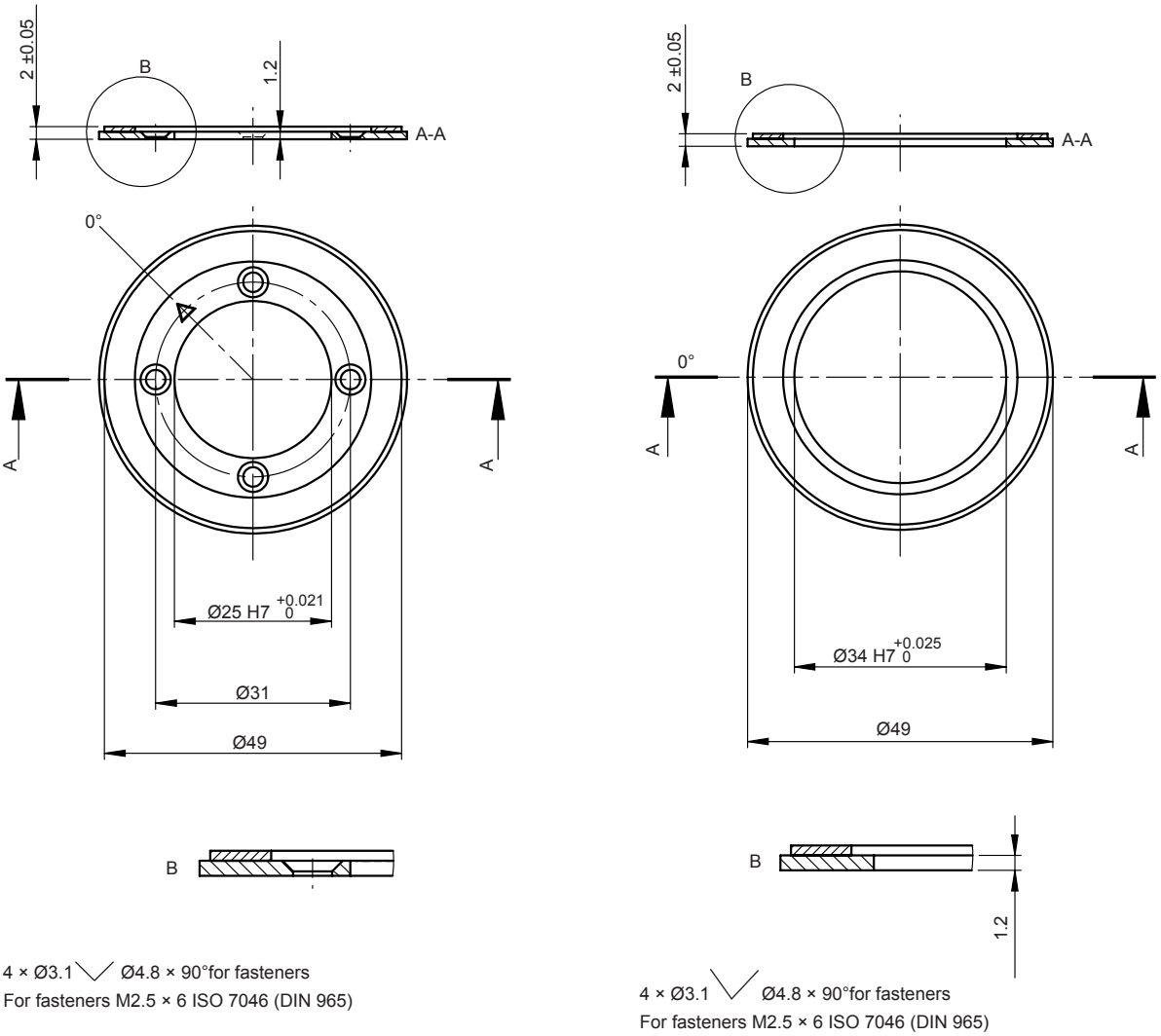
Dimensions continued

Dimensions and tolerances in mm.

MB049



MRA049



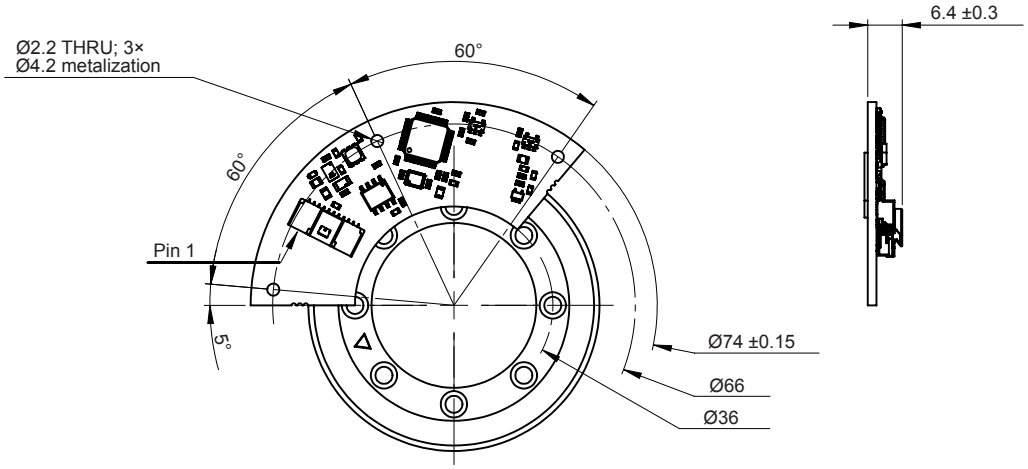
4 × Ø3.1 ⌵ Ø4.8 × 90°for fasteners
For fasteners M2.5 × 6 ISO 7046 (DIN 965)

4 × Ø3.1 ⌵ Ø4.8 × 90°for fasteners
For fasteners M2.5 × 6 ISO 7046 (DIN 965)

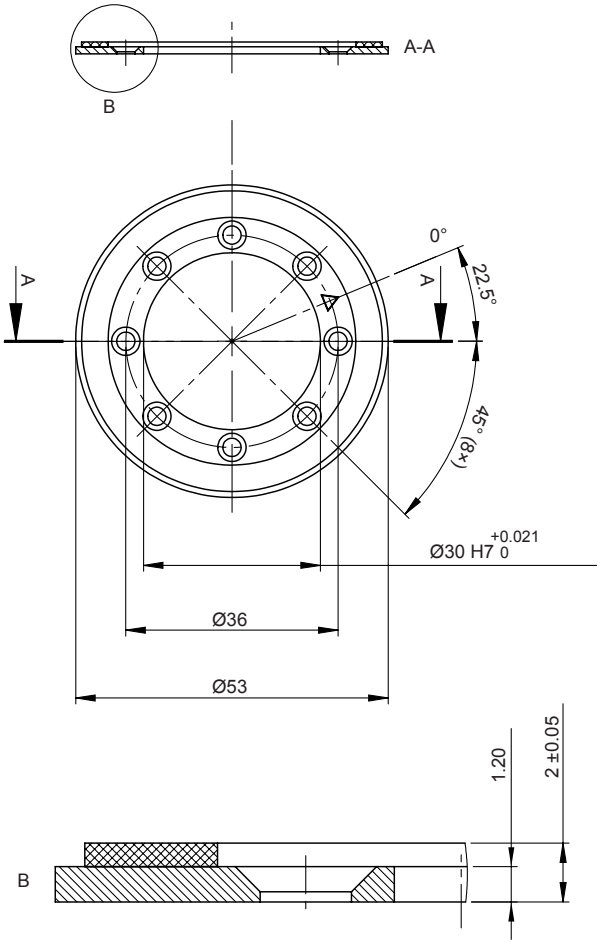
Dimensions continued

Dimensions and tolerances in mm.

MB053



MRA053

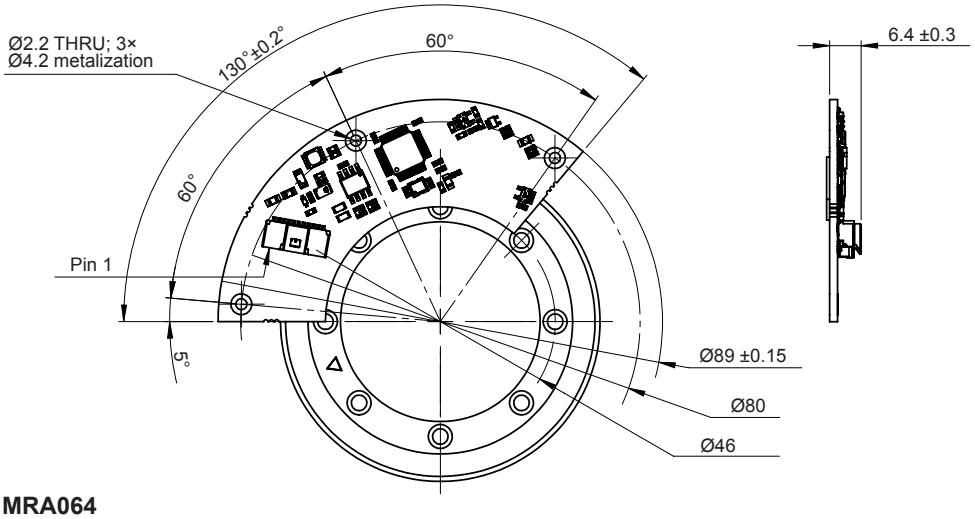


Ø 3.1 THRU ⌵ Ø4.8 × 90° (8×)
For fastener M2.5 ISO 7046 (DIN 965)
For ring attachment are required 4 fasteners

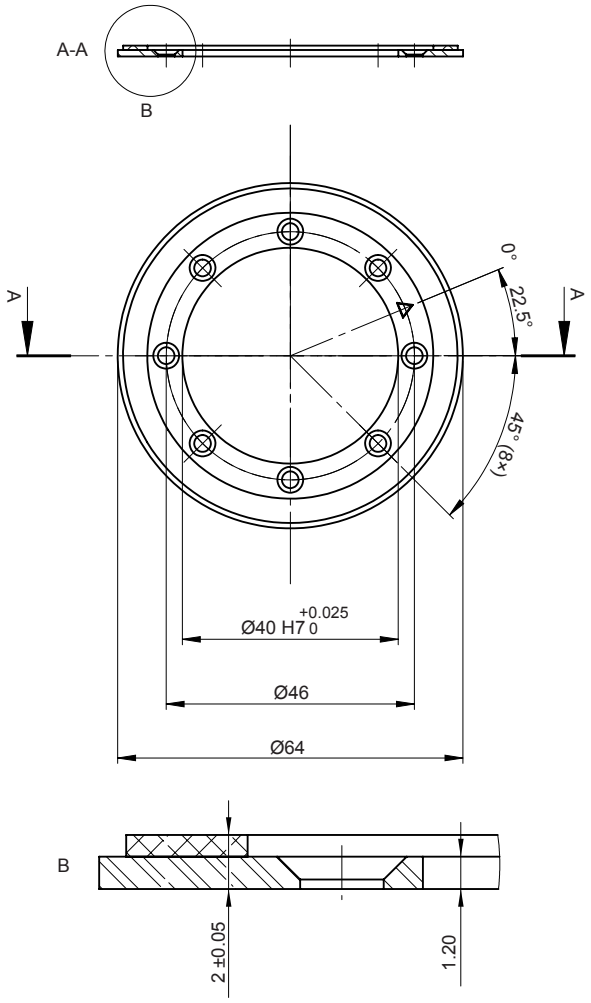
Dimensions continued

Dimensions and tolerances in mm.

MB064



MRA064

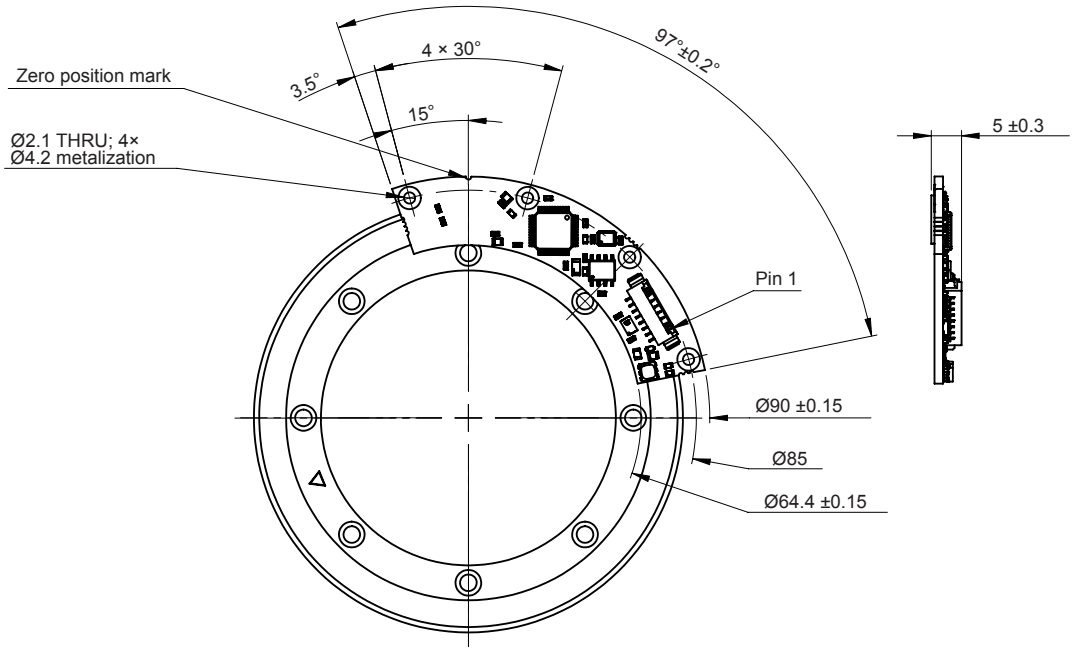


Ø 3.1 THRU ⌵ Ø4.8 × 90° (8×)
For fastener M2.5 ISO 7046

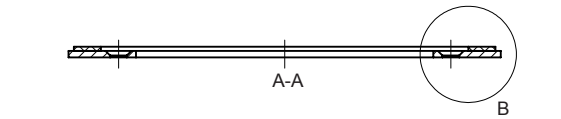
Dimensions continued

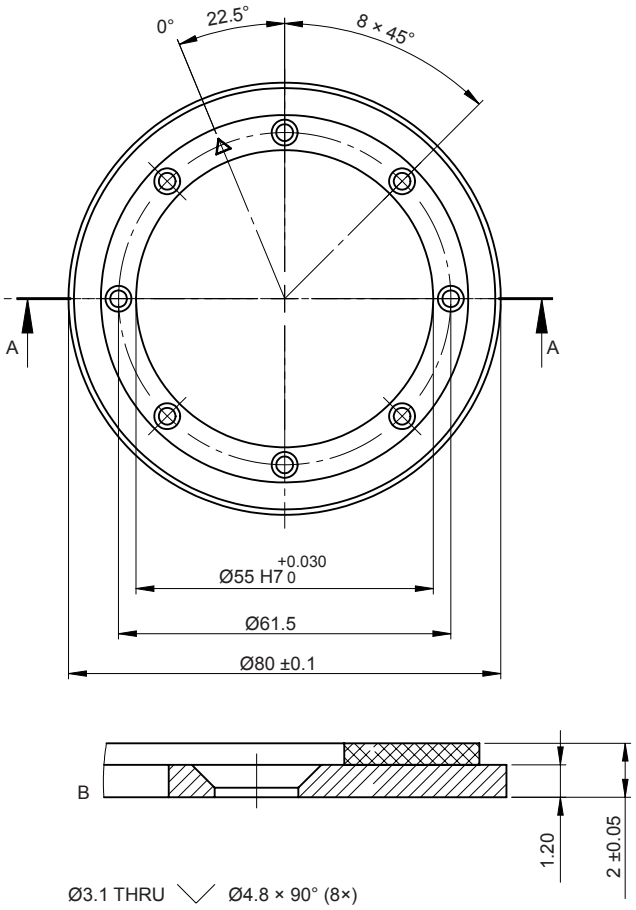
Dimensions and tolerances in mm.

MB080



MRA080





Technical specifications

System data		
Reading type	Axial reading	
Resolution	From 17 to 20 bit and 16 bit multiturn counter option (see chapter Available resolutions on page 17)	
Maximum speed	10,000 rpm (for higher speed contact RLS)	
Encoder accuracy	±0.05° (before installation - errors caused by mounting inaccuracy of the readhead, ring and drive shaft are not included)	
Final system accuracy	Typ. ±0.1° (within defined installation tolerances - see chapter Installation instructions on page 9)	
Hysteresis	Less than unit of resolution	
Repeatability	Better than unit of resolution	
Encoder speed	9 kHz bandwidth, 18 kHz sampling rate, up to 44 kHz refresh rate	
Electrical data		
Supply voltage	4.5 V to 5.5 V (at the connector)	
Set-up time	36 ms (first data ready after switch-on), 59 ms with multiturn counter	
Power consumption	Typ. 120 mA, max. 150 mA	
Connection	11-pin locking connector, 8-pin low-profile connector or soldering pads	
Output load	RS422	120 mA short term, 60 mA limited
ESD protection	HBM, Class 2, ±2 kV (as per Mil-Std 883 Method 3015.7)	
Mechanical data		
Available ring sizes (outer diameter)	29 mm, 39 mm, 49 mm, 53 mm, 64 mm, 80 mm	
Material type	Ring	EN 1.4005 / AISI416 or EN 1.4104 / AISI430F with glued rubber filled with ferrite particles
Mass	Readhead:MB029: 4.5 g; MB039: 4.8 g; MB049: 4.53 g; MB053: 5.3 g; MB064: 6.9 g; MB080: 3.97 g Rings: MRA029: 5.9 g; MRA039: 9.2 g; MRA049: 15 g; MRA053: 15.5 g; MRA064: 20.1 g; MRA080: 26 g	
Inertia	Rings: MRA029: 0.75 kg×mm^2; MRA039: 2.3 kg×mm^2; MRA049: 5.5 kg×mm^2; MRA053: 7.4 kg×mm^2; MRA064: 14.8 kg×mm^2; MRA080: 31.8 kg×mm^2	
Environmental data		
Operating and storage temperature	–30 °C to +85 °C (standard) –40 °C to +105 °C (extended temperature range option)	
Humidity	0 to 70 % non-condensing	
External magnetic field	±25 mT	

Status indicator LED

The LED provides visual feedback of signal strength, error condition and is used for set-up and diagnostics.
Flashing LED indicates the encoder is powered but communication has not been established. When communication is running at a rate of minimum 5 readings per second LED is constantly lit. Repeatable two short red flashes indicate the readhead can not start.

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
No light	No power supply

Installation instructions

Axial position adjustment (ride height)
The nominal gap between the gold mounting areas on the PCB mounting side and the rubber band on the ring is 0.8 mm ±0.15 mm. We recommend using gold plated surfaces on the bottom of the PCB as a reference for mounting the readhead. If the top side of the readhead is used, user must adjust the ride height carefully due to wide PCB thickness tolerances.
Any nonmagnetic tool with 0.2 mm thickness can be used to mechanically check the ride height between the sensor and the ring.
The integrated LED can be used as an indicator. When the correct ride height is achieved, the LED glows green and does not change colour when the ring rotates.
Center point of the ring and center point of the readhead arc must be coaxial. Allowed tolerances are listed in the table below.

Installation tolerances (readhead to ring)

Axial displacement (air gap)	0.2 mm nominal ±0.15 mm
Readhead to ring distance*	0.8 mm ±0.15 mm
Radial displacement	±0.3 mm
Tangential displacement	MRA029: ±0.3 mm MRA039: ±0.4 mm MRA049, MRA053, MRA064, MRA080: ±0.5 mm
Non-paralell mounting	±0.05 mm

* The nominal gap between the gold mounting areas on the PCB mounting side and the rubber band on the ring.

Installation tolerances (ring to shaft)

Ring / shaft fit	**Encoder accuracy**					
	MRA029	**MRA039**	**MRA049**	**MRA053**	**MRA064**	**MRA080**
H7/g6 worst case	±0.15°	±0.15°	±0.11°	±0.11°	±0.10°	±0.09°
H7/g6 average	±0.08°	±0.07°	±0.06°	±0.06°	±0.05°	±0.05°

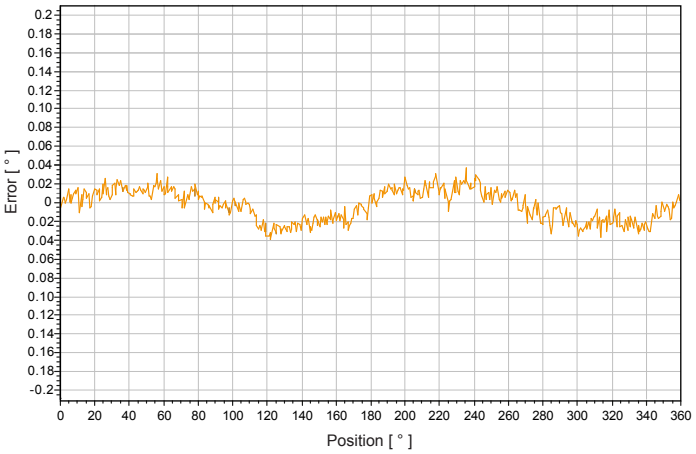
Accuracy of the encoder system

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

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

A typical accuracy plot after good installation of MRA080 (without eccentricty) is shown in the graph on the right.

For highest accuracy options contact RLS.



Self-calibration after installation

A self-calibration function eliminates the eccentricity-caused error, which is the dominant part of the encoder accuracy and is caused by the eccentric mounting of the ring. This function can be triggered over selected communication interfaces by user or by using appropriate USB encoder interface. Not available with PWM encoder output. For details refer to the chosen communication interface description.

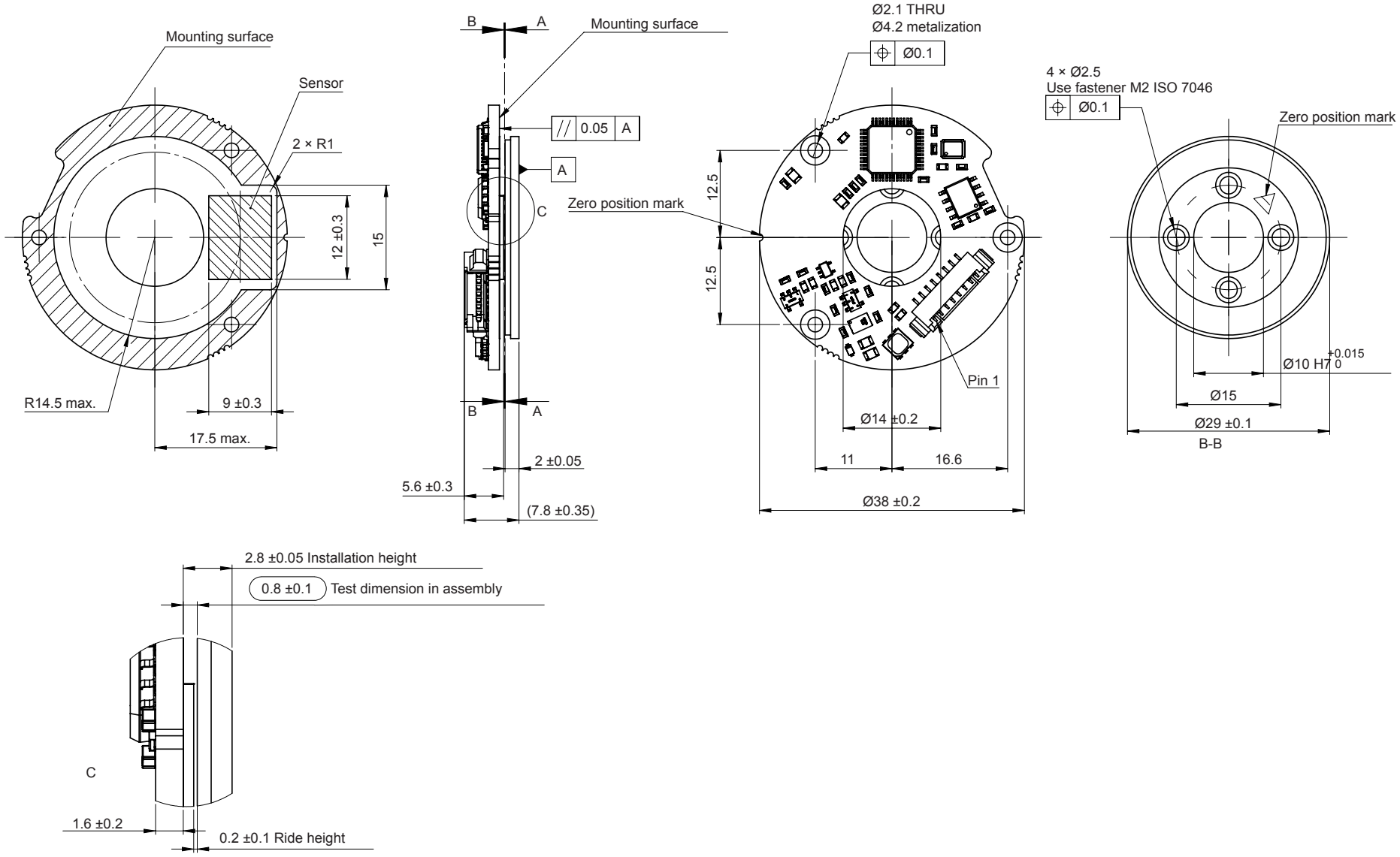
External magnetic field

Principle of operation of any magnetic encoder is sensing changes in the magnetic field of the magnetised ring. External magnetic fields, generated by permanent magnets, electric motors, coils, magnetic brakes, etc. may influence the operation of the encoder. When magnetic field is between 0 mT and 25 mT perpendicularly to the readhead it might affect accuracy. When bigger than 25 mT it temporarily causes the encoder to malfunction. Fields stronger than 50 mT can permanently damage the ring.

Unwanted magnetic fields must be blocked at the source. When this is not possible, encoder can be shielded with ferromagnetic metal plate. The ring can also be used for partial shielding. It is recommended to mount the bottom side of the ring towards the source of the leaking magnetic field and readhead pointing away.

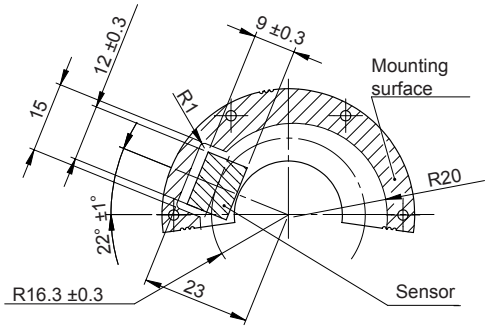
Installation drawings

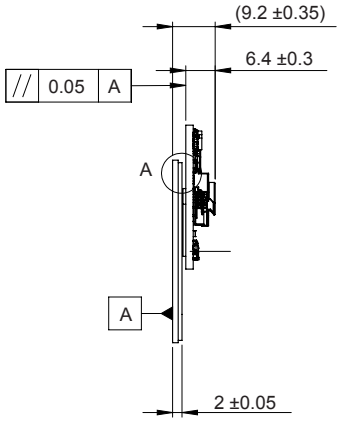
Installation drawing for MB029 and MRA029

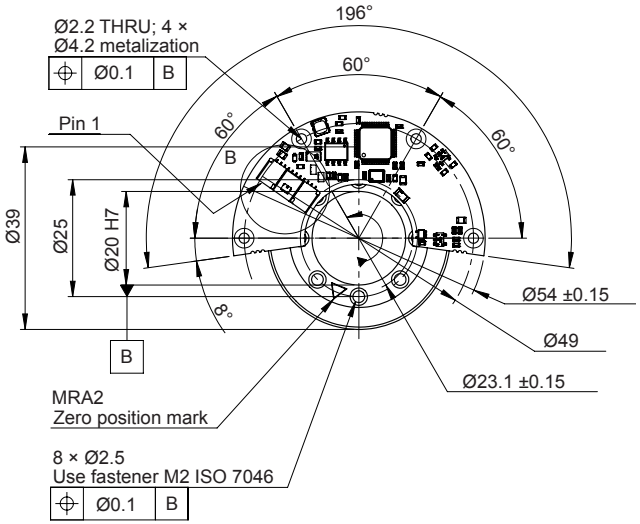


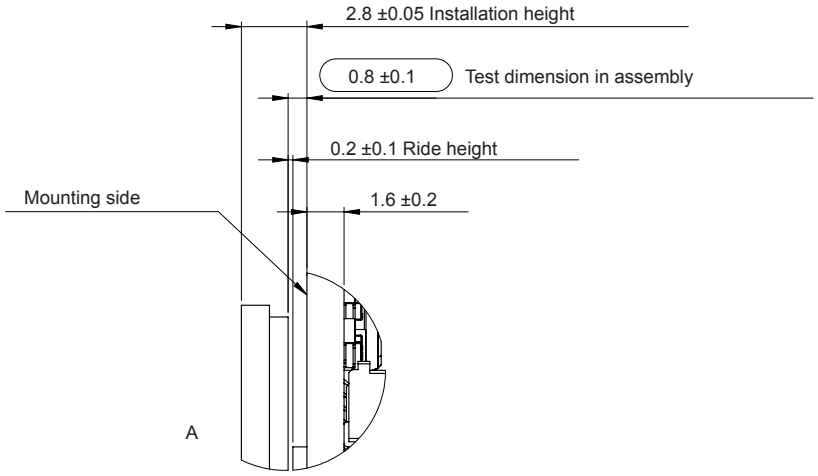
Installation drawings continued

Installation drawing for MB039 and MRA039



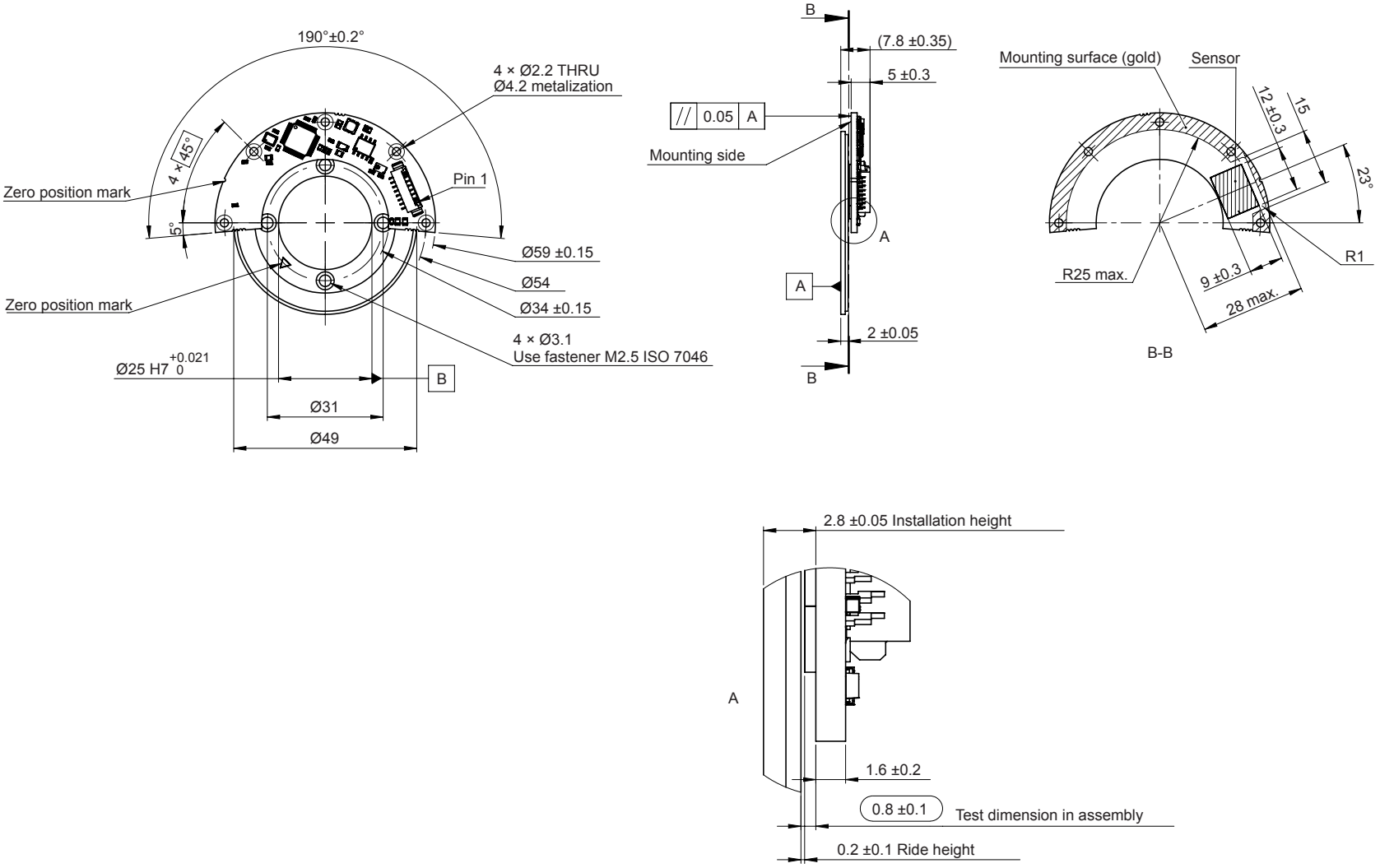






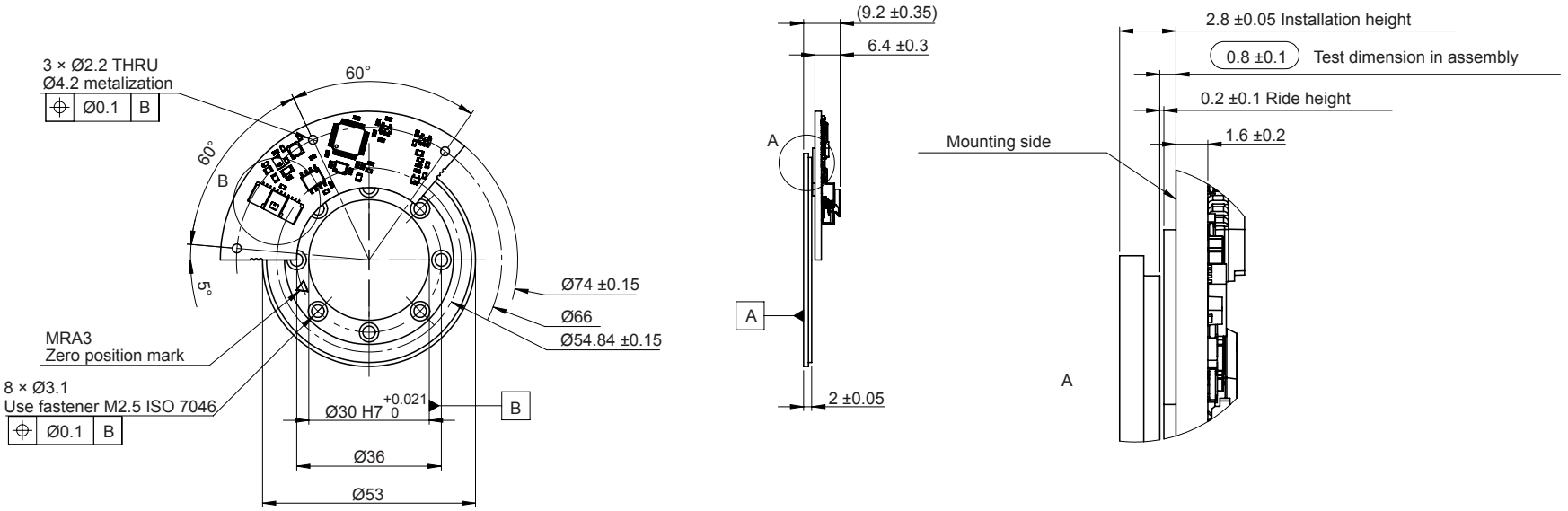
Installation drawings continued

Installation drawing for MB049 and MRA049



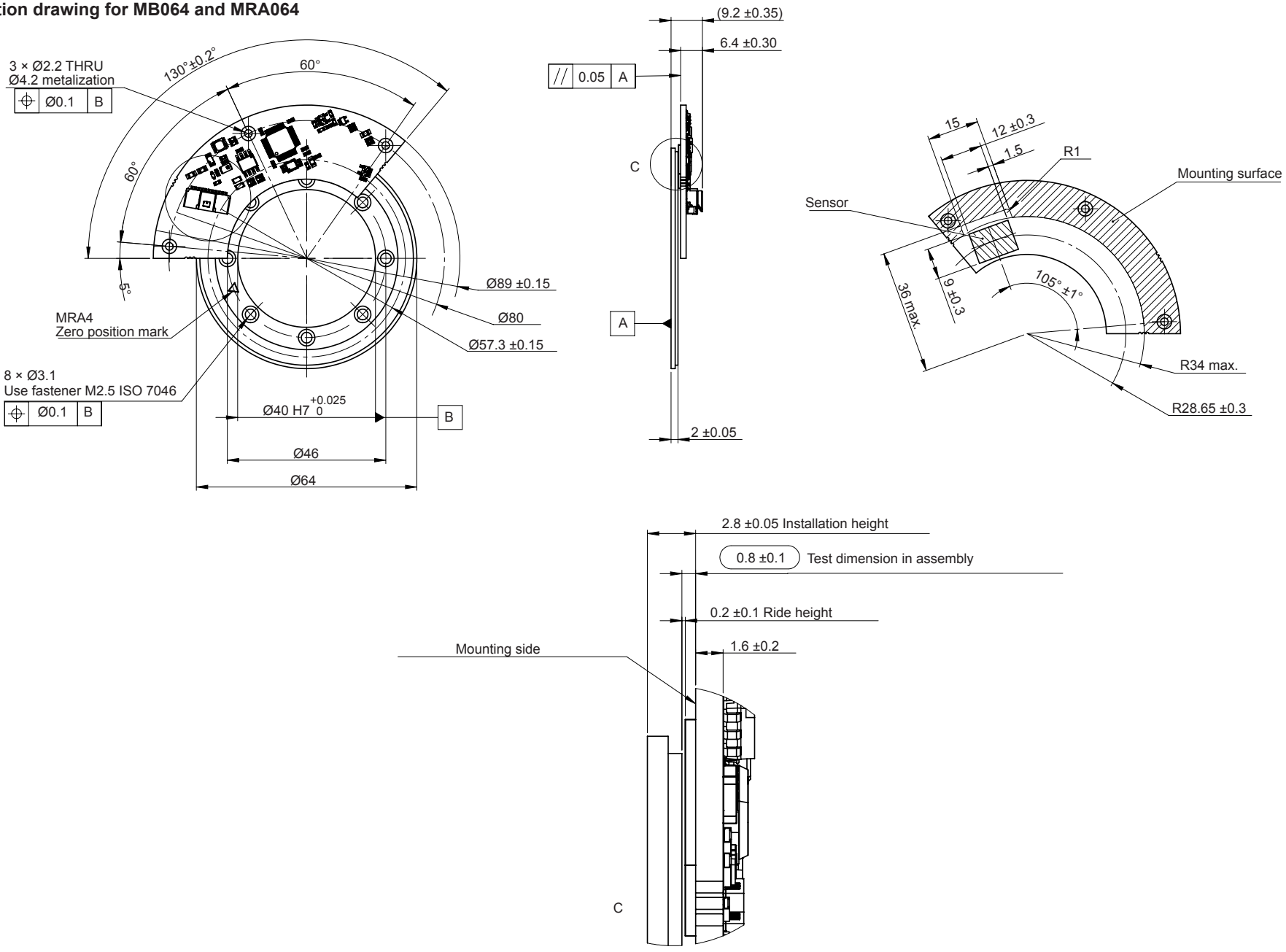
Installation drawings continued

Installation drawing for MB053 and MRA053



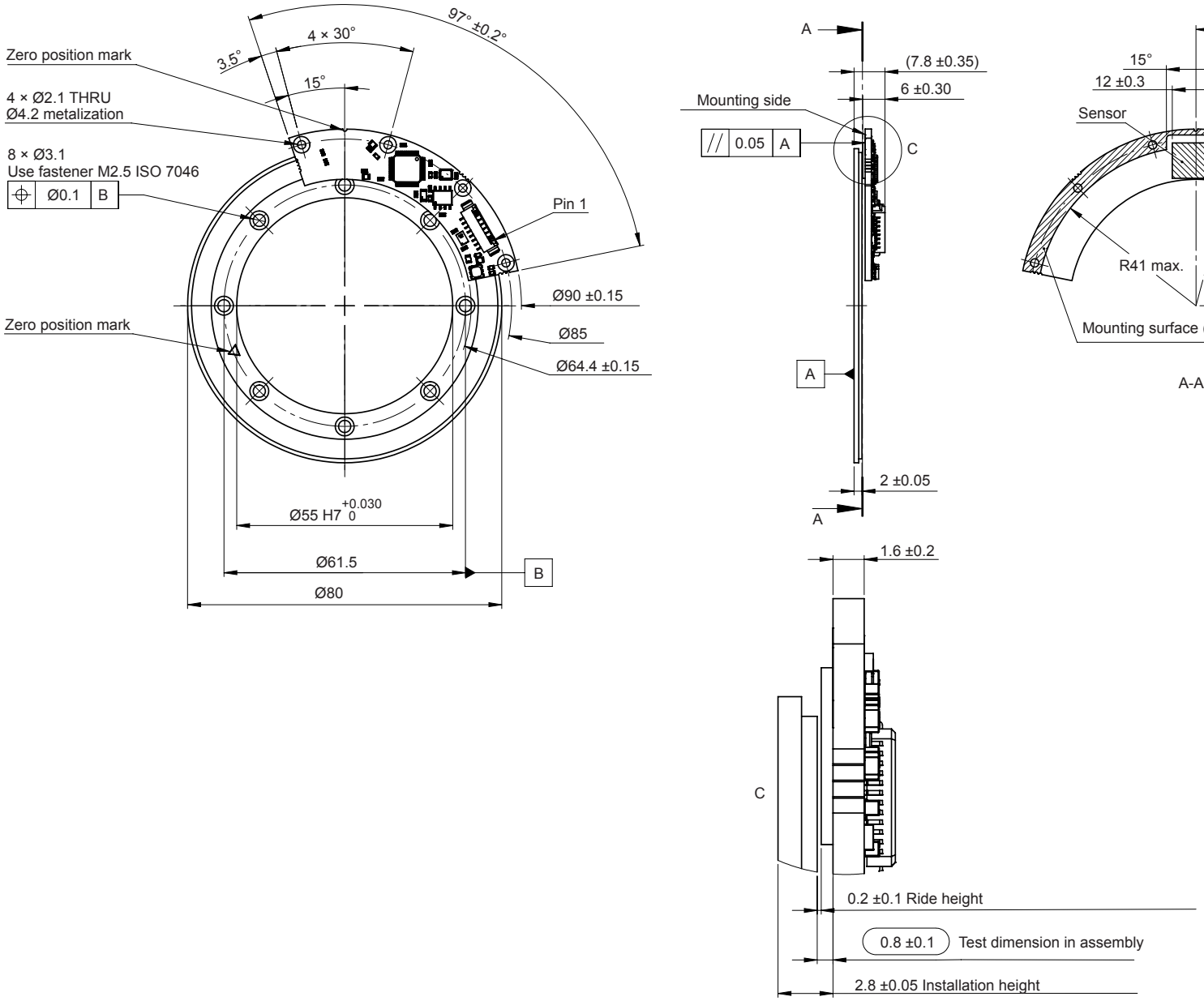
Installation drawings continued

Installation drawing for MB064 and MRA064



Installation drawings continued

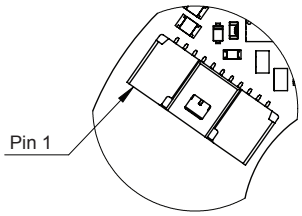
Installation drawing for MB080 and MRA080



Electrical connections

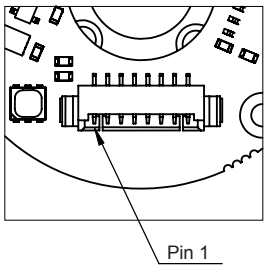
11-pin connector, (MB039, MB053, MB064)	8-pin connector, (MB029, MB049, MB080)	Soldering pads (MB029, MB049, MB080)	Asynchronous serial	SSI	BiSS-C
1			V_{dd}		
2	1	1			
3	2	2	GND		
4					
5	3		Temp. Sens. 1		
6	4		Temp. Sens. 2		
7	5	3	RX Command in+	Clock+	MA+
8	6	4	RX Command in–	Clock–	MA–
9			-	-	-
10	7	5	TX Data out+	Data+	SLO+
11	8	6	TX Data out–	Data–	SLO–

Pinout



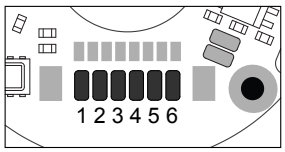
11-pin locking connector Molex 501568-1107, available on readhead sizes 39, 53 and 64.

Counterpart mating connector:
Molex 501330-1100
and 501334-0000



8-pin low profile connector FCI 10114830-11108LF, available on readhead sizes 29, 49 and 80.

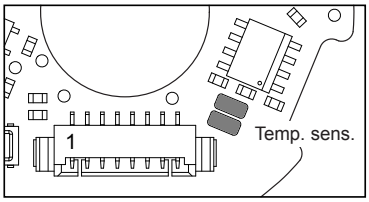
Counterpart mating connector:
FCI 10114826-00008LF
and 10114827-002LF

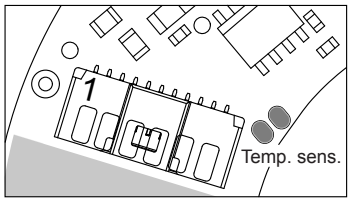


Soldering pads, available on readhead sizes 29, 49 and 80.

External isolated temperature sensor

Encoders provide two pass-through signals for connecting an external temperature sensor in an application. It can be Pt100, Pt1000, NTC, 1-wire or any other similar low-voltage analog or digital sensor. Signals are isolated from the encoder circuit and are just routed from the "Temp. Sens." pins on the connector to the soldering pads, where external sensor in an application is to be connected. Purpose of this is to add temperature monitoring to an application like an electric motor, gearbox, etc. where precise monitoring is required close to the encoder. This solution simplifies the cable management of the application, as existing encoder cable can be used to carry these two signals. Voltage must be limited to ±30 V relatively to the other encoder signals and current to ±500 mA.
If measurement of the temperature on the readhead is enough, Special option "05" specifies Pt1000 sensor soldered directly on the readhead.





Communication interfaces

Asynchronous serial RS422 (UART)		
	Baud rate	115.2 kbps, 128 kbps, 230.4 kbps, 256 kbps, 500 kbps, 1 Mbps
	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 below
	Latency	<10 µs
SSI		
	Maximum clock frequency	500 kHz standard 2.5 MHz with *Delay First Clock* function on the controller
	Mechanical sample rate rate	18 kHz
	Resolution	See table below
	Latency	55 µs to 110 µs
	Timeout (monoflop time)	20 µs
BiSS		
	Maximum clock frequency	5 MHz
	Maximum request rate	44 kHz (38 kHz multiturn counter option)
	Mechanical sample rate rate	18 kHz
	Bandwidth	9 kHz
	Resolution	See table below
	Latency	<10 µs
	Timeout (monoflop time)	13.5 µs

Available resolutions

Resolution	Ring MRA029	Ring MRA039, MRA049	Ring MRA053, MRA064, MRA080
Binary	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.

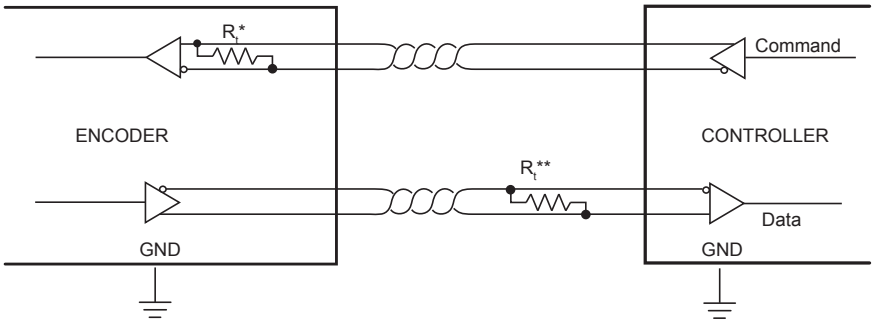
Multiturn counter

Multi-turn counter is available on the following communication interfaces: BiSS, SSI, SPI and Asynchronous serial.
Multiturn option is chosen with Resolution in part number on page 27. Multi-turn counter is 16 bit (0 to 65535 counts). Counting is available only when the encoder is powered on, but the counter state is stored in a non-volatile memory at power off and is restored at power up. Maximum permissible rotation during power-down is ±90°. If rotation is bigger, encoder will signal an error to indicate invalid multiturn counter value. Power cycle is needed to reset this condition.

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, forming a full-duplex bidirectional data link. Every 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
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 the "Special commands" section.

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)
't'	't' + 3 (5) bytes (Position + E/W bits) + 1 byte (Temperature)
'a'	'a' + 3 (5) bytes (Position + E/W bits) + 2 bytes (Signal amplitude)
'v'	'v' + 41 bytes (Version info and serial number)

Command '3' is used as a request for the shortest possible response. In this case, only 3 (or 5 bytes in multiturn variant) bytes of position with integrated general error and warning bits is 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 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). There are zero padding bits between LSB of position and error bit. The structure of position data bytes for each encoder resolution is presented in 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 site)
Command 's'	
Byte transmitted	**Contents**
B1	ASCII header 's'
B2 - B4	Position + E/W
B5 - B7	(Signed binary) speed in number of counts per 1 us multiplied by 65536
Command 't'	
Byte transmitted	**Contents**
B1	ASCII header 't'
B2 - B4	Position + E/W
B5	(Signed binary) temperature in ºC
Command 'a'	
Byte transmitted	**Contents**
B1	ASCII header 'a'
B2 - B4	Position + E/W
B5 - B6	(Unsigned binary) Signal level
Command 'v'	
Byte transmitted	**Contents**
B1	ASCII header 'v'
B2 - B8	ASCII identification string 'AksIM-2'
B9	ASCII space character
B10 - B17	ASCII serial number
B18	ASCII space character
B19 - B34	ASCII part number
B35	ASCII space character
B36	Binary firmware major version
B37	Binary firmware minor version
B38	Binary communication interface version
B39 - B42	Binary revision

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 off. Cycle the power to clear this error.
	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. 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. 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.

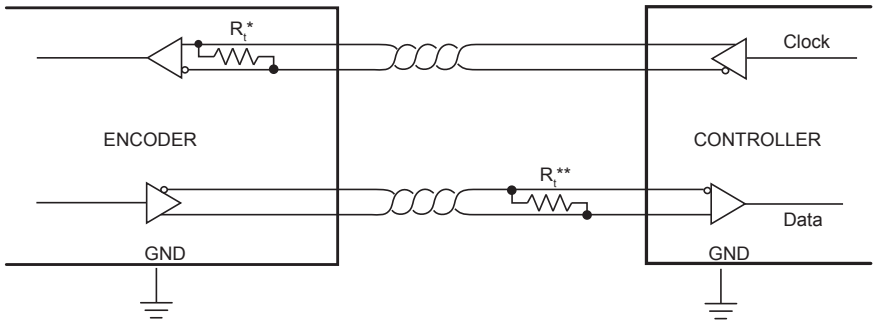
Encoder programming

Encoder supports changing default baud rate, running self-calibration function, automatic transmission of selected data packet at programmable frame rate.
This additional information can be found in the "Application note: Programming encoders with Async serial interface", document number MBD03.

SSI - Synchronous serial interface

The encoder position, in up to 20 bit natural binary code, and the encoder status are available through the SSI protocol. The position data is left aligned. After the position data there are 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

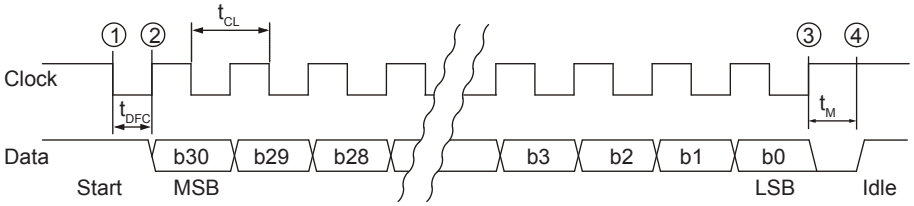


* The Clock and Data signals are 5 V RS422 compatible differential pairs with RC termination inside the readhead.
** Termination at the controller is required, if total cable length is longer than 5 m. The nominal impedance of the cable is 120 Ω.

Output protection

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.

SSI timing diagram

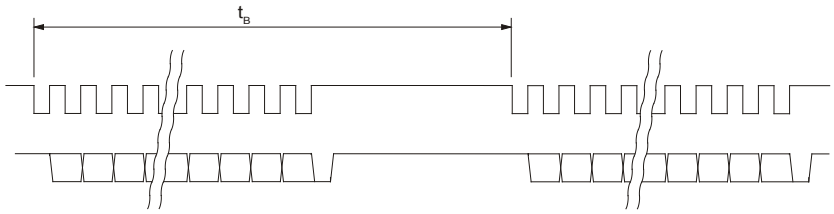


The controller interrogates the readhead for its position and status data by sending a pulse train to the Clock input. The Clock signal always starts from high. The first falling edge ① latches the last position data available and on the first rising edge ② the most significant bit (MSB) of the position is transmitted to the Data output. The Data output should then be latched on the following falling edge. On subsequent rising edges of the Clock signal the next bits are transmitted. If time between ① and ② is extended for additional 1 µs, then maximum clock frequency limit is 2.5 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.

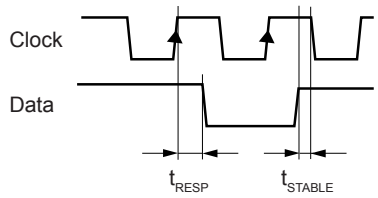
While reading the data the period t_{CL} must always be less than t_M. However, reading the encoder position can be terminated at any time by setting the Clock signal to high for the duration of t_M.

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.



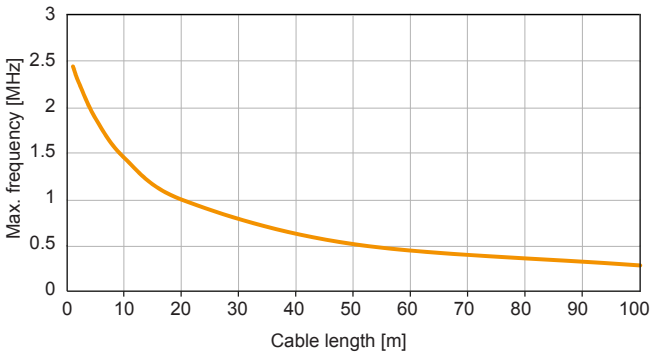
The power supply must be applied at least 60 ms before the clock sequence is being sent to the encoder.

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	55 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

Singleturn variant

Bit	b29 : b10	b9 : b8	b7 : b0
Data length	20 bits	2 bits	8 bits
Meaning	Encoder position	General status	Detailed status

Multiturn variant

Bit	b45 : b30	b29 : b10	b9 : b8	b7 : b0
Data length	16 bits	20 bits	2 bits	8 bits
Meaning	Multiturn counter	Encoder position	General status	Detailed status

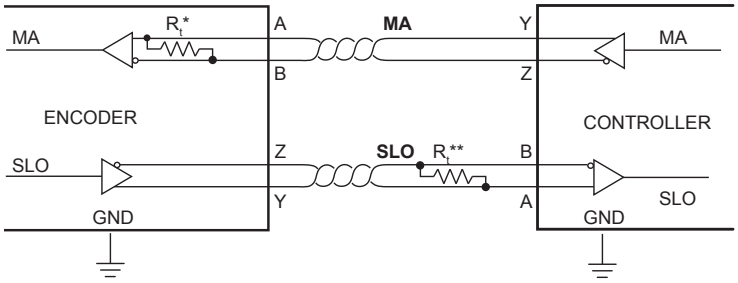
Multiturn counter (if present)	
b45 : b30	Multiturn counter - Occupying full 16 bits. Can be interpreted as signed number (±32768) or unsigned number (0 to 65535) that represents number of shaft turns.
Encoder position	
b29 : b10	Encoder position – Left aligned, MSB first, LSB last. If the encoder resolution is lower than 20 bits, the last few bits of the encoder position, which are not used, are set to zero.
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. 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.

BiSS-C interface

The encoder position, in up to 20 bit natural binary code, and the encoder status are available through 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



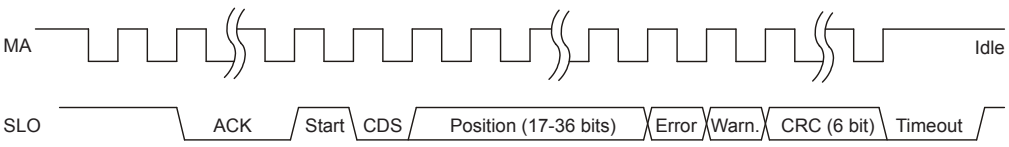
Signals	
MA	Master clock. Max clock frequency is 5 MHz.
SLO	Slave out. Data is output on rising edge on SCK.

* 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

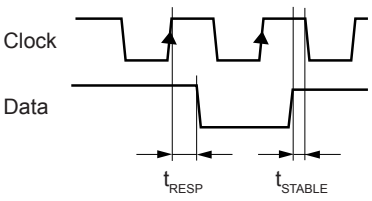
Excessive output current and power dissipation caused by faults or by bus contention are prevented by two mechanisms. A foldback current limit on the output stage provides immediate protection against short circuits. In addition, a thermal shutdown circuit forces the driver outputs into a high-impedance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

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 CRC data is in binary format and sent MSB first.

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. Total cable length must be taken into account, from the encoder to the receiver.

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

The data signal must be stable before the value is latched. Therefore with a cable longer than 1 meter and a clock frequency higher than 2.5 MHz this delay must be compensated for 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 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.

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 Appendix 2 of this document.

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 (like motor parameters, assembly data or similar).
This additional information can be foundin the "Application note: AksIM-2 BiSS-C register access", document number MBD02.

Readhead part numbering

MB 049 DC C 18B D N A 00

Series
MB - AksIM board-level readhead

MRA ring compatibility
029 - For use with MRA029 ring
039 - For use with MRA029 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
SC - Synchronous serial interface (SSI), RS422
SF - Asynchronous serial, 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 **SF**: Link speed in kbps:

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

Resolution
17B - 17 bits per revolution
18B - 18 bits per revolution
19B - 19 bits per revolution (for size 039 and up)
20B - 20 bits per revolution (for size 053 and up)

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

Shape and connector orientation
D - Partial arc, radial connector exit (only on sizes 49 and 80)
E - Partial arc, tangential connector exit (only on sizes 39, 53, 64)
F - Full circle, radial connector exit (only on size 29)

Connector option
D - Molex 501568-1107 locking connector (only on sizes 39, 53, 64)
N - FCI 10114830-11108LF (only on sizes 29, 49, 80)
P - Soldering pads

Option
A - No options (standard)
T - Extended temperature range
P - High pressure (up to 600 bar)

Special requirements
00 - No special requirements (standard)
05 - Temperature sensor Pt1000 added

Ring part numbering

MRA 049 B C 025 D S E 00

Series
MRA - Magnetic ring AksIM

Outer diameter and readhead compatibility
029 - 29 mm
039 - 39 mm
049 - 49 mm
053 - 53 mm
064 - 64 mm
080 - 80 mm

Thickness
A - 3.9 mm
B - 2.0 mm
C - 2.1 mm

Installation type
C - Countersunk fasteners
F - Flat-head fasteners
G - Glue

Inner diameter
010 - 10 mm
020 - 20 mm
025 - 25 mm
030 - 30 mm
034 - 34 mm
040 - 40 mm
055 - 55 mm

Accuracy grade
D - ±0.1°

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

Zero marking
E - Engraved
H - Hole
N - None

Special requirements
00 - No special requirements (standard)

Currently available rings:

MRA029BC010DSE00
MRA039BC020DSE00
MRA049BC025DSE00
MRA049BG034DSN00
MRA053BC030DSE00
MRA064BC040DSE00
MRA080BC055DSE00

Accessories

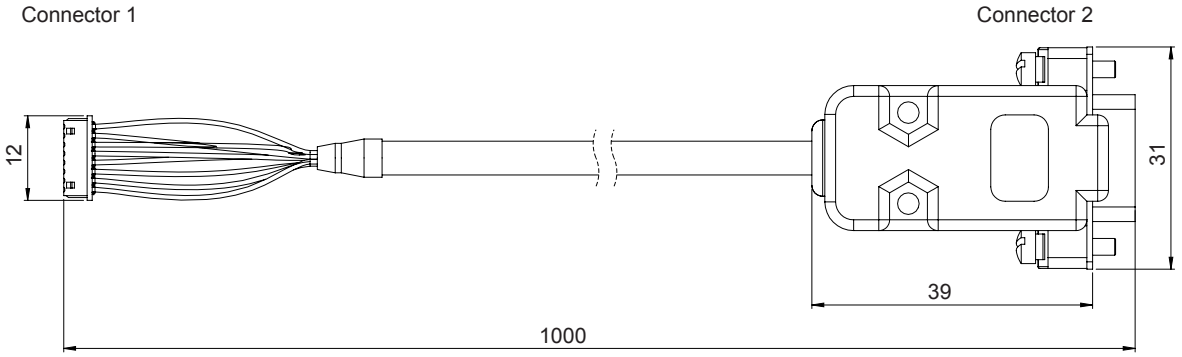
Cables with crimped connectors

Compatible readhead	Part number	Length	Connector 1	Connector 2	Notes
MB039, MB053, MB064	ACC012	1.0 m	Molex 501330-1100 and 501334-0000	Flying leads	Single-shielded
	ACC013	1.6 m			Double-shielded
MB029, MB049, MB080	ACC015	1.0 m	FCI 10114826-00008LF and 10114827-002LF	Flying leads	Single-shielded
	ACC016			DSUB-9 M	

ACC012, ACC015, ACC016 specifications

Cable specifications	LI12YC12Y
Configuration	4 × 2 × 0.14 mm²
Sheath color	Grey (RAL7032)
Rated voltage	250 V
Temperature range	Stationary –40 °C to +130 °C Moving –30 °C to +125 °C
Environmental conformation	Conform to RoHS Conform to 73/23/EWG-Guideline CE 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.



Connector 1 pin	Connector 2 pin	Wire color	BiSS, SSI	Asynchronous serial
	1	Shield		
1	5	Brown	V_{dd}	V_{dd}
2	9	White	GND	GND
3	8	Pink	Temp 1	Temp 1
4	4	Grey	Temp 2	Temp 2
5	2	Red	Clock+	Cmd+
6	3	Blue	Clock–	Cmd–
7	6	Green	Data+	Data+
8	7	Yellow	Data–	Data–

Appendix 1 - 8-bit CRC calculation with 0x97 polynome

Some of the communication interfaces offer a CRC value to check the correctness of the data read from the encoder. This chapter gives an example of the CRC calculation on the receiver side. The CRC calculation must always be done over the complete set of data including all the reserved bits. The polynomial for the CRC calculation is $P(x) = x^8 + x^7 + x^4 + x^2 + x^1 + 1$, also represented as 0x97.

Code example:

```
//poly = 0x97
static u8 tableCRC [256] = {
                        0x00, 0x97, 0xB9, 0x2E, 0xE5, 0x72, 0x5C, 0xCB, 0x5D, 0xCA, 0xE4, 0x73, 0xB8, 0x2F, 0x01, 0x96,
                        0xBA, 0x2D, 0x03, 0x94, 0x5F, 0xC8, 0xE6, 0x71, 0xE7, 0x70, 0x5E, 0xC9, 0x02, 0x95, 0xBB, 0x2C,
                        0xE3, 0x74, 0x5A, 0xCD, 0x06, 0x91, 0xBF, 0x28, 0xBE, 0x29, 0x07, 0x90, 0x5B, 0xCC, 0xE2, 0x75,
                        0x59, 0xCE, 0xE0, 0x77, 0xBC, 0x2B, 0x05, 0x92, 0x04, 0x93, 0xBD, 0x2A, 0xE1, 0x76, 0x58, 0xCF,
                        0x51, 0xC6, 0xE8, 0x7F, 0xB4, 0x23, 0x0D, 0x9A, 0x0C, 0x9B, 0xB5, 0x22, 0xE9, 0x7E, 0x50, 0xC7,
                        0xEB, 0x7C, 0x52, 0xC5, 0x0E, 0x99, 0xB7, 0x20, 0xB6, 0x21, 0x0F, 0x98, 0x53, 0xC4, 0xEA, 0x7D,
                        0xB2, 0x25, 0x0B, 0x9C, 0x57, 0xC0, 0xEE, 0x79, 0xEF, 0x78, 0x56, 0xC1, 0x0A, 0x9D, 0xB3, 0x24,
                        0x08, 0x9F, 0xB1, 0x26, 0xED, 0x7A, 0x54, 0xC3, 0x55, 0xC2, 0xEC, 0x7B, 0xB0, 0x27, 0x09, 0x9E,
                        0xA2, 0x35, 0x1B, 0x8C, 0x47, 0xD0, 0xFE, 0x69, 0xFF, 0x68, 0x46, 0xD1, 0x1A, 0x8D, 0xA3, 0x34,
                        0x18, 0x8F, 0xA1, 0x36, 0xFD, 0x6A, 0x44, 0xD3, 0x45, 0xD2, 0xFC, 0x6B, 0xA0, 0x37, 0x19, 0x8E,
                        0x41, 0xD6, 0xF8, 0x6F, 0xA4, 0x33, 0x1D, 0x8A, 0x1C, 0x8B, 0xA5, 0x32, 0xF9, 0x6E, 0x40, 0xD7,
                        0xFB, 0x6C, 0x42, 0xD5, 0x1E, 0x89, 0xA7, 0x30, 0xA6, 0x31, 0x1F, 0x88, 0x43, 0xD4, 0xFA, 0x6D,
                        0xF3, 0x64, 0x4A, 0xDD, 0x16, 0x81, 0xAF, 0x38, 0xAE, 0x39, 0x17, 0x80, 0x4B, 0xDC, 0xF2, 0x65,
                        0x49, 0xDE, 0xF0, 0x67, 0xAC, 0x3B, 0x15, 0x82, 0x14, 0x83, 0xAD, 0x3A, 0xF1, 0x66, 0x48, 0xDF,
                        0x10, 0x87, 0xA9, 0x3E, 0xF5, 0x62, 0x4C, 0xDB, 0x4D, 0xDA, 0xF4, 0x63, 0xA8, 0x3F, 0x11, 0x86,
                        0xAA, 0x3D, 0x13, 0x84, 0x4F, 0xD8, 0xF6, 0x61, 0xF7, 0x60, 0x4E, 0xD9, 0x12, 0x85, 0xAB, 0x3C};

// use this function to calculate CRC from 32-bit number

u8 crc8_4B(u32 bb)
 {
 u8 crc;
 u32 t;
 t = (bb >> 24) & 0x000000FF;
 crc = ((bb >> 16) & 0x000000FF);
 t = crc ^ tableCRC[t];
 crc = ((bb >> 8) & 0x000000FF);
 t = crc ^ tableCRC[t];
 crc = (bb & 0x000000FF);
 t = crc ^ tableCRC[t];
 crc = tableCRC[t];
 return crc;
 }

// use this function to calculate CRC from fixed length buffer

u8 CRC_Buffer(u8 NumOfBytes)  // parameter = how many bytes from buffer to use to calculate CRC
 {
 u32 t;
 u8 icrc;
 NumOfBytes -= 1;
 icrc = 1;
 t = Buffer[0];
 while (NumOfBytes--)
  {
  t = Buffer[icrc++] ^ tableCRC[t];
  }
 crc = tableCRC[t];
 return crc;
 }

example:

u8 Buffer[BufferLength];

crc_value = u8 CRC_Buffer(BufferLength);
```

Recommended literature:

- Painless guide to CRC error detection algorithm; Ross N. Williams.
- Cyclic Redundancy Code (CRC) Polynomial Selection For Embedded Networks; P. Koopman, T. Chakravarty

Appendix 2 - 6-bit CRC calculation with 0x43 polynome for BiSS

BiSS communication offers a CRC value to check the correctness of the data read from the encoder. This chapter gives an example of the CRC calculation on the receiver side. The CRC calculation must always be done over the complete set of data. The polynomial for the CRC calculation is $P(x) = x^6 + x^1 + 1$, also represented as 0x43.
Following code example must be modified to fit actual data length. Position data, error and warning bits must all be included into calculation in the same order as in the BiSS data packet. ACK, Start and CDS bits are not included in the CRC calculation.

Code example:

```
u8 tableCRC6[64] =  {
                      0x00, 0x03, 0x06, 0x05, 0x0C, 0x0F, 0x0A, 0x09,
                      0x18, 0x1B, 0x1E, 0x1D, 0x14, 0x17, 0x12, 0x11,
                      0x30, 0x33, 0x36, 0x35, 0x3C, 0x3F, 0x3A, 0x39,
                      0x28, 0x2B, 0x2E, 0x2D, 0x24, 0x27, 0x22, 0x21,
                      0x23, 0x20, 0x25, 0x26, 0x2F, 0x2C, 0x29, 0x2A,
                      0x3B, 0x38, 0x3D, 0x3E, 0x37, 0x34, 0x31, 0x32,
                      0x13, 0x10, 0x15, 0x16, 0x1F, 0x1C, 0x19, 0x1A,
                      0x0B, 0x08, 0x0D, 0x0E, 0x07, 0x04, 0x01, 0x02};

u8 crcBiSS(u32 bb)
 {
 u8 crc;
 u32 t;
 t = (bb >> 30) & 0x00000003;
 crc = ((bb >> 24) & 0x0000003F);
 t = crc ^ tableCRC6[t];
 crc = ((bb >> 18) & 0x0000003F);
 t = crc ^ tableCRC6[t];
 crc = ((bb >> 12) & 0x0000003F);
 t = crc ^ tableCRC6[t];
 crc = ((bb >> 6) & 0x0000003F);
 t = crc ^ tableCRC6[t];
 crc = (bb & 0x0000003F);
 t = crc ^ tableCRC6[t];
 crc = tableCRC6[t];
 return crc;
 }
```

Recommended literature:

- Painless guide to CRC error detection algorithm; Ross N. Williams.
- Cyclic Redundancy Code (CRC) Polynomial Selection For Embedded Networks; P. Koopman, T. Chakravarty

Head office

RLS merilna tehnika d.o.o.
Poslovna cona Žeje pri Komendi
Pod vrbami 2
SI-1218 Komenda
Slovenia

T +386 1 5272100
F +386 1 5272129
E mail@rls.si
www.rls.si

Document issues

Issue	Date	Page	Corrections made
1	18. 12. 2017	General	New document