AksIM

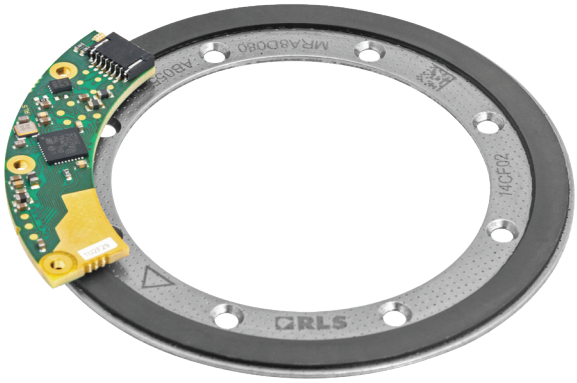
Off-Axis Rotary Absolute Magnetic Encoder

TRUE ABSOLUTE

CUSTOM MAGNETIC SENSOR ASIC

NO HYSTERESIS

AksIM™ 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 board level encoder system consists of an axially magnetised ring and a readhead board.



AksIM MBA encoder is not recommended for new designs. Please use AksIM-2. For more information please contact your local sales representative.

Features and benefits

- Resolutions up to 20 bits
- Multiturn counter option
- High speed operation
- Operation up to 690 bar pressure
- Low profile, non-contact
- Built-in self-monitoring
- Integrated status LED
- SSI, SPI, PWM, BiSS, I2C, asynchronous serial communication interfaces
- Corrosion resistant magnetic ring

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

General information

The AksIM™ board level encoder is specifically designed for integration into applications where there is no space for the classic AksIM™ readhead with T-shaped housing. An external case (provided by the customer) must serve as environmental protection of the encoder.

The 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 digital interfaces and are visualised with the on-board LED.
The 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 readhead board design service for OEM integration is also available.

AksIM MBA encoder is not recommended for new designs. Please use AksIM-2. For more information please contact your local sales representative.

Storage and handling

Storage temperature

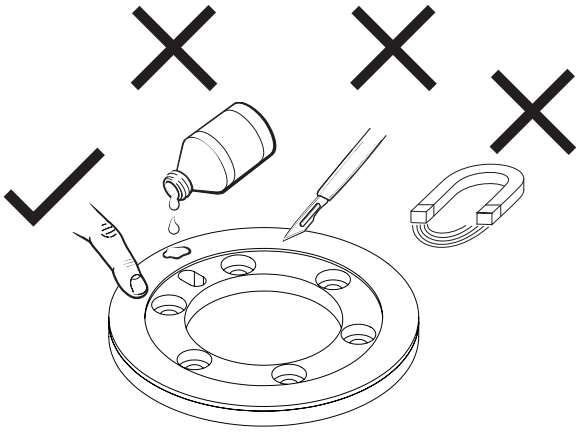
–40 °C to +100 °C

Operating temperature

–30 °C to +70 °C

Humidity

Up to 70 % non-condensing



HANDLE WITH CARE. This encoder system is a high performance metrology product and should be treated with the same care as any other precision instrument. Use of heavy duty industrial tools or exposure to strong magnets, such as a magnetic base, is unacceptable and risks of irreparable damage to the product.

The magnetic ring should not be exposed to magnetic field densities higher than 50 mT on its surface, as this can damage the ring.

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

Packaging

There are two packaging options. Less than 20 products are packed individually in an antistatic box. If more than 20 systems are ordered, the parts are packed in antistatic plastic trays. Magnetic rings and readheads are packed separately.

Bulk packaging:

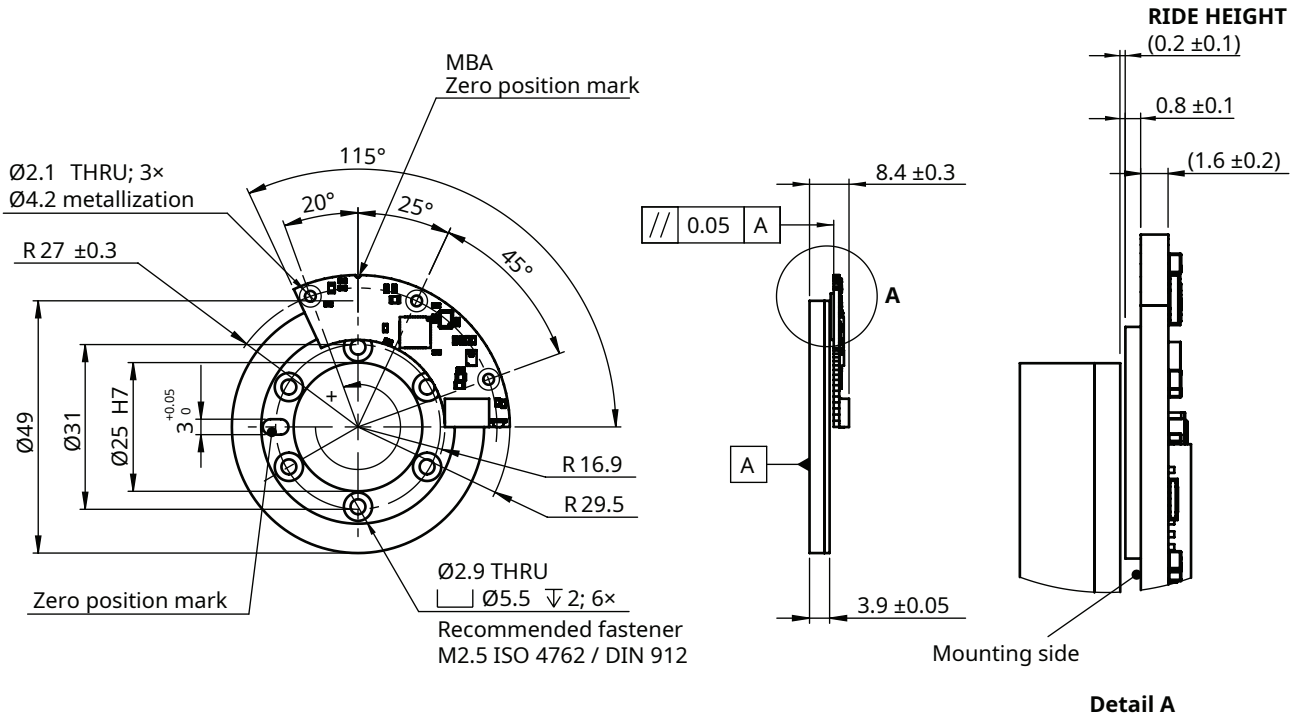
Readheads		
Part	**Tray size**	**Box size**
MBA7	20 units per tray	12 trays per box
MBA8		

Magnetic rings		
Part	**Tray size**	**Box size**
MRA7	10 units per tray	12 trays per box
MRA8	5 units per tray	

Dimensions and installation drawings

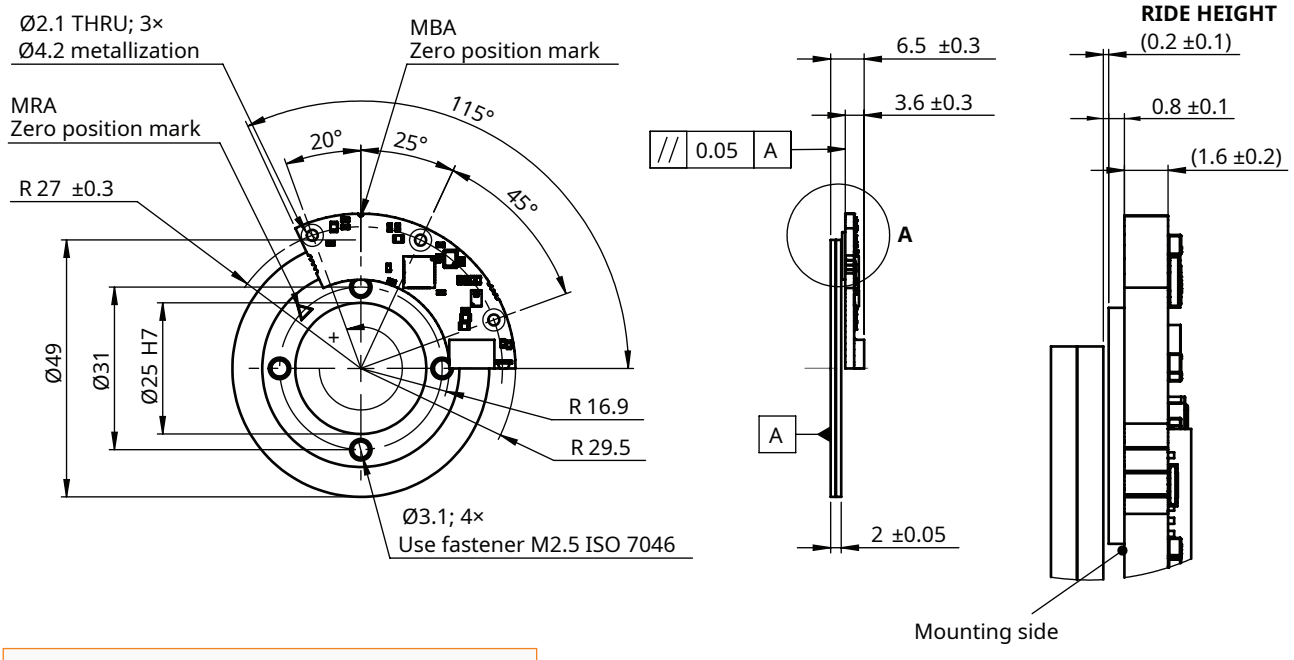
Dimensions and tolerances are in mm.

Encoder assembly MBA7 with MRA7D049AA025B00 ring



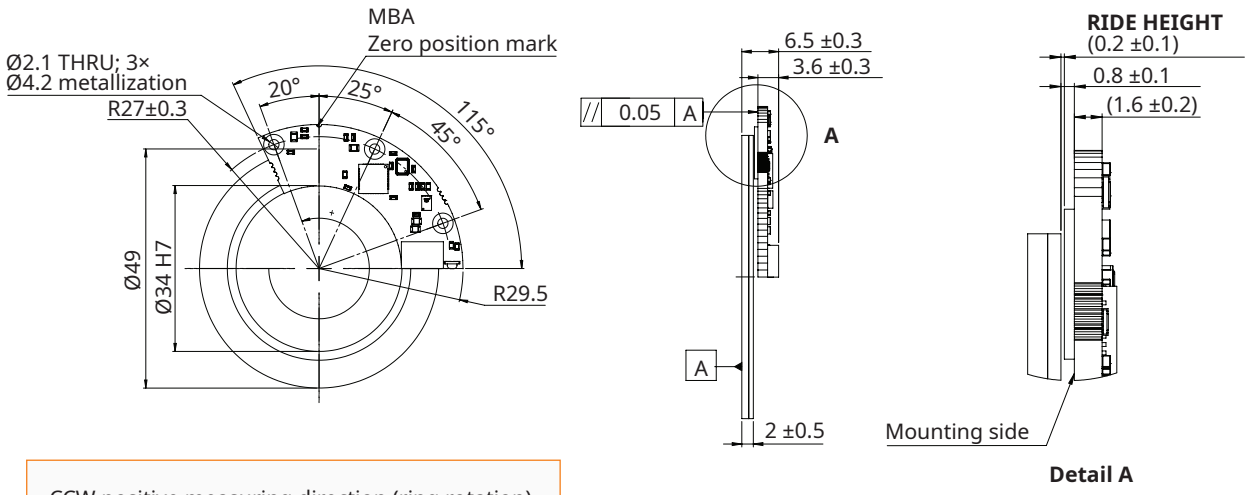
CCW positive measuring direction (ring rotation).

Encoder assembly MBA7 with MRA7D049AB025E00 ring



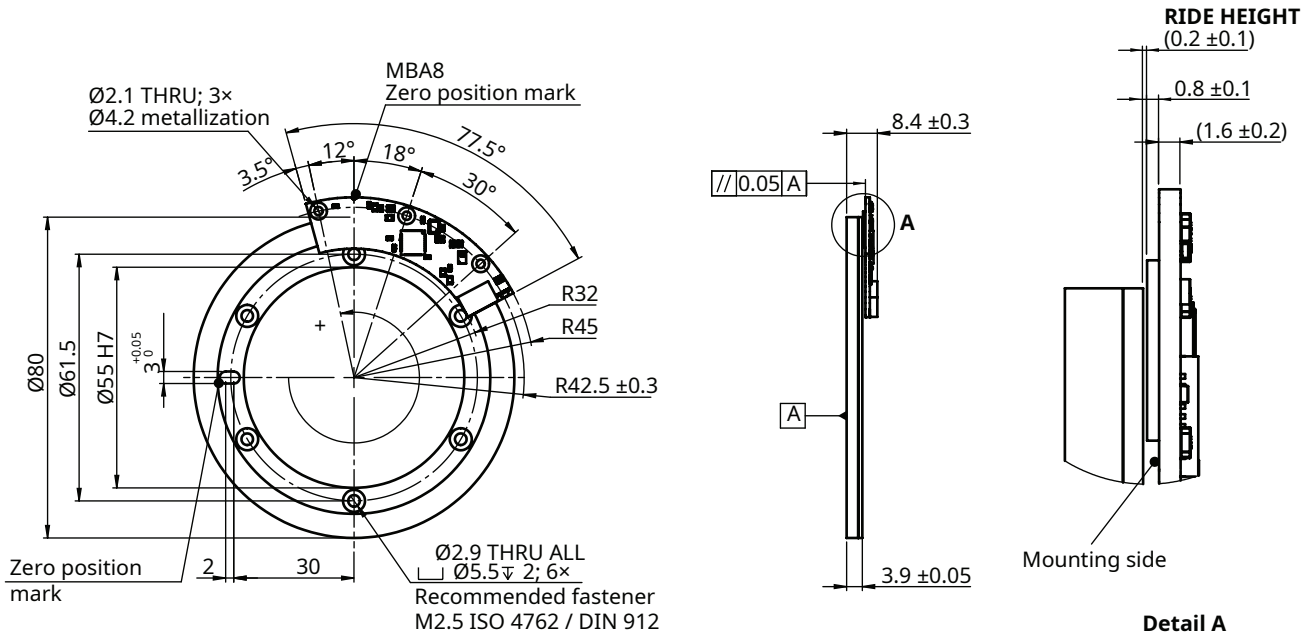
CCW positive measuring direction (ring rotation).

Encoder assembly MBA7 with MRA7D049AB034A00 ring



CCW positive measuring direction (ring rotation).

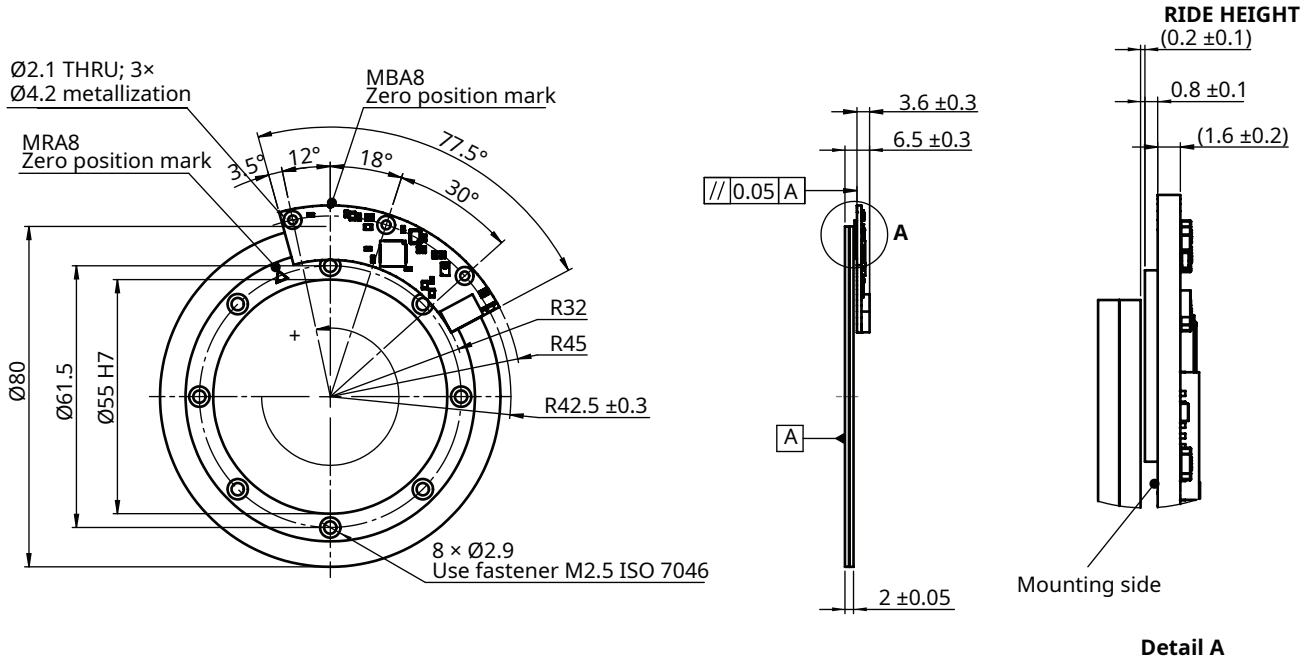
Encoder assembly MBA8 with MRA8D080AA055B00 ring



CCW positive measuring direction (ring rotation).

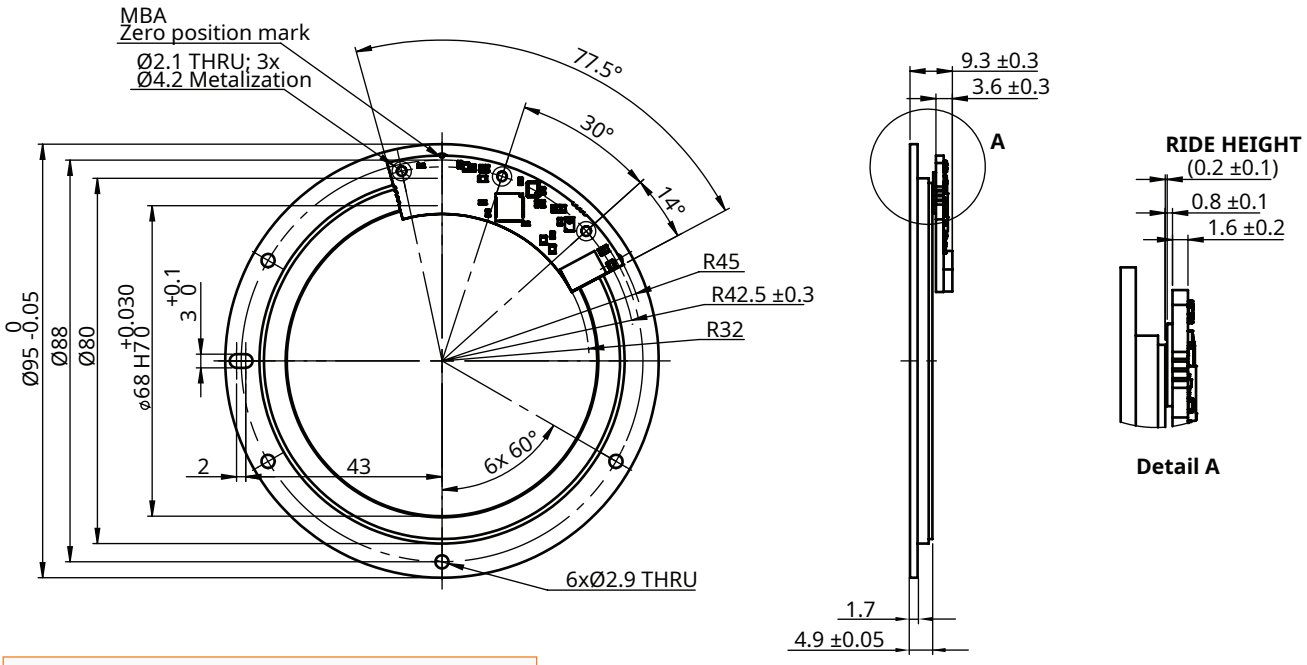
Dimensions and installation drawings continued

Encoder assembly MBA8 with MRA8D080AB055E00 ring



CCW positive measuring direction (ring rotation).

Encoder assembly MBA8 with MRA8D095AD068B00 ring



CCW positive measuring direction (ring rotation).

Technical specifications

System data

Reading type	Axial reading
Resolution	From 16 bit to 20 bit and 16 bit multiturn counter option (see chapter **Resolutions**)
Maximum speed	> 10,000 rpm
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**)
Hysteresis	Less than unit of resolution
Repeatability	Better than unit of resolution

Electrical data

Supply voltage	4 V to 6 V (3.3 V option available upon request)
Set-up time	10 ms (first data ready after switch-on)
Power consumption	Typ. 115 mA, max. 150 mA
Connection	FFC connector, 6 pins, 1 mm pitch Mating connector: standard FFC, 6 way, 1 mm pitch (can be ordered as ACC006)
Output load	Max. ±20 mA
ESD protection	HBM, Class 2, max. 2 kV

Mechanical data

Available ring sizes (outer diameter)		49 mm (ring MRA7), 80 mm (ring MRA8)	
Ring material type		EN 1.4005 / AISI416 or EN 1.4104 / AISI430F with glued rubber filled with ferrite particles	
Readhead thickness		4.3 mm	
System thickness		With MRA7D049AA025B00 or MRA8D080AA055B00	8.4 ± 0.3 mm
		With MRA7D049AB025E00 or MRA8D080AB055E00	6.5 ± 0.3 mm
Mass	Readheads	MBA7 2.6 g, MBA8 2.9 g;	
	Rings	MRA7D049AA025B00 32 g, MRA7D049AB025E00 15 g, MRA7D049AB034A00 11g, MRA8D080AA055B00 64 g, MRA8D080AB055E00 26 g, MRA8D095AD068B00 72 g	
Inertia		MRA7D049AA025B00 13.1 kg×mm^2, MRA7D049AB025E00 5.5 kg×mm^2, MRA7D049AB034A00 4.8 kg×mm^2, MRA8D080AA055B00 79.1 kg×mm^2, MRA8D080AB055E00 31.2 kg×mm^2, MRA8D095AD068B00 114 kg×mm^2	

Environmental data

Temperature	Operating	–30 °C to +70 °C
	Storage	–40 °C to +100 °C
Humidity		0 % to 70 % non-condensing
Environmental protection		None (conformal coating available upon request)
External magnetic field		Max. ±3 mT (DC or AC) on top side of readhead
Pressure		Up to 600 bar / 10,000 PSI (with a special option)

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 signal		Status
●	Green	Normal operation; position data is valid
●	Orange	Warning; position is valid, but the resolution and/or accuracy might be out of specification. Some operating conditions are outside limits.
●	Red	Error; position data is not valid
○	No light	No power supply

Installation instructions

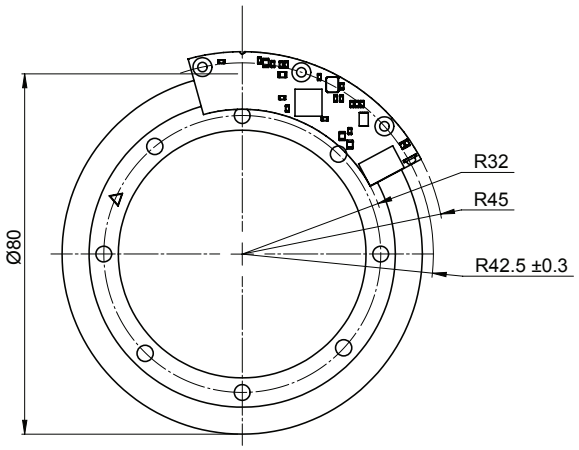
Axial position adjustment (ride height)

The nominal gap between the gold mounting areas on the PCB mounting side and the rubber band on the ring is 0.8 mm ±0.1 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. Only gold plated area around the mounting holes should be used as a mounting surface. Bottom side of the readhead, although it seems flat, is not controlled and might contain solder bumps. Also electrical signals may come into contact with mechanical parts and cause short circuits. Any non-magnetic 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 (Z) displacement (ride height)	0.2 mm nominal ±0.1 mm
PCB to ring distance*	0.8 mm ±0.1 mm
Radial (Y) displacement	±0.3 mm
Off center (X) displacement	±0.5 mm
Nonparalell 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 on MRA7	Worst case accuracy
H7/g6	±0.08°
H7/f7	±0.11°

Ring/shaft fit on MRA8	Worst case accuracy
H7/g6	±0.07°
H7/f7	±0.10°

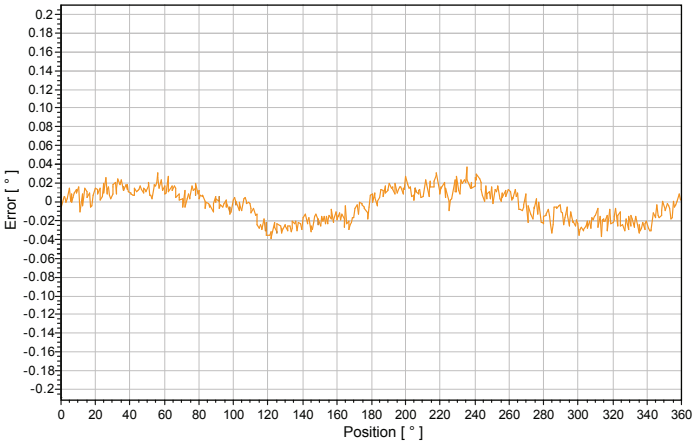
Accuracy of the encoder system

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 MRA8 rings or ±0.06° on MRA7 rings.

A typical accuracy plot after good installation of MRA8 is shown in the graph on the right.

For highest accuracy options **contact RLS**.



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 3 mT perpendicularly to the readhead it might affect accuracy. When bigger than 3 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.

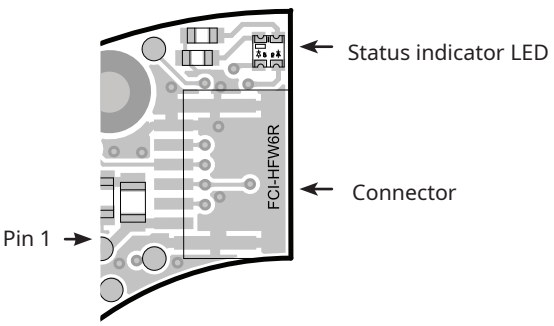
Electrical connections

FFC connector, 6 pins, 1 mm pitch, contacts on bottom side. All data signals are 3.3 V LVTTL. Inputs are 5 V tolerant.

Pin	Asynchronous serial	SPI slave simple	SPI slave advanced	I²C slave	SSI	BiSS	PWM
1	5 V supply	5 V supply	5 V supply	5 V supply	5 V supply	5 V supply	5 V supply
2	-	Status	-	-	-	-	OK
3	-	MISO	MISO	-	Data *	SLO *	Warning
4	TX data out	SCK	SCK	SCL	Clock *	MA *	PWM out
5	RX data in	$\overline{CS}$	$\overline{CS}$	SDA	-	-	-
6	0 V (GND)	0 V (GND)	0 V (GND)	0 V (GND)	0 V (GND)	0 V (GND)	0 V (GND)

* Single-ended signals. No line driver.
Second revision of the read heads (green color) has mounting holes isolated from the GND signal.

Pinout



Communication interfaces

Asynchronous serial RS422

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
Update rate	On demand or continuous
Resolution	See chapter **Resolutions**
Latency	200 µs

PWM

Base frequency	122.07 Hz, 244.14 Hz, 325.52 Hz, 488.28 Hz, 976.56 Hz
Update rate	Same as Base frequency
Resolution	16 bits
Latency	200 µs

SSI*

Maximum clock frequency	500 kHz standard 2.5 MHz with *Delay First Clock* function on the controller
Update rate	5 kHz
Resolution	See chapter **Resolutions**
Latency	200 µs to 400 µs
Timeout (monoflop time)	20 µs

BiSS

Maximum clock frequency	5 MHz
Maximum request rate	31 kHz (28 kHz multiturn counter option)
Bandwidth	2.5 kHz
Resolution	See chapter **Resolutions**
Latency	<10 µs
Timeout (monoflop time)	20 µs

SPI slave*

Maximum clock frequency	3 MHz
Update rate	5 kHz
Resolution	16 bits fixed (option S) or up to 20 bits (option A) - See chapter **Resolutions**
Latency	200 µs to 400 µs

I²C slave*

Maximum clock frequency	400 kHz
Update rate	5 kHz
Resolution	See chapter **Resolutions**
Latency	200 µs to 400 µs

* Slave type interfaces might not be suitable for high-speed closed control loops because of the variable latency time.
See "Latency" chapter on page 23 for detailed information.

Resolutions

Resolution	Ring MRA7	Ring MRA8
Binary	16 bits per revolution	16 bits per revolution
	17 bits per revolution	17 bits per revolution
	18 bits per revolution *	18 bits per revolution
	19 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

On selected digital interfaces additional 16 bit counter is available to count number of shaft turns (±32,768 turns). Counting is available only when encoder is powered. During initialization process after switch on multiturn counter is reset to zero. Currently available only via BiSS interface. Please see **Part numbering** for ordering information.

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. Data is transmitted LSB first; big-endian order.

Electrical connection

All data signals are 3.3 V LVTTL. Inputs are 5 V tolerant. Signal lines are single-ended. For connections to RS422 compatible controllers please use an external line driver (see Accessories section on page 26).

Communication parameters

Character length	8 bits
Parity	None
Stop bits	1
Repetition rate	5 kHz max. Transmission time lowers this frequency.
Position latency	Fixed at 200 µs between the position acquisition and first start bit sent out. Transmission time is not included here and should be added to calculate the loop time.

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 below.
Serial device that supports RS422 signal levels is required.

Procedure:
1. Mount the encoder according to the installation drawing. Green LED should be lit.
2. Set the serial device to the link speed of the encoder. See table above.
3. Send "v" command. Encoder should answer with a version string.
4. Send reconfiguration string. Details below.
   Encoder returns "FLASH 0" and restarts with the new settings.
   If encoder returns "RX_ERROR" and LED turns red the procedure was not successful. Power cycle and start from the beginning.
5. Change the serial device to the new link speed.
6. Send "v" command and verify encoder is operating correctly with the new link speed.

Configuration data to be sent:
1 byte: 0x62, fixed header
4 bytes: new link speed, LSB first (Big endian order)
4 bytes: new link speed, binary inverted
1 byte checksum of all previous 8 bytes + data byte counter

The sequence to set link speed to 115200 baud is (hex): 62 00 01 C2 00 FF FE 3D FF 04
Checksum is calculated from all data bytes + number of data bytes (=8).
New link speed can be any number. In an example above it is 0x1C200 (hex) = 115200 (dec) baud.
Data should not be sent in a burst, but separate bytes with 1 ms delay in between.

It is not possible to revert to factory settings. New settings are permanent until encoder is reprogrammed again with different settings.

Command set

Command "v" (0x76) - version request

Response - version info and serial number
5 bytes ASCII identification string ("AksIM")
1 byte ASCII space character
8 bytes ASCII serial number
16 bytes ASCII part number
1 byte binary firmware version
1 byte binary communication interface version (5)
1 byte binary ASIC revision
3 bytes ASCII resolution identifier

Command "1" (0x31) - single position data request

Response - position and status, transmitted once
1 byte header 0xEA
3 bytes binary absolute position, big-endian, left aligned
2 bytes encoder status – see below
1 byte constant footer 0xEF

The next request should not be sent sooner than 250 µs after the end of the previous response from the readhead to allow refreshing of the position data. If request is sent sooner, data will arrive at the end of the refresh cycle.

Command "2" (0x32) - continuous position data request

Response - position and status, transmitted continuously
1 byte constant header 0xEA
3 bytes binary absolute position, big-endian, left aligned
2 bytes encoder status – see below
1 byte constant footer 0xEF

Command "3" (0x33) - request for continuous position data with reduced length

Response - position and status, transmitted continuously
3 bytes binary absolute position, big-endian, left aligned
1 byte detailed encoder status – see below

Command "0" (0x30) - stop

Stop continuous transmission

Command "4" (0x34) - single position data request including velocity information

Response - position, status, and velocity transmitted once
1 byte header 0xEA
3 bytes binary absolute position, big-endian, left aligned, unsigned
2 bytes encoder status - see below
3 bytes binary velocity information, right aligned, signed
1 byte constant footer 0xEF

Velocity resolution: Number of counts per 1 microsecond multiplied by 65536.
Counts per second (CPS) = velocity × 106 / 216
Degrees per second (DPS) = CPS × 360 / 220 (at 20-bit resolution)

The next request should not be sent sooner than 250 µs after the end of the previous response from the readhead to allow refreshing of the position data. If request is sent sooner, data will arrive at the end of the refresh cycle.

Command "t" (0x74) - temperature request

Response - temperature of the encoder
1 byte signed binary number - temperature of the sensor in °C

Accuracy of the readings is ±3 °C
This function is available with firmware version 30 and higher (see command "v" for firmware version).

Structure of data packet

Encoder status (two bytes):		
	b15 : b10	Reserved, always zero
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		
	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.

PWM - Pulse width modulation interface

The PWM communication interface consists of two digital signals: the Status signal and the PWM Out signal. It is 3.3 V TTL compatible.

Electrical connection

The Status and PWM Out signals are 3.3 V TTL compatible.

Status signal

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

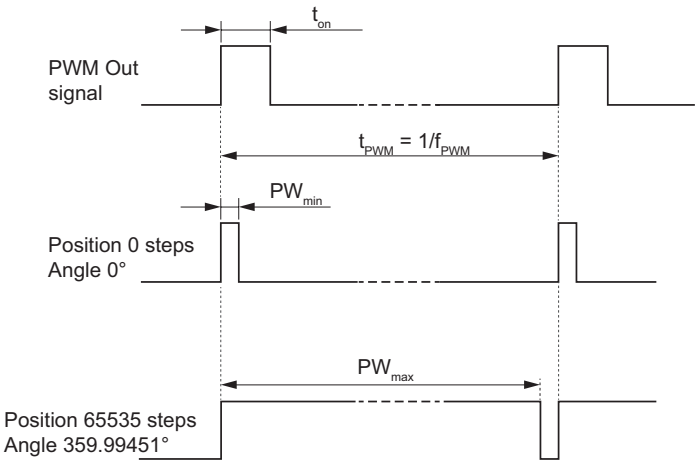
- Operation outside the installation tolerances
- Invalid or damaged magnetisation of the ring
- Sensor malfunction
- System error
- No power supply

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, it does not affect the currently transmitted position information.

PWM Out signal

The PWM Out is a pulse width modulation output with 16-bit resolution whose duty cycle is proportional to the measured position. The change of the pulse width by PWmin corresponds to a change in position by one count (change in angle 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	244.14	325.52	488.28	976.56	Hz	
Signal period	t_{PWM}	8,192.00	4,096.00	3,072.00	2,048.00	1,024.00	µs	
Minimum pulse width	PW_{min}	0.1250	0.0625	0.0469	0.0313	0.0156	µs	Position 0 (Angle 0°)
Maximum pulse width	PW_{max}	8,191.88	4,095.94	3,071.95	2,047.97	1,023.98	µs	Positions 65534 and 65535 *
Min. counter frequency	f_{CNTR}	8	16	21	32	64	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"

* Note that positions 65534 and 65535 (Angle 359.98901° and 359.99451°) result in the same pulse width PW_{max}.

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

SSI - Synchronous serial interface

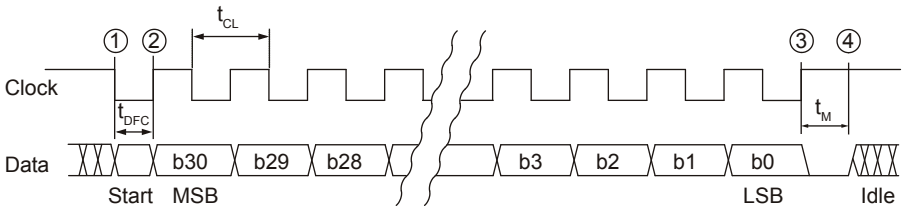
The encoder position, in up to 20 bit natural binary code, and the encoder status are available through the SSI protocol. The position data is left aligned. After the position data there are two general status bits followed by the detailed status information.

Electrical connection

All data signals are 3.3 V LVTTL. Inputs are 5 V tolerant. Signal lines are single-ended. For connections to RS422 compatible controllers please use an external line driver (see Accessories section on page 26).

Power supply must be applied at least 10 ms before the clock sequence is being sent to the encoder.
Clock line must be high during encoder power-up (or connected to the 10k pull-up resistor).

SSI timing diagram

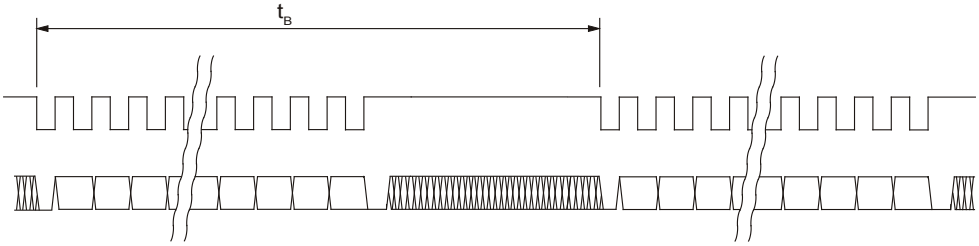


The controller interrogates the readhead for its position and status data by sending a pulse train to the Clock input. The Clock signal always starts from high. The first falling edge ① latches the last position data available and on the first rising edge ② the most significant bit (MSB) of the position 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.

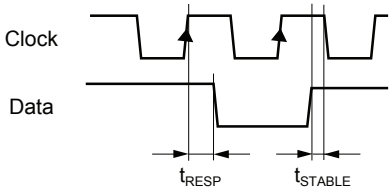
While reading the data the period t_{CL} must always be less than t_M. However, reading the encoder position can be terminated at any time by setting the Clock signal to high for the duration of t_M.

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.



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. The data signal must be stable for at least 10 % of clock period length before the value is latched.



SSI - Synchronous serial interface continued

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 *)
Monoflop time	t_M		20 µs	
Repetition rate	t_B	200 µs		
Readhead response delay	t_{RESP}		170 ns	

* 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
A	Start bit = 0; idle line = 0	Not recommended for new design
B	Start bit = 1; idle line = 1	Standard

Structure of data packet

Bit	b30 : b11	b10 : b9	b8 : b1	b0
Data length	20 bits	2 bits	8 bits	1 bit
Meaning	Encoder position	General status	Detailed status	Reserved

Encoder position

b30 : b11	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

b10	Error bit. If set, the position is not valid.
b9	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

b8	Warning - Signal amplitude too high. The readhead is too close to the ring or an external magnetic field is present.
b7	Warning - Signal amplitude low. The distance between the readhead and the ring is too large.
b6	Error - Signal lost. The readhead is out of alignment with the ring or the ring is damaged.
b5	Warning - Temperature. The readhead temperature is out of specified range.
b4	Error - Power supply error. The readhead power supply voltage is out of specified range.
b3	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.
b2	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.
b1	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.
b0	Reserved, always zero.

BiSS C interface

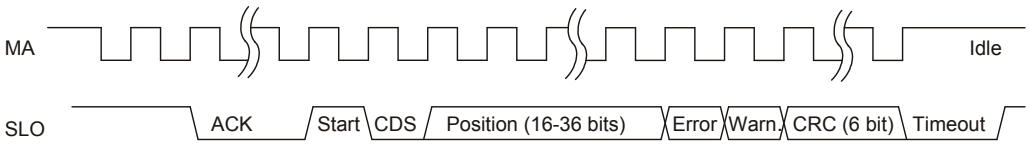
The encoder position, in up to 20 bit natural binary code, and the encoder status are available through the BiSS C protocol. The position data is left aligned. After the position data there are two status bits (active low) followed by CRC (inverted).

BiSS is implemented for point-to-point operation; multiple slaves are not supported.
Communication is unidirectional, the readhead is not user programmable and custom parameters can not be stored into the readhead.

Electrical connection

All data signals are 3.3 V LVTTL. Inputs are 5 V tolerant. Signal lines are single-ended. For connections to RS422 compatible controllers please use an external line driver (see Accessories section on page 26).
Power supply must be applied at least 10 ms before the clock sequence is being sent to the encoder.
Clock line must be high during encoder power-up (or connected to the 10k pull-up resistor).

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 12 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.
Multicycle data is not implemented, therefore CDS bit is always zero.

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
H	MA frequency	Max. 5 MHz

Parameter	Symbol	Worst case
Latency		<10 µs
Bandwidth *		2.5 kHz
Maximum request rate		31 kHz (28 kHz Multiturn counter option)
Timeout		20 µs
Readhead response delay	t_{RESP}	170 ns

* Bandwidth parameter is mechanical bandwidth. AksIM samples at 5 kHz therefore any mechanical changes that are appearing faster than 2.5 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.

Data packet description

Data packet length depends on the resolution and can be from 24 to 44 bits long. It consists of 16 bits for the multiturn counter (if selected) and 16 to 20 bits of Position selected by (resolution), followed by 2 Status bits and 6 CRC bits (see table below).

			Status		
Resolution	**Multiturn counter**	**Position**	**Error**	**Warning**	**CRC (inverted)**
16B	0 bits	16 bits	1 bit	1 bit	6 bits
17B		17 bits			
18B		18 bits			
19B		19 bits			
20B		20 bits			
16M	16 bits	16 bits	1 bit	1 bit	6 bits
17M		17 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: x6 + x1 + 1. Represented also as 0x43.
It is inverted and transmitted MSB first.
CRC calculation example is in application note document CRCD01, available for download from **RLS media center**.

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

SPI - Serial peripheral interface

The SPI interface is designed for communication with nearby devices.

Electrical connection

All data signals are 3.3 V LVTTL. Inputs are 5 V tolerant.

Signal	Description
$\overline{CS}$	Active low. $\overline{CS}$ line is used for synchronisation between master and slave devices. During communication it must be held low. Idle is high. Rising edge on $\overline{CS}$ signal resets the SPI interface.
SCK	Clocks out the data on rising edge. Max frequency 3 MHz at 1.5 m cable length.
MISO	Data is output on rising edge on SCK after $\overline{CS}$ low. Data is valid on the falling edge of SCK signal. During $\overline{CS}$=1 MISO line is in high-Z mode.
Status	Indicates normal operation (only available with S option).

Communication parameters

Communication interface variant in the part number defines the SPI interface type and all dependent parameters.

Communication interface variant	Description	Parameter	Value
S	SPI slave - simple mode	Resolution	Fixed - resolution in part number must be set as "16B"
		Status	Error status available on a separate wire
		Data length	16 bit data packet - position only
A	SPI slave - advanced mode	Resolution	Selectable (see part numbering)
		Status	All status bits are available through the SPI
		Data length	40 bit data packet - position, status, CRC
T	SPI slave - advanced mode with timestamp	Resolution	Selectable (see part numbering)
		Status	All status bits are available through the SPI
		Data length	56 bit data packet - position, status, timestamp, CRC

Parameter	Symbol	Min	Typ	Max	Note
Clock frequency	f_{CLK}	1 Hz		3 MHz	Max frequency with 1.5 m cable
Time after $\overline{CS}$ low to first CLK rising edge	t_S	2 µs			
Time after last CLK falling edge to $\overline{CS}$ high	t_H	1 µs			
$\overline{CS}$ high time	t_R	8 µs			Time to complete SPI reset
Read repetition rate	f_{REP}			5 kHz	If higher, the same position data might be transmitted twice

SPI slave - simple mode (variant S)

Structure of data packet

Data packet is 16 bits long. MSB first. Left aligned. Position only, no status bits. Only 16-bit resolution available. Repetition of reading is maximum 5000 times per second. If higher, it is possible to read the same position data twice.

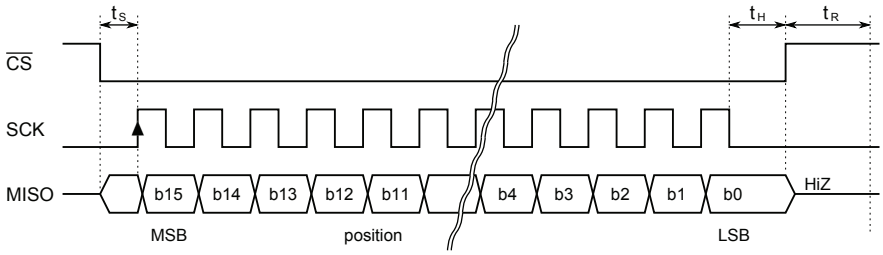
Status signal

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

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

When the Status signal is low, the data read through the SPI interface is invalid. The Status signal should be checked at the first rising edge of the SCK signal. If the Status signal changes during the data transmission, it does not affect the currently transmitted position information.

SPI slave timing diagram (variant S)



SPI slave - advanced mode (variant A)

Structure of data packet

Data packet is 40 bits long. MSB first. Position data is left aligned.
Repetition of reading is maximum 5000 times per second. If higher, it is possible to read the same position data twice.

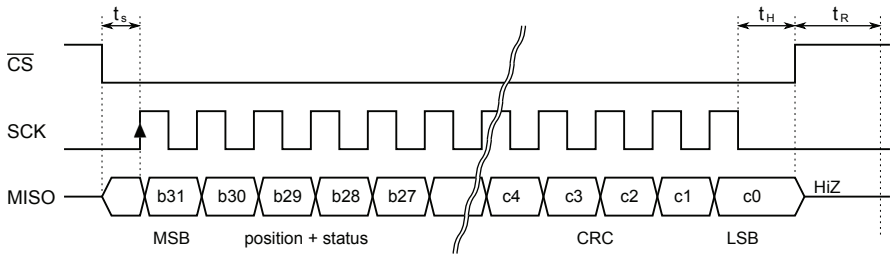
Bit	b31 : b12	b11 : b10	b9 : b2	b1 : b0	c7 : c0
Data length	20 bits	2 bits	8 bits	2 bits	8 bits
Meaning	Encoder position	General status	Detailed status	Reserved always 1	CRC

Encoder position	
b31 : b12	Encoder position, left aligned, MSB first. 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	
b11	Error. If bit is set, position is not valid.
b10	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 color 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	
b9	Warning - Signal amplitude too high. The readhead is too close to the ring or an external magnetic field is present.
b8	Warning - Signal amplitude low. The distance between the readhead and the ring is too large.
b7	Error - Signal lost. The readhead is out of alignment with the ring or the ring is damaged.
b6	Warning - Temperature. The readhead temperature is out of specified range.
b5	Error - Power supply error. The readhead power supply voltage is out of specified range.
b4	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.
b3	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.
b2	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.
CRC	
c7 : c0	CRC check with polynomial 0x97 - CRC calculation example is in application note document CRCD01, available for download from **RLS media center**.

Status signal

The Status signal is not available in Advanced mode.

SPI slave timing diagram (variant A)



SPI interface continued

SPI slave - advanced mode with timestamp (variant T)

Structure of data packet

Data packet is 56 bits long. MSB first. Position data is left aligned.
Repetition of reading is maximum 5000 times per second. If higher, it is possible to read the same position data twice.

Bit	b31 : b12	b11 : b10	b9 : b2	b1 : b0	t15 : t0	c7 : c0
Data length	20 bits	2 bits	8 bits	2 bits	16 bits	8 bits
Meaning	Encoder position	General status	Detailed status	Reserved always 1	Timestamp	CRC

Encoder position

b31 : b12	Encoder position, left aligned, MSB first. 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

b11	Error. If bit is set, position is not valid.
b10	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 color 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

b9	Warning - Signal amplitude too high. The readhead is too close to the ring or an external magnetic field is present.
b8	Warning - Signal amplitude low. The distance between the readhead and the ring is too large.
b7	Error - Signal lost. The readhead is out of alignment with the ring or the ring is damaged.
b6	Warning - Temperature. The readhead temperature is out of specified range.
b5	Error - Power supply error. The readhead power supply voltage is out of specified range.
b4	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.
b3	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.
b2	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.

Timestamp

t15 : t0	Time between latch of mechanical position and $\overline{CS}$ falling edge in 1/4 µsec. Resolution is 0.25 µs.

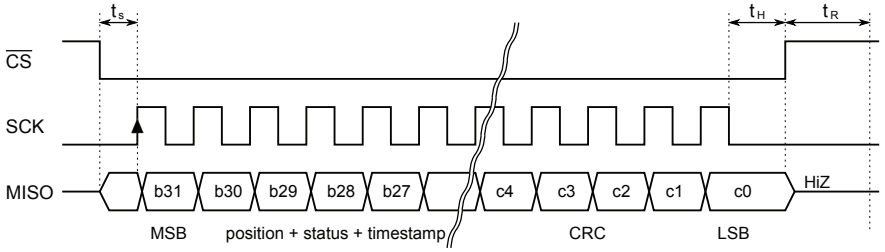
CRC

c7 : c0	CRC check with polynomial 0x97 - CRC calculation example is in application note document CRCD01, available for download from **RLS media center**.

Status signal

The Status signal is not available in this mode.

SPI slave timing diagram (variant T)



I²C / TWI interface

Inter-integrated circuit interface or Two-wire interface on AksIM encoders supports read-only access of position data including status bits and CRC for data transmission verification. Interface supports standard and fast speed modes. Encoder works as a slave unit on a multi-drop bus. Slave address is factory preset to 0x18 and can be reprogrammed by user.

Electrical connection

All data signals are 3.3 V LVTTL. Inputs are 5 V tolerant. Pull-up resistors must be installed externally.

Signal	Description
SCL	Master clock. Max clock frequency is 400 kHz in fast mode.
SDA	Slave out. MSB first.

Parameter	Symbol	Min	Typ	Max	Note
Clock frequency	f_{CLK}	100 kHz		400 kHz	Master clock frequency.
Read repetition rate	f_{REP}		5 kHz		Time to update a new position. If higher, the same position data might be transmitted twice

Output type variant must be selected as “A”.

I²C Timing diagram (slave transmitter)

Start condition is generated by the master for starting the communication.
ACK (acknowledge): if address is correct, slave generates ACK.
When each data is received, master sends ACK.
At the end of transaction master sends NACK (not acknowledge) and stop condition.

Structure of data packet

Complete data packet is 32 bits long + 8 bits of CRC. MSB first. Position data is left aligned.
Repetition of reading is maximum 5000 times per second. If higher, it is possible to read the same position data twice.

Address is 7 bits long + Read / Write bit. (Read – LSB is set, Write – LSB is reset). Factory preset address is 0x18.
Data section consists of 4 bytes and CRC is 1 byte long.
Data byte 1 = MSB bits of position
Data byte 2 = Middle bits of position
Data byte 3 = LSB bits of position + MSB bits of status
Data byte 4 = LSB bits of status + reserved bits
After each data ACK must be sent.
CRC calculation is performed on all 4 data bytes. Polynomial for CRC calculation is 0x97. For details how to calculate CRC please see Appendix 1 of this document.

If status and CRC data are not needed, master can terminate the communication after every byte with NACK and Stop condition. For example if only 16 bits of position are needed, Master should send Start condition, Address, read first two bytes of data and generate NACK and Stop.

I²C / TWI interface continued

Number of bits in different sections of data packet:

Resolution	Position	Reserved0*	Status			Reserved1*	CRC
			Error	Warning	Status		
16B	16 bits	4	1 bit	1 bit	8 bits	2 bits	8 bits
17B	17 bits	3					
18B	18 bits	2					
19B	19 bits	1					
20B	20 bits	/					

* Reserved0 bits are always 0. Reserved1 bits are always 1.

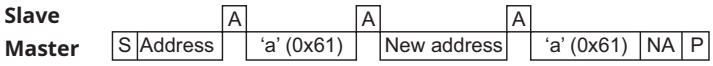
Encoder position	
b31 : b12	Encoder position, left aligned, MSB first. If the encoder resolution is lower than 20 bits, the last few bits of the encoder position, which are not used, are set to zero.
General status	
b11	Error. If bit is set, position is not valid.
b10	Warning. If bit is set, encoder 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 color 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	
b9	Warning - Signal amplitude too high. The readhead is too close to the ring or an external magnetic field is present.
b8	Warning - Signal amplitude low. The distance between the readhead and the ring is too large.
b7	Error - Signal lost. The readhead is out of alignment with the ring or the ring is damaged.
b6	Warning - Temperature. The readhead temperature is out of specified range.
b5	Error - Power supply error. The readhead power supply voltage is out of specified range.
b4	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.
b3	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.
b2	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.
CRC	
c7 : c0	CRC check with polynomial 0x97 - CRC calculation example is in application note document CRCD01, available for download from **RLS media center**.

Changing slave address

Address of the AksIM encoder on the I²C bus can be changed by writing special sequence to it.
After transmit sequence is complete encoder will store new address into non-volatile memory and immediately switch to the new address. This process should not be repeated more than 1000 times. After writing new address the I²C bus must be idle for 10 ms.

I²C new address sequence (slave receiver)

S – Start condition
A – Acknowledge
'a' – Header and footer for changing address
NA – Not Acknowledge
P – Stop condition



Latency on Asynchronous serial communication

Readhead has its internal cycle of acquiring position that is running at 5 kHz (±10 %). One cycle takes 200 µs. This does not depend on the request frequency.
Controller sends the request. If the request arrives into the readhead just after new cycle has started, it will take 200 µs for the new position to be ready. It is transmitted to controller, always at the end of the cycle. In this case there will be 200 µs of delay between request and answer (transmission time is not taken into account).
If the request arrives into the readhead just before the end of the cycle, the position is just ready and response will be transmitted instantly. Position was acquired 200 µs ago at the beginning of the cycle.

Second mode is continuous transmission after every cycle. In this mode there is no need to query the encoder for position but it sends it immediately when it is ready.
When the controller receives the first bit of the data position it is 200 µs old. This time is constant (±10 %). The additional delay is due to time needed to complete the data transmission. This varies depending on the selected bit-rate.

(Per special request timing information and/or speed can be provided in the same data packet as position.)

Latency on other slave type interfaces (SSI, SPI slave)

All interfaces transmit the last valid data available.
Internal cycle of the encoder is 200 µs. This is the delay from the time when the mechanical position is latched by the sensor to when the data is ready to be transmitted over the interface.
If the request comes right after the data is ready, latency will be 200 µs.
If request comes just before the new data will be calculated, then latency is 400 µs.

For example:
At t = 0 µs the physical position is latched but position data is not yet calculated. It will be available at 200 µs.
If the request comes at t = 1 µs – 199 µs, the last available data will be sent - the one from previous cycle when position was latched at t = –200 µs.

Latency on BiSS interface

BiSS uses a different approach and calculation so the request rate can be higher than 5 kHz. Typically, request rate can be up to 30 kHz. Position is latched at the first falling edge on the MA (clock) line and calculated instantly, therefore latency is shorter than 10 µs.

Part numbering

AksIM MBA encoder is not recommended for new designs. Please use AksIM-2. For more information please contact your local sales representative.

Readhead

MBA 7 SG A 16B C 42 C 00

Series
MBA - AksIM board-level readhead

MRA ring compatibility
7 - For use with MRA7 ring
8 - For use with MRA8 ring

Communication interface
DD - BiSS C, no line driver
FC - I²C / two wire interface
PW - Pulse Width Modulation (PWM)
SD - Synchronous serial interface (SSI), no line driver
SG - Asynchronous serial
SP - SPI slave, LVTTL

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

For **DD**: **H** - BiSS C, low lateny, 12 ACK bits, max. 5 MHz
For **FC**: **A** - Standard
For **SP**: **L** - Pulse Width Modulation (PWM), LVTTL
For **PW**: Base frequency in Hz (16 bits resolution only):

A	B	C	D	E
122	244	325	488	976

For **SD**: **A** - Start bit and idle data line 0 (NRND)
B - Start bit and idle data line 1 (standard)

For **SG**: Link speed in kbps:

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

For **SP**: **A** - SPI slave advanced
S - SPI slave simple
T - SPI slave advanced with timestamp

Resolution
For **PWx** and **SPS:**
16B - 16 bits per revolution
For **DDH, FCA, SDx, SGx, SPA** and **SPT:**
16B - 16 bits per revolution
17B - 17 bits per revolution
18B - 18 bits per revolution
19B - 19 bits per revolution
20B - 20 bits per revolution
(For MBA8 readhead only)

Multiturn counter options
16M - 16 bits per revolution + 16 bits multiturn counter
17M - 17 bits per revolution + 16 bits multiturn counter
18M - 18 bits per revolution + 16 bits multiturn counter
19M - 19 bits per revolution + 16 bits multiturn counter
20M - 20 bits per revolution + 16 bits multiturn counter
(For MBA8 readhead only)

Housing
C - Partial arc, axial installation (standard)

Ring main diameter
42 - 42 mm (For MBA7 readhead only)
73 - 73 mm (For MBA8 readhead only)

Connector option
C - FFC connector, 1 mm pitch, 6 way, bottom contacts

Special requirements
00 - No special requrements (standard)

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

Table of available combinations

Series	Ring compatibility	Communication interface	Communication interface variant	Resolution	Housing	Ring main diameter	Connector option	Special requirements
MBA	7	DD	H	16B / 17B / 18B / 19B / 20B / 16M / 17M / 18M / 19M	C	42	C	00
		FC	A					
		PW	A / B / C / D / E	16B				
		SD	A / B	16B / 17B / 18B / 19B / 20B / 16M / 17M / 18M / 19M				
		SG	A / B / C / D / E / F					
		SP	A / T					
			S	16B				
	8	DD	H	16B / 17B / 18B / 19B / 20B / 16M / 17M / 18M / 19M / 20M	C	73	C	
		FC	A					
		PW	A / B / C / D / E	16B				
		SD	A / B	16B / 17B / 18B / 19B / 20B / 16M / 17M / 18M / 19M / 20M				
		SG	A / B / C / D / E / F					
		SP	A / T					
			S	16B				

Magnetic ring

MRA 7 D 049 A A 025 B 00

Series
MRA - AksIM magnetic ring

MRA ring type
7 - For use with MRA7 readhead
8 - For use with MRA8 readhead

Accuracy grade
D - ±0.1°

Outer diameter
049 - 49 mm
080 - 80 mm
095 - 95 mm

Material
A - Stainless steel with glued rubber bonded ferrite

Cross section
A - 3.9 mm thick
B - 2 mm thick, lightweight
D - 4.9 mm thick

Inner diameter
025 - 25 mm
034 - 34 mm
055 - 55 mm
068 - 68 mm

Zero position
B - Marked by additional hole in metal hub
E - Engraved
A - No marking

Special requirements
00 - No special requrements (standard)

Not all part number combinations are valid. Please refer to the table of available combinations below.

Table of available combinations

Series	MRA ring type	Accuracy grade	Outer diameter	Material	Cross section	Inner diameter	Zero position	Special requirements
MRA	7	D	049	A	A / B	025	B	00
						025	E	
						034	A	
	8		080			055		
						055	E	
			095		D	068	B	

Accessories

Cable
ACC006, FFC flat cable, 152 mm length, 6 way, 1 mm pitch

Adapter
ACC009, 6-pin, 1 mm pitch FFC to DSUB 9-pin adapter with RS422 line driver for BiSS and SSI, with housing

Adapter
ACC010, 6-pin, 1 mm pitch FFC to DSUB 9-pin adapter with RS422 line driver for BiSS and SSI, without housing

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Global support

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Document issues

Date	Issue	Page	Description
22. 11. 2021	**10**	-	New design
		24	Timestamp definition amended

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