AksIM-4™ Dual Stacked
Off-Axis Rotary Absolute Magnetic Encoder

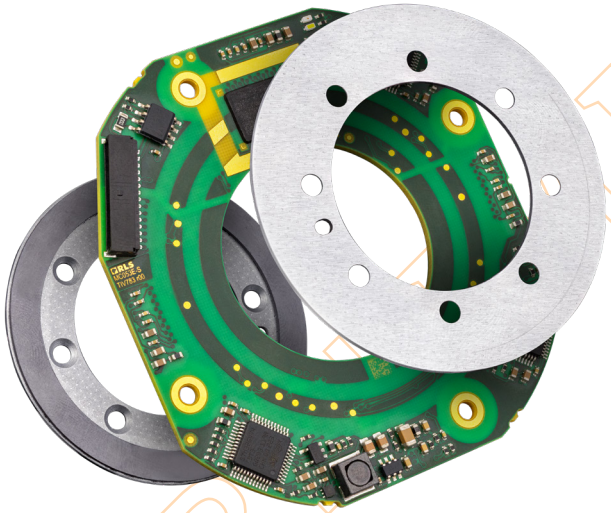
2 IN 1 POSITION FEEDBACK

HIGH ACCURACY & REPEATABILITY

COMPACT INTEGRATION

The AksIM-4 Dual Stacked high-performance encoder comprises a central readhead with a magnetic ring on each side. One side reads its ring with two sensors, combining both readings into an enhanced position with ring eccentricity compensated. The other side reads its ring with one sensor.

Its compact, space-saving design suits advanced robotics and other space-constrained installations, while the multi-sensor architecture delivers the accuracy and reliability required for the most demanding applications.



PRELIMINARY

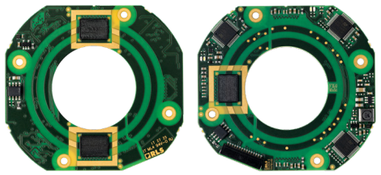
Features and benefits

- Two-in-one encoder solution
- Ultra-compact, low-profile design
- Plug and play solution
- Immunity to external magnetic fields
- Saves space
- Reduces complexity in robotic joints
- Immediate feedback at power-up
- Reliable performance in demanding environments

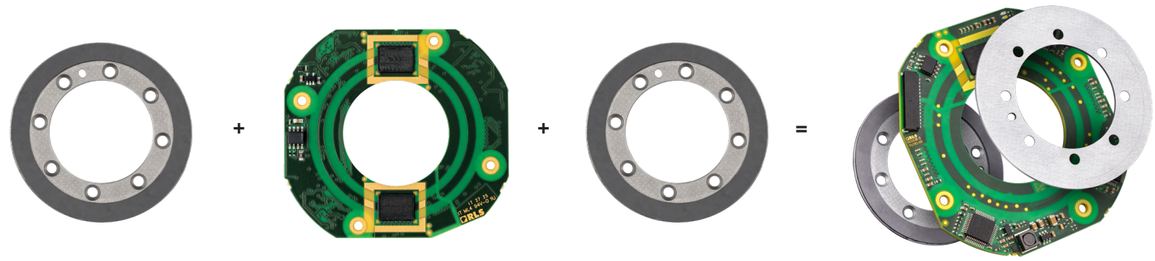
COLLABORATIVE & INDUSTRIAL ROBOTS | SURGICAL ROBOTS | HUMANOID ROBOTS | ROBOTIC JOINTS | MEDICAL

General information

The AksIM-4 Dual Stacked high-performance encoder consists of a central readhead with a magnetic ring on each side. The double-sensor side reads its ring with two sensors, combining both readings to provide an enhanced position with ring eccentricity compensated. The single-sensor side reads its ring with one sensor.



Double-sensor side Single-sensor side



MRA axial magnetic ring + MD readhead + MRA axial magnetic ring = AksIM Dual Stacked system

Selection guide	Magnetic ring					Readhead					
Part number	**Inner diameter**	**Circle for fasteners**	**Outer diameter**	**Thickness**	**Inertia (kg × mm²)**	**Inner diameter**	**Circle for fasteners**	**Outer diameter**	**Arc length**	**System thickness (Typ.)**	**Mass (g)**
MD053 assembly											
MD053						32.5	62	75	360°	7.75	14.1
MRA053	30	36	53	2	7.4						15

All dimensions in mm.

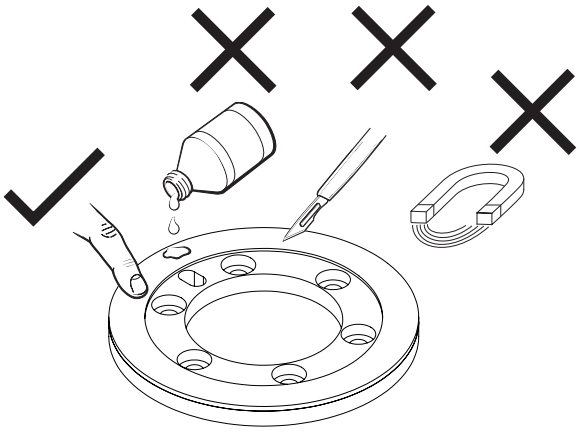
Storage and handling

Operating and storage temperature

–40 °C to +120 °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 causing irreparable damage to the product.

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

Please see **Chemical resistance** or **contact RLS**.



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

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Technical specifications

System data

Reading type	Axial reading
Maximum speed	7,500 rpm
Hysteresis	Less than unit of resolution
Repeatability	Within the range of position noise
Encoder speed	12.5 kHz bandwidth, 32 kHz sampling rate, up to 44 kHz refresh rate
Thermal drift	None (accuracy does not change with temperature)

Resolution	**Single-sensor side**	**Double-sensor side**
Binary	22 bit per revolution	23 bit per revolution

Accuracy		**Single-sensor side**	**Double-sensor side**
System accuracy		±0.006°	±0.006°
Typical installed accuracy	**Calibrated**	±0.012°	N/A (automatic eccentricity compensation)
	Uncalibrated	±0.040°	±0.007°

Total installed accuracy without calibration is influenced by mounting precision (e.g. eccentricity and bearing wander).

Accurate centering of the ring is key to good overall accuracy. Minimising the eccentricity of the ring assembly (using a gauge) and using a drive shaft with precision bearings can usually reduce the error. Double-sensor side automatically compensates the eccentricity. For single-sensor side, to improve accuracy after installation, we recommend performing self-calibration.

Electrical data

Supply voltage (V_{in})	Single-sensor side: 4.5 V to 5.5 V at the connector Double-sensor side: 4.5 V to 5.5 V at the connector
Set-up time	100 ms (first data ready after supply voltage is in range), worst case: 200 ms
Current consumption	Single-sensor side: 130 mA Double-sensor side: 250 mA
Connection	15-pin low-profile connector or board-to-board connector
Output load	RS422: ±40 mA
ESD protection	HBM, Class 2, ±2 kV (valid only on RS422 signals on connector; do not touch other components)

Mechanical data

Ring material type	EN 1.4016 / AISI430 with glued rubber filled with ferrite particles

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Environmental and operational conditions

Environmental data

Operating and storage temperature	–40 °C to +120 °C
Humidity	Up to 70 % non-condensing (for higher with conformal coating **contact RLS**)
External magnetic field	±15 mT
Shock	100 g (6 ms, half-sine, EN 60068-2-27:2009)
Vibration	80 g (55 Hz - 2000 Hz, EN 60068-2-6:2008)
Environmental compliance	RoHS, REACH

Chemical resistance

RLS products are commonly used in industrial applications and are exposed to chemicals that can affect their internal and external components. Although our products are designed to withstand many harsh chemicals and environments, long-term resistance depends on exposure, temperature and concentration. Most chemicals product encounters are applied briefly, not continuously. A material that cannot withstand prolonged immersion may still perform indefinitely under occasional, short-term exposure.

External magnetic field

Magnetic encoders operate by detecting changes in the magnetic field of a magnetised ring. In typical applications, nearby magnetic sources such as motors do not affect performance when the encoder is properly integrated.
In a dual-stacked configuration (ring – readhead – ring), the rings naturally act as shields between the motor and the readhead, reducing the influence of stray magnetic fields. In most applications, no additional shielding is required. If unusually strong magnetic fields are present, simple shielding, such as a thin ferromagnetic plate, can be placed between the source and the readhead.
During handling and storage, avoid placing strong magnetic objects near the ring, as they may affect its magnetic properties. Magnetic fields above 50 mT can permanently damage the ring.

Operation in high-pressure applications

The encoder can be operated at ambient pressures of up to 600 bar. Typical applications include ROV submarines where the entire system is submerged in oil.

Operation in ultra-high-vacuum applications

AksIM encoders are suitable for operation in ultra-high-vacuum environments down to 1.0×10^{-7} Pa. The encoders were tested for outgassing under ultra-high-vacuum conditions with test parameters similar to those in the ECSS-Q-ST-70-02C (2008) and ASTM E595-15 (2021) standards. No critical outgassing was detected. The relative mass loss (RML) of the ring and readhead was 0.01 % and 0.09 %, respectively. The ultra-high-vacuum test had no effect on the performance of the encoder.

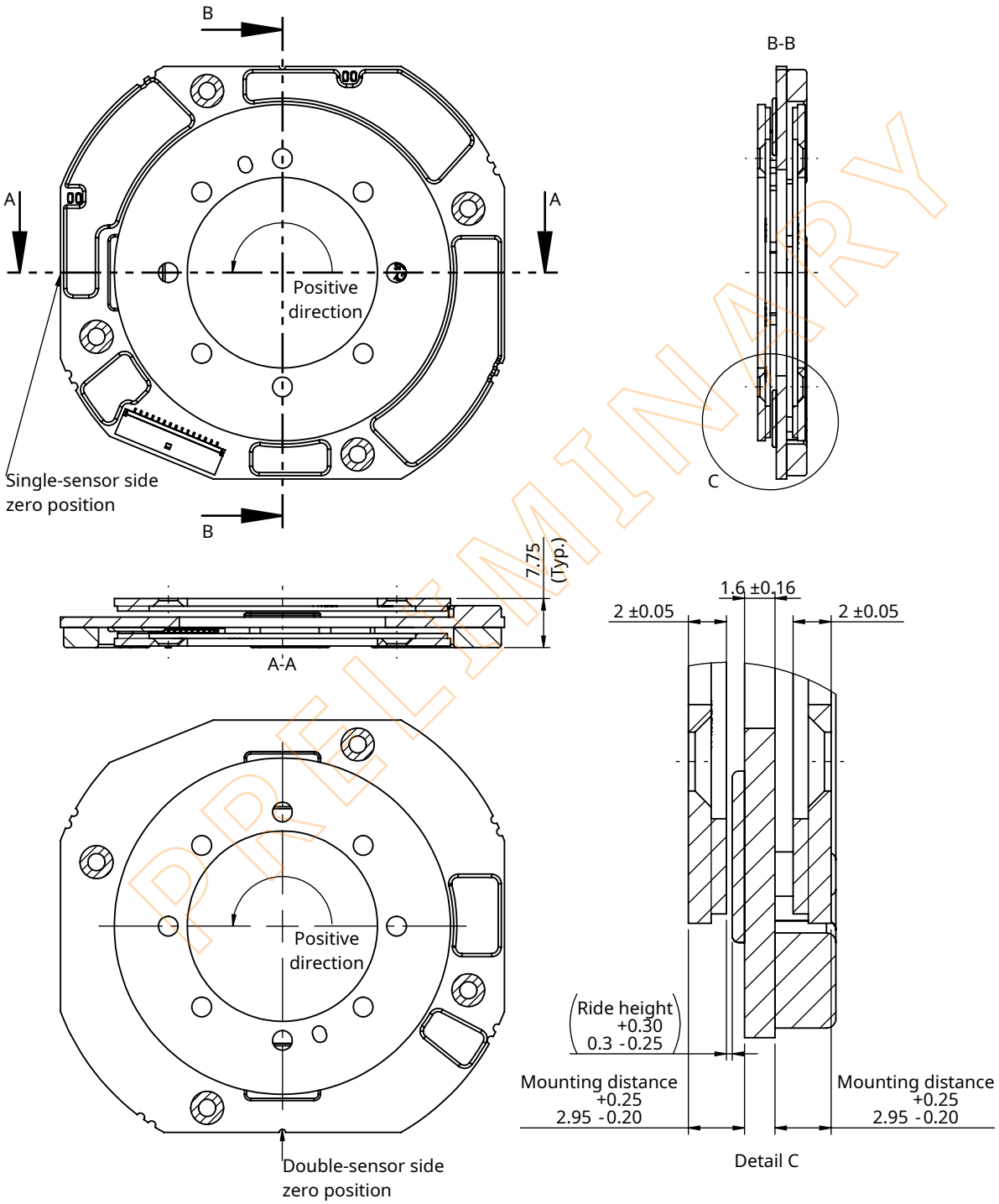
For additional details, please **contact RLS.**

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Dimension and installation drawings

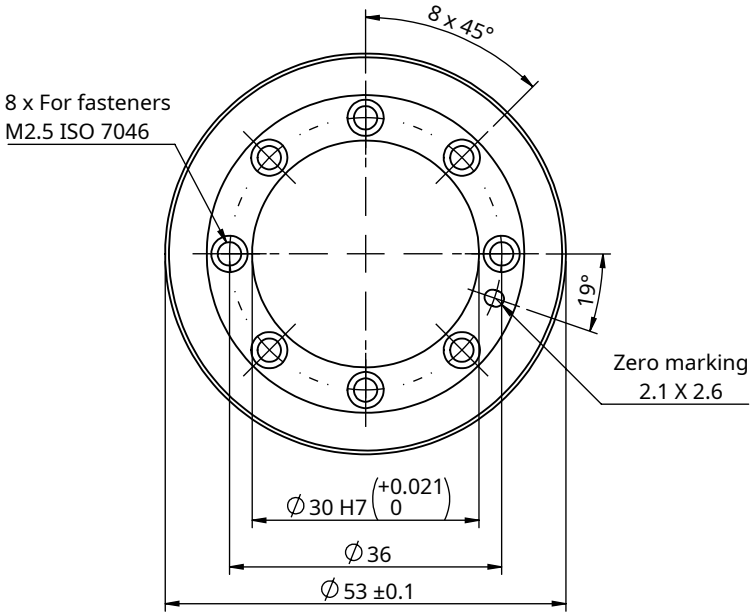
Dimensions and tolerances are in mm. Dimensions without tolerance values are in accordance with ISO 2768-m.

Encoder assembly MD053E readhead with two MRA053 magnetic rings



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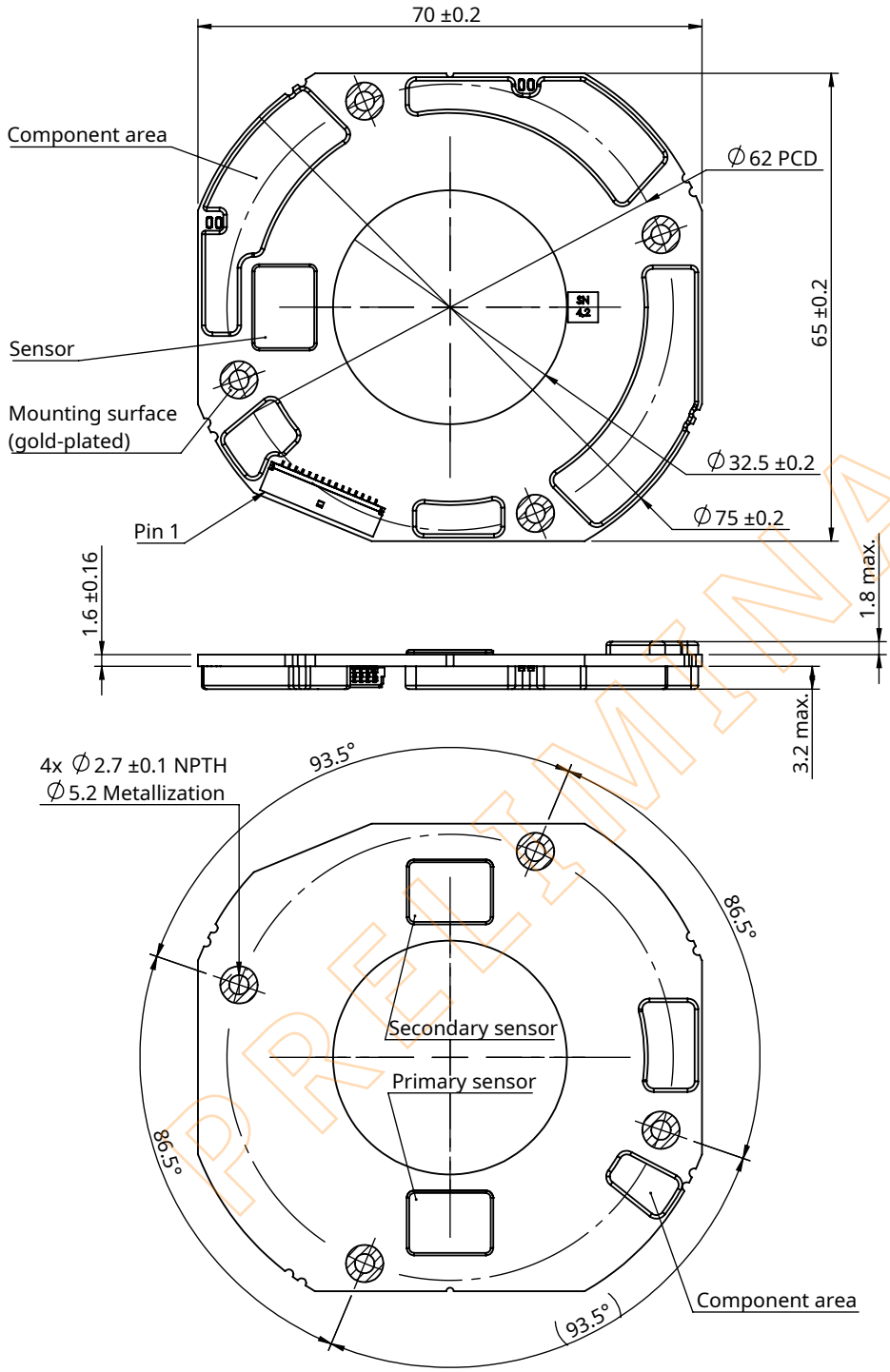
MRA053 magnetic ring



PRELIMINARY

Dimensions and installation drawings continued

MD053E readhead



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Installation instructions

Axial position adjustment (ride height)

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

The integrated LED can be used as an indicator. If the ride height is within the installation tolerances, the indicator LED will be green and will not change when the ring rotates. The center of the ring and the center of the readhead arc must be coaxial. The permissible installation tolerances are given in the table below. Precise centering of the ring is essential, as the eccentricity of the ring mounting plays a major role in the overall accuracy.

Installation tolerances (readhead to ring)

Axial displacement / ride height	See detail A on **dimension drawings** of encoder assemblies. Tight ride height (tight mounting distance) is recommended. **Increasing the ride height exponentially increases encoder noise even if it is within installation tolerances.**	
Tangential displacement of the readhead	±0.3 mm	
Radial displacement of the readhead	±0.5 mm	
Non-parallel mounting	Tilt angle <0.2°	

For additional information about installation types and ring properties, see the data sheet MRAD01 available at **RLS Media center**.

AksIM-4 installation video

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Measuring ride height between the ring and the readhead

Option 1: For a ready-to-use ride height (air gap) measurement, connect the encoder to a PC via the E201 interface and view the value directly using the RLS software. See chapter **Accessories**.

Option 2: The signal level information read out via communication interface can be used to calculate the ride height (distance between rubber on the ring and sensor on the readhead).

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

$$\text{Ride height} = K \times \text{Ln}(\text{SignalLevel}) + N$$

Ln stands for natural logarithm.
K and N are depending on the encoder size and can be read from the register access.*
SignalLevel value can be read from the register access.*
Calculated ride height has tolerance of ±20 µm.
* For more information **contact RLS**.

Installation tolerances (ring to shaft)

Recommended shaft tolerance is g6. See table of recommended tightening torques for RLS products (document TTD01) available at **RLS media center**.

Self-calibration after installation

Only applicable to the single-sensor side of encoder.

The self-calibration function eliminates the error caused by eccentricity, which is a dominant contributor to the accuracy of the encoder and is caused by the eccentric mounting of the ring. It cannot compensate for the magnetisation error between different rings. The Subdivisional Error (SDE) is negligible with AksIM. This function removes the error from one sine wave per revolution. The self-calibration function can be initiated by the user via selected communication interfaces or by using the appropriate USB encoder interface. Refer to the description of the selected communication interface for details.

Requirements:

- Free mechanical rotation of 360°
- Good signal over the entire calibration angle.
- Maximum time available is 40 seconds.
- Variation of direction and speed are not important. Minimum speed depends on self-calibration timeout value. Default is 6 rpm.
- Suitable communication interface or adapter that enables the function to be triggered.

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

LED		Self-calibration status
🟢🟢🟢🟢🟢	Green flashing fast	Self-calibration succesfully performed.
🟠🟠🟠🟠🟠	Orange flashing fast	Ring positioning is already perfect - correction was not performed.
🔴🔴🔴🔴🔴	Red flashing fast	Self-calibration not performed. Possible reasons: • Eccentricity or radial offset is very high. • Timeout. Ring is rotating too slowly (<6 rpm). • Any error present during self-calibration procedure.

Explainer video: AksIM-4 self-calibration feature

Refer to the selected communication interface chapter for more details, as each interface supports different calibration capabilities.

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Description of encoder operation

The AksIM-4 Dual Stacked encoder consists of a central two-sided readhead with a magnetic ring on each side. One side of the readhead carries a single sensor (single-sensor side); the other side carries two sensors (double-sensor side).

On the single-sensor side, the sensor reads the absolute position directly from its magnetic ring.

On the double-sensor side, two sensors – Primary and Secondary – read the absolute position of the second magnetic ring. The two readings are combined into a single enhanced position with ring eccentricity compensated. If one of the two sensors is compromised, the encoder continues to output a valid position from the remaining sensor and raises a warning flag; see **Double-sensor side status**.

Each side outputs its position separately: the single-sensor side position is transmitted in one BiSS frame, and the enhanced position from the double-sensor side in a second BiSS frame, each over dedicated pins.

Double-sensor side status

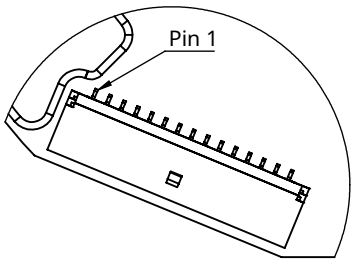
General status	Encoder output	Status combination
-	Enhanced position (ring eccentricity compensated)	Primary sensor: OK Secondary sensor: OK
Warning	Enhanced position (ring eccentricity compensated)	Primary sensor: OK or WARNING Secondary sensor: OK or WARNING
Warning	Primary sensor position only	Primary sensor: OK or WARNING Secondary sensor: ERROR
Warning	Secondary sensor position only	Primary sensor: ERROR Secondary sensor: OK or WARNING
Error + Warning	Position replaced with final detailed status (see Detailed status)	Primary sensor: ERROR Secondary sensor: ERROR
Error + Warning	Position replaced with final detailed status (see Detailed status)	Unplausible position, or acceleration error on Primary sensor/Secondary sensor channel

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Electrical connections

Right-angle connector pinout

	Connector pin	RS422 (BiSS)
Single-sensor side	1	SLO–
	2	SLO+
	3	MA+
	4	MA–
	5	V_{in}
	6	GND
	7	NC
Double-sensor side	8	SLO–
	9	SLO+
	10	MA–
	11	MA+
	12	NC
	13	NC
	14	GND
	15	V_{in}

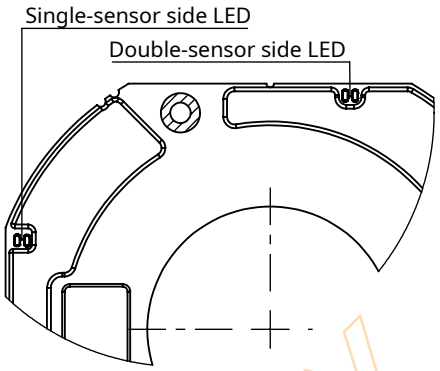


Right-angle 15-pin low profile connector part number
Samtec T1M-15-GF-S-RA-FR

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Status indicator LEDs

Two separate LED's are available, one for the Single-sensor side and one for the Double-sensor side. The LED's provide visual feedback on signal strength, error status, and are used for setup and diagnostics. Flashing LED indicates that power is being supplied to the encoder, but communication has not been established. When communication is running at a rate of at least 5 readings per second, LED will be constantly lit.



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

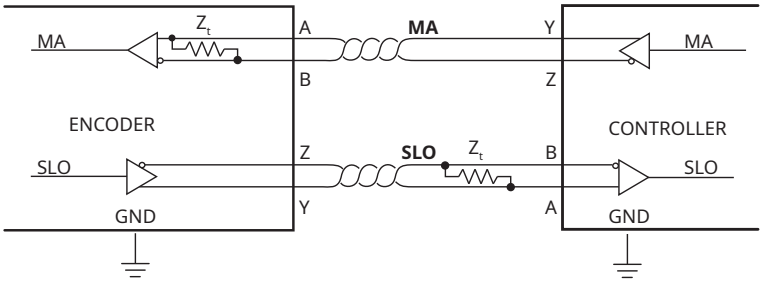
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BiSS C interface

Encoder position in natural binary code and encoder status are available via the BiSS C protocol. The position data is followed by two status bits (active low) followed by CRC (inverted).

BiSS is implemented for point-to-point operation, multiple slaves are not supported. Communication is bidirectional, the readhead is user programmable. Additional data can be read from the readhead.

Electrical connection

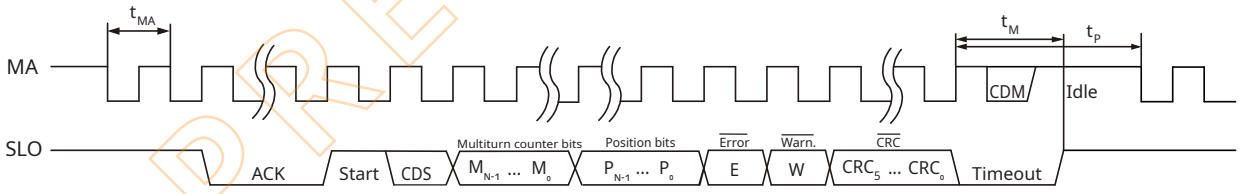


The signal MA is Master Clock with a maximum frequency of 5 MHz and SLO is Slave Out, whose data is transmitted on the rising edges on the line MA. The MA and SLO lines are 5 V RS422 compatible differential pairs. The RC termination on the MA line is built into in the encoder. If the total cable length exceeds 5 m, termination on the controller is required. The nominal impedance of the cable should be 120 Ω.

Output protection

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

BiSS C timing diagram



Data package description

Data	Length (N)	Description
M_{N-1} - M_0	0 bits	Multiturn counter value, 16 bit (length 0 when single turn option is selected)
P_{N-1} - P_0	22 or 23 bits	Absolute position inside one revolution
E	1 bit	Error status bit; inverted (for double-sensor side status explanation see chapter “Double-sensor side status”)
W	1 bit	Warning status bit; inverted (for double-sensor side status explanation see chapter “Double-sensor side status”)
CRC_5 - CRC_0	6 bits	Cyclic redundancy check; polynomial 0x43; inverted

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Communication parameters

Parameter	Symbol	Min	Typ	Max
MA period	t_{MA}	200 ns		2.5 µs
MA frequency	$f_{MA} = 1/t_{MA}$	400 kHz		5 MHz
ACK length	ACK		13 bits	
Transfer timeout	t_M		13 µs	
Pause time	t_P	t_M + 1 µs		
Latency				5 µs
Mechanical bandwidth*				12.5 kHz
Mechanical sample rate				32 kHz
Maximum request rate				44 kHz (singleturn)

* AksIM samples at 25 kHz, so mechanical changes faster than 12.5 kHz cannot be detected at the output (Nyquist theorem). If the position request comes faster than the sampling frequency, the encoder recalculates the position at the time of the request based on the current ring velocity.

If number of clocks from master is less than specified, SLO within timeout is not necessarily in low state.

First valid frame is expected after encoder set-up time.

The request cycle starts with MA in idle state (MA is high). Its first falling edge initiates communication. The encoder responds by setting SLO to low on the second rising edge on the MA line and generating the ACK signal (Acknowledge). When the encoder is ready for the next request cycle, it indicates this to the master by setting SLO to high. The absolute position and the CRC data are available in binary format and are initially transmitted in MSB format.

Encoder data packet structure

For singleturn

Bit	Status	Description
b30 : b8	Encoder position	MSB first (for 23 bit resolution)
b7	Error	If low, the position data is not valid.
b6	Warning	If low, the position data is valid, but some operating conditions are close to limits.
b5 : b0		Inverted CRC, calculated by using 0x43 polynomial

When error is active (error bit is low) singleturn position data (b30 : b8) is replaced (b23 : b8) by detailed status bits (see table on next page). Detailed status bits are right aligned, so that b0 of the status matches b8 of the encoder data packet. When the warning bit is active, the position data remains valid.

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Single-sensor side detailed status (replaces position data while error bit is active)

Bit	Status	Description
b15	Reserved	
b14	Warning	Temperature out of range. The readhead temperature is out of specified range (T_{min}, T_{max}).
b13	Warning	Signal amplitude low. The distance between the readhead and the ring is too large.
b12	Warning	Signal amplitude high. The readhead is too close to the ring.
b11	Warning	Signal decoding below certain threshold - position decoding might be inaccurate or fail.
b10	Warning	Overspeed. Ring rotation speed is too high.
b9	Error	Multiturn counter error (value always 0 when singleturn option is selected)
b8	Error	Acceleration error. The position data changed unexpectedly. A stray magnetic field is present or metal particles are present between the readhead and the ring.
b7	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.
b6	Error	Signal lost. The readhead is out of alignment with the ring or the ring is damaged.
b5	Error	Signal amplitude too high. External magnetic field is present.
b4	Error	System error. Malfunction inside the circuitry. To reset the System error bit try to cycle the power supply while the rise time is shorter than 20 ms.
b3	Error	Internal power supply error
b2	Error	System error. 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	Reserved	
b0	Reserved	

Double-sensor side detailed status (replaces position data while error bit is active)

Bit	Status	Description
b15	Reserved	
b14	Warning	Position difference warning. The position difference between channels exceeds the specified tangential offset threshold.
b13	Warning	Signal amplitude low. The distance between the readhead and the ring is too large.
b12	Warning	Signal amplitude high. The readhead is too close to the ring.
b11	Warning	Accuracy may be out of specification.
b10	Warning	Overspeed. Ring rotation speed is above the specified threshold.
b9	Warning	Multiturn counter mismatch. The encoder was rotated more than ±90° during power-down. Cycle the power supply to clear this warning.
b8	Error	Acceleration error. The position data changed unexpectedly. A stray magnetic field is present or metal particles are present between the readhead and the ring.
b7	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.
b6	Error	Signal lost. The readhead is out of alignment with the ring or the ring is damaged.
b5	Error	Signal amplitude too high. External magnetic field is present.
b4	Error	System error. Malfunction inside the circuitry. To reset the System error bit, cycle the power supply.
b3	Error	Power supply error.
b2	Error	Position difference error. The position difference between both channels exceeds the specified threshold.
b1	Error	Temperature out of range. The readhead temperature is out of specified range (Tmin, Tmax). The readhead may be damaged as a consequence.
b0	Reserved	

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Encoder programming

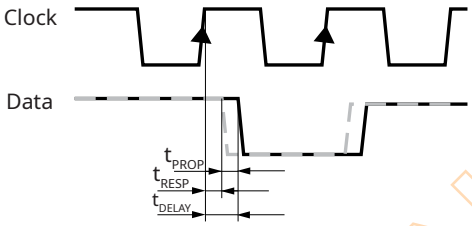
For certain communications encoder supports register access which allows setting zero position, running self-calibration function, configuring the encoder, reading signal level indicator, temperature and detailed status bits. For more information **contact RLS.**

Cable length compensation

The readhead needs 60 ns to respond to incoming clocks (t_{RESP}). The change on the Data signal is delayed by 60 ns after the rising edge on the Clock line. An additional delay is caused by the time the signal takes to propagate through the cable to the readhead and back (t_{PROP}). This delay is typically 14 ns per 1 meter cable. The total cable length from the encoder to the receiver must be considered.

The total delay (t_{DELAY}) is calculated as in the formula below.

A proper implementation of BiSS Master should automatically measure t_{DELAY} and adjust the internal timing to compensate for it. BiSS Master without compensation for cable delay will work even with short wiring (up to 1 meter at 5 MHz clock frequency).



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

PRELIMINARY

Part numbering

Readhead

MD 053E DB JH R S B M 00

Series
MD - Dual AksIM-4 board-level readhead

MRA ring compatibility
053E - For use with MRA053 and MRA rings

Communication protocol combination
DB - Double-sensor side: BiSS C, RS422 and
Single-sensor side: BiSS C, RS422

Resolution combination
JH - Double-sensor side: 23 bit per revolution,
Single-sensor side: 22 bit per revolution

Option
R - Standard

Dual type and connector orientation
S - Stacked dual, radial connector exit

Connector option
B - Samtec T1M-15-GF-S-RA-FR

Option
M - High pressure/vacuum and temperature range –40 °C to +120 °C, extended ride height

Special requirements
00 - No special requirements (standard)

For more dimensions and configurations please **contact RLS.**

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Readhead part number combinations

MD053EDBJHRSBM00 (currently available as an engineering sample 999-0634-01)

Magnetic ring

MRA 053 B C 030 A H H 00

Series
MRA - AksIM magnetic ring

Outer diameter and readhead compatibility
053 - 53 mm

Thickness
B - 2.0 mm

Installation type
C - Countersunk holes type A (use flat-head fasteners DIN 965 / 7046)

Inner diameter
030 - 30 mm

Magnetization type
A - AksIM-4, ring OD ≥ 049, extended ride height

Material
H - Stamped metal plate with HNBR rubber

Zero marking
H - Hole

Special requirements
00 - No special requirements (standard)

For more dimensions and configurations please **contact RLS.**

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Ring part number combinations

MRA053BC030AHH00 (currently available as an engineering sample 999-0563-00)

Accessories

Illustrative

Cable assembly, 1 m
999-0675-00 (Engineering Sample PN)

See chapter **Cable assemblies**.



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



Magnet viewer
MM0001

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**
MD053E	TBD	TBD

Magnetic rings		
Part	**Tray size**	**Box size**
MRA053	10 units per tray	12 trays per box

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Cable assemblies

Cable specifications

Part numbers	999-0675-00, an engineering sample (cable length: 1 m)
Compatibile readhead	Readhead with connector option “D”
Connector 1	15-pin, SAMTEC ISS1-15
Connector 2	2 × DSUB-9 M

Connector 1		**Connector 2**			
Pin number		**Pin number**		**BiSS C**	**Wire colour**
		Connector 2-A (Single-sensor side)	1	/	Shield
Connector 1	1		7	SLO–	Yellow
	2		6	SLO+	Green
	3		2	MA+	Red
	4		3	MA–	Blue
	5		5	V_{inA} (5V)	Brown
	6		9	GND	White
	7		/	NC	/
	8	**Connector 2-B (Double-sensor side)**	7	SLO–	Yellow
	9		6	SLO+	Green
	10		3	MA–	Blue
	11		2	MA+	Red
	12		/	NC	Pink
	13		/	NC	Gray
	14		9	GND	White
	15		5	V_{inB} (5V)	Brown
			1	/	Shield

PRELIMINARY

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Document issues

Issue	Date	Page	Description
1	24. 8. 2026	-	New document

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