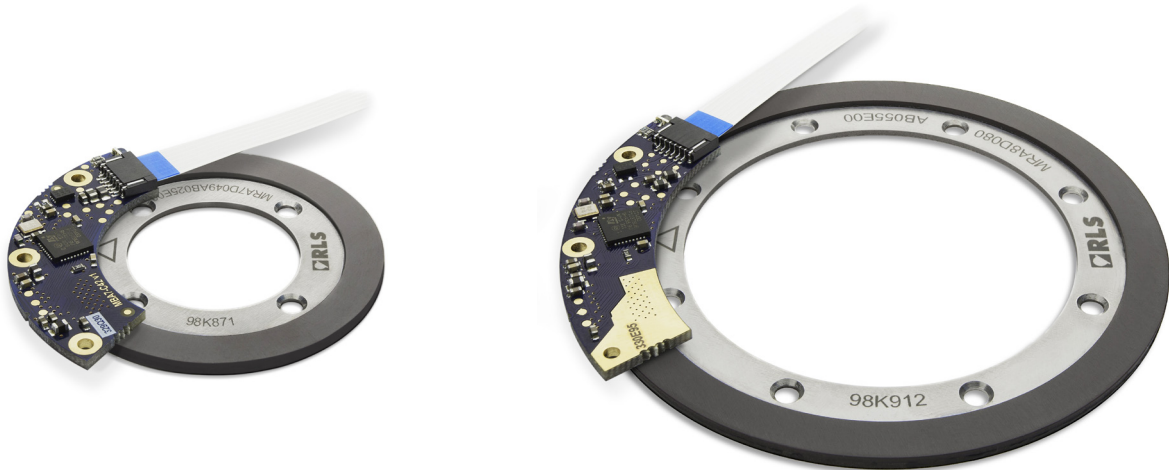


AksIM™ rotary absolute encoder module



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

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.

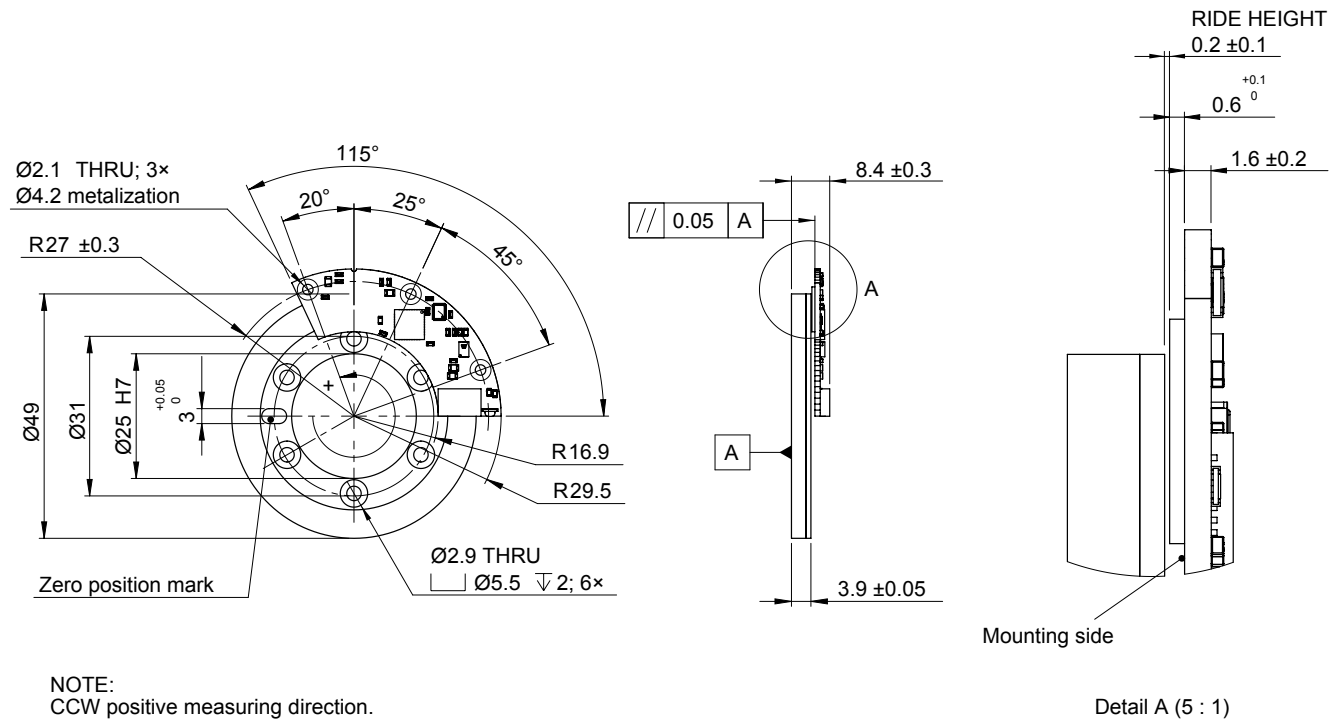
- True absolute system
- Custom magnetic sensor ASIC
- No hysteresis
- Resolution to 20 bits
- High speed operation
- Low profile, non-contact
- Built-in self-monitoring
- Integrated status LED
- SSI, SPI, PWM, BiSS, asynchronous serial communication interfaces
- I²C available upon request
- Corrosion resistant magnetic ring

Data sheet
MBAD01_04

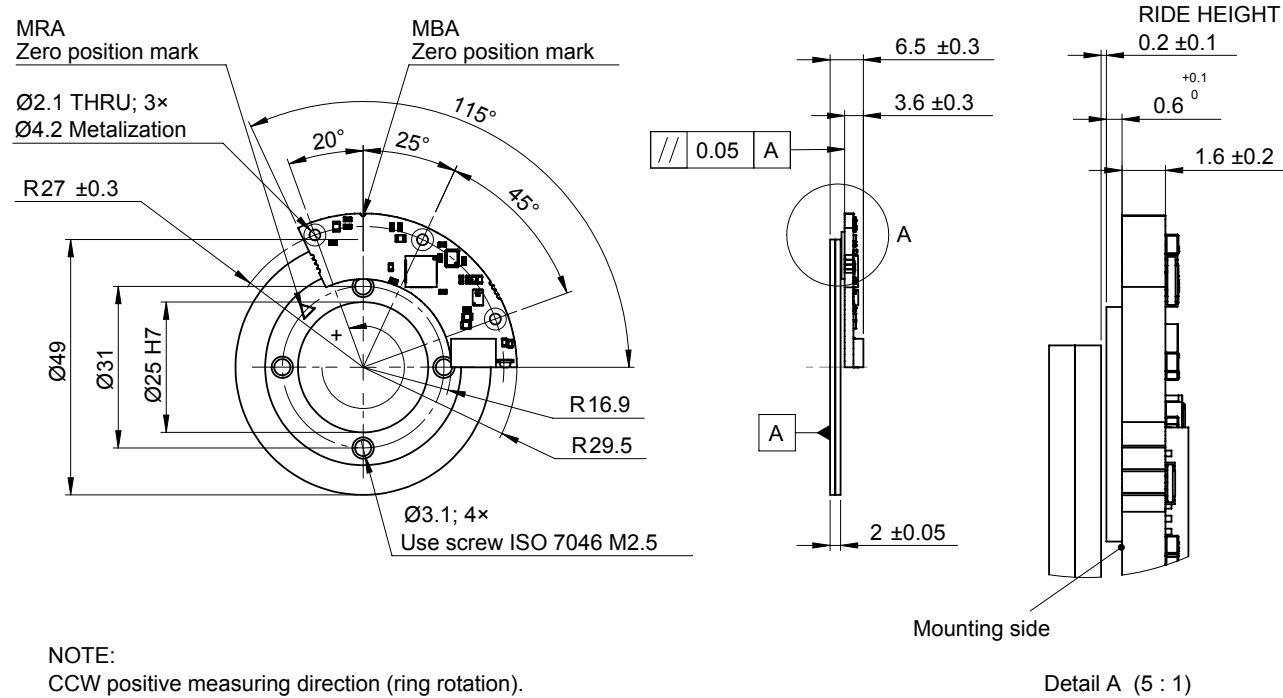
Dimensions

Dimensions and tolerances in mm.

MBA7 with MRA7D049AA025B00 ring



MBA7 with MRA7D049AB025E00 ring



Technical specifications

System data	
Reading type	Axial reading
Resolution	From 15 bit to 20 bit (see chapter Available resolutions on page 6)
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° (including installation tolerances - see chapter Installation instructions on page 5)
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	FPC/FFC connector, 6 pins, 1 mm pitch
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, MRA8D080AA055B00 64 g, MRA8D080AB055E00: 26 g
Inertia	MRA7D049AA025B00 13.1 kg×mm ² , MRA7D049AB025E00 5.5 kg×mm ² , MRA8D080AA055B00 79.1 kg×mm ² , MRA8D080AB055E00 31.2 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. ±6 mT (DC or AC) on top side of readhead

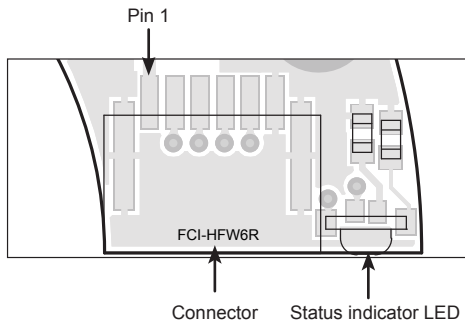
Electrical connections

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

Pin	Asynchronous serial	SPI slave simple	SPI slave advanced	I ² C 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 *	MA	Warning
4	TX data out	SCK	SCK	SCL	Clock *	SLO	PWM out
5	RX data in	$\overline{\text{CS}}$	$\overline{\text{CS}}$	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.

Pinout



Status indicator LED

The LED provides visual feedback of signal strength, error condition and for set-up and diagnostic use.

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 (air gap)

The nominal gap between the sensor on the readhead and the rubber band on the ring is 0.2 ± 0.1 mm.

Golden plated surfaces on the bottom of the readhead should be used as a reference plane for mounting the readhead. If the top side of the readhead is used as a mounting surface, user must adjust the air gap carefully due to big tolerances in the PCB thickness. Any nonmagnetic tool with 0.2 mm thickness can be used to check the correct air gap setting mechanically.

The integrated LED can be used as a coarse indicator. When the correct air gap 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.

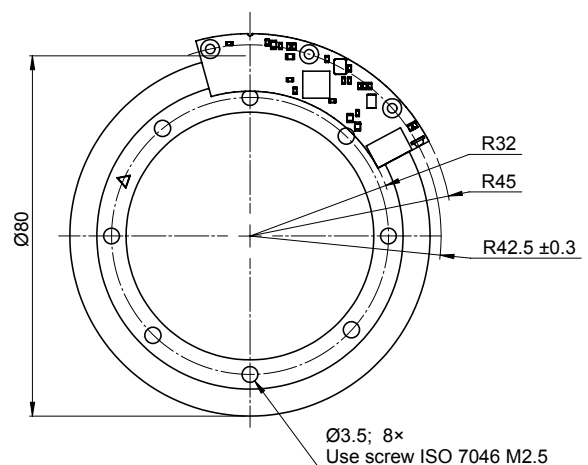
Installation tolerances (readhead to ring)

Axial (Z) displacement (ride height)	0.2 mm nominal ± 0.1 mm
Radial (Y) displacement	± 0.3 mm
Off center (X) displacement	± 0.5 mm
Nonparallel mounting	± 0.05 mm

Installation tolerances (ring to shaft)

Ring/shaft fit on MRA7	Worst case accuracy
H7/g6	$\pm 0.08^\circ$
H7/f7	$\pm 0.11^\circ$

Ring/shaft fit on MRA8	Worst case accuracy
H7/g6	$\pm 0.07^\circ$
H7/f7	$\pm 0.10^\circ$



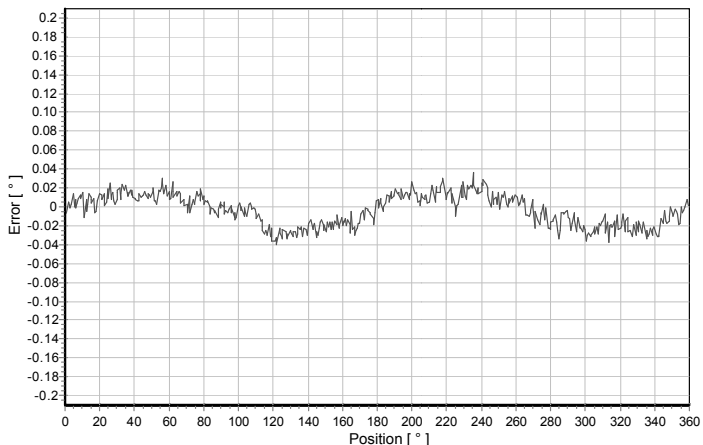
Accuracy of the encoder system

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

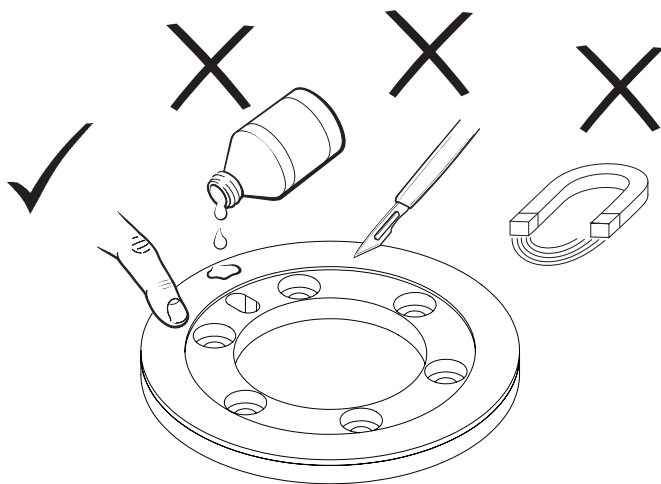
By minimising the eccentricity of the ring installation (using a gauge) and using a drive shaft with precision bearings, the error can be reduced typically to $\pm 0.05^\circ$ on MRA8 rings or $\pm 0.060^\circ$ on MRA7 rings.

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

For highest accuracy options contact RLS.

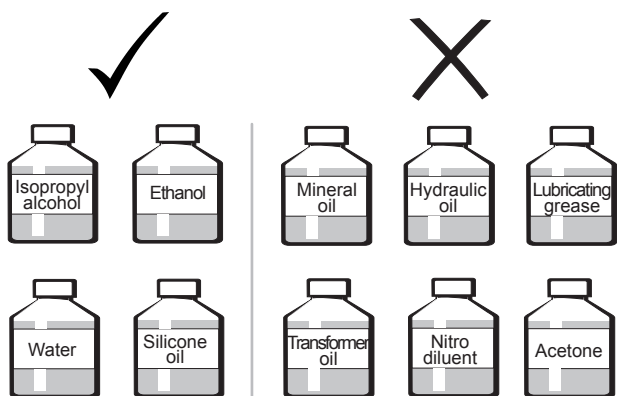


Storage and handling

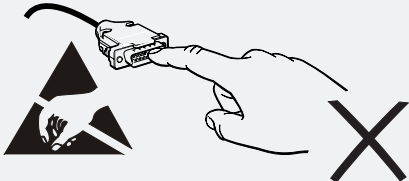


WARNING: Magnetic rings should not be exposed to magnetic field densities higher than 50 mT on its surface. Magnetic fields higher than 50 mT can damage the ring.

Chemical resistance



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. It is 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.

Communication interfaces

Asynchronous serial	
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 table below
Latency	250 μ s
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	250 μ s
SSI*	
Maximum clock frequency	500 kHz standard 2.5 MHz with <i>Delay First Clock</i> function on the controller
Update rate	4 kHz
Resolution	See table below
Latency	250 μ s to 500 μ s
Timeout (monoflop time)	20 μ s
BiSS	
Maximum clock frequency	3 MHz or 5 MHz
Maximum request rate	20 kHz
Bandwidth	2 kHz
Resolution	See table below
Latency	<10 μ s
Timeout (monoflop time)	20 μ s
SPI slave*	
Maximum clock frequency	3 MHz
Update rate	4 kHz
Resolution	16 bits fixed (option S) or up to 20 bits (option A) - see table below
Latency	250 μ s to 500 μ s

* Note: Slave type interfaces might not be suitable for high-speed closed control loops because of the variable latency time. See "Latency" chapter on page 17 for detailed information.

For I²C option contact your local sales representative.

Available resolutions

Resolution	Ring MRA7	Ring MRA8
Binary	15 bits per revolution 16 bits per revolution 17 bits per revolution 18 bits per revolution * 19 bits per revolution *	16 bits per revolution 17 bits per revolution 18 bits per revolution 19 bits per revolution * 20 bits per revolution *

* Note: High resolution options may contain noise on the output. This is suitable for smoother operation of the control loops or averaging to get fine position. Noise margin increases exponentially with increasing air gap between the ring and readhead.

Asynchronous serial communication

Encoder identification, position data and temperature are available over the 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 MSB first; Big-endian order.

Electrical connection

All data signals are 3.3 V LVTTTL. Inputs are 5 V tolerant. Signal lines are single-ended. For connections to RS422 compatible controllers please use an external line driver.

Communication parameters

Character length	8 bits
Parity	None
Stop bits	1
Repetition rate	4 kHz max. Transmission time lowers this frequency.
Position latency	Fixed 250 μ s 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 *Output type variant* in the part number:

Output type variant	A	B	C	D	E	F
Value	115.2 kbps	128 kbps	230.4 kbps	256 kbps	500 kbps	1 Mbps

Command set

<p>Command "v" (0x76) - version request</p> <p>Response - version info and serial number 5 bytes ASCII identification string ("AksIM") 1 byte ASCII space character 8 bytes ASCII serial number 1 byte binary firmware version 1 byte binary communication interface version (4) 1 byte binary ASIC revision 1 byte binary code identification (7 or 8) 1 byte binary Resolution</p>
<p>Command "1" (0x31) - single position data request</p> <p>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</p> <p>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.</p>
<p>Command "2" (0x32) - continuous position data request</p> <p>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</p>
<p>Command "3" (0x33) - continuous position data with reduced length request</p> <p>Response - position and status, transmitted continuously 3 bytes binary absolute position, big-endian, left aligned 1 byte detailed encoder status – see below</p>
<p>Command "0" (0x30) - stop</p> <p>Stop continuous transmission</p>
<p>Command "t" (0x74) - temperature request</p> <p>Response - temperature of the encoder 1 byte signed binary number - temperature of the sensor in $^{\circ}$C</p> <p>Accuracy of the readings is ± 3 $^{\circ}$C This function is available with firmware version 30 and later (see command "v" for firmware version).</p>

Structure of the 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 operation limits. Position is valid. Resolution and / or accuracy might be lower than specified.
<p>Error and Warning bits can be set at the same time; in this case Error bit has priority. Those two bits are synchronized to the LED indicator on the housing of the encoder: 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.</p>	
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 high.
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 range.
b3	Error - Power supply error. The readhead power supply voltage is out of specified range.
b2	Error - System error. Malfunction detected 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 output

The PWM 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. These signals have weak ESD protection. Handle with care.

Status signal

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

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

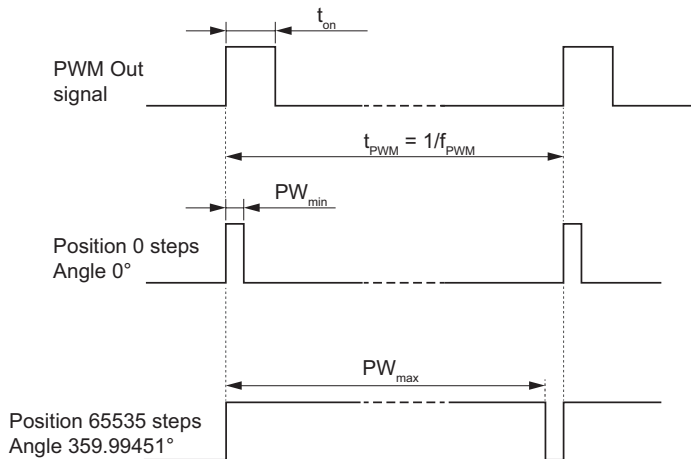
When the Status signal is low, the PWM Out signal is low and no pulses are output.

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 modulated output with 16-bit resolution whose duty cycle is proportional to the measured position. The change of the pulse width by PW_{min} corresponds to a change in position by one count (change in angle for $360^\circ / 65536 \approx 0.00549^\circ$).

PWM Out signal timing diagram



Communication parameters

Output type variant in the part number defines the PWM frequency and all other dependent parameters.

Parameter	Symbol	Output type variant					Unit	Note
		A	B	C	D	E		
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} .

$$Position [counts] = \frac{t_{on} \times 65536}{t_{PWM}} - 1$$

$$Position [^\circ] = \frac{(t_{on} - PW_{min}) \times 360^\circ}{t_{PWM}}$$

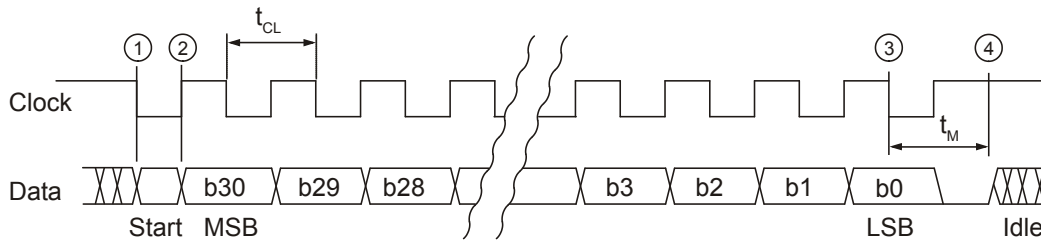
SSI - Synchronous serial interface

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 LVTTTL. Inputs are 5 V tolerant. Signal lines are single-ended. For connections to a RS-422 compatible controllers please use an external line driver.

SSI timing diagram

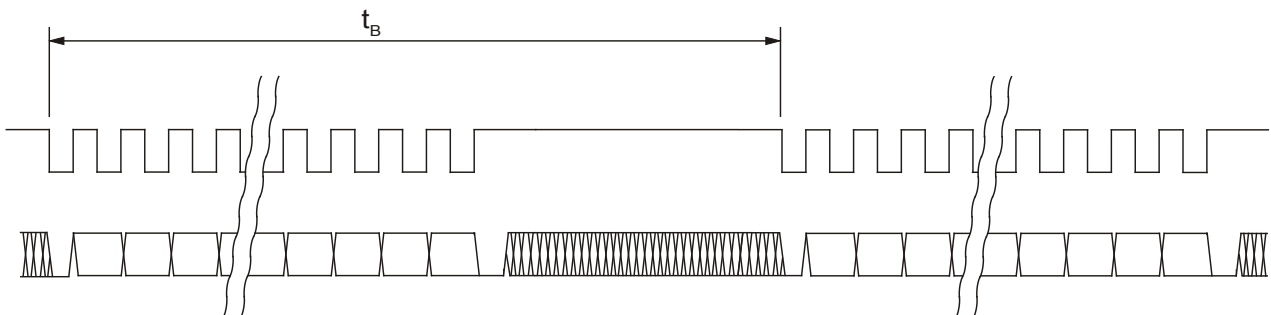


The controller interrogates the readhead for its position and status data by sending a pulse train to the Clock input. The Clock signal always starts from high. The first falling edge ① latches the last position data available and on the first rising edge ② the most significant bit (MSB) of the position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

After the transmission of the last bit ③ the Data output goes 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.

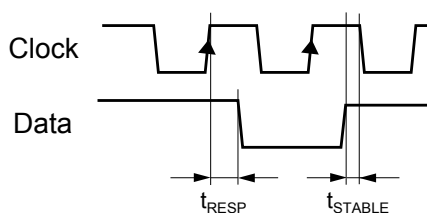
While reading the data, the period t_{CL} must always be less than t_M . However, reading the encoder position can be terminated at any time by setting the Clock signal to high for the duration of t_M .

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.



The power supply must be applied at least 10 ms before the clock sequence is being sent to the encoder.

Communication parameters

Parameter	Symbol	Min	Typ	Max
Clock period	t_{CL}	2 μ s		20 μ s
Clock frequency	f_{CL}	50 kHz		500 kHz (2.5 MHz *)
Monoflop time	t_M		20 μ s	
Update time	t_B	250 μ s		
Readhead response delay	t_{RESP}		160 ns	

* With Delay First Clock function on the controller.

Start bit and idle line value are defined by the *Output type variant*.

Output type variant	Line state selection
A	Start bit = 0; idle line = 0
B	Start bit = 1; idle line = 1

Structure of the 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 operation 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 high.

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 range.

b4 Error - Power supply error. The readhead power supply voltage is out of specified range.

b3 Error - System error. Malfunction detected 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).

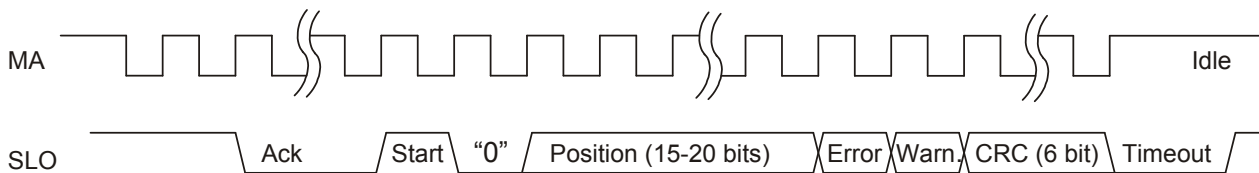
BiSS is implemented for point-to-point operation; multiple slaves are not supported.

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 LVTTTL. Inputs are 5 V tolerant. Signal lines are single-ended. For connections to a RS-422 compatible controllers please use an external line driver.

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.

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.

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

Output type variant in the part number defines the functionality of the encoder.

Output type variant	Description	Parameter	Value
G	Short response low frequency	Ack length	4 bits
		MA frequency	Max. 3 MHz
H	Long response high frequency	Ack time	12 bits
		MA frequency	Max. 5 MHz

Parameter	Symbol	Min	Typ	Max
Latency			<10 μ s	
Bandwidth			2 kHz	
Maximum request rate			20 kHz	
Timeout			20 μ s	

Data sheet
MBAD01_04

Data packet description

Data packet length depends on the resolution and can be from 24 to 28 bits long. It consists of 16 to 20 bits of Position (resolution), 2 Status bits and 6 CRC bits (see table below).

Resolution	Position	Status		CRC (inverted)
		Error	Warning	
16B	16 bits	1 bit	1 bit	6 bits
17B	17 bits			
18B	18 bits			
19B	19 bits			
20B	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.

SPI - Serial peripheral interface – slave mode

The SPI interface is designed for communication with nearby devices.

Electrical connection

All data signals are 3.3 V LVTTTL. 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

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

Output type 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

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	1 μ s			
Time after last CLK falling edge to \overline{CS} high	t_h	1 μ s			
\overline{CS} high time	t_r	8 μ s			Time to complete SPI reset
Read repetition rate	f_{REP}			4 kHz	If higher, the same position data might be transmitted twice

SPI slave - simple mode (option S)

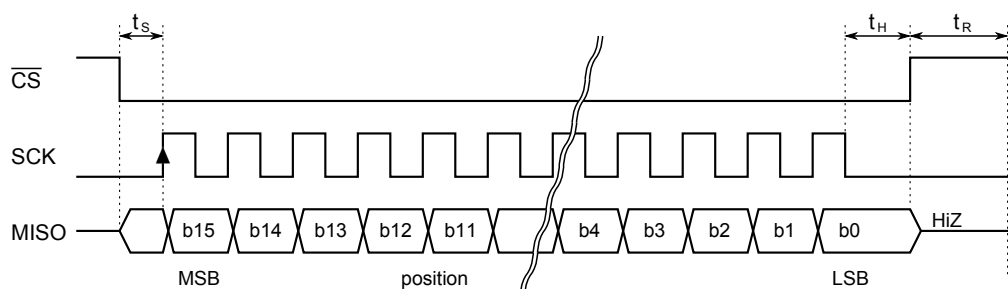
Structure of the data packet

Data packet is 16 bits long. MSB first. Left aligned. Position only, no status bits. Only 16-bit resolution available. Repetition of reading maximum 4000 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 for 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 corrupt magnetic pattern of the ring, sensor malfunction, system error or 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)



Data sheet
MBAD01_04

SPI slave - advanced mode (option A)

Structure of the data packet

Data packet is 40 bits long. MSB first. Position data is left aligned.

Repetition of reading maximum 4000 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 operation 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. Those two bits are synchronized to the LED indicator on the housing of the encoder:
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 high.

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 range.

b5 Error - Power supply error. The readhead power supply voltage is out of specified range.

b4 Error - System error. Malfunction detected 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.

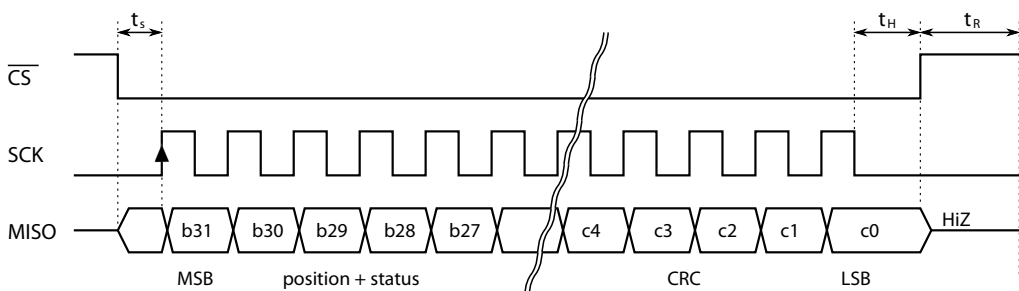
CRC

c7 : c0 CRC check with polynomial 0x97 - see Appendix 1 of this document.

Status signal

The Status signal is not available in Advanced mode.

SPI slave timing diagram (variant A)



Latency on Async serial communication

Readhead has its internal cycle of acquiring the position that is running at about 4 kHz ($\pm 10\%$). One cycle takes 250 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 250 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 250 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 250 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 250 μs old. This time is constant ($\pm 10\%$). 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

All interfaces transmit the last valid data that is available.

Internal cycle of the encoder is 250 μs . This is delay from 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 250 μs .

If request comes just before the new data will be calculated, then latency is 500 μs .

For example:

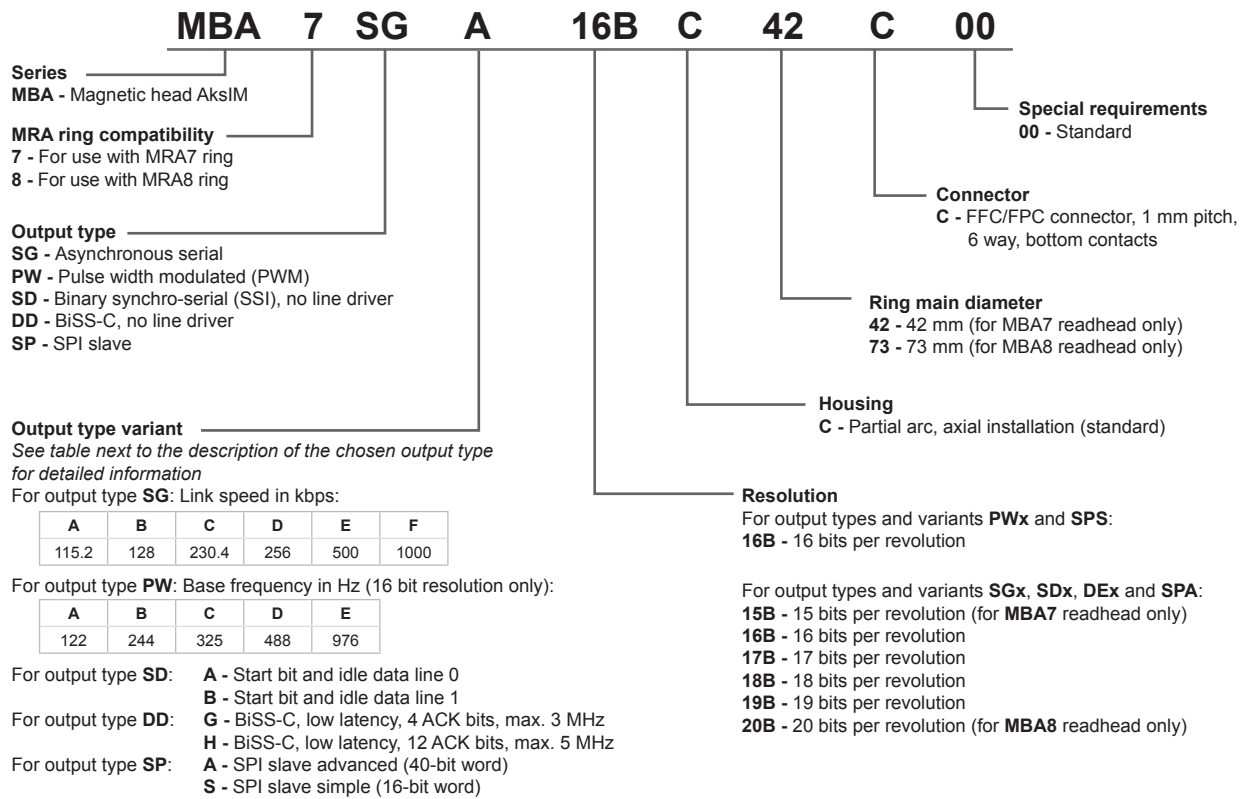
At $t = 0 \mu\text{s}$ the physical position is latched but position data is not yet calculated. It will be available at 250 μs .

If the request comes at $t = 1 \mu\text{s} - 249 \mu\text{s}$, the last available data will be sent - the one from previous cycle when position was latched at $t = -250 \mu\text{s}$.

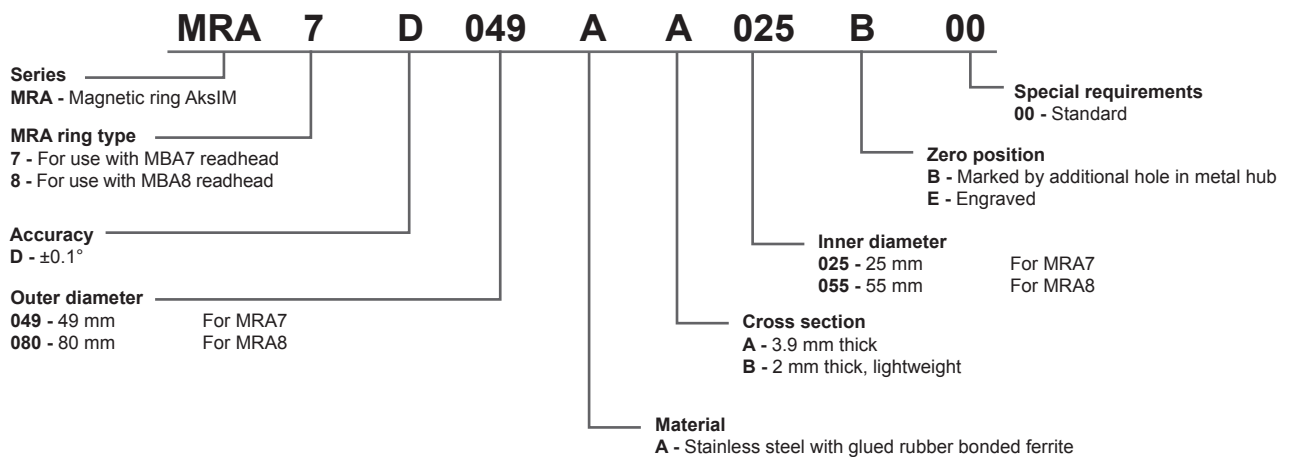
Latency on BiSS interface

BiSS uses a different approach and calculation so the request rate can be higher than 4 kHz. Typically, request rate can be up to 20 kHz. Position is latched at the first falling edge on the MA (clock) line and calculated instantly, therefore latency is shorter than 10 μs .

AksIM readhead part numbering



AksIM ring part numbering



Currently available ring options:

- MRA7D049AA025B00
- MRA7D049AB025E00
- MRA8D080AA055B00
- MRA8D080AB055E00

Accessories

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

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

Some of the output protocols 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, 0xDD, 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;
    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
example:

u8 Buffer[BufferLength];

crc_value = u8_CRC_Buffer(BufferLength);

u8_CRC_Buffer(u8 NumOfBytes) // parameter = how many bytes from buffer to use to calculate CRC
{
    NumOfBytes -= 1;
    icrc = 1;
    t = Buffer[0];
    while (NumOfBytes--)
    {
        t = Buffer[icrc++] ^ tableCRC[t];
    }
    crc = tableCRC[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

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.

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;
    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

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Document issues

Issue	Date	Page	Corrections made
1	21. 2. 2013	-	Preliminary product information
2	10. 5. 2013	2, 3	Dimensional drawings updated, minor text amends
3	5. 8. 2014	-	Part numbering, detailed interface specifications, MBA8 and MRA8 details added
4	24. 10. 2014	2	MRA7D049AB025E00 drawing amended
		7	BiSS maximum request rate added
		11	Output load specifications added
		17	Latency information added

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