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

**Chemical resistance**

**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.

**Readhead**

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

**Magnetic ring**

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

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

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

**WARNING!**

**ESD protection**

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

MBA7 with MRA7D049AA025B00 ring

NOTE:
CCW positive measuring direction.

MBA7 with MRA7D049AB025E00 ring

NOTE:
CCW positive measuring direction (ring rotation).
Dimensions continued

Dimensions and tolerances in mm.

MBA8 with MRA8D080AA055B00 ring

NOTE:
CCW positive measuring direction.

MBA8 with MRA8D080AB055E00 ring

NOTE:
CCW positive measuring direction (ring rotating).
## Technical specifications

### System data
- **Reading type**: Axial reading
- **Resolution**: From 15 bit to 20 bit and 16 bit multiturn counter option (see chapter Available resolutions on page 8)
- **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 on page 6)
- **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 under: 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, MRA8D080AA055B00 64 g, MRA8D080AB055E00 26 g
- **Inertia**: MRA7D049AA025B00 13.1 kg×mm², MRA7D049AB025E00 5.5 kg×mm², MRA8D080AA055B00 79.1 kg×mm², MRA8D080AB055E00 31.2 kg×mm²

### 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
**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.

<table>
<thead>
<tr>
<th>LED</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>Normal operation; position data is valid</td>
</tr>
<tr>
<td>Orange</td>
<td>Warning; position is valid, but the resolution and/or accuracy might be out of specification. Some operating conditions are outside limits.</td>
</tr>
<tr>
<td>Red</td>
<td>Error; position data is not valid</td>
</tr>
<tr>
<td>No light</td>
<td>No power supply</td>
</tr>
</tbody>
</table>

**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.

Any nonmagnetic tool with 0.2 mm thickness can be used to mechanically check the ride height between the sensor and the ring. The integrated LED can be used as an indicator. When the correct ride height is achieved, the LED glows green and does not change colour when the ring rotates.

Center point of the ring and center point of the readhead arc must be coaxial. Allowed tolerances are listed in the table below.

**Installation tolerances (readhead to ring)**

<table>
<thead>
<tr>
<th>Axial (Z) displacement (ride height)</th>
<th>0.2 mm nominal ±0.1 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB to ring distance*</td>
<td>0.8 mm ±0.1 mm</td>
</tr>
<tr>
<td>Radial (Y) displacement</td>
<td>±0.3 mm</td>
</tr>
<tr>
<td>Off center (X) displacement</td>
<td>±0.5 mm</td>
</tr>
<tr>
<td>Nonparalell mounting</td>
<td>±0.05 mm</td>
</tr>
</tbody>
</table>

* 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)**

<table>
<thead>
<tr>
<th>Ring/shaft fit on MRA7</th>
<th>Worst case accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>H7/g6</td>
<td>±0.08°</td>
</tr>
<tr>
<td>H7/f7</td>
<td>±0.11°</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ring/shaft fit on MRA8</th>
<th>Worst case accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>H7/g6</td>
<td>±0.07°</td>
</tr>
<tr>
<td>H7/f7</td>
<td>±0.10°</td>
</tr>
</tbody>
</table>
**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.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Asynchronous serial</th>
<th>SPI slave simple</th>
<th>SPI slave advanced</th>
<th>I²C slave</th>
<th>SSI</th>
<th>BiSS</th>
<th>PWM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 V supply</td>
<td>5 V supply</td>
<td>5 V supply</td>
<td>5 V supply</td>
<td>5 V supply</td>
<td>5 V supply</td>
<td>5 V supply</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>OK</td>
</tr>
<tr>
<td>3</td>
<td>MISO</td>
<td>MISO</td>
<td>-</td>
<td>Data *</td>
<td>SLO *</td>
<td>Warning</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>TX data out</td>
<td>SCK</td>
<td>SCK</td>
<td>SCL</td>
<td>Clock *</td>
<td>MA *</td>
<td>PWM out</td>
</tr>
<tr>
<td>5</td>
<td>RX data in</td>
<td>CS</td>
<td>-</td>
<td>SDA</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>0 V (GND)</td>
<td>0 V (GND)</td>
<td>0 V (GND)</td>
<td>0 V (GND)</td>
<td>0 V (GND)</td>
<td>0 V (GND)</td>
<td>0 V (GND)</td>
</tr>
</tbody>
</table>

* Single-ended signals. No line driver.

*Position [°]*

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>108</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>101</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>121</td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>142</td>
<td>0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>182</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>212</td>
<td>-0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>232</td>
<td>-0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>252</td>
<td>-0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>282</td>
<td>-0.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>312</td>
<td>-0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>342</td>
<td>-0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>372</td>
<td>-0.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>402</td>
<td>-0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>432</td>
<td>-0.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Warning*
Available resolutions

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Ring MRA7</th>
<th>Ring MRA8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binary</td>
<td>15 bits per revolution</td>
<td>16 bits per revolution</td>
</tr>
<tr>
<td></td>
<td>16 bits per revolution</td>
<td>17 bits per revolution</td>
</tr>
<tr>
<td></td>
<td>17 bits per revolution</td>
<td>18 bits per revolution</td>
</tr>
<tr>
<td></td>
<td>18 bits per revolution</td>
<td>19 bits per revolution</td>
</tr>
<tr>
<td></td>
<td>19 bits per revolution</td>
<td>20 bits per revolution</td>
</tr>
</tbody>
</table>

* 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 on page 24 for ordering information.
Asynchronous serial communication interface

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 MSB 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 24).

Communication parameters

<table>
<thead>
<tr>
<th>Character length</th>
<th>8 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parity</td>
<td>None</td>
</tr>
<tr>
<td>Stop bits</td>
<td>1</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>5 kHz max. Transmission time lowers this frequency.</td>
</tr>
<tr>
<td>Position latency</td>
<td>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.</td>
</tr>
</tbody>
</table>

Link speed is selectable by the Communication interface variant in the part number:

<table>
<thead>
<tr>
<th>Communication interface variant</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link speed</td>
<td>115.2 kbps</td>
<td>128 kbps</td>
<td>230.4 kbps</td>
<td>256 kbps</td>
<td>500 kbps</td>
<td>1 Mbps</td>
</tr>
</tbody>
</table>
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 × 10\(^6\) / 2\(^{20}\)
Degrees per second (DPS) = CPS × 360 / 2\(^{10}\) (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):**

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>b15 : b10</td>
<td>Reserved, always zero</td>
</tr>
</tbody>
</table>

**General status**

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>b9</td>
<td>Error. If bit is set, position is not valid.</td>
</tr>
<tr>
<td>b8</td>
<td>Warning. If bit is set, encoder is near operational limits. Position is valid. Resolution and/or accuracy might be lower than specified.</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>b7</td>
<td>Warning - Signal amplitude too high. The readhead is too close to the ring or an external magnetic field is present.</td>
</tr>
<tr>
<td>b6</td>
<td>Warning - Signal amplitude low. The distance between the readhead and the ring is too large.</td>
</tr>
<tr>
<td>b5</td>
<td>Error - Signal lost. The readhead is out of alignment with the ring or the ring is damaged.</td>
</tr>
<tr>
<td>b4</td>
<td>Warning - Temperature. The readhead temperature is out of specified range.</td>
</tr>
<tr>
<td>b3</td>
<td>Error - Power supply error. The readhead power supply voltage is out of specified range.</td>
</tr>
<tr>
<td>b2</td>
<td>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.</td>
</tr>
<tr>
<td>b1</td>
<td>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.</td>
</tr>
<tr>
<td>b0</td>
<td>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.</td>
</tr>
</tbody>
</table>
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 $PW_{\text{min}}$ corresponds to a change in position by one count (change in angle for $360^\circ / 65536 \approx 0.00549^\circ$).

**Position 0 steps**
Angle 0°

**Position 65535 steps**
Angle 359.99451°

**PWM Out signal timing diagram**

\[ t_{\text{on}} = \frac{1}{f_{\text{PWM}}} \]

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

\[ t_{\text{on}} = \frac{PW_{\text{max}}}{65536} \]

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

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

**Position ["] = \frac{(t_{\text{on}} - PW_{\text{max}}) \times 360^\circ}{t_{\text{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 24).

The 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 \( t_1 \) latches the last position data available and on the first rising edge \( t_2 \) 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 \( t_1 \) and \( t_2 \) 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 \( t_3 \) the Data output goes to low. When the \( t_M \) time expires the Data output is undefined \( t_4 \). The Clock signal must remain high for at least \( t_B \) before the next reading can take place.

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

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.
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 LVTTTL. 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 24).

BiSS-C timing diagram

MA SLO

Start | CDS | Position (16-36 bits) | Error | Warn | CRC (6 bit) | Timeout

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Value 0</th>
<th>Value 1</th>
<th>Possible reason for failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error</td>
<td>Position data is invalid.</td>
<td>OK</td>
<td>Error bit is active low. If low, the position is not valid.</td>
</tr>
<tr>
<td>Warning</td>
<td>Position data is valid.</td>
<td>OK</td>
<td>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.</td>
</tr>
</tbody>
</table>

Communication parameters

Communication interface variant in the part number defines the functionality of the encoder.

<table>
<thead>
<tr>
<th>Communication interface variant</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>MA frequency</td>
<td>Max. 5 MHz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Worst case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency</td>
<td></td>
<td>&lt;10 µs</td>
</tr>
<tr>
<td>Bandwidth *</td>
<td></td>
<td>2.5 kHz</td>
</tr>
<tr>
<td>Maximum request rate</td>
<td></td>
<td>31 kHz (28 kHz Multiturn counter option)</td>
</tr>
<tr>
<td>Timeout</td>
<td></td>
<td>20 µs</td>
</tr>
<tr>
<td>Readhead response delay</td>
<td>$t_{RESP}$</td>
<td>170 ns</td>
</tr>
</tbody>
</table>

* 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 15 to 20 bits of Position selected by (resolution), followed by 2 Status bits and 6 CRC bits (see table below).

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Multiturn counter</th>
<th>Position</th>
<th>Status</th>
<th>CRC (inverted)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Error</td>
<td>Warning</td>
</tr>
<tr>
<td>15B</td>
<td>0 bits</td>
<td>15 bits</td>
<td>1 bit</td>
<td>1 bit</td>
</tr>
<tr>
<td>16B</td>
<td></td>
<td>16 bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17B</td>
<td></td>
<td>17 bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18B</td>
<td></td>
<td>18 bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19B</td>
<td></td>
<td>19 bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20B</td>
<td></td>
<td>20 bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15M</td>
<td>16 bits</td>
<td>15 bits</td>
<td>1 bit</td>
<td>1 bit</td>
</tr>
<tr>
<td>16M</td>
<td></td>
<td>16 bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17M</td>
<td></td>
<td>17 bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18M</td>
<td></td>
<td>18 bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19M</td>
<td></td>
<td>19 bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20M</td>
<td></td>
<td>20 bits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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](http://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 LVTTL. Inputs are 5 V tolerant.

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

Communication parameters

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

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock frequency</td>
<td>f_CLK</td>
<td>1 Hz</td>
<td></td>
<td>3 MHz</td>
<td></td>
</tr>
<tr>
<td>Time after CS low to first CLK rising edge</td>
<td>t_S</td>
<td>2 μs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time after last CLK falling edge to CS high</td>
<td>t_I</td>
<td>1 μs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS high time</td>
<td>t_H</td>
<td>8 μs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Read repetition rate</td>
<td>f_REP</td>
<td></td>
<td></td>
<td>5 kHz</td>
<td></td>
</tr>
</tbody>
</table>

Max frequency with 1.5 m cable
Time to complete SPI reset
If higher, the same position data might be transmitted twice
Data sheet
MBAD01_08

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.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Data length</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>b31 : b12</td>
<td>20 bits</td>
<td>Encoder position</td>
</tr>
<tr>
<td>b11 : b10</td>
<td>2 bits</td>
<td>General status</td>
</tr>
<tr>
<td>b9 : b2</td>
<td>8 bits</td>
<td>Detailed status</td>
</tr>
<tr>
<td>b1 : b0</td>
<td>2 bits</td>
<td>Reserved</td>
</tr>
<tr>
<td>c7 : c0</td>
<td>8 bits</td>
<td>CRC</td>
</tr>
</tbody>
</table>

**Encoder position**
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**
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)**

![SPI Slave Timing Diagram](image-url)
Data sheet
MBAD01_08

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.

<table>
<thead>
<tr>
<th>Bit</th>
<th>b31 : b12</th>
<th>b11 : b10</th>
<th>b9 : b2</th>
<th>b1 : b0</th>
<th>t15 : t0</th>
<th>c7 : c0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data length</td>
<td>20 bits</td>
<td>2 bits</td>
<td>8 bits</td>
<td>2 bits</td>
<td>16 bits</td>
<td>8 bits</td>
</tr>
<tr>
<td>Meaning</td>
<td>Encoder position</td>
<td>General status</td>
<td>Detailed status</td>
<td>Reserved always 1</td>
<td>Timestamp</td>
<td>CRC</td>
</tr>
</tbody>
</table>

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.
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 CS falling edge in µsec.

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

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.

<table>
<thead>
<tr>
<th>Signal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCL</td>
<td>Master clock. Max clock frequency is 400 kHz in fast mode.</td>
</tr>
<tr>
<td>SDA</td>
<td>Slave out. MSB first.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock frequency</td>
<td>( f_{\text{CLK}} )</td>
<td>100 kHz</td>
<td></td>
<td>400 kHz</td>
<td>Master clock frequency.</td>
</tr>
<tr>
<td>Read repetition rate</td>
<td>( f_{\text{REP}} )</td>
<td>5 kHz</td>
<td></td>
<td></td>
<td>Time to update a new position. If higher, the same position data might be transmitted twice</td>
</tr>
</tbody>
</table>

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.

Number of bits in different sections of data packet:

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Position</th>
<th>Reserved0</th>
<th>Status</th>
<th>Reserved1</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Error</td>
<td>Warning</td>
<td>Status</td>
</tr>
<tr>
<td>16B</td>
<td>16 bits</td>
<td>4</td>
<td>1 bit</td>
<td>1 bit</td>
<td>8 bits</td>
</tr>
<tr>
<td>17B</td>
<td>17 bits</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18B</td>
<td>18 bits</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19B</td>
<td>19 bits</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20B</td>
<td>20 bits</td>
<td>/</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>b11</th>
<th>Error. If bit is set, position is not valid.</th>
</tr>
</thead>
<tbody>
<tr>
<td>b10</td>
<td>Warning. If bit is set, encoder is near operational limits. Position is valid. Resolution and / or accuracy might be lower than specified.</td>
</tr>
</tbody>
</table>

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

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

CRC

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

**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)**

<table>
<thead>
<tr>
<th>Slave</th>
<th>Master</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Address</td>
</tr>
</tbody>
</table>

- **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.
Data sheet
MBAD01_08

Readhead part numbering

<table>
<thead>
<tr>
<th>MBA</th>
<th>7</th>
<th>SG</th>
<th>A</th>
<th>16B</th>
<th>C</th>
<th>42</th>
<th>C</th>
<th>00</th>
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</thead>
<tbody>
<tr>
<td>Series</td>
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<td></td>
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</tr>
<tr>
<td>MBA - Magnetic board AksIM</td>
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<tr>
<td>MRA ring compatibility</td>
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<td></td>
</tr>
<tr>
<td>7 - For use with MBA7 ring</td>
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<td></td>
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<tr>
<td>8 - For use with MRA8 ring</td>
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<tr>
<td>Communication interface</td>
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<tr>
<td>DD - BiSS-C, no line driver</td>
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<tr>
<td>FC - I²C / Two-wire interface</td>
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<td>PW - Pulse width modulation (PWM)</td>
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<td>SD - Synchronous serial interface (SSI), no line driver</td>
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<tr>
<td>SG - Asynchronous serial</td>
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<td>SP - SPI slave, LVTTL</td>
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<td>C - FFC connector, 1 mm pitch, 6 way, bottom contacts</td>
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<tr>
<td>42 - 42 mm (for MBA7 readhead only)</td>
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<tr>
<td>73 - 73 mm (for MBA8 readhead only)</td>
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<td>C - Partial arc, axial installation (standard)</td>
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<td>Special requirements</td>
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<tr>
<td>00 - No special requirements (standard)</td>
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Ring part numbering

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<td>7 - For use with MBA7 readhead</td>
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<td>8 - For use with MBA8 readhead</td>
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<td>D - ±0.1°</td>
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<td>Outer diameter</td>
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<td>For MBA7 ring type: 049 - 49 mm</td>
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<tr>
<td>B - Marked by additional hole in metal hub</td>
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<td>E - Engraved</td>
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<td>Special requirements</td>
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<tr>
<td>00 - No special requirements (standard)</td>
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<td>Inner diameter</td>
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<tr>
<td>For MBA7 ring type: 025 - 25 mm</td>
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<td>For MBA8 ring type: 055 - 55 mm</td>
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<tr>
<td>Cross section</td>
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<tr>
<td>A - 3.9 mm thick</td>
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<tr>
<td>B - 2 mm thick, lightweight</td>
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<tr>
<td>Material</td>
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<tr>
<td>A - Stainless steel with glued rubber bonded ferrite</td>
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</tbody>
</table>

Currently available ring options:
MRA7D049AA025B00
MRA7D049AB025E00
MRA8D080AA055B00
MRA8D080AB055E00

Accessories

ACC006 FFC flat cable, 152 mm length, 6 way, 1 mm pitch
ACC009 6-pin, 1 mm pitch FFC to DSUB 9-pin adapter with RS422 line driver for BiSS and SSI
ACC010 ACC009 without housing
Some of the communication interfaces offer a CRC value to check the correctness of the data read from the encoder. This chapter gives an example of the CRC calculation on the receiver side. The CRC calculation must always be done over the complete set of data including all the reserved bits. The polynomial for the CRC calculation is $P(x) = x^8 + x^7 + x^4 + x^2 + x + 1$, 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, 0x7C, 0x52, 0xC5, 0x0E, 0x99, 0xB7, 0x20, 0x86, 0x21, 0x0F, 0xF9, 0x59, 0xC0, 0xEA, 0x7D,
    0xB2, 0x25, 0x0B, 0x9C, 0x57, 0xC6, 0xE8, 0x7F, 0xB4, 0x23, 0x00, 0x91, 0xBB, 0x29, 0x07, 0x9E,
    0xA2, 0x35, 0x1B, 0x8C, 0x47, 0xD0, 0xF6, 0x69, 0xA4, 0x34, 0xA3, 0x30, 0x1D, 0x8F, 0xA1, 0x36,
    0xF9, 0x6A, 0x44, 0xD3, 0x45, 0xD2, 0x7C, 0xA0, 0x27, 0x19, 0x9E, 0x41, 0xD6, 0xF8, 0x6F, 0xA6, 0x33,
    0x1D, 0x8D, 0xA1, 0x35, 0x18, 0x81, 0xA5, 0x32, 0xF7, 0xA9, 0x31, 0xA7, 0x39, 0x17, 0x85, 0xA3, 0x3A,
    0x10, 0x87, 0xA0, 0x3E, 0xF5, 0x62, 0x4C, 0xD6, 0x4D, 0xDA, 0xF4, 0x63, 0xA8, 0x3F, 0x11, 0x86,
    0xA9, 0x3D, 0x13, 0x84, 0x4F, 0xD8, 0xF6, 0x61, 0x7F, 0x60, 0x4E, 0xD9, 0x12, 0x85, 0xA8, 0x3C};

// use this function to calculate CRC from 32-bit number
u8 crc8_4B(u32 bb)
{
    u8 crc;
    u32 t;
    t = ((bb >> 24) & 0x000000FF);
    crc = (bb >> 16) & 0x000000FF;
    t = crc ^ tableCRC[t];
    crc = (bb >> 8) & 0x000000FF;
    t = crc ^ tableCRC[t];
    crc = (bb & 0x000000FF);
    t = crc ^ tableCRC[t];
    return crc;
}

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

example:

u8 Buffer[BufferLength];

crc_value = u8 CRC_Buffer(BufferLength);

**Recommended literature:**
- Painless guide to CRC error detection algorithm; Ross N. Williams.
- Cyclic Redundancy Code (CRC) Polynomial Selection For Embedded Networks; P. Koopman, T. Chakravarty
Appendix 2 - 6-bit CRC calculation with 0x43 polynome for BiSS

BiSS communication offers a CRC value to check the correctness of the data read from the encoder. This chapter gives an example of the CRC calculation on the receiver side. The CRC calculation must always be done over the complete set of data. The polynomial for the CRC calculation is \( P(x) = x^6 + x^1 + 1 \), also represented as 0x43.

Following code example must be modified to fit actual data length. Position data, error and warning bits must all be included into calculation in the same order as in the BiSS data packet.

**Code example:**

```c
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, 0x38, 0x3B, 0x36, 0x3F, 0x37, 0x34, 0x31, 0x32, 0x13, 0x10, 0x15, 0x16, 0x1F, 0x1C, 0x19, 0x1A, 0x0B, 0x08, 0x0D, 0x0E, 0x07, 0x04, 0x01, 0x02};

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

**Recommended literature:**
- Painless guide to CRC error detection algorithm; Ross N. Williams.
- Cyclic Redundancy Code (CRC) Polynomial Selection For Embedded Networks; P. Koopman, T. Chakravarty
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<table>
<thead>
<tr>
<th>Issue</th>
<th>Date</th>
<th>Page</th>
<th>Corrections made</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>26. 2. 2016</td>
<td>2</td>
<td>Storage and handling - magnetic ring and readhead added</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3, 4</td>
<td>Ride height amended</td>
</tr>
<tr>
<td></td>
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<td>5</td>
<td>External magnetic field data amended</td>
</tr>
<tr>
<td></td>
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<td>6</td>
<td>Flashing LED information added</td>
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<tr>
<td></td>
<td></td>
<td>8 - 23</td>
<td>Latency changed from 250 µs to 200 µs</td>
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<tr>
<td></td>
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<td></td>
<td>Update rate changed from 4 kHz to 5 kHz</td>
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<td>8, 15, 24</td>
<td>BiSS output variant G removed, BiSS maximum request rate amended</td>
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<td>Command “v” amended, command 4 added, command 3 description amended</td>
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<td>14</td>
<td>SSI output type variant usage added</td>
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<td>Bandwidth description added, communication parameters tables amended</td>
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<td>17, 20, 24</td>
<td>SPI variant T added</td>
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<td>25, 26</td>
<td>Appendix 1 and 2 amended</td>
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<tr>
<td>8</td>
<td>20. 6. 2016</td>
<td>5, 8, 16, 24</td>
<td>Multiturn counter function added and BiSS interface amended</td>
</tr>
</tbody>
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