**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, I²C, asynchronous serial communication interfaces
- Corrosion resistant magnetic ring
Data sheet MBAD01_05

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).
NOTE:
CCW positive measuring direction (ring rotating).
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**: FFC connector, 6 pins, 1 mm pitch
  - Mating connector: standard FFC flat cable, 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. ±6 mT (DC or AC) on top side of readhead

### 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>PC 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></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>Status</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>MISO</td>
<td>MISO</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>C$</td>
<td>C$</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></td>
</tr>
</tbody>
</table>

* Single-ended signals. No line driver.
A **associate company**

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**Pinout**

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**Status indicator LED**

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

<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 outside limits. 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>

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**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 mm ± 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)**

<table>
<thead>
<tr>
<th>Axial (Z) displacement (ride height)</th>
<th>0.2 mm nominal ±0.1 mm</th>
</tr>
</thead>
<tbody>
<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>Nonparallel mounting</td>
<td>±0.05 mm</td>
</tr>
</tbody>
</table>

---

**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/i7</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/i7</td>
<td>±0.10°</td>
</tr>
</tbody>
</table>

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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 ±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 this encoder is sensing changes in the magnetic field of the magnetized 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 6 mT perpendicular to the readhead it might affect accuracy. When bigger than 6 mT it temporarily renders encoder to malfunction. Field stronger than 50 mT permanently damages the ring.

Unwanted magnetic fields must be blocked on the source. When this is not possible, encoder can be shielded with ferromagnetic metal plate. Also the ring can 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.

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.

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.

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baud rate</strong></td>
<td>115.2 kbps, 128 kbps, 230.4 kbps, 256 kbps, 500 kbps, 1 Mbps</td>
</tr>
<tr>
<td><strong>Data format</strong></td>
<td>8 bits, no parity, 1 stop bit</td>
</tr>
<tr>
<td><strong>Update rate</strong></td>
<td>On demand or continuous</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>See table below</td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td>250 µs</td>
</tr>
</tbody>
</table>

### PWM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base frequency</strong></td>
<td>122.07 Hz, 244.14 Hz, 325.52 Hz, 488.28 Hz, 976.56 Hz</td>
</tr>
<tr>
<td><strong>Update rate</strong></td>
<td>Same as Base frequency</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>16 bits</td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td>250 µs</td>
</tr>
</tbody>
</table>

### SSI*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum clock frequency</strong></td>
<td>500 kHz standard 2.5 MHz with <em>Delay First Clock</em> function on the controller</td>
</tr>
<tr>
<td><strong>Update rate</strong></td>
<td>4 kHz</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>See table below</td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td>250 µs to 500 µs</td>
</tr>
<tr>
<td><strong>Timeout (monoflop time)</strong></td>
<td>20 µs</td>
</tr>
</tbody>
</table>

### BiSS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum clock frequency</strong></td>
<td>3 MHz or 5 MHz</td>
</tr>
<tr>
<td><strong>Maximum request rate</strong></td>
<td>20 kHz</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>2 kHz</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>See table below</td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td>&lt;10 µs</td>
</tr>
<tr>
<td><strong>Timeout (monoflop time)</strong></td>
<td>20 µs</td>
</tr>
</tbody>
</table>

### SPI slave*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum clock frequency</strong></td>
<td>3 MHz</td>
</tr>
<tr>
<td><strong>Update rate</strong></td>
<td>4 kHz</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>16 bits fixed (option S) or up to 20 bits (option A) - see table below</td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td>250 µs to 500 µs</td>
</tr>
</tbody>
</table>

### I²C slave*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum clock frequency</strong></td>
<td>400 kHz</td>
</tr>
<tr>
<td><strong>Update rate</strong></td>
<td>4 kHz</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>See table below</td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td>250 µs to 500 µs</td>
</tr>
</tbody>
</table>

* 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 19 for detailed information.

## 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>

* 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.
Data sheet
MBAD01_06

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 LVTTL. Inputs are 5 V tolerant. Signal lines are single-ended. For connections to RS422 compatible controllers please use an external line driver.

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>4 kHz max. Transmission time lowers this frequency.</td>
</tr>
<tr>
<td>Position latency</td>
<td>Fixed 250 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 *Output type variant* in the part number:

<table>
<thead>
<tr>
<th>Output type 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>Value</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
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

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) - continuous position data with reduced length request

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 "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 later (see command "v" for firmware version).
Structure of the data packet

<table>
<thead>
<tr>
<th>Encoder status (two bytes):</th>
</tr>
</thead>
<tbody>
<tr>
<td>b15 : b10</td>
</tr>
<tr>
<td>Reserved, always zero</td>
</tr>
</tbody>
</table>

**General status**

<table>
<thead>
<tr>
<th>b9</th>
<th>Error. If bit is set, position is not valid.</th>
</tr>
</thead>
<tbody>
<tr>
<td>b8</td>
<td>Warning. If bit is set, encoder is near operation 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.

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**

<table>
<thead>
<tr>
<th>b7</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>b6</td>
<td>Warning - Signal amplitude low. The distance between the readhead and the ring is too high.</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 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 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.</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 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 $PW_{\text{min}}$ corresponds to a change in position by one count (change in angle for $360° / 65536 \approx 0.00549°$).

**PWM Out signal timing diagram**

![PWM Out signal timing diagram](image)

**Communication parameters**

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>Unit</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWM frequency</td>
<td>$f_{\text{PWM}}$</td>
<td>122.07</td>
<td>244.14</td>
<td>325.52</td>
<td>488.28</td>
<td>976.56</td>
<td>Hz</td>
<td></td>
</tr>
<tr>
<td>Signal period</td>
<td>$t_{\text{ PWM}}$</td>
<td>8,192.00</td>
<td>4,096.00</td>
<td>3,072.00</td>
<td>2,048.00</td>
<td>1,024.00</td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>Minimum pulse width</td>
<td>$PW_{\text{min}}$</td>
<td>0.1250</td>
<td>0.0625</td>
<td>0.0469</td>
<td>0.0313</td>
<td>0.0156</td>
<td>μs</td>
<td>Position 0 (Angle 0°)</td>
</tr>
<tr>
<td>Maximum pulse width</td>
<td>$PW_{\text{max}}$</td>
<td>8,191.88</td>
<td>4,095.94</td>
<td>3,071.95</td>
<td>2,047.97</td>
<td>1,023.98</td>
<td>μs</td>
<td>Positions 65534 and 65535 *</td>
</tr>
<tr>
<td>Min. counter frequency</td>
<td>$f_{\text{CNTR}}$</td>
<td>8.0000</td>
<td>16.0000</td>
<td>21.0000</td>
<td>32.0000</td>
<td>64.0000</td>
<td>MHz</td>
<td>Receiving counter frequency</td>
</tr>
<tr>
<td>Resolution</td>
<td></td>
<td>16 Bit</td>
<td>16 Bit</td>
<td>16 Bit</td>
<td>16 Bit</td>
<td>16 Bit</td>
<td></td>
<td>Fixed; resolution in part number must be set as &quot;16B&quot;</td>
</tr>
</tbody>
</table>

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

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

$$
\text{Position [°]} = \frac{(t_{\text{on}} - PW_{\text{max}}) \times 360°}{f_{\text{PWM}}}
$$
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 a RS-422 compatible controllers please use an external line driver.

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 latches the last position data available and on the first rising edge 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 and 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 the encoder is connected to.

After the transmission of the last bit the Data output goes to low. When the time expires, the Data output is undefined. The Clock signal must remain high for at least before the next reading can take place.

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

To allow updating of the position data at least should pass between two subsequent readings. If the reading request arrives earlier than 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.
Communication parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock period</td>
<td>$t_{CL}$</td>
<td>2 µs</td>
<td></td>
<td>20 µs</td>
</tr>
<tr>
<td>Clock frequency</td>
<td>$f_{CL}$</td>
<td>50 kHz</td>
<td></td>
<td>500 kHz (2.5 MHz *)</td>
</tr>
<tr>
<td>Monoflop time</td>
<td>$t_m$</td>
<td>20 µs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Update time</td>
<td>$t_u$</td>
<td>250 µs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Readhead response delay</td>
<td>$t_{RESP}$</td>
<td>170 ns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Output type variant</th>
<th>Line state selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Start bit = 0; idle line = 0</td>
</tr>
<tr>
<td>B</td>
<td>Start bit = 1; idle line = 1</td>
</tr>
</tbody>
</table>

Structure of the data packet

<table>
<thead>
<tr>
<th>Bit</th>
<th>b30 : b11</th>
<th>b10 : b9</th>
<th>b8 : b1</th>
<th>b0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data length</td>
<td>20 bits</td>
<td>2 bits</td>
<td>8 bits</td>
<td>1 bit</td>
</tr>
<tr>
<td>Meaning</td>
<td>Encoder position</td>
<td>General status</td>
<td>Detailed status</td>
<td>Reserved</td>
</tr>
</tbody>
</table>

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 LVTTL. 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

<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

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

<table>
<thead>
<tr>
<th>Output type variant</th>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>Short response low frequency</td>
<td>Ack length</td>
<td>4 bits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MA frequency</td>
<td>Max. 3 MHz</td>
</tr>
<tr>
<td>H</td>
<td>Long response high frequency</td>
<td>Ack time</td>
<td>12 bits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MA frequency</td>
<td>Max. 5 MHz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency</td>
<td>&lt;10 μs</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>2 kHz</td>
</tr>
<tr>
<td>Maximum request rate</td>
<td>20 kHz</td>
</tr>
<tr>
<td>Timeout</td>
<td>20 μs</td>
</tr>
</tbody>
</table>
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).

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

### Signal Description

<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 the 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

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

<table>
<thead>
<tr>
<th>Output type 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>
</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>3 MHz</td>
<td>Max frequency with 1.5 m cable</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>$t_{HI}$</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>Time to complete SPI reset</td>
<td></td>
</tr>
<tr>
<td>Read repetition rate</td>
<td>$f_{REP}$</td>
<td>4 kHz</td>
<td></td>
<td>If higher, the same position data might be transmitted twice</td>
<td></td>
</tr>
</tbody>
</table>

### 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)

[Diagram of SPI slave timing diagram (variant S)]
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.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Meaning</th>
<th>Data length</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>b31 : b12</td>
<td>Encoder position</td>
<td>20 bits</td>
<td></td>
</tr>
<tr>
<td>b11 : b10</td>
<td>General status</td>
<td>2 bits</td>
<td></td>
</tr>
<tr>
<td>b9 : b2</td>
<td>Detailed status</td>
<td>8 bits</td>
<td></td>
</tr>
<tr>
<td>b1 : b0</td>
<td>Reserved</td>
<td>2 bits</td>
<td></td>
</tr>
<tr>
<td>c7 : c0</td>
<td>CRC</td>
<td>8 bits</td>
<td></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 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)
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_CLK</td>
<td>100 kHz</td>
<td>400 kHz</td>
<td></td>
<td>Master clock frequency.</td>
</tr>
<tr>
<td>Read repetition rate</td>
<td>f_REP</td>
<td>4 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 the data packet

Complete data packet is 32 bits long + 8 bits of CRC. MSB first. Position data is left aligned.
Repetition of reading is 4000 times per second maximum. If higher, it is possible to read the same position data twice. Polynomial for CRC is $x^8 + x^7 + x^4 + x^2 + x + 1$. Represented also as 0x97.

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 is not needed, master can terminate the communication after every byte with NACK and Stop condition. For example if only 16 bits of position is 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 the 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>16B</td>
<td>16 bits</td>
<td>4</td>
<td>1 bit</td>
<td>2 bits</td>
<td>8 bits</td>
</tr>
<tr>
<td>17B</td>
<td>17 bits</td>
<td>3</td>
<td>1 bit</td>
<td>2 bits</td>
<td>8 bits</td>
</tr>
<tr>
<td>18B</td>
<td>18 bits</td>
<td>2</td>
<td>8 bits</td>
<td>2 bits</td>
<td>8 bits</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**

*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.

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**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 Master</th>
<th>S</th>
<th>Address</th>
<th>A</th>
<th>A</th>
<th>A</th>
<th>'a' (0x61)</th>
<th>New address</th>
<th>'a' (0x61)</th>
<th>NA</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S</strong> – Start condition</td>
<td><strong>A</strong> – Acknowledge</td>
<td>'a’– Header and footer for changing address</td>
<td><strong>NA</strong> – Not Acknowledge</td>
<td><strong>P</strong> – Stop condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Data sheet**

**MBAD01_06**
Latency on Async serial communication

Readhead has its internal cycle of acquiring the position that is running at about 4 kHz (±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 (±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 \( t = 0 \) µs the physical position is latched but position data is not yet calculated. It will be available at 250 µs.
If the request comes at \( t = 1 \) µs – 249 µs, the last available data will be sent - the one from previous cycle when position was latched at \( t = -250 \) µs.

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

**Series**
- MBA - Magnetic head AksIM

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

**Output type**
- SG - Asynchronous serial
- PW - Pulse width modulated (PWM)
- SD - Binary synchro-serial (SSI), no line driver
- SP - SPI slave
- FC - I2C / Two-wire interface

**Output type variant**
- See table next to the description of the chosen output type for detailed information

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

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
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<tbody>
<tr>
<td>115.2</td>
<td>128</td>
<td>230.4</td>
<td>256</td>
<td>500</td>
<td>1000</td>
</tr>
</tbody>
</table>

For output type **PW**: Base frequency in Hz (16 bit resolution only):

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>122</td>
<td>244</td>
<td>325</td>
<td>488</td>
<td>976</td>
</tr>
</tbody>
</table>

For output type **SD**:
- A - Start bit and idle line 0
- B - Start bit and idle line 1

For output type **DD**:
- G - BiSS-C, low latency, 4 ACK bits, max. 3 MHz
- H - BiSS-C, low latency, 12 ACK bits, max. 5 MHz

For output type **SP**:
- A - SPI slave advanced (40-bit word)
- S - SPI slave simple (16-bit word)

For output type **FC**: A - Standard

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

**Housing**
- C - Partial arc, axial installation (standard)

**Resolution**

For output types and variants PWx and SPS:
- 16B - 16 bits per revolution

For output types and variants SGx, SDx, DDx, SPA and FCA:
- 15B - 15 bits per revolution (for MBA7 readhead only)
- 16B - 16 bits per revolution
- 17B - 17 bits per revolution
- 18B - 18 bits per revolution
- 19B - 19 bits per revolution
- 20B - 20 bits per revolution (for MBA8 readhead only)

**Current available ring options:**
- MRA7D049AA025B00
- MRA7D049AB025E00
- MRA8D080A055B00
- MRA8D080AB055E00

**AksIM ring part numbering**

**Series**
- MRA - Magnetic ring AksIM

**MRA ring type**
- 7 - For use with MBA7 readhead
- 8 - For use with MBA8 readhead

**Accuracy**
- D - ±0.1°

**Outer diameter**
- For MBA7: 049 - 49 mm
- For MBA8: 080 - 80 mm

**Special requirements**
- 00 - Standard

**Cross section**
- A - 3.9 mm thick
- B - 2 mm thick, lightweight

**Material**
- A - Stainless steel with glued rubber bonded ferrite

**Zero position**
- B - Marked by additional hole in metal hub
- E - Engraved

**Inner diameter**
- For MBA7: 025 - 25 mm
- For MBA8: 055 - 55 mm

**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 \( P(x) = x^8 + x^7 + x^4 + x^2 + 1 \), also represented as 0x97.

Code example:

```c
//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, 0xB6, 0x2C,
  0xE3, 0x74, 0x5A, 0xC4, 0x06, 0x91, 0xBF, 0x28, 0xBE, 0x29, 0x07, 0x90, 0x5B, 0xC7, 0x0A, 0x9D,
  0xB7, 0x20, 0xB6, 0x21, 0x0F, 0x99, 0x53, 0xC4, 0x0E, 0xA0, 0x27, 0x19, 0x9E, 0xA1, 0x36, 0xFD,
  0x6A, 0x44, 0xD3, 0x45, 0xD2, 0xFC, 0x68, 0xA0, 0x2E, 0x1E, 0x81, 0xAF, 0x38, 0xAE, 0x39, 0x17,
  0x80, 0xA4, 0x3A, 0xF9, 0x6D, 0x42, 0xD8, 0xF6, 0x6F, 0xA5, 0x3B, 0xF1, 0x66, 0xA8, 0x3F, 0x11,
  0x86, 0xAA, 0x3D, 0x13, 0x84, 0x4F, 0xD8, 0xF6, 0x61, 0xF7, 0x60, 0x4E, 0xD9, 0x12, 0x85, 0xA8,
  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];
  return crc;
}

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

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];
  return crc;
}

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 \( P(x) = x^8 + x^7 + x^4 + x^2 + 1 \), also represented as 0x97.

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  0xBA, 0x2D, 0x03, 0x94, 0x5F, 0xC8, 0xE6, 0x71, 0xE7, 0x70, 0x5E, 0xC9, 0x02, 0x95, 0xB6, 0x2C,
  0xE3, 0x74, 0x5A, 0xC4, 0x06, 0x91, 0xBF, 0x28, 0xBE, 0x29, 0x07, 0x90, 0x5B, 0xC7, 0x0A, 0x9D,
  0xB7, 0x20, 0xB6, 0x21, 0x0F, 0x99, 0x53, 0xC4, 0x0E, 0xA0, 0x27, 0x19, 0x9E, 0xA1, 0x36, 0xFD,
  0x6A, 0x44, 0xD3, 0x45, 0xD2, 0xFC, 0x68, 0xA0, 0x2E, 0x1E, 0x81, 0xAF, 0x38, 0xAE, 0x39, 0x17,
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  0x86, 0xAA, 0x3D, 0x13, 0x84, 0x4F, 0xD8, 0xF6, 0x61, 0xF7, 0x60, 0x4E, 0xD9, 0x12, 0x85, 0xA8,
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  t = (bb >> 24) & 0x000000FF;
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  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
example:

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];
  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 polynomial 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:**

```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, 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
Document issues

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