Orbis™ true absolute rotary encoder

Orbis™ is a true absolute rotary encoder suitable for applications where a typical OnAxis encoder cannot be mounted at the end of the rotating shaft due to space constraints or if hollow shaft is required.

The encoder comprises a diametrically magnetized permanent ring magnet and a printed circuit board. Geometric arrangement of RLS' proprietary Hall sensors on a PCB enables generation of one period of sine and cosine signals per mechanical magnet revolution. Moreover, it also enables cancellation of third harmonic component.

An adaptive filtering function ensures high resolution at low rotation speeds and low angle phase delay at high rotational speeds. Orbis™ also features an additional built-in self-calibration algorithm that improves encoder’s accuracy after installation.

Orbis™ through-hole measuring principle allows customisation with various board and magnet sizes to suit your application.

- True absolute encoder
- 14 bit resolution
- Multi-turn counter option
- Through-hole design enables its mounting anywhere along the shaft
- Optional self-calibration after assembly
- Buit-in self-diagnostics
- Status LED
- BiSS-C, SSI, SPI, Asynchronous serial and communication PWM
- Wide installation tolerances
Dimensions
Dimensions and tolerances in mm.

Encoder readhead

With connector

Without connector

Permanent magnet

Available magnets:

<table>
<thead>
<tr>
<th>ID</th>
<th>OD</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>24</td>
<td>3.5</td>
</tr>
</tbody>
</table>

ID and OD tolerances are ±0.05.

Magnetic actuator (magnet included)

Available actuators:

<table>
<thead>
<tr>
<th>ID</th>
<th>OD</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>21</td>
<td>9.5</td>
</tr>
<tr>
<td>8</td>
<td>21</td>
<td>9.5</td>
</tr>
<tr>
<td>10</td>
<td>22</td>
<td>9.5</td>
</tr>
<tr>
<td>12</td>
<td>27</td>
<td>10</td>
</tr>
<tr>
<td>14</td>
<td>27</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>27</td>
<td>10</td>
</tr>
</tbody>
</table>

ID tolerances are H7.

Installation drawing
Standard option

Shaft tolerance g6
Readhead
Magnet or Magnetic actuator
Spacer *
OD < 4 mm
L > 6 mm
(not provided)

Fastener *
3× M2, DIN 912
(not provided)

Fastener
3× M3, DIN 913
(included)

* Readhead should be only mounted on the golden plated surfaces around the mounting holes.
### Technical specifications

<table>
<thead>
<tr>
<th>System data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading type</td>
<td>Axial reading</td>
</tr>
<tr>
<td>Resolution</td>
<td>14 bit</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>12,000 RPM</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±0.25°</td>
</tr>
<tr>
<td>Accuracy thermal drift</td>
<td>±0.01°/°C</td>
</tr>
<tr>
<td>Repeatability</td>
<td>±2 LSB (counts, unidirectional)</td>
</tr>
<tr>
<td>Digital hysteresis</td>
<td>±2 LSB (counts)</td>
</tr>
<tr>
<td>Position update rate</td>
<td>50 kHz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electrical data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>4.5 V to 5.5 V (at the connector)</td>
</tr>
<tr>
<td>Set-up time</td>
<td>100 ms (worst case: 200 ms)</td>
</tr>
<tr>
<td>Current consumption</td>
<td>Typ. 65 mA (no output load)</td>
</tr>
<tr>
<td>Connection</td>
<td>Molex 501568-1107 or soldering pads (through holes)</td>
</tr>
<tr>
<td>Output load</td>
<td>PWM, SPI Max. ±5 mA at 3.3 V</td>
</tr>
<tr>
<td></td>
<td>RS422 Max. ±100 mA at 5 V</td>
</tr>
<tr>
<td>ESD protection</td>
<td>HBM, max. ±2 kV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>Readhead: 5.3 g</td>
</tr>
<tr>
<td></td>
<td>Magnetic actuators (ID): 6 mm: 6.0 g ; 8 mm: 5.5 g ; 10 mm: 5.7 g ; 12 mm: 8.7 g ; 15 mm: 7.1 g</td>
</tr>
<tr>
<td></td>
<td>Magnets (ID): 12 mm: 3.8 g ; 16 mm: 6.4 g</td>
</tr>
<tr>
<td>Magnet material</td>
<td>Neodymium with Ni-Cu-Ni protective layer</td>
</tr>
<tr>
<td>Actuator material</td>
<td>Anodised aluminium</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Operating: 0 °C to +85 °C</td>
</tr>
<tr>
<td></td>
<td>Storage: -40 °C to +105 °C</td>
</tr>
<tr>
<td></td>
<td>Not valid for cables with DSUB-9 connector.</td>
</tr>
<tr>
<td>Humidity</td>
<td>0 % to 70 % non-condensing</td>
</tr>
<tr>
<td>External magnetic field</td>
<td>Max. ±3 mT (DC or AC) on top side of readhead</td>
</tr>
</tbody>
</table>
**Status indicator LED**

The LED provides visual feedback of signal strength, error condition and is used 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 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>Slow flashing</td>
<td>Communication has not been established.</td>
</tr>
<tr>
<td>No light</td>
<td>No power supply.</td>
</tr>
<tr>
<td>Continuously fast flashing red</td>
<td>System error during start-up or operation.</td>
</tr>
<tr>
<td>3 sec. fast flashing</td>
<td>Self-calibration result - see documents BRD04 or BRD05</td>
</tr>
</tbody>
</table>

**Installation instructions**

**Installation tolerances**

Precise magnet and readhead installation is key to achieve good overall accuracy.

<table>
<thead>
<tr>
<th></th>
<th>Magnet with 12 mm ID</th>
<th>Magnet with 16 mm ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial (ΔZ) displacement (ride height)</td>
<td>4 mm nominal ±1 mm</td>
<td>5.5 mm nominal ±1 mm</td>
</tr>
<tr>
<td>Radial (ΔR) displacement</td>
<td>max 0.3 mm</td>
<td>max 0.3 mm</td>
</tr>
</tbody>
</table>

Nominal axial (ΔZ) displacement is valid with non-ferromagnetic shaft (aluminum, copper, plastic,...). If ferromagnetic shaft is used, nominal axial displacement has to be bigger for approximately 20 % to 30 %. For more information contact RLS support.

**Axial position adjustment (ride height)**

Any non-magnetic and non-conductive tool with nominal ride height thickness can be used to check the correct ride height setting mechanically. The integrated LED can be used as a coarse indicator. When correct ride height is achieved, the LED glows green and should not change colour when the magnet rotates.

**External magnetic field**

Principle of operation of any magnetic encoder is sensing changes in the magnetic field of the magnetic actuator. External magnetic fields, generated by permanent magnets, electric motors, coils, magnetic brakes, etc. may influence the encoder operation. The accuracy of Orbis is degraded in case of magnetic field gradients in axial direction.

**Self-calibration after installation**

The self-calibration function eliminates eccentricity-caused error, which is a dominant part of the encoder accuracy and is caused by the eccentric mounting of the ring. This function removes the one sine wave per revolution error. The self-calibration function can be triggered by user over selected communication interfaces or by using the appropriate USB encoder interface.

For details refer to the chosen communication interface description. If multiturn counter is being used in the encoder and if rotational speed is higher than ±300 RPM, it may have incorrect value after self-calibration. Multiturn error flag will be set in such case.

**Requirements:**

- Free mechanical rotation between 180° and 360° (desired angle can be selected over communication interface)
- Good signal throughout the calibration angle
- Maximum available time is 10 seconds
- Direction is not important
- Maximum speed during self-calibration up to 600 RPM
- Suitable communication interface or adaptor that allows triggering the function
- Self-calibration must be started when no error is present (green LED)
- When using SPI encoder version, LED must be visible for checking self-calibration status
Electrical connections

<table>
<thead>
<tr>
<th>Pin</th>
<th>Wire color</th>
<th>BiSS-C</th>
<th>Asynchronous serial</th>
<th>PWM</th>
<th>SSI</th>
<th>SPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brown</td>
<td></td>
<td></td>
<td>5 V supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>White</td>
<td></td>
<td></td>
<td>0 V (GND)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Pink</td>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Grey</td>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Red</td>
<td>MA+</td>
<td>RX command in+</td>
<td>Status out</td>
<td>Clock+</td>
<td>SCK</td>
</tr>
<tr>
<td>8</td>
<td>Blue</td>
<td>MA−</td>
<td>RX command in−</td>
<td>-</td>
<td>Clock−</td>
<td>NCS</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Cable shield</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Green</td>
<td>SLO+</td>
<td>TX data out+</td>
<td>PWM out</td>
<td>Data+</td>
<td>MISO</td>
</tr>
<tr>
<td>11</td>
<td>Yellow</td>
<td>SLO−</td>
<td>TX data out−</td>
<td>-</td>
<td>Data−</td>
<td>MOSI</td>
</tr>
</tbody>
</table>

**Pinout**

- **Connector Molex 501568-1107**
- **With Molex connector**
- **With soldering pads** (through holes)
- **Pitch is 1.9 mm**
- **Cable shield** (connected to pin 9)

**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.
Data sheet
BRD01_06

Chemical resistance of magnetic actuator

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Test performed with</th>
<th>Temperature (°C)</th>
<th>Adhesive joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>deionized</td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Sea water</td>
<td>Instant Ocean® sea salt, 3.5 %</td>
<td>25</td>
<td>✗</td>
</tr>
<tr>
<td>Ethanol</td>
<td>technical, ≥ 95 %</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Acetone</td>
<td>technical, ≥ 95 %</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Motor oil</td>
<td>SAE 15W-40</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Cutting oil</td>
<td>Rezilol SCM BCL</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Brake fluid</td>
<td>DOT-4</td>
<td>85</td>
<td>✔</td>
</tr>
<tr>
<td>Coolant</td>
<td>Blasocut® 2000 CF, 5%</td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Grease</td>
<td>ISOFLEX® Topas NB 52</td>
<td></td>
<td>✔</td>
</tr>
</tbody>
</table>

✔ Resistant
✗ Not resistant

Test samples were immersed in the chemicals for 4 weeks at 25 °C or 85 °C in accordance to standard ISO 175:2010. During the test axial load on the samples was monitored every 7 days.

Multiturn counter

Multiturn counter is available on the following communication interfaces: BiSS, Asynchronous serial (UART), SPI and SSI. Multiturn option is chosen with Resolution in part number on page 16. Multiturn counter is 16 bit (0 to 65535 counts). Counting is available only when the encoder is powered, but the counter state is stored in a non-volatile memory at power-down and is restored at power-up. Maximum permissible rotation during power-down is ±90°. If encoder is rotated for ±360° or multiple rotations, this movement is not registered and also multiturn error is not set. If any other error is set during a 90° rotation or more, the multiturn counter value might become inconsistent with mechanical position.

Multiturn counter limitations

Counter may have invalid value in following circumstances:

<table>
<thead>
<tr>
<th>Possible reasons for failure</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>If encoder is rotated ±360° or multiple rotations during off state.</td>
<td>Use mechanical brake.</td>
</tr>
<tr>
<td>If error flag (red LED) is present for 90° rotation or more.</td>
<td>Read and evaluate error bit.</td>
</tr>
<tr>
<td>When encoder has moved for 90° or more or rotating at 300 RPM or more when encoder is performing blocking operation (saving information to non-volatile memory, factory reset, write protect, self-calibration).</td>
<td>Stop rotation before performing those operations.</td>
</tr>
<tr>
<td>If user changes single-turn position offset for 90° or more.</td>
<td>Set new multiturn counter value right after setting zero position offset.</td>
</tr>
<tr>
<td>If any function for saving information to non-volatile memory (save configuration, factory reset, write protect, self-calibration) is active when power-down happens.</td>
<td>Keep power supply stable when performing those operations.</td>
</tr>
</tbody>
</table>

Multiturn error flag

Error flag is set in one of the following conditions:

- Detected movement of >90° and <270° when powered off
- Detected speed of more than 300 RPM during blocking operation
- High, unexpected positional difference detected (acceleration error)

Multiturn error bit can be cleared by writing new multiturn counter value into the encoder or by power cycle. Clearing error bit on SSI interface requires power cycle.
BiSS-C interface

The encoder position, in 14 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.

Electrical connection

![BiSS-C Timing Diagram](image)

<table>
<thead>
<tr>
<th>Line signals</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA+</td>
</tr>
<tr>
<td>MA−</td>
</tr>
<tr>
<td>SLO+</td>
</tr>
<tr>
<td>SLO−</td>
</tr>
</tbody>
</table>

* The MA and SLO signals are 5 V RS422 compatible differential pairs. MA signal is terminated with RC (100 Ω, 1 nF) inside the encoder.

BiSS-C timing diagram (single-turn)

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, left aligned, MSB first.

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>MA period</td>
<td>t_{MA}</td>
<td>200 ns</td>
<td></td>
<td>10 μs</td>
</tr>
<tr>
<td>MA frequency</td>
<td>f_{MA}</td>
<td>100 kHz</td>
<td></td>
<td>5 MHz</td>
</tr>
<tr>
<td>ACK length</td>
<td>t_{ACK}</td>
<td>5 bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfer timeout</td>
<td>t_{M}</td>
<td>13.5 μs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pause time</td>
<td>t_{p}</td>
<td>20 μs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Data sheet  
BRD01_06

Structure of data packet

<table>
<thead>
<tr>
<th>Bit</th>
<th>b37 : b22</th>
<th>b21 : b8</th>
<th>b7 : b6</th>
<th>b5 : b0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Multi-turn counter (if specified in part number)</td>
<td>Encoder position</td>
<td>General status</td>
<td>CRC (inverted)</td>
</tr>
<tr>
<td>Data length</td>
<td>16 bits</td>
<td>14 bits</td>
<td>2 bits</td>
<td>6 bits</td>
</tr>
</tbody>
</table>

Encoder position

| b37 : b22 | Multiturn counter (if specified in part number) - Left aligned, MSB first. |
| b21 : b8 | Encoder position – Left aligned, MSB first. |

General status

| b7 | Error - If low, the position data is not valid. Bits b21 - b8 are replaced with error status bits. |
| b6 | Warning - If low, the position data is valid, but some operating conditions are close to limits. |

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. LED is flashing (duty cycle 50 %, frequency 2.5 Hz), when the encoder is in idle state. If the controller requests the data every 200 ms or more often, the duty cycle of the LED is 100 % (always on).

CRC (inverted)

| b5 : b0 | Polynomial for CRC calculation of position, error and warning data is: x^6 + x^1 + 1. Represented also as 0x43. Number must be inverted before comparison with calculated CRC. |

CRC calculation example is in application note document CRCD01, available for download from www.rls.si/orbis.

Error status

| b21 : b16 | Reserved |
| b15 | Signal amplitude too high. The readhead is too close to the magnet or an external magnetic field is present. |
| b14 | Signal amplitude low. The distance between the readhead and the ring is too large. |
| b13 | The readhead temperature is out of specified range. |
| b12 | Speed too high. |
| b11 | Multiturn counter error. |
| b10 : b8 | Reserved. |

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

Encoder programming

Encoder supports register access which allows setting position offset, multiturn counter, running self-calibration function, configuring the encoder, reading signal level indicator, temperature, detailed status bits and electronic datasheet. It also allows storing up to 4 kB of user data into the encoder (eg. motor parameters, assembly data or similar). Additional information can be found in the "Application note: Orbis BiSS-C register access", document BRD05, available for download from www.rls.si/orbis.
Asynchronous serial communication interface

Asynchronous serial communication is supported by a universal asynchronous receiver/transmitter commonly known as UART. It comprises two unidirectional communications channels, forming a full-duplex bidirectional data link. Every channel consists of a two wire differential twisted-pair connection conforming to the RS422 signalling standard.

Electrical connection

* The RX and TX signals are 5 V RS422 compatible differential pairs. RX signal is terminated with RC (100 Ω, 1 nF) inside the encoder.

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>Flow control</td>
<td>None</td>
</tr>
<tr>
<td>Bit order</td>
<td>LSB first (standard)</td>
</tr>
</tbody>
</table>

Communication speed is set with 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>Baud rate [kbps]</td>
<td>115.2</td>
<td>128</td>
<td>230.4</td>
<td>256</td>
<td>500</td>
<td>1000</td>
</tr>
</tbody>
</table>

Command set

Command "1" (0x31) – position request

<table>
<thead>
<tr>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 byte ASCII &quot;1&quot;</td>
</tr>
<tr>
<td>2 bytes (4 for multturn) hex – see Encoder position data structure</td>
</tr>
</tbody>
</table>

Command "3" (0x33) – short position request

<table>
<thead>
<tr>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 bytes (4 for multturn) hex – see Encoder position data structure</td>
</tr>
</tbody>
</table>

Command "d" (0x64) – position request + detailed status

<table>
<thead>
<tr>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 byte ASCII &quot;d&quot;</td>
</tr>
<tr>
<td>2 bytes (4 for multturn) hex – see Encoder position data structure</td>
</tr>
<tr>
<td>1 byte hex – see Detailed status data structure</td>
</tr>
</tbody>
</table>

Command "t" (0x74) – position request + temperature

<table>
<thead>
<tr>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 byte ASCII &quot;t&quot;</td>
</tr>
<tr>
<td>2 bytes (4 for multturn) hex – see Encoder position data structure</td>
</tr>
<tr>
<td>2 bytes hex – temperature (temperature of the readhead in °C multiplied by 10)</td>
</tr>
<tr>
<td>(Signed binary) Temperature of the sensor in (°C). This value is typically 10 °C to 15 °C higher than ambient.</td>
</tr>
<tr>
<td>Tolerance of the readout is ±5 °C.</td>
</tr>
</tbody>
</table>

Command "v" (0x76) – serial number

<table>
<thead>
<tr>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 byte ASCII &quot;v&quot;</td>
</tr>
<tr>
<td>6 bytes ASCII – serial number</td>
</tr>
</tbody>
</table>
## Encoder position data structure

<table>
<thead>
<tr>
<th>Encoder position</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>b31 : b16</td>
<td>Multiturn counter (if specified in part number) - Left aligned, MSB first.</td>
</tr>
<tr>
<td>b15 : b2</td>
<td>Encoder position – Left aligned, MSB first.</td>
</tr>
</tbody>
</table>

## General status

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>b1</td>
<td>Error - If low, the position data is not valid. The last valid position is sent out.</td>
</tr>
<tr>
<td>b0</td>
<td>Warning - If low, the position data is valid, but some operating conditions are close to limits.</td>
</tr>
</tbody>
</table>

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. LED is flashing (duty cycle 50 %, frequency 2.5 Hz), when the encoder is in idle state. If the controller requests the data every 200 ms or more often, the duty cycle of the LED is 100 % (always on).

## Detailed status

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>b7</td>
<td>Signal amplitude too high. The readhead is too close to the magnet or an external magnetic field is present.</td>
</tr>
<tr>
<td>b6</td>
<td>Signal amplitude low. The distance between the readhead and the ring is too large.</td>
</tr>
<tr>
<td>b5</td>
<td>The readhead temperature is out of specified range.</td>
</tr>
<tr>
<td>b4</td>
<td>Speed too high.</td>
</tr>
<tr>
<td>b3</td>
<td>Multiturn counter error.</td>
</tr>
<tr>
<td>b2 : b0</td>
<td>Reserved.</td>
</tr>
</tbody>
</table>

## Encoder programming

Encoder supports changing default baud rate, position offset, multiturn counter, running self-calibration function, automatic transmission of selected data packet at programmable frame rate. Additional information on encoder programming can be found in the "Application note: Programming encoders with Async serial interface", document BRD04, available for download from www.rls.si/orbis.
PWM - Pulse width modulation interface

The PWM interface transmits the information about the absolute angle position over the pulse width modulated PWM Out signal. An additional digital Status signal indicates the encoder's error condition.

**Electrical connection**
The Status and PWM Out signals are 3.3 V LVTTL compatible. These signals have weak ESD protection. Handle with care. Maximum current sourced from or sunk into signal lines should not exceed 5 mA.

**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
- 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 14-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 \( 360^\circ / 65536 \approx 0.00549^\circ \)).

**PWM Out signal timing diagram**

![PWM Out signal timing diagram](image)

**Communication parameters**
*Communication interface 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>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>549.32</td>
<td>1098.63</td>
<td>Hz</td>
<td></td>
</tr>
<tr>
<td>Signal period</td>
<td>( t_{\text{PWM}} )</td>
<td>8192</td>
<td>1820.44</td>
<td>910.22</td>
<td>( \mu s )</td>
<td></td>
</tr>
<tr>
<td>Minimum pulse width</td>
<td>( PW_{\text{min}} )</td>
<td>0.5</td>
<td>0.111</td>
<td>0.0556</td>
<td>( \mu s )</td>
<td>Position 0 (Angle 0°)</td>
</tr>
<tr>
<td>Maximum pulse width</td>
<td>( PW_{\text{max}} )</td>
<td>8191.5</td>
<td>1820.33</td>
<td>910.17</td>
<td>( \mu s )</td>
<td>Position 16383</td>
</tr>
<tr>
<td>Min. counter frequency</td>
<td>( f_{\text{CNTR}} )</td>
<td>2</td>
<td>9</td>
<td>18</td>
<td>MHz</td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td></td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>Bit</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Position [counts]} = \frac{(t_{\text{on}} - PW_{\text{min}}) \times 16383}{PW_{\text{max}} - PW_{\text{min}}}
\]
SSI - Synchronous serial interface

The encoder position, in 14 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

* The Clock and Data signals are 5 V RS422 compatible differential pairs. Clock signal is terminated with RC (100 Ω, 1 nF) inside the encoder.

SSI timing diagram

The controller requests the position and status data of the encoder by sending a pulse train to the Clock input. The Clock signal always starts from high. The first falling edge of the Clock latches the last position data available and on the first rising edge of the Clock the most significant bit (MSB) of the position is transmitted to the Data output. The Data output should then be read on the following falling or rising edge. On subsequent rising edges of the Clock signal the next bits are transmitted.

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

While reading the data, the half of a Clock 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 .

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 (400 ns *)</td>
<td></td>
<td>15 µs</td>
</tr>
<tr>
<td>Clock frequency</td>
<td>$f_{cl}$</td>
<td>70 kHz</td>
<td>500 kHz (2.5 MHz *)</td>
<td></td>
</tr>
<tr>
<td>Delay first clock</td>
<td>$t_{fc}$</td>
<td>1.25 µs</td>
<td></td>
<td>13 µs</td>
</tr>
<tr>
<td>Transfer timeout</td>
<td>$t_{M}$</td>
<td>14 µs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pause time</td>
<td>$t_{p}$</td>
<td>20 µs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* With Delay First Clock function of the controller.
## Structure of data packet

<table>
<thead>
<tr>
<th>Bit</th>
<th>b39 : b24</th>
<th>b23 : b10</th>
<th>b9 : b8</th>
<th>b7 : b0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data length</td>
<td>16 bits</td>
<td>14 bits</td>
<td>2 bits</td>
<td>8 bits</td>
</tr>
<tr>
<td>Meaning</td>
<td>Multiturn counter (if specified in part number)</td>
<td>Encoder position</td>
<td>General status</td>
<td>Detailed status</td>
</tr>
</tbody>
</table>

### Encoder position

- **b39 : b24**: Multiturn counter (if specified in part number) - Left aligned, MSB first.
- **b23 : b10**: Encoder position – Left aligned, MSB first.

### General status

- **b9**: Error - If high, the position data is not valid. The last valid position is sent out.
- **b8**: Warning - If high, the position data is valid, but some operating conditions are close to limits.

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. LED is flashing (duty cycle 50 %, frequency 2.5 Hz), when the encoder is in idle state. If the controller requests the data every 200 ms or more often, the duty cycle of the LED is 100 % (always on).

### Detailed status

- **b7**: Signal amplitude too high. The readhead is too close to the magnet or an external magnetic field is present.
- **b6**: Signal amplitude low. The distance between the readhead and the ring is too large.
- **b5**: The readhead temperature is out of specified range.
- **b4**: Speed too high.
- **b3**: Multiturn counter error.
- **b2 : b0**: Reserved.
SPI - Serial peripheral interface (slave mode)

The Serial Peripheral Interface (SPI) bus is a four wire bidirectional synchronous serial communication interface, typically used for short distance communication. It operates in full duplex mode, where master (controller) selects the slave with NCS line, generates clock signal on SCK line, sends command over MOSI line and receives data over MISO line.

Electrical connection

All data signals are 3.3 V LVTTL. Inputs are 5 V tolerant. Maximum current sourced or sunk from signal lines should not exceed 20 mA. Single-ended signals should be as short as possible, especially if high frequencies are used.

<table>
<thead>
<tr>
<th>Signal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCS</td>
<td>Active low. NCS line is used for synchronisation between master and slave devices. During communication it must be held low. Idle is high. When NCS is high, MISO line is in high-Z mode. This allows connection of multiple slaves in parallel, sharing all lines except NCS.</td>
</tr>
<tr>
<td>SCK</td>
<td>Serial clock. Shifts out the data on rising edge.</td>
</tr>
<tr>
<td>MOSI</td>
<td>Master output → Slave input. Command from the controller to encoder.</td>
</tr>
<tr>
<td>MISO</td>
<td>Master input ← Slave output. Data is output on rising edge on SCK after NCS low. When NCS is high, MISO line is in high-Z mode.</td>
</tr>
</tbody>
</table>

SPI timing diagram

Controller starts the communication by setting the NCS signal low. The last available position data is latched at the same time. A delay of \( t_s \) is required for the encoder to prepare the data which is shifted to MISO output on rising edges of clock signal SCK. The command is received on 8 consecutive rising edges of SCK. 16 bits of Position and General Status (active low) data are sent out regardless of the received command. The following Requested data length as well as the content depends on the command. The last eight bits contain CRC (inverted) of the complete data packet.

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_{C1} )</td>
<td>250 ns</td>
<td>4 MHz</td>
<td></td>
</tr>
<tr>
<td>Clock frequency</td>
<td>( f_{C1} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time after NCS low to first SCK rising edge</td>
<td>( t_s )</td>
<td>2.5 ( \mu )s for 14B resolution</td>
<td>8 ( \mu )s for 14M resolution</td>
<td></td>
</tr>
<tr>
<td>Pause time</td>
<td>( t_p )</td>
<td>5 ( \mu )s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Structure of data packet

<table>
<thead>
<tr>
<th>Bit</th>
<th>Data length</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>b31 : b16</td>
<td>16 bits</td>
<td>Multi-turn counter (if specified in part number)</td>
</tr>
<tr>
<td>b15 : b2</td>
<td>14 bits</td>
<td>Encoder position</td>
</tr>
<tr>
<td>b1 : b0</td>
<td>2 bits</td>
<td>General status</td>
</tr>
<tr>
<td>rN : r0</td>
<td>Variable</td>
<td>Requested data</td>
</tr>
<tr>
<td>c7 : c0</td>
<td>8 bits</td>
<td>CRC (inverted)</td>
</tr>
</tbody>
</table>

Encoder position - for all commands

- **b31 : b16**: Multi-turn counter (if specified in part number) - Left aligned, MSB first.
- **b15 : b2**: Encoder position - Left aligned, MSB first.

General status - for all commands

- **b1**: Error - If low, position data is not valid. Last valid position is sent out.
- **b0**: Warning - If low, position data is valid, but some operating conditions are close to limits.

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. LED is flashing (duty cycle 50 %, frequency 2.5 Hz), when the encoder is in idle state. If the controller request the data every 20 ms or more often, the duty cycle of the LED is 100 % (always on).

Requested data - Command "v" (0x76) - serial number request

- **r47 - r0**: 6 bytes (48 bits) of ASCII serial number.

Requested data - Command "t" (0x74) - temperature request

- **r15 - r0**: 16 bits, signed. Number represents temperature of the readhead in °C multiplied by 10.

Requested data - Command "d" (0x64) - detailed status request

- **r7**: Signal amplitude too high. Readhead is too close to the magnet or an external magnetic field is present.
- **r6**: Signal amplitude low. Distance between the readhead and the magnet is too large.
- **r5**: Readhead temperature is out of range.
- **r4**: Speed is too high.
- **r3**: Multiturn counter error.
- **r2 - r0**: Reserved.

CRC (inverted)

- **c7 : c0**: Polynomial for CRC calculation of the sent data is: x^8 + x^7 + x^4 + x^2 + x + 1. Represented also as 0x97. Number must be inverted before comparison with calculated CRC.

CRC calculation example is in application note document CRCD01, available for download from www.rls.si/orbis.

If command byte does not match any of listed commands, encoder will send only Position, Status, CRC data. If additional data is not required, MOSI line of the encoder should be tied to GND.

Encoder programming

Encoder supports setting position offset, presetting multiturn counter value and running self-calibration function.

Additional information on encoder programming can be found in the "Application note: Programming encoders with SPI interface", document BRD09. Contact RLS Support to obtain this document.
Readhead part numbering

BR10  SF  A  14B  16  C  D  00

Communication interface
DC - BiSS-C, RS422
PW - Pulse width modulation (PWM), LVTTL
SC - Synchronous serial (SSI), RS422
SF - Asynchronous serial, RS422
SP - SPI slave, LVTTL

Communication interface variant
See table next to the description of the chosen communication interface for detailed information
For DC: D - BiSS-C, 5 ACK bits, bidirectional
For PW: Base frequency in Hz:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>122.07</td>
<td>549.32</td>
<td>1098.63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For SC: B - Start bit and idle data line
For SF: 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>
</thead>
<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 SP: C - Standard, full duplex

Valid combinations

<table>
<thead>
<tr>
<th>Series</th>
<th>Communication protocol</th>
<th>Communication protocol variant</th>
<th>Resolution</th>
<th>Magnet type compatibility</th>
<th>Temperature range</th>
<th>Connector option</th>
<th>Special requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR10</td>
<td>DC</td>
<td>D</td>
<td>14B</td>
<td></td>
<td>12 / 16</td>
<td>D / H</td>
<td>00</td>
</tr>
<tr>
<td></td>
<td>PW</td>
<td>A / D / E</td>
<td>14B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SC</td>
<td>B</td>
<td>14B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>A / B / C / D / E / F</td>
<td>14B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>C</td>
<td>14B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Special requirements
00 - No special requirements (standard)

Connector option
D - Molex 501568-1107
H - Soldering pads with through holes

Operating temperature range
C - 0 °C to +85 °C

Magnet type compatibility
12 - BM120A190A1ABx00 or actuator BA060–BA100
16 - BM160B240A1ABx00 or actuator BA120–BA150

Resolution
14B - 14 bits per revolution
14M - 14 bits per revolution + 16 bit multi-turn counter
(for DC, SC, SF and SP only)
Magnet part numbering

Series
BM - Orbis magnet

Inner diameter
120 - 12 mm
160 - 16 mm

Thickness
A - 3 mm
B - 3.5 mm

Outer diameter
190 - 19 mm
240 - 24 mm

Valid combinations

<table>
<thead>
<tr>
<th>Series</th>
<th>Inner diameter</th>
<th>Thickness</th>
<th>Outer diameter</th>
<th>Material</th>
<th>Grade</th>
<th>Surface finishing</th>
<th>Temperature range</th>
<th>Packaging</th>
<th>Special requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM</td>
<td>120</td>
<td>A</td>
<td>190</td>
<td>A</td>
<td>1</td>
<td>A</td>
<td></td>
<td>A / B</td>
<td>00</td>
</tr>
<tr>
<td></td>
<td>160</td>
<td>B</td>
<td>240</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td>A / B</td>
<td></td>
</tr>
</tbody>
</table>

Magnetic actuator part numbering

Series
BA - Orbis magnetic actuator

Shaft diameter
060 - 6 mm
080 - 8 mm
100 - 10 mm
120 - 12 mm
140 - 14 mm
150 - 15 mm

Form
AB - With 3 fasteners

Magnet type
01 - BM120A190A1ABA00
02 - BM160B240A1ABA00

Valid combinations

<table>
<thead>
<tr>
<th>Series</th>
<th>Shaft Size</th>
<th>Form</th>
<th>Magnet type</th>
<th>Material</th>
<th>Packaging</th>
<th>Special requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>060</td>
<td>AB</td>
<td>01</td>
<td>A</td>
<td>A / B</td>
<td>00</td>
</tr>
</tbody>
</table>
Accessories
Cables with crimped connectors

<table>
<thead>
<tr>
<th>Part number</th>
<th>Length</th>
<th>Connector 1</th>
<th>Connector 2</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC012</td>
<td>1.0 m</td>
<td>Molex 501330-1100 and 501334-0000</td>
<td>Flying leads</td>
<td>Single-shielded</td>
</tr>
<tr>
<td>ACC024</td>
<td>3.0 m</td>
<td></td>
<td>DSUB-9 M</td>
<td></td>
</tr>
<tr>
<td>ACC027</td>
<td>1.0 m</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Connector specifications**

<table>
<thead>
<tr>
<th>Connector 1 pin</th>
<th>Connector 2 pin</th>
<th>Wire color</th>
<th>BiSS-C</th>
<th>Asynchronous serial</th>
<th>PWM</th>
<th>SSI</th>
<th>SPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>Brown</td>
<td></td>
<td></td>
<td>5 V supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>White</td>
<td></td>
<td></td>
<td>0 V (GND)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>Pink</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>Grey</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>Red</td>
<td>MA+</td>
<td>RX command in+</td>
<td>Status out</td>
<td>Clock+</td>
<td>SCK</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>Blue</td>
<td>MA–</td>
<td>RX command in–</td>
<td>-</td>
<td>Clock–</td>
<td>NCS</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>Cable shield</td>
<td></td>
<td></td>
<td>Cable shield</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>6</td>
<td>Green</td>
<td>SLO+</td>
<td>TX data out+</td>
<td>PWM out</td>
<td>Data+</td>
<td>MISO</td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>Yellow</td>
<td>SLO–</td>
<td>TX data out–</td>
<td>-</td>
<td>Data–</td>
<td>MOSI</td>
</tr>
</tbody>
</table>

**Cable specifications**

<table>
<thead>
<tr>
<th>Part numbers</th>
<th>ACC012, ACC024, ACC027</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable specifications</td>
<td>LI12YC12Y</td>
</tr>
<tr>
<td>Configuration</td>
<td>4 × 2 × 0.14 mm²</td>
</tr>
<tr>
<td>Sheath colour</td>
<td>Grey (RAL7032)</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>250 V</td>
</tr>
<tr>
<td>Temperature range</td>
<td>Operating: −30 °C to +125 °C Storage: −40 °C to +130 °C Not valid for cables with DSUB-9 M connector.</td>
</tr>
<tr>
<td>Environmental conformation</td>
<td>RoHS conform 73/23/EWG-Guideline CE conform Halogen free</td>
</tr>
<tr>
<td>Chemical resistance</td>
<td>Largely resistant to acids, bases and usual oils. Free from lacquer damaging substances and silicone.</td>
</tr>
</tbody>
</table>

ACC027 can be used for direct connection to E201-9S or E201-9B USB encoder interface.
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