

# Orbis™

## Through-hole 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 limitations or where a hollow shaft is required. Orbis through-hole measuring principle allows customisation with various board and magnet sizes to suit your application.

EASY  
INSTALLATION

14 BIT  
RESOLUTION

MULTITURN  
COUNTER



## Features and benefits

- ▶ True absolute
- ▶ 14 bit resolution
- ▶ Multiturn counter option
- ▶ Through-hole design
- ▶ Built-in self-diagnostics
- ▶ Optional self-calibration after installation
- ▶ Integrated status LED
- ▶ BiSS C, SSI, SPI, Asynchronous serial and PWM communication interfaces
- ▶ Wide installation tolerances



GIMBALS



AGVs



MOTOR FEEDBACK  
AND COMMUTATION



ROBOTIC JOINTS



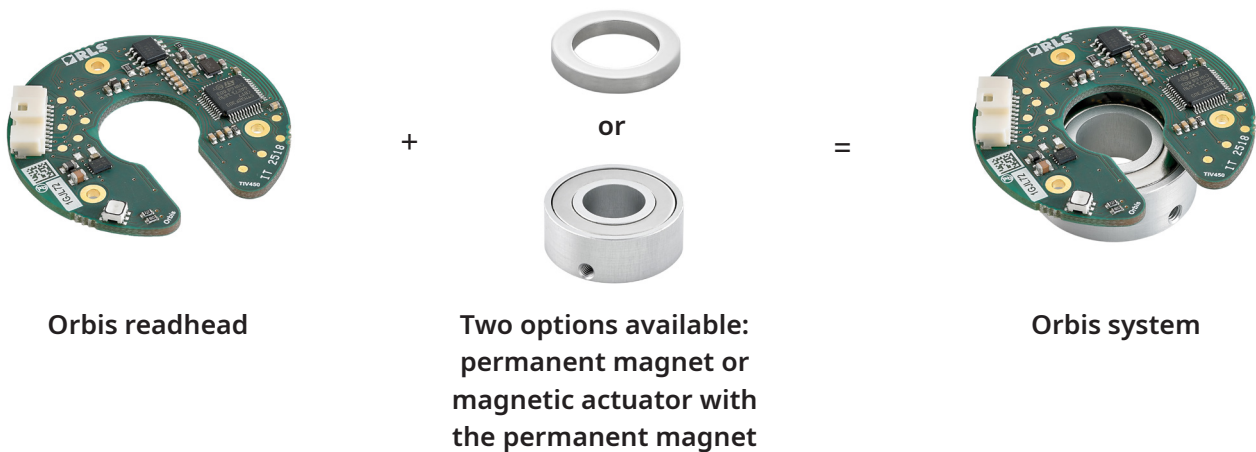
AGRICULTURAL  
AUTOMATION

## General information

The encoder consists of a diametrically magnetized permanent ring magnet and a printed circuit board. The geometrical arrangement of RLS' proprietary Hall sensors on the PCB enables the generation of one period of sine and cosine signals per mechanical magnetic revolution. In addition, it also allows cancelation of the third harmonic component.

An adaptive filtering function provides high resolution at low rotation speeds and low angular phase delay at high rotation speeds. Orbis also has an additional built-in self-calibration algorithm that improves the accuracy of the encoder after installation.

For output Sin/Cos and Commutation see **BRD14** data sheet at [RLS Media Center](#).



## Choose your Orbis magnetic encoder system

Orbis BR10 system



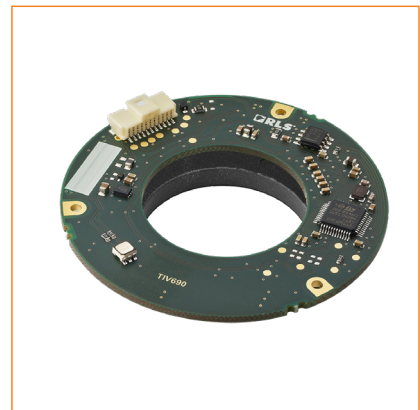
For installations on shaft diameters up to 15 mm.

Orbis BR20 system



For installation on shaft diameters up to 22 mm.

Orbis BR30 system



For installation on shaft diameters up to 30 mm.

## Storage and handling

### Storage temperature



With connector  
-40 °C to +105 °C

Without connector  
+15 °C to +30 °C (before soldering)  
-40 °C to +105 °C (after wires are soldered)

### Operating temperature



-40 °C to +105 °C

### Humidity



With connector  
Up to 70% non- condensing

Without connector  
Up to 10 % (before soldering)  
Up to 70 % non-condensing (after wires are soldered)



#### **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.

## Chemical resistance

RLS products are often used in industrial applications and exposed to chemicals that can affect their internal and external components. While our products are designed to be resistant to many harsh chemicals and environments, long-term resistance will depend on exposure, temperature, and concentration. Most chemicals our products are exposed to are not in continuous contact. Therefore, a material that might not be resistant when submerged in a chemical will last indefinitely when wiped down by that same chemical once a day.

For further information or to confirm compatibility with a chemical in your environment, [contact RLS](#).

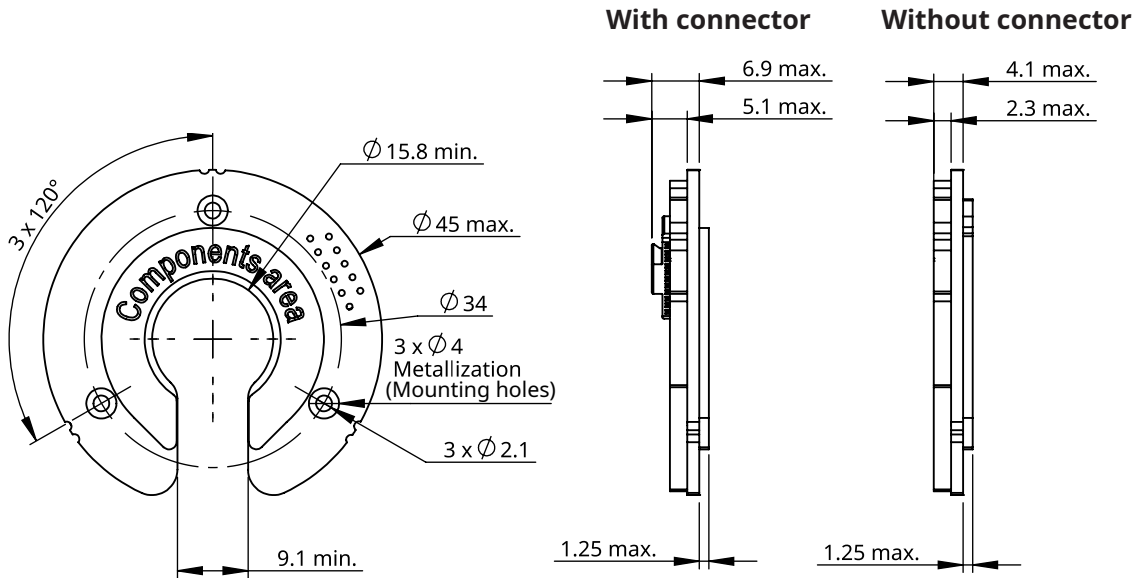
## Packaging

Less than 20 products are packed individually in an antistatic box. If the order quantity is 20 systems and larger, the parts are packed in antistatic plastic trays. Magnets and readheads are packed separately.

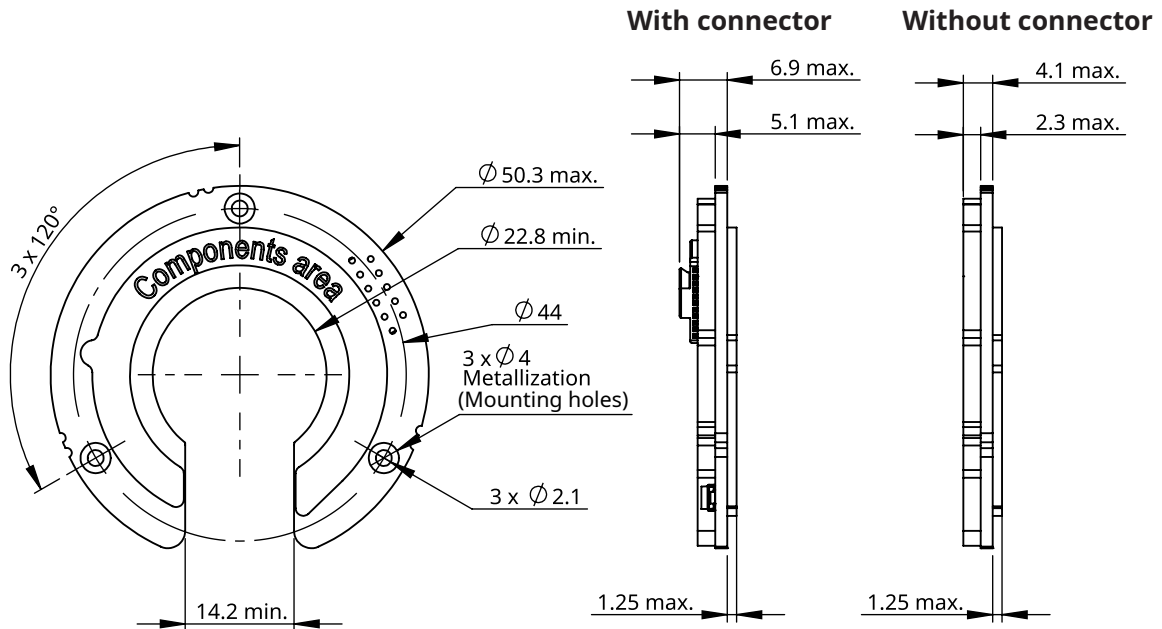
# Dimensions and installation drawings

Dimensions and tolerances are in mm.

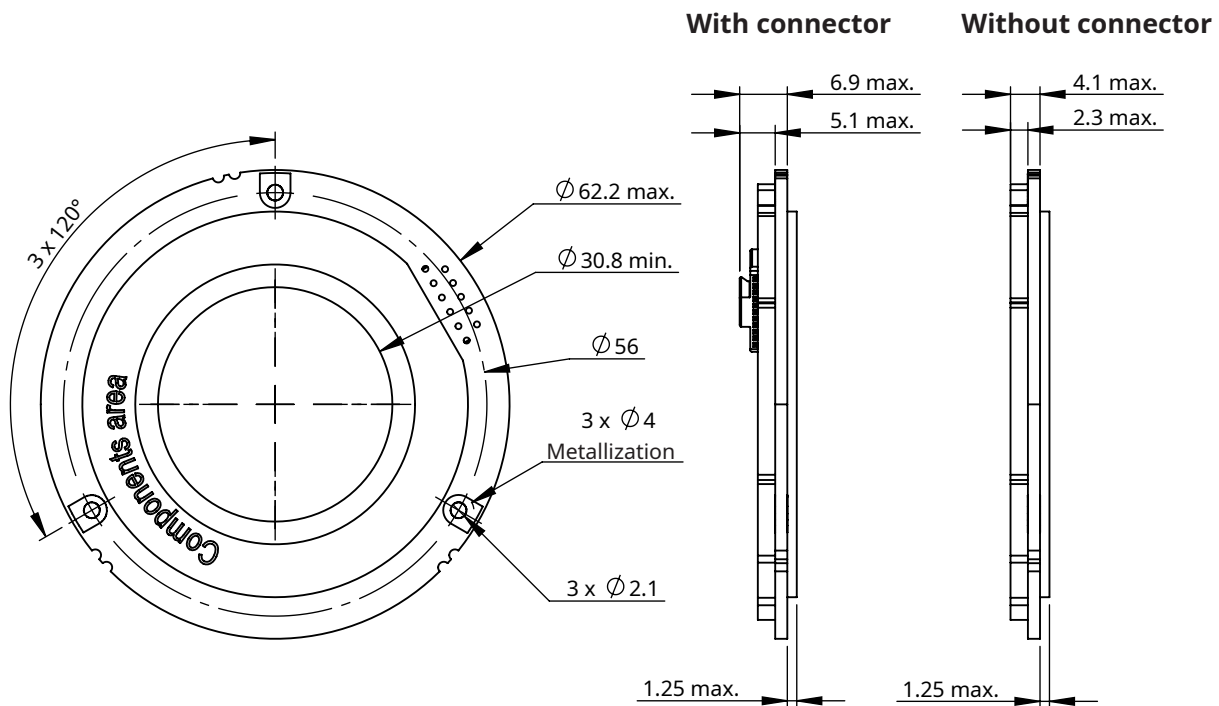
## BR10 Readhead



## BR20 Readhead

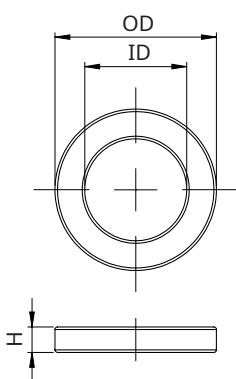


## BR30 Readhead



## BM magnets and magnetic actuators

### Permanent magnet

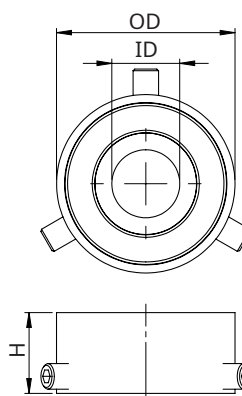


#### Available magnets:

ID	OD	H
12	19	3
16	24	3.5
22	32	4
30	44	4

ID, OD and H tolerances are  $\pm 0.05$ .

### Magnetic actuator (magnet included)

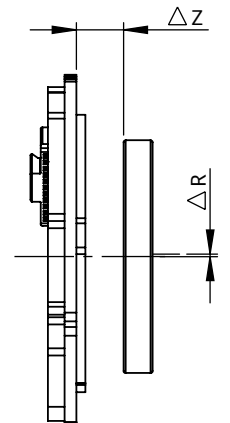
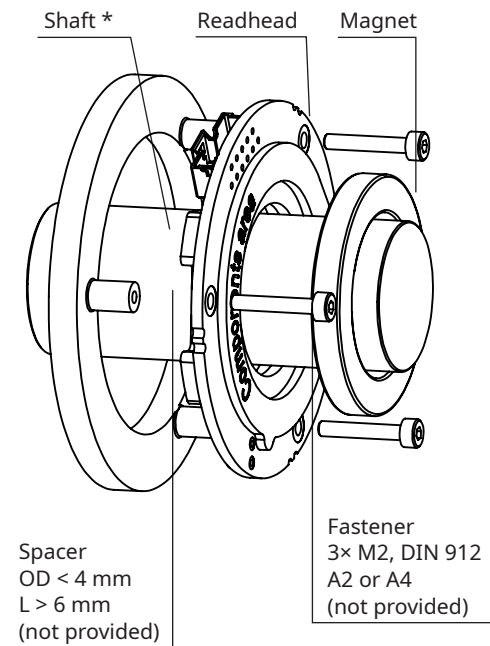
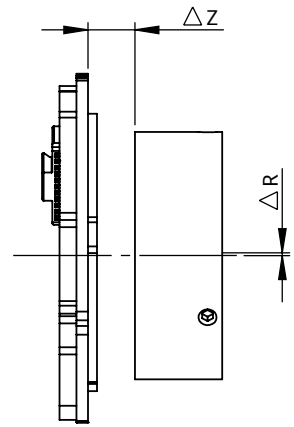
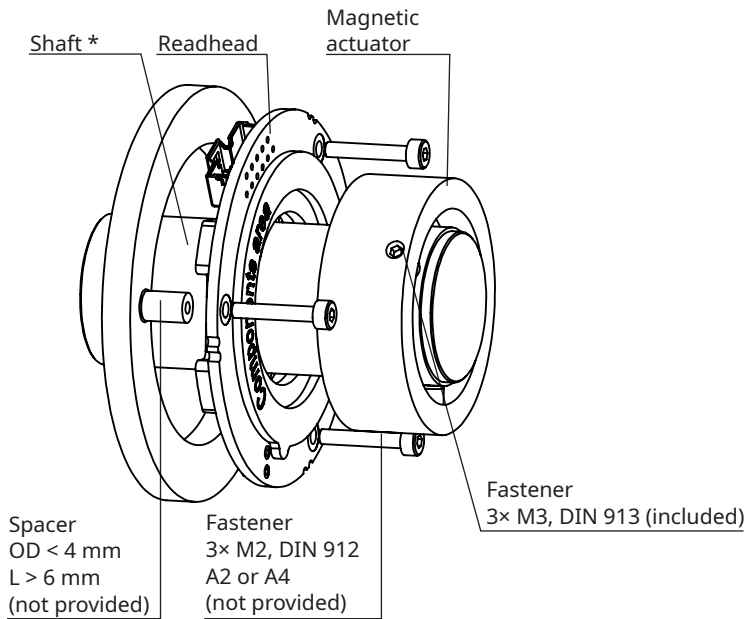


#### Available actuators:

ID	OD	H
6	21	9.5
8	21	9.5
10	22	9.5
12	27	10
14	27	10
15	27	10
20	34	12
25	48	13

ID tolerances are H7.

## Installation drawing



\* Recommended shaft tolerance for application with magnetic actuator is g6.

Readhead should only be mounted on the gold plated surfaces around the mounting holes. See **Installation instructions**.

For recommended tightening torques, refer to the document TTD01 available at **RLS Media center**.

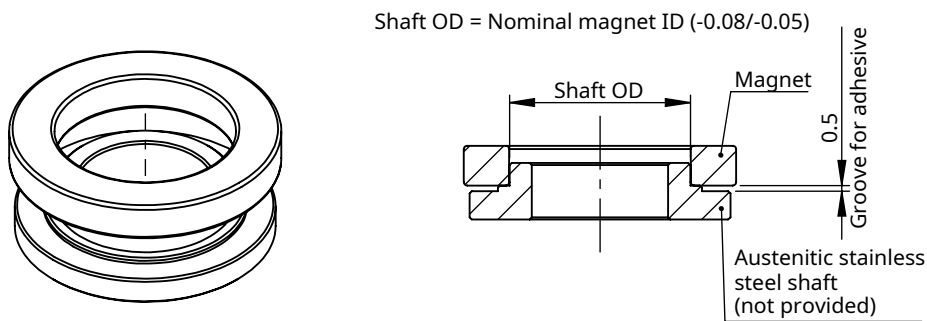
**Specifications in this data sheet applies to magnet mounting with non-ferrous shafts. If ferrous shafts are used, the encoder specifications may change. In this case, the use of actuators is recommended.**

## Installation by gluing

### Application

Adhesive mounting is based on the use of adhesive materials such as tapes, glues or epoxies to bond objects together. Cleaning and degreasing of bounded surfaces is essential. Adhesive materials should be applied according to manufacturer specification. Assembly recommendation (shown in the image below):

- Adhesive Loctite EA 9514.
- Curing at max 130 °C for 45 min
- Apply glue around the entire magnet perimeter



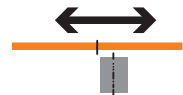
## Installation instructions

### Installation tolerances

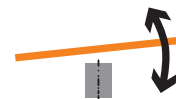
Axial ( $\Delta Z$ ) displacement (ride height)*	Magnet with 12 mm ID	4 mm $\pm$ 1 mm
	Magnet with 16 mm ID	5.5 mm $\pm$ 1 mm
	Magnet with 22 mm ID	6.5 mm $\pm$ 1 mm
	Magnet with 30 mm ID	4 mm $\pm$ 1 mm



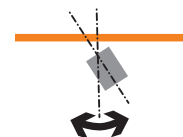
Radial ( $\Delta R$ ) displacement of the sensor Max. 0.5 mm



Perpendicularity of readhead 1°



Perpendicularity magnet 2°



— Readhead ■ Magnet

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

\*See **Installation drawing**.

Specifications in this data sheet applies to magnet mounting with non-ferrous shafts. If ferrous shafts are used, the encoder specifications may change. In this case, the use of actuators is recommended.

## Axial position adjustment (ride height)

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Any non-magnetic and non-conductive tool can be used to mechanically check for correct ride height adjustment. The integrated LED can be used as a rough indicator. When the correct ride height is achieved, the LED will glow green and should not change colour as the magnet rotates.

## External magnetic field

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The operating principle of any magnetic encoder is to sense changes in the magnetic field of the magnetic actuator. External magnetic fields generated by permanent magnets, electric motors, coils, magnetic brakes, etc. can affect the operation of the encoder. The accuracy of Orbis is degraded in the presence of magnetic field in radial and axial direction. Axial component is less critical.

## Self-calibration after installation

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The self-calibration function eliminates eccentricity-related errors, which are a dominant contributor to the accuracy of the encoder and are caused by the eccentric mounting of the ring. This function eliminates the error of one sine wave per revolution. The self-calibration function can be triggered by the user via selected communication interfaces or via using the corresponding USB encoder interface.

For details, refer to the description of the selected communication interface. If the multiturn counter is used in the encoder and the rotational speed is higher than  $\pm 300$  RPM, it may have an incorrect value after self-calibration. In this case the multiturn error flag is set.

Requirements:

- Free mechanical rotation for one full revolution (360°)
- Good signal over the entire calibration angle
- Maximum time available is 10 seconds
- Direction is not important
- Maximum speed during self-calibration up to 600 RPM
- Suitable communication interface (DC, SP or SF) or adapter that allows the function to be triggered
- Self-calibration must be started when no error is present (green LED)
- When using the SPI encoder version, LED must be visible to check the self-calibration status



## Technical specifications

### System data

<b>Reading type</b>	Axial reading
<b>Resolution</b>	14 bit
<b>Repeatability</b>	±2 LSB (counts, unidirectional)
<b>Maximum speed</b>	12,000 rpm
<b>Accuracy</b>	±0.25° (BR10), ±0.3° (BR20), ± 0,5° (BR30)
<b>Accuracy thermal drift</b>	±0.003°/°C
<b>Digital hysteresis</b>	±2 LSB (counts)
<b>Position update rate</b>	50 kHz

### Electrical data

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

### Mechanical data

<b>Mass</b>	Readhead	5.3 g
	Magnetic actuator (ID)	6 mm: 6.0 g; 8 mm: 5.5 g; 10 mm: 5.7 g; 12 mm: 8.7 g; 14 mm: 13.7 g 15 mm: 7.1 g; 20 mm: 25 g; 25 mm: 48 g
	Magnet (ID)	12 mm: 3.8 g; 16 mm: 6.4 g; 22 mm: 12.7 g; 30 mm: 16.8 g
<b>Magnet material</b>	12, 16, 22 mm	NdFeB with Ni-Cu-Ni protective layer
	30 mm	NdFeB + epoxy resin
<b>Actuator material</b>		Anodised aluminium

### Environmental data

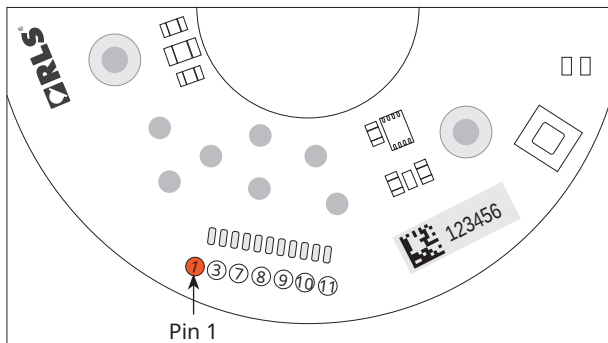
<b>Temperature</b>	Operating	-40 °C to +105 °C
	Storage	-40 °C to +105 °C*
<b>Humidity</b>		0 % to 70 % non-condensing*
<b>External magnetic field</b>		Max. ±10 mT (DC) on top side of readhead. External magnetic field decreases accuracy of encoder.
<b>Shock</b>		100 G (6 ms, standard EN 60068-2-27:2009)
<b>Vibration</b>		40 G (55 Hz – 2000 Hz, standard EN 60068-2-6:2008)

\* For limitations see chapter **Storage and Handling**.

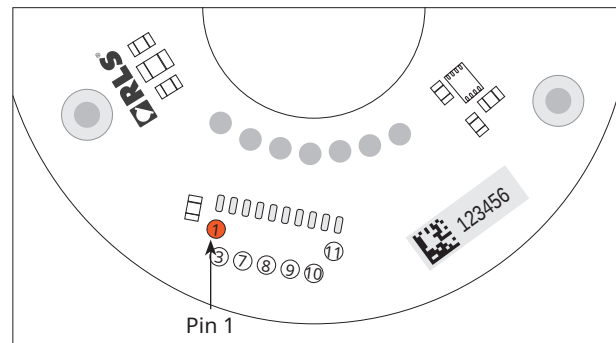
# Electrical connections

Pin	DC	SF	PW	SC	SP
1			Vdd		
2					
3			GND		
4					
5					
6			-		
7	MA+	RX command in+	Status out	Clock+	SCK
8	MA-	RX command in-	-	Clock-	NCS
9			Cable shield		
10	SLO+	TX data out+	PWM out	Data+	MISO
11	SLO-	TX data out-	-	Data-	MOSI

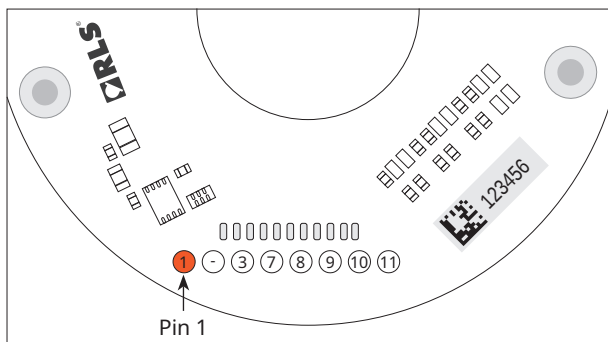
## Pinout



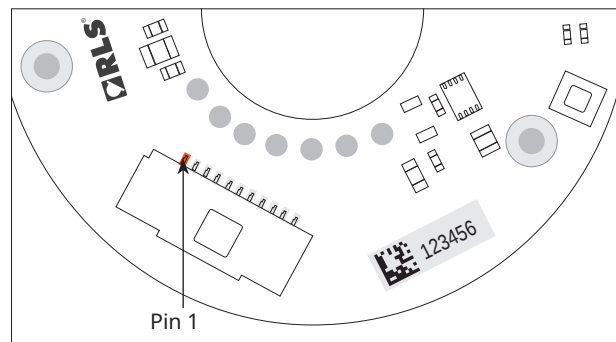
**Soldering pads**  
Size BR10



**Soldering pads**  
Size BR20



**Soldering pads**  
Size BR30



**With connector Molex 501568-1107**  
Sizes BR10, BR20, BR30










**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.

## Status indicator LED

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

LED	Status
	Green Normal operation; position data is valid.
	Orange Warning; position is valid, but the resolution and/or accuracy might be out of specification. Some operating conditions are outside limits.
	Red Error; position data is not valid.
	Slow flashing Communication has not been established. Position was not requested within last 200 ms. Color of flashing - see above.
	No light No power supply.
	Continuously fast flashing red System error during start-up or operation.
	3 sec. fast flashing Self-calibration results - Refer to the documents <a href="#">BRD04</a> (Programming Orbis with Asynchronous serial interface) or <a href="#">BRD05</a> (Orbis BiSS C register access) available at <a href="#">RLS Media center</a> .

## 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 numbering**. 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  $\pm 90^\circ$ . If encoder is rotated for  $\pm 360^\circ$  or multiple rotations, this movement is not registered and also multiturn error is not set. If any other error is set during a  $90^\circ$  rotation or more, the multiturn counter value might become inconsistent with mechanical position.

### Multiturn counter limitations

Counter may have invalid value in following circumstances:

Possible reasons for failure	Solution
If encoder is rotated for $\pm 360^\circ$ or multiple rotations during off state.	Use mechanical brake.
If error flag (red LED) is present for $90^\circ$ rotation or more.	Read and evaluate error bit.
When encoder has moved for $90^\circ$ 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).	Stop rotation before performing those operations.
If user changes single-turn position offset for $90^\circ$ or more.	Set new multiturn counter value right after setting zero position offset.
If any function for saving information to non-volatile memory (save configuration, factory reset, write protect, self-calibration) is active when power-down happens.	Keep power supply stable when performing those operations.

### Multiturn error flag

Error flag is set in one of the following conditions:

- Detected movement of  $>90^\circ$  and  $<270^\circ$  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.

### Battery powered multiturn counter

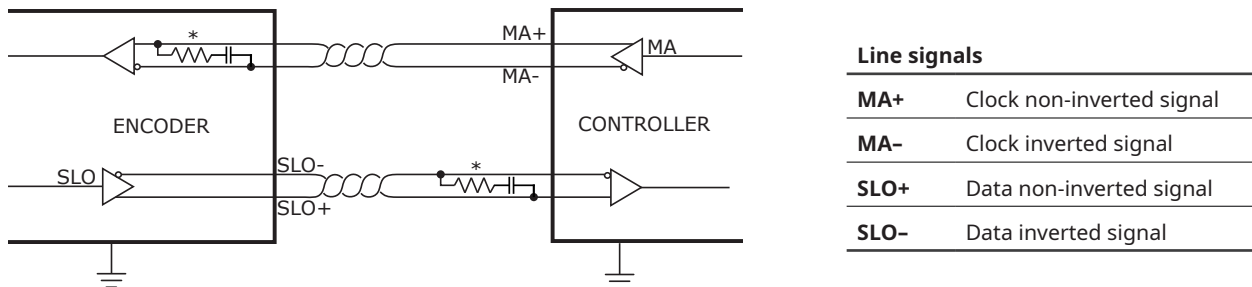
Orbis encoder can also be powered by external battery to keep counting the revolutions even when main power is not available. For further information regarding Orbis battery backup multiturn (BBM) refer to the document BRD08 available at [RLS Media center](#).

## 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).

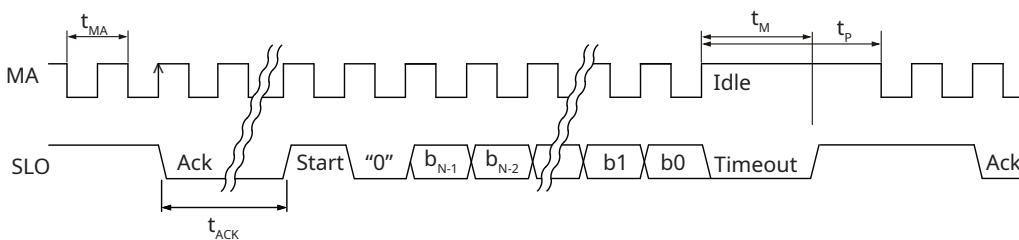
BiSS is implemented for point-to-point operation; multiple slaves are not supported.

### Electrical connection



\* The MA and SLO signals are 5 V RS422 compatible differential pairs. MA signal is terminated with RC (100  $\Omega$ , 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

Parameter	Symbol	Min	Typ	Max
MA period	$t_{MA}$	200 ns		10 $\mu$ s
MA frequency	$f_{MA}$	100 kHz		5 MHz
ACK length	$t_{ACK}$		5 bits	
Transfer timeout	$t_M$		13.5 $\mu$ s	
Pause time	$t_p$	20 $\mu$ s		

### Structure of data packet

Bit	b37 : b22	b21 : b8	b7 : b6	b5 : b0
Data length	16 bits	14 bits	2 bits	6 bits
Meaning	Multiturn counter (if specified in part number)	Encoder position	General status	CRC (inverted)

Encoder position	
<b>b37 : b22</b>	Multiturn counter (if specified in part number) - Left aligned, MSB first.
<b>b21 : b8</b>	Encoder position – Left aligned, MSB first.
General status	
<b>b7</b>	Error - If low, the position data is not valid. Bits b21 - b8 are replaced with error status bits.
<b>b6</b>	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)	
<b>b5 : b0</b>	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.

For further information regarding CRC calculation example, refer to the document CRCD01 available at [RLS Media center](#).

Detailed status (in BiSS registers)	
<b>b21 : b16</b>	Reserved
<b>b15</b>	Warning: Limit of lower ride height tolerance. Error: Signal amplitude too high. The readhead is too close to the magnet or an external magnetic field is present and too large.
<b>b14</b>	Warning: Limit of upper ride height tolerance. Error: Signal amplitude low. The distance between the readhead and the ring is too large.
<b>b13</b>	Warning: The readhead temperature is out of specified range.
<b>b12</b>	Warning: Speed too high.
<b>b11</b>	Error: Multiturn counter error.
<b>b10 : b8</b>	Reserved.

For more information regarding BiSS protocol see [www.biss-interface.com](http://www.biss-interface.com).

## Encoder programming

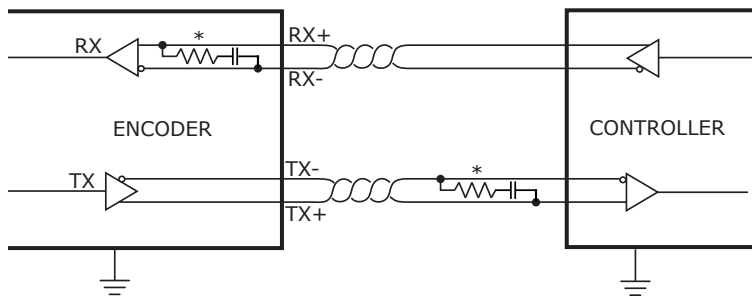
Encoder supports register access which allows setting position offset, multiturn counter, running self-calibration function, configuring the encoder, reading signal level indicator, temperature, detailed status bits and electronic datasheet. It also allows storing up to 4 kB of user data into the encoder (eg. motor parameters, assembly data or similar).

For further information regarding Orbis BiSS C register access, refer to the document BRD05 available at [RLS Media center](#).

# Asynchronous serial communication interface over RS422 (UART)

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



### Line signals

<b>RX+</b>	RX data in +
<b>RX-</b>	RX data in -
<b>TX+</b>	TX data out +
<b>TX-</b>	TX data out -

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

## Communication parameters

<b>Character length</b>	8 bits
<b>Parity</b>	None
<b>Stop bits</b>	1
<b>Flow control</b>	None
<b>Bit order</b>	LSB first (standard)

Communication speed is set with the *Communication interface variant* in the part number:

Communication interface variant	A	B	C	D	E	F
<b>Baud rate [kbps]</b>	115.2	128	230.4	256	500	1000

## Command set

<b>Command "1" (0x31) - position request</b>	
Response	1 byte ASCII "1" 2 bytes (4 for multiturn) hex - see Encoder position data structure
<b>Command "3" (0x33) - short position request</b>	
Response	2 bytes (4 for multiturn) hex - see Encoder position data structure
<b>Command "d" (0x64) - position request + detailed status</b>	
Response	1 byte ASCII "d" 2 bytes (4 for multiturn) hex - see Encoder position data structure 1 byte hex - see Detailed status data structure
<b>Command "t" (0x74) - position request + temperature</b>	
Response	1 byte ASCII "t" 2 bytes (4 for multiturn) hex - see Encoder position data structure 2 bytes hex - temperature (temperature of the readhead in $^{\circ}\text{C}$ multiplied by 10) (Signed binary) Temperature of the sensor in ( $^{\circ}\text{C}$ ). This value is typically 10 $^{\circ}\text{C}$ to 15 $^{\circ}\text{C}$ higher than ambient. Tolerance of the readout is $\pm 5$ $^{\circ}\text{C}$ .

Command "v" (0x76) – serial number	
Response	1 byte ASCII "v" 6 bytes ASCII – serial number

## Encoder position data structure

Encoder position	
<b>b31 : b16</b>	Multiturn counter (if specified in part number) - Left aligned, MSB first.
<b>b15 : b2</b>	Encoder position – Left aligned, MSB first.
General status	
<b>b1</b>	Error - If low, the position data is not valid. The last valid position is sent out.
<b>b0</b>	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).	
Detailed status	
<b>b7</b>	Warning: Limit of lower ride height tolerance. Error: Signal amplitude too high. The readhead is too close to the magnet or an external magnetic field is present and too large.
<b>b6</b>	Warning: Limit of upper ride height tolerance. Error: Signal amplitude low. The distance between the readhead and the ring is too large.
<b>b5</b>	Warning: The readhead temperature is out of specified range.
<b>b4</b>	Warning: Speed too high.
<b>b3</b>	Error: Multiturn counter error.
<b>b2 : b0</b>	Reserved.

## 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.

For further information regarding Programming encoders with Async serial interface can be found in the document BRD04, available for download at [RLS Media center](#).



# 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 LVTTTL 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

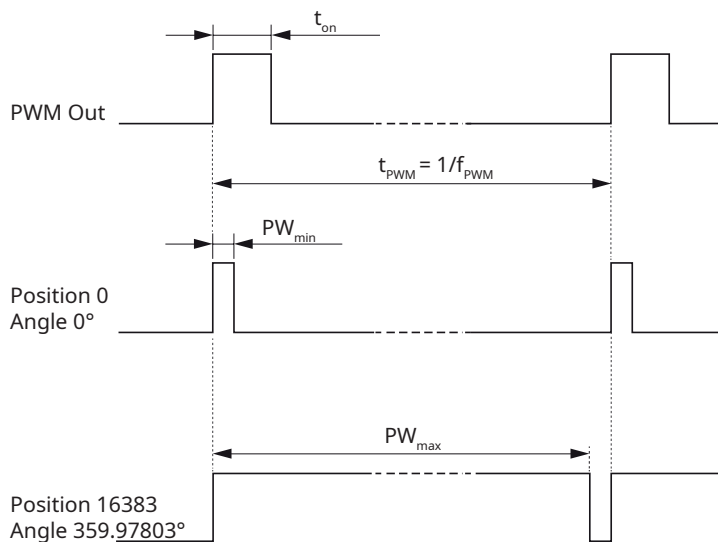
When the Status signal is low, the PWM Out signal is low and no pulses are output.

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  $PW_{min}$  corresponds to a change in position by one count (change in angle for  $360^\circ / 65536 \approx 0.00549^\circ$ ).

## PWM Out signal timing diagram



## Communication parameters

*Communication interface variant* in the part number defines the PWM frequency and all other dependent parameters.

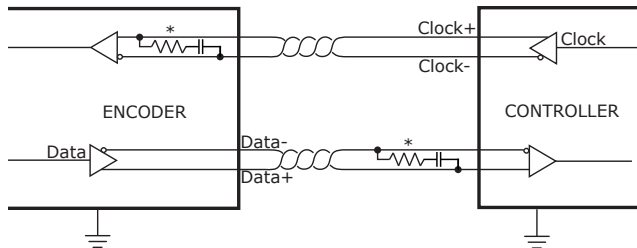
Parameter	Symbol	Communication interface variant			Unit	Note
		A	D	E		
PWM frequency	$f_{\text{PWM}}$	122.07	549.32	1098.63	Hz	
Signal period	$t_{\text{PWM}}$	8192	1820.44	910.22	$\mu\text{s}$	
Minimum pulse width	$\text{PW}_{\text{min}}$	0.5	0.111	0.0556	$\mu\text{s}$	Position 0 (Angle 0°)
Maximum pulse width	$\text{PW}_{\text{max}}$	8191.5	1820.33	910.17	$\mu\text{s}$	Position 16383
Min. counter frequency	$f_{\text{CNTR}}$	2	9	18	MHz	
Resolution		14	14	14	Bit	

$$\text{Position [counts]} = \frac{(t_{\text{on}} - \text{PW}_{\text{min}}) \times 16383}{\text{PW}_{\text{max}} - \text{PW}_{\text{min}}}$$

# 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

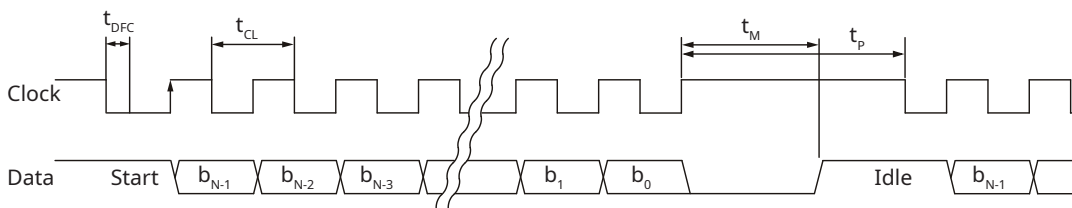


### Line signals

<b>Clock+</b>	Clock non-inverted signal
<b>Clock-</b>	Clock inverted signal
<b>Data+</b>	Data non-inverted signal
<b>Data-</b>	Data inverted signal

\* 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  $t_M$  time expires, the Data output goes high. The Clock signal must remain high for at least  $t_P$  before the next reading can take place.

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

## Communication parameters

Parameter	Symbol	Min	Typ	Max
Clock period	$t_{CL}$	2 μs (400 ns *)		15 μs
Clock frequency	$f_{CL}$	70 kHz		500 kHz (2.5 MHz *)
Delay first clock	$t_{DFC}$	1.25 μs		13 μs
Transfer timeout	$t_M$		14 μs	
Pause time	$t_P$	20 μs		

\* With *Delay First Clock* function of the controller.

## Structure of data packet

Bit	b39 : b24	b23 : b10	b9 : b8	b7 : b0
Data length	16 bits	14 bits	2 bits	8 bits
Meaning	Multiturn counter (if specified in part number)	Encoder position	General status	Detailed status

### 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** Warning: Limit of lower ride height tolerance. Error: Signal amplitude too high. The readhead is too close to the magnet or external magnetic field is present and too large.

**b6** Warning: Limit of upper ride height tolerance. Error: Signal amplitude low. The distance between the readhead and the ring is too large.

**b5** Warning: The readhead temperature is out of specified range.

**b4** Warning: Speed too high.

**b3** Error: Multiturn counter error.

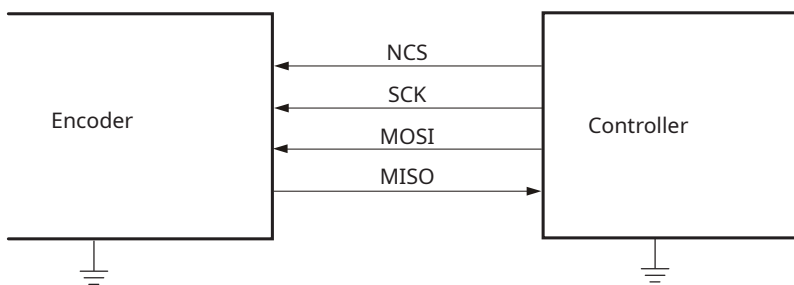
**b2 : b0** Reserved.

# SPI - Serial peripheral interface

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.

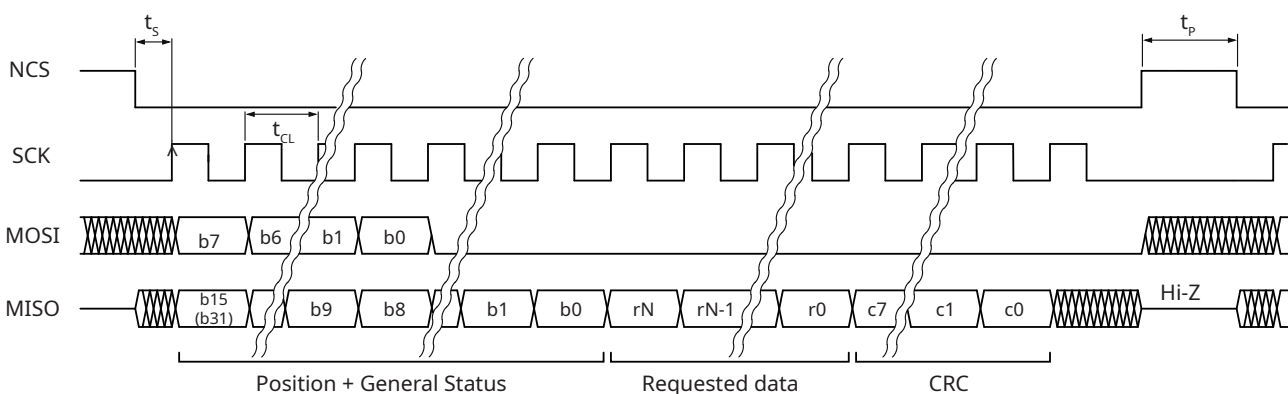
## Electrical connection

All data signals are 3.3 V LVTTTL. 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.



Signal	Description
NCS	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.
SCK	Serial clock. Shifts out the data on rising edge.
MOSI	Master output → Slave input. Command from the controller to encoder.
MISO	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.

## SPI timing diagram



The controller starts communication by setting the NCS signal low. At the same time, the last available position data is latched. A delay of  $t_s$  is required to allow the encoder to prepare the data to be shifted to the output MISO on rising edges of the clock signal SCK. The command is received on 8 consecutive rising edges of SCK. Regardless of the command received, 16 bits of Position and General Status data (active low) are sent out. The following length of the requested data and the content depend on the command. The last eight bits contain CRC (inverted) of the complete data packet.

## Communication parameters

Parameter	Symbol	Min	Max
Clock period	$t_{CL}$	250 ns	
Clock frequency	$f_{CL}$		4 MHz
Time after NCS low to first SCK rising edge	$t_s$	9 $\mu$ s for 14B resolution 14 $\mu$ s for 14M resolution	
Pause time	$t_p$	20 $\mu$ s	
Frame rate			$(1 / (t_s + (\text{Data length} / f_{CL}) + t_p))$ Hz

## Structure of data packet

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

### 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** Warning: Limit of lower ride height tolerance. Error: Signal amplitude too high. The readhead is too close to the magnet or an external magnetic field is present and too large.

**r6** Warning: Limit of upper ride height tolerance. Error: Signal amplitude low. The distance between the readhead and the ring is too large.

**r5** Warning: The readhead temperature is out of specified range.

**r4** Warning: Speed too high.

**r3** Error: Multiturn counter error.

**r2** Reserved.

**r1** Error: Measured acceleration too high. Check magnet mounting.

**r0** Error: Safety comparison error. Latched. Power cycle to clear.

Requested data - Command "a" (0x61) - Signal level	
<b>r15 : r0</b>	16 bits, unsigned. Value represents air gap distance between magnet and readhead. Use formula to calculate gap in millimeters.
Requested data - Command "i" (0x69) - Self-calibration procedure result	
<b>b7</b>	Procedure has finished.
<b>b3</b>	Error. Calibration was not successful.
<b>b2</b>	Error. Timeout has expired. Magnet did not make one full turn in 10 seconds.
<b>b1 : b0</b>	Counter increments after every procedure completion.
Requested data - Command "f" (0x66) - Firmware version	
Returns 7 bytes, without position and CRC.	
<b>B6 : B5</b>	Must be discarded.
<b>B4</b>	8 bits unsigned. Firmware version major.
<b>B3</b>	8 bits unsigned. Firmware version minor.
<b>B2</b>	8 bits unsigned. Comm driver version.
<b>B1 : B0</b>	16 bits unsigned. Firmware commit number.
Requested data - Command "p" (0x70) - Part number of the encoder	
Returns 18 bytes, without position and CRC.	
<b>B17 : B16</b>	Must be discarded.
<b>B15 : B0</b>	16 ASCII characters with readhead's part number.
CRC (inverted)	
<b>c7 : c0</b>	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.

For further information regarding CRC calculation example, refer to the document CRCD01 available at [RLS Media center](#).

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.

For further information regarding programming encoders with SPI interface can be found in the document BRD09 available at [RLS media center](#).

# Part numbering

## Readhead

	BR	10	SF	A	14B	16	D	D	00																		
<b>Series</b>	BR - Orbis board-level readhead																										
<b>Size</b>	10 - Magnet type compatibility 12 and 16 20 - Magnet type compatibility 22 30 - Magnet type compatibility 30																										
<b>Communication interface</b>	DC - BiSS C, RS422 PW - Pulse Width Modulation (PWM), LVTTTL SC - Synchronous serial interface (SSI), RS422 SF - Asynchronous serial, RS422 SP - SPI (Serial peripheral interface), LVTTTL																										
<b>Communication interface variant</b>	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 border="1" style="margin-left: 20px;"> <thead> <tr> <th>A</th> <th>D</th> <th>E</th> </tr> </thead> <tbody> <tr> <td>122.07</td> <td>549.32</td> <td>1098.63</td> </tr> </tbody> </table> For SC: B - Start bit and idle data line 1 For SF: Link speed in kbps: <table border="1" style="margin-left: 20px;"> <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									A	D	E	122.07	549.32	1098.63	A	B	C	D	E	F	115.2	128	230.4	256	500	1000
A	D	E																									
122.07	549.32	1098.63																									
A	B	C	D	E	F																						
115.2	128	230.4	256	500	1000																						
<b>Resolution</b>	14B - 14 bits per revolution 14M - 14 bits per revolution + 16 bit multiturn counter																										
<b>Magnet type compatibility</b>	12 - BM120A190A1ABA00 or actuator BA060-BA100 16 - BM160B240A1ABA00 or actuator BA120-BA150 22 - BM220C320A1ABA00 or actuator BA200AB03AA00 30 - BM300C440B1BBA00 or actuator BA250AB06AA00																										
<b>Operating temperature range</b>	D - -40 °C to +105 °C																										
<b>Connector option</b>	D - Molex 501568-1107 H - Soldering pads with through holes																										
<b>Special requirements</b>	00 - No special requirements																										

Not all part number combinations are valid. Refer to the table of available combinations on the following page.



### Table of available combinations

Series	Readhead size	Communication interface	Communication interface variant	Resolution	Magnet type compatibility	Operating temperature range	Connector option	Special requirements		
BR	10	DC	D	14B	12 / 16	D	D / H	00		
				14M						
		PW	A / D / E	14B						
				14M						
		SC	B	14B						
				14M						
		SF	A / B / C / D / E / F	14B						
				14M						
		SP	C	14B						
				14M						
		20	DC	D					14B	22
									14M	
	PW		A / D / E	14B						
				14M						
	SC		B	14B						
				14M						
	SF		A / B / C / D / E / F	14B						
				14M						
	SP		C	14B						
				14M						
	30		DC	D	14B				30	
					14M					
		PW	A / D / E	14B						
				14M						
SC		B	14B							
			14M							
SF		A / B / C / D / E / F	14B							
			14M							
SP		C	14B							
			14M							

For analogue sin/cos and commutation outputs see BRD14 data sheet at [RLS Media Center](#).

## Magnet

**BM 220 C 320 A 1 A B A 00**

### Series

**BM** - Orbis magnet

### Inner diameter

**120** - 12 mm  
**160** - 16 mm  
**220** - 22 mm  
**300** - 30 mm

### Thickness

**A** - 3 mm  
**B** - 3.5 mm  
**C** - 4 mm

### Outer diameter

**190** - 19 mm  
**240** - 24 mm  
**320** - 32 mm  
**440** - 44 mm

### Material

**A** - NdFeB  
**B** - NdFeB + plastic resin

### Grade

**1** - Grade 1 tested magnet

### Surface finishing

**A** - NiCuNi  
**B** - None

### Temperature range

**B** - -40 °C to 120 °C

### Packaging

**A** - Standard packaging

### Special requirements

**00** - No special requirements

Not all part number combinations are valid. Refer to the table of available combinations below.

### Table of available combinations

Series	Inner diameter	Thickness	Outer diameter	Material	Grade	Surface finishing	Temperature range	Packaging	Special requirements
BM	120	A	190	A	1	A	B	A	00
	160	B	240						
	220	C	320						
	300	C	440	B					

## Magnetic actuator

	BA	060	AB	01	A	A	00
<b>Series</b>	BA - Orbis magnetic actuator						
<b>Shaft diameter</b>	060 - 6 mm 080 - 8 mm 100 - 10 mm 120 - 12 mm 140 - 14 mm 150 - 15 mm 200 - 20 mm 250 - 25 mm						
<b>Form</b>	AB - With 3 fasteners						
<b>Magnet type</b>	01 - BM120A190A1ABA00 02 - BM160B240A1ABA00 03 - BM220C320A1ABA00 06 - BM300C440B1BBA00						
<b>Material</b>	A - Anodized aluminium						
<b>Packaging</b>	A - Standard packaging						
<b>Special requirements</b>	00 - No special requirements						

Not all part number combinations are valid. Refer to the table of available combinations below.

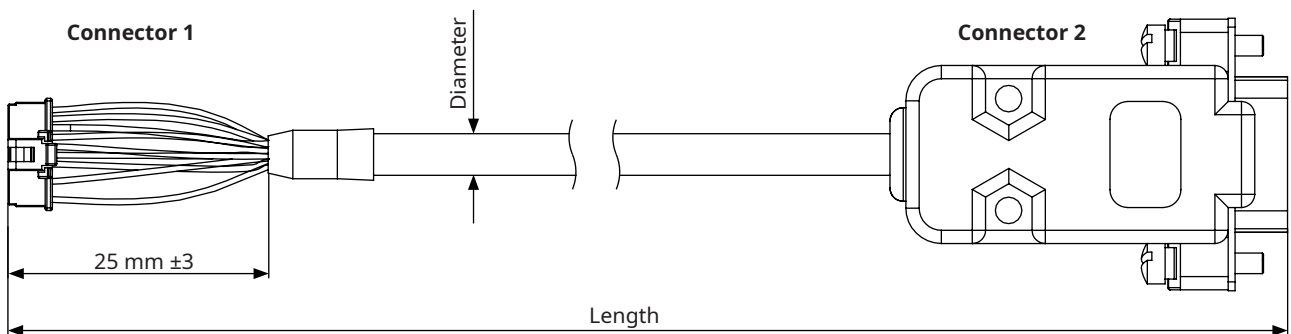
### Table of available combinations

Series	Shaft diameter	Form	Magnet type	Material	Packaging	Special requirements	
BA	060	AB	01	A	A	00	
	080						
	100						
	120						
	140		02				
	150						
	200						03
	250						

## Cable assemblies

Cables with crimped connectors

Part number	Diameter	Length	Connector 1	Connector 2	Notes
ACC012	5 mm	1.0 m	Molex 501330-1100 and 501334-0000	Flying leads	Twisted pairs, shielded, up to +100 °C
ACC024		3.0 m			
ACC027		1.0 m		DSUB-9 M	
ACC048	6.2 mm	1.0 m		Flying leads	Twisted pairs, shielded, up to +75 °C
ACC066		3.0 m			
ACC067		1.0 m		DSUB-9 M	



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

\*Pins are internally connected on PCB.

## Cable specifications

<b>Part numbers</b>	ACC012, ACC024, ACC027	ACC048, ACC066, ACC067
<b>Cable specifications</b>	LI12YC12Y	LiYCY (TP)
<b>Configuration</b>	4 × 2 × 0.14 mm <sup>2</sup>	4 × 2 × 0.14 mm <sup>2</sup>
<b>Rated voltage</b>	250 V	350 V
<b>Temperature range</b>	Operating -30 °C to +100 °C Storage -40 °C to +105 °C Not valid for cables with DSUB-9 M connector.	Operating -40 °C to +75 °C (fixed) -5 °C to +70 °C (bending) Storage -40 °C to +80 °C
<b>Environmental conformation</b>	RoHS conform 73/23/EWG-Guideline CE conform Halogen free	RoHS and REACH compliant Flame-retardant according IEC 60332-1-2 Approvals based on VDE 0812 Classification ETIM 5.0 Class-ID: EC000104

ACC027 and ACC067 can be used for direct connection to E201-9S or E201-9B USB encoder interface.

ACC012, ACC024 and ACC027 may be discontinued in future.

# Accessories

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Cable assembly, 1 m

**ACC048**

**ACC012**

See chapter **Cable assemblies.**



Cable assembly, 3 m

**ACC066**

**ACC024**

See chapter **Cable assemblies.**



Cable assembly, 1 m

**ACC067**

**ACC027**

See chapter **Cable assemblies.**



USB interface (for BiSS C communication interface)

**E201-9B**



USB interface (For SSI communication interface)

**E201-9S**



Magnet viewer

**MM0001**

## Head office

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## Document issues

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Issue	Date	Page	Description
11	27. 10. 2022	General	Orbis BR30 added
12	5. 9. 2024	-	Instalation drawing amended, new acctuator added
13	10. 10. 2024	22 - 23	Added functions on the SPI interface (read self-calibration status, signal level, firmware version and part number); SPI timing amended.

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