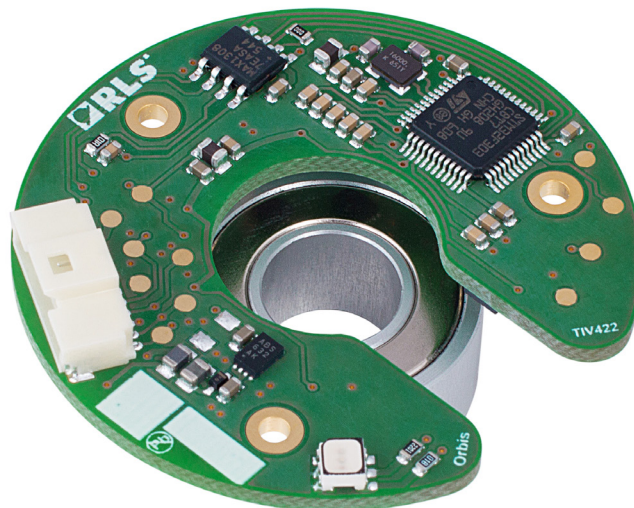


Orbis™ true absolute rotary encoder



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 that becomes non-negligible at low magnet ride height.

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.

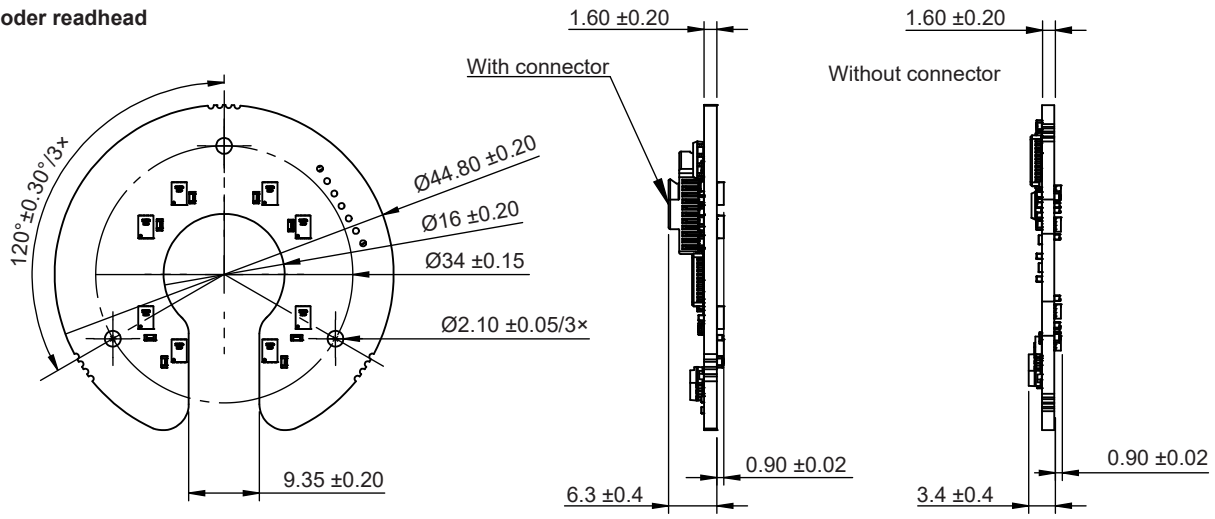
Orbis™ through-hole measuring principle allows customisation with various board and magnet sizes to suit your application.

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

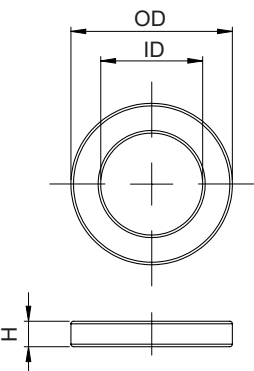
Dimensions

Dimensions and tolerances in mm.

Encoder readhead



Permanent magnets

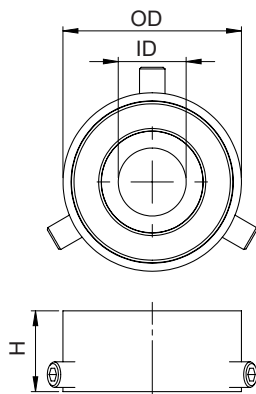


Available magnets:

ID	OD	H
12	19	3
16	24	3.5

ID and OD tolerances are ±0.05.

Magnetic actuators

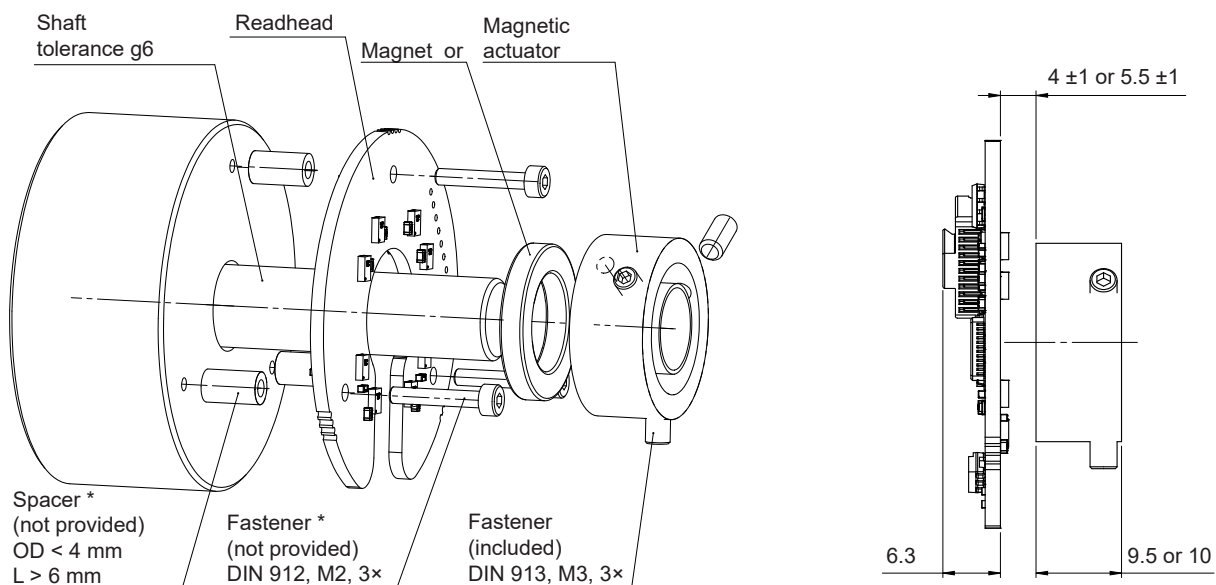


Available actuators:

ID	OD	H
6	21	9.5
8	21	9.5
10	22	9.5
12	27	10
15	27	10

ID tolerances are H7.

Installation drawing



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

Technical specifications

System data	
Reading type	Axial reading
Resolution	14 bit
Maximum speed	10,000 RPM
Accuracy	±0.25° (optimal installation)
Accuracy thermal drift	±0.01°/°C
Repeatability	±2 LSB (counts)
Digital hysteresis	±2 LSB (counts)
Position update rate	50 kHz
Electrical data	
Supply voltage	4.5 V to 5.5 V (at the connector)
Set-up time	100 ms
Current consumption	65 mA typical (no output load)
Connection	Molex 501568-1107 or soldering pads (through holes)
Output load	PWM, SPI Max. ±20 mA at 3.3 V
	RS422 Max. ±100 mA at 5 V
ESD protection	HBM, max. ±2 kV
Mechanical data	
Available magnet sizes (ID)	12 mm, 16 mm
Available magnetic actuator sizes (ID)	6 mm, 8 mm, 10 mm, 12 mm, 15 mm
Readhead outer diameter	45 mm
Readhead inner diameter	16 mm
Mass	Readhead: 5.3 g
	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
	Magnets (ID): 12 mm: 3.8 g ; 16 mm: 6.4 g
Magnet material	Neodymium with Ni-Cu-Ni protective layer
Actuator material	Anodised aluminium
Environmental data	
Temperature	Operating 0 °C to +85 °C
	Storage -40 °C to +105 °C
Humidity	0 % to 70 % non-condensing
External magnetic field	Max. ±3 mT (DC or AC) on top side of readhead

Status indicator LED

The LED provides visual feedback of signal strength, error condition and is used for set-up and diagnostic use. Flashing LED indicates the encoder is powered but communication has not been established. When communication is running at a rate of minimum 5 readings per second LED is constantly lit. Fast red flashes indicate the readhead can not start.

LED	Status
Green	Normal operation; position data is valid.
Orange	Warning; position is valid, but some operating conditions are close to limits.
Red	Error; position data is not valid.
Flashing	Communication has not been established.
No light	No power supply.

Multi-turn counter

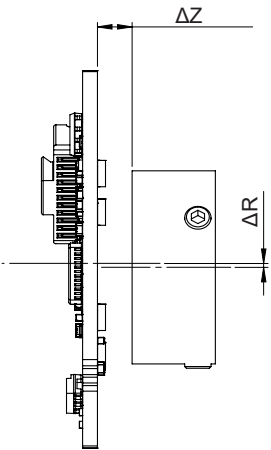
Multi-turn counter is available on the following communication interfaces: BiSS, SSI, SPI and Asynchronous serial communication. Multiturn option is chosen with *Resolution* in part number on page 15. Multi-turn counter is 16 bit (0 to 65535 counts). Counting is available only when the encoder is powered on, but the counter state is stored in a non-volatile memory at power off and is restored at power up. The number of non-volatile memory write-in cycles is limited to 10^7 . Maximum permissible rotation during power-down is $\pm 90^\circ$. If rotation is bigger, encoder will signal an error to indicate invalid multiturn counter value. Power cycle or setting a new counter value is needed to reset this condition.

Installation instructions

Installation tolerances

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

	Magnet with 12 mm ID	Magnet with 16 mm ID
Axial (ΔZ) displacement (ride height)	4 mm nominal ± 1 mm	5.5 mm nominal ± 1 mm
Radial (ΔR) displacement	0.3 mm	0.3 mm



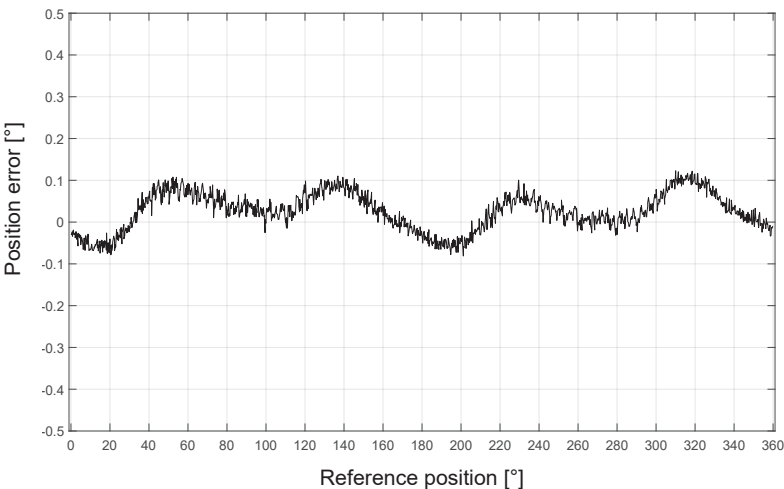
Axial position adjustment (ride height)

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 does not change colour when the magnet rotates.

Accuracy of encoder system

Best accuracy plot after good installation and self-calibration of Orbis encoder is shown in the graph on the right.

Precise centering of the magnet on the shaft is key to achieve good overall accuracy.



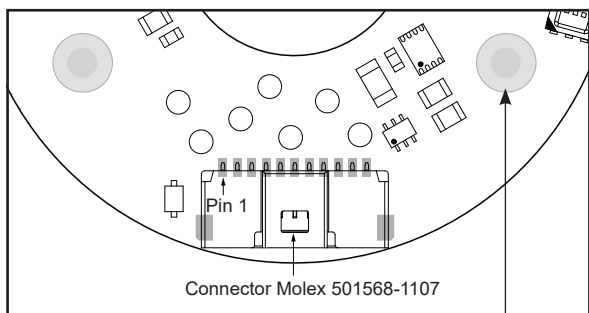
External magnetic field

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.

Electrical connections

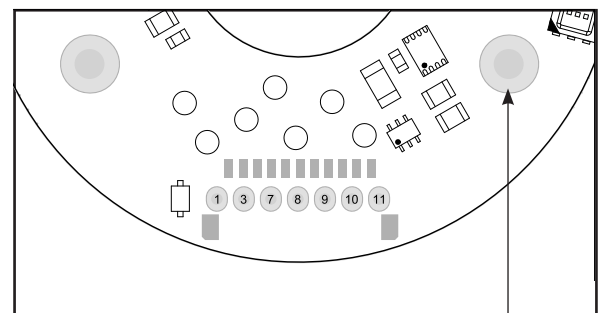
Pin	Wire colour (ACC012, ACC024)	Asynchronous serial	PWM	SSI	BiSS-C	SPI
1	Brown	5 V supply				
2	-					
3	White	0 V (GND)				
4	-					
5	Pink	-	-	-	-	-
6	Grey	-	-	-	-	-
7	Red	RX data in +	Status	Clock +	MA +	SCK
8	Blue	RX data in -	-	Clock -	MA -	NCS
9	Cable Shield	Cable Shield	Cable Shield	Cable Shield	Cable Shield	Cable Shield
10	Green	TX data out +	PWM Out	Data +	SLO +	MISO
11	Yellow	TX data out -	-	Data -	SLO -	MOSI

Pinout



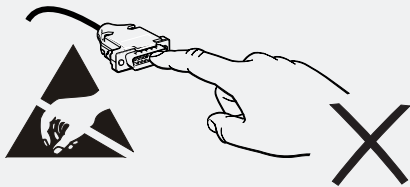
With Molex connector

Cable shield
(connected to pin 9)



With soldering pads
(through holes)

Cable shield
(connected to pin 9)



WARNING!

ESD protection

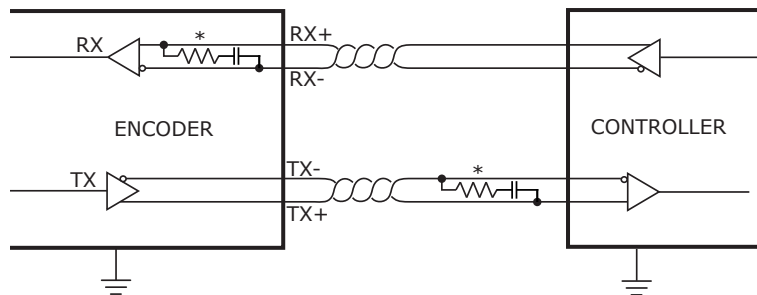
Readhead is ESD sensitive - handle with care. Do not touch electronic circuit, wires or sensor area without proper ESD protection or outside of ESD controlled environment.

Communication interfaces

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



Line signals	
RX+	RX data in +
RX-	RX data in -
TX+	TX data out +
TX-	TX data out -

* 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

Character length	8 bits
Parity	None
Stop bits	1
Flow control	None
Bit order	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
Baud rate [kbps]	115.2	128	230.4	256	500	1000

Command set

Command "1" (0x31) – position request	
Response	1 byte ASCII "1" 2 bytes (4 for multi-turn) hex – see Encoder position data structure
Command "d" (0x64) – position request + detailed status	
Response	1 byte ASCII "d" 2 bytes (4 for multi-turn) hex – see Encoder position data structure 1 byte hex – see Detailed status data structure
Command "s" (0x73) – position request + speed	
Response	1 byte ASCII "s" 2 bytes (4 for multi-turn) hex – see Encoder position data structure 2 bytes hex – speed (in revolutions per second multiplied by 10)
Command "t" (0x74) – position request + temperature	
Response	1 byte ASCII "t" 2 bytes (4 for multi-turn) hex – see Encoder position data structure 2 bytes hex – temperature (temperature of the readhead in °C multiplied by 10)
Command "v" (0x76) – serial number	
Response	1 byte ASCII "v" 6 bytes ASCII – serial number

Encoder position data structure

Encoder position	
b31 : b16	Multi-turn counter (if specified in part number) - Left aligned, MSB first.
b15 : b2	Encoder position – Left aligned, MSB first.
General status	
b1	Error - If low, the position data is not valid. The last valid position is sent out.
b0	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	
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.

Encoder programming

Encoder supports changing default baud rate, 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 TTL compatible. These signals have weak ESD protection. Handle with care. Maximum current sourced from or sunk into signal lines should not exceed 20 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

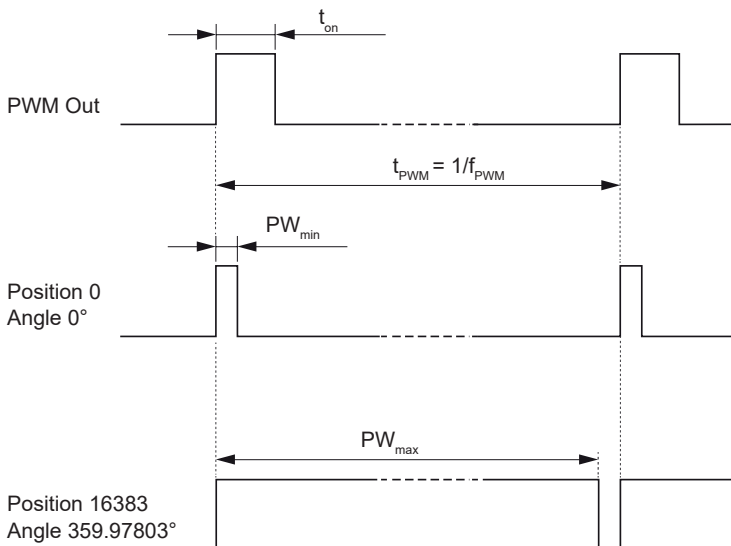
When the Status signal is low, the PWM Out signal is low and no pulses are output.

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.

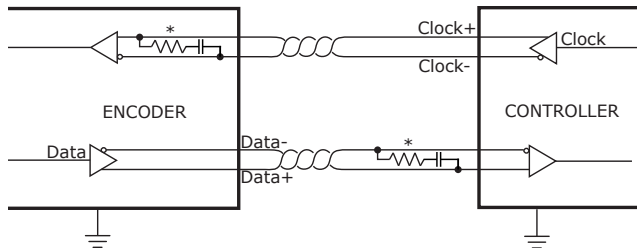
Communication interface variant						
Parameter	Symbol	A	D	E	Unit	Note
PWM frequency	f_{PWM}	122.07	549.32	1098.63	Hz	
Signal period	t_{PWM}	8192	1820.44	910.22	μs	
Minimum pulse width	PW_{min}	0.5	0.111	0.0556	μs	Position 0 (Angle 0°)
Maximum pulse width	PW_{max}	8191.5	1820.33	910.17	μs	Position 16383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

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

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.

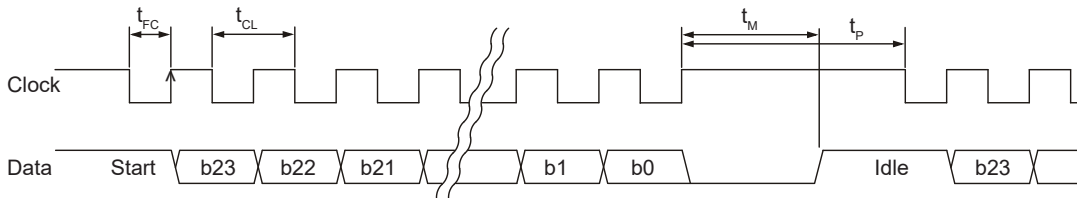
Electrical connection



Line signals	
Clock+	Clock non-inverted signal
Clock-	Clock inverted signal
Data+	Data non-inverted signal
Data-	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 μ s (400 ns *)		15 μ s
Clock frequency	f_{CL}	70 kHz		500 kHz (2.5 MHz *)
Delay first clock	t_{FC}	1.25 μ s		14 μ s
Transfer timeout	t_M		14 μ s	
Pause time	t_P	20 μ s		

* 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	Multi-turn counter (if specified in part number)	Encoder position	General status	Detailed status

Encoder position

b39 : b24 Multi-turn 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.

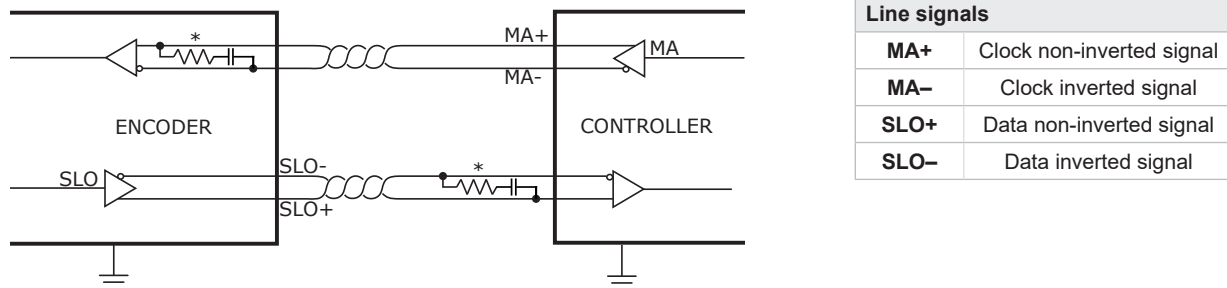
b2 : b0 Reserved.

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).

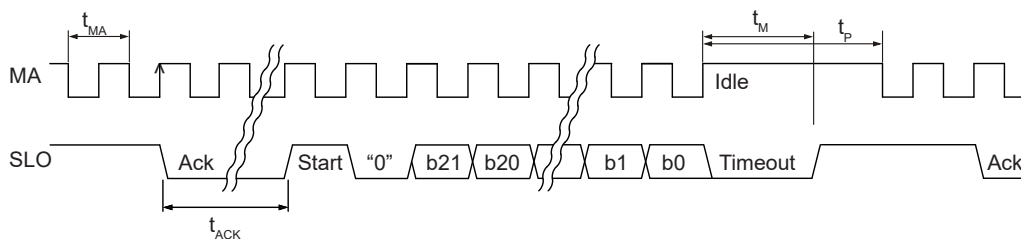
BiSS is implemented for point-to-point operation; multiple slaves are not supported.

Electrical connection



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

Parameter	Symbol	Min	Typ	Max
MA period	t_{MA}	200 ns		14 μ s
MA frequency	f_{MA}	70 kHz		5 MHz
ACK length	t_{ACK}		5 bits	
Transfer timeout	t_M		14 μ s	
Pause time	t_P	20 μ 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	Multi-turn counter (if specified in part number)	Encoder position	General status	CRC

Encoder position	
b37 : b22	Multi-turn 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.

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 zero position, 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).

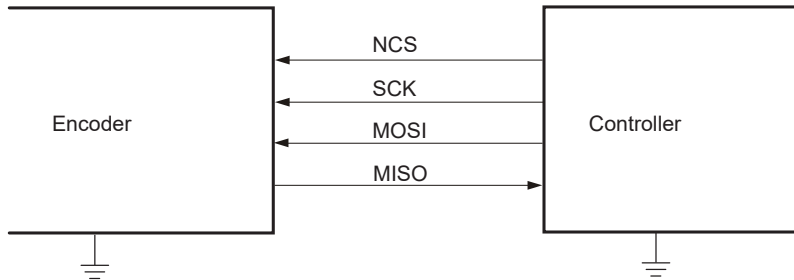
Additional information can be found in the "Application note: Orbis BiSS-C register access", document BRD05, available for download from www.rls.si/orbis.

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.

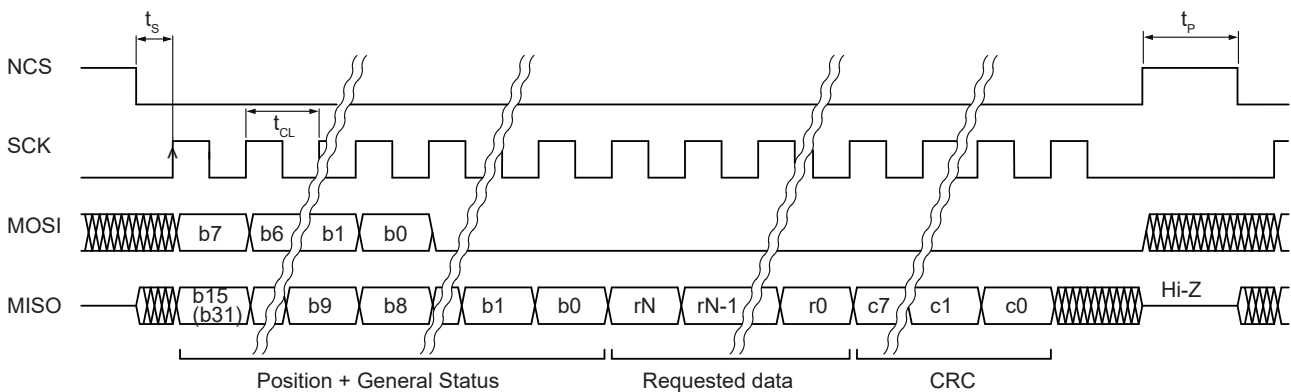
Electrical connection

All data signals are 3.3 V TTL. Inputs are 5 V tolerant. Maximum current sourced or sunk from signal lines should not exceed 20 mA.



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



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

Parameter	Symbol	Min	Typ	Max
Clock period	t_{CL}	250 ns		
Clock frequency	f_{CL}			4 MHz
Time after NCS low to first SCK rising edge	t_s	1.25 μ s		
Pause time	t_p	5 μ s		

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

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 "s" (0x73) - speed request

r15 - r0 16 bits, signed. Number represents speed in revolutions per second multiplied by 10.

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.

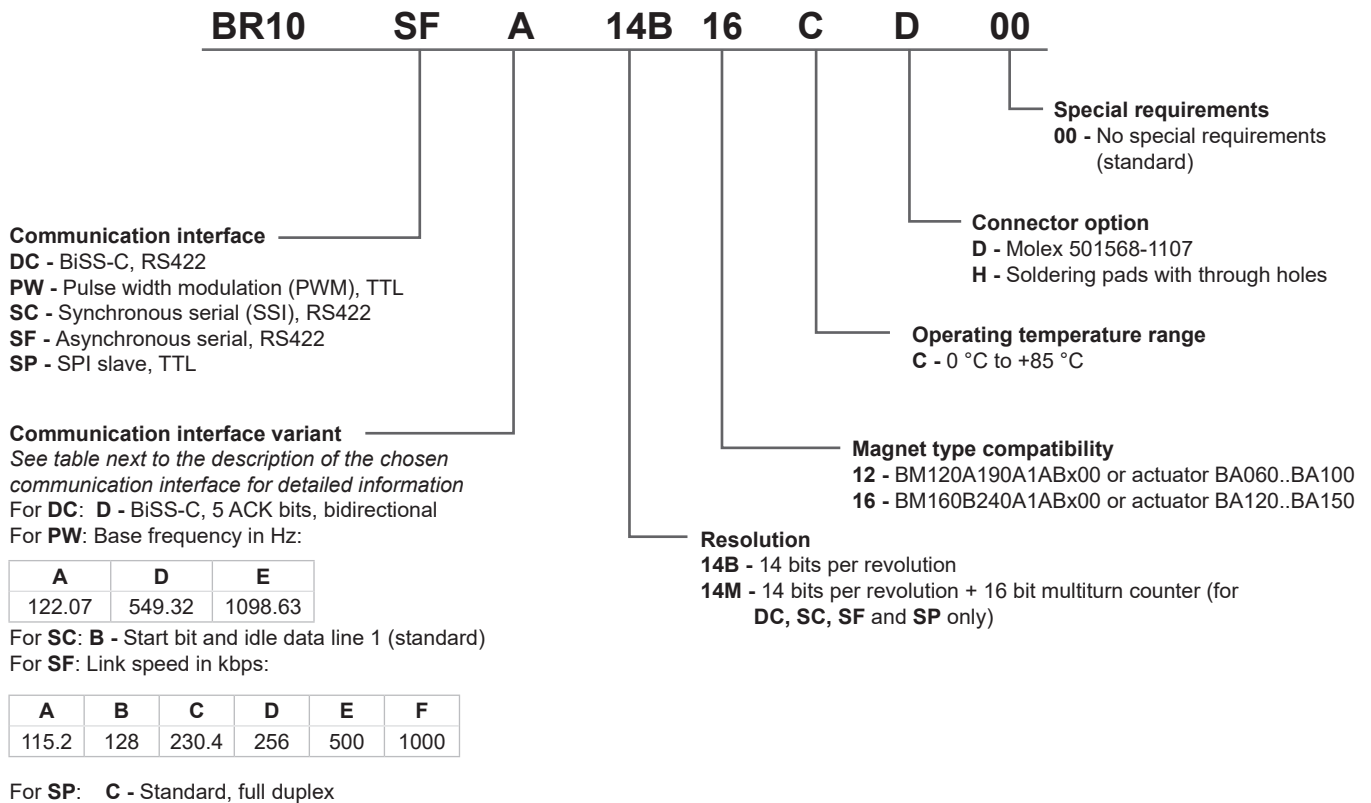
CRC (inverted)

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.

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 can be tied to GND.

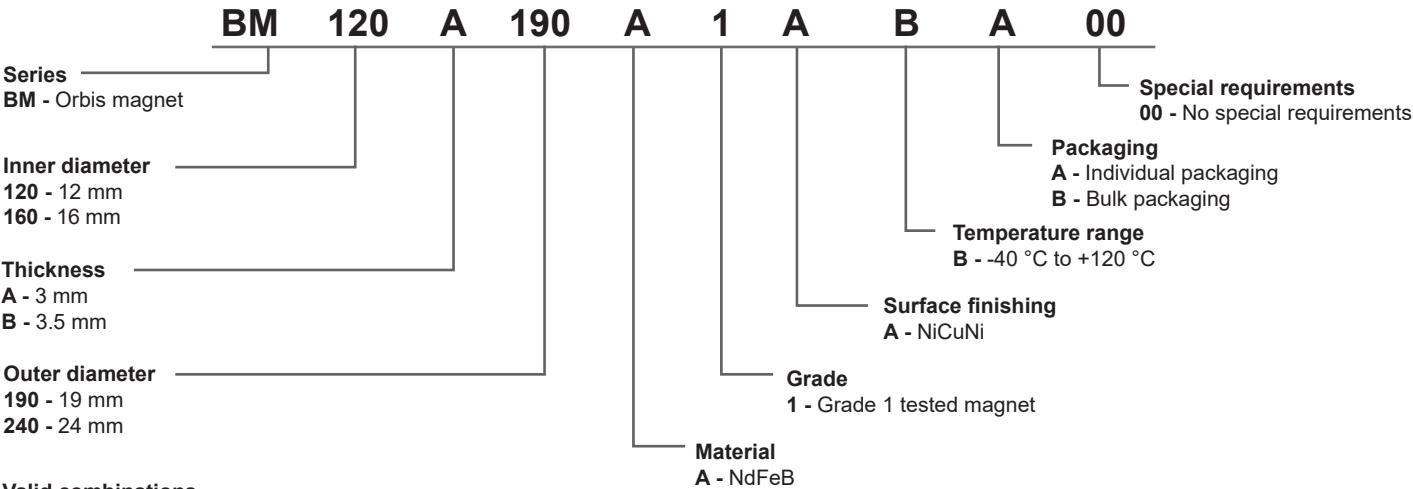
Readhead part numbering



Valid combinations

Series	Communication protocol	Communication protocol variant	Resolution	Magnet type compatibility	Temperature range	Connector option	Special requirements
BR10	DC	D	14B	12 / 16	C	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				

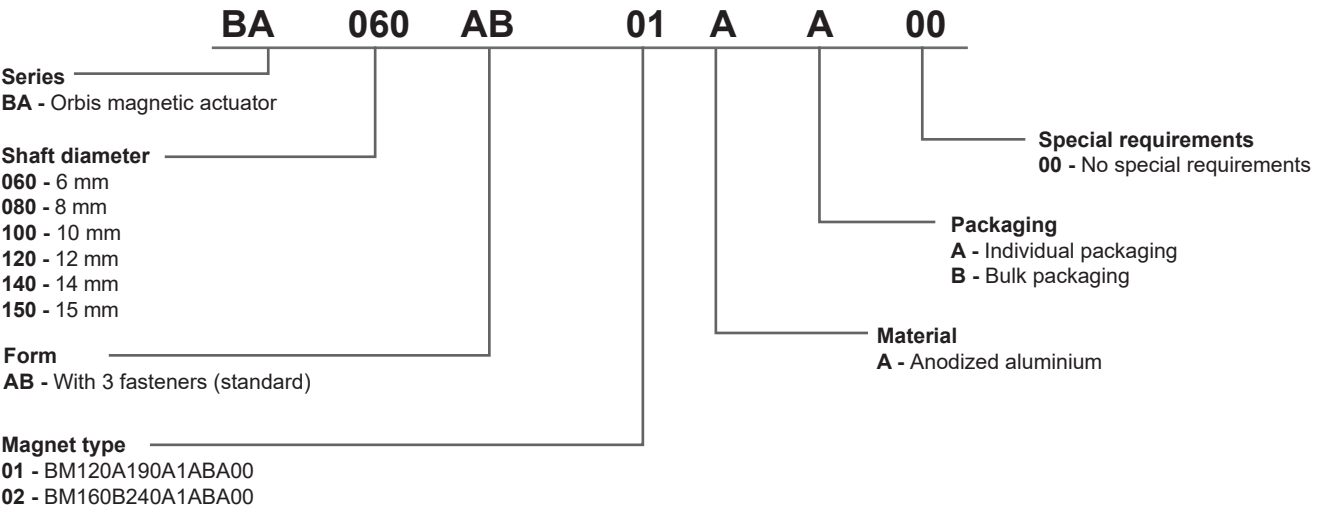
Magnet part numbering



Valid 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 / B	00
	160	B	240						

Magnetic actuator part numbering



Valid combinations

Series	Shaft Size	Form	Magnet type	Material	Packaging	Special requirements
BA	060	AB	01	A	A / B	00
	080					
	100					
	120		02			
	140					
	150					

Accessories part numbering

- ACC012** Cable, 1 m length, Molex 11-pin connector, flying leads
ACC024 Cable, 3 m length, Molex 11-pin connector, flying leads

Head office

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Document issues

Issue	Date	Page	Corrections made
1	4. 10. 2017	-	New document
2	8. 11. 2017	2	Installation drawing amended
		3	Technical specifications amended
		4	Multi-turn counter amended
		6	Asynchronous serial communication parameters amended
		15	Readhead part numbering amended
3	12. 3. 2018	3	Permanent magnets tolerances amended
4	7. 9. 2018	2	New dimension drawings
		5	Wire colour amended
		6, 9, 11	New electrical connection drawing
		8	PWM output signal timing diagram amended
		15-16	Part numbering table added

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