LinACE™ Flat-Board

InAxis Linear Absolute Magnetic Shaft Encoder

TRUE ABSOLUTE SYSTEM

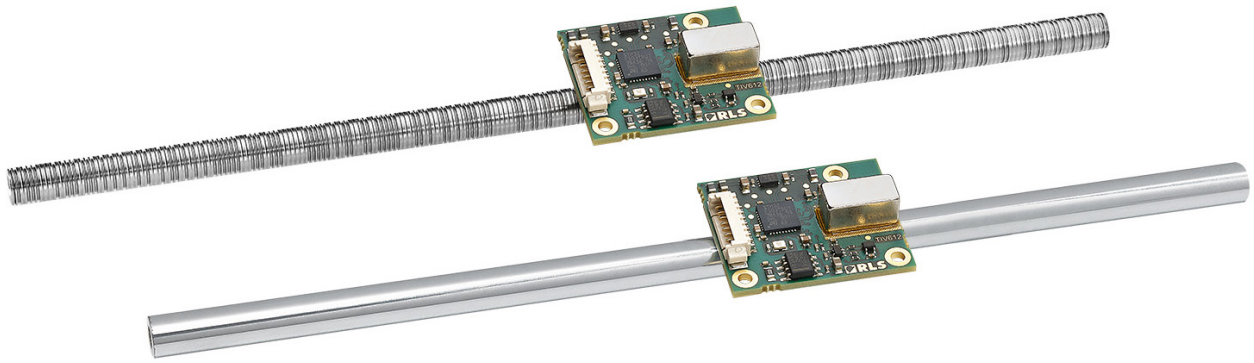
ACCURACY UP TO ±10 µm

HIGH DYNAMIC CONTROL LOOPS

LinACE™ flat-board is a board-level absolute linear magnetic encoder system designed for motion control applications as a position and speed control loop element.

With a readhead length of only 30 mm and a low weight, the encoder system is suitable for applications with limited space.

LinACE™ flat-board provides accurate measurements with excellent resolution and repeatability. The encoders are available in asynchronous serial over RS422, SSI and BiSS C output versions and offer a range of selectable resolutions from 10 µm to 0.5 µm with speeds up to 5 m/s. The position of the encoder is maintained even when the shaft rotates during forward and backward motion.



Features and benefits

- Non-contact technology for high reliability
- Absolute position at power-up
- Resolutions up to 0.5 µm
- Measuring lengths up to 300 mm
- Built-in self-monitoring
- Excellent resistance to stray magnetic fields
- Stable over whole temperature range
- Suitable for highly dynamic control loops
- Small footprint 30 × 25 × 8.5 mm

MACHINE TOOL | INDUSTRIAL AUTOMATION | MEDICAL | PROCESS AND CONTROL | SERVO MECHANISMS

General information

The LinACE™ flat-board encoder system consists of a board level encoder readhead and a coded solid steel shaft that serves as the measuring standard.

By replacing the main actuator shaft or one of the guide shafts with a LinACE coded, hard-chrome plated shaft, the encoder becomes part of the actuator and enables measurements in the motion axis.

The LinACE encoder has a built-in advanced self-monitoring function that continuously checks several internal parameters. Error reports, warnings and other status signals are available on all digital interfaces.

The encoder has excellent resistance to external magnetic fields and is resistant to shock and vibration. Accuracy can be as high as ±10 µm with a resolution of 0.5 µm and is very stable over the entire temperature range from –40 °C to +105 °C. The repeatability of the encoder is less than the unit of resolution and the signal noise is very low with an average value of 0.5 µm and a maximum value of 1 µm. The position of the encoder is maintained even when the shaft rotates during forward and backward motion.

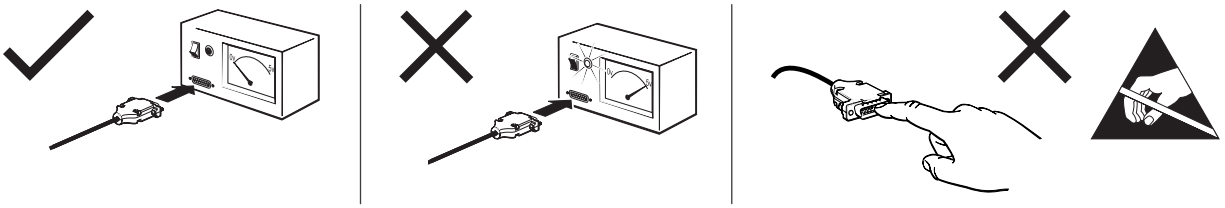
A custom design service for OEM integration is also available.

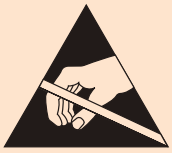
The maximum measuring length is 300 mm.

Storage and handling

Operating and storage temperature

–40 °C to +105 °C (with standard cable)





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.

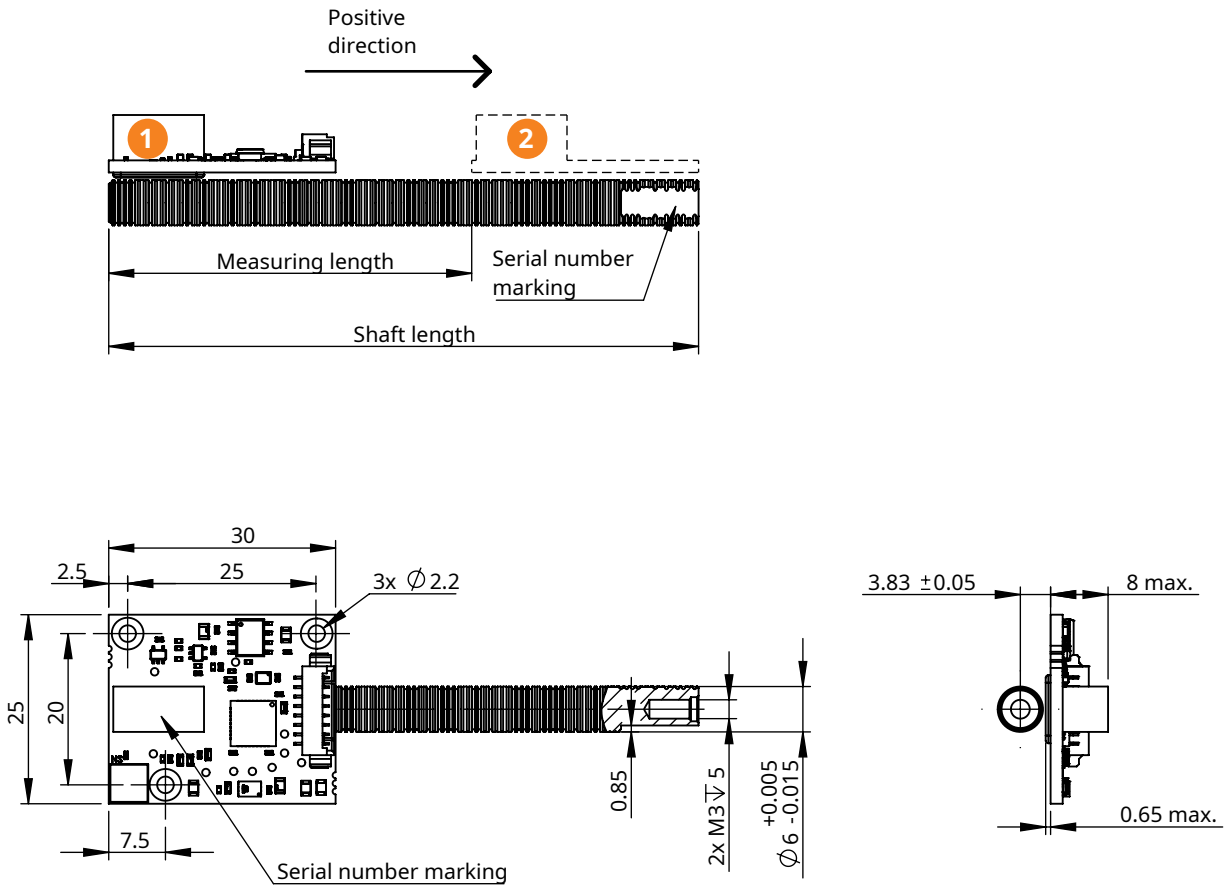
Packaging

Packed individually in an antistatic bag.

Dimensions and installation drawings

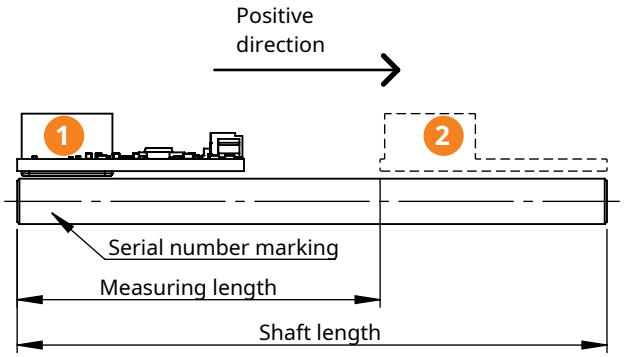
Dimensions and tolerances are in mm. Dimensions without tolerance values are in accordance with ISO 2768-m.

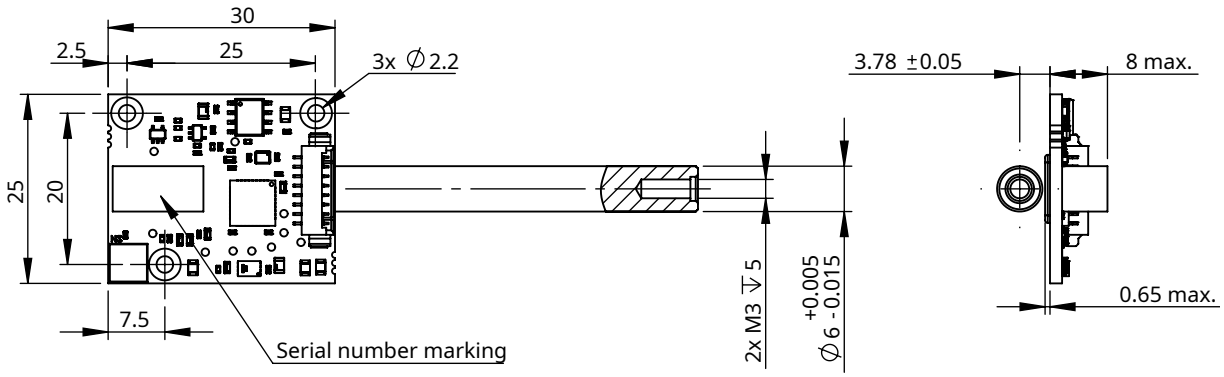
Option A - Open grooves



- Keep the shaft and board as matched pairs. Ser. No. must be same on the shaft and readhead.
- The shaft must be installed with the alignment as shown in the drawing. Pay attention to the position of the serial numbers.
- The encoder shaft can be rotated independently of the linear travel.

Option B - Hard Crome Coating

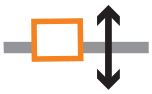




- Keep the shaft and board as matched pairs. Ser. No. must be same on the shaft and readhead.
- The shaft must be installed with the alignment as shown in the drawing. Pay attention to the position of the serial numbers.
- The encoder shaft can be rotated independently of the linear travel.

Installation tolerances

Installation tolerances (readhead to shaft)

Ride height	See dimension drawing of encoder assembly. Tight ride height is recommended. Increasing the ride height exponentially increases encoder noise even if it is within installation tolerances.	
Pitch	Tilt angle <0.2°	
Yaw	Tilt angle <0.2°	
Lateral offset	<0.2 mm	

Technical specifications

System data

Maximum measuring length	300 mm
Shaft diameter	6 mm
Shaft linear expansion coefficient	~11 × 10^{-6}/K
Maximum speed	5 m/s
Resolution	0.5 µm, 1 µm, 5 µm, 10 µm
System accuracy	±10 µm, ±25 µm, ±50 µm, ±100 µm
Hysteresis	Less than unit of resolution (without mechanical assembly influence)
Repeatability	Less than unit of resolution

Electrical data

Supply voltage	4.5 V to 5.5 V – voltage on readhead
Set-up time	5 ms (after power-up)
Power-up time	For correct encoder functionality min. 4.5 V should be achieved in less than 10 ms after power-up.
Current consumption	Typ. 115 mA, max. 150 mA (without output load)
Output load	±40 mA
Connection	8-pin low-profile connector FCI 0114830-11108LF

Mechanical data

Material	Coded shaft option A	Carbon steel, nickel coating, code is visible
	Coded shaft option B	Carbon steel, 30 µm to 40 µm hard-chrome coating 800 HV to 1100 HV (except end surfaces and threaded holes), code is hidden
	Readhead	Assembled PCB
Mass	Shaft	22 g / 100 mm
	Readhead	7.1 g

Environmental data

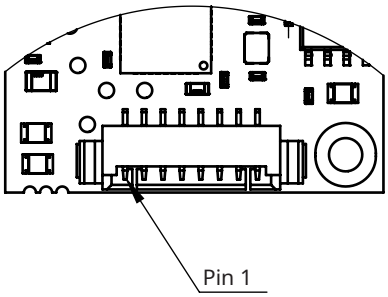
Temperature	Operating and storage	–40 °C to +105 °C
Humidity		Up to 70 % non-condensing
Stray magnetic fields		Readhead: max. 100 mT. Stray magnetic fields bigger than 100 mT may result in wrong position reading. Coded shaft: insensitive to stray magnetic fields.
Small particles with high permeability (eg. steel dust)		Not permitted

Electrical connections

	Asynchronous serial RS422	SSI	BiSS C
1	5 V supply	5 V supply	5 V supply
2	0 V (GND)	0 V (GND)	0 V (GND)
3	–	–	–
4	–	–	–
5	RX command in+	Clock+	MA+
6	RX command in–	Clock–	MA–
7	TX data out+	Data+	SLO+
8	TX data out–	Data–	SLO–

The voltage difference between ground (white wire and inner shield) and encoder housing (outer shield) should not exceed 10 V_{pp}.

Pinout



8-pin low profile connector

FCI 10114830-11108LF

Counterpart mating connector

FCI 10114826-00008LF

and 10114827-002LF

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 RS422 (UART)

Baud rate	115.2 kbps, 256 kbps, 1 Mbps
Data format	8 bits, no parity, 1 stop bit
Update rate	On demand or continuous
Resolutions	0.5 µm, 1 µm, 5 µm, 10 µm
Latency	250 µs

SSI*

Data format	Binary
Clock frequency	50 kHz to 500 kHz (2.5 MHz**)
Update rate	4 kHz
Resolutions	0.5 µm, 1 µm, 5 µm, 10 µm
Latency	250 µs to 500 µs
Timeout (monoflop time)	20 µs

BiSS C

Maximum clock frequency	5 MHz
Maximum request rate	30 kHz
Mechanical bandwidth	2 kHz max.
Resolutions	0.5 µm, 1 µm, 5 µm, 10 µm
Latency	<10 µs
Timeout (monoflop time)	20 µs

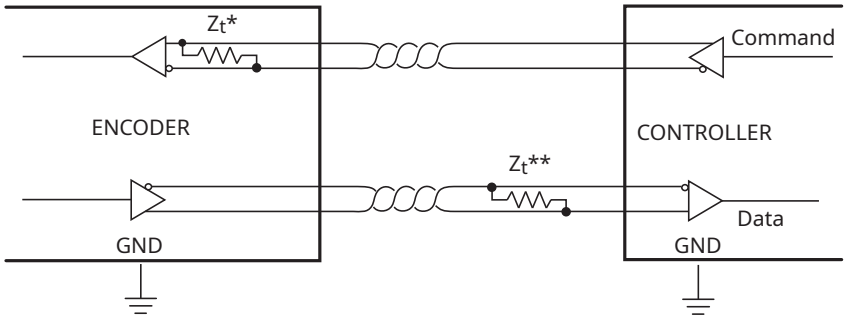
* Slave type interfaces might not be suitable for high-speed closed control loops because of the variable latency time.
** With *Delay First Clock* function on the controller.

Asynchronous serial communication interface (UART) over RS422

SF output type

Encoder identification and position data are available via the request-response type of communication through the asynchronous serial link. There are two unidirectional communication channels that form a bidirectional full duplex data link. Each channel consists of a two-wire differential twisted-pair connection that complies with the RS422 signalling standard.

Electrical connection



* The Command and Data signals are 5 V RS422 compatible differential pairs with RC termination inside the readhead.
** Termination at the controller is required if total cable length is longer than 5 m. The nominal impedance of the cable is 120 Ω. Recommended termination is 120 Ω or RC termination (120 Ω and 1 nF in series) if there is requirement for lower power consumption.

Output protection

An excessive output current and power dissipation caused by errors or bus conflicts are prevented by two mechanisms. A foldback current limit on the output stage provides immediate protection against short circuits. In addition, a thermal shutdown circuit forces the driver outputs into a high-impedance state if the chip temperature becomes too high.

Communication parameters

Link speed	115.2 kbps, 256 kbps, 1 Mbps
Character length	8 bits
Parity	None
Stop bits	1
Repetition rate	4 kHz max.
Sample rate	115.2 kbps 1.05 kHz max. 256 kbps 1.77 kHz max. 1 Mbps 3 kHz max.
Position latency	Fixed at 250 µs between the position acquisition and first start bit sent out.

Command set

Command “v” (small character “v”)
6b header (LinACE) 1b space 6b serial number 2b space 1b Firmware version major (1) 1b Firmware version minor (48) 1b Firmware version comm interface (3) 4b Firmware build number 1b sensor revision (32) 1b resolution of encoder 6b string with shaft code type
Command “1” (ASCII one)
Response - position and status, transmitted once 1 byte constant header 0xEA 4 bytes binary absolute position, big-endian, right aligned 2 bytes encoder status – see table on next page 1 byte constant footer 0xEF
The next request should not be sent sooner than 250 µs after the end of the previous response from the readhead to allow refreshing of the position data. If request is sent sooner, data will arrive on the end of the refresh cycle.
Command “2” (ASCII two)
Response - position and status, transmitted continuously every cycle (250 µs + time of transmission depandant on baud rate) 1 byte constant header 0xEA 4 bytes binary absolute position, big-endian, right aligned 2 bytes encoder status – see table on next page 1 byte constant footer 0xEF
Command “0” (ASCII zero)
Stop continuous transmission

Structure of Detailed status bits (two bytes)

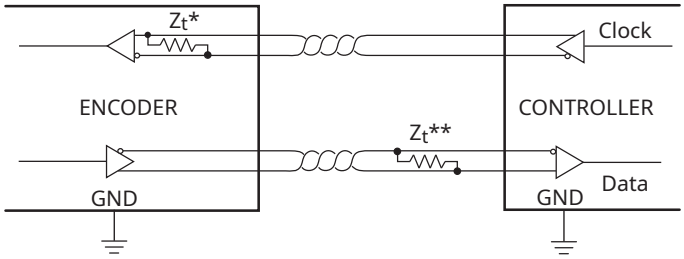
Encoder status (two bytes):		
	b15 : b10	Reserved; always zero
General status		
	b9	Error bit. If set, the position is not valid.
	b8	Warning bit. If set, the encoder operational is close to its limits. The position is still valid, but the resolution and / or accuracy might be lower than specified.
		Error and Warning bits can be set at the same time; in this case Error bit has priority. The general warning or error status is more closely defined by the Detailed status bits.
Detailed status		
	b7	Warning - Signal amplitude too high. The readhead is too close to the shaft.
	b6	Warning - Signal amplitude low. The distance between the readhead and the shaft is too large.
	b5	Error - Signal lost. The readhead is too far away from the shaft.
	b4	Warning - Temperature. The readhead temperature is out of specified range.
	b3	Error - Power supply error. The readhead power supply voltage out of specified range.
	b2	Error - System error. Malfunction inside the circuitry or inconsistent calibration data is detected. To reset the System error bit try to cycle the power supply while the rise time is shorter than 20 ms.
	b1	Error - Wrong code. Shaft might be inserted in the wrong direction.
	b0	Error - Acceleration error. The position data changed too fast. Shaft might be inserted in the wrong direction.

SSI - Synchronous serial interface

SC output type

The encoder position, in 21 bit natural binary code, and the encoder status are available through the SSI protocol. The position data is right aligned. LSB represents selected encoder resolution. After the position data there are two general status bits followed by the detailed status information.

Electrical connection

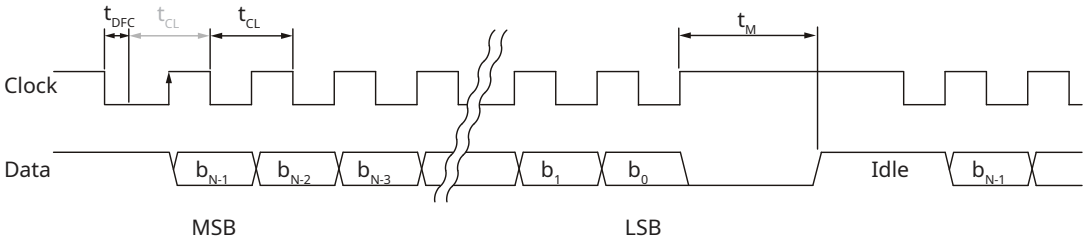


* The Clock and Data signals are 5 V RS422 compatible differential pairs with RC termination inside the readhead.
** Termination at the controller is required if the total cable length exceeds 5 m. The nominal impedance of the cable is 120 Ω. A termination of 120 Ω or RC (120 Ω and 1 nF in series) is recommended if lower power consumption is required.

Output protection

An excessive output current and power dissipation caused by errors or bus conflicts are prevented by two mechanisms. A foldback current limit on the output stage provides immediate protection against short circuits. In addition, a thermal shutdown circuit forces the driver outputs into a high-impedance state, if the chip temperature becomes too high.

Timing diagram

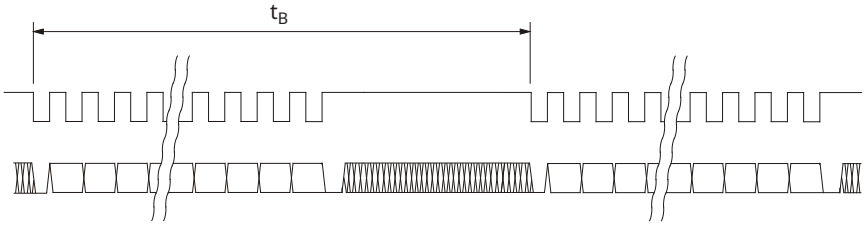


The controller requests the position and status data of the encoder by sending a pulse train to the Clock input. The Clock signal always starts from high. The first falling edge of the Clock latches the last position data available and on the first rising edge of the Clock the most significant bit (MSB) 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 tM time expires, the Data output goes high. The Clock signal must remain high until TB expires. If encoder is queried more frequently, same position value will be transmitted twice.

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.

In order for the position data to be updated, at least t_B should elapse between two successive readings. If the read request arrives earlier than t_B after the previous read, the encoder position is not updated.

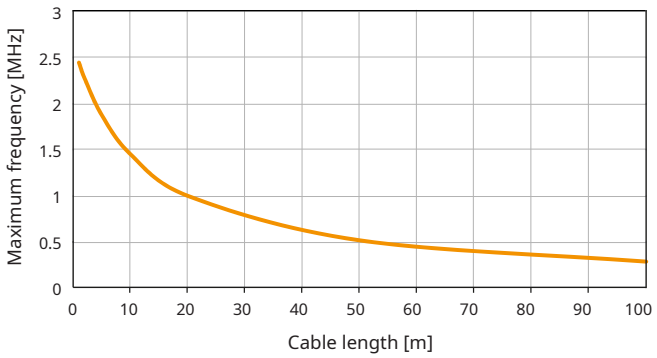


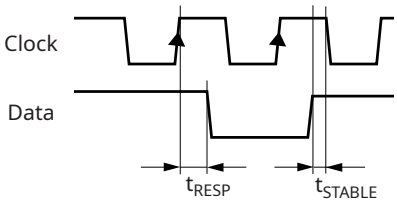
The power supply must be applied at least 5 ms before the clock sequence is being sent to the encoder.

Maximum frequency

The readhead needs 170 ns to respond to incoming clocks (t_{RESP}). Change on Data signal is delayed for 170 ns after the rising edge on Clock line. An additional delay is caused by the time it takes for the signal to propagate through the cable to the readhead and back (t_{PROP}). This delay is typically 14 ns per 1 meter cable. The Data signal must be stable over at least 10 % of the length of the clock period before the value is latched. The clock frequency must be reduced with a longer cable. The total cable length from the encoder to the receiver must be considered.

Frequency derating versus cable length:





$t_{DELAY} = t_{RESP} + t_{PROP} \times$ cable length

Communication parameters

Parameter	Symbol	Min	Typ	Max
Delay first clock	t_{DFC}	1 µs		10 µs
Clock period	t_{CL}	2 µs		20 µs
Clock frequency	f_{CL}	50 kHz		500 kHz (2.5 MHz *)
Timeout (Monoflop time)	t_{M}		20 µs	
Update time	t_{B}	250 µs		
Readhead response delay	t_{RESP}		170 ns	
Cable propagation delay	t_{PROP}		14 ns/m	
Latency		250 µs		500 µs

* With *Delay First Clock* function on the controller.

Start bit and idle line value are defined by the *Communication interface variant.*

Communication interface variant	Line state selection	Usage
B	Start bit = 1; idle line = 1	Standard

Structure of data packet

Bit	b30 : b10	b9 : b8	b7 : b0
Data length	21 bits	2 bits	8 bits
Meaning	Encoder position	General status	Detailed status

Structure of data packet

Encoder status		
	b30 : b10	Encoder position – Right aligned, MSB
General status		
	b9	Error bit. If set, the position is not valid.
	b8	Warning bit. If set, the encoder operational is close to its limits. The position is still valid, but the resolution and/or accuracy might be out of specification.
		The Error and Warning bits can be set at the same time, in this case the Error bit has priority. The general warning or error status is more closely defined by the Detailed status bits.
Detailed status		
	b7	Warning - Signal amplitude too high. The readhead is too close to the shaft.
	b6	Warning - Signal amplitude low. The distance between the readhead and the shaft is too large.
	b5	Error - Signal lost. The readhead is too far away from the shaft.
	b4	Warning - Temperature. The readhead temperature is out of specified range.
	b3	Error - Power supply error. The readhead power supply voltage out of specified range.
	b2	Error - System error. Malfunction inside the circuitry or inconsistent calibration data is detected. To reset the System error bit try to cycle the power supply while the rise time is shorter than 20 ms.
	b1	Error - Wrong code. Shaft might be inserted in the wrong direction.
	b0	Error - Acceleration error. The position data changed too fast. Shaft might be inserted in the wrong direction.

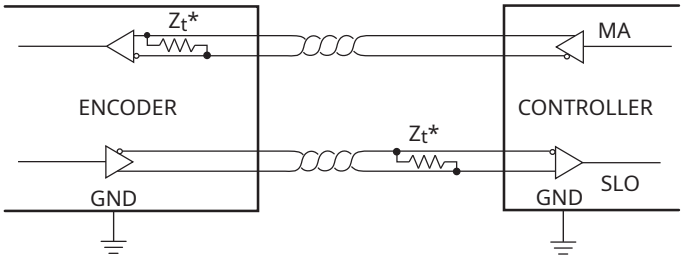
BiSS C unidirectional

DC output type

Encoder position, in 26-bit natural binary code, and encoder status are available via BiSS C protocol. The position data is right-aligned. Position data is followed by two status bits (active low), followed by CRC (inverted).

BiSS C is implemented for point-to-point operation; multiple slaves are not supported.
Communication is unidirectional, the readhead is not user programmable, also custom parameters can not be stored into the readhead.

Electrical connection



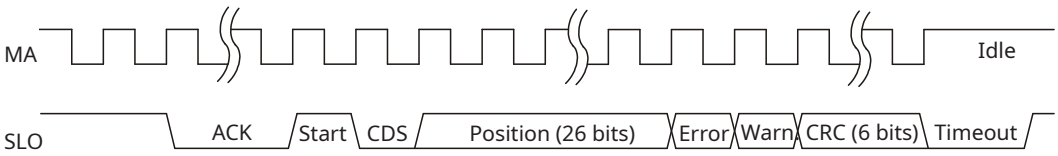
Signals	
MA	Master clock. Max. clock frequency is 5 MHz.
SLO	Slave out. Data is output on rising edge on MA. Data is valid on the falling edge of MA signal.

* The MA and SLO lines are 5 V RS422-compatible differential pairs. The termination resistor on the MA line is integrated in the encoder.

Output protection

Excessive output current and power dissipation caused by errors or bus conflicts are prevented by two mechanisms. A foldback current limit on the output stage provides immediate protection against short circuits. In addition, a thermal shutdown circuit forces the driver outputs into a high-impedance state if the chip temperature becomes too high.

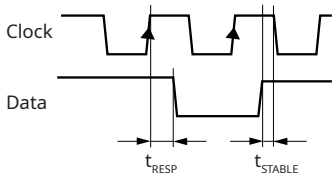
Timing diagram



MA is idle high. Communication is initiated with the first falling edge. The encoder responds by setting the 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 to high. The absolute position and the CRC data are in binary format and are sent MSB first. Multicycle data is not implemented, therefore the CDS bit is always zero. The power supply must be applied at least 5 ms before the clock sequence is being sent to the encoder.

Cable length compensation

The readhead needs 170 ns to respond to incoming clocks (t_{RESP}). The change on the Data signal is delayed by 170 ns after the rising edge on the Clock line. An additional delay is caused by the time the signal takes to propagate through the cable to the readhead and back (t_{PROP}). This delay is typically 14 ns per 1 m cable. The total cable length from the encoder to the receiver must be considered.



$t_{DELAY} = t_{RESP} + t_{PROP} \times \text{cable length}$

The data signal must be stable before the value is latched. If the cable is longer than 1 m and has a clock frequency of more than 2.5 MHz, this delay must therefore be compensated in the receiver (controller) to which the encoder is connected.

Communication parameters

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

Communication interface variant	Description	Parameter	Value
H	Long response High frequency	ACK length	12 bits
		MA frequency	Max. 5 MHz

Parameter	Symbol	Worst case
Latency		<10 µs
Mechanical bandwidth *		2 kHz
Maximum request rate		30 kHz
Timeout (Monoflop time)		20 µs
Readhead response delay	t_{RESP}	170 ns
Cable propagation delay	t_{PROP}	14 ns/m

* Bandwidth parameter is mechanical bandwidth. LinACE samples at 4 kHz therefore any mechanical changes that are appearing faster than 2 kHz are not detectable on the output (Nyquist theorem). If request for position comes faster than sampling frequency, LinACE encoder recalculates the position at the time of request based on current shaft velocity.

Structure of data packet

Data packet length is fixed to 34 bits. It consists of 26 bits of Position, 2 Status bits and 6 CRC bits (see table below).

Encoder position		
	b33 : b8	Encoder position - Right aligned
General status		
	b7	Error bit. If set, the position is not valid.
	b6	Warning bit. If set, the encoder operational is close to its limits. The position is still valid, but the resolution and/or accuracy might be out of specification.
		The Error and Warning bits can be set at the same time, in this case the Error bit has priority. The general warning or error status is more closely defined by the Detailed status bits.
CRC (inverted)		
	b5 : b0	Polynomial for CRC calculation of position, error and warning data is: x6 + x1 + 1. Represented also as 0x43. It is inverted and transmitted MSB first.

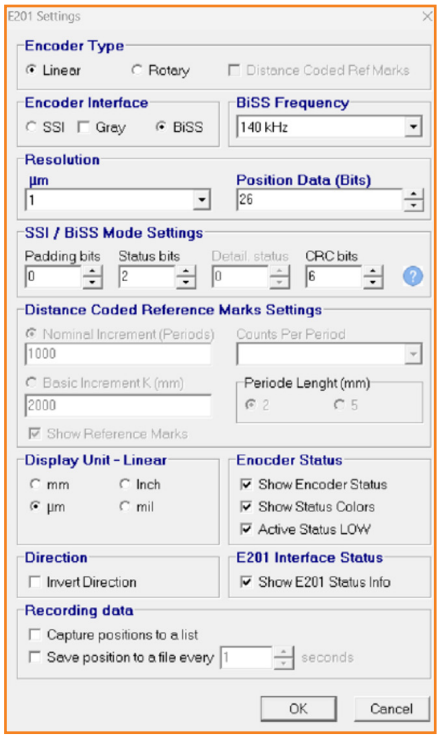
For further information regarding CRC calculation example, refer to the document CRCD01 available at **RLS Media center**.

Deatiled status

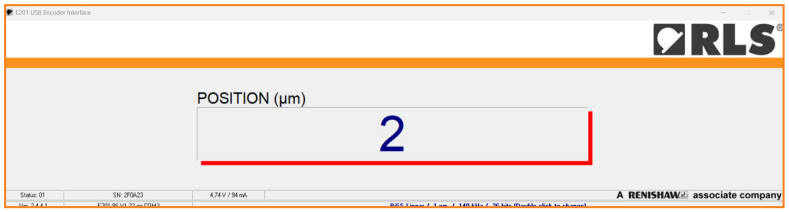
In case of problems with the encoder, detailed status bits are available that communicate the type of error.

When the encoder is in the error state, the red LED is on and the error bit is active. Position information is replaced by detailed status information (red line is visible, which represents error state). For easy reading of the BiSS encoder, the E201-9S interface can be used and the Demo software set to a resolution of 1 um.

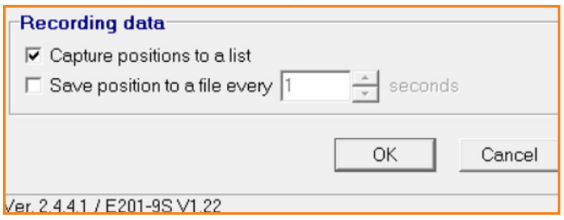
The software settings must be as follows:



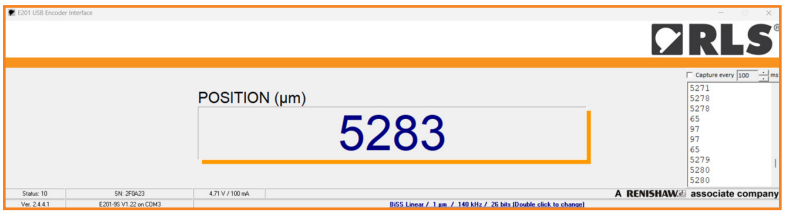
In the event of an active error on the encoder, the software display is as follows (red line is visible, which represents error state):

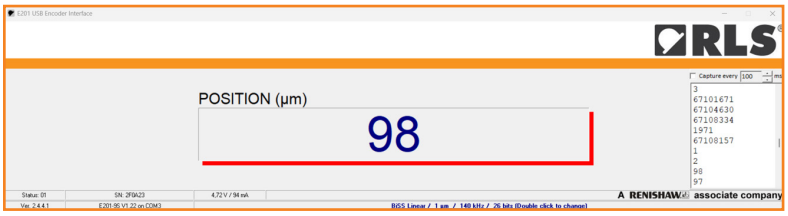


If the error only occurs for a very short time, the data storage function can be enabled in the software:



Only the values where error was active should be observed.





The numbers displayed by the software can be converted to the individual status bits using a Windows Calculator to convert from Decimal to Binary value:

The binary value is then used to look-up the active warning and error bits in the table Detailed status.

Detailed status

b7	Warning - Signal amplitude too high. The readhead is too close to the shaft.
b6	Warning - Signal amplitude low. The distance between the readhead and the shaft is too large.
b5	Error - Signal lost. The readhead is too far away from the shaft.
b4	Warning - Temperature. The readhead temperature is out of specified range.
b3	Error - Power supply error. The readhead power supply voltage out of specified range.
b2	Error - System error. Malfunction inside the circuitry or inconsistent calibration data is detected. To reset the System error bit try to cycle the power supply while the rise time is shorter than 20 ms.
b1	Error - Wrong code. Shaft might be inserted in the wrong direction.
b0	Error - Acceleration error. The position data changed too fast. Shaft might be inserted in the wrong direction.

Warning bits can be observed only if they are active together with one of the error bits. In case only warning is active, encoder will output valid position information, not status bits.

Example:
- Decimal value: 97
- Binary value: 0110 0001
- Active bits: b6, b5, b0
- Active errors: Signal low, Signal lost, Acceleration error.
- Solution: Move readhead closer to the shaft.

Alternatively, common values can be directly interpreted using the table below.

Position reading	Detailed status	Cause and solution
01	Acceleration error	Indicates that Corrupted pattern error was active in the past, causing position value to jump.
02	Corrupted pattern	Adjust mechanical alignment and check for external magnetic field.
65	Signal low & Acceleration error	Adjust readhead closer to the shaft.
66	Signal low & Corrupted pattern	Adjust readhead closer to the shaft and check for external magnetic field.
67	Signal low & Corrupted pattern & Acceleration error	Adjust readhead closer to the shaft and check for external magnetic field.
97	Signal lost & Acceleration error	Readhead is too far away from the shaft.
98	Signal lost & Corrupted pattern	Readhead is too far away from the shaft.

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

Part numbering

CR B 06 DCH 020 A N B 00

Accuracy

B - ±10 µm
C - ±25 µm
D - ±50 µm
E - ±100 µm

Shaft diameter

06 - Ø6 mm

Output type and parameter

DCH - BiSS C, RS422, 5 V
SCB - Binary synchro-serial (SSI), RS422, 5 V
SFx - Asynchronous-serial, RS422, 5 V, link speed in kbps:

A	D	F
115.2	256	1000

Measuring length Overall shaft length

020 - 20 mm	50 mm
050 - 50 mm	80 mm
100 - 100 mm	130 mm
150 - 150 mm	180 mm
200 - 200 mm	230 mm
250 - 250 mm	280 mm
300 - 300 mm	330 mm

Resolution

A - 0.5 µm
B - 1 µm
D - 5 µm
E - 10 µm

Connector and temperature range

N - FCI 10114830-11108LF, 8-pin connector; ext. temp. (–40 °C to +105 °C)

Coded shaft

A - Option with open grooves
B - Option with hard-chrome coating (suitable for sliding bearing)

Customization

00 - No special requirements
01 - No conformal coating

Not all part number combinations are valid. Please refer to the Table of available combinations on the next page.

Table of available combinations

Series	Accuracy	Shaft diameter	Output type	Output type parameter	Measuring length	Resolution	Connector and temp. range	Coded shaft	Customiza-tion
CR	B	06	DC	H	020 / 050 / 100 / 150 / 200 / 250 / 300	A / B	N	A / B	00 / 01
			SC	B					
			SF	A / D / F					
	C		DC	H		A \ B \ D			
			SC	B					
			SF	A / D / F					
	D \ E		DC	H		A \ B \ D \ E			
			SC	B					
			SF	A / D / F					

Accessories

Cable assembly, 1 m
ACC015
ACC049

Cable assembly, 1 m
ACC016
ACC065

Cable assembly, 3 m
ACC061
ACC070

USB interface (for SSI and BiSS communication interface)
E201-9S

LinACE Serial Demo software will work with LinACE with Asynchronous Serial Interface using FTDI (FTDI USB-RS44-WE-1800_BT)

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Issue	Date	Page	Description
01	6. 6. 2023	-	New document
02	8. 8. 2023	16	Table amended
03	10. 9. 2024	3	Dimensions drawing amended
04	14. 4. 2025	11	SSI timing diagram amended
		14-18	BiSS Structure of data packet amended
		20	Accesories amended