LinACE™ flat-board

InAxis Linear Absolute Magnetic Shaft Encoder

TRUE ABSOLUTE SYSTEM

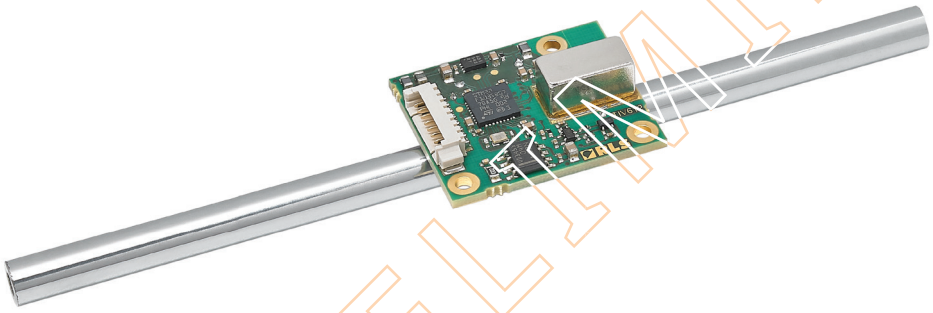
ACCURACY UP TO ±5 µm

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 velocity control loop element.

The readhead length only 30 mm and low weight of the encoder system make it 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 if the shaft rotates during forward and backward movement.



Features and benefits

- Non-contact technology for high reliability in extreme environments
- Absolute position upon power-on
- Resolutions up to 0.5 µm
- Measuring lengths up to 300 mm
- Built-in self monitoring
- Excellent resistance to stray magnetic fields
- Stable across temperature
- 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 within ±5 µm with resolution to 0.5 µm and is very stable across whole temperature range from –40 °C to +105 °C. The encoder repeatability is less than unit of resolution and signal noise is very low with average value 0.5 µm and maximum value 1 µm. The position of the encoder is maintained even if the shaft rotates during forward and backward movement.

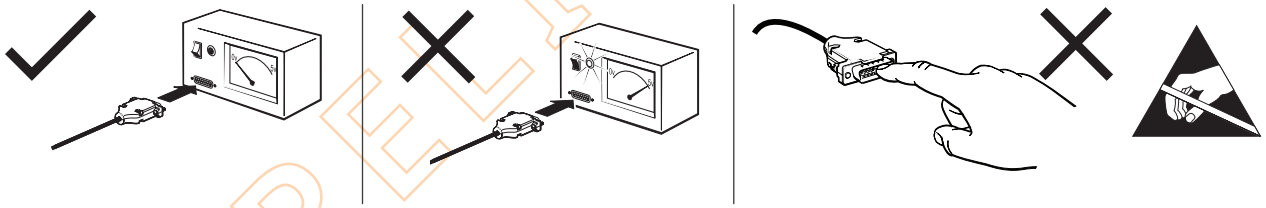
A custom design service for OEM integration is also available.

The maximum measuring length is 300 mm.

Storage and handling

Operating and storage temperature

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



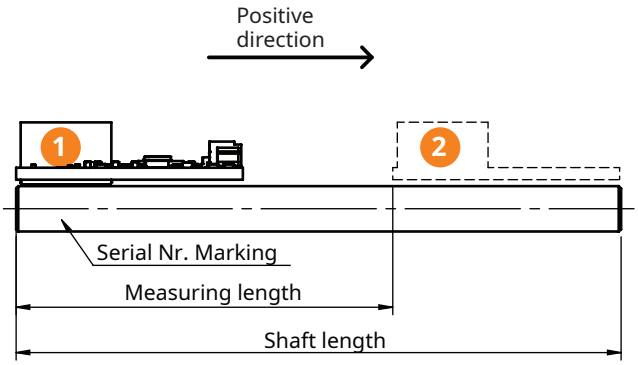
Readhead is ESD sensitive - handle with care.
Do not touch electronic circuit, wires or sensor area without proper ESD protection or outside of ESD controlled environment.

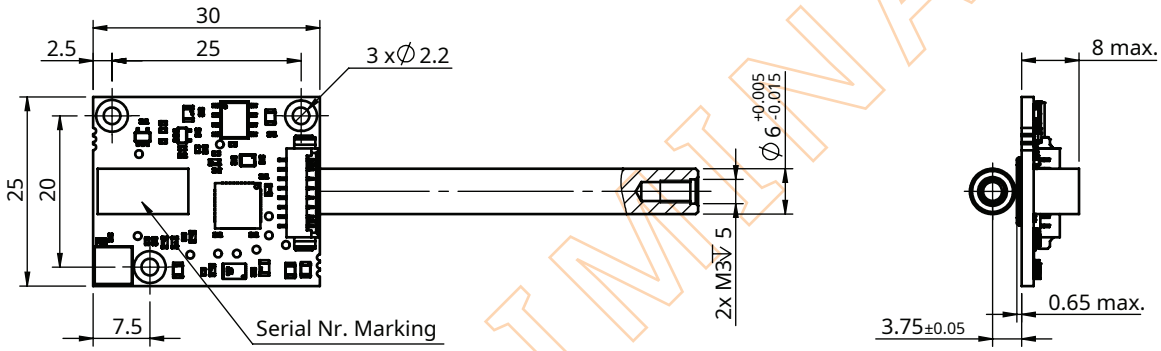
Packaging

Packed individually in an antistatic bag.

Dimensions and installation drawings

Dimensions and tolerances are in mm.

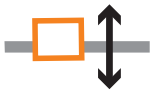




The shaft must be installed with the alignment as shown in the drawing. Pay attention to the position of the serial numbers. The encoder shaft can be rotated independently of the linear travel.

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	±5 µm – only available for measuring lengths up to 100 mm ±10 µm, ±25 µm, ±50 µm, ±100 µm – for measuring lengths up to 300 mm
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 switch-on)
Power-up time	For correct encoder functionality min. 4.5 V should be achieved in less than 20 ms after switch-on.
Current consumption	Typ. 115 mA, max. 150 mA (without output load)
Output load	Asynchronous serial, SSI and BiSS ±40 mA
Connection	8-pin low-profile connector FCI 0114830-11108LF

Mechanical data

Material	Shaft	Carbon steel, 30 µm to 40 µm Hard chrome coating 800 HV to 1100 HV (except end surfaces and threaded holes)
	Readhead	Assembled PCB
Mass	Shaft	Ø6 mm: 22 g / 100 mm;
	Readhead	7.1 g

Environmental data

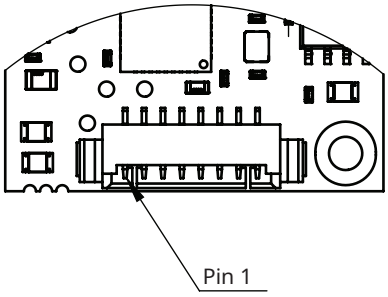
Temperature	Operating	–40 °C to +105 °C
	Storage	–40 °C to +105 °C
Humidity		Up to 70 % non-condensing
Stray magnetic fields		Readhead max. 100 mT. Stray magnetic fields bigger than 100 mT may result in wrong position reading. Coded shaft is insensitive to stray magnetic fields.
Small particles with 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-

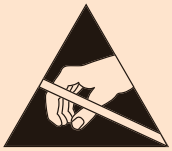
Voltage difference between Ground (white wire and inner shield) and encoder housing (outer shield) should not exceed 10 V_{pp}.

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
Bandwidth	2 kHz max.
Resolutions	0.5 µm, 1 µm, 5 µm, 10 µm
Latency	<10 µs
Timeout (monoflop time)	20 µs

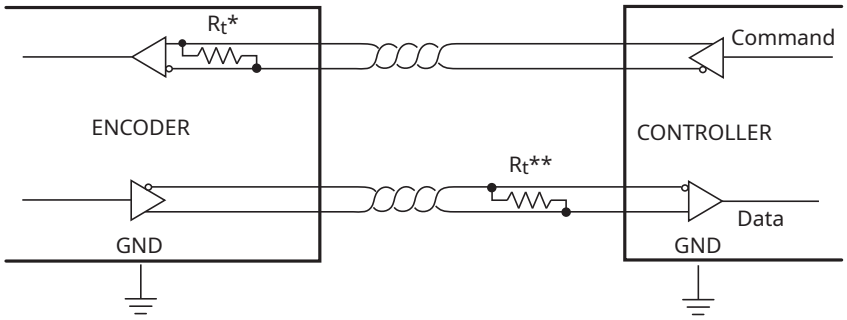
* Slave type interfaces might not be suitable for high-speed closed control loops because of the variable latency time.
** With *Delay First Clock* function on the controller.

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)

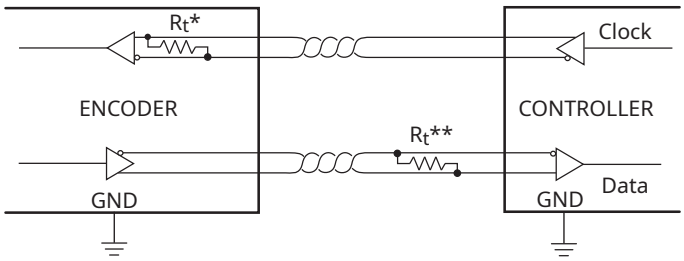
Encoder status (two bytes):	
b15 : b10	Reserved; always zero
General status	
b9	Error bit. If set, the position is not valid.
b8	Warning bit. If set, the encoder operational is close to its limits. The position is still valid, but the resolution and / or accuracy might be lower than specified.
	Error 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

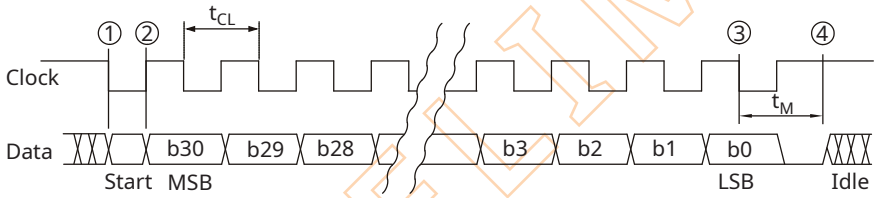


* The Clock and Data signals are 5 V RS422 compatible differential pairs with RC termination inside the readhead.
** Termination at the controller is required, if total cable length is longer than 5 m. The nominal impedance of the cable is 120 Ω. Recommended termination is 120 Ω or RC termination (120 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.

Timing diagram

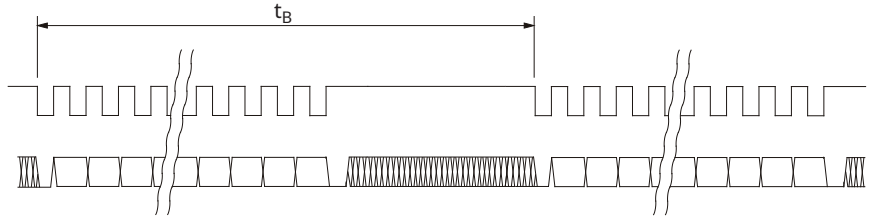


The controller queries the readhead for its position and status data by sending a pulse train to the Clock input. The Clock signal always starts from High. The first falling edge ① latches the last available position data, and on the first rising edge ② the most significant bit (MSB) of the position is transmitted to the Data output. The Data output should then be latched on the following falling edge. On the subsequent rising edges of the Clock signal, the next bits are transmitted. If the time between ① and ② is extended for additional 1 µs, the maximum clock frequency limit is 2.5 MHz instead of 500 kHz. This function is called “Delay First Clock” and must be supported by the controller to which the encoder is connected.

After transmission of the last bit ③ the Data output goes to low. When the time t_M has expired, the Data output is undefined ④. The Clock signal must remain high at least for t_M before the next reading can take place.

When reading the data, the period t_{CL} must always be less than t_M. However, reading the encoder position can be stopped 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.

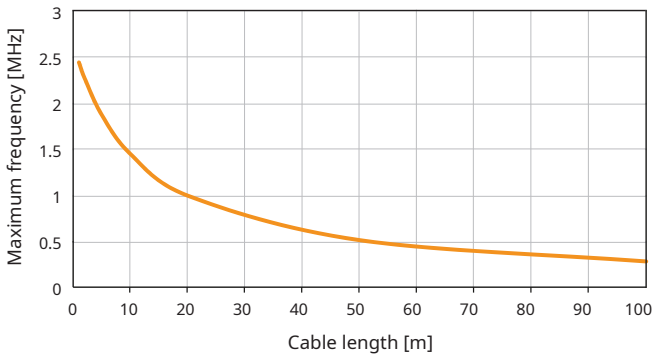


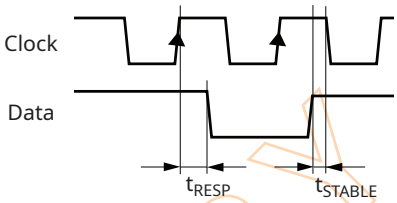
The power supply must be applied at least 200 ms before the clock sequence is being sent to the encoder.

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 needs 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 position	
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.

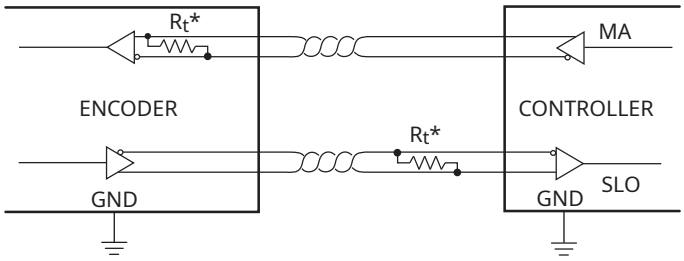
BiSS C unidirectional

DC output type

The encoder position, in 26 bit natural binary code, and the encoder status are available through the BiSS C protocol. The position data is right aligned. After the position data there are 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, readhead is not user programmable, also custom parameters can not be stored into the readhead.

Electrical connection



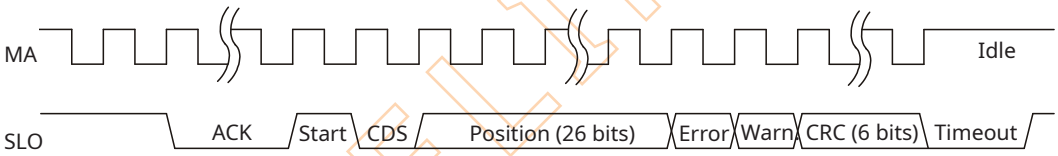
Signals	
MA	Master clock. Max. clock frequency is 5 MHz.
SLO	Slave out. Data is output on rising edge on MA. Data is valid on the falling edge of MA signal.

* 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

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.

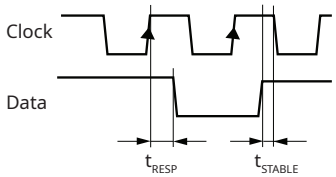
Timing diagram



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 200 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.



$t_{DELAY} = t_{RESP} + t_{PROP} \times$ 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.

Status bits

Type	Value 0	Value 1	Possible reason for failure
Error	Position data is invalid.	OK	Error bit is active low. If low, the position is not valid.
Warning	Position data is valid.	OK	Warning bit is active low. If low, the encoder operation is close to its limits. The position is still valid but the resolution and/or accuracy might be out of specification.

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
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.

Data packet description

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).

	Status		
Position	**Error**	**Warning**	**CRC (inverted)**
26 bits	1 bit	1 bit	6 bits

Polynomial for CRC calculation of position, error and warning data is: $x^6 + x^1 + 1$. Represented also as 0x43.
It is inverted and transmitted MSB first.
Example of calculation routine for 6-bit CRC can be found in CRCD01 application note document downloadable from RLS Media center.

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

Accessories

Cable assembly
ACC015, 1 m

Cable assembly
ACC016, 1 m

Cable assembly
ACC061, 3 m

USB interface (for BiSS C communication interface)
E201-9B

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

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Document issues

Issue	Date	Page	Description
01	27. 1. 2022	-	New document