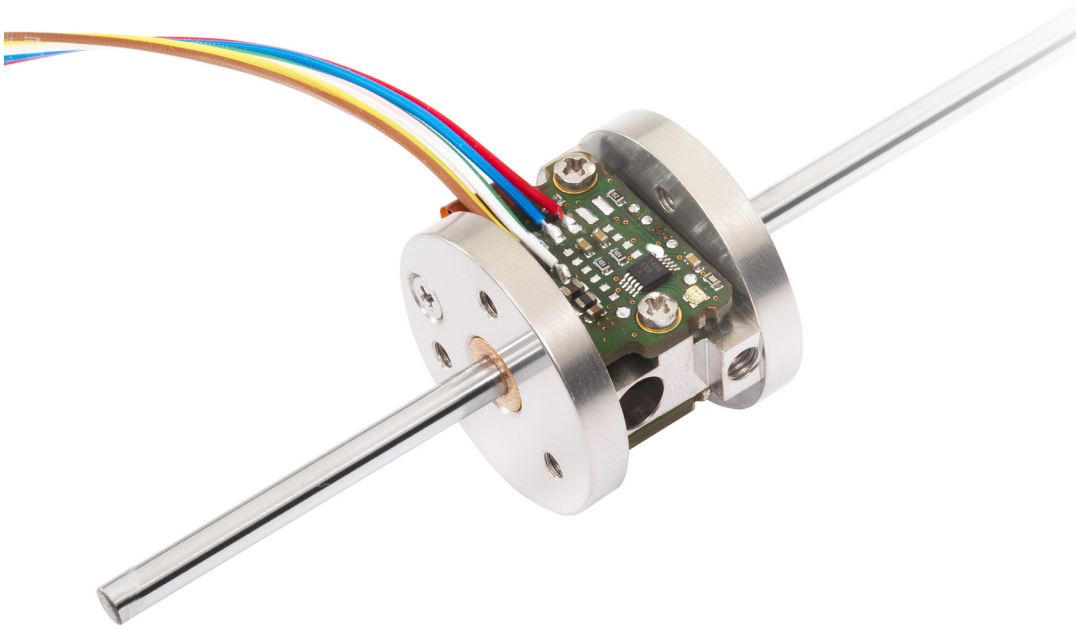
BETA SAMPLES AVAILABLE

Preliminary product information
LinACE™ absolute shaft encoder
7th April 2015

LinACE™ absolute linear shaft encoder



LinACE™ is an extremely robust absolute linear cylindrical encoder system designed for direct integration into hydraulic, pneumatic, electromechanical actuators and linear motors as a feedback element for position or velocity.

The LinACE™ encoder system consists of a sliding encoder readhead and a solid steel shaft acting as a measuring standard.

By replacing the main shaft of the actuator or one of the guide shafts with LinACE™ hard chrome plated shaft the encoder becomes part of the actuator and provides measuring in the axis of movement. The readhead can replace the existing sliding bearing eliminating the need for an external encoder and thereby reducing space consumption.

The encoders come in asynchronous serial RS422, PWM, SSI, and CAN proprietary output variants and offer a range of selectable resolutions from 50 µm to 0.5 µm with speeds up to 5 m/s.

The LinACE™ encoder has a built-in advanced self-monitoring function, continually checking several internal parameters. Error reporting, warnings and other status signals are available on all digital interfaces and visualised with the on-board LED.

The encoder is insensitive to external magnetic fields, operates from -30 °C to +85 °C and is resistant to shock and vibration. The encoder position is retained even if the shaft rotates while moving backwards and forwards.

The LinACE™ encoder system is suitable for integration into electric, hydraulic and pneumatic actuators for motion control in industrial and medical applications. Custom design service for OEM integration is also available.

- **True absolute system**
- **Encoder for direct integration into an actuator**
- **No magnetically induced position hysteresis**
- **Resolution to 0.5 µm**
- **Length up to 320 mm**
- **Speed up to 5 m/s**
- **Built-in self-monitoring**
- **Integrated status LED**
- **Asynchronous serial RS422 communication, PWM, SSI and CAN proprietary interface**
- **Non-magnetised hard chrome plated shaft**
- **Shaft insensitive to stray magnetic fields**

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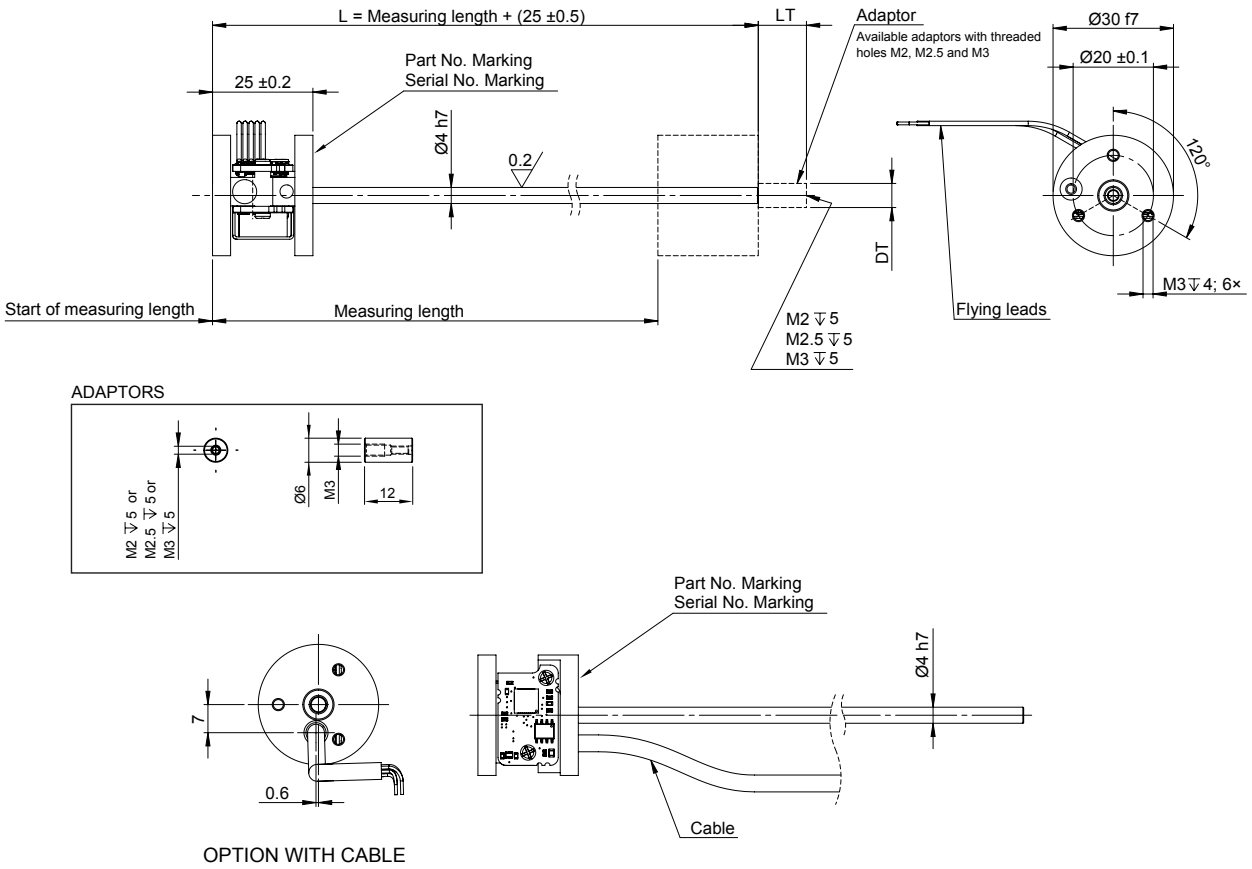
LinACE™ absolute shaft encoder

LinACE™ dimensions

Dimensions and tolerances in mm.



OPTION WITH CABLE

NOTES:
- Start of measuring length may be any number bigger than zero.
- Shaft/readhead module fit: F7/h7.
- Encoder shaft may be rotated as it moves in and out.

Sliding bearing material	Unit	Sint-A51 bronze Impregnated with oil	Sint-A51 bronze Impregnated with low temperature oil
p × v	N/mm^2 × m/s	1.6	1.6
p_{max}, continuous operation at ~0.17 m/s speed	N/mm^2	10	10
Max. speed, continuous operation	m/s	5	5
Thermal expansion coefficient	K^{-1}	18×10^{-6}	18×10^{-6}
Operating temperature	°C	-12 to +85	-30 to +85
Friction coefficient	-	0.05 to 0.10	0.05 to 0.10

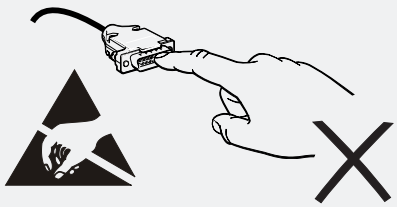
LinACE™ technical specifications

System data		
Maximum shaft overall length	320 mm	
Shaft diameter	4 mm	
Shaft linear expansion coefficient	~11 × 10^{-6}/K	
Maximum speed	5 m/s	
System accuracy	±5 µm - available as KIT up to shaft overall length 125 mm ±10 µm, ±20 µm, ±50 µm - available as KIT with full shaft length (in KITs readhead and shaft are not exchangeable)	
Hysteresis	Less than unit of resolution	
Repeatability	Better than unit of resolution	
Electrical data		
Supply voltage	4 V to 6 V – voltage on readhead *	
Set-up time	5 ms (after switch-on)	
Power consumption	Typ. 115 mA, max. 150 mA	
Mechanical data		
Material type	Shaft	EN 1.1203 / AISI 1055 or EN 1.0601 / AISI 1060 30 µm to 40 µm Hard chrome coating 800 HV to 1100 HV
	Readhead	EN 1.4305 / AISI 303
	Sliding bearing	Sint-A51 bronze impregnated with standard oil Sint-A51 bronze impregnated with low temperature oil
Environmental data		
Temperature	Operating	-12 °C to +85 °C for bearings impregnated with standard oil -30 °C to +85 °C for bearings impregnated with low temperature oil
	Storage	-40 °C to +90 °C
Humidity	90 % (non-condensing)	

* Consider voltage drop over cable.

Status indicator LED

LED	Status
Green	Normal operation; position data is valid
Orange	Warning; position data is valid; one parameter is near limits
Red	Error; position data is not valid
No light	No power supply



WARNING!

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

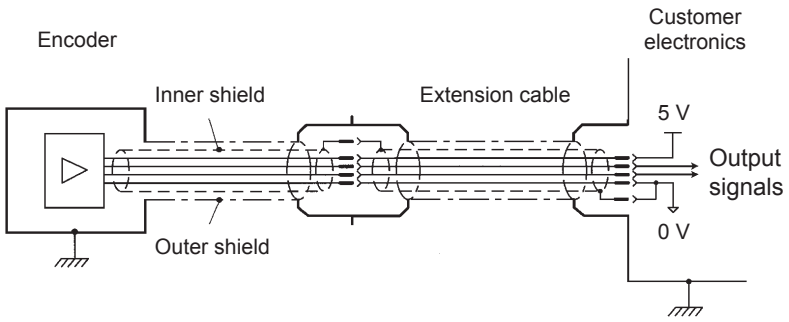
Electrical connections

Pin	Wire Colour	Asynchronous serial RS422	PWM	SSI	CAN bus
Housing	Outer shield	Encoder / machine case (Earth connection)	Encoder / machine case (Earth connection)	Encoder / machine case (Earth connection)	Encoder / machine case (Earth connection)
1	Inner shield	0 V (GND)	0 V (GND)	0 V (GND)	0 V (GND)
2	Red	RX data in +	-	Clock +	-
3	Blue	RX data in -	-	Clock -	-
4	Grey	-	Status	-	CANL
5	Brown	5 V supply	5 V supply	5 V supply	5 V supply
6	Green	TX data out +	-	Data +	-
7	Yellow	TX data out -	-	Data -	-
8	Pink	-	PWM Out	-	CANH
9	White	0 V (GND)	0 V (GND)	0 V (GND)	0 V (GND)

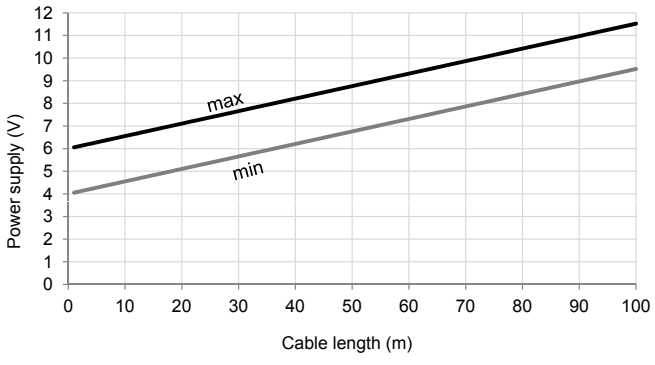
Voltage difference between Ground (white wire and inner shield) and encoder housing (outer shield) should not exceed 10 V_{pp}.

Cable specifications

Outer diameter	4.2 mm ±0.2 mm
Jacket material	Extruded polyurethane (PUR)
White wire	0.9 mm ±0.07 mm diameter, 26 AWG (19 strands REF 6), 0.13 Ω/m
Other wires	0.6 mm ±0.07 mm diameter, 30 AWG (7 strands REF 6), 0.35 Ω/m
Power supply lines resistance	0.48 Ω/m at 20 °C
Durability	20 million cycles at 20 mm bend radius
Bend radius	Dynamic 25 mm, static 10 mm (internal radius)
Weight	34 g/m nominal



Voltage drop over cable



For cables longer than 5 meters input voltage on the cable must be adjusted so the voltage drop is taken into account.
Voltage drop over cable ~55 mV/m – without load.

LinACE™ communication interfaces

Asynchronous serial RS422		
	Baud rate	115.2 kbps, 128 kbps, 230.4 kbps, 256 kbps, 500 kbps, 1 Mbps
	Data format	8 bits, no parity, 1 stop bit
	Update rate	On demand or continuous
	Resolution	0.5 µm, 1 µm, 2 µm, 5 µm, 10 µm
	Latency	250 µs
PWM		
	Base frequency	122.07 Hz, 274.66 Hz, 366.21 Hz, 549.32 Hz, 1098.6 Hz
	Update rate	Same as base frequency
	Output resolution	16 bits
	Resolution	1 µm/step at up to 50 mm stroke 2 µm/step at up to 100 mm stroke 5 µm/step at up to 250 mm stroke 10 µm/step at up to 500 mm stroke
	Latency	250 µs
SSI *		
	Maximum clock frequency	500 kHz
	Update rate	4 kHz
	Resolution	0.5 µm, 1 µm, 2 µm, 5 µm, 10 µm
	Latency	250 µs to 500 µs
	Timeout (monoflop time)	20 µs
CAN bus		
	Standard	Proprietary
	Update rate	Up to 4 kHz
	Resolution	0.5 µm, 1 µm, 2 µm, 5 µm, 10 µm
	Latency	250 µs

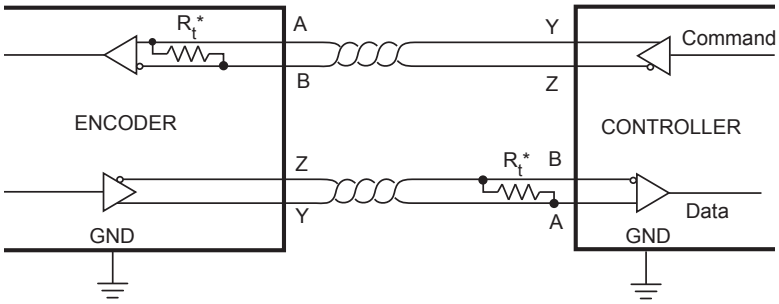
* Slave type interfaces might not be suitable for high-speed closed control loops because of the variable latency time.

Asynchronous serial communication over RS422

Encoder identification and position data is available over the request-response type of communication through the asynchronous serial link. There are two unidirectional communication channels, forming a full-duplex bidirectional data link. Every channel consists of a two wire differential twisted-pair connection conforming to an RS422 signalling standard.

Electrical connection

Communication channels are two 5 V RS422 compatible differential pairs including ground connection.



* The Command and Data signals are 5 V RS422 compatible differential pairs with RC termination inside the readhead. The termination at the controller is required if total cable length is longer than 5 m.

Communication parameters

Link speed	115.2 kbps, 128 kbps, 230.4 kbps, 256 kbps, 500 kbps or 1 Mbps
Character length	8 bits
Parity	None
Stop bits	1
Repetition rate	4 kHz max
Position latency	Fixed 250 µs between the position acquisition and first start bit sent out

Command set

Command "v" (small character "v")
Response - version info and serial number
8 bytes ASCII Serial number
1 byte binary Firmware version (42)
1 byte binary ASIC revision (31)
1 byte binary Resolution (factor 0.1 µm)
6 bytes ASCII code description

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

Data packet definition

Encoder status (two bytes):		
	b15:b10	Reserved; always zero
General status		
	b9	Error. If bit is set, position is not valid.
	b8	Warning. If bit is set, encoder is near operation limits. Position is valid. 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. Those two bits are synchronised to the LED indicator on the housing of the encoder: Red = Error, Orange = Warning, Green = Normal operation, No light = No power supply. 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 high.
	b5	Error - Signal lost. The readhead is too far away from the shaft.
	b4	Warning - Temperature. The readhead temperature is out of range.
	b3	Error - Power supply error. The readhead power supply voltage out of specified range.
	b2	Error - System error. Malfunction detected 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 kept below 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.

PWM communication interface

The PWM interface consists of two digital signals: the Status signal and the PWM Out signal. It is 3.3 V TTL compatible.

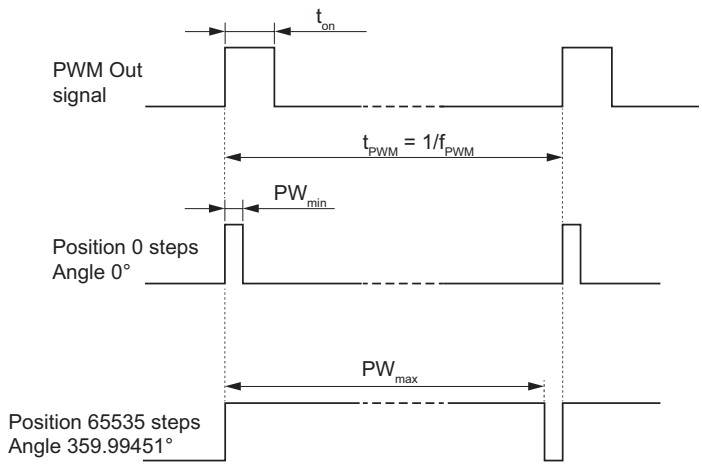
Status signal
The Status signal indicates the current status of the encoder. The Status signal is high for faultless operation and valid position information. The low state of the Status signal indicates an error state of the encoder which can be caused by:

- Operation outside installation tolerances,
- Invalid or corrupted magnetic pattern of ring,
- 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 16-bit resolution whose duty cycle is proportional to the measured position. The change of the pulse width by 1 step corresponds to a change in position by one unit of the selected encoder resolution.

PWM signal output



Communication parameters
Output type variant in the part number defines the PWM frequency and all other dependent parameters.

		Output type variant						
Parameter	**Symbol**	**A**	**B**	**C**	**D**	**E**	**Unit**	**Note**
PWM frequency	f_{PWM}	122.07	244.14	325.52	488.28	976.56	Hz	
Signal period	t_{PWM}	8,192.00	4,096.00	3,072.00	2,048.00	1,024.00	µs	
Minimum pulse width	PW_{min}	0.1250	0.0625	0.0469	0.0313	0.0156	µs	Position 0
Maximum pulse width	PW_{max}	8,191.88	4,095.94	3,071.95	2,047.97	1,023.98	µs	Positions 65534 and 65535 *
Min. counter frequency	f_{CNTR}	8	16	21	32	64	MHz	Receiving counter frequency

* Note that positions 65534 and 65535 result in the same pulse width PW_{max}.

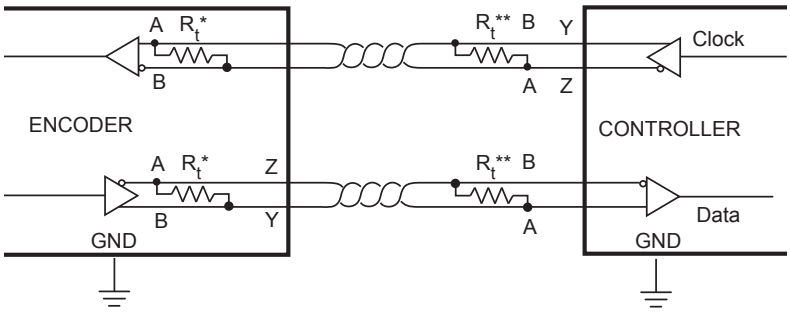
$$\text{Position [µm]} = \left(\frac{t_{on} \times 65536}{T_{PWM}} - 1 \right) \times \text{Resolution}$$

Electrical connection
The status signal and the PWM Out signal are 3.3 V TTL compatible. These signals have weak ESD protection. Handle with care.

Binary synchronous serial output SSI

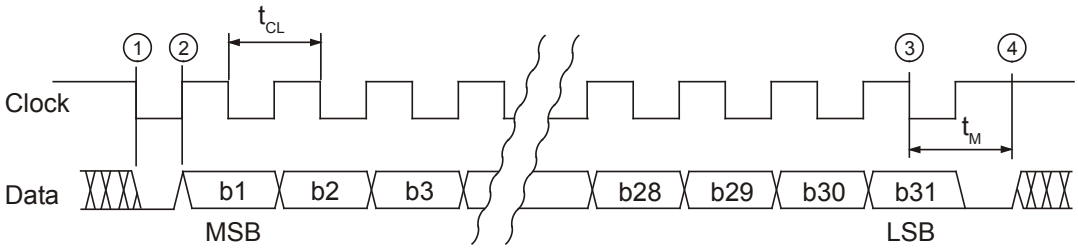
The encoder position, in 21 bit natural binary code, and the encoder status are available through the SSI protocol. The position data is right aligned. After the position data there are two general status bits followed by the detailed status information.

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.

SSI timing diagram

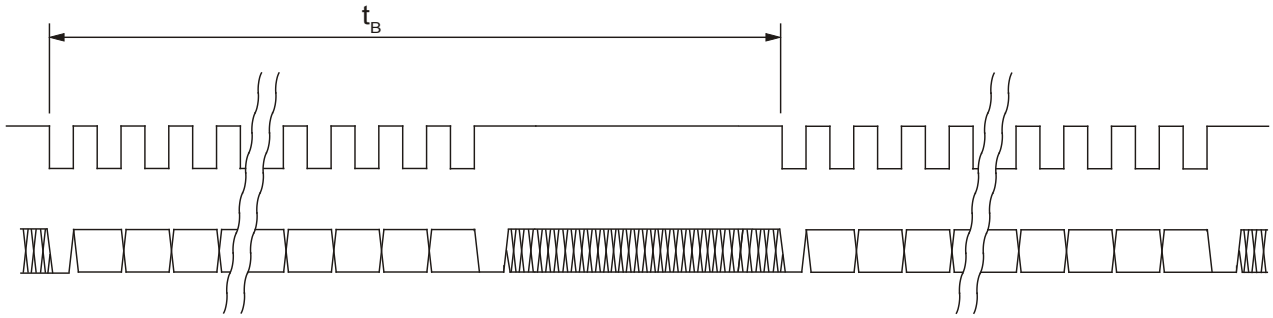


The controller interrogates the readhead for its position and status data by sending a pulse train to the Clock input. The Clock signal always starts from high. The first falling edge ① latches the current position data and on the first rising edge ② the most significant bit (MSB) of the position is transmitted to the Data output. The Data output should then be latched on the following falling edge. On subsequent rising edges of the Clock signal the next bits are transmitted.

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

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

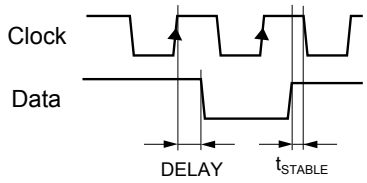
To allow updating of the position data at least t_B should pass between two subsequent readings. If the reading request arrives earlier than t_B after the previous reading, the encoder position will not be updated.



Timing

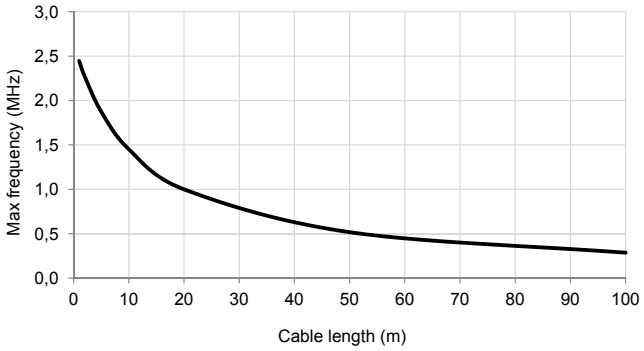
		Min	Typ	Max
t_{CL}	Clock period	2 µs		20 µs
f_{CL}	Clock frequency	50 kHz		500 kHz
t_M	Monoflop time		20 µs	
t_B	Update time	250 µs		

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. Additional delay is caused by the time the signal needs to propagate through cable to the readhead and back (t_{PROP}). This delay is typically 14 ns per 1 meter of cable. Data signal must be stable for at least 10 % of the clock period length before the value is latched.
The clock frequency must be reduced with a longer cable. Total cable length must be taken into account, from the encoder to the receiver.
$t_{DELAY} = t_{RESP} + t_{PROP} \times$ cable length

Frequency derating versus cable length:



Communication parameters

Parameter	Symbol	Min	Typ	Max
Clock period	t_{CL}	2 µs		20 µs
Clock frequency	f_{CL}	50 kHz		500 kHz (2.5 MHz *)
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	

* With Delay First Clock function on the controller.

Start bit and idle line value are defined by the *Output type variant*.

Output type variant	Line state selection
A	Start bit = 0; idle line = 0
B	Start bit = 1; idle line = 1

Structure of data packet

Bit	b1 : b21	b22 : b23	b24 : b31
Data length	21 bits	2 bits	8 bits
Meaning	Encoder position	General status	Detailed status

Encoder position		
	b1 : b21	Encoder position – Right aligned, MSB (b1) first, LSB (b21) last.
General status		
	b22	Error bit. If set, the position is not valid.
	b23	Warning bit. If set, the encoder operation 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. Those two bits are synchronised to the LED indicator on the housing of the encoder: Red = Error, Orange = Warning, Green = Normal operation, No light = No power supply. The general warning or error status is more closely defined by the Detailed status bits.	
Detailed status		
	b24	Warning - Signal amplitude too high. The readhead is too close to the shaft.
	b25	Warning - Signal amplitude low. The distance between the readhead and the shaft is too high.
	b26	Error - Signal lost. The readhead is too far away from the shaft.
	b27	Warning - Temperature. The readhead temperature is out of range.
	b28	Error - Power supply error. The readhead power supply voltage out of specified range.
	b29	Error - System error. Malfunction detected 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 kept below 20 ms.
	b30	Error - Wrong code. Shaft might be inserted in the wrong direction.
	b31	Error - Acceleration error. The position data changed too fast. Shaft might be inserted in thewrong direction.

CAN – Controller Area Network

Upon power-up the readhead starts sending messages at a frame rate of 1 kHz. Each message consists of an 11 bit identifier and six data bytes, including the encoder position, time stamp of the message and status of the readhead. The byte order of the position data is little-endian, i.e. the least significant byte is sent first. The automatic retransmission on the CAN bus is disabled.

Communication parameters

Protocol	Proprietary
Identifier length	11 bits
Identifier	0x127
Data length	6 bytes
Data rate	1000 Hz
Bit rate	250 kbit/s
Byte order	Little-endian
Bit alignment	MSB first

Electrical connection

The LinACE readhead has a 120 Ohm line terminating bias circuit (TBC) installed (supplying +2.5 V on the bus for the Recessive state).

Structure of data packet

Byte	B1 : B3	B4	B5	B6
Data length	3 bytes	1 byte	1 byte	1 byte
Bit	b47 : b24	b23 : b16	b15 : b8	b7 : b0
Meaning	Encoder position	Time stamp	General status	Detailed status

Encoder position		
		Encoder position in chosen resolution as 24 bit signed value – Least significant byte (B1) first, most significant byte (B3) last.
Time stamp		
		Time stamp of the message as 8 bit unsigned value in range from 1 ms to 200 ms. Time stamp is incremented every packet by 1.
General Status		
	b15 : b10	Reserved. Always zero.
	b9	Warning bit. If set, the encoder operation is close to its limits. The position is still valid, but the resolution and/or accuracy might be out of specification.
	b8	Error bit. If set, the position is not valid.
	The Error and Warning bits can be set at the same time, in this case the Error bit has priority. Those two bits are synchronised to the LED indicator on the housing of the encoder: Red = Error, Orange = Warning, Green = Normal operation, No light = No power supply. The general warning or error status is more closely defined by the Detailed status bits.	
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	b5	Error - Signal lost. The readhead is too far away from the shaft.
	b4	Warning - Temperature. The readhead temperature is out of range.
	b3	Error - Power supply error. The readhead power supply voltage is out of specified range.
	b2	Error - System error. Malfunction detected 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. The shaft might be inserted in the wrong direction.

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