General technical data – Incremental encoders

2026/10/28 24-105926

Safety instructions

- If a riskless operation can no longer be assured, the unit has to be shut down immediately and be secured against unintended start up.
- In any case of possible hazard of people or possible damage of equipment if the encoder fail, precautions have to be taken to prevent it before start.

Optical principle

All the EI incremental encoders from Leuze (except output circuits B1, B2, D1, D2) are based on non-contact optical scanning. The light from a high-performance LED is parallel aligned by means of a lens and shines through a lens aperture disc and a pulse disc. The aperture disc is integrated in the flange. The pulse disc is mounted on the stainless-steel shaft that is free from backlash thanks to its special bearings. If the shaft is rotated, then the combination of aperture and pulse discs cause finely defined fields to open and close. Either light is let through the grid or not. This layout means two signals are detected, phase-shifted by 90º, as well as a zero (index) pulse. The difference between light and dark is detected by receiving transistors, working differentially, mounted on the PCB on the opposite side. From this the electronic circuitry preprocesses high-precision signals and then amplifies them into industrially usable pulse-forms, for example sinusoidal or square-wave, HTL or TTL and their inverted signals.

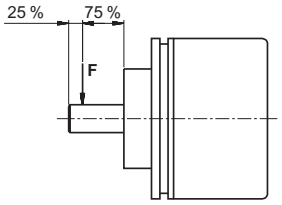
Our encoders are finely-tuned measuring systems, made up of a combination of precision mechanics, a compact optical segment and highperformance electronics.

Magnetic principle

The EI incremental encoders with output circuits B1, B2, D1, D2 work on a non-contact magnetic scanning principle. A diametral agnetised magnet is mounted in the stainless-steel shaft with its backlash-free bearings. If the shaft is rotated, the magnet and the magnetic field rotate with it. This change in the magnetic field is detected and processed by a sensor chip on the PCB opposite. The evaluation enables 2 signals to be generated that are 90° phase-shifted as well as a zero pulse. The downstream electronics conditions these into high-precision signals and amplifies them into industrially usable square-wave pulses in HTL and TTL plus their inverted signals. Our magnetic encoders are finely-tuned measuring systems, combining precision mechanics, efficient sensor technology and high-performance electronics.

Mechanically rugged

All encoders have double and clearance-free shaft bearings with the maximum possible distance between the bearings, thus obtaining maximum long-term load capacity.



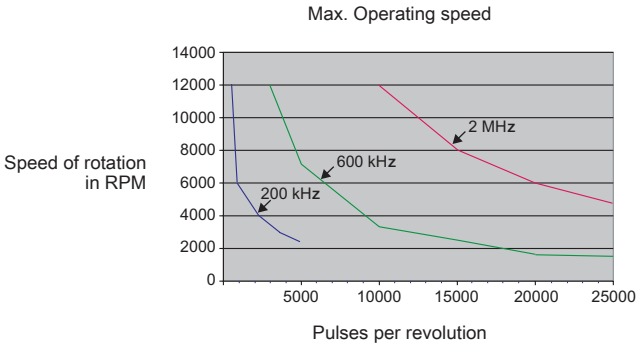
The bearings are treated with a special grease able to withstand extreme temperatures, high speeds and loads, as well as constant operation in reverse. The grease remains stable over a long period of time. The indicated radial-bearing load relates to the point F of the applied force. The useful life of the bearings is stated in the number of revolutions. The life can be converted into hours using the following formula:

$$\text{Life in hours} = \frac{\text{Number of Revolutions}}{\text{(RPM) * 60}}$$

Maximum Operating Speeds

The maximum operating speed is limited by the maximum mechanical operating speed (shaft speed) and by the number of pulses per revolution (PPR). The maximum operating speed is given in the specifications. The maximum speed with relation to the pulse frequency can be expressed as follows:

$$\text{Max. speed of rotation RPM} = \frac{\text{Max. Frequency of encoder in Hz x 60}}{\text{PPR of encoder}}$$



Accuracy incremental encoders

Shaft encoders have two defined types of accuracy. In each case the accuracy is given as a % of the period duration, which consists of a pulse and a pause. The pulse/pause ratio describes the ratio of the pulse length from the period duration. The phase displacement describes the accuracy of two successive edges.

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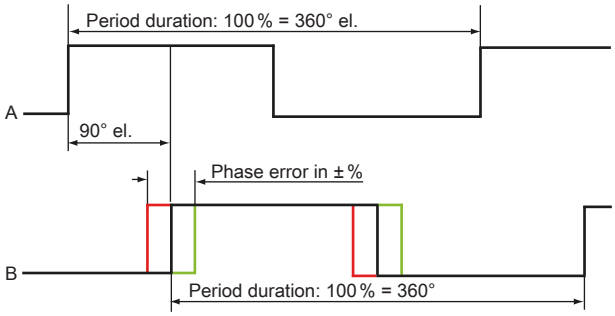
General technical data – Incremental encoders

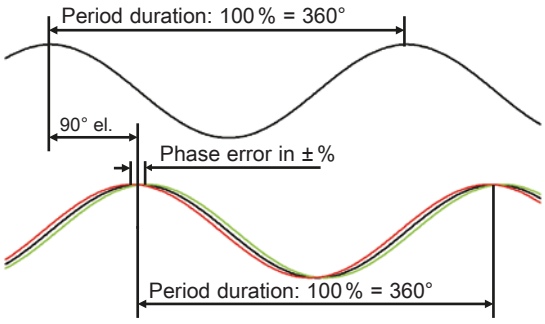
Phase offset:



EI. phase offset:

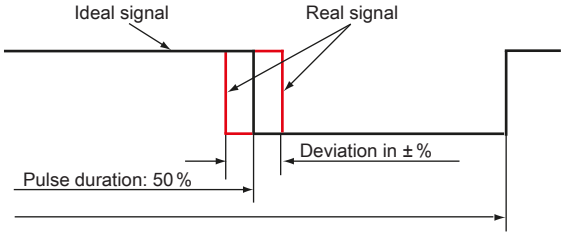
90° ± max. phase error 7,5 % of a period duration at EI: B1, B2, D1, D2
90° ± max. phase error 25 % of a period duration

Accuracy sinus encoders
Phase offset:



EI. phase offset:
90° ± max. phase error 7,5 % of a period duration

Pulse-/ Pulse-ratio:



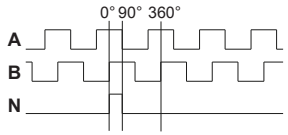
Pulse-/Pause-ratio:

EI C1: 50 % max. ±7 %, C5, C6, C7, D5, D6, D7
EI C2: 50 % max. ±10 %, C3, C4, D3, D4

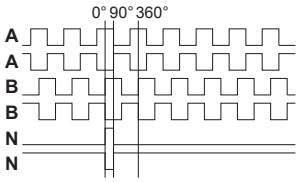
EI B1/B2:	Max. Operating speed 1 ppr up to 128 ppr: 50 % max. ±7 % 256 ppr: 50 % max. ±9 % 512 prr: 50 % max. ±13 %
EI D2/D1:	1024 ppr: 50 % max. ±18 % 50 % max. ±7 %

Pulse diagram*

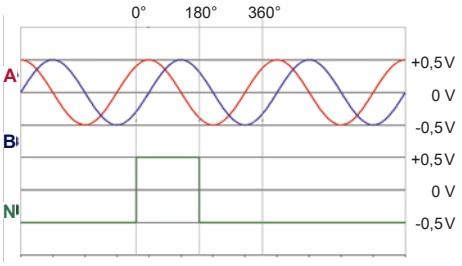
C3, C4, C5, C6, C7, D2, B2



C1, C2, D1, D3, D4, D5, D7, B1



SINUS-Pulse figure (differential input)



*View of shaft, clockwise rotation in each case

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General technical data – Incremental encoders

Maximum Output Frequency:

The maximum output frequency is given for the various encoders. For limiting factors such as cable lengths and diameters, please see the section on cable lengths. When designing the electronic evaluation circuitry for maximum frequencies and noise suppression, tolerances should be taken into account in order to provide a safety margin so as to handle maximum output frequencies which may occur in the specific application.

The maximum occurring frequency $f_{(max)}$ can be calculated using the following formula:

$$f\ \text{in Hz}_{(max)} = \frac{(\text{max shaft speed in RPM}) \times (\text{pulses per revolution PPR})}{60}$$

Maximum output frequency $f_{(max)}$ in relation to cable length and operating voltage at 25 °C and 20 mA load with our Leuze cable:

Output circuit	Power supply	C6 f_{aus}	D6 f_{aus}
10 meter	10 – 30 V	200 kHz	200 kHz
50 meter	12 V	200 kHz	200 kHz
	24 V	200 kHz	100 kHz
	30 V	150 kHz	50 kHz
100 meter	12 V	200 kHz	200 kHz
	24 V	200 kHz	50 kHz
	30 V	70 kHz	

Output circuit	Power supply	C6 f_{aus}	D6 f_{aus}
10 meter	12 V	560 kHz	450 kHz
	24 V	350 kHz	350 kHz
	30 V	280 kHz	280 kHz
50 meter	12 V	250 kHz	200 kHz
	24 V	150 kHz	100 kHz
	30 V	100 kHz	50 kHz
100 meter	12 V	300 kHz	150 kHz
	24 V	100 kHz	50 kHz

Output circuit	Power supply	C5 f_{aus}	D5 f_{aus}
100 meter	5 V	200 kHz	200 kHz

Output circuit	Power supply	C3 f_{aus}	D3 f_{aus}
100 meter	5 V	2 MHz	2 MHz

Output circuit	Power supply	C1 f_{aus}	C2 f_{aus}
100 meter	10 – 30 V	200 kHz	200 MHz

Output circuit	Power supply	B1/B2 f_{aus}
25 meter	5 – 30 V	200 kHz

Output circuit	Power supply	B1/B2 f_{aus}
10 meter	4.75 – 5.5 V	20 kHz

Output circuit	Power supply	D7/C7 f_{aus}	D2 (EI) f_{aus}	D1 (EI) f_{aus}
10 meter	5 V	200 kHz	1 MHz	1 MHz
	12 V	200 kHz	1 MHz	1 MHz
	24 V	200 kHz	460 kHz	370 kHz
	30 V	200 kHz	280 kHz	210 kHz
50 meter	5 V	200 kHz	1 MHz	1 MHz
	12 V	155 kHz	1 MHz	1 MHz
	24 V	75 kHz	200 kHz	120 kHz
	30 V	58 kHz	130 kHz	70 kHz
100 meter	5 V	200 kHz	1 MHz	1 MHz
	12 V	70 kHz	800 kHz	600 kHz
	24 V	30 kHz	140 kHz	70 kHz
	30 V	24 kHz	70 kHz	35 kHz

Cable length:

Using Leuze encoder cable a cable run of up to 100 m is possible (150 m for SINUS encoders). However the actual achievable cable length depends on the possible effects of noise interference and should therefore be checked for each individual case. Please refer to the tables regarding the max. output frequency depending on the cable length on this page.

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General technical data – Incremental encoders

	Cable for encoders without low-temperature				Cable T-C	Cable for encoders with low-temperature LT -40 °C (-40 °F)	
Encoder types	58 SY/CL/RN/CH/BB/ HO/RC/CA 67 SQ, 70 CL, 80 HO 100 HO/HI, 115 TM/TS	58 SF	24 RN	36 SY/RN/BB/RC/SR	58 TM	24 RN, 36 SY/RN/BB/RC/SR	58 SY/CL/RN/CH/BB/ HO/RC/CA 67 SQ, 70 CL, 80 HO 100 HO/HI, 115 TM/TS
Core	stranded copper wire						
Cross-section for							
signal lines	0.14 mm² [AWG 26]	0.14 mm²	0.14 mm²	0.14 mm²	0.14 mm²	0.14 mm²	0.14 mm²
power lines	0.34 mm² [AWG 22]	0.34 mm²	0.34 mm²	0.34 mm²	0.34 mm²	0.34 mm²	0.34 mm²
Cable diameter							
at circuits:							
inverted	7.7 mm² [0.3"]	8.3 mm²	6.0 mm²	7.0 mm² [0.276"]	6.0 mm²	6.0 mm²	8.3 mm²
not inverted	6.3 mm² [0.25"]	8.3 mm² [0.327"]	6.0 mm² [0.236"]	6.0 mm² [0.236"]	6.0 mm² [0.236"]	6.0 mm² [0.236"]	8.3 mm² [0.327"]
Shield	Tinned braided copper. Stranded filter wire for simple connection						
Outer sheath	PVC, grey	TPE, grey	PVC, grey		PVC, black	PUR, black	TPE, grey
Line resistance							
for 0.14 mm2 max.:	148 Ω/km		148 Ω/km		148 Ω/km	148 Ω/km	148 Ω/km
for 0.34 mm2 max.:	57 Ω/km						57 Ω/km
Operating capacity							
Core/Core:	140 nF/km				120 nF/km	140 nF/km	
Core/shield:	ca. 155 nF/km				ca. 120 nF/km	ca. 155 nF/km	

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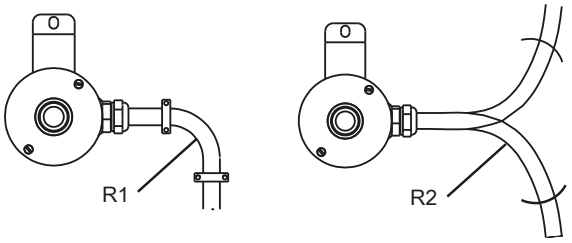
Permissible bending radii Cable:



Encoders without low-temperature

Cable Ø	R1	R2	Temperature
≤ 7 mm [0.276"]	31.5 mm [1.24"]	94.5 mm [3.72"]	T > -20 °C (-4 °F)
> 7 mm [0.276"]	41.5 mm [1.634"]	124.5 mm [4.9"]	T > -20 °C (-4 °F)

Encoders with low-temperature

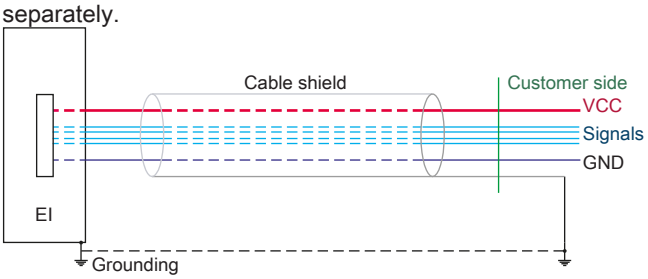
Cable Ø	R1	R2	Temperature
≤ 7 mm [0.276"]	31.5 mm [1.24"]	94.5 mm [3.72"]	T > -20 °C (-4 °F)
> 7 mm [0.276"]	41.5 mm [1.634"]	124.5 mm [4.9"]	T > -20 °C (-4 °F)

Encoders with cable T-C

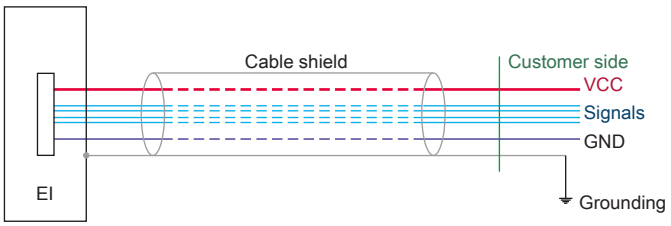
Cable Ø	R1	R2
6 mm [0.236"]	30 mm [1.181"] T > -40 °C (-40 °F)	90 mm [3.543"] T > -10 °C (-14 °F)

Typical shielding concepts for encoders with cable outlet

R-IPN, A-N, R-N: Screen separated at encoder. Cable screening earthed on customer side The encoder housing must be earthed separately.



A-C/R-C T-C: Cable shield connected to encoder housing. Encoder housing not earthed separately.



Note:
In order to avoid compensating flows which will damage the ball bearing in an earth loop, earthing on both sides is not recommended.

Protection from Noise Interference

For efficient protection of the entire system we recommend the following measures:

For normal applications it is sufficient to connect the shield of the encoder cable to the earth potential. The entire system, consisting of the encoder and the signal processing equipment should be grounded at one single location by using a low resistance connection (e.g. braided copper).

- In all cases the connecting cables should be shielded and should be locally kept away from power lines and other noise-generating equipment.
- Sources of interference such as motors, solenoid valves, frequency converters etc should always have their noise suppressed at source.
- Encoders should not be powered from the same mains supply as solenoid valves or contactors, as this may cause interference.

In certain applications it may be necessary to install additional protection against interference, depending on the way the system is earthed and on the noise fields present. Such measures would include: capacitive coupling of the screen, the installation of HF-filters in the encoder cable or the installation of transient protection diodes. If these or any other measures are necessary, please contact us.

We reserve the right to make technical changes

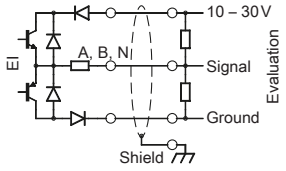
General technical data – Incremental encoders

Key	Output circuit	Power supply	Current consumption	Channels	Output	Load	Signal level	Pulse frequency	Light reserve warning
C6	HTL	10 VDC up to 30 VDC	typ. 70 mA	A, B, N		max. 40 mA / channel	H > UB – 2,5 VDC L < 2,5 VDC	max. 200 kHz	no
C4			typ. 100 mA					max. 600 kHz	
D6				A, B, N				max. 200 kHz	no
D4			typ. 100 mA	A, B, N				max. 600 kHz	
C5	TTL	4.75 VDC up to 5.5 VDC	typ. 70 mA	A, B, N		max. 40 mA / channel	H > 2,5 VDC L < 0,5 VDC	max. 200 kHz	no
C3			typ. 100 mA					max. 2 MHz	
B2			typ. 40 mA			max. 30 mA / channel		max. 20 kHz	
B1	RS422 (TTL)			A, B, N					
D5			typ. 70 mA			max. 40 mA / channel		max. 200 kHz	no
D3			typ. 100 mA	A, B, N				max. 2 MHz	
C1		10 VDC up to 30 VDC	typ. 70 mA				H > 2,5 VDC L < 1,2 VDC	max. 200 kHz	yes
C2			typ. 100 mA					max. 2 MHz	no
B2	HTL (TTL at 5 VDC)	5 VDC up to 30 VDC	typ. 40 mA	A, B, N		max. 30 mA / channel	H > UB – 10 % UB L < 2,5 VDC	max. 200 kHz	
B1				A, B, N					
D7			typ. 70 mA	A, B, N		max. 40 mA / channel			
C7				A, B, N					
D1 (EI)		4.75 VDC up to 30 VDC		A, B, N				max. 600 kHz HTL max. 1 MHz TTL	
D2 (EI)				A, B, N					

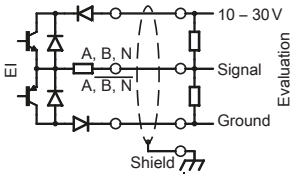
Key	Channels / Output	Power supply	Current consumption	Cable length	Signal level	Limit frequency (-3dB)	Load on the output	Light reserve warning
D8	Sinus, Cosinus (N)	4.75 VDC up to 5.5 VDC	typ. 100 mA without load	max. 150 m at <260 pF/m	1 Vpp ± 25 %	100 kHz	min. 120 Ω terminating resistor between + and – output	no
								yes

Output circuits

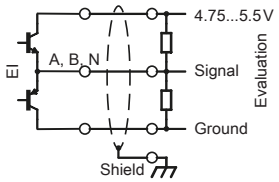
C6, C4



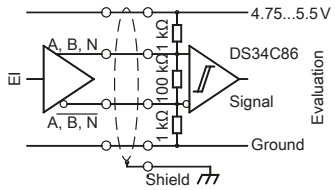
D6, D4



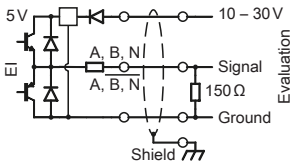
C5, C3, B2



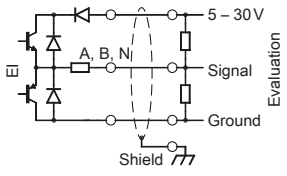
D5, D3, B1



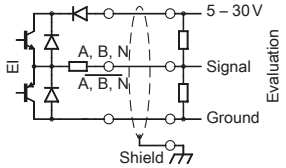
C1, C2



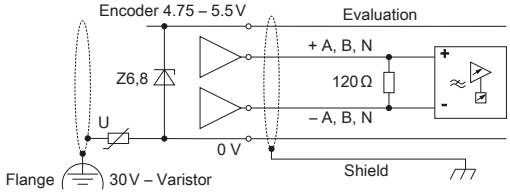
B2, C7, D2



B1, D7, D1



D8



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Key	Circuit protection	Inverse-polarity protection	Short circuit protection
C6	yes	yes	yes
C4	yes	yes	yes
D6	yes	yes	yes
D4	yes	yes	yes
C5	no	no	yes
C3	no	no	yes
B2	no	no	no
D5	no	no	yes
D3	no	no	yes
B1	no	no	no

Key	Circuit protection	Inverse-polarity protection	Short circuit protection
C1	no	no	yes*
C2	no	no	yes*
B2	no	no	no
D2 (EI)	yes	yes	yes
C7	no	yes	yes
D7	no	yes	yes
D1 (EI)	yes	yes	yes
B1	no	no	no
D8	no	no	yes

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Inverse-polarity protection:

Reversing the connection cables of the power supply when the outputs are connected correctly will not result in damage. However, the function is not guaranteed.

Short circuit protection:

Requirements:

- Supply lines not reversed!
- Only one output is short-circuit-proof against GND, +UB (max. allowable supply voltage) or another output.
  * for C1/C2 only between two outputs or GND.

Circuit protection:

Reversing the polarity of the power supply while simultaneously short-circuiting the outputs to each other or to GND or +UB will not result in damage. Applying GND and +UB to two outputs is not permitted and can lead to failure.

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