HEIDENHAIN

Encoders for Servo Drives

August 2010

This catalog is not intended as an overview of the HEIDENHAIN product program. Rather it presents a selection of **encoders for use on servo drives.**

In the **selection tables** you will find an overview of all HEIDENHAIN encoders for use on electric drives and the most important specifications. The descriptions of the **technical features** contain fundamental information on the use of rotary, angular, and linear encoders on electric drives.

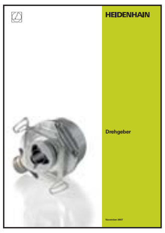
The **mounting information** and the detailed **specifications** refer to the **rotary encoders** developed specifically for drive technology. Other rotary encoders are described in separate product catalogs.

For the **linear and angular encoders** listed in the selection tables, you will find detailed information such as mounting information, specifications and dimensions in the respective **product catalogs.**

This catalog supersedes all previous editions, which thereby become invalid. The basis for ordering from HEIDENHAIN is always the catalog edition valid when the contract is made.

Standards (ISO, EN, etc.) apply only where explicitly stated in the catalog.

Further Product Catalogs



Catalog
Rotary Encoders

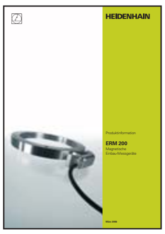
Contents:
Incremental Rotary Encoders
ERN, ROD
Absolute Rotary Encoders
ECN, EQN, ROC, ROQ

Catalog
Angle Encoders with Integral Bearing

Contents:
Incremental Angle Encoders
RON, RPN, ROD
Absolute Angle Encoders
RCN

Catalog
Angle Encoders without Integral Bearing

Contents:
Incremental Angle Encoders
ERA, ERP



Product Information
ERM 200

Contents:
Incremental Modular Magnetic Encoders

Catalog
Exposed Linear Encoders

Contents:
Incremental Linear Encoders
LIP, PP, LIF, LIDA

Catalog
Linear Encoders
for Numerically Controlled Machine Tools
Contents:
Incremental Linear Encoders
LB, LF, LS
Absolute Linear Encoders
LC

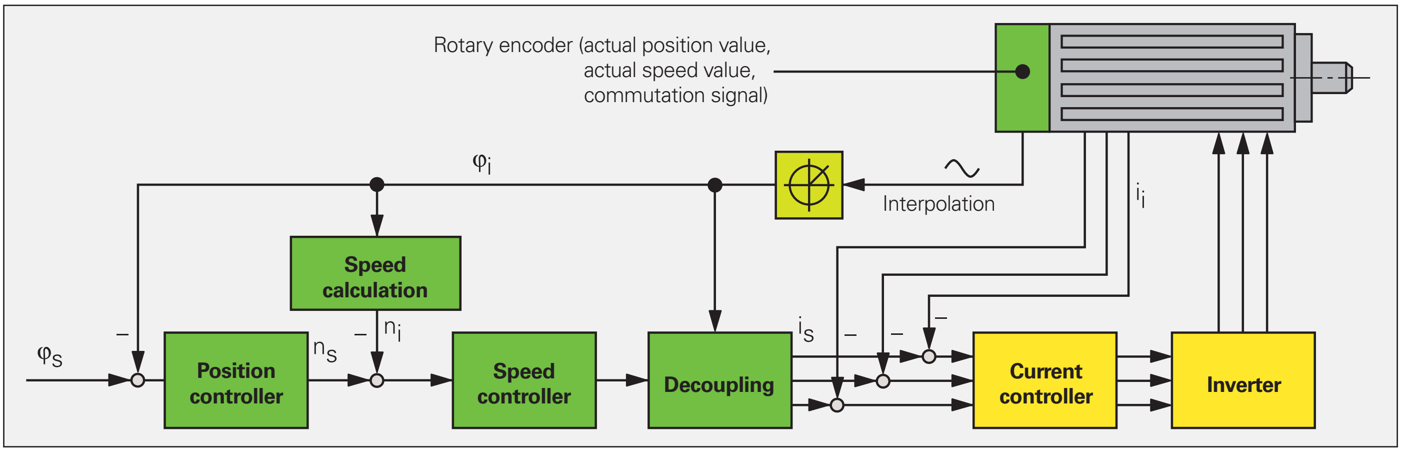
Contents

Encoders for Servo Drives

Controlling systems for servo drives require measuring systems that provide feedback for the position and speed controllers and for electronic commutation.

The properties of encoders have decisive influence on important motor qualities such as:
- Positioning accuracy
- Speed stability
- Bandwidth, which determines drive command-signal response and disturbance rejection capability
- Power loss
- Size
- Quietness

Digital position and speed control



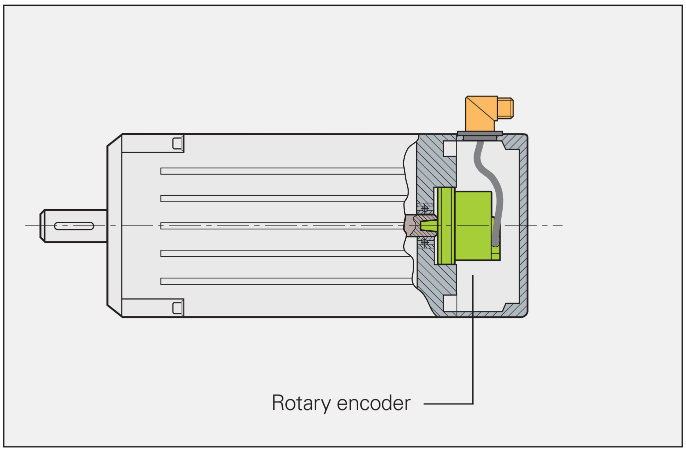
HEIDENHAIN offers the appropriate solution for any of a wide range of applications using both rotary and linear motors:

- Incremental rotary encoders with and without commutation tracks, absolute rotary encoders
- Incremental and absolute angle encoders
- Incremental and absolute linear encoders

Rotary encoders

All the HEIDENHAIN encoders shown in this catalog involve very little cost and effort for the motor manufacturer to mount and wire. Encoders for rotary motors are of short overall length. Some encoders, due to their special design, can perform functions otherwise handled by safety devices such as limit switches.

Motor for "digital" drive systems (digital position and speed control)



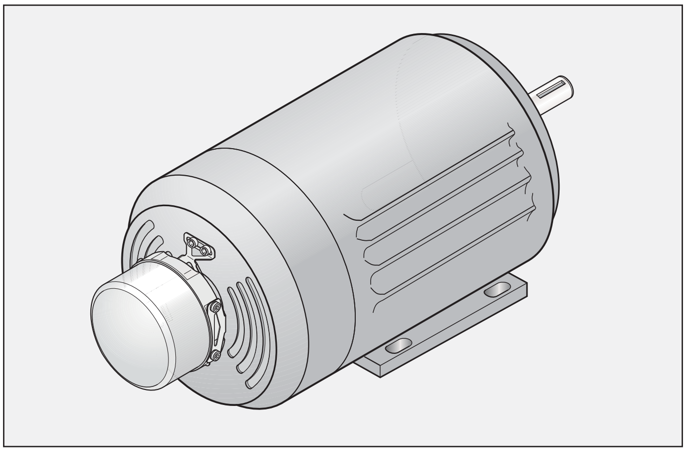
Linear encoders

Angle encoders

Explanation of the Selection Tables

The tables on the following pages list the encoders suited for individual motor designs. The encoders are available with dimensions and output signals to fit specific types of motors (DC or AC).

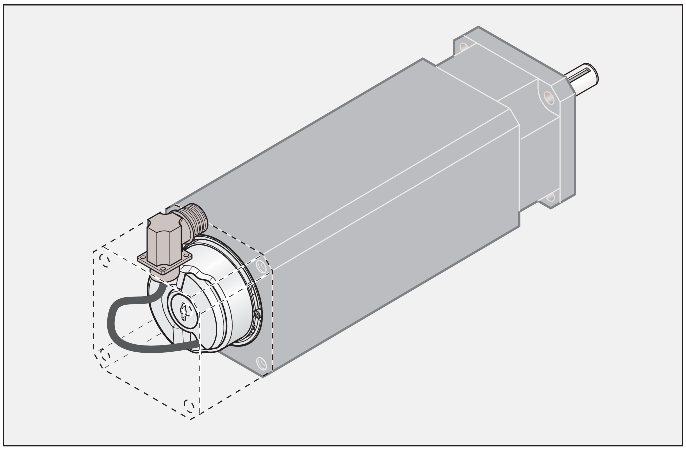
Rotary encoders for mounting on motors
Rotary encoders for motors with forced ventilation are either built onto the motor housing or integrated. As a result, they are frequently exposed to the unfiltered forced-air stream of the motor and must have a high degree of protection, such as IP 64 or better. The permissible operating temperature seldom exceeds 100 °C.



In the selection table you will find
- Rotary encoders with mounted **stator couplings** with high natural frequency—virtually eliminating any limits on the bandwidth of the drive
- Rotary encoders for **separate shaft couplings,** which are particularly suited for **insulated mounting**
- Incremental rotary encoders with high quality **sinusoidal output signals** for digital speed control
- Absolute rotary encoders with purely digital data transfer or complementary sinusoidal incremental signals
- Incremental rotary encoders with **TTL- or HTL-compatible output signals**

For Selection Table see page 8

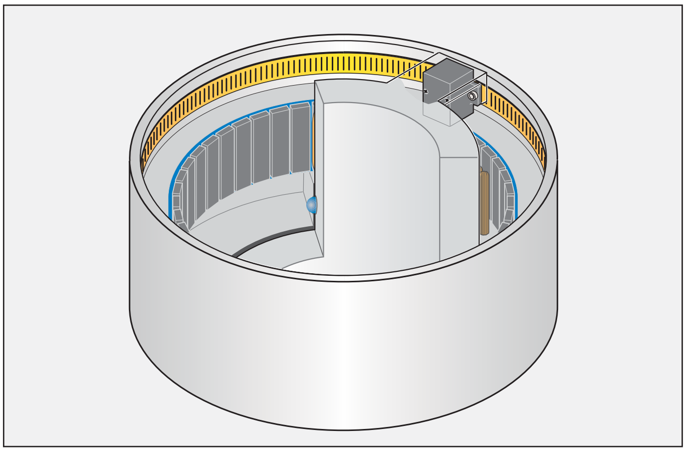
Rotary encoders for integration in motors
For motors without separate ventilation, the rotary encoder is built into the motor housing. This configuration places no stringent requirements on the encoder for a high degree of protection. The operating temperature within the motor housing, however, can reach 100 °C and higher.



In the selection table you will find
- Incremental rotary encoders for **operating temperatures** up to 120 °C, and absolute rotary encoders for operating temperatures up to 115 °C
- Rotary encoders with mounted **stator couplings** with high natural frequency—virtually eliminating any limits on the bandwidth of the drive
- Incremental rotary encoders for digital speed control with **sinusoidal output signals** of high quality—even at high operating temperatures
- Absolute rotary encoders with purely digital data transfer or complementary sinusoidal incremental signals
- Incremental rotary encoders with additional **commutation signal** for synchronous motors
- Incremental rotary encoders with **TTL-compatible output signals**

For Selection Table see page 10

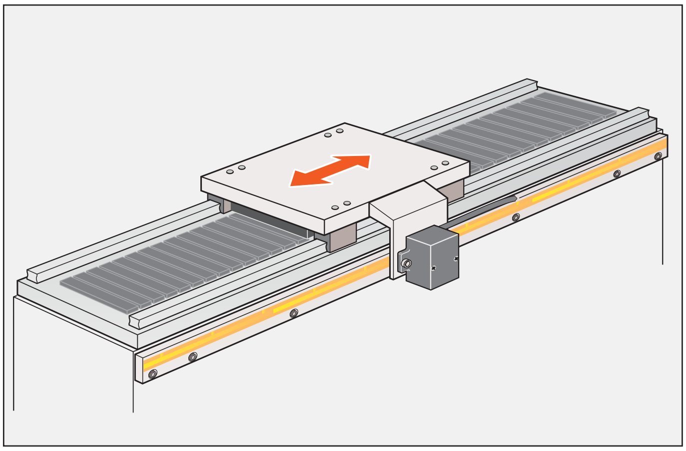
Rotary encoders and angle encoders for integrated and hollow-shaft motors
Rotary encoders and angle encoders for these motors have **hollow through shafts** in order to allow supply lines, for example, to be conducted through the motor shaft—and therefore through the encoder. Depending on the conditions of the application, the encoders must either feature IP 66 protection or—for example with modular encoders using optical scanning—the machine must be designed to protect them from contamination.



In the selection table you will find
- Rotary encoders with the measuring standard on a steel drum for **shaft speeds up to 42000 min^{-1}**
- Encoders with integral bearing, with stator coupling or modular design
- Encoders with high quality **absolute and/or incremental output signals**
- Encoders with **good acceleration performance** for a broad bandwidth in the control loop

For Selection Table see page 12

Linear encoders for linear motors
Linear encoders on linear motors supply the actual value both for the position controller and the velocity controller. They therefore form the basis for the servo characteristics of a linear drive. The linear encoders recommended for this application
- Have low position deviation during acceleration in the measuring direction
- Have high tolerance to acceleration and vibration in the lateral direction
- Are designed for high velocities
- Supply sinusoidal incremental signals of high quality



Exposed linear encoders are characterized by:
- Higher accuracy grades
- Higher traversing speeds
- Contact-free scanning, i.e., no friction between scanning head and scale

Exposed linear encoders are suited for applications in clean environments, for example on measuring machines or production equipment in the semiconductor industry.

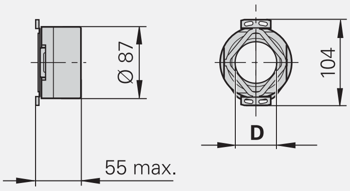
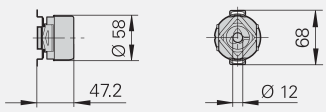
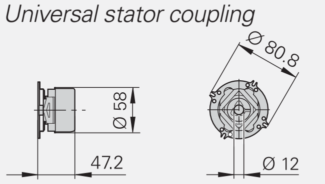
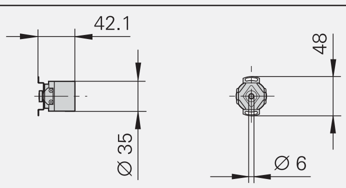
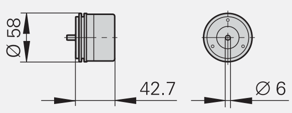
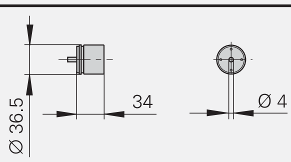
For Selection Table see page 14

Sealed linear encoders are characterized by:
- A high degree of protection
- Simple installation

Sealed linear encoders are therefore ideal for applications in environments with airborne liquids and particles, such as on machine tools.

For Selection Table see page 16

Selection Guide
Rotary Encoders for Mounting on Motors
Protection: up to IP 64 (EN 60529)

Series	Overall dimensions	Mechanically permissible speed	Natural freq. of the stator connection	Maximum operating temperature	Power supply
Rotary encoders with integral bearing and mounted stator coupling					
ECN/ERN 100		*D ≤ 30 mm:* ≤ 6000 min^{-1} *D > 30 mm:* ≤ 4000 min^{-1}	≥1100 Hz	100 °C	5 V ± 5 %
					3.6 to 5.25 V
					5 V ± 10 %
				85 °C	10 to 30 V
				100 °C	5 V ± 10 %
ECN/EQN/ERN 400	*Stator coupling*  *Universal stator coupling* 	≤ 6000 min^{-1} *With two shaft clamps (only for hollow through shaft):* ≤ 12000 min^{-1}	*Stator coupling:* ≥1500 Hz *Universal stator coupling:* ≥1400 Hz	100 °C	3.6 to 14 V
					5 V ± 10 %
					10 to 30 V
				70 °C	
				100 °C	5 V ± 10 %
ECN/EQN/ERN 1000		≤ 12000 min^{-1}	≥1800 Hz	100 °C	3.6 to 14 V
					5 V ± 10 %
				70 °C	10 to 30 V
					5 V ± 5 %
				100 °C	5 V ± 10 %
Rotary encoders with integral bearing for separate shaft coupling					
ROC/ROQ/ROD 400		≤ 12000 min^{-1}	–	100 °C	3.6 to 14 V
		≤ 16000 min^{-1}			5 V ± 10 %
					10 to 30 V
				70 °C	
				100 °C	5 V ± 10 %
ROC/ROQ/ROD 1000		≤ 12000 min^{-1}	–	100 °C	5 V ± 10 %
				70 °C	10 to 30 V
					5 V ± 5 %
				100 °C	5 V ± 10 %

	Incremental signals		Absolute position values			Model	For more information
	Output signals	Signal periods per revolution	Positions per revolution	Distinguishable revolutions	Data interface		
	∼ 1 V_{PP}	2048	8192	–	EnDat 2.2 / 01	**ECN 113**	**Catalog:** ***Rotary Encoders***
	–	–	33554432		EnDat 2.2/**22**	**ECN 125**	
	⊓⊔TTL	1000 to 5000	–			**ERN 120**	
	⊓⊔ HTL					**ERN 130**	
	∼ 1 V_{PP}					**ERN 180**	
	∼ 1 V_{PP}	512. 2048	8192	–/4096	EnDat 2.2 / 01	**ECN 413/EQN 425**	
	–	–	33554432		EnDat 2.2/**22**	**ECN 425/EQN 437**[1)]	
	⊓⊔TTL	250 to 5000	–			**ERN 420**	
	⊓⊔ HTL					**ERN 430**	
	⊓⊔TTL					**ERN 460**	
	∼ 1 V_{PP}	1000 to 5000				**ERN 480**	
	∼ 1 V_{PP}	512	8192	–/4096	EnDat 2.2 / 01	**ECN 1013/EQN 1025**	
	–	–	8388608		EnDat 2.2/**22**	**ECN 1023/EQN 1035**[1)]	
	⊓⊔TTL	100 to 3600	–			**ERN 1020**	
	⊓⊔ HTLs					**ERN 1030**	
	⊓⊔TTL	5000 to 36000[2)]				**ERN 1070**	
	∼ 1 V_{PP}	100 to 3600				**ERN 1080**	
		512. 2048	Z1 track for sine commutation			**ERN 1085**	**Product Info.**
	∼ 1 V_{PP}	512.2048	8192	–/4096	EnDat 2.2 / 01	**ROC 413/ROQ 425**	**Catalog:** ***Rotary Encoders***
	–	–	33554432		EnDat 2.2/**22**	**ROC 425/ROQ 437**[1)]	
	⊓⊔TTL	50 to 10000	–			**ROD 426**	
	⊓⊔ HTL	50 to 5000				**ROD 436**	
	⊓⊔TTL	50 to 10000				**ROD 466**	
		1000 to 5000				**ROD 486**	
	⊓⊔TTL	100 to 3600	–			**ROD 1020**	
	⊓⊔ HTLs					**ROD 1030**	
	⊓⊔TTL	5000 to 36000[2)]				**ROD 1070**	
	∼ 1 V_{PP}	100 to 3600				**ROD 1080**	

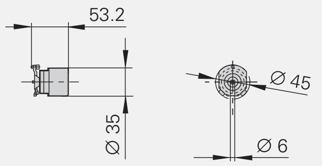
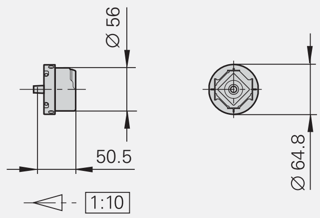
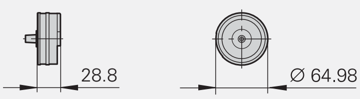
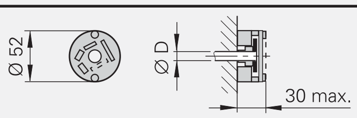
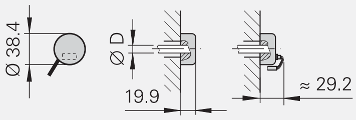
1) **Functional Safety** upon request

2) after internal 5/10-fold interpolation

Selection Guide

Rotary Encoders for Integration in Motors

Protection: up to IP 40 (EN 60529)

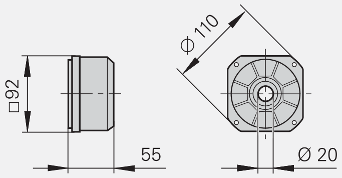
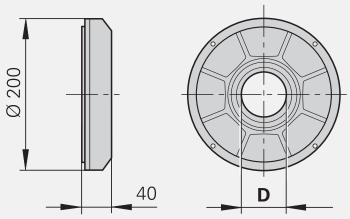
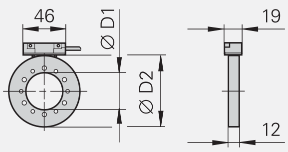
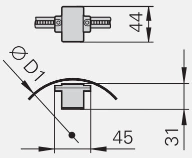
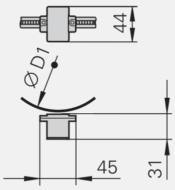
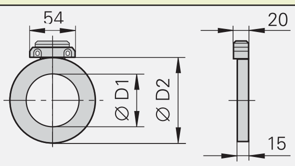
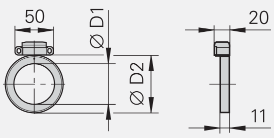
Series	Overall dimensions	Diameter	Mechanically permissible speed	Natural freq. of the stator connection	Maximum operating temperature
Rotary encoders with integral bearing and mounted stator coupling					
ECN/EQN/ ERN 1100		–	≤ 12000 min^{-1}	≥1500 Hz	115 °C
					100 °C
					115 °C
ECN/EQN/ ERN 1300		–	≤ 15000 min^{-1}	≥ 2000 Hz	115 °C
			≤ 12000 min^{-1}		
			≤ 15000 min^{-1}		120 °C *ERN 1381/4096:* 80 °C
Rotary encoders without integral bearing					
ECI/EQI 1100		D: 6 mm	≤ 15000 min^{-1}	–	115 °C
			≤ 12000 min^{-1}		
ECI/EQI 1300		–	≤ 15000 min^{-1}	–	115 °C
			≤ 12000 min^{-1}		
ERO 1200		D: 10/12 mm	≤ 25000 min^{-1}	–	100 °C
ERO 1400		D: 4/6/8 mm	≤ 30000 min^{-1}	–	70 °C

1) **Functional safety** upon request
2) After internal 5/10/20/25-fold interpolation

	Power supply	Incremental signals		Absolute position values			Model	For more information
		Output signals	Signal periods per revolution	Positions per revolution	Distinguishable revolutions	Data interface		
	3.6 to 14 V	∼ 1 V_{PP}	512	8 192	–	EnDat 2.2 / 01	**ECN 1113**	**Page 36**
		–	–	8 388 608		EnDat 2.2/**22**	**ECN 1123**[1]	
		∼ 1 V_{PP}	512	8 192	4 096	EnDat 2.2 / 01	**EQN 1125**	
		–	–	8 388 608		EnDat 2.2/**22**	**EQN 1135**[1]	
	5 V ± 10 %	⊓⊔TTL	1 024/2 048/3 600	–			**ERN 1120**	**Page 38**
		∼ 1 V_{PP}					**ERN 1180**	
			512/2 048/	Z1 track for sine commutation			**ERN 1185**	
	3.6 to 14 V	∼ 1 V_{PP}	512/2 048/	8 192	–	EnDat 2.2 / 01	**ECN 1313**	**Page 40**
		–	–	33 554 432		EnDat 2.2/**22**	**ECN 1325**[1]	
		∼ 1 V_{PP}	512/2 048/	8 192	4 096	EnDat 2.2 / 01	**EQN 1325**	
		–	–	33 554 432		EnDat 2.2/**22**	**EQN 1337**[1]	
	5 V ± 10 %	⊓⊔TTL	1 024/2 048/4 096	–			**ERN 1321**	**Page 42**
	5 V ± 5 %			3 block commutation signals			**ERN 1326**	
	5 V ± 10 %	∼ 1 V_{PP}	512/2 048/4 096	–			**ERN 1381**	
	5 V ± 5 %		2 048	Z1 track for sine commutation			**ERN 1387**	
	5 V ± 5 %	∼ 1 V_{PP}	16	262 144	–	EnDat 2.1 / 01	**ECI 1118**	**Page 44**
		–	–			EnDat 2.1 / 21		
		∼ 1 V_{PP}	16		4 096	EnDat 2.1 / 01	**EQI 1130**	
		–	–			EnDat 2.1 / 21		
	5 V ± 5 %/ 7 to 10 V	∼ 1 V_{PP}	32	524 288	–	EnDat 2.1 / 01	**ECI 1319**	**Page 46**
					4 096		**EQI 1331**	
	5 V ± 10 %	⊓⊔TTL	1 024/2 048	–			**ERO 1225**	**Page 48**
		∼ 1 V_{PP}					**ERO 1285**	
	5 V ± 10 %	⊓⊔TTL	512/1 000/1 024	–			**ERO 1420**	**Page 50**
	5 V ± 5 %	⊓⊔TTL	5 000 to 37 500[2]				**ERO 1470**	
	5 V ± 10 %	∼ 1 V_{PP}	512/1 000/1 024				**ERO 1480**	

Selection Guide

Rotary Encoders and Angle Encoders for Integrated and Hollow-Shaft Motors

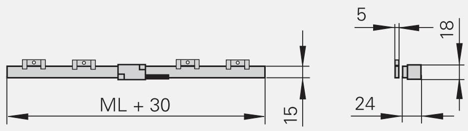
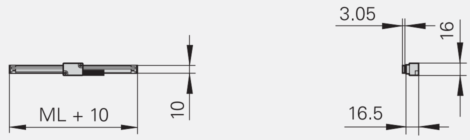
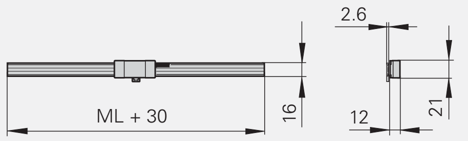
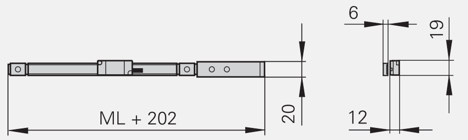
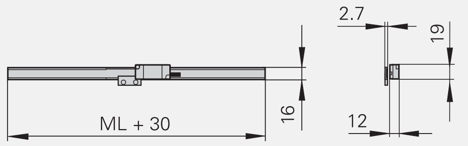
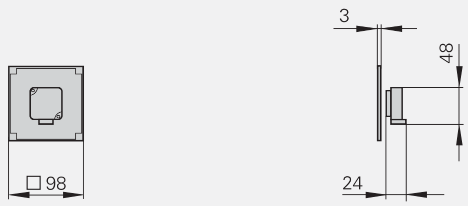
Series	Overall dimensions	Diameter	Mechanically permissible speed	Natural freq. of the stator connection	Maximum operating temperature
Angle encoders with integral bearing and integrated stator coupling					
RCN 200		–	≤ 3000 min^{-1}	≥1200 Hz	70 °C
RCN 700		D: 60 mm and 100 mm	≤ 1000 min^{-1}	*Ø 60 mm:* ≥ 1000 Hz *Ø 100 mm:* ≥ 900 Hz	50 °C
RPN 800		D: 60 mm		≥ 500 Hz	
Angle encoders without integral bearing					
ERA 4000 Steel scale drum		D1: 40 to 512 mm D2: 76.75 to 560.46 mm	≤ 10000 min^{-1} to ≤ 1500 min^{-1}	–	80 °C
ERA 700 For inside diameter mounting		D1: 458.62 mm 573.20 mm 1 146.1 mm	≤ 500 min^{-1}	–	50 °C
ERA 800 For outside diameter mounting		D1: 458.04 mm 572.63 mm	≤ 100 min^{-1}	–	50 °C
Modular encoders without integral bearing					
ERM 200 With magnetic graduation		D1: 40 to 410 mm D2: 75.44 to 452.64 mm	≤ 19000 min^{-1} to ≤ 3000 min^{-1}	–	100 °C
ERM 2400 With magnetic graduation		D1: 40 mm D2 = 64.37 mm	≤ 42000 min^{-1}	–	100 °C
		D1: 55 mm D2 = 75.44 mm	≤ 36000 min^{-1}		

1) Interfaces for Fanuc and Mitsubishi controls upon request

2) Segment solutions upon request

	Power supply	Incremental signals		Absolute position values		Model	For more information
		Output signals	Signal periods per revolution	Positions per revolution	Data interface[1]		
	3.6 to 5.25 V	∿ 1 V_{PP}	16384	67108864 ≙ 26 bits	EnDat 2.2 / 02	**RCN 226**	**Catalog:** ***Angle Encoders*** *with Integral Bearing*
				268435456 ≙ 28 bits		**RCN 228**	
		–	–	67108864 ≙ 26 bits	EnDat 2.2 / 22	**RCN 226**	
				268435456 ≙ 28 bits		**RCN 228**	
	3.6 to 5.25 V	∿ 1 V_{PP}	32768	536870912 ≙ 29 bits	EnDat 2.2 / 02	**RCN 729**	
		–	–		EnDat 2.2 / 22	**RCN 729**	
	5 V ± 10 %	∿ 1 V_{PP}	180000	–		**RPN 886**	
	5 V ± 10 %	∿ 1 V_{PP}	12000 to 52000	–		**ERA 4280 C**	**Catalog:** ***Angle Encoders*** *without Integral Bearing*
			6000 to 44000			**ERA 4480 C**	
			3000 to 13000			**ERA 4880 C**	
	5 V ± 10 %	∿ 1 V_{PP}	**Full circle**[2] 36000/45000/90000	–		**ERA 780 C**	
	5 V ± 10 %	∿ 1 V_{PP}	**Full circle**[2] 36000/45000	–		**ERA 880 C**	
	5 V ± 10 %	⊓⊔ TTL	512	–		**ERM 220**	**Product Information** ***ERM 200***
		∿ 1 V_{PP}				**ERM 280**	
	5 V ± 10 %	∿ 1 V_{PP}	600	–		**ERM 2485**	**Product Information** ***ERM 2400***
			512				

Selection Guide
Exposed Linear Encoders for Linear Drives

Series	Overall dimensions	Traversing speed	Acceleration in measuring direction	Measuring lengths
LIP 400		≤ 30 m/min	≤ 200 m/s²	70 to 420 mm
LIF 400		≤ 72 m/min	≤ 200 m/s²	70 to 1 020 mm
LIDA 200		≤ 600 m/min	≤ 150 m/s²	Up to 10 000 mm
LIDA 400		≤ 480 m/min	≤ 200 m/s²	140 to 30 040 mm
				240 to 6 040 mm
PP 200 Two-coordinate encoder		≤ 72 m/min	≤ 200 m/s²	Measuring range 68 mm x 68 mm

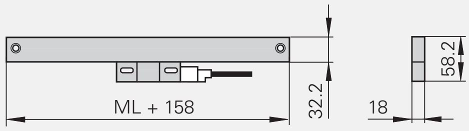
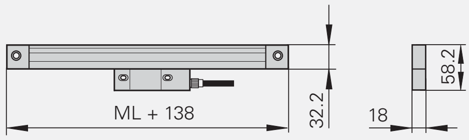
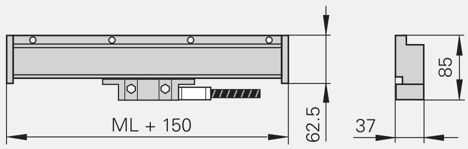
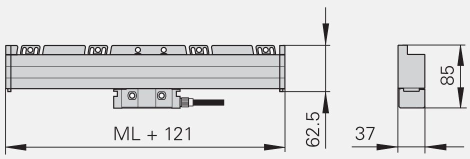
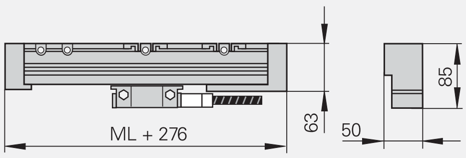
1) After linear error compensation

Power supply	Incremental signals			Absolute position values	Model	For more information
	Output signals	Signal period/ Accuracy grade	Cutoff frequency –3 dB			
5 V ± 5 %	∼ 1 V_{PP}	2 µm/to ± 0.5 µm	≥ 250 kHz	–	**LIP 481**	**Catalog:** ***Exposed Linear Encoders***
5 V ± 5 %	∼ 1 V_{PP}	4 µm/± 3 µm	≥ 300 kHz	Homing track Limit switches	**LIF 481**	
5 V ± 5 %	∼ 1 V_{PP}	200 µm/± 30 µm	≥ 50 kHz	–	**LIDA 287**	
5 V ± 5 %	∼ 1 V_{PP}	20 µm/± 5 µm	≥ 400 kHz	Limit switches	**LIDA 485**	
		20 µm/± 5 µm[1)]			**LIDA 487**	
5 V ± 5 %	∼ 1 V_{PP}	4 µm/± 2 µm	≥ 300 kHz	–	**PP 281**	

Selection Guide

Sealed Linear Encoders for Linear Drives

Protection: IP 53 to IP 64[1)] (EN 60529)

Series	Overall dimensions	Traversing speed	Acceleration in measuring direction	Natural frequency of coupling	Measuring lengths
Linear encoders with slimline scale housing					
LF		≤ 30 m/min	≤ 30 m/s^2	≥ 2000 Hz	50 to 1220 mm
LC		≤ 180 m/min	≤ 100 m/s^2	≥ 2000 Hz	70 to 2040 mm
Linear encoders with full-size scale housing					
LF		≤ 60 m/min	≤ 100 m/s^2	≥ 780 Hz	140 to 3040 mm
LC		≤ 180 m/min	≤ 100 m/s^2	≥ 2000Hz	140 to 4240 mm
LB		≤ 120 m/min (180 m/min upon request)	≤ 60 m/s^2	≥ 650 Hz	440 to 30040 mm

1) After installation according to mounting instructions
2) Interfaces for Fanuc and Mitsubishi controls upon request
3) Depending on the adapter cable

	Power supply	Incremental signals			Absolute position values		Model	For more information
		Output signals	Signal periods/ Accuracy grade	Cutoff frequency –3 dB	Resolution	Data interface[2]		
	5 V ± 5 %	∿ 1 V_{PP}	4 µm/to ± 3 µm	≥ 200 kHz	–		**LF 481**	**Catalog:** ***Linear Encoders*** *for Numerically Controlled Machine Tools*
	3.6 to 5.25 V	∿ 1 V_{PP}[3]	20 µm/to ± 3 µm	≥ 150 kHz	Up to 0.005 µm	EnDat 2.2	**LC 483**	
	5 V ± 5 %	∿ 1 V_{PP}	4 µm/± 2 µm	≥ 200 kHz	–		**LF 183**	**Catalog:** ***Linear Encoders*** *for Numerically Controlled Machine Tools*
	3.6 to 5.25 V	∿ 1 V_{PP}[3]	20 µm/to ± 3 µm	≥ 150 kHz	Up to 0.005 µm	EnDat 2.2	**LC 183**	
	5 V ± 5 %	∿ 1 V_{PP}	40 µm/to ± 5 µm	≥ 250 kHz	–		**LB 382**	

Rotary Encoders and Angle Encoders for Three-Phase AC and DC Motors
General Information

Speed stability
To ensure **smooth drive performance,** an encoder must provide a **large number of measuring steps per revolution.** The encoders in the HEIDENHAIN product program are therefore designed to supply the necessary numbers of signal periods per revolution to meet the speed stability requirement.

HEIDENHAIN rotary and angular encoders featuring integral bearings and stator couplings provide very good performance: shaft misalignment within certain tolerances (see *Specifications*) do not cause any position error or impair speed stability.

At low speeds, the **position error of the encoder within one signal period** affects speed stability. In encoders with purely serial data transmission, the LSB (Least Significant Bit) goes into the speed stability. (See also *Measuring Accuracy.*)

Transmission of measuring signals
To ensure the best possible dynamic performance with digitally controlled motors, the sampling time of the speed controller should not exceed approx. 256 µs. The feedback values for the position and speed controller must therefore be available in the controlling system with the least possible delay.

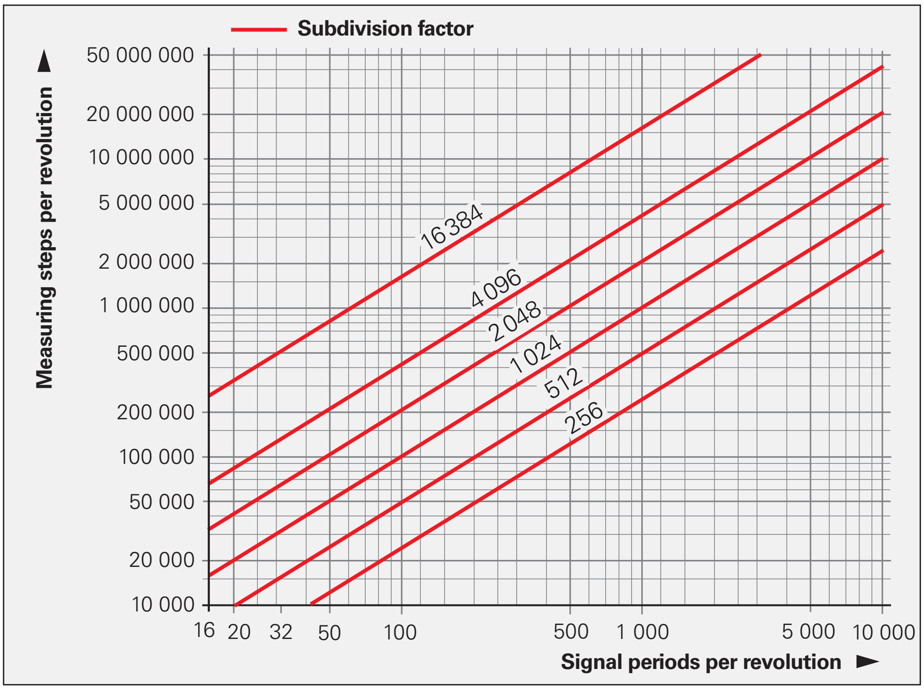
High clock frequencies are needed to fulfill such demanding time requirements on position values transfer from the encoder to the controlling system with a serial data transmission (see also *Interfaces; Absolute Position Values*). HEIDENHAIN encoders for electric drives therefore provide the position values via the fast, purely serial EnDat 2.2 interface, or transmit additional **incremental signals,** which are available immediately for use in the subsequent electronics for speed and position control.

For **standard drives,** manufacturers primarily use HEIDENHAIN absolute encoders without integral bearing (ECI/EQI) or rotary encoders with **TTL** or **HTL compatible output signals**—as well as additional commutation signals for permanent-magnet DC drives.

For **digital speed control** on machines with **high requirements for dynamics,** a large number of measuring steps is required—usually above 500 000 per revolution. For applications with standard drives, as with resolvers, approx. 60 000 measuring steps per revolution are sufficient.

HEIDENHAIN encoders for drives with digital position and speed control therefore provide **sinusoidal incremental signals with signal levels of 1 V_{PP}** which, thanks to their high quality, can be highly interpolated in the subsequent electronics (Diagram 1). For example, a rotary encoder with 2 048 signal periods per revolution and a 1 024-fold or 4 096-fold subdivision in the subsequent electronics produces approx. **2 (8) million measuring steps per revolution, respectively.** This corresponds to a resolution of 23 bits. Even at shaft speeds of 12 000 min^{-1}, the signal arrives at the input circuit of the controlling system with a frequency of only approx. 400 kHz (Diagram 2). 1 V_{PP} incremental signals permit cable lengths up to 150 meters. (See also *Incremental Signals – 1 V_{PP}*)

Diagram 1:
Signal periods per revolution and the resulting number of measuring steps per revolution as a function of the subdivision factor



HEIDENHAIN absolute encoders for "digital" drives also supply additional sinusoidal incremental signals with the same characteristics as those described above. Absolute encoders from HEIDENHAIN use the EnDat interface (for **En**coder **Dat**a) for the **serial data transmission** of absolute position values and other information for **automatic self-configuration, monitoring and diagnosis.** (See *Absolute Position Values – EnDat.*) This makes it possible to use the same subsequent electronics and cabling technology for all HEIDENHAIN encoders.

Important encoder specifications can be read from the memory of the EnDat encoder for automatic self-configuration, and motor-specific parameters can be saved in the OEM memory area of the encoder. The usable size of the OEM memory on the rotary encoders in the current catalogs is at least 1.4 KB (≙ 704 EnDat words); for the ATEX encoders it is 0.44 KB (≙ 224 EnDat words).

Most absolute encoders themselves already subdivide the sinusoidal scanning signals by a factor of 4096 or greater. If the transmission of absolute positions is fast enough (for example, EnDat 2.1 with 2 MHz or EnDat 2.2 with 8 MHz clock frequency), these systems can do without incremental signal evaluation.

Benefits of this data transmission technology include greater noise immunity of the transmission path and less expensive connectors and cables. Encoders with EnDat 2.2 interface offer the additional feature of being able to evaluate an external temperature sensor, located in the motor coil, for example. The digitized temperature values are transmitted as part of the EnDat 2.2 protocol without an additional line.

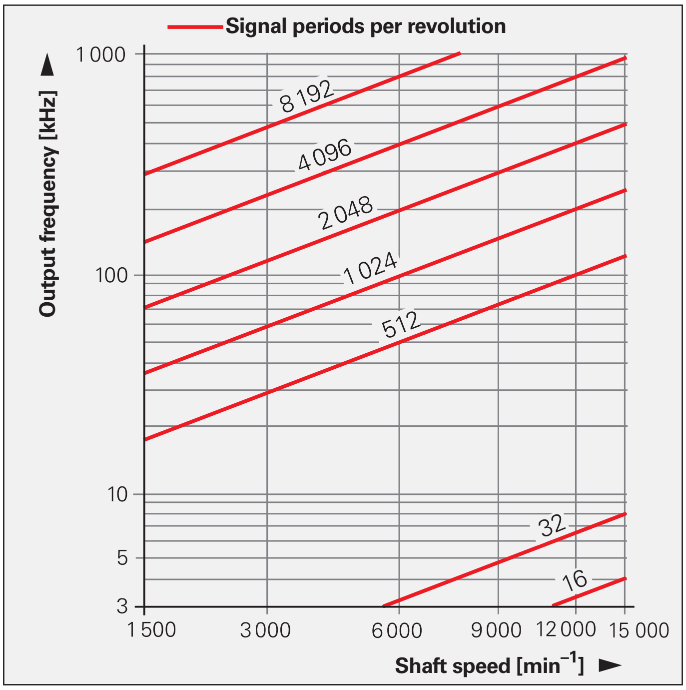
Bandwidth
The attainable amplification factors for the position and speed control loops, and therefore the bandwidth of the drives for command response and control reliability is sometimes limited by the rigidity of the coupling between the motor shaft and encoder shaft as well as by the natural frequency of the coupling. HEIDENHAIN therefore offers rotary and angular encoders for high-rigidity shaft coupling. The stator couplings mounted on the encoders have a **high natural frequency** up to 2 kHz. For the inductive rotary encoders, the stator and rotor are firmly screwed to the motor housing and to the shaft. This means that the rigidity of the motor shaft is of the most significance for the attainable natural frequency. (See also *Mechanical Design and Installation.*)

Functional safety
Encoders with purely serial data transmission (ordering designation EnDat 22) are prepared for safety technology according to IEC 61508. They can very easily be integrated in new types of machines, drives or facilities. (See also the *Safety-Related Position Measuring Systems* Technical Information sheet).

Size
A higher permissible operating temperature permits a smaller motor size for a specific rated torque. Since the temperature of the motor also affects the temperature of the encoder, HEIDENHAIN offers encoders for **permissible operating temperatures up to 120 °C.** These encoders make it possible to design machines with smaller motors.

Power loss and quietness
The power loss of the motor, the accompanying heat generation, and the acoustic noise during operation are influenced by the position error of the encoder within one signal period. For this reason, rotary encoders with a high signal quality of better than ± 1 % of the signal period are preferred. (See also *Measuring Accuracy.*)

Diagram 2:
Shaft speed and resulting output frequency as a function of the number of signal periods per revolution



Linear Encoders for Linear Drives
General Information

Selection criteria for linear encoders
HEIDENHAIN recommends the use of **exposed linear encoders** whenever the severity of contamination inherent in a particular machine environment does not preclude the use of optical measuring systems, and if relatively high accuracy is desired, e.g. for high-precision machine tools and measuring equipment, or for production, testing and inspecting equipment in the semiconductor industry.

Particularly for applications on machine tools that release coolants and lubricants, HEIDENHAIN recommends **sealed linear encoders.** Here the requirements on the mounting surface and on machine guideway accuracy are less stringent than for exposed linear encoders, and therefore installation is faster.

Speed stability
To ensure smooth-running servo performance, the linear encoder must permit a resolution commensurate with the given speed control range:

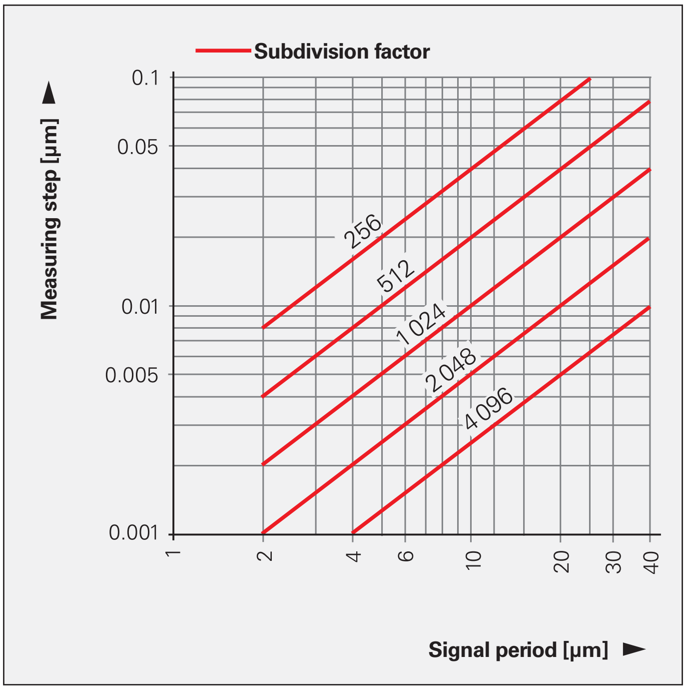
- On handling equipment, resolutions in the range of several microns are sufficient.
- Feed drives for machine tools need resolutions of 0.1 µm and finer.
- Production equipment in the semiconductor industry requires resolutions of a few nanometers.

At low traversing speeds, the **position error within one signal period** has a decisive influence on the speed stability of linear motors. (See also *Measuring Accuracy.*)

Traversing speeds
Exposed linear encoders function without contact between the scanning head and the scale. The maximum permissible traversing speed is limited only by the cutoff frequency (–3 dB) of the output signals.

On sealed linear encoders, the scanning unit is guided along the scale on a ball bearing. Sealing lips protect the scale and scanning unit from contamination. The ball bearing and sealing lips permit mechanical traversing speeds up to **180 m/min.**

Signal period and resulting measuring step as a function of the subdivision factor



Transmission of measuring signals
The information above on rotary and angle encoder signal transmission essentially applies also to linear encoders. If, for example, one wishes to traverse at a minimum velocity of 0.01 m/min with a sampling time of 250 µs, and if one assumes that the measuring step should change by at least one measuring step per sampling cycle, then one needs a measuring step of approx. 0.04 µm. To avoid the need for special measures in the subsequent electronics, input frequencies should be limited to less than 1 MHz.
Linear encoders with sinusoidal output signals are therefore best suited for high traversing speeds and small measuring steps. Sinusoidal voltage signals with levels of **1 V_{PP}** attain a –3 dB cutoff frequency of approx. 200 kHz and more at a permissible cable length of up to 150 m.

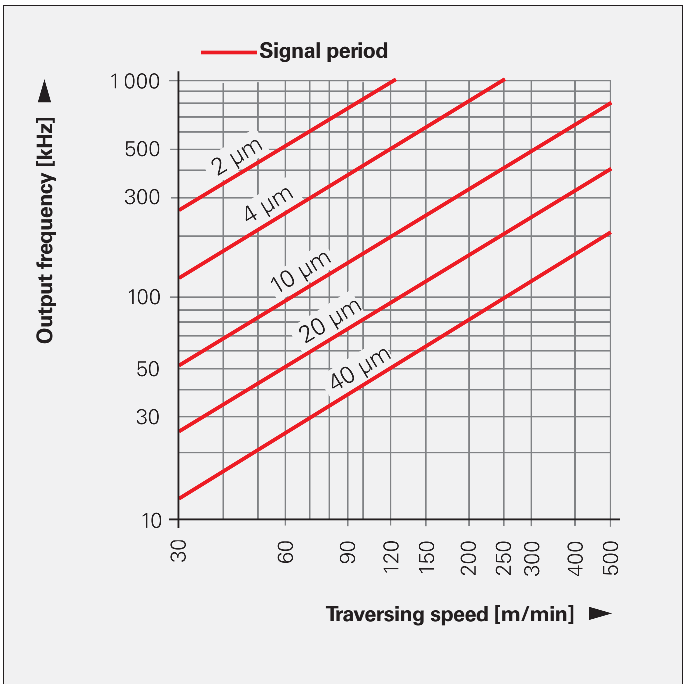
The figure below illustrates the relationship between output frequency, traversing speeds, and signal periods of linear encoders. Even at a signal period of 4 µm and a traversing velocity of 70 m/min, the frequency reaches only 300 kHz.

Bandwidth
On linear motors, a coupling lacking in rigidity can limit the bandwidth of the position control loop. The manner in which the linear encoder is mounted on the machine has a very significant influence on the rigidity of the coupling. (See *Design Types and Mounting*.)

On sealed linear encoders, the scanning unit is guided along the scale. A coupling connects the scanning carriage with the mounting block and compensates the misalignment between the scale and the machine guideways. This permits relatively large mounting tolerances. The coupling is very rigid in the measuring direction and is flexible in the perpendicular direction. If the coupling is insufficiently rigid in the measuring direction, it could cause low natural frequencies in the position and velocity control loops and limit the bandwidth of the drive.

The sealed linear encoders recommended by HEIDENHAIN for linear motors generally have a **natural frequency of coupling greater than 650 Hz or 2 kHz** in the measuring direction, which in most applications exceeds the mechanical natural frequency of the machine and the bandwidth of the velocity control loop by factors of at least 5 to 10. HEIDENHAIN linear encoders for linear motors therefore have practically no limiting effect on the position and speed control loops.

Traversing speed and resulting output frequency as a function of the signal period



For more information on linear encoders for linear drives, refer to our catalogs *Exposed Linear Encoders* and *Linear Encoders for Numerically Controlled Machine Tools.*

Measuring Principles
Measuring Standard

HEIDENHAIN encoders with optical scanning incorporate measuring standards of periodic structures known as graduations. These graduations are applied to a carrier substrate of glass or steel. The scale substrate for large diameters is a steel tape.

These precision graduations are manufactured in various photolithographic processes. Graduations are fabricated from:
- extremely hard chromium lines on glass or gold-plated steel drums,
- matte-etched lines on gold-plated steel tape, or
- three-dimensional structures on glass or steel substrates.

The photolithographic manufacturing processes developed by HEIDENHAIN produce grating periods of typically 40 µm to 4 µm.

These processes permit very fine grating periods and are characterized by a high definition and homogeneity of the line edges. Together with the photoelectric scanning method, this high edge definition is a precondition for the high quality of the output signals.

The master graduations are manufactured by HEIDENHAIN on custom-built high-precision ruling machines.

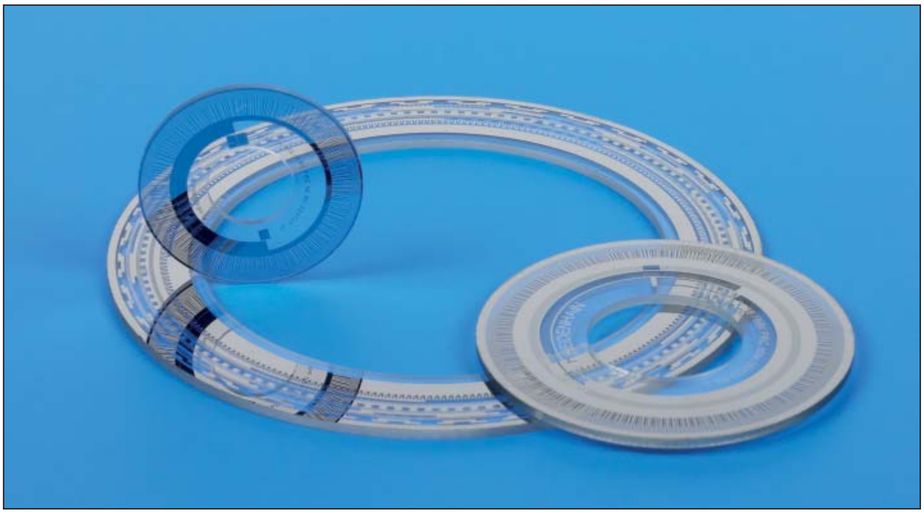
Magnetic encoders use a graduation carrier of magnetizable steel alloy. A graduation consisting of north poles and south poles is formed with a grating period of 400 µm. Due to the short distance of effect of electromagnetic interaction, and the very narrow scanning gaps required, finer magnetic graduations are not practical.

Encoders using the inductive scanning principle have graduation structures of copper. The graduation is applied to a carrier material for printed circuits.

With the **absolute measuring method,** the position value is available from the encoder immediately upon switch-on and can be called at any time by the subsequent electronics. There is no need to move the axes to find the reference position. The absolute position information is read from the **grating on the circular scale,** which is designed as a serial code structure or consists of several parallel graduation tracks.

A separate incremental track or the track with the finest grating period is interpolated for the position value and at the same time is used to generate an optional incremental signal.

In **singleturn encoders,** the absolute position information repeats itself with every revolution. **Multiturn encoders** can also distinguish between revolutions.



Circular graduations of absolute rotary encoders

With the **incremental measuring method,** the graduation consists of a periodic grating structure. The position information is obtained **by counting** the individual increments (measuring steps) from some point of origin. Since an absolute reference is required to ascertain positions, the graduated disks are provided with an additional track that bears a **reference mark.**

The absolute position established by the reference mark is gated with exactly one measuring step.

The reference mark must therefore be scanned to establish an absolute reference or to find the last selected datum.

Circular graduations of incremental rotary encoders

Scanning Methods

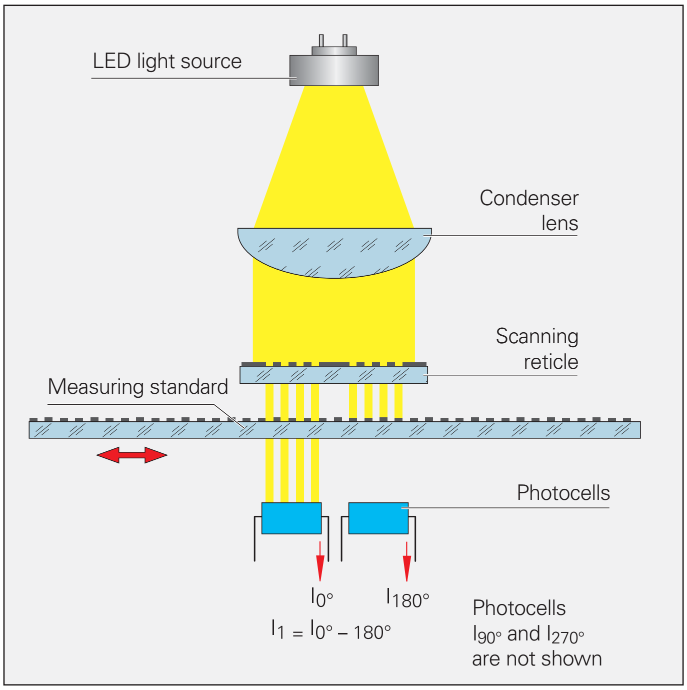
Photoelectric scanning
Most HEIDENHAIN encoders operate using the principle of photoelectric scanning. Photoelectric scanning of a measuring standard is contact-free, and as such free of wear. This method detects even very fine lines, no more than a few microns wide, and generates output signals with very small signal periods.

The ERN, ECN, EQN, ERO and ROD, RCN, RQN rotary encoders use the imaging scanning principle.

Put simply, the imaging scanning principle functions by means of projected-light signal generation: two graduations with equal grating periods are moved relative to each other—the scale and the scanning reticle. The carrier material of the scanning reticle is transparent, whereas the graduation on the measuring standard may be applied to a transparent or reflective surface.

When parallel light passes through a grating, light and dark surfaces are projected at a certain distance. An index grating with the same grating period is located here. When the two gratings move in relation to each other, the incident light is modulated: if the gaps are aligned, light passes through. If the lines of one grating coincide with the gaps of the other, no light passes through. Photovoltaic cells convert these variations in light intensity into nearly sinusoidal electrical signals. Practical mounting tolerances for encoders with the imaging scanning principle are achieved with grating periods of 10 µm and larger.

The ECN 1325 and EQN 1337 absolute rotary encoders with optimized scanning have a single large photosensor instead of a group of individual photoelements. Its structures have the same width as that of the measuring standard. This makes it possible to do without the scanning reticle with matching structure.



Photoelectric scanning according to the imaging scanning principle

Other scanning principles
Some encoders function according to other scanning methods. ERM encoders use a permanently magnetized MAGNODUR graduation that is scanned with magnetoresistive sensors.

ECI/EQI rotary encoders operating according to the inductive measuring principle. Here, moving graduation structures modulate a high-frequency signal in its amplitude and phase. The position value is always formed by sampling the signals of all receiver coils distributed evenly around the circumference.

Electronic Commutation with Position Encoders

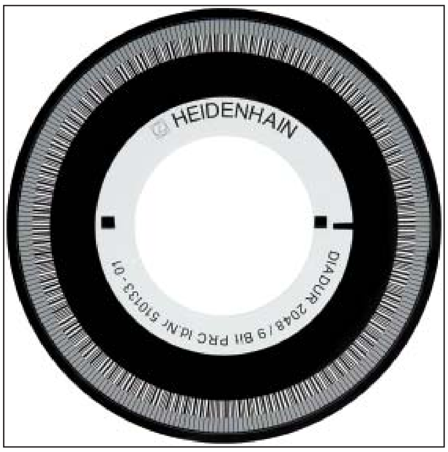
Commutation in permanent-magnet three-phase motors
Before start-up, permanent-magnet three-phase motors must have an absolute position value available for electrical commutation. HEIDENHAIN rotary encoders are available with different types of rotor position recognition:

- **Absolute rotary encoders** in singleturn and multiturn versions provide the absolute position information immediately after switch-on. This makes it immediately possible to derive the exact position of the rotor and use it for electronic commutation.

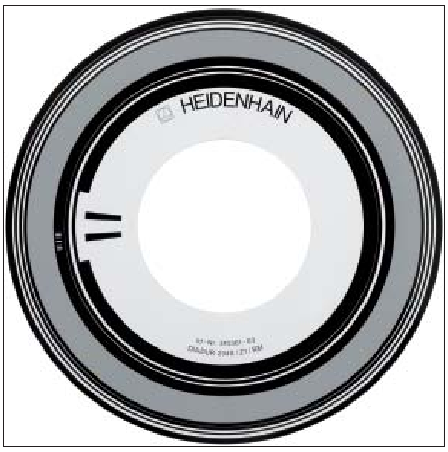
- **Incremental rotary encoders with** a second track—the **Z1 track**—provide one sine and one cosine signal (C and D) for each motor shaft revolution in addition to the incremental signals. For sine commutation, rotary encoders with a Z1 track need only a subdivision unit and a signal multiplexer to provide both the absolute rotor position from the Z1 track with an accuracy of ± 5° and the position information for speed and position control from the incremental track (see also *Interfaces—Commutation signals*).

- **Incremental rotary encoders with block commutation tracks** also output three commutation signals I, II, and III, which are used to drive the power electronics directly. These encoders are available with various commutation tracks. Typical versions provide 3 signal periods (120° mech.) or 4 signal periods (90° mech.) per commutation and revolution. Independently of these signals, the incremental square-wave signals serve for position and speed control. (See also *Interfaces—Commutation signals*.)

Commutation of synchronous linear motors
Like absolute rotary and angular encoders, absolute linear encoders of the LC series provide the exact position of the moving motor part immediately after switch-on. This makes it possible to start with maximum holding load on vertical axes even at a standstill.



Circular scale with serial code track and incremental track



Circular scale with Z1 track

Circular scale with block commutation tracks

Keep in mind the switch-on behavior of the encoders (see *General Electrical Information*).

Measuring Accuracy

The quantities influencing the accuracy of **linear encoders** are listed in the *Linear Encoders for Numerically Controlled Machine Tools* and *Exposed Linear Encoders* catalogs.

The **accuracy of angular measurement** is mainly determined by:

1. Quality of the graduation
2. Scanning quality
3. Quality of the signal processing electronics
4. Eccentricity of the graduation to the bearing
5. Error due to radial deviation of the bearing
6. Elasticity of the encoder shaft and coupling with the drive shaft
7. Elasticity of the stator coupling (ERN, ECN, EQN) or shaft coupling (ROD, ROC, ROQ)

In positioning tasks, the accuracy of the angular measurement determines the accuracy of the positioning of a rotary axis. The **system accuracy** given in the Specifications applies to a temperature of 20 °C, and is defined as follows:
The extreme values of the total deviations of a position are—referenced to their mean value—within the system accuracy ± a.

- For rotary encoders with integral bearing and integrated stator coupling, this value also includes the deviation due to the shaft coupling.
- For rotary encoders with integral bearing and separate shaft coupling, the angle error of the coupling must be added.
- For rotary encoders without integral bearing, deviations resulting from mounting, from the bearing of the drive shaft, and from adjustment of the scanning head must be expected in addition to the system error (see next page).

The system accuracy reflects position errors within one revolution as well as those within one signal period.

Position error within one revolution becomes apparent in larger angular motions.

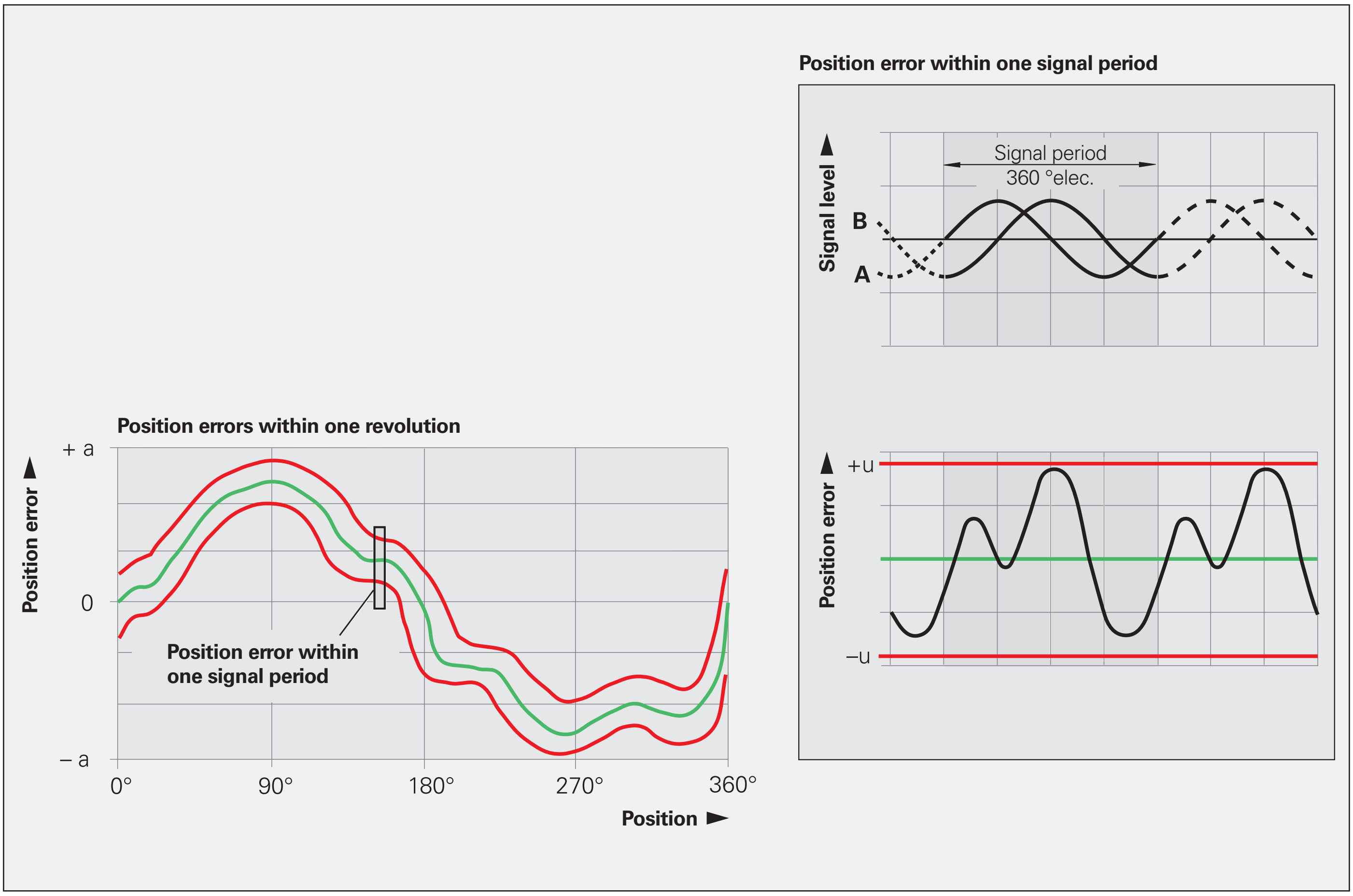
Position deviations within one signal period already become apparent in very small angular motions and in repeated measurements. They especially lead to speed ripples in the rotational-speed control loop. HEIDENHAIN rotary encoders with integral bearing permit interpolation of the sinusoidal output signal with subdivision accuracies of better than ± 1 % of the signal period.

Example
Rotary encoder with 2 048 sinusoidal signal periods per revolution:
One signal period corresponds to approx. 600". This results in maximum position deviations within one signal period of approx. ± 6".

The position error of the encoder within one signal period always affects the calculation of the actual speed on the basis of the actual position values of two successive sampling cycles. The position error of the encoder within one revolution is relevant for the speed control loop only if no more than a few actual position values per revolution are being evaluated. For example: a sampling time of 250 µs and a speed of n ≈ 24 000 min^{-1} result in only 10 samples per revolution.

Temperatures as high as 120 C, which can typically be found in motors, cause only a very small position error in HEIDENHAIN encoders.

Encoders with square-wave output signals have a position error of approx. ± 3 % of the signal period. These signals are suitable for up to 100-fold phase-locked loop subdivision.



Measuring Accuracy
Rotary Encoders without Integral Bearing

Rotary Encoders with Photoelectric Scanning

In addition to the system accuracy, the mounting and adjustment of the scanning head normally have a significant effect on the accuracy that can be achieved by rotary encoders without integral bearings with photoelectric scanning. Of particular importance are the mounting eccentricity and radial runout of the measured shaft.

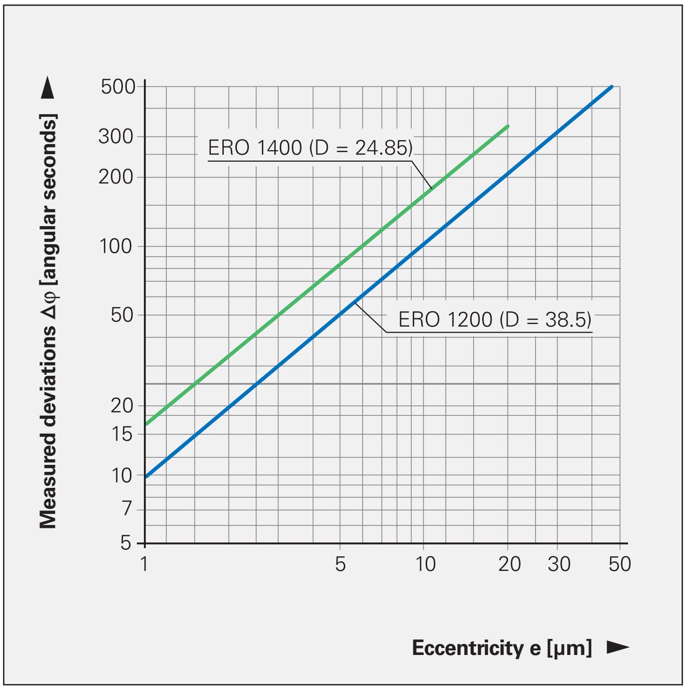
Example
ERO 1420 rotary encoder with a mean graduation diameter of 24.85 mm:
A radial runout of the measured shaft of 0.02 mm results in a position error within one revolution of ± 330 angular seconds.

To evaluate the **accuracy of modular rotary encoders without integral bearing** (ERO), each of the significant errors must be considered individually.

1. Directional deviations of the graduation
ERO: The extreme values of the directional deviation with respect to their mean value are shown in the *Specifications* as the graduation accuracy for each model. The graduation accuracy and the position error within a signal period comprise the system accuracy.

2. Errors due to eccentricity of the graduation to the bearing
Under normal circumstances, the bearing will have a certain amount of radial deviation or geometric error after the disk/hub assembly is mounted. When centering using the centering collar of the hub, please note that, for the encoders listed in this catalog, HEIDENHAIN guarantees an eccentricity of the graduation to the centering collar of under 5 µm. For the modular rotary encoders, this accuracy value presupposes a diameter deviation of zero between the drive shaft and the "master shaft."

If the centering collar is centered on the bearing, then in a worst-case situation both eccentricity vectors could be added together.



Resultant measured deviations Δφ for various eccentricity values e as a function of mean graduation diameter D

The following relationship exists between the eccentricity e, the mean graduation diameter D and the measuring error Δφ (see illustration below):

$$\Delta\varphi = \pm 412 \cdot \frac{e}{D}$$

Δφ = Measuring error in " (angular seconds)
e = Eccentricity of the radial grating to the bearing in µm
D = Mean graduation diameter in mm

Model	Mean graduation diameter D	Error per 1 µm of eccentricity
ERO 1420 **ERO 1470** **ERO 1480**	D = 24.85 mm	± 16.5"
ERO 1225 **ERO 1285**	D = 38.5 mm	± 10.7"

3. Error due to radial deviation of the bearing
The equation for the measuring error Δφ is also valid for radial deviation of the bearing if the value e is replaced with the eccentricity value, i.e. half of the radial deviation (half of the displayed value). Bearing compliance to radial shaft loading causes similar errors.

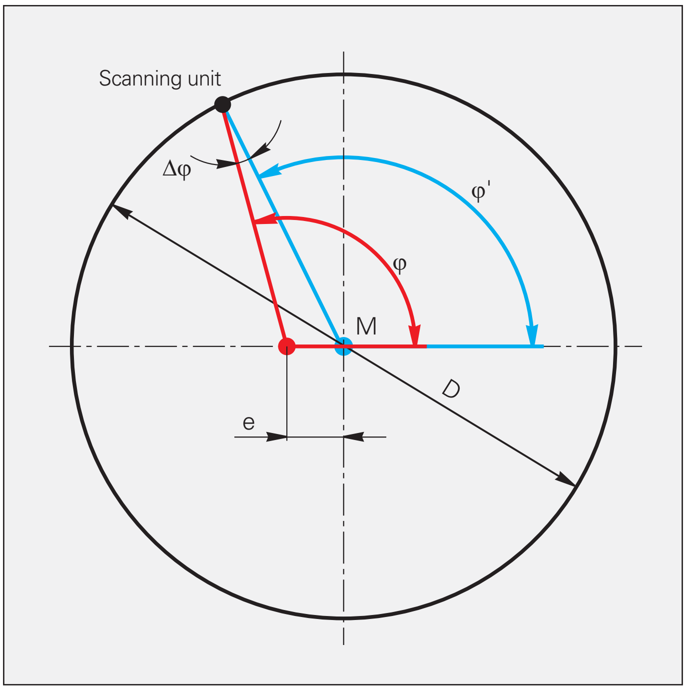
4. Position error within one signal period $\Delta\varphi_u$
The scanning units of all HEIDENHAIN encoders are adjusted so that without any further electrical adjustment being necessary while mounting, the maximum position error values within one signal period will not exceed the values listed below.

Model	Line count	Position error within one signal period $\Delta\varphi_u$	
		TTL	1 V_{PP}
ERO	2048 1500 1024 1000 512	≤ ± 19.0" ≤ ± 26.0" ≤ ± 38.0" ≤ ± 40.0" ≤ ± 76.0"	≤ ± 6.5" ≤ ± 8.7" ≤ ± 13.0" ≤ ± 14.0" ≤ ± 25.0"

The values for the position errors within one signal period are already included in the system accuracy. Larger errors can occur if the mounting tolerances are exceeded.

Rotary Encoders with Inductive Scanning

For rotary encoders without integrated bearing with inductive scanning, the attainable accuracy depends on the power supply, the temperature, the rotational speed, the working gap between the rotor and stator, and on the mounting conditions. The system accuracy stated in the Specifications takes all these factors of influence into account, as long as the permissible operating parameters and mounting tolerances are maintained.



Measuring error Δφ as a function of the mean graduation diameter D and the eccentricity e

M Center of graduation
φ "True" angle
φ' Scanned angle

Mechanical Design Types and Mounting
Rotary Encoders with Integral Bearing and Stator Coupling

ECN/EQN/ERN rotary encoders have integrated bearings and a mounted stator coupling. The encoder shaft is directly connected with the shaft to be measured. During angular acceleration of the shaft, the stator coupling must absorb only that torque caused by friction in the bearing. ECN/EQN/ERN rotary encoders therefore provide excellent dynamic performance and a high natural frequency.

Benefits of the stator coupling:
- No axial mounting tolerances between shaft and stator housing for ExN 1300 and ExN 1100
- High natural frequency of the coupling
- High torsional rigidity of shaft coupling
- Low mounting or installation space requirement
- Simple installation

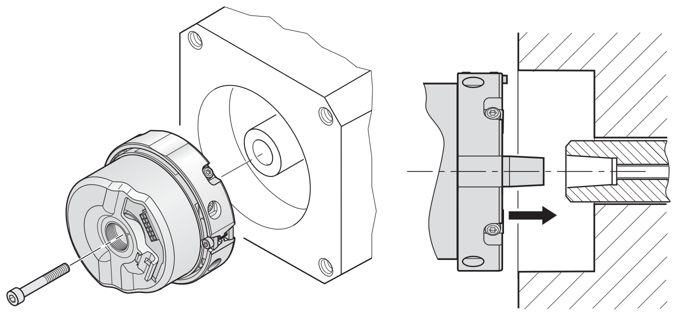
Mounting the ECN/EQN/ERN 1100 and ECN/EQN/ERN 1300
The blind hollow shaft or the taper shaft of the encoder is connected at its end through a central screw with the measured shaft. The encoder is centered on the motor shaft by the hollow shaft or taper shaft. The stator of the encoder is clamped by an axially tightened screw in the location hole.

Mounting the ECN/EQN/ERN 1000
The rotary encoder is slid by its blind hollow shaft onto the measured shaft and fastened by two screws or three eccentric clamps. The stator is mounted without a centering flange to a flat surface with four cap screws or with 2 cap screws and special washers.

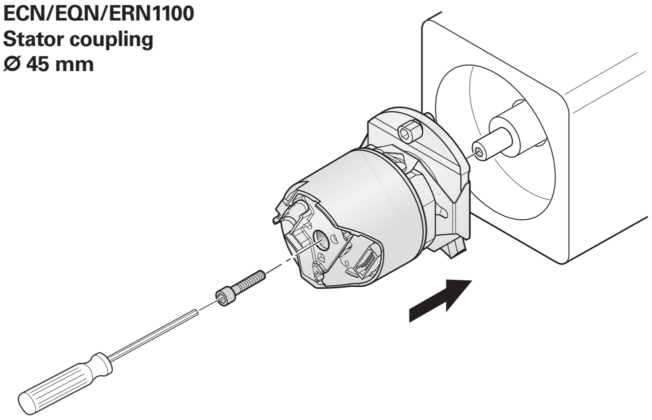
Mounting accessories for the ECN/EQN/ERN 1000

Washer
For increasing the natural frequency f_E and mounting with only two screws.
ID 334653-01 (2 pieces)

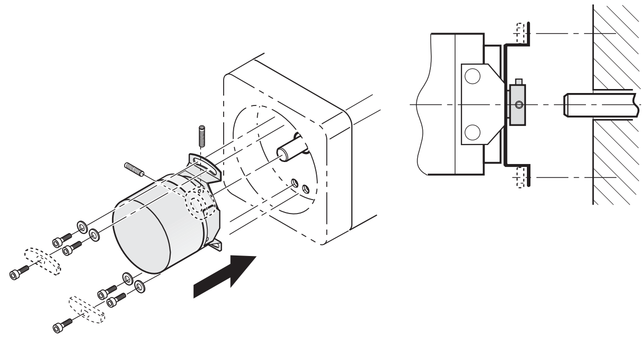
ECN/EQN/ERN 1300



ECN/EQN/ERN1100
Stator coupling
Ø 45 mm



ECN/EQN/ERN 1000



Mounting accessories

Screwdriver bit
For HEIDENHAIN shaft couplings,
For ExN 100/400/1000 shaft couplings
For ERO shaft couplings

Width across flats	Length	ID
1.5	70 mm	350378-01
1.5 (ball head)		350378-02
2		350378-03
2 (ball head)		350378-04
2.5		350378-05
3 (ball head)		350378-08
4		350378-07
4 (with dog point)[1]		350378-14
TX8	89 mm 152 mm	350378-11 350378-12

[1] For screws as per DIN 6912 (low head screw with pilot recess)

Screwdriver
Adjustable torque
0.2 Nm to 1.2 Nm ID 350379-04
1 Nm to 5 Nm ID 350379-05

Extraction tool
For removing the PCB connector from the ERN 1120 and ERN 1180
ID 592818-01

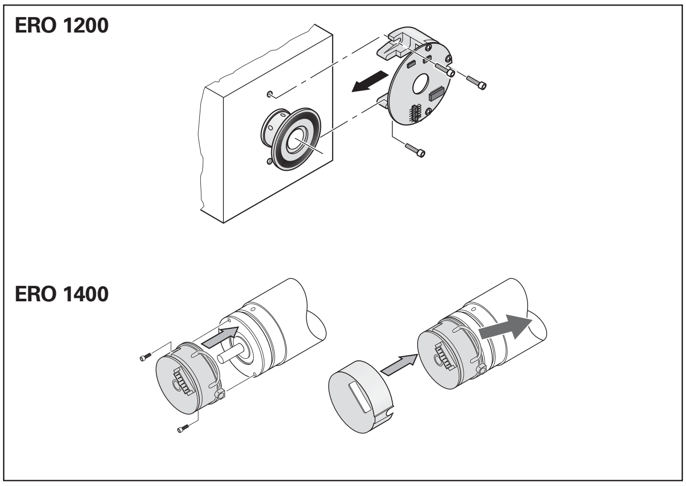
Mechanical Design Types and Mounting
Rotary Encoders without Integral Bearing

The **ERO, ECI/EQI** rotary encoders without integral bearing consist of a scanning head and a graduated disk, which must be adjusted to each other very exactly. A precise adjustment is an important factor for the attainable measuring accuracy.

The **ERO** modular rotary encoders consist of a graduated disk with hub and a scanning unit. They are particularly well suited for applications with limited installation space and negligible axial and radial runout, or for applications where friction of any type must be avoided.

In the **ERO 1200** series, the disk/hub assembly is slid onto the shaft and adjusted to the scanning unit. The scanning unit is aligned on a centering collar and fastened on the mounting surface.

The **ERO 1400** series consists of miniature modular encoders. These rotary encoders have a special built-in **mounting aid** that centers the graduated disk to the scanning unit and adjusts the gap between the disk and the scanning reticle. This makes it possible to install the encoder in a very short time. The encoder is supplied with a cover cap for protection from extraneous light.



Mounting the **ERO** modular rotary encoder

Mounting accessories for ERO 1400

Mounting accessories
Aid for removing the clip for optimal encoder mounting.
ID 510 175-01

Accessories
Housing for ERO 14xx with axial PCB connector and central hole
ID 331 727-23

Mounting accessories **ERO 1400**

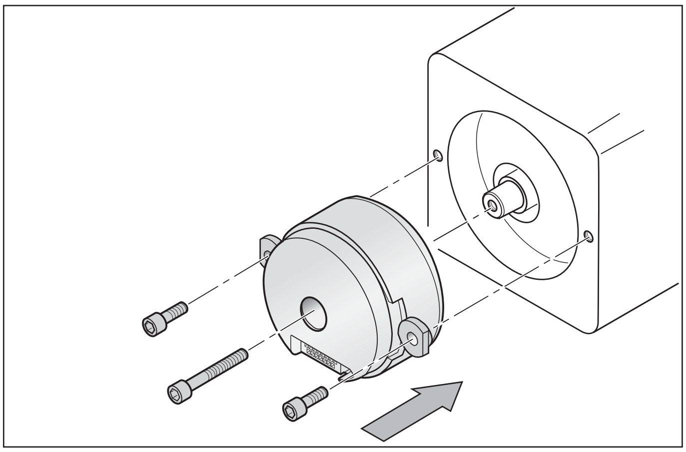
The **ECI/EQI 1100** inductive rotary encoders are mounted in axial direction. The blind hollow shaft is attached with a central screw. The stator of the encoder is clamped against a shoulder by two axial screws.

The scanning gap between the rotor and stator is predetermined by the mounting situation. Retroactive adjustment is not possible.

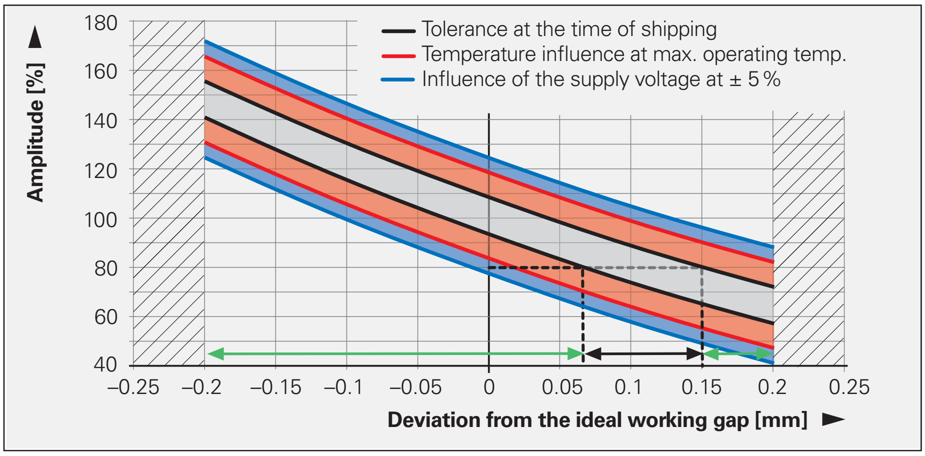
The maximum permitted deviation indicated in the mating dimensions applies to mounting as well as to operation. Tolerances used during mounting are therefore not available for axial motion of the shaft during operation.

Once the encoder has been mounted, the actual working gap between the rotor and stator can be measured indirectly via the signal amplitude in the rotary encoder, using the IK 215 PC card and the ATS software. The characteristic curves show the correlation between the signal amplitude and the deviation from the ideal scanning gap, depending on various ambient conditions.

The example shows the resulting deviation from the ideal scanning gap for a signal amplitude of 80 % at ideal conditions. Due to tolerances within the rotary encoder, the deviation is between +0.07 mm and +0.15 mm. This means that the maximum permissible motion of the drive shaft during operation is between –0.27 mm and +0.05 mm (green arrows).



Mounting the **ECI/EQI 1100**

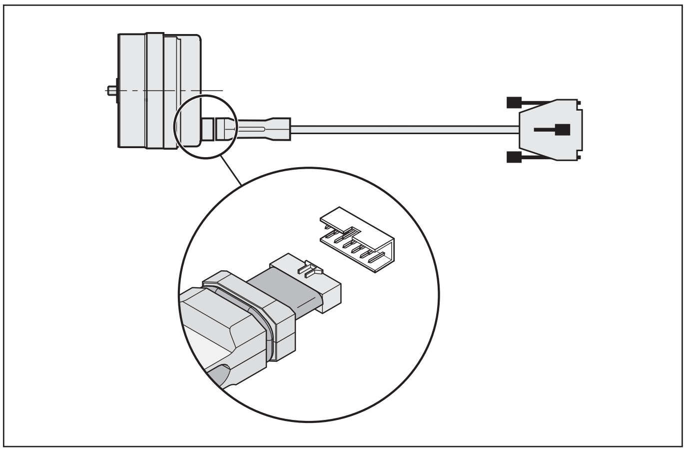


Accessories
For testing the scanning gap

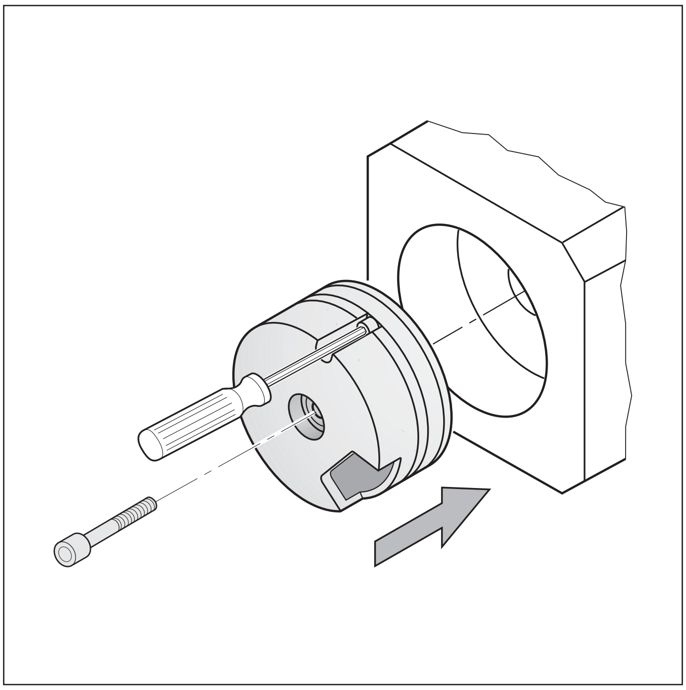
Encoder cable
For IK 215, inc. 3 adapter connectors, 12-pin and 3 adapter connectors, 15-pin
ID 621 742-01

Software (for Windows 2000/XP)
For inspecting the output signals in combination with the absolute value card IK 215
(see *HEIDENHAIN Measuring and Testing Devices*)
ID 539862-xx

15-pin adapter connector
Three units
ID 528694-02



The **ECI/EQI 1300** inductive rotary encoders are mechanically compatible with the ExN 1300 photoelectric encoders. The taper shaft (a bottomed hollow shaft is available as an alternative) is fastened with a central screw. The stator of the encoder is clamped by an axially tightened screw in the location hole.



Mounting the **ECI/EQI 1300**

Accessories for adjustment of the ECI/EQI 1300
To adjust the encoder, you will need:

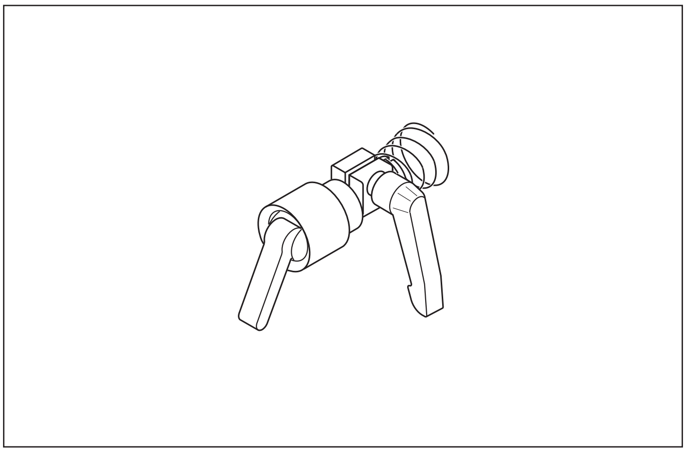
Adjustment aid for setting the gap
ID 335529-xx

Mounting aid for adjusting the rotor position to the motor emf
ID 352481-xx

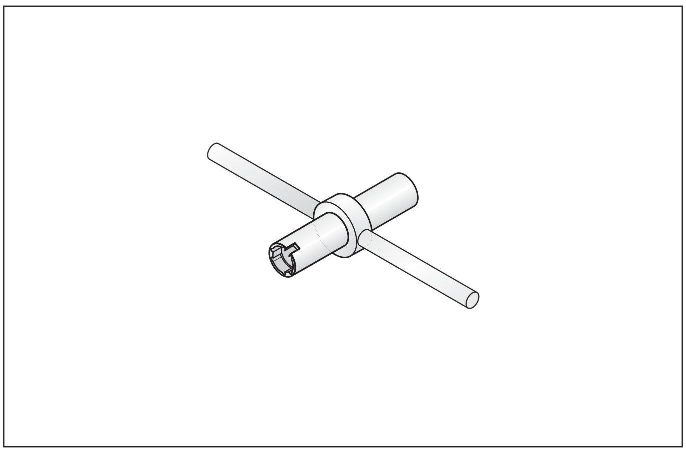
Encoder cable
For IK 215, inc. 3 adapter connectors, 12-pin and 3 adapter connectors, 15-pin
ID 621742-01

Software (for Windows 2000/XP)
For inspecting the output signals in combination with the absolute value card IK 215
(see *HEIDENHAIN Measuring and Testing Devices*)
ID 539862-xx

12-pin adapter connector
Three connectors for replacement
ID 528694-01



Adjustment aid



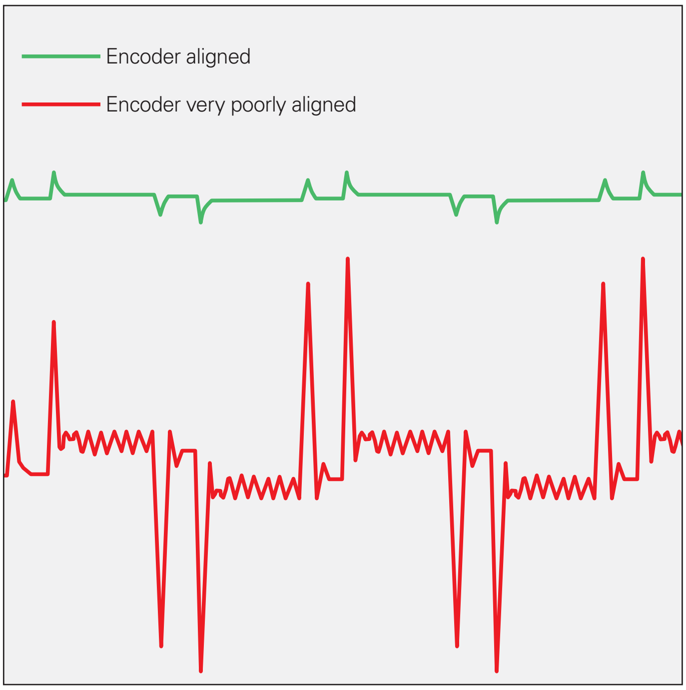
Mounting aid

Aligning the Rotary Encoders to the Motor EMF

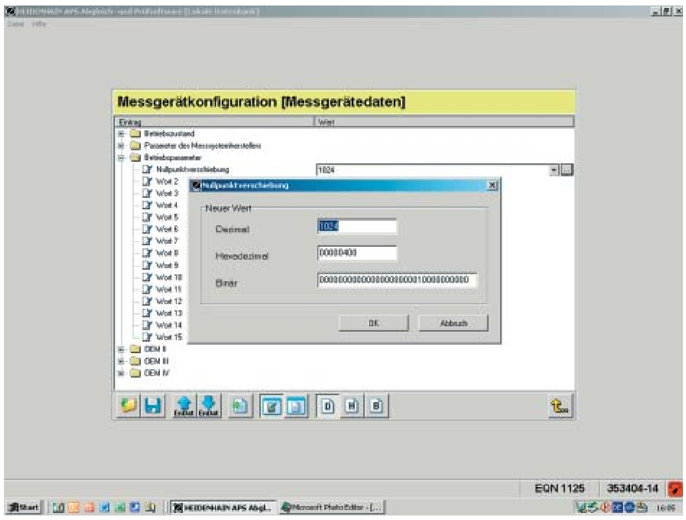
Synchronous motors require information on the rotor position immediately after switch-on. This information can be provided by rotary encoders with additional commutation signals, which provide relatively rough position information. Also suitable are absolute rotary encoders in multiturn and singleturn versions, which transmit the exact position information within a few angular seconds (see also *Electronic Commutation with Position Encoders*). When these encoders are mounted, the rotor positions of the encoder must be assigned to those of the motor in order to ensure the most constant possible motor current. Inadequate assignment to the motor emf will cause loud motor noises and high power loss.

Rotary encoders with integral bearing
First, the rotor of the motor is brought to a preferred position by the application of a dc current. **Rotary encoders with commutation signals** are aligned approximately—for example with the aid of the line markers on the encoder or the reference mark signal—and mounted on the motor shaft. The fine adjustment is quite easy with a PWM 8 phase angle measuring device (see *HEIDENHAIN Measuring and Testing Devices*): the stator of the encoder is turned until the PWM 8 displays, for example, the value zero as the distance from the reference mark.
Absolute rotary encoders are at first mounted as a complete unit. Then the preferred position of the motor is assigned the value zero. The IK 215 adapter card for PCs and the accompanying software (see *HEIDENHAIN Measuring and Testing Devices*) serve this purpose. They feature the complete range of EnDat functions and make it possible to shift datums, set write protection against unintentional changes in saved values, and use further inspection functions.

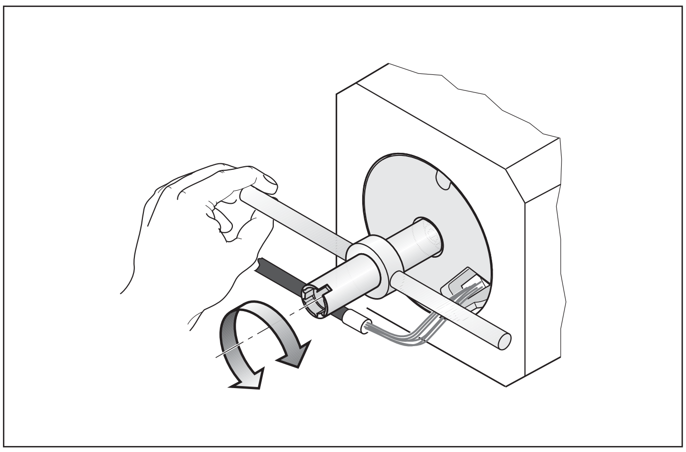
Rotary encoders without integral bearing
ECI/EQI rotary encoders are mounted as complete units and then adjusted with the aid of the IK 215 adapter card for PCs and the accompanying software. For the ECI/EQI 1300, the central screw is loosened again and the encoder rotor is turned with the mounting aid to the desired position until, for example, an absolute value of approximately zero appears in the position data. The stator housing of the ECI/EQI 1100 must be turned. For the ECI/EQI with pure serial operation (EnDat 21), electronic compensation is also possible: the ascertained compensation value is saved in the encoder and can be read out by the control electronics to calculate the position value.



Motor current of adjusted and very poorly adjusted rotary encoder



Aligning the rotary encoder to the motor emf with the aid of the adjusting and testing software for the IK 215



Manual alignment of ECI/EQI 1300

General Mechanical Information

UL certification
All rotary encoders and cables in this brochure comply with the UL safety regulations for the USA and the "CSA" safety regulations for Canada.

Acceleration
Encoders are subject to various types of acceleration during operation and mounting.

- **Vibration**
  The encoders are qualified on a test stand to operate with the specified acceleration values from 55 to 2000 Hz in accordance with EN 60068-2-6. However, if the application or poor mounting cause long-lasting resonant vibration, it can limit performance or even damage the encoder. **Comprehensive tests of the entire system are required.**
- **Shock**
  The encoders are qualified on a test stand to operate with the specified acceleration values and duration in accordance with EN 60068-2-27. This does not include **permanent shock loads,** which **must be tested in the application.**
- The **maximum angular acceleration** is 10^5 rad/s^2 (DIN 32878). This is the highest permissible acceleration at which the rotor will rotate without damage to the encoder. The angular acceleration actually attainable depends on the shaft connection. A sufficient safety factor is to be determined through system tests.

Humidity
The max. permissible relative humidity is 75 %. 95 % is permissible temporarily. Condensation is not permissible.

Magnetic fields
Magnetic fields > 30 mT can impair the proper function of encoders. If required, please contact HEIDENHAIN, Traunreut.

RoHS
HEIDENHAIN has tested the products for harmlessness of the materials as per European Directives 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) and 2002/96/EC (WEEE) on waste electrical and electronic equipment. For a Manufacturer Declaration on RoHS, please refer to your sales agency.

Natural frequencies
The rotor and the couplings of ROC/ROQ/ROD and RIC/RIQ rotary encoders, as also the stator and stator coupling of ECN/EQN/ERN rotary encoders, form a single vibrating spring-mass system.

The **natural frequency f_N** should be as high as possible. A prerequisite for the highest possible natural frequency on **ROC/ROQ/ROD rotary encoders** is the use of a diaphragm coupling with a high torsional rigidity C (see *Shaft Couplings).*

$$f_E = \frac{1}{2 \cdot \pi} \cdot \sqrt{\frac{C}{I}}$$

f_N: Natural frequency in Hz
C: Torsional rigidity of the coupling in Nm/rad
I: Moment of inertia of the rotor in kgm^2

ECN/EQN/ERN rotary encoders with their stator couplings form a vibrating spring-mass system whose **natural frequency f_N** should be as high as possible. If radial and/or axial acceleration forces are added, the stiffness of the encoder bearings and the encoder stators are also significant. If such loads occur in your application, HEIDENHAIN recommends consulting with the main facility in Traunreut.

Protection against contact (EN 60529)
After encoder installation, all rotating parts must be protected against accidental contact during operation.

Protection (EN 60529)
The degree of protection shown in the catalog is adapted to the usual mounting conditions. You will find the respective values in the Specifications. If the given degree of protection is not sufficient (such as when the encoders are mounted vertically), the encoders should be protected by suited measures such as covers, labyrinth seals, or other methods. Splash water must not contain any substances that would have harmful effects on the encoder parts.

Expendable parts
Encoders from HEIDENHAIN are designed for a long service life. Preventive maintenance is not required. They contain components that are subject to wear, depending on the application and manipulation. These include in particular moving cables.

On encoders with integral bearing, other such components are the bearings, shaft sealing rings on rotary and angle encoders, and sealing lips on sealed linear encoders.

System tests
Encoders from HEIDENHAIN are usually integrated as components in larger systems. Such applications require **comprehensive tests of the entire system** regardless of the specifications of the encoder.

The specifications given in the brochure apply to the specific encoder, not to the complete system. Any operation of the encoder outside of the specified range or for any other than the intended applications is at the user's own risk.
In safety-related systems, the higher-level system must verify the position value of the encoder after switch-on.

Mounting
Work steps to be performed and dimensions to be maintained during mounting are specified solely in the mounting instructions supplied with the unit. All data in this catalog regarding mounting are therefore provisional and not binding; they do not become terms of a contract.

Changes to the encoder
The correct operation and accuracy of encoders from HEIDENHAIN is ensured only if they have not been modified. Any changes, even minor ones, can impair the operation and reliability of the encoders, and result in a loss of warranty. This also includes the use of additional retaining compounds, lubricants (e.g. for screws) or adhesives not explicitly prescribed. In case of doubt, we recommend contacting HEIDENHAIN in Traunreut.

Temperature ranges
For the unit in its packaging, the **storage temperature range** is –30 to 80 °C. The **operating temperature range** indicates the temperatures the encoder may reach during operation in the actual installation environment. The function of the encoder is guaranteed within this range (DIN 32878). The operating temperature is measured on the face of the encoder flange (see dimension drawing) and must not be confused with the ambient temperature.

The temperature of the encoder is influenced by:
- Mounting conditions
- The ambient temperature
- Self-heating of the encoder

The self-heating of an encoder depends both on its design characteristics (stator coupling/solid shaft, shaft sealing ring, etc.) and on the operating parameters (rotational speed, power supply). Temporarily increased self-heating can also occur after very long breaks in operation (of several months). Please take a two-minute run-in period at low speeds into account. Higher heat generation in the encoder means that a lower ambient temperature is required to keep the encoder within its permissible operating temperature range.

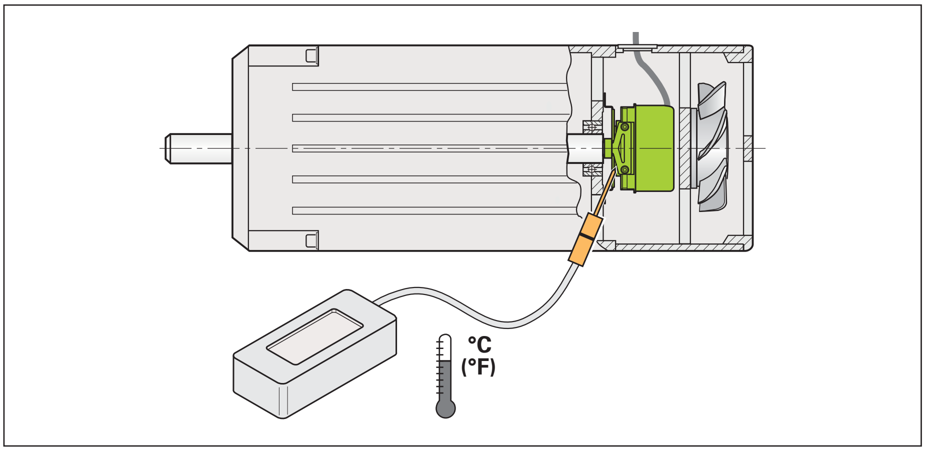
These tables show the approximate values of self-heating to be expected in the encoders. In the worst case, a combination of operating parameters can exacerbate self-heating, for example a 30 V power supply and maximum rotational speed. Therefore, the actual operating temperature should be measured directly at the encoder if the encoder is operated near the limits of permissible parameters. Then suitable measures should be taken (fan, heat sinks, etc.) to reduce the ambient temperature far enough so that the maximum permissible operating temperature will not be exceeded during continuous operation.

For high speeds at maximum permissible ambient temperature, special versions are available on request with reduced degree of protection (without shaft seal and its concomitant frictional heat).

Self-heating at supply voltage		**15 V**	**30 V**
	ERN/ROD	Approx. + 5 K	Approx. + 10 K
	ECN/EQN/ROC/ROQ	Approx. + 5 K	Approx. + 10 K

Heat generation at speed n_{max}		
Solid shaft	**ROC/ROQ/ROD**	Approx. + 5 K with IP 64 protection Approx. + 10 K with IP 66 protection
Blind hollow shaft	**ECN/EQN/ERN 400**	Approx. + 30 K with IP 64 protection Approx. + 40 K with IP 66 protection
	ECN/EQN/ERN 1000	Approx. +10 K
Hollow through shaft	**ECN/ERN 100** **ECN/EQN/ERN 400**	Approx. + 40 K with IP 64 protection Approx. + 50 K with IP 66 protection

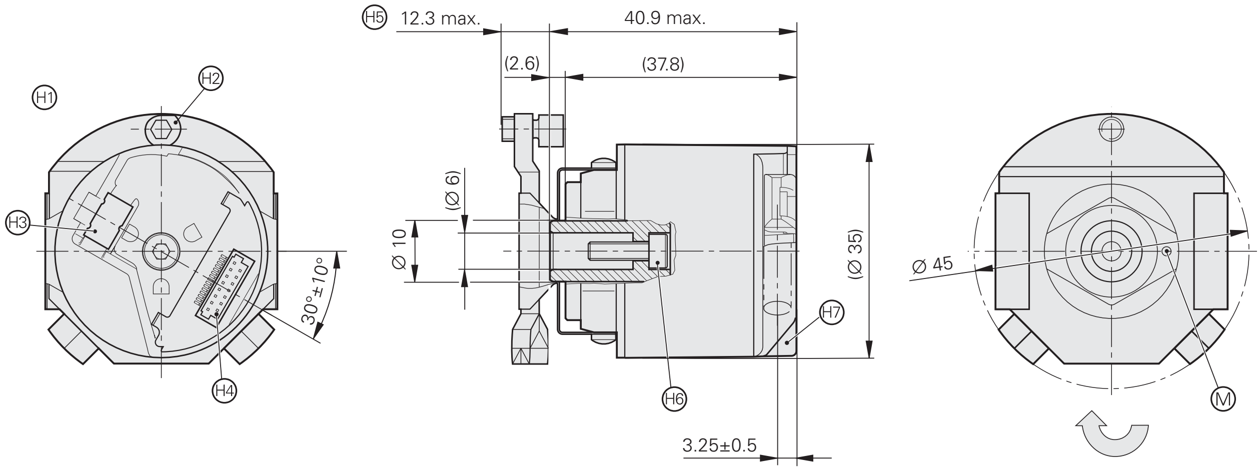
An encoder's typical self-heating values depend on its design characteristics at maximum permissible speed. The correlation between rotational speed and heat generation is nearly linear.

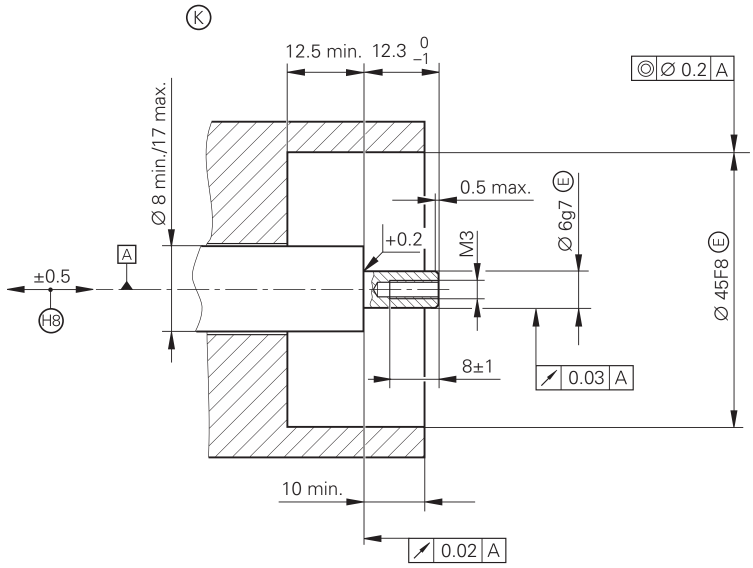


Measuring the actual operating temperature at the defined measuring point of the rotary encoder (see *Specifications*)

ECN/EQN 1100 Series

Rotary encoders with integral bearing for integration in motors
- **Mounted stator coupling**
- **Installation diameter Ø 45 mm**
- **Compact size**
- **Blind hollow shaft**





Dimensions in mm

Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

A = Bearing
K = Required mating dimensions
M = Measuring point for operating temperature
H1 = Encoder shown without cover
H1 = Mounting screw (M4, width A/F 3). Turn back by one revolution, and tighten with 2 ± 0.1 Nm
H3 = Cable outlet for cables with crimp sleeve Ø 4.3 ± 0.1 – 7 long
H4 = 15-pin plug connector
H5 = Variable depending on the coupling
H6 = Screw ISO 4762, width A/F 2.5, with patch coating. Tightening torque: 1.2 ± 0.1 Nm
ECN: M3 x 10
EQN: M3 x 22
H7 = Removable cover
H8 = Compensation of mounting tolerances and thermal expansion, no dynamic motion permitted
Direction of shaft rotation for output signals as per the interface description

	Absolute			
	ECN 1113	**ECN 1123**	**EQN 1125**	**EQN 1135**
Incremental signals	$\sim V_{PP}$[1]	–	$\sim V_{PP}$[1]	–
Line count/system accuracy	512/± 60"			
Cutoff frequency –3 dB	≥ 190 kHz	–	≥ 190 kHz	–
Absolute position values	EnDat 2.2			
Ordering designation	EnDat 01	EnDat 22	EnDat 01	EnDat 22
Position values per rev	8192 (13 bits)	8388608 (23 bits)	8192 (13 bits)	8388608 (23 bits)
Revolutions	–		4096 (12 bits)	
Elec. permissible speed/ Deviation[2]	4000 min^{-1}/± 1 LSB 12000 min^{-1}/± 16 LSB	12000 min^{-1} (for continuous position value)	4000 min^{-1}/± 1 LSB 12000 min^{-1}/± 16 LSB	12000 min^{-1} (for continuous position value)
Calculation time t_{cal}	≤ 9 µs	≤ 7 µs	≤ 9 µs	≤ 7 µs
Power supply	3.6 V to 14 V			
Power consumption (maximum)	*3.6 V:* ≤ 600 NW *14 V:* ≤ 700 NW		*3.6 V:* ≤ 800 NW *14 V:* ≤ 700 NW	
Current consumption (typical)	*5 V:* 85 mA (without load)		*5 V:* 105 mA (without load)	
Electrical connection Via PCB connector	15-pin	15-pin[3]	15-pin	15-pin[3]
Shaft	Blind hollow shaft ∅ 6 mm			
Mech. permissible speed n	12000 min^{-1}			
Starting torque	≤ 0.001 Nm (at 20 °C)		≤ 0.002 Nm (at 20 °C)	
Moment of inertia of rotor	Approx. $0.4 \cdot 10^{-6}$ kgm^2			
Permissible axial motion of measured shaft	± 0.5 mm			
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 200 m/s^2 (EN 60068-2-6) ≤ 1000 m/s^2 (EN 60068-2-27)			
Max. operating temperature	115 °C			
Min. operating temperature	–40 °C			
Protection EN 60529	IP 40 when mounted			
Weight	Approx. 0.1 kg			

[1] Restricted tolerances

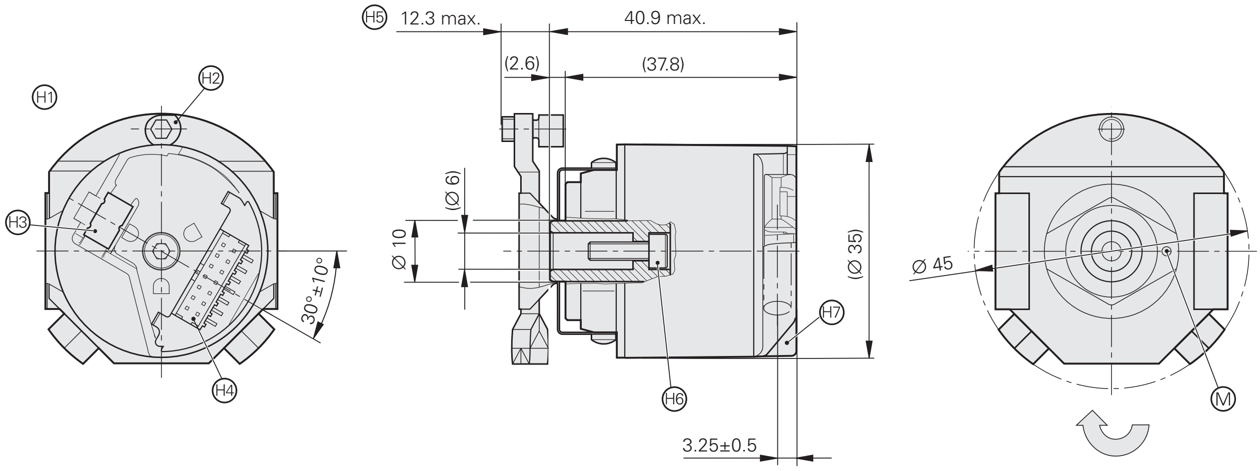
Signal amplitude	0.80 to 1.2 V_{PP}
Asymmetry:	0.05
Amplitude ratio:	0.9 to 1.1
Phase angle:	90° ± 5° elec.

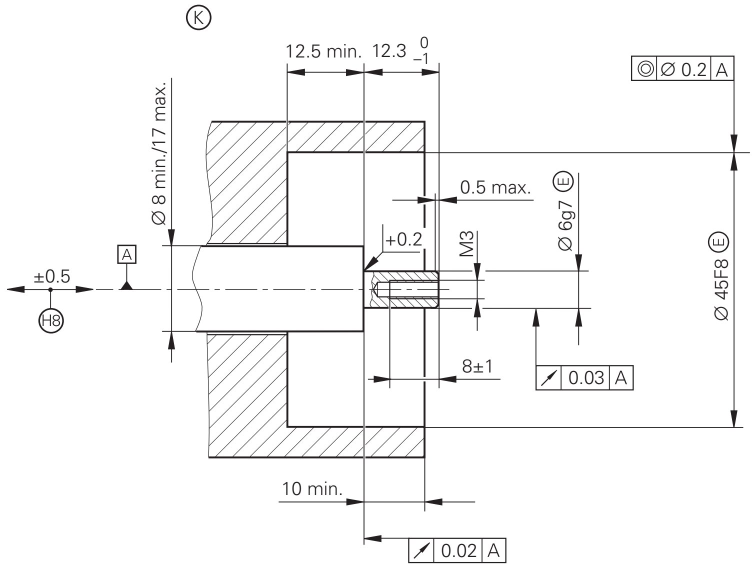
[2] Velocity-dependent deviations between the absolute and incremental signals
[3] With connection for temperature sensor, evaluation optimized for KTY 84-130

Functional Safety for ECN 1123 and EQN 1135 upon request

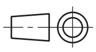
ERN 1100 Series

Rotary encoders with integral bearing for integration in motors
- **Mounted stator coupling**
- **Installation diameter Ø 45 mm**
- **Compact size**
- **Blind hollow shaft**





Dimensions in mm



Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

A = Bearing
K = Required mating dimensions
M = Measuring point for operating temperature
H1 = Encoder shown without cover
H1 = Mounting screw (M4, width A/F 3). Turn back by one revolution, and tighten with 2 ± 0.1 Nm
H3 = Cable outlet for cables with crimp sleeve Ø 4.3 ± 0.1 – 7 long
H4 = ERN: JAE connector 15-pin
ERN with Z1 track: FCI connector, 14-pin
H5 = Variable depending on the coupling
H6 = Screw M3 x 10, ISO 4762, with patch coating, width A/F 2.5. Tightening torque: 1.2±0.1 Nm
H7 = Removable cover
H8 = Compensation of mounting tolerances and thermal expansion, no dynamic motion permitted
Direction of shaft rotation for output signals as per the interface description

	Incremental		
	ERN 1120	ERN 1180	ERN 1185
Incremental signals	⊓⊔TTL	∿ V_{PP} [1)]	∿ V_{PP} [1)]
Line count*/system accuracy	1024/± 64" 2048/± 32" 3600/± 18"		512/± 60" 2048/± 40"
Reference mark	One		
Scanning frequency Edge separation a Cutoff frequency –3 dB	≥ 300 kHz ≥ 0.39 µs –	– – ≥ 180 kHz	– – *512 lines:* ≥ 100 kHz *2048 lines:* ≥ 350 kHz
Absolute position values	–		∿ V_{PP} [1)]
Position values per rev	–		Z1 track[2)]
Power supply	5 V ± 10 %		
Current consumption without load	≤ 120 mA		
Electrical connection	Via 15-pin PCB connector		14-pin
Shaft	Blind hollow shaft ∅ 6 mm		
Mech. permissible speed n	12000 min^{-1}		
Starting torque	≤ 0.001 Nm (at 20 °C)		
Moment of inertia of rotor	Approx. $0.3 \cdot 10^{-6}$ kgm^2		
Permissible axial motion of measured shaft	± 0.5 mm		
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 100 m/s^2 (EN 60068-2-6) ≤ 1000 m/s^2 (EN 60068-2-27)		
Max. operating temperature	100 °C		115 °C
Min. operating temperature	–30 °C		
Protection EN 60529	IP 40 when mounted		
Weight	Approx. 0.1 kg		

* Please select when ordering
1) Restricted tolerances

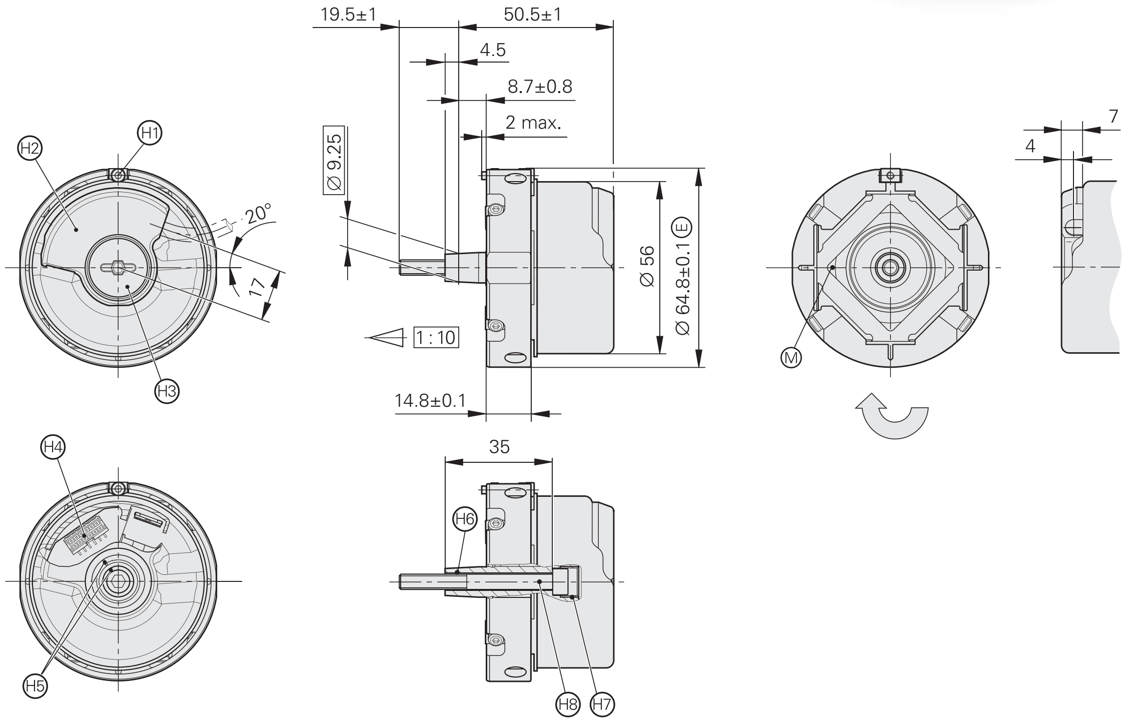
Signal amplitude	0.80 to 1.2 V_{PP}
Asymmetry:	0.05
Amplitude ratio:	0.9 to 1.1
Phase angle:	90° ± 5° elec.
Signal-to-noise ratio E, F:	100 mV

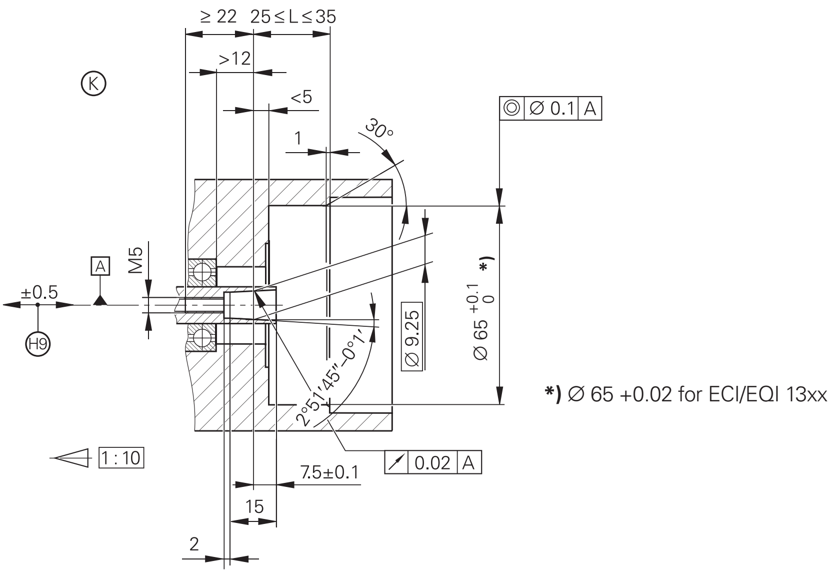
2) For sine commutation: One sine and one cosine signal per revolution

ERN 1185: The ERN 1185 is not available in the depicted version.
The specifications and mating dimensions of the currently available version is in the Product Information sheet ERN 1185 under **www.heidenhain.de/docu**

ECN/EQN 1300 Series

Rotary encoders with integral bearing for integration in motors
- **Mounted stator coupling**
- **Installation diameter 65 mm**
- **Taper shaft**





*) Ø 65 +0.02 for ECI/EQI 13xx

Dimensions in mm

Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

- A = Bearing of mating shaft
- B = Bearing of encoder
- K = Required mating dimensions
- M = Measuring point for operating temperature
- H1 = Clamping screw for coupling ring, width A/F 2. Tightening torque: 1.25-0.2 Nm
- H2 = Die-cast cover
- H3 = Screw plug, width A/F 3 and 4. Tightening torque: 5+0.5 Nm
- H4 = ERN: Plug connector, 12-pin
  ERN with Z1 track: Plug connector, 14-pin
  ERN with block commutation: Plug connector, 16-pin
  ECN/EQN plug connector, 12-pin
  ECN/EQN plug connector, 12-pin + 4-pin
- H5 = ERN: Reference mark position indicated on shaft and cap
  ECN/EQN: Zero position indicated on shaft and cap
- H6 = Back-off thread M6
- H7 = Back-off thread M10
- H8 = Self-tightening screw, M5 x 50, DIN 6912, width A/F 4. Tightening torque: 5+0.5 Nm
- H9 = Compensation of mounting tolerances and thermal expansion, no dynamic motion permitted
- ↻ Direction of shaft rotation for output signals as per the interface description

	Absolute			
	ECN 1313	**ECN 1325**	**EQN 1325**	**EQN 1337**
Incremental signals	∼ V_{PP}[1]	–	∼ V_{PP}[1]	–
Line count*/system accuracy	512/± 60" 2048/± 20"	2048/± 20"	512/± 60" 2048/± 20"	2048/± 20"
Cutoff frequency –3 dB	*2048 lines:* ≥ 400 kHz *512 lines:* ≥ 130 kHz	–	*2048 lines:* ≥ 400 kHz *512 lines:* ≥ 130 kHz	–
Absolute position values	EnDat 2.2			
Ordering designation	EnDat 01	EnDat 22	EnDat 01	EnDat 22
Position values per rev	8192 (13 bits)	33554432 (25 bits)	8192 (13 bits)	33554432 (25 bits)
Revolutions	–		4096 (12 bits)	
Elec. permissible speed/ Deviation[2]	*512 lines:* 5000 min^{-1}/± 1 LSB 12000 min^{-1}/± 100 LSB *2048 lines:* 1500 min^{-1}/± 1 LSB 12000 min^{-1}/± 50 LSB	12000 min^{-1} (for continuous position value)	*512 lines:* 5000 min^{-1}/± 1 LSB 12000 min^{-1}/± 100 LSB *2048 lines:* 1500 min^{-1}/± 1 LSB 12000 min^{-1}/± 50 LSB	12000 min^{-1} (for continuous position value)
Calculation time t_{cal}	≤ 5 µs			
Power supply	3.6 to 14 V			
Power consumption (maximum)	*3.6 V:* ≤ 600 NW *14 V:* ≤ 700 NW		*3.6 V:* ≤ 800 NW *14 V:* ≤ 700 NW	
Current consumption (typical)	*5 V:* 85 mA (without load)		*5 V:* 105 mA (without load)	
Electrical connection via PCB connector	12-pin	*Rotary encoder:* 12-pin *Temperature sensor*[3]*:* 4-pin	12-pin	*Rotary encoder:* 12-pin *Temperature sensor*[3]*:* 4-pin
Shaft	Taper shaft ∅ 9.25 mm; taper 1:10			
Mech. permissible speed n	≤ 15000 min^{-1}		≤ 12000 min^{-1}	
Starting torque at 20 °C	≤ 0.01 Nm			
Moment of inertia of rotor	$2.6 \cdot 10^{-6}$ kgm^2			
Natural frequency of the stator coupling	≥1800 Hz			
Permissible axis motion of measured shaft	± 0.5 mm			
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 300 m/s^2 [4] (EN 60068-2-6) ≤ 2000 m/s^2 (EN 60068-2-27)			
Max. operating temp.	115 °C			
Min. operating temp.	–40 °C			
Protection EN 60529	IP 40 when mounted			
Weight	Approx. 0.25 kg			

* Please select when ordering

[1] Restricted tolerances

Signal amplitude:	0.8 to 1.2 V_{PP}
Asymmetry:	0.05
Amplitude ratio:	0.9 to 1.1
Phase angle:	90° ± 5° elec.
Signal-to-noise ratio E, F:	100 mV

Functional Safety for ECN 1325 and EQN 1337 upon request

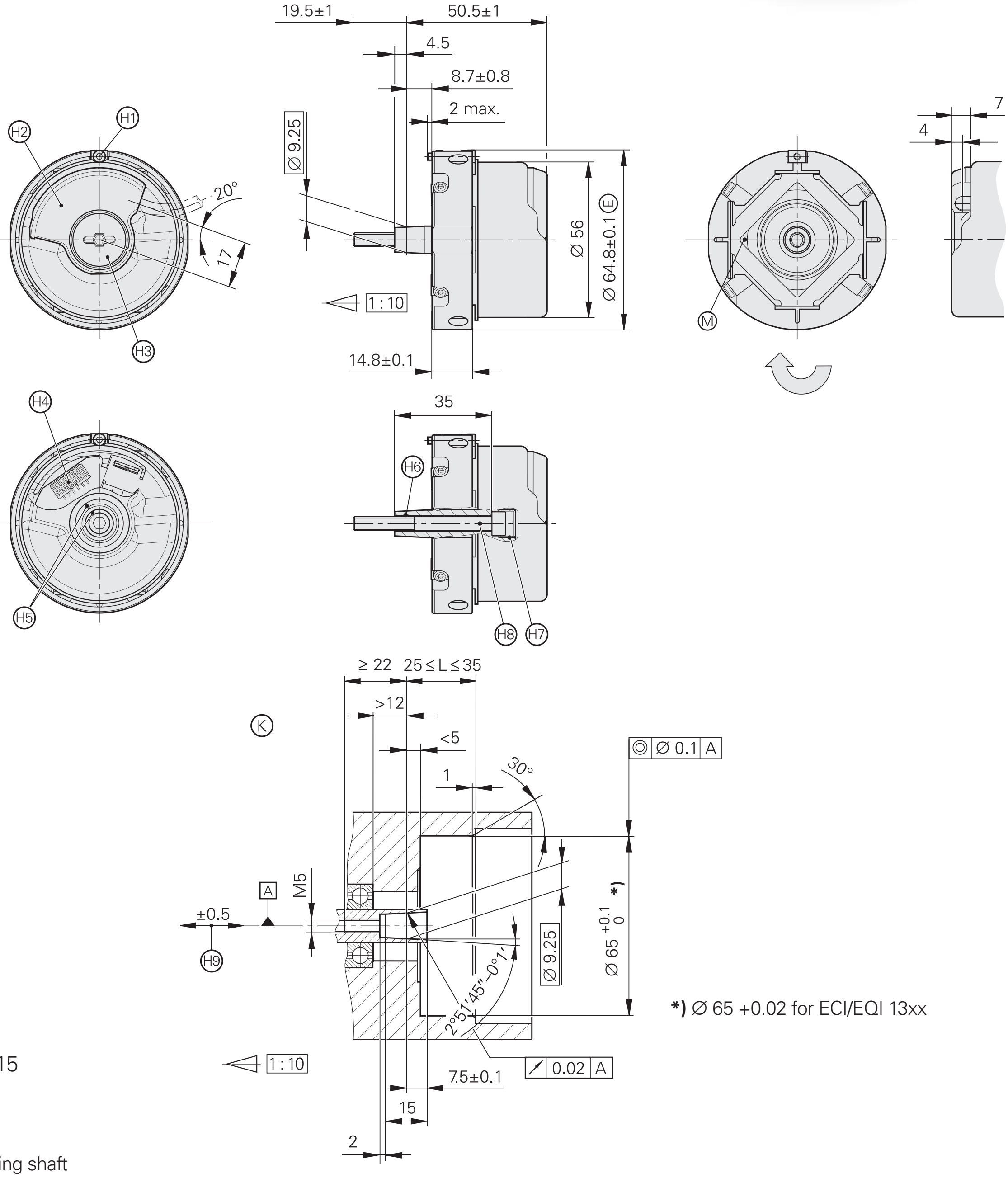
[2] Velocity-dependent deviations between the absolute and incremental signals

[3] Evaluation optimized for KTY 84-130

[4] As per standard for room temperature; the following applies for operating temperature Up to 100 °C: ≤ 300 m/s^2; to 115 °C: ≤ 150 m/s^2

ERN 1300 Series

Rotary encoders with integral bearing for integration in motors
- **Mounted stator coupling**
- **Installation diameter 65 mm**
- **Taper shaft**



Dimensions in mm

Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

A = Bearing of mating shaft
B = Bearing of encoder
K = Required mating dimensions
M = Measuring point for operating temperature
H1 = Clamping screw for coupling ring, width A/F 2. Tightening torque: 1.25–0.2 Nm
H2 = Die-cast cover
H3 = Screw plug, width A/F 3 and 4. Tightening torque: 5 + 0.5 Nm
H4 = ERN: Plug connector, 12-pin
ERN with Z1 track: Plug connector, 14-pin
ERN with block commutation: Plug connector, 16-pin
ECN/EQN plug connector, 12-pin
ECN/EQN plug connector, 12-pin + 4-pin
H5 = ERN: Reference mark position indicated on shaft and cap
ECN/EQN: Zero position indicated on shaft and cap
H6 = Back-off thread M6
H7 = Back-off thread M10
H8 = Self-tightening screw, M5 x 50, DIN 6912, width A/F 4. Tightening torque: 5 + 0.5 Nm
H9 = Compensation of mounting tolerances and thermal expansion, no dynamic motion permitted
Direction of shaft rotation for output signals as per the interface description

	Incremental				
	ERN 1321	**ERN 1381**	**ERN 1387**	**ERN 1326**	
Incremental signals	⊓⊔TTL	∼ V_{PP}[1]		⊓⊔TTL	
Line count*/system accuracy	1024/± 64" 2048/± 32" 4096/± 16"	512/± 60" 2048/± 20" 4096/± 16"	2048/± 20"	1024/± 64" 2048/± 32" 4096/± 16"	8192/± 16"[5]
Reference mark	One				
Scanning frequency Edge separation a Cutoff frequency –3 dB	≥ 300 kHz ≥ 0.35 µs –	– ≥ 210 kHz		≥ 300 kHz ≥ 0.35 µs –	≥ 150 kHz ≥ 0.22 µs
Absolute position values	–		∼ V_{PP}[1]	⊓⊔TTL	
Position values per rev	–		Z1 track[2]	3 x ⊓⊔TTL[3]	
Power supply	5 V ± 10 %		5 V ± 5 %		
Current consumption without load	≤ 120 mA		≤ 130 mA	≤ 150 mA	
Electrical connection via PCB connector	12-pin		14-pin	16-pin	
Shaft	Taper shaft ∅ 9.25 mm; taper 1:10				
Mech. permissible speed n	≤ 15000 min^{-1}				
Starting torque at 20 °C	≤ 0.01 Nm				
Moment of inertia of rotor	$2.6 \cdot 10^{-6}$ kgm^2				
Natural frequency of the stator coupling	≥1800 Hz				
Permissible axis motion of measured shaft	± 0.5 mm				
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 300 m/s^2 [4] (EN 60068-2-6) ≤ 2000 m/s^2 (EN 60068-2-27)				
Max. operating temp.	120 °C	120 °C *4096 lines:* 80 °C	120 °C		
Min. operating temp.	–40 °C				
Protection EN 60529	IP 40 when mounted				
Weight	Approx. 0.25 kg				

* Please select when ordering

1) Restricted tolerances

Signal amplitude:	0.8 to 1.2 V_{PP}
Asymmetry:	0.05
Amplitude ratio:	0.9 to 1.1
Phase angle:	90° ± 5° elec.
Signal-to-noise ratio E, F:	100 mV

2) One sine and one cosine signal per revolution

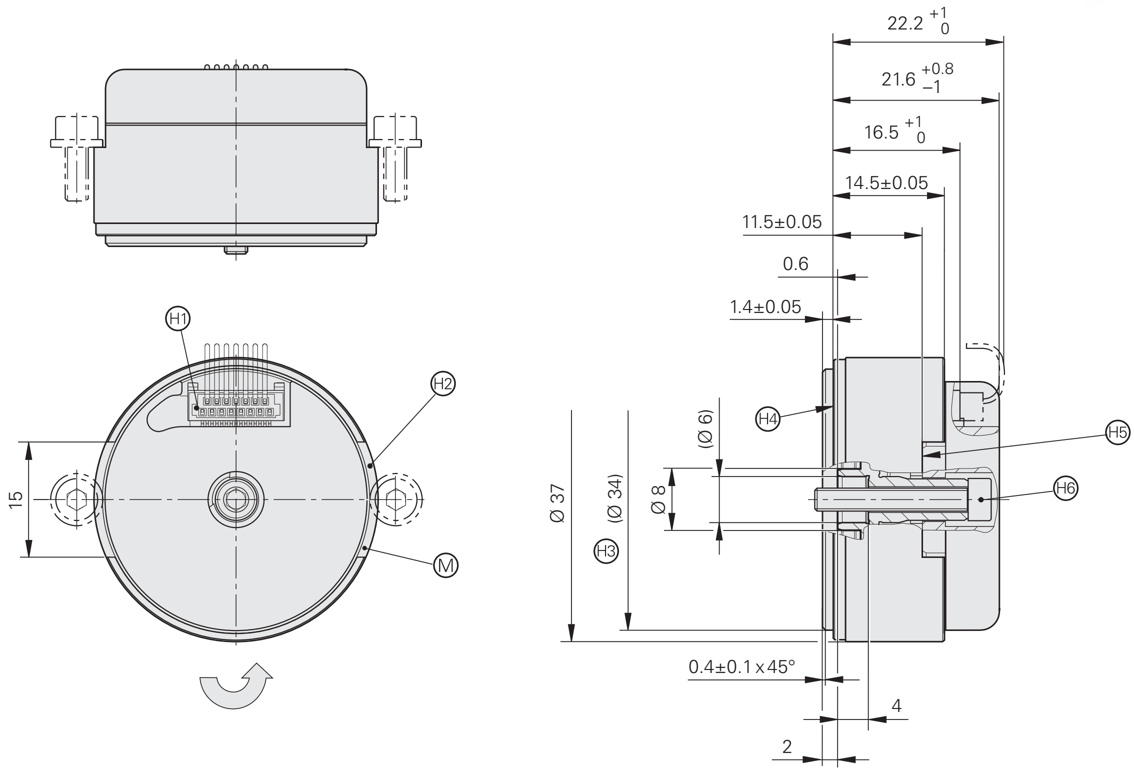
3) Three square-wave signals with signal periods of 90° or 120° mechanical phase shift

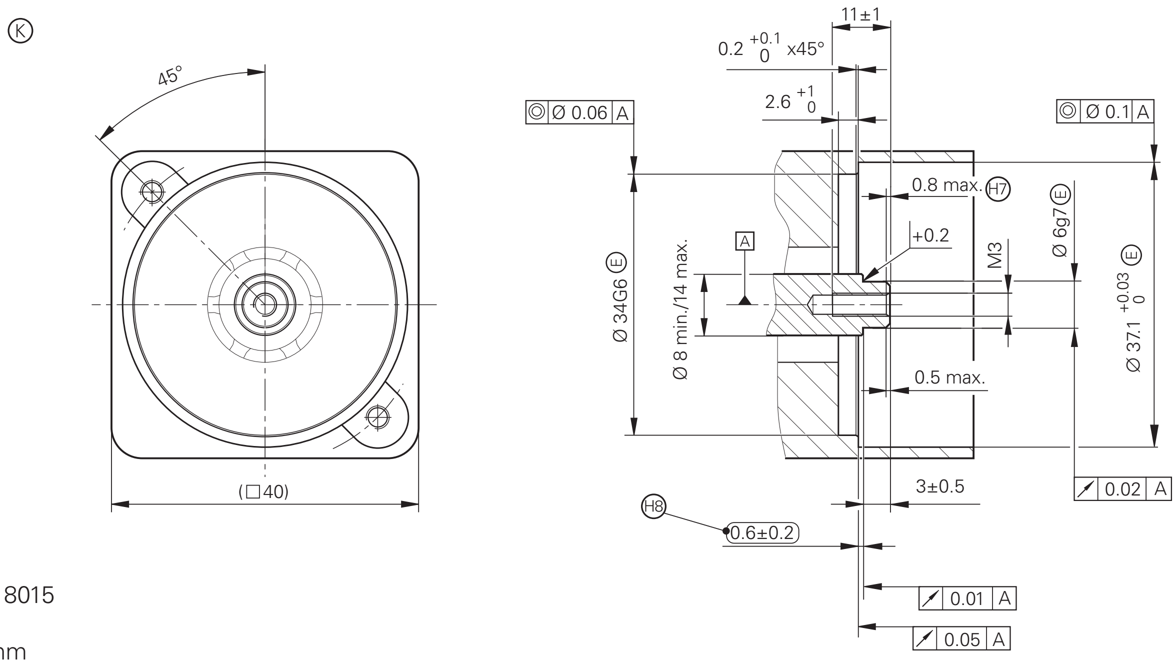
4) As per standard for room temperature, the following applies for operating temperature: Up to 100 °C: ≤ 300 m/s^2; Up to 120 °C: ≤ 150 m/s^2

5) Through integrated signal doubling

ECI/EQI 1100 Series

Rotary encoders without integral bearing for integration in motors
- **Installation diameter 37 mm**
- **Blind hollow shaft**





Dimensions in mm

Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

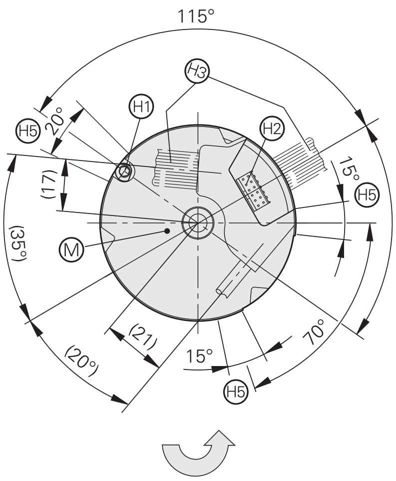
A = Bearing
K = Required mating dimensions
M = Measuring point for operating temperature
H1 = 15-pin plug connector
H2 = Permissible surface pressure (material: aluminum 230 N/mm^2)
H3 = Centering collar
H4 = Supporting surface
H5 = Clamping surfaces
H6 = Self-locking screw, M3 x 20, ISO 4762, width A/F 2.5. Tightening torque: 1.2 ± 0.1 Nm
H7 = Start of thread
H8 = Maximum permissible deviation between shaft and flange surfaces. Compensation of mounting tolerances and thermal expansion, no dynamic motion permitted
↻ Direction of shaft rotation for output signals as per the interface description

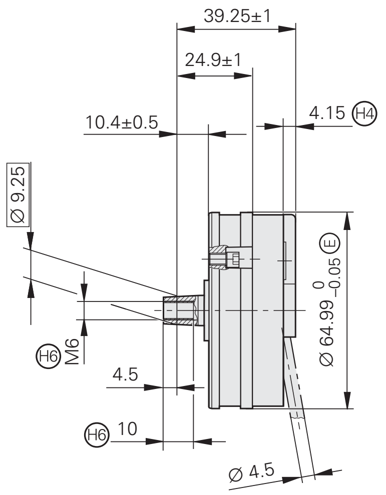
	Absolute			
	ECI 1118		**EQI 1130**	
Incremental signals	∿ 1 V_{PP}	None	∿ 1 V_{PP}	None
Line count	16	–	16	–
Cutoff frequency –3 dB	≥ 6 kHz	–	≥ 6 kHz	–
Absolute position values	EnDat 2.1			
Ordering designation*	EnDat 01	EnDat 21	EnDat 01	EnDat 21
Position values per rev	262 144 (18 bits)			
Revolutions	–		4 096 (12 bits)	
Elec. permissible speed/ Deviation[1)]	4 000 min^{-1}/± 400 LSB 15 000 min^{-1}/± 800 LSB	15 000 min^{-1} (for continuous position value)	4 000 min^{-1}/± 400 LSB 12 000 min^{-1}/± 800 LSB	12 000 min^{-1} (for continuous position value)
System accuracy	± 480"			
Calculation time t_{cal}	≤ 8 µs			
Power supply	5 V ± 5 %			
Current consumption without load	≤ 160 mA		≤ 190 mA	
Electrical connection	Via PCB connector, 15-pin			
Shaft	Blind hollow shaft ∅ 6 mm, axial clamping			
Mech. permissible speed n	≤ 15 000 min^{-1}		≤ 12 000 min^{-1}	
Moment of inertia of rotor	$0.76 \cdot 10^{-6}$ kgm^2			
Permissible axial motion of measured shaft	± 0.2 mm			
Vibration 55 to 2 000 Hz **Shock** 6 ms	≤ 300 m/s^2 (EN 60 068-2-6) ≤ 1 000 m/s^2 (EN 60 068-2-27)			
Max. operating temperature	115 °C			
Min. operating temperature	–20 °C			
Protection EN 60 529	IP 20 when mounted			
Weight	Approx. 0.06 kg			

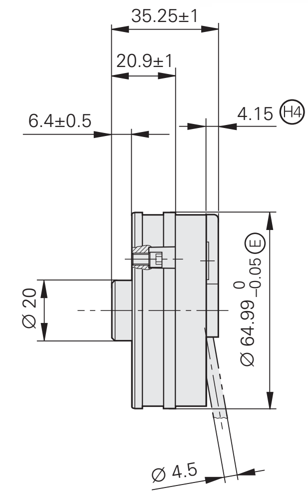
* Please select when ordering
1) Velocity-dependent deviation between the absolute and incremental signals

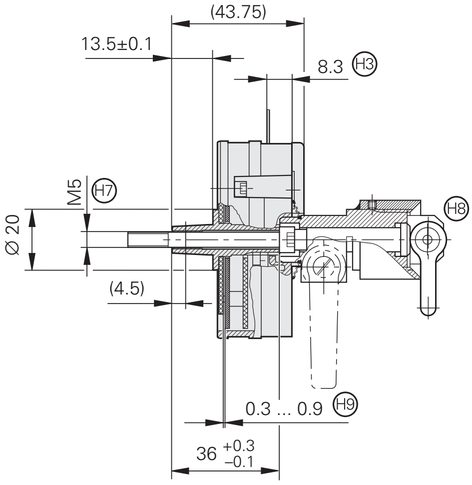
ECI/EQI 1300 Series

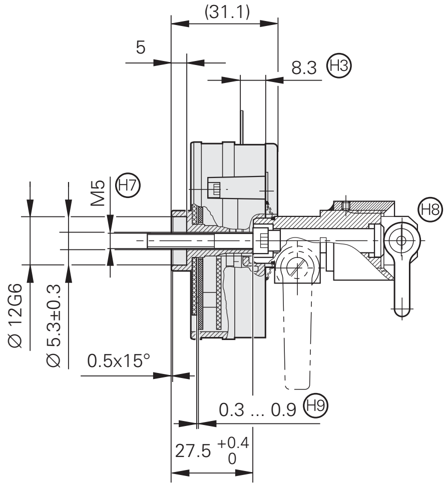
Rotary encoders without integral bearing for integration in motors
- **Installation diameter 65 mm**
- **Taper shaft or blind hollow shaft**







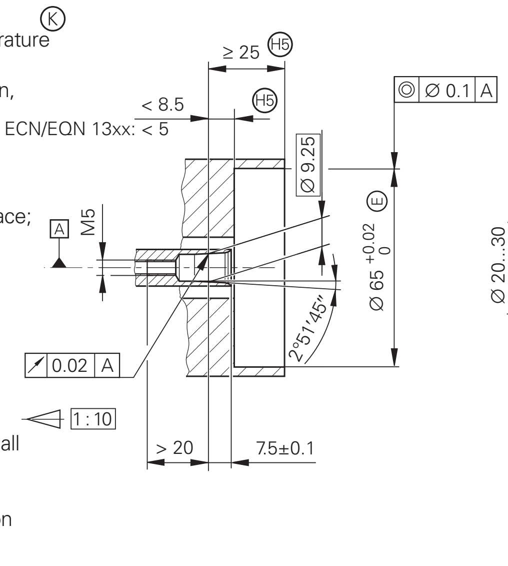


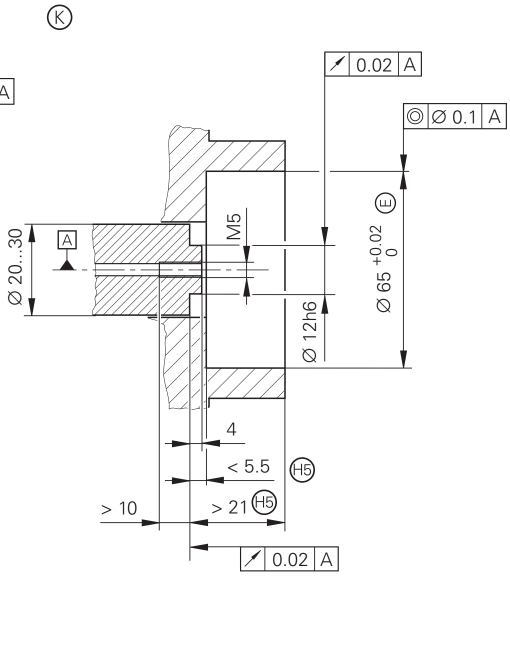


Dimensions in mm

Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

A = Bearing
K = Required mating dimensions
M = Measuring point for operating temperature
H1 = Mounting screw
Turn back by more than one revolution, and tighten with 2-0.5 Nm
H2 = Plug connector, 12-pin
H3 = Cable outlet for ribbon cable
H4 = Cable outlet for round cable
H5 = Minimum clamping and support surface; a closed diameter is best
H6 = Back-off thread M6
H7 = Cheese-head screw for hollow shaft:
ISO 4762 – M5 x 35-A2
Cheese-head screw for taper shaft:
ISO 4762 – M5 x 50-A2
Tightening torque: 5 Nm
H8 = Setting tool for scanning gap
H9 = Permissible scanning gap range over all operating conditions
Direction of shaft rotation for output signals as per the interface description



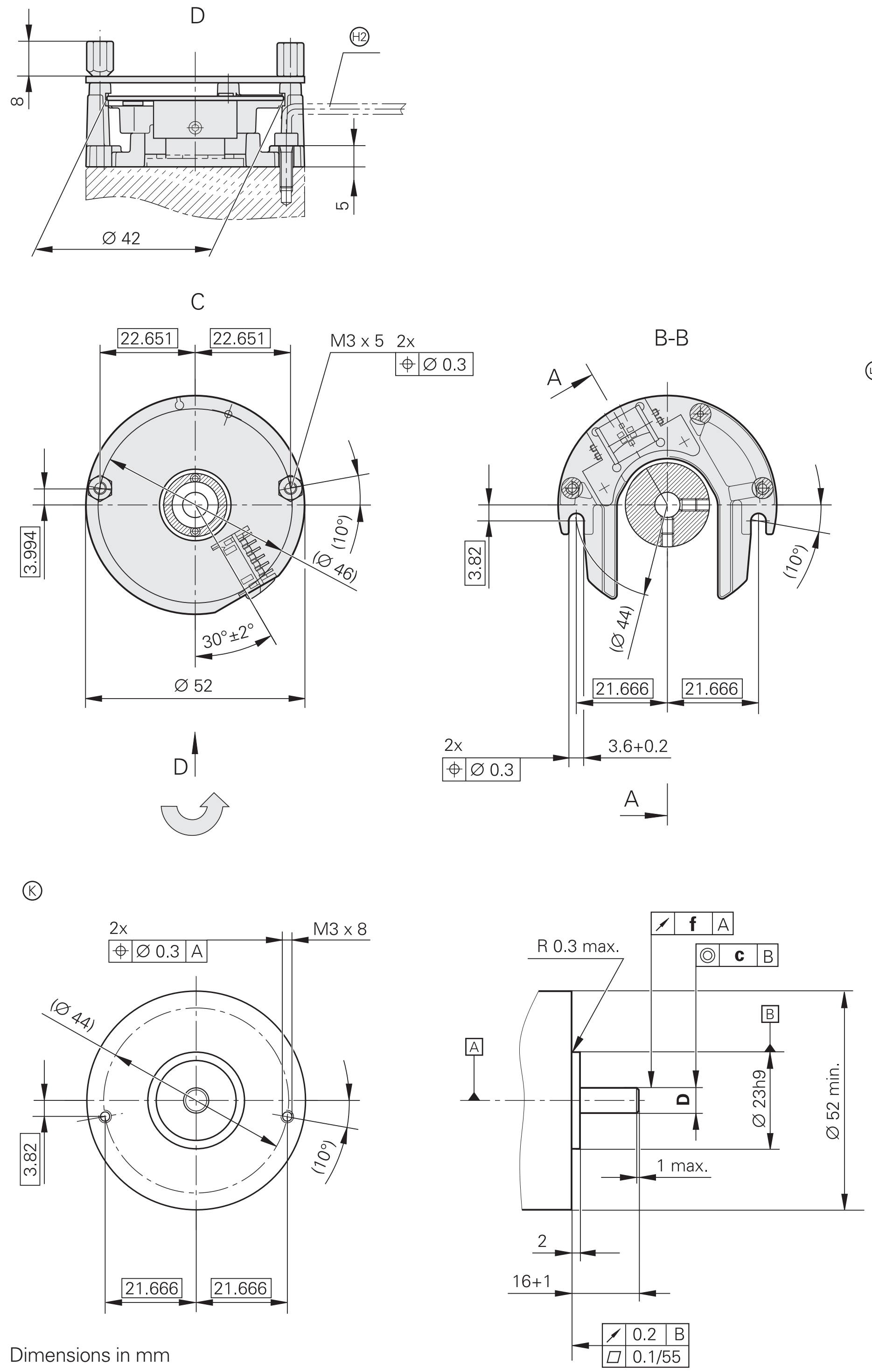


	Absolute	
	ECI 1319	**EQI 1331**
Incremental signals	∿ 1 V_{PP}	
Line count/system accuracy	32/± 280"	
Cutoff frequency –3 dB	≥ 6 kHz typical	
Absolute position values	EnDat 2.1	
Ordering designation	EnDat 01	
Position values per rev	524288 (19 bits)	
Revolutions	–	4096 (12 bits)
Elec. permissible speed/ Deviation[1)]	≤ 3750 min^{-1}/± 128 LSB ≤ 15000 min^{-1}/± 512 LSB	≤ 4000 min^{-1}/± 128 LSB ≤ 12000 min^{-1}/± 512 LSB
Calculation time t_{cal}	≤ 8 µs	
Power supply*	5 V ± 5 % or 7 to 10 V	
Current consumption without load	≤ 170 mA	
Electrical connection	Via 12-pin PCB connector	
Shaft*/Moment of inertia of rotor	Taper shaft Ø 9.25 mm; Taper 1:10 /2.2 x 10^{-6} kgm^2 Blind hollow shaft Ø 12.0 mm; Length 5 mm /3.2 x 10^{-6} kgm^2	
Mech. permissible speed n	≤ 15000 min^{-1}	≤ 12000 min^{-1}
Permissible axial motion of measured shaft	–0.2/+0.4 mm with 0.5 mm scanning gap	
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 100 m/s^2 (EN 60068-2-6) ≤ 1000 m/s^2 (EN 60068-2-27)	
Max. operating temperature	115 °C	
Min. operating temperature	–20 °C	
Protection EN 60529	IP 20 when mounted	
Weight	Approx. 0.13 kg	

* Please select when ordering
1) Velocity-dependent deviations between the absolute and incremental signals

ERO 1200 Series

Rotary encoders without integral bearing for integration in motors
- **Installation diameter 52 mm**
- **Hollow through shaft**



Dimensions in mm

Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

A = Bearing
K = Required mating dimensions
H1 = Disk/hub assembly
H2 = Offset screwdriver ISO 2936 – 2.5 (l_2 shortened)
Direction of shaft rotation for output signals as per the interface description

D
Ø 10h6 E
Ø 12h6 E

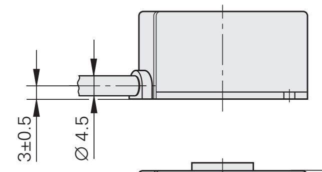
	Z	a	f	c
ERO 1225	1024	0.6 ± 0.2	Ø 0.05	Ø 0.02
	2048	0.2 ± 0.05		
ERO 1285	1024 2048	0.2 ± 0.03	Ø 0.03	Ø 0.02

	Incremental	
	ERO 1225	ERO 1285
Incremental signals	⊓⊔TTL	∼ 1 V_{PP}
Line count*	1024 2048	
System accuracy[1])/ Accuracy of the graduation[2])	*1024 lines:* ± 92"/± 6" *2048 lines:* ± 73"/± 6"	*1024 lines:* ± 67"/± 6" *2048 lines:* ± 60"/± 6"
Reference mark	One	
Scanning frequency Edge separation a Cutoff frequency –3 dB	≤ 300 kHz ≥ 0.39 µs –	– – ≥ 180 kHz typical
Power supply	5 V ± 10 %	
Current consumption without load	≤ 150 mA	
Electrical connection	Via 12-pin PCB connector	
Shaft*	Hollow through shaft ∅ 10 mm or ∅ 12 mm	
Moment of inertia of rotor	*Shaft ∅ 10 mm:* 2.2 · 10^{-6} kgm^2 *Shaft ∅ 12 mm:* 2.15 · 10^{-6} kgm^2	
Mech. permissible speed n	≤ 25000 min^{-1}	
Permissible axial motion of measured shaft	*1024 lines:* ± 0.2 mm *2048 lines:* ± 0.05 mm	± 0.03 mm
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 100 m/s^2 (EN 60068-2-6) ≤ 1000 m/s^2 (EN 60068-2-27)	
Max. operating temperature	100 °C	
Min. operating temperature	–40 °C	
Protection EN 60529	IP 00	
Weight	Approx. 0.07 kg	

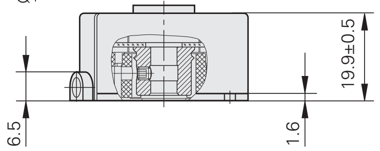
* Please select when ordering
1) Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.
2) For other errors, see *Measuring Accuracy*

ERO 1400 Series

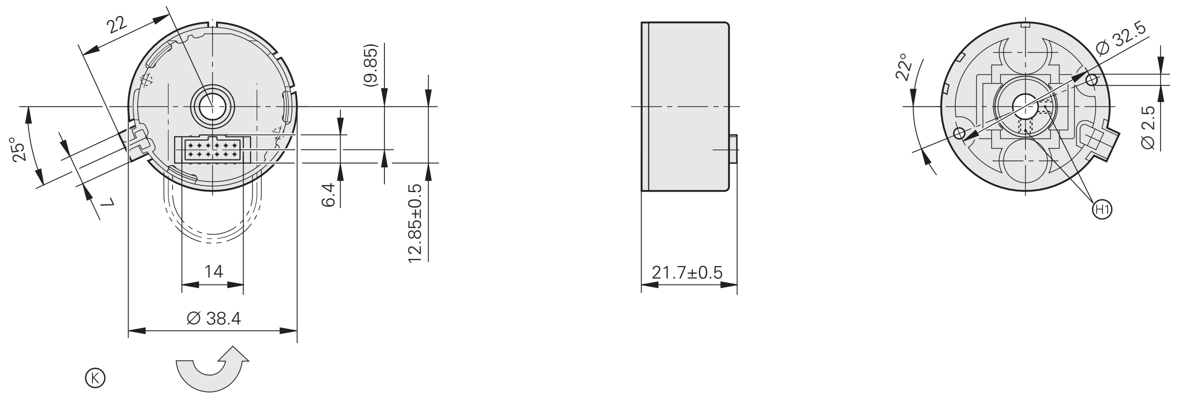
Rotary encoders without integral bearing
- **For integration in motors with PCB connector (protection IP 00)**
- **For mounting on motors with cable outlet (protection IP 40)**
- **Installation diameter 44 mm**

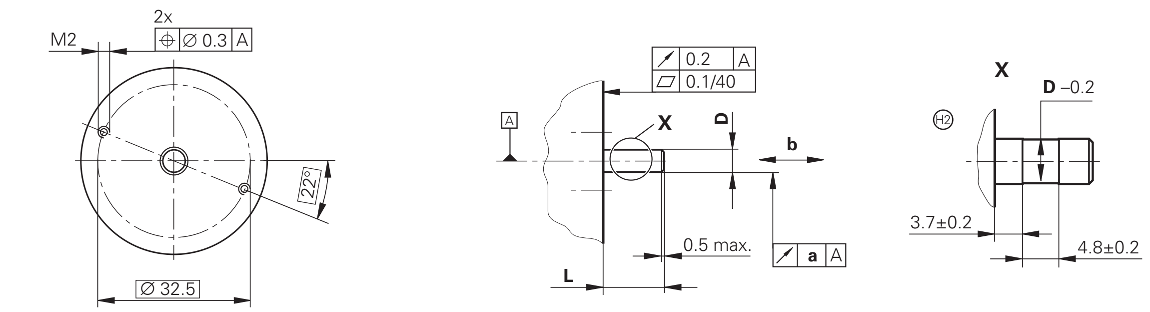


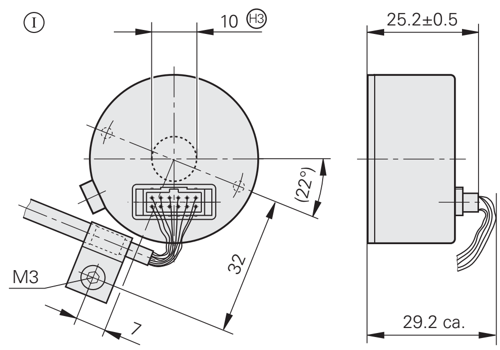
With cable exit



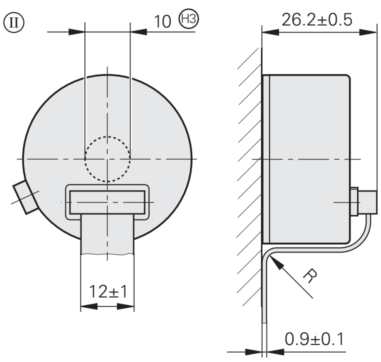
With axial PCB connector







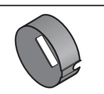
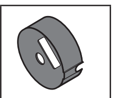
Axial PCB connector and round cable



Axial PCB connector and ribbon cable

Dimensions in mm

Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

		
L	13+4.5/–3	10 min.

Bend radius R	**Rigid configuration**	**Frequent flexing**
Ribbon cable	R ≥ 2 mm	R ≥ 10 mm

A = Bearing
K = Required mating dimensions
I = Accessory: Round cable
II = Accessory: Ribbon cable
H1 = Setscrew, 2x90° offset, M3, width A/F 1.5 Md = 0.25 ±0.05 Nm
H2 = Version for repeated assembly
H3 = Version featuring housing with central hole (accessory)
Direction of shaft rotation for output signals as per the interface description

	a	**b**	**D**
ERO 1420	0.03	± 0.1	Ø 4h6 Ⓔ
ERO 1470	0.02	± 0.05	Ø 6h6 Ⓔ
ERO 1480			Ø 8h6 Ⓔ

	Incremental					
	ERO 1420	**ERO 1470**				**ERO 1480**
Incremental signals	⊓⊔TTL	⊓⊔TTL x 5	⊓⊔TTL x 10	⊓⊔TTL x 20	⊓⊔TTL x 25	∼ $1\ V_{PP}$
Line count*	512 **1000** **1024**	**1000** 1500				512 **1000** **1024**
Integrated interpolation*	–	5-fold	**10-fold**	20-fold	25-fold	–
Signal periods/rev	512 1000 1024	5000 7500	10000 15000	20000 30000	25000 37500	512 1000 1024
Edge separation a	≥ 0.39 µs	≥ 0.47 µs	≥ 0.22 µs	≥ 0.17 µs	≥ 0.07 µs	–
Scanning frequency	≤ 300 kHz	≤ 100 kHz		≤ 62.5 kHz	≤ 100 kHz	–
Cutoff frequency –3 dB	–					≥ 180 kHz
System accuracy	*512 lines:* ± 139" *1000 lines:* ± 112" *1024 lines:* ± 112"	*1000 lines:* ± 130" *1500 lines:* ± 114"				*512 lines:* ± 190" *1000 lines:* ± 163" *1024 lines:* ± 163"
Reference mark	One					
Power supply	5 V ± 10 %	5 V ± 5 %				5 V ± 10 %
Current consumption without load	≤ 150 mA	≤ 155 mA		≤ 200 mA		≤ 150 mA
Electrical connection*	• Over 12-pin axial **PCB connector** • Cable 1 m, radial, without connecting element (not with ERO 1470)					
Shaft*	**Blind hollow shaft** ∅ 4 mm; **∅ 6 mm** or ∅ 8 mm or hollow through shaft in housing with bore (accessory)					
Moment of inertia of rotor	*Shaft ∅ 4 mm:* $0.28 \cdot 10^{-6}$ kgm² *Shaft ∅ 6 mm:* $0.27 \cdot 10^{-6}$ kgm² *Shaft ∅ 8 mm:* $0.25 \cdot 10^{-6}$ kgm²					
Mech. permissible speed n	≤ 30000 min^{-1}					
Permissible axial motion of measured shaft	± 0.1 mm	± 0.05 mm				
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 100 m/s^2 (EN 60068-2-6) ≤ 1000 m/s^2 (EN 60068-2-27)					
Max. operating temperature	70 °C					
Min. operating temperature	–10 °C					
Protection EN 60529	*With PCB connector:* IP 00 *With cable outlet:* IP 40					
Weight	Approx. 0.07 kg					

Bold: These preferred versions are available on short notice
* Please select when ordering
1) Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.

Interfaces
Incremental Signals ∿ 1 V_{PP}

HEIDENHAIN encoders with ∿ 1 V_{PP} interface provide voltage signals that can be highly interpolated.

The sinusoidal **incremental signals** A and B are phase-shifted by 90° elec. and have an amplitude of typically 1 V_{PP}. The illustrated sequence of output signals—with B lagging A—applies for the direction of motion shown in the dimension drawing.

The **reference mark signal** R has a usable component G of approx. 0.5 V. Next to the reference mark, the output signal can be reduced by up to 1.7 V to a quiescent level H. This must not cause the subsequent electronics to overdrive. Even at the lowered signal level, signal peaks with the amplitude G can also appear.

The data on **signal amplitude** apply when the power supply given in the specifications is connected to the encoder. They refer to a differential measurement at the 120 ohm terminating resistor between the associated outputs. The signal amplitude decreases with increasing frequency. The **cutoff frequency** indicates the scanning frequency at which a certain percentage of the original signal amplitude is maintained:
- –3 dB ≙ 70 % of the signal amplitude
- -6 dB ≙ 50 % of the signal amplitude

The data in the signal description apply to motions at up to 20 % of the –3 dB cutoff frequency.

Interpolation/resolution/measuring step
The output signals of the 1-V_{PP} interface are usually interpolated in the subsequent electronics in order to attain sufficiently high resolutions. For **velocity control,** interpolation factors are commonly over 1000 in order to receive usable velocity information even at low speeds.

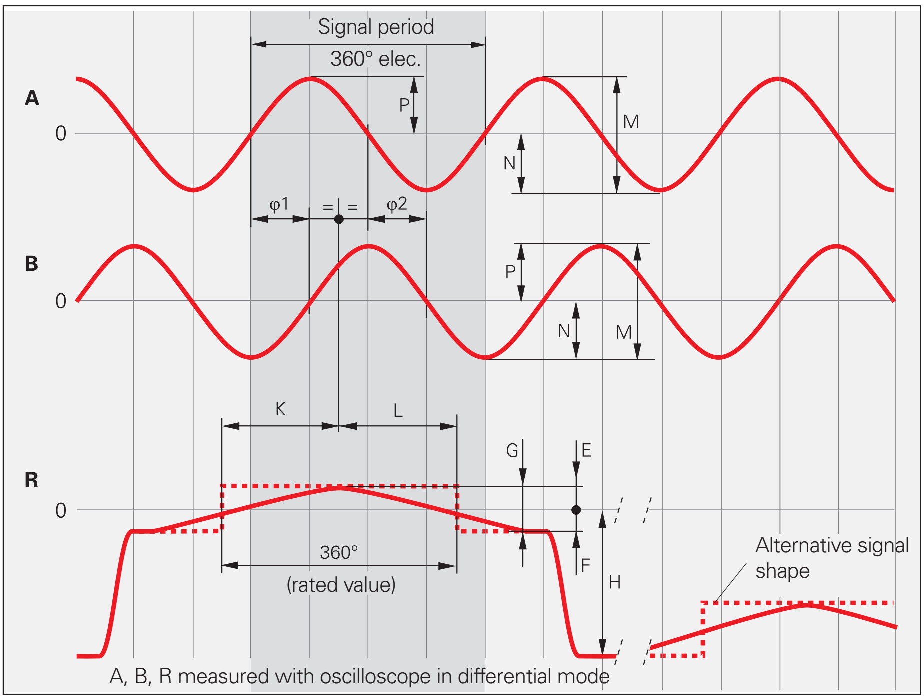
Measuring steps for **position measurement** are recommended in the specifications. For special applications, other resolutions are also possible.

Short-circuit stability
A temporary short circuit of one signal output to 0 V or U_P (except encoders with U_{Pmin} = 3.6 V) does not cause encoder failure, but it is not a permissible operating condition.

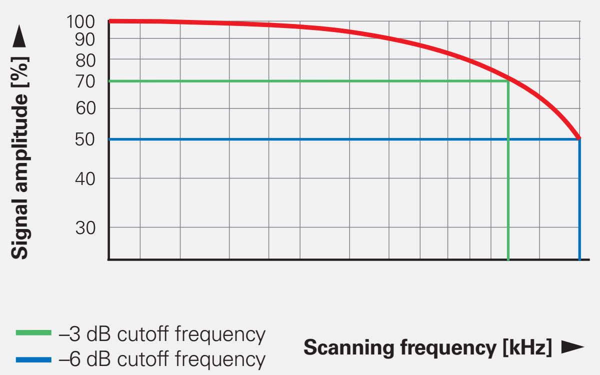
Short circuit at	20 °C	125 °C
One output	< 3 min	< 1 min
All outputs	< 20 s	< 5 s

Interface	Sinusoidal voltage signals ∿ **1 V_{PP}**
Incremental signals	**2 nearly sinusoidal signals A and B** Signal amplitude M: 0.6 to 1.2 V_{PP}; typically 1 V_{PP} Asymmetry |P – N|/2M: ≤ 0.065 Amplitude ratio M_A/M_B: 0.8 to 1.25 Phase angle |φ1 + φ2|/2: 90° ± 10° elec.
Reference-mark signal	**One or several signal peaks R** Usable component G: ≥ 0.2 V Quiescent value H: ≤ 1.7 V Switching threshold E, F: 0.04 to 0.68 V Zero crossovers K, L: 180° ± 90° elec.
Connecting cable Cable length Propagation time	Shielded HEIDENHAIN cable PUR [4(2 x 0.14 mm²) + (4 x 0.5 mm²)] Max. 150 m with 90 pF/m distributed capacitance 6 ns/m

These values can be used for dimensioning of the subsequent electronics. Any limited tolerances in the encoders are listed in the specifications. For encoders without integral bearing, reduced tolerances are recommended for initial operation (see the mounting instructions).



Cutoff frequency
Typical signal amplitude curve with respect to the scanning frequency



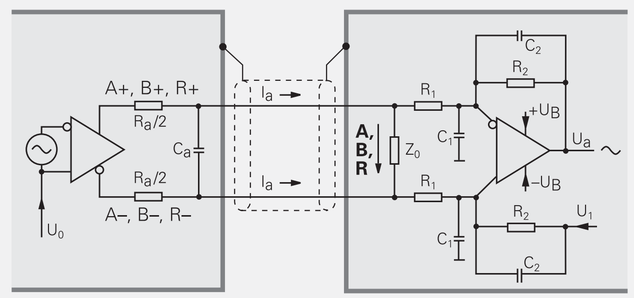
Input circuitry of the subsequent electronics

Dimensioning
Operational amplifier MC 34074
$Z_0 = 120\ \Omega$
$R_1 = 10\ k\Omega$ and $C_1 = 100\ pF$
$R_2 = 34.8\ k\Omega$ and $C_2 = 10\ pF$
$U_B = \pm 15\ V$
U_1 approx. U_0

–3dB cutoff frequency of circuitry
Approx. 450 kHz
Approx. 50 kHz with $C_1 = 1000\ pF$
and $C_2 = 82\ pF$
The circuit variant for 50 kHz does reduce the bandwidth of the circuit, but in doing so it improves its noise immunity.

Incremental signals
Reference-mark signal

$R_a < 100\ \Omega$, typically 24 Ω
$C_a < 50\ pF$
$\Sigma I_a < 1\ mA$
$U_0 = 2.5\ V \pm 0.5\ V$ (relative to 0 V of the power supply)

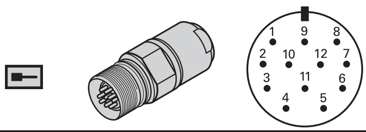


Circuit output signals
$U_a = 3.48\ V_{PP}$ typically
Gain 3.48

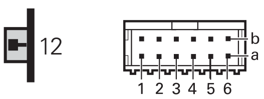
Monitoring of the incremental signals
The following thresholds are recommended for monitoring of the signal level M:
Lower threshold: $0.30\ V_{PP}$
Upper threshold: $1.35\ V_{PP}$

Pin Layout

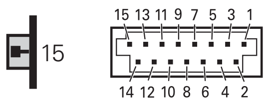
12-pin M23 **coupling**



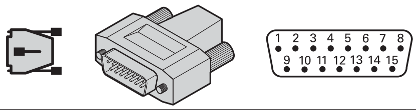
12-pin PCB connector



15-pin PCB connector



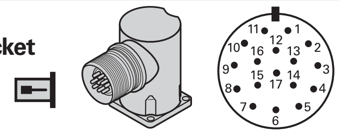
15-pin D-sub connector
For IK 215



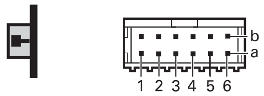
	Power supply				Incremental signals						Other signals		
	12	**2**	**10**	**11**	**5**	**6**	**8**	**1**	**3**	**4**	**9**	**7**	**/**
	4	**12**	**2**	**10**	**1**	**9**	**3**	**11**	**14**	**7**	**5/6/8/15**	**13**	**/**
12	**2a**	**2b**	**1a**	**1b**	**6b**	**6a**	**5b**	**5a**	**4b**	**4a**	**3b**	**3a**	**/**
15	**13**	**11**	**14**	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**8/9/10/15**	**7**	**/**
	U_P	**Sensor** U_P	**0 V**	**Sensor** 0 V	**A+**	**A–**	**B+**	**B–**	**R+**	**R–**	**Vacant**	**Vacant**	**Vacant**
	Brown/ Green	Blue	White/ Green	White	Brown	Green	Gray	Pink	Red	Black	/	Violet	Yellow

Output cable for ERN 1381 in the motor
ID 340 111-xx

17-pin flange socket
M23



12-pin PCB connector



	Power supply				Incremental signals						Other signals		
	7	**1**	**10**	**4**	**15**	**16**	**12**	**13**	**3**	**2**	**5**	**6**	**8/9/11/ 14/17**
12	**2a**	**2b**	**1a**	**1b**	**6b**	**6a**	**5b**	**5a**	**4b**	**4a**	**/**	**/**	**3a/3b**
	U_P	**Sensor** U_P	**0 V**	**Sensor** 0 V	**A+**	**A–**	**B+**	**B–**	**R+**	**R–**	**T+**1)	**T–**1)	**Vacant**
	Brown/ Green	Blue	White/ Green	White	Brown	Green	Gray	Pink	Red	Black	Brown1)	White1)	/

Cable shield connected to housing; **U_P** = power supply; 1) Only for encoder cable inside the motor housing
Sensor: The sensor line is connected in the encoder with the corresponding power line
Vacant pins or wires must not be used!

Interfaces

Incremental Signals ⊓⊔TTL

HEIDENHAIN encoders with ⊓⊔TTL interface incorporate electronics that digitize sinusoidal scanning signals with or without interpolation.

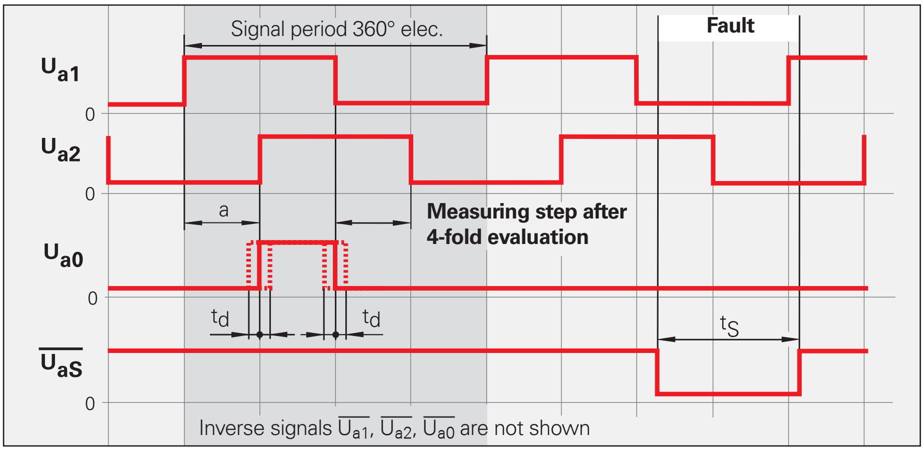
The **incremental signals** are transmitted as the square-wave pulse trains U_{a1} and U_{a2}, phase-shifted by 90° elec. The **reference mark signal** consists of one or more reference pulses U_{a0}, which are gated with the incremental signals. In addition, the integrated electronics produce their **inverted signals** $\overline{U_{a1}}$, $\overline{U_{a2}}$ and $\overline{U_{a0}}$ for noise-proof transmission. The illustrated sequence of output signals—with U_{a2} lagging U_{a1}—applies to the direction of motion shown in the dimension drawing.

The **fault-detection signal** $\overline{U_{aS}}$ indicates fault conditions such as breakage of the power line or failure of the light source. It can be used for such purposes as machine shut-off during automated production.

The distance between two successive edges of the incremental signals U_{a1} and U_{a2} through 1-fold, 2-fold or 4-fold evaluation is one **measuring step.**

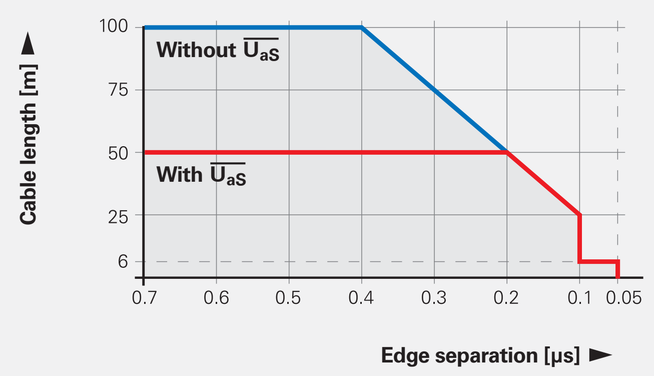
The subsequent electronics must be designed to detect each edge of the square-wave pulse. The minimum **edge separation a** listed in the *Specifications* applies to the illustrated input circuitry with a cable length of 1 m, and refers to a measurement at the output of the differential line receiver. Propagation-time differences in cables additionally reduce the edge separation by 0.2 ns per meter of cable length. To prevent counting errors, design the subsequent electronics to process as little as 90 % of the resulting edge separation. The max. permissible **shaft speed** or **traversing velocity** must never be exceeded.

Interface	Square-wave signals **⊓⊔TTL**
Incremental signals	**2 TTL square-wave signals U_{a1}, U_{a2}** and their inverted signals $\overline{U_{a1}}$, $\overline{U_{a2}}$
Reference-mark signal Pulse width Delay time	**1 or more TTL square-wave pulses U_{a0}** and their inverted pulses $\overline{U_{a0}}$ 90° elec. (other widths available on request); *LS 323:* ungated $\vert t_d\vert \leq 50$ ns
Fault-detection signal Pulse width	**1 TTL square-wave pulse $\overline{U_{aS}}$** Improper function: LOW (upon request: U_{a1}/U_{a2} high impedance) Proper function: HIGH $t_S \geq 20$ ms
Signal amplitude	Differential line driver as per EIA standard RS-422 $U_H \geq 2.5$ V at $-I_H = 20$ mA $U_L \leq 0.5$ V at $I_L = 20$ mA
Permissible load	$Z_0 \geq 100\ \Omega$ between associated outputs $\vert I_L\vert \leq 20$ mA max. load per output $C_{load} \leq 1000$ pF with respect to 0 V Outputs protected against short circuit to 0 V
Switching times (10 % to 90 %)	$t_+ / t_- \leq 30$ ns (typically 10 ns) with 1 m cable and recommended input circuitry
Connecting cable Cable length Propagation time	Shielded HEIDENHAIN cable PUR [4(2 × 0.14 mm^2) + (4 × 0.5 mm^2)] Max. 100 m ($\overline{U_{aS}}$ max. 50 m) at distributed capacitance 90 pF/m 6 ns/m



The permissible **cable length** for transmission of the TTL square-wave signals to the subsequent electronics depends on the edge separation a. It is at most 100 m, or 50 m for the fault detection signal. This requires, however, that the power supply (see *Specifications*) be ensured at the encoder. The sensor lines can be used to measure the voltage at the encoder and, if required, correct it with an automatic control system (remote sense power supply).

Permissible cable length
with respect to the edge separation

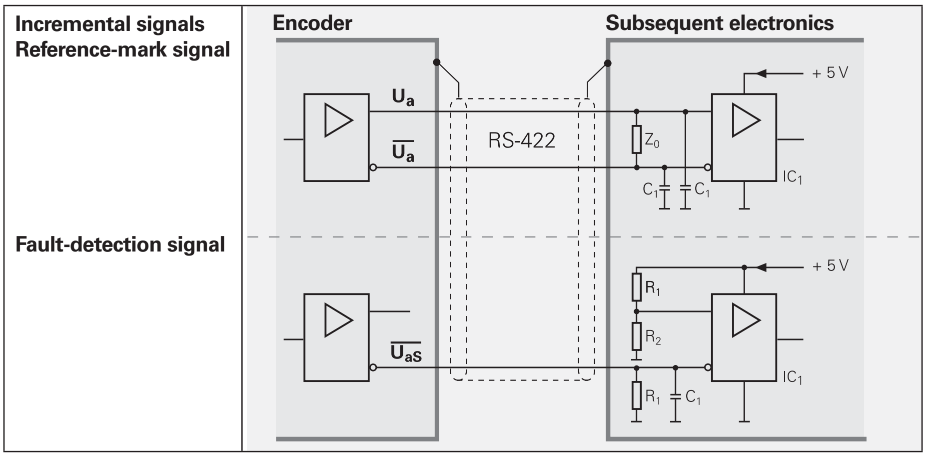


Input circuitry of the subsequent electronics

Dimensioning

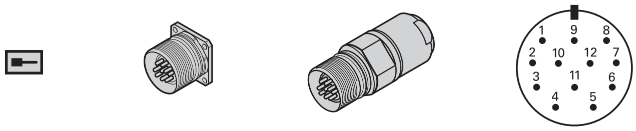
IC_1 = Recommended differential line receiver
DS 26 C 32 AT
Only for a > 0.1 µs:
AM 26 LS 32
MC 3486
SN 75 ALS 193

R_1 = 4.7 kΩ
R_2 = 1.8 kΩ
Z_0 = 120 Ω
C_1 = 220 pF (serves to improve noise immunity)

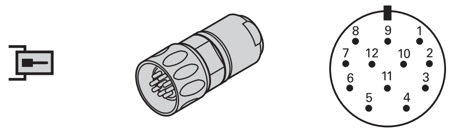


Pin Layout

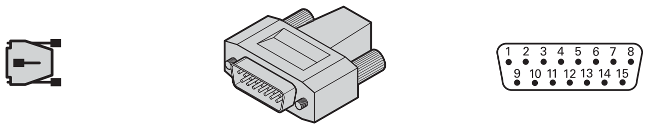
12-pin flange socket or M23 **coupling**



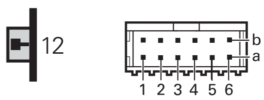
12-pin M23 **connector**



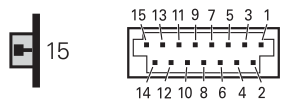
15-pin D-sub connector
for IK 215



12-pin PCB connector



15-pin PCB connector



	Power supply				Incremental signals						Other signals		
	12	**2**	**10**	**11**	**5**	**6**	**8**	**1**	**3**	**4**	**7**	**/**	**9**
	4	**12**	**2**	**10**	**1**	**9**	**3**	**11**	**14**	**7**	**13**	**5/6/8**	**15**
12	**2a**	**2b**[1]	**1a**	**1b**[1]	**6b**	**6a**	**5b**	**5a**	**4b**	**4a**	**3a**	**3b**	**/**
15	**13**	**11**	**14**	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8/9/10/15**	**/**
	U_P	**Sensor** U_P	**0 V**	**Sensor** 0 V	U_{a1}	$\overline{U_{a1}}$	U_{a2}	$\overline{U_{a2}}$	U_{a0}	$\overline{U_{a0}}$	$\overline{U_{aS}}$[1]	**Vacant**	**Vacant**[2]
	Brown/Green	Blue	White/Green	White	Brown	Green	Gray	Pink	Red	Black	Violet	/	Yellow

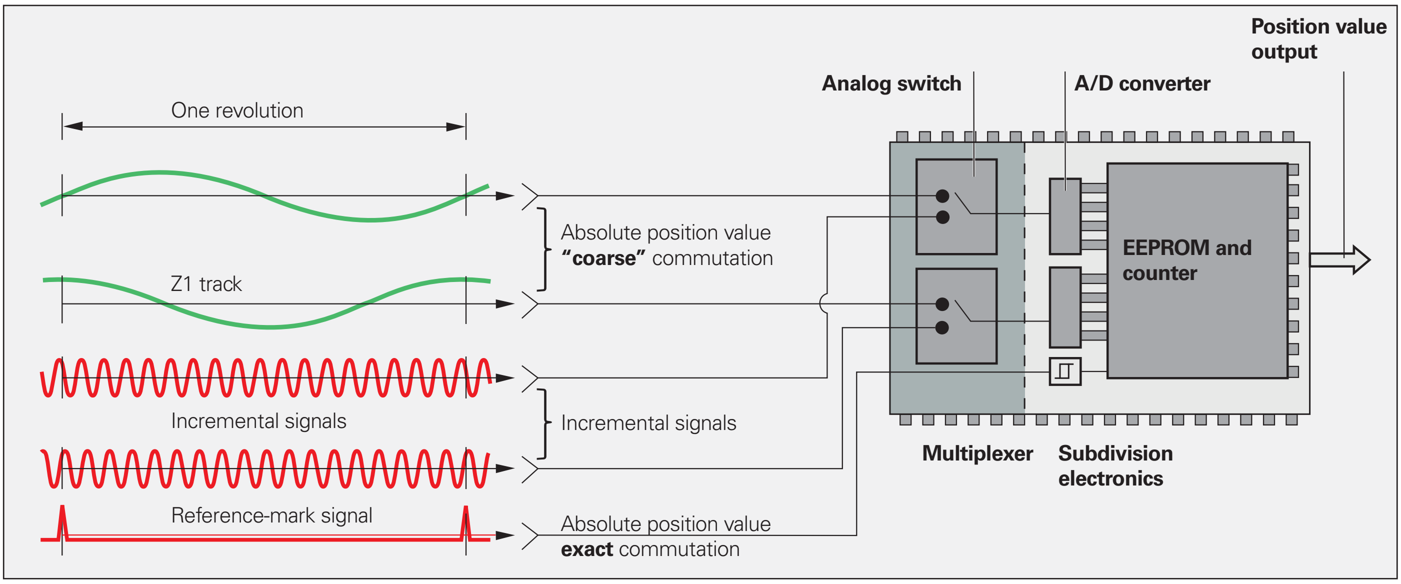
Cable shield connected to housing; U_P = power supply voltage
Sensor: The sensor line is connected in the encoder with the corresponding power line
Vacant pins or wires must not be used!
1) **ERO 14xx:** Vacant
2) **Exposed linear encoders:** Switchover TTL/11 µAPP for PWT, otherwise vacant

Interfaces
Commutation Signals for Sinusoidal Commutation

The **commutation signals C and D** are taken from the so-called Z1 track and form one sine or cosine period per revolution. They have a signal amplitude of typically 1 V_{PP} at 1 kΩ. The input circuitry of the subsequent electronics is the same as for the ∿ 1 V_{PP} interface. The required terminating resistor of Z_0 however, is 1 kΩ instead of 120 Ω. The **ERN 1185** and **ERN 1387** are rotary encoders with commutation signals for sinusoidal commutation.

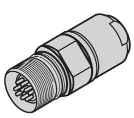
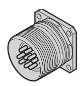
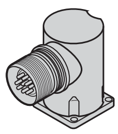
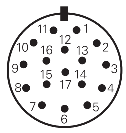
Interface	Sinusoidal voltage signals ∿ **1 V_{PP}**
Commutation signals	**2 nearly sinusoidal signals C and D** See *Incremental Signals* ∿ *1 V_{PP}*
Incremental signals	See *Incremental Signals* ∿ *1 V_{PP}*
Connecting cable Cable length Propagation time	Shielded HEIDENHAIN cable PUR [4(2 x 0.14 mm^2) + 4(2 x 0.14 mm^2) + (4 x 0.5 mm^2)] Max. 150 m 6 ns/m

Electronic commutation with Z1 track

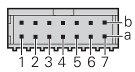


Pin Layout

17-pin HEIDENHAIN M23 coupling or M23 flange socket

14-pin PCB connector



	Power supply					Incremental signals					
	7	1	10	4	11	15	16	12	13	3	2
	1b	7a	5b	3a	/	6b	2a	3b	5a	4b	4a
	U_P	**Sensor** U_P [1]	**0 V**	**Sensor** 0 V [1]	**Internal shield**	**A+**	**A–**	**B+**	**B–**	**R+**	**R–**
	Brown/ Green	Blue	White/ Green	White	/	Green/ Black	Yellow/ Black	Blue/Black	Red/Black	Red	Black

	Other signals					
	14	17	9	8	5	6
	7b	1a	2b	6a	/	/
	C+	**C–**	**D+**	**D–**	**T+** [2]	**T–** [2]
	Gray	Pink	Yellow	Violet	Green	Brown

Cable shield connected to housing;
U_P = power supply; **T** = temperature
Sensor: The sensor line is connected internally with the corresponding power line.
Vacant pins or wires must not be used!

[1] Not assigned if a power of 7 to 10 V is supplied via motor-internal adapter cable
[2] Only for motor-internal adapter cables

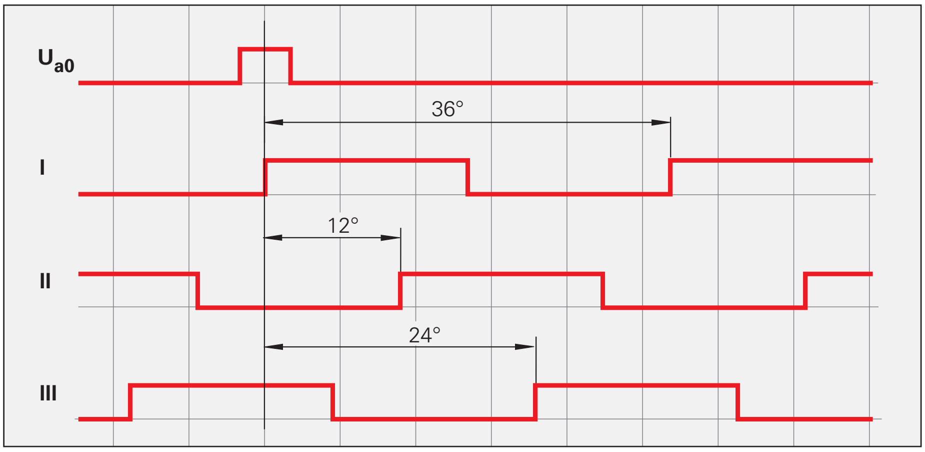
Commutation Signals for Block Commutation

The **block commutation signals I, II and III** are derived from three separate absolute tracks. They are transmitted as square-wave signals in TTL levels.

The **ERN 1326.** is a rotary encoder with output signals for block commutation.

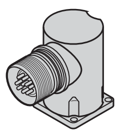
Interface	Square-wave signals **⊓⊔TTL**
Commutation signals Width Signal levels	Three square-wave signals I, II, III and their inverse signals $\overline{I}$, $\overline{II}$, $\overline{III}$ 120° mech. or 90° mech. (other versions upon request) See *Incremental Signals* ⊓⊔ *TTL*
Incremental signals	See *Incremental Signals* ⊓⊔ *TTL*
Connecting cable Cable length Propagation time	Shielded HEIDENHAIN cable PUR [4(2 x 0.14 mm²) + 4(2 x 0.14 mm²) + (4 x 0.5 mm²)] Max. 100 m 6 ns/m

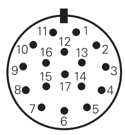
Example of a signal sequence for block commutation



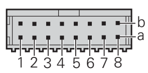
Pin Layout

17-pin flange socket
M23





16-pin PCB connector



	Power supply				Incremental signals					
	7	**1**	**10**	**11**	**15**	**16**	**12**	**13**	**3**	**2**
	1b	**2b**	**1a**	**/**	**5b**	**5a**	**4b**	**4a**	**3b**	**3a**
	U_P	**Sensor** U_P	**0 V**	**Internal shield**	U_{a1}	$\overline{U_{a1}}$	U_{a2}	$\overline{U_{a2}}$	U_{a0}	$\overline{U_{a0}}$
	Brown/ Green	Blue	White/ Green	/	Green/ Black	Yellow/ Black	Blue/ Black	Red/ Black	Red	Black

	Other signals						
	4	**5**	**6**	**14**	**17**	**9**	**8**
	2a	**8b**	**8a**	**6b**	**6a**	**7b**	**7a**
	$\overline{U_{aS}}$	**I**	$\overline{I}$	**II**	$\overline{II}$	**III**	$\overline{III}$
	White	Green	Brown	Yellow	Violet	Gray	Pink

Cable shield connected to housing; **U_P** = power supply
Sensor: The sensor line is connected internally with the corresponding power line.
Vacant pins or wires must not be used!

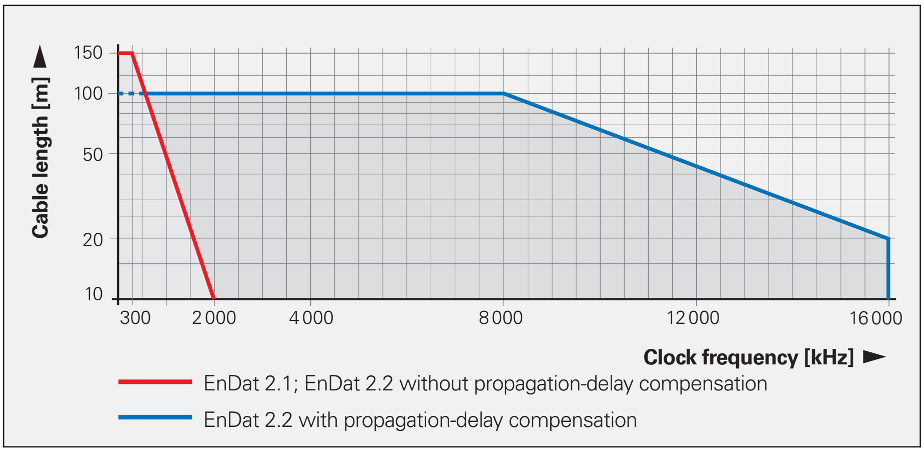
Interfaces
Absolute Position Values EnDat

The EnDat interface is a digital, **bidirectional** interface for encoders. It is capable of transmitting **position values** from both absolute and—with EnDat 2.2—incremental encoders, as well as reading and updating information stored in the encoder, or of saving new information. Thanks to the **serial transmission method**, only **four signal lines** are required. The data is transmitted in **synchronism** with the CLOCK signal from the subsequent electronics. The type of transmission (position values, parameters, diagnostics, etc.) is selected through mode commands that the subsequent electronics send to the encoder.

Clock frequency and cable length
Without propagation-delay compensation, the **clock frequency**—depending on the cable length—is variable between **100 kHz** and **2 MHz.**

Because large cable lengths and high clock frequencies increase the signal run time to the point that they can disturb the unambiguous assignment of data, the delay can be measured in a test run and then compensated. With this **propagation-delay compensation** in the subsequent electronics, clock frequencies **up to 16 MHz** at cable lengths up to a maximum of 100 m ($f_{CLK} \leq 8$ MHz) are possible. The maximum clock frequency is mainly determined by the cables and connecting elements used. To ensure proper function at clock frequencies above 2 MHz, use only original ready-made HEIDENHAIN cables.

Interface	**EnDat** serial bidirectional
Data transfer	Absolute position values, parameters and additional information
Data input	Differential line receiver according to EIA standard RS 485 for the signals CLOCK, $\overline{\text{CLOCK}}$, DATA and $\overline{\text{DATA}}$
Data output	Differential line driver according to EIA standard RS 485 for the signals DATA and $\overline{\text{DATA}}$
Code	Pure binary code
Position values	Ascending during traverse in direction of arrow (see dimensions of the encoders)
Incremental signals	∼ 1 V_{PP} (see *Incremental Signals 1* V_{PP}) depending on the unit
Connecting cable With Incremental Without signals	Shielded HEIDENHAIN cable PUR [(4 x 0.14 mm^2) + 4(2 x 0.14 mm^2) + (4 x 0.5 mm^2)] PUR [(4 x 0.14 mm^2) + (4 x 0.34 mm^2)]
Cable length	Max. 150 m
Propagation time	Max. 10 ns; typically 6 ns/m



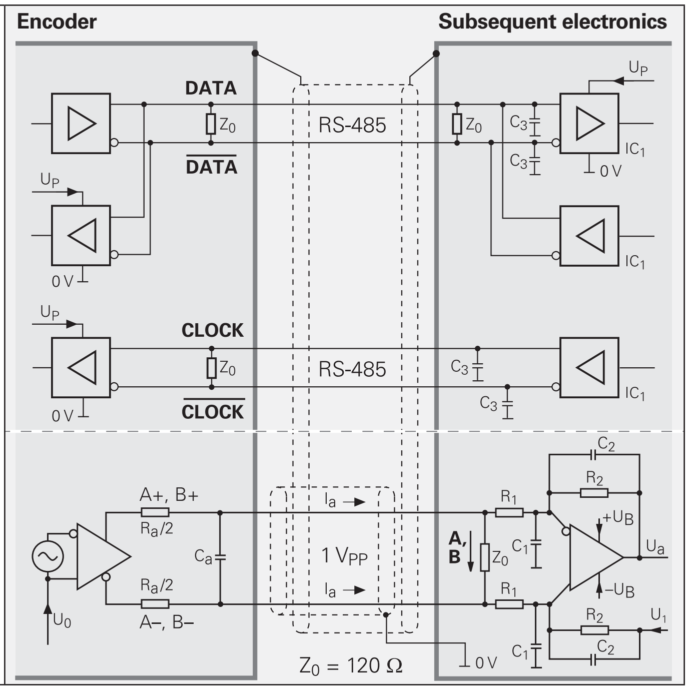
Input circuitry of the subsequent electronics

Dimensioning
IC_1 = RS 485 differential line receiver and driver

C_3 = 330 pF
Z_0 = 120 Ω

Data transfer

Incremental signals
depending on encoder



Benefits of the EnDat Interface

- **Automatic self-configuration:** All information required by the subsequent electronics is already stored in the encoder.
- **High system security** through alarms and messages for monitoring and diagnosis.
- **High transmission reliability** through cyclic redundancy checks.
- **Datum shift** for faster commissioning.

Other benefits of EnDat 2.2

- **A single interface** for all absolute and incremental encoders.
- **Additional information** (limit switch, temperature, acceleration)
- **Quality improvement:** Position value calculation in the encoder permits shorter sampling intervals (25 µs).
- **Online diagnostics** through valuation numbers that indicate the encoder's current functional reserves and make it easier to plan the machine servicing.
- **Safety system** for designing safety-oriented control systems consisting of safe controls and safe encoders based on the IEC 61 508 standards and DIN EN ISO 13 849-1 standard.

Advantages of purely serial transmission specifically for EnDat 2.2 encoders

- Cost optimization through **simple subsequent electronics** with EnDat receiver component and **simple connection technology:** Standard connecting element (M12; 8-pin), single-shielded standard cables and low wiring cost.
- **Minimized transmission times** through **high clock frequencies** up to 16 MHz. Position values available in the subsequent electronics after only approx. 10 µs.
- **Support for state-of-the-art machine designs** e.g. direct drive technology.

Ordering designation	Command set	Incremental signals	Clock frequency	Power supply
EnDat 01	EnDat 2.1 or EnDat 2.2	With	≤ 2 MHz	See specifications of the encoder
EnDat 21		Without		
EnDat 02	EnDat 2.2	With	≤ 2 MHz	Extended range 3.6 to 5.25 V or 14 V
EnDat 22	EnDat 2.2	Without	≤ 16 MHz	

Specification of the EnDat interface (bold print indicates standard versions)

Versions

The extended EnDat 2.2 interface version is compatible in its communication, command set and time conditions with version 2.1, but also offers significant advantages. It makes it possible, for example, to transfer additional information with the position value without sending a separate request for it. The interface protocol was expanded and the time conditions (clock frequency, processing time, recovery time) were optimized.

Ordering designation
Indicated on the ID label and can be read out via parameter.

Command set
The command set is the sum of all available mode commands. (See "Selecting the transmission type"). The EnDat 2.2 command set includes EnDat 2.1 mode commands. When a mode command from the EnDat 2.2 command set is transmitted to EnDat-01 subsequent electronics, the encoder or the subsequent electronics may generate an error message.

Incremental signals
EnDat 2.1 and EnDat 2.2 are both available with or without incremental signals. EnDat 2.2 encoders feature a high internal resolution. Therefore, depending on the control technology being used, interrogation of the incremental signals is not necessary. To increase the resolution of EnDat 2.1 encoders, the incremental signals are interpolated and evaluated in the subsequent electronics.

Power supply
Encoders with ordering designations EnDat 02 and EnDat 22 have an extended power supply range.

Functions

The EnDat interface transmits absolute position values or additional physical quantities (only EnDat 2.2) in an unambiguous time sequence and serves to read from and write to the encoder's internal memory. Some functions are available only with EnDat 2.2 mode commands.

Position values can be transmitted with or without additional information. The additional information types are selectable via the Memory Range Select (MRS) code. Other functions such as *Read parameter* and *Write parameter* can also be called after the memory area and address have been selected. Through simultaneous transmission with the position value, additional information can also be requested of axes in the feedback loop, and functions executed with them.

Parameter reading and writing is possible both as a separate function and in connection with the position value. Parameters can be read or written after the memory area and address are selected.

Reset functions serve to reset the encoder in case of malfunction. Reset is possible instead of or during position value transmission.

Servicing diagnosis makes it possible to inspect the position value even at standstill. A test command has the encoder send the required test values.

You can find more information on the EnDat 2.2 on the Internet under www.endat.de or in the *Technical Information EnDat 2.2.*

Selecting the Transmission Type

Transmitted data are identified as either position values, position values with additional information, or parameters. The type of information to be transmitted is selected by mode commands. **Mode commands** define the content of the transmitted information. Every mode command consists of 3 bits. To ensure reliable transmission, every bit is transmitted redundantly (inverted or double). The EnDat 2.2 interface can also transfer parameter values in the additional information together with the position value. This makes the current position values constantly available for the control loop, even during a parameter request.

Control cycles for transfer of position values

The transmission cycle begins with the first falling **clock edge.** The measured values are saved and the position value is calculated. After two clock pulses (2T), to **select the type of transmission,** the subsequent electronics transmit the mode command "Encoder transmit position value" (with/without additional information). The subsequent electronics continue to transmit clock pulses and observe the data line to detect the start bit. The **start bit** starts data transmission from the encoder to the subsequent electronics. Time t_{cal} is the smallest time duration after which the position value can be read by the encoder. The subsequent **error messages,** error 1 and error 2 (only with EnDat 2.2 commands), are group signals for all monitored functions and serve as failure monitors.

Beginning with the LSB, the encoder then transmits the absolute **position value** as a complete data word. Its length varies depending on which encoder is being used. The number of required clock pulses for transmission of a position value is saved in the parameters of the encoder manufacturer. The data transmission of the position value is completed with the **Cyclic Redundancy Check** (CRC).

In EnDat 2.2, this is followed by additional information 1 and 2, each also concluded with a CRC. With the end of the data word, the clock must be set to HIGH. After 10 to 30 µs or 1.25 to 3.75 µs (with EnDat 2.2 parameterizable recovery time t_m) the data line falls back to LOW. Then a **new data transmission** can begin by starting the clock.

Mode commands

Mode commands		
• Encoder send position value • Selection of memory area • Encoder receive parameter • Encoder send parameter • Encoder receive reset[1] • Encoder send test values • Encoder receive test command	**EnDat 2.1**	**EnDat 2.2**
• Encoder send position value with additional information • Encoder transmit position value and receive selection of memory area [2] • Encoder send position value and receive parameter[2] • Encoder send position value and send parameter[2] • Encoder transmit position value and receive error reset[2] • Encoder send position value and receive test command[2] • Encoder receive communication command[3]		

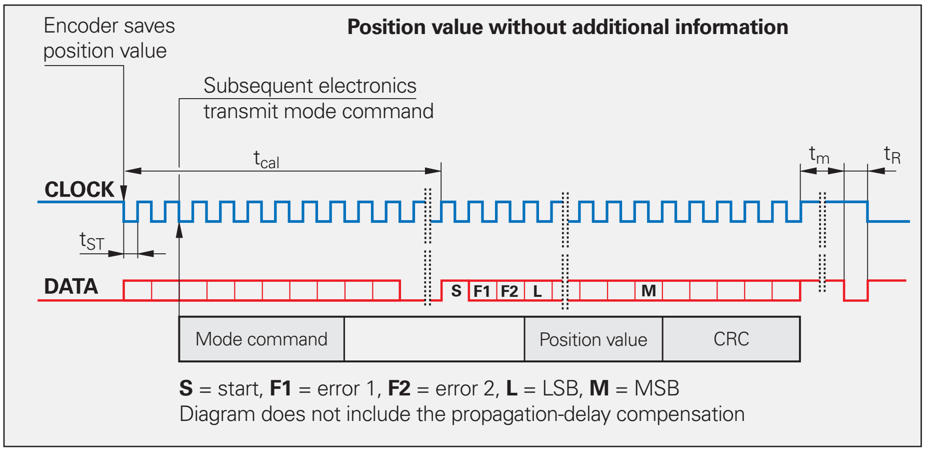
[1] Same reaction as from switching the power supply off and on
[2] Selected additional information is also transmitted
[3] Reserved for encoders that do not support the safety system

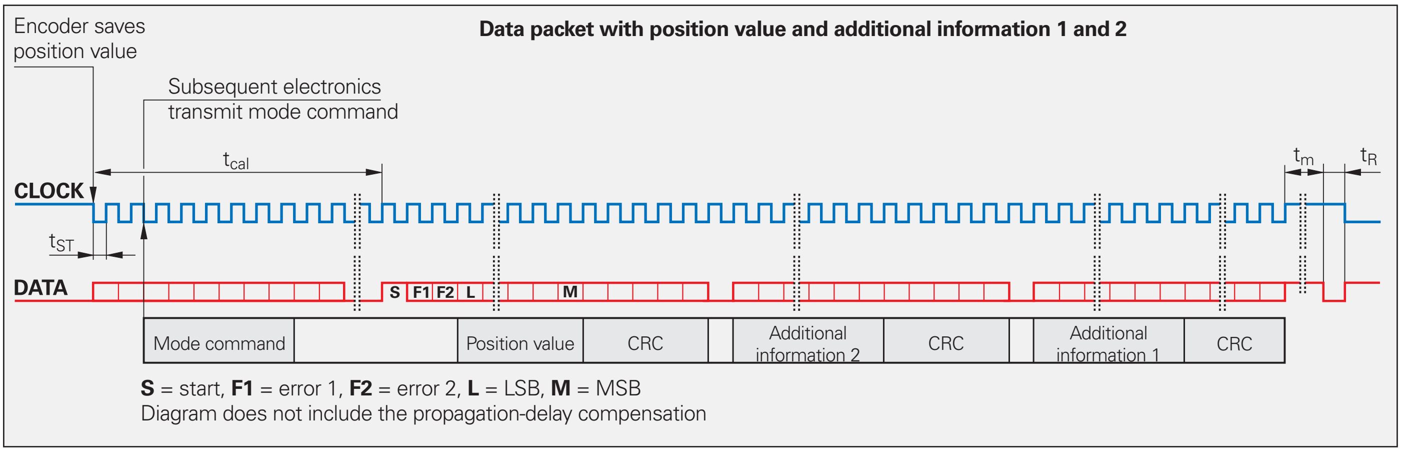
The time absolute linear encoders need for calculating the position values t_{cal} differs depending on whether EnDat-2.1 or EnDat-2.2 mode commands are transmitted (see catalog: *Linear Encoders for Numerically Controlled Machine Tools – Specifications*). If the incremental signals are evaluated for axis control, then the EnDat 2.1 mode commands should be used. Only in this manner can an active error message be transmitted synchronously with the currently requested position value. EnDat 2.1 mode commands should not be used for pure serial position-value transfer for axis control.

		Without delay compensation	**With delay compensation**
Clock frequency	f_c	100 kHz ... 2 MHz	100 kHz ... 16 MHz
Calculation time for			
Position value	t_{cal}	See *Specifications*	
Parameter	t_{ac}	Max. 12 ms	
Recovery time	t_m	*EnDat 2.1:* 10 to 30 µs *EnDat 2.2:* 10 to 30 µs or 1.25 to 3.75 µs ($f_c \geq$ 1 MHz) (parameterizable)	
	t_R	Max. 500 ns	
	t_{ST}	–	2 to 10 µs
Data delay time	t_D	(0.2 + 0.01 x cable length in m) µs	
Pulse width	t_{HI}	0.2 to 10 µs	Pulse width fluctuation HIGH to LOW max. 10%
	t_{LO}	0.2 to 50 ms/30 µs (with LC)	

EnDat 2.2 – Transmission of Position Values

EnDat 2.2 can transmit position values with or without additional information.

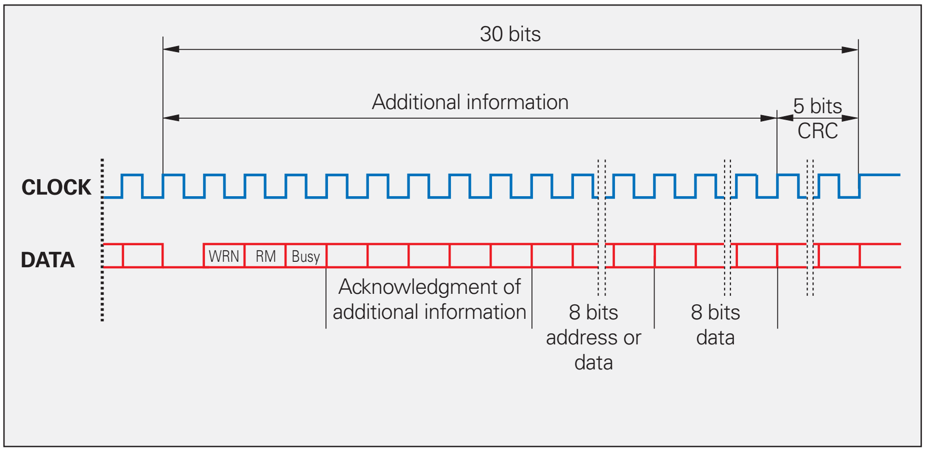




Additional information

With EnDat 2.2, one or two pieces of additional information can be appended to the position value. Each additional datum is 30 bits long with LOW as first bit, and ends with a CRC check. The additional information supported by the respective encoder is saved in the encoder parameters.

The content of the additional information is determined by the MRS code and is transmitted in the next sampling cycle for additional information. This information is then transmitted with every sample until a selection of a new memory area changes the content.



The additional information always begins with:	The additional information can contain the following data:	
Status data Warning – WRN Reference mark – RM Parameter request – busy **Acknowledgment** of additional information	**Additional information 1** Diagnosis (valuation numbers) Position value 2 Memory parameters MRS-code acknowledgment Test values Encoder temperature External temperature sensors Sensor data	**Additional information 2** Commutation Acceleration Limit position signals Operating status error sources

EnDat 2.1 – Transmission of Position Values

EnDat 2.1 can transmit position values with interrupted clock pulse (as in EnDat 2.2) or continuous clock pulse.

Interrupted clock

The interrupted clock is intended particularly for time-clocked systems such as closed control loops. At the end of the data word, the clock signal is set to HIGH level. After 10 to 30 µs (t_m) the data line falls back to LOW. Then a new data transmission can begin by starting the clock.

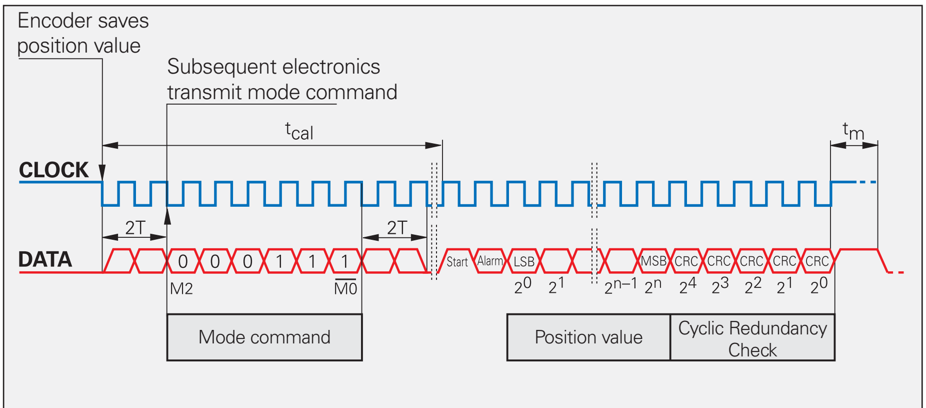
Continuous clock

For applications that require fast acquisition of the measured value, the EnDat interface can have the clock run continuously. Immediately after the last CRC bit has been sent, the data line is switched to HIGH for one clock cycle, and then to LOW. The new position value is saved with the very next falling edge of the clock and is output in synchronism with the clock signal immediately after the start bit and alarm bit. Because the mode command *Encoder transmit position value* is needed only before the first data transmission, the continuous-clock transfer mode reduces the length of the clock-pulse group by 10 periods per position value.

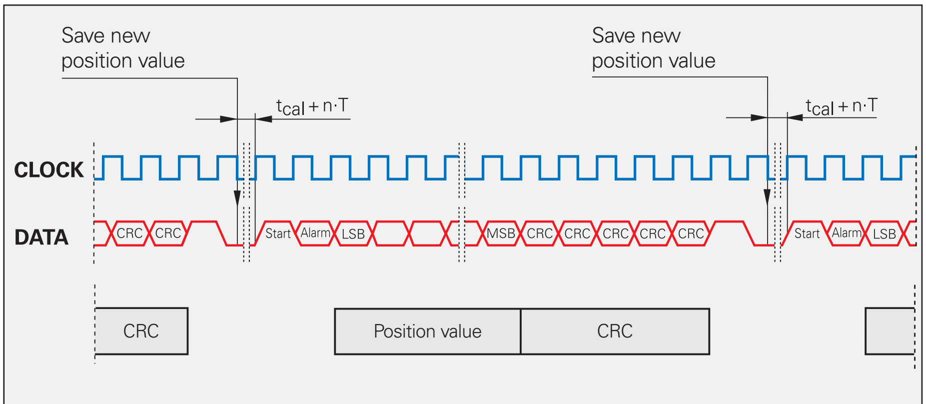
Synchronization of the serially transmitted code value with the incremental signal

Absolute encoders with EnDat interface can exactly synchronize serially transmitted absolute position values with incremental values. With the first falling edge (latch signal) of the CLOCK signal from the subsequent electronics, the scanning signals of the individual tracks in the encoder and counter are frozen, as are the A/D converters for subdividing the sinusoidal incremental signals in the subsequent electronics.

The code value transmitted over the serial interface unambiguously identifies one incremental signal period. The position value is absolute within one sinusoidal period of the incremental signal. The subdivided incremental signal can therefore be appended in the subsequent electronics to the serially transmitted code value.

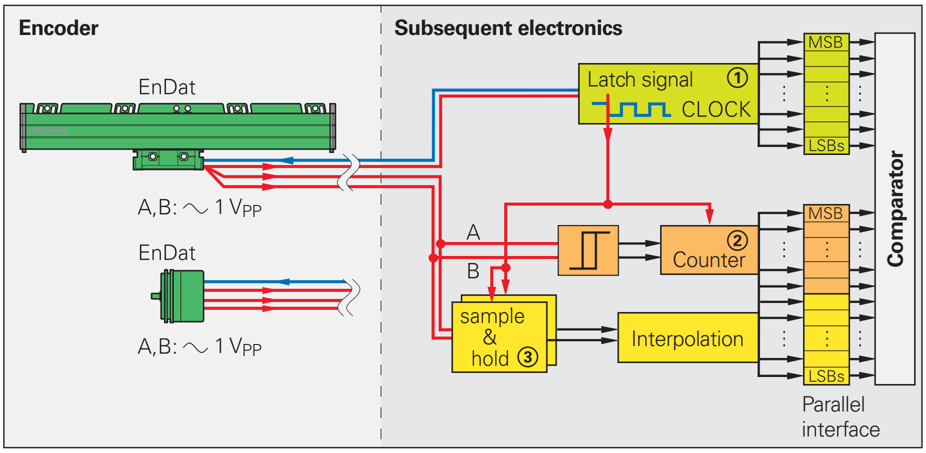


Interrupted clock



n = 0 to 7; depending on system

Continuous clock



After switch-on and initial transmission of position values, two redundant position values are available in the subsequent electronics. Since encoders with EnDat interface guarantee a precise synchronization—regardless of cable length—of the serially transmitted code value with the incremental signals, the two values can be compared in the subsequent electronics. This monitoring is possible even at high shaft speeds thanks to the EnDat interface's short transmission times of less than 50 µs. This capability is a prerequisite for modern machine design and safety systems.

Parameters and Memory Areas

The encoder provides several memory areas for parameters. These can be read from by the subsequent electronics, and some can be written to by the encoder manufacturer, the OEM, or even the end user. Certain memory areas can be write-protected.

The parameters, which in most cases are set by the OEM, largely define the function of the encoder and the EnDat interface. When the encoder is exchanged, it is therefore essential that its parameter settings are correct. Attempts to configure machines without including OEM data can result in malfunctions. If there is any doubt as to the correct parameter settings, the OEM should be consulted.

Parameters of the encoder manufacturer

This write-protected memory area contains all **information specific to the encoder,** such as encoder type (linear/angular, singleturn/multiturn, etc.), signal periods, position values per revolution, transmission format of position values, direction of rotation, maximum speed, accuracy dependent on shaft speeds, warnings and alarms, part number and serial number. This information forms the basis for **automatic configuration.** A separate memory area contains the parameters typical for EnDat 2.2, such as status of additional information, temperature, acceleration, and support of diagnostic and error messages.

Parameters of the OEM

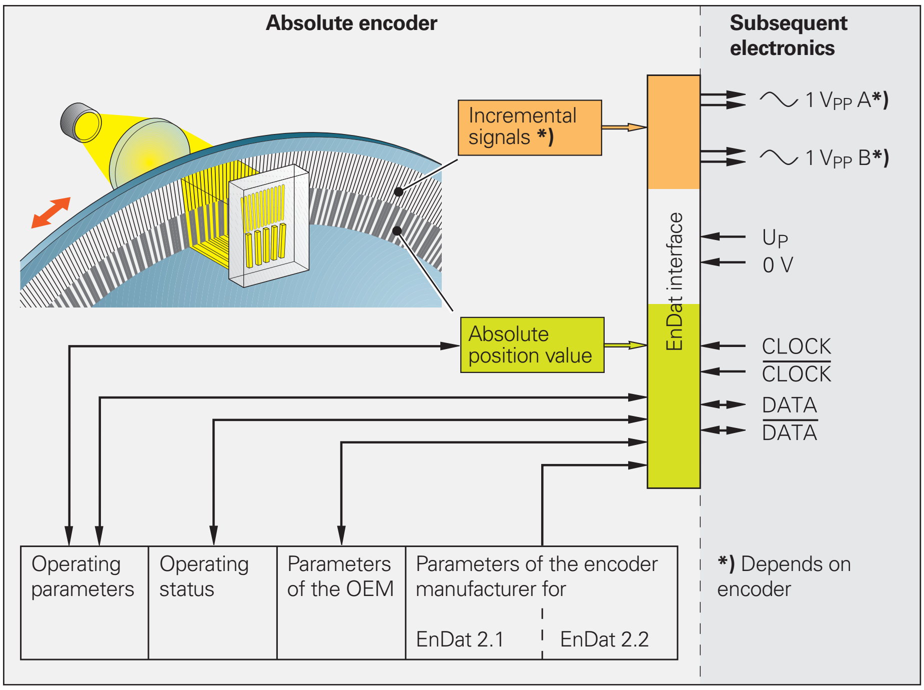
In this freely definable memory area, the OEM can store his information, e.g. the "electronic ID label" of the motor in which the encoder is integrated, indicating the motor model, maximum current rating, etc. The usabel size of the OEM memory depends on the encoder and must be read from the encoder via the EnDat parameter. The further processing of the subsequent electronics must be adjusted to the actual size of the OEM memory.

Operating parameters

This area is available for a **datum shift** and the configuration of diagnostics. It can be protected against overwriting.

Operating status

This memory area provides detailed alarms or warnings for diagnostic purposes. Here it is also possible to activate write protection for the OEM parameter and operating parameter memory areas, and to interrogate their status. Once **write protection** is activated, it cannot be removed.



Monitoring and Diagnostic Functions

The EnDat interface enables comprehensive monitoring of the encoder without requiring an additional transmission line. The alarms and warnings supported by the respective encoder are saved in the "parameters of the encoder manufacturer" memory area.

Error message

An error message becomes active if a **malfunction of the encoder** might result in incorrect position values. The exact cause of the disturbance is saved in the encoder's "operating status" memory. It is also possible to interrogate over the additional information "operating status error sources." Here the EnDat interface transmits the error bits—error 1 and error 2 (only with EnDat 2.2 commands). These are group signals for all monitored functions and serve for failure monitoring. The two error messages are generated independently from each other.

Warning

This collective bit is transmitted in the status data of the additional information. It indicates that certain **tolerance limits of the encoder** have been reached or exceeded—such as shaft speed or the limit of light source intensity compensation through voltage regulation—without implying that the measured position values are incorrect. This function makes it possible to issue preventive warnings in order to minimize idle time.

Online diagnostics

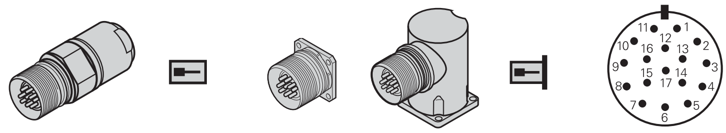
Encoders with purely serial interfaces do not provide incremental signals for evaluation of encoder function. EnDat 2.2 encoders can therefore cyclically transmit so-called valuation numbers from the encoder. The valuation numbers provide the current state of the encoder and ascertain the encoder's "functional reserves." The identical scale for all HEIDENHAIN encoders allows uniform valuation. This makes it easier to plan machine use and servicing.

Cyclic Redundancy Check

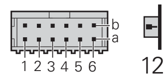
To ensure **reliability of data transfer,** a cyclic redundancy check (CRC) is performed through the logical processing of the individual bit values of a data word. This 5 bit long CRC concludes every transmission. The CRC is decoded in the receiver electronics and compared with the data word. This largely eliminates errors caused by disturbances during data transfer.

Pin Layout EnDat

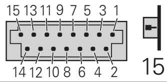
17-pin coupling or flange socket M23



12-pin PCB connector



15-pin PCB connector



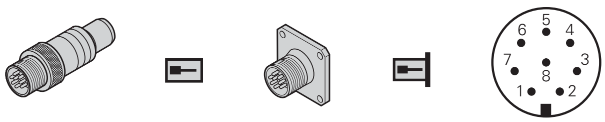
	Power supply					Incremental signals[1]				Absolute position values			
	7	1	10	4	11	15	16	12	13	14	17	8	9
12	1b	6a	4b	3a	/	2a	5b	4a	3b	6b	1a	2b	5a
15	13	11	14	12	/	1	2	3	4	7	8	9	10
	U_P	**Sensor**[2] U_P	**0 V**	**Sensor**[2] 0 V	**Internal shield**	**A+**	**A–**	**B+**	**B–**	**DATA**	**$\overline{DATA}$**	**CLOCK**	**$\overline{CLOCK}$**
	Brown/Green	Blue	White/Green	White	/	Green/Black	Yellow/Black	Blue/Black	Red/Black	Gray	Pink	Violet	Yellow

	Other signals	
	5	6
12	/	/
15	/	/
	T+[3]	**T–**[3]
	Brown[3]	White[3]

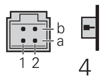
Cable shield connected to housing; **U_P** = power supply voltage; **T** = temperature
Sensor: The sensor line is connected internally with the corresponding power line.
Vacant pins or wires must not be used!

[1] Only with ordering designations 01 and 02
[2] Not assigned if a power of 7 to 10 V is supplied via motor-internal adapter cable
[3] Only for motor-internal adapter cables
[4] For parallel supply lines
[5] Connections for temperature sensor

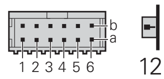
8-pin coupling or flange socket M12



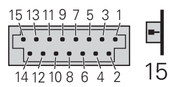
4-pin PCB connector



12-pin PCB connector



15-pin PCB connector



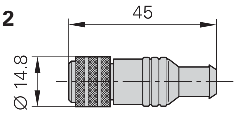
	Power supply				Absolute position values				Other signals[3]			
	2	8	1	5	3	4	7	6	/	/	/	/
4	/	/	/	/	/	/	/	/	1a	1b	/	/
12	6a	1b	3a	4b	6b	1a	2b	6a	/	/	/	/
15	11	13	12	14	7	8	9	10	5	6	/	/
	U_P[4]	**U_P**	**0 V**[4]	**0 V**	**DATA**	**$\overline{DATA}$**	**CLOCK**	**$\overline{CLOCK}$**	**T+**	**T–**	**T+**[5]	**T–**[5]
	Blue	Brown/Green	White	White/Green	Gray	Pink	Violet	Yellow	Brown	Green	Brown	White

Cables and Connecting Elements
General Information

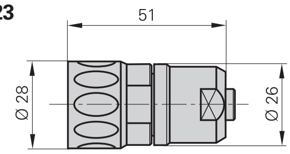
Connector (insulated): A connecting element with a coupling ring. Available with male or female contacts.

Symbols 

M12



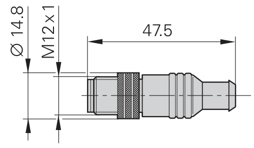
M23



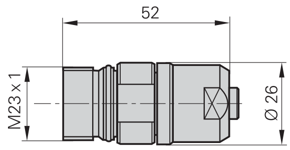
Coupling (insulated): Connecting element with external thread; available with male or female contacts.

Symbols 

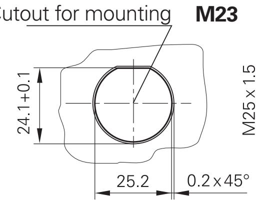
M12



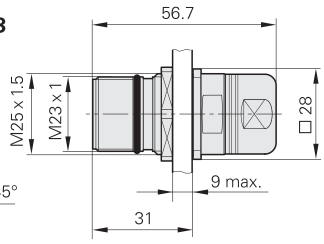
M23



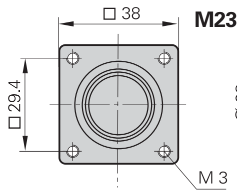
Mounted coupling with central fastening



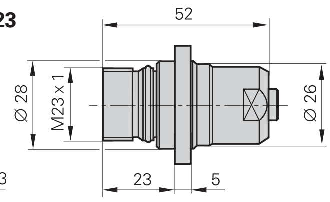
M23



Mounted coupling with flange



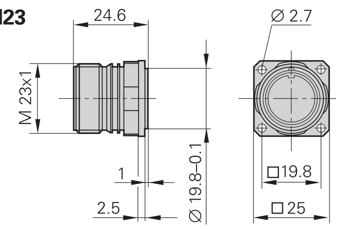
M23



Flange socket: Permanently mounted on the encoder or a housing, with external thread (like a coupling), available with male or female contacts.

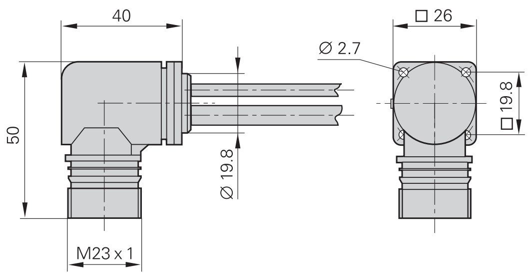
Symbols 

M23



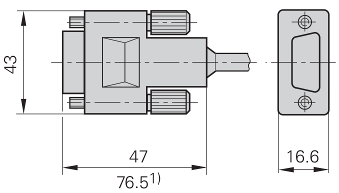
Right-angle flange socket (rotatable) on adapter cable inside the motor with connection for temperature sensor

M23



D-sub connector: For HEIDENHAIN controls, counters and IK absolute value cards.

Symbols 



1) Interface electronics integrated in connector

The pins on connectors are **numbered** in the direction opposite to those on couplings or flange sockets, regardless of whether the connecting elements are

male contacts or

female contacts.

When engaged, the connections are **protected** to IP 67 (D-sub connector: IP 50; EN 60529). When not engaged, there is no protection.

Accessories for flange sockets and M23 mounted couplings

Bell seal
ID 266526-01

Threaded metal dust cap
ID 219926-01

Cables and Connecting Elements

Cables inside the Motor Housing

Encoder cables in the motor housing usually have a sheathing of a special elastomer (EPG). They are resistant to oil in accordance with VDE 0472 (Part 803/test type B) and to hydrolysis in accordance with VDE 0282 (Part 10). They are free of silicone and halogens. In comparison with PUR cables, EPG cables are only conditionally resistant to media, frequent flexing and continuous torsion. In rigid configuration they can be used at up to 120 °C.

Cables inside the motor housing Cable diameter 4.5 mm For			**Complete** With PCB connector and right-angle socket M23, 17-pin	**Complete** With PCB connector and right-angle socket M12, 8-pin for pure serial data transmission	**With one connector** With PCB connector
	PCB connector	Crimp sleeve			
ECN 1113 **EQN 1125**	15-pin	Ø 4.5 mm	606079-xx (EPG) 16xAWG30/7	–	605090-xx (EPG) 16xAWG30/7
ECN 1123 **EQN 1135**	15-pin	Ø 4.5 mm	–	Upon request	–
ECI 1118 **EQI 1130**	15-pin	–	–	–	640030-xx[1] 12xAWG26/19
ERN 1120 **ERN 1180**	15-pin	Ø 4.5 mm	–	–	675537-xx [6 × (2 x 0.09 mm^2)]
ERN 1185	14-pin	Ø 4.5 mm	316594-xx (EPG) 16xAWG30/7	–	317900-xx (EPG) 16xAWG30/7
ECN 1313 **EQN 1325** **ECI 1319** **EQI 1331**	12-pin	Ø 6 mm	332201-xx (EPG) 16xAWG30/7	–	332202-xx (EPG) 16xAWG30/7
ECN 1325 **EQN 1337**	12-pin, 4-pin	Ø 6 mm	–	Upon request	–
ERN 1387	14-pin	Ø 6 mm	332199-xx (EPG) 16xAWG30/7	–	332200-xx (EPG) 16xAWG30/7
ERN 1326	16-pin	Ø 6 mm	341370-xx[2] (EPG) 16xAWG30/7	–	341369-xx (EPG) 16xAWG30/7
ERN 1321 **ERN 1381**	12-pin	Ø 6 mm	667343-xx (EPG) 16xAWG30/7	–	333276-xx (EPG) 16xAWG30/7

[1] Single wires with heat-shrink tubing; shield must be connected to the motor
[2] Without separate connections for temperature sensor

Encoder Cable

	Encoder cable		Cable	ID number
ECI 1118 **EQI 1130**	**Complete** With 15-pin PCB connector and M23 coupling (male), 17-pin		PUR 16xAWG30/7 w/ shield connection ∅ 4.5 mm	639 528-xx
ERO 1225 **ERO 1285** **ERO 1384**	**With one connector** With 12-pin PCB connector		PUR [4(2 × 0.05 mm^2) + (4 × 0.14 mm^2)] With shield connection ∅ 4.5 mm	372 164-xx[1)]
ERO 1324			PUR [4(2 × 0.14 mm^2) + (4 × 0.25 mm^2)] ∅ 6 mm	295 545-xx
ERO 1420 **ERO 1470** **ERO 1480**			PUR [4(2 × 0.05 mm^2) + (4 × 0.14 mm^2)] With shield connection ∅ 4.5 mm	346 439-xx[1)]
ECI 1118 **EQI 1130** **ECI 1319** **EQI 1331** **ECN 11xx** **EQN 11xx** **ECN 13xx** **EQN 13xx** **ERN 11xx** **ERN 13x1** **ERN 1387**	**Complete** With 12-pin PCB connector and 15-pin D-sub connector (male) (incl. 3 adapter connectors, 12-pin and 3 adapter connectors, 15-pin)		EPG 16xAWG30/7 ∅ 6 mm	621 742-01

Cables and Connecting Elements

Connecting Cables

		8-pin M12	12-pin M23	17-pin M23
		For EnDat without incremental signals	**For** ∿ **1 VPP** ⊓⊔ **TTL**	**For EnDat** with incremental signals **SSI**
PUR connecting cables	**8-pin:** [(4 × 0.14 mm²) + (4 × 0.34 mm²)] **Ø 6 mm** **12-pin:** [4(2 × 0.14 mm²) + (4 × 0.5 mm²)] **Ø 8 mm** **17-pin:** [(4 × 0.14 mm²) + 4(2 × 0.14 mm²) + (4 × 0.5 mm²)] **Ø 8 mm**			
Complete with connector (female) and coupling (male)		368330-xx	298401-xx	323897-xx
Complete with connector (female) and connector (male)		–	298399-xx	–
Complete with connector (female) and D-sub connector (female) for IK 220		533627-xx	310199-xx	332115-xx
Complete with connector (female) and D-sub connector (male) for IK 115/IK 215		524599-xx	310196-xx	324544-xx
With one connector (female)		559346-xx	309777-xx	309778-xx
Cable without connectors, Ø 8 mm		–	244957-01	266306-01
Mating element on connecting cable to connector on encoder cable	**Connector (female)** for cable Ø 8 mm	–	291697-05	291697-26
Connector on connecting cable for connection to subsequent electronics	**Connector (male)** for cable Ø 8 mm Ø 6 mm	–	291697-08 291697-07	291697-27
Coupling on connecting cable	**Coupling (male)** for cable Ø 4.5 mm Ø 6 mm Ø 8 mm	–	291698-14 291698-03 291698-04	291698-25 291698-26 291698-27
Flange socket for mounting on subsequent electronics	**Flange socket (female)**	–	315892-08	315892-10
Mounted couplings	**With flange (female)** Ø 6 mm Ø 8 mm	–	291698-17 291698-07	291698-35
	With flange (male) Ø 6 mm Ø 8 mm	–	291698-08 291698-31	291698-41 291698-29
	With central fastening (male) Ø 6 to 10 mm	–	741045-01	741045-02
Adapter ∿ **1 VPP/11 µAPP** For converting the 1 VPP signals to 11 µAPP; 12-pin M23 connector (female) and 9-pin M23 connector (male)		–	364914-01	–

General Electrical Information

For Rotary Encoders for Electrical Drives

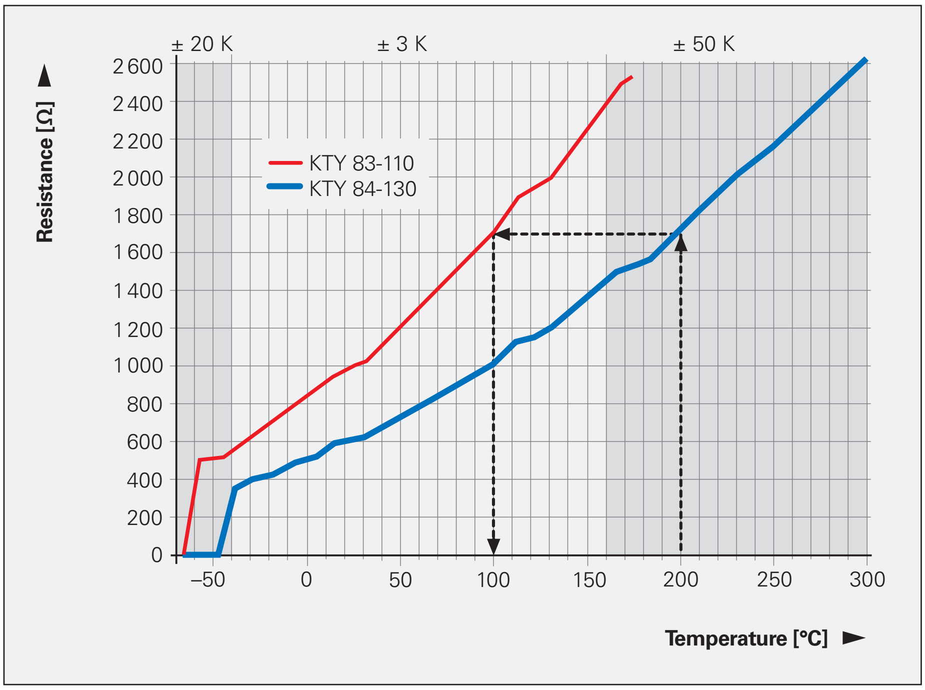
Temperature measurement in motors
In order to protect a motor from an excessive load, the motor manufacturer usually installs a temperature sensor near the motor coil. In classic applications, the values from the temperature sensor are led via two separate lines to the subsequent electronics, where they are evaluated. With HEIDENHAIN encoders for servo drives, the temperature sensor can be connected to the encoder cable inside the motor housing, and the values transmitted via the encoder cable. This means that no separate lines from the motor to the drive controller are necessary.

Integrated temperature evaluation
The temperature can already be evaluated by the encoder if it features the EnDat 2.2 interface and the possibility of connecting an external temperature sensor. The digitized temperature value is transmitted purely serially via the EnDat interface as additional information.

Connectable temperature sensors
The temperature evaluation within the rotary encoder is designed for a KTY 84-130 PTC thermistor. If other temperature sensors are used, then the temperature must be converted according to the resistance curve. In the example shown, the temperature of 200 °C reported via the EnDat interface is actually 100 °C if a KTY 83-110 is used as temperature sensor.

Information for the connection of temperature sensors

- Only connect passive temperature sensors
- Only use temperature sensors with double or reinforced insulation
- No galvanic separation of the sensor input in the electronics of the rotary encoder
- The accuracy of the temperature measurement depends on the temperature range:
  – Approx. ± 3 K at –40 °C to 160 °C
  – Approx. ± 20 K at ≤ –40 °C
  – Approx. ± 50 K at ≥ 160 °C



Correlation between the temperature and resistance value for KTY 84-130, with conversion example to KTY 83-110

General Electrical Information

Power Supply

Connect HEIDENHAIN encoders only to subsequent electronics whose power supply is generated from PELV systems **(EN 50178).** In addition, overcurrent protection and overvoltage protection are required in safety-related applications.

If HEIDENHAIN encoders are to be operated in accordance with IEC 61010-1, the power must be supplied from a secondary circuit with current or power limitation as per IEC 61010-1:2001, section 9.3 or IEC 60950-1:2005, section 2.5 or a Class 2 secondary circuit as specified in UL1310.

The encoders require a **stabilized DC voltage U_P** as power supply. The respective *Specifications* state the required power supply and the current consumption. The permissible ripple content of the DC voltage is:
- High frequency interference U_{PP} < 250 mV with dU/dt > 5 V/µs
- Low frequency fundamental ripple U_{PP} < 100 mV

The values apply as measured at the encoder, i.e., without cable influences. The voltage can be monitored and adjusted with the encoder's **sensor lines.** If a controllable power supply is not available, the voltage drop can be halved by switching the sensor lines parallel to the corresponding power lines.

Calculation of the **voltage drop**:

$$\Delta U = 2 \cdot 10^{-3} \cdot \frac{1.05 \cdot L_C \cdot I}{56 \cdot A_P}$$

where
- ΔU: Voltage attenuation in V
- 1.05: Length factor due to twisted wires
- L_C: Cable length in m
- I: Current consumption in mA
- A_P: Cross section of power lines in mm^2

The voltage actually applied to the encoder is to be considered when **calculating the encoder's power requirement.** This voltage consists of the supply voltage U_P provided by the subsequent electronics minus the line drop at the encoder. For encoders with an expanded supply range, the voltage drop in the power lines must be calculated under consideration of the nonlinear current consumption (see next page).

If the voltage drop is known, all parameters for the encoder and subsequent electronics can be calculated, e.g. voltage at the encoder, current requirements and power consumption of the encoder, as well as the power to be provided by the subsequent electronics.

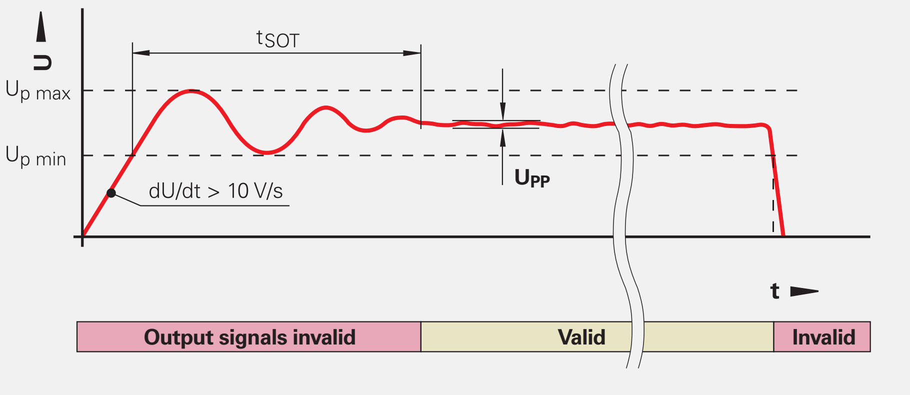
Switch-on/off behavior of the encoders
The output signals are valid no sooner than after switch-on time t_{SOT} = 1.3 s (2 s for PROFIBUS-DP) (see diagram). During time t_{SOT} they can have any levels up to 5.5 V (with HTL encoders up to U_{Pmax}). If an interpolation electronics unit is inserted between the encoder and the power supply, this unit's switch-on/off characteristics must also be considered. If the power supply is switched off, or when the supply voltage falls below U_{min}, the output signals are also invalid. During restart, the signal level must remain below 1 V for the time t_{SOT} before power up. These data apply to the encoders listed in the catalog—customer-specific interfaces are not included.

Encoders with new features and increased performance range may take longer to switch on (longer time t_{SOT}). If you are responsible for developing subsequent electronics, please contact HEIDENHAIN in good time.

Isolation
The encoder housings are isolated against internal circuits.

Rated surge voltage: 500 V
(preferred value as per VDE 0110 Part 1, overvoltage category II, contamination level 2)

Transient response of supply voltage and switch-on/switch-off behavior



Cable	Cross section of power supply lines A_P			
	1 V_{PP}/TTL/HTL	11 µA_{PP}	EnDat/SSI 17-pin	EnDat[5] 8-pin
Ø 3.7 mm	0.05 mm^2	–	–	0.09 mm^2
Ø 4.3 mm	0.24 mm^2	–	–	–
Ø 4.5 mm EPG	0.05 mm^2	–	0.05 mm^2	0.09 mm^2
Ø 4.5 mm Ø 5.1 mm	0.14/0.09[2] mm^2 0.05[2), 3)] mm^2	0.05 mm^2	0.05 mm^2	0.14 mm^2
Ø 6 mm Ø 10 mm[1]	0.19/0.14[2), 4)] mm^2	–	0.08 mm^2	0.34 mm^2
Ø 8 mm Ø 14 mm[1]	0.5 mm^2	1 mm^2	0.5 mm^2	1 mm^2

1) Metal armor 2) Rotary encoders 3) Length gauges 4) LIDA 400
5) Also Fanuc, Mitsubishi

Encoders with expanded voltage supply range
For encoders with expanded supply voltage range the current consumption has a nonlinear relationship with the supply voltage. On the other hand, the power consumption follows a linear curve (see *Current and power consumption* diagram). The maximum power consumption at minimum and maximum supply voltage is listed in the **Specifications.** The power consumption at maximum supply voltage (worst case) accounts for:

- Recommended receiver circuit
- Cable length: 1 m
- Age and temperature influences
- Proper use of the encoder with respect to clock frequency and cycle time

The typical current consumption at no load (only supply voltage is connected) for 5 V supply is specified.

The actual power consumption of the encoder and the required power output of the subsequent electronics are measured while taking the voltage drop on the supply lines in four steps:

Step 1: **Resistance of the supply lines**
The resistance values of the power lines (adapter cable and encoder cable) can be calculated with the following formula:

$$R_L = 2 \cdot \frac{1.05 \cdot L_C}{56 \cdot A_P}$$

Step 2: **Coefficients for calculation of the drop in line voltage**

$$b = -R_L \cdot \frac{P_{Emax} - P_{Emin}}{U_{Emax} - U_{Emin}} - U_P$$

$$c = P_{Emin} \cdot R_L + \frac{P_{Emax} - P_{Emin}}{U_{Emax} - U_{Emin}} \cdot R_L \cdot (U_P - U_{Emin})$$

Step 3: **Voltage drop based on the coefficients b and c**

$$\Delta U = -0.5 \cdot (b + \sqrt{b^2 - 4 \cdot c})$$

Step 4: **Parameters for subsequent electronics and the encoder**
Voltage at encoder:
$U_E = U_P - \Delta U$

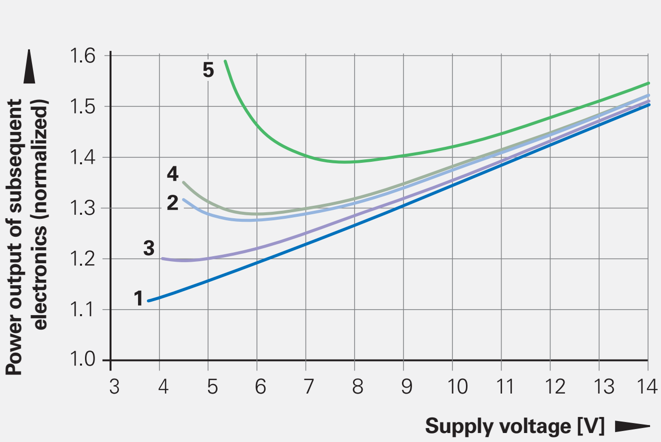
Current requirement of encoder:
$I_E = \Delta U / R_L$

Power consumption of encoder:
$P_E = U_E \cdot I_E$

Power output of subsequent electronics:
$P_S = U_P \cdot I_E$

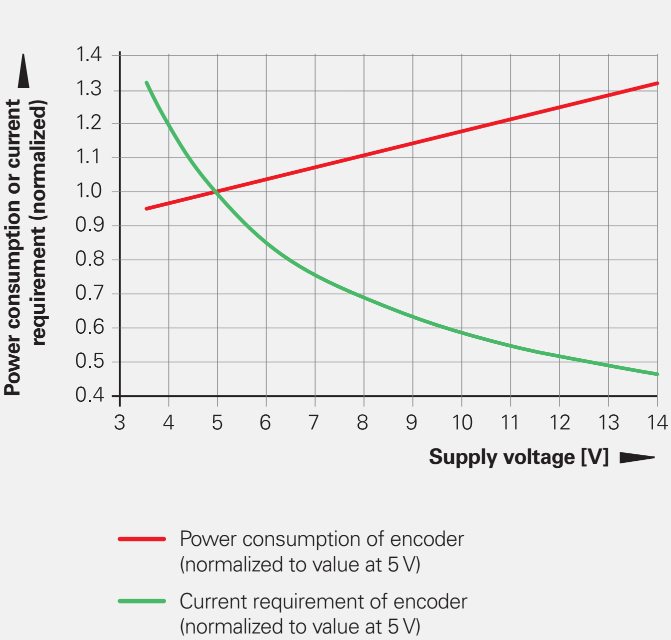
Where:
U_{Emax}, U_{Emin}: Minimum or maximum supply voltage of the encoder in V
P_{Emin}, P_{Emax}: Maximum power consumption at minimum and maximum power supply, respectively, in W
U_S: Supply voltage of the subsequent electronics in V
R_L: Cable resistance (for both directions) in ohms
ΔU: Voltage drop in the cable in V
1.05: Length factor due to twisted wires
L_C: Cable length in m
A_P: Cross section of power lines in mm^2

Influence of cable length on the power output of the subsequent electronics (example representation)



	Encoder cable/adapter cable	Connecting cable	Total
1	3 m	/	3 m
2	20 m	/	20 m
3	3 m	17 m	20 m
4	3 m	47 m	50 m
5	3 m	97 m	100 m

Current and power consumption with respect to the supply voltage (example representation)



Electrically Permissible Speed/ Traversing Speed

The maximum permissible shaft speed or traversing velocity of an encoder is derived from

- the **mechanically** permissible shaft speed/traversing velocity (if listed in the *Specifications*)
  and
- the **electrically** permissible shaft speed/ traversing velocity.

  For encoders with **sinusoidal output signals,** the electrically permissible shaft speed/traversing velocity is limited by the –3dB/ –6dB cutoff frequency or the permissible input frequency of the subsequent electronics.

  For encoders with **square-wave signals,** the electrically permissible shaft speed/ traversing velocity is limited by
  – the maximum permissible scanning frequency f_{max} of the encoder and

  – the minimum permissible edge separation a for the subsequent electronics.

For angular or rotary encoders

$$n_{max} = \frac{f_{max}}{z} \cdot 60 \cdot 10^3$$

For linear encoders

$$v_{max} = f_{max} \cdot SP \cdot 60 \cdot 10^{-3}$$

Where:
n_{max}: Elec. permissible speed in min^{-1}
v_{max}: Elec. permissible traversing velocity in m/min
f_{max}: Max. scanning/output frequency of encoder or input frequency of subsequent electronics in kHz
z: Line count of the angle or rotary encoder per 360 °
SP: Signal period of the linear encoder in µm

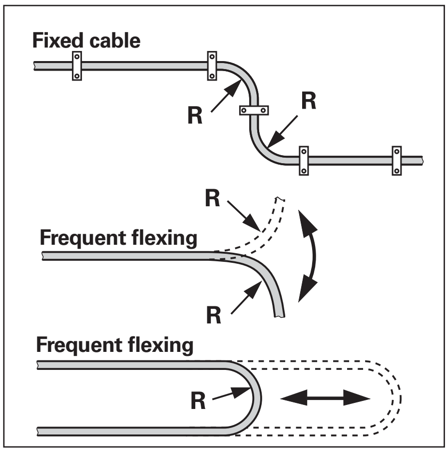
Cable

For safety-related applications, use HEIDENHAIN cables and connectors.

Versions
The cables of almost all HEIDENHAIN encoders and all adapter and connecting cables are sheathed in **polyurethane (PUR cable).** Most adapter cables for within motors and a few cables on encoders are sheathed in a **special elastomer (EPG cable).** These cables are identified in the specifications or in the cable tables with "EPG."

Durability
PUR cables are resistant to oil and hydrolysis in accordance with **VDE 0472** (Part 803/test type B) and resistant to microbes in accordance with **VDE 0282** (Part 10). They are free of PVC and silicone and comply with UL safety directives. The **UL certification** AWM STYLE 20963 80 °C 30 V E63216 is documented on the cable.

EPG cables are resistant to oil in accordance with **VDE 0472** (Part 803/test type B) and to hydrolysis in accordance with **VDE 0282** (Part 10). They are free of silicone and halogens. In comparison with PUR cables, they are only conditionally resistant to media, frequent flexing and continuous torsion.



Temperature range
HEIDENHAIN cables can be used for

rigid configuration (PUR)	–40 to 80 °C
rigid configuration (EPG)	–40 to 120 °C
frequent flexing (PUR)	–10 to 80 °C

PUR cables with limited resistance to hydrolysis and microbes are rated for up to 100 °C. If needed, please ask for assistance from HEIDENHAIN Traunreut.

Lengths
The **cable lengths** listed in the *Specifications* apply only for HEIDENHAIN cables and the recommended input circuitry of subsequent electronics.

Cable	Bend radius R	
	Fixed cable	Frequent flexing
Ø 3.7 mm	≥ 8 mm	≥ 40 mm
Ø 4.3 mm	≥ 10 mm	≥ 50 mm
Ø 4.5 mm EPG	≥ 18 mm	–
Ø 4.5 mm **Ø 5.1 mm**	≥ 10 mm	≥ 50 mm
Ø 6 mm **Ø 10 mm**[1)]	≥ 20 mm ≥ 35 mm	≥ 75 mm ≥ 75 mm
Ø 8 mm **Ø 14 mm**[1)]	≥ 40 mm ≥ 100 mm	≥ 100 mm ≥ 100 mm

[1)] Metal armor

Noise-Free Signal Transmission

Electromagnetic compatibility/ CE -compliance
When properly installed, and when HEIDENHAIN connecting cables and cable assemblies are used, HEIDENHAIN encoders fulfill the requirements for electromagnetic compatibility according to 2004/108/EC with respect to the generic standards for:

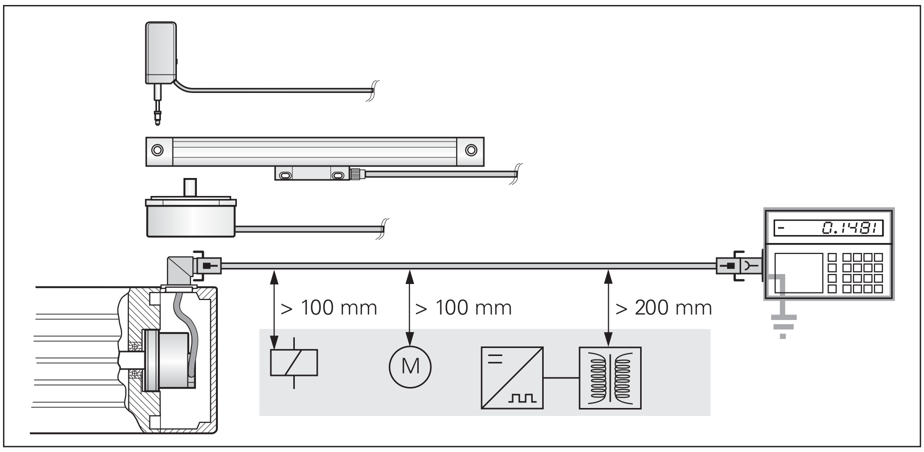
- **Noise EN 61 000-6-2:**
  Specifically:
  - ESD — EN 61 000-4-2
  - Electromagnetic fields — EN 61 000-4-3
  - Burst — EN 61 000-4-4
  - Surge — EN 61 000-4-5
  - Conducted disturbances — EN 61 000-4-6
  - Power frequency magnetic fields — EN 61 000-4-8
  - Pulse magnetic fields — EN 61 000-4-9
- **Interference EN 61 000-6-4:**
  Specifically:
  - For industrial, scientific and medical equipment (ISM) — EN 55 011
  - For information technology equipment — EN 55 022

Transmission of measuring signals—electrical noise immunity
Noise voltages arise mainly through capacitive or inductive transfer. Electrical noise can be introduced into the system over signal lines and input or output terminals.
Possible sources of noise include:

- Strong magnetic fields from transformers, brakes and electric motors
- Relays, contactors and solenoid valves
- High-frequency equipment, pulse devices, and stray magnetic fields from switch-mode power supplies
- AC power lines and supply lines to the above devices

Protection against electrical noise
The following measures must be taken to ensure disturbance-free operation:

- Use only original HEIDENHAIN cables. Consider the voltage attenuation on supply lines.
- Use connecting elements (such as connectors or terminal boxes) with metal housings. Only the signals and power supply of the connected encoder may be routed through these elements. Applications in which additional signals are sent through the connecting element require specific measures regarding electrical safety and EMC.
- Connect the housings of the encoder, connecting elements and subsequent electronics through the shield of the cable. Ensure that the shield has complete contact over the entire surface (360°). For encoders with more than one electrical connection, refer to the documentation for the respective product.
- For cables with multiple shields, the inner shields must be routed separately from the outer shield. Connect the inner shield to 0 V of the subsequent electronics. Do not connect the inner shields with the outer shield, neither in the encoder nor in the cable.
- Connect the shield to protective ground as per the mounting instructions.
- Prevent contact of the shield (e.g. connector housing) with other metal surfaces. Pay attention to this when installing cables.
- Do not install signal cables in the direct vicinity of interference sources (inductive consumers such as contacts, motors, frequency inverters, solenoids, etc.).
  - Sufficient decoupling from interference-signal-conducting cables can usually be achieved by an air clearance of 100 mm or, when cables are in metal ducts, by a grounded partition.
  - A minimum spacing of 200 mm to inductors in switch-mode power supplies is required.
- If compensating currents are to be expected within the overall system, a separate equipotential bonding conductor must be provided. The shield does not have the function of an equipotential bonding conductor.
- Only provide power from PELV systems **(EN 50 178)** to position encoders. Provide high-frequency grounding with low impedance **(EN 60 204-1 Chap. EMC).**
- For encoders with 11-µApp interface: For extension cables, use only HEIDENHAIN cable ID 244 955-01. Overall length: max. 30 m.



Minimum distance from sources of interference

HEIDENHAIN Measuring Equipment
For Incremental Encoders

The **PWM 9** is a universal measuring device for checking and adjusting HEIDENHAIN incremental encoders. There are different expansion modules available for checking the different encoder signals. The values can be read on an LCD monitor. Soft keys provide ease of operation.

	PWM 9
Inputs	Expansion modules (interface boards) for 11 μA_{PP}; 1 V_{PP}; TTL; HTL; EnDat*/SSI*/commutation signals *No display of position values or parameters
Functions	• **Measures** signal amplitudes, current consumption, operating voltage, scanning frequency • **Graphically displays** incremental signals (amplitudes, phase angle and on-off ratio) and the reference-mark signal (width and position) • **Displays symbols** for the reference mark, fault detection signal, counting direction • **Universal counter,** interpolation selectable from single to 1 024-fold • **Adjustment support** for exposed linear encoders
Outputs	• Inputs are connected through to the subsequent electronics • BNC sockets for connection to an oscilloscope
Power supply	10 to 30 V, max. 15 W
Dimensions	150 mm × 205 mm × 96 mm

For Absolute Encoders

HEIDENHAIN offers an adjusting and testing package for diagnosis and adjustment of HEIDENHAIN encoders with absolute interface.

- PC expansion board **IK 215**
- **ATS** adjusting and testing software

	IK 215
Encoder input	• EnDat 2.1 or EnDat 2.2 (absolute value with/without incremental signals) • FANUC serial interface • Mitsubishi High Speed Serial Interface • SSI
Interface	PCI bus, Rev. 2.1
System requirements	• Operating system: Windows XP (Vista upon request) • Approx. 20 MB free space on the hard disk
Signal subdivision for incremental signals	Up to 65 536-fold
Dimensions	100 mm x 190 mm

	ATS
Languages	Choice between English or German
Functions	• Position display • Connection dialog • Diagnostics • Mounting wizard for ECI/EQI • Additional functions (if supported by the encoder) • Memory contents

Evaluation Electronics

IK 220
Universal PC counter card
The IK 220 is an expansion board for PCs for recording the measured values of two incremental or absolute linear or angle encoders. The subdivision and counting electronics subdivide the sinusoidal input signals up to 4096-fold. A driver software package is included in delivery.

For more information, see the *IK 220* Product Information document as well as the Product Overview of *Interface Electronics.*

	IK 220			
Input signals (switchable)	~ 1 V_{PP}	~ 11 μA_{PP}	EnDat 2.1	SSI
Encoder inputs	Two D-sub connections (15-pin, male)			
Input frequency	≤ 500 kHz	≤ 33 kHz	–	
Cable length	≤ 60 m		≤ 50 m	≤ 10 m
Signal subdivision (signal period : meas. step)	Up to 4096-fold			
Data register for measured values (per channel)	48 bits (44 bits used)			
Internal memory	For 8192 position values			
Interface	PCI bus			
Driver software and demonstration program	**For Windows 98/NT/2000/XP** in VISUAL C++, VISUAL BASIC and BORLAND DELPHI			
Dimensions	Approx. 190 mm × 100 mm			

HEIDENHAIN

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208 922-2A · 30 · 8/2010 · H · Printed in Germany