HEIDENHAIN

Rotary Encoders

November 2012

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.

These precision graduations are manufactured in various photolithographic processes. Graduations are fabricated from:
- extremely hard chromium lines on glass,
- 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 50 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.

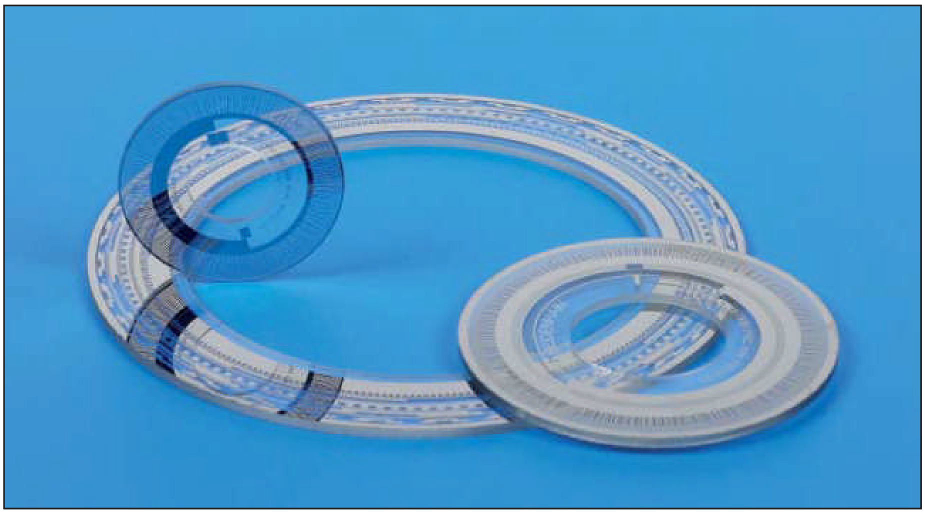
Encoders using the **inductive scanning principle** have graduation structures of copper/nickel. The graduation is applied to a carrier material for printed circuits.

Measuring methods

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 graduated disk**, which is designed as a serial code structure or—as on the ECN 100—consists of several parallel graduation tracks.

A separate incremental track (on the ECN 100 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

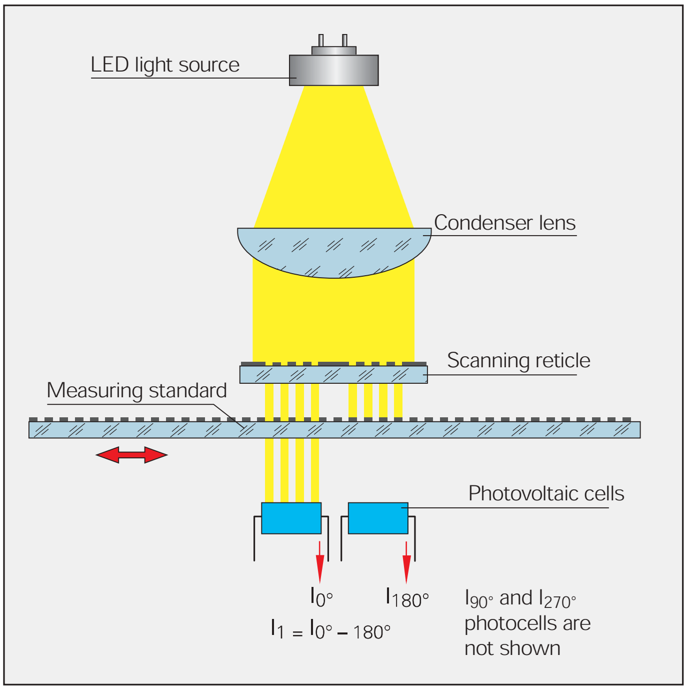
Scanning methods

Accuracy

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 ECN, EQN, ERN and ROC, ROQ, ROD 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—the circular scale and the scanning reticle—are moved relative to each other. The carrier material of the scanning reticle is transparent. The graduation on the measuring standard can likewise be applied to a transparent surface, but also a 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 relative to each other, the incident light is modulated. If the gaps in the gratings 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.



Photoelectric scanning according to the imaging scanning principle

The ROC/ROQ 400/1000 and ECN/EQN 400/1000 absolute rotary encoders with optimized scanning have a single large photosensor instead of a group of individual photocells. 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.

Other scanning principles
ECI/EBI/EQI and RIC/RIQ rotary encoders operate according to the inductive measuring principle. Here, 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.

The accuracy of position measurement with rotary encoders is mainly determined by
- the directional deviation of the radial grating,
- the eccentricity of the graduated disk to the bearing,
- the radial deviation of the bearing,
- the error resulting from the connection with a shaft coupling (on rotary encoders with stator coupling this error lies within the system accuracy),
- the interpolation error during signal processing in the integrated or external interpolation and digitizing electronics.

For **incremental rotary encoders** with line counts up to 5000:
The maximum directional deviation at 20 °C ambient temperature and slow speed (scanning frequency between 1 kHz and 2 kHz) lies within

$$\pm \frac{18° \text{ mech.} \cdot 3600}{\text{Line count } z} \text{ [angular seconds]}$$

which equals

$$\pm \frac{1}{20} \text{ grating period.}$$

The ROD rotary encoders generate 6000 to 10000 signal periods per revolution through signal doubling. The line count is important for the system accuracy.

The accuracy of absolute position values from **absolute rotary encoders** is given in the specifications for each model.

For absolute rotary encoders with **complementary incremental signals**, the accuracy depends on the line count:

Line count	**Accuracy**
16	± 480 angular seconds
32	± 280 angular seconds
512	± 60 angular seconds
2048	± 20 angular seconds
2048	± 10 angular seconds (ROC 425 with high accuracy)

The above accuracy data refer to incremental measuring signals at an ambient temperature of 20 °C and at slow speed.

Mechanical design types and mounting
Rotary encoders with stator coupling

ECN/EQN/ERN rotary encoders have integrated bearings and a mounted stator coupling. They compensate radial runout and alignment errors without significantly reducing the accuracy. 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. The stator coupling permits axial motion of the measured shaft:

ECN/EQN/ERN 400:	± 1 mm
ECN/EQN/ERN 1000:	± 0.5 mm
ECN/ERN 100:	± 1.5 mm

Mounting
The rotary encoder is slid by its hollow shaft onto the measured shaft, and the rotor is fastened by two screws or three eccentric clamps. For rotary encoders with hollow through shaft, the rotor can also be fastened at the end opposite to the flange. Rotary encoders of the ECN/EQN/ERN 1300 series with taper shaft are particularly well suited for repeated mounting (see brochure titled *Position Encoders for Servo Drives*). The stator is connected without a centering collar on a flat surface. The **universal stator coupling** of the ECN/EQN/ERN 400 permits versatile mounting, e.g. by its thread provided for fastening it from outside to the motor cover.

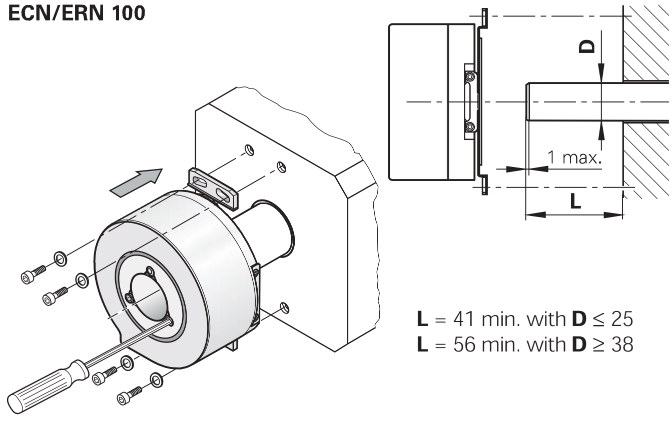
Dynamic applications require the highest possible natural frequencies f_N of the system (also see *General mechanical information)*. This is attained by connecting the shafts on the flange side and fastening the coupling by four cap screws or, on the ECN/EQN/ERN 1000, with special washers.

Natural frequency f_N with coupling fastened by 4 screws

	Stator coupling	Cable	Flange socket	
			Axial	Radial
ECN/EQN/ ERN 400	Standard Universal	1550 Hz 1400 Hz[1)]	1500 Hz 1400 Hz	1000 Hz 900 Hz
ECN/ERN 100		1000 Hz	–	400 Hz
ECN/EQN/ERN 1000		1500 Hz[2)]	–	–

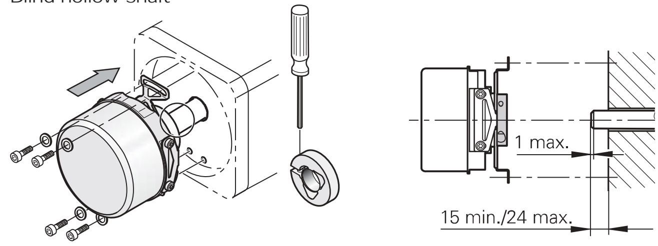
1) Also when fastening with 2 screws
2) Also when fastening with 2 screws and washers

ECN/ERN 100

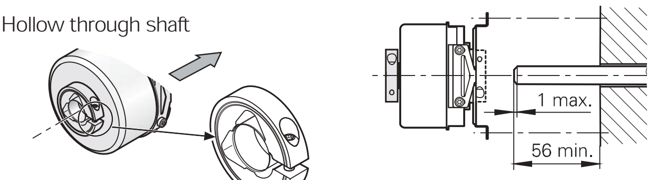


ECN/EQN/ERN 400 e.g. with standard stator coupling

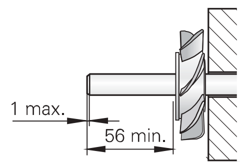
Blind hollow shaft



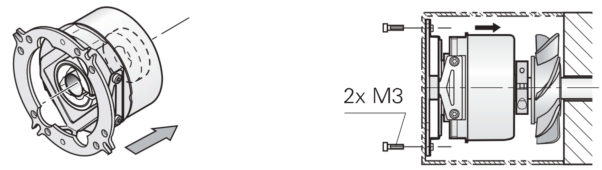
Hollow through shaft



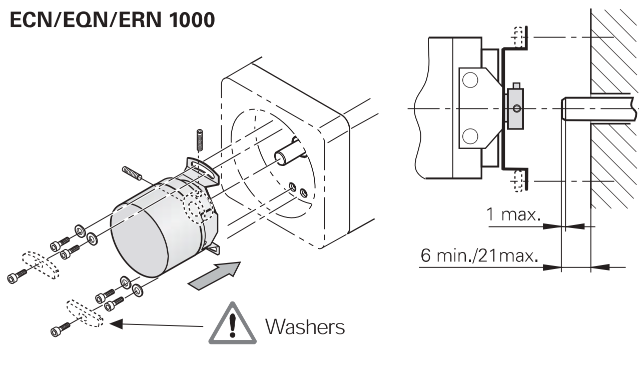
ECN/EQN/ERN 400
e.g. with universal stator coupling



Hollow through shaft

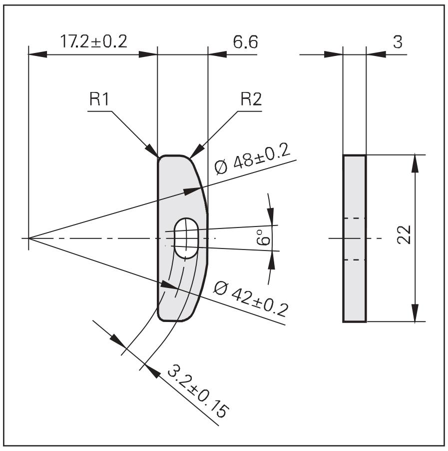


ECN/EQN/ERN 1000

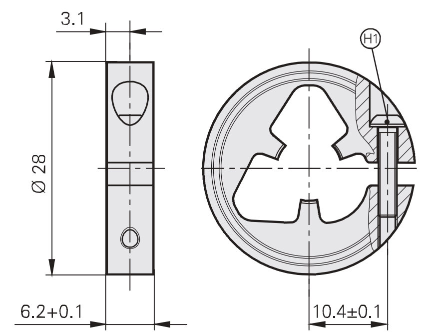


Mounting accessories

Washer
For ECN/EQN/ERN 1000
For increasing the natural frequency f_N and mounting with only two screws.
ID 334653-01



Shaft clamp ring
For ECN/EQN/ERN 400
By using a second shaft clamp ring, the mechanically permissible speed of rotary encoders with hollow through shaft can be increased to a maximum of 12000 min^{-1}.
ID 540741-xx



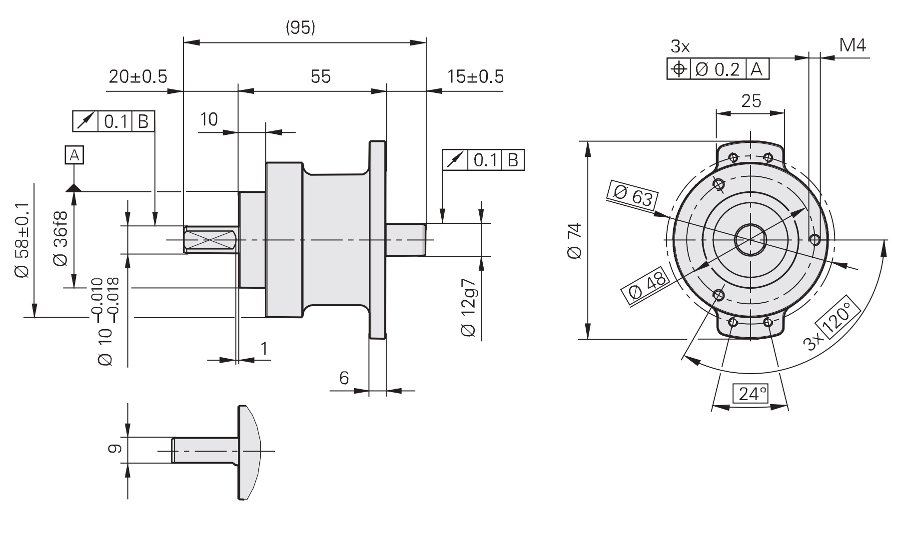
H1 = Clamping screw with X8 hexalobular socket, tightening torque 1.1 ± 0.1 Nm

If the encoder shaft is subject to high loads, for example from friction wheels, pulleys, or sprockets, HEIDENHAIN recommends mounting the ECN/EQN/ERN 400 with a bearing assembly.

	Bearing assembly
Permissible speed n	≤ 6000 min^{-1}
Shaft load	Axial: 150 N; Radial: 350 N
Operating temperature	–40 to 100 °C

Bearing assembly
For ERN/ECN/EQN 400
series with blind hollow shaft
ID 574185-03

The bearing assembly is capable of absorbing large radial shaft loads. It prevents overload of the encoder bearing. On the encoder side, the bearing assembly has a stub shaft with 12 mm diameter and is well suited for the ERN/ECN/EQN 400 encoders with blind hollow shaft. Also, the threaded holes for fastening the stator coupling are already provided. The flange of the bearing assembly has the same dimensions as the clamping flange of the ROD 420/430 series. The bearing assembly can be fastened through the threaded holes on its face or with the aid of the mounting flange or the mounting bracket (see page 15).



Torque supports for ECN/EQN/ERN 400
For simple applications with the ECN/EQN/ERN 400, the stator coupling can be replaced by torque supports. The following kits are available:

Wire torque support
The stator coupling is replaced by a flat metal ring to which the provided wire is fastened.
ID 510955-01

Pin torque support
Instead of a stator coupling, a "synchro flange" is fastened to the encoder. A pin serving as torque support is mounted either axially or radially on the flange. As an alternative, the pin can be pressed in on the customer's surface, and a guide can be inserted in the encoder flange for the pin.
ID 510861-01

General 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
TX15	70 mm	756768-42

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

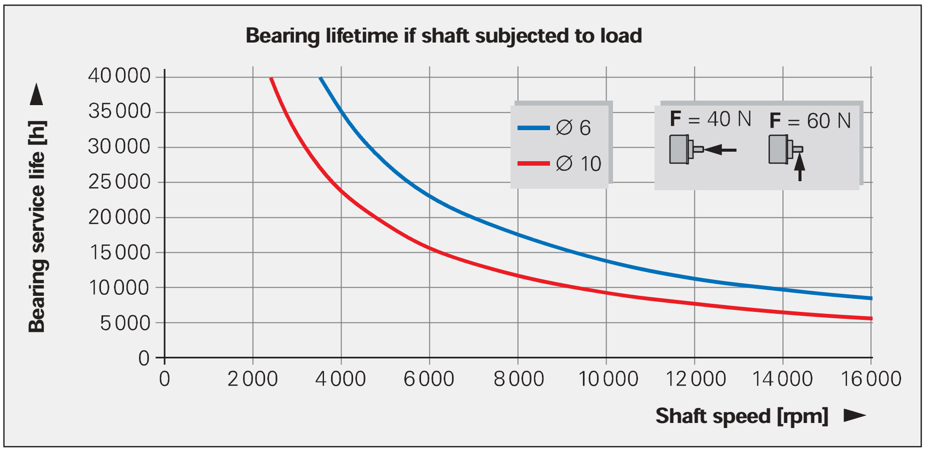
Screwdriver
Adjustable torque
0.2 Nm to 1.2 Nm ID 350379-04
1 Nm to 5 Nm ID 350379-05

Rotary encoders for separate shaft coupling

ROC/ROQ/ROD and **RIC/RIQ** rotary encoders have integrated bearings and a solid shaft. The encoder shaft is connected with the measured shaft through a separate rotor coupling. The coupling compensates axial motion and misalignment (radial and angular offset) between the encoder shaft and measured shaft. This relieves the encoder bearing of additional external loads that would otherwise shorten its service life. Diaphragm and metal bellows couplings designed to connect the rotor of the ROC/ROQ/ROD/RIC/RIQ encoders are available (see *Shaft couplings*).

ROC/ROQ/ROD 400 and RIC/RIQ 400 series rotary encoders permit high bearing loads (see diagram). They can therefore also be mounted directly onto mechanical transfer elements such as gears or friction wheels.
If the encoder shaft is subject to relatively high loads, for example from friction wheels, pulleys, or sprockets, HEIDENHAIN recommends mounting the ECN/EQN/ERN 400 with a bearing assembly.

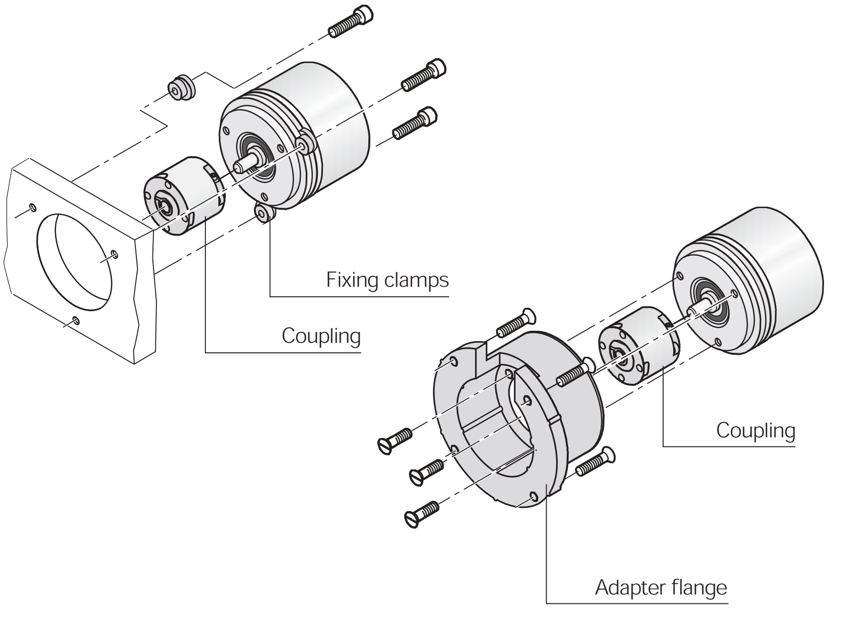
Bearing life span of ROC/ROQ/ROD 400 and RIC/RIQ 400
The service life to be expected of the bearings depends on the shaft speed and the shaft load as a function of the force application point. The maximum permissible load of the shaft at shaft end is listed in the specifications. The relationship between the bearing service life and the shaft speed at maximum shaft load is illustrated in the diagram for the shaft diameters 6 mm and 10 mm. With a load of 10 N axially and 20 N radially at the shaft end, the expected bearing service life at maximum shaft speed is more than 40000 hours.



Rotary encoders with synchro flange

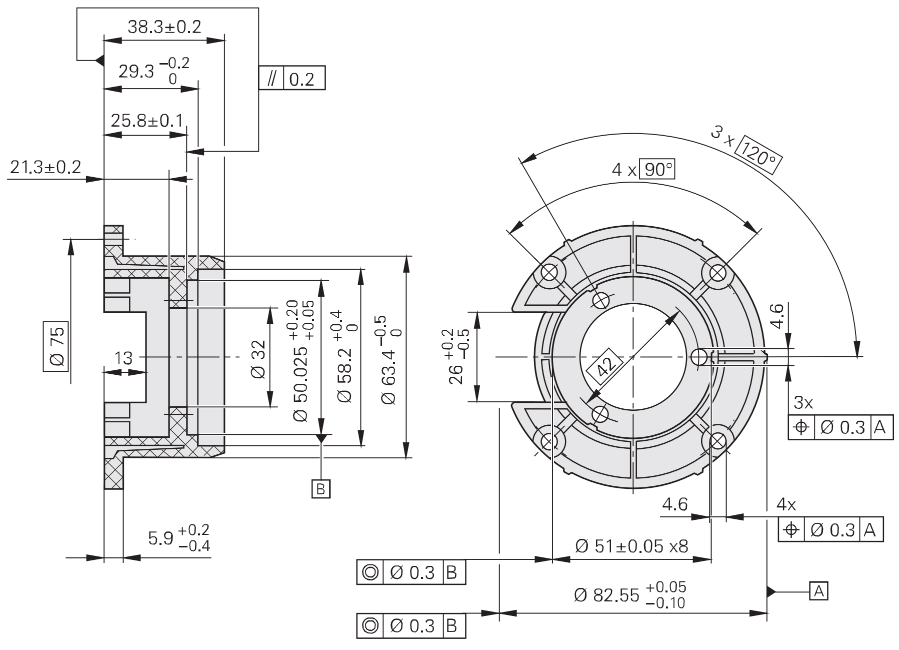
Mounting
- by the synchro flange with three fixing clamps or
- by fastening threaded holes on the encoder flange to an adapter flange (for ROC/ROQ/ROD 400 or RIC/RIQ 400).

Rotary encoders with synchro flange

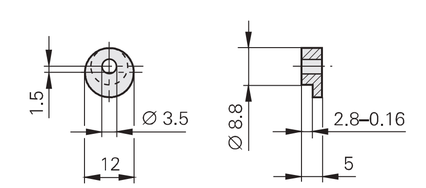


Mounting accessories

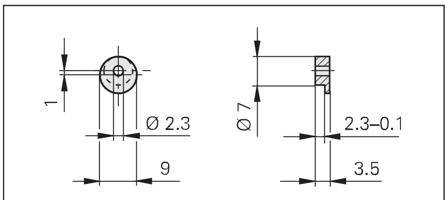
Adapter flange
(electrically nonconducting)
ID 257044-01



Fixing clamps
For ROC/ROQ/ROD 400 and RIC/RIQ 400 series
(3 per encoder)
ID 200032-01



Fixing clamps
For ROC/ROQ/ROD 1000 series
(3 per encoder)
ID 200032-02

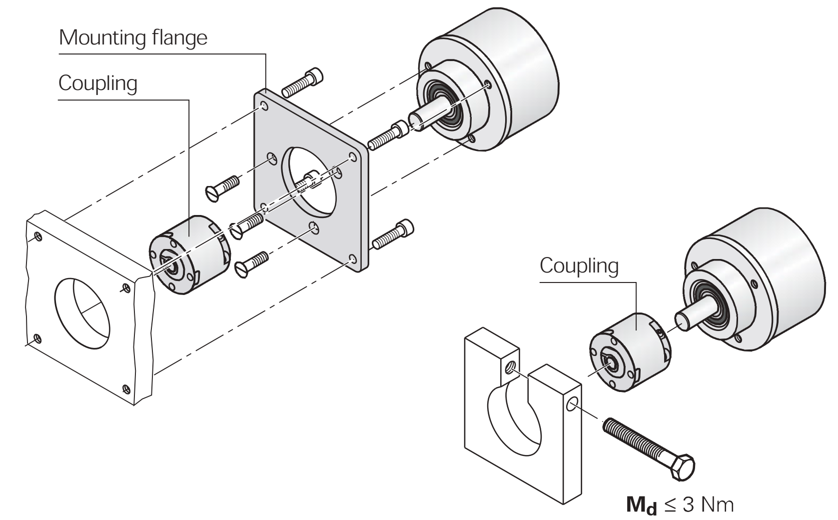


Rotary encoders with clamping flange

Mounting
- by fastening the threaded holes on the encoder flange to an adapter flange or
- by clamping at the clamping flange.

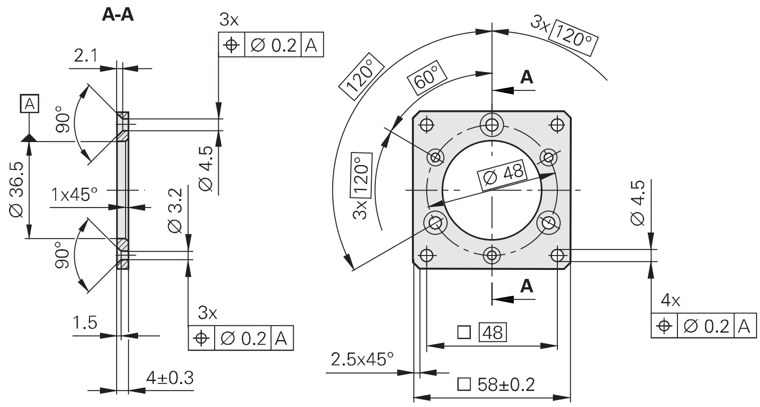
The centering collar on the synchro flange or clamping flange serves to center the encoder.

ROC/ROQ/ROD 400 with clamping flange

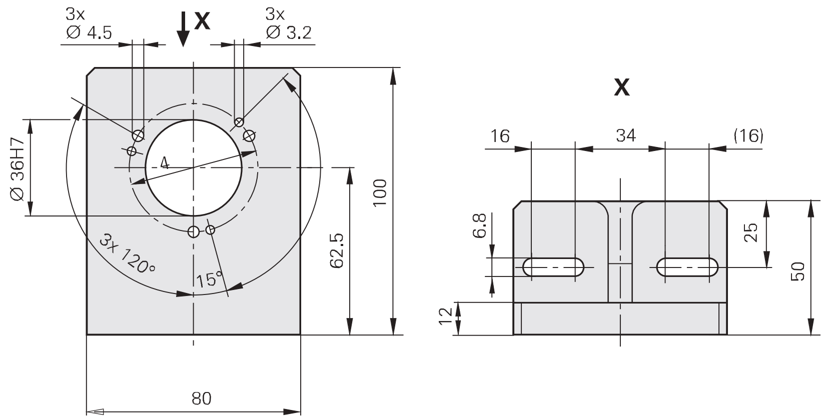


Mounting accessories

Mounting flange
ID 201437-01



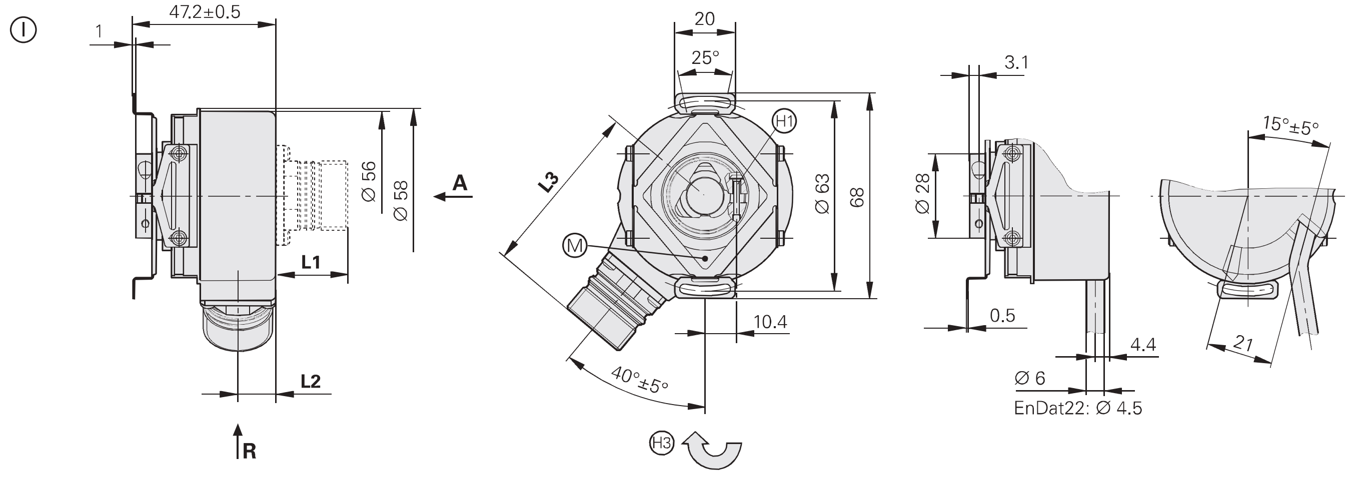
Mounting bracket
ID 581296-01



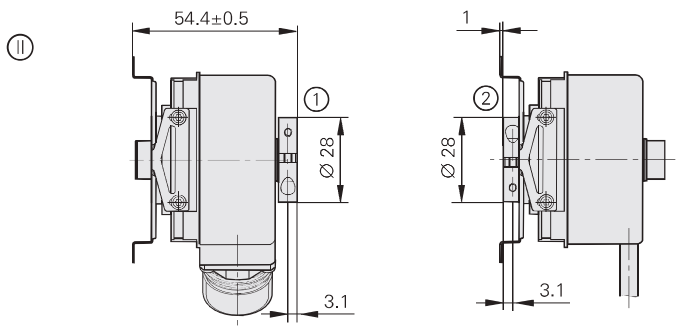
ECN/EQN/ERN 400 series

- Absolute and incremental rotary encoders
- Stator coupling for plane surface
- Blind hollow shaft or hollow through shaft

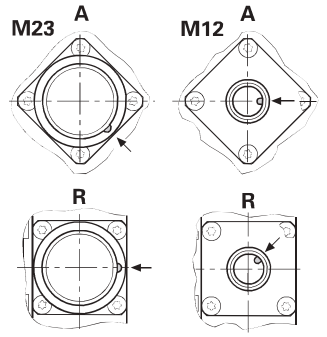
Blind hollow shaft

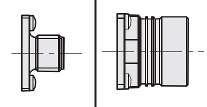


Hollow through shaft

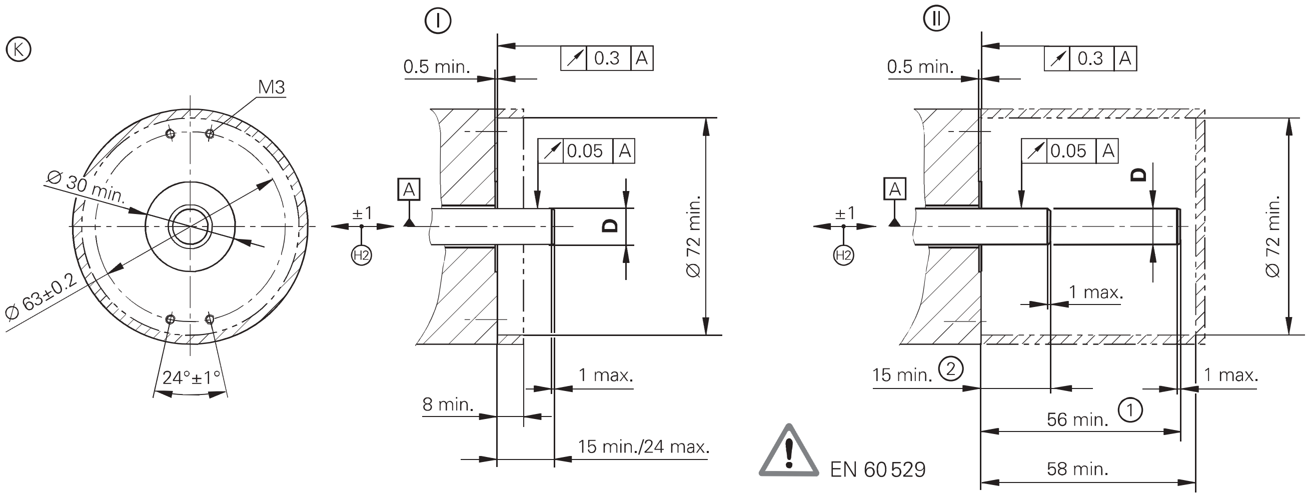


Connector coding
A = axial, **R** = radial



	Flange socket	
	M12	M23
		
L1	14	23.6
L2	12.5	12.5
L3	48.5	58.1

D
Ø 8g7 Ⓔ
Ø 12g7 Ⓔ



EN 60529

mm

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

Cable radial, also usable axially
A = Bearing of mating shaft
K = Required mating dimensions
M = Measuring point for operating temperature
H1 = Clamping screw with X8 hexalobular socket
H2 = Compensation of mounting tolerances and thermal expansion, no dynamic motion permitted
H3 = Direction of shaft rotation for output signals as per the interface description
1 = Clamping ring on housing side (condition upon delivery)
2 = Clamping ring on coupling side (optionally mountable)

	Absolute Singleturn		
	ECN 425	**ECN 413**	
Absolute position values*	**EnDat 2.2**	**EnDat 2.2**	**SSI**
Ordering designation	EnDat 22	EnDat 01	SSI 39r1
Positions per revolution	33 554 432 (25 bits)	8 192 (13 bits)	
Revolutions	–		
Code	Pure binary		Gray
Elec. permissible speed Deviations[1]	≤ 12 000 min^{-1} for continuous position value	*512 lines:* ≤ 5 000/12 000 min^{-1} ± 1 LSB/± 100 LSB *2048 lines:* ≤ 1 500/12 000 min^{-1} ± 1 LSB/± 50 LSB	≤ 12 000 min^{-1} ± 12 LSB
Calculation time t_{cal} Clock frequency	≤ 7 µs ≤ 8 MHz	≤ 9 µs ≤ 2 MHz	≤ 5 µs –
Incremental signals	Without	∼ 1 V_{PP}[2]	
Line counts*	–	**512** 2048	**512**
Cutoff frequency –3 dB Scanning frequency Edge separation a	– – –	*512 lines:* ≥ 130 kHz; *2048 lines:* ≥ 400 kHz – –	
System accuracy	± 20"	*512 lines:* ± 60"; *2048 lines:* ± 20"	
Power supply*	**3.6 to 14 V DC**	**3.6 to 14 V DC**	5 V DC ± 5% or **10 to 30 V DC**
Power consumption (max.)	*3.6 V:* ≤ 600 mW *14 V:* ≤ 700 mW		*5 V:* ≤ 800 mW *10 V:* ≤ 650 mW *30 V:* ≤ 1 000 mW
Current consumption (typical; without load)	*5 V:* 85 mA		*5 V:* 90 mA *24 V:* 24 mA
Electrical connection*	• **Flange socket** M12, radial • Cable 1 m, with M12 coupling	• **Flange socket** M23, radial • Cable 1 m, with M23 coupling or without connecting element	
Shaft*	**Blind hollow shaft** or **hollow through shaft; D = 8 mm** or **D = 12 mm**		
Mech. perm. speed n[3]	≤ 6 000 min^{-1}/≤ 12 000 min^{-1} [4]		
Starting torque At 20 °C Below –20 °C	*Blind hollow shaft:* ≤ 0.01 Nm *Hollow through shaft:* ≤ 0.025 Nm ≤ 1 Nm		
Moment of inertia of rotor	≤ 4.3 · 10^{-6} kgm^2		
Permissible axial motion of measured shaft	± 1 mm		
Vibration 55 to 2 000 Hz **Shock** 6 ms	≤ 300 m/s^2; *flange socket version:* ≤ 150 m/s^2 (EN 60 068-2-6); higher values on request ≤ 1 000 m/s^2 (EN 60 068-2-27)		
Max. operating temp.[3]	100 °C		
Min. operating temp.	*Flange socket or fixed cable:* –40 °C *Moving cable:* –10 °C		
Protection EN 60 529	IP 67 at housing; IP 64 at shaft inlet		
Weight	Approx. 0.3 kg		

Bold: These preferred versions are available on short notice
* Please select when ordering
1) Speed-dependent deviations between the absolute value and incremental signal

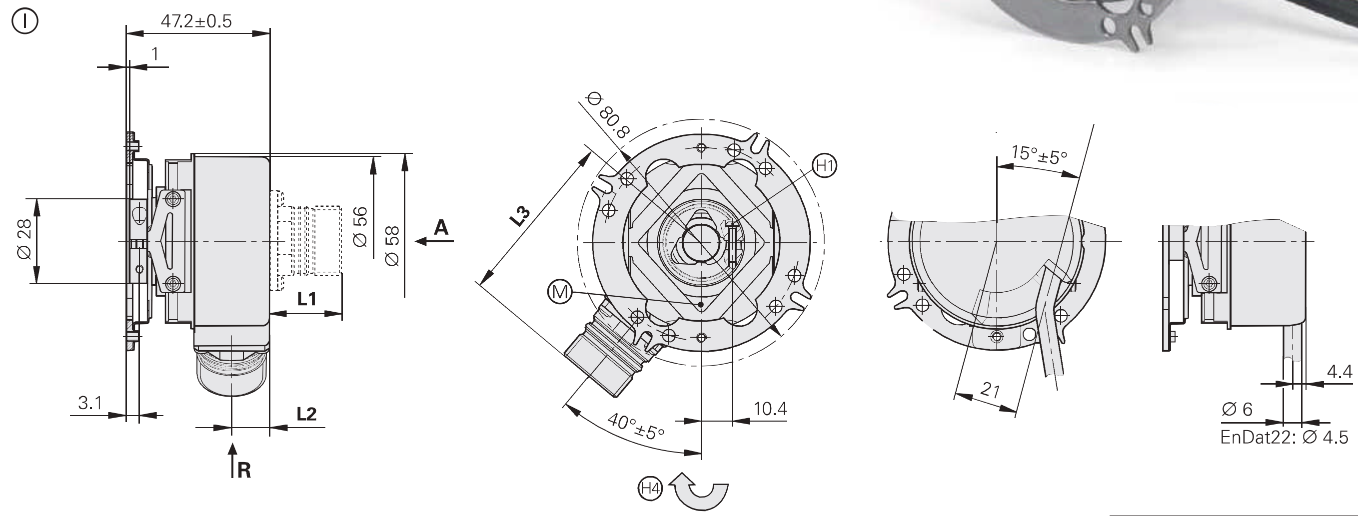
Multiturn		
EQN 437	**EQN 425**	
EnDat 2.2	**EnDat 2.2**	**SSI**
EnDat 22	EnDat 01	SSI 41r1
33 554 432 (25 bits)	8 192 (13 bits)	
4 096		
Pure binary		Gray
≤ 12 000 min^{-1} for continuous position value	*512 lines:* ≤ 5 000/10 000 min^{-1} ± 1 LSB/± 100 LSB *2048 lines:* ≤ 1 500/10 000 min^{-1} ± 1 LSB/± 50 LSB	≤ 12 000 min^{-1} ± 12 LSB
≤ 7 µs ≤ 8 MHz	≤ 9 µs ≤ 2 MHz	≤ 5 µs –
Without	$\sim$ 1 V_{PP}[2]	
–	**512** 2 048	**512**
– – –	*512 lines:* ≥ 130 kHz; *2048 lines:* ≥ 400 kHz – –	
± 20"	*512 lines:* ± 60"; *2048 lines:* ± 20"	
3.6 to 14 V DC	**3.6 to 14 V DC**	5 V DC ± 5 % or **10 to 30 V DC**
3.6 V: ≤ 700 mW *14 V:* ≤ 800 mW		*5 V:* ≤ 950 mW *10 V:* ≤ 750 mW *30 V:* ≤ 1 100 mW
5 V: 105 mA		*5 V:* 120 mA *24 V:* 28 mA
• **Flange socket** M12, radial • Cable 1 m, with M12 coupling	• **Flange socket** M23, radial • Cable 1 m, with M23 coupling or without connecting element	

[2] Restricted tolerances: Signal amplitude: 0.8 to 1.2 V_{PP}
[3] For the correlation between the operating temperature and the shaft speed or power supply, see *General mechanical information*
[4] With 2 shaft clamps (only for hollow through shaft)

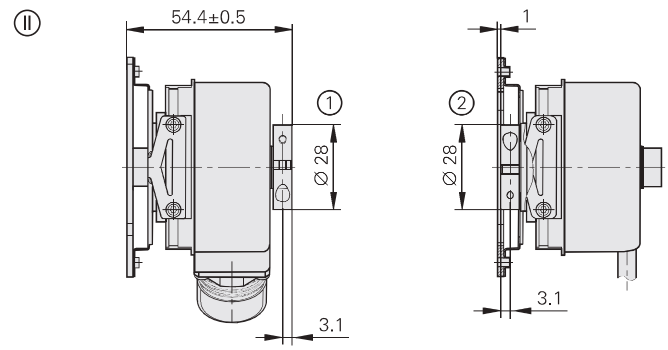
ECN/EQN/ERN 400 series

- **Absolute and incremental rotary encoders**
- **Stator coupling for universal mounting**
- **Blind hollow shaft or hollow through shaft**

Blind hollow shaft



Hollow through shaft



Connector coding
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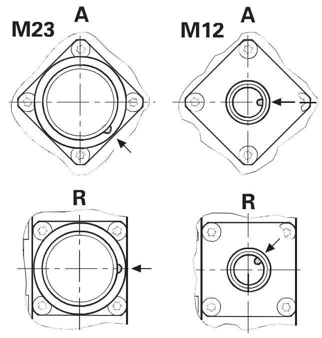
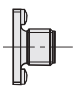
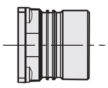
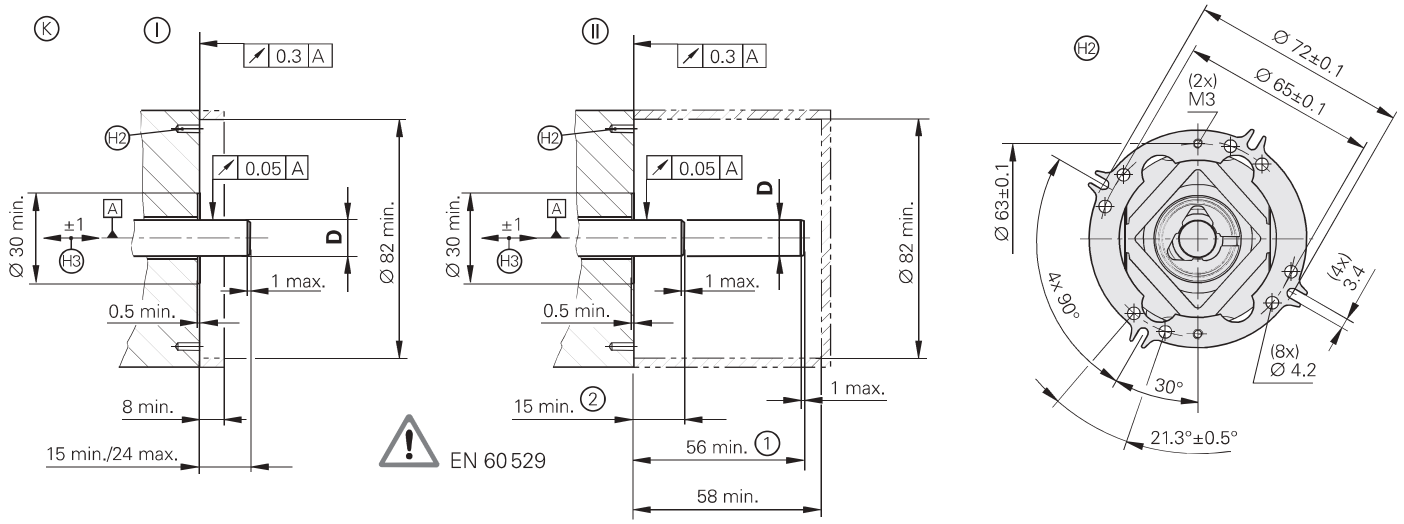


	Flange socket	
	M12 	M23 
L1	14	23.6
L2	12.5	12.5
L3	48.5	58.1

D
Ø 8g7 Ⓔ
Ø 12g7 Ⓔ



mm

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

Cable radial, also usable axially
Ⓐ = Bearing of mating shaft
Ⓚ = Required mating dimensions
Ⓜ = Measuring point for operating temperature
Ⓗ1 = Clamping screw with X8 hexalobular socket
Ⓗ2 = Hole circle for fastening, see coupling
Ⓗ3 = Compensation of mounting tolerances and thermal expansion, no dynamic motion permitted
Ⓗ4 = Direction of shaft rotation for output signals as per the interface description
① = Clamping ring on housing side (condition upon delivery)
② = Clamping ring on coupling side (optionally mountable)

	Absolute Singleturn ECN 425	ECN 413	ECN 413
Absolute position values*	**EnDat 2.2**	**EnDat 2.2**	**SSI**
Ordering designation	EnDat 22	EnDat 01	SSI 39r1
Positions per revolution	33554432 (25 bits)	8192 (13 bits)	
Revolutions	–		
Code	Pure binary		Gray
Elec. permissible speed Deviations[1]	≤ 12000 min^{-1} for continuous position value	*512 lines:* ≤ 5000/12000 min^{-1} ± 1 LSB/± 100 LSB *2048 lines:* ≤ 1500/12000 min^{-1} ± 1 LSB/± 50 LSB	≤ 12000 min^{-1} ± 12 LSB
Calculation time t_{cal} Clock frequency	≤ 7 µs ≤ 8 MHz	≤ 9 µs ≤ 2 MHz	≤ 5 µs –
Incremental signals	Without	∿ 1 V_{PP}[2]	
Line counts*	–	**512** 2048	**512**
Cutoff frequency –3 dB Scanning frequency Edge separation a	– – –	*512 lines:* ≥ 130 kHz; *2048 lines:* ≥ 400 kHz – –	
System accuracy	± 20"	*512 lines:* ± 60"; *2048 lines:* ± 20"	
Power supply*	**3.6 to 14 V DC**	**3.6 to 14 V DC**	5 V DC ± 5% or **10 to 30 V DC**
Power consumption (max.)	*3.6 V:* ≤ 600 mW *14 V:* ≤ 700 mW		*5 V:* ≤ 800 mW *10 V:* ≤ 650 mW *30 V:* ≤ 1000 mW
Current consumption (typical; without load)	*5 V:* 85 mA		*5 V:* 90 mA *24 V:* 24 mA
Electrical connection*	• **Flange socket** M12, radial • Cable 1 m, with M12 coupling	• **Flange socket** M23, radial • Cable 1 m, with M23 coupling or without connecting element	
Shaft*	**Blind hollow shaft** or **hollow through shaft; D = 8 mm** or **D = 12 mm**		
Mech. perm. speed n[3]	≤ 6000 min^{-1}/≤ 12000 min^{-1} [4]		
Starting torque At 20 °C Below –20 °C	*Blind hollow shaft:* ≤ 0.01 Nm *Hollow through shaft:* ≤ 0.025 Nm ≤ 1 Nm		
Moment of inertia of rotor	≤ $4.3 \cdot 10^{-6}$ kgm^2		
Permissible axial motion of measured shaft	± 1 mm		
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 300 m/s^2; *flange socket version:* 150 m/s^2 (EN 60068-2-6); higher values on request ≤ 1000 m/s^2 (EN 60068-2-27)		
Max. operating temp.[3]	100 °C		
Min. operating temp.	*Flange socket or fixed cable:* –40 °C *Moving cable:* –10 °C		
Protection EN 60529	IP 67 at housing, IP 64 at shaft end (IP 66 available on request)		
Weight	Approx. 0.3 kg		

Bold: This preferred version is available on short notice
[1] Speed-dependent deviations between the absolute value and incremental signal

* Please indicate when ordering
[2] Restricted tolerances: Signal amplitude 0.8 to 1.2 V_{PP}

Multiturn		
EQN 437	**EQN 425**	**EQN 425**
EnDat 2.2	**EnDat 2.2**	**SSI**
EnDat 22	EnDat 01	SSI 41r1
33 554 432 (25 bits)	8 192 (13 bits)	
4 096		
Pure binary		Gray
≤ 12 000 min^{-1} for continuous position value	*512 lines:* ≤ 5 000/10 000 min^{-1} ± 1 LSB/± 100 LSB *2048 lines:* ≤ 1 500/10 000 min^{-1} ± 1 LSB/± 50 LSB	≤ 12 000 min^{-1} ± 12 LSB
≤ 7 µs ≤ 8 MHz	≤ 9 µs ≤ 2 MHz	≤ 5 µs –
Without	∼ 1 V_{PP}[2]	
–	**512** 2 048	**512**
– – –	*512 lines:* ≥ 130 kHz; *2048 lines:* ≥ 400 kHz – –	
± 20"	*512 lines:* ± 60"; *2048 lines:* ± 20"	
3.6 to 14 V DC	**3.6 to 14 V DC**	5 V DC ± 5 % or **10 to 30 V DC**
3.6 V: ≤ 700 mW *14 V:* ≤ 800 mW		*5 V:* ≤ 950 mW *10 V:* ≤ 750 mW *30 V:* ≤ 1 100 mW
5 V: 105 mA		*5 V:* 120 mA *24 V:* 28 mA
• **Flange socket** M12, radial • Cable 1 m, with M12 coupling	• **Flange socket** M23, radial • Cable 1 m, with M23 coupling or without connecting element	

[3] For the correlation between the operating temperature and the shaft speed or power supply, see *General mechanical information*
[4] With 2 shaft clamps (only for hollow through shaft)

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, 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 drop 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 in the power lines. 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).

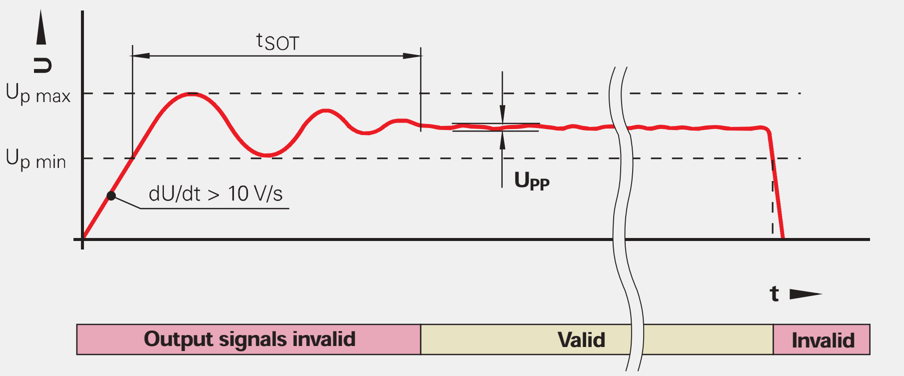
If the voltage drop is known, all parameters for the encoder and subsequent electronics can be calculated, e.g. voltage at the encoder, current requirements and power consumption of the encoder, as well as the power to be provided by the subsequent electronics.

Switch-on/off behavior of the encoders
The output signals are valid no sooner than after the switch-on time t_{SOT} = 1.3 s (2 s for PROFIBUS-DP) (see diagram). During the 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 on. These data apply to the encoders listed in the catalog—customer-specific interfaces are not considered.

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	0.05/0.14[6] mm^2	0.14 mm^2
Ø 5.5 mm PVC	0.1 mm^2	–	–	–
Ø 6 mm **Ø 10 mm**[1]	0.19/0.14[2), 4)] mm^2	–	0.08/0.19[6] 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
6) Adapter cables for RCN, LC

Encoders with expanded supply voltage 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 maximum power consumption (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 for comparison.

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 into consideration, in four steps:

Step 1: **Resistance of the supply lines**

The resistance values of the supply 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 or maximum power supply, respectively, in W

U_P: Supply voltage of the subsequent electronics in V

R_L: Cable resistance (for both directions) in ohms

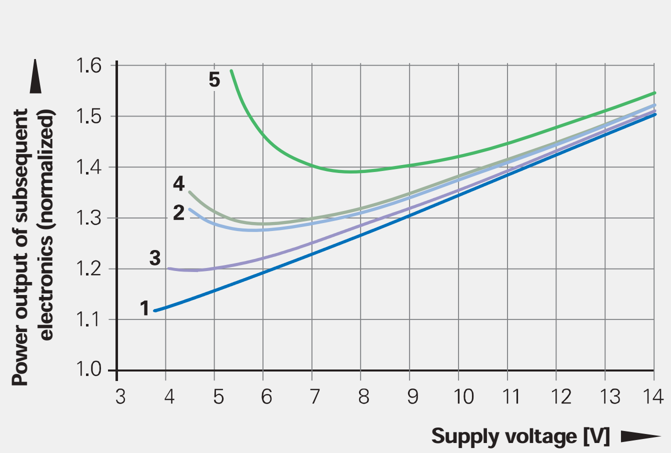
ΔU: Voltage drop in the cable in V

1.05: Length factor due to twisted wires

L_C: Cable length in m

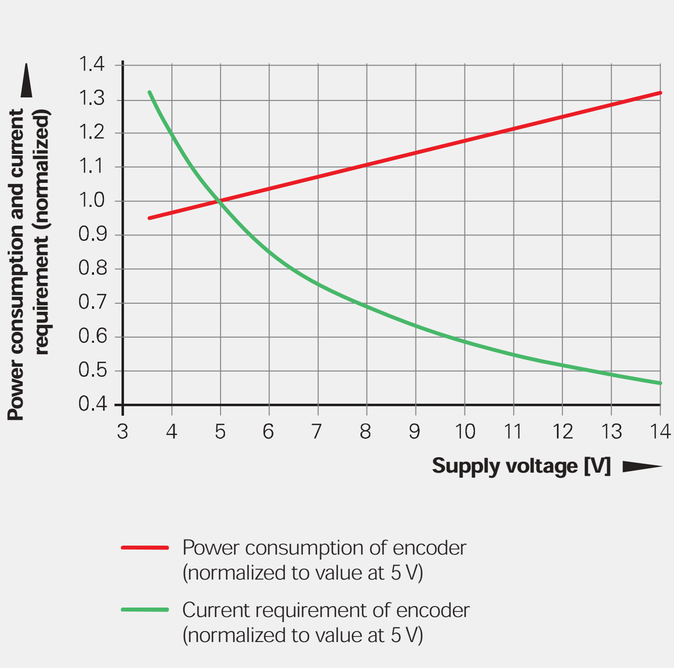
A_P: Cross section of power lines in mm^2

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



	Encoder cable/adapter cable	Connecting cables	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 –3 dB/ –6 dB 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/ output frequency f_{max} of the encoder, and
  – the minimum permissible edge separation a for the subsequent electronics.

For angle 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

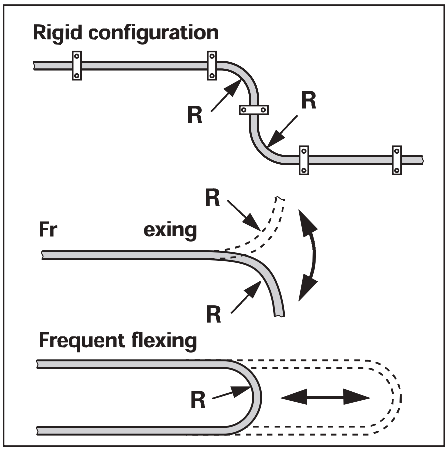
Cable

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 cables).** Most adapter cables for within motors and a few cables on encoders are sheathed in a **special elastomer (EPG cables).** These cables are identified in the specifications or in the cable tables with "EPG".

Durability
PUR cables are resistant to oil in accordance with **VDE 0472** (Part 803/test type B) and to hydrolysis and 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 PVC, silicone and halogens. In comparison with PUR cables, they are only somewhat 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	
	Rigid configuration	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:

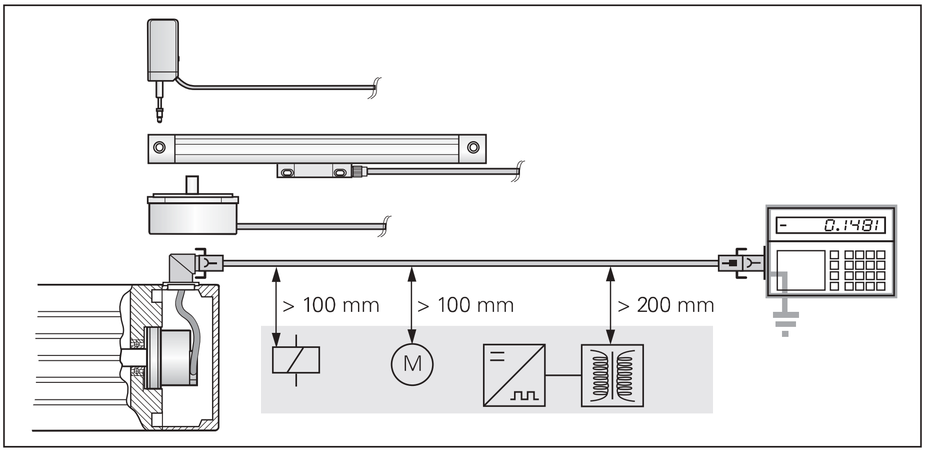
- **Noise immunity EN 61000-6-2:**
  Specifically:
  - ESD EN 61000-4-2
  - Electromagnetic fields EN 61000-4-3
  - Burst EN 61000-4-4
  - Surge EN 61000-4-5
  - Conducted disturbances EN 61000-4-6
  - Power frequency magnetic fields EN 61000-4-8
  - Pulse magnetic fields EN 61000-4-9
- **Interference EN 61000-6-4:**
  Specifically:
  - For industrial, scientific and medical equipment (ISM) EN 55011
  - For information technology equipment EN 55022

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 drop 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 0V 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 contactors, 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.
- Provide power only from PELV systems **(EN 50178)** to position encoders. Provide high-frequency grounding with low impedance **(EN 60204-1 Chap. EMC).**
- For encoders with 11 µAPP interface: For extension cables, use only HEIDENHAIN cable ID 244955-01. Overall length: max. 30 m.



Minimum distance from sources of interference

Sales and Service
More information

Other devices for angular measurement from HEIDENHAIN include rotary encoders, which are used primarily on electrical motors, for elevator control and for potentially explosive atmospheres.
Angle encoders from HEIDENHAIN serve for high-accuracy position acquisition of angular movements.

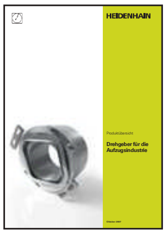
Catalog
Encoders for Servo Drives

Contents:
Rotary encoders
Angle encoders
Linear encoders

Catalog
Modular Magnetic Encoders

Catalog
Absolute Angle Encoders with Optimized Scanning

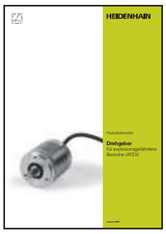
Contents:
Absolute angle encoders
RCN 2000, RCN 5000, RCN 8000



Product Overview
Rotary Encoders for the Elevator Industry

Catalog
Angle Encoders with Integral Bearing

Contents:
Absolute angle encoders
RCN
Incremental angle encoders
RON, RPN, ROD



Product Overview
Rotary Encoders for Potentially Explosive Atmospheres

Catalog
Angle Encoders without Integral Bearing

Contents:
Incremental angle encoders
ERA, ERP

Further HEIDENHAIN products
- Linear encoders
- Length gauges
- Measuring systems for machine tool inspection and acceptance testing
- Subsequent electronics
- NC controls for machine tools
- Touch probes

HEIDENHAIN on the Internet
Visit our home page at www.heidenhain.com for up-to-date information on:
- The company
- The products

Also included:
- Technical articles
- Press releases
- Addresses
- CAD drawings

Addresses in Germany

HEIDENHAIN is represented in Germany and all other important industrial nations as well. In addition to the addresses listed on the back page, there are many service agencies located worldwide. For their addresses, please refer to the Internet or contact HEIDENHAIN Traunreut.

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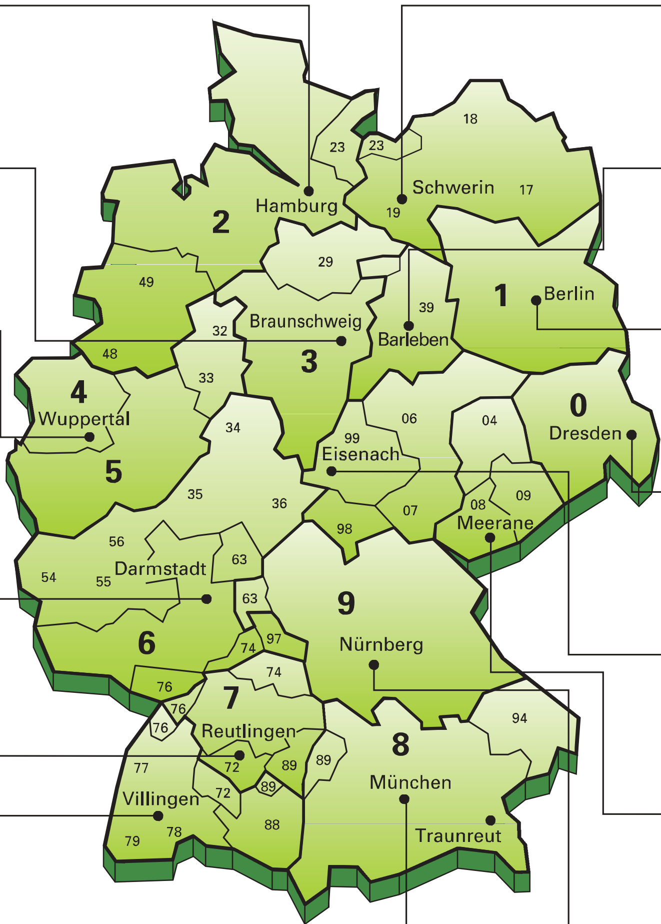

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