HEIDENHAIN

# Rotary Encoders

12/2021

**Rotary encoders from HEIDENHAIN** serve as feedback devices for rotary motion and angular speed. When used in conjunction with mechanical measuring standards such as lead screws, they can also measure linear motion. Possible applications include electric motors, machine tools, printing machines, woodworking machines, textile machines, robots, and handling devices, as well as a wide variety of measuring, testing, and inspection devices. The high quality of their sinusoidal incremental signals permits high interpolation factors for digital speed control.

Rotary encoders for separate shaft coupling

Electronic handwheel

Rotary encoders with mounted stator coupling

Information about
- Encoders for servo drives
- Sealed angle encoders
- Modular angle encoders with optical scanning
- Modular angle encoders with magnetic scanning
- Linear encoders for numerically controlled machine tools
- Exposed linear encoders
- Signal converters
- HEIDENHAIN controls, and
- Cables and connecting elements

is available upon request as well as on the Internet at *www.heidenhain.com*.

**Further information:**

For detailed descriptions of all available interfaces, as well as general electrical information, please refer to the *Interfaces of HEIDENHAIN Encoders* brochure.

*This brochure supersedes all previous editions, which thereby become invalid. The basis for ordering from HEIDENHAIN is always the current product documentation at the time the order is placed.*

*Standards (ISO, EN, etc.) apply only where explicitly stated in this brochure.*



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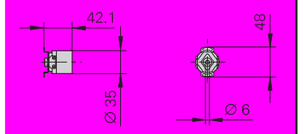
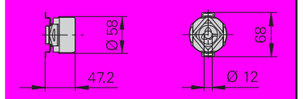
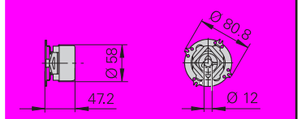
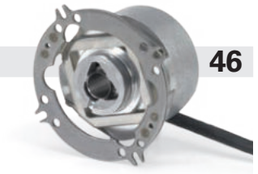
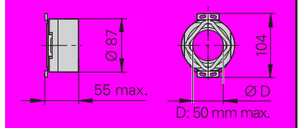
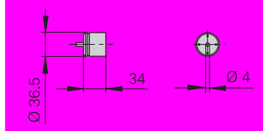
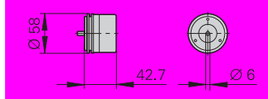
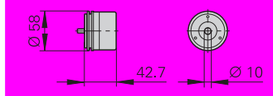
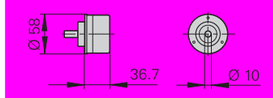
| Rotary encoders | Absolute<br>**Singleturn** | | | **Multiturn** 4096 revolutions | | | Incremental | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Interface | EnDat | Fanuc<br>Siemens | SSI | EnDat | Fanuc<br>Siemens | SSI | ⊓⊔ TTL | ⊓⊔ HTL | ~ 1 $V_{PP}$ | |
| **With mounted stator coupling** | | | | | | | | | | |
| **ECN/EQN/ERN 1000** series<br>  | **ECN 1023**<br>Positions/rev: 23 bits<br>EnDat 2.2/22<br>**ECN 1013**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **ECN 1023 S**<br>Positions/rev: 23 bits<br>DRIVE-CLiQ | – | **EQN 1035**<br>Positions/rev: 23 bits<br>EnDat 2.2/22<br>**EQN 1025**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **EQN 1035 S**<br>Positions/rev: 23 bits | – | **ERN 1020**<br>100 to 3600 lines<br>**ERN 1070**<br>1000/2500/3600 lines [1] | **ERN 1030**<br>100 to 3600 lines | **ERN 1080**<br>100 to 3600 lines |  **32** |
| **ECN/EQN/ERN 400** series<br>  | **ECN 425**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>Available with<br>functional safety<br>**ECN 413**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **ECN 425 F**<br>Positions/rev: 25 bits<br>Fanuc αi<br>**ECN 424 S**<br>Positions/rev: 24 bits<br>DRIVE-CLiQ<br>Available with<br>functional safety | **ECN 413**<br>Positions/rev: 13 bits | **EQN 437**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>Available with<br>functional safety<br>**EQN 425** [3]<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **EQN 437 F**<br>Positions/rev: 25 bits<br>Fanuc αi<br>**EQN 436 S**<br>Positions/rev: 24 bits<br>DRIVE-CLiQ<br>Available with<br>functional safety | **EQN 425** [3]<br>Positions/rev: 13 bits | **ERN 420**<br>250 to 5000 lines<br>**ERN 460** [2]<br>250 to 5000 lines | **ERN 430**<br>250 to 5000 lines | **ERN 480** [4]<br>1000 to 5000 lines |  **36** |
| **ECN/EQN/ERN 400** series<br>with universal stator coupling<br>  | **ECN 425**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>**ECN 413**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | – | **ECN 413**<br>Positions/rev: 13 bits | **EQN 437**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>**EQN 425**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | – | **EQN 425**<br>Positions/rev: 13 bits | **ERN 420**<br>250 to 5000 lines<br>**ERN 460** [2]<br>250 to 5000 lines | **ERN 430**<br>250 to 5000 lines | **ERN 480**<br>1000 to 5000 lines |  **46** |
| **ECN/ERN 100** series<br>  | **ECN 125**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>**ECN 113**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | – | – | – | – | – | **ERN 120**<br>1000 to 5000 lines | **ERN 130**<br>1000 to 5000 lines | **ERN 180**<br>1000 to 5000 lines |  **50** |

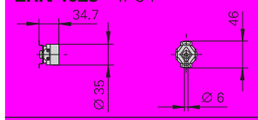
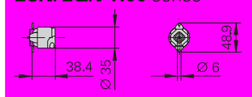
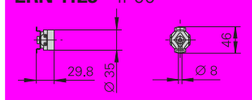
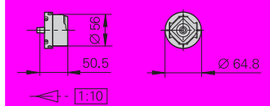
[1] Up to 36000 signal periods via integrated 5/10-fold interpolation (higher interpolation upon request)
[2] Supply voltage: DC 10 V to 30 V
[3] Also available with TTL or HTL signal transmission
[4] Available with mechanical fault exclusion; for restrictions on specifications and for special mounting information, see the *Fault Exclusion* customer information document

# Rotary encoders for standard applications

| Rotary encoders | Absolute<br>**Singleturn** | | | **Multiturn** 4096 revolutions | | | **Incremental** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Interface | EnDat | Fanuc<br>Siemens | SSI | EnDat | Fanuc<br>Siemens | SSI | ⊓⊔ TTL | ⊓⊔ HTL | ∿ 1 $V_{PP}$ | |
| **For separate shaft coupling, with synchro flange** | | | | | | | | | | |
| **ROC/ROQ/ROD 1000** series<br>  | **ROC 1023**<br>Positions/rev: 23 bits<br>EnDat 2.2/22<br>**ROC 1013**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **ROC 1023 S**<br>Positions/rev: 23 bits<br>DRIVE-CLiQ | – | **ROQ 1035**<br>Positions/rev: 23 bits<br>EnDat 2.2/22<br>**ROQ 1025**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **ROQ 1035 S**<br>Positions/rev: 23 bits<br>DRIVE-CLiQ | – | **ROD 1020**<br>100 to 3600 lines<br>**ROD 1070**<br>1000/2500/3600 lines[2] | **ROD 1030**<br>100 to 3600 lines | **ROD 1080**<br>100 to 3600 lines |  **52** |
| **ROC/ROQ/ROD 400** series<br>with synchro flange<br>  | **ROC 425**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>Available with<br>functional safety<br>**ROC 413**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **ROC 425 F**<br>Positions/rev: 25 bits<br>Fanuc αi<br>**ROC 424 S**<br>Positions/rev: 24 bits<br>DRIVE-CLiQ<br>Available with<br>functional safety | **ROC 413**<br>Positions/rev: 13 bits | **ROQ 437**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>Available with<br>functional safety<br>**ROQ 425**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **ROQ 437 F**<br>Positions/rev: 25 bits<br>Fanuc αi<br>**ROQ 436 S**<br>Positions/rev: 24 bits<br>DRIVE-CLiQ<br>Available with<br>functional safety | **ROQ 425**<br>Positions/rev: 13 bits | **ROD 426**<br>50 to 5000 lines[1]<br>**ROD 466**[3]<br>50 to 5000 lines[2] | **ROD 436**<br>50 to 5000 lines | **ROD 486**[5]<br>1000 to 5000 lines |  **56** |
| **ROC 425**<br>for high accuracy<br>  | **ROC 425**<br>Positions/rev: 25 bits<br>EnDat 2.2/01 | – | – | – | – | – | – | – | – |  **66** |
| **For separate shaft coupling, with clamping flange** | | | | | | | | | | |
| **ROC/ROQ/ROD 400** series<br>with clamping flange<br>  | **ROC 425**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>Available with<br>functional safety<br>**ROC 413**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **ROC 425 F**<br>Positions/rev: 25 bits<br>Fanuc αi<br>**ROC 424 S**<br>Positions/rev: 24 bits<br>DRIVE-CLiQ<br>Available with<br>functional safety | **ROC 413**<br>Positions/rev: 13 bits | **ROQ 437**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>Available with<br>functional safety<br>**ROQ 425**[4]<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **ROQ 437 F**<br>Positions/rev: 25 bits<br>Fanuc αi<br>**ROQ 436 S**<br>Positions/rev: 24 bits<br>DRIVE-CLiQ<br>Available with<br>functional safety | **ROQ 425**<br>Positions/rev: 13 bits | **ROD 420**<br>50 to 5000 lines | **ROD 430**<br>50 to 5000 lines | **ROD 480**[5]<br>1000 to 5000 lines |  **68** |

[1] Up to 10000 signal periods via integrated 2-fold interpolation
[2] Up to 36000 signal periods via integrated 5/10-fold interpolation (higher interpolation upon request)
[3] Supply voltage: DC 10 V to 30 V
[4] Also available with TTL or HTL signal transmission
[5] Available with mechanical fault exclusion; for deviating specifications and special mounting information, see the *Fault Exclusion* Customer Information document

# Rotary encoders for motors

| Rotary encoders | Absolute<br>Singleturn | | Multiturn | | Incremental | |
|---|---|---|---|---|---|---|
| Interface | EnDat | Siemens | EnDat | Siemens | ⊓⊔TTL | ∿ 1 $V_{PP}$ |
| **With integral bearing and mounted stator coupling** | | | | | | |
| **ERN 1023** IP64<br>  | – | – | – | – | – | **ERN 1023**<br>500 to 8192 lines<br>Three signals for block commutation | – |
| **ECN/EQN 1100** series<br>  | **ECN 1123**<br>Positions/rev: 23 bits<br>EnDat 2.2/22<br>Available with functional safety | **ECN 1113**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **ECN 1123S**<br>Positions/rev: 23 bits<br>DRIVE-CLiQ<br>Available with functional safety | **EQN 1135**<br>Positions/rev: 23 bits<br>4096 revolutions<br>EnDat 2.2/22<br>Available with functional safety | **EQN 1125**<br>Positions/rev: 13 bits<br>4096 revolutions<br>EnDat 2.2/01 | **EQN 1135S**<br>Positions/rev: 23 bits<br>4096 revolutions<br>DRIVE-CLiQ<br>Available with functional safety | – | – |
| **ERN 1123** IP00<br>  | – | – | – | – | – | – | **ERN 1123**<br>500 to 8192 lines<br>Three signals for block commutation | – |
| **ECN/EQN/ERN 1300** series IP40<br>**ECN/EQN/ERN 400** series IP64<br>  | **ECN 1325**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>EnDat 3/E30-R2<br>Available with functional safety<br>**ECN 425**<br>Positions/rev: 25 bits<br>EnDat 2.2/22<br>Available with functional safety | **ECN 1313**<br>Positions/rev: 13 bits<br>EnDat 2.2/01<br>**ECN 413**<br>Positions/rev: 13 bits<br>EnDat 2.2/01 | **ECN 1324S**<br>Positions/rev: 24 bits<br>DRIVE-CLiQ<br>Available with functional safety | **EQN 1337**<br>Positions/rev: 25 bits<br>4096 revolutions<br>EnDat 2.2/22<br>EnDat 3/E30-R2<br>Available with functional safety<br>**EQN 437**<br>Positions/rev: 25 bits<br>4096 revolutions<br>EnDat 2.2/22<br>Available with functional safety | **EQN 1325**<br>Positions/rev: 13 bits<br>4096 revolutions<br>EnDat 2.2/01<br>**EQN 425**<br>Positions/rev: 13 bits<br>4096 revolutions<br>EnDat 2.2/01 | **EQN 1336S**<br>Positions/rev: 24 bits<br>4096 revolutions<br>DRIVE-CLiQ<br>Available with functional safety | **ERN 1321**<br>1024 to 4096 lines<br>**ERN 1326** [1]<br>1024 to 4096 lines<br>Three TTL signals for block commutation<br>**ERN 421**<br>1024 to 4096 lines | **ERN 1381** [2]<br>512 to 4096 lines<br>**ERN 1387** [2]<br>2048 lines<br>Z1 track for sine commutation<br>**ERN 487**<br>2048 lines<br>Z1 track for sine commutation |

[1] 8192 signal periods through integrated 2-fold interpolation
[2] Available with mechanical fault exclusion; for restrictions on specifications and for special mounting information, see the *Fault Exclusion* customer information document

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These rotary encoders are described in the ***Encoders for Servo Drives*** brochure.

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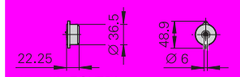
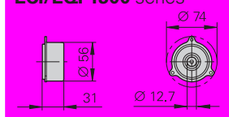
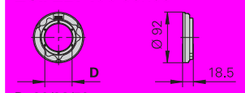
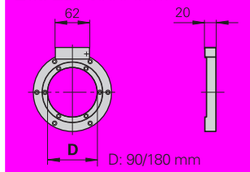
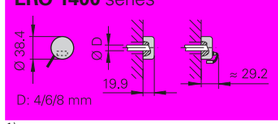
| Rotary encoders | Absolute<br>Singleturn | | | Multiturn | | | Incremental | |
|---|---|---|---|---|---|---|---|---|
| Interface | EnDat | | Siemens | EnDat | | Siemens | ⊓⊔TTL | ∿ 1 $V_{PP}$ |
| **Without integral bearing** | | | | | | | | |
| **ECI/EQI/EBI 1100** series<br>  <br>13 with ECI/EBI | **ECI 1118**<br>Positions/rev: 18 bits<br>EnDat 2.2/22 | **ECI 1119**<br>Positions/rev: 19 bits<br>EnDat 2.2/22,<br>EnDat 3/E30-R2<br>Available with<br>functional safety | – | **EBI 1135**<br>Positions/rev: 18 bits<br>65536 revolutions<br>(buffer battery backup)<br>EnDat 2.2/22 | **EQI 1131**<br>Positions/rev: 19 bits<br>4096 revolutions<br>EnDat 2.2/22,<br>EnDat 3/E30-R2<br>Available with<br>functional safety | – | – | – |
| **ECI/EQI 1300** series<br>  | **ECI 1319**<br>Positions/rev: 19 bits<br>EnDat 2.2/22<br>EnDat 3/E30-R2<br>Available with<br>functional safety | **ECI 1319**<br>Positions/rev: 19 bits<br>EnDat 3/E30-R2<br>Available with<br>functional safety | **ECI 1319 S**<br>Positions/rev: 19 bits<br>DRIVE-CLiQ<br>Available with<br>functional safety | **EQI 1331**<br>Positions/rev: 19 bits<br>4096 revolutions<br>EnDat 2.2/22<br>EnDat 3/E30-R2<br>Available with<br>functional safety | **EQI 1331**<br>Positions/rev: 19 bits<br>4096 revolutions<br>EnDat 3/E30-R2<br>Available with<br>functional safety | **EQI 1331 S**<br>Positions/rev: 19 bits<br>4096 revolutions<br>DRIVE-CLiQ<br>Available with<br>functional safety | – | – |
| **ECI/EBI 100** series<br>  <br>D: 30/38/50 mm | **ECI 119**<br>Positions/rev: 19 bits<br>EnDat 2.2/22 or<br>EnDat 2.1/01 | – | – | **EBI 135**<br>Positions/rev: 19 bits<br>65536 revolutions<br>(buffer battery backup)<br>EnDat 2.2/22 | – | – | – | – |
| **ECI/EBI 4000** series<br>  <br>D: 90/180 mm | **ECI 4010**<br>Positions/rev: 20 bits<br>EnDat 2.2/22<br>Available with<br>functional safety | – | **ECI 4090S**<br>Positions/rev: 20 bits<br>DRIVE-CLiQ<br>Available with<br>functional safety | **EBI 4010**<br>Positions/rev: 20 bits<br>65536 revolutions<br>(buffer battery backup)<br>EnDat 2.2/22<br>Available with<br>functional safety | – | – | – | – |
| **ERO 1400** series<br>  <br>D: 4/6/8 mm | – | – | – | – | – | – | **ERO 1420**<br>512 to 1024 lines<br><br>**ERO 1470** [1]<br>1000/1500 lines | **ERO 1480**<br>512 to 1024 lines |

[1] Up to 37500 signal periods via integrated 5/10/20/25-fold interpolation

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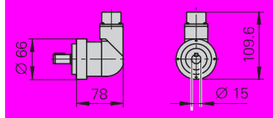
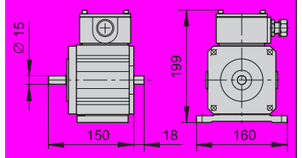
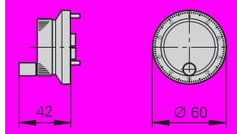
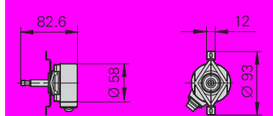
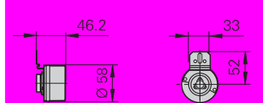
# Rotary encoders for special applications

| Rotary encoders | Absolute<br>**Singleturn** | | **Multitum** 4096 revolutions | | Incremental | | | |
|---|---|---|---|---|---|---|---|---|
| Interface | EnDat | SSI | EnDat | SSI | ⊓⊔ TTL | ⊓⊔ HTL | ∿ 1 $V_{PP}$ | |
| **For high bearing loads** | | | | | | | | |
| **ROD 600**<br>  | – | – | – | – | **ROD 620**<br>512 to 5000 lines | **ROD 630**<br>512 to 5000 lines | – |  **74** |
| **ROD 1930**<br>  | – | – | – | – | – | **ROD 1930**<br>600 to 2400 lines | – |  **76**<br>***For more information, please refer to the respective Product Information document*** |
| **Electronic handwheel** | | | | | | | | |
| **HR 1120**<br>  | – | – | – | – | **ERN 421**<br>1024 lines | **ERN 431**<br>1024 lines | – |  **78** |
| **For Siemens asynchronous motors** | | | | | | | | |
| **ERN 401** series<br>  | – | – | – | – | **HR 1120**<br>100 lines | – | – |  <br>***For more information, please refer to the respective Product Information document*** |
| **EQN/ERN 400** series<br>  | – | – | **EQN 425**<br>Positions/rev: 13 bits<br>EnDat 2.1/01 | **EQN 425**<br>Positions/rev: 13 bits | **ERN 420**<br>1024 lines | **ERN 430**<br>1024 lines | – |  <br>***For more information, please refer to the respective Product Information document*** |

# Measuring principles

## Measuring standards

HEIDENHAIN encoders with **optical scanning** use measuring standards consisting of periodic structures known as graduations. These precision graduations are applied to a carrier substrate made of glass or steel and are manufactured by means of various photolithographic processes. Graduations are made from the following materials:

- Extremely hard chromium lines on glass
- Matte-etched lines on gold-plated steel tape
- Three-dimensional structures on glass or steel substrates

The photolithographic manufacturing processes developed by HEIDENHAIN allow for typical grating periods ranging from 50 µm down to 4 µm.

These processes yield fine grating periods characterized by excellent edge definition and high homogeneity. In combination with the photoelectric scanning method, these characteristics are crucial for attaining high-quality output signals.

The master graduations are manufactured by HEIDENHAIN on custom-built, high-precision dividing engines.

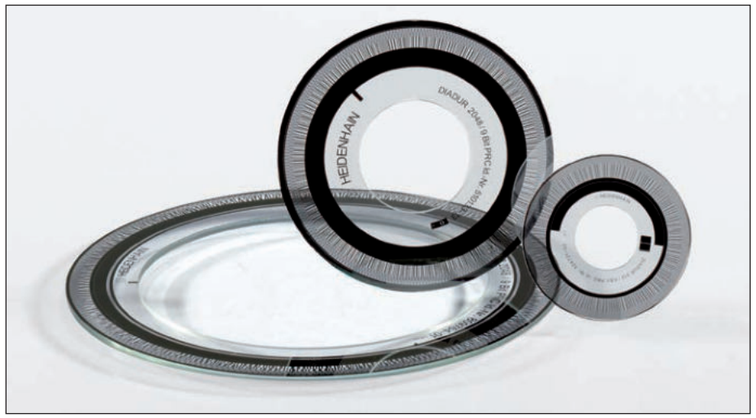
Encoders that use the **inductive scanning principle** employ metal graduations or copper/nickel-based graduation structures. These graduation structures are applied to a printed-circuit carrier material.

## Measuring methods

In the **absolute measuring method**, the position value is available immediately upon encoder switch-on and can be requested by the downstream electronics at any time. There is therefore no need to search for the reference position by jogging the axes. The resulting absolute position information **is read from the circular scale**, which exhibits a code structure.

A separate incremental track is interpolated for the position value and is simultaneously used for generating an optional incremental signal.

**Singleturn rotary encoders** repeat the absolute position information with each revolution. **Multiturn encoders** can distinguish between additional revolutions.

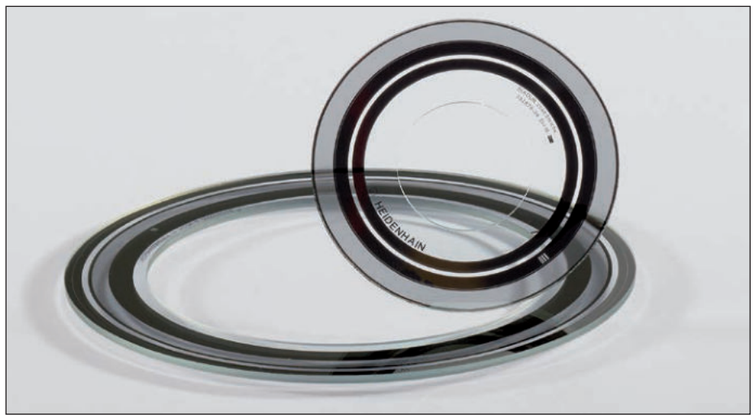



Circular scales of absolute rotary encoders

In the **incremental measuring method**, the graduation consists of a periodic grating structure. Position information is obtained **through the counting** of individual increments (measuring steps) starting from a freely settable point of origin. Since position ascertainment requires an absolute reference, the circular scales have an additional track containing a **reference mark**.

The absolute position established by the reference mark is assigned to exactly one measuring step.

Thus, before an absolute reference can be established or the most recently selected reference point can be refound, this reference mark must first be traversed.




Circular scales of incremental rotary encoders



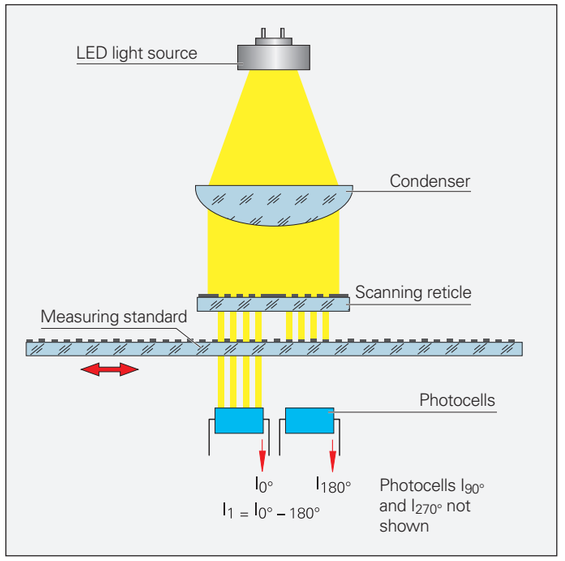
# Scanning methods

**Photoelectric scanning**
Most HEIDENHAIN encoders utilize the photoelectric scanning principle. Photoelectric scanning is performed contact-free and thus does not induce wear. This method detects even extremely fine graduation lines down to a width of only a few micrometers and generates output signals with very small signal periods.

The ECN, EQN, ERN, ROC, ROQ, and ROD rotary encoders utilize the imaging scanning principle.

Put simply, the imaging scanning principle uses projected-light signal generation; for example, two gratings (a scale and a scanning reticle) with the same grating period are moved relative to each other. The carrier material of the scanning reticle is transparent. The graduation on the measuring standard can be applied to either a transparent surface or a reflective surface.

When parallel light passes through a grating structure, light and dark fields are projected at a certain interval. At the place where these fields are projected lies an index grating with the same grating period. When these two graduations move relative 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. Photocells convert these light fluctuations into nearly sinusoidal electrical signals. In encoders that use the imaging scanning principle, workable mounting tolerances are attainable starting at a minimum grating period of 10 µm.




Photoelectric scanning according to the imaging scanning principle

The absolute rotary encoders that use this scanning principle have a single, large, and finely structured photosensor as opposed to a group of discrete photocells. The width of the photosensor's structures is identical to the width of the measuring standard's grating structure. A scanning reticle with a matching structure is therefore not needed.

**Other scanning principles**
The ECI/EBI/EQI rotary encoders utilize the inductive measuring principle. In this case, the graduation structures modulate the amplitude and phase of a high-frequency signal. By means of circumferential scanning, the position value is always generated based on the signals from the receiver coils that are evenly distributed along the circumference.

# Accuracy

Rotary encoder accuracy is primarily determined by the following factors:

- The directional error of the radial grating
- The eccentricity of the circular scale relative to the bearing
- The radial runout of the bearing
- The error arising from connection via a shaft coupling; for rotary encoders with stator coupling, this error lies within the system accuracy
- The interpolation error that arises during signal processing in the integrated or external digitizing and interpolation electronics

The following applies to **incremental rotary encoders** with line counts of up to 5000: The maximum direction error at 20 °C ambient temperature and slow rotation (sampling frequency between 1 kHz and 2 kHz) is within

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

which equals

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

In the case of ROD rotary encoders, the 6000 to 10 000 signal periods per revolution are generated via signal doubling. The line count must be considered in determining the system accuracy.

For **absolute rotary encoders**, the accuracy of the absolute position values is provided in the specifications of the respective encoder.

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

| Line count | Accuracy |
|---|---|
| 512 | ±60 arc seconds |
| 2048 | ±20 arc seconds |
| 2048 | ±10 arc seconds (ROC 425 with high accuracy) |

This accuracy information applies to incremental measurement signals at 20 °C ambient temperature and slow rotation.