HEIDENHAIN

# Modular Angle Encoders
with Circular Scale

www.heidenhain.com/angle-encoders

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# Modular angle encoders with circular scale

**Modular angle encoders with a circular scale** are deployed on machines and automated systems that require high measurement accuracy. Typical applications include the following:
- Production and measurement equipment in the semiconductor industry
- Automated PCB assembly machines
- Ultra-precision equipment such as diamond lathes for optical components
- High-accuracy machine tools
- Measuring machines, comparators, measuring microscopes and other precision measuring devices
- Direct-drive motors

**Mechanical design**
Modular angle encoders consist of a circular scale and a scanning head, and feature non-contact operation.

In the case of modular angle encoders, the circular scale is attached to a mounting surface. In order for the high accuracy of the angle encoder to be leveraged, this mounting surface must exhibit a high degree of evenness.

Information on the following topics is available upon request or online at www.heidenhain.com:
- Angle encoders with integral bearing
- Modular angle encoders with scale drum or scale tape
- Rotary encoders
- Encoders for servo drives
- Linear encoders for numerically controlled machine tools
- Signal converters
- HEIDENHAIN controls

*This brochure supersedes all previous editions, which thereby become invalid. The basis for ordering from HEIDENHAIN is always the brochure edition valid when the order is placed.*

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

**Further information:**

For detailed descriptions of all available interfaces, as well as general electrical information, refer to the *Interfaces of HEIDENHAIN Encoders* brochure (ID 1078628-xx).

For the required cables, refer to the *Cables and Connectors* brochure (ID 1206103-xx).

# Contents

# Angle encoders from HEIDENHAIN

Angle encoders are found in applications requiring precision angular measurement at accuracies within several arc seconds.

Examples:
- Rotary tables on machine tools
- Swivel heads on machine tools
- C axes on lathes
- Measuring machines for gears
- Printing units of printing machines
- Spectrometers
- Telescopes
- Laser trackers
- Rotary tables on measuring machines
- Rotary tables on wafer-handling machines

In contrast, rotary encoders are used in applications where accuracy requirements are less stringent (e.g., in automation, motors and many other applications).

Angle encoders differ in terms of the following physical design characteristics:

**Sealed angle encoders with a hollow shaft and stator coupling**
The stator coupling is designed so that the coupling absorbs only the torque arising from bearing friction, especially during angular acceleration of the shaft. These angle encoders therefore provide excellent dynamic performance. Due to the stator coupling, the stated system accuracy includes the error of the shaft coupling. The RCN, RON and RPN angle encoders have an integrated stator coupling, while the stator coupling of the ECN is externally mounted.

Other benefits:
- Compact size for limited installation space
- Hollow-shaft diameters of up to 100 mm
- Easy installation
- Available with functional safety

**RCN 8000** absolute angle encoder


**ECA 4000** absolute angle encoder with scale drum


**ERO 2000** incremental angle encoder with scale drum

**ECM 2000** absolute angle encoder

**Modular angle encoders with optical scanning**
The ERP, ERO, ERA and ECA modular angle encoders are particularly well suited for high-accuracy applications with low installation space and offer the following benefits:

- Wide hollow-shaft diameters (of up to 10 m with a scale tape)
- High speeds of up to 20 000 rpm
- No additional starting torque from shaft seals
- Segment solutions
- Available with functional safety

Modular angle encoders with optical scanning are available with various graduation carriers:

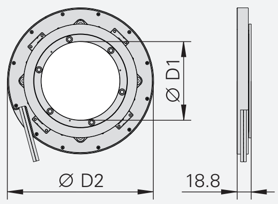
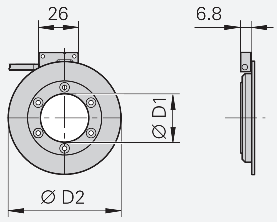
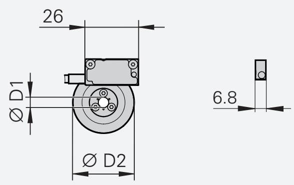
- *ERP/ERO:* Glass circular scale on a hub
- *ERA/ECA 4000:* Steel drum
- *ERA 7000/8000:* Steel scale tape

Because these angle encoders do not come with an enclosure, the required protection rating must be ensured through proper installation.

**Modular angle encoders with magnetic scanning**
Thanks to their robust design, the ERM and ECM modular angle encoders are resistant to cooling lubricant and contamination in production machines. They are ideal for medium- to high-accuracy requirements and low installation space:

- Large shaft diameters
- High speeds of up to 60 000 rpm
- No additional starting torque from shaft seals
- High immunity to contamination
- Available with functional safety

# Selection guide
## Modular angle encoders with optical scanning and circular scale

| Series | Version and mounting | Overall dimensions in mm | Diameter D1/D2 | Graduation accuracy | Mechanically permissible speed[1)] |
|---|---|---|---|---|---|
| **Angle encoders with graduation on circular scale** | | | | | |
| **ERP 1080 D*plus*** | OPTODUR graduation on glass disk with hub; screwed onto front of shaft |  | D1: 104 mm<br>D2: 194 mm | ±0.4″ | ≤ 950 rpm |
| **ERP 1000** | OPTODUR graduation on glass disk with hub; screwed onto front of shaft |  | D1: 104 mm<br>D2: 151 mm | ±0.9″/1.5″ | ≤ 950 rpm |
| | | | D1: 62 mm<br>D2: 109 mm | ±1.8″ | ≤ 1200 rpm |
| | | | D1: 32 mm<br>D2: 75 mm | ±3″ | ≤ 2000 rpm |
| | | | D1: 13 mm<br>D2: 57 mm | ±4″ | ≤ 2600 rpm |
| **ERO 2000** | SUPRADUR graduation on glass |  | D1: 5 mm<br>D2: 30 mm | ±8″ | ≤ 14000 rpm |
| | | | D1: –<br>D2: 18.6 mm | ±10″ | ≤ 24000 rpm |

1) May be limited during operation due to electrically permissible speed
2) Through integrated interpolation

| | Signal periods per revolution | Reference marks | Interface | Model | Page |
|---|---|---|---|---|---|
| | | | | | |
| | 63000 | One | ∿ 1 $V_{PP}$ (4 x) | **ERP 1080 D*plus*** | **24** |
| | 63000 | One | ∿ 1 $V_{PP}$<br>⊓⊔ TTL<br>EnDat 2.2 | **ERP 1080**<br>**ERP 1070**<br>**ERP 1010** | **28** |
| | 50000 | | | | |
| | 30000 | | | | |
| | 23000 | | | | |
| | 4096 | One | ∿ 1 $V_{PP}$ | **ERO 2080** | **34** |
| | 2500 | | | | |

**ERP 1080 D*plus***


**ERP 1000**


**ERO 2000**

# Measuring principles

**Measuring standard**
HEIDENHAIN encoders with optical scanning incorporate measuring standards consisting of periodic structures known as graduations. These graduations are applied to a carrier substrate made of glass or steel. For encoders with long measuring lengths, steel tape is used as the graduate carrier.

HEIDENHAIN manufactures its precision graduations in specially developed, photolithographic processes:

- AURODUR: matte-etched lines on gold-plated steel tape; typical grating period: 40 µm
- METALLUR: contamination-tolerant graduation consisting of metal lines on gold; typical grating period: 20 µm
- DIADUR: extremely robust chromium lines on glass (typical grating period: 20 µm), or three-dimensional chromium structures (typical grating period: 8 µm) on glass
- SUPRADUR phase grating: optically three-dimensional, planar structure; particularly tolerant to contamination; typical grating period: 8 µm and finer
- OPTODUR phase grating: optically three-dimensional, planar structure with particularly high reflectance; typical grating period: 2 µm and finer

Along with these very fine grating periods, these processes permit high edge definition and homogeneity. Together with the photoelectric scanning method, this is critical for the high quality of the output signals.

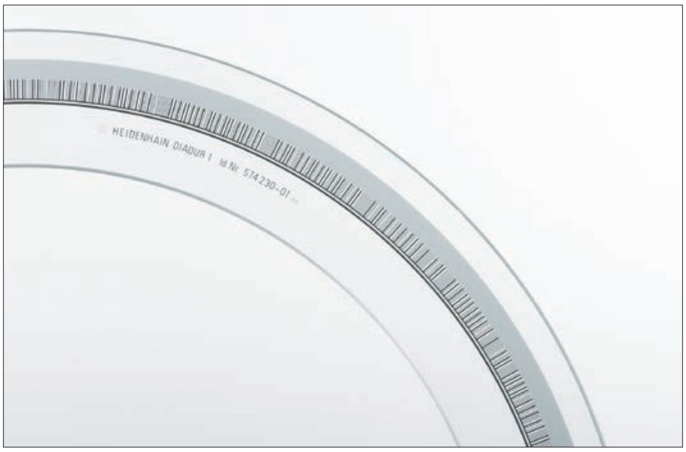
The master graduations are manufactured by HEIDENHAIN on high-precision dividing engines made by HEIDENHAIN for this purpose.

DIADUR, AURODUR and METALLUR are registered trademarks of DR. JOHANNES HEIDENHAIN GmbH, Traunreut.

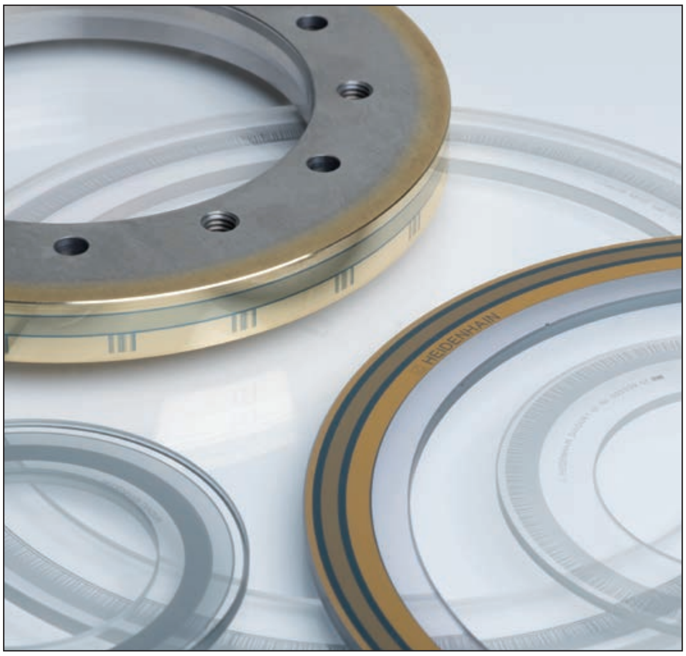
**Absolute measuring method**
In the **absolute measuring method**, the position is available immediately upon encoder switch-on and can be requested by the downstream electronics at any time. There is therefore no need to search for the reference position by jogging the axes.

The absolute position information is read from the **circular scale**, which is designed with a serial absolute code structure. The code structure is unique over one revolution. A separate incremental track is read with the single-field scanning principle and interpolated for the position value.

**Incremental measuring method**
In the **incremental measuring method**, the graduation is a periodic grating structure. The position information is obtained **through counting** the individual increments (measuring steps) starting at a freely defined point of origin. Since position measurement requires an absolute point of reference, the measuring standard features an additional track containing a **reference mark**. The scale's absolute position, which is established by the reference mark, is assigned to exactly one measuring step. The reference mark must therefore be traversed before an absolute point of reference can be established or before the most recently selected reference point is refound.



Circular scale with serial absolute track and incremental track

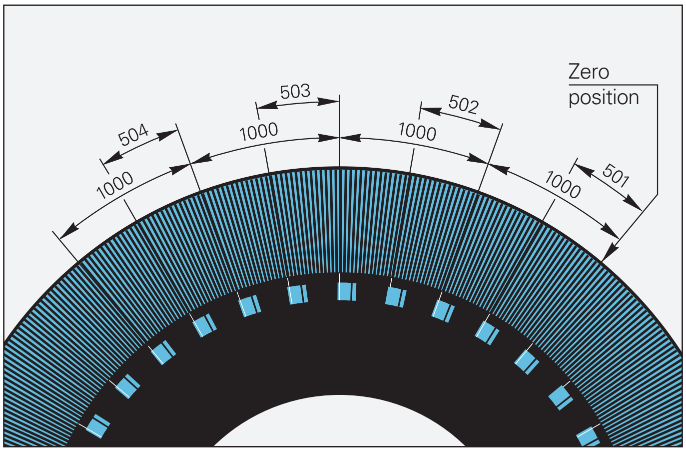



Absolute and incremental circular scales and scale drum

In some cases, referencing may require rotation by up to 360°. To simplify this process, many HEIDENHAIN encoders feature **distance-coded reference marks**: the reference-mark track has multiple reference marks at different defined distances. The downstream electronics determine the absolute reference point after just two neighboring reference marks have been traversed; in other words, after just a few degrees of rotational motion (see "Nominal increment N" in the table).

With distance-coded reference marks, the **absolute reference** is determined by counting the increments between two reference marks.

| Line count *z* | Number of reference marks | Nominal increment N |
|---|---|---|
| 36 000<br>18 000 | 72<br>36 | 10°<br>20° |



Schematic representation of a circular scale with distance-coded reference marks

# Photoelectric scanning principle

Most HEIDENHAIN encoders utilize the photoelectric scanning principle. Photoelectric scanning is non-contact and therefore 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 finer the grating period of a measuring standard, the greater the effect of diffraction on photoelectric scanning. HEIDENHAIN angle encoders use two scanning principles:

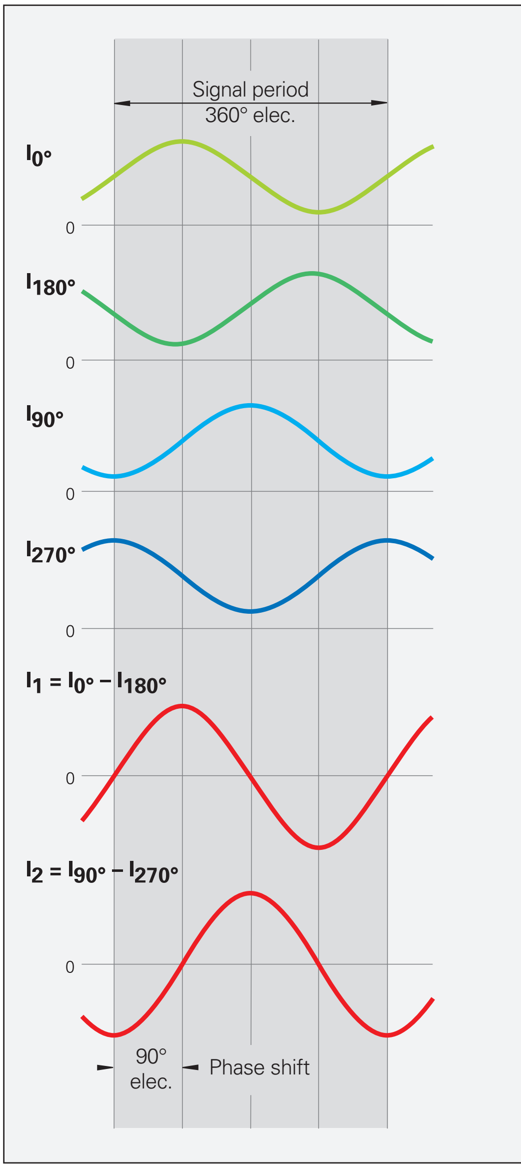
- The **imaging scanning principle** for grating periods of 20 µm and 40 µm
- The **interferential scanning principle** for very fine grating periods of, for example, 8 µm

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

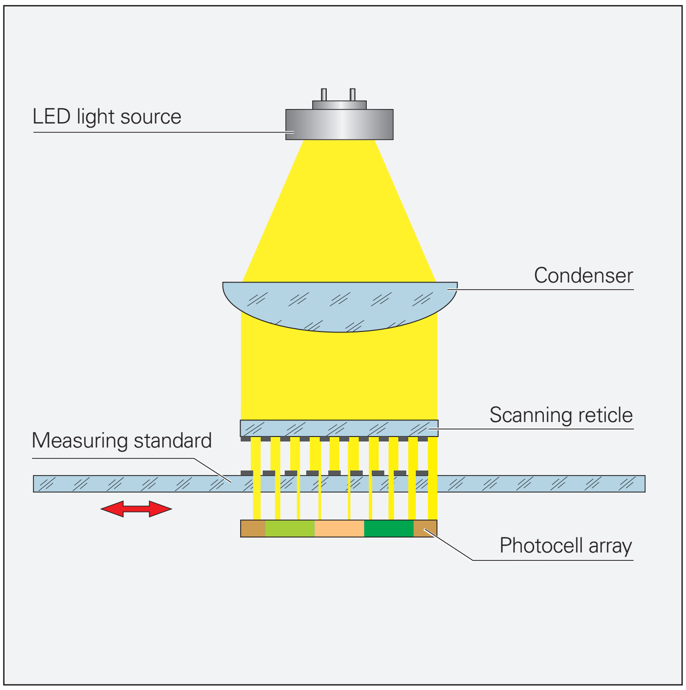
When parallel light passes through a grating structure, light and dark fields are projected at a certain distance. At this location there is an index grating. When the two gratings move relative to each other, the incident light is modulated: If the gaps are aligned, light passes through. If the lines of one grating coincide with the gaps of the other, no light passes through. A photocell array converts these variations in light intensity into electrical signals. The specially structured grating of the scanning reticle filters the light to generate nearly sinusoidal output signals.

The smaller the graduation period of the grating structure, the closer and more tightly toleranced the gap must be between the scanning reticle and the scale. In encoders that use the imaging scanning principle, workable mounting tolerances are attainable starting at a minimum grating period of 10 µm.

The ERO angle encoders, for example, operate in accordance with the imaging scanning principle.

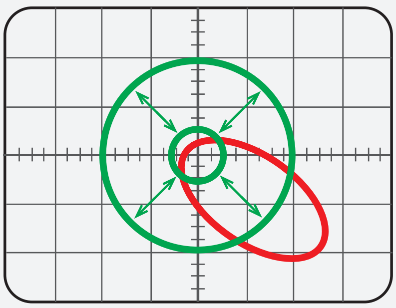



Imaging scanning principle



The sensor generates four nearly sinusoidal current signals ($I_{0°}$, $I_{90°}$, $I_{180°}$, and $I_{270°}$), phase-shifted relative to each other by 90° elec. These scanning signals do not initially exhibit symmetry about the zero line. For this reason, the photocells are connected in anti-parallel, thereby producing two 90° elec. phase-shifted output signals, **I1** and **I2**, which are symmetrical about the zero line.

In the XY-representation on an oscilloscope, the signals form a Lissajous figure. Ideal output signals appear as a centered circle. Deviations in circularity and position are caused by position errors and therefore go directly into the measurement result. The size of the circle, which corresponds to the amplitude of the output signal, can vary within certain limits without influencing the measuring accuracy.



XY-representation of the output signals

**Interferential scanning principle**
The interferential scanning principle uses the diffraction and interference of light on finely divided gratings in order to produce the signals from which motion is measured.

A step grating is used as the measuring standard: reflective lines with a height of 0.2 µm are applied to a flat, reflective surface. In front of this is the scanning reticle—a transparent phase grating with the same grating period as the scale.

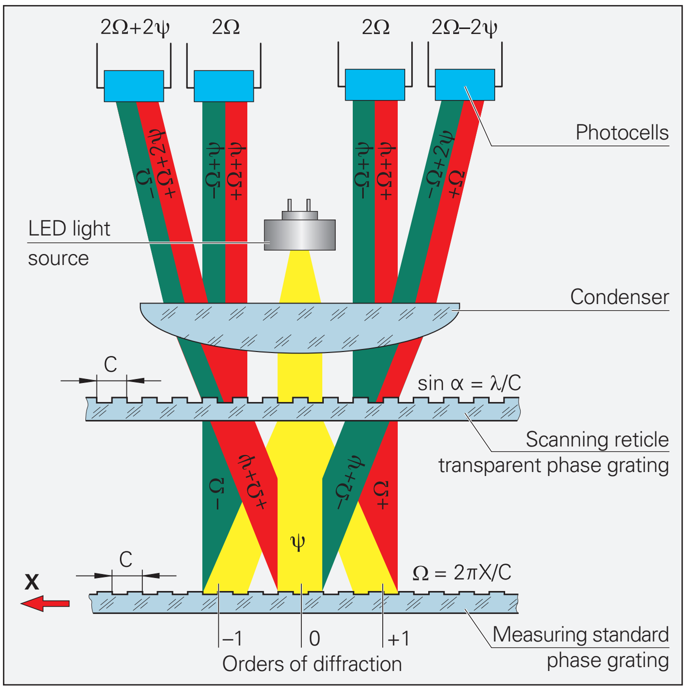
When a light wave passes through the scanning reticle, it is diffracted into three partial waves of the orders +1, 0, and –1, with nearly equal luminous intensity. The waves are diffracted by the scale such that most of the luminous intensity is found in the reflected diffraction orders +1 and –1. These partial waves meet again at the phase grating of the scanning reticle, where they are diffracted again and interfere. This produces essentially three waves that leave the scanning reticle at different angles. Photocells convert these alternating light intensities into electrical signals.

When there is relative motion between the scale and the scanning reticle, the diffracted wavefronts undergo a phase shift: movement by the amount of one grating period shifts the positive first-order diffraction wavefront by one wavelength in the positive direction, while the negative first-order diffraction wavefront is displaced by one wavelength in the negative direction. Since the two waves interfere with each other upon exiting the phase grating, these waves are shifted relative to each other by two wavelengths. This results in two signal periods when there is relative motion of just one grating period.

Interferential encoders use grating periods of, for example, 8 µm, 4 µm, or finer. Their scanning signals are largely free of harmonics and can be highly interpolated. These encoders are therefore especially well suited for small measuring steps and high accuracy.

The ERP angle encoders, for example, operate in accordance with the interferential scanning principle.

Interferential scanning principle (optical diagram)
C Grating period
ψ Phase shift of the light wave when passing through the scanning reticle
Ω Phase shift of the light wave due to motion X of the scale



# Measurement accuracy

The accuracy of angular measurement is mainly determined by:
- The quality of the graduation
- The stability of the graduation carrier
- The scanning quality
- The quality of the signal processing electronics
- The eccentricity of the graduation relative to the bearing
- The bearing-related error
- The coupling to the measured shaft

These factors can be divided into encoder-specific error and application-dependent factors. All these individual factors must be considered in order for the attainable overall accuracy to be evaluated.

The accuracy of the graduation is indicated by the uncompensated maximum value of the **baseline error**. This accuracy is ascertained under ideal conditions via position error measurement with a serially produced scanning head. The distance between the measuring points is equivalent to the integer multiple of the signal period. As a result, the interpolation error has no effect. The accuracy of the graduation *a* defines the upper limit of the baseline error within any section of up to 360°. For special encoders, an additional baseline error is stated for defined angular intervals of the graduation.

## Encoder-specific error

The encoder-specific error is provided in the specifications:
- The graduation accuracy
- The interpolation error within one signal period
- The position noise

### The graduation accuracy

The accuracy ±*a* of the graduation results from its quality. This includes:
- The homogeneity and period resolution of the graduation
- The alignment of the graduation on the graduation carrier
- The stability of the graduation carrier (in order to ensure accuracy when mounted)

### The interpolation error within one signal period

The interpolation error within one signal period ±*u* is primarily influenced by:
- The fineness of the signal period
- The homogeneity and period resolution of the graduation
- The quality of the scanning filter structures
- The characteristics of the sensors
- The quality of the signal processing electronics

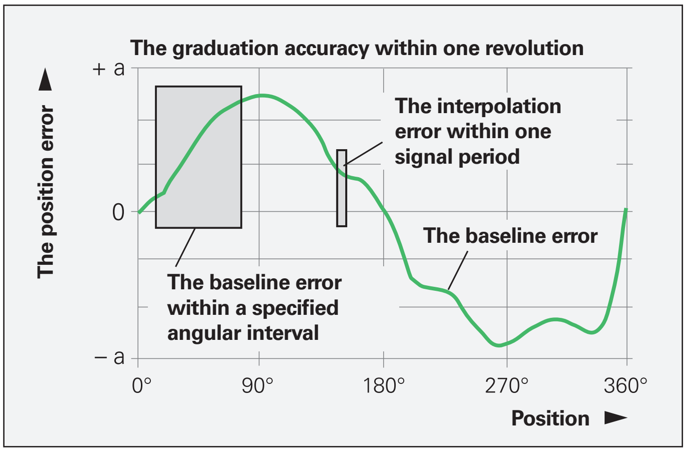
The interpolation error within one signal period has an effect even during very small rotational movements and during repeated measurements. This error causes speed ripples, particularly in the speed control loop.

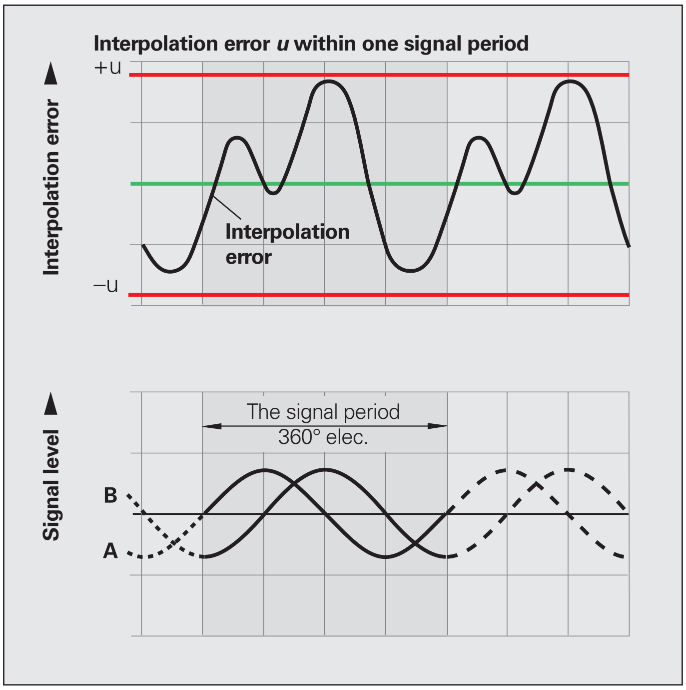
### Position noise

Position noise is a random process leading to unpredictable position error. The position values are grouped around an expected value in the form of a frequency distribution.

The amount of position noise depends on the signal processing bandwidths necessary for forming the position values. It is ascertained within a defined time interval and is stated as a product-specific RMS value.

In the speed control loop, position noise influences the speed stability at low speeds.



## Application-dependent error

The quality of the mounting and adjustment of the scanning head, in addition to the given encoder-specific error, has a significant effect on the accuracy that can be achieved by **encoders without integral bearings**. Of particular importance are the mounting eccentricity of the graduation and the radial runout of the measured shaft. The application-dependent error values must be measured and calculated individually in order to evaluate the overall accuracy.

In contrast, the specified system accuracy for encoders with an integral bearing already includes the error of the bearing and the shaft coupling (see the *Angle Encoders with Integral Bearing* brochure).

**Error due to eccentricity of the graduation relative to the bearing**

Mounting-related eccentricity between the graduation and the bearing can be expected during mounting of the disk/hub assembly. In addition, dimensional and form error of the customer's shaft can result in added eccentricity. The following relation exists between the eccentricity *e*, the graduation diameter D, and the measuring error Δφ (see figure below):

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

Δφ = Measurement error in ″ (arc seconds)
*e* = Eccentricity of the scale drum relative to the bearing in µm (1/2 radial runout)
D = Graduation diameter in mm
M = Center of graduation
φ = "True" angle
φ' = Scanned angle

**Calculation example:**

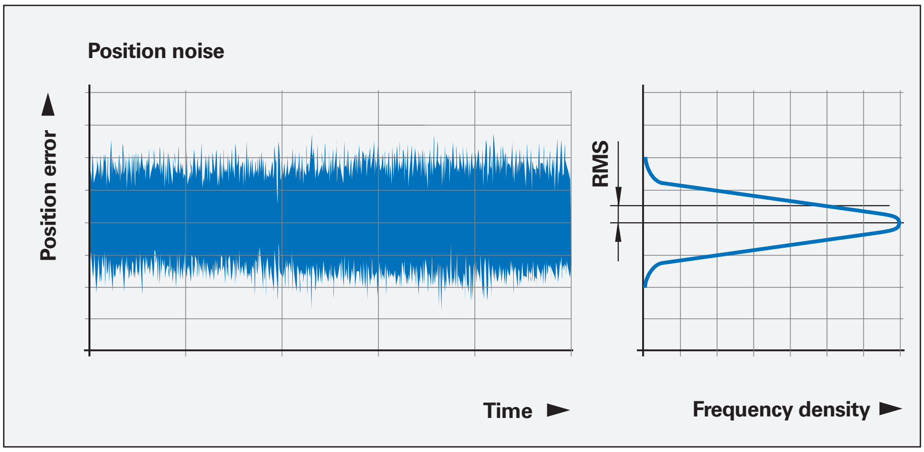
ERP 1000 angle encoder with drum diameter of 146.5 mm and 2 µm radial runout of the disk/hub assembly (≙ eccentricity of 1 µm)

$$\Delta\varphi = \pm 412 \cdot \frac{1}{146.5} \approx \pm 2.8''$$

**Graduation diameter D:**

| | |
|---|---|
| **ERP 1080 D*plus***** | D = 146.5 mm |
| **ERP 1000** | D = 52.5 mm<br>D = 71 mm<br>D = 104.5 mm<br>D = 146.5 mm |
| **ERO 2000** | D = 26.7 mm<br>D = 16.3 mm |

* During operation with one scanning head





The eccentricity of the graduation relative to the bearing

**Radial runout error of the bearing**
The function for finding the measurement error Δφ also applies to the radial runout error of the bearing when the eccentricity (half of the displayed radial runout error) is entered for *e*. The mechanical compliance of the bearing under radial shaft loads causes similar errors.

**Deformation of the graduation resulting from mounting**
The profile, reference surfaces, position of the graduation relative to the mounting surface, threaded holes, etc., of the disk/hub assemblies are all designed such that mounting and operation only marginally affect the accuracy of the encoders.

**Geometric and diameter errors of the bearing surface (for TKN ERP 1002)**
Geometric errors of the bearing surface can affect the attainable system accuracy.

The segment solutions exhibit additional angular error Δφ if the nominal mounting diameter is not precisely complied with:

$$\Delta\varphi = (1 - D'/D) \cdot \varphi \cdot 3600$$

Where
Δφ = Error for segment in arc seconds
φ = Segment angle in degrees
D = Nominal mounting diameter
D' = Actual mounting diameter

This error can be eliminated if the signal period per 360° z' that is valid for the actual mounting diameter D' can be entered into the controller. The following relationship is valid:

$$z' = z \cdot D'/D$$

Where z = Nominal signal period per 360°
z' = Actual signal period per 360°

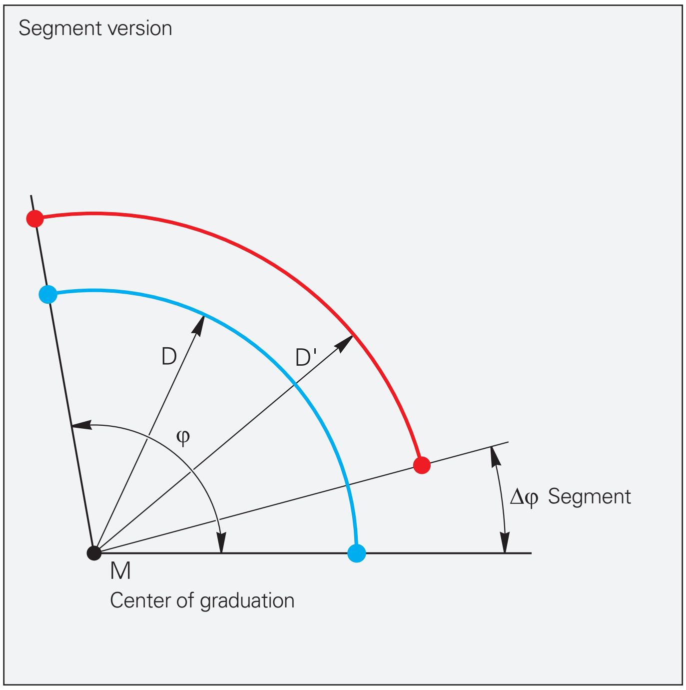
The angle actually traversed in segment solutions should be measured with a comparative encoder, such as an angle encoder with an integral bearing.

**Compensation possibilities**
The mounting eccentricity of the graduation and the radial runout of the measured shaft cause a large share of the application-dependent errors. A common and effective method for eliminating these errors is to mount two or even more scanning heads equidistantly around the graduation carrier. The separate position values are mathematically combined in the downstream electronics.

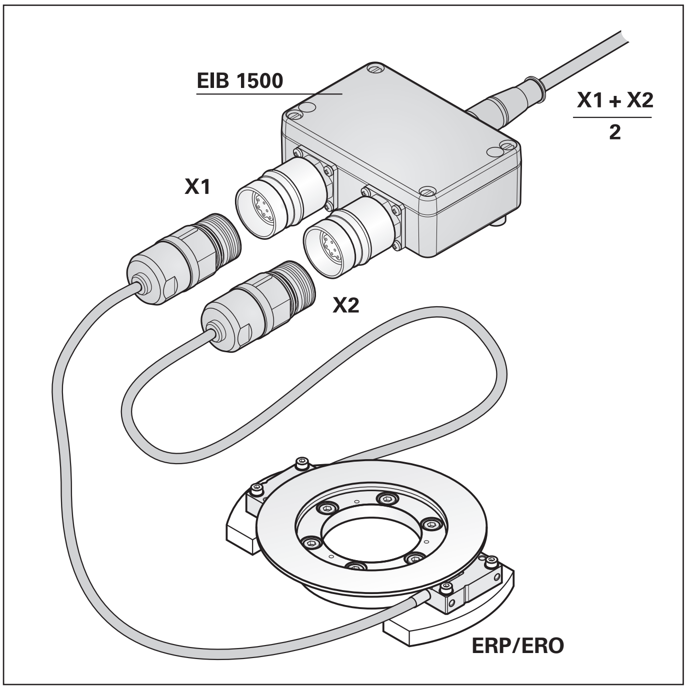
The EIB 1500 from HEIDENHAIN is an electronics unit suitable for mathematically combining the position values from two scanning heads in real time and without negative effects on the control loop (see *Evaluation and display units*).

The accuracy improvement actually attained by this in practice strongly depends on the installation situation and the application. All eccentricity errors (reproducible errors due to mounting errors, non-reproducible errors due to radial eccentricity of the bearing) and all uneven-numbered harmonics of the graduation error are eliminated.

Angular error resulting from variations in the mounting diameter




Position calculation of two scanning heads in order to compensate for eccentricity and radial runout



# Calibration chart

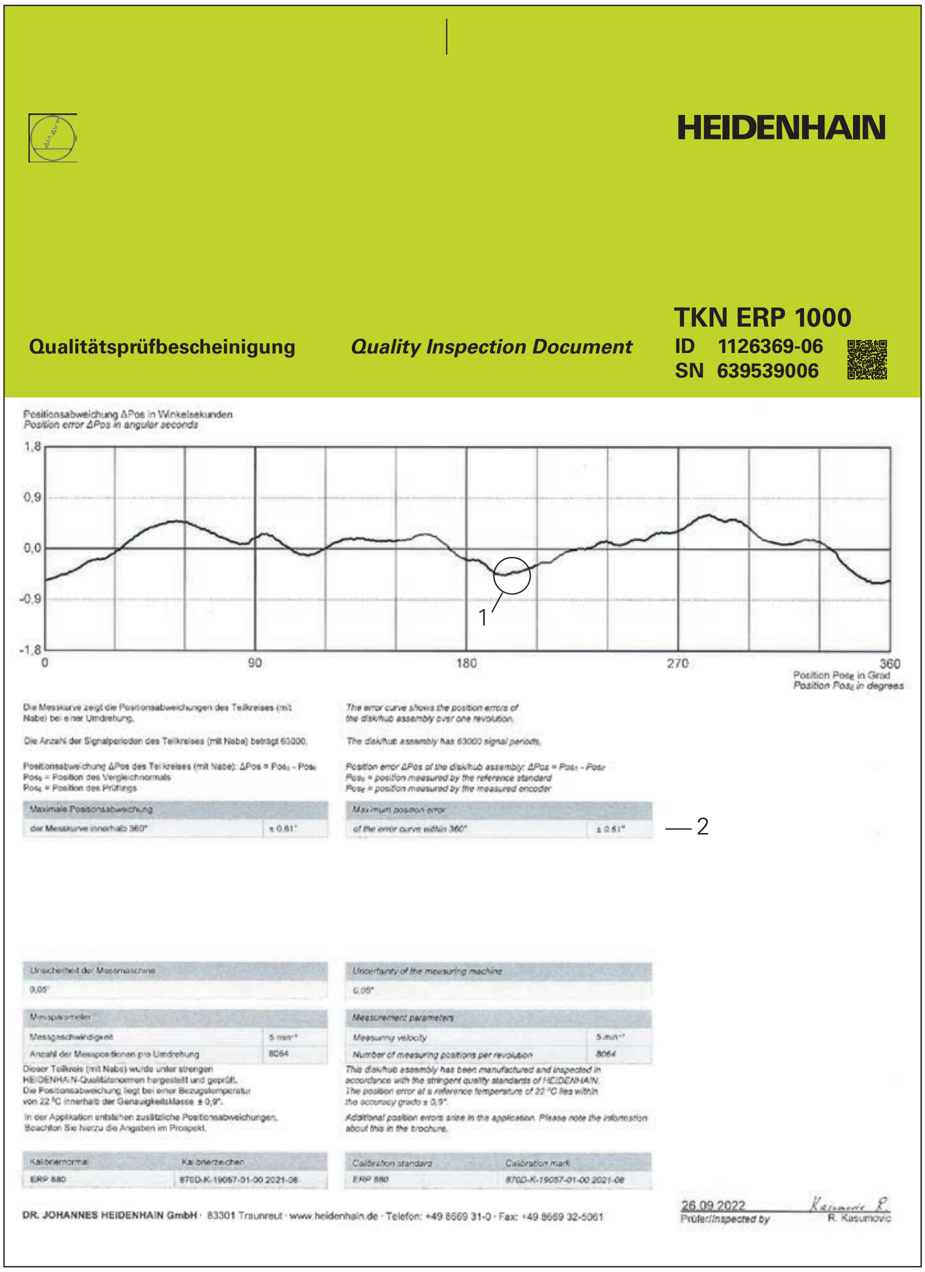
For all angle encoders from HEIDENHAIN, proper functioning is checked and accuracy is measured prior to shipment. The accuracy of the angle encoders is determined during rotation over one revolution. The number of measuring positions is selected such that both the long-range error and the interpolation error within a single signal period are precisely measured. Errors resulting from mounting are not measured.

The **Quality Inspection Document** confirms the stated **graduation accuracy** of each encoder. The listed **calibration standards** ensure traceability to recognized national or international standards, as required by EN ISO 9001.

Additionally for the ERP and ERO encoder series, a calibration chart documents the ascertained **position error**. It also specifies the measuring parameters and the measurement uncertainty.

**Temperature range**
The angle encoders are inspected at a **reference temperature** of 22 °C. This is the temperature at which the position error documented in the calibration chart is valid.

When measured at HEIDENHAIN, the modular angle encoders with a circular scale are mounted exactly as they will later be in the application. This ensures that the accuracy determined at HEIDENHAIN will match the accuracy in the machine upon installation.


HEIDENHAIN

Qualitätsprüfbescheinigung | *Quality Inspection Document*

TKN ERP 1000
ID 1126369-06
SN 639539006



Die Messkurve zeigt die Positionsabweichungen des Teilkreises (mit Nabe) bei einer Umdrehung.

*The error curve shows the position errors of the disk/hub assembly over one revolution.*

Die Anzahl der Signalperioden des Teilkreises (mit Nabe) beträgt 63000.

*The disk/hub assembly has 63000 signal periods.*

Positionsabweichung ΔPos des Teilkreises (mit Nabe): $\Delta Pos = Pos_S - Pos_E$
$Pos_S$ = Position des Vergleichnormals
$Pos_E$ = Position des Prüflings

*Position error ΔPos of the disk/hub assembly:* $\Delta Pos = Pos_S - Pos_E$
*$Pos_S$ = position measured by the reference standard*
*$Pos_E$ = position measured by the measured encoder*

| Maximale Positionsabweichung | |
|---|---|
| der Messkurve innerhalb 360° | ± 0,61" |

| *Maximum position error* | |
|---|---|
| *of the error curve within 360°* | *± 0.61"* |

| Unsicherheit der Messmaschine |
|---|
| 0,05" |

| *Uncertainty of the measuring machine* |
|---|
| *0.05"* |

| Messparameter | |
|---|---|
| Messgeschwindigkeit | 5 min⁻¹ |
| Anzahl der Messpositionen pro Umdrehung | 8064 |

| *Measurement parameters* | |
|---|---|
| *Measuring velocity* | *5 min⁻¹* |
| *Number of measuring positions per revolution* | *8064* |

Dieser Teilkreis (mit Nabe) wurde unter strengen HEIDENHAIN-Qualitätsnormen hergestellt und geprüft. Die Positionsabweichung liegt bei einer Bezugstemperatur von 22 °C innerhalb der Genauigkeitsklasse ± 0,9".

In der Applikation entstehen zusätzliche Positionsabweichungen. Beachten Sie hierzu die Angaben im Prospekt.

*This disk/hub assembly has been manufactured and inspected in accordance with the stringent quality standards of HEIDENHAIN. The position error at a reference temperature of 22 °C lies within the accuracy grade ± 0.9".*

*Additional position errors arise in the application. Please note the information about this in the brochure.*

| Kalibriernormal | Kalibrierzeichen |
|---|---|
| ERP 880 | 870D-K-19057-01-00 2021-08 |

| *Calibration standard* | *Calibration mark* |
|---|---|
| *ERP 880* | *870D-K-19057-01-00 2021-08* |

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26.09.2022
Prüfer/*Inspected by* R. Kasumovic

**Calibration chart of the ERP 1000 scale drum**
1 Graph representing the graduation error
2 Calibration results

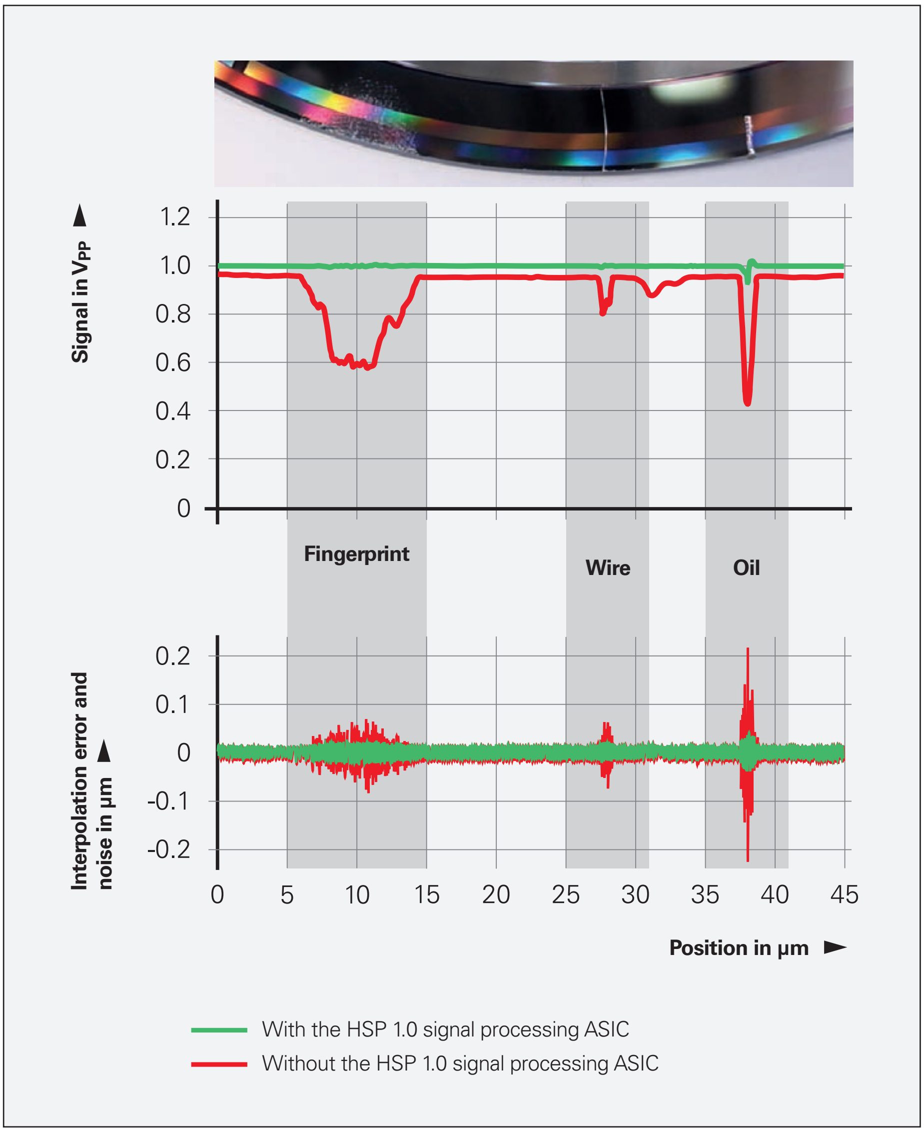
# Reliability

Modular angle encoders with optical scanning from HEIDENHAIN are optimized for use on fast and accurate machines. Even with their exposed mechanical design, these encoders are highly immune to contamination, ensure high long-term stability and are both fast and easy to install.

**High immunity to contamination**
These encoders owe their accuracy and reliability to their scanning methods and high-quality gratings. For generating their scanning signals, these HEIDENHAIN encoders use **single-field scanning**. Contamination on the measuring standard (e.g., fingerprints or oil residues) equally affects the light intensity of the signal components and thus the scanning signals. This changes the amplitude of the output signals but not their offset or phase position. As a result, the signals are still highly interpolable, and the position error per signal period remains small.

The **large scanning field** further reduces the encoder's sensitivity to contamination. Depending on the nature of the contamination, this feature can even prevent encoder failure. The encoders continue to provide high-quality measurement signals even if the contamination comes from printer's ink, PCB dust, water or oil and is up to 3 mm in diameter. The position error per revolution remains well within the specified accuracy.

The ERP 1000 and ERO 2000 encoders are equipped with the HSP 1.0 signal processor ASIC from HEIDENHAIN. This ASIC continuously monitors the scanning signal and nearly fully compensates for fluctuations in signal amplitude. If the signal amplitude decreases as a result of contamination on the scanning reticle or measuring standard, then the ASIC reacts by increasing the LED current. The ensuing increase in LED light intensity barely raises the noise level, even if the intervention for signal stabilization is significant. As a result, contamination has only a slight effect on interpolation error and position noise.




Measuring standard with contamination and the resulting signal amplitudes with conventional scanning and scanning with the HSP 1.0 signal processing ASIC

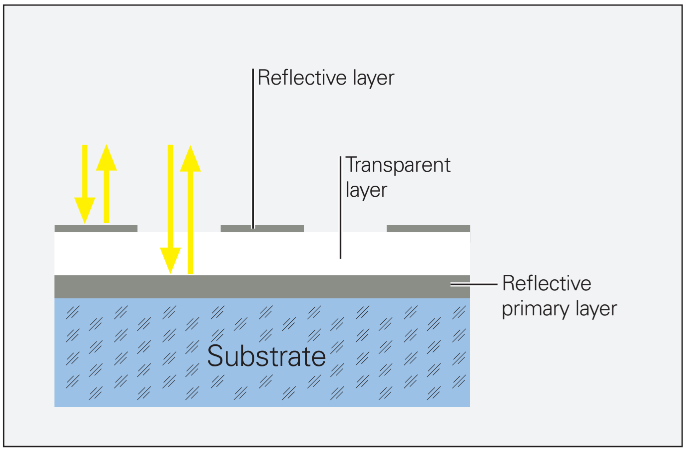
**Durable measuring standards**
Due to their exposed design, the measuring standards of modular angle encoders with a circular scale are inherently more exposed to their environment. For this reason, HEIDENHAIN always uses robust graduations made using special processes.

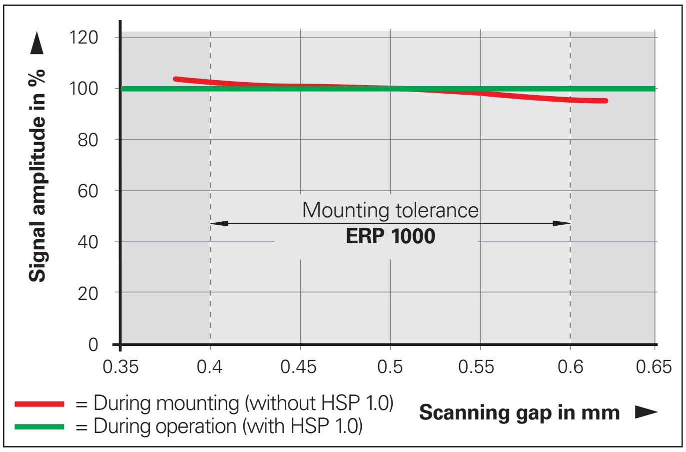
In the OPTODUR and SUPRADUR processes, a transparent layer is first applied onto the reflective primary layer. For creating an optically three-dimensional phase grating, an extremely thin, hard chromium layer is applied at a thickness of only a few nanometers. Measuring standards with OPTODUR or SUPRADUR graduations have proven to be particularly robust and insensitive to contamination because the low height of their structure leaves practically no surface for dust, dirt, or water particles to accumulate.

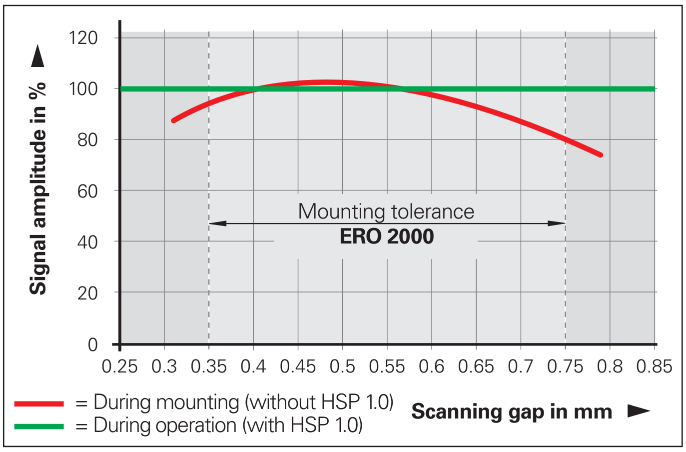
**Manageable mounting tolerances**
Very small signal periods usually require very tight mounting tolerances for the gap between the scanning head and scale tape. This is due to the diffractive properties of the grating structures, which can attenuate the signal by 50% at just ±0.1 mm of gap change. The interferential scanning principle and the innovative index gratings used by the imaging-principle encoders permit manageable mounting tolerances despite tiny signal periods.

The mounting tolerances of the HEIDENHAIN modular angle encoders with a circular scale have minimal influence on the output signals. In particular, the specified distance tolerance between the circular scale and scanning head (scanning gap) causes only a negligible change in the signal amplitude. During operation, the reliability and stability of the signals are additionally improved by the HSP 1.0. The two graphs illustrate the correlation between the scanning gap and signal amplitude for the encoders of the ERP 1000 and ERO 2000 series.

OPTODUR
SUPRADUR



# Signal-quality indicator

The ERP 1010 and ERP 1070 modular angle encoders feature a built-in signal-quality indicator with a multicolor LED, permitting fast and easy signal-quality checks during operation.

This feature provides a number of benefits:
- Scanning-signal quality visualization via a multicolor LED
- Continuous monitoring of incremental signals over the entire angular measurement range
- Indication of the reference-mark signal behavior
- Quick signal-quality checks in the field without additional aids

The built-in signal-quality indicator permits both a reliable assessment of the incremental signals and inspection of the reference mark signal. The quality of the **incremental signals** is indicated by different colors. A blue LED indicates traversal of the **reference mark**.

**LED indicator for incremental signals**

| LED color | Quality of the scanning signals |
|---|---|
| 🟢 | Optimal |
| 🟠 | Acceptable |
| 🔴 | Unsatisfactory |

In the encoders with a serial interface (ERP 1010), an error bit is set when a red LED is displayed. Error bits can be displayed and cleared with the ATS mounting wizard.

**LED indicator for the reference mark signal**
When the reference mark is traversed, the LED briefly switches to blue. In the ERP 1070 encoders, the LED can also be used for checking proper functioning of the reference mark signal:
- 🔴 Out of tolerance
- 🔵 In tolerance

**LED indicator for control margin**
In the encoders with a TTL interface (ERP 1070), a flashing LED (goes dark briefly every 2.5 s) indicates when the control margin of the scanning ASIC (HSP) is nearly exhausted. Clean the measuring standard and the scanning window of the scanning head in compliance with the relevant information in the mounting instructions. Also check for proper mounting of the encoder as needed.

*ERP 1010 and ERP 1070:*
Signal-quality indicator in the interface electronics

# Transferable accuracy

In order to achieve accuracies in the high-end range, customers must often perform a very complex and time-consuming calibration of the entire machine. Under the rubric "transferable accuracy," HEIDENHAIN helps customers to simplify the installation process and to transfer the high accuracy of its encoders to the customer's application without loss. For the ERP 1080 D*plus* encoders, this is achieved through the following features:

- A sturdy mechanical interface for mounting at the customer
- Robust angular measurement through four scanning heads for position calculation

**Electrical connection**
The ERP 1080 D*plus* angle encoder provides four separate connections (15-pin D-sub) with the 1 $V_{PP}$ interface. The encoder can be operated with EIB 74x signal converters from HEIDENHAIN. The encoder can also be connected to downstream electronics from third-party suppliers if they provide four 1 $V_{PP}$ inputs.

**Position calculation with an EIB 74x or downstream electronics from third-party suppliers**
For the system to be able to reach the specified accuracy, the positions of all scanning heads need to be averaged.

$$X_{avg} = \frac{(X1_{abs} + X2_{abs} + X3_{abs} + X4_{abs})}{4}$$

$X1_{abs}$ ... $X4_{abs}$: Positions of the scanning heads
$X_{avg}$: Arithmetic mean value of inputs $X1_{abs}$ to $X4_{abs}$

**Further information:**
For more information about implementing the position calculation, please refer to the ERP 1080 D*plus* installation instructions.

# Mechanical design types and mounting

The modular angle encoders with a circular scale consist of a scanning head and a disk/hub assembly. The position of the scanning head and graduation relative to each other is determined solely via the machine guideway. For this reason, the machine must be designed to meet the following requirements from the very beginning:

- The **bearing** must be designed such that it meets the accuracy requirements of the axis and the scanning-gap tolerances of the encoder, including during operation (see the *Specifications*).
- The **mounting surface** for the graduation carrier must meet the flatness, roundness, radial runout and diameter requirements of the given encoder.
- To simplify **adjustment** of the scanning head relative to the graduation, the scanning head should be fastened via a mounting bracket or via appropriate fixed stops.

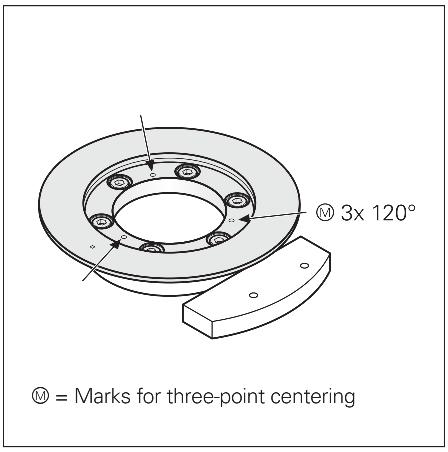
All modular angle encoders with a circular scale are designed such that the specified accuracy can be reached in the actual application. The various types of mounting and mounting designs ensure the highest possible reproducibility.

**Centering the graduation**
Since graduations from HEIDENHAIN have a very high degree of accuracy, the attainable overall accuracy is predominantly affected by mounting errors (mainly eccentricity errors). Depending on the encoder and mounting method, there are various centering options for minimizing the eccentricity errors that may arise in practice.

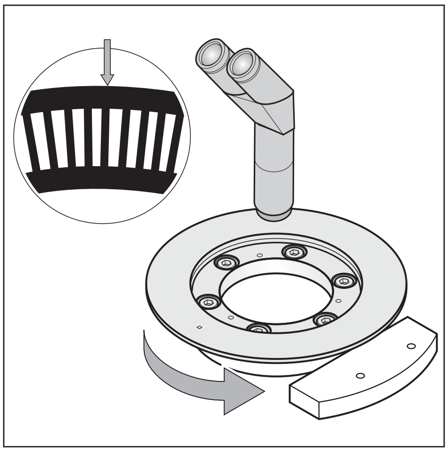
**1. Three-point centering**
The graduation carrier is centered via three positions marked on the graduation carrier at 120° increments. As a result, any circularity errors of the surface on which the carrier is to be centered do not affect the exact alignment of the axis center point.

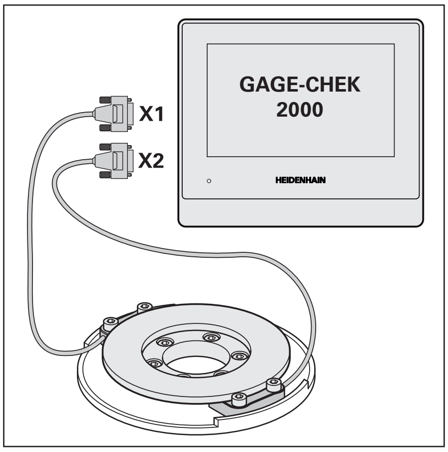
**2. Optical centering**
Graduation carriers made from glass are often centered by means of a microscope. This method applies unambiguous reference edges or centering rings onto the graduation carriers.

**3. Centering with two scanning heads**
This method is suitable for all modular angle encoders with a circular scale. Because HEIDENHAIN graduations exhibit a long-range characteristic error, and because the graduation or the position value itself serves as the reference, this is the most accurate centering method.



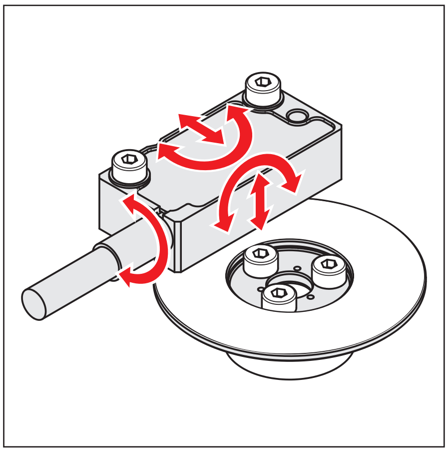
Three-point centering


Optical centering



Centering with two scanning heads

**Scanning heads**
Because final assembly of the modular angle encoders with circular scale takes place on the machine, exact mounting of the scanning head is necessary once the graduation carrier has been mounted. In order for the scanning head to be exactly aligned, it must in principle be aligned and adjustable in five axes (see illustration). This adjustment is greatly simplified by the design of the scanning heads, their mounting strategy and their wide mounting tolerances.



# ERP 1000
# ERO 2000

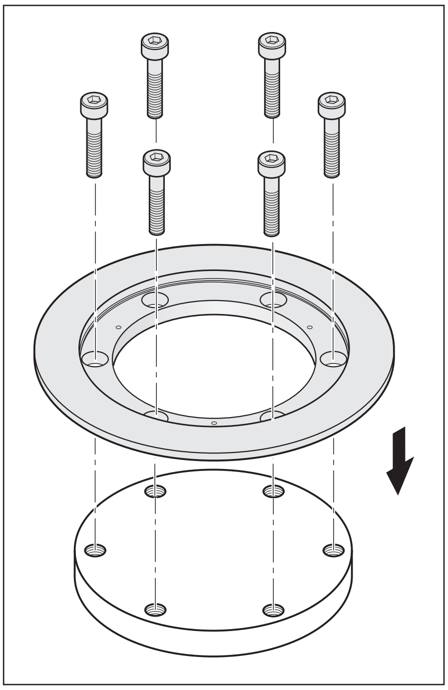
The ERP 1000 and ERO 2000 modular angle encoders consist of a scanning head and a disk/hub assembly or a circular scale with a pin. They are positioned and adjusted relative to each other on the machine.

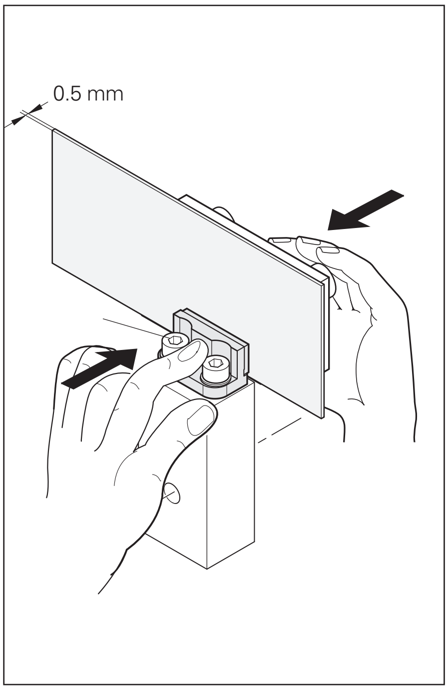
**Mounting the disk/hub assembly**
The disk/hub assembly is pressed axially onto the shaft, centered using the inside diameter of the hub, and fastened with screws. The circular scale can be centered using a dial indicator on the inside diameter of the hub, or optically using the graduation track integrated in the circular scale, or electrically with the aid of a second, diametrically opposed scanning head.

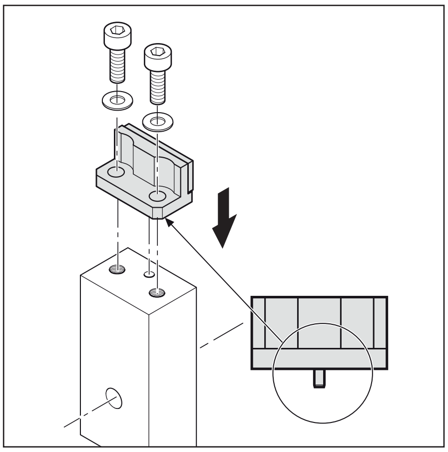
**Mounting the circular scale with a pin**
The TKN ERP 1002 segments feature a centering pin for easy mounting to the mating component. This procedure is sufficient for applications where only small angles need to be measured. The gap to the scanning head is adjusted by means of a spacer shim (0.5 mm). Each segment has two threaded holes for fastening.

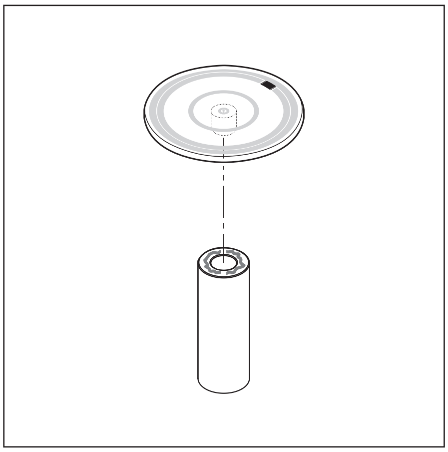
The TKN ERO 2000 full circles as well as the TKN ERO 2002 segments can be mounted via an H7 fitting hole for fast and easy installation. To increase accuracy, the circular scale can also be optically centered. For this purpose, the hole in the mating component must be made with a larger diameter. The measuring standard and the mating component must be fastened by means of an adhesive bond. A UV-curing adhesive is recommended.

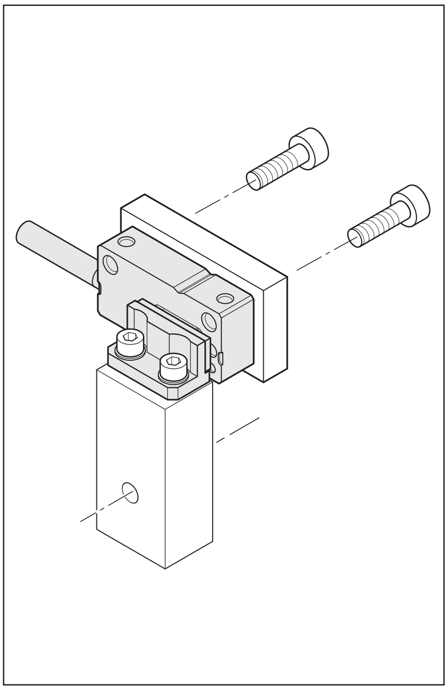
**Mounting the scanning head**
Because the modular angle encoders are mounted to the machine, a precise adjustment is then needed. This adjustment critically determines the final accuracy of the encoder. It is therefore advisable to design the machine such that this adjustment is as easy and practical as possible while also ensuring the greatest possible degree of mounting stability. The scanning heads of the ERP 10x0 and ERO 2080 can be fastened from the side as well as from above.

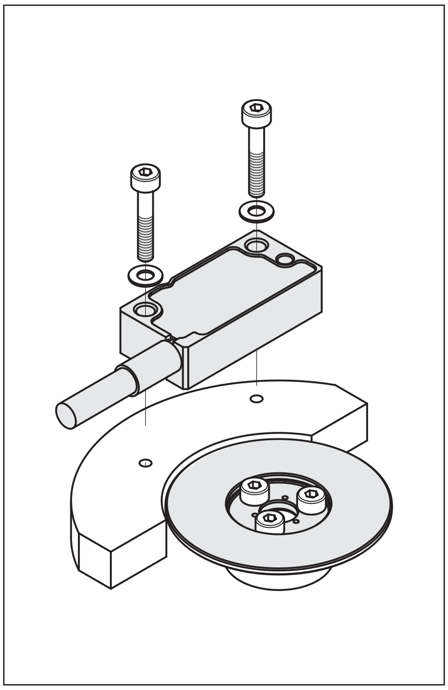








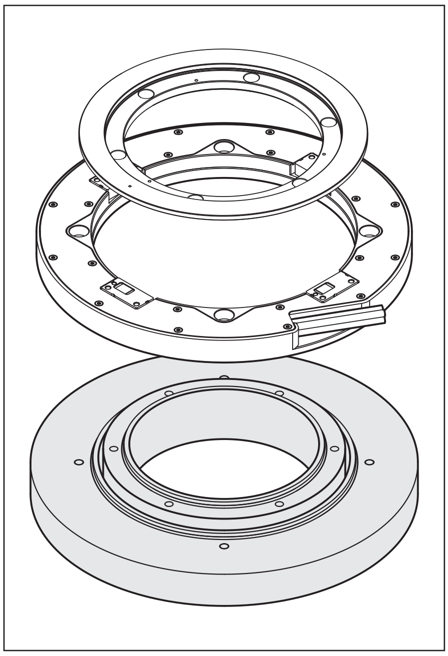


# ERP 1080 D*plus*

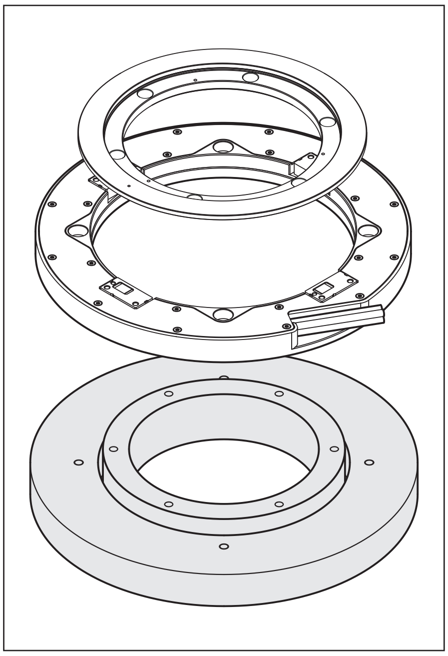
**Mounting**
Thanks to the scanning ring with four built-in scanning windows, the ERP 1080 D*plus* features very robust mounting. As a result, mounting-related eccentricity errors can be compensated for at any time during operation. Mounting can be performed with or without a centering collar.

**Mounting with a centering collar**
A particularly easy centering method is mounting with a centering collar that is already present on the mating components. The required runout tolerances must be adhered to.

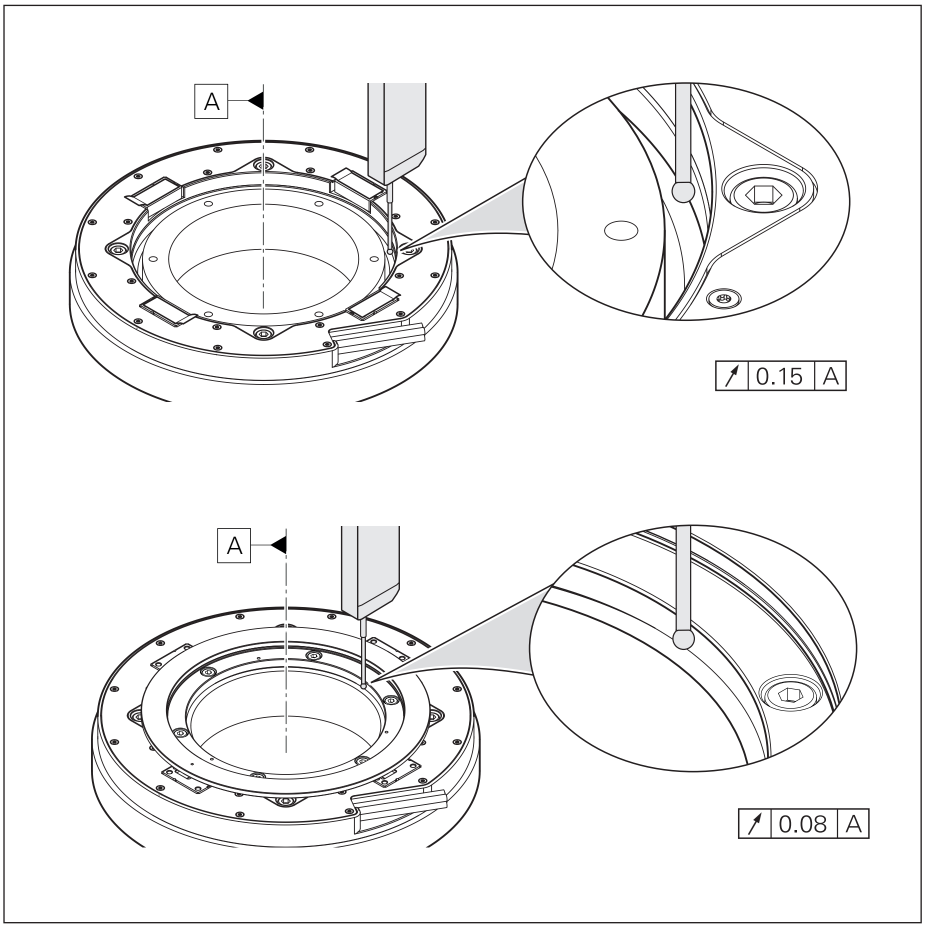
**Mounting without a centering collar**
If the ERP 1080 D*plus* angle encoder is to be mounted without a centering collar, then both the disk/hub assembly and the scanning unit must be aligned to within the stated runout tolerances by means of a dial gage.



Mounting with a centering collar



Mounting without a centering collar

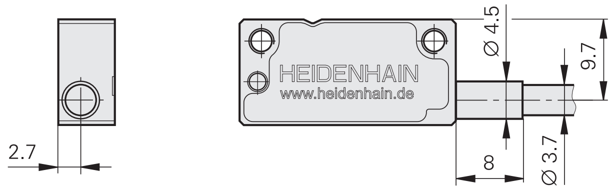



Runout tolerances for mounting without a centering collar

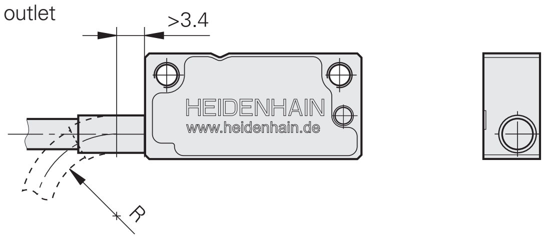
# Cable outlets and connectors for ERP 1000 and ERO 2000

## Cable outlet, straight

Right-side cable outlet

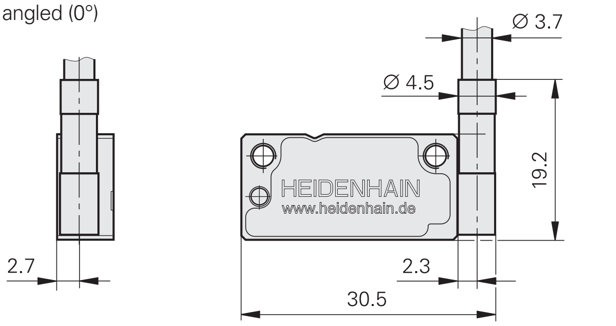



Left-side cable outlet

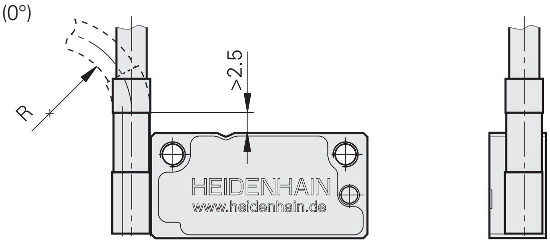



## Cable outlet, angled

Right-side cable outlet, angled (0°)

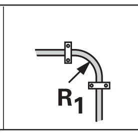


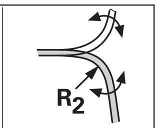

Left-side cable outlet, angled (0°)



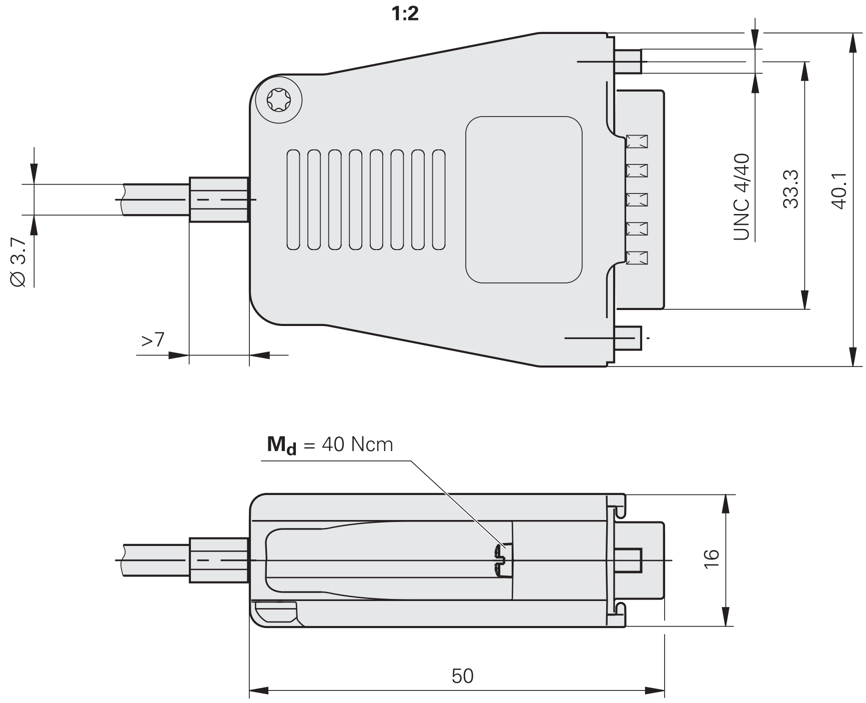

Cable bend radius **R**

Ø 3.7 mm
**$R_1$** ≥ 8 mm
**$R_2$** ≥ 40 mm

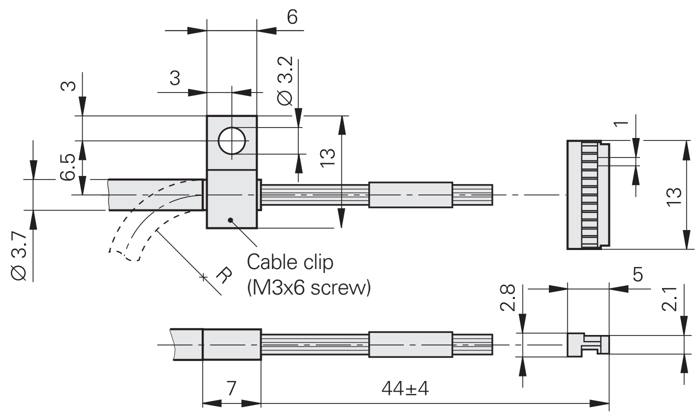


## D-sub connector ∿ 1 $V_{PP}$, TTL, EnDat

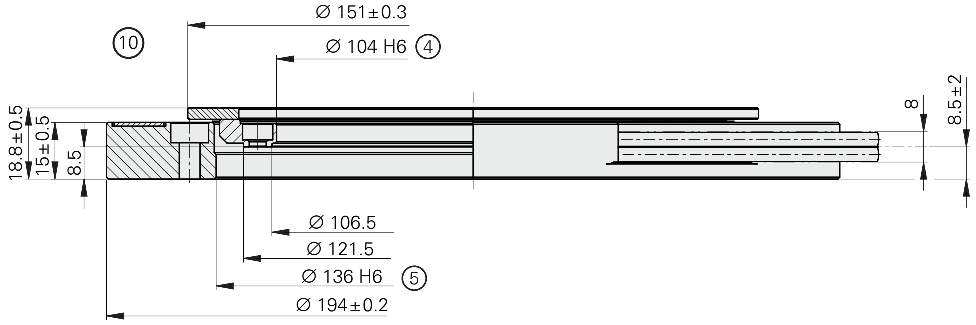


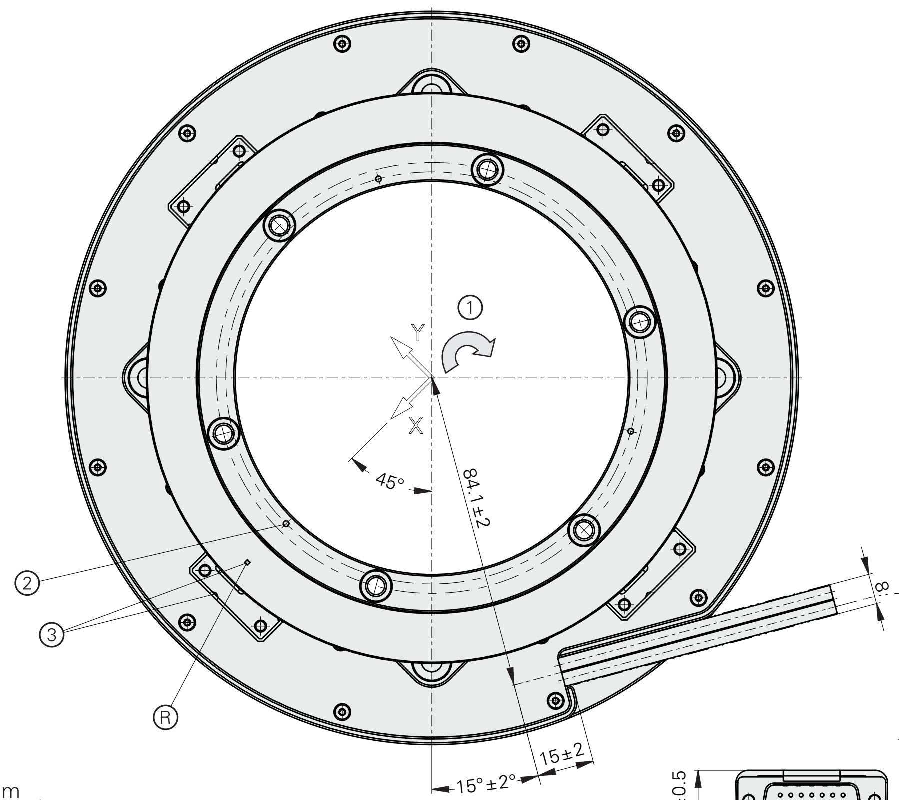

## SHR-12V-S connector ∿ 1 $V_{PP}$

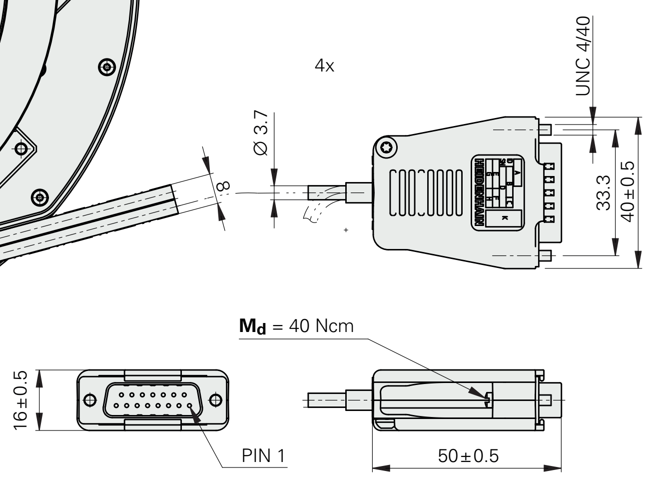


# ERP 1080 D*plus*

- **Very high system accuracy**
- **Robust angular measurement**
- **Low mass and low mass moment of inertia**
- **Consisting of a scanning ring and a circular scale**




mm

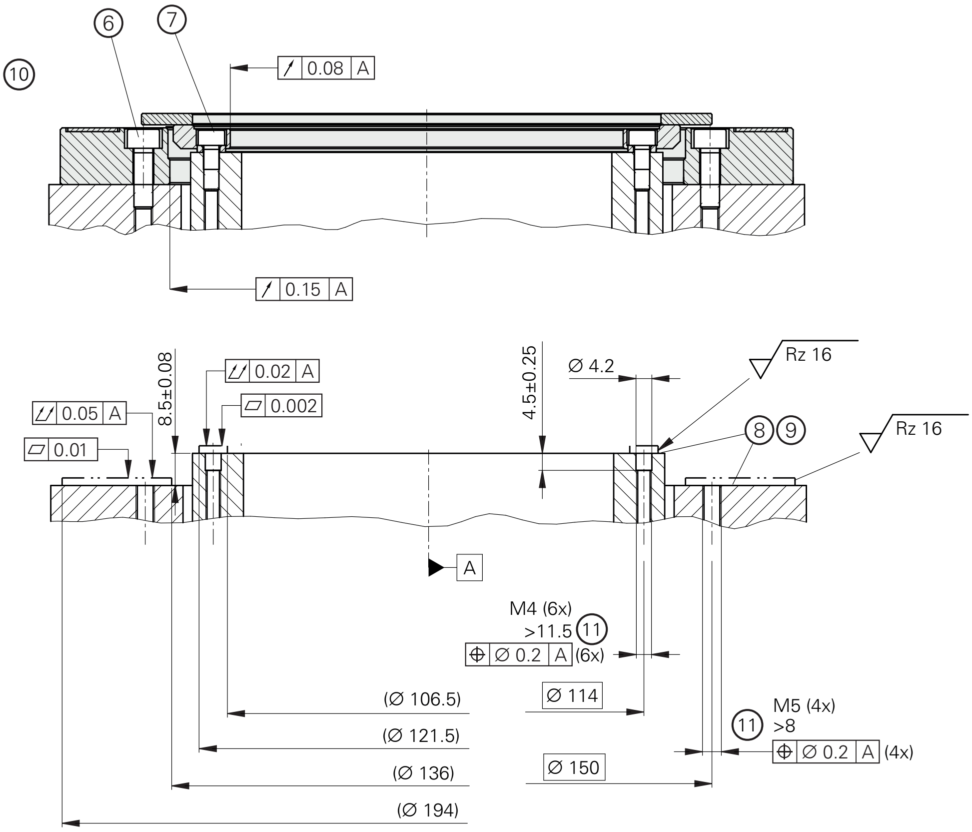
Tolerancing ISO 8015
ISO 2768:1989-mH
≤ 6 mm: ±0.2 mm

A = Bearing of mating shaft
® = Reference mark
K1 = Required mating dimensions
K2 = Required mating dimensions with centering collars
1 = Direction of shaft rotation for ascending position values
2 = Marks for circular scale centering (3x 120°)
3 = Mark for 0° position
4 = Centering collar for scale hub
5 = Centering collar for scanning unit
6 = Screw: ISO 4762 – M5x16 – 8.8
Tightening torque: 500 Ncm ±30 Ncm;
Material bonding threadlocker required
7 = Screw: ISO 4762 – M4x12 – 8.8
Tightening torque: 220 Ncm ±13 Ncm
Material bonding threadlocker required
8 = Customer's mounted parts

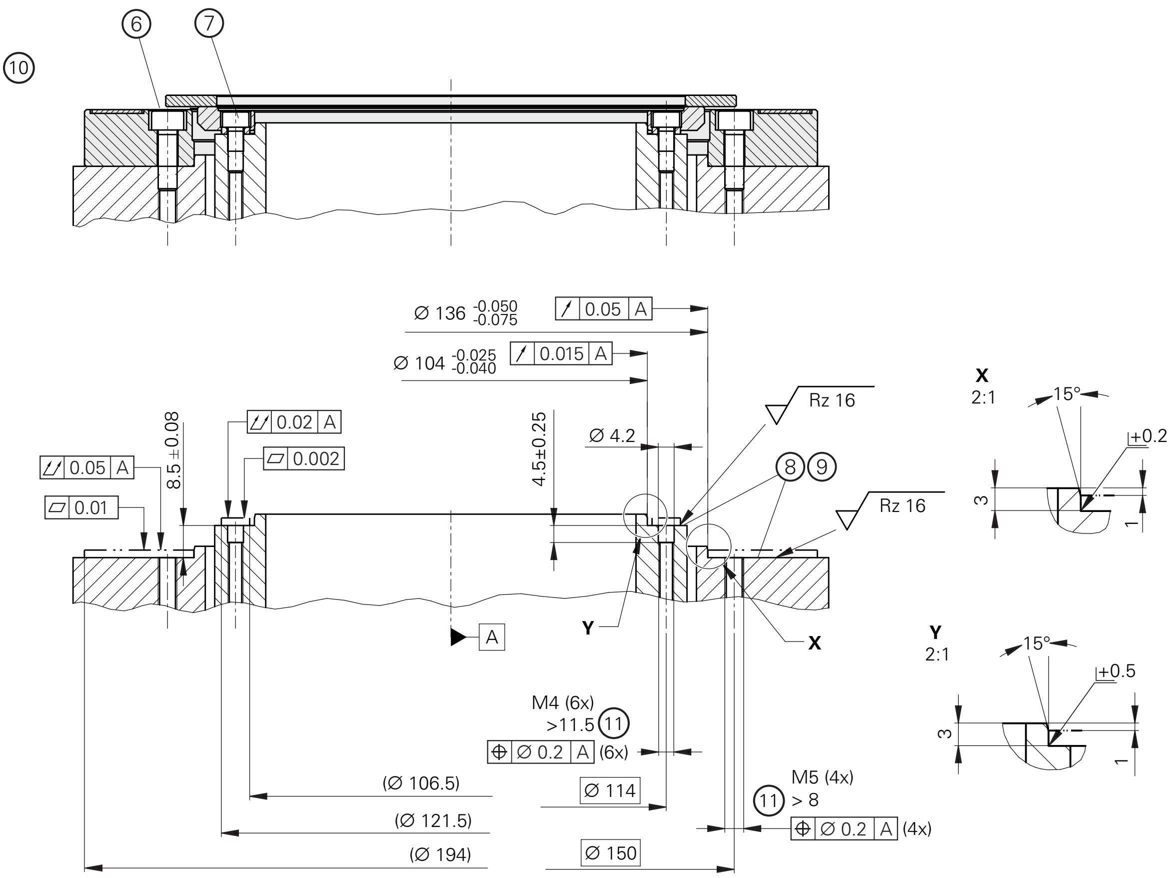
| | |
|---|---|
| Material: | Steel |
| Tensile strength: | Rm > 600 N/mm$^2$ |
| Yield point: | Re > 400 N/mm$^2$ |
| Shear strength: | Tau > 390 N/mm$^2$ |
| Modulus of elasticity: | 20 °C: E >200000 N/mm$^2$ ... 215000 N/mm$^2$ |
| Coefficient of thermal expansion: | 20 °C: (10<α<13) x $10^{-6}$ 1/K |

9 = Mounting surface must be clean and free of grease
10 = Hub shown rotated by 45°
11 = Depth of thread

K1


6
7
10
0.08 A
0.15 A
0.05 A
0.01
8.5±0.08
0.02 A
0.002
4.5±0.25
Ø 4.2
Rz 16
8 9
Rz 16
A
M4 (6x)
>11.5 11
Ø 0.2 A (6x)
(Ø 106.5)
Ø 114
(Ø 121.5)
M5 (4x)
11 >8
Ø 0.2 A (4x)
(Ø 136)
Ø 150
(Ø 194)

K2


6
7
10
Ø 136 -0.050 -0.075
0.05 A
Ø 104 -0.025 -0.040
0.015 A
Rz 16
X
2:1
15°
+0.2
3
1
0.05 A
0.01
8.5 ±0.08
0.02 A
0.002
4.5±0.25
Ø 4.2
8 9
Rz 16
A
Y
X
Y
2:1
15°
+0.5
3
1
M4 (6x)
>11.5 11
Ø 0.2 A (6x)
(Ø 106.5)
Ø 114
11 > 8
M5 (4x)
(Ø 121.5)
Ø 0.2 A (4x)
(Ø 194)
Ø 150

# Specifications

| Encoder | | ERP 1080 D*plus* |
|---|---|---|
| **Interface**[1)] | | 4 × ∿ 1 $V_{PP}$ |
| Reference mark signal | | Square-wave pulse |
| Cutoff frequency | –3 dB | ≥ 500 kHz |
| **Electrical connection**[1)] | | Four 1.5 m cables with 15-pin D-sub connector (male) |
| Cable length[1)] | | With HEIDENHAIN cable: ≤ 20 m; during signal adjustment with the PWM 21: ≤ 3 m |
| Voltage supply[1)] | | DC 5 V ±0.5 V |
| Current consumption[1)] | | ≤ 150 mA (without load) |
| **Vibration** 55 Hz to 2000 Hz<br>**Shock** 6 ms | | ≤ 200 $m/s^2$ (EN 60068-2-6)<br>≤ 200 $m/s^2$ (EN 60068-2-27) |
| **Operating temperature** | | 0 °C to 50 °C |
| **Storage temperature** | | –20 °C to 60 °C |
| **Mass** | Scanning ring<br>Connector<br>Cable<br>Scale hub | ≈ 1.1 kg (without cable)<br>≈ 75 g<br>≈ 22 g/m<br>≈ 289 g |

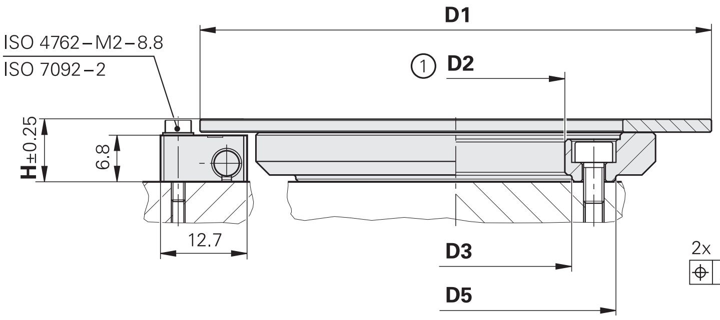
1) Separate electrical connection for each scanning head

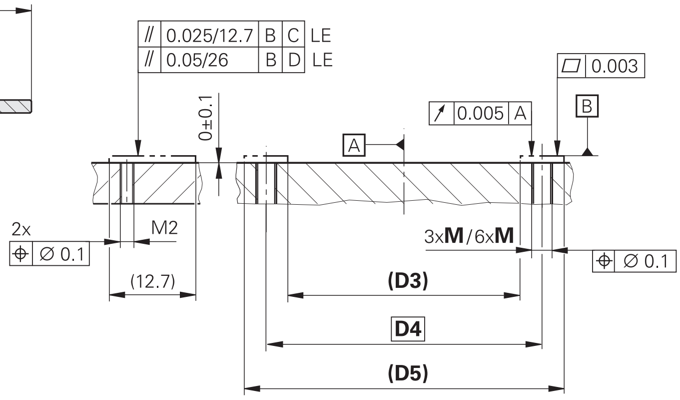
| | ERP 1080 D*plus* |
|---|---|
| **Measuring standard** | OPTODUR circular scale on glass |
| **Signal periods** | 63000 |
| **System accuracy** | ±0.4″ |
| **Position error per signal period**[1] | ±0.02″ |
| **RMS position noise** (500 kHz) | 0.001″ |
| **Reference marks** | One |
| **Outside diameter of scanning ring** | 194 mm |
| **Inside diameter of hub** | 104 mm |
| **Outside diameter of circular scale** | 151 mm |
| Mech. permissible speed | ≤ 950 rpm |
| Elec. permissible speed | ≤ 475 rpm |
| Moment of inertia of the scale hub | $1.1 \cdot 10^{-3}$ kgm$^2$ |
| **Protection** EN 60529 | Complete encoder when mounted: IP00 |

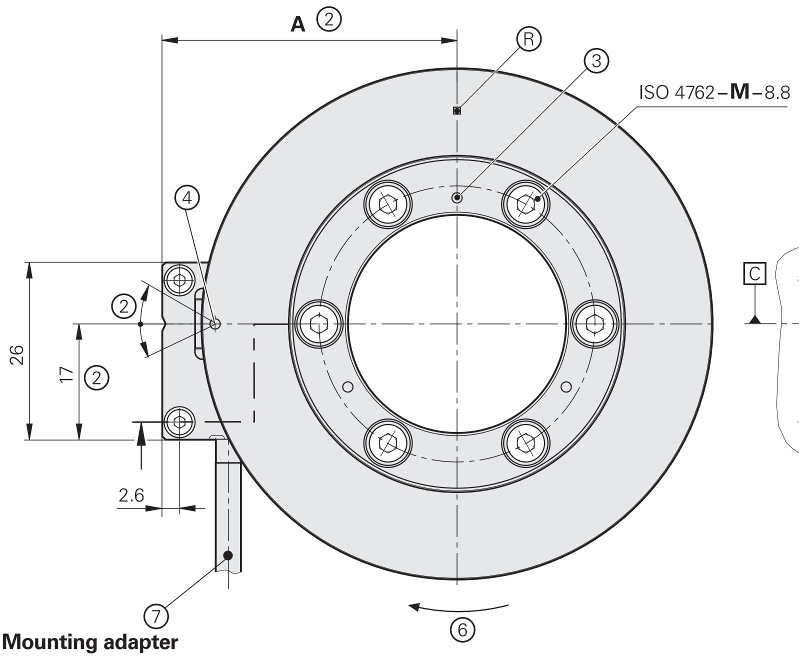
[1] The position error per signal period and the accuracy of the graduation together yield the encoder-specific error; for additional errors arising from installation and the bearing of the measured shaft, see *Measurement accuracy*

# ERP 1000 series

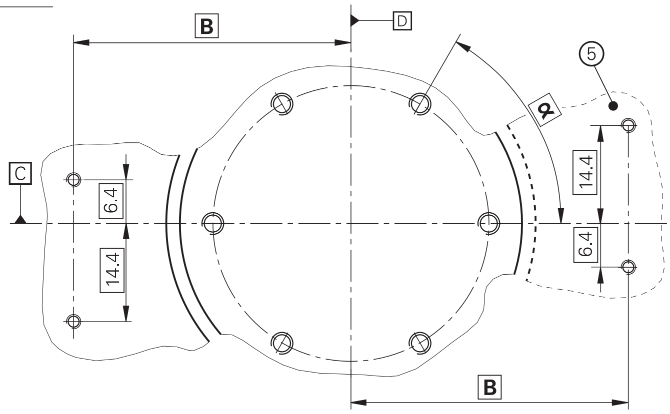
- Very high resolution and accuracy
- Low mass and low mass moment of inertia
- Consisting of an AK scanning head and TKN circular scale




**Mounting adapter**



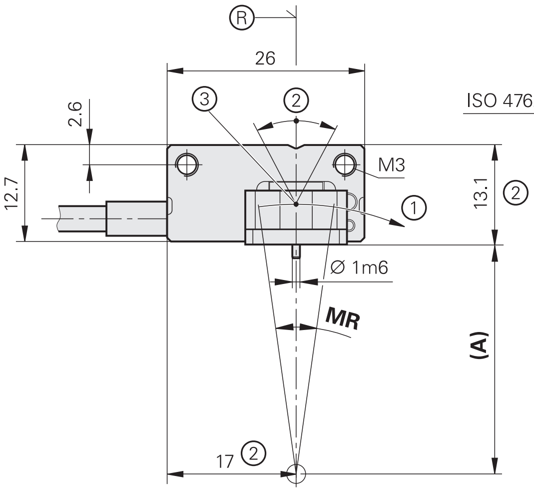

| SP/360° | 23000 | 30000 | 50000 | 63000 |
|---|---|---|---|---|
| A | 34.08 | 43.3 | 60.05 | 81.05 |
| B | 31.48 | 40.7 | 57.45 | 78.45 |
| D1 | Ø 57 | Ø 75 | Ø 109 | Ø 151 |
| D2 | Ø 13H6 | Ø 32H6 | Ø 62H6 | Ø 104H6 |
| D3 | Ø 15.1 | Ø 34.1 | Ø 64.5 | Ø 106.5 |
| D4 | Ø 21.5 | Ø 40.5 | Ø 72 | Ø 114 |
| D5 | Ø 27.9 | Ø 46.9 | Ø 79.5 | Ø 121.5 |
| H | 9.2 | 9.2 | 10.2 | 10.2 |
| α | 3 x 120° = 360° | 6 x 60° = 360° | 6 x 60° = 360° | 6 x 60° = 360° |
| M | M3 | M3 | M4 | M4 |

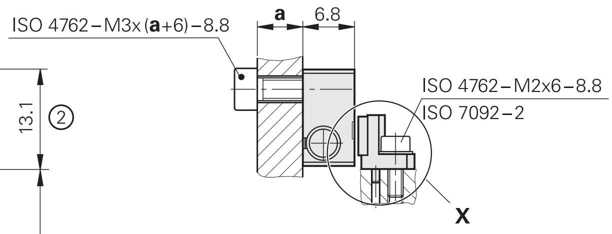
mm

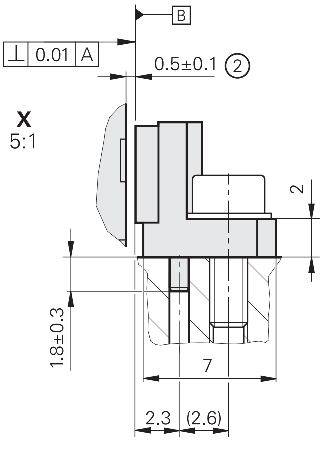
Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

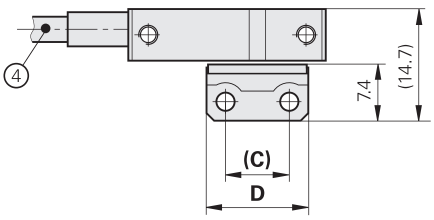
A = Bearing
® = Reference mark
1 = Centering collar
2 = Fine adjustment of the scanning head for attaining optimal incremental signals
3 = Marks for circular scale centering (3x120°)
4 = Optical centering point
5 = For centering of circular scale with two scanning heads
6 = Positive direction of rotation
7 = Alternative cable outlet and connector are available

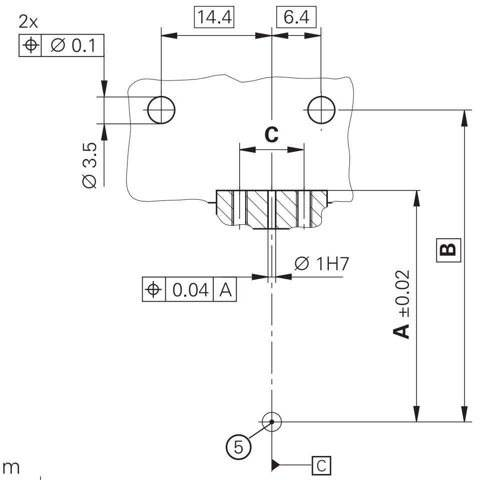
LE = Line element (ISO 1101: 2008)
SP = Signal periods

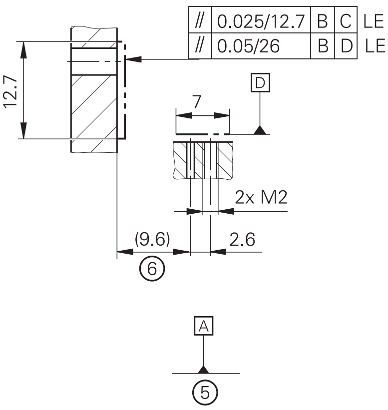




mm

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

A = Bearing
R = Position of the reference mark
1 = Positive direction of rotation
2 = Fine adjustment of the scanning head for attaining optimal incremental signals
3 = Optical center point
4 = Alternative cable outlet and connector are available
5 = Center of rotation
6 = Adjustable

LE = Line element (ISO 1101: 2008)
SP = Signal periods
MR = Measuring range
MR* = Required range for electronic fine adjustment

| SP/360° | 23000 | | | 30000 | | | 50000 | | | 63000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MR** | 10° | 23° | 36° | 8° | 16° | 31° | 5° | 11° | 21° | 4° | 8° | 15° |
| **MR*** | 6.6° | | | 5.2° | | | 3.2° | | | 2.4° | | |
| **A** | 20.98 | | | 30.2 | | | 46.95 | | | 67.95 | | |
| **B** | 31.48 | | | 40.7 | | | 57.45 | | | 78.45 | | |
| **C** | 5 | 8.4 | 13 | 5 | 8.4 | 13 | 5 | 8.4 | 13 | 5 | 8.4 | 13 |
| **D** | 10 | 13.4 | 22.9 | 10 | 13.4 | 22.9 | 10 | 13.4 | 22.9 | 10 | 13.4 | 22.9 |

# Specifications

| **Scanning head** | **AK ERP 1070** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Interface** | ⊓⊔TTL | | | | | | | |
| Reference mark signal | Square-wave pulse | | | | | | | |
| Integrated interpolation* | 1-fold[1] | 5-fold | 10-fold | 25-fold | 50-fold | 100-fold | 500-fold | 1000-fold |
| Scanning frequency[2] | ≤ 450 kHz | ≤ 312.5 kHz | | ≤ 250 kHz | ≤ 125 kHz | ≤ 62.5 kHz | ≤ 12.5 kHz | ≤ 6.25 kHz |
| Edge separation *a* | ≥ 0.125 µs | ≥ 0.135 µs | ≥ 0.07 µs | ≥ 0.03 µs | | | | |
| **Electrical connection*** | 15-pin D-sub connector (male) with 0.5 m/1 m/1.5 m cable, interface electronics in the connector;<br>cable outlet: left or right and straight or angled | | | | | | | |
| Cable length | With HEIDENHAIN cable: ≤ 20 m; during signal adjustment with the PWM 21: ≤ 3 m | | | | | | | |
| Supply voltage | DC 5 V ±0.5 V | | | | | | | |
| Current consumption | ≤ 300 mA (without load) | | | | | | | |

| **Scanning head** | **AK ERP 1080** |
|---|---|
| **Interface** | ∼ 1 $V_{PP}$ |
| Reference mark signal | Square-wave pulse |
| Cutoff frequency –3 dB | ≥ 1 MHz |
| **Electrical connection*** | 15-pin D-sub connector (male) with 0.5 m/1 m/1.5 m/3 m cable;<br>12-pin SHR-12V-S connector (female) with 0.5 m/1 m/1.5 m/3 m cable;<br>cable outlet: left or right and straight or angled |
| Cable length | With HEIDENHAIN cable: ≤ 20 m; during signal adjustment with the PWM 21: ≤ 3 m |
| Supply voltage | DC 5 V ±0.5 V |
| Current consumption | ≤ 150 mA (without load) |

* Please select when ordering
1) Suitable for applications that measure the time between individual TTL output signal clock edges; non-clocked output signals keep edge jitter low
2) Maximum scanning frequency during referencing: 70 kHz

| Scanning head | AK ERP 1010 |
|---|---|
| **Interface** | EnDat 2.2[1)] |
| Ordering designation | EnDat22 |
| Clock frequency | ≤ 16 MHz |
| Calculation time $t_{cal}$ | ≤ 5 µs |
| **Electrical connection*** | 15-pin D-sub connector (male) with 0.5 m/1 m/1.5 m/3 m cable; interface electronics inside the connector; cable outlet: left or right and straight or angled |
| Cable length | With HEIDENHAIN cable: ≤ 100 m; during signal adjustment with the PWM 21: ≤ 3 m |
| Supply voltage | DC 3.6 V to 14 V |
| Power consumption (max.) | *At 3.6 V:* 1220 mW; *at 14 V:* 1430 mW |
| Current consumption (typical) | *At 5 V:* 175 mA (without load) |

1) Absolute position value after crossing of the reference mark in "Position value 2"

| Scanning head | Generally valid (AK ERP 1070 / AK ERP 1080 / AK ERP 1010) |
|---|---|
| **Vibration** 55 Hz to 2000 Hz<br>**Shock** 6 ms | ≤ 500 $m/s^2$ (EN 60068-2-6)<br>≤ 1000 $m/s^2$ (EN 60068-2-27) |
| **Operating temperature** | –10 °C to 70 °C |
| **Protection** | IP50 |
| **Mass** Scanning head<br>Connector<br>Cable | ≈ 5 g (without cable)<br>≈ 75 g<br>≈ 22 g/m |

| Circular scale | TKN ERP 1000 (full circle) | | | |
|---|---|---|---|---|
| **Measuring standard** | OPTODUR graduation on glass | | | |
| **Signal periods*** | 23000 | 30000 | 50000 | 63000 |
| **Accuracy of graduation**[1] | ±4″ | ±3″ | ±1.8″ | ±1.5″ or ±0.9″ |
| **Baseline error**[2] | ≤ ±0.8″/10° | | ≤ ±0.6″/10° | ≤ ±0.5″/10° or<br>≤ ±0.4″/10° |
| **Position error per signal period**[3] | ±0.06″ | ±0.04″ | ±0.025″ | ±0.02″ |
| **RMS position noise** (1 MHz) | 0.006″ | 0.004″ | 0.003″ | 0.002″ |
| **Positions/rev.**[4] | 376832000 | 491520000 | 819200000 | 1032192000 |
| **Measuring step**[4] | 0.0034″ | 0.0026″ | 0.0016″ | 0.0013″ |
| **Reference marks** | One | | | |
| **Hub inside diameter (D1)** | 13 mm | 32 mm | 62 mm | 104 mm |
| **Scale outside diameter (D2)** | 57 mm | 75 mm | 109 mm | 151 mm |
| Mech. permissible speed | ≤ 2600 rpm | ≤ 2000 rpm | ≤ 1200 rpm | ≤ 950 rpm |
| Elec. permiss. shaft speed[4][5] | ≤ 2600 rpm | ≤ 2000 rpm | ≤ 1200 rpm | ≤ 950 rpm |
| Moment of inertia | $1.6 \cdot 10^{-5}$ kgm$^2$ | $5.7 \cdot 10^{-5}$ kgm$^2$ | $3.1 \cdot 10^{-4}$ kgm$^2$ | $1.1 \cdot 10^{-3}$ kgm$^2$ |
| **Protection** EN 60529 | Complete, mounted encoder: IP00 | | | |
| **Mass** | ≈ 57 g | ≈ 92 g | ≈ 185 g | ≈ 289 g |

* Please select when ordering
[1] When centered with two scanning heads
[2] For mechanical centering as per the mounting instructions
[3] The position error per signal period and the accuracy of the graduation together yield the encoder-specific error; for additional errors arising from installation and the bearing of the measured shaft, see *Measurement accuracy*
[4] With serial interface
[5] With TTL serial interface and depending on the selected interpolation

| Circular scale | TKN ERP 1002 (segment) | | | |
|---|---|---|---|---|
| **Measuring standard** | OPTODUR graduation on glass | | | |
| **Signal periods*** | 23000 | 30000 | 50000 | 63000 |
| **Position error per signal period** | ±0.06″ | ±0.04″ | ±0.025″ | ±0.02″ |
| **RMS position noise** (1 MHz) | 0.006″ | 0.004″ | 0.003″ | 0.002″ |
| **Positions/rev.**[1] over 360° | 376832000 | 491520000 | 819200000 | 1032192000 |
| **Measuring step**[1] | 0.0034″ | 0.0026″ | 0.0016″ | 0.0013″ |
| **Reference marks** | One | | | |
| **Measuring range** | 10°/23°/36° | 8°/16°/31° | 5°/11°/21° | 4°/8°/15° |
| Elec. permiss. shaft speed[1)2)] | ≤ 2600 rpm | ≤ 2000 rpm | ≤ 1200 rpm | ≤ 950 rpm |
| **Protection** EN 60529 | Complete encoder when mounted: IP00 | | | |
| **Mass** | ≈ 0.6 g/1 g/1.7 g | | | |

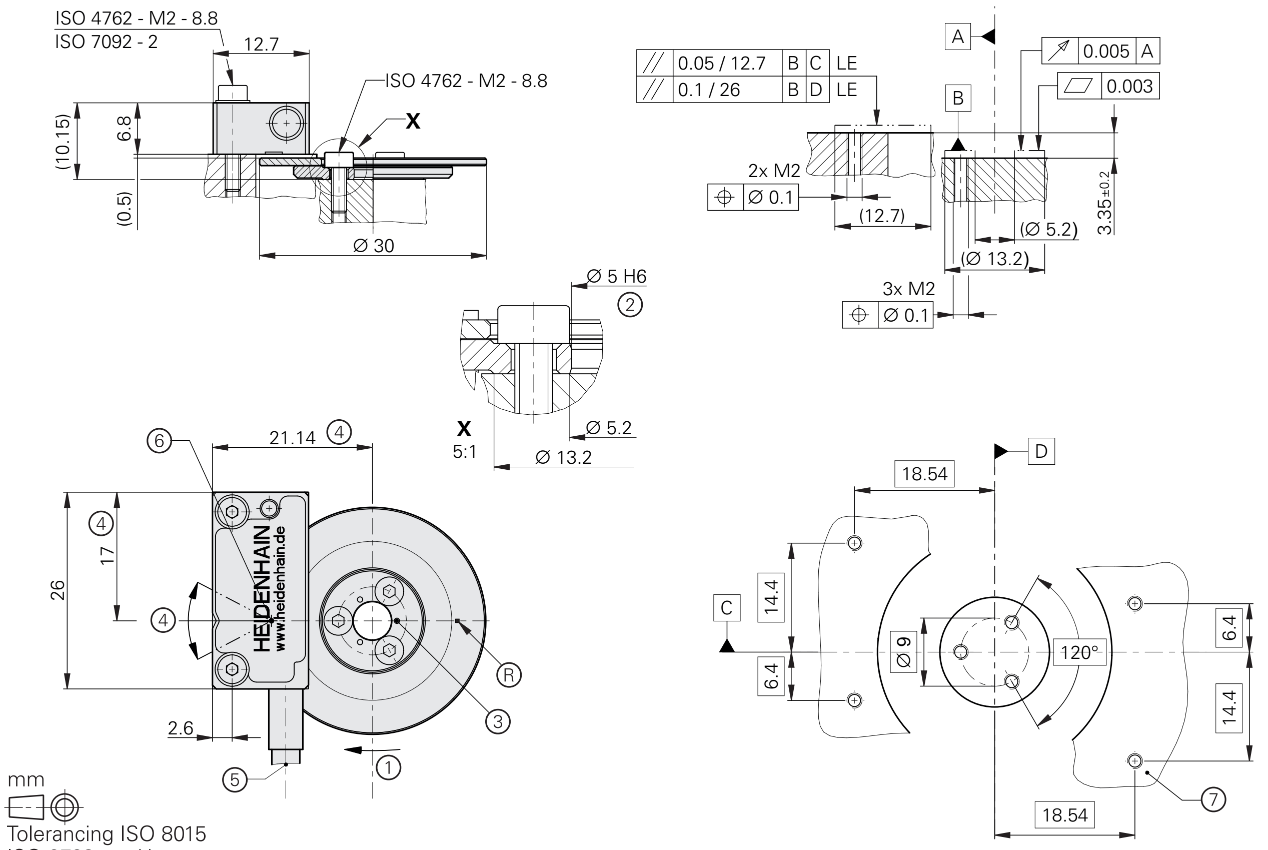
* Please select when ordering
1) With serial interface
2) With TTL serial interface and depending on the selected interpolation

# ERO 2000 series

- **High resolution and accuracy**
- **Low mass and low mass moment of inertia**
- **Consisting of an AK scanning head and TKN circular scale**
- **TKN segment versions with position detection via homing track**


**Graduation carrier (Ø 30 mm)**

**Required mating dimensions**



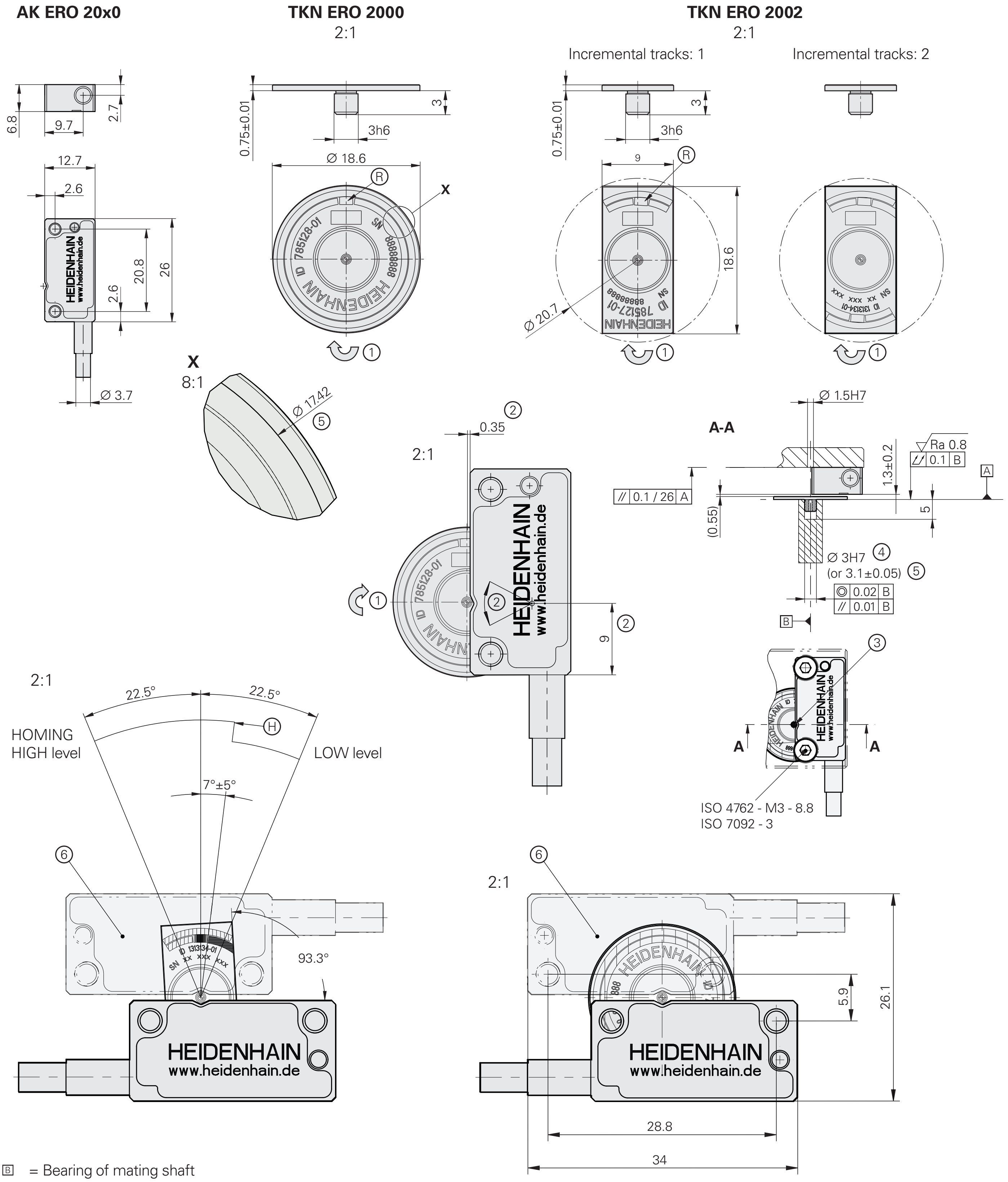

mm

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

A = Bearing
® = Reference mark
1 = Positive direction of rotation
2 = Centering collar
3 = Marks for circular scale centering (3x120°)
4 = Fine adjustment of the scanning head for obtaining optimal incremental signals
5 = Alternative cable outlet and connector are available
6 = Optical center point
7 = For centering of circular scale with two scanning heads

LE = Line element (ISO 1101: 2008)

**Graduation carrier (Ø 18.6) mm**
**(segment version: 18.6 mm× 9 mm)**


B = Bearing of mating shaft
H = Signal edge of the homing track
R = Position of the reference mark
1 = Direction of shaft rotation for ascending position values
2 = Fine adjustment of the scanning head for attaining optimal incremental signals
3 = Cylindrical pin for positioning and Moiré adjustment (must be removed after positioning)
4 = Dimension for alignment of the circular scale via the centering pin of the circular scale
5 = Dimension for mounting the circular scale via optical alignment;
do not use the outer glass edge of the circular scale
6 = Optional: mounting with two scanning heads

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

# Specifications

| Scanning head | | AK ERO 2080 |
|---|---|---|
| **Interface** | | ∿ 1 $V_{PP}$ |
| Reference mark signal | | Square-wave pulse |
| Cutoff frequency | –3 dB[1)] | ≥ 1 MHz |
| **Electrical connection*** | | 15-pin D-sub connector (male) with 0.5 m/1 m/1.5 m/3 m cable<br>12-pin SHR-12V-S connector (female) with 0.5 m/1 m/1.5 m/3 m cable<br>Cable outlet on the left or right and straight or angled |
| Cable length | | With HEIDENHAIN cable: ≤ 20 m; during signal adjustment with the PWM 21: ≤ 3 m |
| Supply voltage | | DC 5 V ±0.5 V |
| Current consumption | | ≤ 150 mA (without load) |
| **Vibration** 55 Hz to 2000 Hz<br>**Shock** 6 ms | | ≤ 500 $m/s^2$ (EN 60068-2-6)<br>≤ 1000 $m/s^2$ (EN 60068-2-27) |
| **Operating temperature** | | –10 °C to 70 °C |
| **Protection** | | IP50 |
| **Mass** | Scanning head<br>Connector<br>Cable | ≈ 5 g (without cable)<br>≤ 75 g<br>≈ 22 g/m |

* Please select when ordering
1) Maximum frequency during referencing: 500 kHz

| Circular scale | TKN ERO 2000 (full circle) | | TKN ERO 2002[1] (segment) | |
|---|---|---|---|---|
| **Measuring standard** | SUPRADUR graduation on glass | | | |
| **Measuring range** | 360° | | 45° | |
| **Signal periods** | 4096 | 2500 | 2500 over 360° | |
| **Accuracy of graduation**[2] | ±8″ | ±10″ | – | – |
| **Baseline error**[3] | ≤ ±2″/10° | | | |
| **Position error per signal period**[4] | ±0.3″ | ±0.5″ | ±0.5″ | |
| **RMS position noise** (1 MHz) | 0.03″ | 0.04″ | 0.04″ | |
| **Reference marks** | One | | One | One on every side |
| **Inside diameter of hub** | 5 mm | – | – | |
| **Dimensions of graduation carrier** | Ø 30 mm | Ø 18.6 mm | 18.6 mm x 9 mm | |
| **Centering pin** | – | 3 mm | 3 mm | |
| Mech. permiss. shaft speed | ≤ 14000 rpm | ≤ 24000 rpm | | |
| Moment of inertia | $4.1 \cdot 10^{-7}$ kgm$^2$ | $2.2 \cdot 10^{-8}$ kgm$^2$ | $1.1 \cdot 10^{-8}$ kgm$^2$ | |
| **Protection** EN 60529 | Complete, mounted encoder: IP00 | | | |
| **Mass** | ≈ 5.2 g | ≈ 0.56 g | ≈ 0.36 g | |

1) Along with their incremental graduation, the TKN ERO 2002 segment versions feature a homing track for position detection (see Ⓗ in mating dimensions). The signal for position detection from the scanning head is transmitted in the TTL level via a separate line and is therefore directly available. The incremental signals correspond to the $V_{PP}$ interface.
2) When centered with two scanning heads
3) For mechanical centering as per the mounting instructions
4) The position error per signal period and the accuracy of the graduation together yield the encoder-specific error; for additional errors arising from installation and the bearing of the measured shaft, see *Measurement accuracy*

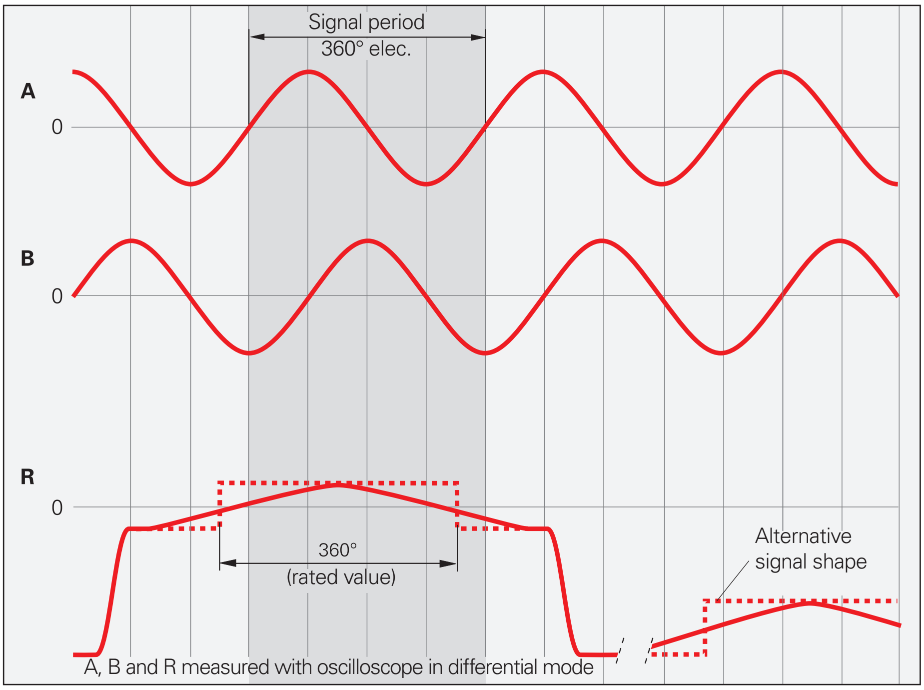
# Interfaces

## 1 $V_{PP}$ incremental signals

HEIDENHAIN encoders with the 1 $V_{PP}$ interface provide highly interpolable voltage signals.

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

The **reference mark signal** R has a unique assignment to the incremental signals. The output signal may be lower next to the reference mark.




**Further information:**

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

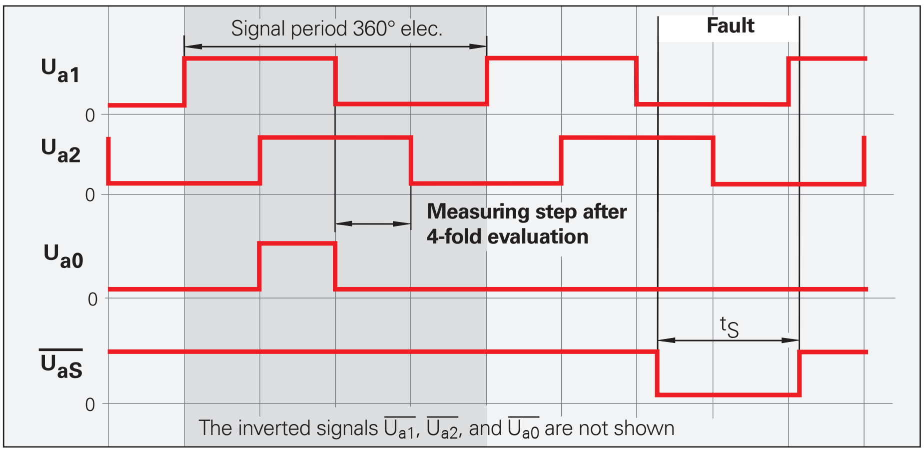
## TTL incremental signals

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

The **incremental signals** are output as the square-wave pulse trains $U_{a1}$ and $U_{a2}$ with a 90° elec. phase shift. 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 generate the **inverted signals** $\overline{U_{a1}}$, $\overline{U_{a2}}$ and $\overline{U_{a0}}$ for noise-immune 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 an interruption in the supply lines and failure of the light source.

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.**




**Further information:**

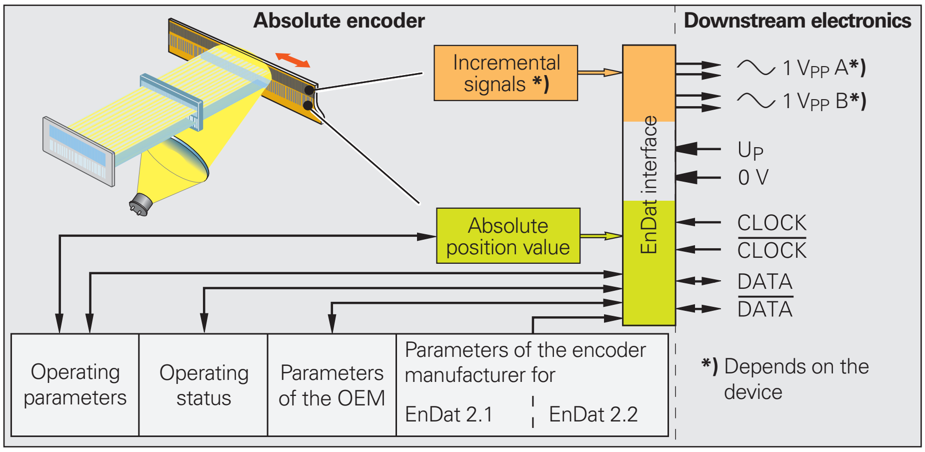
For detailed descriptions of all available interfaces, as well as general electrical information, please refer to the *Interfaces of HEIDENHAIN Encoders* brochure.

# EnDat position values

The EnDat interface is a digital **bidirectional** interface for encoders. It is capable of outputting **position values**, reading and updating information stored in the encoder, and storing new information in the encoder. Because the interface uses **serial transmission**, only **four signal lines** are required. The data (DATA) are transmitted in **synchronism** with the CLOCK signal from the downstream electronics. The type of transmission (position values, parameters, diagnostics, etc.) is selected via mode commands sent to the encoder by the downstream electronics. Some functions are available only with EnDat 2.2 mode commands.

| Ordering designation | Command set | Incremental signals |
|---|---|---|
| **EnDat01** | EnDat 2.1 or EnDat 2.2 | With |
| EnDat21 | | Without |
| EnDat02 | EnDat 2.2 | With |
| **EnDat22** | EnDat 2.2 | Without |

Versions of the EnDat interface



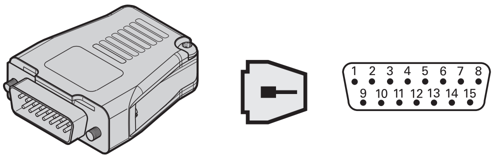

**Further information:**

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

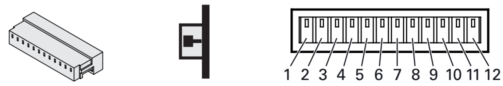
# Pin layout

## ERP 1000, ERP 1080 D*plus*

**15-pin D-sub connector (male)**




**12-pin SHR-12V-S connector (female)**

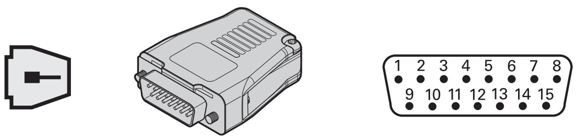



| | Power supply | | | | Incremental signals | | | | | | Serial data transmission/ other signals | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **4** | **12** | **2** | **10** | **1** | **9** | **3** | **11** | **14** | **7** | **13** | **15** | **5** | **6** | **8** |
| | **1** | **–** | **2** | **–** | **3** | **4** | **6** | **5** | **8** | **7** | **9** | **11** | **12** | **10** | **/** |
| **EnDat** | **$U_P$** | **Sensor** $U_P$ | **0 V** | **Sensor** 0 V | **/** | **/** | **/** | **/** | **/** | **/** | **$\overline{DATA}$** | **$\overline{CLOCK}$** | **DATA** | **Vacant** | **CLOCK** |
| **TTL** | | | | | **Ua1** | **$\overline{Ua1}$** | **Ua2** | **$\overline{Ua2}$** | **Ua0** | **$\overline{Ua0}$** | **$\overline{UaS}$** | **Vacant** | **Va-cant**[1)] | **Va-cant**[1)] | **Va-cant**[1)] |
| **~ 1 $V_{PP}$** | | | | | **A+** | **A–** | **B+** | **B–** | **R+** | **R–** | **Va-cant**[1)] | **Va-cant**[1)] | **Vacant** | **Vacant** | **Vacant** |
| | Brown/ Green | / | White/ Green | / | Brown | Green | Gray | Pink | Red | Black | Violet | Yellow | / | / | / |

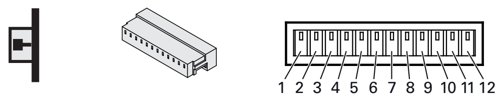
**Shield** lies on housing; **$U_P$** = Power supply voltage
**Sensor:** The sense line is connected in the connector with the corresponding power line.
Vacant wires and pins must not be used.
1) Required for signal adjustment with the PWM 21

## ERO 2000

**15-pin D-sub connector (male)**




**12-pin SHR-12V-S connector (female)**




| | Power supply | | | | Incremental signals | | | | | | Other signals | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **4** | **12** | **2** | **10** | **1** | **9** | **3** | **11** | **14** | **7** | **13** | **8** | **6** | **15** |
| | **1** | **–** | **2** | **–** | **3** | **4** | **6** | **5** | **8** | **7** | **9** | **12** | **10** | **11** |
| **~ 1 $V_{PP}$** | **$U_P$** | **Sensor $U_P$** | **0 V** | **Sensor 0 V** | **A+** | **A–** | **B+** | **B–** | **R+** | **R–** | **Va-cant**[1)] | **H** | **/** | **Vacant**[1)] |
| | Brown/ Green | / | White/ Green | / | Brown | Green | Gray | Pink | Red | Black | Violet | Green/ Black | Yellow/ Black | Yellow |

**Shield** on housing; **$U_P$** = Power supply voltage
**Sensor:** The sense line is connected in the connector with the corresponding power line.
Vacant pins or wires must not be used.
1) Required for signal adjustment with the PWM 21

# Testing equipment and diagnostics

HEIDENHAIN encoders provide all the information needed for initial setup, monitoring and diagnostics. The type of information available depends on whether the encoder is incremental or absolute and on which interface is being used.

Incremental encoders mainly have 1 $V_{PP}$, TTL or HTL interfaces. TTL and HTL encoders monitor their signal amplitudes internally and generate a simple fault detection signal. With 1 $V_{PP}$ signals, an analysis of the output signals is possible only with external testing devices or through the use of computation resources in the downstream electronics (analog diagnostic interface).

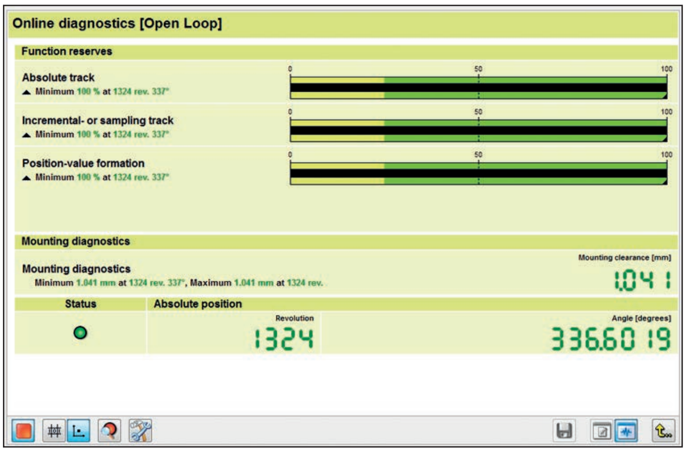
Absolute encoders employ serial data transmission. Depending on the interface, 1 $V_{PP}$ incremental signals can also be output. The signals are extensively monitored within the encoder. The monitoring results (particularly valuation numbers) can be transmitted to the downstream electronics along with the position values via the serial interface (digital diagnostic interface). The following information is available:

- Error message: position value is not reliable
- Warning: an internal functional limit of the encoder has been reached
- Valuation numbers:
  - Detailed information about the encoder's function reserve
  - Identical scaling for all HEIDENHAIN encoders
  - Cyclic reading capability

This enables the downstream electronics to evaluate the current status of the encoder with little effort, even in closed-loop mode.

For the analysis of these encoders, HEIDENHAIN offers the appropriate PWM inspection devices and PWT testing units. Based on how these devices are integrated, a distinction is made between two types of diagnostics:

- Encoder diagnostics: the encoder is connected directly to the testing or inspection device, thereby enabling a detailed analysis of encoder functions.
- Diagnostics in the control loop: the PWM testing unit is inserted within the closed control loop (e.g., via a suitable testing adapter). This enables real-time diagnosis of the machine or system during operation. The available functions depend on the interface.




Diagnostics with the PWM 21 and ATS software


Initial setup with the PWM 21 and ATS software

**PWT 101**
The PWT 101 is a testing device for the functional testing and adjustment of absolute and incremental HEIDENHAIN encoders. Thanks to its compact and rugged design, the PWT 101 is ideal for portable use.


| | PWT 101 |
|---|---|
| **Encoder input**<br>Only for HEIDENHAIN encoders | • EnDat<br>• Fanuc Serial Interface<br>• Mitsubishi high speed interface<br>• Panasonic Serial Interface<br>• Yaskawa Serial Interface<br>• 1 $V_{PP}$<br>• 11 $\mu A_{PP}$<br>• TTL |
| **Display** | 4.3-inch color flat-panel display (touchscreen) |
| **Supply voltage** | DC 24 V<br>Power consumption: max. 15 W |
| **Operating temperature** | 0 °C to 40 °C |
| **Protection** EN 60529 | IP20 |
| **Dimensions** | ≈ 145 mm × 85 mm × 35 mm |

**Further information:**

For a detailed description, refer to the *PWT 101* Product Information document.

**PWM 21**

The PWM 21 phase-angle measuring unit, in conjunction with the included ATS adjusting and testing software, serves as an adjusting and testing package for the diagnosis and adjustment of HEIDENHAIN encoders.

| | PWM 21 |
|---|---|
| **Encoder input** | • EnDat 2.1, EnDat 2.2 or EnDat 3 (absolute value with or without incremental signals)<br>• DRIVE-CLiQ<br>• Fanuc Serial Interface<br>• Mitsubishi high speed interface<br>• Yaskawa Serial Interface<br>• Panasonic Serial Interface<br>• SSI<br>• 1 $V_{PP}$/TTL/11 $\mu A_{SS}$<br>• HTL (via signal adapter) |
| **Interface** | USB 2.0 |
| **Supply voltage** | AC 100 V to 240 V or DC 24 V |
| **Dimensions** | 258 mm × 154 mm × 55 mm |

| | ATS |
|---|---|
| **Languages** | German or English (selectable) |
| **Functions** | • Position display<br>• Connection dialog<br>• Diagnostics<br>• Mounting wizard for the EBI/ECI/EQI, ERP 1000, ERO 2000 and others<br>• Additional functions (if supported by the encoder)<br>• Memory contents |
| **System requirements and recommendations** | PC (dual-core processor > 2 GHz)<br>RAM > 2 GB<br>Operating systems: Windows 7, 8 and 10 (32-bit / 64-bit)<br>500 MB of free hard drive space |

DRIVE-CLiQ is a registered trademark of Siemens Aktiengesellschaft

**Further information:**

For detailed descriptions, refer to the *PWM 21/ATS Software* Product Information document.

HEIDENHAIN

Mastering nanometer accuracy


HEIDENHAIN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