Modular Angle Encoders
with Scale Drum or Scale Tape
Information on
• Sealed angle encoders
• Rotary encoders
• Encoders for servo drives
• Exposed linear encoders
• Linear encoders for numerically controlled machine tools
• HEIDENHAIN interface electronics
• HEIDENHAIN controls
is available upon request as well as on the Internet at www.heidenhain.com.

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 comprehensive descriptions of all available interfaces, as well as general electrical information, please refer to the Interfaces of HEIDENHAIN Encoders brochure.
Angle encoders are used in applications requiring angular measurement at high resolution or at accuracies of down to just a few 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

By contrast, rotary encoders are used in applications where accuracy requirements are less stringent, including automation, electric 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 ECN is externally mounted.

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

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. Particular benefits:
- Wide hollow-shaft diameter (of up to 10 m with a scale tape)
- High shaft speeds of up to 20,000 rpm
- No additional starting torque from shaft seals
- Segment solutions
- Also available with functional safety

Modular angle encoders with optical scanning are available with various graduation carriers:
- ERP/ERO: Glass circular scale with hub
- ERA/ECA 4000: Steel drum
- ERA 7000/8000: Steel scale tape

Because these angle encoders do not come with an enclosure, the required degree of protection 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 highly immune 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 shaft 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 a scale drum

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<th>Series</th>
<th>Overall dimensions in mm</th>
<th>Diameter</th>
<th>Accuracy of graduation</th>
<th>Mechanically permissible speed</th>
<th>Design</th>
<th>Signal periods/revolution</th>
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<tr>
<td>ECA 4400(1)</td>
<td>D1: 70 mm to 512 mm, D2: 104.63 mm to 560.46 mm</td>
<td>±3.7” to ±2”</td>
<td>≤ 15 000 rpm to ≤ 2750 rpm</td>
<td>Steel drum with centering collar</td>
<td>–</td>
<td>EnDat 2.2</td>
<td>Fanuc, Mitsubishi, Panasonic, Yaskawa</td>
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<td>40</td>
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<tr>
<td>ECA 4402</td>
<td>D1: 40 mm to 270 mm, D2: 76.5 mm to 331.31 mm</td>
<td>±4” to ±1.7”</td>
<td>≤ 20 000 rpm to ≤ 4750 rpm</td>
<td>Steel drum with three-point centering</td>
<td>12 000 to 52 000</td>
<td>1 Vpp TTL</td>
<td>Distance-coded or one</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>ERA 4400</td>
<td>D1: 40 mm to 270 mm, D2: 76.5 mm to 331.31 mm</td>
<td>±5” to ±2”</td>
<td>≤ 20 000 rpm to ≤ 2750 rpm</td>
<td>Steel drum with centering collar</td>
<td>3 000 to 52 000</td>
<td>1 Vpp TTL</td>
<td>Distance-coded or one</td>
<td>48</td>
<td></td>
</tr>
</tbody>
</table>

1) May be limited during operation by the electrically permissible shaft speed
2) Also available with functional safety
3) Limited in the case of mechanical fault exclusion
### Modular angle encoders with magnetic scanning and a scale drum

<table>
<thead>
<tr>
<th>Series</th>
<th>Overall dimensions in mm</th>
<th>Diameter</th>
<th>Accuracy of graduation</th>
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<th>Design</th>
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<tr>
<td>ECM 2400</td>
<td>D1: 70 mm to 280 mm; D2: 113.16 mm to 326.9 mm</td>
<td>±8” to ±3.5”</td>
<td>14500 rpm to 4500 rpm</td>
<td>Fastening via screws</td>
<td>900 to 2600</td>
<td>EnDat 2.2</td>
<td>Fanuc, Mitsubishi</td>
<td>58</td>
</tr>
<tr>
<td>ERM 2200</td>
<td>D1: 40 mm to 410 mm; D2: 64.37 mm to 452.64 mm</td>
<td>±12” to ±2.5”</td>
<td>22000 rpm to 3000 rpm</td>
<td>Fastening via screws</td>
<td>1024 to 7200</td>
<td>TTL</td>
<td>1 Vpp</td>
<td>64</td>
</tr>
<tr>
<td>ERM 2203</td>
<td>D1: 40 mm to 296 mm; D2: 64.37 mm to 326.90 mm</td>
<td>±8” to ±1.5”</td>
<td>22000 rpm to 4600 rpm</td>
<td>Fastening via screws</td>
<td>1024 to 5200</td>
<td>TTL</td>
<td>1 Vpp</td>
<td>66</td>
</tr>
<tr>
<td>ERM 2400</td>
<td>D1: 40 mm to 512 mm; D2: 64.37 mm to 603.52 mm</td>
<td>±13” to ±3”</td>
<td>22000 rpm to 1600 rpm</td>
<td>Friction-locked fastening through clamping of the drum</td>
<td>512 to 4800</td>
<td>TTL</td>
<td>1 Vpp</td>
<td>68</td>
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<tr>
<td>ERM 2404</td>
<td>D1: 30 mm to 100 mm; D2: 45.26 mm to 128.76 mm</td>
<td>±24” to ±9”</td>
<td>60000 rpm to 20 000 rpm</td>
<td>Friction-locked fastening through clamping of the drum</td>
<td>360 to 1024</td>
<td>TTL</td>
<td>1 Vpp</td>
<td>70</td>
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<tr>
<td>ERM 2904</td>
<td>D1: 35 mm to 100 mm; D2: 54.43 mm to 120.96 mm</td>
<td>±72” to ±33”</td>
<td>50000 rpm to 16 000 rpm</td>
<td>Friction-locked fastening through clamping of the drum; additional slot for machine key as anti-rotation element</td>
<td>180 to 400</td>
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<td>70</td>
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<tr>
<td>ERM 2405</td>
<td>D1: 40 mm; 64.37 mm; 76.44 mm</td>
<td>±17” to ±14”</td>
<td>33000 rpm; 27000 rpm</td>
<td>Friction-locked fastening through clamping of the drum; additional slot for machine key as anti-rotation element</td>
<td>512; 600</td>
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<td>71</td>
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# Modular angle encoders with optical scanning and a scale tape

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<tbody>
<tr>
<td>ERA 7000</td>
<td>458.62 mm to max. 3000 mm upon request</td>
<td>±3.9” to ±0.7”</td>
<td>≤ 250 rpm to approx. 85 rpm</td>
<td>For inner mounting, full-circle and segment version(^1)</td>
<td>36000 to = 230'000</td>
<td>1 Vpp</td>
<td>Distance-coded</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>ERA 8000</td>
<td>458.11 mm to max. 3000 mm upon request</td>
<td>±4.7” to ±0.9”</td>
<td>≤ 50 rpm to ≤ 15 rpm</td>
<td>For outer mounting, full-circle and segment version(^2)</td>
<td>36000 to = 230'000</td>
<td>1 Vpp</td>
<td>Distance-coded</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>ERA 8900</td>
<td>≥ 3000 mm upon request</td>
<td>Upon request</td>
<td>Upon request</td>
<td>Outer mounting, very wide operating tolerances, full-circle and segment version(^3)</td>
<td>Upon request</td>
<td>1 Vpp</td>
<td>Distance-coded</td>
<td>Upon request</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) May be limited during operation by the electrically permissible shaft speed

\(^2\) Segment solutions upon request
HEIDENHAIN encoders use measuring standards consisting of periodic structures known as graduations. The optical graduations are applied to a glass or steel carrier substrate. For encoders with large measuring lengths, the graduation carrier is a steel tape.

HEIDENHAIN manufactures the precision graduations in the following specially developed, photolithographic processes:
- **METALLUR**: contamination-tolerant graduation consisting of metal lines on gold, typical grating period: 20 μm
- **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
- **TITANID** phase grating: exceptionally robust, optically three-dimensional structure with a high degree of reflectance; typical grating period: 8 μm

Along with the very fine grating periods, these processes permit high edge definition and excellent homogeneity of the graduation. In combination with the photoselective scanning method, these characteristics are critical for attaining high-quality output signals.

Magnetic encoders use a graduation carrier made of a magnetizable steel alloy. A write head creates strong local magnetic fields in different directions, resulting in a graduation consisting of magnetically north and south poles (MAGNODUR procedure). In combination with the magnetoresistive scanning method, this technology delivers a measuring method that is robust despite environmental factors.

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 no need to move the axes to find the reference position. Instead, the absolute position information is read from the graduation on the measuring standard, which is designed as a serial absolute code structure. To obtain the position value, a separate incremental track is interpolated.

Graduation of absolute angle encoders

In the incremental measuring method, the graduation is a periodic grating structure. The position information obtained is obtained through counting the individual increments (measuring steps) starting at a freely selectable point of origin. Since position measurement requires an absolute point of reference, the measuring standard features an additional track containing a reference mark. The absolute position on the scale, established by the reference mark, is gated with 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.

In some cases, this may require rotation up to nearly 360°. To simplify these reference runs, many HEIDENHAIN encoders feature distance-coded reference marks: the reference-mark track contains multiple reference marks at different defined intervals. 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). Encoders with distance-coded reference marks are identified with a "C" after the model designation (e.g., TTR ERA-4200C).

Graduation drum: TTR ERA 4000C

Graduation drum: TTR ERM 2200C

Scale tape: MSB ERA 7480 C, MSB ERA 8480 C

Graduation drum: TTR ERM 2400 C

Number of signal periods| Number of reference marks| Nominal increment N
---|---|---
36000| 72| 10°
45000| 90| 8°
90000| 180| 4°

Number of signal periods| Number of reference marks| Nominal increment N
---|---|---
512| 16| 45°
600| 20| 30°
720| 24| 30°
900| 30| 24°
1024| 32| 22.5°
1200| 30| 24°
1400| 40| 18°
1696| 32| 22.5°
2048| 32| 22.5°
2600| 52| 13.85°
3600| 60| 12°
3850| 70| 10.3°
4800| 80| 9°
Scanning principles

HEIDENHAIN encoders employ different measuring principles. All of these principles involve detecting exceedingly fine graduation lines on a carrier material and generating output signals as a result. The specific characteristics of the scanning principle affect data collection in the target application and should therefore be properly matched.

HEIDENHAIN uses two scanning principles for scale-drum and scale-tape modular angle encoders:
- Optical scanning for the ECA and ERA
- Magnetic scanning for the ECM and ERM

**Optical scanning**

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

Parallel light passes through a grating structure, casting dark and light fields at a certain distance, where there is an index grating with the same or similar grating period. 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. Photocells convert these light fluctuations into electrical signals. The specially structured grating of the scanning reticle filters the light so as to generate nearly sinusoidal output signals. The smaller the graduation period of the grating structure, the closer and more tightly tolerated 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.

**Magnetic scanning**

The permanent-magnet MAGNODUR graduation is scanned by magnetoresistive sensors. They consist of resistive tracks whose resistance values change in response to a magnetic field. When voltage is applied to the sensor, and when there is relative motion between the scanning head and the scale drum, the current is modulated in accordance with the magnetic field.

The special geometric configuration of the resistive sensors, combined with the manufacturing process used for the scanning PCBs on glass substrates, ensures high signal quality. In addition, the large scanning surface enables filtering of the signal harmonics. Such are the requirements for low position error within a signal period.

The graduation periods are at approx. 200 μm to 1000 μm. For this reason, devices with magnetoresistive scanning are used in applications with midlevel accuracy requirements.

Encoders with MAGNODUR scanning are highly immune to contamination and are well suited for use at higher operating temperatures.

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**Diagram:**

- Scale
- Window
- Structured detector
- Scanning reticle
- Index grating
- Condenser lens
- LED light source

**Diagram:**

- Measuring standard
- S N S N
- Scanning reticle
- Rr Rr Rr Rr
- +U
- A+
- A−
Measurement accuracy
Encoder-specific error

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 error
- The coupling to the measured shaft

These factors can be divided into encoder-specific error and application-dependent factors. For assessment of the attainable overall accuracy, all of these individual factors must be taken into account.

Encoder-specific error
The encoder-specific error includes:

- The graduation accuracy
- The interpolation accuracy
- The position noise

The graduation accuracy
The graduation accuracy results from the quality of the graduation. It includes:

- Homogeneity and period definition of the graduation
- The alignment of the graduation on the graduation carrier
- For encoders with solid graduation carriers: the stability of the graduation carrier, ensuring accuracy even after mounting
- For encoders with a steel scale tape: the error due to irregular scale-tape expansion during mounting, as well as the error at the scale-tape butt joints in full-circle applications

The accuracy of the graduation is the baseline error. This accuracy is ascertained under ideal conditions via measurement of the position error by means of 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.

For modular angle encoders, the graduation accuracy is stated in accuracy grades for easier differentiation. Accuracy grade a defines the upper limit of the baseline error within the measuring range.

Accuracy of the interpolation
The interpolation error has an effect even at very low traversing speeds and causes speed fluctuations, especially in the speed control loop. Within the application, the interpolation error affects the machining quality, such as the surface quality.

The accuracy of the interpolation is primarily influenced by:

- The fineness of the signal period
- The homogeneity and period definition of the graduation
- The quality of scanning filter structures
- The characteristics of the sensors
- The quality of the signal processing electronics

These factors are taken into account in the stated interpolation error within one signal period.

The interpolation accuracy is stated in the form of a maximum value $u$ of the interpolation error. For specific values, see the technical data.

Position noise
Position noise causes small, random deviations from the expected position. Position noise is also dependent on signal processing. Typically, the position noise is less than 1% of the signal period.

Static hysteresis during magnetic scanning
Whenever there is a change in direction, there is also the effect of hysteresis. This hysteresis depends on the size of the signal period and on the mounting conditions. HEIDENHAIN therefore recommends measuring this constant value in order to compensate for it. The ERM 2203 series encoders do not exhibit any hysteresis.

Application-dependent error
The quality of the mounting and adjustment of the scanning head, in addition to the given encoder-specific error, normally 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 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, the scale drum or the steel scale tape. Dimensional and geometric errors exhibited by the mating shaft can also add to the eccentricity. The following relationship exists between the eccentricity $e$, the diameter of the graduation $D$, and the measurement error $\Delta e$ (see bottom left figure):

$$\Delta e = \pm \frac{1}{2} \cdot \frac{e}{D}$$

Calculation example:
ERM 4000 angle encoder with a drum outside diameter of 208.89 mm, radial runout of the scale drum $2 \mu$m (eccentricity of $1 \mu$m)

$$\Delta e = \pm \frac{1}{2} \cdot \frac{1}{208.89} = \pm 0.01 \mu\text{m}$$

Alternative: Use the graph at the bottom right
Radial runout error of the bearing
The function for finding the measurement error $\Delta \varepsilon$ 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
Characteristics of the scale drums, such as their cross section, reference surfaces, screw holes and the position of the graduation relative to the mounting surface, are designed such that the accuracy of the encoders is only marginally affected by mounting and operation.

Geometric and diameter errors of the bearing surface (for ERA 7000 and ERA 8000)
Geometric errors of the bearing surface can affect the attainable system accuracy.

The segment solutions exhibit additional angular error $\Delta \varepsilon$ if the nominal scale-tape diameter is not precisely complied with:

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

With

- $\Delta \varepsilon$ = Error for segment in arc seconds
- $D$ = Nominal scale-tape carrier diameter
- $D'$ = Actual scale-tape carrier diameter
- $\varphi$ = Segment angle in degrees

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

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

With

- $z$ = 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.

All modular angle encoders from HEIDENHAIN are inspected for proper functioning prior to shipping and for accuracy during final acceptance. For the ECA 4000, ERA 4000, ECM 2400 and ERM 2203, HEIDENHAIN prepares quality inspection documents and includes them with the scale drums.

The quality inspection document confirms the stated graduation accuracy of each scale drum and documents measurement parameters along with the measurement uncertainty. The calibration standards ensure the traceability, as required by EN ISO 9001, to recognized national or international standards.

The graduation accuracy is determined when a single revolution is traversed, resulting in the display of a measurement curve and the value of the maximum error. The mounting-specific error is not included, nor is interpolation error within one signal period, which is a characteristic of the scanning head.

Temperature range
The angle encoders are inspected at a reference temperature of 22 °C. This is the temperature at which the system accuracy provided in the calibration chart is valid.

Sample calibration chart for an ERM 2203 C scale drum
1 Graphical depiction of the graduation accuracy
2 Calibration result
Compensation possibilities

Reasons for compensation
For modular angle encoders, the stated encoder-specific error is based on ideal mounting. In the real-world application, however, the attainable overall accuracy of the rotary axis is affected by mounting errors in the scale drum or scanning head, and by the guideway accuracy of the bearing under different loads. Within the overall very high accuracy of modular angle encoders from HEIDENHAIN, these external errors make up most of the error. In some cases, it is therefore necessary to perform accuracy compensation for the rotary axis in order to meet requirements.

This can be done via two different methods:
• **Dynamic compensation:** This method enables the continuous, dynamic compensation of certain error components of the overall angular error during operation. It is particularly well suited for sources of error that change over time or under varying loads.
• **Static compensation:** This method allows the angular error to be compensated for at a certain point in time and during a certain operating state. It is especially well suited for constant errors.

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<tr>
<th>Dynamic compensation</th>
<th>Compensable causes for angular error</th>
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<td><strong>Aids</strong></td>
<td><strong>Two scanning heads</strong></td>
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<td></td>
<td>Centering error during mounting</td>
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<tr>
<td></td>
<td>Radial runout error caused by bearing error</td>
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<tr>
<td></td>
<td>Load-dependent radial runout error of the bearing</td>
</tr>
<tr>
<td></td>
<td><strong>More than two scanning heads</strong></td>
</tr>
<tr>
<td></td>
<td>In addition: graduation errors</td>
</tr>
<tr>
<td></td>
<td>For scale-tape systems; in addition, runout errors of the scale-tape slot</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Static compensation</th>
<th>Compensable causes for angular error</th>
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</thead>
<tbody>
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<td><strong>Aids</strong></td>
<td><strong>Comparator system (ISO 230-2) or virtual reference</strong></td>
</tr>
<tr>
<td></td>
<td>Centering error during mounting</td>
</tr>
<tr>
<td></td>
<td><strong>Comparator system (ISO 230-2)</strong></td>
</tr>
<tr>
<td></td>
<td>Graduation error of the encoder</td>
</tr>
<tr>
<td></td>
<td>• Recommended for scale-tape encoders</td>
</tr>
</tbody>
</table>

The following conditions are required for dynamic compensation:
• Two scanning heads that are mounted opposite each other.
• The possibility of calculating the positions of the scanning heads in real time. For the ERA and ERM incremental encoders, HEIDENHAIN offers the EIB 15xx. For position calculation with the ECA and ECM incremental encoders, the controller manufacturers provide solutions integrated directly into the controller software.
• For scale-tape encoders with very wide diameters, such as those used in telescopes, four or more scanning heads are often used. In this case, position calculation occurs individually in accordance with the use case and the configuration of the scanning heads.

**Good static compensation** requires a suitable standard for comparison. There are two general approaches:
• Use of an additional calibrated encoder with higher accuracy and higher reproducibility (e.g., RVM 4000) and calibration of the rotary axis in accordance with ISO 230-2. The calculated compensation values are then stored in the controller.
• Use of a virtual reference based on the encoder to be calibrated, aided by an additional scanning head, an appropriate evaluation unit (e.g., the PWM 21) and a software application from HEIDENHAIN. The compensation values can be stored directly in the scanning head. This method is available only for selected HEIDENHAIN encoders. This is beneficial, for example, if compensation is to occur at the component level and not in a fully assembled machine.
Reliability

The modular angle encoders from HEIDENHAIN are optimized for use in fast and precise machines. Even with their exposed mechanical design, these encoders are highly immune to contamination, ensure high long-term stability and are fast and easy to mount.

Low sensitivity to contamination

Both the high quality of the grating and the scanning method are responsible for the accuracy and reliability of the encoders. These optical encoders from HEIDENHAIN use single-field scanning, by which only one scanning field is used to generate the scanning signals. Local contamination on the measuring standard (e.g., fingerprints or oil residue) influence both the light intensity of the signal components and the quality of the scanning signals. The output signals thereby change in amplitude but not with regard to the offset and phase position. They remain highly interpolable, and the interpolation error within one signal period remains low.

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

The figures at right show the results of contamination tests with the ERA 4000. The maximum interpolation errors within one signal period |u| are shown. Despite significant contamination, the specified value of ±1% is only minimally exceeded.

Magnetic encoders from HEIDENHAIN are fully immune to this contamination test. The measurement signal remains unaffected even under continuous and surrounding contamination. However, metal chips, for example, must be kept out of the cooling lubricant because they could physically damage the cover sheet of the scanning head.

Durable measuring standards

Due to their exposed design, the measuring standards of modular angle encoders with optical scanning are less protected from their environment. For this reason, HEIDENHAIN always uses robust graduations manufactured in special processes.

In the METALLUR process, a reflective gold layer is covered with a thin layer of glass. On this layer are lines of translucent, light-absorbing chrome only several nanometers in thickness. Measuring standards with METALLUR graduations have proven to be particularly robust and insensitive to contamination because the low height of the structure leaves practically no surface for dust, dirt or water particles to accumulate.

In the MAGNODUR process, alternating north and south poles are created on the periphery. Because the graduation lies within the material, contamination on the scale drum has no effect on the signals. This measuring standard becomes damaged only if it comes into direct contact with a magnetic field (e.g., via a tool).

Application-oriented mounting tolerances

The mounting tolerances of modular angle encoders from HEIDENHAIN have minimal influence on the output signals. In particular, a variation in the scanning gap between the graduation carrier and scanning head causes only negligible change in the signal amplitude, and barely affects the interpolation error within one signal period. This behavior is substantially responsible for the high reliability of angle encoders from HEIDENHAIN.

Typical relationship between the signal amplitude and the scanning gap (mounting clearance) for the ECMERM 2000

Influence of the scanning gap on the signal amplitude for the ERA 4000

Design of a METALLUR graduation

Nominal scanning gap (last with a spacer shim)
Angle encoders on direct-drive motors

Direct-drive motors are increasingly being used on rotary axes in order, for example, to boost efficiency by increasing the attainable dynamic performance of the axis motion.

Of particular importance for the performance of a direct-drive feed axis is the choice of encoder. The position and speed feedback of direct-drive motors is achieved with a position encoder. Angle encoder selection must therefore be made on the basis of its usage in the machine:

The higher the speed-stability requirements, particularly at low shaft speeds, the more important are the following factors:

- The signal quality of the encoder, meaning the lowest possible position error within one signal period
- The number of signal periods (with incremental encoders) and the resolution (with absolute encoders)

Limitation in the signal quality of the encoder or the resolution/number of signal periods may cause:

- Increased noise in the motor current and thereby higher power loss and motor heating
- High-frequency noise in the drive train
- Reduced dynamic performance due to the required reduction in gain factors within the position and speed control loops.

The speed \( v \) is calculated from the distance \( \Delta x \) travelled in a time interval \( \Delta t \) (\( v = \frac{\Delta x}{\Delta t} \)). Position errors within one signal period cause the calculated speed to fluctuate despite constant motion. \( \frac{\Delta v}{\Delta t} \neq \frac{\Delta x}{\Delta t} \)

HEIDENHAIN provides various aids for ensuring easy and optimal initial setup of the modular angle encoder.

Mechanical mounting
High-quality physical mounting within tolerance is essential for ensuring the high reliability of the angle encoder. Please follow the mounting instructions.

Mounting support with the PWM 21
The ERA, ECA and ECM encoders, in conjunction with the PWM 21, offer special, device-specific processes in order to simplify and check for proper mounting.

The ATS software guides users through the necessary individual steps for, say, evaluating the signal quality. It also provides notification if the recommended limit values are not attained.

For incremental encoders, this includes the evaluation of the signal amplitudes, as well as the reference mark position and width. For absolute encoders, evaluation is performed based on valuation numbers and alarms.

Functional testing with the PWT 101 and PWM 21
The PWT 101 and the PWM 21 with the ATS software provide basic functions for all angle encoders. In the case of incremental encoders, for example, the signal quality can be evaluated. Function reserves, warnings and alarms can be output for absolute encoders.

Diagnostics in the control loop
The ECA and ECM absolute encoders transmit valuation numbers to the downstream electronics, thereby enabling diagnostics for the encoders status or determination of the function reserve, including directly within the control loop at the controller. The scaling is the same for all HEIDENHAIN encoders and is stated as a function reserve (from 0% to 100%).

Example of the noise behavior of optical and non-optical angle encoders in rotary tables with a direct-drive motor at a continuously increasing shaft speed

- Optical angle encoder with 32 768 lines
- Optical angle encoder with 16 384 lines
- Non-optical angle encoder with 2600 lines

Mounting support, functional testing and diagnostics

Mounting support for the ERA 4000 with the ATS software and PWM 21

Mounting support, such as for the ECM 2000 with the PWM 21 and ATS software

Functionality check, such as for the ERM 2000 with the PWT 101 and ATS software
Signal-quality indicator for the ERA 4000
The ERA 4000 angle encoders feature a built-in signal-quality indicator in the form of a multicolor LED, permitting fast and easy signal-quality checks during operation.

This feature provides a number of benefits:
- Scanning-signal quality visualization through a multicolor LED
- Continuous monitoring of incremental signals over the entire measuring length
- Indication of 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 a range of colors, permitting quite detailed signal-quality differentiation. The tolerance conformity of the reference mark signal is shown by means of a pass/fail indicator.

Test film for magnetic graduation for the ECM/ERM 2000
The test film makes magnetic polarity visible. It is ideal for simple inspection in order to detect and prevent damage to the graduation:
- Damage to the magnetic graduation (e.g., demagnetization via a tool)
- Residual magnetism of the tool or screw prior to mounting

Visible marking on the test film after contact with an Allen wrench, as an indicator of tool magnetization

Test film makes magnetic polarity visible. It is ideal for simple inspection in order to detect and prevent damage to the graduation:
- Damage to the magnetic graduation (e.g., demagnetization via a tool)
- Residual magnetism of the tool or screw prior to mounting

LED indicator for incremental signals

<table>
<thead>
<tr>
<th>LED color</th>
<th>Quality of the scanning signals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimal</td>
</tr>
<tr>
<td></td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Acceptable</td>
</tr>
<tr>
<td></td>
<td>Unsatisfactory</td>
</tr>
</tbody>
</table>

**LED indicator for the reference mark signal**
When the reference mark is traversed, the LED briefly lights up in red or blue:
- Out of tolerance
- In tolerance

**ERA 4000: Signal-quality indicator in the scanning head**

The modular angle encoders are made up of a scanning head and a graduation carrier. The graduation may be implemented in the form of a scale drum or a scale tape. 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 from the very beginning to meet the following prerequisites:
- The bearing must be designed such that it meets the accuracy requirements of the axis and the scanning-gap tolerances of the encoder, even during operation (see the Technical data).
- The mounting surface for the graduation carrier must meet the flatness, roundness, radial runout and diameter requirements of the given encoder.
- To facilitate 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 scanning drums are designed such that the specified accuracy can be reached in the actual application. The 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). Various possibilities for centering, depending on the encoder and mounting method, are possible for minimizing the eccentricity errors in practice.

1. **Centering collar**
The graduation carrier is pressed or shrunk onto the shaft. This very simple method, however, requires a highly exact shaft geometry.

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

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

Scanning heads
Because the modular angle encoders are mounting at the machine, exact mounting of the scanning head is required after mounting of the graduation carrier. 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 facilitated by the design of the scanning heads, with the corresponding mounting strategy and wide mounting tolerances.
The ERA 4000 and ECA 4000 modular angle encoders consist of a scale drum and a scanning head. The scale drums are available in versions with a centering collar and with three-point centering.

The ERA 4x80 versions are available with various grating periods depending on the accuracy requirements. The appropriate scanning heads for the scale drums are shown in the table at the right. Be sure that the diameters or number of signal periods of the scale drum and scanning head match. Protecting the ERA and ECA series encoders from contamination requires special design measures. The ERA 4480 angle encoders can be delivered with an additional sealing-air cover for various scale drum diameters. This requires a special scanning head (with a compressed-air inlet). When ordering the sealing-air cover, be sure that it matches the drum diameter.

Special design features of the ERA and ECA modular angular encoders assure comparatively fast mounting and easy adjustment.

**Mounting the ERA 4x00/ECA 4400 scale drums**
The scale drum is centered along its inner ring via the centering collar. Two centering methods are possible:

a) The scale drum is pressed onto the drive shaft or thermally shrunk (see also the Functional Safety section) and fastened with screws. Adjustment of the drum is therefore unnecessary and impossible. The scale drums can and should be heated for assembly. Back-off threads are provided for disassembly.

b) The scale drums are centered along their inner ring via the centering collar.

**Mounting the ERA 4202/ECA 4402 scale drums**
The scale drums are centered via three positions at 120° increments on their outer circumference and fastened with screws. The benefits of three-point centering and the solid scale-drum design make it possible to attain very high accuracy when the encoder is mounted, with relatively little mounting effort. The positions for centering are marked on the scale drum. Centering via the inner ring is not possible.

**Mounting the scanning head**
In order for the scanning head to be mounted, a mounting aid is placed between the outer curved surface of the scale drum and the scanning head. The scanning head is pressed against it and then fastened. The shim or mounting aid is then removed.

**Mounting the sealing-air cover**
Some variants of the ERA 4400 angle encoders are optionally available with sealing-air covers. This cover provides additional protection from contamination when compressed air is applied.

The scale drum and the scanning unit are mounted as described above. The separate spacer shim supplied with the sealing-air cover is laid around the scale drum. It protects the scale drum during mounting of the sealing-air cover and ensures an even scanning gap. The sealing-air cover is then pressed onto the scale drum and fastened. The spacer shim is removed. For information about the compressed-air inlet, see General mechanical information.

---

**Table:**

<table>
<thead>
<tr>
<th>Scale-drum design</th>
<th>Centering methods</th>
<th>Model of scale drum</th>
<th>Appropriate scanning head</th>
</tr>
</thead>
</table>
| With centering collar |  • Sld or heat-shrunk onto shaft  
  • Centering on the inner ring | TTR ERA 4200  
 TTR ERA 4420  
 TTR ERA 4460  
 TTR ERA 4800  
 TTR ECA 4400  
 TTR ECA 4440  
 TTR ECA 4460 | AK ERA 4280  
 AK ERA 4480  
 AK ERA 4490  
 AK ECA 4410  
 AK ECA 4490 |
| With three-point centering |  • Centering along the outer ring | TTR ERA 4202  
 TTR ECA 4402 | AK ERA 4280  
 AK ECA 4410 |

**Legend:**

- ① Centering collar
- ② Marks for drum centering (3 x 120°)
Mounting the scale drum

Mounting the TTR ERM 2x00 scale drums
The TTR ERM 2404 and TTR ERM 2904 scale drums are clamped to the bearing surface solely via a friction-locked connection. How the scale drum is clamped depends on the mounting situation. The clamping force must be applied circularly over the plane surface of the drum. The necessary mounting elements depend on the design of the customer’s equipment and are therefore the responsibility of the customer. The frictional connection must be strong enough to prevent unintentional rotation or skewing in axial and radial directions, even at high shaft speeds and accelerations.

Mounting the TTR ERM 2405 scale drums
The TTR ERM 2405 scale drums are provided with a keyway. The keyway may be used solely as an anti-rotation element and not for transmitting torque. The special inner shape of the drum for this version also ensures durability even at the highest permissible shaft speeds.

Mounting the TTR ERM 2x05
The TTR ERM 2404 and TTR ERM 2904 scale drums are clamped to the bearing surface solely via a friction-locked connection. How the scale drum is clamped depends on the mounting situation. The clamping force must be applied circularly over the plane surface of the drum. The necessary mounting elements depend on the design of the customer’s equipment and are therefore the responsibility of the customer. The frictional connection must be strong enough to prevent unintentional rotation or skewing in axial and radial directions, even at high shaft speeds and accelerations.

Mounting the TTR ERM 2x00 scale drums
The TTR ERM 2404 and TTR ERM 2904 scale drums are clamped to the bearing surface solely via a friction-locked connection. How the scale drum is clamped depends on the mounting situation. The clamping force must be applied circularly over the plane surface of the drum. The necessary mounting elements depend on the design of the customer’s equipment and are therefore the responsibility of the customer. The frictional connection must be strong enough to prevent unintentional rotation or skewing in axial and radial directions, even at high shaft speeds and accelerations.

Mounting the TTR ERM 2405 scale drums
The TTR ERM 2405 scale drums are provided with a keyway. The keyway may be used solely as an anti-rotation element and not for transmitting torque. The special inner shape of the drum for this version also ensures durability even at the highest permissible shaft speeds.

Mounting the TTR ERM 2x05
The TTR ERM 2404 and TTR ERM 2904 scale drums are clamped to the bearing surface solely via a friction-locked connection. How the scale drum is clamped depends on the mounting situation. The clamping force must be applied circularly over the plane surface of the drum. The necessary mounting elements depend on the design of the customer’s equipment and are therefore the responsibility of the customer. The frictional connection must be strong enough to prevent unintentional rotation or skewing in axial and radial directions, even at high shaft speeds and accelerations.

Mounting the TTR ERM 2x00 scale drums
The TTR ERM 2404 and TTR ERM 2904 scale drums are clamped to the bearing surface solely via a friction-locked connection. How the scale drum is clamped depends on the mounting situation. The clamping force must be applied circularly over the plane surface of the drum. The necessary mounting elements depend on the design of the customer’s equipment and are therefore the responsibility of the customer. The frictional connection must be strong enough to prevent unintentional rotation or skewing in axial and radial directions, even at high shaft speeds and accelerations.

Mounting the scale drum
TTR ERM 2400
TTR ERM 2300
TTR ERM 2200
TTR ECM 2400

Mounting the scale drum
TTR ERM 2404
TTR ERM 2904

Mounting the scale drum
TTR ERM 2405

Mounting the scale drum
TTR ERM 2404

Mounting the scanning head

Mounting the scanning head (e.g., AK ERM 2480)
Possible cable outlets

Tangential, to the right
Tangential, to the left
Axially

Test film for magnetic graduation
A test film can be used to make the magnetic graduation visible. It enables the user to easily check whether there is any damage to the magnetic graduation, such as demagnetization from a tool. The test film can also be used prior to mounting for checking the tool or screws for residual magnetization in order to prevent damage to the graduation. The test film can be "cleaned" with the aid of a demagnetization device and therefore used repeatedly. The test film and demagnetization device are available as accessories.
The ERA 7000 and ERA 8000 series angle encoders consist of a scanning unit and a single-piece steel scale tape. The steel scale tape is available in lengths of up to 30 m.

The tape is mounted on:
- **inner ring** (ERA 7000 series)
- **outer ring** (ERA 8000 series)
of a machine element.

The ERA 74x0 C and ERA 84x0 C angle encoders are designed for full-circle applications. They are therefore ideal for hollow shafts with large inside diameters (approx. 400 mm or larger) and to applications requiring accurate measurement over a large circumference (e.g., large rotary tables, telescopes).

For applications where there is no full circle, or measurement is not required over 360°, segment solutions are available.

### Mounting the scale tape for full-circle applications

**ERA 74x0 C:** An internal slot with a specified diameter is required for receiving the scale tape. The scale tape is inserted starting at the butt joint and is clicked into the slot. The length is cut so that the tape is held in place by its own force.

**ERA 84x0 C:** The scale tape is supplied with the halves of the tensioning cleat already mounted to the tape ends. An external slot is necessary for mounting, and a recess is required for the tensioning cleat. After the scale tape has been inserted, it is pushed up against the slot edge and tensioned there with the tensioning cleat.

The scale tape ends are manufactured so exactly that only slight angular and signal-shape errors may occur in the area of the butt joint. To ensure that the scale tape does not move within the slot, it is attached near the butt joint with dots of adhesive.

### Mounting the scale tape for segment solutions

**ERA 74x1 C:** An internal slot with a specified diameter is required in order to accommodate the scale tape. The two cam disks mounted in this slot are adjusted so that the scale can be pressed into the slot under tension.

**ERA 84x1 C:** The scale tape is delivered with pre-mounted end pieces. An external slot with recesses for the end pieces is required in order to accommodate the scale tape. The end pieces are fitted with tension springs that ensure optimal preloading of the scale tape and evenly distribute expansion along the entire scale-tape length.

**ERA 84x2 C:** To accommodate the scale tape, an external slot or a single axial edge is recommended. The scale tape is supplied without tensioning elements. It must be preloaded with a spring balance and screw-fastened at the two oblong holes.

### Determining the mating diameter

In order to ensure correct functioning of the distance-coded reference marks, the circumference must be a multiple of 1000 grating periods. The relationship between the mating diameter and the signal period can be seen in the table.

### Determining the segment angle

For segment solutions, the angle available as the measuring range must be a multiple of 1000 grating periods. Also, the circumference of the theoretical full circle must be a multiple of 1000 grating periods, since this often simplifies integration with the numerical control.

### Mounting the scanning head

For mounting the scanning head, the spacer shim is held against the outer curved surface of the scale drum. The scanning head is pressed against the shim and fastened. The shim is then removed. In addition, the scanning field can be finely adjusted via an eccentric bushing.

### Checking the output signals at the butt joint

In order to check whether the scale tapes of the ERA 74x0 C and ERA 84x0 C have been mounted correctly, the output signals should be checked at the butt joint before the adhesive has hardened.

The quality of the output signals can be checked using a PWT phase-angle testing unit from HEIDENHAIN. When the scanning head is moved along the scale tape, the PWT graphically displays the signal quality and the reference mark position.

The PWM 9 phase-angle measuring unit quantitatively displays deviations of the output signals from the ideal signal (see HEIDENHAIN measuring and testing devices).

---

### Table: Determining the mating diameter

<table>
<thead>
<tr>
<th>ERA 7000 C</th>
<th>Mating diameter in mm</th>
<th>Measuring range in degrees for segment solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = Signal period of full circle; n1 = Signal period of measuring range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D = Mating diameter [mm]</td>
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</tr>
</tbody>
</table>

### Diagram: Mounting the scanning head

- **Theoretical full circle**
- **Mating diameter**
- **Measuring range**
- **Spacer shim**

### Diagram: Checking the output signals at the butt joint

- **PWT**
- **Space between the scale and the scanning head**
- **Reference mark position**
- **Spring balance**
- **Eccentric bushing**

---
Protection

Modular angle encoders with optical scanning must be protected from particulate and liquid contamination in the application. Suitable encapsulation by means of seals and sealing air may be necessary.

The scanning heads themselves partially fulfill the IP40 (ERA) and IP67 (ECA) protection rating in accordance with EN 60529 and IEC 60529.

Optional sealing-air covers are available for several variants of the ERA 4000 angle encoders, permitting a protection rating increase to IP40. Connection to a source of compressed air slightly above atmospheric pressure provides additional protection against condensation. The sealing-air cover is not designed to provide protection from liquid or dust contamination. In many applications, however, the sealing-air cover provides reliable protection. Design-related constraints and operating conditions have a decisive influence.

At a pressure of approx. 1 · 10⁵ Pa (1 bar), the HEIDENHAIN connecting piece with an integrated air inlet ensure a flow rate of approx. 33 liters/rpm. This configuration provides good protection from dust in most cases.

A proven method of avoiding contamination under difficult ambient conditions, both during operation and at standstill, is to adequately cover the area where the encoder is installed (in addition to the sealing-air cover) and flush it with clean compressed air, or to generate slight overpressure.

The compressed air entering the encoder must be purified by a microfilter and comply with the following quality classes as per ISO 8573-1 (2010 edition):

- Solid contaminants: Class 1
- Particle size: No. of particles per m³
  0.1 μm to 0.5 μm ≤ 20 000
  0.5 μm to 1.0 μm ≤ 400
  1.0 μm to 5.0 μm ≤ 10
- Max. pressure dew point: Class 4
  (pressure dew point at 10 °C)
- Total oil content: Class 1
  (max. oil concentration: 0.01 mg/m³)

The compressed air introduced into the DA 400 must fulfill the requirements of the following purity classes as per ISO 8573-1 (2010 edition):

- Solid contaminants: Class 5
- Particle size: No. of particles per m³
  0.1 μm to 0.5 μm Not specified
  0.5 μm to 1.0 μm Not specified
  1.0 μm to 5.0 μm ≤ 100
- Max. pressure dew point: Class 6
  (pressure dew point at 10 °C)
- Total oil content: Class 4
  (max. oil concentration: 6 mg/m³)

The DA 400 consists of three filter stages (prefilter, microfilter and activated carbon filter) and a pressure regulator with a manometer. The sealing-air function can be effectively monitored using a manometer and pressure switch (available as an accessory).

Temperature range

The operating temperature range indicates the ambient temperature limits between which the angle encoders will function properly.

The storage temperature range applies to the device within its packaging (ERA/ECA: −20 °C to 70 °C, ERM/ECM: −30 °C to 70 °C).

Protection from contact

After installation of the encoder, all rotating parts must be protected from accidental contact during operation.

Acceleration

Angle encoders are subject to various types of acceleration during operation and installation.

- The indicated maximum values for vibration resistance are valid in accordance with EN 60068-2-6.
- The maximum values for the permissible acceleration (sinusoidal shock) for shock and impact loads apply at 6 ms⁻¹ (EN 60068-2-27). Impacts or jarring with a hammer, such as in order to align the encoder, are never permitted.

Shaft speeds

The maximum permissible shaft speeds were determined in accordance with the FKM guideline. This guideline serves as a mathematical attestation of component strength with regard to all relevant influences, and it reflects the current state of the art. The requirements for fatigue strength 10¹⁰ million reversals of load were considered in the calculation of the permissible shaft speeds. Because installation has a significant influence, all requirements and directions in the specifications and mounting instructions must be followed in order for the shaft speed data to be valid.

RoHS

HEIDENHAIN has tested its products to ensure the use of non-hazardous materials in accordance with the European Directives 2002/95/EC (RoHS) and 2002/96/EC (WEEE). For a Manufacturer’s Declaration on RoHS, please consult your sales agency.

Parts subject to wear

Encoders from HEIDENHAIN are designed for a long service life. Preventive maintenance is not required. However, they do contain components that are subject to wear, depending on the application and how they are deployed. This especially applies to cables that are subject to frequent flexing.

Mounting

The steps and dimensions that must be complied with during mounting are specified solely in the mounting instructions supplied with the device. All mounting-related information in this brochure apply only to the encoder and not to the entire system. Any operation of the encoder outside of the specified range or outside of its proper and intended use is at the user’s own risk. In safety-related systems, the encoder’s position value must be tested by the higher-level system after switch-on.

Further information:

For more information, please request our DA 400 Product Information.
Functional safety

Safe axes
Driven axes on machine tools usually pose a significant hazard for humans. Particularly when the human interacts with the machine (e.g., during workpiece setup), it must be ensured that the machine tool does not make any uncontrolled movements. Here, the position information of the axes is needed in order to implement a safety function. As an evaluating safety module, the controller detects faulty position information and reacts to it accordingly.

Various safety strategies can be pursued, depending on the topology of the axis and the evaluation capabilities of the controller. In a single-encoder system, for example, only one encoder per axis is evaluated for the safety function. However, on axes with two encoders, such as a rotational axis with a rotary encoder and an angle encoder, the two redundant position values can be compared with each other in the controller.

Safety-related fault detection can be ensured only if the two components, the controller and the encoder, are properly matched to each other. In this case, it must be noted that the safety designs may vary by controller manufacturer. This also means that the requirements placed on the connected encoders may differ.

Type-examined encoders
Module angle encoders from HEIDENHAIN thrive in a wide variety of safety designs with a variety of controllers. Particularly noteworthy are the type-examined ECA 4410 and ECM 2410 encoders with the EnDat interface. These encoders can be operated as single-encoder systems in conjunction with a suitable controller in applications with the controller category SIL 2 (as per EN 61508) or performance level “d” (as per EN ISO 13848). Unlike incremental encoders, the ECA 4410/ECM 2410 absolute angle encoders always provide a safe absolute position value, including immediately after switch-on or a power failure. The reliable transmission of the position is based on two independently generated absolute position values and on error bits provided to the safe controller. The purely serial data transmission also offers other advantages, such as greater reliability, improved accuracy, diagnostic capabilities and reduced costs through simpler connection technology.

Standard encoders
In addition to those encoders explicitly certified for safety applications, standard angle encoders can also be used in safe axes (e.g., with 1 Vpp signals or Fanuc interface). In this case, the characteristics of the encoders must be matched to the requirements of the respective controller. HEIDENHAIN can provide additional data about the individual encoders (failure rate, fault model as per EN 61800-5-2).

Service life
Unless otherwise specified, HEIDENHAIN encoders are designed for a service life of 20 years (in accordance with ISO 13849).

Fault exclusion for the loosening of the mechanical connection
Irrespective of the interface, many safety designs require the safe mechanical connection of the encoder. The standard for electric motors, EN 61800-5-2, requires that the loosening of the mechanical connection between the encoder and the motor be considered as a fault. Because the controller may not be able to detect these errors, fault exclusion is required in many cases.

This mechanical fault exclusion has been certified for a wide range of encoder applications. This means that the fault exclusion is ensured for the operating conditions listed below.

The requirements for fault exclusion can result in additional constraints in the permissible limit values in the specifications. In addition, fault exclusions for the loosening of the mechanical coupling usually require additional measures during installation of the encoder or in the event of servicing (e.g., anti-rotation lock for screws). These factors must be considered for the selection of a suitable encoder and mounting method.

Further information:
The safety-related characteristic values are listed in the encoder specifications. The Technical Information document Safety-Related Position Encoders provides explanations about the characteristic values.

Upon request, HEIDENHAIN can also provide additional data about the individual products (failure rate, fault model as per EN 61800-5-2) for the use of standard encoders in safety-related applications.

<table>
<thead>
<tr>
<th>Mechanical connection</th>
<th>Fastening</th>
<th>Safe position for the mechanical coupling</th>
<th>Constrained characteristic values</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERA ECA Scale drum</td>
<td>Press-fit as per dimension drawing Screw connection: 1) ISO 4762-M6x20-8.8 screws ISO 4762-M6x25-8.8 screws</td>
<td>Drum outside diameter 104.63 mm to 127/64 mm: ±0.025&quot; Drum outside diameter 148.2 mm or larger: ±0.01&quot;</td>
<td>See Specifications:</td>
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<tr>
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</tr>
<tr>
<td>Scanning head</td>
<td>Mounting type I: Screw connection: 1) ISO 4762-M6x20-8.8 screws</td>
<td>Drum outside diameter 148.2 mm or larger: ±0.01&quot;</td>
<td>See Dimensions:</td>
</tr>
<tr>
<td></td>
<td>Mounting type II: Screw connection: 1) M3x20 ISO 4762 8.8 screws</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERM ECM Scale drum</td>
<td>Press-fit as per dimension drawing (W2) Screw connection: 2) M5 ISO 4762 8.8 screws</td>
<td>±0.025&quot;</td>
<td>See Mounting information:</td>
</tr>
<tr>
<td>Scanning head</td>
<td>Screw connection: 2) M4 ISO 4762 8.8 screws</td>
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</tbody>
</table>

1) A material bonding anti-rotation lock must be used for the screw connections of the scale drums (mountingservice)
2) Friction Class B as per VDI 2230
3) Fault exclusions exist only for the explicitly stated mounting conditions
4) Unlike the ECA/ERA 4xxx and ECM/ERM 2xxx, without mechanical fault exclusion

Encoder with mechanical connection and electrical interface
Mounting the scale drum
A press-fit of the scale drum on the shaft is required for fault exclusion. Preferably, the scale drum should be thermally shrinked onto the mating shaft and fastened with screws. For this purpose, the scale drum must be slowly heated prior to mounting, such as with a heating plate (caution: do not use induction heating sources). The diagram shows the recommended minimum temperatures for the different drum diameters. The maximum temperature must not exceed 140 °C.

During shrink-fitting, make sure that the hole patterns of the scale drum and mating shaft are properly aligned. Appropriate centering aids (setscrews) can facilitate mounting. All of the mounting screws must be tightened at the correct torque after the scale drum has cooled. The mounting screws used for attaching the scanning head and scale drum may be used only to secure the scanning head and the scale drum. These screws may not be used to additionally fasten other components.

Removing the scale drum
The scale drum is removed using the relevant back-off threads in the drum. To do this, insert greased screws, and tighten them in a row until the scale drum comes off the shaft. Prior to renewed mounting of the scale drum, the back-off threads must be recut.

Material
For the mating shaft and the mating stator, use materials in accordance with the table.

Mounting temperature
All information on screw connections is based on a mounting temperature of 15 °C to 35 °C.

Mounting the scanning head
Ensure that the diameter specifications for all encoder components match (scale drum, scanning head, mounting aid for ERA/ECA). The relevant information is indicated on the ID labels. A mounting wizard in the ATS software helps ensure that the scanning head and the scale drum are properly aligned.

Accessories:
• Mounting aid for the ERA/ECA (as per drum diameter)
• Mounting wizard in ATS software

Further information:
Comply with the requirements described in the following documents to ensure correct and intended operation:
• Mounting Instructions and possibly Operating Instructions of the given product
  AK ECA 4410 Functional Safety 1177157
  TTR ECA 4400 1177156
  TTR ECA 4402 1125430
  Mounting assistant for the ECA 44xx 1126455
  AK ECM 2410/2490 M/2490 F 1308377
  TTR ECM 2400 1308375
  Mounting assistant for the ECM 24x0 1356342
• Technical Information: Safety-Related Position Measuring Systems 596632
• Specification for safe controller 533095
ECA 4000 series

Absolute angle encoder with high accuracy
- Steel scale drums with three-point centering or centering collar
- Consists of a scanning head and scale drum
- Also for safety-related applications
- Mechanical fault exclusion for scanning heads and scale drum

With mechanical fault exclusion

<table>
<thead>
<tr>
<th>Scanning head</th>
<th>AK ECA 4410</th>
<th>AK ECA 4410</th>
<th>AK ECA 4490F</th>
<th>AK ECA 4490M</th>
<th>AK ECA 4490P</th>
<th>AK ECA 4490Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface</td>
<td>EnDat 2.2</td>
<td>Fanuc Serial interface; ai Interface</td>
<td>Mitsubishi high speed interface</td>
<td>Panasonic Serial interface</td>
<td>Yaskawa Serial interface</td>
<td></td>
</tr>
<tr>
<td>Ordering designation</td>
<td>EnDat22</td>
<td>Fanuc05</td>
<td>Mit03-4</td>
<td>Pana02</td>
<td>YEC07</td>
<td></td>
</tr>
<tr>
<td>Clock frequency</td>
<td>≤ 16 MHz</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Calculation time ( t_{calc} )</td>
<td>≤ 5 μs</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td></td>
</tr>
</tbody>
</table>
| Functional safety for applications with up to | • SIL 2 as per EN 61508 (other basis for testing: IEC 61800-5-2)
• Category 4, PL “d” as per EN ISO 13849-1:2015 |
| Functional safety for applications with up to | – |
| PFH | ≤ 20 · 10⁻⁹ (up to 6000 m above sea level) | – |
| Electrical connection | Cable (1 m or 3 m) with 8-pin M12 coupling (male) or 15-pin D-sub connector |
| Cable length \(^1\) | ≤ 100 m | ≤ 50 m | ≤ 30 m | ≤ 50 m |
| Supply voltage | DC 3.6 V to 14 V |
| Power consumption (max.) | At 3.6 V: 700 mW
At 14 V: 800 mW |
| Power consumption (max.) | At 3.6 V: 850 mW
At 14 V: 950 mW |
| Current consumption (typical) | At 5 V: 90 mA (without load) |
| Current consumption (typical) | At 5 V: 100 mA (without load) |
| Vibration: 55 to 2000 Hz |
| Shock: 6 ms | ≤ 200 m/s² (EN 60068-2-6)
≤ 200 m/s² (EN 60068-2-27) |
| Operating temperature | –10 °C to 70 °C \(^2\) |
| Protection EN 60529 \(^3\) | IP67 |
| Mass | Scanning head 18 g (without cable)
Cable 20 g
M12 coupling 15 g
D-sub connector 32 g |

\(^1\) With HEIDENHAIN cable; clock frequency ≤ 8 MHz
\(^2\) With a drum outside diameter of 104.63 mm; 10 °C to 70 °C
\(^3\) In the application, the device must be protected from contamination by solids and liquids.
If necessary, use a suitable enclosure with sealing air and a seal
## Optionally with mechanical fault exclusion

<table>
<thead>
<tr>
<th>Scale drum</th>
<th>TTR ECA 4400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring standard</td>
<td>Steel drum with centering collar</td>
</tr>
<tr>
<td>Coefficient of expansion</td>
<td>ρ_eff = 10.4 · 10⁻⁶ k⁻¹</td>
</tr>
<tr>
<td>Drum inside diameter*</td>
<td>70 mm, 80 mm, 120 mm, 150 mm</td>
</tr>
<tr>
<td>Drum outside diameter*</td>
<td>104.63 mm, 127.64 mm, 149.2 mm, 176.55 mm</td>
</tr>
<tr>
<td>Safe position[1,2]</td>
<td>±0.9°, ±0.44°, ±0.22°, ±0.11°</td>
</tr>
<tr>
<td>Measuring step</td>
<td>SM</td>
</tr>
<tr>
<td>1)</td>
<td>±0.1°</td>
</tr>
<tr>
<td>2)</td>
<td>±1°</td>
</tr>
<tr>
<td>Measuring step SM</td>
<td>0.392° (10 bits), 0.176° (11 bits), 0.088° (12 bits), 0.044° (13 bits)</td>
</tr>
<tr>
<td>Mech. permissible speed</td>
<td>8500 rpm, 6250 rpm, 5250 rpm, 4500 rpm, 4250 rpm, 3250 rpm, 2500 rpm, 1900 rpm, 1500 rpm</td>
</tr>
<tr>
<td>Without mechanical fault exclusion</td>
<td>15000 rpm, 12250 rpm, 10500 rpm, 8750 rpm, 7500 rpm, 6250 rpm, 4750 rpm, 3250 rpm, 2750 rpm</td>
</tr>
<tr>
<td>Max. angular acceleration</td>
<td>14000 rad/s², 6600 rad/s², 7800 rad/s², 2700 rad/s², 1800 rad/s², 1000 rad/s², 1300 rad/s², 900 rad/s², 1200 rad/s²</td>
</tr>
<tr>
<td>Elec. permissible speed</td>
<td>≤ 7000 rpm, ≤ 5750 rpm, ≤ 4400 rpm, ≤ 3000 rpm, ≤ 2550 rpm, ≤ 2100 rpm, ≤ 900 rpm, ≤ 600 rpm, ≤ 550 rpm</td>
</tr>
<tr>
<td>Moment of inertia</td>
<td>0.81 · 10⁻³ kgm², 1.9 · 10⁻³ kgm², 2.3 · 10⁻³ kgm², 2.1 · 10⁻³ kgm², 12 · 10⁻³ kgm², 28 · 10⁻³ kgm², 59 · 10⁻³ kgm², 196 · 10⁻³ kgm², 258 · 10⁻³ kgm²</td>
</tr>
<tr>
<td>Permissible axial movement</td>
<td>≤ ±0.4 mm (scale drum relative to the scanning head)</td>
</tr>
<tr>
<td>Positions per revolution</td>
<td>134.217726 (27 bits)</td>
</tr>
<tr>
<td>Measuring step</td>
<td>0.0097°, 0.0048°, 0.0024°</td>
</tr>
<tr>
<td>Signal periods</td>
<td>8195, 10010, 14003, 11616, 16379, 19998, 25993, 37994, 44000</td>
</tr>
<tr>
<td>Accuracy of graduation</td>
<td>±3.7°, ±3.0°, ±2.8°, ±2.5°, ±2.5°, ±2.5°, ±2.5°, ±2.5°, ±2.0°</td>
</tr>
<tr>
<td>Interpolation error per signal period</td>
<td>±0.20°, ±0.16°, ±0.14°, ±0.12°, ±0.10°, ±0.08°, ±0.06°, ±0.04°, ±0.04°</td>
</tr>
<tr>
<td>Protection EN 60529[1]</td>
<td>Complete encoder after mounting: IP00</td>
</tr>
<tr>
<td>Mass</td>
<td>0.4 kg, 0.68 kg, 0.51 kg, 1.2 kg, 1.5 kg, 2.3 kg, 2.6 kg, 3.8 kg, 3.6 kg</td>
</tr>
</tbody>
</table>

* Please select when ordering
1) Further deviations may arise in the downstream electronics after position value comparison (contact mfr. of the downstream electronics)
2) Mechanical coupling: Fault exclusion for the loosening of the scanning head and scale drum, see Functional safety
3) In the application, the device must be protected from contamination by solids and liquids. If necessary, use a suitable enclosure with a seal and sealing air

## Without mechanical fault exclusion

<table>
<thead>
<tr>
<th>Scale drum</th>
<th>TTR ECA 4402</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring standard</td>
<td>Steel drum with three-point centering</td>
</tr>
<tr>
<td>Coefficient of expansion</td>
<td>ρ_eff = 10.4 · 10⁻⁶ k⁻¹</td>
</tr>
<tr>
<td>Drum inside diameter*</td>
<td>70 mm, 80 mm, 120 mm, 150 mm</td>
</tr>
<tr>
<td>Drum outside diameter*</td>
<td>104.63 mm, 127.64 mm, 176.55 mm, 148.20 mm</td>
</tr>
<tr>
<td>Mech. permissible speed</td>
<td>15000 rpm, 12250 rpm, 8750 rpm, 10500 rpm, 7500 rpm, 6250 rpm, 4750 rpm, 3250 rpm, 2750 rpm</td>
</tr>
<tr>
<td>Elec. permissible speed</td>
<td>≤ 7000 rpm, ≤ 5750 rpm, ≤ 3000 rpm, ≤ 4400 rpm, ≤ 2550 rpm, ≤ 2100 rpm, ≤ 900 rpm, ≤ 600 rpm, ≤ 550 rpm</td>
</tr>
<tr>
<td>Moment of inertia</td>
<td>0.83 · 10⁻³ kgm², 2.0 · 10⁻³ kgm², 7.1 · 10⁻⁴ kgm², 4.5 · 10⁻⁴ kgm², 1.7 · 10⁻⁴ kgm², 12 · 10⁻⁵ kgm², 6.5 · 10⁻⁵ kgm², 28 · 10⁻⁶ kgm², 59 · 10⁻⁶ kgm²</td>
</tr>
<tr>
<td>Permissible axial movement</td>
<td>≤ ±0.4 mm (scale drum relative to the scanning head)</td>
</tr>
<tr>
<td>Positions per revolution</td>
<td>134.217728 (27 bits)</td>
</tr>
<tr>
<td>Measuring step</td>
<td>0.0097°, 0.0048°, 0.0024°</td>
</tr>
<tr>
<td>Signal periods</td>
<td>8195, 10010, 14003, 11616, 16379, 19998, 25993, 37994, 44000</td>
</tr>
<tr>
<td>Accuracy of graduation</td>
<td>±3°, ±2.5°, ±2°, ±2.3°, ±1.9°, ±1.8°, ±1.7°, ±1.5°</td>
</tr>
<tr>
<td>Interpolation error per signal period</td>
<td>±0.20°, ±0.16°, ±0.12°, ±0.14°, ±0.10°, ±0.08°, ±0.06°, ±0.04°, ±0.04°</td>
</tr>
<tr>
<td>Protection EN 60529[1]</td>
<td>Complete encoder after mounting: IP00</td>
</tr>
<tr>
<td>Mass</td>
<td>0.42 kg, 0.69 kg, 1.2 kg/0.66 kg, 1.35 kg, 1.5 kg/0.66 kg, 2.3 kg/1.5 kg, 2.6 kg, 3.8 kg, 3.7 kg</td>
</tr>
</tbody>
</table>

* Please select when ordering
1) In the application, the device must be protected from contamination by solids and liquids. If necessary, use a suitable enclosure with a seal and sealing air
**ECA 4410, ECA 4490** (scale drum with centering collar)  

**Dimensions**

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<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7a</th>
<th>7b</th>
<th>8</th>
<th>9</th>
<th>10</th>
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</thead>
<tbody>
<tr>
<td>W1: Without mechanical fault exclusion</td>
<td>W2: With mechanical fault exclusion</td>
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</tbody>
</table>

**Further information:**  
For CAD data, visit cad.heidenhain.com
ECA 4412, ECA 4492 (scale drum without centering collar)

Dimensions

Further information:
For CAD data, visit cad.heidenhain.com
ERA 4000 series

High-accuracy incremental angle encoder

- Steel scale drum with three-point centering or centering collar
- Optimized scanning performance for very high reliability
- Integrated three-color LED signal-quality indicator
- Consists of a scanning head and scale drum with optional sealing-air cover

### Scanning head AK ERA 4280 with 20 μm graduation period

| Interface | ~1 V, HSP |
| Cutoff frequency | ~3 dB 1 MHz |
| Electrical connection | Cable (1 m or 3 m) 12-pin M12 coupling or 12-pin M23 coupling or 15-pin D-sub connector |
| Cable length | ≤ 150 m (with HEIDENHAIN cable) |
| Supply voltage | DC 5 V ±0.5 V |
| Current consumption | < 130 mA (without load) |
| Vibration | 55 Hz to 2000 Hz |
| Shock | 11 ms 6 ms |
| Operating temperature | -10 °C to 70 °C |
| Relative air humidity | ≤ 93% (at 40 °C/4d as per EN 60068-2-78); condensation excluded |
| Protection | IP40 |

### Summary of Scanning Head Specifications

| Mass Scanning Head | 20 g (without cable) |
| Connecting Cable | 20 g/m |
| Coupling (M12) | 15 g |
| Coupling (N23) | 50 g |
| D-sub Connector | 32 g |

### Scanning head AK ERA 4480 with 40 μm graduation period and sealing-air cover

| Interface | ~1 V, HSP |
| Cutoff frequency | ~3 dB 1 MHz |
| Electrical connection | Cable (1 m or 3 m) 12-pin M12 coupling or 12-pin M23 coupling |
| Cable length | ≤ 150 m (with HEIDENHAIN cable) |
| Supply voltage | DC 5 V ±0.5 V |
| Current consumption | < 130 mA (without load) |
| Vibration | 55 Hz to 2000 Hz |
| Shock | 11 ms 6 ms |
| Operating temperature | -10 °C to 70 °C |
| Relative air humidity | ≤ 93% (at 40 °C/4d as per EN 60068-2-78); condensation excluded |
| Protection | IP40 |

### Summary of Scanning Head Specifications

| Mass Scanning Head | 28 g (without cable) |
| Connecting Cable | 20 g/m |
| Coupling (M12) | 15 g |
| Coupling (N23) | 50 g |

### Scanning Head AK ERA 4470

| Interface | TTL |
| Integrated interpolation | 1-fold 10-fold 50-fold 100-fold 500-fold 1000-fold |
| Scanning frequency | ≤ 450 kHz ≤ 312.5 kHz ≤ 125 kHz ≤ 62.5 kHz ≤ 12.5 kHz ≤ 6.25 kHz |
| Edge separation | ≥ 0.220 μs ≥ 0.07 μs ≥ 0.03 μs |
| Electrical connection | Cable (1 m or 3 m) 15-pin D-sub connector (male), with interface electronics in the connector |
| 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 | 250 mA (without load) |
| Vibration | 55 Hz to 2000 Hz |
| Shock | 11 ms 6 ms |
| Operating temperature | -10 °C to 70 °C |
| Relative air humidity | ≤ 93% (at 40 °C/4d as per EN 60068-2-78); condensation excluded |
| Protection | IP40 |

### Summary of Scanning Head Specifications

| Mass Scanning Head | 20 g (without cable) |
| Connecting Cable | 20 g/m |
| D-sub Connector | 74 g |

* Please select when ordering

1) Suitable for applications that measure the time between individual TTL output signal clock edges; non-clocked output signals enable low edge jitter

2) Maximum scanning frequency during referencing: 70 kHz
### Scale drum with centering collar

**TTR ERA 4200C** with 20 μm graduation period  
**TTR ERA 4400C** with 40 μm graduation period  
**TTR ERA 4800C** with 80 μm graduation period

<table>
<thead>
<tr>
<th>Measuring standard</th>
<th>Coefficient of expansion</th>
<th>Measuring standard</th>
<th>Coefficient of expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel drum</td>
<td>$\alpha_{\text{therm}} = 10.4 \cdot 10^{-6} \text{ K}^{-1}$</td>
<td>Steel drum</td>
<td>$\alpha_{\text{therm}} = 10.4 \cdot 10^{-6} \text{ K}^{-1}$</td>
</tr>
</tbody>
</table>

### Signal periods/interpolation error per signal period

<table>
<thead>
<tr>
<th>Encoder Type</th>
<th>Signal Periods</th>
<th>Interpolation Error</th>
<th>Accuracy of Graduation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTR ERA 4200</td>
<td>12000/±0.32&quot;</td>
<td>16384/±0.24&quot;</td>
<td>±5&quot;</td>
</tr>
<tr>
<td></td>
<td>20000/±0.19&quot;</td>
<td>28000/±0.14&quot;</td>
<td>±3.7&quot;</td>
</tr>
<tr>
<td></td>
<td>32000/±0.12&quot;</td>
<td>40000/±0.10&quot;</td>
<td>±3&quot;</td>
</tr>
<tr>
<td></td>
<td>52000/±0.07&quot;</td>
<td>±2&quot;</td>
<td></td>
</tr>
<tr>
<td>TTR ERA 4400</td>
<td>6000/±1.06&quot;</td>
<td>8192/±0.79&quot;</td>
<td>±3.7&quot;</td>
</tr>
<tr>
<td></td>
<td>10000/±0.65&quot;</td>
<td>14000/±0.46&quot;</td>
<td>±3&quot;</td>
</tr>
<tr>
<td></td>
<td>16384/±0.40&quot;</td>
<td>20000/±0.32&quot;</td>
<td>±2&quot;</td>
</tr>
<tr>
<td></td>
<td>26000/±0.26&quot;</td>
<td>38000/±0.17&quot;</td>
<td>±2&quot;</td>
</tr>
<tr>
<td>TTR ERA 4800</td>
<td>3000/±2.16&quot;</td>
<td>4096/±1.68&quot;</td>
<td>±3.7&quot;</td>
</tr>
<tr>
<td></td>
<td>5000/±1.30&quot;</td>
<td>7000/±0.93&quot;</td>
<td>±3&quot;</td>
</tr>
<tr>
<td></td>
<td>8192/±0.79&quot;</td>
<td>10000/±0.65&quot;</td>
<td>±2&quot;</td>
</tr>
<tr>
<td></td>
<td>13000/±0.90&quot;</td>
<td>±2&quot;</td>
<td></td>
</tr>
</tbody>
</table>

### Reference marks

- Distance-coded or one

### Drum inside diameter

- 40 mm  
- 70 mm  
- 80 mm  
- 120 mm  
- 150 mm  
- 180 mm  
- 270 mm  
- 425 mm  
- 512 mm

### Drum outside diameter

- 76.75 mm  
- 104.63 mm  
- 127.64 mm  
- 178.55 mm  
- 208.89 mm  
- 254.93 mm  
- 331.31 mm  
- 484.07 mm  
- 560.46 mm

### Mech. permissible speed

**With mechanical fault exclusion**

- 10000 rpm  
- 8500 rpm  
- 6250 rpm  
- 4500 rpm  
- 4250 rpm  
- 3250 rpm  
- 2500 rpm  
- 1800 rpm  
- 1500 rpm

**Without mechanical fault exclusion**

- 20000 rpm  
- 16000 rpm  
- 12500 rpm  
- 8750 rpm  
- 7500 rpm  
- 6250 rpm  
- 4750 rpm  
- 3250 rpm  
- 2750 rpm

### Moment of inertia

- $0.27 \cdot 10^{-3}$ kgm$^2$  
- $0.81 \cdot 10^{-3}$ kgm$^2$  
- $1.9 \cdot 10^{-3}$ kgm$^2$  
- $1.7 \cdot 10^{-3}$ kgm$^2$  
- $12 \cdot 10^{-3}$ kgm$^2$  
- $28 \cdot 10^{-3}$ kgm$^2$  
- $69 \cdot 10^{-3}$ kgm$^2$  
- $186 \cdot 10^{-3}$ kgm$^2$  
- $298 \cdot 10^{-3}$ kgm$^2$

### Maximum angular acceleration with mechanical fault exclusion

- 20000 rad/s$^2$  
- 14000 rad/s$^2$  
- 6600 rad/s$^2$  
- 2700 rad/s$^2$  
- 1800 rad/s$^2$  
- 1000 rad/s$^2$  
- 1300 rad/s$^2$  
- 900 rad/s$^2$  
- 1200 rad/s$^2$

### Permissible axial movement

- ≤±0.5 mm (scale drum relative to the scanning head)

### Protection

**EN 60529**  
Complete encoder after mounting: IP00; with sealing-air cover: IP40

### Mass

- $0.28$ kg  
- $0.41$ kg  
- $0.68$ kg  
- $1.2$ kg  
- $1.5$ kg  
- $2.3$ kg  
- $2.6$ kg  
- $3.8$ kg  
- $3.6$ kg

---

1) The interpolation error within one 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
### ERA 4280C, ERA 4480C, ERA 4880C

#### Dimensions

**ISO 4762 – M5x20 – 8.8**
- Dimensions: W1, W2 / Ø D1

- **ISO 4762 – M6x25 – 8.8**
- Dimensions: Ø D9

- **ISO 7092 – 6H – 200HV – 8.8**
- Dimensions: Ø D10

- **ISO 4762 – M3x25 – 8.8**
- Dimensions: Ø D11

---

**Signal periods**
- 12 000
- 16 384
- 20 000
- 28 000
- 32 768
- 40 000
- 52 000

**Accuracy of graduation**
- ±4°
- ±3°
- ±2.5°
- ±2°
- ±1.9°
- ±1.8°
- ±1.7°

**Interpolation error per signal period**
- ±0.36°
- ±0.24°
- ±0.19°
- ±0.14°
- ±0.12°
- ±0.1°
- ±0.07°

**Reference marks**
- Distance-coded or one

**Drum inside diameter**
- 40 mm
- 70 mm
- 80 mm
- 120 mm
- 150 mm
- 160 mm
- 180 mm
- 210 mm
- 270 mm

**Drum outside diameter**
- 76.75 mm
- 104.63 mm
- 127.64 mm
- 178.55 mm
- 208.89 mm
- 254.93 mm
- 331.31 mm

**Mech. permissible speed**
- 20 000 rpm
- 15 000 rpm
- 12 250 rpm
- 8 750 rpm
- 7 500 rpm
- 6 250 rpm
- 4 750 rpm

**Moment of inertia**
- 0.28 x 10⁻³ kgm²
- 0.83 x 10⁻³ kgm²
- 2.0 x 10⁻³ kgm²
- 21 x 10⁻³ kgm²
- 4.5 x 10⁻³ kgm²
- 12 x 10⁻³ kgm²
- 6.4 x 10⁻³ kgm²
- 28 x 10⁻³ kgm²
- 20 x 10⁻³ kgm²
- 59 x 10⁻³ kgm²

**Permissible axial movement**
- ±0.5 mm (scale drum relative to the scanning head)

**Protection**
- EN 60529
- Complete encoder after mounting: IP00, with sealing-air cover: IP40

**Mass**
- 0.30 kg
- 0.42 kg
- 0.69 kg
- 1.2 kg
- 0.66 kg
- 1.5 kg
- 0.66 kg
- 2.3 kg
- 1.5 kg
- 2.6 kg

---

*Please select when ordering*

1) The interpolation error within one 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.
ERA 4480C
With sealing-air cover

ISO 4762 – M3x(a+4) – 8.8
ISO 7092 – 2 – 200HV – 8.8

Further information:
For CAD data, visit cad.heidenhain.com
### ECM 2400 series

**Absolute angle encoder with magnetic scanning**
- Consists of a scanning head and scale drum
- Also for safety-related applications
- Resistant to contamination

<table>
<thead>
<tr>
<th>Scanning head</th>
<th>AK ECM 2410</th>
<th>AK ECM 2490 F</th>
<th>AK ECM 2490 M</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interface</strong></td>
<td>EnDat 2.2</td>
<td>Fanuc Serial Interface; at Interface</td>
<td>Mitsubishi high speed interface</td>
</tr>
<tr>
<td><strong>Ordering designation</strong></td>
<td>EnDat22</td>
<td>Fanuc05</td>
<td>Mt03-4</td>
</tr>
<tr>
<td><strong>Clock frequency</strong></td>
<td>≤ 16 MHz</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Calculation time</strong> $t_{calc}$</td>
<td>≤ 5 μs</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Functional safety</strong> for applications with up to</td>
<td>- SIL 2 as per EN 61508 (further basis for testing: IEC 61800-5-3); Category 3, PL “d” as per EN ISO 13849-1:2015</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>PFH</strong></td>
<td>≤ 25 · $10^{-9}$ (up to 6000 m above sea level)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Electrical connection</strong></td>
<td>Cable (1 m) with 8-pin M12 coupling (male)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Cable length</strong></td>
<td>≤ 30 m</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Supply voltage</strong></td>
<td>DC 3.6 V to 14 V</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Power consumption (max.)</strong></td>
<td>At 3.6 V: 1.1 W, At 5 V: 1.3 W</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Current consumption (typical)</strong></td>
<td>At 5 V: &lt; 200 mA (without load)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Vibration</strong> 55 Hz to 2000 Hz</td>
<td>≤ 400 m/s² (EN 60068-2-6)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Shock 6 ms</strong></td>
<td>≤ 400 m/s² (EN 60068-2-27)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>With mechanical fault exclusion</td>
<td>≤ 1000 m/s² (EN 60068-2-27)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Without mechanical fault exclusion</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Operating temperature</strong></td>
<td>−10 °C to 80 °C</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Protection</strong></td>
<td>EN 60529</td>
<td>IP67</td>
<td>-</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scanning head</td>
<td>40 g (without cable)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cable</td>
<td>26 g/m</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M23 coupling</td>
<td>15 g</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1) With HEIDENHAIN cable; clock frequency ≤ 8 MHz
# Scale drum

**TTR ECM 2400** with a graduation period = 400 μm

<table>
<thead>
<tr>
<th>Measuring standard</th>
<th>Steel drum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of expansion</td>
<td>$\alpha_{\text{Steel}} = 10 \cdot 10^{-6} \text{ K}^{-1}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signal periods</th>
<th>900</th>
<th>1024</th>
<th>1200</th>
<th>1400</th>
<th>1698</th>
<th>2048</th>
<th>2600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drum inside diameter*</td>
<td>70 mm</td>
<td>80 mm/95 mm</td>
<td>105 mm/120 mm</td>
<td>130 mm</td>
<td>160 mm</td>
<td>180 mm</td>
<td>260 mm</td>
</tr>
<tr>
<td>Drum outside diameter*</td>
<td>113.16 mm</td>
<td>128.75 mm</td>
<td>150.88 mm</td>
<td>176.03 mm</td>
<td>213.24 mm</td>
<td>257.50 mm</td>
<td>326.90 mm</td>
</tr>
<tr>
<td>Accuracy of graduation</td>
<td>±8&quot;</td>
<td>±7&quot;</td>
<td>±6&quot;/±8&quot;</td>
<td>±5.5&quot;</td>
<td>±4.5&quot;</td>
<td>±4&quot;</td>
<td>±3.5&quot;</td>
</tr>
<tr>
<td>Interpolation error per signal period</td>
<td>±9&quot;</td>
<td>±8&quot;</td>
<td>±7&quot;</td>
<td>±6&quot;</td>
<td>±5&quot;</td>
<td>±4&quot;</td>
<td>±3&quot;</td>
</tr>
<tr>
<td>Positions per revolution</td>
<td>8 388 608 (23 bits)</td>
<td>16 777 216 (24 bits)</td>
<td>33 554 432 (25 bits)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring step</td>
<td>0.154&quot;</td>
<td>0.077&quot;</td>
<td>0.039&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety-relevant measuring step</td>
<td>0.7&quot; (9 bits)</td>
<td>0.35&quot; (10 bits)</td>
<td>0.18&quot; (11 bits)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safe position**</td>
<td>1.76°</td>
<td>0.88°</td>
<td>0.44°</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mech. permissible speed</td>
<td>≤ 14 500 rpm</td>
<td>≤ 13 000 rpm/ ≤ 12 500 rpm</td>
<td>≤ 10 500 rpm</td>
<td>≤ 9 000 rpm</td>
<td>≤ 7 000 rpm</td>
<td>≤ 6 000 rpm</td>
<td>≤ 4 500 rpm</td>
</tr>
<tr>
<td>Max. angular acceleration</td>
<td>9000 rad/s²</td>
<td>6000 rad/s²/ 9000 rad/s²</td>
<td>4900 rad/s²/ 7000 rad/s²</td>
<td>3300 rad/s²</td>
<td>1900 rad/s²</td>
<td>820 rad/s²</td>
<td>560 rad/s²</td>
</tr>
<tr>
<td>Electrically permissible shaft speed</td>
<td>≤ 29 000 rpm</td>
<td>≤ 25 000 rpm</td>
<td>≤ 21 500 rpm</td>
<td>≤ 18 500 rpm</td>
<td>≤ 1 500 rpm</td>
<td>≤ 12 500 rpm</td>
<td>≤ 10 000 rpm</td>
</tr>
<tr>
<td>Moment of inertia</td>
<td>1.5 \cdot 10^{-3} \text{ kgm}²</td>
<td>2.6 \cdot 10^{-3} \text{ kgm}²/ 2.1 \cdot 10^{-3} \text{ kgm}²</td>
<td>4.4 \cdot 10^{-3} \text{ kgm}²/ 3.4 \cdot 10^{-3} \text{ kgm}²</td>
<td>7.4 \cdot 10^{-3} \text{ kgm}²</td>
<td>16 \cdot 10^{-3} \text{ kgm}²</td>
<td>37 \cdot 10^{-3} \text{ kgm}²</td>
<td>76 \cdot 10^{-3} \text{ kgm}²</td>
</tr>
<tr>
<td>Permissible axial movement</td>
<td>≤ ±0.75 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>= 0.69 kg</td>
<td>= 0.89 kg/ = 0.65 kg</td>
<td>= 1.0 kg/ = 0.72 kg</td>
<td>= 1.2 kg</td>
<td>= 1.8 kg</td>
<td>= 3.0 kg</td>
<td>= 3.5 kg</td>
</tr>
</tbody>
</table>

* Please select when ordering
** Further deviations may arise in the downstream electronics after position value comparison (contact mfr. of the downstream electronics)
** Mechanical coupling: for fault exclusion for the loosening of the scanning head and scale drum, see Functional safety
**ECM 2400**

**Dimensions**

- **A-A**
- **B-B**

**W1** = Without mechanical fault exclusion

**W2** = With mechanical fault exclusion

<table>
<thead>
<tr>
<th>TTR ECM 2400</th>
<th>D1</th>
<th>W1</th>
<th>W2</th>
<th>D2</th>
<th>D3</th>
<th>E</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ø 70 +0/–0.008</td>
<td>Ø 70 +0.010/0.002</td>
<td>Ø 70 +0.013/0.011</td>
<td>Ø 85</td>
<td>Ø 113.16</td>
<td>62.3</td>
<td>6x M6</td>
<td></td>
</tr>
<tr>
<td>Ø 80 +0/–0.008</td>
<td>Ø 80 +0.010/0.002</td>
<td>Ø 80 +0.022/0.014</td>
<td>Ø 95</td>
<td>Ø 128.75</td>
<td>70.1</td>
<td>6x M6</td>
<td></td>
</tr>
<tr>
<td>Ø 95 +0/–0.010</td>
<td>Ø 95 +0.013/0.006</td>
<td>Ø 95 +0.019/0.016</td>
<td>Ø 110</td>
<td>Ø 138.75</td>
<td>70.1</td>
<td>6x M6</td>
<td></td>
</tr>
<tr>
<td>Ø 105 +0/–0.010</td>
<td>Ø 105 +0.013/0.005</td>
<td>Ø 105 +0.031/0.021</td>
<td>Ø 120</td>
<td>Ø 155.88</td>
<td>81.2</td>
<td>6x M6</td>
<td></td>
</tr>
<tr>
<td>Ø 130 +0/–0.012</td>
<td>Ø 130 +0.015/0.003</td>
<td>Ø 130 +0.041/0.029</td>
<td>Ø 145</td>
<td>Ø 176.63</td>
<td>93.7</td>
<td>6x M6</td>
<td></td>
</tr>
<tr>
<td>Ø 180 +0/–0.012</td>
<td>Ø 180 +0.016/0.003</td>
<td>Ø 180 +0.049/0.037</td>
<td>Ø 175</td>
<td>Ø 213.24</td>
<td>112.3</td>
<td>6x M6</td>
<td></td>
</tr>
<tr>
<td>Ø 180 +0/–0.012</td>
<td>Ø 180 +0.016/0.003</td>
<td>Ø 180 +0.055/0.043</td>
<td>Ø 195</td>
<td>Ø 252.50</td>
<td>134.5</td>
<td>6x M6</td>
<td></td>
</tr>
<tr>
<td>Ø 260 +0/–0.016</td>
<td>Ø 260 +0.020/0.004</td>
<td>Ø 260 +0.082/0.066</td>
<td>Ø 275</td>
<td>Ø 326.90</td>
<td>169.2</td>
<td>6x M6</td>
<td></td>
</tr>
</tbody>
</table>

- **ISO 7092-4-200HV**
- **ISO 4762-M4-8.8**

- **W1** = Without mechanical fault exclusion
- **W2** = With mechanical fault exclusion

1. **Shaft fit**: ensure full-surface contact
2. **Axial tolerance of mating shaft**
3. **Cable support**
4. **Centering collar**
5. **Direction of shaft rotation for ascending position values**

**Dimensions**

- **A-A**
- **B-B**

**W1** = Without mechanical fault exclusion

**W2** = With mechanical fault exclusion

- **Shaft fit**: ensure full-surface contact
- **Axial tolerance of mating shaft**
- **Cable support**
- **Centering collar**
- **Direction of shaft rotation for ascending position values**

**Notes**

- **ISO 7092-4-200HV**
- **ISO 4762-M4-8.8**

- **W1** = Without mechanical fault exclusion
- **W2** = With mechanical fault exclusion

- **Shaft fit**: ensure full-surface contact
- **Axial tolerance of mating shaft**
- **Cable support**
- **Centering collar**
- **Direction of shaft rotation for ascending position values**
## ERM 2200/2400/2900 series

Incremental angle encoder with magnetic scanning
- Consists of a scanning head and scale drum
- Multiple graduation periods in accordance with accuracy and speed requirements
- Various drum shapes for rotary axes and main spindles
- High variety of drum diameters

### Scanning head

<table>
<thead>
<tr>
<th>Graduation period = 200 μm</th>
<th>Graduation period = 400 μm</th>
<th>Graduation period = 1000 μm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interface</strong></td>
<td><strong>Interface</strong></td>
<td><strong>Interface</strong></td>
</tr>
<tr>
<td>– 1 Vpp</td>
<td>Mitsubishi high-speed interface (Mit 02-4)</td>
<td>– 1 Vpp</td>
</tr>
<tr>
<td>– 300 kHz</td>
<td>– 300 kHz</td>
<td>– 300 kHz</td>
</tr>
<tr>
<td>– 350 kHz</td>
<td>– 350 kHz</td>
<td>– 350 kHz</td>
</tr>
<tr>
<td>16,384 (14 bits)</td>
<td>16,384 (14 bits)</td>
<td>16,384 (14 bits)</td>
</tr>
<tr>
<td>– 8 MHz</td>
<td>– 8 MHz</td>
<td>– 8 MHz</td>
</tr>
<tr>
<td>– 5 μs</td>
<td>– 5 μs</td>
<td>– 5 μs</td>
</tr>
</tbody>
</table>

### Electrical connection

- Cable (1 m) with or without 12-pin M23 coupling
- Cable (1 m) with 12-pin M23 coupling or 12-pin M12 coupling
- Cable (1 m) with or without 12-pin M23 coupling

### Cable outlet

- Tangential, to the left or right
- Tangential, to the left or right, axial
- Tangential, to the right
- Tangential, to the left or right, axial

### Supply voltage

- DC 5 V ±0.5 V
- DC 3.6 V to 14 V
- DC 5 V ±0.5 V
- DC 3.6 V to 14 V
- DC 5 V ±0.5 V
- DC 3.6 V to 14 V
- DC 5 V ±0.5 V
- DC 3.6 V to 14 V

### Current consumption (typical)

- ≤ 150 mA (without load)
- ≤ 35 mA (without load)
- ≤ 150 mA (without load)
- ≤ 150 mA (without load)
- ≤ 150 mA (without load)
- ≤ 150 mA (without load)

### Power consumption (max.)

- ≤ 400 mW (EN 60068-2-6)
- ≤ 1000 mW (EN 60068-2-6)
- ≤ 400 mW (EN 60068-2-6)
- ≤ 1000 mW (EN 60068-2-6)
- ≤ 400 mW (EN 60068-2-6)
- ≤ 1000 mW (EN 60068-2-6)
- ≤ 400 mW (EN 60068-2-6)
- ≤ 1000 mW (EN 60068-2-6)

### Cable length

- ≤ 150 m
- ≤ 30 m
- ≤ 150 m
- ≤ 100 m
- ≤ 150 m

### Vibration

- 55 Hz to 2000 Hz
- ≤ 400 m/s² (EN 60068-2-6)
- ≤ 1000 m/s² (EN 60068-2-6)
- ≤ 400 m/s² (EN 60068-2-6)
- ≤ 1000 m/s² (EN 60068-2-6)
- ≤ 400 m/s² (EN 60068-2-6)
- ≤ 1000 m/s² (EN 60068-2-6)
- ≤ 400 m/s² (EN 60068-2-6)
- ≤ 1000 m/s² (EN 60068-2-6)

### Shock 6 ms

- ≤ 1000 m/s² (EN 60068-2-7) With fault exclusion for the loosening of the mechanical connection
- ≤ 400 m/s² (EN 60068-2-7)
- ≤ 1000 m/s² (EN 60068-2-7)
- ≤ 400 m/s² (EN 60068-2-7)
- ≤ 1000 m/s² (EN 60068-2-7)
- ≤ 400 m/s² (EN 60068-2-7)
- ≤ 1000 m/s² (EN 60068-2-7)
- ≤ 400 m/s² (EN 60068-2-7)

### Operating temperature

- –10 °C to 60 °C
- –10 °C to 60 °C
- –10 °C to 60 °C
- –10 °C to 100 °C

### Protection

- IP67

### Mass

- Scanning head
- Cable
- M23 coupling
- M12 coupling
- 30 g (without cable)
- 37 g
- 50 g
- 15 g

1) With HEIDENHAIN cable
2) Absolute position value after crossing two reference marks
3) EnDat 2.2 for incremental encoders can be used only after consultation with the controller manufacturer
<table>
<thead>
<tr>
<th>Scale drum</th>
<th>TTR ERM 2200</th>
<th>TTR ERM 2203</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grating period = 200 μm</td>
<td></td>
</tr>
<tr>
<td>Measuring standard</td>
<td>Steel drum</td>
<td>$\nu_{\text{therm}} = 10 \cdot 10^{-6}$ K$^{-1}$</td>
</tr>
<tr>
<td>Signal periods</td>
<td>1024</td>
<td>1200</td>
</tr>
<tr>
<td>Drum inside diameter*</td>
<td>40 mm</td>
<td>40 mm/55 mm</td>
</tr>
<tr>
<td>Drum outside diameter*</td>
<td>64.37 mm</td>
<td>76.44 mm</td>
</tr>
<tr>
<td>Accuracy of graduation TTR ERM 2200</td>
<td>±12&quot;</td>
<td>±10&quot;</td>
</tr>
<tr>
<td>TTR ERM 2203</td>
<td>±10&quot;</td>
<td>±8&quot;</td>
</tr>
<tr>
<td>Interpolation error per signal period TTR ERM 2200</td>
<td>±8&quot;</td>
<td>±4.5&quot;</td>
</tr>
<tr>
<td>TTR ERM 2203</td>
<td>±4.5&quot;</td>
<td>±2&quot;</td>
</tr>
<tr>
<td>Reference mark</td>
<td>One or distance-coded</td>
<td></td>
</tr>
<tr>
<td>Mech. permissible speed</td>
<td>≤ 22 000 rpm</td>
<td>≤ 19 000 rpm/16 000 rpm</td>
</tr>
<tr>
<td>Maximum angular acceleration*</td>
<td>50 000 rad/s²</td>
<td>27 000 rad/s²/48 000 rad/s²</td>
</tr>
<tr>
<td>Moment of inertia</td>
<td>0.15 · 10⁻³ kgm²</td>
<td>3.2 · 10⁻³ kgm²/0.24 · 10⁻³ kgm²</td>
</tr>
<tr>
<td>Permissible axial movement</td>
<td>≤ ±1.25 mm</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>= 0.21 kg</td>
<td>= 0.35 kg/0.22 kg</td>
</tr>
</tbody>
</table>

* Please select when ordering
*1) With fault exclusion for the loosening of the mechanical connection
<table>
<thead>
<tr>
<th>Scale drum</th>
<th>TTR ERM 2400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grating period</td>
<td>400 μm</td>
</tr>
<tr>
<td>Measuring standard</td>
<td>Steel drum</td>
</tr>
<tr>
<td>Coefficient of expansion</td>
<td>$\alpha_{\text{therm}} = 10 \cdot 10^{-6} \text{ K}^{-1}$</td>
</tr>
<tr>
<td>Signal periods</td>
<td></td>
</tr>
<tr>
<td></td>
<td>512 600 720 900 1024 1200 1400 1696 2048 2600 3600 3850 4800</td>
</tr>
<tr>
<td>Drum inside diameter*</td>
<td>40 mm 40 mm/55 mm 55 mm 70 mm 80 mm/95 mm 105 mm/120 mm 130 mm/140 mm 160 mm 180 mm/220 mm 260 mm/295 mm 360 mm/410 mm 450 mm 512 mm</td>
</tr>
<tr>
<td>Drum outside diameter*</td>
<td>64.37 mm 75.44 mm 90.53 mm 113.16 mm 128.75 mm 150.88 mm 176.03 mm 213.24 mm 257.50 mm 326.90 mm 452.64 mm 484.07 mm 603.52 mm</td>
</tr>
<tr>
<td>Accuracy of graduation</td>
<td>±13&quot; ±11&quot; ±10&quot; ±9&quot; ±7&quot; ±6.5/7&quot; ±6&quot; ±5.5/6&quot; ±5&quot; ±4.5/6&quot; ±4.5/5&quot; ±4&quot; ±3.5/4&quot; ±3.5/4.5&quot; ±3.5&quot; ±3&quot;</td>
</tr>
<tr>
<td>Interpolation error per signal period</td>
<td>±18&quot; ±15.5&quot; ±13&quot; ±10.5&quot; ±9&quot; ±8&quot; ±6.5&quot; ±5.5&quot; ±4.5/6&quot; ±4&quot; ±3&quot; ±2.5&quot; ±2&quot;</td>
</tr>
<tr>
<td>Reference mark</td>
<td>One or distance-coded 1)</td>
</tr>
<tr>
<td>Mech. permissible speed</td>
<td>≤ 22 000 rpm  ≤ 19 000 rpm  ≤ 16 000 rpm  ≤ 14 500 rpm  ≤ 13 000 rpm  ≤ 12 500 rpm  ≤ 10 500 rpm  ≤ 9 000 rpm  ≤ 8 500 rpm  ≤ 7 000 rpm  ≤ 6 000 rpm  ≤ 4 500 rpm  ≤ 3 000 rpm  ≤ 3 000 rpm  ≤ 1 600 rpm</td>
</tr>
<tr>
<td>Maximum angular acceleration</td>
<td>50 000 rad/s  27 000 rad/s  48 000 rad/s  20 000 rad/s  9 000 rad/s  6 000 rad/s  9 000 rad/s  4 900 rad/s  7 000 rad/s  4 400 rad/s  1 900 rad/s  8 000 rad/s  1 800 rad/s  5 70 rad/s  9 60 rad/s  4 70 rad/s  230 rad/s</td>
</tr>
<tr>
<td>Moment of inertia</td>
<td>0.15 \cdot 10^{-3} \text{ kgm}^2 0.32 \cdot 10^{-3} \text{ kgm}^2 0.63 \cdot 10^{-3} \text{ kgm}^2 1.5 \cdot 10^{-3} \text{ kgm}^2 2.6 \cdot 10^{-3} \text{ kgm}^2 2.1 \cdot 10^{-3} \text{ kgm}^2 4.4 \cdot 10^{-3} \text{ kgm}^2 6.3 \cdot 10^{-3} \text{ kgm}^2 16 \cdot 10^{-3} \text{ kgm}^2 37 \cdot 10^{-3} \text{ kgm}^2 32 \cdot 10^{-3} \text{ kgm}^2 235 \cdot 10^{-3} \text{ kgm}^2 153 \cdot 10^{-3} \text{ kgm}^2 713 \cdot 10^{-3} \text{ kgm}^2</td>
</tr>
<tr>
<td>Permissible axial movement</td>
<td>≤ 1.25 mm</td>
</tr>
<tr>
<td>Mass</td>
<td>= 0.21 kg  = 0.36 kg/ = 0.22 kg  = 0.44 kg  = 0.69 kg  = 0.89 kg/ = 0.65 kg  = 1.0 kg/0.72 kg  = 1.2 kg/ = 0.99 kg  = 1.8 kg  = 3.0 kg/ = 1.7 kg  = 3.5 kg/ = 3.2 kg  = 2.8 kg  = 9.1 kg</td>
</tr>
</tbody>
</table>

* Please select when ordering

1) With fault exclusion for the loosening of the mechanical connection
## Scale drum TTR ERM 2404
Grating period = 400 μm

<table>
<thead>
<tr>
<th>Measuring standard</th>
<th>Coefficient of expansion</th>
<th>Steel drum</th>
<th>$\delta_{\text{therm}} = 10 \cdot 10^{-6} \text{ K}^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal periods</td>
<td></td>
<td>360</td>
<td>400</td>
</tr>
<tr>
<td>Drum inside diameter*</td>
<td></td>
<td>30 mm</td>
<td>30 mm</td>
</tr>
<tr>
<td>Drum outside diameter*</td>
<td></td>
<td>45.26 mm</td>
<td>50.29 mm</td>
</tr>
<tr>
<td>Accuracy of graduation</td>
<td></td>
<td>±24”</td>
<td>±21”</td>
</tr>
<tr>
<td>Interpolation error per signal period</td>
<td></td>
<td>±25.5”</td>
<td>±23”</td>
</tr>
<tr>
<td>Reference mark</td>
<td></td>
<td>One</td>
<td>One</td>
</tr>
<tr>
<td>Mech. permissible speed</td>
<td></td>
<td>≤ 60 000 rpm</td>
<td>≤ 54 000 rpm</td>
</tr>
<tr>
<td>Moment of inertia</td>
<td></td>
<td>0.027 · 10^{-3} kgm²</td>
<td>0.045 · 10^{-3} kgm²</td>
</tr>
<tr>
<td>Permissible axial movement</td>
<td></td>
<td>≤ ±0.5 mm</td>
<td>≤ ±0.5 mm</td>
</tr>
<tr>
<td>Mass</td>
<td></td>
<td>= 0.07 kg</td>
<td>= 0.10 kg</td>
</tr>
</tbody>
</table>

## Scale drum TTR ERM 2904
Grating period = 1000 μm

<table>
<thead>
<tr>
<th>Measuring standard</th>
<th>Coefficient of expansion</th>
<th>Steel drum</th>
<th>$\delta_{\text{therm}} = 10 \cdot 10^{-6} \text{ K}^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal periods</td>
<td></td>
<td>180</td>
<td>192</td>
</tr>
<tr>
<td>Drum inside diameter*</td>
<td></td>
<td>35 mm</td>
<td>40 mm</td>
</tr>
<tr>
<td>Drum outside diameter*</td>
<td></td>
<td>54.43 mm</td>
<td>58.06 mm</td>
</tr>
<tr>
<td>Accuracy of graduation</td>
<td></td>
<td>±7.2”</td>
<td>±8”</td>
</tr>
<tr>
<td>Interpolation error per signal period</td>
<td></td>
<td>±7.2”</td>
<td>±8”</td>
</tr>
<tr>
<td>Reference mark</td>
<td></td>
<td>One</td>
<td>One</td>
</tr>
<tr>
<td>Mech. permissible speed</td>
<td></td>
<td>≤ 50 000 rpm</td>
<td>≤ 47 000 rpm</td>
</tr>
<tr>
<td>Moment of inertia</td>
<td></td>
<td>0.08 · 10^{-3} kgm²</td>
<td>0.07 · 10^{-3} kgm²</td>
</tr>
<tr>
<td>Permissible axial movement</td>
<td></td>
<td>≤ ±0.5 mm</td>
<td>≤ ±0.5 mm</td>
</tr>
<tr>
<td>Mass</td>
<td></td>
<td>= 0.11 kg</td>
<td>= 0.11 kg</td>
</tr>
</tbody>
</table>

* Please select when ordering
ERM 2200/2203/2400

Dimensions

<table>
<thead>
<tr>
<th>W1</th>
<th>W2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without mechanical fault exclusion</td>
<td>With mechanical fault exclusion</td>
</tr>
<tr>
<td>1</td>
<td>Shaft fit; ensure full-surface contact</td>
</tr>
<tr>
<td>2</td>
<td>Axial tolerance of mating shaft</td>
</tr>
<tr>
<td>3</td>
<td>Reference mark position</td>
</tr>
<tr>
<td>4</td>
<td>Cable support</td>
</tr>
<tr>
<td>5</td>
<td>Centering collar</td>
</tr>
<tr>
<td>6</td>
<td>Direction of shaft rotation for ascending position values</td>
</tr>
</tbody>
</table>

**Scanning head**

<table>
<thead>
<tr>
<th>AK ERM 2280/2283</th>
<th>AK ERM 2293</th>
<th>AK ERM 2420/2480</th>
<th>AK ERM 2410</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>T</td>
<td>Mounting clearance d (with spacer shim)</td>
<td>K</td>
</tr>
<tr>
<td>17 mm</td>
<td>0.02 mm</td>
<td>0.05 mm</td>
<td>13.6 mm</td>
</tr>
<tr>
<td>19.5 mm</td>
<td>0.02 mm</td>
<td>0.06 mm</td>
<td>15.9 mm</td>
</tr>
<tr>
<td>17 mm</td>
<td>0.04 mm</td>
<td>0.15 mm</td>
<td>13.6 mm</td>
</tr>
<tr>
<td>19.5 mm</td>
<td>0.04 mm</td>
<td>0.15 mm</td>
<td>15.9 mm</td>
</tr>
</tbody>
</table>

Further information:
For CAD data, visit cad.heidenhain.com
### ERM 2404/2405/2904

#### Dimensions

<table>
<thead>
<tr>
<th>TIR ERM 2404</th>
<th>D1</th>
<th>W1</th>
<th>D2</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIR ERM 2405</td>
<td>Ø 30 +0.010/0.002</td>
<td>Ø 30 +0.006</td>
<td>Ø 45.26</td>
<td>28.3</td>
</tr>
<tr>
<td>TIR ERM 2405</td>
<td>Ø 35 +0.010/0.002</td>
<td>Ø 35 +0.006</td>
<td>Ø 54.43</td>
<td>32.9</td>
</tr>
<tr>
<td>TIR ERM 2405</td>
<td>Ø 40 +0.010/0.002</td>
<td>Ø 40 +0.006</td>
<td>Ø 64.37</td>
<td>37.9</td>
</tr>
<tr>
<td>TIR ERM 2405</td>
<td>Ø 45 +0.010/0.002</td>
<td>Ø 45 +0.006</td>
<td>Ø 74.29</td>
<td>43.4</td>
</tr>
<tr>
<td>TIR ERM 2405</td>
<td>Ø 50 +0.010/0.002</td>
<td>Ø 50 +0.006</td>
<td>Ø 89.72</td>
<td>51.1</td>
</tr>
<tr>
<td>TIR ERM 2904</td>
<td>Ø 60 +0.010/0.002</td>
<td>Ø 60 +0.006</td>
<td>Ø 113.16</td>
<td>62.3</td>
</tr>
</tbody>
</table>

**TIR ERM 2405/2904/2404**

<table>
<thead>
<tr>
<th>Scanning head</th>
<th>Mounting clearance d (with spacer shim)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK ERM 2480</td>
<td>0.15 mm</td>
</tr>
<tr>
<td>AK ERM 2380</td>
<td>0.30 mm</td>
</tr>
</tbody>
</table>

---

**Notes:**

- **D** = Mounting possibility for scanning head
- **W** = Bearing
- **E** = Mounting possibility for scanning head
- **d** = Direction of shaft rotation for ascending position values
- **C** = Centering collar
- **F** = Clamping area (valid for both sides)
- **A** = Slot for machine key 4 x 4 x 10 (as per DIN 6885 Form A)

---

**Further information:**

For CAD data, visit [cad.heidenhain.com](http://cad.heidenhain.com)
ERA 7000 series

Incremental angle encoder for high accuracy
• Steel scale tape for internal mounting
• Full-circle and segment versions, also for very large diameters
• Consisting of a scanning head and scale tape

**ERA 7480**

**ERA 7481**

---

**Scanning head** | **AK ERA 7480**
---|---
**Interface** | 1 Vpp
**Cutoff frequency** -3 dB | ≥ 350 kHz
**Electrical connection** | Cable 1 m with M23 coupling (12-pin)
**Cable length** | ≤ 150 m (with HEIDENHAIN cable)
**Supply voltage** | DC 5 V ± 0.5 V
**Current consumption** | ≤ 100 mA (without load)
**Vibration** | ≤ 200 m/s² (EN 60068-2-6)
**Shock** | ≤ 1000 m/s² (EN 60068-2-27)
**Operating temperature** | –10 °C to 80 °C
**Mass** | = 20 g (without cable)

**Scale tape**

**MSB ERA 7400C** full circle version
**MSB ERA 7401C** segment version

**Measuring standard**

**Grating period** | Steel scale-tape with METALLUR graduation
**Coefficient of expansion** | 40 μm 2.05 · 10⁻⁶ K⁻¹

**Signal periods** (1)

| 36 000 | 45 000 | 90 000 |

**Accuracy of graduation** (2)

| ±3.9” | ±3.2” | ±1.6” |

**Interpolation error per signal period** (2)

| ±0.4” | ±0.3” | ±0.1” |

**Accuracy of the scale tape**

| ±3 μm/m of tape length |

**Reference marks**

Distance-coded

**Mating diameter**

| Full circle | 456.62 mm | 573.20 mm | 1146.10 mm |
| Segment | ≥ 400 mm |

**Mech. permissible speed**

| ≤ 250 rpm | ≤ 250 rpm | ≤ 220 rpm |

**Permissible axial movement**

| ≤ 0.5 mm (scale relative to the scanning head) |

**Permissible expansion coefficient of shaft**

| σₚₑₓₘᵢₙ = 9 · 10⁻⁶ K⁻¹ to 12 · 10⁻⁶ K⁻¹ |

**Protection rating**

EN 60529 Complete encoder after mounting: IP00

**Mass**

= 30 g/m

---

* Please select when ordering; wider diameters of up to 3 m are available upon request
1) Validity for full-circle version; for segment solution depending on the mating diameter and the tape length
2) The accuracy of the graduation and the interpolation error within one signal period together yield the encoder-specific error; for additional errors arising from mounting and the bearing of the measured shaft, see Measurement accuracy
ERA 8000 series

High-accuracy incremental angle encoder
- Steel scale tape for external mounting
- Full-circle and segment versions, including for very large diameters
- Optimized scanning performance for very high reliability
- Integrated three-color LED signal quality indicator
- Consisting of a scanning head and scale tape

Scanning head

<table>
<thead>
<tr>
<th>AK ERA 8480</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interface</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Cutoff frequency</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Electrical connection</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Cable length</strong></td>
</tr>
<tr>
<td><strong>Supply voltage</strong></td>
</tr>
<tr>
<td><strong>Current consumption</strong></td>
</tr>
<tr>
<td><strong>Vibration</strong></td>
</tr>
<tr>
<td><strong>Shock</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Operating temperature</strong></td>
</tr>
<tr>
<td><strong>Mass</strong></td>
</tr>
<tr>
<td>Scanning head</td>
</tr>
<tr>
<td>Cable</td>
</tr>
<tr>
<td>Coupling (M12)</td>
</tr>
<tr>
<td>Coupling (M23)</td>
</tr>
</tbody>
</table>

Scale tape

| MSB ERA 8400C full-circle version |
| MSB ERA 8401C segment version with tensioning elements |
| MSB ERA 8402C segment version without tensioning elements |
| **Measuring standard** | Steel scale-tape with METALLUR graduation |
| **Grating period** | 40 μm |
| **Coefficient of expansion** | $\alpha_{\text{met}} = 10.5 \cdot 10^{-6} \text{ K}^{-1}$ |
| **Signal periods** | 36000 | 45000 | 90000 |
| **Accuracy of graduation** | ±4.7" | ±3.9" | ±1.9" |
| **Interpolation error per signal period** | ±0.4" | ±0.3" | ±0.1" |
| **Accuracy of the scale tape** | ±3 μm/m of tape length |
| **Reference marks** | Distance-coded |
| **Mating diameter** | Full circle 458.11 mm | 572.72 mm | 1145.73 mm |
| Segment | ≥ 400 mm |
| **Mech. permissible speed** | ≤ 50 rpm |
| | ≤ 50 rpm |
| | ≤ 45 rpm |
| **Permissible axial movement** | ≤ 0.5 mm (scale relative to the scanning head) |
| **Permissible expansion coefficient of shaft** | $\alpha_{\text{met}} = 9 \cdot 10^{-6} \text{ K}^{-1}$ to $12 \cdot 10^{-6} \text{ K}^{-1}$ |
| **Protection rating** | EN 60034-9 |
| Complete encoder after mounting: IP00 |
| **Mass** | = 30 g/m |

* Please select when ordering, additional diameters of up to 3 m are available upon request
1) Validity for full-circle version; for segment solution depending on the mating diameter and the tape length
2) The accuracy of the graduation and the interpolation error within one signal period together yield the encoder-specific error; for additional errors arising from mounting and the bearing of the measured shaft, see Measurement accuracy
ERA 8000

Dimensions

ERA 84x0 scale tape (full circle)

ERA 84x1 scale tape (segment)

ERA 84x2 scale tape (segment)

Mounting aid

ISO 7984

© = Mounting possibilities
= Bearing
= Required mating dimensions
1 = Scale-tape slot Ø D
2 = Bend radius R of the cable – Fixed cable > 8 mm – Frequent flexing > 40 mm
3 = Positive direction of rotation for output signals as per interface description
4 = Reference mark
5 = Scale-tape thickness
6 = Distance between the scale-tape slot floor and the fastening screw
7 = Distance between scale-tape slot floor and scanning head’s rear mounting surface
8 = Floor of pocket is ferromagnetic for fixing the tensioning cleat
9 = Permissible axial motion (scale tape relative to the scanning head) ≤ ±0.5 mm
10 = Space for mounting aid
11 = Spacer shim
12 = Mounting aid
13 = Signal-quality indicator
14 = Length of the chamfer

Mounting aid

<table>
<thead>
<tr>
<th>Mounting aid</th>
<th>ID number</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERA 84x0</td>
<td>1372104-08</td>
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ID number
HEIDENHAIN encoders provide all of 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 have 1 Vpp, TTL or HIL interfaces. TTL and HIL encoders monitor their signal amplitudes internally and generate a simple fault detection signal. With 1 Vpp 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 use serial data transmission. Depending on the interface, additional 1 Vpp incremental signals can 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 devices. 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.
- Monitoring mode: the PWM inspection device is inserted within the closed control loop (via suitable testing adapters as needed). This enables real-time diagnosis of the machine or equipment during operation. The available functions depend on the interface.

Further information:

For detailed descriptions regarding diagnostics, inspection devices and testing devices, please refer to the Interfaces of HEIDENHAIN Encoders brochure.