



HEIDENHAIN



Angle Encoders without Integral Bearing

September 2007



Information on

- Angle encoders with integral bearing
 - Rotary encoders
 - Encoders for servo drives
 - Exposed linear encoders
 - Linear encoders for numerically controlled machine tools
 - HEIDENHAIN interface electronics
 - HEIDENHAIN controls
- is available on request as well as on the Internet at www.heidenhain.de.

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

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

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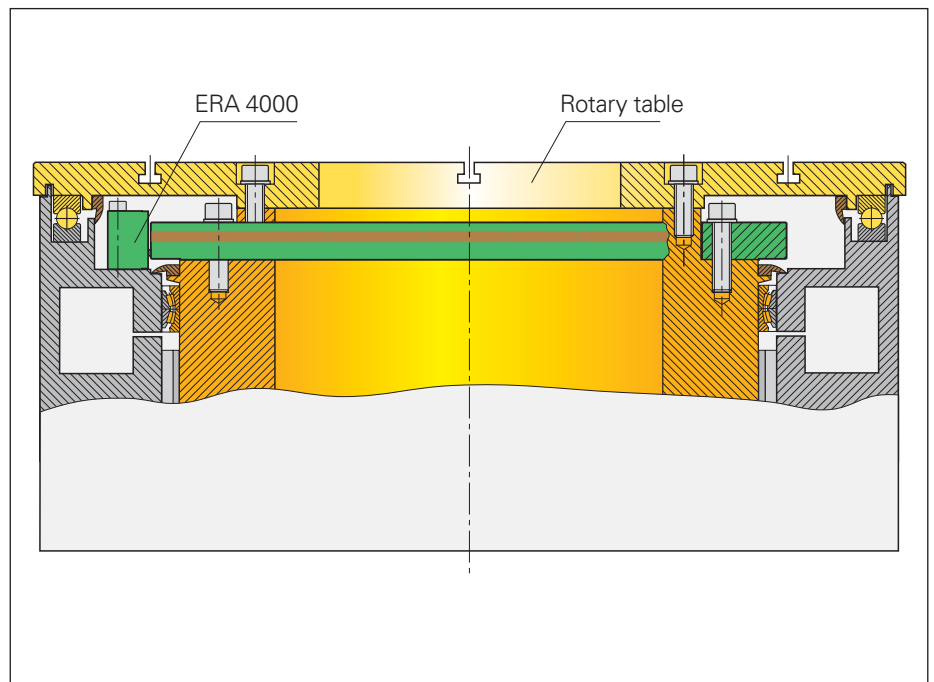
HEIDENHAIN Angle Encoders

The term angle encoder is typically used to describe encoders that have an accuracy of better than $\pm 5''$ and a line count above 10000. In contrast, rotary encoders are encoders that typically have an accuracy of more than $\pm 10''$. Angle encoders are found in applications requiring precision angular measurement to accuracies within several arc seconds.

Examples:

- Rotary tables
 - Swivel heads
 - Measuring machines
 - Handling systems for wafers
 - Printing units of printing machines
 - Spectrometers
 - Telescopes
- etc.

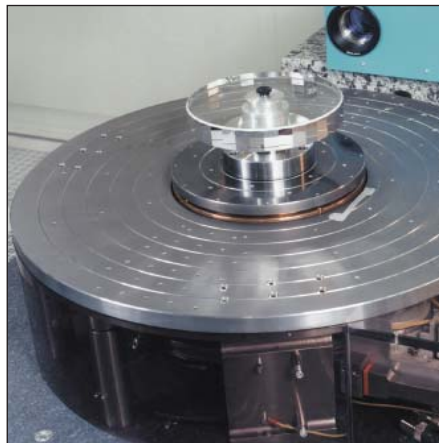
The tables on the following pages list different types of angle encoders to suit the various applications and meet different requirements.



The **ERA 4000** angle encoder mounted onto the rotary table of a machine tool



Rotary table on a machine tool



Angle comparator



Radio telescope

Angle encoders without integral bearing

The angle encoders without integral bearing (modular angle encoders) **ERP** and **ERA** consist of two components—a scanning head and a graduation carrier, which must be adjusted to each other during mounting. Eccentricity of the shaft as well as installation and adjustment therefore have a decisive effect on the achievable accuracy.

Modular angle encoders are available with various graduation carriers

- ERP: Glass circular scale with hub
- ERA 4000: Steel drum
- ERA 700/800: Steel tape

Angle encoders without integral bearing are designed for integration in machine elements or components. They are designed to meet the following requirements:

- Large hollow shaft diameter (up to 10 mm with a scale tape)
- High shaft speeds
- No additional starting torque from shaft seals
- High reproducibility
- High adaptability to mounting space (versions with scale tape available in full circle or circle segment)

Because angle encoders without integral bearings are supplied without enclosure, the required degree of protection must be ensured through installation.

Selection Guide on pages 6/7



Angle encoders with integral bearing

The angle encoders with integral bearing, **RCN**, **RON**, **RPN** and **ROD**, are complete, sealed systems. They are characterized by their simple mounting and uncomplicated adjustment. The integrated stator coupling (with the RCN, RON and RPN) or the separate shaft coupling (with the ROD) compensates axial motion of the measured shaft.

Angle encoders with integral stator coupling therefore provide excellent dynamic performance because the coupling absorbs only that torque caused by friction in the bearing during angular acceleration of the shaft.

Other advantages:

- Compact size for limited installation space
- Hollow shaft diameters up to 100 mm for leading power cables, etc.
- Simple installation

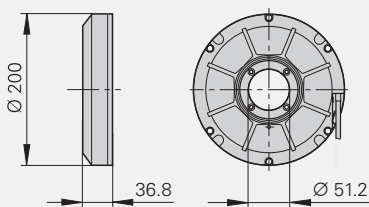
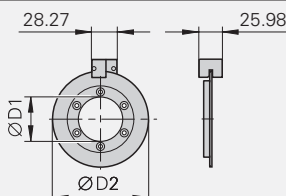
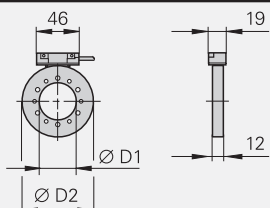
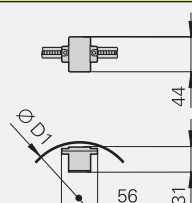
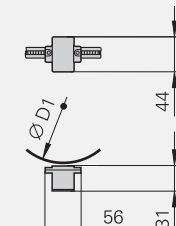
Selection Guide on pages 8 to 11



You can find more detailed information on **angle encoders with integral bearings** on the Internet at www.heidenhain.de or in our separate catalog.

Selection Guide

Angle Encoders without Integral Bearing

Series	Overall dimensions in mm	Diameter D1/D2	Line count/ System accuracy ¹⁾	Recommended measuring step ³⁾	Mechanically perm. speed
Grating on solid scale carrier					
ERP 880 Glass disk with interferential grating		–	90000/± 1″ (180000 signal periods)	0.00001°	≤ 1000 min ^{–1}
ERP 4000		D1: 8 mm D2: 44 mm	65536/± 5″ (131 072 signal periods)	0.00001°	≤ 300 min ^{–1}
ERP 8000		D1: 50 mm D2: 108 mm	180000/± 2″ (360000 signal periods)	0.000005°	≤ 100 min ^{–1}
ERA 4x80 Steel circumfer- ential-scale drum with centering collar		D1: 40 mm to 512 mm D2: 76.75 mm to 560.46 mm	3000/± 9.4″ to 52000/± 2.3″	0.002° to 0.00005°	≤ 10000 min ^{–1} to ≤ 1500 min ^{–1}
ERA 4x81 Steel circumfer- ential scale drum with low weight and low moment of inertia		D1: 26 mm to 280 mm D2: 52.65 mm to 305.84 mm	4096/± 10.2″ to 48000/± 2.8″		≤ 6000 min ^{–1} to ≤ 2000 min ^{–1}
ERA 4282 Steel circumfer- ential scale drum for increased accuracy requirements		D1: 40 mm to 270 mm D2: 76.75 mm to 331.31 mm	12000/± 5.1″ to 52000/± 2″		≤ 10000 min ^{–1} to ≤ 2500 min ^{–1}
Grating on steel tape					
ERA 700 For inside diameter mounting		458.62 mm 573.20 mm 1146.10 mm	Full circle ¹⁾ 36000/± 3.5″ 45000/± 3.4″ 90000/± 3.2″	0.0002° to 0.00002°	≤ 500 min ^{–1}
		318.58 mm 458.62 mm 573.20 mm	Segment ²⁾ 5000 10000 20000		
ERA 800 For outside diameter mounting		458.04 mm 572.63 mm	Full circle ¹⁾ 36000/± 3.5″ 45000/± 3.4″	0.0002° to 0.00005°	≤ 100 min ^{–1}
		317.99 mm 458.04 mm 572.63 mm	Segment ²⁾ 5000 10000 20000		

¹⁾ Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.

²⁾ Angular segment from 50° to 200°; see *Measuring Accuracy*

³⁾ For position measurement

	Incremental signals/ Grating period	Reference marks	Model	Page
	$\sim 1 V_{pp}/-$	One	ERP 880	28
		None	ERP 4080	30
			ERP 8080	
	$\sim 1 V_{pp}/20 \mu m$	Distance-coded	ERA 4280C	32
	$\sim 1 V_{pp}/40 \mu m$		ERA 4480C	
	$\sim 1 V_{pp}/80 \mu m$		ERA 4880C	
	$\sim 1 V_{pp}/20 \mu m$		ERA 4281C	36
	$\sim 1 V_{pp}/40 \mu m$		ERA 4481C	
	$\sim 1 V_{pp}/20 \mu m$		ERA 4282C	38
	$\sim 1 V_{pp}/40 \mu m$	Distance-coded (nominal increment of 1 000 grating periods)	ERA 780C full circle	40
			ERA 781C segment	
	$\sim 1 V_{pp}/40 \mu m$	Distance-coded (nominal increment of 1 000 grating periods)	ERA 880C full circle	42
			ERA 881C segment with tensioning elements	
			ERA 882C segment with- out tensioning elements	



ERP 880



ERP 4080



ERA 4000



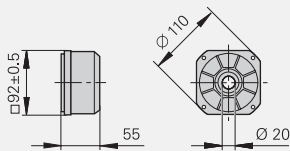
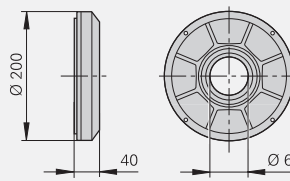
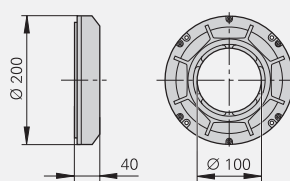
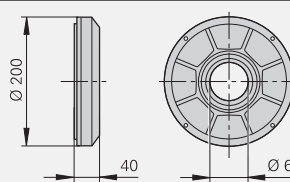
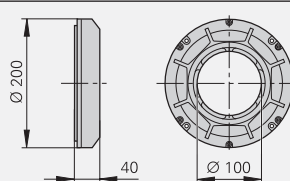
ERA 780



ERA 880

Selection Guide

Absolute Angle Encoders with Integral Bearing

Series	Overall dimensions in mm	System accuracy	Recommend- ed measuring step ¹⁾	Mechanically perm. speed	Incremental signals	Signal periods/rev
With integrated stator coupling						
RCN 200		± 5"	0.000 1°	3 000 min ⁻¹	~ 1 V _{PP}	16 384
					—	—
					—	—
					—	—
		± 2.5"			~ 1 V _{PP}	16 384
					—	—
RCN 700	 	± 2"	0.000 1°	1 000 min ⁻¹	~ 1 V _{PP}	32 768
					—	—
					—	—
					—	—
					~ 1 V _{PP}	32 768
					—	—
RCN 800	 	± 1"	0.000 05°	1 000 min ⁻¹	~ 1 V _{PP}	32 768
					—	—
					—	—
					—	—
					~ 1 V _{PP}	32 768
					—	—

¹⁾ For position measurement

	Absolute position values	Absolute positions per revolution	Model	For more information
	EnDat 2.2 / 02	67 108 864 $\triangleq$ 26 bits	RCN 226	Catalog: <i>Angle Encoders with Integral Bearing</i>
	EnDat 2.2/22	67 108 864 $\triangleq$ 26 bits	RCN 226	
	Fanuc 02	8388608 $\triangleq$ 23 bits	RCN 223 F	
	Mit 02-4	8388608 $\triangleq$ 23 bits	RCN 223 M	
	EnDat 2.2 / 02	268 435 456 $\triangleq$ 28 bits	RCN 228	
	EnDat 2.2/22	268 435 456 $\triangleq$ 28 bits	RCN 228	
	Fanuc 02	134 217 728 $\triangleq$ 27 bits	RCN 227 F	
	Mit 02-4	134 217 728 $\triangleq$ 27 bits	RCN 227 M	
	EnDat 2.2 / 02	536 870 912 $\triangleq$ 29 bits	RCN 729	
	EnDat 2.2/22	536 870 912 $\triangleq$ 29 bits	RCN 729	
	Fanuc 02	134 217 728 $\triangleq$ 27 bits	RCN 727 F	
	Mit 02-4	134 217 728 $\triangleq$ 27 bits	RCN 727 M	
	EnDat 2.2 / 02	536 870 912 $\triangleq$ 29 bits	RCN 729	
	EnDat 2.2/22	536 870 912 $\triangleq$ 29 bits	RCN 729	
	Fanuc 02	134 217 728 $\triangleq$ 27 bits	RCN 727 F	
	Mit 02-4	134 217 728 $\triangleq$ 27 bits	RCN 727 M	
	EnDat 2.2 / 02	536 870 912 $\triangleq$ 29 bits	RCN 829	
	EnDat 2.2/22	536 870 912 $\triangleq$ 29 bits	RCN 829	
	Fanuc 02	134 217 728 $\triangleq$ 27 bits	RCN 827 F	
	Mit 02-4	134 217 728 $\triangleq$ 27 bits	RCN 827 M	
	EnDat 2.2 / 02	536 870 912 $\triangleq$ 29 bits	RCN 829	
	EnDat 2.2/22	536 870 912 $\triangleq$ 29 bits	RCN 829	
	Fanuc 02	134 217 728 $\triangleq$ 27 bits	RCN 827 F	
	Mit 02-4	134 217 728 $\triangleq$ 27 bits	RCN 827 M	



RCN 200



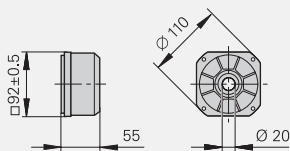
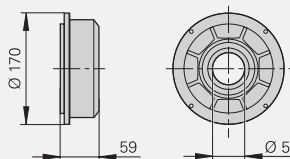
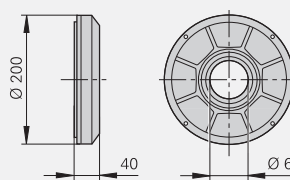
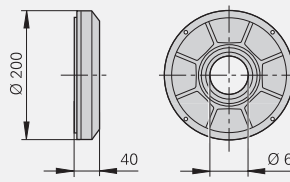
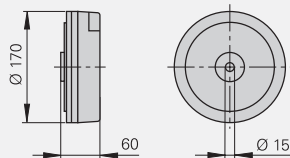
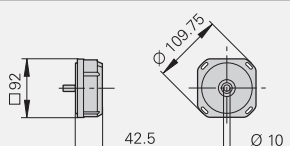
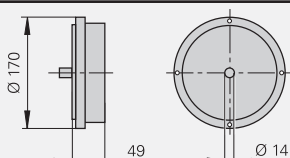
RCN 700
Ø 60 mm



RCN 800
Ø 100 mm

Selection Guide

Incremental Angle Encoders with Integral Bearing

Series	Overall dimensions in mm	System accuracy	Recommended measuring step ¹⁾	Mechanically perm. speed
With integrated stator coupling				
RON 200		± 5"	0.005°	3 000 min ⁻¹
			0.001°/0.0005°	
		± 2.5"	0.0001°	
RON 700		± 2"	0.0001°	1 000 min ⁻¹
				
RON 800 RPN 800		± 1"	0.00005°	1 000 min ⁻¹
			0.00001°	
RON 900		± 0.4"	0.00001°	100 min ⁻¹
For separate shaft coupling				
ROD 200		± 5"	0.005°	10 000 min ⁻¹
			0.0005°	
			0.0001°	
ROD 700		± 2"	0.0001°	1 000 min ⁻¹
ROD 800		± 1"	0.00005°	1 000 min ⁻¹

¹⁾ For position measurement

²⁾ After integrated interpolation

	Incremental signals	Signal periods/rev	Model	For more information
		18000 ²⁾	RON 225	Catalog: <i>Angle Encoders with Integral Bearing</i>
		180000/90000 ²⁾	RON 275	
		18000	RON 285	
		18000	RON 287	
		18000	RON 785	
		18000/36000	RON 786	
		36000	RON 886	
		180000	RPN 886	
		36000	RON 905	

		18000 ²⁾	ROD 220	Catalog: <i>Angle Encoders with Integral Bearing</i>
		180000 ²⁾	ROD 270	
		18000	ROD 280	
		18000/36000	ROD 780	
		36000	ROD 880	



RON 285



RON 786



RON 905



ROD 280



ROD 780

Measuring Principles

Measuring Standard

HEIDENHAIN encoders incorporate measuring standards of periodic structures known as graduations.

These graduations are applied to a glass or steel substrate. Glass scales are used primarily in encoders for speeds up to $10\,000\text{ min}^{-1}$. For higher speeds—up to $20\,000\text{ min}^{-1}$ —steel drums are used. The scale substrate for large diameters is a steel tape.

These precision graduations are manufactured in various photolithographic processes. Graduations are fabricated from:

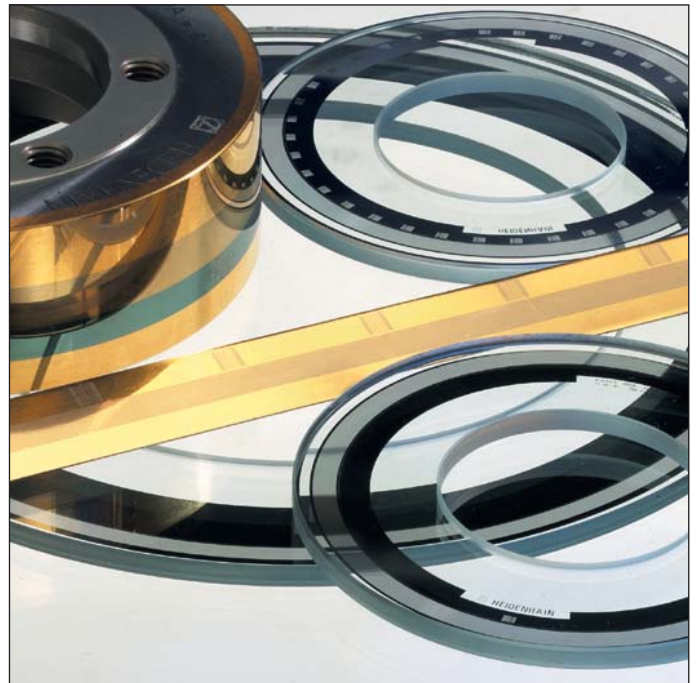
- extremely hard chromium lines on glass or gold-plated steel drums,
- matte-etched lines on gold-plated steel tape, or
- three-dimensional structures etched into quartz glass.

These photolithographic manufacturing processes—DIADUR, AURODUR or METALLUR—developed by HEIDENHAIN produce grating periods of:

- $40\text{ }\mu\text{m}$ for AURODUR
- $20\text{ }\mu\text{m}$ for METALLUR
- $10\text{ }\mu\text{m}$ for DIADUR
- $4\text{ }\mu\text{m}$ with etched quartz glass

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

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



Circular graduations of incremental angle encoders

Incremental Measuring Method

With the **incremental measuring method**, the graduation consists of a periodic grating structure. The position information is obtained **by counting** the individual increments (measuring steps) from some point of origin. Since an absolute reference is required to ascertain positions, the measuring standard is provided with an additional track that bears 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 scanned to establish an absolute reference or to find the last selected datum.

In some cases, however, this may require a rotation up to nearly 360°. To speed and simplify such "reference runs," many encoders feature **distance-coded reference marks**—multiple reference marks that are individually spaced according to a mathematical algorithm. The subsequent electronics find the absolute reference after traversing two successive reference marks—meaning only a few degrees of traverse (see nominal increment I in the table).

Encoders with distance-coded reference marks are identified with a "C" behind the model designation (e.g. ERA 780C).

With distance-coded reference marks, the **absolute reference** is calculated by counting the signal periods between two reference marks and using the following formula:

$$\alpha_1 = (\text{abs } A - \text{sgn } A - 1) \times \frac{I}{2} + (\text{sgn } A - \text{sgn } D) \times \frac{\text{abs } M_{RR}}{2}$$

where:

$$A = \frac{2 \times \text{abs } M_{RR} - I}{GP}$$

where:

α_1 = Absolute angular position of the first traversed reference mark to the zero position in degrees

abs = Absolute value

sgn = Sign function (" +1 " or " -1 ")

M_{RR} = Measured distance between the traversed reference marks in degrees

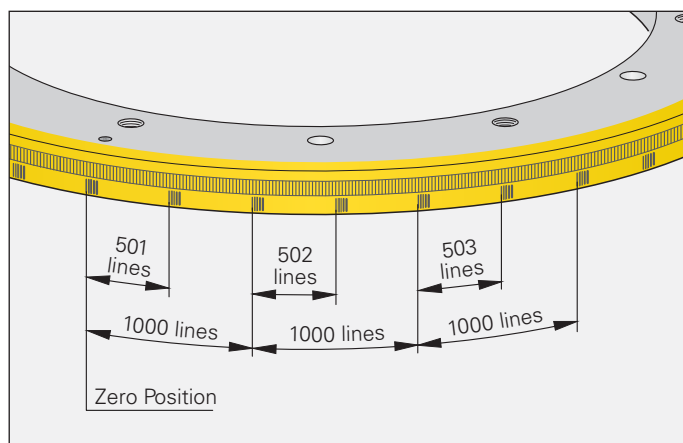
I = Nominal increment between two fixed reference marks (see tables)

GP = Grating period ($\frac{360^\circ}{\text{Line count}}$)

D = Direction of rotation (+1 or -1)
The rotation to the right (as seen from the shaft side of the angle encoder – see Dimensions) gives "+1"

ERA 780C, ERA 880C

Line count z	Number of reference marks	Nominal increment I
36000	72	10°
45000	90	8°
90000	180	4°



Schematic representation of a circular graduation with distance-coded reference marks (ERA 4480 with 20000 lines as example)

ERA 4000C

Line count for grating period			Number of reference marks	Nominal increment I
20 µm	40 µm	80 µm		
–	–	3000	6	120°
8192	4096	4096	8	90°
–	–	5000	10	72°
12000	6000	–	12	60°
–	–	7000	14	51.429°
16384	8192	8192	16	45°
20000	10000	10000	20	36°
24000	12000	12000	24	30°
–	–	13000	26	27.692°
28000	14000	–	28	25.714°
32768	16384	–	32	22.5°
40000	20000	–	40	18°
48000	24000	–	48	15°
52000	26000	–	52	13.846°
–	38000	–	76	9.474°
–	44000	–	88	8.182°

Scanning the Measuring Standard

Photoelectric Scanning

Most HEIDENHAIN encoders operate using the principle of photoelectric scanning. The photoelectric scanning of a measuring standard is contact-free, and therefore without wear. This method detects even very fine lines, no more than a few microns wide, and generates output signals with very small signal periods.

The finer the grating period of a measuring standard is, the greater the effect of diffraction on photoelectric scanning. HEIDENHAIN uses two scanning principles with angle encoders:

- The **imaging scanning principle** for grating periods from 10 μm to approx. 70 μm .
- The **interferential scanning principle** for very fine graduations with grating periods of 4 μm and smaller.

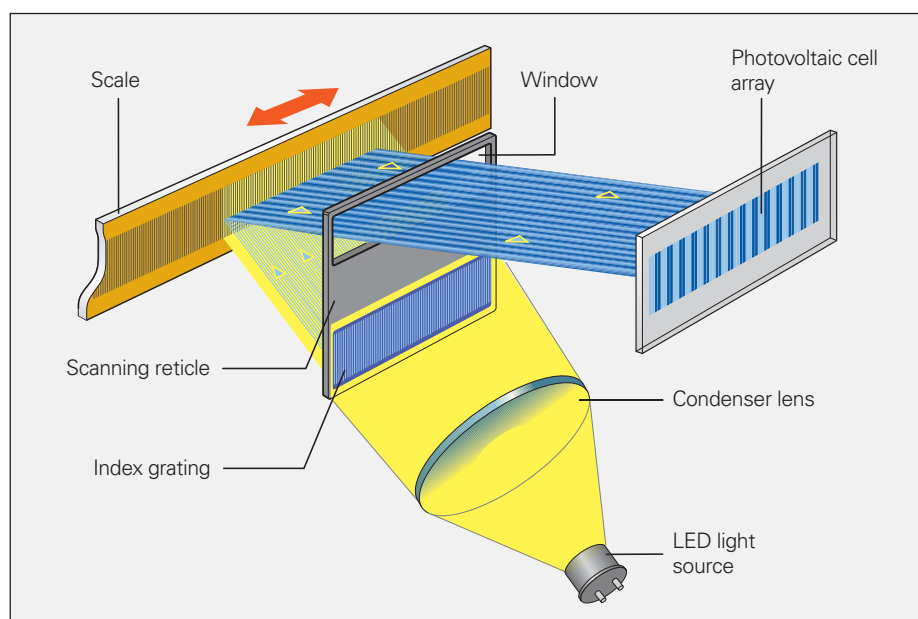
Imaging scanning principle

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

When parallel light passes through a grating, light and dark surfaces are projected at a certain distance. An index grating with the same grating period is located here. When the two gratings move relative to each other, the incident light is modulated. If the gaps in the gratings are aligned, light passes through. If the lines of one grating coincide with the gaps of the other, no light passes through.

Photovoltaic cells convert these variations in light intensity into electrical signals. The specially structured grating of the scanning reticle filters the light current to generate nearly sinusoidal output signals. The smaller the period of the grating structure is, the closer and more tightly tolerated the gap must be between the scanning reticle and circular scale. Practical mounting tolerances for encoders with the imaging scanning principle are achieved with grating periods of 10 μm and larger.

The ERA angle encoders, for example, operate according to the imaging scanning principle.



Photoelectric scanning in accordance with the imaging principle with a steel scale and single-field scanning

Interferential scanning principle

The interferential scanning principle exploits the diffraction and interference of light on a fine graduation to produce signals used to measure displacement.

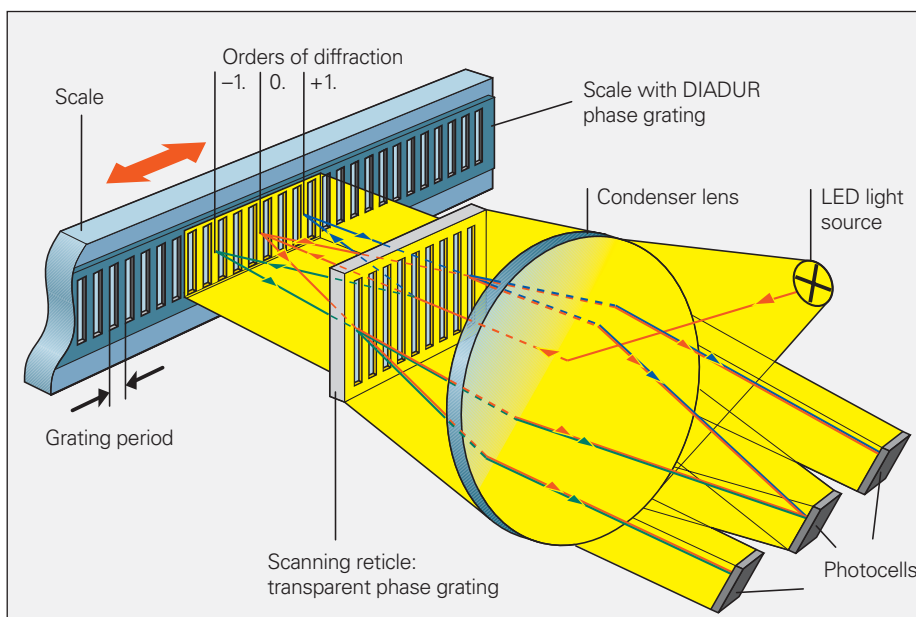
A step grating is used as the measuring standard: reflective lines $0.2\text{ }\mu\text{m}$ high are applied to a flat, reflective surface. In front of that is the scanning reticle—a transparent phase grating with the same grating period as the scale.

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

A relative motion of the scanning reticle to the scale causes the diffracted wave fronts to undergo a phase shift: when the grating moves by one period, the wave front of the first order is displaced by one wavelength in the positive direction, and the wavelength of diffraction order -1 is displaced by one wavelength in the negative direction. Since the two waves interfere with each other when exiting the grating, the waves are shifted relative to each other by two wavelengths. This results in two signal periods from the relative motion of just one grating period.

Interferential encoders function with average grating periods of $4\text{ }\mu\text{m}$ and finer. Their scanning signals are largely free of harmonics and can be highly interpolated. These encoders are therefore especially suited for high resolution and high accuracy. Even so, their generous mounting tolerances permit installation in a wide range of applications.

The ERP angle encoders, for example, operate according to the interferential scanning principle.



Photoelectric scanning in accordance with the interferential scanning principle and single-field scanning

Measuring Accuracy

The accuracy of angular measurement is mainly determined by:

- Quality of the graduation
- Quality of the scanning process
- Quality of the signal processing electronics
- Eccentricity of the graduation to the bearing
- Error of the bearing
- The coupling to the measured shaft

The **system accuracy** for angle encoders without integral bearing given in the *Specifications* is defined as follows:

The system accuracy reflects position error within one revolution as well as that within one signal period. The extreme values of the total deviations of a position are within the system accuracy $\pm a$.

For **angle encoders without integral bearing**, additional deviations resulting from mounting, error in the bearing of the measured shaft, and adjustment of the scanning head must be expected (see *Application-dependent error*). These deviations are not reflected in the system accuracy.

For **angle encoders with integral bearing** and integrated stator coupling, this value also includes the deviation due to the shaft coupling. For angle encoders with integral bearing and separate shaft coupling, the angle error of the coupling must be added to the system accuracy of the encoder (see *Angle Encoders with Integral Bearing* catalog).

Position errors within one revolution become apparent in larger angular motions.

Position errors within one signal period already become apparent in very small angular motions and in repeated measurements. They especially lead to speed ripples in the speed control loop. These deviations within one signal period are caused by the quality of the sinusoidal scanning signals and their subdivision.

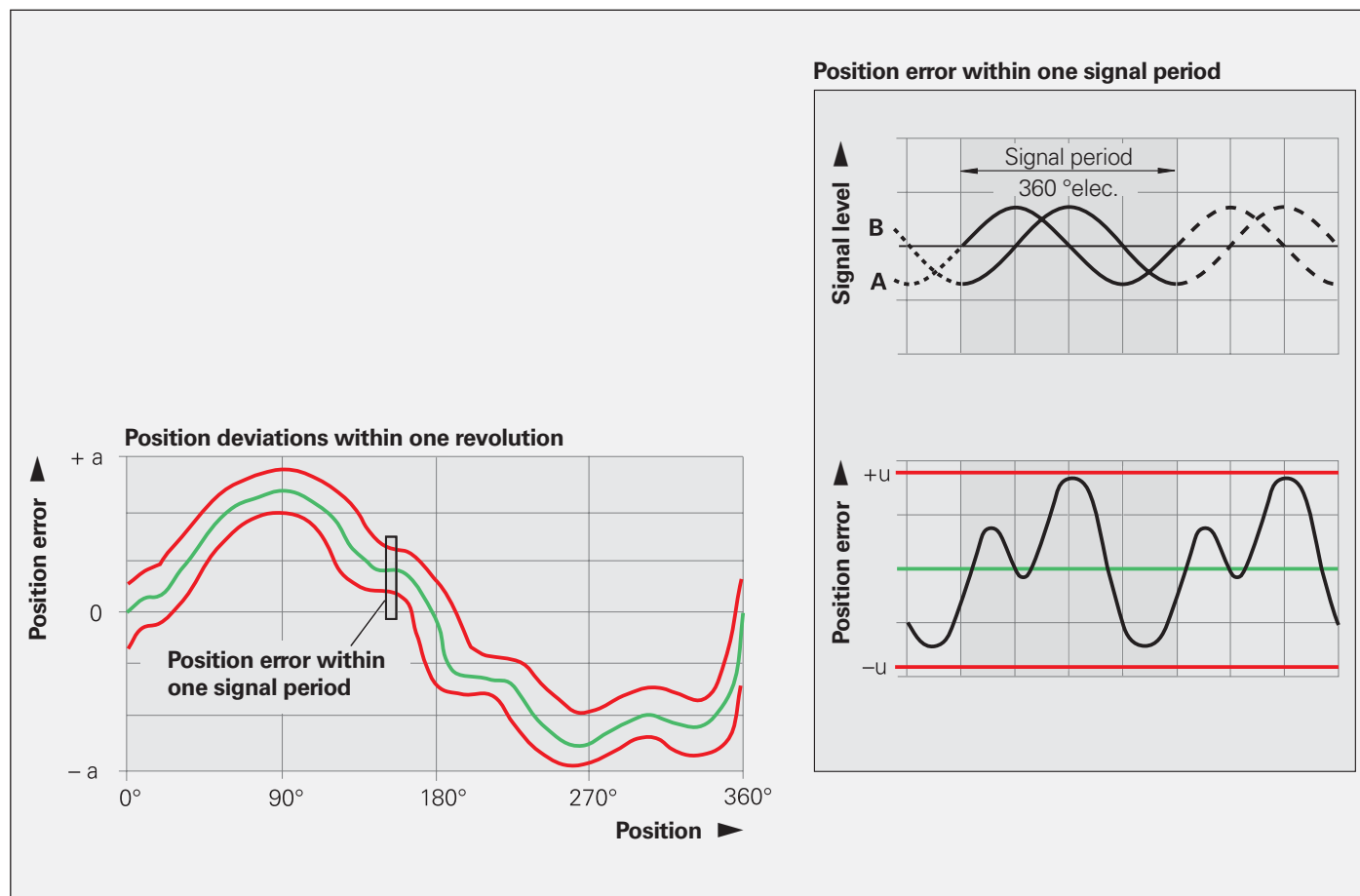
The following factors influence the result:

- The size of the signal period
- The homogeneity and edge definition of the graduation
- The quality of the optical filter structures
- The characteristics of the photoelectric detectors
- The stability and dynamics during the further processing of the analog signals

HEIDENHAIN angle encoders take these factors of influence into account and permit interpolation of the sinusoidal output signal with subdivision accuracies of better than $\pm 1\%$ of the signal period (ERP 880: $\pm 1.5\%$).

Example:

Angle encoder with 32 768 sinusoidal signal periods per revolution
One signal period corresponds to approx. 0.011° , or approx. $40''$. With a signal quality of $\pm 1\%$, this results in maximum position error within one signal period of approx. $\pm 0.00011^\circ$, or approx. $\pm 0.40''$.



For its ERP and ERA 4000 angle encoders, HEIDENHAIN prepares individual calibration charts and ships them with the encoder.

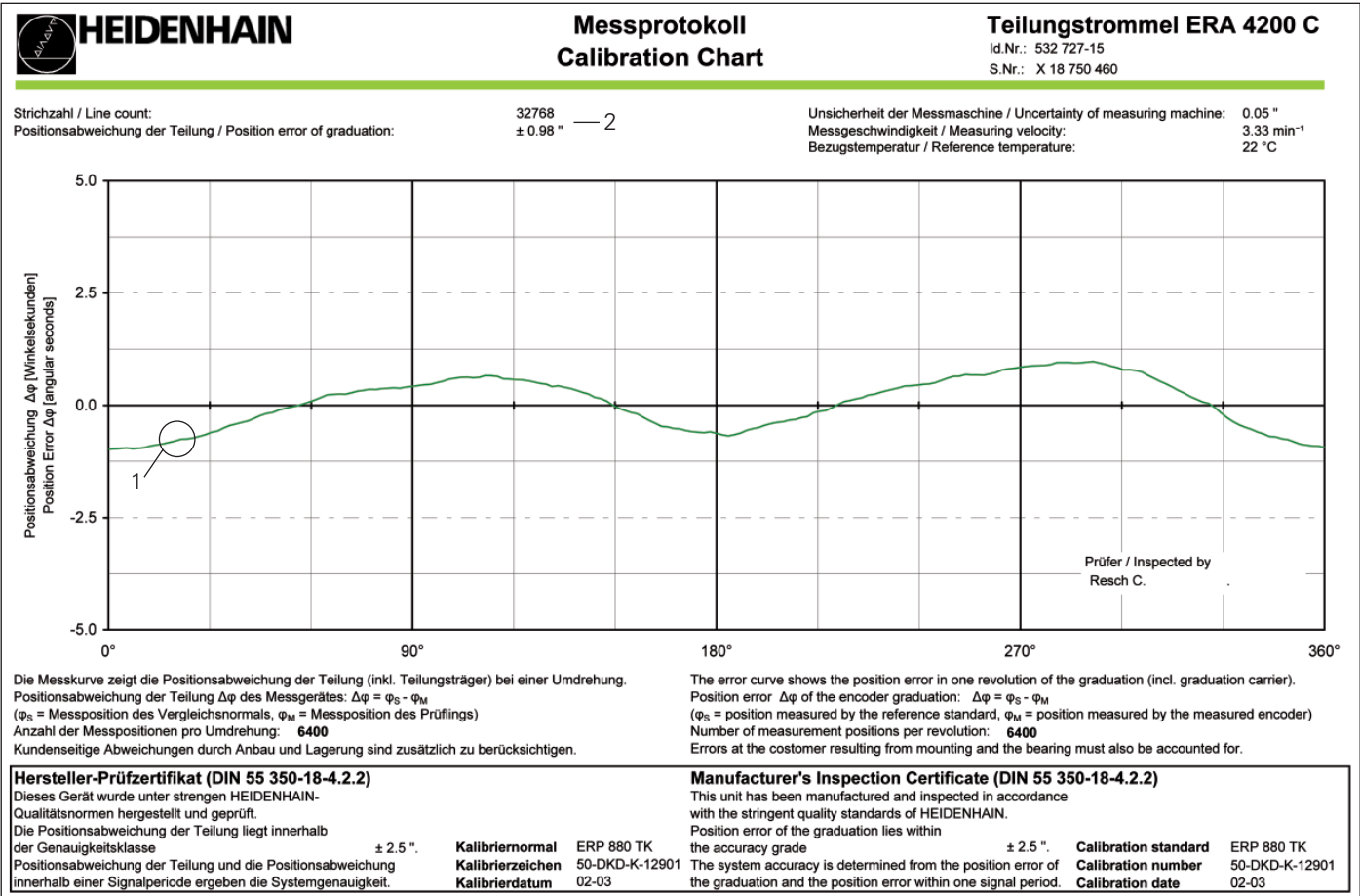
The calibration chart documents the accuracy of the graduation (including its substrate or hub) and serves as a traceability record to a calibration standard. Additional error caused by mounting and the bearing of the measured shaft is not included in the accuracy data.

The graduation accuracy of the ERP and ERA 4000 angle encoders is ascertained through a large number of measuring points during one graduation. The positions per revolution are chosen to include error within the graduation period in the measurement. All measured values acquired in this manner lie within the specified graduation accuracy (see *Specifications*).

The **calibration chart** confirms the specified accuracy of the encoder. The **calibration standard** indicated in the manufacturer's inspection certificate documents traceability to recognized national and international standards. The deviations are ascertained at constant temperatures (22 °C) during the final inspection and are indicated on the calibration chart.

Calibration chart example: ERA 4200C

- 1 Graphic representation of the graduation error
- 2 Result of calibration



Application-Dependent Error

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

In order to evaluate the **total accuracy**, each of the significant errors must be considered individually.

1. Directional deviations of the graduation ERP and ERA 4000

The extreme values of the directional deviation with respect to their mean value are shown in the *Specifications* as the graduation accuracy. The graduation accuracy and the position error within a signal period comprise the system accuracy.

ERA 700 and ERA 800

The extreme values of the directional deviations depend on

- the graduation accuracy (*Specifications*),
- the irregular scale-tape expansion during mounting,
- mounting surface form deviations, and
- deviations in the scale-tape butt joints (only for ERA 780C/ERA 880C).

The special graduation manufacturing process and the butt joints precisely machined by HEIDENHAIN reduce directional deviations of the graduation to within 3 to 5 angular seconds (with accurate mounting).

ERA 781C, ERA 881C, ERA 882C

In these segment solutions, the additional angular error $\Delta\phi$ occurs when the nominal scale-tape bearing-surface diameter is not exactly maintained:

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

where

$\Delta\phi$ = Segment deviation in angular seconds

ϕ = Segment angle in degrees

D = Nominal scale-tape carrier diameter

D' = Actual scale-tape carrier diameter

This error can be eliminated if the line count per 360° z' valid for the actual scale-tape carrier diameter D' can be entered in the control. The following relationship is valid:

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

where z = Nominal line count per 360°

z' = Actual line count per 360°

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

2. Error due to eccentricity of the graduation to the bearing

Under normal circumstances the graduation will have a certain amount of eccentricity to the bearing after the disk/hub assembly (ERP), circumferential-scale drum (ERA 4000) or scale tape (ERA 78xC and ERA 88xC) is mounted. In addition, dimensional and form deviations of the mating shaft caused by the positioning of the centering collar can result in added eccentricity.

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

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

$\Delta\phi$ = Measuring error in " (angular seconds)

e = Eccentricity of the radial grating to the bearing in μm

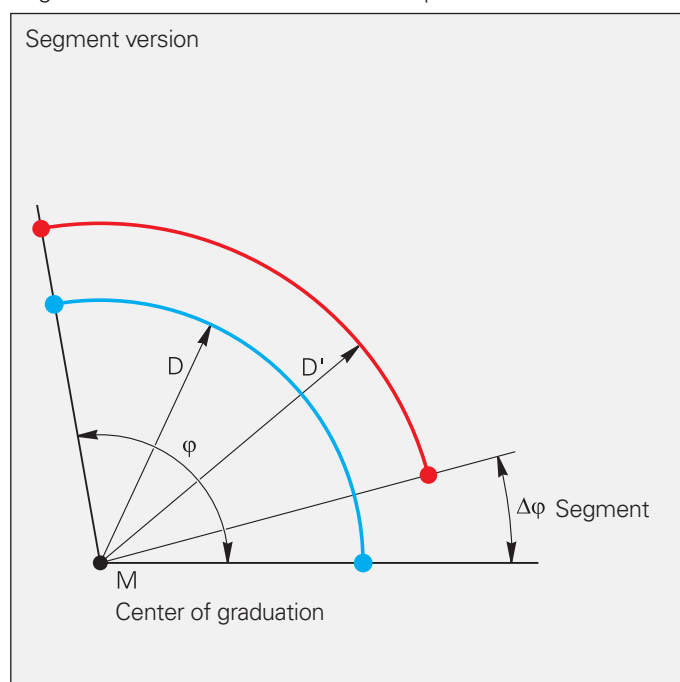
D = Mean graduation diameter (ERP) or drum outside diameter (ERA 4000) and scale-tape carrier diameter (ERA 78xC/ERA 88xC) in mm

M = Center of graduation

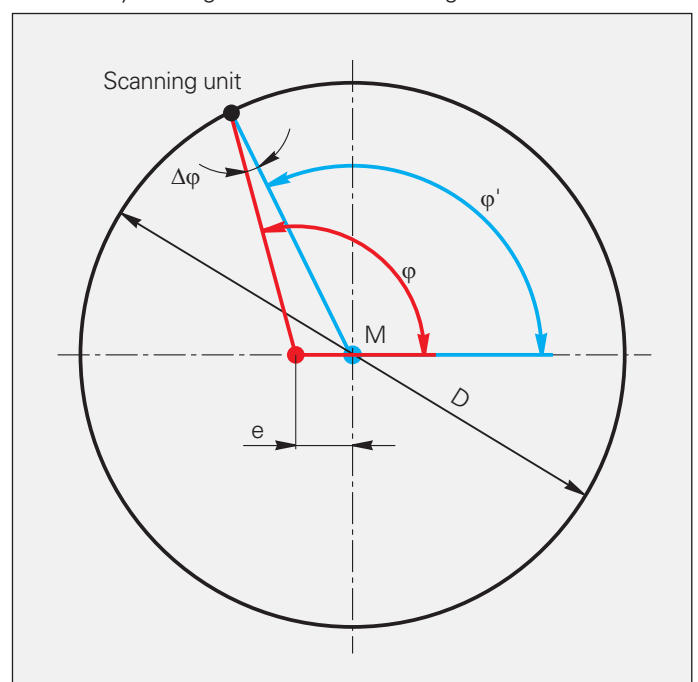
ϕ = "True" angle

ϕ' = Scanned angle

Angular error due to variations in scale-tape carrier diameter



Eccentricity of the graduation to the bearing



Model	Mean graduation diameter D	Deviation per 1 μm eccentricity
ERP 880	D = 126 mm	$\pm 3.3''$
ERP 4080	D = 40 mm	$\pm 10.3''$
ERP 8080	D = 104 mm	$\pm 4.0''$
ERA 4000	D = 53 mm	$\pm 7.8''$
	D = 77 mm	$\pm 5.4''$
	D = 105 mm	$\pm 3.9''$
	D = 128 mm	$\pm 3.2''$
	D = 153 mm	$\pm 2.7''$
	D = 179 mm	$\pm 2.3''$
	D = 209 mm	$\pm 2.0''$
	D = 255 mm	$\pm 1.6''$
	D = 306 mm	$\pm 1.3''$
	D = 331 mm	$\pm 1.2''$
	D = 484 mm	$\pm 0.9''$
	D = 560 mm	$\pm 0.7''$
ERA 78xC	D = 320 mm	$\pm 1.3''$
	D = 460 mm	$\pm 0.9''$
	D = 570 mm	$\pm 0.7''$
	D = 1 145 mm	$\pm 0.4''$
ERA 88xC	D = 320 mm	$\pm 1.3''$
	D = 460 mm	$\pm 0.9''$
	D = 570 mm	$\pm 0.7''$

3. Error due to radial deviation of the bearing

The equation for the measuring error $\Delta\phi$ is also valid for radial deviation of the bearing if the value e is replaced with the eccentricity value, i.e. half of the radial deviation (half of the displayed value).

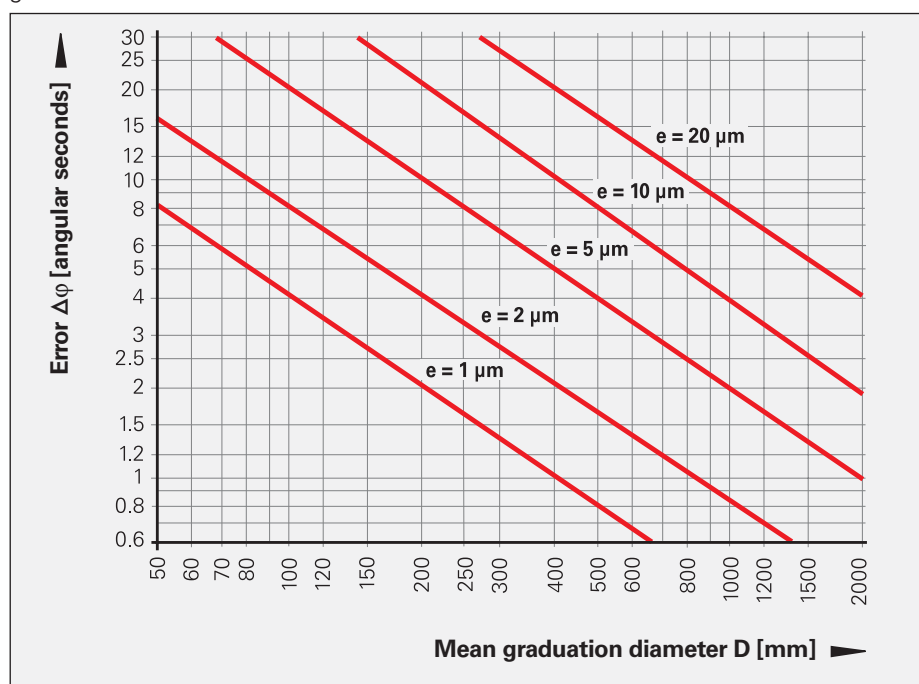
Bearing compliance to radial shaft loading causes similar errors.

4. Position error within one signal period $\Delta\phi_u$

The scanning units of all HEIDENHAIN encoders are adjusted so that, with no further electrical adjustment during mounting, the maximum position error within one signal period remains within $\pm 1\%$ (ERP 880: $\pm 1.5\%$). Below are the values for the ERP and ERA 4000 encoders as an example:

Model	Line count	Position error within one signal period $\Delta\phi_u$
ERP 880	90 000 ($\geq 180\,000$ signal periods)	$\leq \pm 0.1''$
ERP 4080	65 536 ($\geq 131\,072$ signal periods)	$\leq \pm 0.1''$
ERP 8080	180 000 ($\geq 360\,000$ signal periods)	$\leq \pm 0.04''$
ERA 4000	3000	$\leq \pm 4.4''$
	4096	$\leq \pm 3.2''$
	5000	$\leq \pm 2.6''$
	6000	$\leq \pm 2.2''$
	7000	$\leq \pm 1.9''$
	8192	$\leq \pm 1.6''$
	10000	$\leq \pm 1.3''$
	12000	$\leq \pm 1.1''$
	13000	$\leq \pm 1.0''$
	14000	$\leq \pm 1.0''$
	16384	$\leq \pm 0.8''$
	20000	$\leq \pm 0.7''$
	24000	$\leq \pm 0.6''$
	26000	$\leq \pm 0.5''$
	28000	$\leq \pm 0.5''$
	32768	$\leq \pm 0.4''$
	38000	$\leq \pm 0.4''$
	40000	$\leq \pm 0.4''$
	44000	$\leq \pm 0.3''$
	48000	$\leq \pm 0.3''$
	52000	$\leq \pm 0.3''$

Resultant measured deviations $\Delta\phi$ for various eccentricity values e as a function of mean graduation diameter D



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

Mechanical Design Types and Mounting

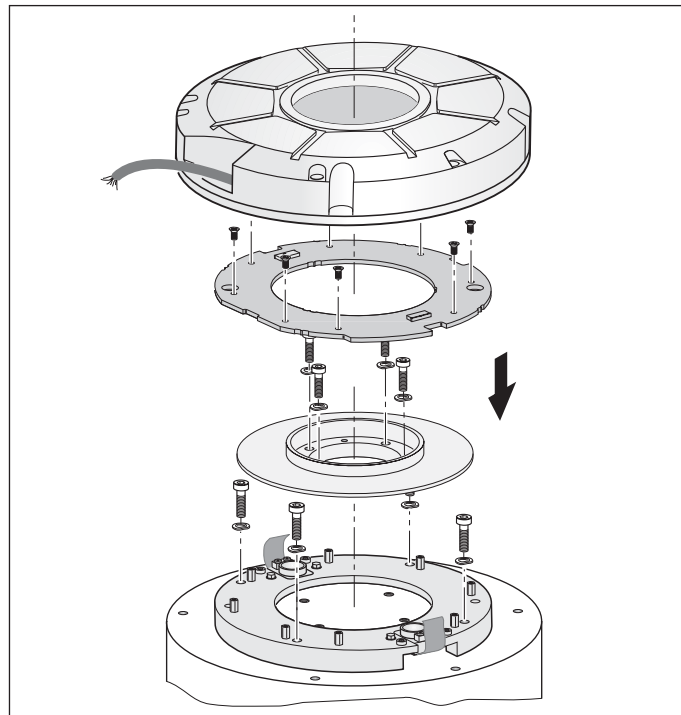
ERP 880

The ERP 880 modular angle encoder consists of the following components: scanning unit, disk/hub assembly, and PCB. Cover caps for protection from contact or contamination can be supplied as accessories.

Mounting the ERP 880

First the scanning unit is mounted on the stationary machine part with an alignment of $\pm 1.5 \mu\text{m}$ to the shaft. Then the front side of the disk/hub assembly is screwed onto the shaft, and is also aligned with a maximum eccentricity of $\pm 1.5 \mu\text{m}$ to the scanning unit. Then the PCB is attached and connected to the scanning unit. Fine adjustment takes place with "electrical centering" using the PWM 9 (see *HEIDENHAIN Measuring Equipment*) and an oscilloscope. The ERP 880 can be protected from contamination by covering it with a housing.

Mounting the
ERP 880
(in principle)



IP 40 housing

With sealing ring for IP 40 protection
Cable, 1 m, with male coupling, 12-pin
ID 369 774-01

IP 64 housing

With shaft sealing ring for IP 64 protection
Cable, 1 m, with male coupling, 12-pin
ID 369 774-02



ERP 4080/ERP 8080

The ERP 4080 and ERP 8080 modular angle encoders are high-precision encoders with interferential scanning of a special phase grating. They consist of a scanning head and a disk/hub assembly.

Determining the axial mounting tolerance

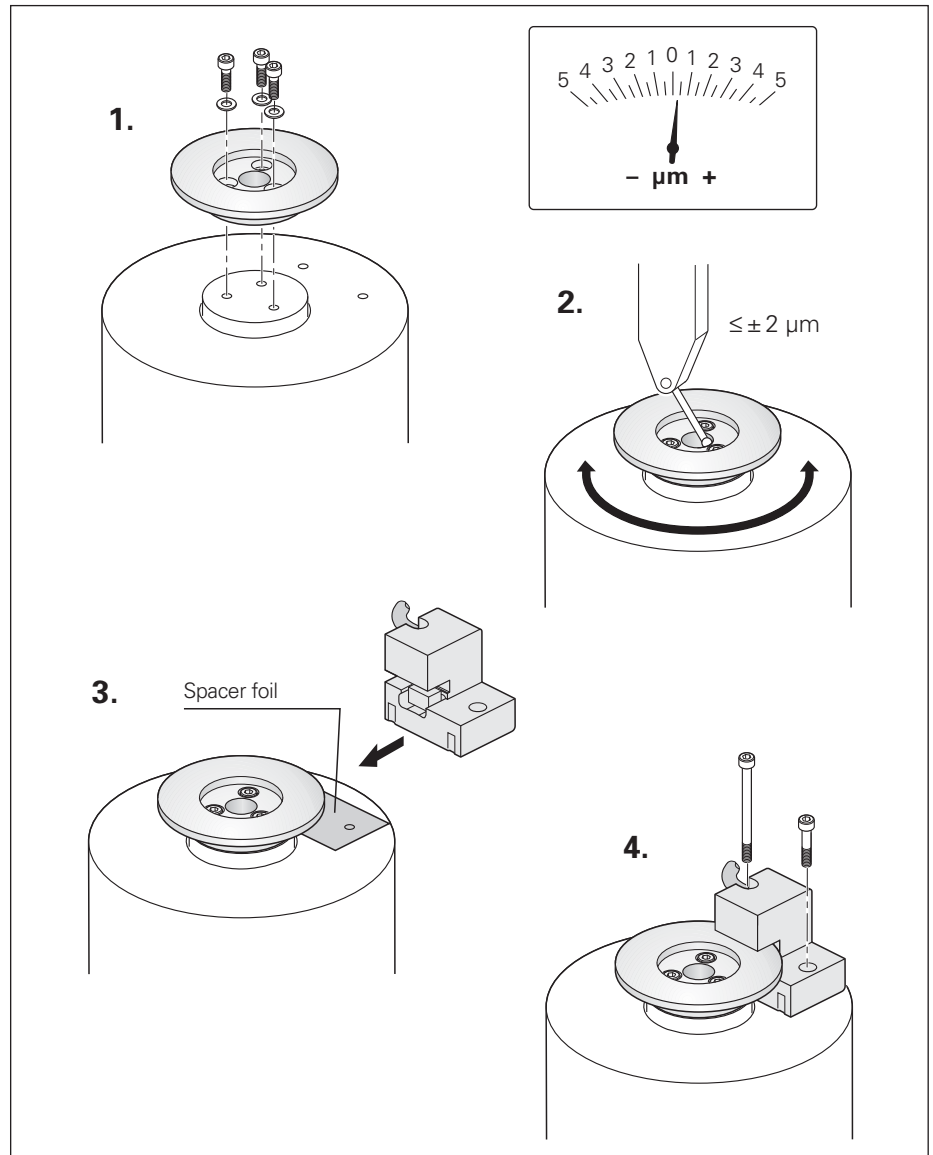
To attain the greatest possible accuracy, it is important to ensure that the wobble of the shaft and the wobble of the disk/hub assembly do not add to each other. The positions of the maximum and minimum wobble of the hub are marked on the graduated disk. The wobble of the shaft is determined by measuring at various positions the maximum and minimum distances between the bearing surfaces for the hub and the scanning head. The disk/hub assembly is mounted in such a way that the position with the maximum value marked on the graduated disk is aligned with the position with the minimum difference value, and the position with the minimum value marked on the graduated disk is aligned with the position with the maximum difference value.

Mounting the disk/hub assembly

The disk/hub assembly is slid onto the drive shaft, centered using the inside diameter of the hub, and fastened with screws. A dial gauge or a centering ball (only for ERP 4080) can be used for centering on the mating shaft. For high-accuracy applications, the graduated disk can be centered optically (using a centering circle) or electrically (using the phase shift of a second, diametrically opposed scanning head).

Mounting the scanning head

The scanning head is fastened with two screws (or with the mounting aid) and the appropriate spacer foils on the mounting surface so that it can be moved. The scanning head is adjusted electronically with the aid of the PWM 9 or PWT 18 (see HEIDENHAIN Measuring Equipment) by moving the scanning head within the mounting holes until the output signals reach an amplitude of $\geq 0.9 V_{PP}$.



Accessories

Mounting aid

For adjusting the scanning head
ID 622 976-02

Adapter for length gauges

For measuring the mounting tolerances
ID 627 142-01

Spacer foils

For axial position adjustment

10 μm	ID 619943-01
20 μm	ID 619943-02
30 μm	ID 619943-03
40 μm	ID 619943-04
50 μm	ID 619943-05
60 μm	ID 619943-06
70 μm	ID 619943-07
80 μm	ID 619943-08
90 μm	ID 619943-09
100 μm	ID 619943-10

Set (one foil per gap from
10 μm to 100 μm): ID 619943-11

ERA 4000 Series

The ERA 4000 modular angle encoders are supplied as two components: the scale drum and the scanning head.

The **scanning heads** of the ERA 4000 series feature very compact dimensions. The **scale drums** of the ERA 4000 are available in three versions to suit the particular application. The ERA 4x80 and ERA 4x81 versions are available with various grating periods depending on the accuracy requirements. The appropriate scanning heads are shown in the table at right. Special design measures are required to protect the ERA from contamination. The ERA 4480 angle encoders are also available for various drum diameters with a protective cover. A special scanning head (with compressed-air inlet) is needed for versions with protective cover. The protective cover suited to the scale drum diameter must be ordered separately.

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

Mounting the ERA 4x00C scale drum

The solid circumferential scale drum is slid onto the drive shaft and fastened with screws. The scale drum is centered via the **centering collar** on its inner circumference. HEIDENHAIN recommends using a slight oversize on the shaft for mounting the scale drum. For mounting, the scale drum may be slowly warmed on a heating plate over a period of approx. 10 minutes to a maximum temperature of 100 °C.

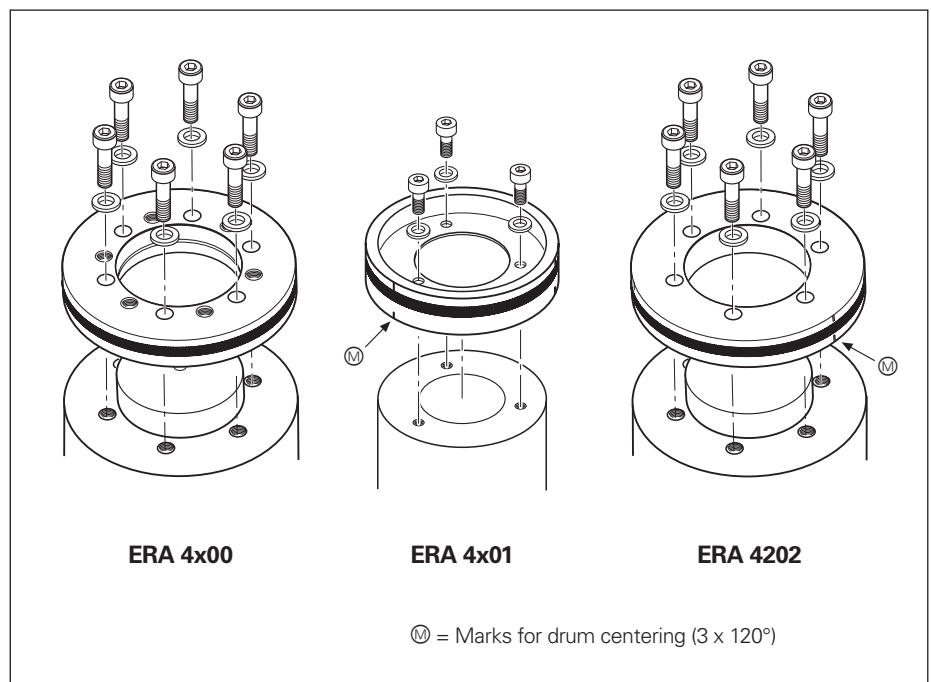
Mounting the ERA 4x01 scale drum

The scale drum has a T-section and is centered over three positions at 120° increments on its circumference and fastened with screws. Negative influences on accuracy caused by deviations of the drive shaft, such as radial runout, can be avoided through this type of centering. The positions for centering are marked on the scale drum.

Mounting the ERA 4202 scale drum

The solid scale drum is centered over three positions at 120° increments on its circumference and fastened with screws. The benefits of three-point centering and the solid design of the scale drum make it possible to attain a very high accuracy when the encoder is mounted. The positions for centering are marked on the scale drum.

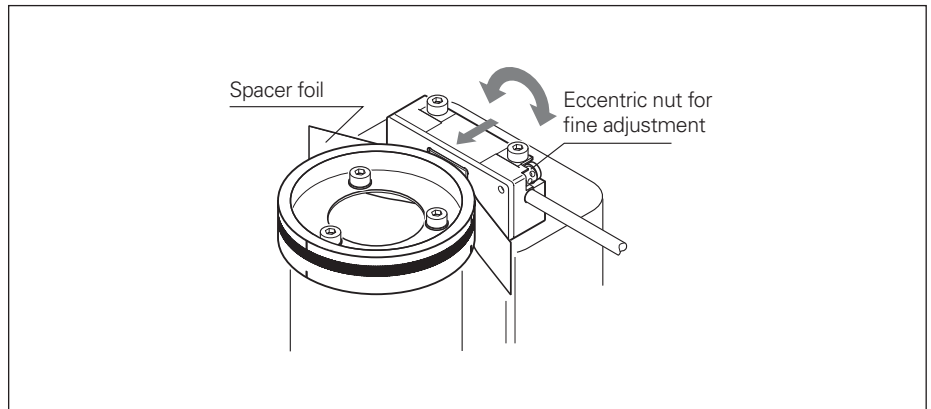
Application	Scale drum	Grating periods	Model	Fitting scanning head
High shaft speeds	Solid version with centering collar	20 µm	ERA 4200	ERA 4280
		40 µm	ERA 4400	ERA 4480
		80 µm	ERA 4800	ERA 4880
Low weight, low moment of inertia	T section, 3-point centering	20 µm	ERA 4201	ERA 4280
		40 µm	ERA 4401	ERA 4480
Increased positioning accuracy and high shaft speeds	Solid version, 3-point centering	20 µm	ERA 4202	ERA 4280



Mounting the scale drums

Mounting the scanning head

To mount the scanning head, the spacer foil is placed on the surface of the scale drum. The scanning head is pressed against the foil, fastened, and the foil is removed. ERA 4000 encoders with 20 µm grating period also feature an eccentric nut for fine adjustment of the scanning field.

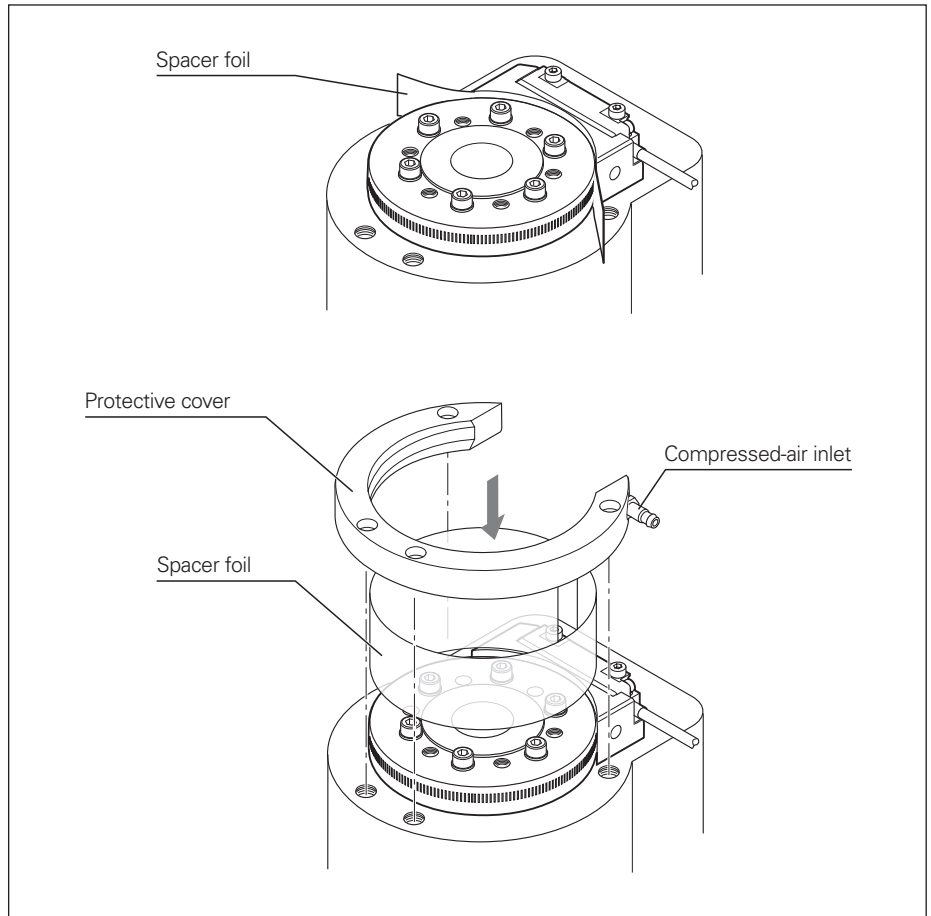


Mounting the scanning head (ERA 4280 as example)

Mounting the protective cover

The ERA 4480 modular angle encoders are available for various diameters with a protective cover. This provides additional protection against contamination when compressed air is applied.

The scale drum and the scanning unit are mounted as described above. The spacer foil that is specifically supplied with the protective cover is placed around the scale drum. It protects the scale drum when mounting the protective cover, and ensures that a constant scanning gap is maintained. Then the protective cover is slid onto the scale drum and secured. The spacer foil is removed. For information about the compressed-air inlet see *General Mechanical Information*.



Mounting an ERA 4480 with protective cover

Mechanical Design Types and Mounting

ERA 700 and ERA 800 Series

The ERA 700 and ERA 800 angle encoders consist of a scanning unit and a one-piece steel scale tape. The steel scale tape is available up to a length of 30 m.

The tape is mounted on the

- **inside diameter** (ERA 700 series), or
- **outside diameter** (ERA 800 series) of a machine element.

The ERA 780C und ERA 880C angle encoders are designed for **full-circle applications**. Thus, they are particularly well suited to hollow shafts with large inside diameters (from approx. 300 mm) and to applications requiring an accurate measurement over a large circumference, e.g. large rotary tables, telescopes, etc.

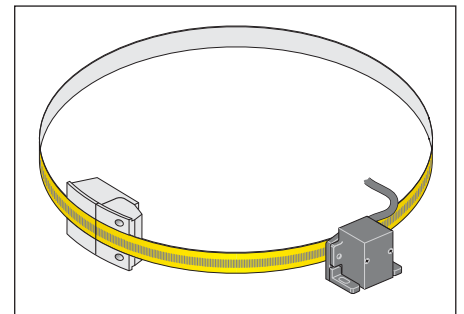
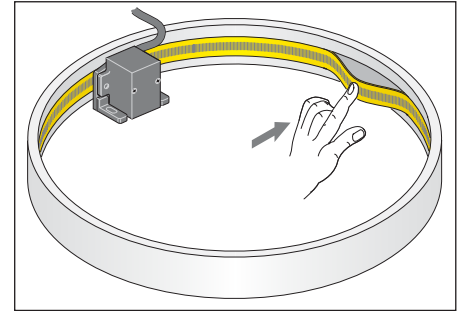
For applications where there is no full circle, or measurement is not required over 360°, **segment angles** are available for diameters from 300 mm.

Mounting the scale tape for full-circle applications

ERA 780C: An **internal slot** with a certain diameter is required as scale tape carrier. The 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. To make sure that the scale tape does not move within the slot, it is fixed with adhesive at multiple points in the area of the butt joint.

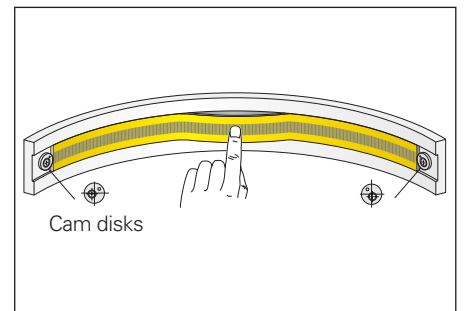
ERA 880C: The scale tape is supplied with the halves of the tensioning cleat already mounted on the tape ends. An **external slot** is necessary for mounting. Space must also be provided for the tensioning cleat. The tape is placed in the outside slot of the machine (along slot edge) and is tensioned using the tensioning cleat.

The scale tape ends are manufactured so exactly that only minor signal-form deviations can occur in the area of the butt joint.

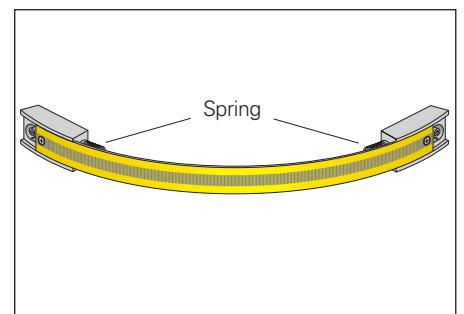


Mounting the scale tape for segment angles

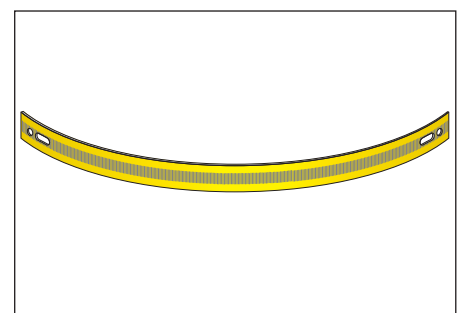
ERA 781C: An internal slot with a certain diameter is required. The two cam disks fixed in this slot are adjusted so that the scale can be snapped into the slot under pressure.



ERA 881C: The scale tape is supplied with premounted end pieces. An external slot with recesses for the bearing pieces is required for placing the scale tape. The scale tape is fitted with tension springs, which create an optimal bearing preload for increasing the accuracy of the scale tape, and evenly distribute the expansion over the entire length of the scale tape.



ERA 882C: An external slot or one-sided axial stop is recommended for placing the scale tape. The scale tape is supplied without tensioning elements. It must be preloaded with a spring balance, and fixed with the two oblong holes.



The following must be kept in mind for segment applications:

- **Specification of slot-floor diameter**

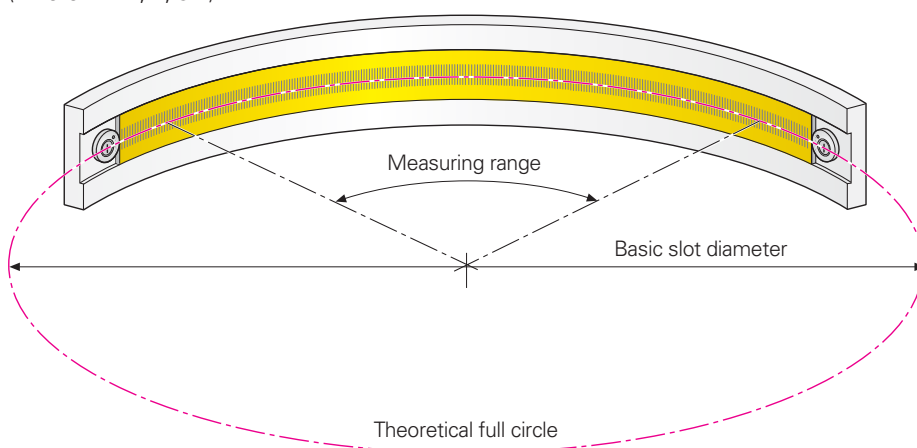
In order to guarantee the correct functioning of the distance-coded reference marks, the circumference of the theoretical full circle must be a multiple of 1000 grating periods. This also facilitates adaptation to the NC control, which mostly can only calculate integer line counts. The connection between the basic slot diameter and the line count can be seen in the table.

- **Segment angle**

The measuring range for the segment angle should be a multiple of 1000 signal periods, since these versions can be supplied sooner.

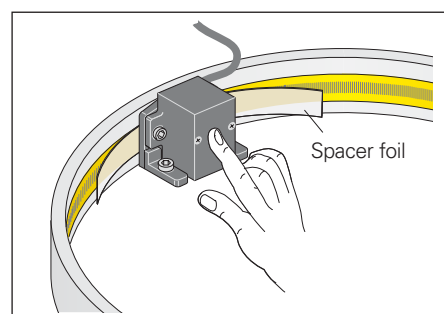
	Basic slot diameter	Line count projected onto a full circle
ERA 781 C	$318.58 + n \cdot 12.73111$	$25000 + n \cdot 1000$
ERA 881 C/ ERA 882 C	$317.99 + n \cdot 12.73178$	$25000 + n \cdot 1000$

(where $n = 1, 2, 3 \dots$)



Mounting the scanning head

A spacer foil is placed against the scale tape. The mounting bracket of the scanning head is pushed up against the spacer foil in such a way that the foil is only located between the two mechanical support points on the mounting bracket. First the mounting bracket and then the scanning head is secured in this position and the foil is removed.

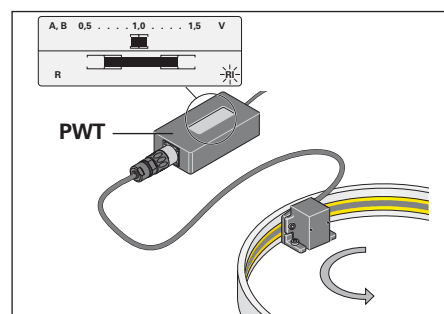


Adjusting the scanning head

Accurate alignment of the scanning head with the scale tape is critical for the ERA 700/800 to provide accurate and reliable measurements (Moiré setting). If the scanning head is not properly aligned, the quality of the output signals will be poor.

The quality of the output signals can be checked using HEIDENHAIN's **PWT phase-angle testing unit**. When the scanning head is moved along the scale tape, the PWT unit graphically displays the quality of the signals as well as the position of the reference mark.

The **PWM 9 phase angle measuring unit** calculates a quantitative value for the deviation of the actual output signals from the ideal signal (see *HEIDENHAIN Measuring Equipment*).



General Mechanical Information

Protection

For angle encoders **without integral bearing**, the necessary protection against contamination and contact must be ensured during installation through design measures such as additional labyrinth seals.

Unless otherwise indicated, all RCN, RON, RPN and ROD angle encoders **with integral bearing** meet protection standard IP 67 according to EN 60529 or IEC 60529 for the housing and cable outlet, and IP 64 at shaft inlet.

Some versions of the ERA 4480 angle encoders up to the drum inside diameter of 180 mm are available with an optional protective cover. Connection to a source of compressed air slightly above atmospheric pressure provides additional protection against contamination.

The compressed air introduced directly onto the encoders must be appropriately conditioned, and must comply with the following quality classes as per **ISO 8573-1** (1995 edition):

- Solid contaminants: Class 1 (max. particle size 0.1 μm and max. particle density 0.1 mg/m^3 at $1 \cdot 10^5$ Pa)
- Total oil content: Class 1 (max. oil concentration 0.01 mg/m^3 at $1 \cdot 10^5$ Pa)
- Max. pressure dew point: Class 4, but with reference conditions of +3 °C at $2 \cdot 10^5$ Pa

The required air flow varies depending on the encoder (e.g. 7 to 10 l/min per linear encoder); permissible pressure is in the range of 0.6 to 1 bar (9 to 14 psi). The compressed air must flow through connecting pieces with integrated throttle.

Accessories:

Connecting piece, straight
with throttle and gasket
ID 226270-xx

Connecting piece, straight, short
with throttle and gasket
ID 275239-xx

M5 coupling joint, swiveling
with seal
ID 207834-xx

HEIDENHAIN offers the **DA 300 compressed air unit** for purifying and conditioning compressed air. It consists of two filter stages (fine filter and activated carbon filter), automatic condensation trap, and a pressure regulator with pressure gauge. It also includes 25 meters of pressure tubing, as well as T-joints and connecting pieces for four encoders. The DA 300 can supply air for up to 10 encoders with a maximum total measuring length of 35 meters.

Accessories:

DA 300 compressed air unit
ID 348249-01

The compressed air introduced into the DA 300 must fulfill the requirements of the following quality classes as per ISO 8573-1 (1995 edition):

- Max. particle size and density of solid contaminants:
Class 4 (max. particle size 15 μm , max. particle density 8 mg/m^3)
- Total oil content:
Class 4 (oil content: 5 mg/m^3)
- Max. pressure dew point:
Not defined
Class 7

DA 300



For more information, ask for our *DA 300* Product Information sheet.

Temperature range

The angle encoders are inspected at a **reference temperature** of 22 °C. The system accuracy given in the calibration chart applies at this temperature.

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

The **storage temperature range** of –30 °C to +80 °C is valid when the unit remains in its packaging (ERP 4080/ERP 8080: 0 °C to 60 °C).

Protection against contact

After encoder installation, all rotating parts must be protected against accidental contact during operation.

Acceleration

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

- The indicated maximum values for **vibration** are valid according to IEC 60068-2-6.
- The maximum permissible acceleration values (semi-sinusoidal shock) for **shock and impact** are valid for 6 ms (IEC 60068-2-27).
Under no circumstances should a hammer or similar implement be used to adjust or position the encoder.

Rotational velocity

The maximum permissible shaft speeds for the ERA 4000 angle encoders series were determined according to FKM guidelines. This guideline serves as mathematical attestation of component strength with regard to all relevant influences and it reflects the latest state of the art. The requirements for fatigue strength (10^7 changes of load) were considered in the calculation of the permissible shaft speeds. Because installation has significant influence, all requirements and instructions in the Specifications and Mounting Instructions must be followed for the rotational velocity data to be valid.

Parts subject to wear

HEIDENHAIN encoders contain components that are subject to wear, depending on the application and manipulation. These include in particular the following parts:

- LED light source
- Cables with frequent flexing

System tests

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

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

Mounting

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

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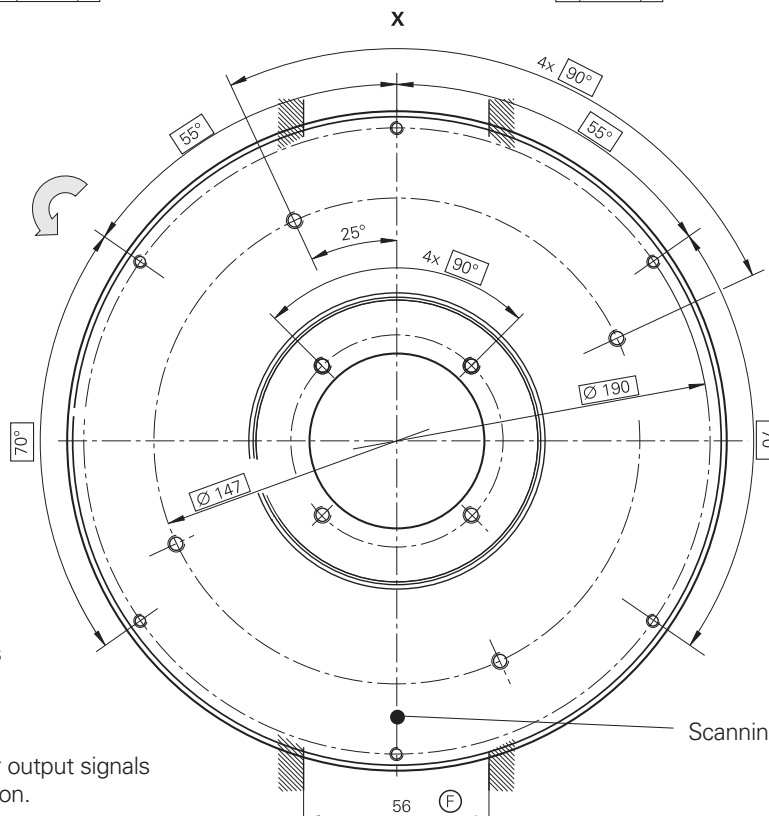
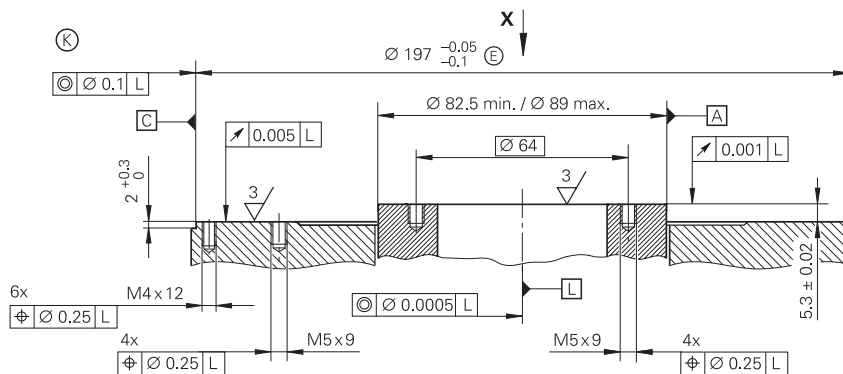
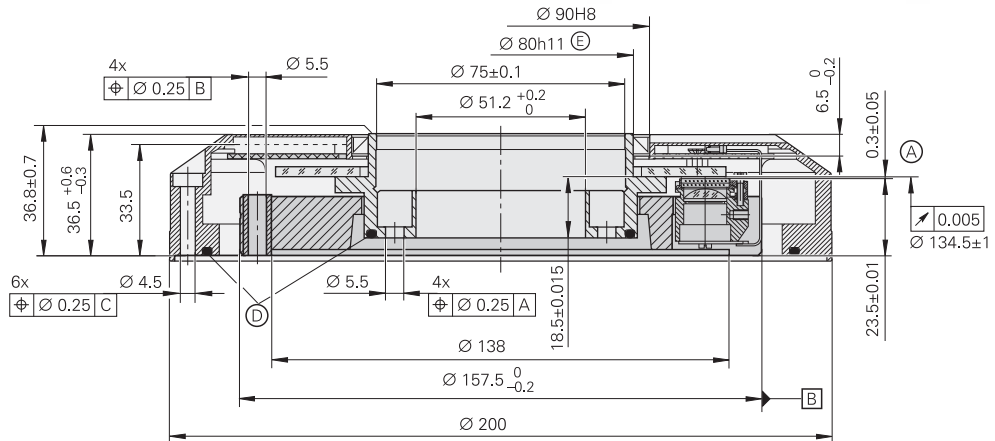
ERP 880

- High accuracy
due to interferential scanning principle

Dimensions in mm



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



Cable radial, also usable axially

Ⓐ = Disk-to-scanning-reticle gap

Ⓚ = Required mating dimensions

Ⓛ = Space needed for service

Ⓢ = Seal

Ⓜ = Axis of bearing rotation

↻ Direction of shaft rotation for output signals
as per the interface description.

	Incremental ERP 880		
Incremental signals	$\sim 1\text{ V}_{\text{PP}}$		
Line count	90 000 ($\triangleq$ 180 000 signal periods)		
Reference mark	One		
Cutoff frequency	-3 dB -6 dB	$\geq 800\text{ kHz}$ $\geq 1.3\text{ MHz}$	
Recommended measuring step for position measurement	0.00001°		
System accuracy ¹⁾	$\pm 1''$		
Accuracy of graduation	$\pm 0.9''$ (without hub)		
Power supply without load	5 V $\pm$ 10 %/max. 250 mA		
Electrical connection	With housing: Cable 1 m, with M23 coupling Without housing: Via 12-pin PCB connector (adapter cable ID 372 164-xx)		
Cable length	$\leq 150\text{ m}$ (with HEIDENHAIN cable)		
Hub inside diameter	51.2 mm		
Mech. permissible speed	$\leq 1\,000\text{ min}^{-1}$		
Moment of inertia of rotor	$1.2 \cdot 10^{-3}\text{ kgm}^2$		
Permissible axial motion of measured shaft	$\leq \pm 0.05\text{ mm}$		
Vibration 55 to 2000 Hz Shock 6 ms	$\leq 50\text{ m/s}^2$ (IEC 60068-2-6) $\leq 1\,000\text{ m/s}^2$ (IEC 60068-2-27)		
Operating temperature	0 °C to 50 °C		
Protection* IEC 60529	Without housing: IP 00	With housing: IP 40	With housing and shaft seal: IP 64
Starting torque	–		0.25 Nm
Weight	3.0 kg	3.1 kg incl. housing	

* Please indicate when ordering

¹⁾ Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.

ERP 4080/ERP 8080

- High accuracy
due to interferential scanning principle
- Compact design

Dimensions in mm



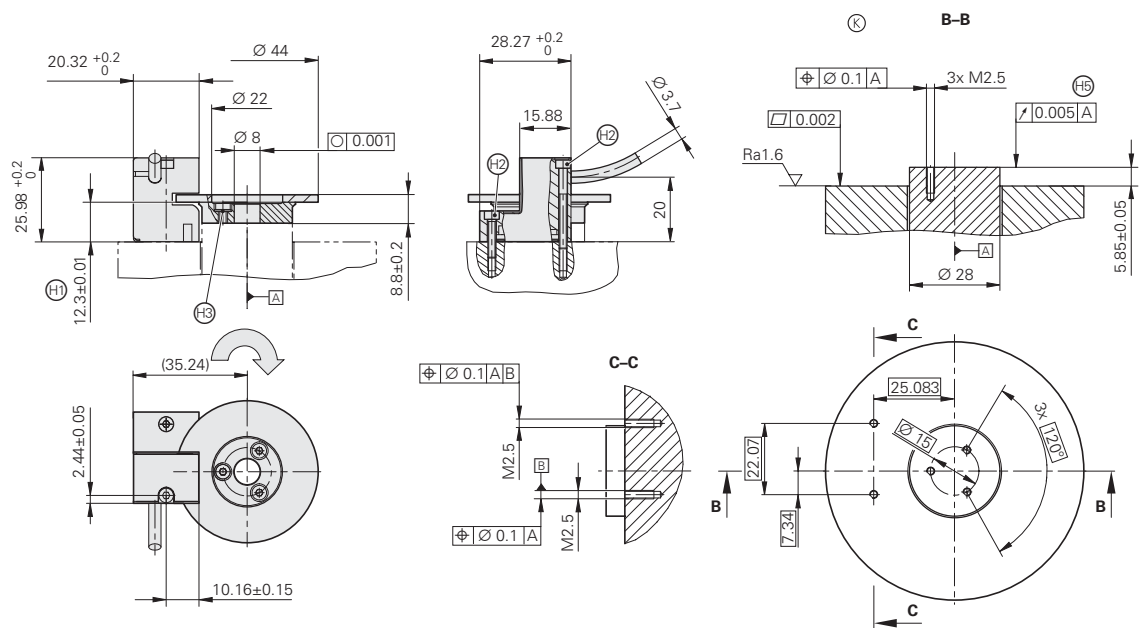
Tolerancing ISO 8015

ISO 2768 - m H

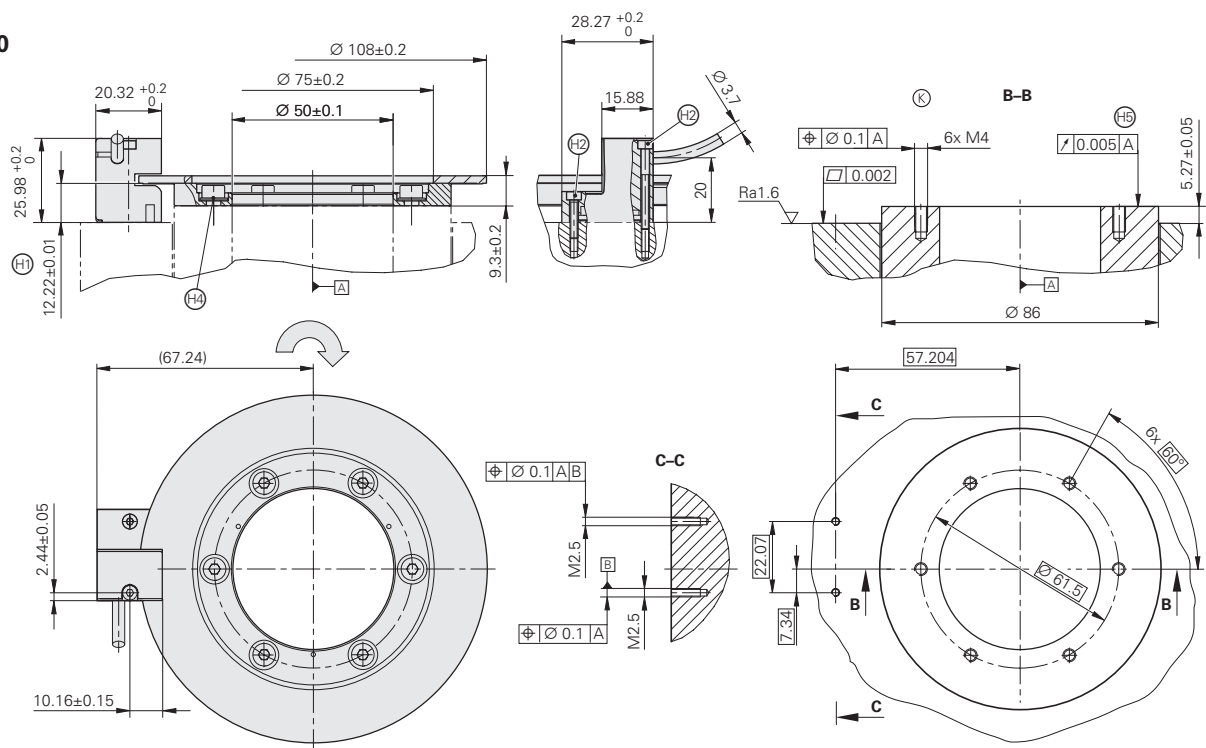
< 6 mm: ± 0.2 mm



ERP 4080



ERP 8080



Ⓐ = Bearing

Ⓚ = Required mating dimensions

Ⓜ = Mounting clearance set with spacer foil

Ⓜ = Cylinder head screw ISO 4762-A2-M2.5

Ⓜ = Cylinder head screw ISO 4762-A2-M2.5 and washer ISO 7089-2.5-140HV-A2

Ⓜ = Cylinder head screw ISO 4762-A2-M4 and washer ISO 7089-4-140HV-A2

Ⓜ = Mounting surface not convex

↻ Direction of shaft rotation for output signals as per the interface description.

	Incremental	
	ERP 4080	ERP 8080
Incremental signals	$\sim 1 V_{PP}$	
Line count	65 536 ($\pm 131\,072$ signal periods)	180 000 ($\pm 360\,000$ signal periods)
Reference mark	None	
Cutoff frequency –3 dB	≥ 250 kHz	
Recommended measuring step for position measurement	0.000 01°	0.000 005°
System accuracy ¹⁾	$\pm 5''$	$\pm 2''$
Accuracy of graduation	$\pm 2''$ (without hub)	$\pm 1''$ (without hub)
Power supply without load	5 V $\pm$ 5%/max. 150 mA	
Electrical connection	Cable 1 m, with D-sub connector 15-pin	
Cable length	≤ 30 m (with HEIDENHAIN cable)	
Hub inside diameter	8 mm	50 mm
Mech. permissible speed	$\leq 300 \text{ min}^{-1}$	$\leq 100 \text{ min}^{-1}$
Moment of inertia of rotor	$5 \cdot 10^{-6} \text{ kgm}^2$	$250 \cdot 10^{-6} \text{ kgm}^2$
Permissible axial motion of measured shaft	$\leq \pm 0.01$ mm (including wobble)	
Vibration 55 to 2 000 Hz Shock 6 ms	$\leq 50 \text{ m/s}^2$ (IEC 60 068-2-6) $\leq 500 \text{ m/s}^2$ (IEC 60 068-2-27)	
Operating temperature	15 °C to 40 °C	
Protection IEC 60529	IP 00 (for clean room application)	
Weight		
Disk/hub assembly	Approx. 0.036 kg	Approx. 0.180 kg
Scanning head without cable	Approx. 0.033 kg	

¹⁾ Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.

ERA 4280C, ERA 4480C, ERA 4880C

- Steel circumferential-scale drum with centering collar
- Optional protective cover available for ERA 4480C



ERA 4000



ERA 4000 with protective cover

Incremental signals	
Reference marks	
Cutoff frequency –3dB	
Power supply without load	
Electrical connection	
Cable length	
Drum inside diameter*	
Drum outside diameter*	
Line count	ERA 4280C
	ERA 4480C
	ERA 4880C
System accuracy ¹⁾	ERA 4280C
	ERA 4480C
	ERA 4880C
Accuracy of the graduation ²⁾	
Mech. permissible speed	
Moment of inertia of rotor	
Permissible axial motion	
Vibration 55 to 2000 Hz	
Shock 6 ms	
Operating temperature	
Protection* IEC 60529	
Without protective cover	
With protective cover ³⁾ and compressed air	
Weight (approx.)	Scale drum
	Protective cover
Scanning head without cable	

ERA 4280C grating period 20 μm—consisting of ERA 4280 scanning head and ERA 4200C drum ERA 4480C grating period 40 μm—consisting of ERA 4480 scanning head and ERA 4400C drum ERA 4880C grating period 80 μm—consisting of ERA 4880 scanning head and ERA 4800C drum									
~ 1 V _{pp}									
Distance-coded									
≥ 350 kHz									
5 V ± 10%/max. 100 mA									
Cable, 1 m, with M23 coupling (12-pin)									
≤ 150 m (with HEIDENHAIN cable)									
40 mm	70 mm	80 mm	120 mm	150 mm	180 mm	270 mm	425 mm	512 mm	
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	
12 000	16 384	20 000	28 000	32 768	40 000	52 000	–	–	
6 000	8 192	10 000	14 000	16 384	20 000	26 000	38 000	44 000	
3 000	4 096	5 000	7 000	8 192	10 000	13 000	–	–	
± 6.1"	± 4.5"	± 3.7"	± 3.0"	± 2.9"	± 2.9"	± 2.8"	–	–	
± 7.2"	± 5.3"	± 4.3"	± 3.5"	± 3.3"	± 3.2"	± 3.0"	± 2.4"	± 2.3"	
± 9.4"	± 6.9"	± 5.6"	± 4.4"	± 4.1"	± 3.8"	± 3.5"	–	–	
± 5"	± 3.7"	± 3"	± 2.5"				± 2"		
10 000 min ^{−1}	8 500 min ^{−1}	6 250 min ^{−1}	4 500 min ^{−1}	4 250 min ^{−1}	3 250 min ^{−1}	2 500 min ^{−1}	1 800 min ^{−1}	1 500 min ^{−1}	
0.27 · 10 ^{−3} kgm ²	0.81 · 10 ^{−3} kgm ²	1.9 · 10 ^{−3} kgm ²	7.1 · 10 ^{−3} kgm ²	12 · 10 ^{−3} kgm ²	28 · 10 ^{−3} kgm ²	59 · 10 ^{−3} kgm ²	195 · 10 ^{−3} kgm ²	258 · 10 ^{−3} kgm ²	
≤ ± 0.5 mm (scale drum relative to scanning head)									
≤ 200 m/s ² (IEC 60068-2-6) ≤ 1 000 m/s ² (IEC 60068-2-27)									
−10 °C to 80 °C (coefficient of expansion of the scale drum approx. 10.5 · 10 ^{−6} K ^{−1})									
IP 00									
IP 40	–	IP 40	IP 40	–	IP 40	–			
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	
0.07 kg	–	0.12 kg	0.17 kg	–	0.26 kg	–			
Approx. 0.020 kg; <i>Scanning head for protective cover</i> : Approx.. 0.035 kg									

* Please indicate when ordering

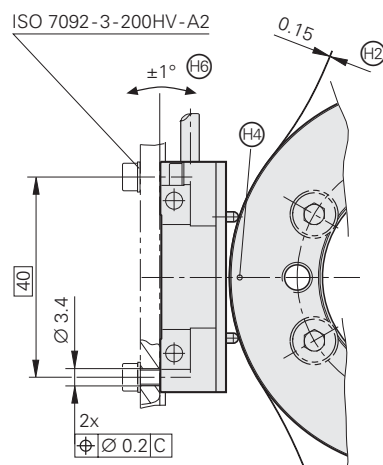
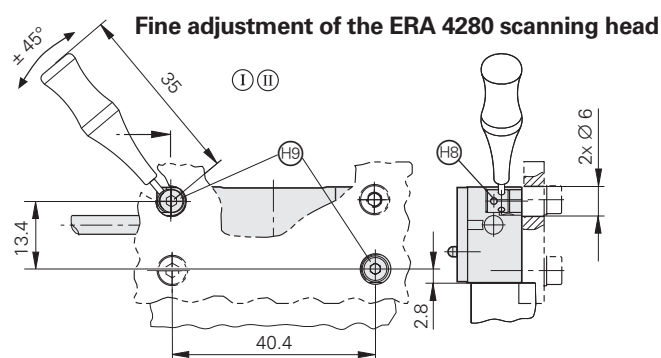
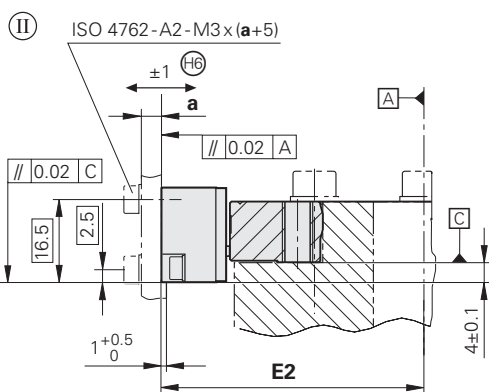
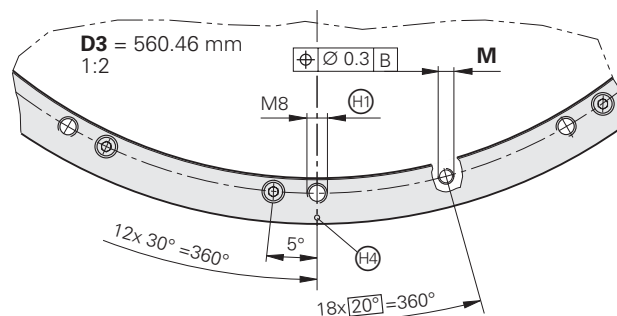
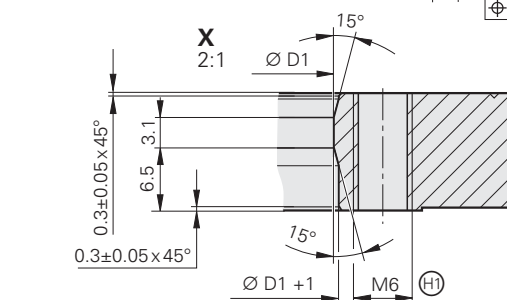
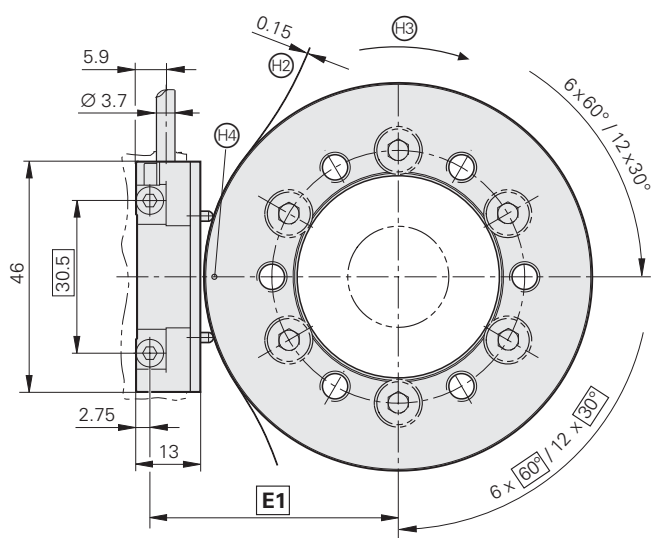
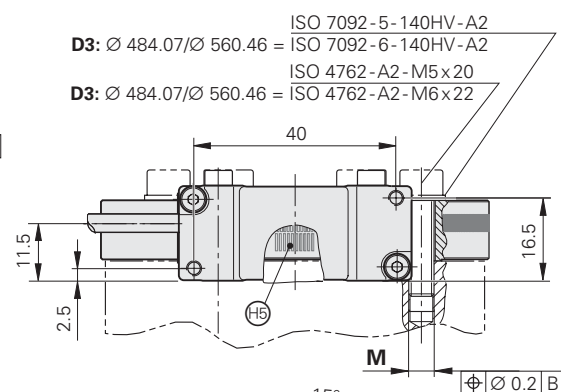
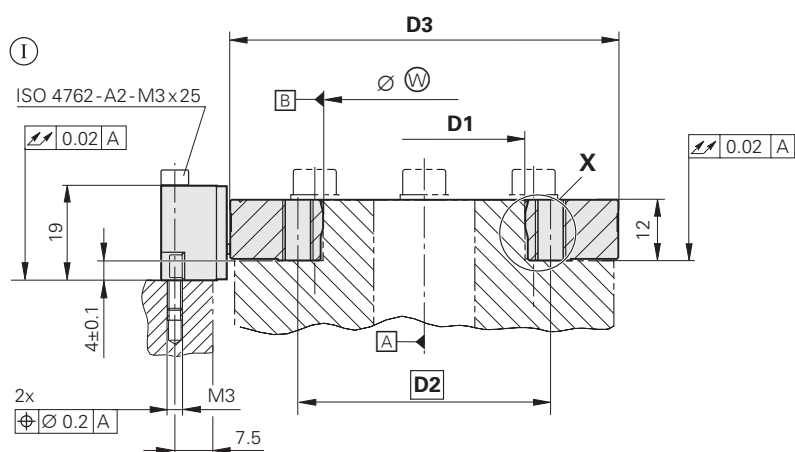
¹⁾ Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.

²⁾ For other errors, see *Measuring Accuracy*

³⁾ Only with ERA 4480; the protective cover must be ordered separately

ERA 4280C, ERA 4480C, ERA 4880C

Without Protective Cover



Dimensions in mm

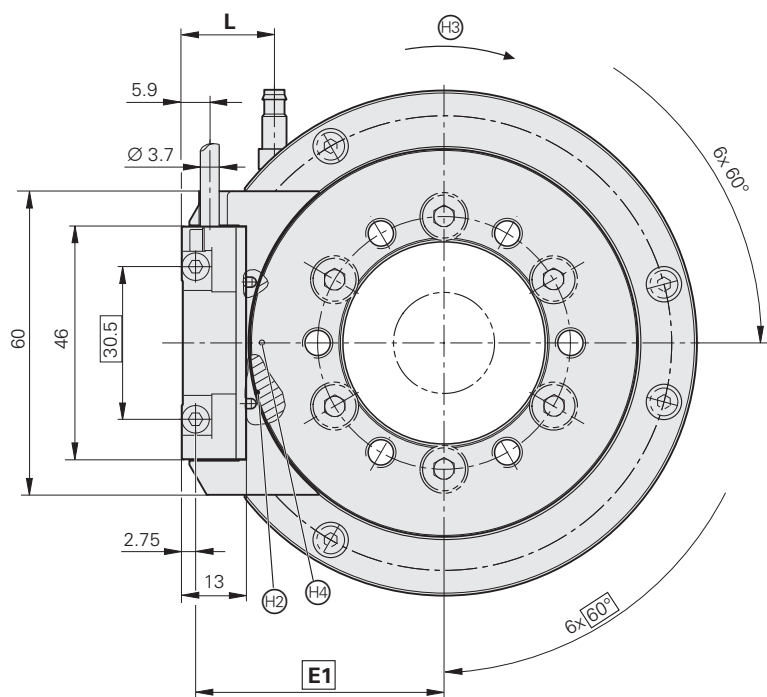


Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

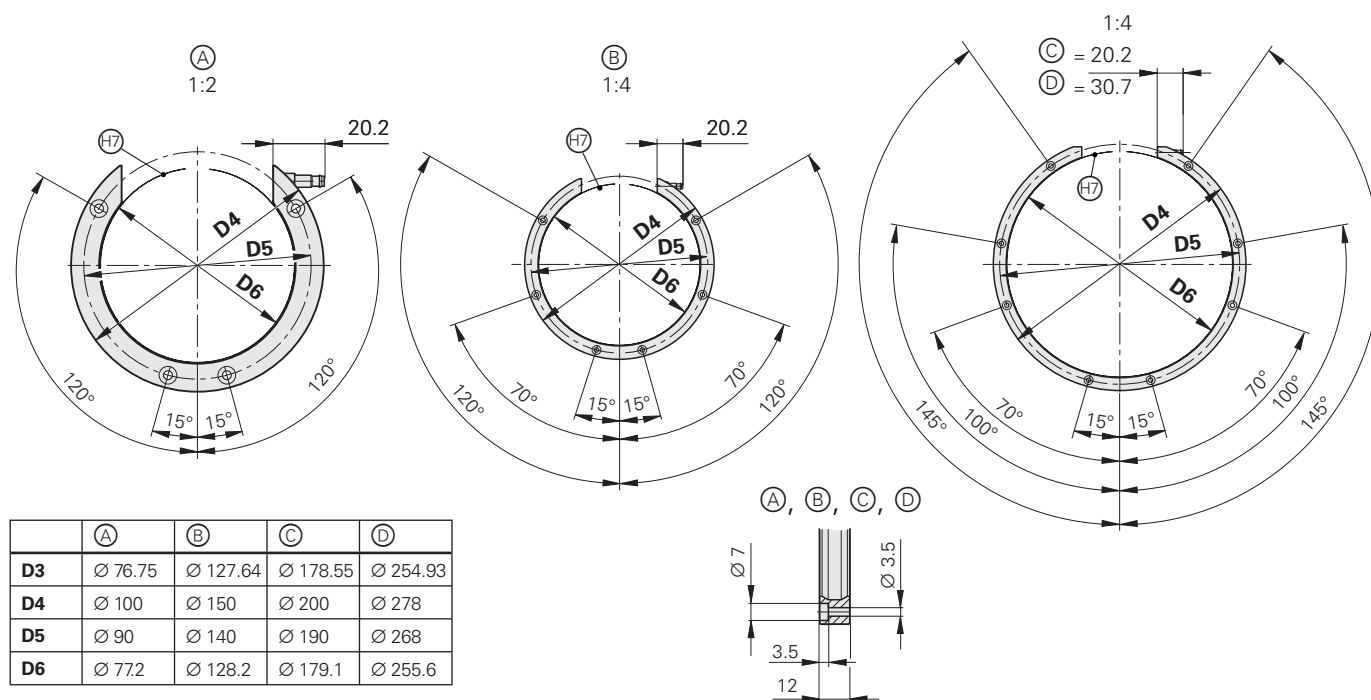
D1	W	*)	D2	D3	E1	E2	L	M
Ø 40 -0.001/-0.005	Ø 40 +0.004	0.001	Ø 50	Ø 76.75	49.34	52.08	18.6	6x M5
Ø 70 -0.001/-0.005	Ø 70 +0.005	0.001	Ø 85	Ø 104.63	63.28	66.02	/	6x M5
Ø 80 -0.001/-0.005	Ø 80 +0.006	0.0015	Ø 95	Ø 127.64	74.78	77.52	173	6x M5
Ø 120 -0.001/-0.008	Ø 120 +0.008	0.002	Ø 140	Ø 178.55	100.24	102.98	14.5	6x M5
Ø 150 -0.001/-0.008	Ø 150 +0.008	0.002	Ø 165	Ø 208.89	115.41	118.15	/	6x M5
Ø 180 -0.001/-0.008	Ø 180 +0.010	0.003	Ø 200	Ø 254.93	138.43	141.17	12.7	6x M5
Ø 270 0/-0.01	Ø 270 +0.012	0.003	Ø 290	Ø 331.31	176.62	179.36	/	12x M5
Ø 425 0/-0.01	Ø 425 +0.015	0.006	Ø 445	Ø 484.07	253.00	255.74	/	12x M6
Ø 512 0/-0.015	Ø 512 +0.016	0.007	Ø 528	Ø 560.46	291.19	293.93	/	18x M6

*) Roundness of mating diameter for shaft

With Protective Cover

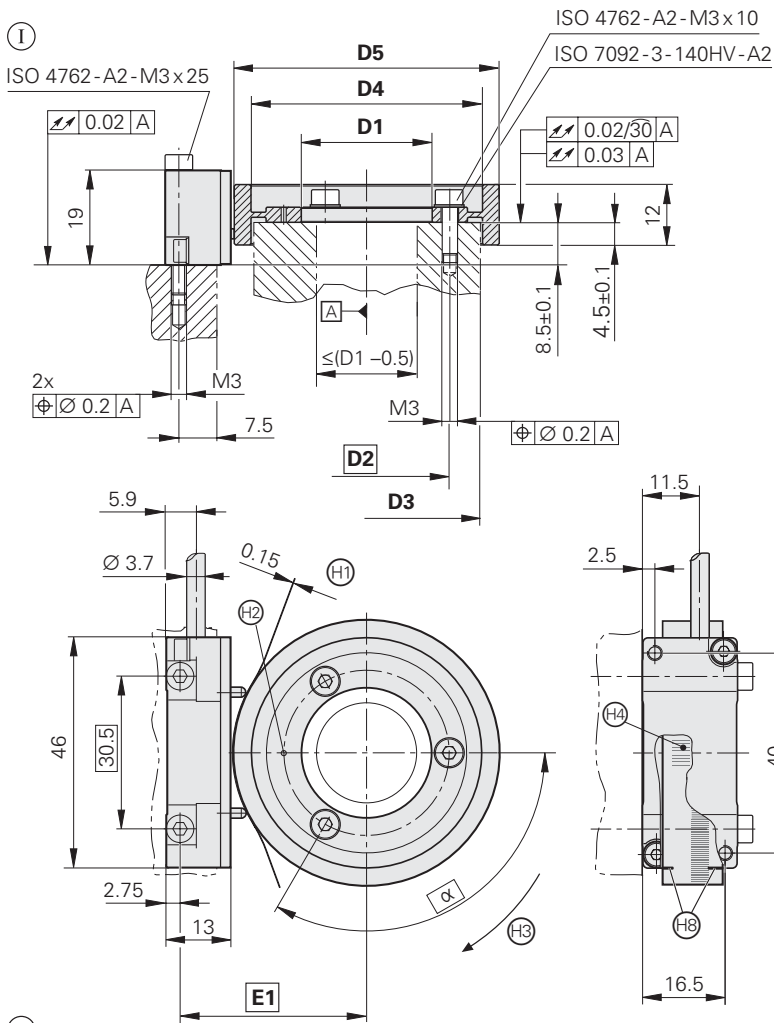


- ①, ② = Mounting options
- Ⓐ = Bearing
- ⊕ = Back-off thread
- Ⓜ = Mounting clearance (spacer foil)
- ⊕ = Positive direction of rotation for output signals as per the interface description
- Ⓜ = Marker for reference mark, position tolerance with respect to reference mark ± 1.0 mm
- Ⓜ = Scale reference mark
- ⊕ = Ensure adjustability of mounting surface for scanning head
- Ⓜ = Mounting clearance 0.15 mm (protective cover)
- ⊕ = Eccentric nut
- ⊕ = Holes required for fine adjustment



ERA 4281C, ERA 4481C

- Steel circumferential scale drum with low weight and low moment of inertia



Dimensions in mm



Tolerancing ISO 8015

ISO 2768 - m H

< 6 mm: ±0.2 mm

①, ② = Mounting options

A = Bearing

H1 = Mounting clearance (spacer foil)

H2 = Marker for reference mark

H3 = Positive direction of rotation for output signals as per the interface description

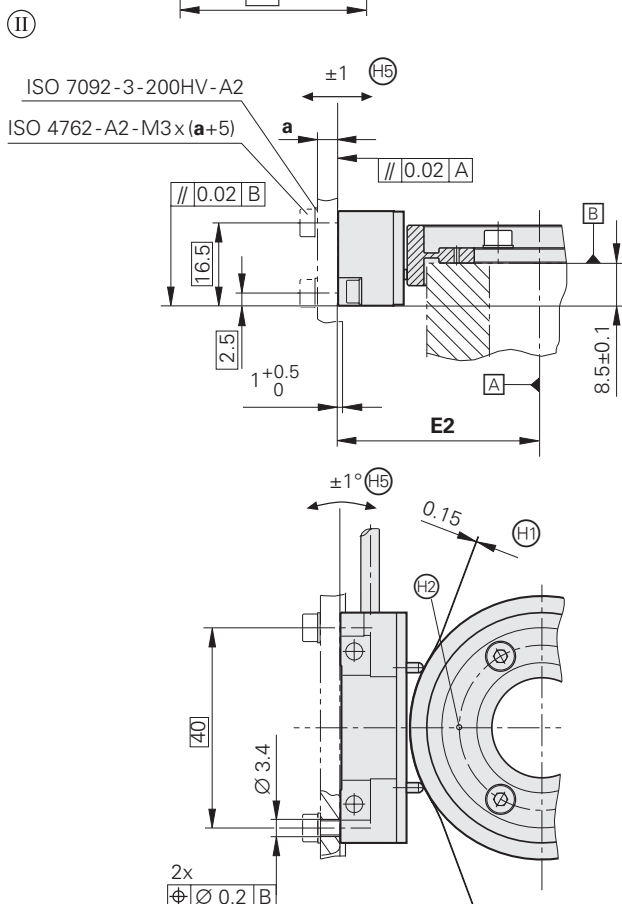
H4 = Scale reference mark

H5 = Ensure adjustability of mounting surface for scanning head

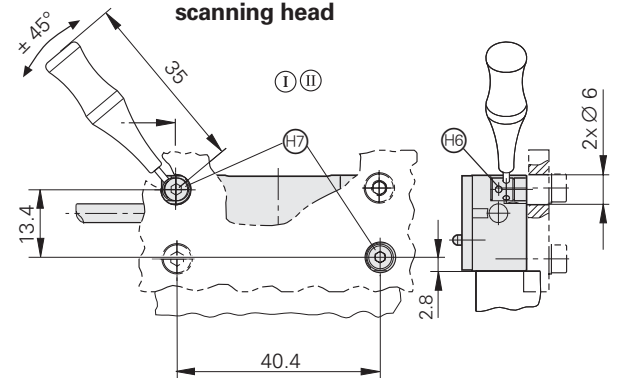
H6 = Eccentric nut

H7 = Mounting holes for fine adjustment (only for ERA 4280 scanning head)

H8 = Marks for drum centering (3 x 120°)



Fine adjustment of the ERA 4280 scanning head



D1	D2	D3	D4	D5	E1	E2	α
Ø 26	Ø 33	Ø 44±1	Ø 46	Ø 52.65	37.29	40.03	3 x 120° = 360°
Ø 50	Ø 57	Ø 68±1	Ø 70	Ø 76.75	49.34	52.08	
Ø 78	Ø 85	Ø 96±1	Ø 98	Ø 104.63	63.28	66.02	6 x 60° = 360°
Ø 127	Ø 134	Ø 145±1	Ø 147	Ø 153.09	87.51	90.25	
Ø 183	Ø 190	Ø 201±1	Ø 203	Ø 208.89	115.41	118.15	8 x 45° = 360°
Ø 229	Ø 236	Ø 247±1	Ø 249	Ø 254.93	138.43	141.17	16 x 22.5° = 360°
Ø 280	Ø 287	Ø 298±1	Ø 300	Ø 305.84	163.88	166.62	

	ERA 4281 C grating period 20 µm—consisting of ERA 4280 scanning head and ERA 4201 C drum ERA 4481 C grating period 40 µm—consisting of ERA 4480 scanning head and ERA 4401 C drum						
Incremental signals	~ 1 V _{pp}						
Reference marks	Distance-coded						
Cutoff frequency –3dB	≥ 350 kHz						
Power supply without load	5 V ± 10%/max. 100 mA						
Electrical connection	Cable 3 m with D-sub connector (15-pin)						
Cable length	≤ 150 m (with HEIDENHAIN cable)						
Drum inside diameter*	26 mm	50 mm	78 mm	127 mm	183 mm	229 mm	280 mm
Drum outside diameter*	52.65 mm	76.75 mm	104.63 mm	153.09 mm	208.89 mm	254.93 mm	305.84 mm
Line count							
ERA 4281 C	8 192	12 000	16 384	24 000	32 768	40 000	48 000
ERA 4481 C	4 096	6 000	8 192	12 000	16 384	20 000	24 000
System accuracy¹⁾							
ERA 4281 C	± 8.6"	± 6.1"	± 4.5"	± 3.1"	± 2.9"	± 2.9"	± 2.8"
ERA 4481 C	± 10.2"	± 7.2"	± 5.3"	± 3.6"	± 3.3"	± 3.2"	± 3.1"
Accuracy of the graduation²⁾	± 7"	± 5"	± 3.7"	± 2.5"			
Mech. permissible speed	6 000 min ⁻¹		4 000 min ⁻¹		2 000 min ⁻¹		
Moment of inertia of rotor	0.034 · 10 ⁻³ kgm ²	0.12 · 10 ⁻³ kgm ²	0.33 · 10 ⁻³ kgm ²	1.1 · 10 ⁻³ kgm ²	2.8 · 10 ⁻³ kgm ²	5.2 · 10 ⁻³ kgm ²	9.0 · 10 ⁻³ kgm ²
Permissible axial motion	≤ ± 0.5 mm (scale drum relative to scanning head)						
Vibration 55 to 2000 Hz Shock 6 ms	≤ 200 m/s ² (IEC 60068-2-6) ≤ 1 000 m/s ² (IEC 60068-2-27)						
Operating temperature	–10 °C to 80 °C (coefficient of expansion of the scale drum approx. 10.5 · 10 ⁻⁶ K ⁻¹)						
Protection IEC 60529	IP 00						
Weight (approx.)							
Scale drum	0.065 kg	0.11 kg	0.15 kg	0.21 kg	0.28 kg	0.35 kg	0.41 kg
Scanning head without cable	0.020 kg						

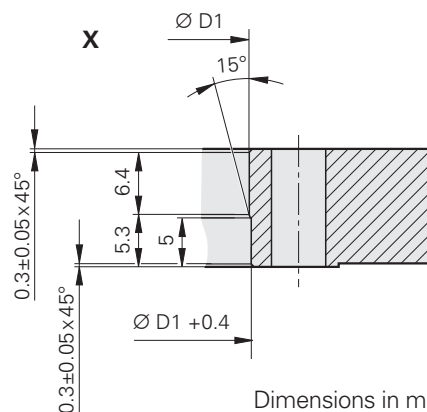
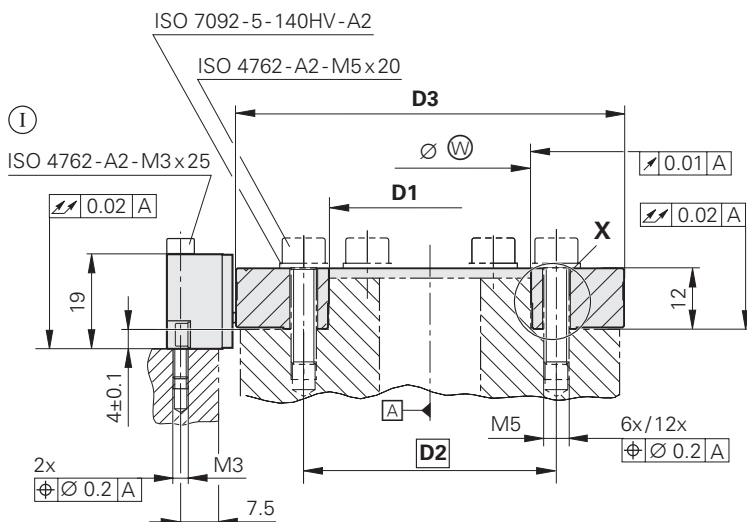
* Please indicate when ordering

¹⁾ Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.

²⁾ For other errors, see *Measuring Accuracy*

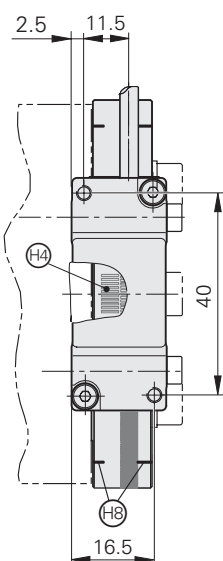
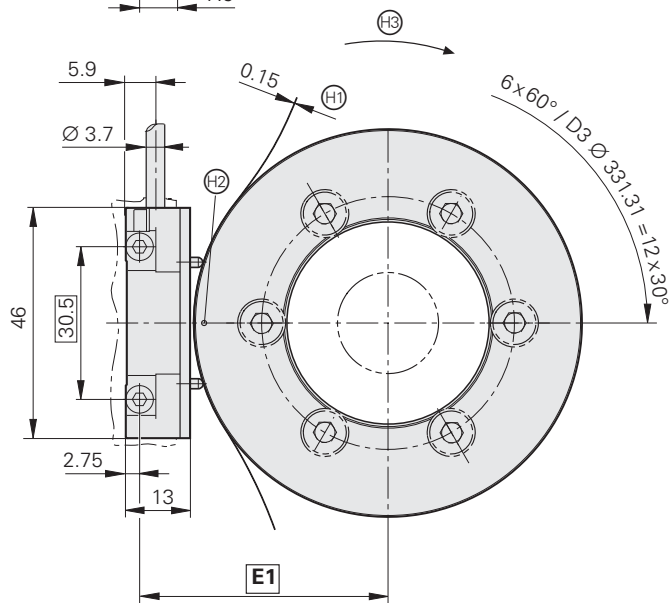
ERA 4282 C

- **Steel circumferential scale drum for increased accuracy requirements**

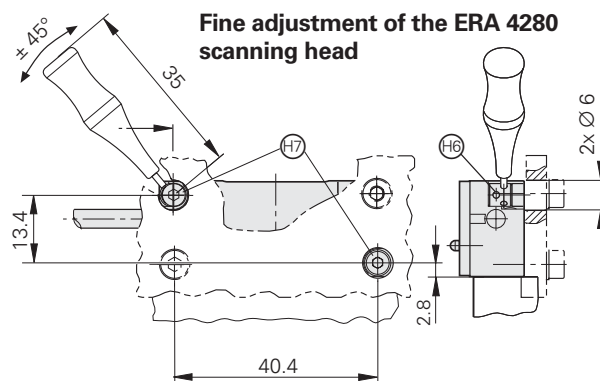
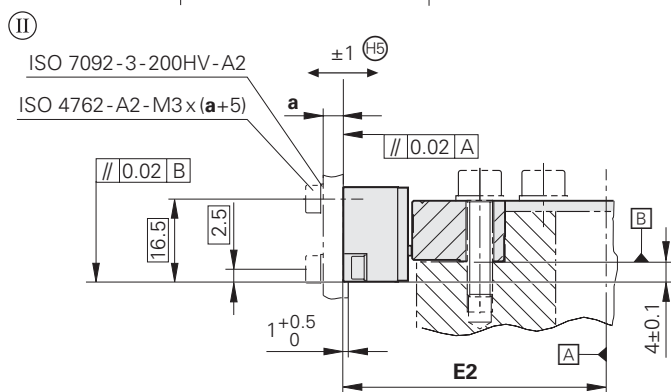


Dimensions in mm

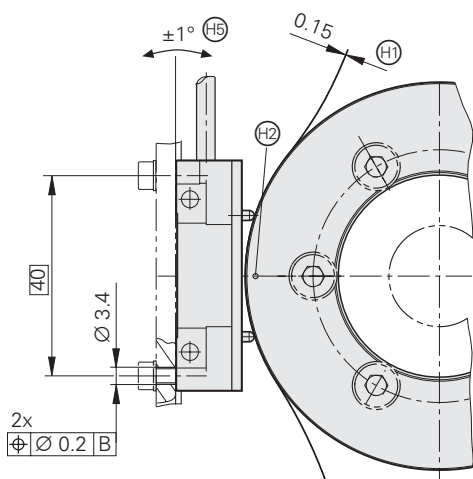
Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ± 0.2 mm



- ①, ② = Mounting options
- Ⓐ = Bearing
- ⊕ = Mounting clearance (spacer foil)
- ⊗ = Marker for reference mark
- ⊕ = Positive direction of rotation for output signals as per the interface description
- ⊗ = Scale reference mark
- ⊕ = Ensure adjustability of mounting surface for scanning head
- ⊕ = Eccentric nut
- ⊗ = Mounting holes for fine adjustment (only for ERA 4280 scanning head)
- ⊕ = Marks for drum centering (3 x 120°)
- Ⓜ = Mating shaft



Fine adjustment of the ERA 4280 scanning head



D1	⊙	D2	D3	E1	E2
Ø 40 +0.07/+0.05	Ø 40 +0.015	Ø 50	Ø 76.75	49.34	52.08
Ø 70 +0.07/+0.05	Ø 70 +0.015	Ø 85	Ø 104.63	63.28	66.02
Ø 80 +0.07/+0.05	Ø 80 +0.015	Ø 95	Ø 127.64	74.78	77.52
Ø 120 +0.07/+0.05	Ø 120 +0.015	Ø 140	Ø 178.55	100.24	102.98
Ø 150 +0.07/+0.05	Ø 150 +0.015	Ø 165	Ø 208.89	115.41	118.15
Ø 180 +0.07/+0.05	Ø 180 +0.015	Ø 200	Ø 254.93	138.43	141.17
Ø 270 +0.07/+0.05	Ø 270 +0.015	Ø 290	Ø 331.31	176.62	179.36

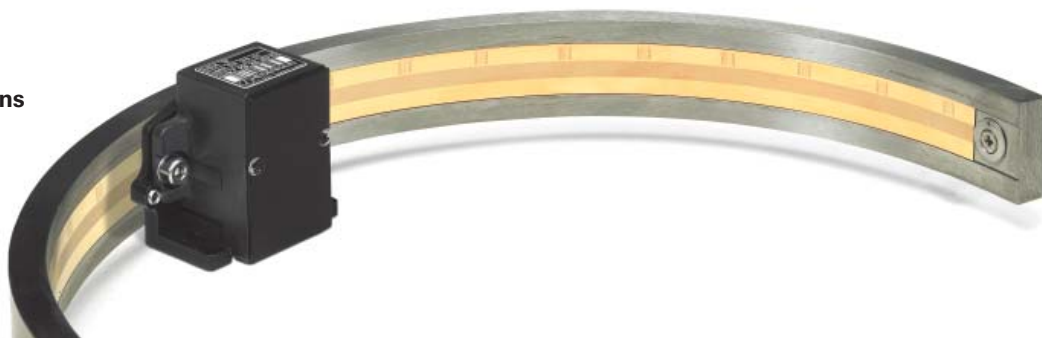
	ERA 4282C grating period 20 µm—consisting of ERA 4280 scanning head and ERA 4202C drum						
Incremental signals	$\sim 1 V_{pp}$						
Reference marks	Distance-coded						
Cutoff frequency –3dB	≥ 350 kHz						
Power supply without load	5 V $\pm$ 10%/max. 100 mA						
Electrical connection	Cable, 1 m, with M23 coupling (12-pin)						
Cable length	≤ 150 m (with HEIDENHAIN cable)						
Drum inside diameter*	40 mm	70 mm	80 mm	120 mm	150 mm	180 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
Line count	12 000	16 384	20 000	28 000	32 768	40 000	52 000
System accuracy¹⁾	$\pm 5.1''$	$\pm 3.8''$	$\pm 3.2''$	$\pm 2.5''$	$\pm 2.3''$	$\pm 2.2''$	$\pm 2.0''$
Accuracy of the graduation²⁾	$\pm 4''$	$\pm 3''$	$\pm 2.5''$	$\pm 2''$	$\pm 1.9''$	$\pm 1.8''$	$\pm 1.7''$
Mech. permissible speed	10 000 min ⁻¹	8 500 min ⁻¹	6 250 min ⁻¹	4 500 min ⁻¹	4 250 min ⁻¹	3 250 min ⁻¹	2 500 min ⁻¹
Moment of inertia of rotor	$0.28 \cdot 10^{-3}$ kgm ²	$0.83 \cdot 10^{-3}$ kgm ²	$2.0 \cdot 10^{-3}$ kgm ²	$7.1 \cdot 10^{-3}$ kgm ²	$12 \cdot 10^{-3}$ kgm ²	$28 \cdot 10^{-3}$ kgm ²	$59 \cdot 10^{-3}$ kgm ²
Permissible axial motion	$\leq \pm 0.5$ mm (scale drum relative to scanning head)						
Vibration 55 to 2000 Hz Shock 6 ms	≤ 100 m/s ² (IEC 60068-2-6) ≤ 500 m/s ² (IEC 60068-2-27)						
Operating temperature	–10 °C to 80 °C (coefficient of expansion of the scale drum approx. $10.5 \cdot 10^{-6} K^{-1}$)						
Protection IEC 60529	IP 00						
Weight (approx.)							
Scale drum	0.30 kg	0.42 kg	0.70 kg	1.2 kg	1.5 kg	2.3 kg	2.6 kg
Scanning head without cable	0.020 kg						

* Please indicate when ordering

¹⁾ Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.

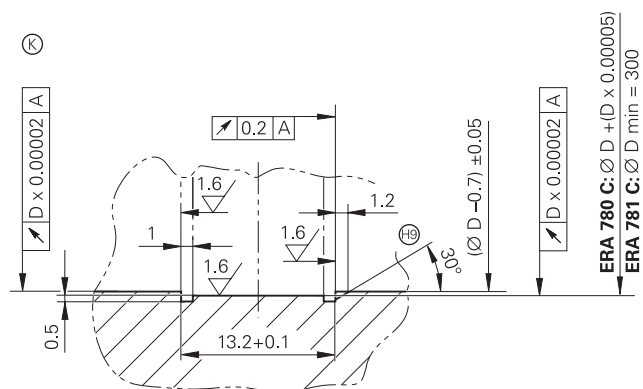
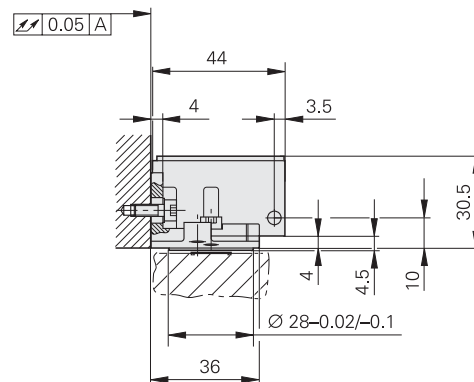
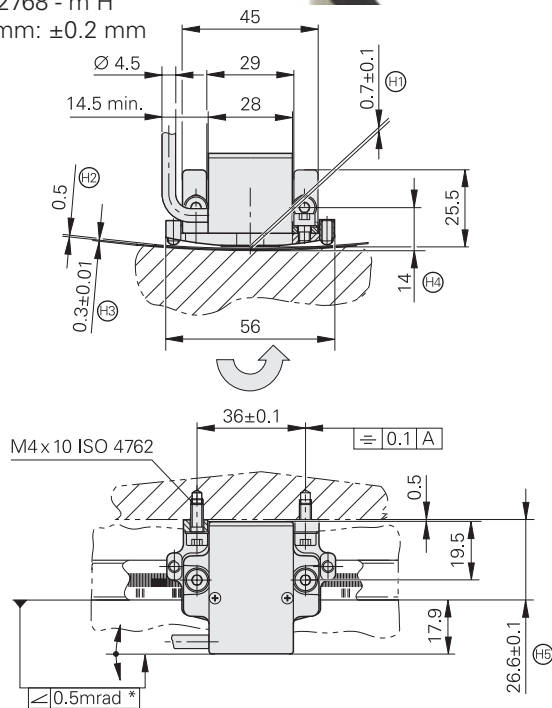
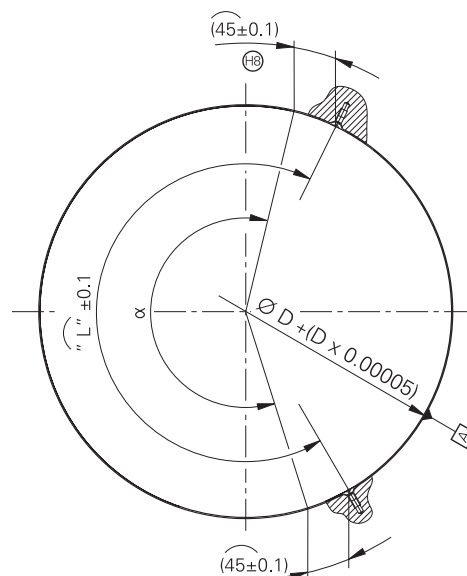
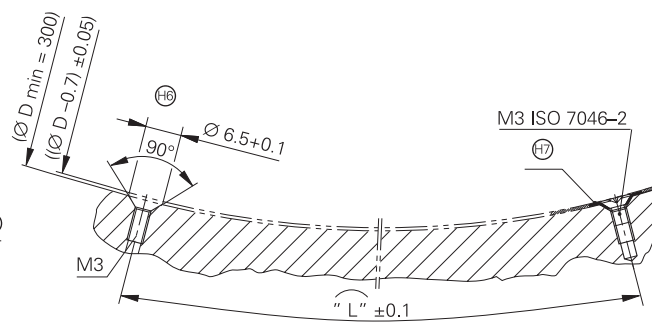
²⁾ For other errors, see *Measuring Accuracy*

- For internal mounting
- Full-circle and segment versions



ISO 2768 - m H

< 6 mm: ± 0.2 mm

[illegible]

- * = Max. change during operation
-  = Bearing
-  = Required mating dimensions for the scale tape (not to scale)
-  = Traverse path
-  = Measuring range
-  = Scanning gap (distance between scanning reticle and scale-tape surface)
-  = Mounting clearance for mounting bracket. Spacer foil 0.5 mm
-  = Scale-tape thickness
-  = Distance between floor of scale-tape slot and threaded mounting hole
-  = Distance between mounting surface and scale-tape slot
-  = View of holes provided by customer
-  = Cam disk for tensioning the scale tape
-  = Position of first reference mark
-  = Notch for removing scale tape (1 x b = 2 mm)
-  Direction of shaft rotation for output signals as per the interface description

	Incremental ERA 780C full-circle version ERA 781C segment, scale tape secured with tensioning elements			
Incremental signals	 1 V _{pp}			
Reference mark	Distance-coded, nominal increment of 1 000 grating periods			
Cutoff frequency –3 dB	≥ 180 kHz			
Power supply without load	5 V ± 10%/max. 150 mA			
Electrical connection	Cable 3 m with M 23 coupling			
Cable length	≤ 150 m (with HEIDENHAIN cable)			
Scale-slot diameter*	318.58 mm	458.62 mm	573.20 mm	1 146.10 mm
Line count				
ERA 780C full circle	–	36 000	45 000	90 000
ERA 781C segment*	72°: 5000 ³⁾ 144°: 10000 ³⁾	50°: 5000 100°: 10000 200°: 20000	160°: 20000	–
Recommended measuring step for position measurement	0.0002°	0.0001°	0.00005°	0.00002°
System accuracy¹⁾				
ERA 780C full circle	–	± 3.5"	± 3.4"	± 3.2"
ERA 781C segment	See <i>Measuring Accuracy</i>			
Accuracy of the graduation²⁾	± 3"			
Mech. permissible speed	≤ 500 min ^{–1}			
Permissible axial motion of measured shaft	± 0.2 mm			
Vibration 55 to 2000 Hz Shock 6 ms	≤ 100 m/s ² (IEC 60068-2-6) ≤ 1000 m/s ² (IEC 60068-2-27)			
Operating temperature	–10 °C to 50 °C (thermal coefficient of expansion of the scale substrate between 9 · 10 ^{–6} K ^{–1} and 12 · 10 ^{–6} K ^{–1})			
Protection IEC 60529	IP 00			
Weight				
Scanning unit	Approx. 0.35 kg			
Scale tape	Approx. 30 g/m			

* Please indicate when ordering; other versions available upon request.

¹⁾ Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.

²⁾ For other errors, see *Measuring Accuracy*

³⁾ Corresponds to 25000 lines of the theoretical full circle

ERA 800 Series

- For outside diameters
- Full-circle and segment versions



ERA 880C full-circle version



ERA 881C circle-segment version
Scale tape secured with tensioning elements



ERA 882C circle-segment version
Scale tape without tensioning elements

	Incremental ERA 880C full-circle version ERA 881C segment, scale tape secured with tensioning elements ERA 882C segment, scale tape secured without tensioning elements		
Incremental signals	 1 V _{pp}		
Reference mark	Distance-coded, nominal increment of 1 000 grating periods		
Cutoff frequency –3 dB	≥ 180 kHz		
Power supply without load	5 V ± 10%/max. 150 mA		
Electrical connection	Cable 3 m with M 23 coupling		
Cable length	≤ 150 m (with HEIDENHAIN cable)		
Scale-slot diameter*	317.99 mm	458.04 mm	572.63 mm
Line count			
ERA 880C full circle	–	36 000	45 000
ERA 881 C/ ERA 882 C segment*	72°: 5 000 ³⁾ 144°: 10 000 ³⁾	50°: 5 000 100°: 10 000 200°: 20 000	160°: 20 000
Recommended measuring step for position measurement	0.0002°	0.0001°	0.00005°
System accuracy ¹⁾			
ERA 880C full circle	–	± 3.5"	± 3.4"
ERA 881 C/ ERA 882 C segment	See <i>Measuring Accuracy</i>		
Accuracy of the graduation ²⁾	± 3"		
Mech. permissible speed	≤ 100 min ^{–1}		
Permissible axial motion of measured shaft	± 0.2 mm		
Vibration 55 to 2000 Hz Shock 6 ms	≤ 100 m/s ² (IEC 60068-2-6) ≤ 1 000 m/s ² (IEC 60068-2-27)		
Operating temperature	–10 °C to 50 °C (thermal coefficient of expansion of the scale substrate between 9 · 10 ^{–6} K ^{–1} and 12 · 10 ^{–6} K ^{–1})		
Protection IEC 60529	IP 00		
Weight			
Scanning unit	Approx. 0.35 kg		
Scale tape	Approx. 30 g/m		

* Please indicate when ordering; other versions available upon request.

¹⁾ Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.

²⁾ For other errors, see *Measuring Accuracy*

³⁾ Corresponds to 25 000 lines of the theoretical full circle

ERA 800 Series

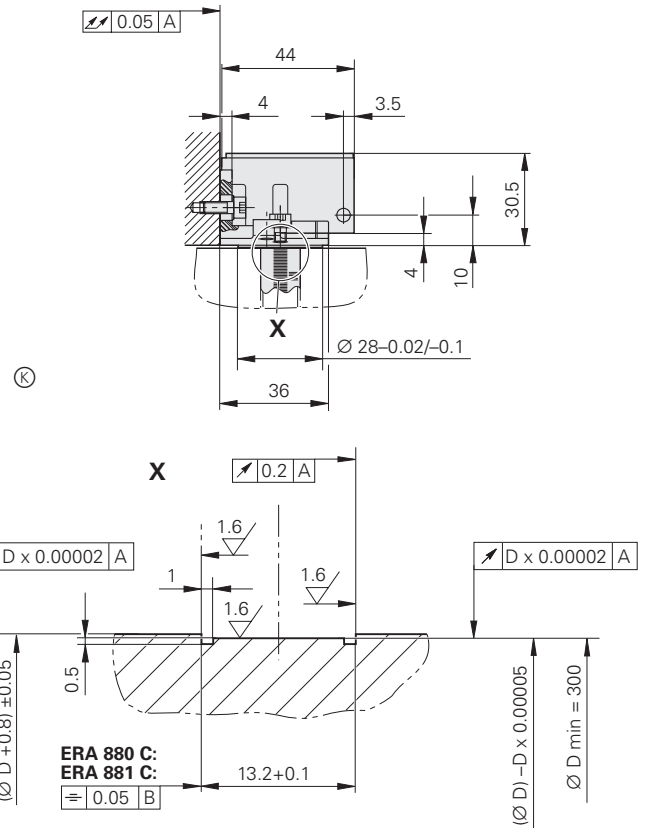
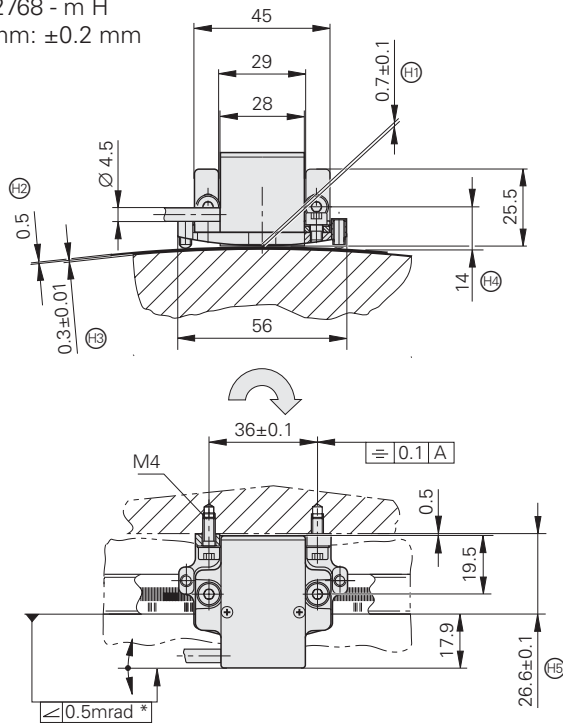
Dimensions in mm



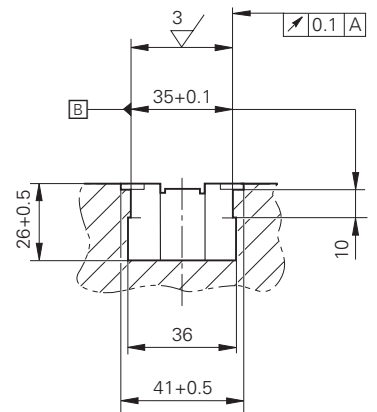
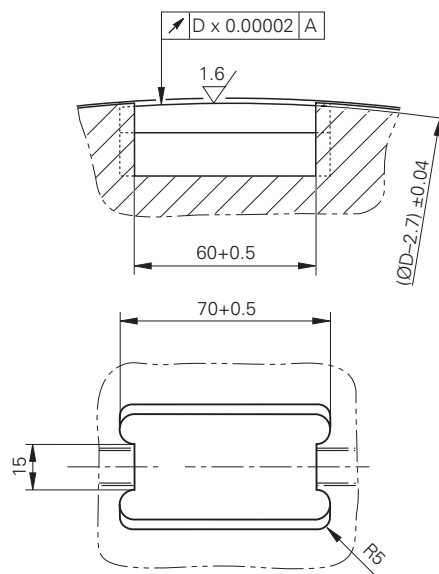
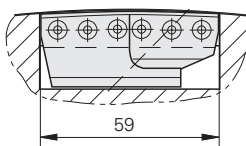
Tolerancing ISO 8015

ISO 2768 - m H

< 6 mm: ± 0.2 mm



ERA 880C scale tape



* = Max. change during operation

A = Bearing

K = Required mating dimensions for the scale tape (not to scale)

H1 = Scanning gap (distance between scanning reticle and scale-tape surface)

H2 = Mounting clearance for mounting bracket. Spacer foil 0.5 mm

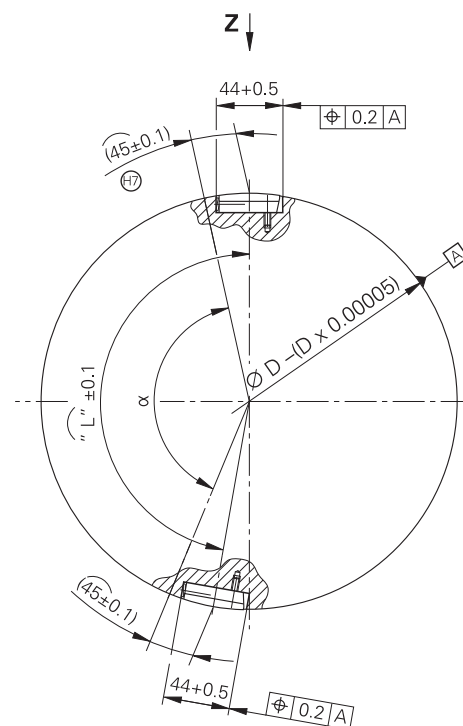
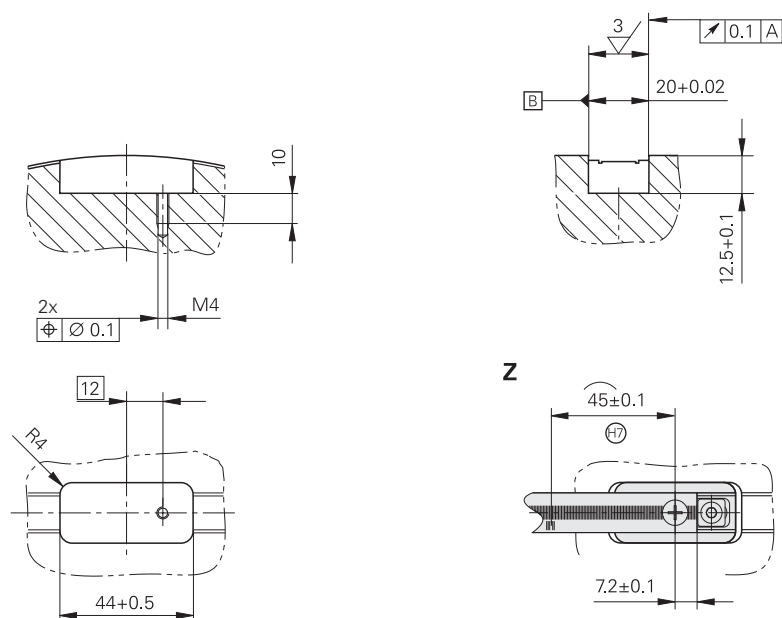
H3 = Scale-tape thickness

H4 = Distance between floor of scale-tape slot and threaded mounting hole

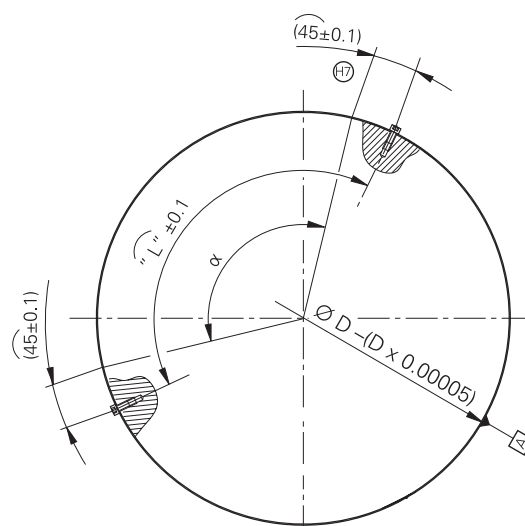
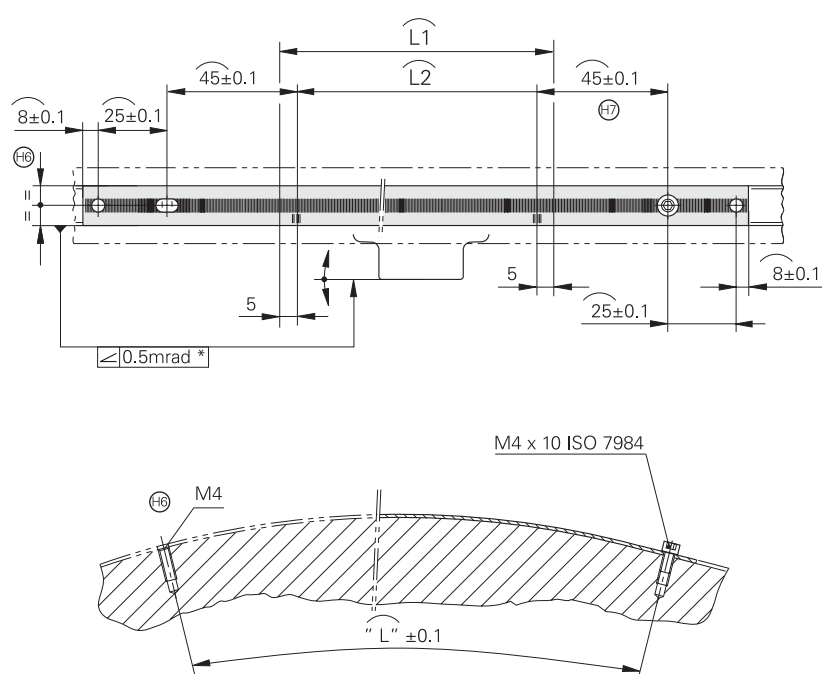
H5 = Distance between mounting surface and scale-tape slot

Direction of shaft rotation for output signals as per the interface description

ERA 881 C scale tape



ERA 882C scale tape



* = Max. change during operation

[A] = Bearing

⊕ = Bearing
⊕H6 = View of holes provided by customer

Ⓗ7 = Position of first reference mark

(L) = With *ERA 881 C*: Positions of the tensioning elements

With *ERA 882 C*: Distance of mounting holes

$\widehat{L1}$ = Traverse path

$\widehat{L2}$ = Measuring range in radian measure

α = Measuring range in degrees (segment angle)

Interfaces

Incremental Signals $\sim 1 V_{PP}$

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

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

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

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

- $-3 \text{ dB} \triangleq 70\%$ of the signal amplitude
- $-6 \text{ dB} \triangleq 50\%$ of the signal amplitude

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

Interpolation/resolution/measuring step

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

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

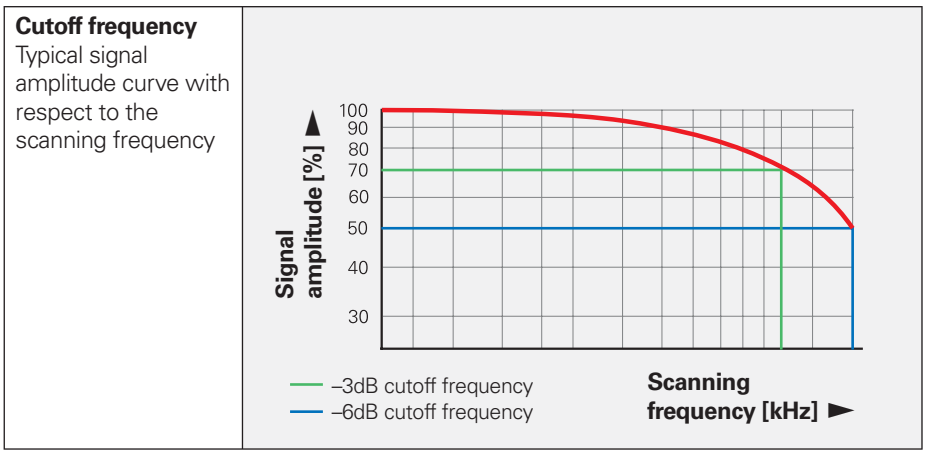
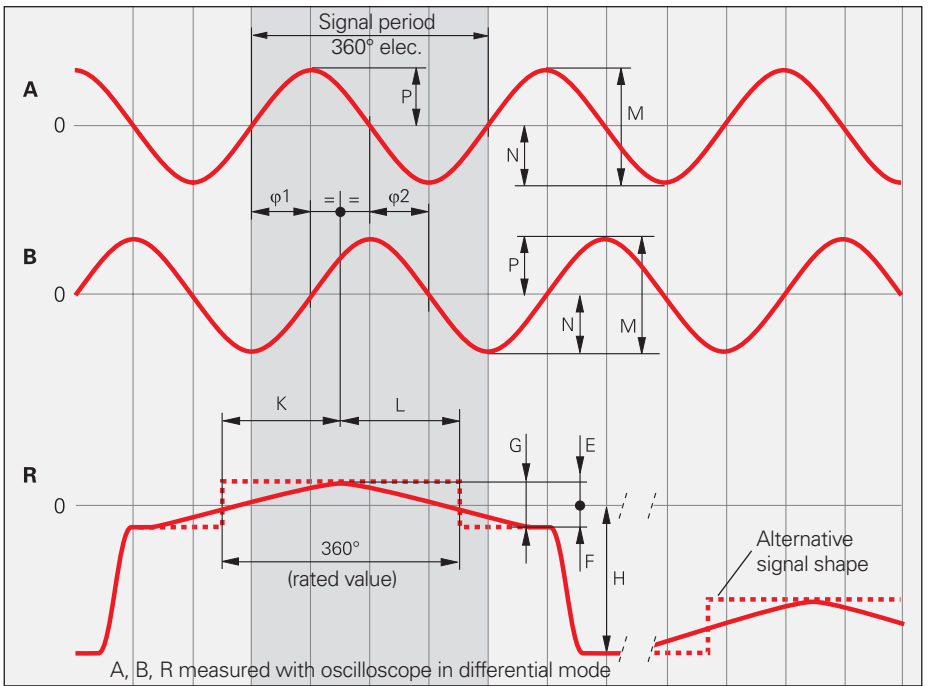
Short circuit stability

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

Short circuit at	$20^\circ C$	$125^\circ C$
One output	< 3 min	< 1 min
All outputs	< 20 s	< 5 s

Interface	Sinusoidal voltage signals $\sim 1 V_{PP}$
Incremental signals	2 nearly sinusoidal signals A and B Signal amplitude M: 0.6 to $1.2 V_{PP}$; typically $1 V_{PP}$ Asymmetry $ P - N /2M$: ≤ 0.065 Signal ratio M_A/M_B : 0.8 to 1.25 Phase angle $ \varphi_1 + \varphi_2 /2$: $90^\circ \pm 10^\circ$ elec.
Reference-mark signal	One or several signal peaks R Usable component G: $\geq 0.2 V$ Quiescent value H: $\leq 1.7 V$ Switching threshold E, F: 0.04 to $0.68 V$ Zero crossovers K, L: $180^\circ \pm 90^\circ$ elec.
Connecting cable	Shielded HEIDENHAIN cable PUR $[4(2 \times 0.14 \text{ mm}^2) + (4 \times 0.5 \text{ mm}^2)]$ Cable length Propagation time Max. 150 m with 90 pF/m distributed capacitance 6 ns/m

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



Input Circuitry of the Subsequent Electronics

Dimensioning

Operational amplifier MC 34074

$Z_0 = 120\ \Omega$

$R_1 = 10\ \text{k}\Omega$ and $C_1 = 100\ \text{pF}$

$R_2 = 34.8\ \text{k}\Omega$ and $C_2 = 10\ \text{pF}$

$U_B = \pm 15\ \text{V}$

U_1 approx. U_0

-3dB cutoff frequency of circuitry

Approx. 450 kHz

Approx. 50 kHz and $C_1 = 1000\ \text{pF}$
and $C_2 = 82\ \text{pF}$

The circuit variant for 50 kHz does reduce the bandwidth of the circuit, but in doing so it improves its noise immunity.

Circuit output signals

$U_a = 3.48\ \text{V}_{PP}$ typical

Gain 3.48

Monitoring of the incremental signals

The following thresholds are recommended for monitoring of the signal level M:

Lower threshold: 0.30 V_{PP}

Upper threshold: 1.35 V_{PP}

Incremental signals Reference-mark signal

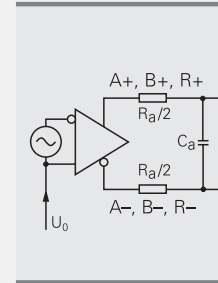
$R_a < 100\ \Omega$, typ. 24 Ω

$C_a < 50\ \text{pF}$

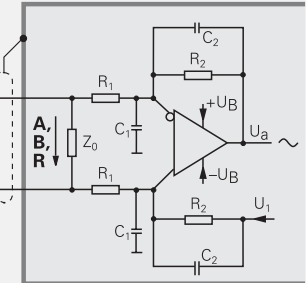
$\Sigma I_a < 1\ \text{mA}$

$U_0 = 2.5\ \text{V} \pm 0.5\ \text{V}$
(relative to 0 V of the power supply)

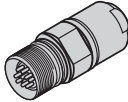
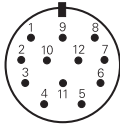
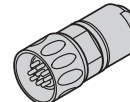
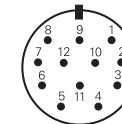
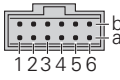
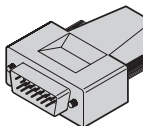
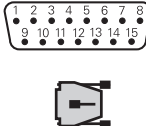
Encoder



Subsequent electronics



Pin Layout

12-pin coupling M23					12-pin connector M23								
  					  								
12-pin PCB connector on ERP 880					15-pin D-sub connector¹⁾								
 					 								
	Power supply				Incremental signals						Other signals		
	12	2	10	11	5	6	8	1	3	4	9	7	/
	2a	2b	1a	1b	6b	6a	5b	5a	4b	4a	3b	3a	/
	4	12	2	10	1	9	3	11	14	7	5/6/8	13	15
	U_P	Sensor U _P	0 V	Sensor 0 V	A+	A–	B+	B–	R+²⁾	R–²⁾	Vacant	Vacant	Vacant
	Brown/ Green	Blue	White/ Green	White	Brown	Green	Gray	Pink	Red	Black	/	Violet	Yellow

Shield on housing; **U_P** = power supply voltage

Sensor: The sensor line is connected internally with the corresponding power line

Vacant pins or wires must not be used!

¹⁾ Only for ERA 4x81: color assignment applies only to connecting cable

²⁾ **ERP 4080/ERP 8080:** Vacant

HEIDENHAIN Measuring Equipment

for Incremental Angle Encoders

With modular angle encoders, the scanning head moves over the graduation without mechanical contact. Thus, to ensure highest quality output signals, the scanning head needs to be aligned very accurately during mounting. HEIDENHAIN offers various measuring and testing equipment for checking the quality of the output signals.

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



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

The **PWT** is a simple adjusting aid for HEIDENHAIN incremental encoders. In a small LCD window the signals are shown as bar charts with reference to their tolerance limits.



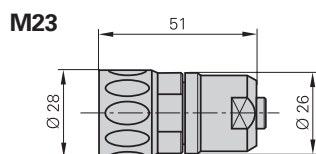
	PWT 10	PWT 17	PWT 18
Encoder input	~ 11 μ A _{PP}	□□TTL	~ 1 V _{PP}
Functions	Measurement of signal amplitude Wave-form tolerance Amplitude and position of the reference mark signal		
Power supply	Via power supply unit (included)		
Dimensions	114 mm x 64 mm x 29 mm		

Connecting Elements and Cables

General Information

Connector (insulated): Connecting element with coupling ring; available with male or female contacts.

Symbols

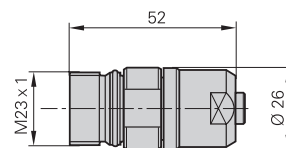


Insulated coupling: Connecting element with external thread; available with male or female contacts.

Symbols



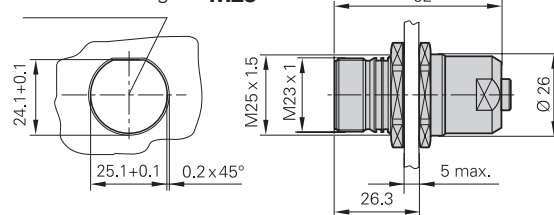
M23



Mounted coupling with central fastening

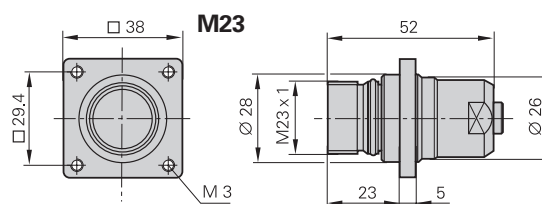
Cutout for mounting

M23



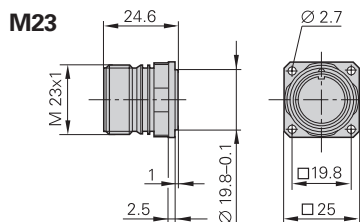
Mounted coupling with flange

M23



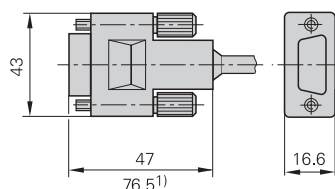
Flange socket: Permanently mounted on the encoder or a housing, with external thread (like the coupling), and available with male or female contacts.

Symbols



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

Symbols



¹⁾ With integrated interpolation electronics

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

Male contacts or



Female contacts.



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

Accessories for flange sockets and M23 mounted couplings

Bell seal

ID 266526-01

Threaded metal dust cap

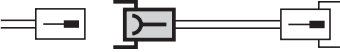
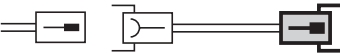
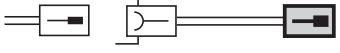
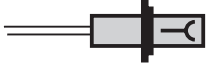
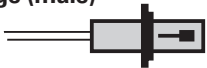
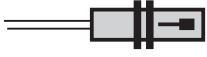
ID 219926-01

Connecting Cables

			12-pin M23	
PUR connecting cable [6(2 × 0.19 mm ²)]				
PUR connecting cable [4(2 × 0.14 mm ²) + (4 × 0.5 mm ²)]			Ø 8 mm	Ø 6 mm ¹⁾
Complete with connector (female) and coupling (male)		298401-xx		
Complete with connector (female) and connector (male)		298399-xx		
Complete with connector (female) and D-sub connector (female) for IK 220		310199-xx		
Complete with connector (female) and D-sub connector (male) for IK 115/IK 215		310196-xx		
One connector (female)		309777-xx		
Complete with D-sub connector (female) and M23 connector (male)		331693-xx	355215-xx	
One D-sub connector (female)		332433-xx	355209-xx	
Complete with D-sub connectors (female and male)		335074-xx	355186-xx	
Complete with D-sub connectors (female) Assignment for IK 220		335077-xx	349687-xx	
Cable without connectors		244957-01	291639-01	
Output cable for ERP 880		Ø 4.5 mm		
One PCB connector 12-pin	 Length 1 m	372164-01		

¹⁾ Cable length for Ø 6 mm max. 9 m

Connectors

			12-pin M23
Mating element on connecting cable to connecting element on encoder	Connector (female) for cable Ø 8 mm 	291 697-05	
Connector for connection to subsequent electronics	Connector (male) for cable Ø 8 mm Ø 6 mm 	291 697-08 291 697-07	
Coupling on encoder cable or connecting cable	Coupling (male) for cable Ø 3.7 mm Ø 4.5 mm Ø 6 mm Ø 8 mm 	291 698-14 291 698-14 291 698-03 291 698-04	
Flange socket for mounting on the subsequent electronics	Flange socket (female) 	315892-08	
Mounted couplings	With flange (female)  Ø 6 mm Ø 8 mm	291 698-17 291 698-07	
	With flange (male)  Ø 6 mm Ø 8 mm	291 698-08 291 698-31	
	With central fastening (male)  Ø 6 mm	291 698-33	
Adapter connector $\sim 1 V_{PP}/11 \mu A_{PP}$ For converting the $1 V_{PP}$ signals to $11 \mu A_{PP}$; M23 connector (female) 12-pin and M23 connector (male) 9-pin		364914-01	

General Electrical Information

Power Supply

The encoders require a **stabilized dc voltage U_P** as power supply. The respective *Specifications* state the required power supply and the current consumption. The permissible ripple content of the dc voltage is:

- High frequency interference
 $U_{PP} < 250 \text{ mV}$ with $dU/dt > 5 \text{ V}/\mu\text{s}$
- Low frequency fundamental ripple
 $U_{PP} < 100 \text{ mV}$

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

Calculation of the **line drop**:

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

where

- ΔU : Line drop in V
- L_C : Cable length in m
- I : Current consumption in mA
- A_P : Cross section of power lines in mm^2

Switch-on/off behavior of the encoders

The output signals are valid no sooner than after switch-on time $t_{SOT} = 1.3 \text{ s}$ (see diagram). During time t_{SOT} they can have any levels up to 5.5 V (with HTL encoders up to U_{Pmax}). If an interpolation electronics unit is inserted between the encoder and the power supply, the unit's switch-on/off characteristics must also be considered. When the power supply is switched off, or when the supply voltage falls below U_{min} , the output signals are also undefined. These data apply only for the encoders listed in the catalog—customized interfaces are not considered.

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

Isolation

The encoder housings are isolated against internal circuits.

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

Cables

It is absolutely necessary to use HEIDENHAIN cables for **safety-related applications**. The **cable lengths** listed in the *Specifications* apply only for HEIDENHAIN cables and the recommended input circuitry of the subsequent electronics.

Durability

All encoders have polyurethane (PUR) cables. PUR cables are resistant to oil, hydrolysis and microbes in accordance with **VDE 0472**. They are free of PVC and silicone and comply with UL safety directives. The **UL certification** AWM STYLE 20963 80 °C 30 V E63216 is documented on the cable.

Temperature range

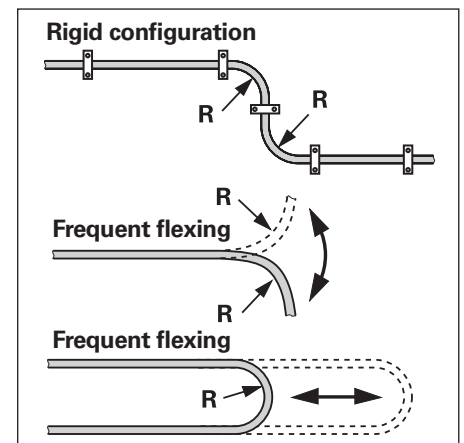
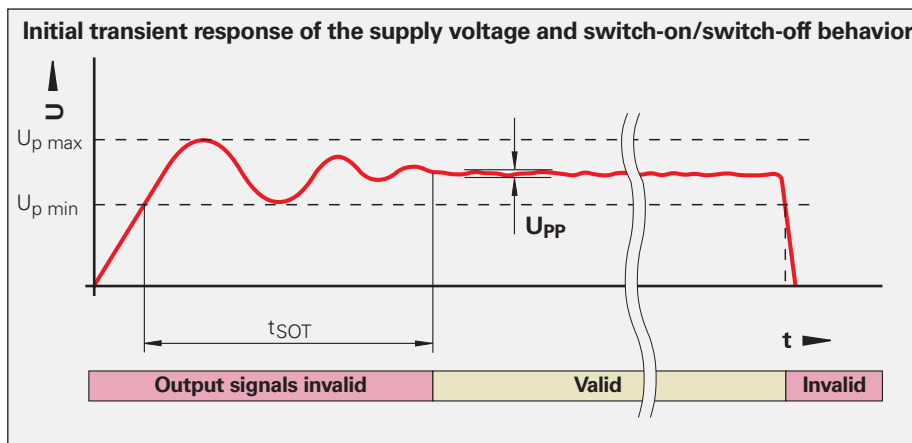
HEIDENHAIN cables can be used for

- rigid configuration -40 °C to 85 °C
- frequent flexing -10 °C to 85 °C

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

Bend radius

The permissible bend radii R depend on the cable diameter and the configuration:



Connect HEIDENHAIN position encoders only to subsequent electronics whose power supply is generated through double or strengthened insulation against line voltage circuits. Also see **IEC 364-4-41: 1992**, modified Chapter 411 regarding "protection against both direct and indirect touch" (PELV or SELV). If position encoders or electronics are used in safety-related applications, they must be operated with protective extra-low voltage (PELV) and provided with overcurrent protection or, if required, with overvoltage protection.

Cables	Cross section of power supply lines A_P				Bend radius R	
	$1 V_{PP}/TTL/HTL$	$11 \mu A_{PP}$	EnDat/SSI 17-pin	EnDat ⁽⁴⁾ 8-pin	Rigid configuration	Frequent flexing
$\varnothing 3.7 \text{ mm}$	0.05 mm^2	—	—	—	$\geq 8 \text{ mm}$	$\geq 40 \text{ mm}$
$\varnothing 4.5 \text{ mm}$ $\varnothing 5.1 \text{ mm}$	$0.14/0.05^{(2)} \text{ mm}^2$	0.05 mm^2	0.05 mm^2	0.14 mm^2	$\geq 10 \text{ mm}$	$\geq 50 \text{ mm}$
$\varnothing 6 \text{ mm}$ $\varnothing 10 \text{ mm}^{(1)}$	$0.19/0.14^{(3)} \text{ mm}^2$	—	0.08 mm^2	0.34 mm^2	$\geq 20 \text{ mm}$ $\geq 35 \text{ mm}$	$\geq 75 \text{ mm}$ $\geq 75 \text{ mm}$
$\varnothing 8 \text{ mm}$ $\varnothing 14 \text{ mm}^{(1)}$	0.5 mm^2	1 mm^2	0.5 mm^2	1 mm^2	$\geq 40 \text{ mm}$ $\geq 100 \text{ mm}$	$\geq 50 \text{ mm}$ $\geq 100 \text{ mm}$

⁽¹⁾Metal armor

⁽²⁾Length gauges

⁽³⁾LIDA 400

⁽⁴⁾Also Fanuc, Mitsubishi

Electrically Permissible Speed/ Traversing Speed

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

- the **mechanically** permissible shaft speed/traversing velocity (if listed in *Specifications*) and
- the **electrically** permissible shaft speed or traversing velocity.
For encoders with **sinusoidal output signals**, the electrically permissible shaft speed or traversing velocity is limited by the -3dB/-6dB cutoff frequency or the permissible input frequency of the subsequent electronics.
For encoders with **square-wave signals**, the electrically permissible shaft speed/traversing velocity is limited by
 - the maximum permissible scanning frequency $f_{\max}$ of the encoder and
 - the minimum permissible edge separation a for the subsequent electronics.

For angular or rotary encoders

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

For linear encoders

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

where:

$n_{\max}$: Electrically perm. speed in min^{-1}

$v_{\max}$: Electrically permissible traversing velocity in m/min

$f_{\max}$: Max. scanning/output frequency of encoder or input frequency of subsequent electronics in kHz

z : Line count of the angle or rotary encoder per 360°

SP : Signal period of the linear encoder in μm

Noise-Free Signal Transmission

Electromagnetic compatibility/ CE compliance

When properly installed, and when HEIDENHAIN connecting cables and cable assemblies are used, HEIDENHAIN encoders fulfill the requirements for electromagnetic compatibility according to 89/336/EEC with respect to the generic standards for:

• Noise immunity IEC 61000-6-2:

Specifically:	
– ESD	IEC 61000-4-2
– Electromagnetic fields	IEC 61000-4-3
– Burst	IEC 61000-4-4
– Surge	IEC 61000-4-5
– Conducted disturbances	IEC 61000-4-6
– Power frequency magnetic fields	IEC 61000-4-8
– Pulse magnetic fields	IEC 61000-4-9

• Interference IEC 61000-6-4:

Specifically:	
– For industrial, scientific and medical (ISM) equipment	IEC 55011
– For information technology equipment	IEC 55022

Transmission of measuring signals— electrical noise immunity

Noise voltages arise mainly through capacitive or inductive transfer. Electrical noise can be introduced into the system over signal lines and input or output terminals.

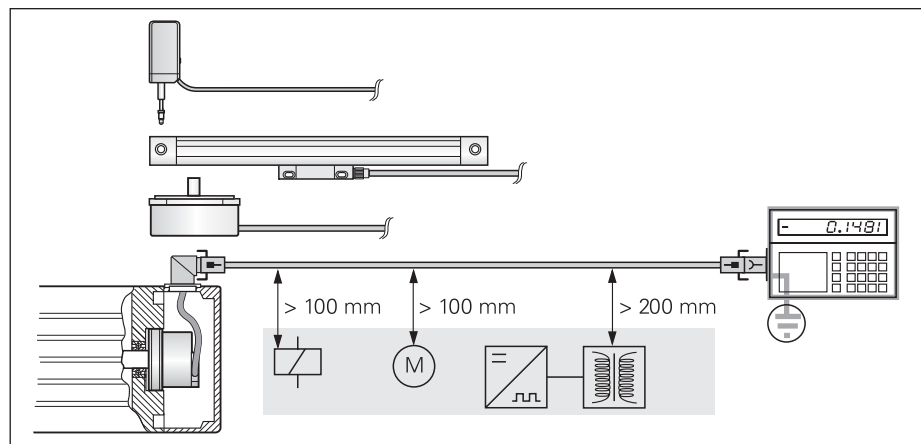
Possible sources of noise are:

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

Protection against electrical noise

The following measures must be taken to ensure disturbance-free operation:

- Use only HEIDENHAIN cables.
- Use connectors or terminal boxes with metal housings. Do not conduct any extraneous signals.
- Connect the housings of the encoder, connector, terminal box and evaluation electronics through the shield of the cable. Connect the shielding in the area of the cable outlets to be as induction-free as possible (short, full-surface contact).
- Connect the entire shielding system with the protective ground.
- Prevent contact of loose connector housings with other metal surfaces.
- The cable shielding has the function of an equipotential bonding conductor. If compensating currents are to be expected within the entire system, a separate equipotential bonding conductor must be provided. Also see **EN 50178/4.98** Chapter 5.2.9.5 regarding "protective connection lines with small cross section."
- Do not lay signal cables in the direct vicinity of interference sources (inductive consumers such as contacts, motors, frequency inverters, solenoids, etc.).
- Sufficient decoupling from interference-signal-conducting cables can usually be achieved by an air clearance of 100 mm or, when cables are in metal ducts, by a grounded partition.
- A minimum spacing of 200 mm to inductors in switch-mode power supplies is required. Also see **EN 50178/4.98** Chapter 5.3.1.1, regarding cables and lines, as well as **EN 50174-2/09.01**, Chapter 6.7, regarding grounding and potential compensation.
- When using **multiturn encoders in electromagnetic fields** greater than 30 mT, HEIDENHAIN recommends consulting with the main facility in Traunreut.



Minimum distance from sources of interference

Both the cable shielding and the metal housings of encoders and subsequent electronics have a shielding function. The housings must have the **same potential** and be connected to the main signal ground over the machine chassis or by means of a separate potential compensating line. Potential compensating lines should have a minimum cross section of 6 mm^2 (Cu).

Evaluation and Display Units

ND 281 B

Position display unit

The ND 281 B display unit contains special display ranges for angle measurement. You can directly connect incremental angle encoders with $\sim 1\text{-V}_{PP}$ output signals and any line count up to 999999 signal periods per revolution. The display value is available via the RS-232-C/V.24 interface for further processing or print-out.



For more information, see Digital Readouts brochure *Digital readouts / Linear encoders*

	ND 281 B	
Input signals	$\sim 1\text{ V}_{PP}$	$\sim 11\text{ }\mu\text{A}_{PP}$
Encoder inputs	Flange socket, 12-pin female	Flange socket, 9-pin female
Input frequency	Max. 500 kHz	Max. 100 kHz
Max. cable length	60 m	30 m
Signal subdivision	Up to 1024-fold (adjustable)	
Display step (adjustable)	<i>Decimal degrees:</i> 0.1° to 0.000002° <i>Degrees, minutes, seconds:</i> to 1"	
Display range (adjustable)	0° to 360° -180° 0 +180° 0 to $\pm$ max. display range	
Functions	Sorting and tolerance check mode with two limit values Display freeze Two switching limits REF reference mark evaluation	
External operation	Zero reset, preset and latch command	
Interface	RS-232-C/V.24; max. 38400 baud	

IK 220

Universal PC counter card

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



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

	IK 220			
Input signals (switchable)	 1 V _{PP}	 11 μA _{PP}	EnDat 2.1	SSI
Encoder inputs	2 D-sub connections (15-pin) male			
Input frequency	≤ 500 kHz	≤ 33 kHz	–	
Cable length	≤ 60 m		≤ 10 m	
Signal subdivision (signal period : meas. step)	Up to 4 096-fold			
Data register for measured values (per channel)	48 bits (44 bits used)			
Internal memory	For 8 192 position values			
Interface	PCI bus			
Driver software and demonstration program	For Windows 98/NT/2000/XP in VISUAL C++, VISUAL BASIC and BORLAND DELPHI			
Dimensions	Approx. 190 mm × 100 mm			

IBV/APE series

Interpolation and digitizing electronics

Interpolation and digitizing electronics interpolate and digitize the sinusoidal output signals ($\sim 1 V_{PP}$) from HEIDENHAIN encoders up to 400-fold, and convert them to TTL square-wave pulse trains.



IBV 101

For more information, see Product Information *IBV 100*, *IBV 600* and *APE 371* as well as the Product Overview of *Interface Electronics*.

	IBV 101	IBV 102	IBV 660	APE 371
Design	Housing			Connector
Protection	IP 65			IP 40
Input	$\sim 1 V_{PP}$			
Encoder connection	<i>IBV</i> : M23 flange socket 12-pin, female <i>APE</i> : D-sub connector 15-pin or M23 connector 12-pin, female			
Interpolation switchable	5-fold 10-fold	25-fold 50-fold 100-fold	25-fold 50-fold 100-fold 200-fold 400-fold	5-fold 10-fold 20-fold 25-fold 50-fold 100-fold
Output	- Two $\square$ TTL square-wave pulse trains U_{a1} and U_{a2} and their inverted signals $\overline{U_{a1}}$ and $\overline{U_{a2}}$ - Reference pulse U_{a0} and $\overline{U_{a0}}$ - Fault detection signal $\overline{U_{as}}$ - Limit and homing signals H, L (for APE 371)			
Power supply	$5 V \pm 5\%$			

EIB series

External Interface Box

The External Interface Box subdivides the sinusoidal output signals from HEIDENHAIN encoders and converts them into absolute position values with the aid of the integrated counting function. After the reference mark has been crossed, the position value is defined with respect to a fixed reference point.



EIB 392

For more information, see Product Information *EIB 100* and *EIB 300* as well as the Product Overview of *Interface Electronics*.

	EIB 192	EIB 392
Design	Housing	Connector
Protection	IP 65	IP 40
Input	$\sim 1 V_{PP}$	
Encoder connection	M23 connector 12-pin, female	- D-sub connector 15-pin - M23 connector 12-pin, female
Subdivision	≤ 16384	
Output	Absolute position values	
Interface	<i>EIB 192/EIB 392</i> : EnDat 2.2 <i>EIB 192 F/EIB 392 F</i> : Fanuc Serial Interface <i>EIB 192 M/EIB 392 M</i> : Mitsubishi High Speed Serial Interface	
Power supply	$5 V \pm 5\%$	

HEIDENHAIN

DR. JOHANNES HEIDENHAIN GmbH

Dr.-Johannes-Heidenhain-Straße 5
83301 Traunreut, Germany
 ☎ +49 (8669) 31-0
 ☎ +49 (8669) 5061
 E-Mail: info@heidenhain.de

www.heidenhain.de

- DE HEIDENHAIN Technisches Büro Nord**
 12681 Berlin, Deutschland
 ☎ (030) 547 05-240
 E-Mail: tbn@heidenhain.de
- HEIDENHAIN Technisches Büro Mitte**
 08468 Heinsdorfergrund, Deutschland
 ☎ (03765) 69544
 E-Mail: tbn@heidenhain.de
- HEIDENHAIN Technisches Büro West**
 58093 Hagen, Deutschland
 ☎ (02331) 9579-0
 E-Mail: tbw@heidenhain.de
- HEIDENHAIN Technisches Büro Südwest**
 70771 Leinfelden-Echterdingen, Deutschland
 ☎ (0711) 993395-0
 E-Mail: tbsw@heidenhain.de
- HEIDENHAIN Technisches Büro Südost**
 83301 Traunreut, Deutschland
 ☎ (08669) 31-1345
 E-Mail: tbso@heidenhain.de

- AR NAKASE SRL.**
 B1653AOX Villa Ballester, Argentina
 ☎ +54 (11) 47684242
 E-Mail: nakase@nakase.com
- AT HEIDENHAIN Techn. Büro Österreich**
 83301 Traunreut, Germany
 ☎ +49 (8669) 31-1337
 E-Mail: tba@heidenhain.de
- AU FCR Motion Technology Pty. Ltd**
 Laverton North 3026, Australia
 ☎ +61 (3) 93626800
 E-Mail: vicsales@fcrmotion.com
- BE HEIDENHAIN NV/SA**
 1760 Roosdaal, Belgium
 ☎ +32 (54) 343158
 E-Mail: sales@heidenhain.be
- BG ESD Bulgaria Ltd.**
 Sofia 1172, Bulgaria
 ☎ +359 (2) 9632949
 E-Mail: info@esd.bg
- BR DIADUR Indústria e Comércio Ltda.**
 04763-070 – São Paulo – SP, Brazil
 ☎ +55 (11) 5696-6777
 E-Mail: diadur@diadur.com.br
- BY Belarus → RU**
- CA HEIDENHAIN CORPORATION**
 Mississauga, Ontario L5T 2N2, Canada
 ☎ +1 (905) 670-8900
 E-Mail: info@heidenhain.com
- CH HEIDENHAIN (SCHWEIZ) AG**
 8603 Schwerzenbach, Switzerland
 ☎ +41 (44) 8062727
 E-Mail: verkauf@heidenhain.ch
- CN DR. JOHANNES HEIDENHAIN (CHINA) Co., Ltd.**
 Beijing 101312, China
 ☎ +86 10-80420000
 E-Mail: sales@heidenhain.com.cn

- CS Serbia and Montenegro → BG**
- CZ HEIDENHAIN s.r.o.**
 106 00 Praha 10, Czech Republic
 ☎ +420 2 72658131
 E-Mail: heidenhain@heidenhain.cz
- DK TP TEKNIK A/S**
 2670 Greve, Denmark
 ☎ +45 (70) 100966
 E-Mail: tp-gruppen@tp-gruppen.dk
- ES FARRESA ELECTRONICA S.A.**
 08028 Barcelona, Spain
 ☎ +34 934092491
 E-Mail: farresa@farresa.es
- FI HEIDENHAIN Scandinavia AB**
 02770 Espoo, Finland
 ☎ +358 (9) 8676476
 E-Mail: info@heidenhain.fi
- FR HEIDENHAIN FRANCE sarl**
 92310 Sèvres, France
 ☎ +33 01 41 143000
 E-Mail: info@heidenhain.fr
- GB HEIDENHAIN (G.B.) Limited**
 Burgess Hill RH15 9RD, United Kingdom
 ☎ +44 (1444) 247711
 E-Mail: sales@heidenhain.co.uk
- GR MB Milionis Vassilis**
 17341 Athens, Greece
 ☎ +30 (210) 9336607
 E-Mail: bmilioni@otenet.gr
- HK HEIDENHAIN LTD**
 Kowloon, Hong Kong
 ☎ +852 27591920
 E-Mail: service@heidenhain.com.hk
- HR Croatia → SL**
- HU HEIDENHAIN Kereskedelmi Képviselet**
 1239 Budapest, Hungary
 ☎ +36 (1) 4210952
 E-Mail: info@heidenhain.hu
- ID PT Servitama Era Toolsindo**
 Jakarta 13930, Indonesia
 ☎ +62 (21) 46834111
 E-Mail: ptset@group.gts.co.id
- IL NEUMO VARGUS MARKETING LTD.**
 Tel Aviv 61570, Israel
 ☎ +972 (3) 5373275
 E-Mail: neumo@neumo-vargus.co.il
- IN ASHOK & LAL**
 Chennai – 600 030, India
 ☎ +91 (44) 26151289
 E-Mail: ashoklal@satyam.net.in
- IT HEIDENHAIN ITALIANA S.r.l.**
 20128 Milano, Italy
 ☎ +39 02270751
 E-Mail: info@heidenhain.it
- JP HEIDENHAIN K.K.**
 Tokyo 102-0073, Japan
 ☎ +81 (3) 3234-7781
 E-Mail: sales@heidenhain.co.jp
- KR HEIDENHAIN LTD.**
 Suwon, South Korea, 443-810
 ☎ +82 (31) 2011511
 E-Mail: info@heidenhain.co.kr
- MK Macedonia → BG**
- MX HEIDENHAIN CORPORATION MEXICO**
 20235 Aguascalientes, Ags., Mexico
 ☎ +52 (449) 9130870
 E-Mail: info@heidenhain.com
- MY ISOSERVE Sdn. Bhd**
 56100 Kuala Lumpur, Malaysia
 ☎ +60 (3) 91320685
 E-Mail: isoserve@po.jaring.my

- NL HEIDENHAIN NEDERLAND B.V.**
 6716 BM Ede, Netherlands
 ☎ +31 (318) 581800
 E-Mail: verkoop@heidenhain.nl
- NO HEIDENHAIN Scandinavia AB**
 7300 Orkanger, Norway
 ☎ +47 72480048
 E-Mail: info@heidenhain.no
- PH Machinebanks` Corporation**
 Quezon City, Philippines 1113
 ☎ +63 (2) 7113751
 E-Mail: info@machinebanks.com
- PL APS**
 02-489 Warszawa, Poland
 ☎ +48 228639737
 E-Mail: aps@apserwis.com.pl
- PT FARRESA ELECTRÓNICA, LDA.**
 4470 - 177 Maia, Portugal
 ☎ +351 229478140
 E-Mail: fep@farresa.pt
- RO Romania → HU**
- RU OOO HEIDENHAIN**
 125315 Moscow, Russia
 ☎ +7 (495) 931-9646
 E-Mail: info@heidenhain.ru
- SE HEIDENHAIN Scandinavia AB**
 12739 Skärholmen, Sweden
 ☎ +46 (8) 53193350
 E-Mail: sales@heidenhain.se
- SG HEIDENHAIN PACIFIC PTE LTD.**
 Singapore 408593,
 ☎ +65 6749-3238
 E-Mail: info@heidenhain.com.sg
- SK Slovakia → CZ**
- SL Posredništvo HEIDENHAIN SAŠO HÜBL s.p.**
 2000 Maribor, Slovenia
 ☎ +386 (2) 4297216
 E-Mail: hubl@siol.net
- TH HEIDENHAIN (THAILAND) LTD**
 Bangkok 10250, Thailand
 ☎ +66 (2) 398-4147-8
 E-Mail: info@heidenhain.co.th
- TR T&M Mühendislik San. ve Tic. LTD. ŞTİ.**
 34738 Erenköy-Istanbul, Turkey
 ☎ +90 (216) 3022345
 E-Mail: info@tmmuhendislik.com.tr
- TW HEIDENHAIN Co., Ltd.**
 Taichung 407, Taiwan
 ☎ +886 (4) 23588977
 E-Mail: info@heidenhain.com.tw
- UA Ukraine → RU**
- US HEIDENHAIN CORPORATION**
 Schaumburg, IL 60173-5337, USA
 ☎ +1 (847) 490-1191
 E-Mail: info@heidenhain.com
- VE Maquinaria Diekmann S.A.**
 Caracas, 1040-A, Venezuela
 ☎ +58 (212) 6325410
 E-Mail: purchase@diekmann.com.ve
- VN AMS Advanced Manufacturing Solutions Pte Ltd**
 HCM City, Việt Nam
 ☎ +84 (8) 9123658 - 8352490
 E-Mail: davidgoh@amsvn.com
- ZA MAFEMA SALES SERVICES C.C.**
 Midrand 1685, South Africa
 ☎ +27 (11) 3144416
 E-Mail: mailbox@mafema.co.za

