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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Specifications

	Series or model	*System accuracy*	
Angle encoders without integral bearing	**ERP 880**	± 1"	28
	ERP 4080/ERP 8080	to ± 2.0"	30
	ERA 4000 Series	to ± 2.0"	32
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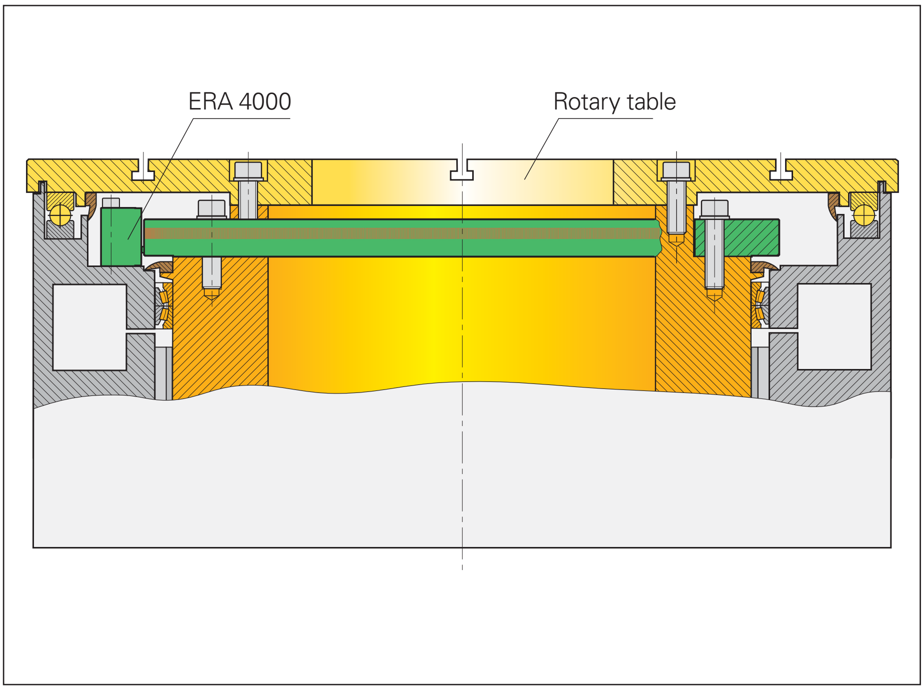
HEIDENHAIN Angle Encoders

The term angle encoder is typically used to describe encoders that have an accuracy of better than ± 5" and a line count above 10 000. In contrast, rotary encoders are encoders that typically have an accuracy of more than ± 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

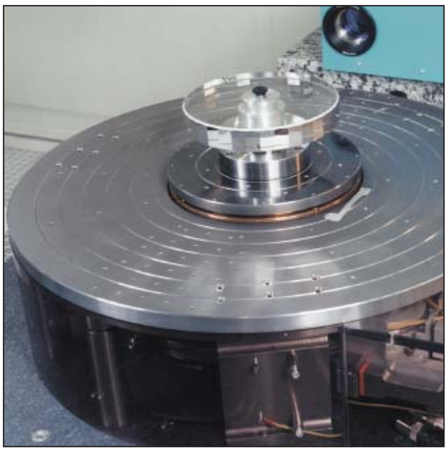
etc.

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

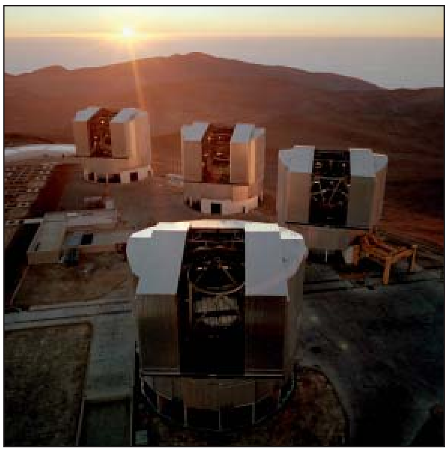


The **ERA 4000** angle encoder mounted onto the rotary table of a machine tool

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 m with a scale tape)
- High shaft speeds
- No additional starting torque from shaft seals
- High reproducibility
- High adaptablity 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.

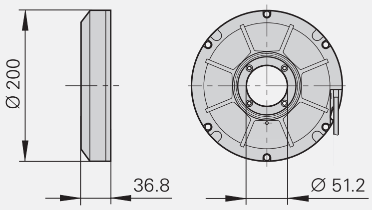
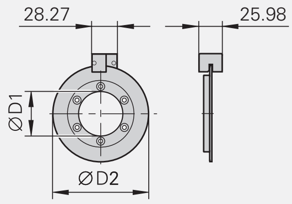
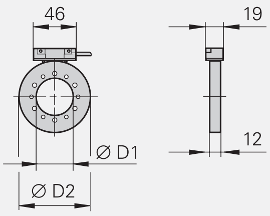
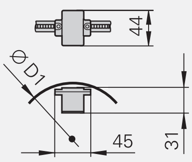
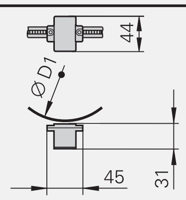
Angle encoders with integral stator coupling therefore provide excellent dynamic performance because the coupling absorbs only that torque caused by friction in the bearing during angular acceleration of the shaft.

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		–	90 000/± 1" (180 000 signal periods)	0.000 01°	≤ 1 000 min^{-1}
ERP 4000		D1: 8 mm D2: 44 mm	65 536/± 5" (131 072 signal periods)	0.000 01°	≤ 300 min^{-1}
ERP 8000		D1: 50 mm D2: 108 mm	180 000/± 2" (360 000 signal periods)	0.000 005°	≤ 100 min^{-1}
ERA 4x80 Steel circumferential-scale drum with centering collar		D1: 40 mm to 512 mm D2: 76.75 mm to 560.46 mm	3 000/± 9.4" to 52 000/± 2.3"	0.002° to 0.000 05°	≤ 10 000 min^{-1} to ≤ 1 500 min^{-1}
ERA 4x81 Steel circumferential scale drum with low weight and low moment of inertia		D1: 26 mm to 280 mm D2: 52.65 mm to 305.84 mm	4 096/± 10.2" to 48 000/± 2.8"		≤ 6 000 min^{-1} to ≤ 2 000 min^{-1}
ERA 4282 Steel circumferential scale drum for increased accuracy requirements		D1: 40 mm to 270 mm D2: 76.75 mm to 331.31 mm	12 000/± 5.1" to 52 000/± 2"		≤ 10 000 min^{-1} to ≤ 2 500 min^{-1}
Grating on steel tape					
ERA 700 For inside diameter mounting		458.62 mm 573.20 mm 1 146.10 mm	**Full circle**[1] 36 000/± 3.5" 45 000/± 3.4" 90 000/± 3.2"	0.000 2° to 0.000 02°	≤ 500 min^{-1}
		318.58 mm 458.62 mm 573.20 mm	**Segment**[2] 5 000 10 000 20 000		
ERA 800 For outside diameter mounting		458.04 mm 572.63 mm	**Full circle**[1] 36 000/± 3.5" 45 000/± 3.4"	0.000 2° to 0.000 05°	≤ 100 min^{-1}
		317.99 mm 458.04 mm 572.63 mm	**Segment**[2] 5 000 10 000 20 000		

[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
	∼ 1 V_{PP}/–	One	**ERP 880**	**28**
		None	**ERP 4080**	**30**
			ERP 8080	
	∼ 1 V_{PP}/20 µm	Distance-coded	**ERA 4280 C**	**32**
	∼ 1 V_{PP}/40 µm		**ERA 4480 C**	
	∼ 1 V_{PP}/80 µm		**ERA 4880 C**	
	∼ 1 V_{PP}/20 µm		**ERA 4281 C**	**36**
	∼ 1 V_{PP}/40 µm		**ERA 4481 C**	
	∼ 1 V_{PP}/20 µm		**ERA 4282 C**	**38**
	∼ 1 V_{PP}/40 µm	Distance-coded (nominal increment of 1 000 grating periods)	**ERA 780 C** full circle	**40**
			ERA 781 C segment	
	∼ 1 V_{PP}/40 µm	Distance-coded (nominal increment of 1 000 grating periods)	**ERA 880 C** full circle	**42**
			ERA 881 C segment with tensioning elements	
			ERA 882 C segment without tensioning elements	

ERP 880

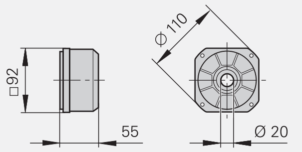
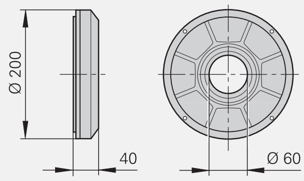
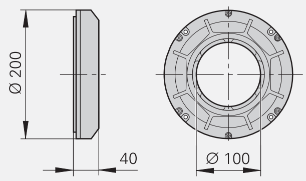
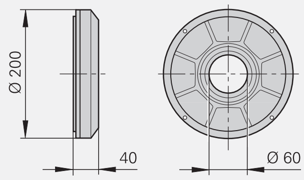
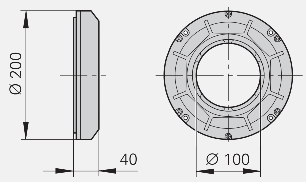
ERP 4080

ERA 4000

ERA 780

ERA 880

Selection Guide
Absolute Angle Encoders with Integral Bearing

Series	Overall dimensions in mm	System accuracy	Recommended measuring step[1]	Mechanically perm. speed	Incremental signals	Signal periods/rev
With integrated stator coupling						
RCN 200		± 5“	0.0001°	3000 min^{-1}	∿ 1 V_{PP}	16384
					–	–
					–	–
					–	–
		± 2.5“			∿ 1 V_{PP}	16384
					–	–
					–	–
					–	–
RCN 700		± 2“	0.0001°	1000 min^{-1}	∿ 1 V_{PP}	32768
					–	–
					–	–
					–	–
					∿ 1 V_{PP}	32768
					–	–
					–	–
					–	–
RCN 800		± 1“	0.00005°	1000 min^{-1}	∿ 1 V_{PP}	32768
					–	–
					–	–
					–	–
					∿ 1 V_{PP}	32768
					–	–
					–	–
					–	–

[1] For position measurement

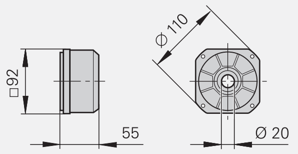
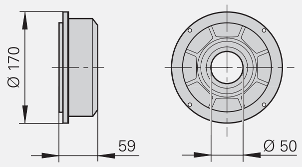
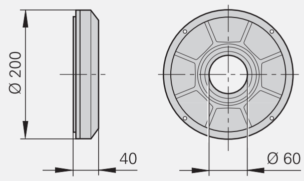
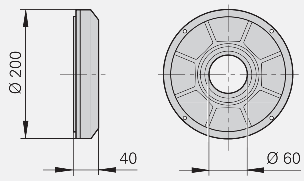
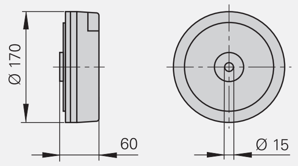
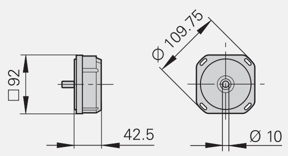
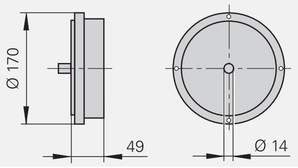
	Absolute position values	Absolute positions per revolution	Model	For more information
	EnDat 2.2 / 02	67 108 864 ≙ 26 bits	**RCN 226**	Catalog: *Angle Encoders with Integral Bearing*
	EnDat 2.2/22	67 108 864 ≙ 26 bits	**RCN 226**	
	Fanuc 02	8 388 608 ≙ 23 bits	**RCN 223 F**	
	Mit 02-4	8 388 608 ≙ 23 bits	**RCN 223 M**	
	EnDat 2.2 / 02	268 435 456 ≙ 28 bits	**RCN 228**	
	EnDat 2.2/22	268 435 456 ≙ 28 bits	**RCN 228**	
	Fanuc 02	134 217 728 ≙ 27 bits	**RCN 227 F**	
	Mit 02-4	134 217 728 ≙ 27 bits	**RCN 227 M**	
	EnDat 2.2 / 02	536 870 912 ≙ 29 bits	**RCN 729**	
	EnDat 2.2/22	536 870 912 ≙ 29 bits	**RCN 729**	
	Fanuc 02	134 217 728 ≙ 27 bits	**RCN 727 F**	
	Mit 02-4	134 217 728 ≙ 27 bits	**RCN 727 M**	
	EnDat 2.2 / 02	536 870 912 ≙ 29 bits	**RCN 729**	
	EnDat 2.2/22	536 870 912 ≙ 29 bits	**RCN 729**	
	Fanuc 02	134 217 728 ≙ 27 bits	**RCN 727 F**	
	Mit 02-4	134 217 728 ≙ 27 bits	**RCN 727 M**	
	EnDat 2.2 / 02	536 870 912 ≙ 29 bits	**RCN 829**	
	EnDat 2.2/22	536 870 912 ≙ 29 bits	**RCN 829**	
	Fanuc 02	134 217 728 ≙ 27 bits	**RCN 827 F**	
	Mit 02-4	134 217 728 ≙ 27 bits	**RCN 827 M**	
	EnDat 2.2 / 02	536 870 912 ≙ 29 bits	**RCN 829**	
	EnDat 2.2/22	536 870 912 ≙ 29 bits	**RCN 829**	
	Fanuc 02	134 217 728 ≙ 27 bits	**RCN 827 F**	
	Mit 02-4	134 217 728 ≙ 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°	
			0.0001°	
		± 2.5“		
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
	⊓⊔TTL	18000[2)]	**RON 225**	Catalog: *Angle Encoders with Integral Bearing*
	⊓⊔TTL	180000/90000[2)]	**RON 275**	
	∼ 1 V_{PP}	18000	**RON 285**	
	∼ 1 V_{PP}	18000	**RON 287**	
	∼ 1 V_{PP}	18000	**RON 785**	
	∼ 1 V_{PP}	18000/36000	**RON 786**	
	∼ 1 V_{PP}	36000	**RON 886**	
	∼ 1 V_{PP}	180000	**RPN 886**	
	∼ 11 μA_{PP}	36000	**RON 905**	
	⊓⊔TTL	18000[2)]	**ROD 220**	Catalog: *Angle Encoders with Integral Bearing*
	⊓⊔TTL	180000[2)]	**ROD 270**	
	∼ 1 V_{PP}	18000	**ROD 280**	
	∼ 1 V_{PP}	18000/36000	**ROD 780**	
	∼ 1 V_{PP}	36000	**ROD 880**	

RON 285

RON 786

RON 905

ROD 280

ROD 780

Measuring Principles
Measuring Standard

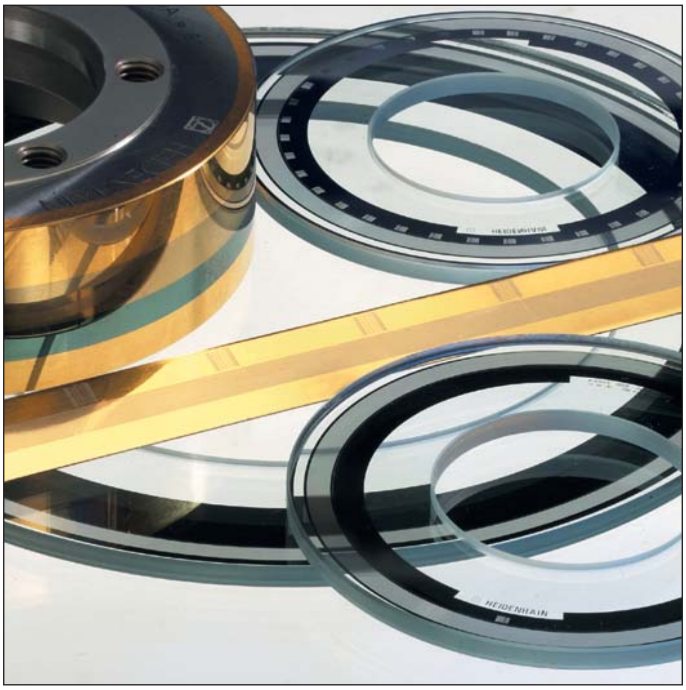
HEIDENHAIN encoders incorporate measuring standards of periodic structures known as graduations.
These graduations are applied to a glass or steel substrate. Glass scales are used primarily in encoders for speeds up to 10000 min^{-1}. For higher speeds—up to 20000 min^{-1}—steel drums are used. The scale 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 µm for AURODUR
- 20 µm for METALLUR
- 10 µm for DIADUR
- 4 µm 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

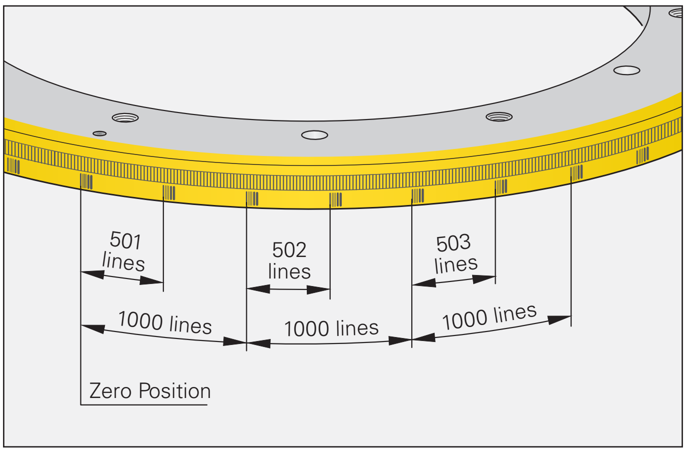
I = Nominal increment between two fixed reference marks (see tables)

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

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.

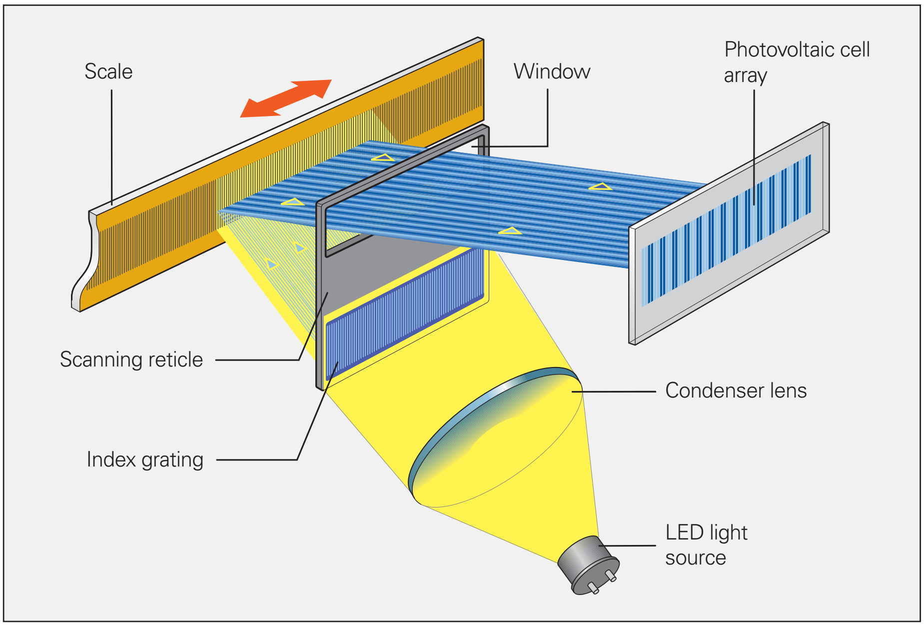
The finer the grating period of a measuring standard is, the greater the effect of diffraction on photoelectric scanning. HEIDENHAIN uses two scanning principles with angle encoders:

- 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 toleranced 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.



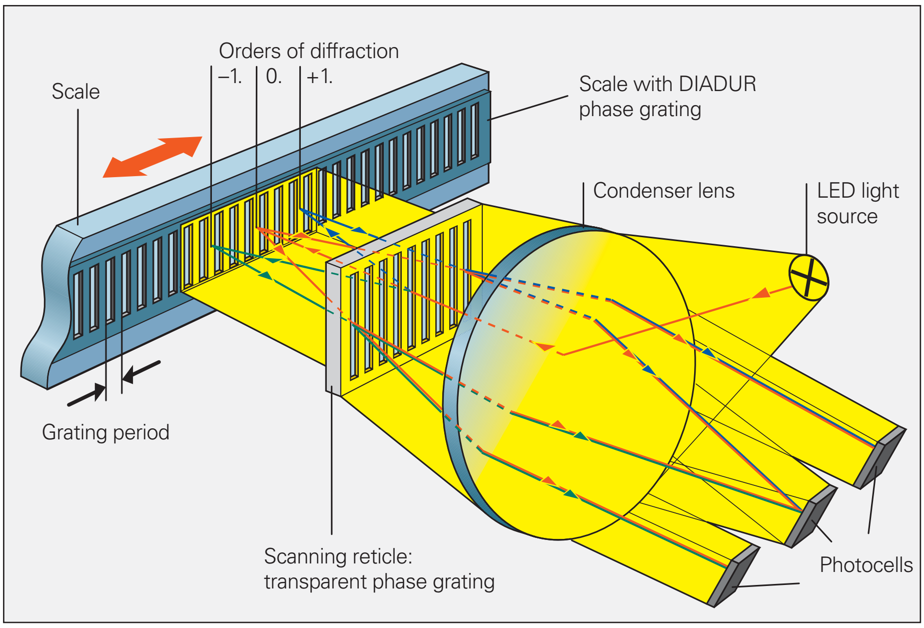
Photoelectric scanning in accordance with the imaging principle with a steel scale and single-field scanning

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 µm 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 µm 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 ± 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).

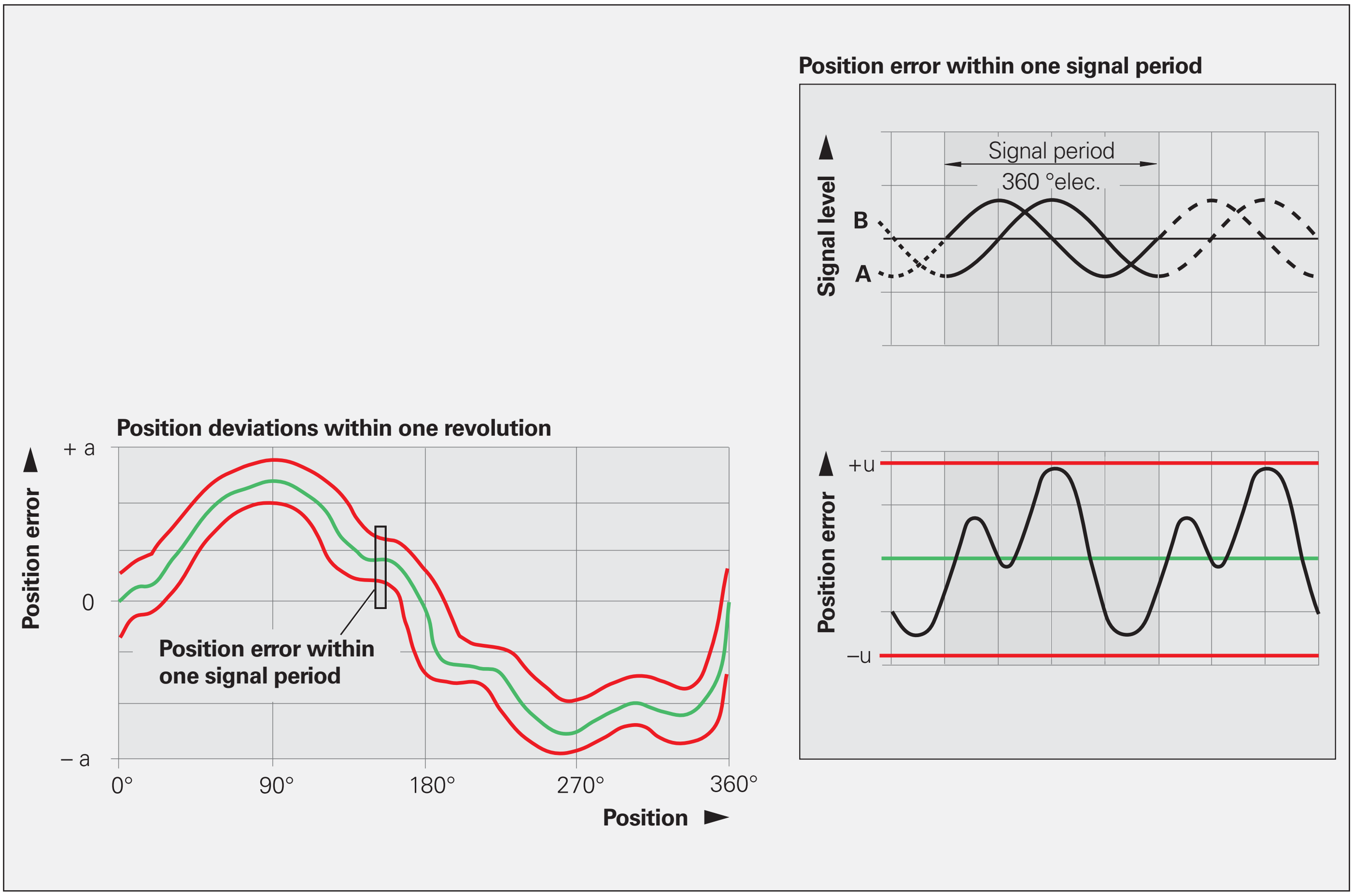
Position errors within one revolution become apparent in larger angular motions.

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 ±1 % of the signal period (ERP 880: ± 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 ± 1 %, this results in maximum position error within one signal period of approx. ± 0.000 11°, or approx. ± 0.40".



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

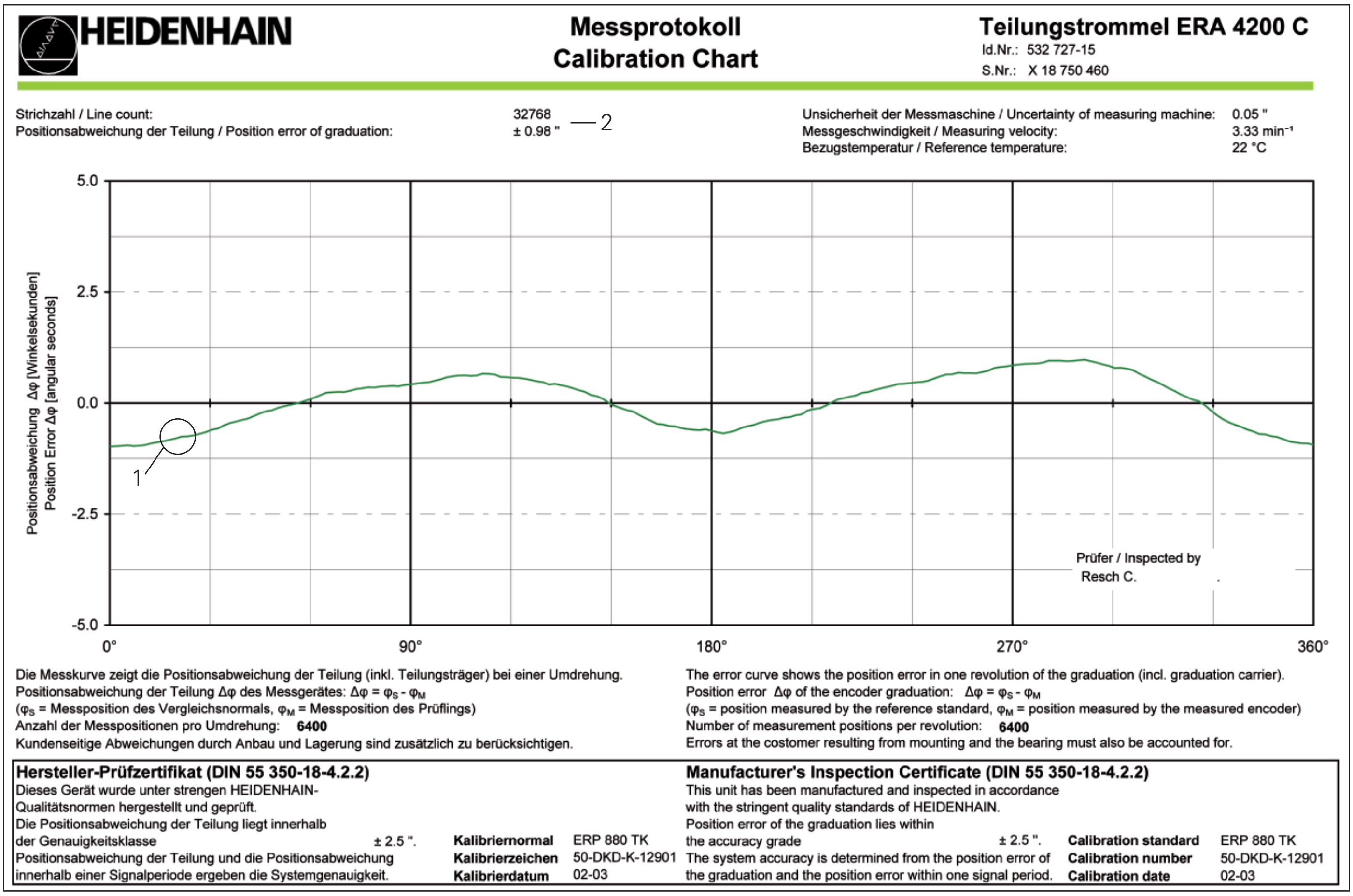
The calibration chart documents the accuracy of the graduation (including its substrate or hub) and serves as a traceability record to a calibration standard. Additional error caused by mounting and the bearing of the measured shaft is not included in the accuracy data.

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 4200 C
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 $\Delta\varphi$ occurs when the nominal scale-tape bearing-surface diameter is not exactly maintained:

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

where
$\Delta\varphi$ = 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.

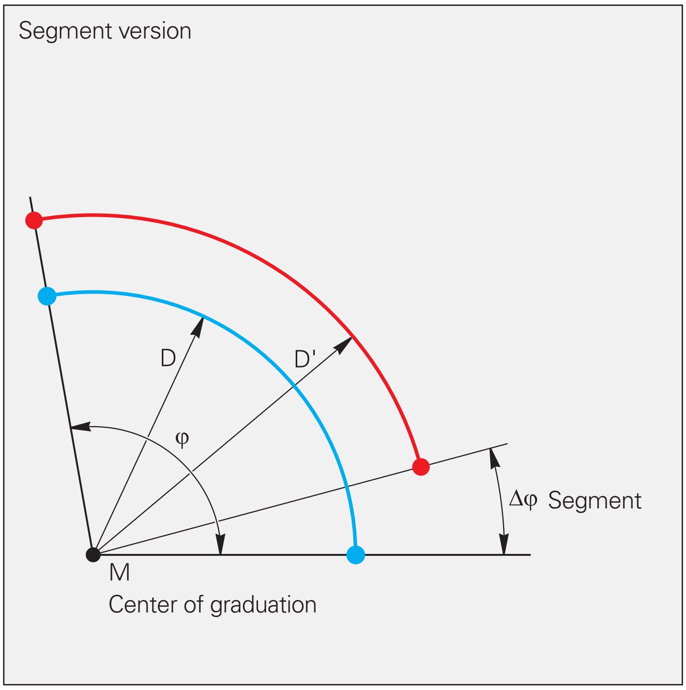
2. Error due to eccentricity of the graduation to the bearing
Under normal circumstances the graduation will have a certain amount of eccentricity to the bearing after the disk/hub assembly (ERP), circumferential-scale drum (ERA 4000) or scale tape (ERA 78xC and ERA 88xC) is mounted. In addition, dimensional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

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

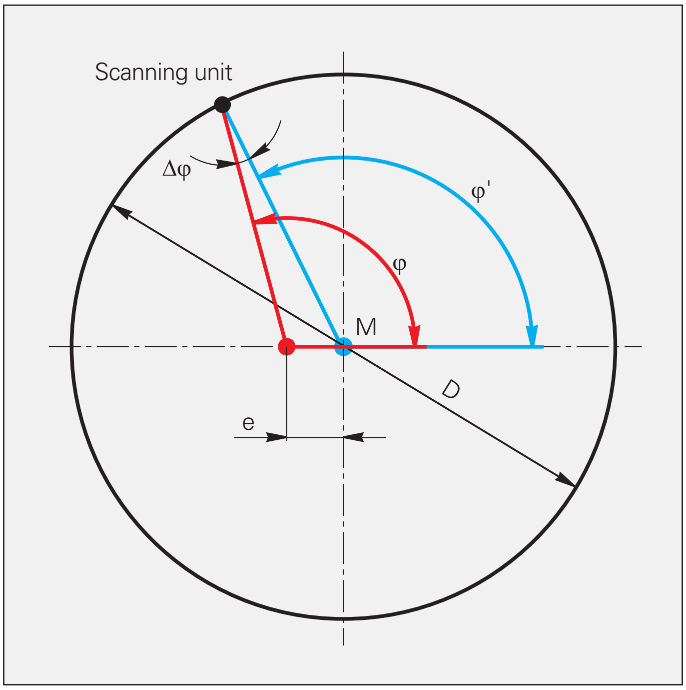
$$\Delta\varphi = \pm 412 \cdot \frac{e}{D}$$

$\Delta\varphi$ = 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



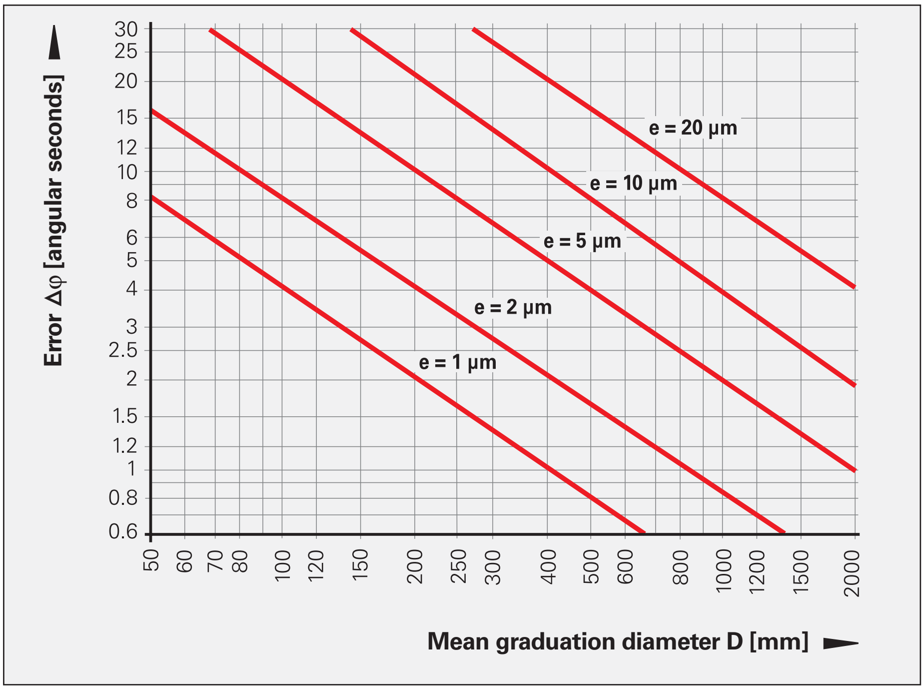
Model	Mean graduation diameter D	Deviation per 1 µm eccentricity
ERP 880	D = 126 mm	± 3.3"
ERP 4080	D = 40 mm	± 10.3"
ERP 8080	D = 104 mm	± 4.0"
ERA 4000	D = 53 mm	± 7.8"
	D = 77 mm	± 5.4"
	D = 105 mm	± 3.9"
	D = 128 mm	± 3.2"
	D = 153 mm	± 2.7"
	D = 179 mm	± 2.3"
	D = 209 mm	± 2.0"
	D = 255 mm	± 1.6"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

3. Error due to radial deviation of the bearing

The equation for the measuring error Δφ 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.

Resultant measured deviations Δφ for various eccentricity values e as a function of mean graduation diameter D



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

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 ± 1 % (ERP 880: ± 1.5 %). Below are the values for the ERP and ERA 4000 encoders as an example:

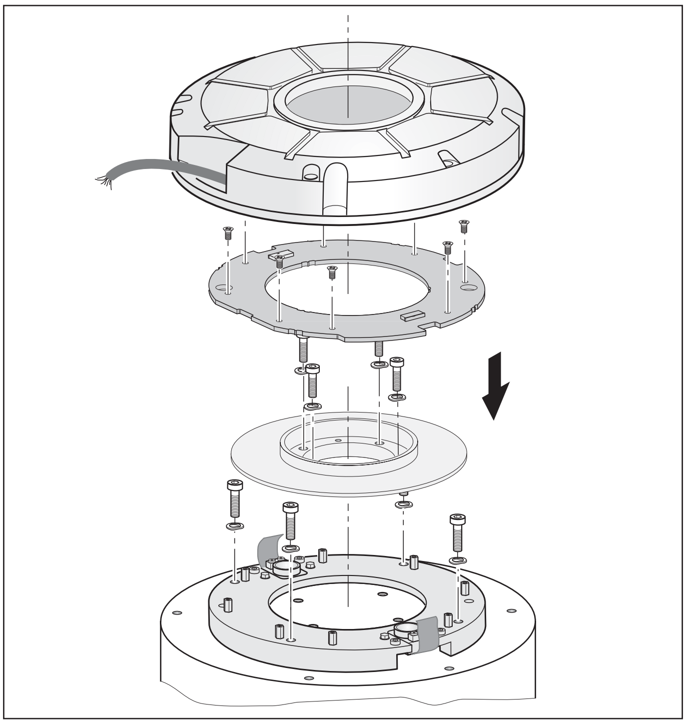
Model	Line count	Position error within one signal period $\Delta\varphi_u$
ERP 880	90 000 (≙ 180 000 signal periods)	≤ ± 0.1"
ERP 4080	65 536 (≙ 131 072 signal periods)	≤ ± 0.1"
ERP 8080	180 000 (≙ 360 000 signal periods)	≤ ± 0.04"
ERA 4000	3 000	≤ ± 4.4"
	4 096	≤ ± 3.2"
	5 000	≤ ± 2.6"
	6 000	≤ ± 2.2"
	7 000	≤ ± 1.9"
	8 192	≤ ± 1.6"
	10 000	≤ ± 1.3"
	12 000	≤ ± 1.1"
	13 000	≤ ± 1.0"
	14 000	≤ ± 1.0"
	16 384	≤ ± 0.8"
	20 000	≤ ± 0.7"
	24 000	≤ ± 0.6"
	26 000	≤ ± 0.5"
	28 000	≤ ± 0.5"
	32 768	≤ ± 0.4"
	38 000	≤ ± 0.4"
	40 000	≤ ± 0.4"
	44 000	≤ ± 0.3"
	48 000	≤ ± 0.3"
	52 000	≤ ± 0.3"

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 ± 1.5 µm 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 ± 1.5 µm 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 369774-01

IP 64 housing
With shaft sealing ring for IP 64 protection
Cable, 1 m, with male coupling, 12-pin
ID 369774-02

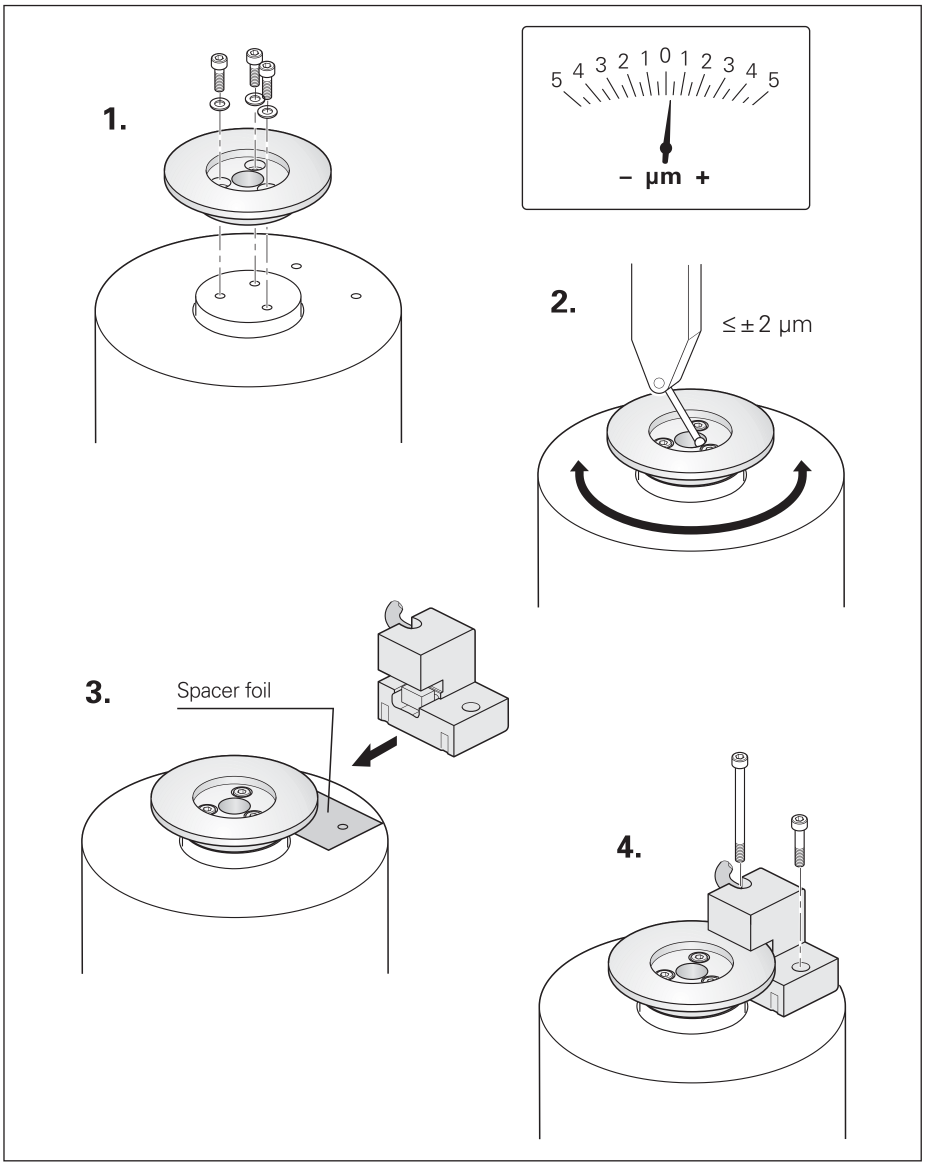
ERP 4080/ERP 8080

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. The wobble of the shaft is to be measured and the maximum and minimum positions determined. The disk/hub assembly is then mounted such that the remaining wobble is minimized.

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. The circular scale can be centered using a dial indicator on the inside diameter of the hub, or optically using the centering circle integrated in the circular scale, or electrically with the aid 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 ≥ 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.

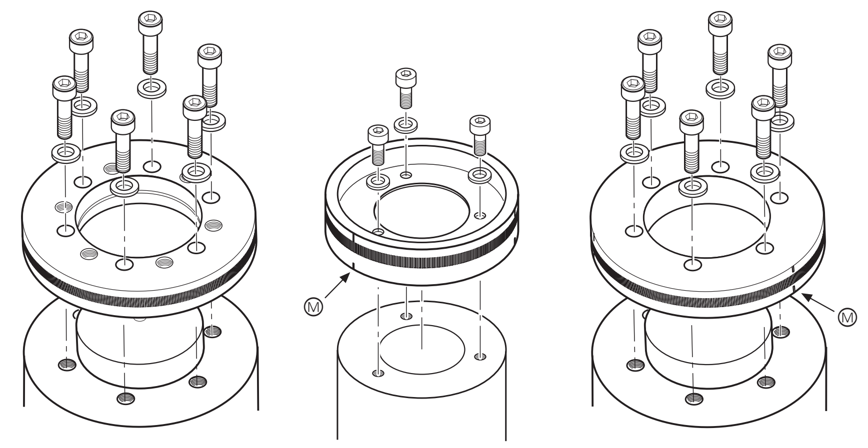
Special design features of the ERA modular angular encoders assure comparitively fast mounting and easy adjustment.

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.

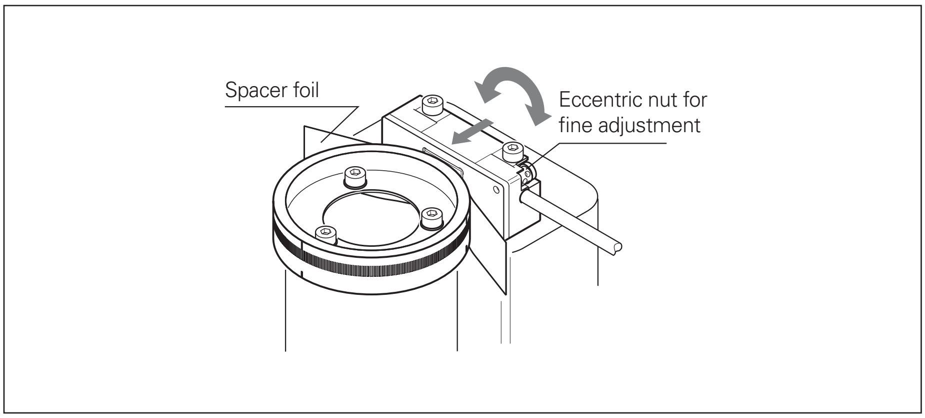
Mounting the ERA 4202 scale drum
The solid scale drum is centered over three positions at 120° increments on its circumference and fastened with screws. The benefits of three-point centering and the solid design of the scale drum make it possible to attain a very high accuracy when the encoder is mounted. 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

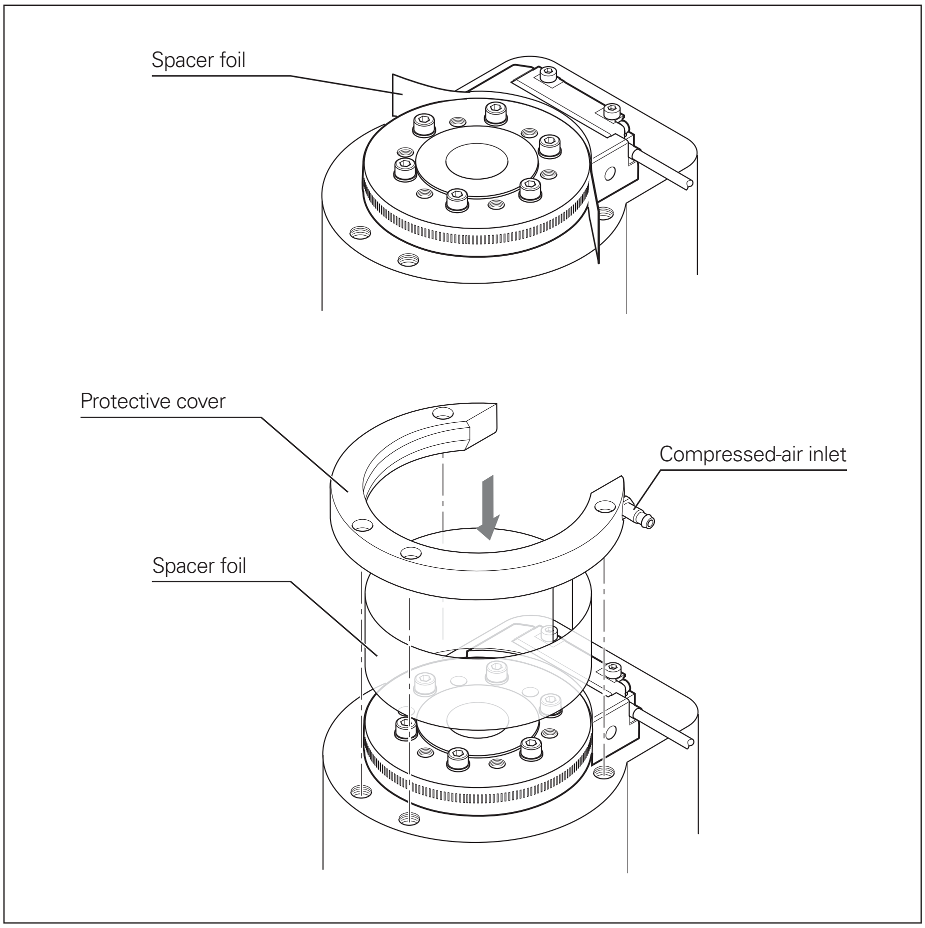
Mounting the scanning head
To mount the scanning head, the spacer foil is placed on the surface of the scale drum. The scanning head is pressed against the foil, fastened, and the foil is removed. ERA 4000 encoders with 20 µm grating period also feature an eccentric nut for fine adjustment of the scanning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

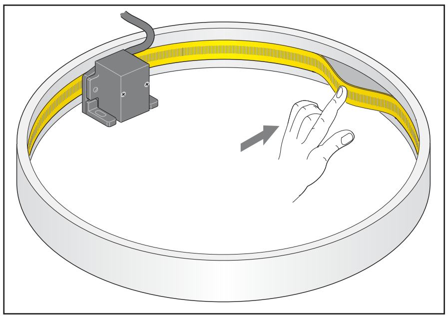
of a machine element.

The ERA 780 C und ERA 880 C 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.

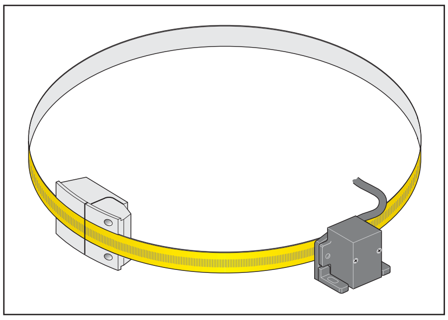
Mounting the scale tape for full-circle applications

ERA 780 C: 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.



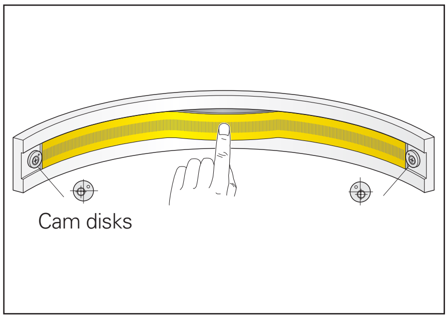
ERA 880 C: The scale tape is supplied with the halves of the tensioning cleat already mounted on the tape ends. An **external slot** is necessary for mounting. Space must also be provided for the tensioning cleat. The tape is placed in the outside slot of the machine (along slot edge) and is tensioned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

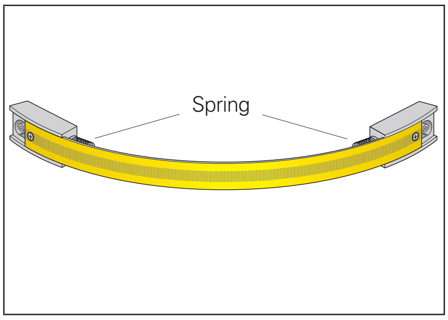


Mounting the scale tape for segment angles

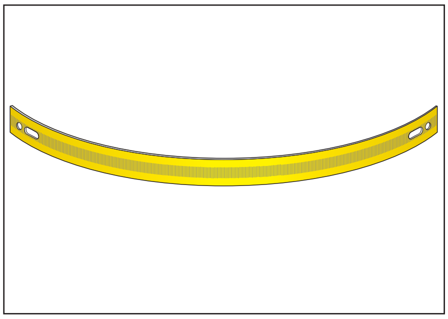
ERA 781 C: An internal slot with a certain diameter is required. The two cam disks fixed in this slot are adjusted so that the scale can be snapped into the slot under pressure.



ERA 881 C: 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 882 C: 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.

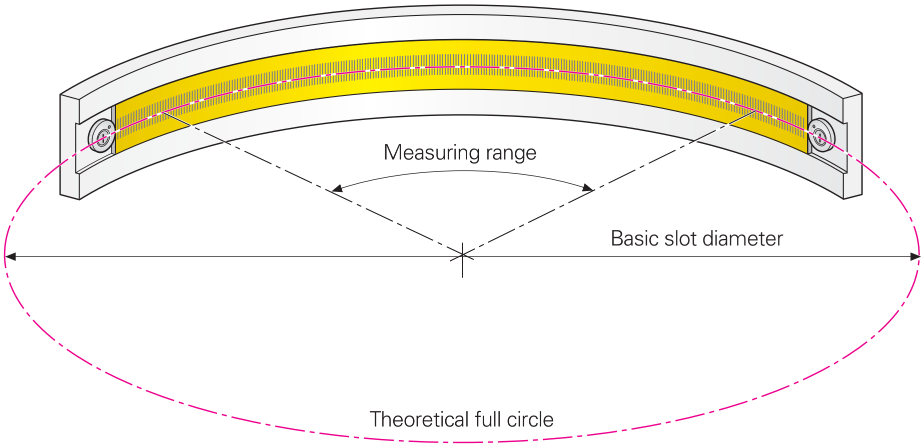


The following must be kept in mind for segment applications:

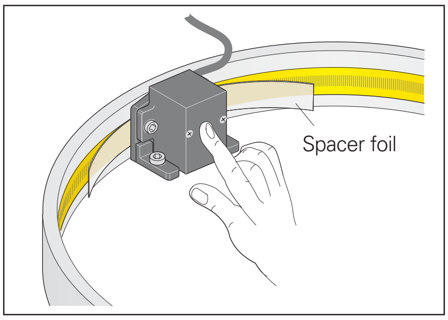
- **Specification of slot-floor diameter**
  In order to guarantee the correct functioning of the distance-coded reference marks, the circumference of the theoretical full circle must be a multiple of 1000 grating periods. This also facilitates adaptation to the NC control, which mostly can only calculate 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 · 12.73111	25000 + n · 1000
ERA 881 C/ ERA 882 C	317.99 + n · 12.73178	25000 + n · 1000

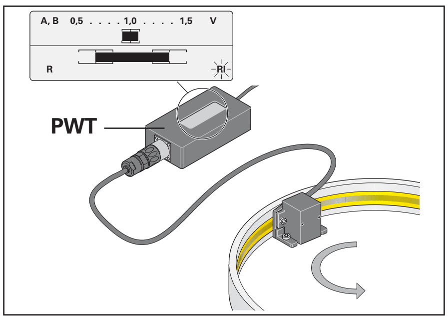
(where n = 1, 2, 3...)



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.

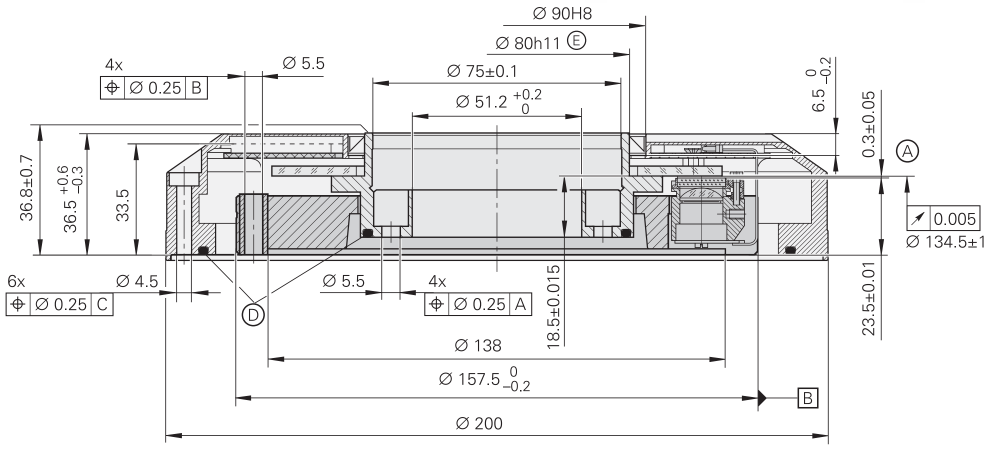
Mounting
Work steps to be performed and dimensions to be maintained during mounting are specified solely in the mounting instructions supplied with the unit. All data in this catalog regarding mounting are therefore provisional and not binding; they do not become terms of a contract.

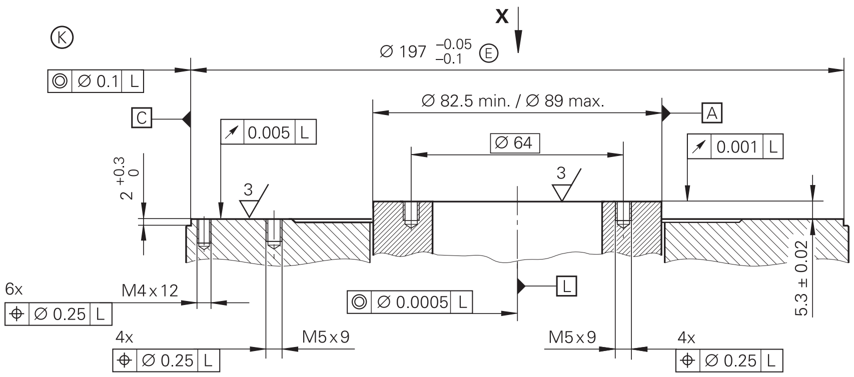
ERP 880

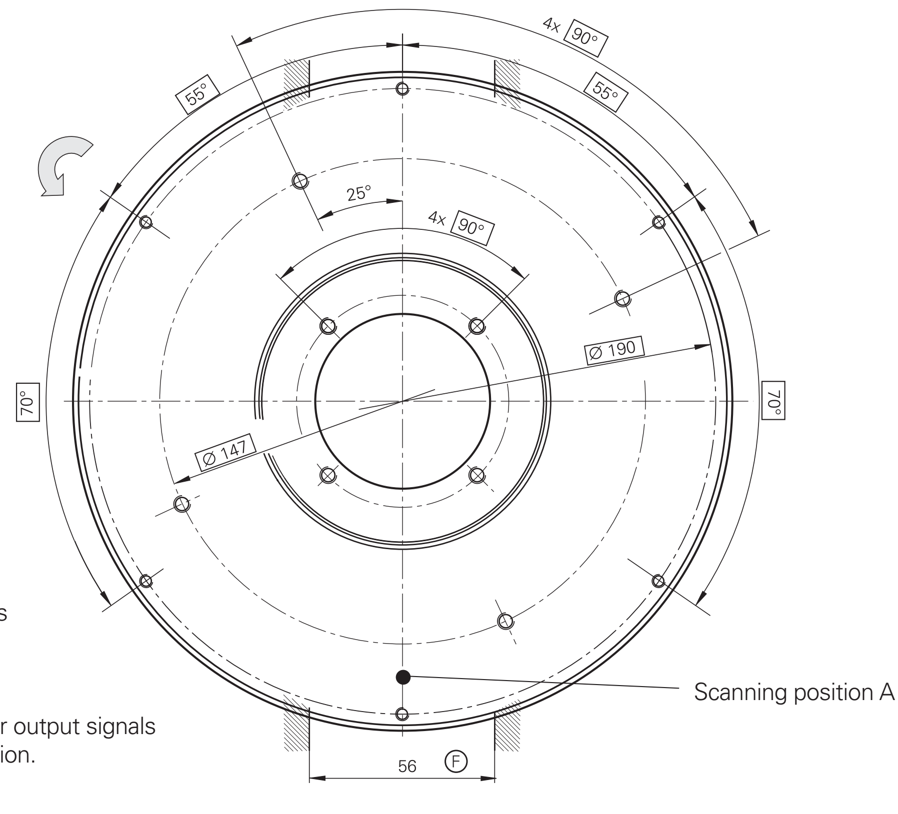
- **High accuracy due to interferential scanning principle**

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	∿ 1 V_{PP}		
Line count	90 000 (≙ 180 000 signal periods)		
Reference mark	One		
Cutoff frequency –3 dB –6 dB	≥ 800 kHz ≥ 1.3 MHz		
Recommended measuring step for position measurement	0.000 01°		
System accuracy[1)]	± 1"		
Accuracy of graduation	± 0.9" (without hub)		
Power supply without load	5 V ± 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	≤ 150 m (with HEIDENHAIN cable)		
Hub inside diameter	51.2 mm		
Mech. permissible speed	≤ 1 000 min^{-1}		
Moment of inertia of rotor	$1.2 \cdot 10^{-3}$ kgm^2		
Permissible axial motion of measured shaft	≤ ± 0.05 mm		
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 50 m/s^2 (IEC 60 068-2-6) ≤ 1 000 m/s^2 (IEC 60 068-2-27)		
Operating temperature	0 °C to 50 °C		
Protection* IEC 60 529	*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.

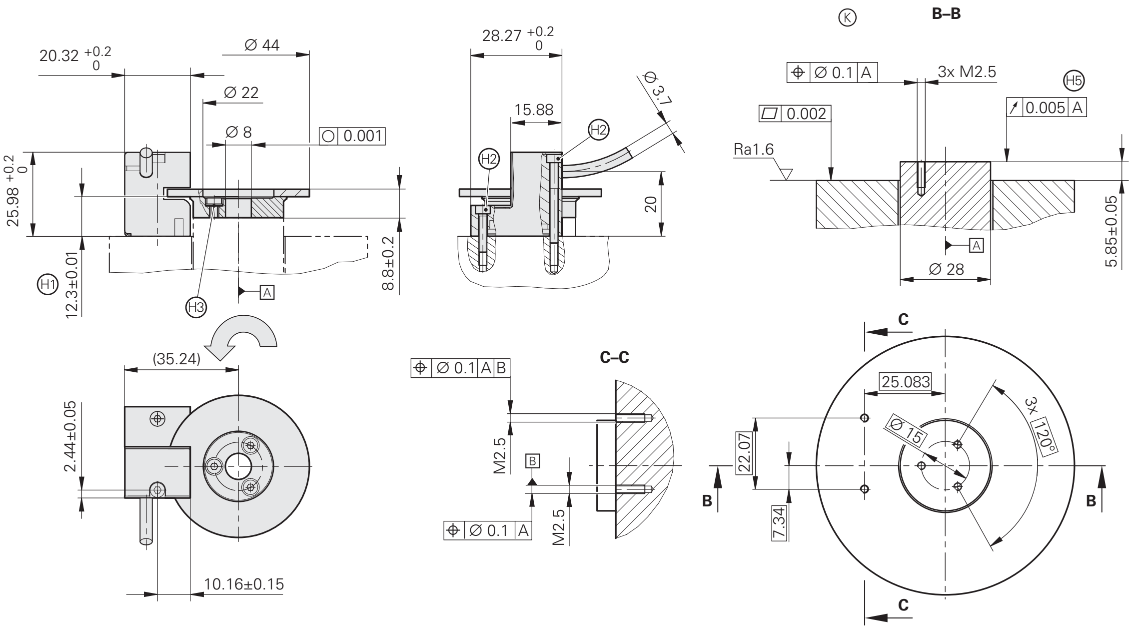
ERP 4080/ERP 8080

- **High accuracy due to interferential scanning principle**
- **Compact design**

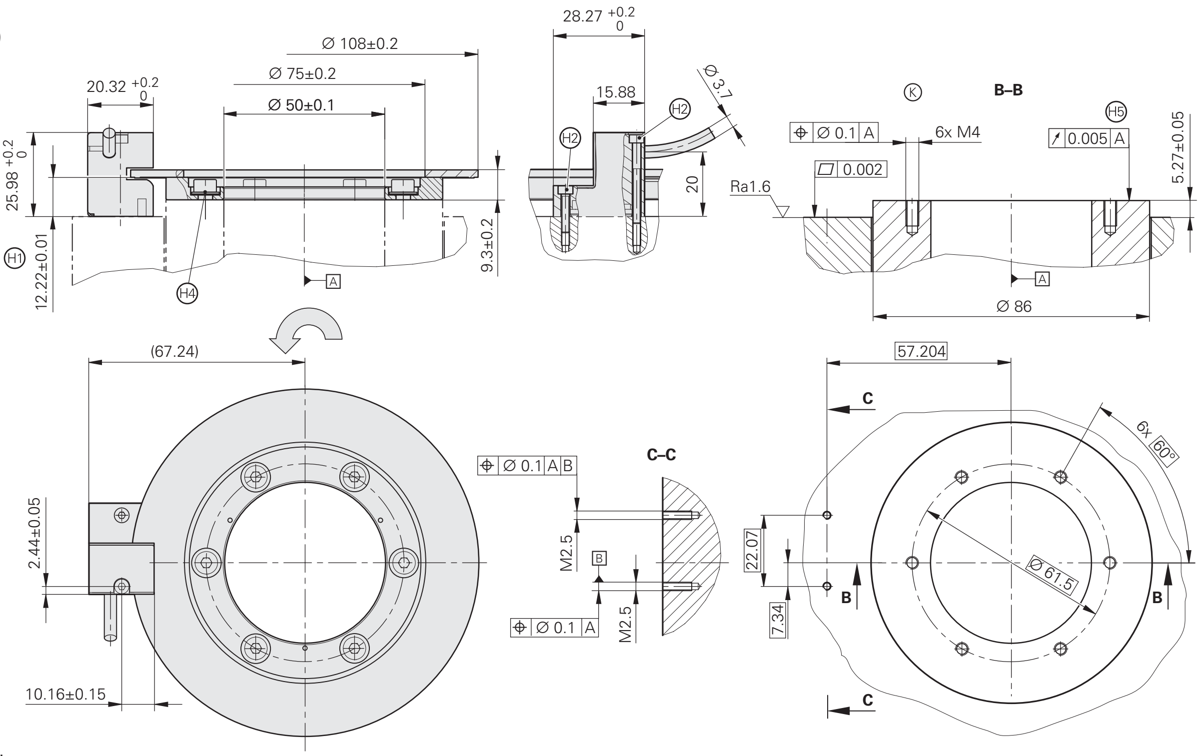
Dimensions in mm

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

ERP 4080



ERP 8080



Ⓐ = Bearing
Ⓚ = Required mating dimensions
Ⓗ1 = Mounting clearance set with spacer foil
Ⓗ2 = Cylinder head screw ISO 4762–A2–M2.5
Ⓗ3 = Cylinder head screw ISO 4762–A2–M2.5 and washer ISO 7089–2.5–140HV–A2
Ⓗ4 = Cylinder head screw ISO 4762–A2–M4 and washer ISO 7089–4–140HV–A2
Ⓗ5 = Mounting surface not convex
Direction of shaft rotation for output signals as per the interface description.

	Incremental	
	ERP 4080	**ERP 8080**
Incremental signals	∿ 1 V_{PP}	
Line count	65536 (≙ 131072 signal periods)	180000 (≙ 360000 signal periods)
Reference mark	None	
Cutoff frequency –3 dB	≥ 250 kHz	
Recommended measuring step for position measurement	0.00001°	0.000005°
System accuracy[1)]	± 5"	± 2"
Accuracy of graduation	± 2" (without hub)	± 1" (without hub)
Power supply without load	5 V ± 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	≤ 300 min^{-1}	≤ 100 min^{-1}
Moment of inertia of rotor	$5 \cdot 10^{-6}$ kgm^2	$250 \cdot 10^{-6}$ kgm^2
Permissible axial motion of measured shaft	≤ ± 0.01 mm (including wobble)	
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 50 m/s^2 (IEC 60068-2-6) ≤ 500 m/s^2 (IEC 60068-2-27)	
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 4280 C, ERA 4480 C, ERA 4880 C

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

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 4280 C
	ERA 4480 C
	ERA 4880 C
System accuracy[1)]	ERA 4280 C
	ERA 4480 C
	ERA 4880 C
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 60 529	
Without protective cover	
With protective cover[3)] and compressed air	
Weight (approx.)	Scale drum
	Protective cover
Scanning head without cable	

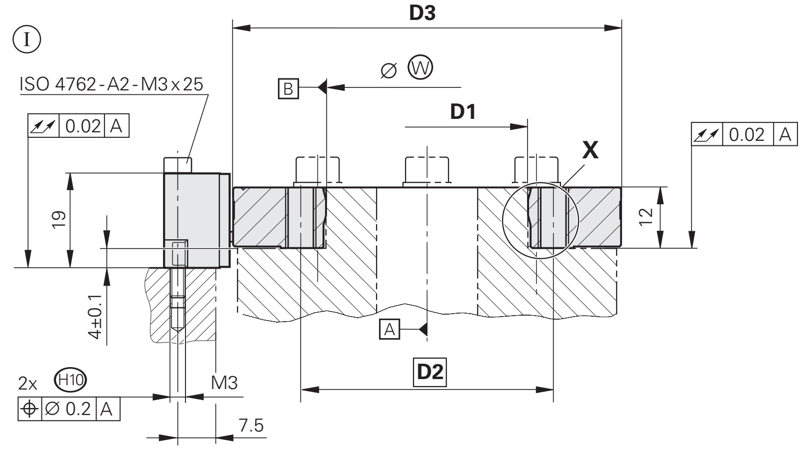
ERA 4280 C grating period 20 µm—consisting of **ERA 4280 scanning head** and **ERA 4200 C drum**
ERA 4480 C grating period 40 µm—consisting of **ERA 4480 scanning head** and **ERA 4400 C drum**
ERA 4880 C grating period 80 µm—consisting of **ERA 4880 scanning head** and **ERA 4800 C drum**

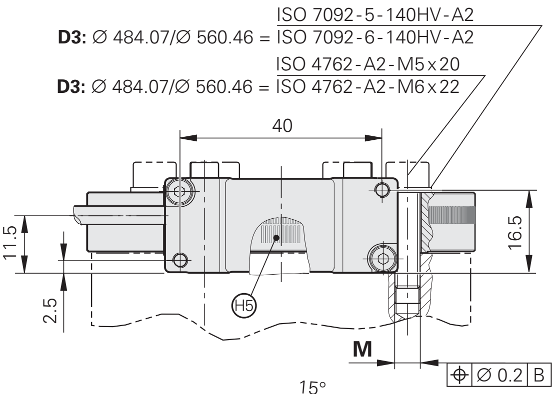
∼ 1 V_{PP}								
Distance-coded								
≥ 350 kHz								
5 V ± 10%/max. 100 mA								
Cable, 1 m, with M23 coupling (12-pin)								
≤ 150 m (with HEIDENHAIN cable)								
40 mm	70 mm	80 mm	120 mm	150 mm	180 mm	270 mm	425 mm	512 mm
76.75 mm	104.63 mm	127.64 mm	178.55 mm	208.89 mm	254.93 mm	331.31 mm	484.07 mm	560.46 mm
12000	16384	20000	28000	32768	40000	52000	–	–
6000	8192	10000	14000	16384	20000	26000	38000	44000
3000	4096	5000	7000	8192	10000	13000	–	–
± 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"	
10000 min^{-1}	8500 min^{-1}	6250 min^{-1}	4500 min^{-1}	4250 min^{-1}	3250 min^{-1}	2500 min^{-1}	1800 min^{-1}	1500 min^{-1}
$0.27 \cdot 10^{-3}$ kgm^2	$0.81 \cdot 10^{-3}$ kgm^2	$1.9 \cdot 10^{-3}$ 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	$195 \cdot 10^{-3}$ kgm^2	$258 \cdot 10^{-3}$ kgm^2
≤ ± 0.5 mm (scale drum relative to scanning head)								
≤ 200 m/s^2 (IEC 60068-2-6) ≤ 1000 m/s^2 (IEC 60068-2-27)								
–10 °C to 80 °C (coefficient of expansion of the scale drum approx. $10.5 \cdot 10^{-6}\text{K}^{-1}$)								
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; *Scanning head for protective cover:* Approx.. 0.035 kg								

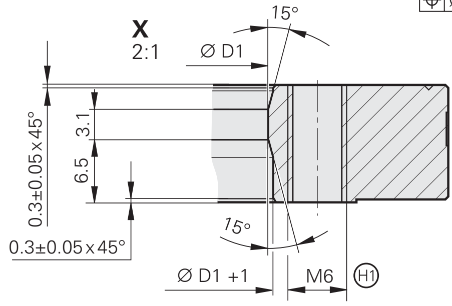
***** Please indicate when ordering
[1] Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.
[2] For other errors, see *Measuring Accuracy*
[3] Only with ERA 4480; the protective cover must be ordered separately

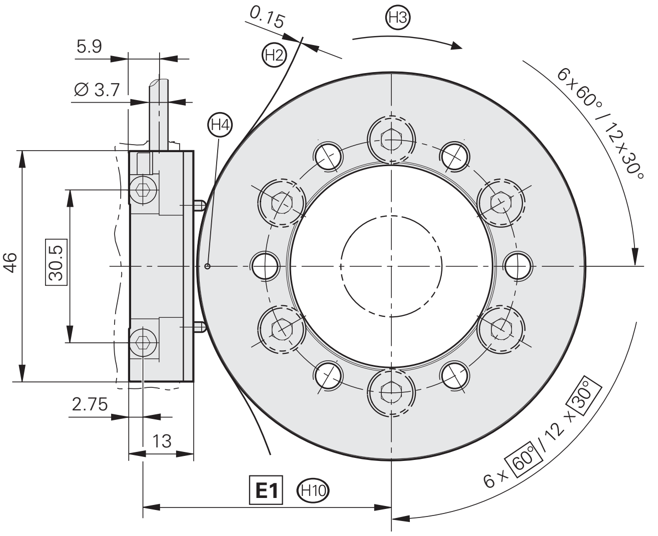
ERA 4280 C, ERA 4480 C, ERA 4880 C

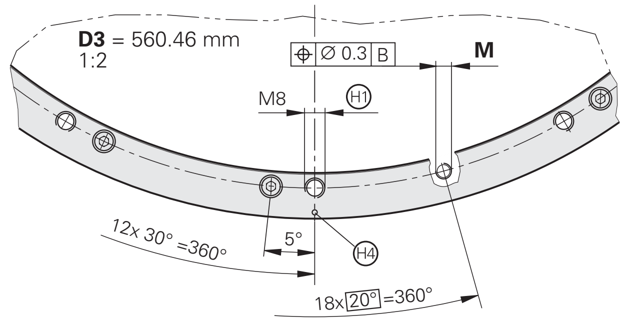
Without Protective Cover

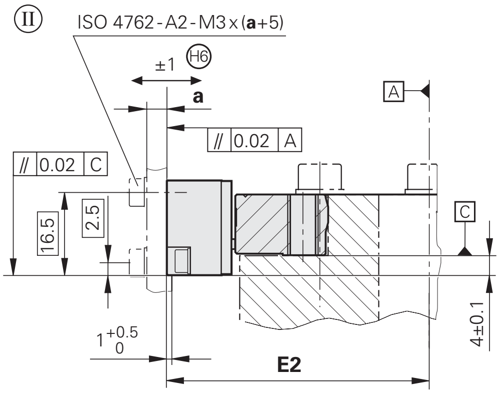




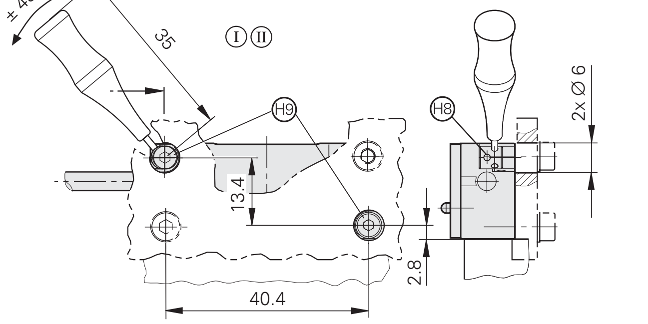


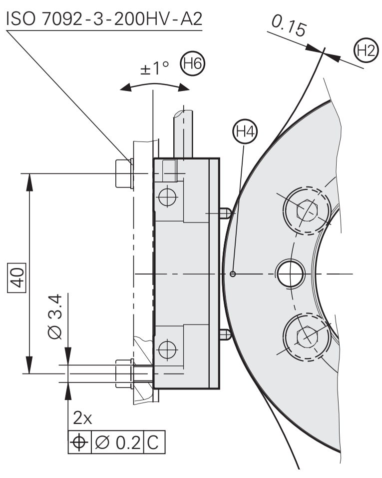






Fine adjustment of the ERA 4280 scanning head





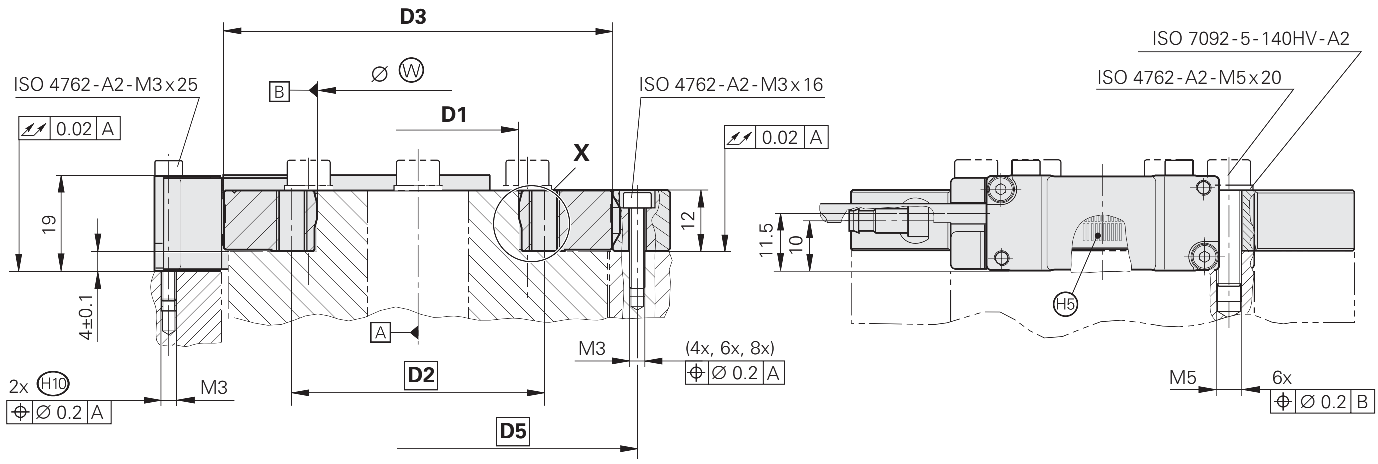
Dimensions in mm

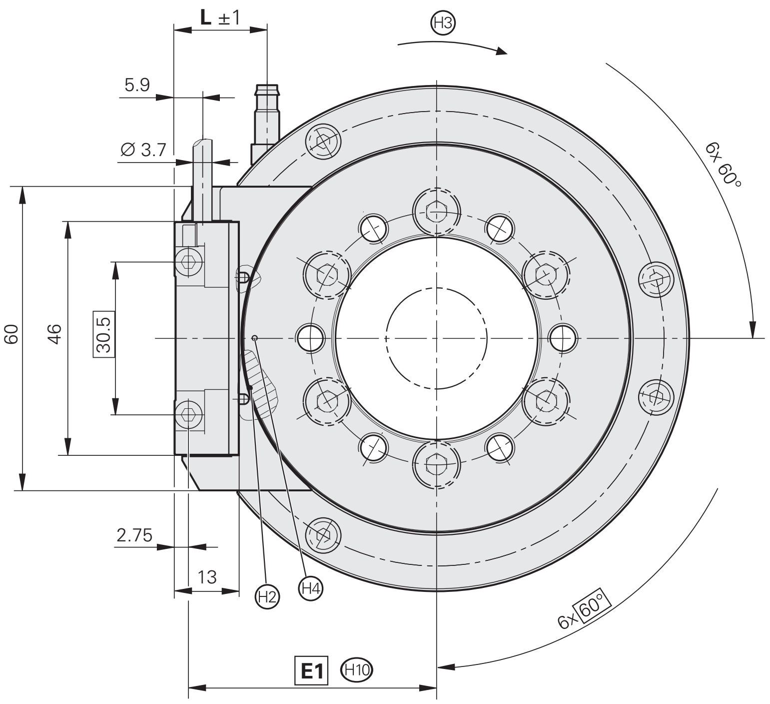
Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

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	15.5	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

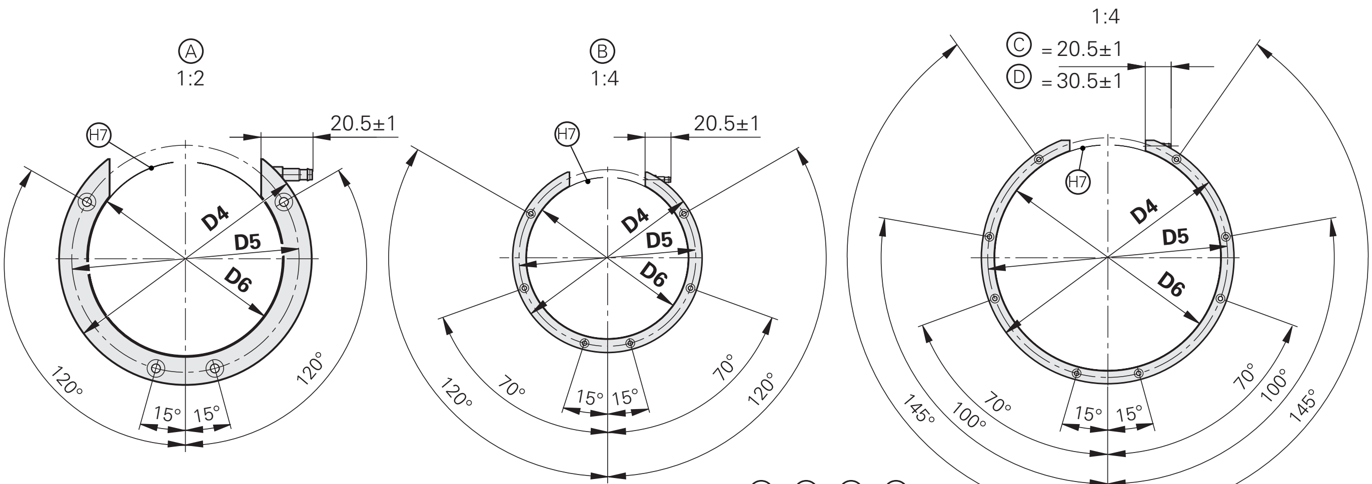
***)** Roundness of mating diameter for shaft

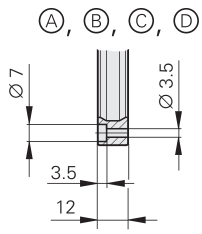
ERA 4480 C
With Protective Cover





Ⓘ, Ⓘⓘ = Mounting options
A = Bearing
(H3) = Back-off thread
(H1) = Mounting clearance (spacer foil)
(H3) = Positive direction of rotation for output signals as per the interface description
(H4) = Marker for reference mark, position tolerance with respect to reference mark ± 1.0 mm
(H4) = Scale reference mark
(H6) = Ensure adjustability of mounting surface for scanning head
(H7) = Mounting clearance 0.15 mm (protective cover)
(H8) = Eccentric nut
(H9) = Holes required for fine adjustment
(H10) = Position tolerance for threaded holes for securing the scanning head

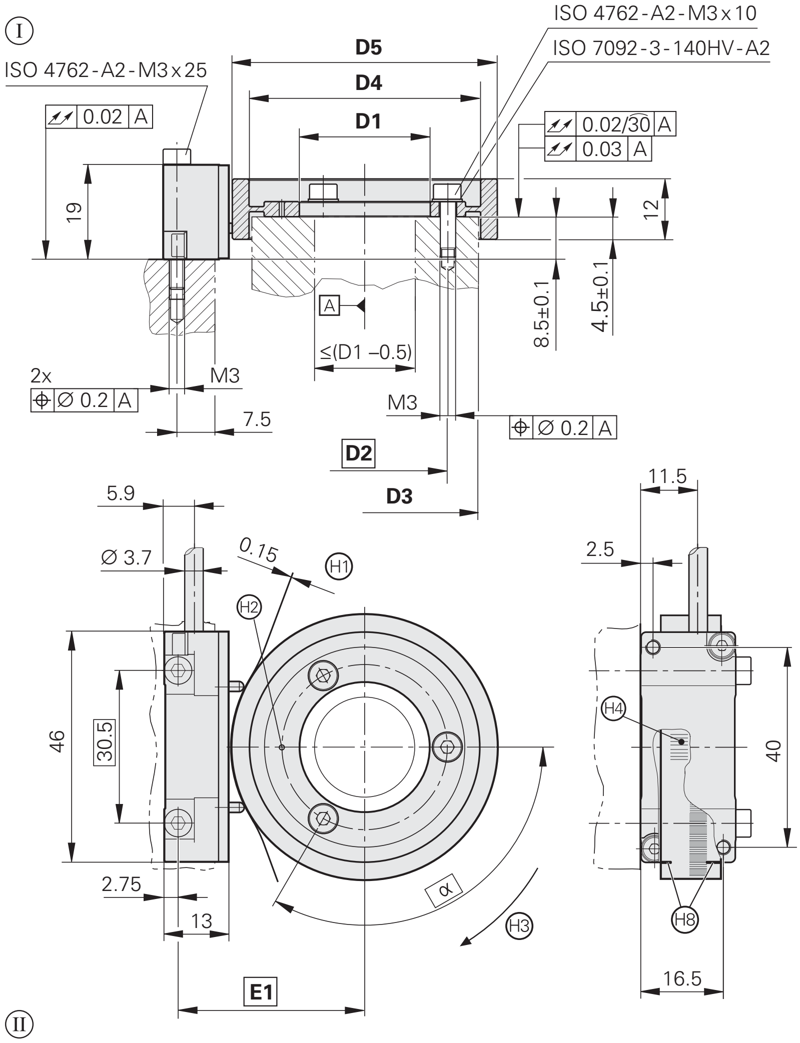




	Ⓐ	Ⓑ	Ⓒ	Ⓓ
D3	Ø 76.75	Ø 127.64	Ø 178.55	Ø 254.93
D4	Ø 100	Ø 150	Ø 200	Ø 278
D5	Ø 90	Ø 140	Ø 190	Ø 268
D6	Ø 77.2	Ø 128.2	Ø 179.1	Ø 255.6

ERA 4281 C, ERA 4481 C

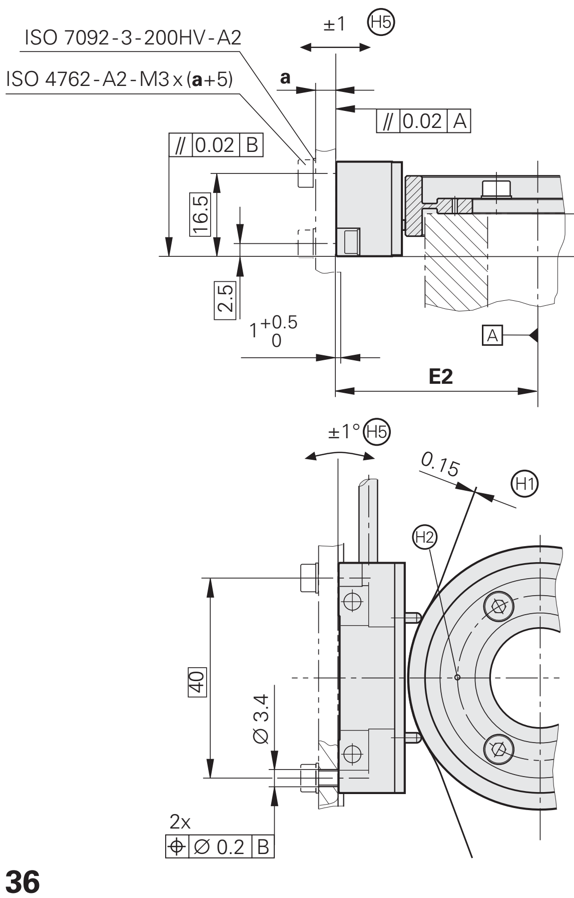
- **Steel circumferential scale drum with low weight and low moment of inertia**



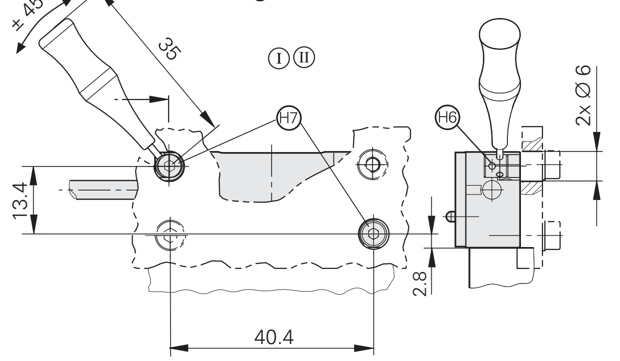
Dimensions in mm

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

Ⓘ, Ⓘⓘ = 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



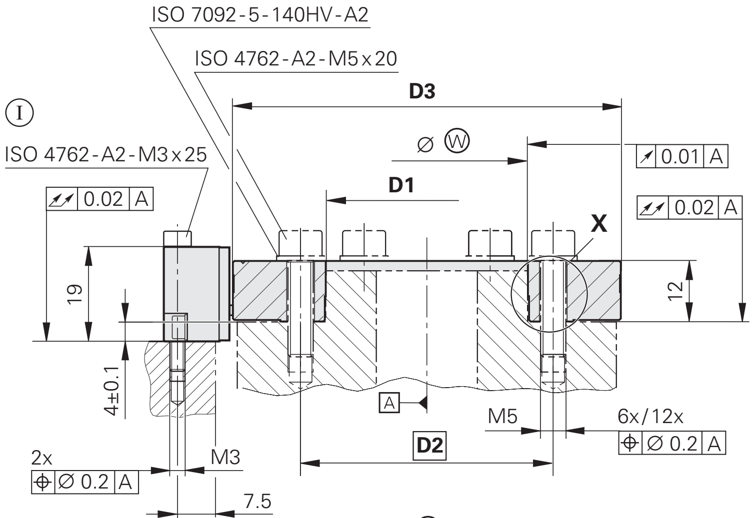
D1	D2	D3	D4	D5	E1	E2	α
Ø 26	Ø 33	Ø 44±1	Ø 46	Ø 52.65	37.29	40.03	3 x 120° = 360°
Ø 50	Ø 57	Ø 68±1	Ø 70	Ø 76.75	49.34	52.08	
Ø 78	Ø 85	Ø 96±1	Ø 98	Ø 104.63	63.28	66.02	6 x 60° = 360°
Ø 127	Ø 134	Ø 145±1	Ø 147	Ø 153.09	87.51	90.25	
Ø 183	Ø 190	Ø 201±1	Ø 203	Ø 208.89	115.41	118.15	8 x 45° = 360°
Ø 229	Ø 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	

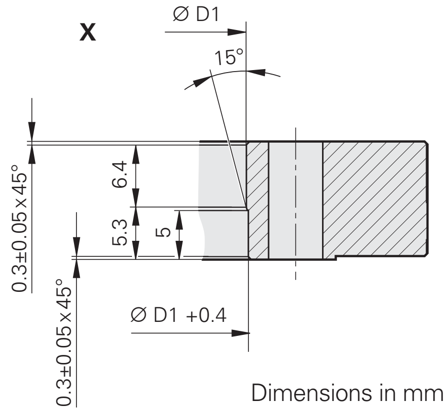
	ERA 4281 C grating period 20 µm—consisting of ERA 4280 scanning head and ERA 4201 C drum ERA 4481 C grating period 40 µm—consisting of ERA 4480 scanning head and ERA 4401 C drum						
Incremental signals	∼ 1 V_{PP}						
Reference marks	Distance-coded						
Cutoff frequency –3dB	≥ 350 kHz						
Power 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	8192	12000	16384	24000	32768	40000	48000
ERA 4481 C	4096	6000	8192	12000	16384	20000	24000
System accuracy[1]							
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 graduation[2]	± 7"	± 5"	± 3.7"	± 2.5"			
Mech. permissible speed	6000 min^{-1}		4000 min^{-1}		2000 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) ≤ 1000 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

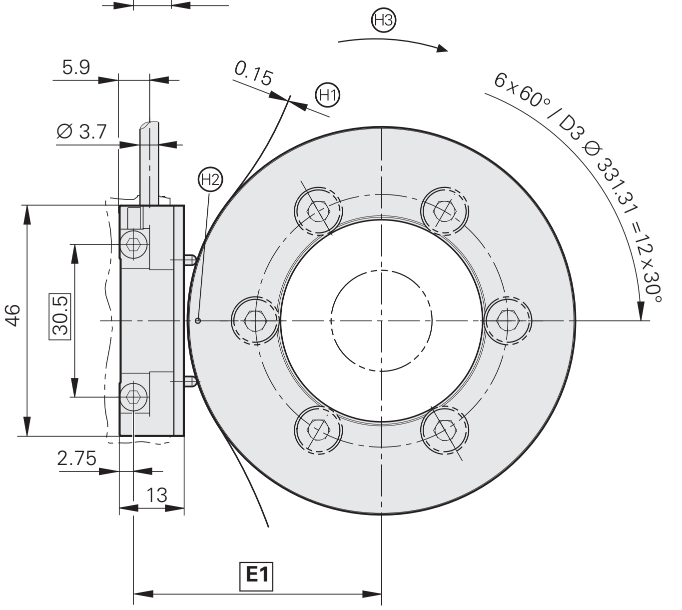
- **Steel circumferential scale drum for increased accuracy requirements**

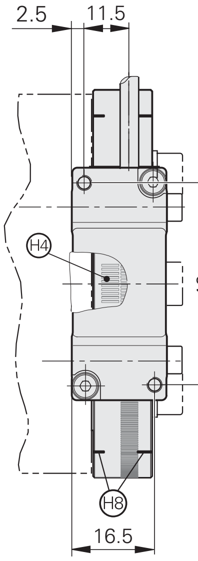




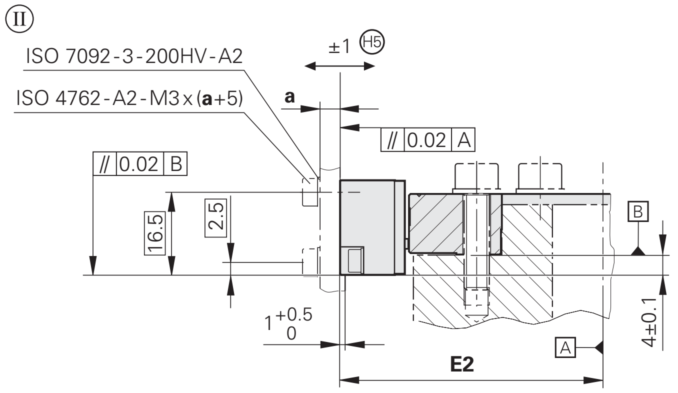
Dimensions in mm

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

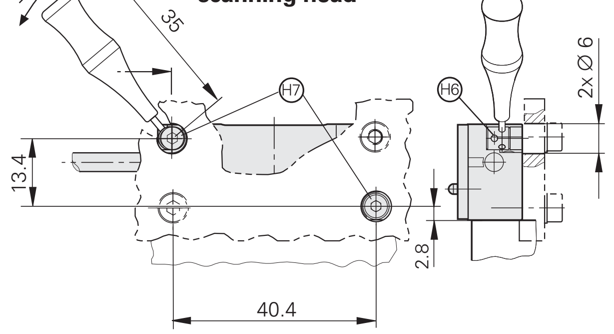


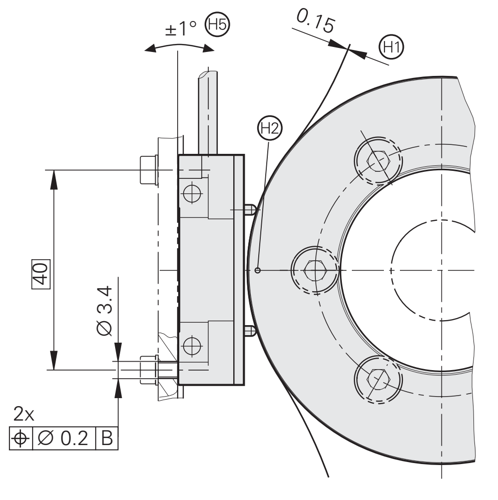


Ⓘ, Ⓘⓘ = Mounting options
Ⓐ = Bearing
H1 = Mounting clearance (spacer foil)
H2 = Marker for reference mark
H3 = Positive direction of rotation for output signals as per the interface description
H4 = Scale reference mark
H5 = Ensure adjustability of mounting surface for scanning head
H6 = Eccentric nut
H7 = Mounting holes for fine adjustment (only for ERA 4280 scanning head)
H8 = Marks for drum centering (3 x 120°)
Ⓦ = 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 4282 C grating period 20 µm—consisting of **ERA 4280 scanning head** and **ERA 4202 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, 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 accuracy[1)]	± 5.1"	± 3.8"	± 3.2"	± 2.5"	± 2.3"	± 2.2"	± 2.0"
Accuracy of the graduation[2)]	± 4"	± 3"	± 2.5"	± 2"	± 1.9"	± 1.8"	± 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	≤ ± 0.5 mm (scale drum relative to scanning head)						
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 100 m/s^2 (IEC 60 068-2-6) ≤ 500 m/s^2 (IEC 60 068-2-27)						
Operating temperature	–10 °C to 80 °C (coefficient of expansion of the scale drum approx. $10.5 \cdot 10^{-6}K^{-1}$)						
Protection IEC 60 529	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						

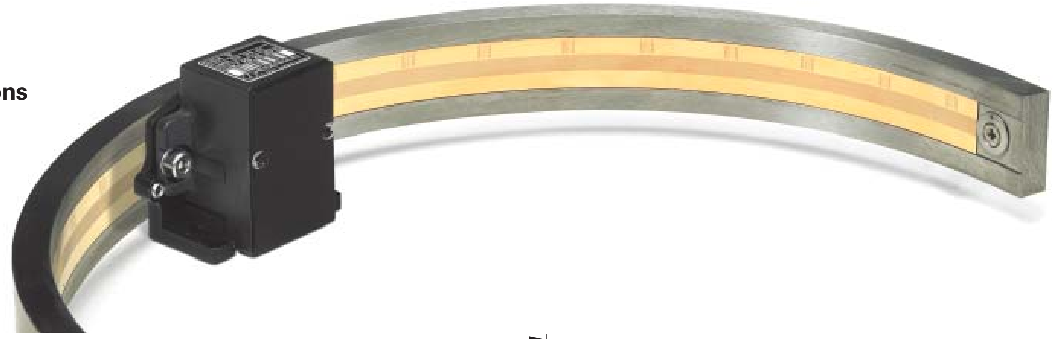
***** Please indicate when ordering

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*

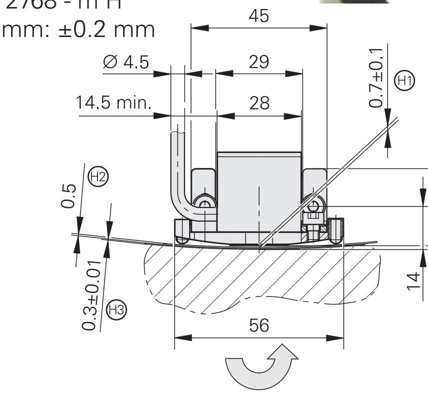
ERA 700 Series

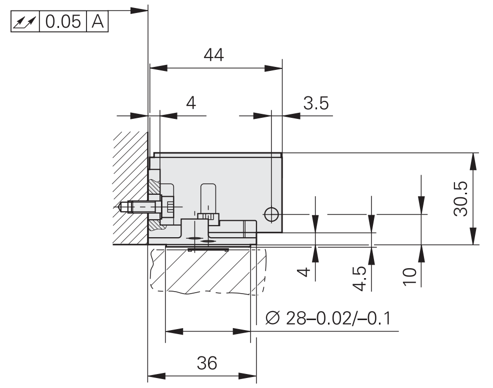
- **For internal mounting**
- **Full-circle and segment versions**

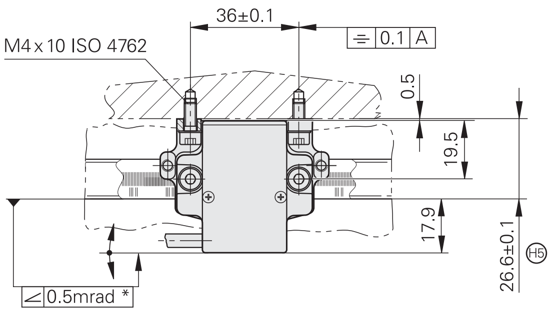


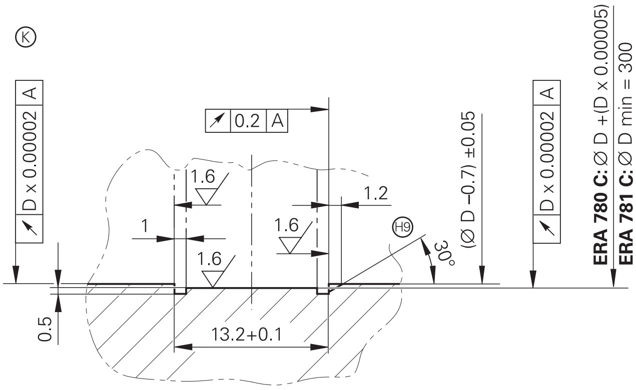
Dimensions in mm

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

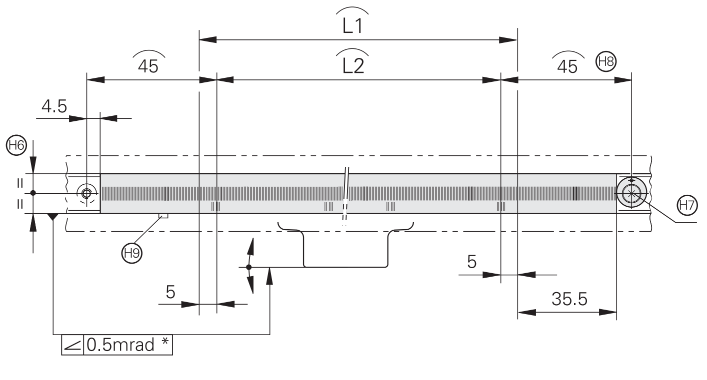


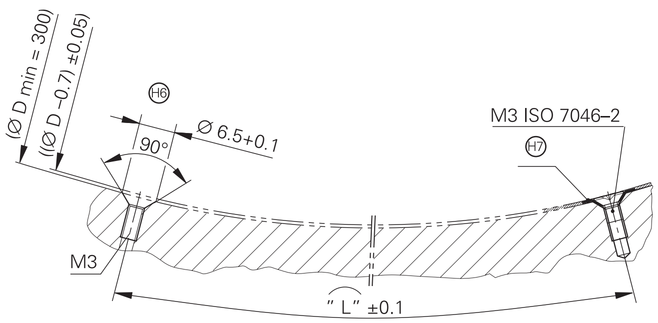


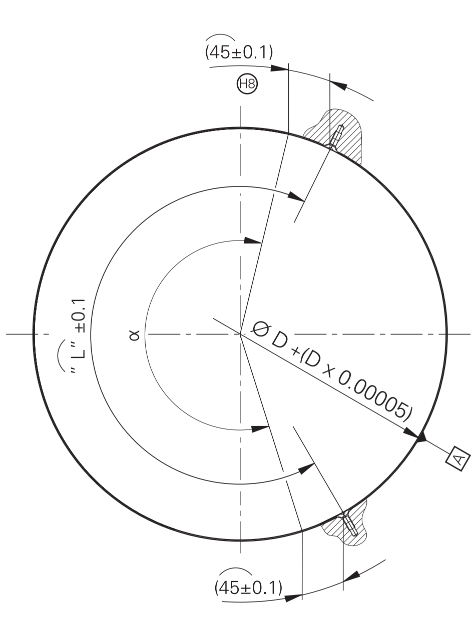




ERA 781 C scale tape







* = Max. change during operation
A = Bearing
K = Required mating dimensions for the scale tape (not to scale)
L1 = Traverse path
L2 = Measuring range
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
H6 = View of holes provided by customer
H7 = Cam disk for tensioning the scale tape
H8 = Position of first reference mark
H9 = Notch for removing scale tape (1 x b = 2 mm)
Direction of shaft rotation for output signals as per the interface description

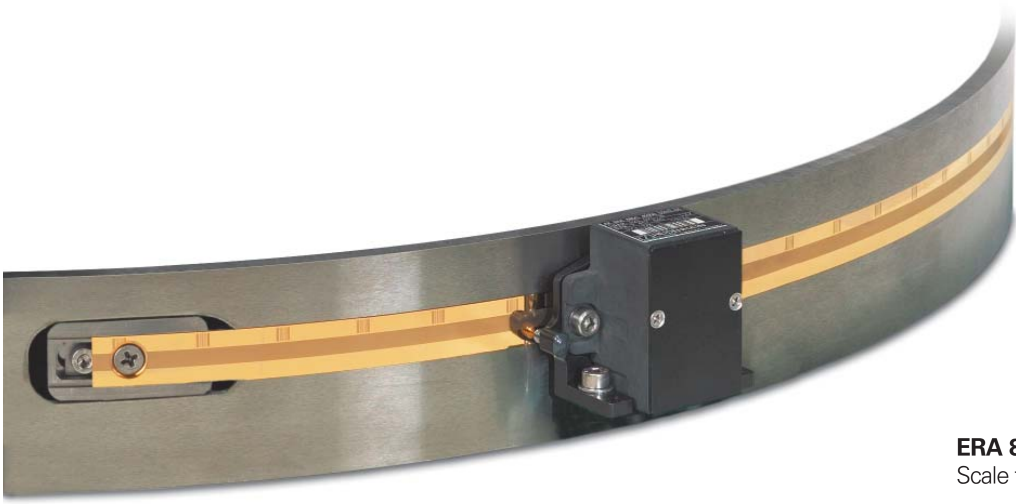
	Incremental **ERA 780 C** full-circle version **ERA 781 C** segment, scale tape secured with tensioning elements			
Incremental signals	∿ 1 V_{PP}			
Reference mark	Distance-coded, nominal increment of 1 000 grating periods			
Cutoff frequency –3 dB	≥ 180 kHz			
Power supply without load	5 V ± 10%/max. 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 780 C full circle	–	36 000	45 000	90 000
ERA 781 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	0.000 2°	0.000 1°	0.000 05°	0.000 02°
System accuracy[1)]				
ERA 780 C full circle	–	± 3.5"	± 3.4"	± 3.2"
ERA 781 C segment	See *Measuring Accuracy*			
Accuracy of the graduation[2)]	± 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 60 068-2-6) ≤ 1 000 m/s^2 (IEC 60 068-2-27)			
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 60 529	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

- For outside diameters
- Full-circle and segment versions

ERA 880 C full-circle version



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

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

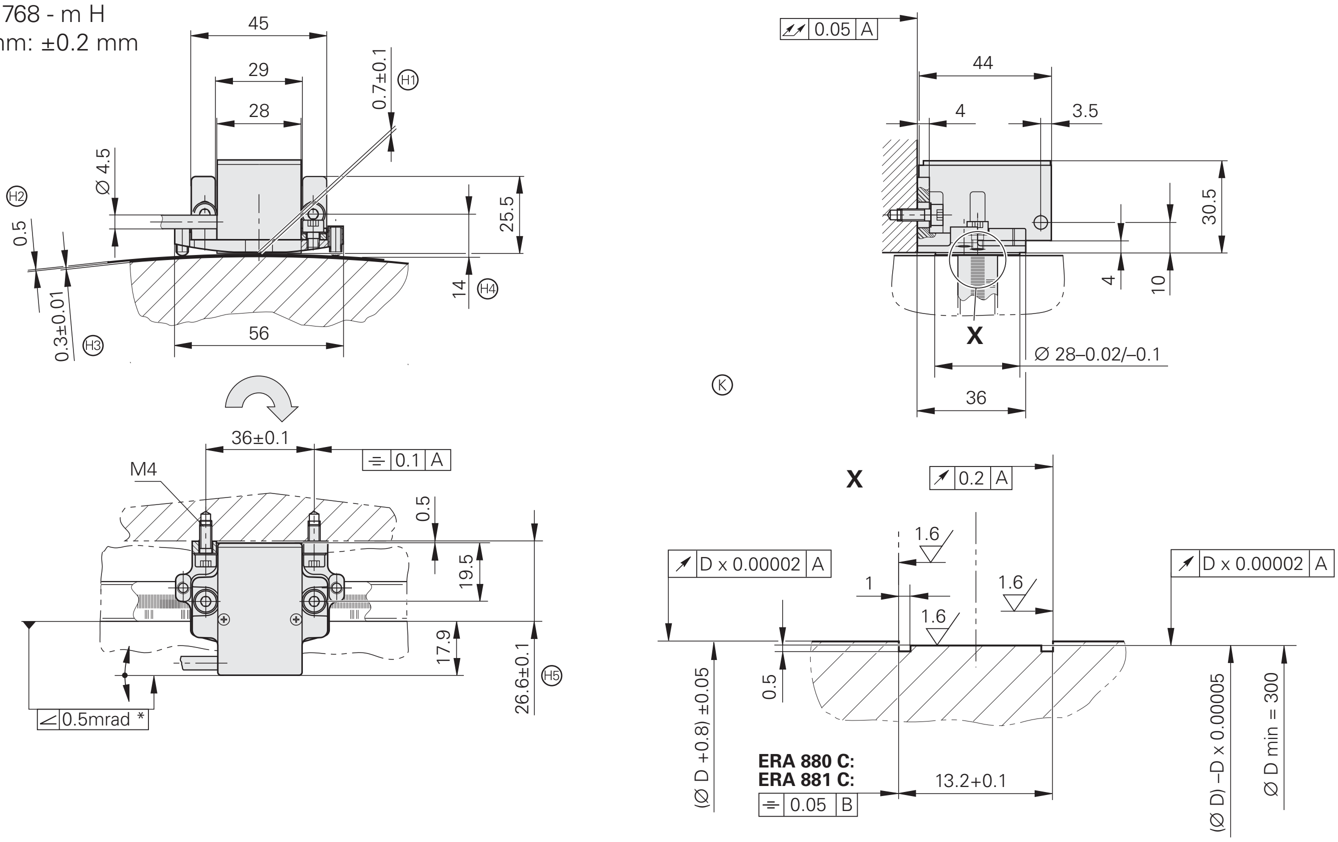
	Incremental		
	ERA 880C full-circle version **ERA 881C** segment, scale tape secured with tensioning elements **ERA 882C** segment, scale tape secured without tensioning elements		
Incremental signals	∼ 1 V_{PP}		
Reference mark	Distance-coded, nominal increment of 1000 grating periods		
Cutoff frequency –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	–	36000	45000
ERA 881C/ ERA 882C 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°
System accuracy[1)]			
ERA 880C full circle	–	± 3.5"	± 3.4"
ERA 881C/ ERA 882C segment	See *Measuring Accuracy*		
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) ≤ 1000 m/s^2 (IEC 60068-2-27)		
Operating temperature	–10 °C to 50 °C (thermal coefficient of expansion of the scale substrate between $9 \cdot 10^{-6}K^{-1}$ and $12 \cdot 10^{-6}K^{-1}$)		
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

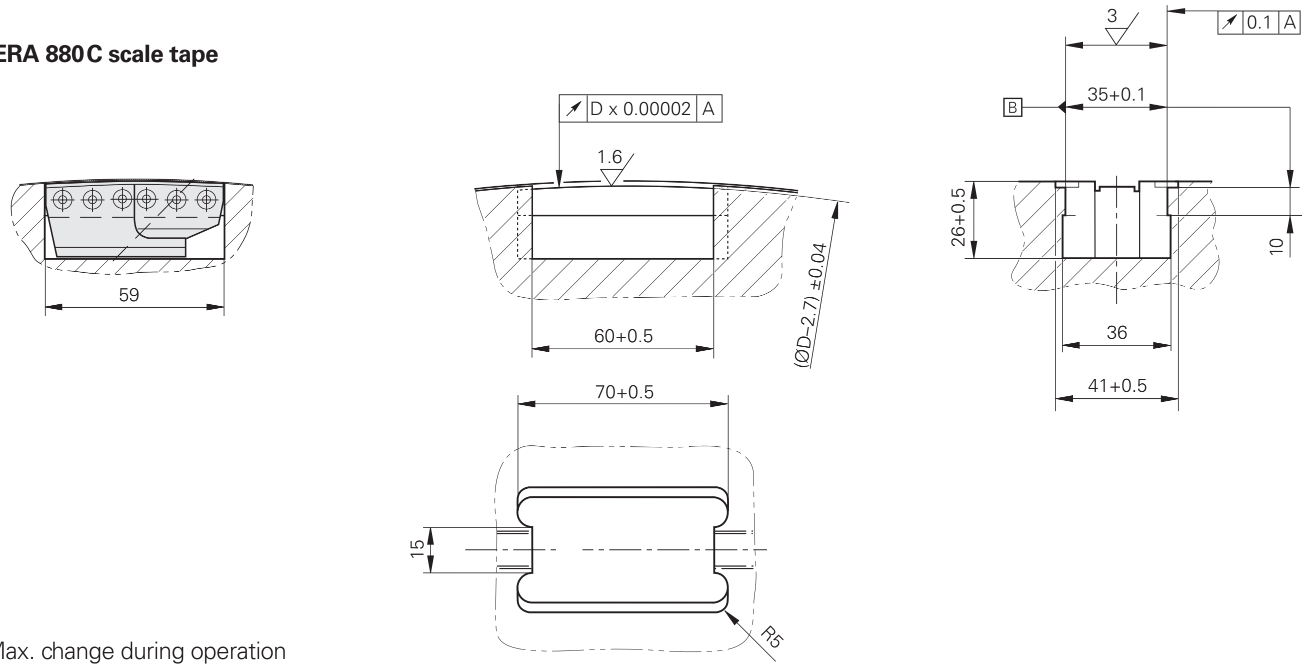
ERA 800 Series

Dimensions in mm

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

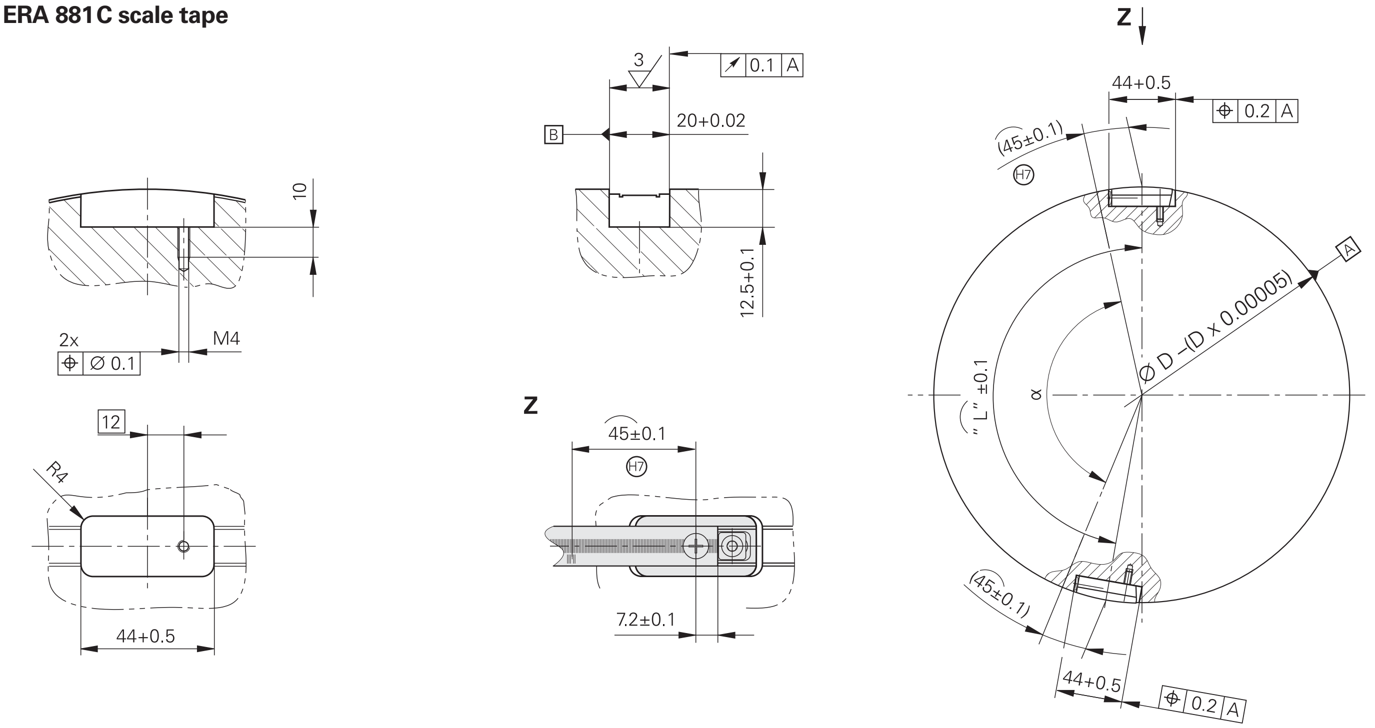


ERA 880C scale tape

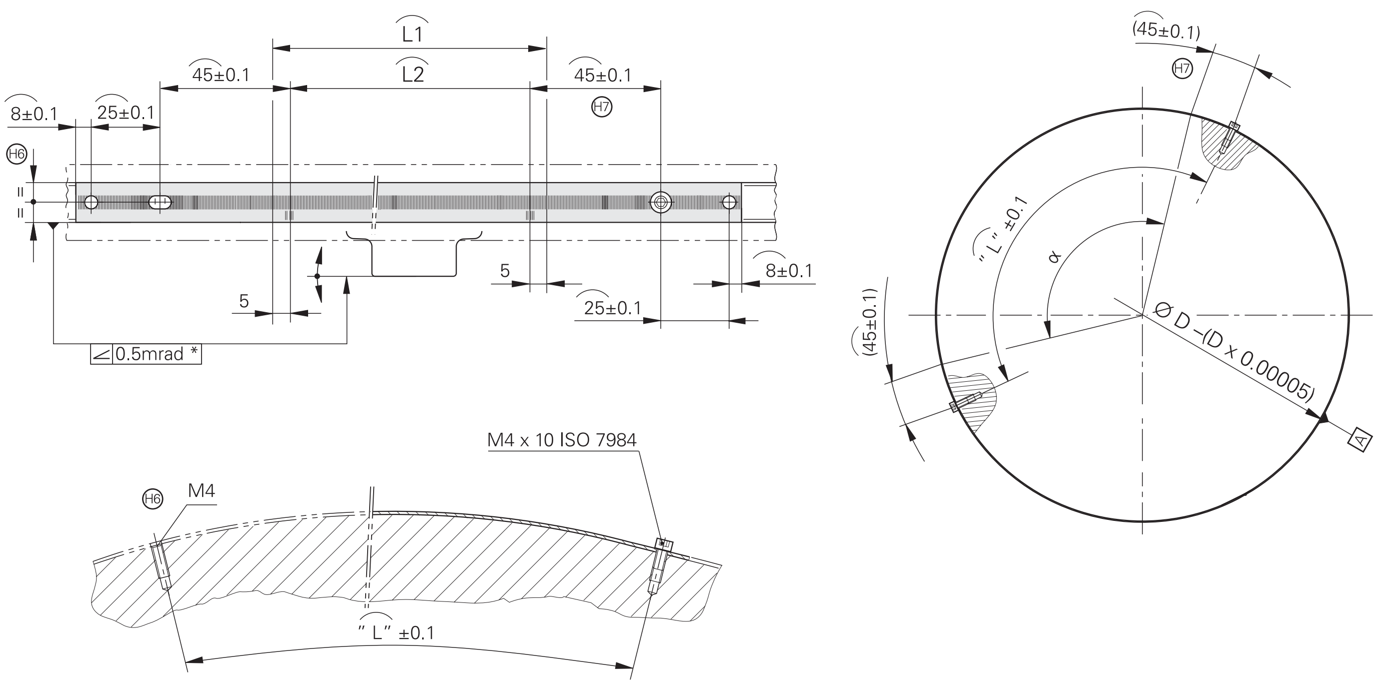


* = Max. change during operation
A = Bearing
K = Required mating dimensions for the scale tape (not to scale)
H1 = Scanning gap (distance between scanning reticle and scale-tape surface)
H2 = Mounting clearance for mounting bracket. Spacer foil 0.5 mm
H3 = Scale-tape thickness
H4 = Distance between floor 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 881C scale tape



ERA 882C scale tape



* = Max. change during operation
A = Bearing
H6 = View of holes provided by customer
H7 = Position of first reference mark
L = With *ERA 881C:* Positions of the tensioning elements
With *ERA 882C:* Distance of mounting holes
L1 = Traverse path
L2 = Measuring range in radian measure
α = Measuring range in degrees (segment angle)

Interfaces

Incremental Signals ∿ 1 V_{PP}

HEIDENHAIN encoders with ∿ 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 dB ≙ 70% of the signal amplitude
- –6 dB ≙ 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.

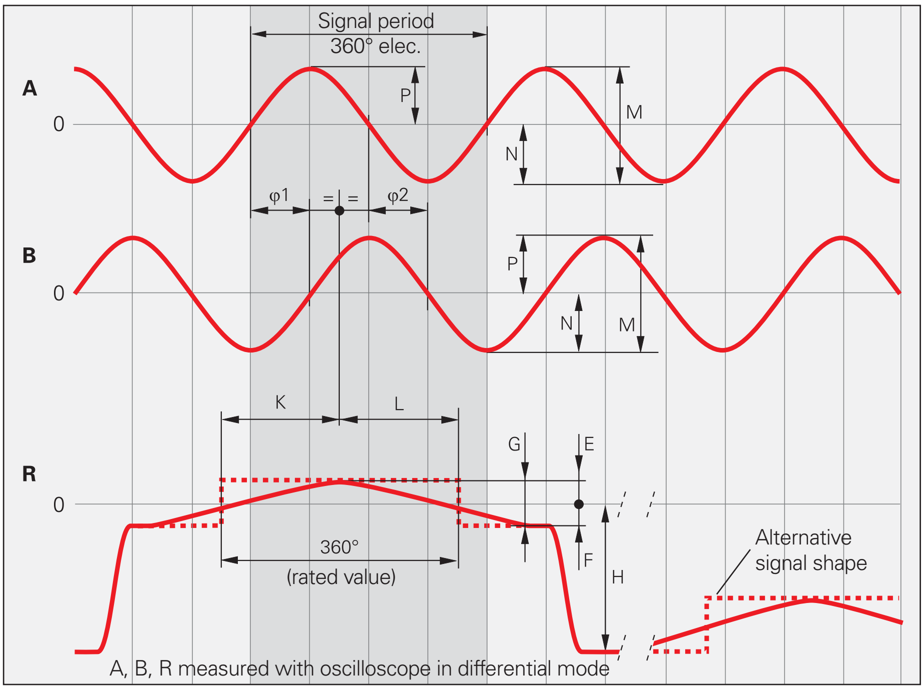
Measuring steps for **position measurement** are recommended in the specifications. For special applications, other resolutions are also possible.

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.

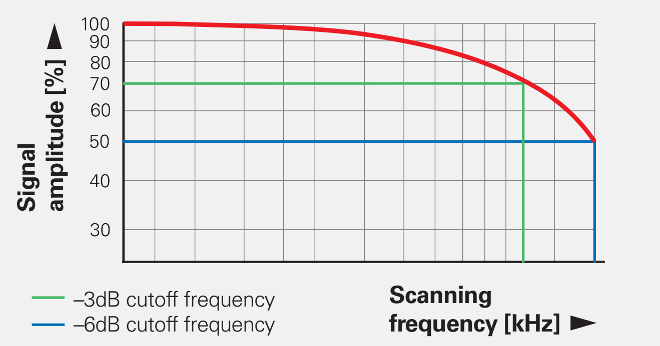
Short circuit at	20 °C	125 °C
One output	< 3 min	< 1 min
All outputs	< 20 s	< 5 s

Interface	Sinusoidal voltage signals ∿ **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 |φ1 + φ2|/2:	90° ± 10° elec.
Reference-mark signal	**One or several signal peaks R**	
	Usable component G:	≥ 0.2 V
	Quiescent value H:	≤ 1.7 V
	Switching threshold E, F:	0.04 to 0.68 V
	Zero crossovers K, L:	180° ± 90° elec.
Connecting cable	Shielded HEIDENHAIN cable PUR [4(2 x 0.14 mm^2) + (4 x 0.5 mm^2)]	
Cable length	Max. 150 m with 90 pF/m distributed capacitance	
Propagation time	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).



Cutoff frequency
Typical signal amplitude curve with respect to the scanning frequency



Input Circuitry of the Subsequent Electronics

Dimensioning
Operational amplifier MC 34074
$Z_0 = 120\ \Omega$
$R_1 = 10\ k\Omega$ and $C_1 = 100\ pF$
$R_2 = 34.8\ k\Omega$ and $C_2 = 10\ pF$
$U_B = \pm\ 15\ V$
U_1 approx. U_0

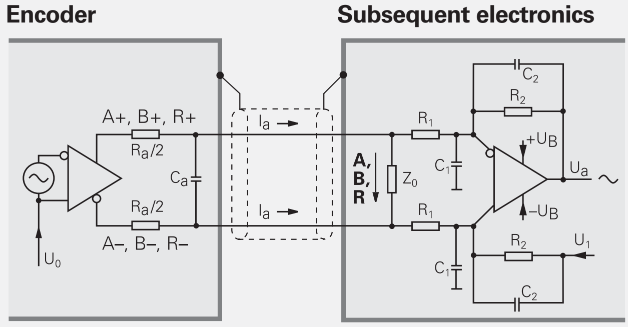
–3dB cutoff frequency of circuitry
Approx. 450 kHz
Approx. 50 kHz and $C_1 = 1000\ pF$
and $C_2 = 82\ pF$
The circuit variant for 50 kHz does reduce the bandwidth of the circuit, but in doing so it improves its noise immunity.

Circuit output signals
$U_a = 3.48\ V_{PP}$ 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: $1.35\ V_{PP}$

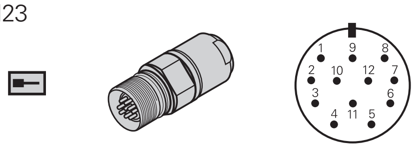
Incremental signals
Reference-mark signal

$R_a < 100\ \Omega$, typ. $24\ \Omega$
$C_a < 50\ pF$
$\Sigma I_a < 1\ mA$
$U_0 = 2.5\ V \pm 0.5\ V$
(relative to 0 V of the power supply)

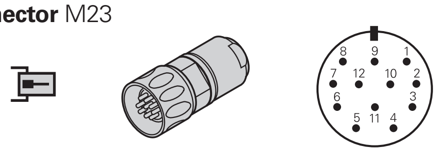


Pin Layout

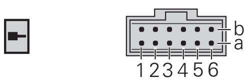
12-pin coupling M23



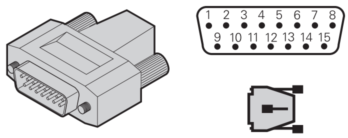
12-pin connector M23



12-pin PCB connector on ERP 880



15-pin D-sub connector[1]



	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 μA_{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 μA_{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		

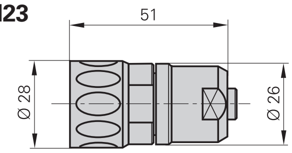
Connecting Elements and Cables

General Information

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

Symbols 

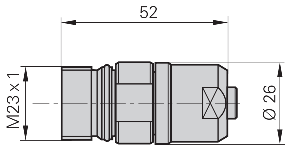
M23



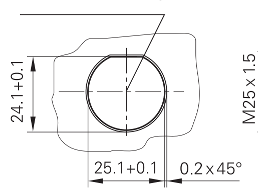
Insulated coupling: Connecting element with external thread; available with male or female contacts.

Symbols 

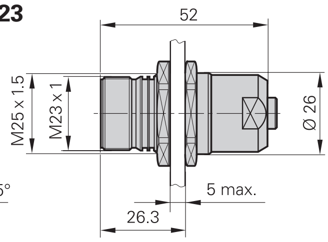
M23



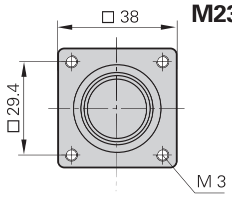
Mounted coupling with central fastening



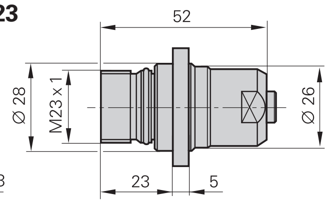
M23



Mounted coupling with flange



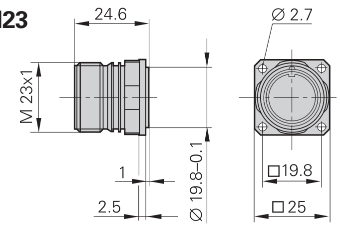
M23



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

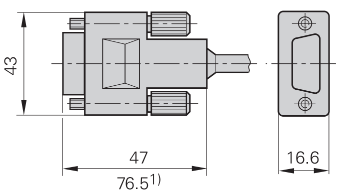
Symbols 

M23



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. 

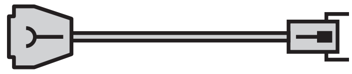
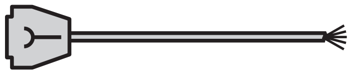
When engaged, the connections provide **protection** to IP 67 (D-sub connector: IP 50; IEC 60529). When not engaged, there is no protection.

Accessories for flange sockets and M23 mounted couplings

Bell seal
ID 266526-01

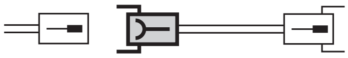
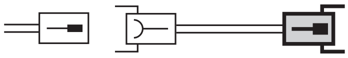
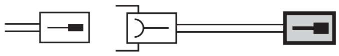
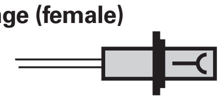
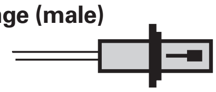
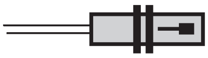
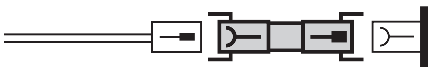
Threaded metal dust cap
ID 219926-01

Connecting Cables

		12-pin M23	
PUR connecting cable [6(2 x 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)** 			315 892-08
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 ∿ 1 V_{PP}/11 μA_{PP} For converting the 1 V_{PP} signals to 11 μA_{PP}; M23 connector (female) 12-pin and M23 connector (male) 9-pin				364 914-01

General Electrical Information

Power supply

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

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

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

Calculation of the **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 $t_{SOT} = 1.3$ s (2 s for PROFIBUS-DP) (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. If the power supply is switched off, or when the supply voltage falls below U_{min}, the output signals are also invalid. This data applies to 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)

Cable

HEIDENHAIN cables are mandatory for **safety-related applications.**
The **cable lengths** listed in the *Specifications* apply only to HEIDENHAIN cables and the recommended input circuitry of the subsequent electronics.

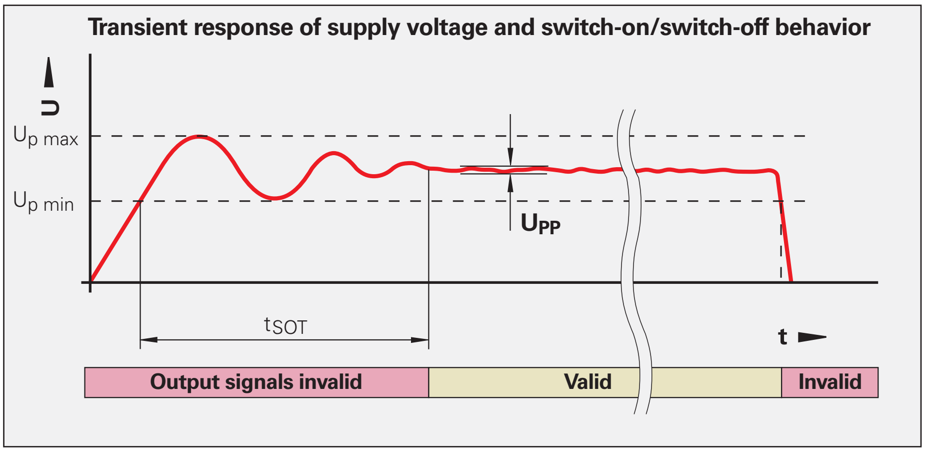
Durability
All encoders have polyurethane (PUR) cables. PUR cables are resistant to oil, hydrolysis and microbes in accordance with **VDE 0472.** They are free of PVC and silicone and comply with UL safety directives. The **UL certification** AWM STYLE 20963 80 °C 30 V E63216 is documented on the cable.

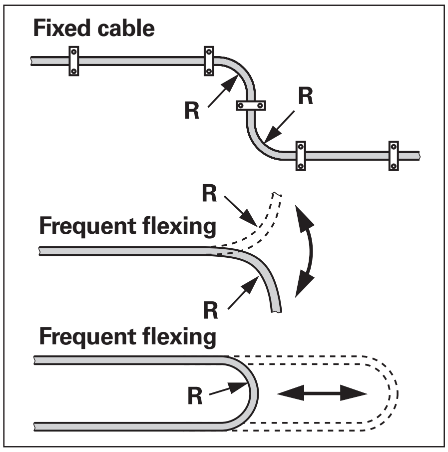
Temperature range
HEIDENHAIN cables can be used for

- fixed cables –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 necessary, 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.

Cable	**Cross section** of power supply lines A_P				**Bend radius R**	
	1 V_{PP}/TTL/HTL	**11 μA_{PP}**	**EnDat/SSI** 17-pin	**EnDat**[5] 8-pin	**Fixed cable**	**Frequent flexing**
Ø 3.7 mm	0.05 mm^2	–	–	–	≥ 8 mm	≥ 40 mm
Ø 4.3 mm	0.24 mm^2	–	–	–	≥ 10 mm	≥ 50 mm
Ø 4.5 mm **Ø 5.1 mm**	0.14/0.09[2]/ 0.05[3] mm^2	0.05 mm^2	0.05 mm^2	0.14 mm^2	≥ 10 mm	≥ 50 mm
Ø 6 mm **Ø 10 mm**[1]	0.19/0.14[4] mm^2	–	0.08 mm^2	0.34 mm^2	≥ 20 mm ≥ 35 mm	≥ 75 mm ≥ 75 mm
Ø 8 mm **Ø 14 mm**[1]	0.5 mm^2	1 mm^2	0.5 mm^2	1 mm^2	≥ 40 mm ≥ 100 mm	≥ 100 mm ≥ 100 mm

[1] Metal armor [2] Rotary encoders [3] Length gauges [4] LIDA 400 [5] Also Fanuc, Mitsubishi

Electrically Permissible Speed/ Traversing Speed

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

- the **mechanically** permissible shaft speed / traversing velocity (if listed in *Specifications*)
  and
- the **electrically** permissible shaft speed/ traversing velocity.
  For encoders with **sinusoidal output signals,** the electrically permissible shaft speed/traversing velocity is limited by the –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/ output frequency f_{max} of the encoder and
  – the minimum permissible edge separation a of 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 permissible speed in min^{-1}
v_{max}: Electrically permissible traversing speed 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 2004/108/EC with respect to the generic standards for:

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

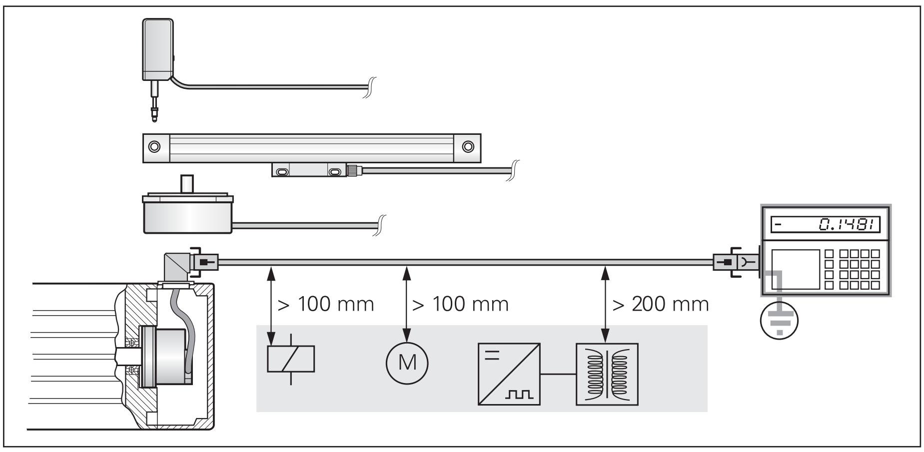
Transmission of measuring signals— electrical noise immunity
Noise voltages arise mainly through capacitive or inductive transfer. Electrical noise can be introduced into the system over signal lines and input or output terminals.
Possible sources of noise are:

- 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. See also **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 **rotary encoders in electromagnetic fields** greater than 30 mT, HEIDENHAIN recommends consulting with the main facility in Traunreut.

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).



Minimum distance from sources of interference

Evaluation and Display Units

ND 200
Position display units
HEIDENHAIN encoders with 11-μA_{PP} or 1-V_{PP} signals and EnDat 2.2 interface can be connected to the position display units of the ND 200 series. The **ND 280** position display provides the basic functions for simple measuring tasks. The **ND 287** also features other functions such as sorting and tolerance check mode, minimum/maximum value storage, measurement series storage. It calculates the mean value and standard deviations and creates histograms and control charts. The ND 287 permits optional connection of a second encoder for sum/difference measurement or of an analog sensor.
The ND 28x have serial interfaces for measured value transfer.

For more information, see the *Digital Readouts/Linear Encoders* brochure.

	ND 280	ND 287
Input signals[1]	1 x ∼ $11\ \mu A_{PP}$, ∼ $1\ \mu A_{PP}$ or EnDat 2.2	
Encoder inputs	D-sub connector (female), 15-pin	
Input frequency	∼ *1* V_{PP}: ≤ 500 kHz; *11* μA_{PP}: ≤ 100 kHz	
Signal subdivision	Up to 1024-fold (adjustable)	
Display step (adjustable)	*Linear axis:* 0.5 to 0.002 µm *Angular axis:* 0.5° to 0.00001° and/or 00°00'00.1"	
Functions	• REF Reference mark evaluation • 2 datums	
	–	• Sorting and tolerance checking • Measurement series (max. 10000 measured values) • Minimum/maximum value storage • Statistics functions • Sum/difference display (option)
Switching I/O	–	Yes
Interface	V.24/RS-232-C; USB (UART); Ethernet (option for ND 287)	

[1] Automatic detection of interface

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 4096-fold			
Data register for measured values (per channel)	48 bits (44 bits used)			
Internal memory	For 8192 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 (∿ 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	∿ 1 V_{PP}			
Encoder connection	*IBV:* M23 flange socket 12-pin, female *APE:* 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 ⊓⊔ 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 ± 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	∿ 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	*EIB 192/EIB 392:* EnDat 2.2 *EIB 192 F/EIB 392 F:* Fanuc Serial Interface *EIB 192 M/EIB 392 M:* Mitsubishi High Speed Serial Interface	
Power supply	5 V ± 5%	

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