HEIDENHAIN

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Angle Encoders without Integral Bearing

November 2006

Information on
- Angle encoders with integral bearing
- Rotary encoders
- Encoders for servo drives
- Exposed linear encoders
- Linear encoders for numerically controlled machine tools
- HEIDENHAIN subsequent electronics
- HEIDENHAIN controls

is available on request as well as on the Internet under *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.

Contents

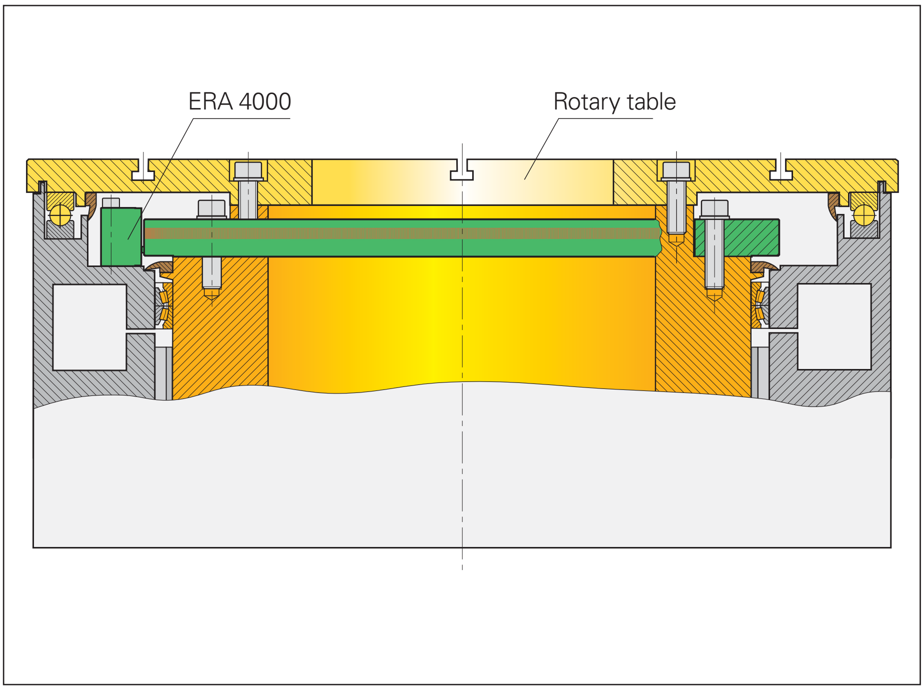
HEIDENHAIN Angle Encoders

The term angle encoder is typically used to describe encoders that have an accuracy of better than ± 5" and a line count above 10000. 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

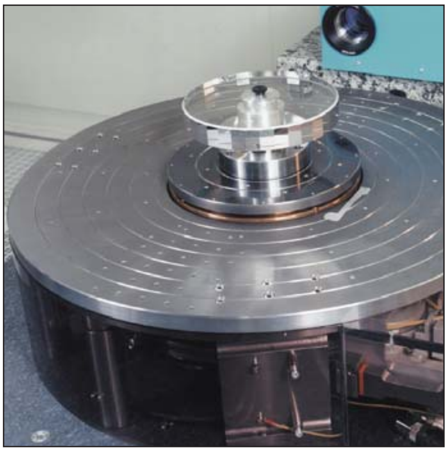
etc.

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 880: Glass circular scale with hub
- ERA 4000: Steel drum
- ERA 180: Steel drum
- ERA 78x/88x: Steel scale 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.

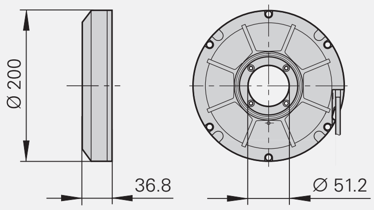
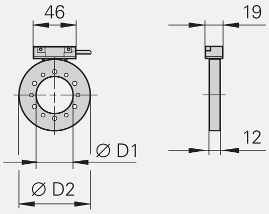
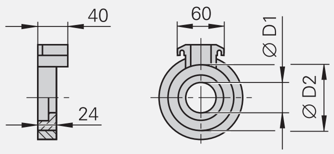
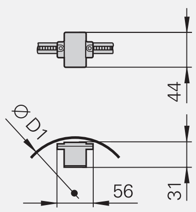
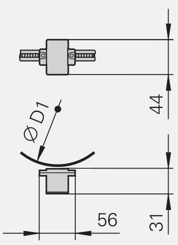
Angle encoders with mounted stator coupling therefore provide excellent dynamic performance because the coupling absorbs only that torque caused by friction in the bearing during angular acceleration of the shaft.

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 under *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 rpm
ERA 4x80 Steel circumferential scale drum with centering collar		D1: 76.75 mm to 331.31 mm D2: 40 mm to 270 mm	3 000/± 9.4“ to 52 000/± 2.8“		≤ 10 000 rpm to ≤ 2 500 rpm
ERA 4x81 Steel circumferential scale drum with low weight and low moment of inertia		D1: 52.65 mm to 305.84 mm D2: 26 mm to 280 mm	4 096/± 10.2“ to 48 000/± 2.8“		≤ 6 000 rpm to ≤ 2 000 rpm
ERA 4282 Steel circumferential scale drum for increased accuracy requirements		D1: 76.75 mm to 331.31 mm D2: 40 mm to 270 mm	12 000/± 5.1“ to 52 000/± 2“		≤ 10 000 rpm to ≤ 2 500 rpm
ERA 180[4)] Steel drum with axial grating		D1: 40 mm to 512 mm D2: 80 mm to 562 mm	6 000/± 7.5“ to 36 000/± 2.5“	0.001 5° to 0.000 1°	≤ 20 000 rpm to ≤ 3 000 rpm
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 rpm
		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 rpm
		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
4) For new applications use the ERA 4000 series

	Incremental signals/ Grating period	Reference marks	Model	Page
	∿ 1 V_{PP}/–	One	**ERP 880**	**26**
	∿ 1 V_{PP}/20 µm	Distance-coded	**ERA 4280 C**	**28**
	∿ 1 V_{PP}/40 µm		**ERA 4480 C**	
	∿ 1 V_{PP}/80 µm		**ERA 4880 C**	
	∿ 1 V_{PP}/20 µm		**ERA 4281 C**	**30**
	∿ 1 V_{PP}/40 µm		**ERA 4481 C**	
	∿ 1 V_{PP}/20 µm		**ERA 4282 C**	**32**
	∿ 1 V_{PP}	One	**ERA 180**	**34**
	∿ 1 V_{PP}/40 µm	Distance-coded (nominal increment of 1000 grating periods)	**ERA 780 C** full circle	**38**
			ERA 781 C segment	
	∿ 1 V_{PP}/40 µm	Distance-coded (nominal increment of 1000 grating periods)	**ERA 880 C** full circle	**40**
			ERA 881 C segment with tensioning elements	
			ERA 882 C segment without tensioning elements	

ERP 880

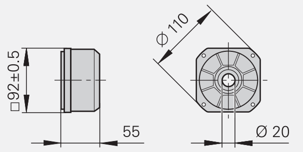
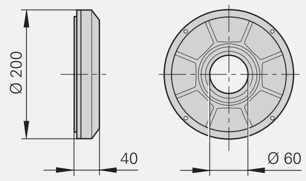
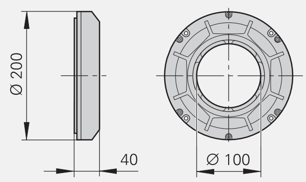
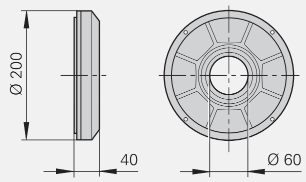
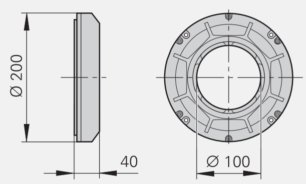
ERA 4000

ERA 180

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/re
With integrated stator coupling						
RCN 200		± 5"	0.0001°	3000 rpm	∼ 1 V_{PP}	16384
					–	–
					–	–
					–	–
		± 2.5"			∼ 1 V_{PP}	16384
					–	–
					–	–
					–	–
RCN 700		± 2"	0.0001°	1000 rpm	∼ 1 V_{PP}	32768
					–	–
					–	–
					–	–
					∼ 1 V_{PP}	32768
					–	–
					–	–
					–	–
RCN 800		± 1"	0.00005°	1000 rpm	∼ 1 V_{PP}	32768
					–	–
					–	–
					–	–
					∼ 1 V_{PP}	32768
					–	–
					–	–
					–	–

1) For position measurement

v	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**	

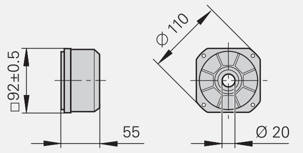
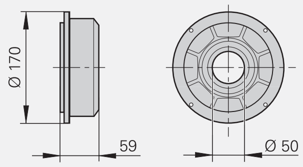
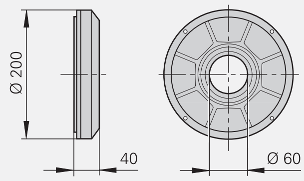
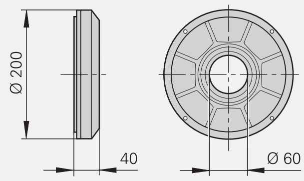
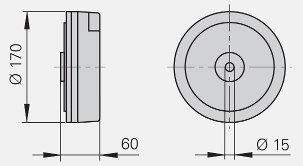
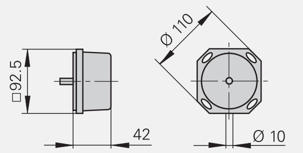
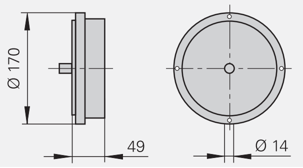
RCN 200

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°	3000 rpm
			0.001°/0.0005°	
			0.0001°	
		± 2.5"		
RON 700		± 2"	0.0001°	1000 rpm
				
RON 800 **RPN 800**		± 1"	0.00005°	1000 rpm
			0.00001°	
RON 900		± 0.4"	0.00001°	100 rpm
For separate shaft coupling				
ROD 200		± 5"	0.005°	10000 rpm
			0.0005°	
			0.0001°	
ROD 700		± 2"	0.0001°	1000 rpm
ROD 800		± 1"	0.00005°	1000 rpm

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 10 000 rpm. For higher speeds—up to 20 000 rpm—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:

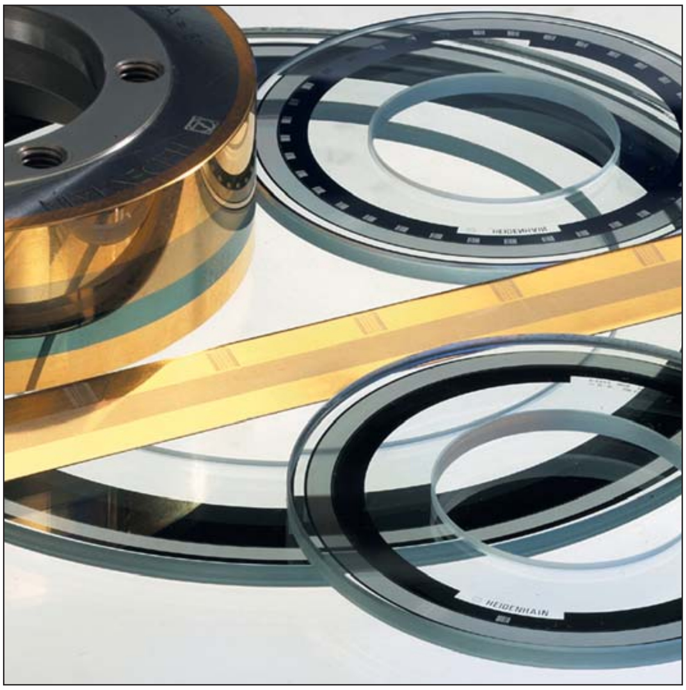
- extremely hard chromium lines on glass or gold-plated steel drums,
- matte-etched lines on gold-plated steel tape, or
- three-dimensional structures etched into quartz glass.

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

- 40 µm with AURODUR, and
- 20 µm with METALLUR, and
- 10 µm with DIADUR, and
- 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:

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

and:

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

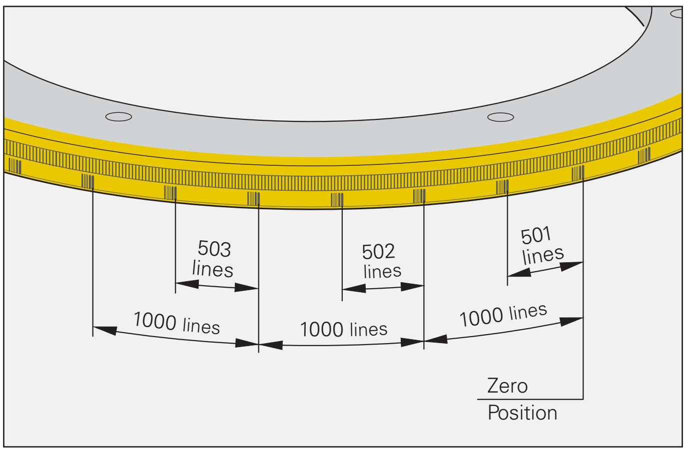
I = Nominal increment between two fixed reference marks (see tables)

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

D = Direction of rotation (+1 or –1)
Rotation to the right (as seen from the shaft side of the angle encoder—see Mating 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 with 20000 lines as example)

ERA 4000C

Line count for grating period 20 µm	40 µm, 80 µm	Number of reference marks	Nominal increment I
–	3000	6	120°
8192	4096	8	90°
–	5000	10	72°
12000	6000	12	60°
–	7000	14	51.428°
16384	8192	16	45°
20000	10000	20	36°
24000	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°

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:

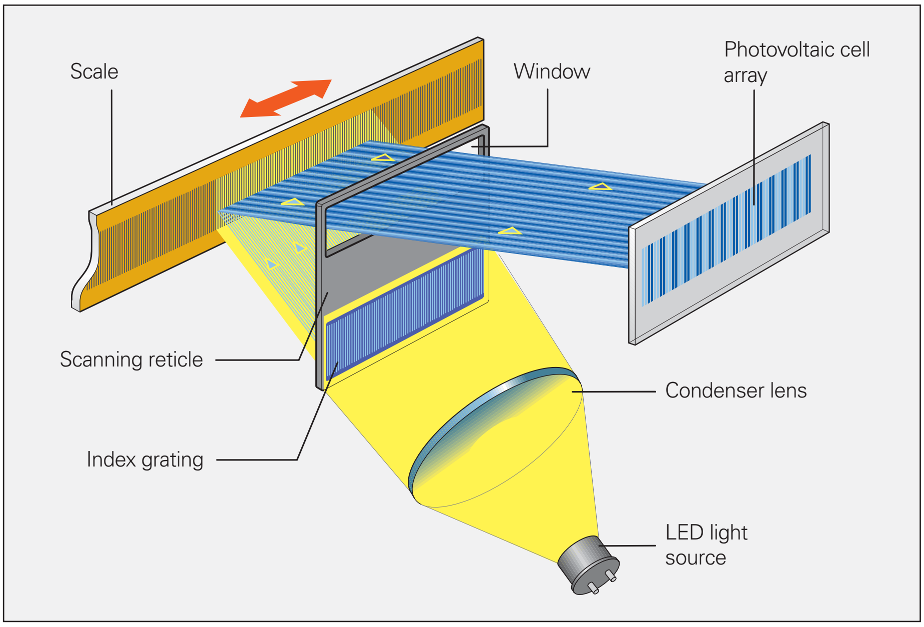
- The **imaging scanning principle** for grating periods from 10 µm to approx. 70 µm.
- The **interferential scanning principle** for very fine graduations with grating periods of 4 µm.

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.

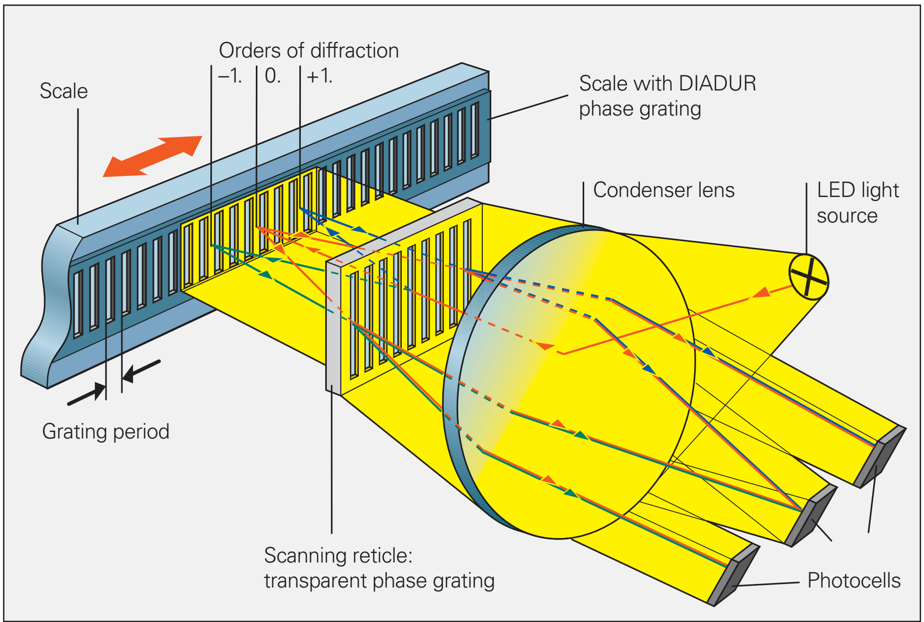
A step grating is used as the measuring standard: reflective lines 0.2 µm high are applied to a flat, reflective surface. In front of that is the scanning reticle—a transparent phase grating with the same grating period as the scale.

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 880 angle encoder, for example, operates according to the interferential scanning principle.



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

Measuring Accuracy

The accuracy of angular measurement is mainly determined by:

- The quality of the graduation
- The quality of the scanning process
- The 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).

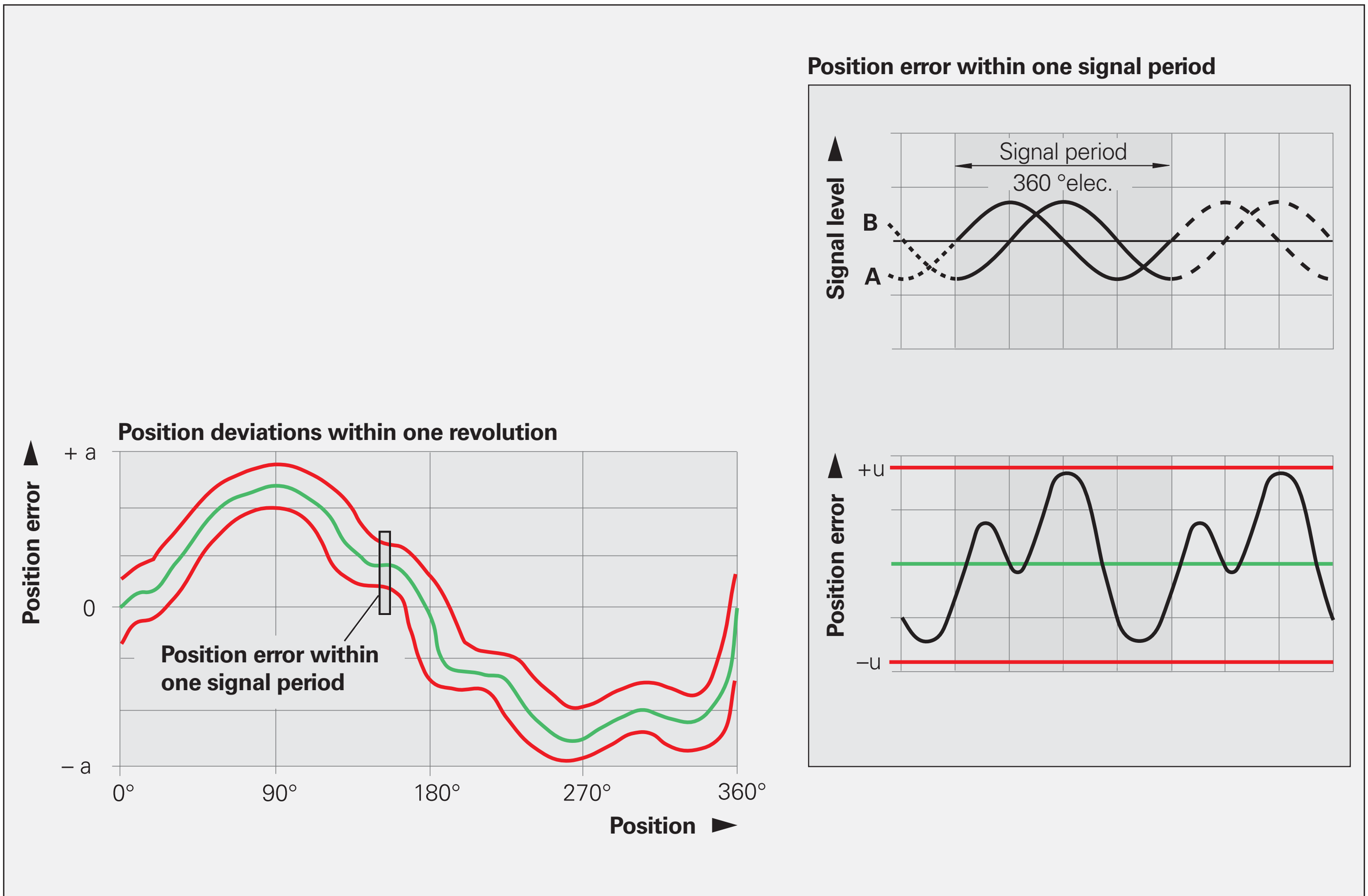
Position errors within one revolution become apparent in larger angular motions.

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 880, ERA 4000 and ERA 180 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) 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 ERA 4000 and ERA 180 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.

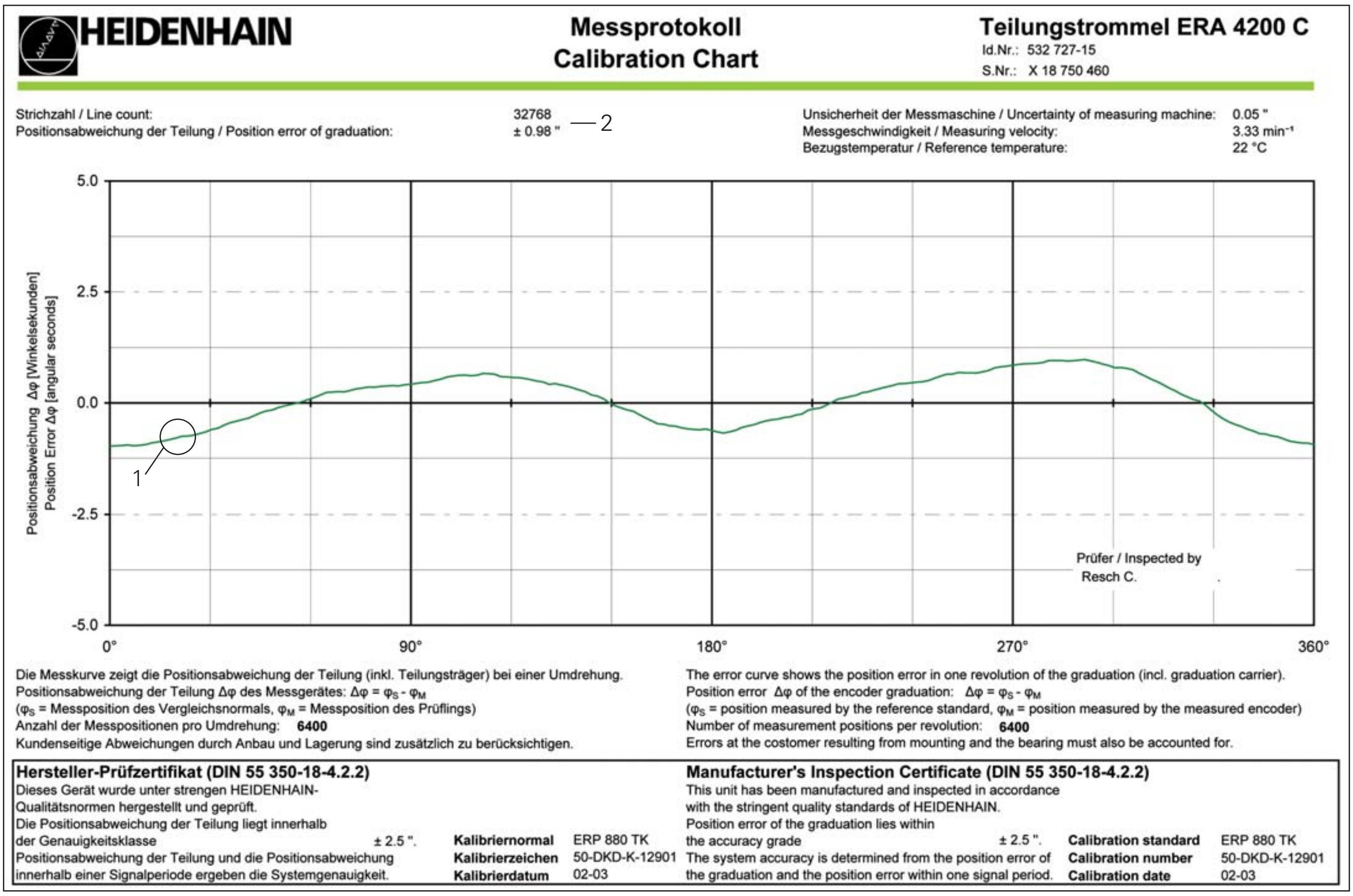
All measured values acquired in this manner lie within the specified graduation accuracy (see *Specifications*).

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


HEIDENHAIN

Messprotokoll
Calibration Chart

Teilungstrommel ERA 4200 C
Id.Nr.: 532 727-15
S.Nr.: X 18 750 460

Strichzahl / Line count: 32768
Positionsabweichung der Teilung / Position error of graduation: ± 0.98 " — 2

Unsicherheit der Messmaschine / Uncertainty of measuring machine: 0.05 "
Messgeschwindigkeit / Measuring velocity: 3.33 min^{-1}
Bezugstemperatur / Reference temperature: 22 °C

Die Messkurve zeigt die Positionsabweichung der Teilung (inkl. Teilungsträger) bei einer Umdrehung.
Positionsabweichung der Teilung Δφ des Messgerätes: $\Delta\varphi = \varphi_S - \varphi_M$
(φ_S = Messposition des Vergleichsnormals, φ_M = Messposition des Prüflings)
Anzahl der Messpositionen pro Umdrehung: **6400**
Kundenseitige Abweichungen durch Anbau und Lagerung sind zusätzlich zu berücksichtigen.

The error curve shows the position error in one revolution of the graduation (incl. graduation carrier).
Position error Δφ of the encoder graduation: $\Delta\varphi = \varphi_S - \varphi_M$
(φ_S = position measured by the reference standard, φ_M = position measured by the measured encoder)
Number of measurement positions per revolution: **6400**
Errors at the costomer resulting from mounting and the bearing must also be accounted for.

Hersteller-Prüfzertifikat (DIN 55 350-18-4.2.2)
Dieses Gerät wurde unter strengen HEIDENHAIN-Qualitätsnormen hergestellt und geprüft.
Die Positionsabweichung der Teilung liegt innerhalb der Genauigkeitsklasse ± 2.5 ".
Positionsabweichung der Teilung und die Positionsabweichung innerhalb einer Signalperiode ergeben die Systemgenauigkeit.

Kalibriernormal ERP 880 TK
Kalibrierzeichen 50-DKD-K-12901
Kalibrierdatum 02-03

Manufacturer's Inspection Certificate (DIN 55 350-18-4.2.2)
This unit has been manufactured and inspected in accordance with the stringent quality standards of HEIDENHAIN.
Position error of the graduation lies within the accuracy grade ± 2.5 ".
The system accuracy is determined from the position error of the graduation and the position error within one signal period.

Calibration standard ERP 880 TK
Calibration number 50-DKD-K-12901
Calibration date 02-03

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 ERA 4000, ERA 180 and ERP
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, and
- mounting surface form deviations,
- 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.

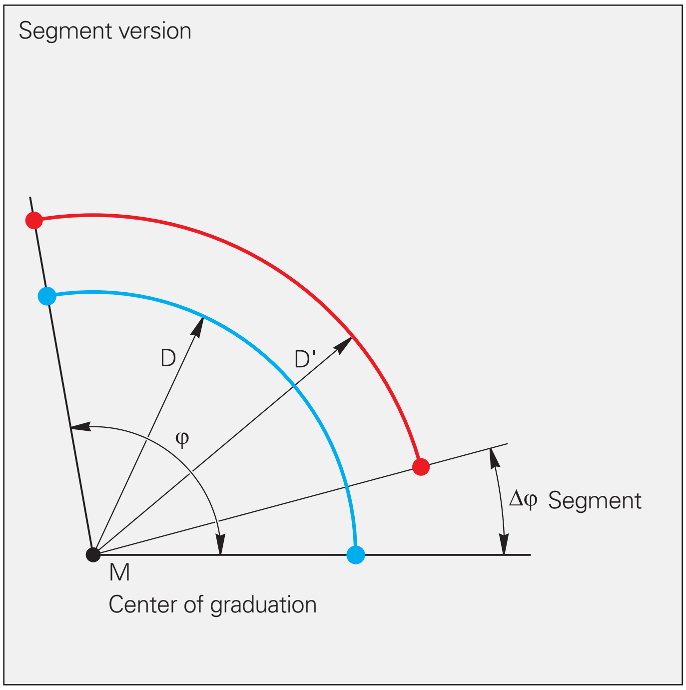
2. Error due to eccentricity of the graduation to the bearing
Under normal circumstances the graduation will have a certain amount of eccentricity to the bearing after the disk/hub assembly (ERP), circumferential-scale drum (ERA 4000, ERA 180) or scale tape (ERA 78xC and ERA 88xC) is mounted. In addition, 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):

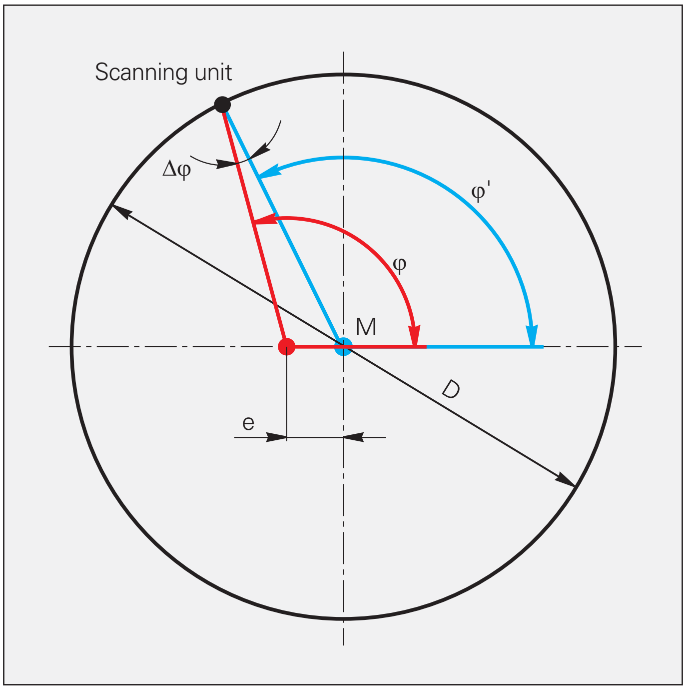
$$\Delta\varphi = \pm 412 \cdot \frac{e}{D}$$

$\Delta\varphi$ = 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, ERA 180) 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“
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“
ERA 180	D = 80 mm	± 5.2“
	D = 130 mm	± 3.2“
	D = 180 mm	± 2.3“
	D = 250 mm	± 1.6“
	D = 330 mm	± 1.2“
	D = 485 mm	± 0.8“
	D = 562 mm	± 0.7“
ERA 78x C	D = 320 mm	± 1.3“
	D = 460 mm	± 0.9“
	D = 570 mm	± 0.7“
	D = 1145 mm	± 0.4“
ERA 88x C	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 $\Delta\varphi$ is also valid for radial deviation of the bearing if the value e is replaced with the eccentricity value, i.e. half of the radial deviation (half of the displayed value).

Bearing compliance to radial shaft loading causes similar errors.

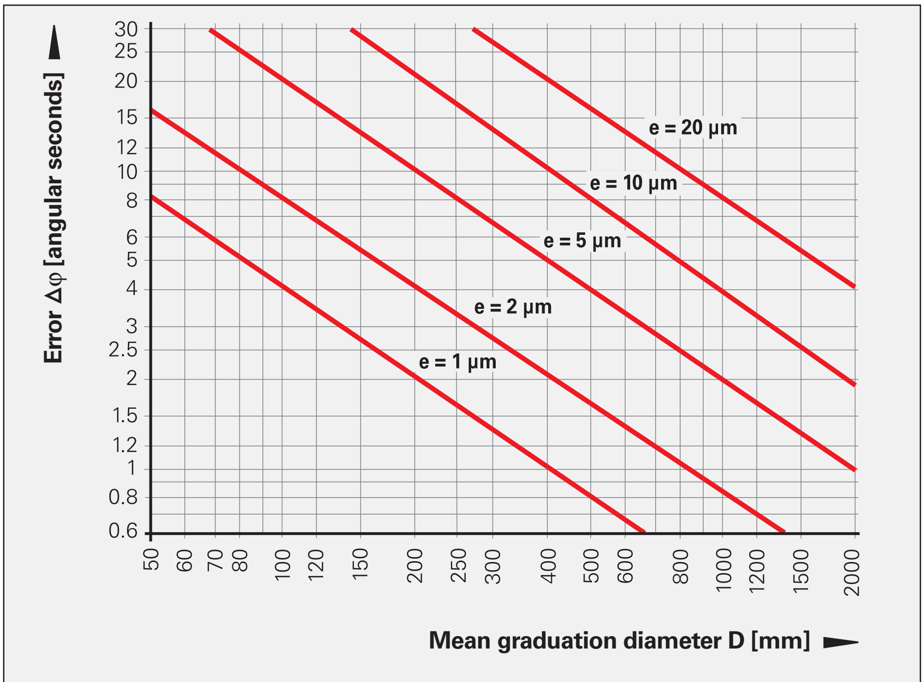
4. Position error within one signal period $\Delta\varphi_u$

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 880 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“
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“
	40 000	≤ ± 0.4“
	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.

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

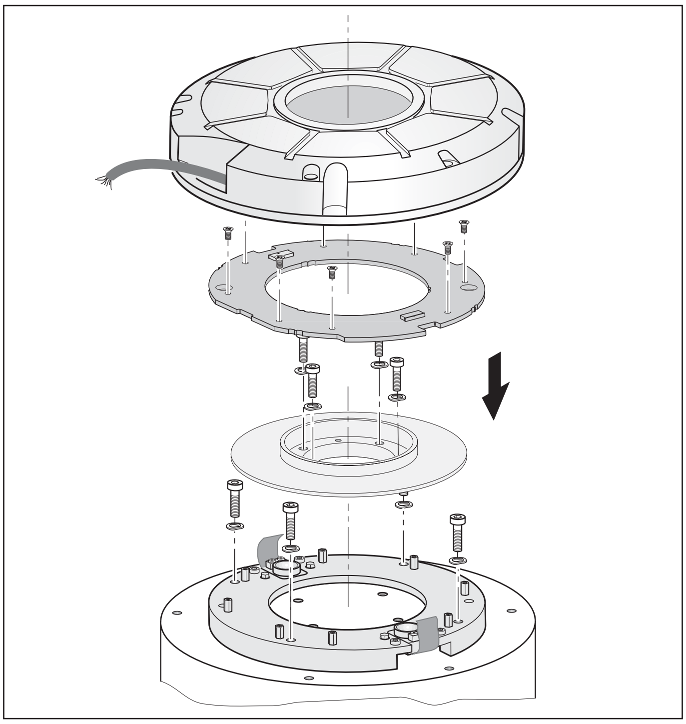


Mechanical Design Types and Mounting

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. Nr. 369774-01

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

ERA 4000, ERA 180 Series

The ERA 4000 und ERA 180 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 180 angle encoders up to the drum inside diameter of 180 mm are available with an optional protective cover.

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

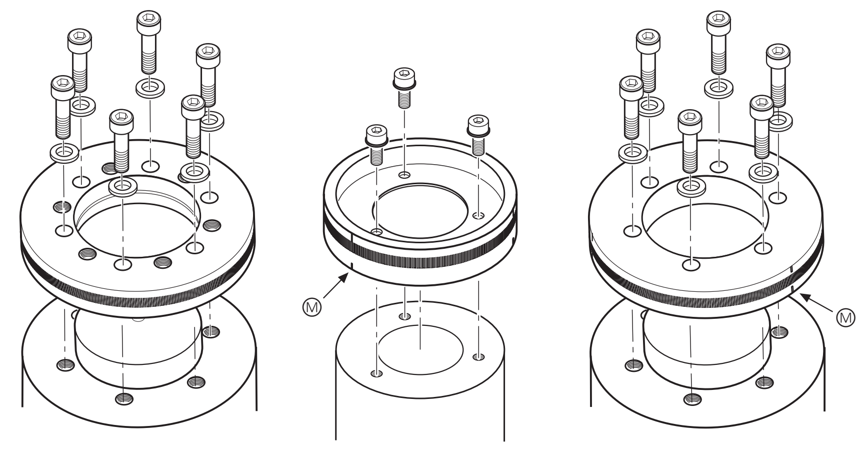
Mounting the scale drum
ERA 4x00 and ERA 180
The solid circumferential scale drum is slid onto the drive shaft and fastened with screws. The scale drum is centered via the **centering collar** on its inner circumference. HEIDENHAIN recommends using a slight oversize on the shaft for mounting the scale 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. The positions for centering are marked on the scale drum.

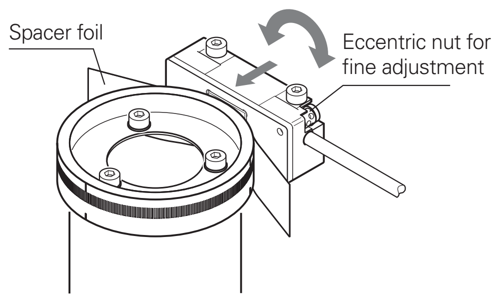
Mounting the ERA 4202 scale drum
The solid scale drum is centered over three positions at 120° increments on its circumference and fastened with screws. The positions for centering are marked on the scale drum.

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.

Application	Scale drum	Grating period	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	Solid version, 3-point centering	20 µm	ERA 4202	ERA 4280



Mounting the scale drums



Mounting the scanning head (ERA 4000 as example)

Mechanical Design Types and Mounting
ERA 700 and ERA 800 Series

The encoders of the ERA 700 and ERA 800 series consist of a scanning unit and a one-piece steel scale tape up to 30 m in length. The tape is mounted on the
- inside diameter for the **ERA 700 series,**
- outside diameter for the **ERA 800 series**

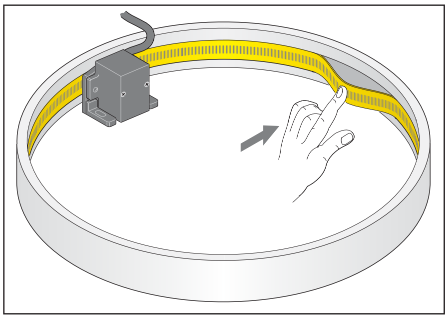
of a machine element.

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

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

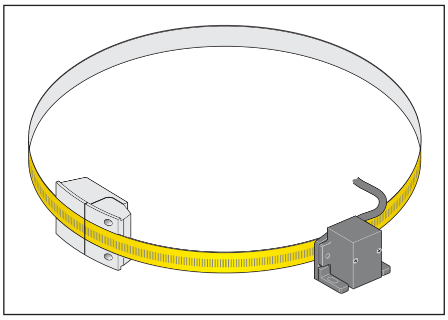
Mounting the scale tape for full-circle applications

ERA 780C: An **internal slot** with a certain diameter is required as scale tape carrier. The tape is inserted starting at the butt joint and is clicked into the slot. The length is cut so that the tape is held in place by its own spring force. To make sure that the scale tape does not move within the slot, it is fixed with adhesive at multiple points in the area of the butt joint.



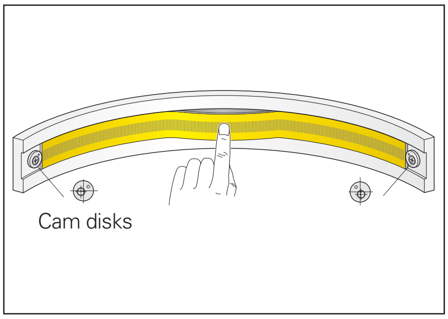
ERA 880C: The scale tape is supplied with the halves of the tensioning cleat already mounted on the tape ends. An **external slot** is necessary for mounting. Space must also be provided for the tensioning cleat. The tape is placed in the outside slot of the machine (along slot edge) and is tensioned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

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

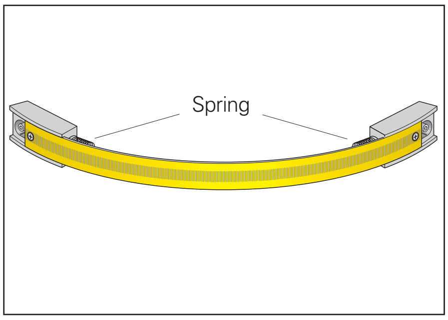


Mounting the scale tape for segment angles

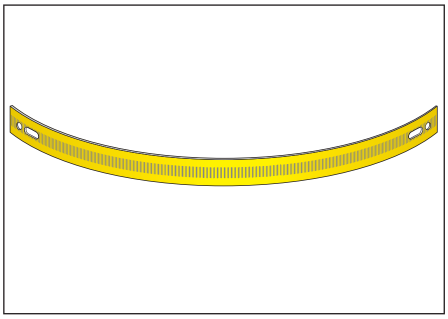
ERA 781C: An internal slot with a certain diameter is required. The two cam disks fixed in this slot are adjusted so that the scale can be snapped into the slot under pressure.



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



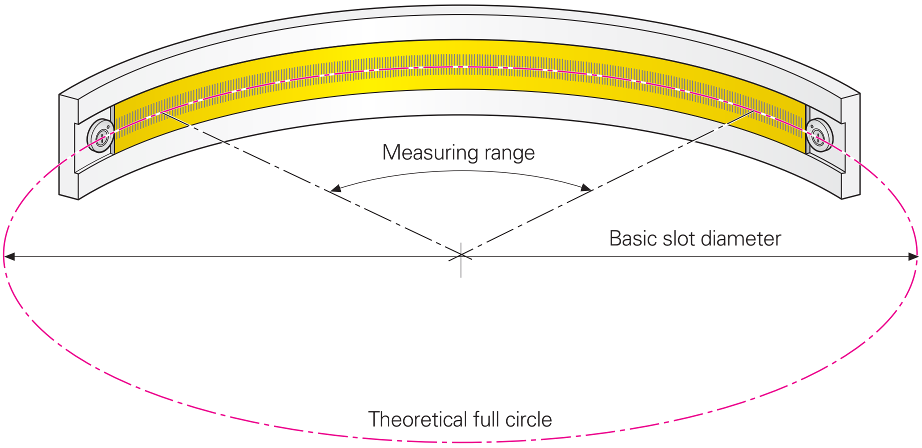
ERA 882C: An external slot or one-sided axial stop is recommended for placing the scale tape. The scale tape is supplied without tensioning elements. It must be preloaded with a spring balance, and fixed with the two oblong holes.



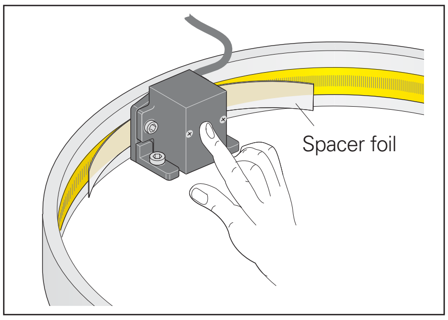
The following must be kept in mind for segment applications:

- **Specification of slot-floor diameter**
  In order to guarantee the correct functioning of the distance-coded reference marks, the circumference of the theoretical full circle must be a multiple of 1000 grating periods. This also facilitates adaptation to the NC control, which mostly can only calculate integer line counts. The connection between the basic slot diameter and the line count can be seen in the table.
- **Segment angle**
  The measuring range for the segment angle should be a multiple of 1000 signal periods, since these versions can be supplied sooner.

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

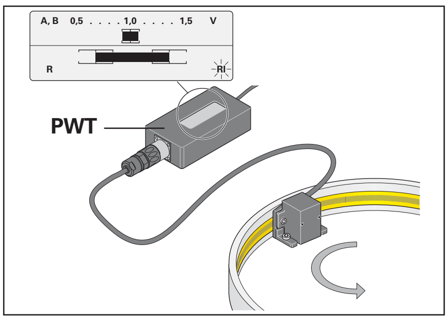


Mounting the scanning head
A spacer foil is placed against the scale tape. The scanning head is pushed up against the spacer foil in such a way that the foil is only located between the two mechanical support points on the mounting bracket. The scanning head is secured in this position and the foil is 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 IEC 60529 and IEC 60529 for the housing and cable outlet, and IP 64 at shaft inlet.

The ERA 180 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.

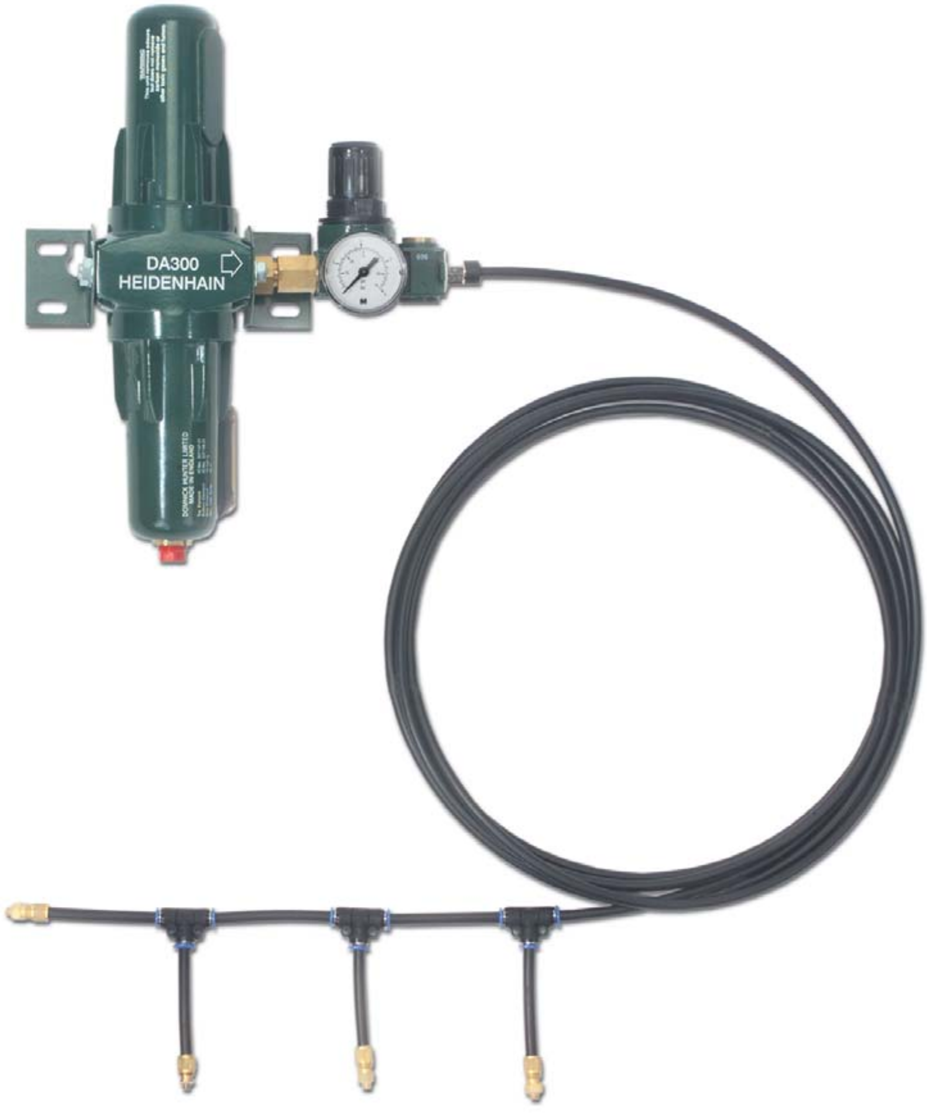
HEIDENHAIN offers the **DA 300 compressed air unit** for this purpose. It consists of two filter stages (fine filter and activated carbon filter), automatic condensation trap, and a pressure regulator with pressure gauge. It also includes 25 meters of pressure tubing as well as T-joints and connecting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

The compressed air with overpressure of typically 7 bars to be led into the DA 300 encoders must comply with the following quality classes as per **ISO 8573-1:**

- 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:
  +29 °C at 10 · 10^5 Pa (not a class)

Its pressure gauge and automatic pressure switch (available as accessories) effectively monitor the DA 300.

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.

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 and ERA 180 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.

Expendable parts
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.

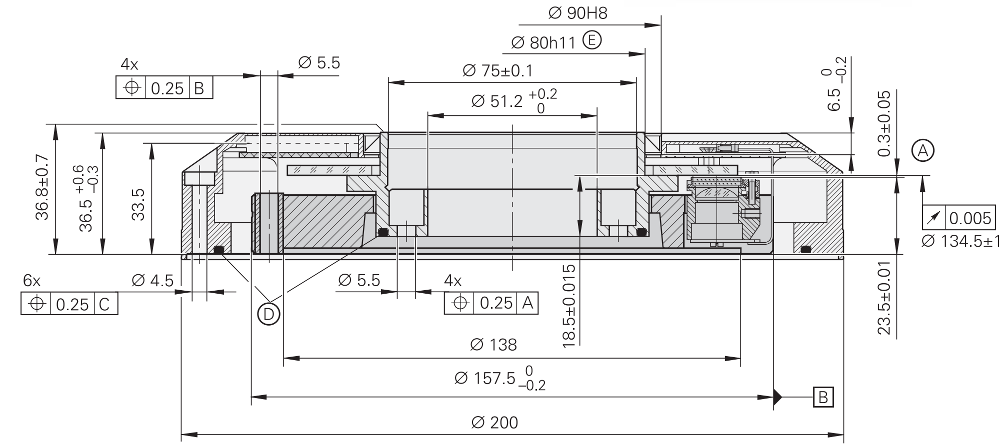
Assembly
Work steps to be performed and dimensions to be maintained during mounting are specified solely in the mounting instructions supplied with the unit. All data in this catalog regarding mounting are therefore provisional and not binding; they do not become terms of a contract.

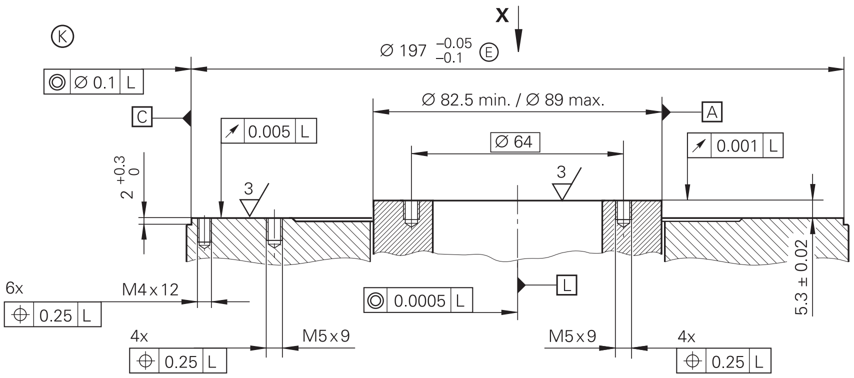
ERP 880

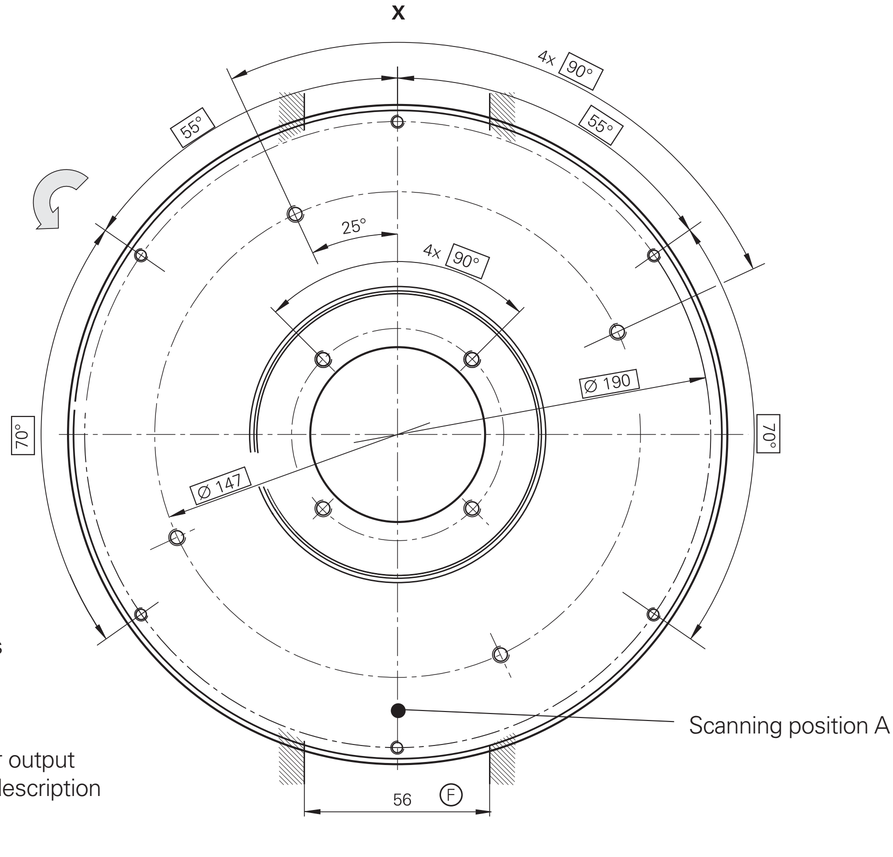
- **High accuracy due to interferential scanning principle**

Dimensions in mm

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







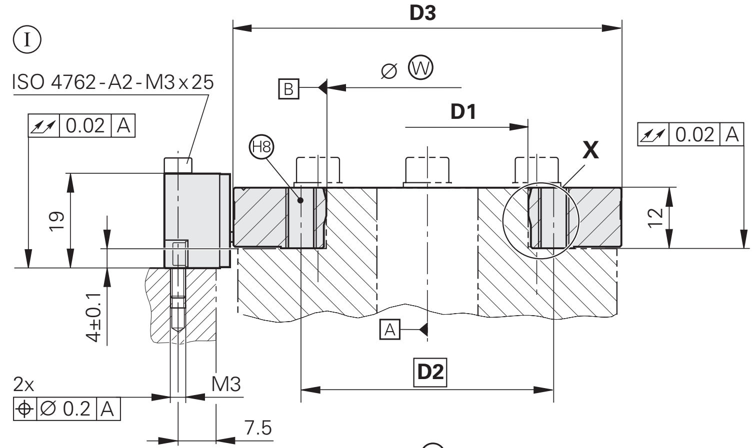
Cable radial, also usable axially
Ⓐ = Disk-to-scanning-reticle gap
Ⓚ = Required mating dimensions
Ⓕ = Space needed for service
Ⓓ = Seal
L = Axis of bearing rotation
Direction of shaft rotation for output signals as per the interface description

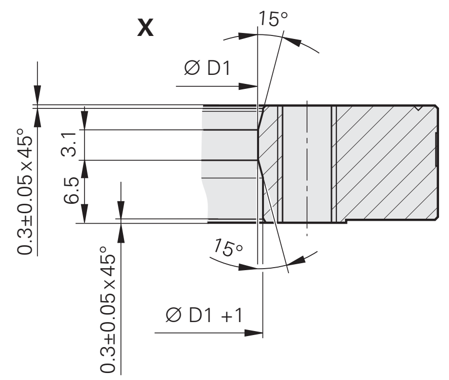
	Incremental ERP 880		
Incremental signals	∼ 1 V_{PP}		
Line count	90000 (≙ 180000 signal periods)		
Reference mark	One		
Cutoff frequency –3 dB –6 dB	≥ 800 kHz ≥ 1.3 MHz		
Recommended measuring step for position measurement	0.00001°		
System accuracy[1)]	± 1“		
Accuracy of the graduation	± 0.9"		
Power 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. Nr. 372164-xx)		
Cable length	≤ 150 m (with HEIDENHAIN cable)		
Hub inside diameter	51.2 mm		
Mech. permissible speed	≤ 1000 rpm		
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 60068-2-6) ≤ 1000 m/s^2 (IEC 60068-2-27)		
Operating temperature	0 °C to 50 °C		
Protection* IEC 60529	*Without housing:* IP 00	*With housing:* IP 40	*With housing and shaft seal:* IP 64
Starting torque	–		0.25 Nm
Weight	3.0 kg	3.1 kg incl. housing	

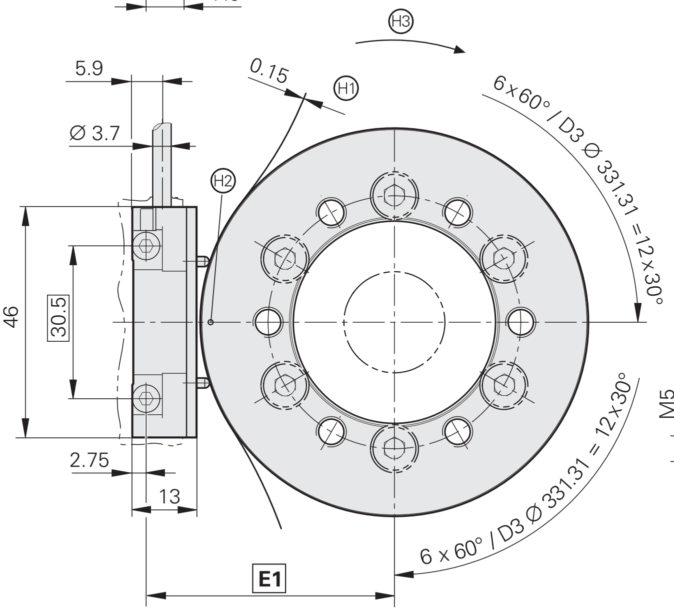
* Please indicate when ordering
1) Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.

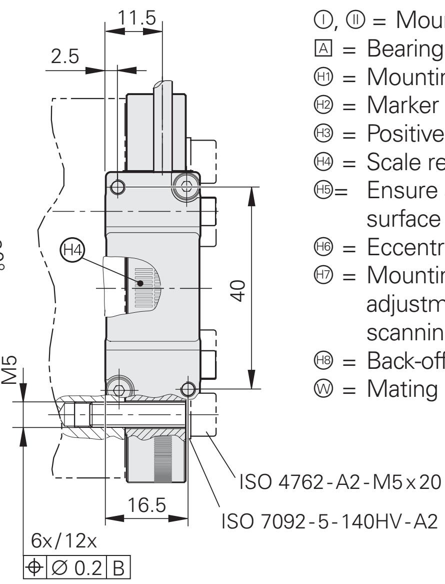
ERA 4280 C, ERA 4480 C, ERA 4880 C

- **Steel circumferential-scale drum with centering collar**

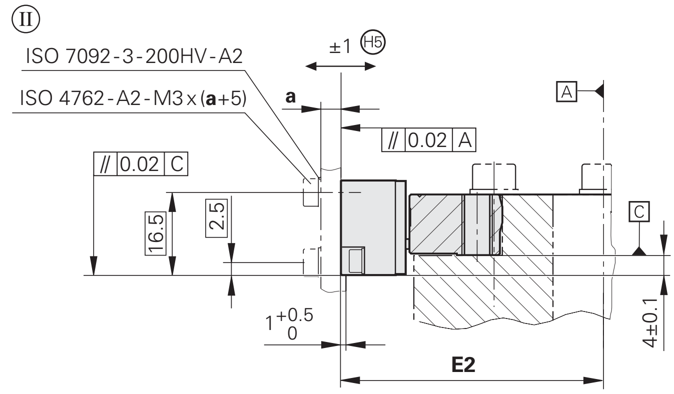




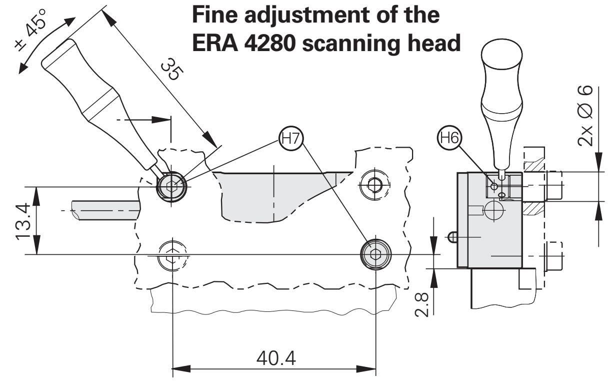


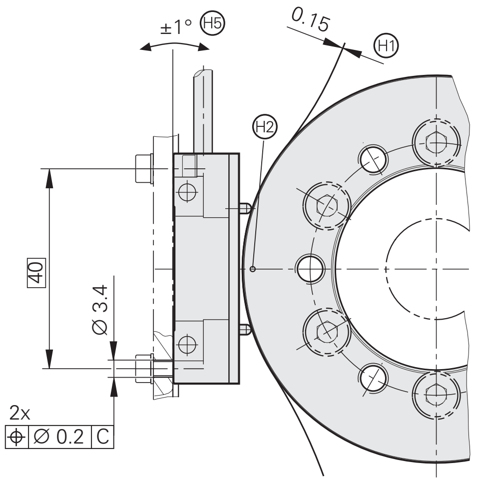


Ⓘ, Ⓘⓘ = Mounting options
Ⓐ = Bearing
H1 = Mounting clearance (spacer foil)
H2 = Marker for reference mark
H3 = Positive direction of rotation
H4 = Scale reference mark
H5 = Ensure adjustability of mounting surface for scanning head
H6 = Eccentric nut
H7 = Mounting holes for fine adjustment (only for ERA 4280 scanning head)
H8 = Back-off thread M6
W = Mating shaft



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
Ø 40 –0.001/–0.005	Ø 40 +0.004	0.001	Ø 50	Ø 76.75	49.34	52.08
Ø 70 –0.001/–0.005	Ø 70 +0.005	0.001	Ø 85	Ø 104.63	63.28	66.02
Ø 80 –0.001/–0.005	Ø 80 +0.006	0.0015	Ø 95	Ø 127.64	74.78	77.52
Ø 120 –0.001/–0.008	Ø 120 +0.008	0.002	Ø 140	Ø 178.55	100.24	102.98
Ø 150 –0.001/–0.008	Ø 150 +0.008	0.002	Ø 165	Ø 208.89	115.41	118.15
Ø 180 –0.001/–0.008	Ø 180 +0.010	0.003	Ø 200	Ø 254.93	138.43	141.17
Ø 270 0/–0.01	Ø 270 +0.012	0.003	Ø 290	Ø 331.31	176.62	179.36

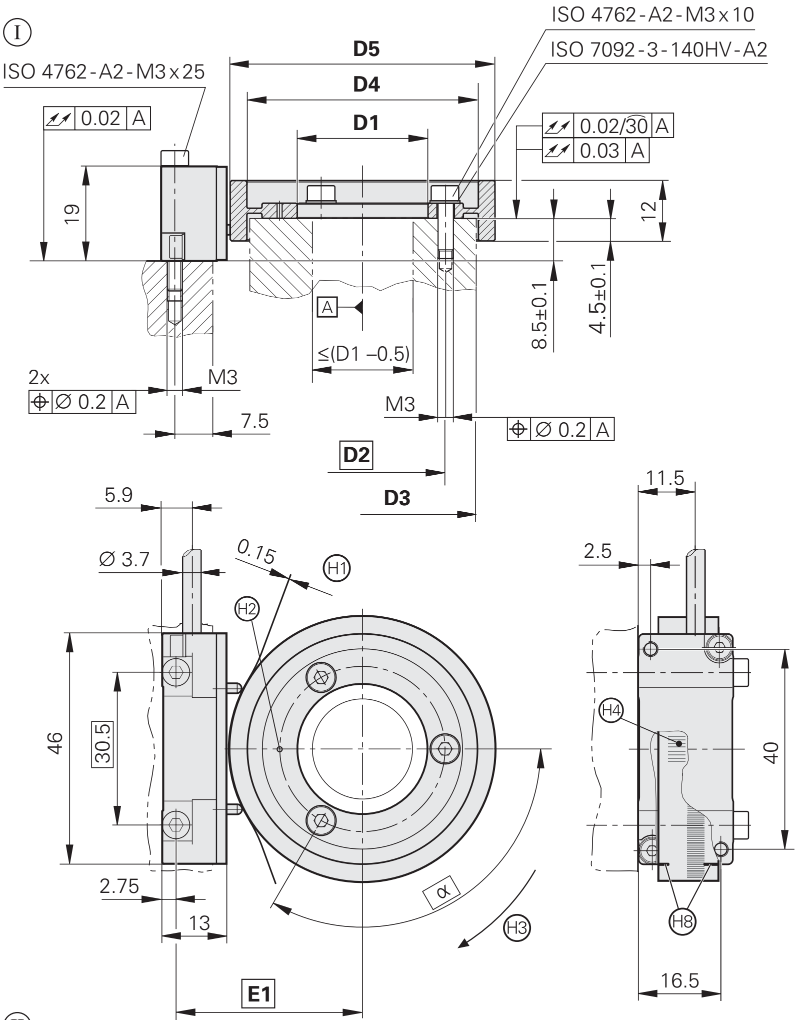
***)** Roundness of mating diameter for shaft

	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**						
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							
ERA 4280 C	12000	16384	20000	28000	32768	40000	52000
ERA 4480 C	6000	8192	10000	14000	16384	20000	26000
ERA 4880 C	3000	4096	5000	7000	8192	10000	13000
System accuracy[1]							
ERA 4280 C	± 6.1"	± 4.5"	± 3.7"	± 3.0"	± 2.9"	± 2.9"	± 2.8"
ERA 4480 C	± 7.2"	± 5.3"	± 4.3"	± 3.5"	± 3.3"	± 3.2"	± 3.0"
ERA 4880 C	± 9.4"	± 6.9"	± 5.6"	± 4.4"	± 4.1"	± 3.8"	± 3.5"
Accuracy of the graduation[2]	± 5"	± 3.7"	± 3"	± 2.5"			
Mech. permissible speed	10000 rpm	8500 rpm	6250 rpm	4500 rpm	4250 rpm	3250 rpm	2500 rpm
Moment of inertia of rotor	$0.27 \cdot 10^{-3}$ 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
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. $10.5 \cdot 10^{-6} K^{-1}$)						
Protection IEC 60529	IP 00						
Weight							
Scale drum (approx.)	0.28 kg	0.41 kg	0.68 kg	1.2 kg	1.5 kg	2.3 kg	2.6 kg
Scanning head without cable (approx.)	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 4281 C, ERA 4481 C

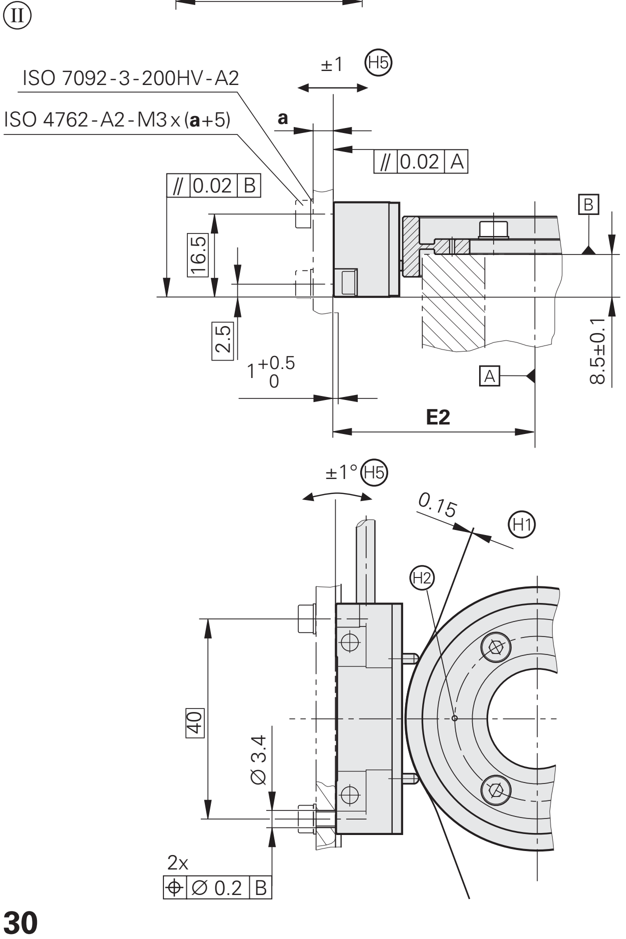
- **Steel circumferential scale drum with low weight and low moment of inertia**



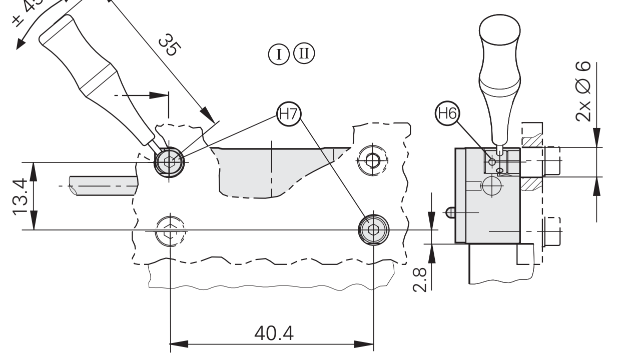
Dimensions in mm

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
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



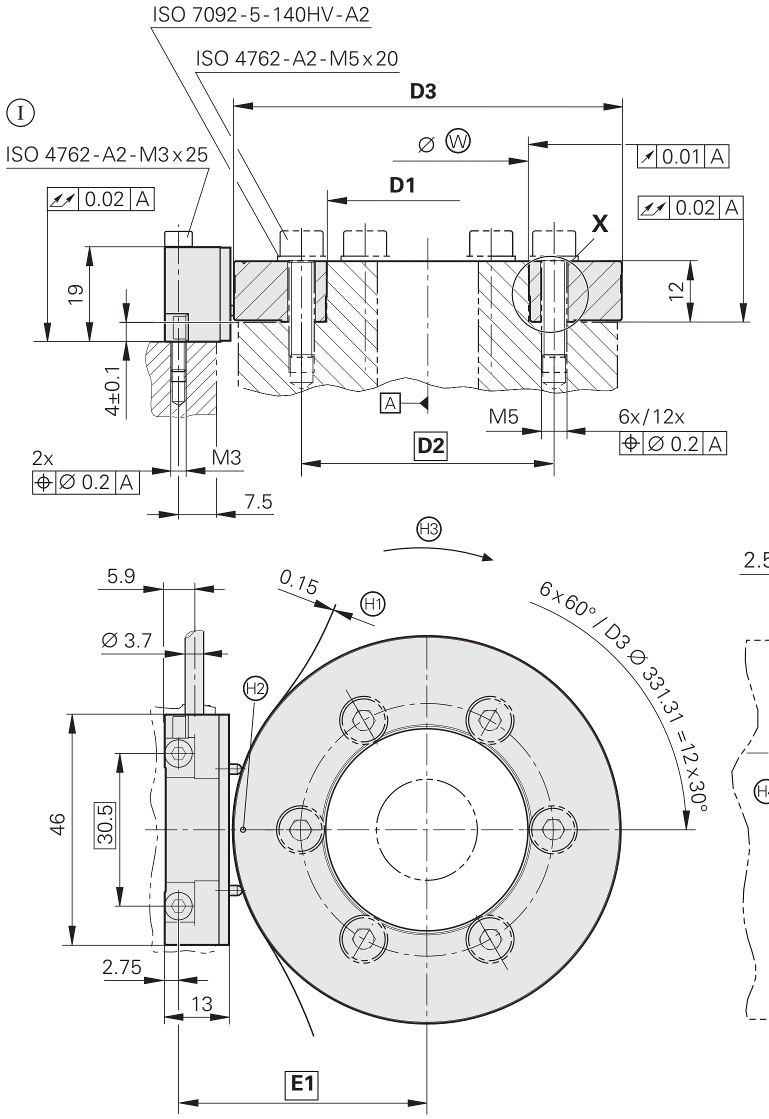
D1	D2	D3	D4	D5	E1	E2	α
Ø 26	Ø 33	Ø 44±1	Ø 46	Ø 52.65	37.29	40.03	3 x 120° = 360°
Ø 50	Ø 57	Ø 68±1	Ø 70	Ø 76.75	49.34	52.08	
Ø 78	Ø 85	Ø 96±1	Ø 98	Ø 104.63	63.28	66.02	6 x 60° = 360°
Ø 127	Ø 134	Ø 145±1	Ø 147	Ø 153.09	87.51	90.25	
Ø 183	Ø 190	Ø 201±1	Ø 203	Ø 208.89	115.41	118.15	8 x 45° = 360°
Ø 229	Ø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

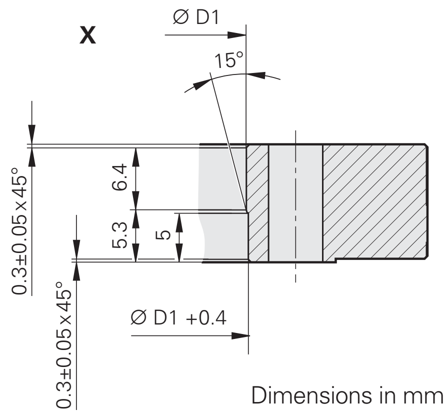
	ERA 4281 C grating period 20 µm—consisting of **ERA 4280 scanning head** and **ERA 4201 C drum** **ERA 4481 C** grating period 40 µm—consisting of **ERA 4480 scanning head** and **ERA 4401 C drum**						
Incremental signals	∿ 1 V_{PP}						
Reference marks	Distance-coded						
Cutoff frequency –3dB	≥ 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 rpm		4000 rpm		2000 rpm		
Moment of inertia of rotor	$0.034 \cdot 10^{-3}$ kgm^2	$0.12 \cdot 10^{-3}$ kgm^2	$0.33 \cdot 10^{-3}$ kgm^2	$1.1 \cdot 10^{-3}$ kgm^2	$2.8 \cdot 10^{-3}$ kgm^2	$5.2 \cdot 10^{-3}$ kgm^2	$9.0 \cdot 10^{-3}$ kgm^2
Permissible axial motion	≤ ± 0.5 mm (scale drum relative to scanning head)						
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 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. $10.5 \cdot 10^{-6}K^{-1}$)						
Protection IEC 60529	IP 00						
Weight							
Scale drum (approx.)	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 (approx.)	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

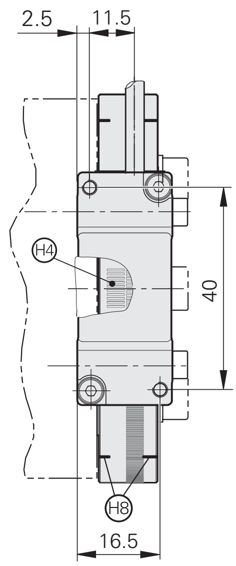
- **Steel circumferential scale drum for increased accuracy requirements**



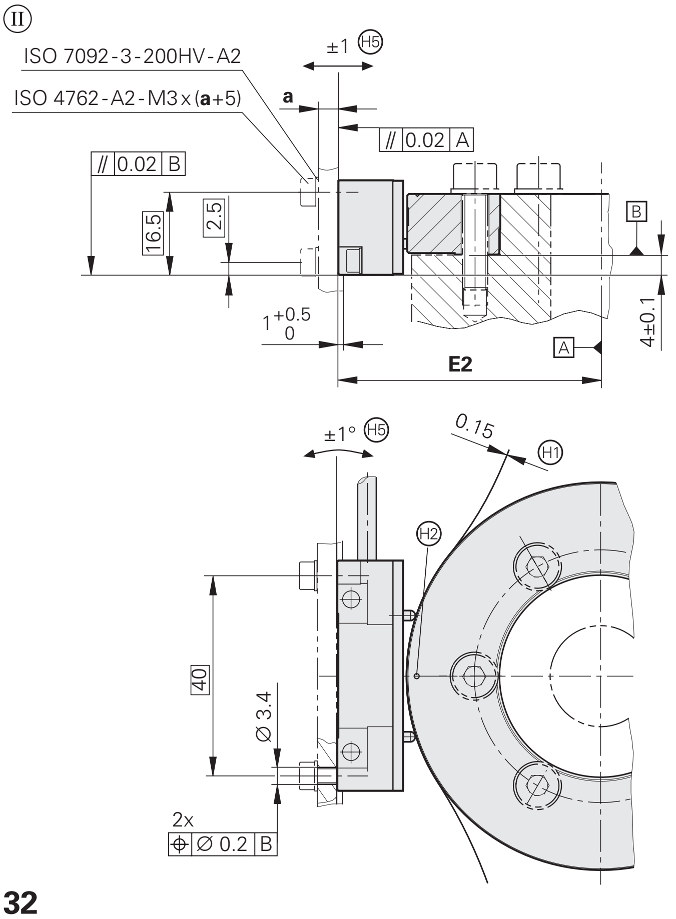


Dimensions in mm

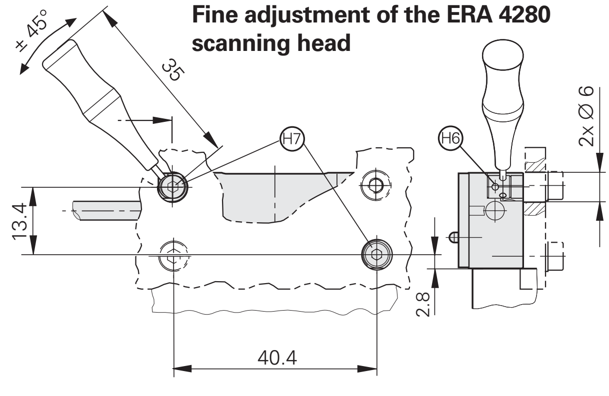
Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm



Ⓘ, Ⓘⓘ = Mounting options
Ⓐ = Bearing
H1 = Mounting clearance (spacer foil)
H2 = Marker for reference mark
H3 = Positive direction of rotation
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°)
W = Mating shaft



Fine adjustment of the ERA 4280 scanning head



D1	W	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 rpm	8 500 rpm	6 250 rpm	4 500 rpm	4 250 rpm	3 250 rpm	2 500 rpm
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							
Scale drum (approx.)	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 (approx.)	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 180

- **Grating on steel drum**

ERA 180

ERA 180 with protective cover

Incremental signals
Reference mark
Cutoff frequency –3 dB
Power supply without load
Electrical connection
Cable length
Drum inside diameter*
Drum outside diameter*
Line count
System accuracy[2)]
Accuracy of the graduation[3)]
Recommended measuring step for position measurement
Mech. permissible speed
Moment of inertia of rotor
Permissible axial motion
Vibration 55 to 2000 Hz **Shock** 6 ms
Operating temperature
Protection* IEC 60529
Weight
Scale drum (approx.)
Protective cover (approx.)
Scanning head with cable (approx.)

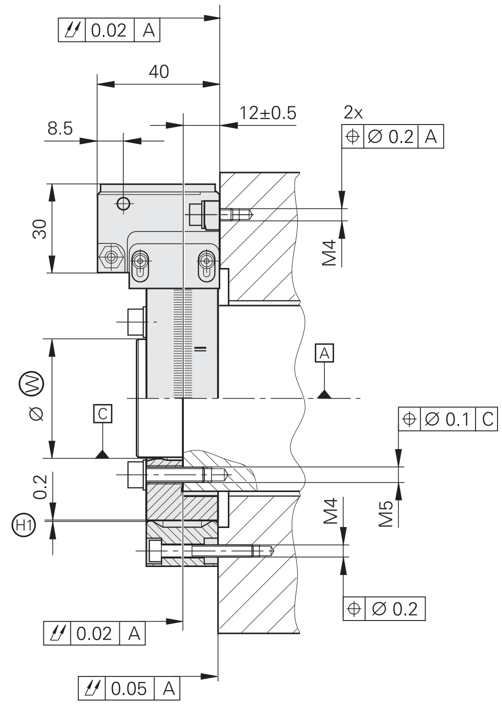
	Incremental						
	ERA 180[1)]						
	∼ 1 V_{PP}						
	One						
	≥ 500 kHz						
	5 V ±10% max. 150 mA						
	Cable 1 m, with M23 coupling						
	≤ 150 m (with HEIDENHAIN cable)						
	40 mm	80 mm	120 mm	180 mm	270 mm	425 mm	512 mm
	80 mm	130 mm	180 mm	250 mm	330 mm	485 mm	562 mm
	6000	9000	9000	18000	18000	36000	36000
	± 7.5"	± 5"	± 5"	± 4"	± 4"	± 2.5"	± 2.5"
	± 5"	± 3"	± 3"	± 3"	± 3"	± 2"	± 2"
	0.001 5°	0.001°	0.001°	0.0005°	0.0005°	0.0001°	0.0001°
	≤ 20000 rpm	≤ 14500 rpm	≤ 11000 rpm	≤ 7500 rpm	≤ 5500 rpm	≤ 3500 rpm	≤ 3000 rpm
	$0.58 \cdot 10^{-3}$ kgm^2	$3.45 \cdot 10^{-3}$ kgm^2	$11.1 \cdot 10^{-3}$ kgm^2	$35.7 \cdot 10^{-3}$ kgm^2	$82.6 \cdot 10^{-3}$ kgm^2	$281.8 \cdot 10^{-3}$ kgm^2	$399.7 \cdot 10^{-3}$ kgm^2
	≤ ± 0.5 mm (scale drum relative to scanning head)						
	≤ 100 m/s^2 (IEC 60068-2-6) ≤ 1000 m/s^2 (IEC 60068-2-27)						
	–10 °C to +80 °C						
	Without protective cover: IP 00 *With protective cover and compressed air:* IP 40				IP 00		
	0.5 kg	1.08 kg	1.17 kg	2.85 kg	3.3 kg	5 kg	5.3 kg
	0.23 kg	0.37 kg	0.51 kg	0.68 kg	–		
	0.2 kg						

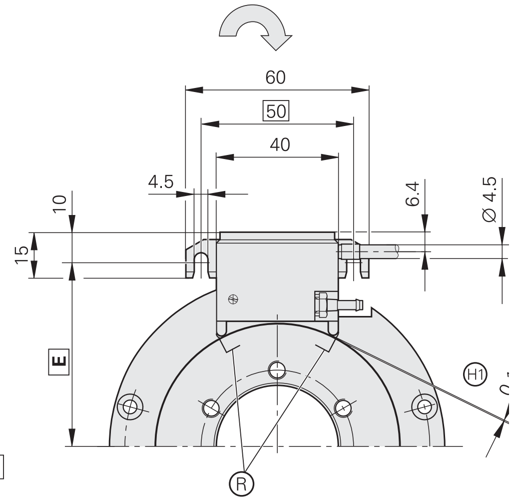
***** Please indicate when ordering
1) For new applications please use the ERA 4000
2) Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.
3) For other errors, see *Measuring Accuracy*

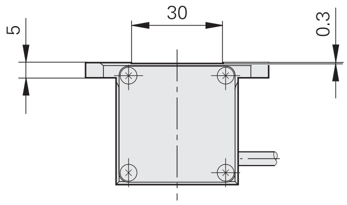
ERA 180

Dimensions in mm

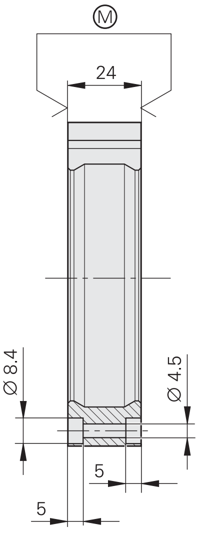
Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

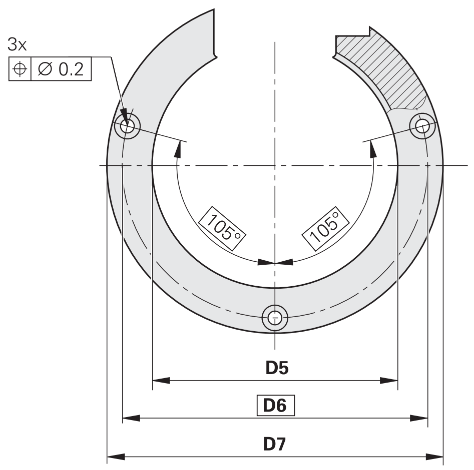


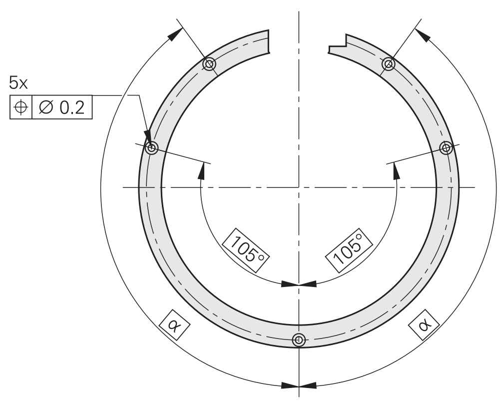




Protective cover



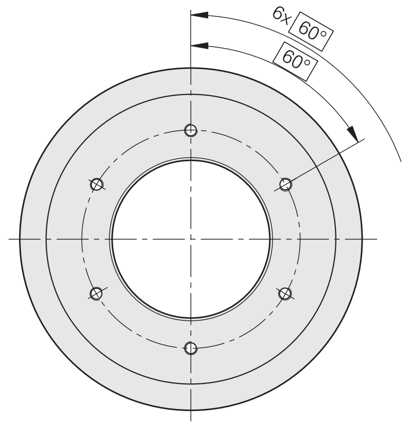


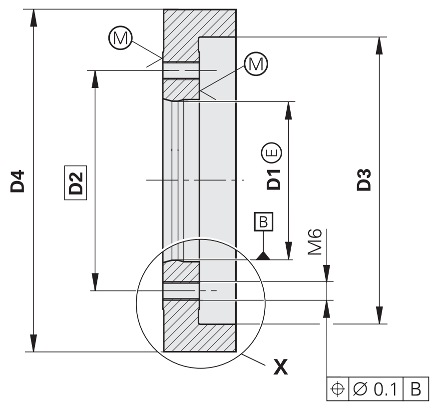


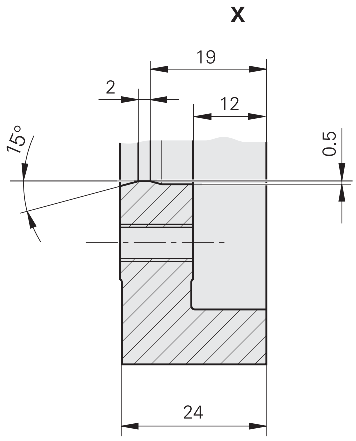
Ⓡ = Reference mark at midpoint between marks
A = Bearing
Ⓜ = Mounting surfaces
H1 = Mounting clearance set with spacer foil
H2 = Mounting hole
H3 = Back-off thread
Ⓦ = Mating shaft
Direction of shaft rotation for output signals as per the interface description

Scale drum inside diameter

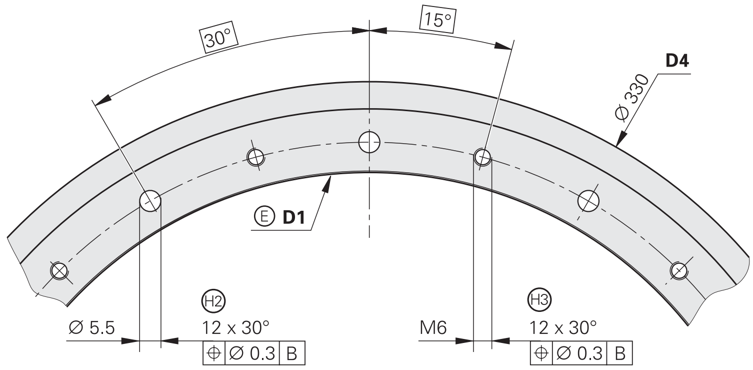
40 mm to 180 mm



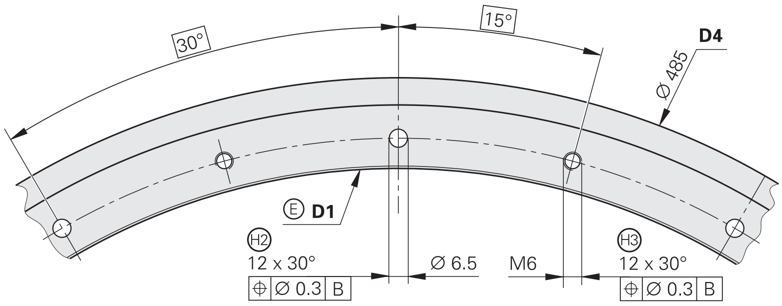




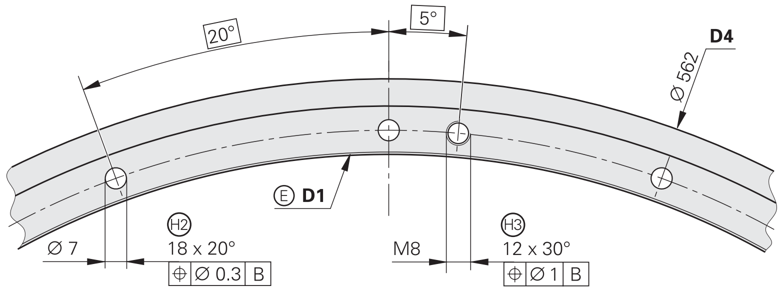
270 mm



425 mm



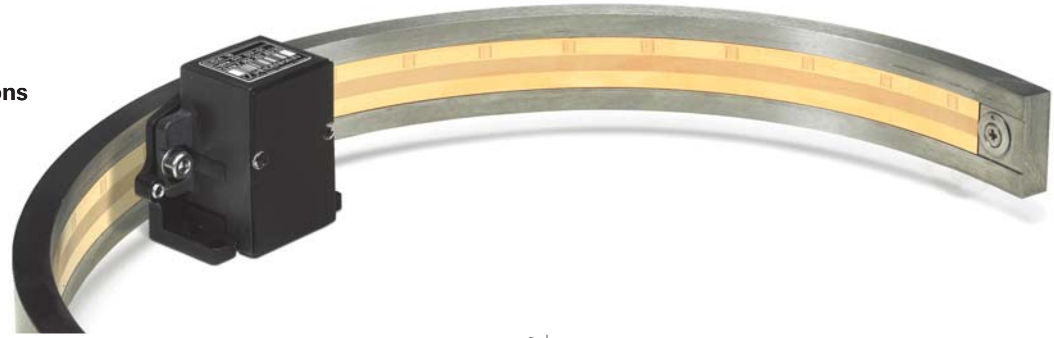
512 mm



Scale drum inside diameter	D1 Ⓔ	Ⓦ	D2	D3	D4	D5	D6	D7	α	E
40 mm	Ø 40 –0.001 –0.005	Ø 40 +0.009 +0.002	Ø 50	Ø 64	Ø 80	Ø 80.4	Ø 100	Ø 110	–	60
80 mm	Ø 80 –0.001 –0.005	Ø 80 +0.013 +0.003	Ø 95	Ø 112	Ø 130	Ø 130.4	Ø 150	Ø 160	–	85
120 mm	Ø 120 –0.001 –0.008	Ø 120 +0.015 +0.003	Ø 140	Ø 162	Ø 180	Ø 180.4	Ø 200	Ø 210	144°	110
180 mm	Ø 180 –0.001 –0.008	Ø 180 +0.018 +0.004	Ø 200	Ø 232	Ø 250	Ø 250.4	Ø 270	Ø 280	150°	145
270 mm	Ø 270 –0 –0.010	Ø 270 +0.020 +0.004	Ø 290	Ø 312	Ø 330	–	–	–	–	185
425 mm	Ø 425 –0 –0.010	Ø 425 +0.020 +0.004	Ø 445	Ø 467	Ø 485	–	–	–	–	262.5
512 mm	Ø 512 –0 –0.015	Ø 512 +0.025 +0.005	Ø 528	Ø 544	Ø 562	–	–	–	–	301

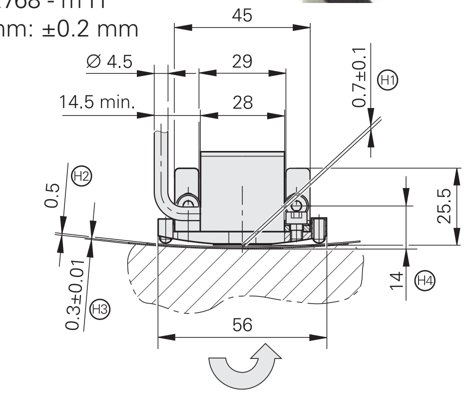
ERA 700 Series

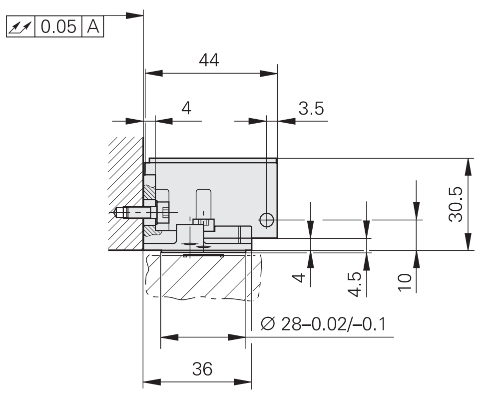
- **For internal mounting**
- **Full-circle and segment versions**

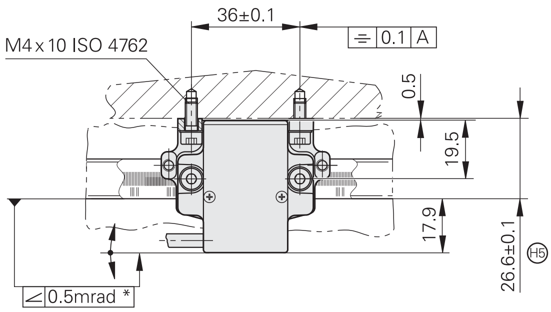


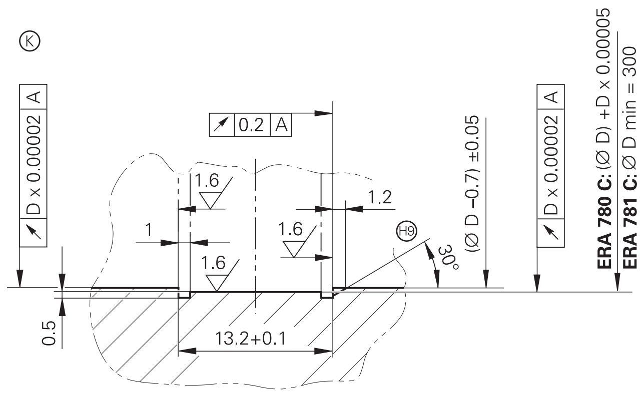
Dimensions in mm

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

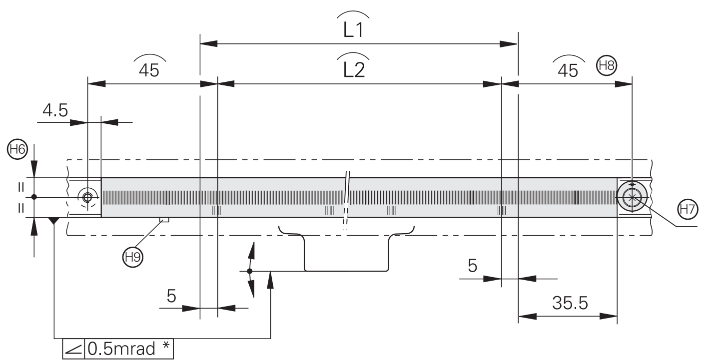


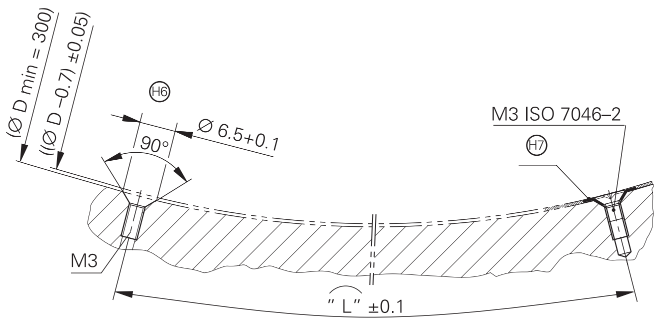


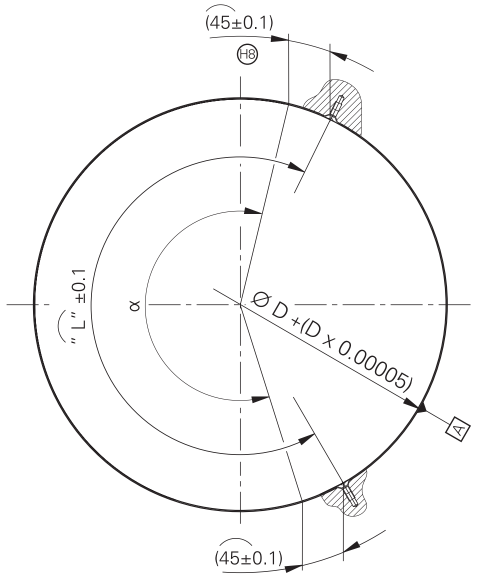




ERA 781C scale tape







* = Max. change during operation
A = Bearing
K = Required mating dimensions for the scale tape (not to scale)
L = Distance of the mounting holes
L1 = Traverse path
L2 = Measuring range in radian measure
α = Measuring range in degrees (segment angle)
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

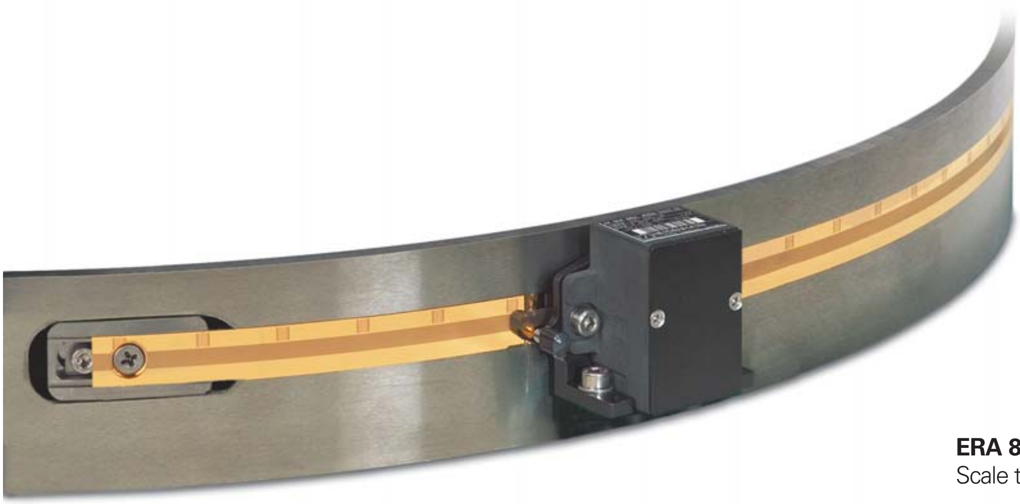
	Incremental **ERA 780 C** full-circle version **ERA 781 C** segment, scale tape secured with tensioning elements			
Incremental signals	∿ 1 V_{PP}			
Reference mark	Distance-coded, nominal increment of 1000 grating periods			
Cutoff frequency –3 dB	≥ 180 kHz			
Power supply without load	5 V ±10% max. 150 mA			
Electrical connection	Cable 3 m, with M23 coupling			
Cable length	≤ 150 m (with HEIDENHAIN cable)			
Scale-slot diameter*	318.58 mm	458.62 mm	573.20 mm	1146.10 mm
Line count				
ERA 780 C full circle	–	36000	45000	90000
ERA 781 C segment*	*72°:* 5000[3] *144°:* 10000[3]	*50°:* 5000 *100°:* 10000 *200°:* 20000	*160°:* 20000	–
Recommended measuring step for position measurement	0.0002°	0.0001°	0.00005°	0.00002°
System 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 rpm			
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 (7.1 oz/m)			

* Please indicate when ordering; other versions available upon request.
1) Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.
2) For other errors, see *Measuring Accuracy*
3) Corresponds to 25000 lines of the theoretical full circle

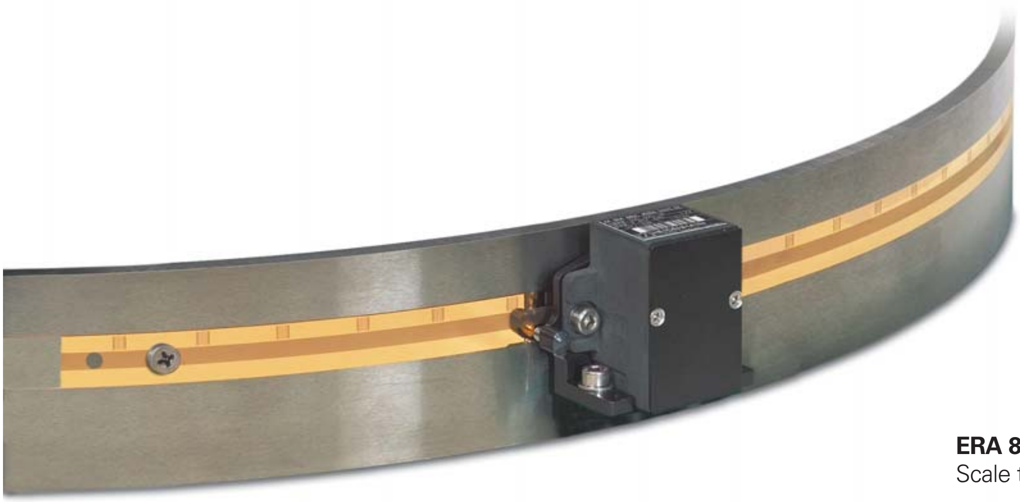
ERA 800 Series

- For outside diameters
- Full-circle and segment versions

ERA 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 w/o tensioning elements

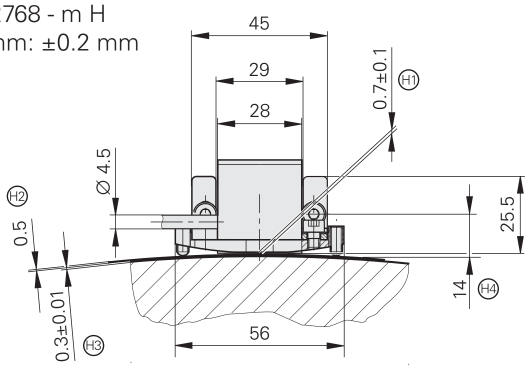
	Incremental **ERA 880 C** full-circle version **ERA 881 C** segment, scale tape secured with tensioning elements **ERA 882 C** segment, scale tape secured without tensioning elements		
Incremental signals	∿ 1 V_{PP}		
Reference mark	Distance-coded, nominal increment of 1 000 grating periods		
Cutoff frequency –3 dB	≥ 180 kHz		
Power supply without load	5 V ±10% max. 150 mA		
Electrical connection	Cable 3 m, with M23 coupling		
Cable length	≤ 150 m (with HEIDENHAIN cable)		
Scale-slot diameter*	317.99 mm	458.04 mm	572.63 mm
Line count			
ERA 880 C full circle	–	36 000	45 000
ERA 881 C/ ERA 882 C segment*	*72°:* 5 000[3)] *144°:* 10 000[3)]	*50°:* 5 000 *100°:* 10 000 *200°:* 20 000	*160°:* 20 000
Recommended measuring step for position measurement	0.000 2°	0.000 1°	0.000 05°
System accuracy[1)]			
ERA 880 C full circle	–	± 3.5"	± 3.4"
ERA 881 C/ ERA 882 C segment	See *Measuring Accuracy*		
Accuracy of the graduation[2)]	± 3"		
Mech. permissible speed	≤ 100 rpm		
Permissible axial motion of measured shaft	± 0.2 mm		
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 100 m/s² (IEC 60 068-2-6) ≤ 1 000 m/s² (IEC 60 068-2-27)		
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 60 529	IP 00		
Weight			
Scanning unit	Approx. 0.35 kg		
Scale tape	Approx. 30 g/m (7.1 oz/m)		

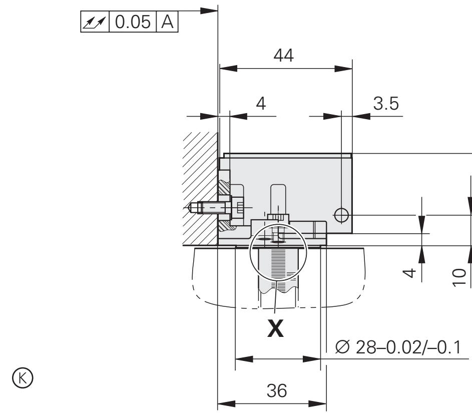
* Please indicate when ordering; other versions available upon request.
1) Before installation. Additional error caused by mounting inaccuracy and inaccuracy from the bearing of the drive shaft are not included.
2) For other errors, see *Measuring Accuracy*
3) Corresponds to 25 000 lines of the theoretical full circle

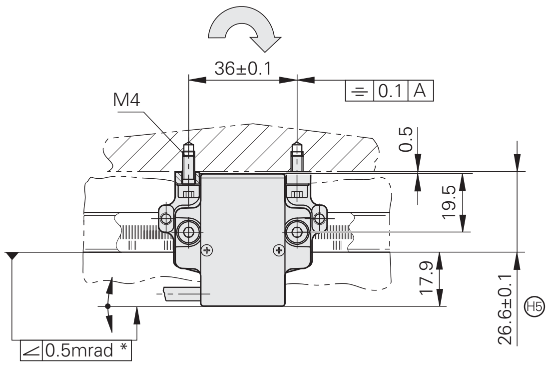
ERA 800 Series

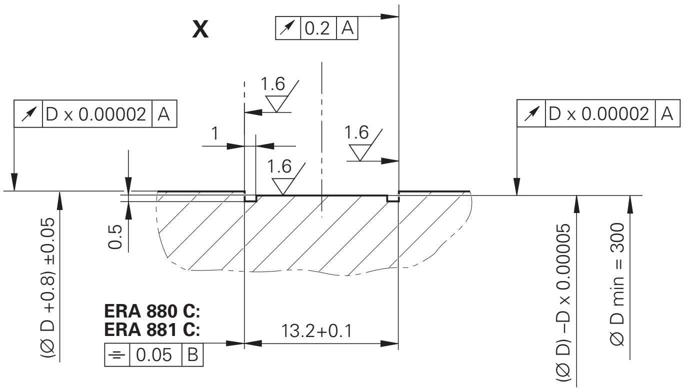
Dimensions in mm

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

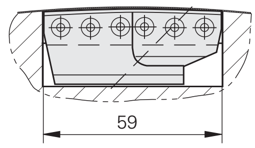


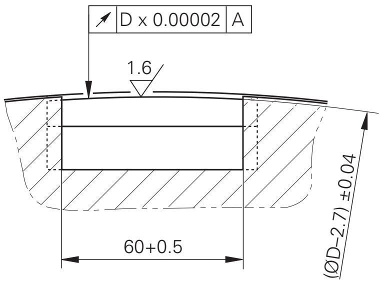


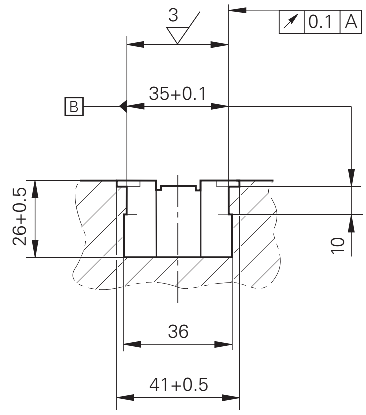


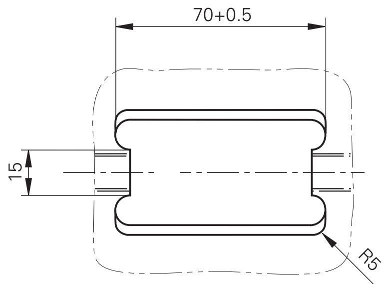


ERA 880C scale tape



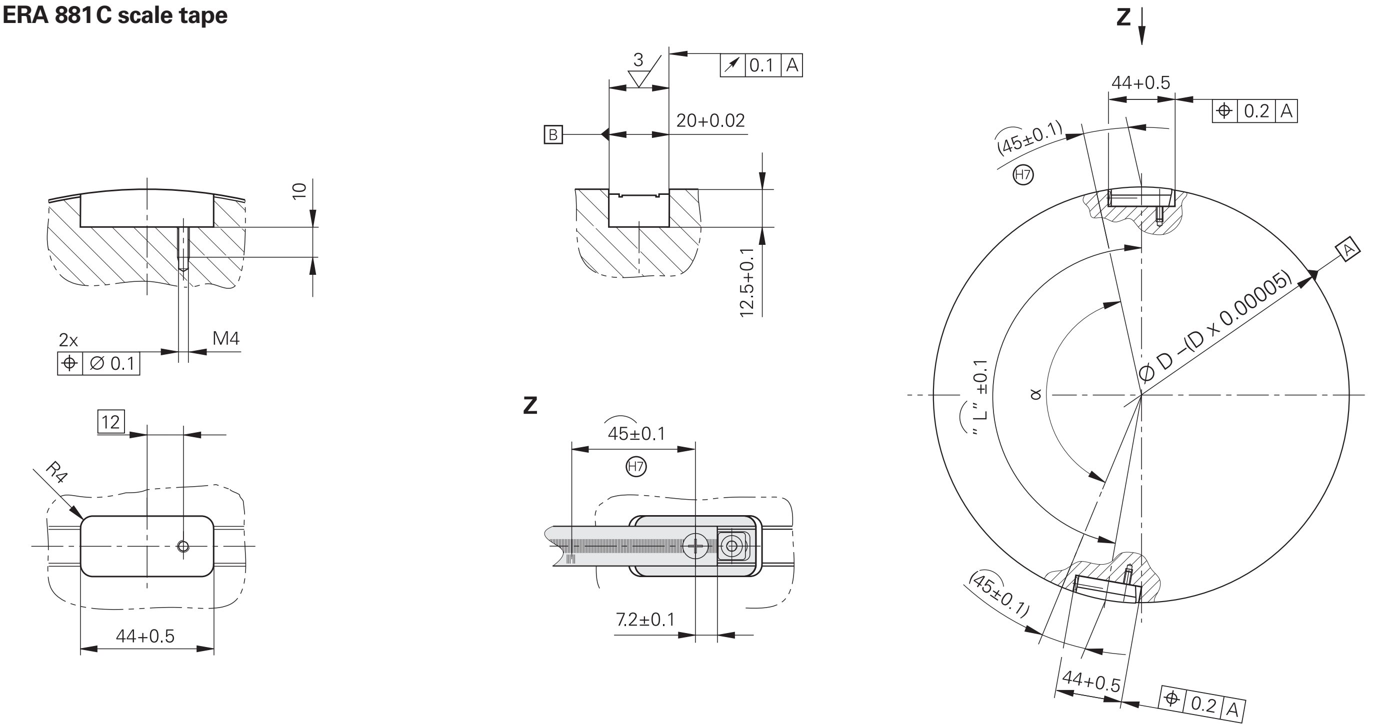




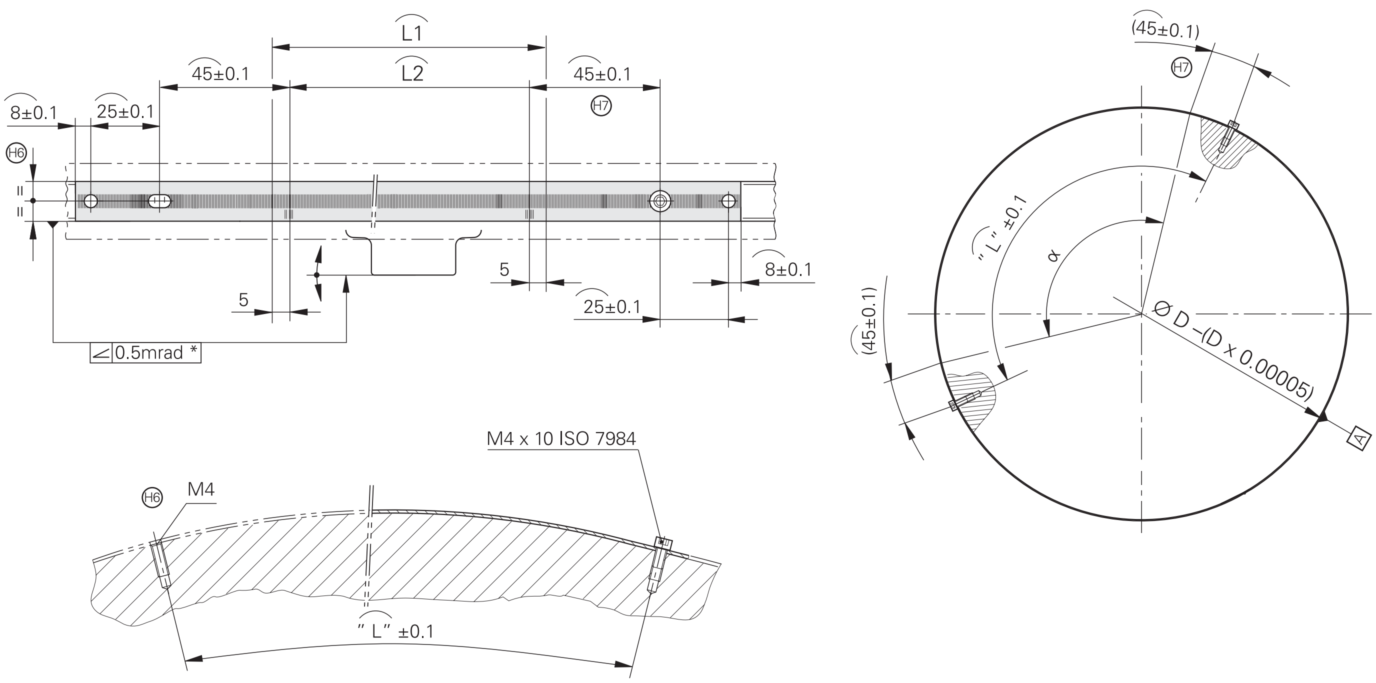


* = Max. change during operation
A = Bearing
K = Required mating dimensions for the scale tape (not to scale)
H1 = Scanning gap (distance between scanning reticle and scale-tape surface)
H2 = Mounting clearance for mounting bracket. Spacer foil 0.5 mm
H3 = Scale-tape thickness
H4 = Distance between floor of scale-tape slot and threaded mounting hole
H5 = Distance between mounting surface and scale-tape slot
Direction of shaft rotation for output signals as per the interface description

ERA 881 C scale tape



ERA 882 C scale tape



* = Max. change during operation
A = Bearing
H6 = View of holes provided by customer
H7 = Position of first reference mark
L = With *ERA 881 C:* Positions of the tensioning elements
With *ERA 882 C:* 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 cutoff frequency:
  70 % of the signal amplitude
- –6 dB cutoff frequency:
  50 % of the signal amplitude

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.

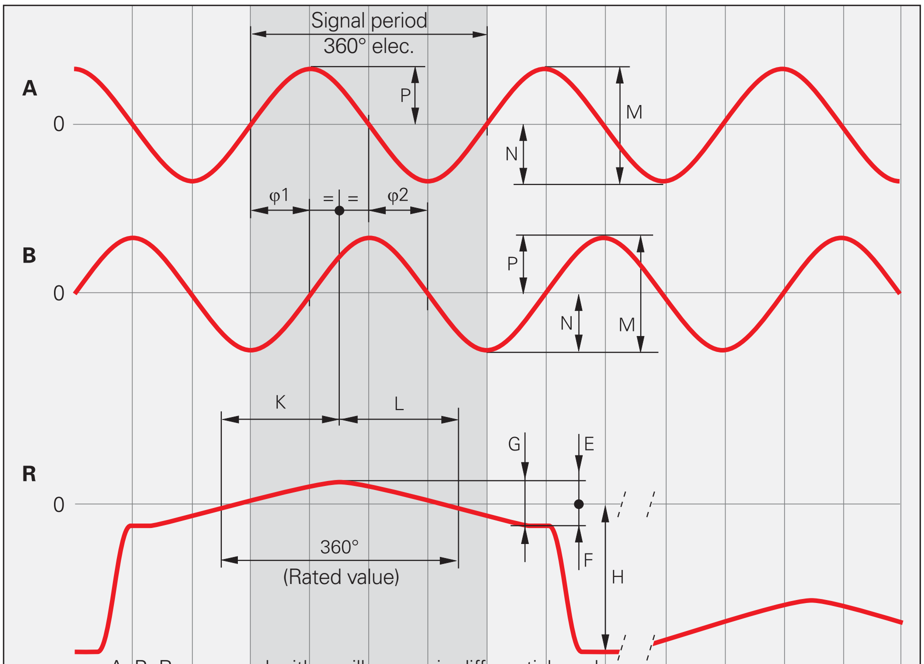
Measuring steps for **position measurement** are recommended in the specifications. For special applications, other resolutions are also possible.

Short-circuit stability
A temporary short circuit of one signal output to 0 V or U_P 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

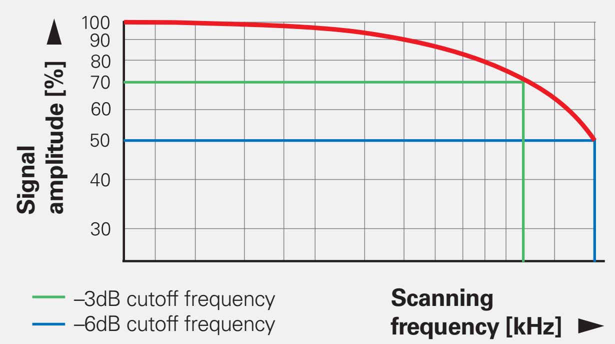
Interface	Sinusoidal voltage signals ∿ **1 V_{PP}**	
Incremental signals	**2 nearly sinusoidal signals A and B**	
	Signal amplitude M:	0.6 to 1.2 V_{PP}; typ. 1 V_{PP}
	Asymmetry $\lvert P – N \rvert /2M$:	≤ 0.065
	Signal ratio M_A/M_B:	0.8 to 1.25
	Phase angle $\lvert \varphi1 + \varphi2 \rvert /2$:	90° ± 10° elec.
Reference mark signal	**1 or more signal peaks R**	
	Usable component G:	0.2 to 0.85 V
	Quiescent value H:	0.04 V to 1.7 V
	Signal-to-noise ratio E, F:	≥ 40 mV
	Zero crossovers K, L:	180° ± 90° elec.
Connecting cable	HEIDENHAIN cable with shielding PUR [4(2 x 0.14 mm^2) + (4 x 0.5 mm^2)]	
Cable length	Max. 150 m distributed capacitance 90 pF/m	
Propagation time	6 ns/m	

Any limited tolerances in the encoders are listed in the specifications.



A, B, R measured with oscilloscope in differential mode

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

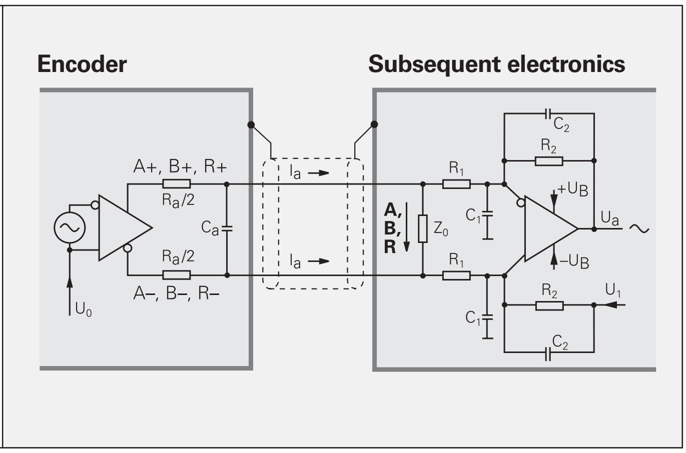
–3dB cutoff frequency of circuitry
Approx. 450 kHz
Approx. 50 kHz and $C_1 = 1000$ pF
and $C_2 = 82$ pF
This circuit variant does reduce the bandwidth of the circuit, but in doing so it improves its noise immunity.

Circuit output signals
$U_a = 3.48\ V_{PP}$ typical
Gain 3.48

Signal monitoring
A threshold sensitivity of 250 mV_{PP} is to be provided for monitoring the 1-V_{PP} incremental signals.

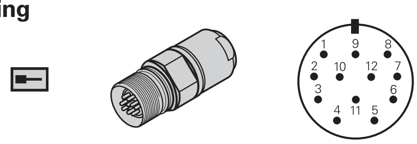
Incremental signals Reference mark signal

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

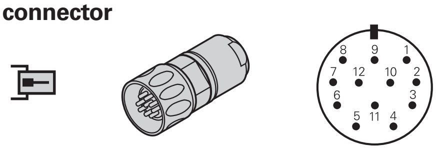


Pin layout

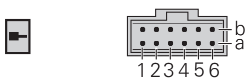
12-pin M23 coupling



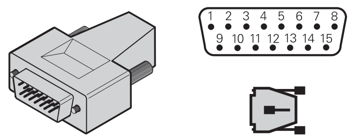
12-pin M23 connector



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+**	**R–**	**Vacant**	**Vacant**	**Vacant**
	Brown/ Green	Blue	White/ Green	White	Brown	Green	Gray	Pink	Red	Black	/	Violet	Yellow

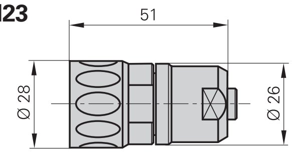
Shield on housing; **U_P** = power supply voltage
Sensor: The sensor line is connected internally with the corresponding power line
Vacant pins or wires must not be used!
1) Only for ERA 4x81; color assignment applies only to connecting cable

Connecting Elements and Cables
General Information

Insulated **connector:** Connecting element with coupling ring; available with male or female contacts.

Symbols 

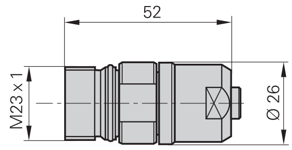
M23



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

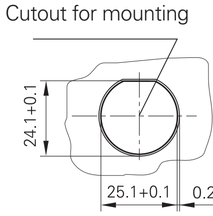
Symbols 

M23

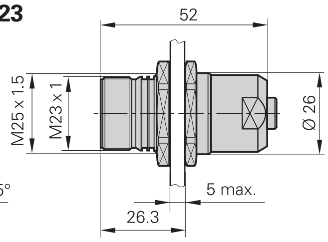


Mounted coupling with central fastening

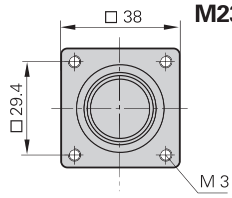
Cutout for mounting



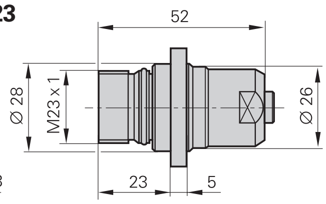
M23



Mounted coupling with flange



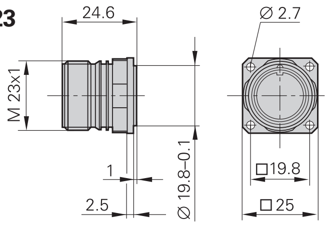
M23



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

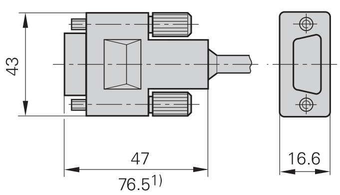
Symbols 

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 socket, 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.

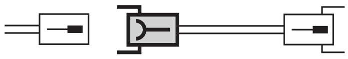
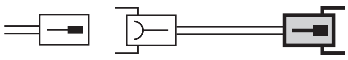
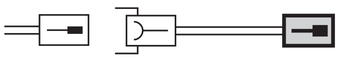
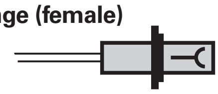
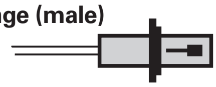
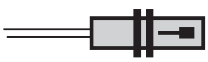
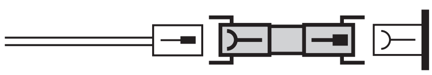
Accessories for flange socket and M23 mounted couplings

Bell seal
Id. Nr. 266526-01

Threaded metal dust cap
Id. Nr. 219926-01

Connecting Cables

12-pin M23

		for ∿ 1 V_{PP}
PUR connecting cable	**12-pin:** [4(2 × 0.14 mm²) + (4 × 0.5 mm²)] **Ø 8 mm**	
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
With one connector (female)		309777-xx
Cable only, Ø 8 mm		244957-01
Mating element on connecting cable to connecting element on encoder	**Connector (female)** for cable Ø 8 mm 	291697-05
Connector for connection to subsequent electronics	**Connector (male)** for cable Ø 8 mm Ø 6 mm 	291697-08 291697-07
Coupling on connecting cable	**Coupling (male)** for cable Ø 3.7 mm Ø 4.5 mm Ø 6 mm Ø 8 mm 	291698-14 291698-14 291698-03 291698-04
Flange socket for mounting on the subsequent electronics	**Coupling (female)** 	315892-08
Mounted couplings	**With flange (female)** Ø 6 mm Ø 8 mm 	291698-17 291698-07
	With flange (male) Ø 6 mm Ø 8 mm 	291698-08 291698-31
	With central fastening (male) Ø 6 mm 	291698-33
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		364914-01

General Electrical Information

Power Supply

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

- High frequency interference
  U_{PP} < 250 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 **voltage drop:**

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

where ΔU: Line drop in V
L_C: Cable length in m
I: Current consumption in mA
A_V: 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 (see diagram). During time t_{SOT} they can have any levels up to 5.5 V (with HTL encoders up to U_{Pmax}). If an interpolation electronics unit is inserted between the encoder and the power supply, the unit's switch-on/off characteristics must also be considered. When the power supply is switched off, or when the supply voltage falls below U_{min}, the output signals are also undefined. These data apply only for the encoders listed in the catalog—customized interfaces are not considered.

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

Isolation
The encoder housings are isolated against internal circuits.
Rated surge voltage: 500 V
(preferred value as per VDE 0110 Part 1, overvoltage category II, contamination level 2)

Cables

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

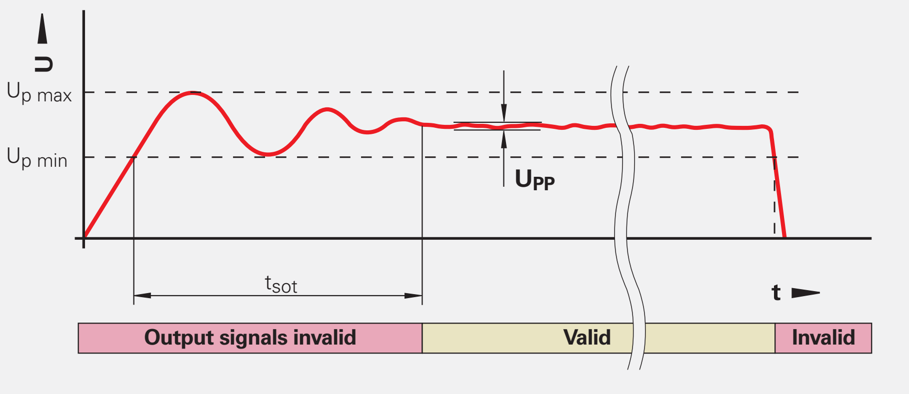
Durability
All encoders have polyurethane (PUR) cables. PUR cables are resistant to oil, hydrolysis and microbes in accordance with **VDE 0472.** They are free of PVC and silicone and comply with UL safety directives. The **UL certification** AWM STYLE 20963 80 °C 30 V E63216 is documented on the cable.

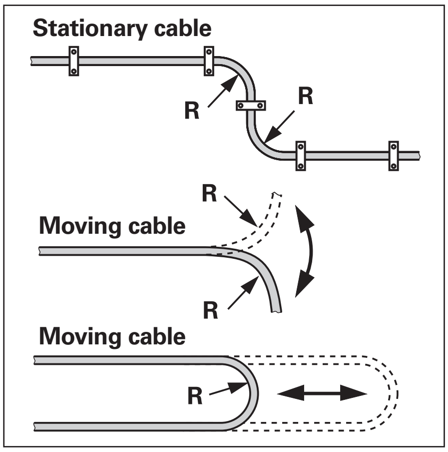
Temperature range
HEIDENHAIN cables can be used
- for rigid configuration –40 to 85 °C
- for frequent flexing –10 to 85 °C

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

Bending radius
The permissible bending radii R depend on the cable diameter and the configuration:

Initial transient response of the supply voltage and switch-on/switch-off behavior





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** 4) 8-pin	**Station-ary cable**	**Moving cable**
Ø 3.7 mm	0.05 mm^2	–	–	–	≥ 8 mm	≥ 40 mm
Ø 4.5 mm **Ø 5.1 mm**	0.14/0.05 2) 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 3) 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	≥ 50 mm ≥ 100 mm

1) Metal armor 2) Length gauges 3) LIDA 400 4) Also Fanuc, Mitsubishi

Electrically Permissible Speed/ Traversing Speed

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

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

For angular or rotary encoders

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

For linear encoders

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

and:

n_{max}: Electrically perm. speed in rpm
v_{max}: Electrically permissible traversing velocity in m/min
f_{max}: Max. scanning/output frequency of encoder or input frequency of subsequent electronics in kHz
z: Line count of the angle or rotary encoder per 360°
SP: Signal period of the linear encoder in µm

Noise-Free Signal Transmission

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

- **Noise immunity IEC 61000-6-2:**
  Specifically:

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

- **Interference IEC 61000-6-4:**

Specifically:

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

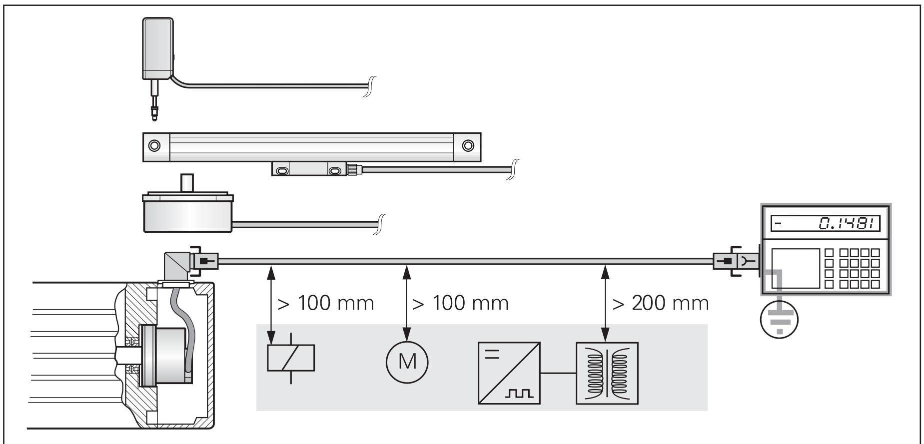
Transmission of measuring signals—electrical noise immunity
Noise voltages arise mainly through capacitive or inductive transfer. Electrical noise can be introduced into the system over signal lines and input or output terminals.
Possible sources of noise are:

- Strong magnetic fields from transformers 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 inlets 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. See also **EN 50178**/4.98 Chapter 5.2.9.5 regarding "protective connection lines with small cross section."
- Do not lay signal cables in the direct vicinity of interference sources (inductive consumers such as contacts, motors, frequency inverters, solenoids, etc.).
- Sufficient decoupling from interference-signal-conducting cables can usually be achieved by an air clearance of 100 mm or, when cables are in metal ducts, by a grounded partition.
- A minimum spacing of 200 mm to inductors in switch-mode power supplies is required. Also see **EN 50178** / 4.98 Chapter 5.3.1.1 regarding cables and lines, **EN 50174-2** / 09.01 Chapter 6.7 regarding grounding and potential compensation.
- When using **multiturn encoders in electromagnetic fields** greater than 30 mT, HEIDENHAIN recommends consulting with the main facility in Traunreut.

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 mm² (Cu).



Minimum distance from sources of interference

Display Unit and Interface Electronics

ND 281 B
The ND 281 B **display unit** contains special display ranges for angle measurement. You can directly connect incremental angle encoders with ∼ 1 V_{PP} output signals and any line count.

For more information, see *Digital Readouts*

	ND 281 B	
Input signals	∼ 1 V_{PP}	∼ 11 μA_{PP}
Signal subdivision	Up to 1024-fold (adjustable)	
Display step adjustable	0.1° to 0.000 002° or to 1“	
Display range adjustable	0 to 360° / –180° .... 0 ..... +180° 0 to ± max. display range	
Features	Sorting and tolerance check/display stop/two switching limits/reference marke evaluation with REF	
External operation	Zero reset, preset and latch command	
Interface	RS-232-C/V.24; max. 38 400 baud	

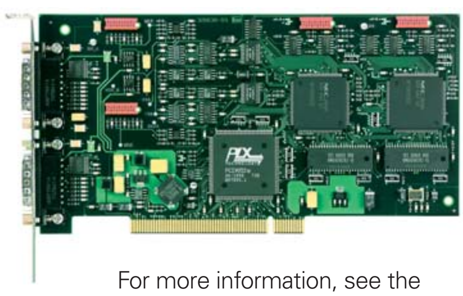
IBV / APE series
Interpolation and digitizing electronics interpolate and digitize the sinusoidal output signals (∼ 1 V_{PP}) from HEIDENHAIN encoders and convert them to TTL square-wave pulse sequences.

IBV 101

For more information, see Product Information *IBV 100, IBV 600* and *APE 371.*

	IBV 101	IBV 102	IBV 660	APE 371
Input signals	∼ 1 V_{PP}			
Interpolation Switchable in IBV Fixed in APE 371	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 signals	⊓⊔ TTL			
Power supply	5 V ± 5%			

IK 220
The IK 220 **universal counter card for PCs** permits recording of the measured values of **two incremental or absolute linear or angle encoders.**



For more information, see the *IK 220 Product Information* sheet.

	IK 220			
Input signals (switchable)	∼ 1 V_{PP}	∼ 11 μA_{PP}	EnDat 2.1	SSI
Signal subdivision	Up to 4096-fold (signal period to measuring step)			
Internal memory	For 8192 position values			
Interface	PCI bus (plug and play)			
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			

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
Features	• **Measurement** of 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 1 to 1024-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 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}
Features	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		

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