Angle Encoder Modules

HEIDENHAIN

May 2015

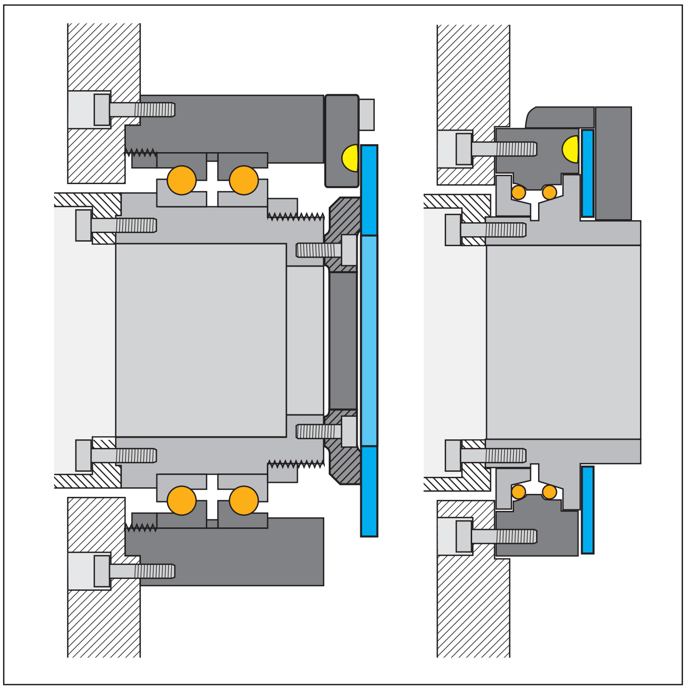
Angle encoder modules

Angle encoder modules from HEIDENHAIN are combinations of angle encoders and high-precision bearings that are optimally adjusted to each other. They are characterized by their high degree of measuring and bearing accuracy, their very high resolution, and the highest degree of repeatability. The low starting torque permits smooth motions. Due to their design as completely specified and tested composite components, handling and installation is very simple.

Setup
Since HEIDENHAIN manufactures the bearings as well as the encoders, the two functional assemblies are highly integrated. Fewer components are necessary than in conventional solutions, resulting in fewer joints. This permits a very compact and rigid design, with particularly low overall heights. Currently, angle encoder modules with hollow shafts of 35 mm and 100 mm are available.

Properties
The **rolling bearings** used are specifically adapted to the requirements of high-precision rotary axes. Distinguishing features are very high guideway accuracies, high rigidities, low starting torques, and constant continuous torques. At the same time, value was placed on compact dimensions and low mass where possible. High speeds and a high load rating are not of primary importance.

The **encoders** fulfill the requirements for metrology applications. Their most important features are very high resolution, excellent signal quality and best repeatability, even when operating temperatures vary. Incremental or absolute encoders can be used as required.



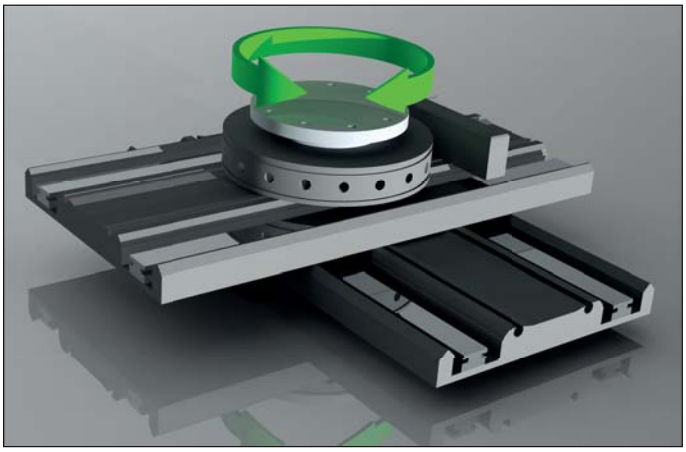
Comparison of the "conventional" setup of a precision axis and a solution with an angle encoder module from HEIDENHAIN

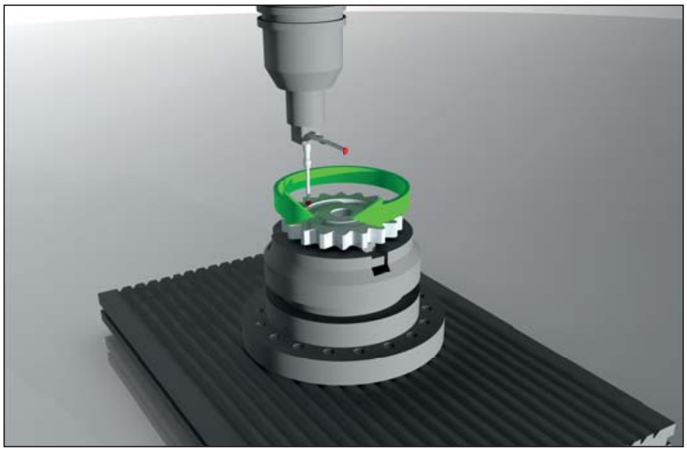
Advantages
Angle encoder modules are a combination of bearing and encoder. HEIDENHAIN has already completed the necessary assembly and adjustments. This means that the properties of the angle encoder modules have already been defined and tested according to the customer's specifications. Simple mechanical interfaces eliminate all critical mounting processes. Not only does this significantly ease the installation, but it also ensures that the specified accuracy is attained in the application. The elaborate matching of all individual components to each other as well as to the machine environment is not necessary, nor is the time-consuming testing.

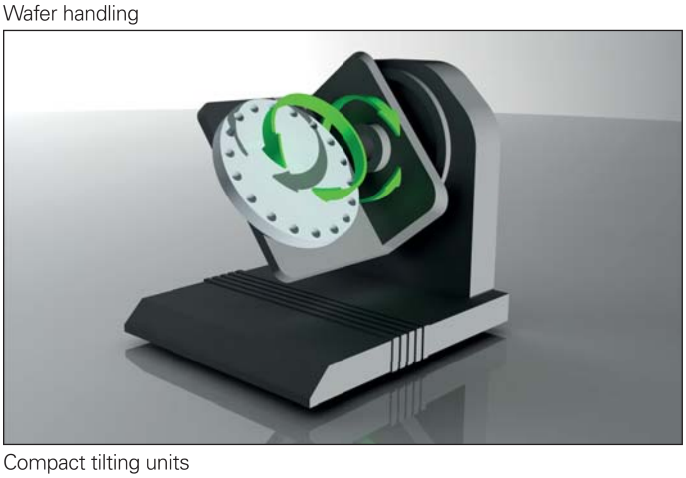
Reproducible guideway accuracy: a decisive property of the bearing
Without question, the absolute guideway accuracy of an unloaded air bearing is better than that of a rolling bearing in many cases. However, in many applications the highest possible **reproducible guideway accuracy** of the bearing is decisive. When this aspect is considered, angle encoder modules can truly be an alternative to axes with air bearings, since the repeatability of rolling bearings from HEIDENHAIN is comparable to the guideway accuracy of an air bearing. Furthermore, the rigidity of rolling bearings from HEIDENHAIN is greater than that of similar sized air bearings by at least a factor of 10. **This means that they are actually the more exact solution for axes under load.** In addition, rolling bearings are in general less sensitive to shock loads and do not require a regulated air supply—so they are more robust and simpler to handle.

Areas of application
The angle encoder modules are designed for low to medium shaft speeds and medium loads, with high to very high bearing accuracies as well as the highest degree of repeatability. They are suited to the specific requirements of metrology applications. Typical applications therefore include laser trackers for metrology, high-precision rotary tables in measuring machines, and wafer-handling machines in the electronics industry. They can also be used on machine tools where only slight loads occur, such as on electrical discharge machines or in micro-precision manufacturing.

Practical solutions
The MRP 5000 and MRP 8000 series presented in this Product Overview can be adapted for customer-specific modifications. These include the mechanical mounting conditions, individual adjustments to the bearing regarding the demands of the application (pre-tensioning, lubrication, contact angle, materials, etc.), as well as the measuring standard and the electrical interface to the subsequent electronics.


Wafer handling


High-precision rotary tables


Compact tilting units


Laser trackers

Angle encoder modules
Measuring and bearing accuracies

The accuracy of angle encoder modules from HEIDENHAIN as composite components results from the measuring accuracy of the integrated angle encoders and the bearing accuracy of the rolling bearings. As already described on the previous page, the reproducible accuracy of an angle encoder module as a composite component can be on par with that of an air bearing.

HEIDENHAIN considers the following measuring and bearing accuracies when evaluating the quality of an angle encoder module:

Measuring accuracies
The measuring accuracies of the integrated angle encoder that are most decisive for the specification of the angle encoder module are its system accuracy and repeatability.

The **system accuracy** of the angle encoder indicates the position error within one revolution. It applies to the entire range of the specified centered load.

A distinction is made between single-sided and double-sided repeatability. **Single-sided repeatability** applies to any number of revolutions in which the direction is not changed while measuring. Specific points are approached multiple times, and the maximum deviation of the measured points from each other is determined. This evaluation is performed by using a reference encoder for comparison.

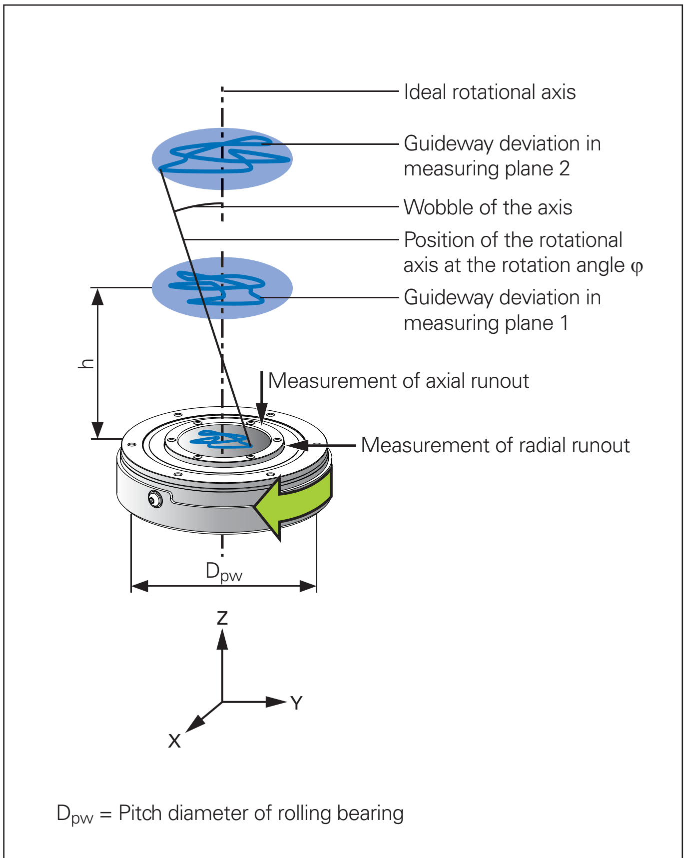
In order to determine the **double-sided repeatability** the direction of measurement is switched while measuring. The points are then each approached alternately from one side and then the other. The maximum deviation of the measured points from each other is thus determined. A reference encoder is used for positioning.

For neither specification is the absolute deviation from the reference of importance, nor is it the goal of the measurement.

Bearing accuracies
When evaluating the bearing accuracy, not the radial runout that is mentioned so often is most important, but rather the guideway accuracy of the bearing. It indicates the deviation of the actual rotational axis of the bearing from the nominal rotational axis. The radial and axial guideway accuracy of the bearing are determined, and also the wobble.

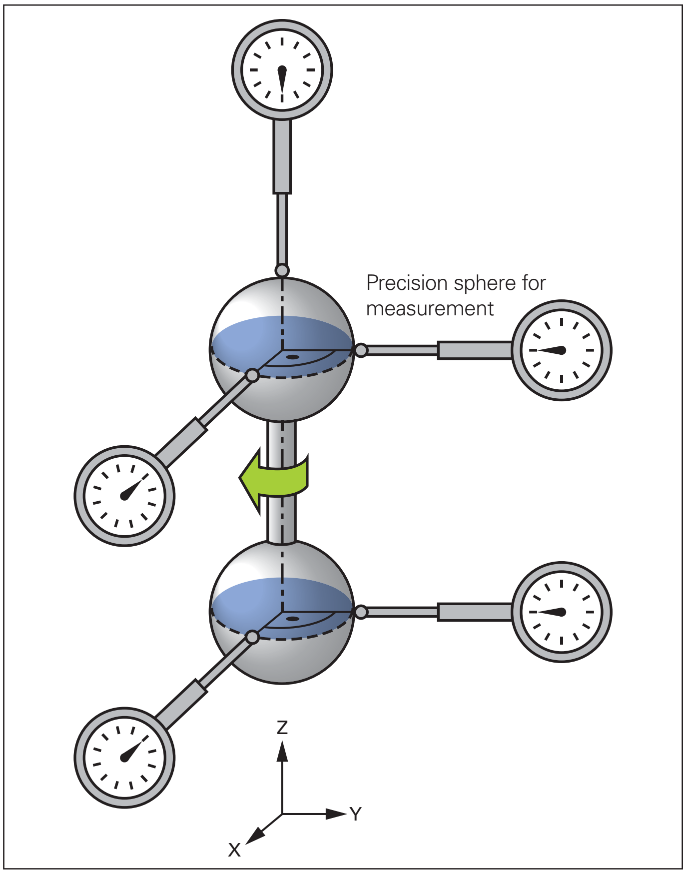
The **guideway accuracy** is measured with a calibration standard, such as a ceramic sphere with a known roundness. The center point of the sphere is positioned at a defined distance vertically above the center of the bearing raceway. This distance usually equals the pitch diameter D_{pw} of the bearing, so that the measurement can be standardized.

Two length gauges are used to measure the **radial guideway accuracy.** They are positioned at the height of the sphere center, at a 90° angle to each other. When the bearing is rotated they measure the respective radial deviations of the sphere in the X and Y directions. The radial guideway accuracy depends on the distance to the bearing plane. For this reason it is advisable to perform the measurement at various distances to the bearing plane.



D_{pw} = Pitch diameter of rolling bearing

Measured variables and measuring points on a rolling bearing (schematic)



Measurement of the axial and radial guideway accuracy with five length gauges

A defined number of revolutions is used for the measurements. The result is a measure of the deviation of the actual rotational axis from the nominal rotational axis for every rotation angle of the bearing. Misalignment of the sphere to the ideal bearing axis as well as inaccuracies of the sphere itself are removed from the result mathematically.

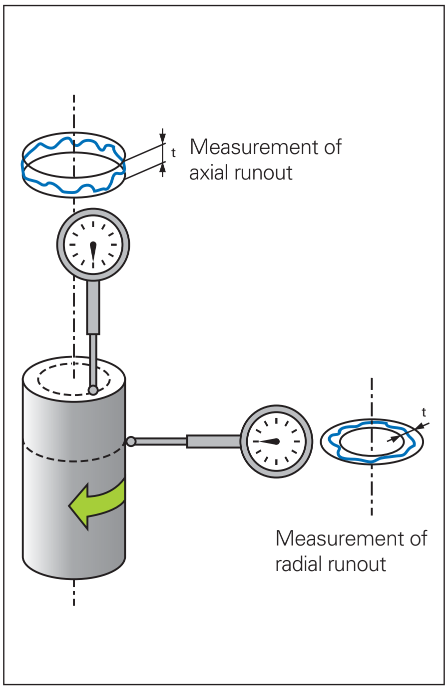
This analysis supplies values that contain repeated (reproducible) errors as well as random (non-reproducible) errors. Since these measurements are always performed with a defined number of revolutions, the reproducible errors can be separated from the non-reproducible errors. This permits a qualified statement regarding both components of the guideway accuracy as well as clear information, free of external influences, about the actual quality of the bearing.

A length gauge is centered above the sphere in order to measure the **axial guideway accuracy.** The gauge records any up and down motions of the sphere in the Z direction while the bearing is rotating.

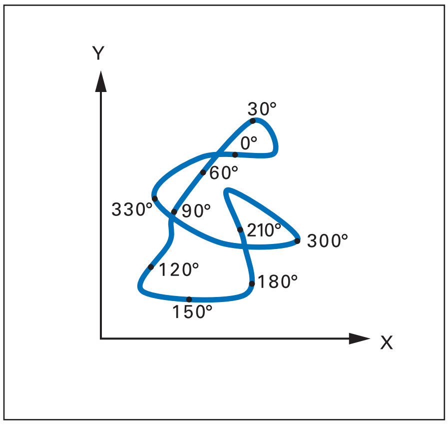
The **wobble** describes the tilt angle of the rotor axis relative to the bearing axis when the bearing is rotated. The maximum value of the measurement is indicated. One possibility of determining the wobble is to measure the radial guideway accuracy in two planes.

As opposed to the guideway accuracy, the **radial runout** is the value measured by a length gauge perpendicular to a surface. The value indicated thus contains both the guideway accuracy of the bearing as well as form errors in the roundness and concentricity of the surface being measured.

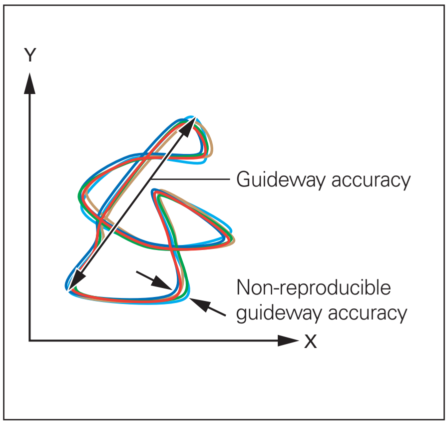
This principle also applies to the **axial runout.** It is the value measured by a length gauge perpendicular to a surface, in the axis of the object. The axial runout also contains both the guideway accuracy of the bearing as well as form errors of the surface.



Measurement of axial and radial runout

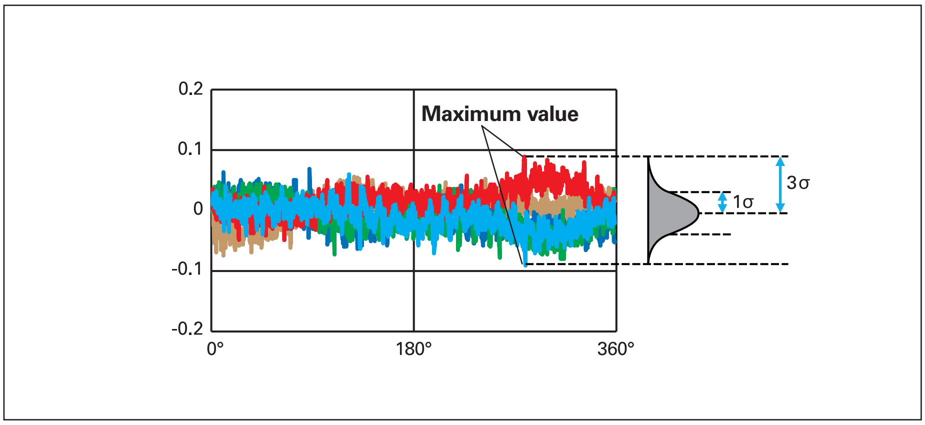


Radial guideway accuracy



Radial guideway accuracy over five revolutions

The value indicated for the non-reproducible guideway accuracy is the largest deviation noted at any position within the entire measuring range.



Non-reproducible guideway accuracy over five revolutions [deviation in µm]

MRP 5000 series

Angle encoder modules with integrated encoder and bearing

- **Compact dimensions**
- **High measuring and bearing accuracy**
- **Hollow shaft Ø 35 mm**

	Incremental **MRP 5080**	***Absolute*** **MRP 5010**
Measuring standard	SUPRADUR circular scale	DIADUR circular scale
Signal periods	30 000	16 384
System accuracy*	± 2.5″ or ± 5″	
Position error per signal period	± 0.5 % (± 0.23″)	± 0.5 % (± 0.40″)
Repeatability	*From one direction:* ± 1″ *From both directions:* ± 0.6″	*From one direction:* ± 1″ *From both directions:* ± 1.2″
Position noise per signal period RMS	0.015 % (0.007″)	0.025 % (0.020″)
Interface	∿ 1 V_{PP}	EnDat 2.2
Ordering designation	–	EnDat22
Position values/revolution	–	28 bits
Clock frequency Calculation time t_{cal}	–	≤ 16 MHz ≤ 5 µs
Reference marks	80 (distance-coded)	–
Cutoff frequency –3 dB	≥ 500 kHz	–
Electrical connection	Cable 1.5 m with D-sub connector (15-pin), interface electronics integrated in the connector	Ribbon cable 0.09 m with M12 mounted coupling; adapter cable with quick disconnect as accessory
Cable length	≤ 30 m (with HEIDENHAIN cable)	
Power supply	5 V DC ± 0.25 V	3.6 V to 14 V DC
Power consumption (max.)	*5.25 V:* ≤ 950 mW	*3.6 V:* ≤ 1.1 W *14 V:* ≤ 1.3 W
Current consumption (typical)	175 mA (without load)	*5 V:* 140 mA (without load)

MRP 5080

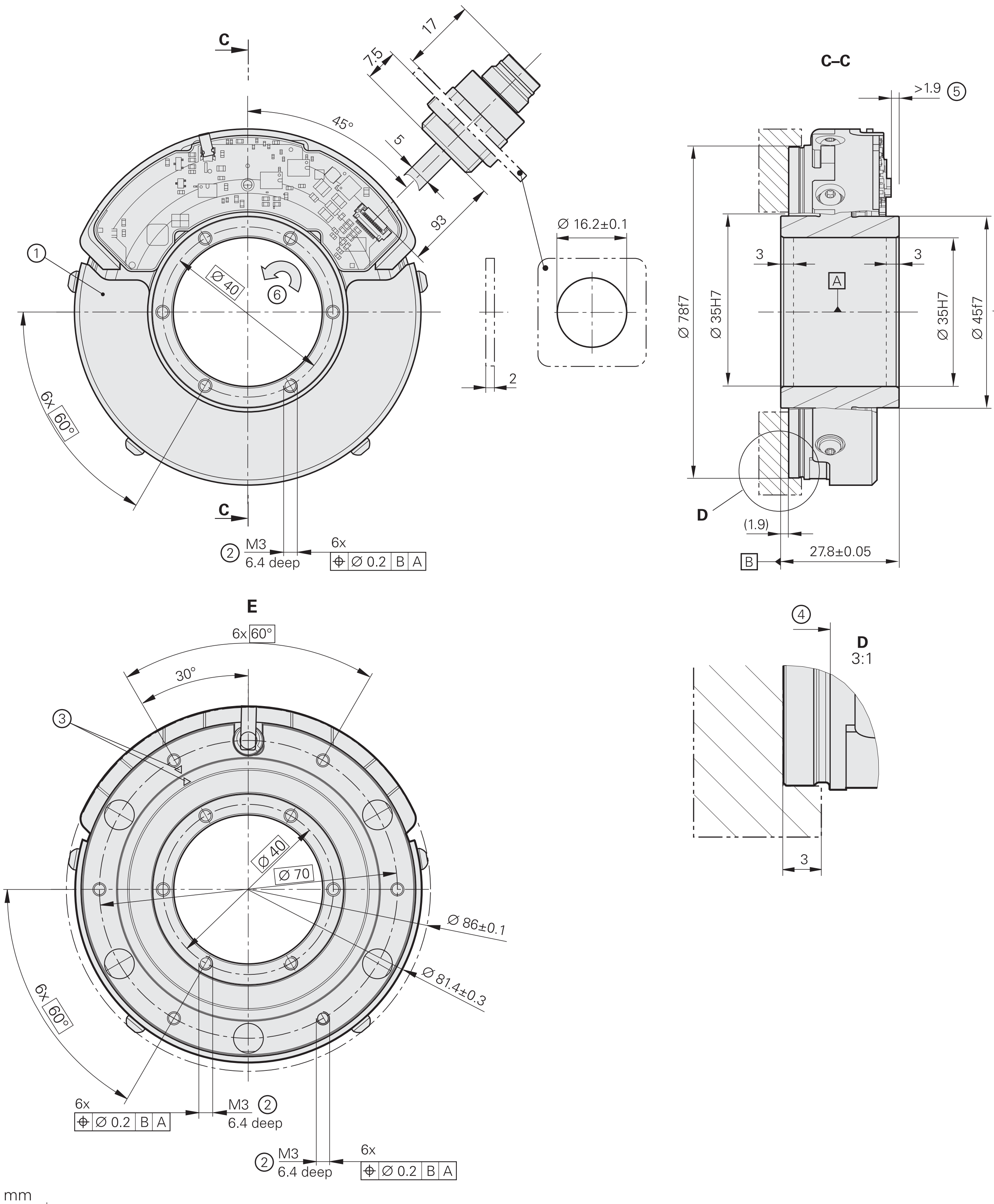
MRP 5010

	Incremental **MRP 5080**	***Absolute*** **MRP 5010**
Shaft	Hollow through shaft D = 35 mm	
Axial load capacity	200 N (load centered, system accuracy is maintained)	
Contact stiffness	*Axial:* 303 N/µm *Radial:* 181 N/µm (values calculated; without load)	
Resistance to tilt	102 Nm/mrad (values calculated; without load)	
Mechanically perm. speed	300 min^{-1}	
Frictional moment	≤ 0.015 Nm (without load)	
Moment of inertia of rotor	$0.13 \cdot 10^{-3}$ kgm^2	
Radial guideway accuracy	Measured at the distance h = D_{pw} from the race: ≤ 0.20 µm (without load)	
Non-reproducible radial guideway accuracy	Measured at the distance h = D_{pw} from the race: ≤ 0.35 µm (without load)	
Axial guideway accuracy	≤ ± 0.2 µm (without load)	
Axial runout of the surface	≤ 5 µm (without load)	
Wobble of the axis	0.7″	
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 200 m/s^2 (EN 60 068-2-6) ≤ 100 m/s^2 (EN 60 068-2-27) (without load)	
Protection EN 60 529	IP 00[1)]	
Operating temperature **Storage temperature**	0 °C to 50 °C 0 °C to 50 °C	
Relative air humidity	≤ 75 % without condensation	
Weight	0.5 kg (without cable or connector)	

* Please select when ordering
[1)] CE compliance of the complete system must be ensured by taking the correct measures during installation

MRP 5000 series

MRP 5010

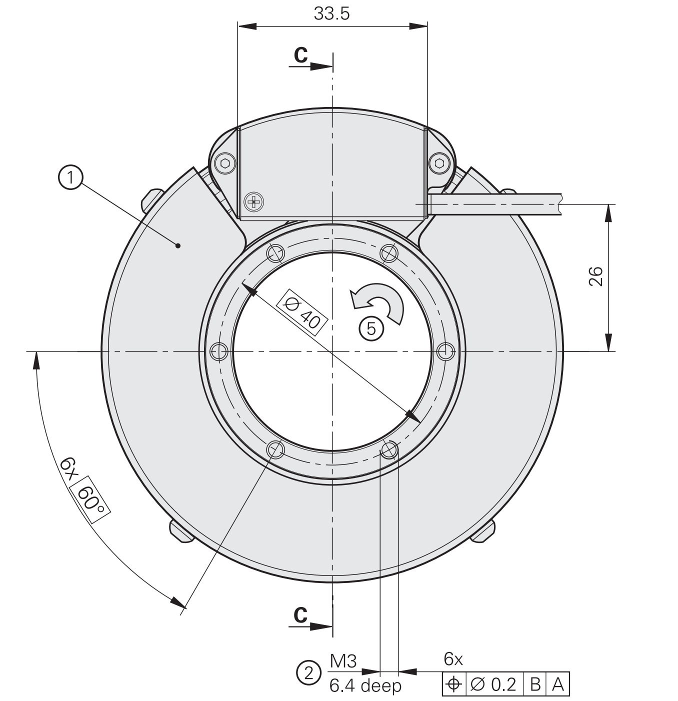


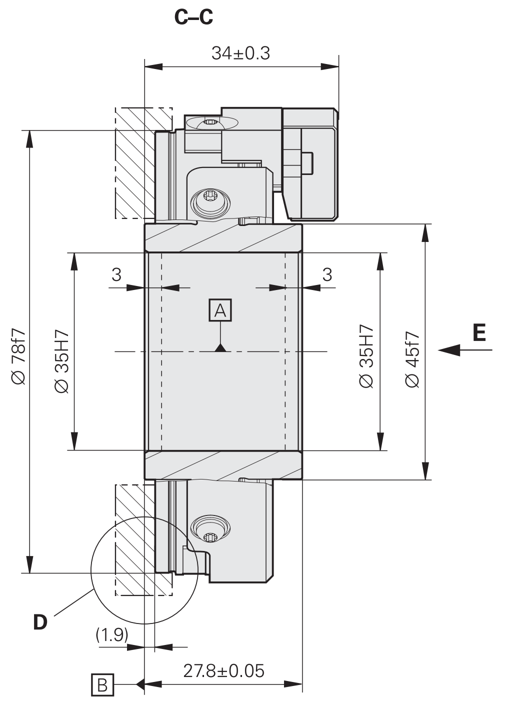
mm

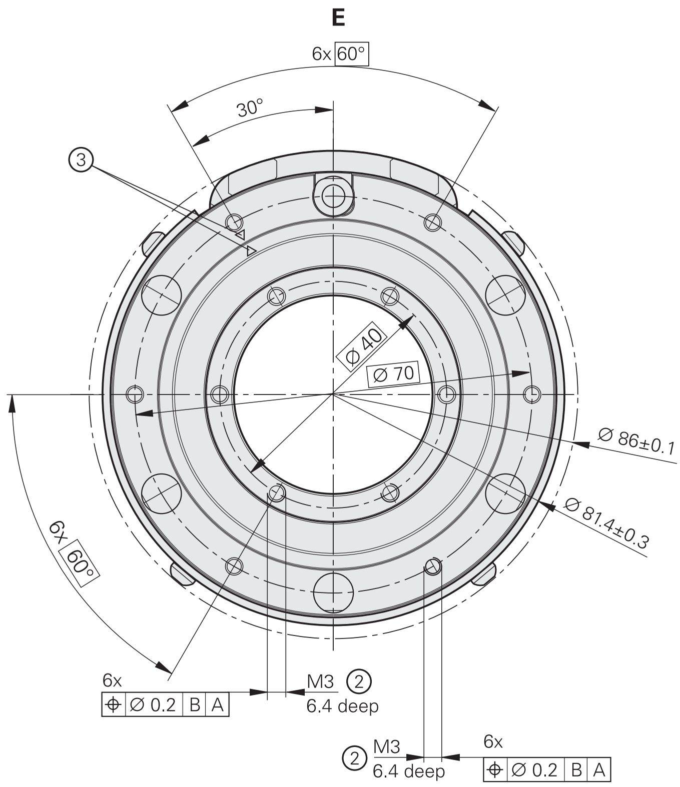
Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm

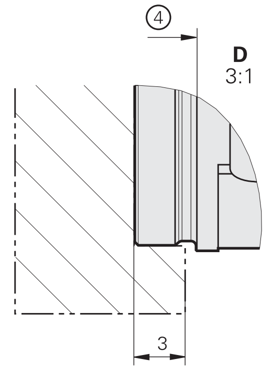
A = Bearing axis
1 = All views show the protective cap, which can be removed by the customer
2 = Tightening torque of the M3 – 8.8 screws: 1.3±0.1 Nm
3 = Mark for 0° position ±5°
4 = Do not use edge as fixed stop!
5 = Maintain the distance to the cover
6 = Direction of shaft rotation for output signals as per the interface description

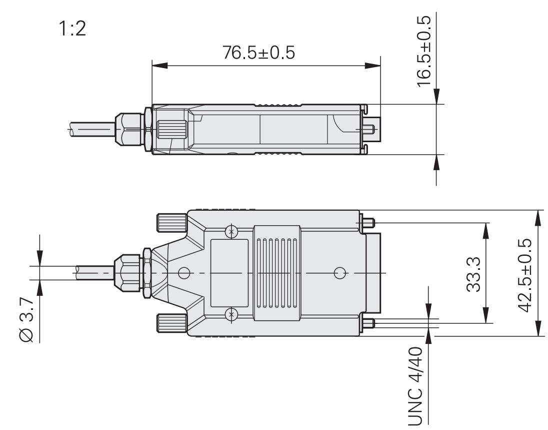
MRP 5080











mm

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A = Bearing axis
1 = All views show the protective cap, which can be removed by the customer
2 = Tightening torque of the M3 – 8.8 screws: 1.3±0.1 Nm
3 = Mark for 0° position ±5°
4 = Do not use edge as fixed stop!
5 = Direction of shaft rotation for output signals as per the interface description

MRP 8000 series

Angle encoder modules with integrated encoder and bearing
- **Compact dimensions**
- **High measuring and bearing accuracy**
- **Hollow shaft Ø 100 mm**

	Incremental **MRP 8080**	***Absolute*** **MRP 8010**
Measuring standard	SUPRADUR circular scale	DIADUR circular scale
Signal periods	63 000	32 768
System accuracy*	± 1″ or ± 2″	
Position error per signal period	± 0.5 % (± 0.10″)	± 0.5 % (± 0.20″)
Repeatability	*From one direction:* ± 0.7″ *From both directions:* ± 0.4″	*From one direction:* ± 0.7″ *From both directions:* ± 0.7″
Position noise per signal period RMS	0.015 % (0.003″)	0.025 % (0.010″)
Interface	∿ 1 V_{PP}	EnDat 2.2
Ordering designation	–	EnDat22
Position values/revolution	–	29 bits
Clock frequency Calculation time t_{cal}	–	≤ 16 MHz ≤ 5 µs
Reference marks	150 (distance-coded)	–
Cutoff frequency –3 dB	≥ 500 kHz	–
Electrical connection	Cable 1.5 m with D-sub connector (15-pin), interface electronics integrated in the connector	Ribbon cable 0.09 m with M12 mounted coupling; adapter cable with quick disconnect as accessory
Cable length	≤ 30 m (with HEIDENHAIN cable)	
Power supply	5 V DC ± 0.25 V	3.6 V to 14 V DC
Power consumption (max.)	*5.25 V:* ≤ 950 mW	*3.6 V:* ≤ 1.1 W *14 V:* ≤ 1.3 W
Current consumption (typical)	175 mA (without load)	*5 V:* 140 mA (without load)

MRP 8080

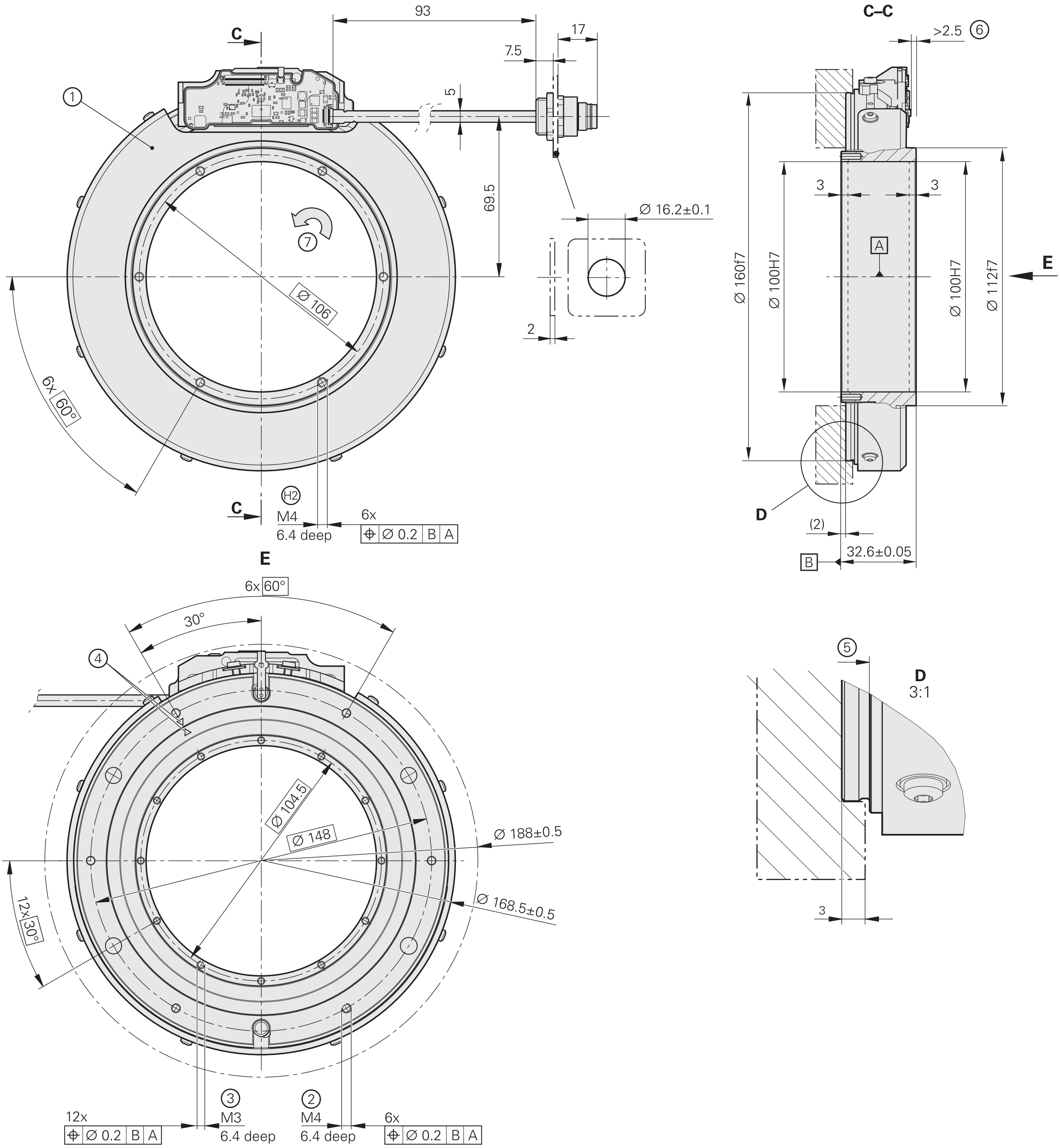
	Incremental **MRP 8080**	*Absolute* **MRP 8010**
Shaft	Hollow through shaft D = 100 mm	
Axial load capacity	300 N (load centered, system accuracy is maintained)	
Contact stiffness	*Axial:* 684 N/µm *Radial:* 367 N/µm (values calculated; without load)	
Resistance to tilt	1250 Nm/mrad (values calculated; without load)	
Mechanically perm. speed	300 min^{-1}	
Frictional moment	≤ 0.200 Nm (without load)	
Moment of inertia of rotor	$2.8 \cdot 10^{-3}$ kgm^2	
Radial guideway accuracy	Measured at the distance h = D_{pw} from the race: ≤ 0.15 µm (without load)	
Non-reproducible radial guideway accuracy	Measured at the distance h = D_{pw} from the race: ≤ 0.20 µm (without load)	
Axial guideway accuracy	≤ ± 0.2 µm (without load)	
Axial runout of the surface	≤ 4 µm (without load)	
Wobble of the axis	0.5″	
Vibration 55 to 2000 Hz **Shock** 6 ms	≤ 200 m/s^2 (EN 60 068-2-6) ≤ 100 m/s^2 (EN 60 068-2-27) (without load)	
Protection EN 60 529	IP 00[1)]	
Operating temperature **Storage temperature**	0 °C to 50 °C 0 °C to 50 °C	
Relative air humidity	≤ 75 % without condensation	
Weight	1.96 kg (without cable or connector)	

* Please select when ordering
1) CE compliance of the complete system must be ensured by taking the correct measures during installation

MRP 8010

MRP 8000 series

MRP 8010

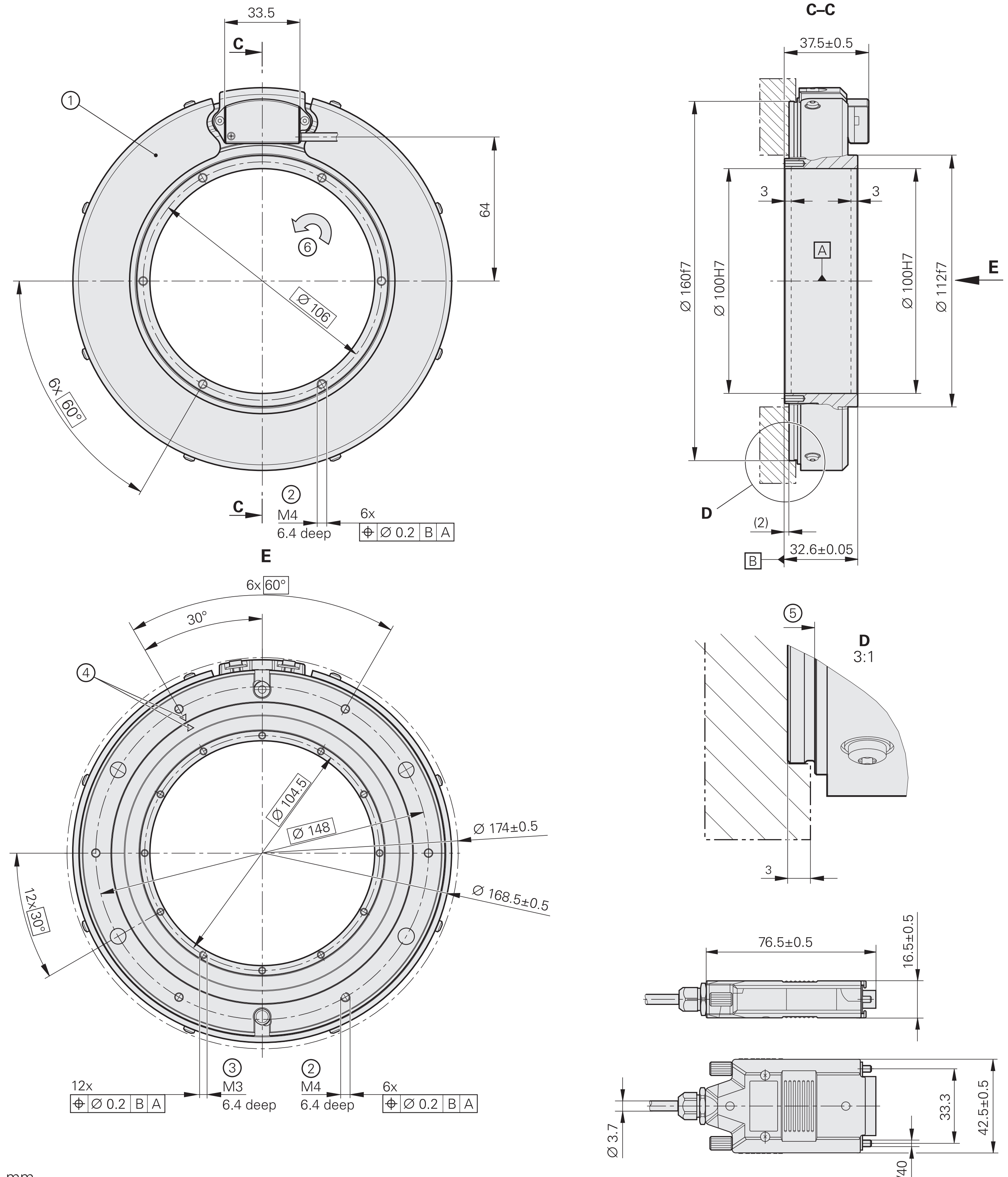


mm

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

A = Bearing axis
1 = All views show the protective cap, which can be removed by the customer
2 = Tightening torque of the M4 – 8.8 screws: 2.9±0.2 Nm
3 = Tightening torque of the M3 – 8.8 screws: 1.3±0.1 Nm
4 = Mark for 0° position ±5°
5 = Do not use edge as fixed stop!
6 = Maintain the distance to the cover
7 = Direction of shaft rotation for output signals as per the interface description

MRP 8080



mm

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5 = Do not use edge as fixed stop!
6 = Direction of shaft rotation for output signals as per the interface description

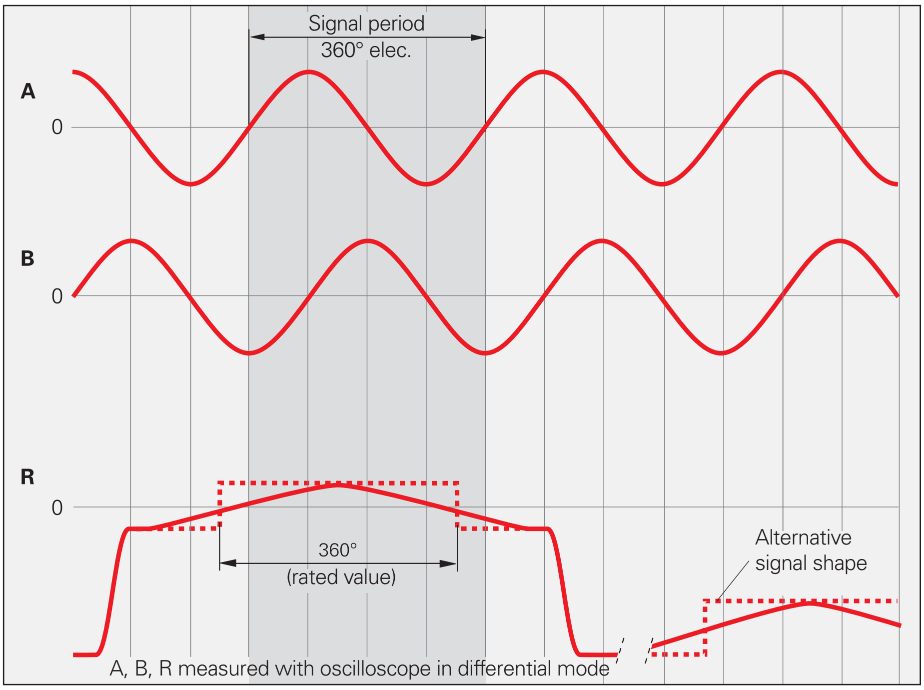
Interfaces
Incremental signals ∿ 1 V_{PP}

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 amplitudes 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.

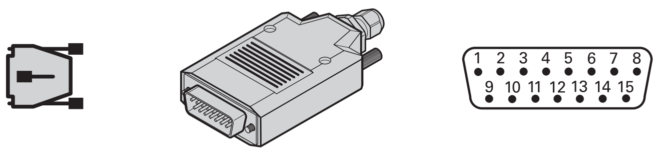
The **reference mark signal** R has an unambiguous assignment to the incremental signals. The output signal might be somewhat lower next to the reference mark.

The *Interfaces of HEIDENHAIN Encoders* brochure includes comprehensive descriptions of all available interfaces as well as general electrical information.



Pin layout

15-pin D-sub connector



	Power supply				Incremental signals						Other signals		
	4	12	2	10	1	9	3	11	14	7	5/6/8/15	13	/
	U_P	**Sensor**[1] U_P	**0 V**	**Sensor**[1] 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

Cable shield connected to housing; **U_P** = Power supply voltage
Sensor: The sensor line is connected in the encoder with the corresponding power line.
Vacant pins or wires must not be used!

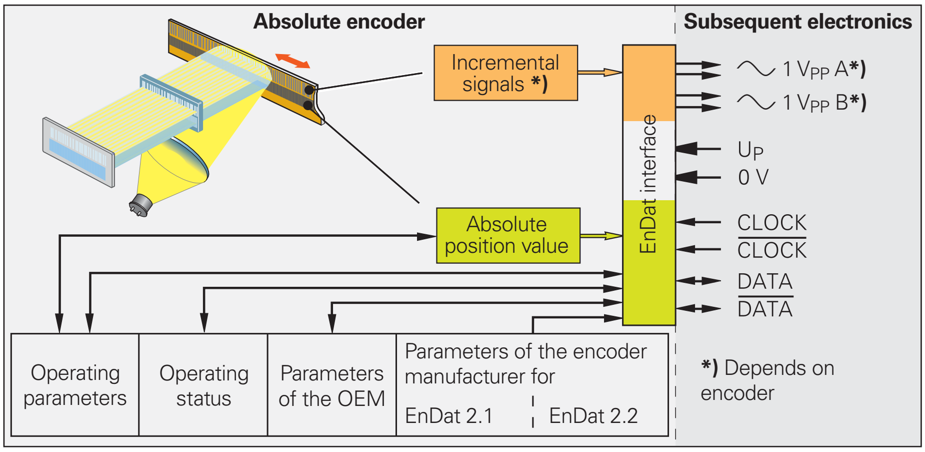
Position values EnDat

The EnDat interface is a digital, **bidirectional** interface for encoders. It is capable both of transmitting **position values** as well as transmitting or updating information stored in the encoder, or saving new information. Thanks to the **serial transmission method,** only **four signal lines** are required. The DATA data is transmitted in **synchronism** with the CLOCK signal from the subsequent electronics. The type of transmission (position values, parameters, diagnostics, etc.) is selected through mode commands that the subsequent electronics send to the encoder. Some functions are available only with EnDat 2.2 mode commands.

The *Interfaces of HEIDENHAIN Encoders* brochure includes comprehensive descriptions of all available interfaces as well as general electrical information.

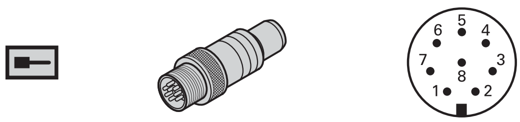
Ordering designation	Command set	Incremental signals
EnDat01	EnDat 2.1 or EnDat 2.2	With
EnDat21		Without
EnDat02	EnDat 2.2	With
EnDat22	EnDat 2.2	Without

Versions of the EnDat interface



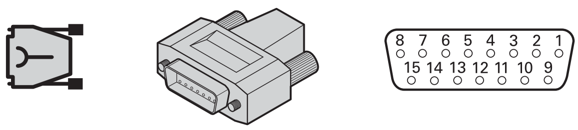
Pin layout

8-pin coupling, M12



	Power supply				Absolute position values			
	8	**2**	**5**	**1**	**3**	**4**	**7**	**6**
	U_P	**Sensor** U_P	**0 V**	**Sensor** 0 V	**DATA**	**$\overline{\text{DATA}}$**	**CLOCK**	**$\overline{\text{CLOCK}}$**
	Brown/Green	Blue	White/Green	White	Gray	Pink	Violet	Yellow

15-pin D-sub connector



	Voltage supply					Absolute position values				
	1	**9**	**2**	**11**	**13**	**5**	**8**	**14**	**15**	**3/4/6/7**
	U_P	**Sensor** U_P	**0 V**	**Sensor** 0 V	**Internal shield**	**DATA**	**$\overline{\text{DATA}}$**	**CLOCK**	**$\overline{\text{CLOCK}}$**	**Vacant**
	Brown/ Green	Blue	White/ Green	White	/	Gray	Pink	Violet	Yellow	/

Cable shield connected to housing; **U_P** = power supply voltage
Sensor: The sensor line is connected in the encoder with the corresponding power line.
Vacant pins or wires must not be used!

Connecting cables

1 V_{PP} connecting cables

PUR connecting cable [6(2 x 0.19 mm^2)] A_P = 0.19 mm^2			
PUR connecting cable [4(2 x 0.14 mm^2) + (4 x 0.5 mm^2)] A_P = 0.5 mm^2		Ø 8 mm	Ø 6 mm 1)
Complete with D-sub connector (female, 15-pin) and M23 connector (male, 12-pin)		331693-xx	355215-xx
With one connector with D-sub connector (female, 15-pin)		332433-xx	355209-xx
Complete with D-sub connectors (female and male, 15-pin)		335074-xx	355186-xx
Cable only		816317-xx	816323-xx

1) Cable length for Ø 6 mm: max. 9 m

A_P: Cross section of power supply lines

EnDat connecting cables

PUR adapter cable [4(2 × 0.14 mm^2)]; A_P = 0.14 mm^2			
Complete with D-sub connector (female, 15-pin)		Ø 4.5 mm	735987-xx
Complete with M12 coupling (male, 8-pin)		Ø 4.5 mm	679671-xx

PUR connecting cables [(4 × 0.14 mm^2) + (4 × 0.34 mm^2)]; A_P = 0.34 mm^2			
Complete with M12 connector (female, 8-pin) and M12 coupling (male, 8-pin)		Ø 6 mm	368330-xx
With one connector with M12 connector (female, 8-pin)		Ø 6 mm	634265-xx

A_P: Cross section of power supply lines

Ø: Cable diameter

HEIDENHAIN

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Further Information
- Catalog: *Angle Encoders with Integral Bearing*
- Catalog: *Interfaces of HEIDENHAIN Encoders*

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