HEIDENHAIN
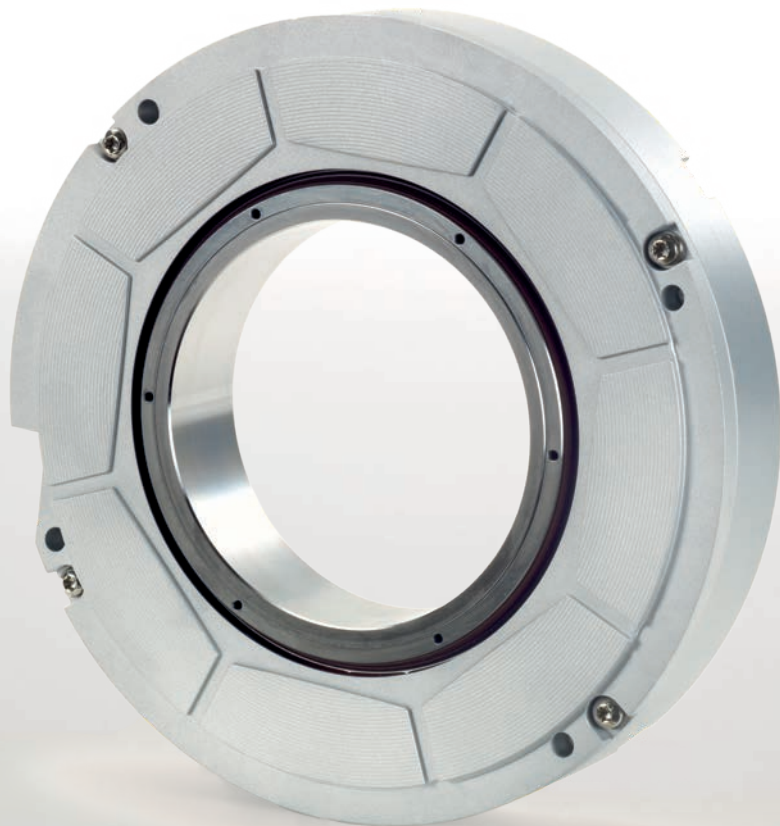
Angle Encoders
with Integral Bearing

Angle encoders with integral bearing and integrated stator coupling

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Angle encoders with integral bearing for a separate shaft coupling

For more information, visit *www.heidenhain.com*, or contact us.

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- Rotary Encoders
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Technical Information Regarding:
- Accuracy of Feed Axes
- Safety-related position measuring systems
- EnDat 2.2: bidirectional interface for position encoders
- Encoders for feed axes with direct drives

This brochure supersedes all previous editions, which thereby become invalid. The basis for ordering from HEIDENHAIN is always the brochure edition valid when the order is placed.

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

Further information:

For detailed descriptions of all available interfaces, as well as general electrical information, please refer to the *Interfaces of HEIDENHAIN Encoders* brochure (ID 1078628-xx).

Angle encoders from HEIDENHAIN

The term "angle encoder" usually refers to encoders with an accuracy better than ±5" and a line count of more than 10 000.

Angle encoders are found in applications requiring precision angular measurement at accuracies within several arc seconds.

Examples:
• Rotary tables on machine tools
• Tilting axes on machining centers
• C axes on lathes
• Measurement and inspection equipment
• Printing units of printing machines
• Telescopes
etc.

In contrast, rotary encoders are used in applications where accuracy requirements are less stringent (e.g., in automation, motors and many other applications).
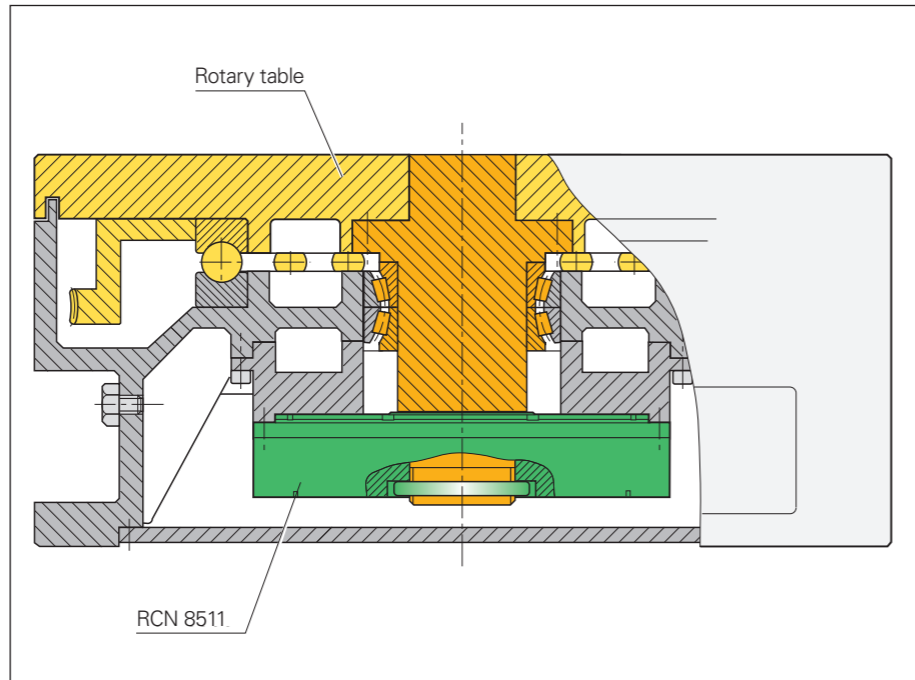
Mounted angle encoder (e.g., **RCN 8511** on the rotary table of a machine tool)

ROC 7380 absolute angle encoder

Angle encoders with an integrated bearing, for a separate shaft coupling
ROC and **ROD** solid-shaft angle encoders are ideal for applications with high shaft speeds or applications requiring wider mounting tolerances. Via the couplings, axial tolerances of up to ±1 mm can be realized for the shaft-side coupling.

For a selection guide, see Page 12/13

Angle encoders differ in the following mechanical design principles:

Angle encoders with an integral bearing, hollow shaft and stator coupling
The structural design of the stator coupling has the effect that the stator coupling must absorb only the torque resulting from the bearing friction, particularly during angular acceleration of the shaft. These angle encoders therefore provide excellent dynamic performance. Thanks to the stator coupling, the system accuracy includes the error of the shaft coupling.

The **RCN, RON** and **RPN** angle encoders feature an integrated stator coupling, whereas the stator coupling of the **ECN** is externally mounted.

Other benefits:
• Compact size for limited installation space
• Hollow shaft diameters of up to 180 mm, providing space for power cabling, etc.
• Easy installation
• Versions with **functional safety**

Selection guide
• *For absolute angle encoders, read starting on Page 6*
• *For incremental angle encodes, read starting on Page 10/11*
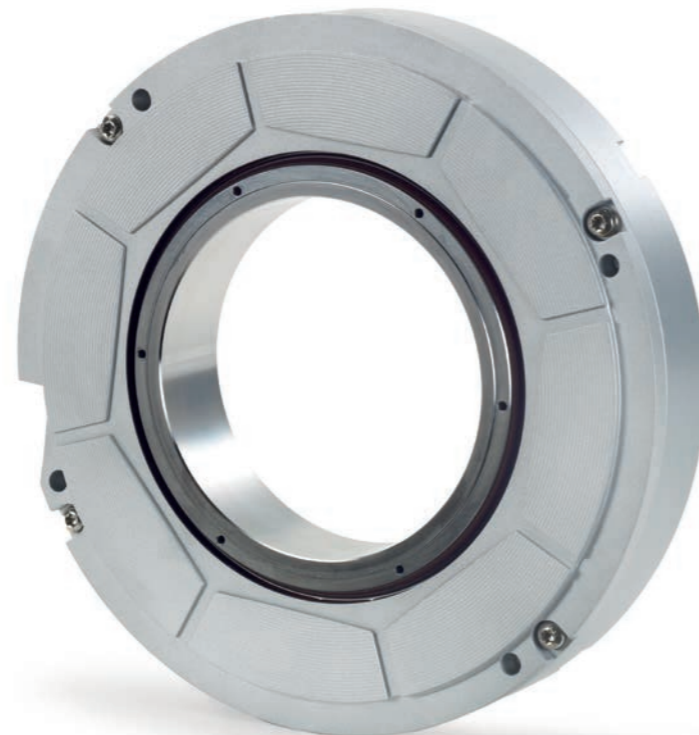
RCN 8511 absolute angle encoder

ECA 4410 absolute angle encoder

Angle encoders without integral bearing
The optical angle encoders without an integral bearing (modular angular encoders), such as the **ECA** and **ERA**, are designed for integration into machine elements or measuring equipment. They meet the following requirements:
• Wide hollow-shaft diameters (up to 10 m with a scale tape)
• High shaft speeds of up to 20 000 rpm
• No additional starting torque caused by rotary shaft seals
• Segment versions

Thanks to their robust design, the **ECM** and **ERM** magnetic modular encoders are especially well suited for use in production machines. Thanks to their large possible inside diameter, low-profile dimensions and compact design, these encoders are ideal for the following:
• The C axis on lathes
• Rotary and tilting axes
• Auxiliary axes or spindle orientation on milling machines

For detailed information about the angle encoders without an integrated bearing, please visit *www.heidenhain.com*.

Selection guide
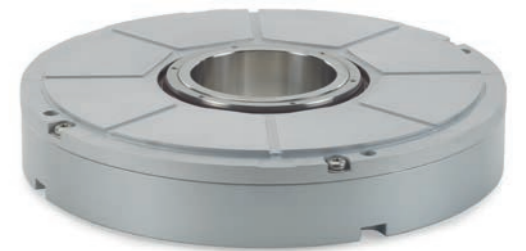Absolute angle encoders with an integral bearing and hollow shaft

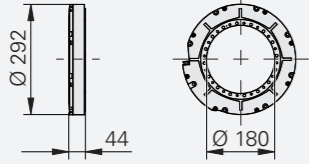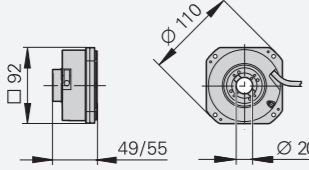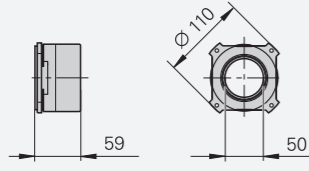| Series	Main dimensions in mm	System accuracy	Mechanically permissible speed[1]	Position values per revolution	Interface	Incremental signals	Signal periods/ revolution	Model	Further information
With integrated stator coupling									
RCN 2001[2]		±4″	≤ 1500 rpm	67 108 864 ≙ 26 bits	EnDat 2.2	∿ 1 V$_{PP}$	16384	**RCN 2381**	**Page 38**
			≤ 3000 rpm		EnDat 2.2	–	–	**RCN 2311**	
					Fanuc αi	–	–	**RCN 2391 F**	
					Mitsubishi	–	–	**RCN 2391 M**	
					Panasonic	–	–	**RCN 2391 P**	
		±2″	≤ 1500 rpm	268 435 456 ≙ 28 bits	EnDat 2.2	∿ 1 V$_{PP}$	16384	**RCN 2581**	
			≤ 3000 rpm		EnDat 2.2	–	–	**RCN 2511**	
					Fanuc αi	–	–	**RCN 2591 F**	
					Mitsubishi	–	–	**RCN 2591 M**	
					Panasonic	–	–	**RCN 2591 P**	
RCN 5001[2]		±4″	≤ 1500 rpm	67 108 864 ≙ 26 bits	EnDat 2.2	∿ 1 V$_{PP}$	16384	**RCN 5381**	**Page 42**
			≤ 2000 rpm		EnDat 2.2	–	–	**RCN 5311**	
					Fanuc αi	–	–	**RCN 5391 F**	
					Mitsubishi	–	–	**RCN 5391 M**	
					Panasonic	–	–	**RCN 5391 P**	
		±2″	≤ 1500 rpm	268 435 456 ≙ 28 bits	EnDat 2.2	∿ 1 V$_{PP}$	16384	**RCN 5581**	
			≤ 2000 rpm		EnDat 2.2	–	–	**RCN 5511**	
					Fanuc αi	–	–	**RCN 5591 F**	
					Mitsubishi	–	–	**RCN 5591 M**	
					Panasonic	–	–	**RCN 5591 P**	
RCN 8001[2]		±2″	≤ 750 rpm	536 870 912 ≙ 29 bits	EnDat 2.2	∿ 1 V$_{PP}$	32 768	**RCN 8381**	**Page 46**
			≤ 1500 rpm (Ø 60 mm) ≤ 1200 rpm (Ø 100 mm)		EnDat 2.2	–	–	**RCN 8311**	
					Fanuc αi	–	–	**RCN 8391 F**	
					Mitsubishi	–	–	**RCN 8391 M**	
					Panasonic	–	–	**RCN 8391 P**	
		±1″	≤ 750 rpm		EnDat 2.2	∿ 1 V$_{PP}$	32 768	**RCN 8581**	
			≤ 1500 rpm (Ø 60 mm) ≤ 1200 rpm (Ø 100 mm)		EnDat 2.2	–	–	**RCN 8511**	
					Fanuc αi	–	–	**RCN 8591 F**	
					Mitsubishi	–	–	**RCN 8591 M**	
					Panasonic	–	–	**RCN 8591 P**	

[1] See permissible shaft speeds on *Page 26/27* and in the relevant encoder *Specifications*
[2] Also available with functional safety

RCN 2001
Ø 20 mm

RCN 5001
Ø 35 mm

RCN 8001
Ø 60 mm

RCN 8001
Ø 100 mm

Selection guide
Absolute angle encoders with an integral bearing and a hollow shaft

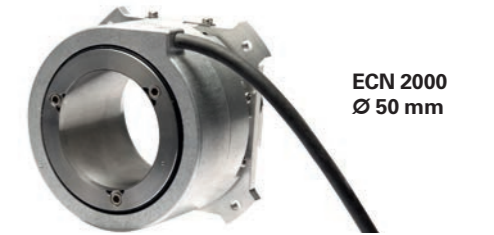| Series	Main dimensions in mm	System accuracy	Mechanically perm. speed	Position values per revolution	Interface	Incremental signals	Signal periods/ revolution	Model	Further information
With mounted stator coupling									
RCN 6000[1]	Ø 292 / 44 / Ø 180	±2″	≤ 200 rpm [2]	268 435 456 ≙ 28 bits	EnDat 2.2	–	19 998	**RCN 6310**	*RCN 6000* Product Information document
					Fanuc αi	–		**RCN 6390 F**	
					Mitsubishi	–		**RCN 6390 M**	
RCN 200	Ø 110 / 92 / 49/55 / Ø 20	±6″	≤ 3000 rpm	33 554 432 ≙ 25 bits	EnDat 2.2	∿ 1 V_{PP}	2048	**RCN 280**	*RCN 200* Product Information document
					EnDat 2.2			**RCN 210**	
					Fanuc αi			**RCN 290 F**	
					Mitsubishi			**RCN 290 M**	
ECN 2000	Ø 110 / 59 / 50	±10″	≤ 3000 rpm	33 554 432 ≙ 25 bits	EnDat 2.2	∿ 1 V_{PP}	2048	**ECN 2180**	*ECN 2000* Product Information document
					EnDat 2.2	–	–	**ECN 2110**	
					Fanuc αi	–	–	**ECN 2190 F**	
					Mitsubishi	–	–	**ECN 2190 M**	

[1] Also available with functional safety
[2] Higher shaft speeds possible depending on the operating temperature (see relevant Product Information document)

RCN 6000
Ø 180 mm

RCN 200
Ø 20 mm

ECN 2000
Ø 50 mm

Selection guide
Incremental angle encoders with an integral bearing and hollow shaft

Series	Overall dimensions in mm	System accuracy	Mechanically permissible speed[1]	Interface	Signal periods/ revolution	Model	Further information
With integrated stator coupling							
RON 200	Ø 110 / □92 / 55 / Ø 20	±5″	≤ 3000 rpm	⎍ TTL	180 000/90 000[2]	**RON 275**	*RON 200/ RON 700/ RON 800/ RPN 800* **Product Information document**
				∿ 1 V$_{PP}$	18 000	**RON 285**	
		±2.5″		∿ 1 V$_{PP}$	18 000	**RON 287**	
RON 700	Ø 170 / 59 / Ø 50	±2″	≤ 1000 rpm	∿ 1 V$_{PP}$	18 000	**RON 785**	
	Ø 200 / 40 / Ø 60			∿ 1 V$_{PP}$	18 000/36 000	**RON 786**	
RON 800 RPN 800	Ø 200 / 40 / Ø 60	±1″	≤ 1000 rpm	∿ 1 V$_{PP}$	36 000	**RON 886**	
				∿ 1 V$_{PP}$	180 000	**RPN 886**	

[1] May be limited during operation due to electrically permissible shaft speed
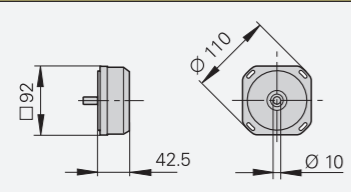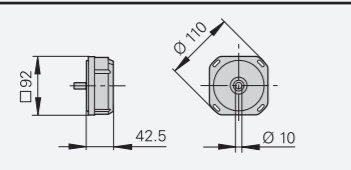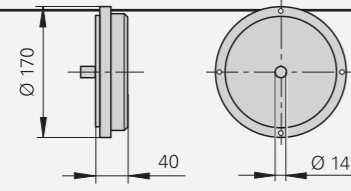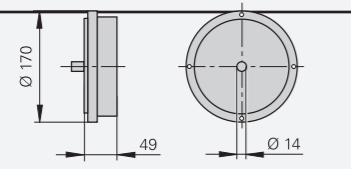[2] With integrated interpolation

RON 200
Ø 20 mm

RON 700
RON 800
RPN 800
Ø 60 mm

Selection guide
Absolute and incremental angle encoders with an integral bearing for a separate shaft coupling

Series	Main dimensions in mm	System accuracy	Mechanically permissible speed[1]	Position values per revolution	Interface	Signal periods/ revolution	Model	Further information
For separate shaft coupling								
ROC 2000		±5″	≤ 3000 rpm	67 108 864 (26 bits)	EnDat 2.2	16384	**ROC 2380**	*ROC 2000/ ROC 7000*
					EnDat 2.2	–	**ROC 2310**	**Product Information document**
					Fanuc αi	–	**ROC 2390 F**	
					Mitsubishi	–	**ROC 2390 M**	
ROD 200		±5″	≤ 10000 rpm	–	⎍ TTL	180000[2]	**ROD 270**	*ROD 200/ ROD 700/ ROD 800*
					∿ 1 V$_{PP}$	18000	**ROD 280**	**Product Information document**
ROC 7000		±2″	≤ 3000 rpm	268 435 456 (28 bits)	EnDat 2.2	16384	**ROC 7380**	*ROC 2000/ ROC 7000*
					EnDat 2.2	–	**ROC 7310**	**Product Information document**
					Fanuc αi	–	**ROC 7390 F**	
					Mitsubishi	–	**ROC 7390 M**	
ROD 700		±2″	≤ 1000 rpm	–	∿ 1 V$_{PP}$	18000/36000	**ROD 780**	*ROD 200/ ROD 700/ ROD 800*
ROD 800		±1″	≤ 1000 rpm	–	∿ 1 V$_{PP}$	36000	**ROD 880**	**Product Information document**

[1] May be limited during operation due to electrically permissible shaft speed
[2] With integrated interpolation

ROC 2000
ROD 200

ROC 7000
ROD 700
ROD 800

Measuring principles

Measuring standard

HEIDENHAIN encoders with optical scanning incorporate measuring standards consisting of periodic structures known as graduations.

These graduations are applied to a carrier substrate made of glass or steel. For encoders with long measuring lengths, steel tape is used as the scale substrate.

HEIDENHAIN manufactures its precision graduations in the following specially developed, photolithographic processes:
• DIADUR: extremely robust chromium lines on glass (typical grating period: 20 µm), or three-dimensional chromium structures (typical grating period: 8 µm) on glass
• METALLUR: contamination-tolerant graduation consisting of metal lines on gold; typical grating period: 20 µm
• SUPRADUR phase grating: optically three-dimensional, planar structure; particularly tolerant to contamination; typical grating period: 8 µm and finer
• OPTODUR phase grating: optically three-dimensional, planar structure with particularly high reflectance; typical grating period: 2 µm and finer

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

The master graduations are manufactured by HEIDENHAIN on custom-built, high-precision dividing engines.
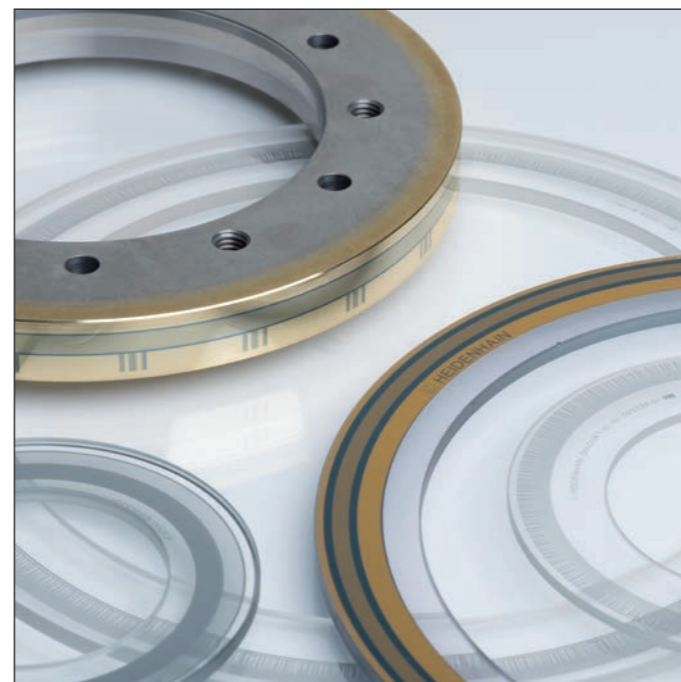
Absolute measuring method

In the absolute measuring method, the position value is available immediately upon encoder switch-on and can be requested by the downstream electronics at any time. There is therefore no need to search for the reference position by jogging the axes.

The absolute position information is read from the **circular scale**, which is designed with a serial absolute code structure. The code structure is unique over one revolution. A separate incremental track is read with the single-field scanning principle and interpolated for the position value.

Circular scale with serial code track and fine track

Absolute and incremental circular scales and scale drums

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 the ascertainment of positions requires an absolute reference, the scales or scale tapes feature an additional track with a **reference mark**. The absolute position on the scale, established by means of 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, this may require rotation by up to 360°. To simplify reference runs, many HEIDENHAIN encoders feature **distance-coded reference marks**: the reference-mark track has multiple reference marks at different defined distances. The downstream electronics determine the absolute reference point after just two neighboring reference marks have been traversed; in other words, after just a few degrees of rotational motion (see "Nominal increment N" in the table). Encoders with distance-coded reference marks are identified with a "C" following the model designation (e.g., RON 786 C).

With distance-coded reference marks, the **absolute reference** is determined by counting the increments between two reference marks.

Line count z	Number of reference marks	Nominal increment N
36000	72	10°
18000	36	20°
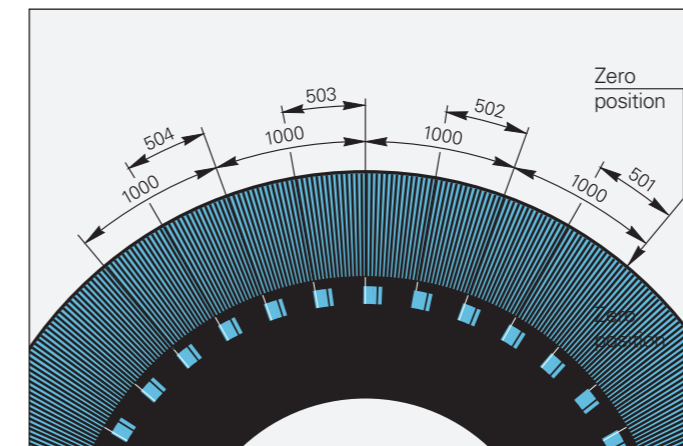
Schematic representation of a circular scale with distance-coded reference marks

Photoelectric scanning

Most HEIDENHAIN encoders utilize the photoelectric scanning principle. Photoelectric scanning is touchless and therefore does not induce wear. This method detects even extremely fine graduation lines down to a width of only a few micrometers 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 angle encoders use two scanning principles:

- The **imaging scanning principle** for graduation periods of 10 µm to approx. 70 µm.
- The **interferential scanning principle** for very fine grid lines with graduation periods of 8 µm, 4 µm and finer.
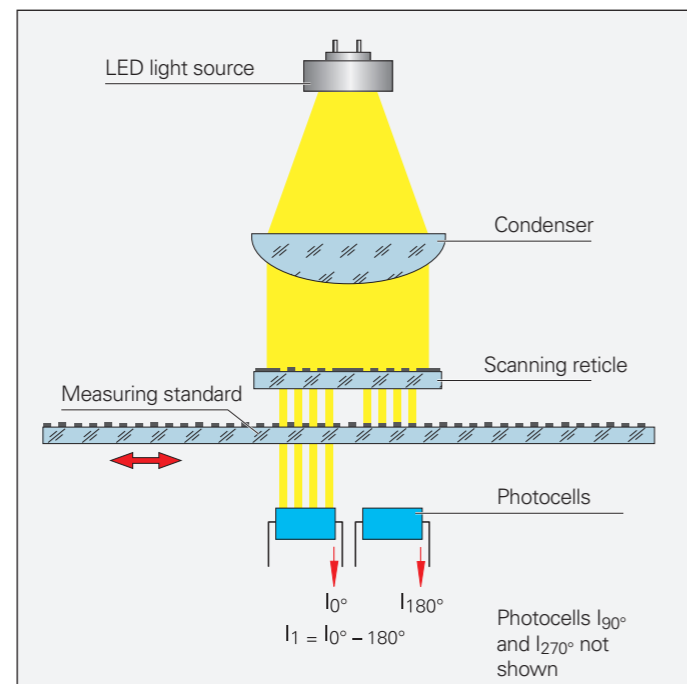
Imaging principle
Put simply, the imaging scanning principle functions by means of projected-light signal generation: two gratings with equal grating periods (the circular scale and the scanning reticle) are moved relative to each other. The carrier material of the scanning reticle is transparent, whereas the graduation on the measuring standard may be applied to a transparent or reflective surface.

Parallel light passes through a grating structure, casting dark and light fields at a certain distance, where there is an index grating with the same or similar grating period. When the two gratings move relative to each other, the incident light is modulated: If the gaps are aligned, light passes through. If the lines of one grating coincide with the gaps of the other, no light passes through.

A wide-surface photocell array converts these variations in light intensity into electrical signals. The specially structured grating of the scanning reticle filters the light 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. In encoders that use the imaging scanning principle, workable mounting tolerances are attainable starting at a minimum grating period of 10 µm.

The RCN, ECN, RON, ROC and ROD angle encoders with an integral bearing use the imaging scanning principle.

Interferential scanning principle
The interferential scanning principle uses the diffraction and interference of light on finely divided gratings in order to produce the signals from which motion is measured.

A step grating is used as the measuring standard: reflective lines just 0.2 µm in height are applied to a flat, reflective surface. In front of this 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 +1st, 0th, and –1st orders, with nearly equal luminous intensity. The waves are diffracted by the scale such that most of the luminous intensity is found in the reflected +1st and –1st diffraction orders. 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. Photocells convert these alternating light intensities into electrical signals.

When there is relative motion between the scale and the scanning reticle, the diffracted wavefronts undergo a phase shift: movement by the amount of one grating period shifts the positive first-order diffraction wavefront by one wavelength in the positive direction, while the negative first-order diffraction wavefront 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 relative motion over one grating period therefore results in two signal periods.

Interferential encoders use average grating periods of 8 µm, 4 µm and finer. Their scanning signals are largely free of harmonics and can be highly interpolated. These encoders are therefore especially well suited for high resolution and high accuracy. At the same time, their generous mounting tolerances permit installation into a wide range of applications.

The RPN 886 angle encoder with an integral bearing uses the interferential scanning principle.

Imaging scanning principle

Interferential scanning principle (optical diagram)
C Grating period
Ψ Phase shift of the light wave when passing through the scanning reticle
Ω Phase shift of the light wave through the X motion of the scale
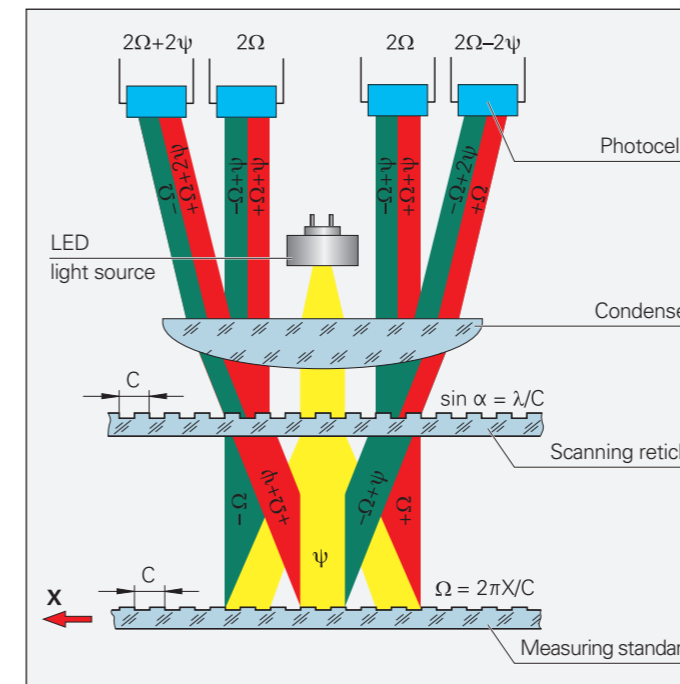
Measurement accuracy

The accuracy of angular measurement is mainly determined by:
- The quality of the graduation
- The quality of the graduation carrier
- The quality of the scanning process
- The quality of the signal processing electronics
- The quality of the encoder mechanics
- The eccentricity of the graduation relative to the bearing
- The bearing errors
- The method of coupling to the measured shaft; in the case of angle encoders with an integral bearing, for example, this is the stator coupling (RCN, ECN, RON, RPN) or the shaft coupling (ROC, ROD)

These factors can be subdivided into encoder-specific position errors and application-dependent factors. For assessment of the attainable **overall accuracy**, all of these individual factors must be taken into account:
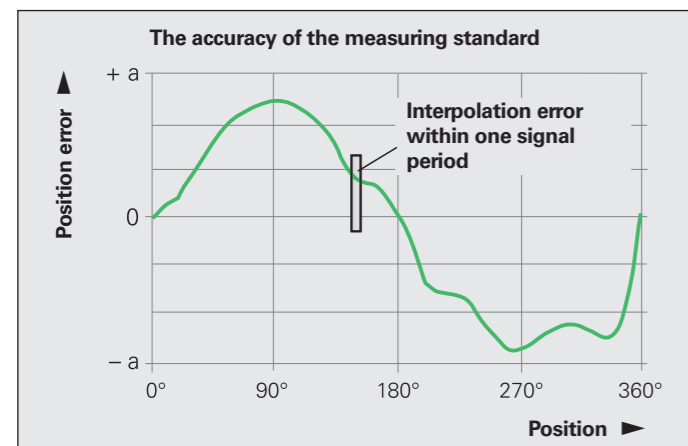
Encoder-specific position error

The encoder-specific error includes:
- The accuracy of the measuring standard
- The interpolation accuracy
- The position noise
- The quality of the encoder's mechanical design

The accuracy of the measuring standard
The accuracy of the measuring standard is primarily dictated by the homogeneity of the graduation.

It is stated as the maximum value of the **baseline error**. The distance between the measuring points is equivalent to the integer multiple of the signal period. As a result, interpolation errors have no effect.

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

The interpolation accuracy is primarily influenced by:
- The fineness of the signal period
- The homogeneity and period resolution of the graduation
- The quality of the scanning filter structures
- The characteristics of the sensors
- The quality of the signal processing

The interpolation accuracy is stated in the form of a maximum value ±u of the interpolation error.

Position noise
Position noise causes small, random deviations from the expected value. Position noise also depends on the quality of the signal processing. Typically, the position noise is less than 1 ‰ of the signal period.

For angle encoders with an integral bearing, the system accuracy is provided in the specifications for better differentiation.

The **system accuracy** defines the upper limit of the position deviations within a given position. It consists of the baseline error combined with the interpolation error. In the case of angle encoders with a stator coupling (RCN, ECN, RON, RPN), the system accuracy also includes the errors of the shaft coupling.

Application-dependent errors

Angle encoders with an integral bearing and stator coupling (RCN, ECN, RON, RPN) compensate for movements between the rotor and stator that are not in the direction of measurement. Due to this principle of operation, very wide mounting tolerances can be realized with minimal effect on the **overall accuracy**.

In the case of angle encoders with a separate **shaft coupling** (ROC, ROD), the overall accuracy of the angular error of the coupling must be considered as well (see *Mechanical design types and mounting: ROC, ROD*).

In the case of **encoders without an integral bearing**, the mounting and adjustment of the scanning head have a significant effect on the attainable overall accuracy. Of particular importance are both the mounting eccentricity of the graduation and the radial runout of the measured shaft. Evaluation of the **overall accuracy** of these encoders requires that their application-dependent errors be individually measured and taken into account (see the *Angle Encoders without Integral Bearing* brochure).

The accuracy of the measuring standard



Interpolation accuracy
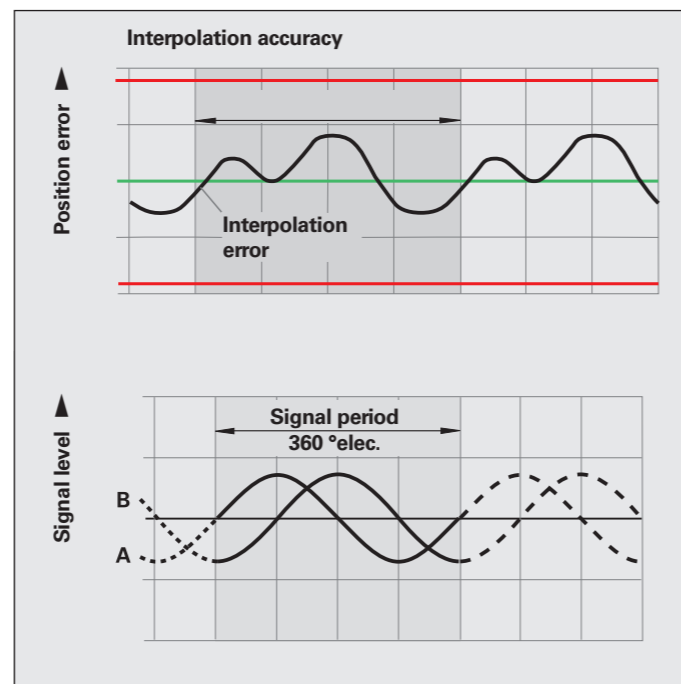
Calibration chart

For angle encoders with an integral bearing, HEIDENHAIN creates quality inspection documents included with the encoder.

The **quality inspection document** states the system accuracy, which is determined through five forward and five reverse measurements during final inspection. The measuring positions per revolution are selected such that both the baseline error and the interpolation error are recorded with great accuracy. The mean value curve shows the arithmetic mean of the measured values. The reversal error is not included.

The **mechanical hysteresis** depends on the shaft coupling. For angle encoders with a stator coupling (RCN, ECN, RON and RPN), it is determined at ten measuring positions during the step cycle. The maximum value and arithmetic mean are documented on the calibration chart. The following limits apply to this hysteresis:

RCN 2xxx/RON 2xx:	≤ 0.6″
RCN 5xxx:	≤ 0.6″
RCN 2xx/ ECN 2xxx:	≤ 2″
RON 7xx:	≤ 0.4″
RCN 8xxx/RON/RPN 8xx:	≤ 0.4″
RCN 6xxx:	≤ 0.8″

By including the **calibration standard**, the quality inspection document establishes the link to national and international standards and ensures traceability. The measuring parameters and the measurement uncertainty are also provided.
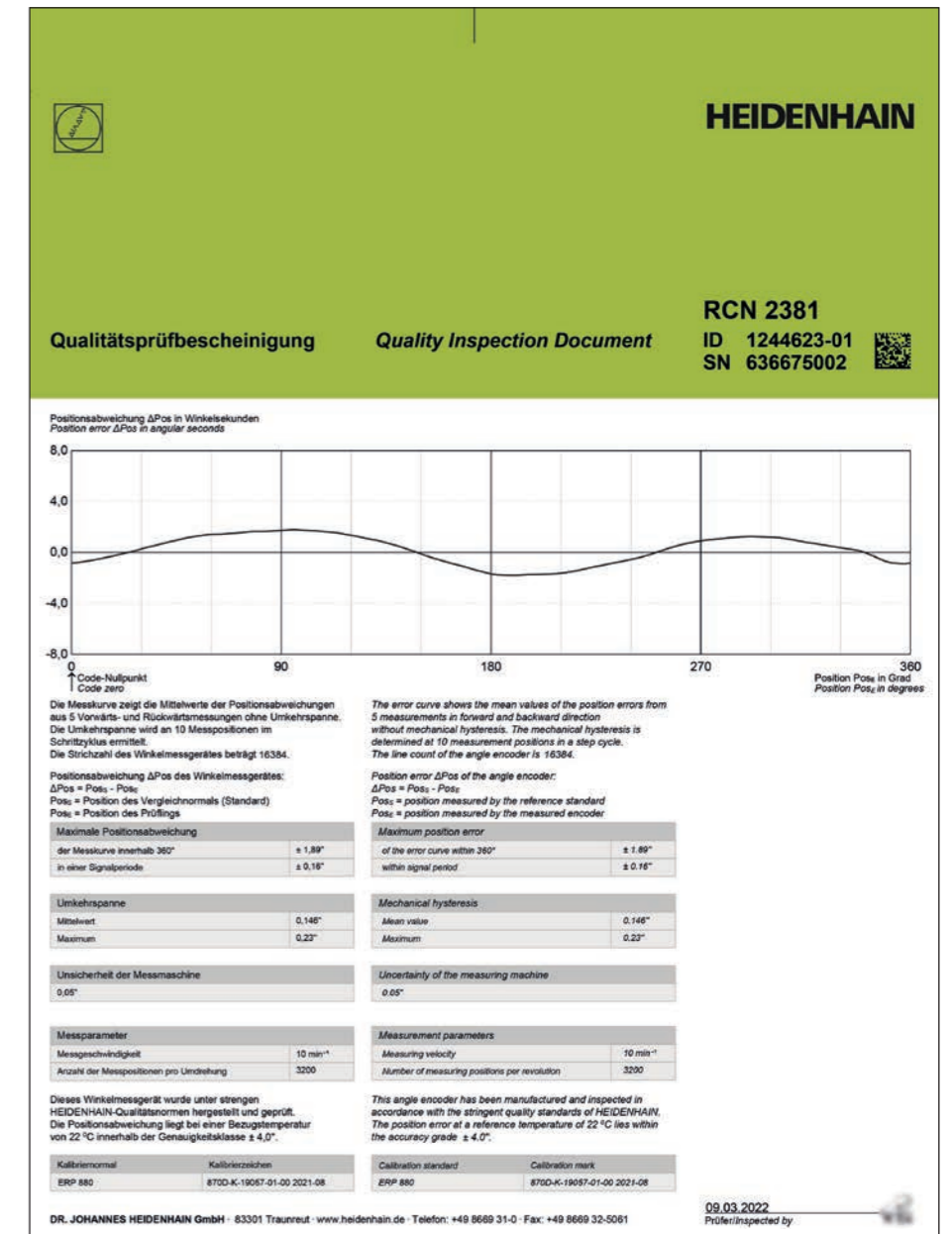
Example

Determination of the reversal error during the step cycle
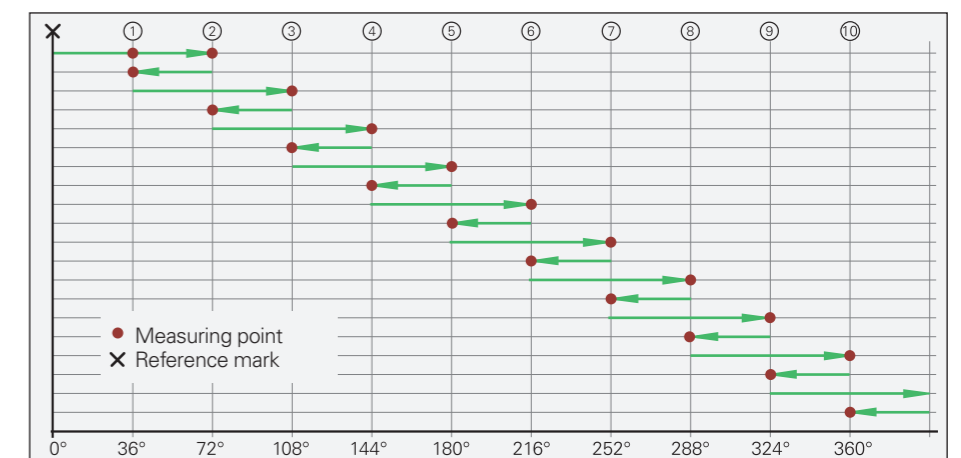
Angle encoders for direct drive motors in machine tools

Direct drive motors are being increasingly used in many fields, particularly in the machine tool industry. Compared with geared rotary axes, direct drive motors are extremely low-wear and low-maintenance. Without intervening mechanical transmission components, torque motors also enable significantly higher dynamic performance of the rotary axes. Thanks to their direct torque delivery, significantly higher accelerations and shaft speeds can be attained. This is particularly beneficial in 5-axis simultaneous machining, where it is typically the rotary axes that limit the speed of simultaneous motion. Higher dynamic performance of the rotary axes translates into uniform tool feed rates and increased productivity.

The performance of a direct-drive feed axis is significantly affected by the choice of encoder for measuring the axis position.

Resonances that excite the natural frequencies of an axis and its assemblies are usually dampened with filters in the control loop. However, the use of filters causes a phase loss in the control loop, thus reducing the control bandwidth. The lower the resonance frequency to be damped is, and the higher the damping value of the required filter is, the more the control bandwidth and thus the dynamic performance of the axis is reduced. Thus, in order to attain high control bandwidth, resonances should have the highest frequency possible with low amplitude.

As a component of the axis, the encoder affects the resonance behavior and thus also the dynamic behavior of the feed unit. The encoder design and type of shaft coupling are key factors in attaining good dynamic behavior for the axis. By way of example, we now wish to demonstrate how the behavior of the feed axis is affected by an RCN 8311 and a mounting-compatible alternative angle encoder of comparable accuracy. In order to evaluate the two angle encoders with regard to their resonances, radial and axial vibrations were induced in the range of 20 Hz to 2000 Hz by means of a shaker. *Figure 1* shows the results (the maximum occurring amplitude is equivalent to 100% in the graph).

The RCN 8311 exhibits resonances only in the upper frequency range, and these resonances have only low amplitudes, whereas the alternative angle encoder exhibits disruptive resonances even at low frequencies.

This difference in frequency behavior has a significant effect on the controller behavior of a direct-drive motor. This can be seen, for example, through a step response in the shaft-speed control loop. Taking comparable controller settings regarding amplitudes and phase reserves into account, *Figure 2* shows the step response in the shaft-speed control loop for the same rotary axis unit with the two angle encoders.

With the RCN 8311, the nominal speed is achieved faster with lower overshoot than by the alternative angle encoder. This is because resonance points of the RCN 8311 do not occur until high frequencies and then at only low amplitudes. As a result, filters are used only at high frequencies with low damping values, thereby barely affecting the control bandwidth. And in the case of the alternative angle encoder, a harmonic can also be seen during the step response in *Figure 2*. This harmonic is based on the natural frequency of this encoder in the range between 100 Hz and 200 Hz.

Achieving high dynamic performance with a direct-drive feed axis requires an encoder with a natural frequency that is as high as possible. Various design measures were taken for the RCN series that achieve excellent vibration behavior, such as their mounting design and shaft coupling. This enables high dynamic performance for the direct-drive rotary axis, enabling faster and more consistent part manufacturing and ultimately improving the productivity of machining centers.

In addition, thanks to its optical scanning method, the RCN series offers strong benefits for direct-drive feed axes in terms of accuracy, running smoothness and temperature behavior. On direct-drive feed axes, the encoder measures both the actual position and the current speed. Due to the absence of mechanical transmission elements between the encoder and the motor, the encoder must provide sufficiently high resolution in order to attain high-quality speed control at low feed rates. And here is another consideration: Higher k_V factors in the position control loop of direct-drive motors permit wider control bandwidths and allow the servo stiffness to be tuned. But this also magnifies the influence of the encoder's signal quality on positioning and control-loop behavior. Position errors within one signal period adversely affect the positioning accuracy and speed stability of the motor. At low feed rates, the feed motor, and thus the rotary axis, reproduce the position errors within one signal period. Because direct drive motors exhibit a wider control bandwidth due to the higher k_V factor, they reproduce these position errors over a wider speed range of the feed axis.

The speed controller calculates the nominal currents that brake or accelerate the motor in accordance with the control error. Inadequate encoder signal quality in the direct-drive axis causes disturbances in the position control loop and in the underlying control loops, extending as far the current control loop. This leads to high noise levels in the motor current signal and, in especially bad cases, to unwanted high-frequency noise in the power train. The loop gain must be reduced. The high noise also causes increased power dissipation in the motor. This results in greater heat build-up within the axis unit. Thermally induced deformations in the axis structure may arise, or greater machine cooling performance may be required. To avoid these problems, direct-drive feed axes call for position encoders with small signal periods and high signal quality.

The RCN series features a high line count and high signal quality. With these encoders, direct-drive rotary axes exhibit low motor current noise and smooth operating behavior. The high signal quality of optical encoders therefore permits better use of the performance potential of direct-drive feed axes.
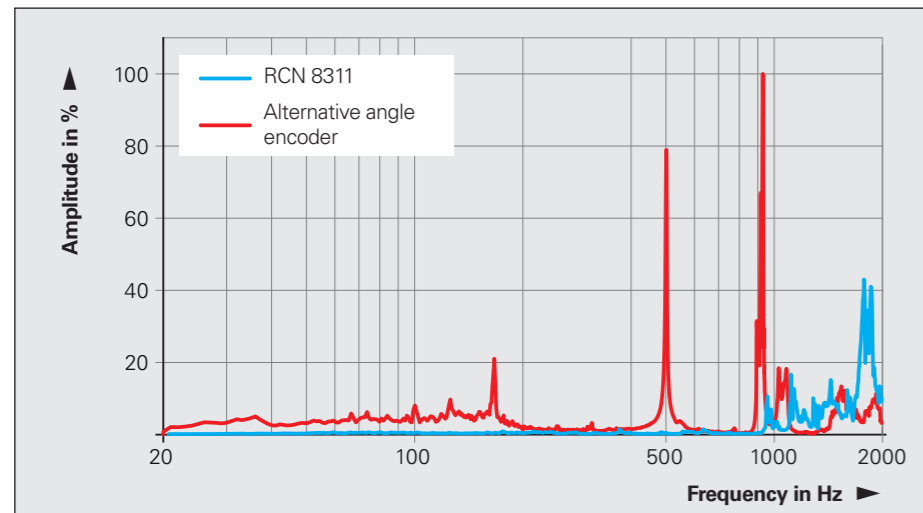

Figure 1: Maximum occurring amplitude during radial and axial excitation of an RCN 8311 and an alternative angle encoder.
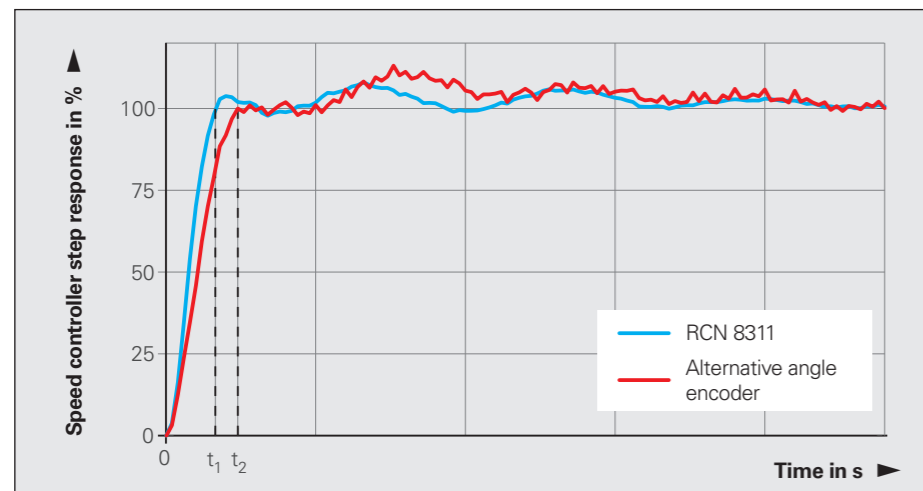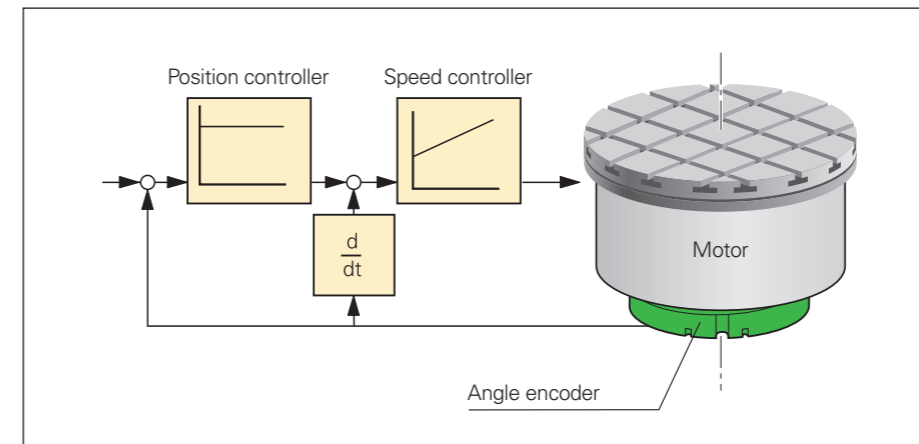

Figure 2: Step response in the shaft speed control loop subject to control with an RCN 8311 and an alternative angle encoder

Control loop with a rotary direct-drive motor (torque motor)

Optical angle encoder with 32 768 lines
Optical angle encoder with 16 384 lines
Non-optical angle encoder with 2600 lines
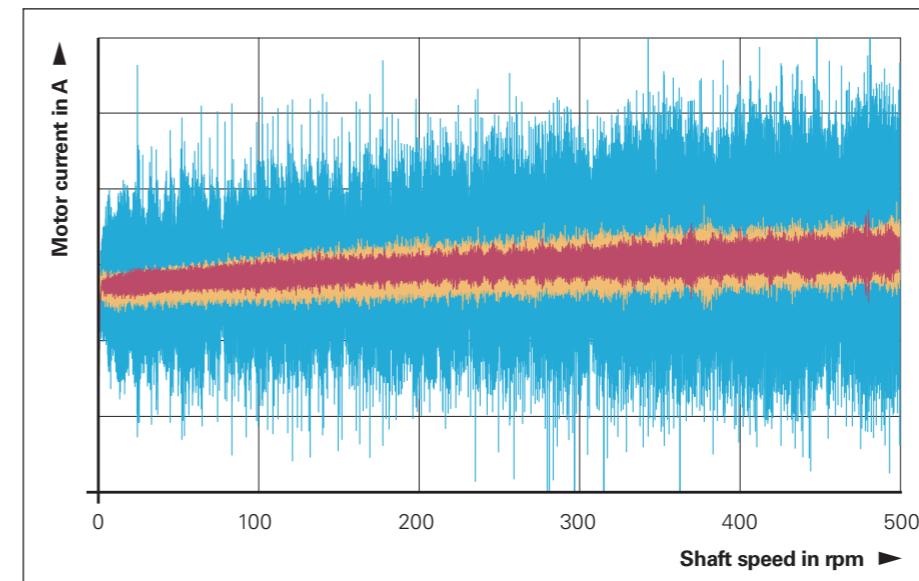
Example of the noise behavior of optical and non-optical angle encoders in rotary tables with a direct-drive motor at a continuously increasing shaft speed

Mechanical design types and mounting
RCN, ECN, RON, RPN

RCN, ECN, RON and **RPN** angle encoders have an integral bearing, hollow shaft and a coupling on the stator side. The measured shaft is directly connected with the shaft of the angle encoder.

Setup
The circular scale is rigidly affixed to the hollow shaft. The scanning unit rides on the shaft on ball bearings and is connected to the housing with a coupling on the stator side. The stator coupling and the sealing design greatly compensate for axial and radial mounting errors without restricting functionality or accuracy. Particularly with the RCN, this permits relatively wide mounting tolerances and therefore simplifies the mounting process. During angular acceleration of the shaft, the stator coupling must absorb only the torque resulting from friction within the bearing. Angle encoders with a stator coupling therefore provide excellent dynamic performance.

Mounting
The housing of the RCN, ECN, RON, and RPN is firmly connected to the mounting surface of the machine part via a mounting flange and a centering collar.

The manner of shaft coupling varies depending on the encoder model. With the RCN 2001, RCN 5001 and RCN 8001, for example, a shaft coupling with a ring nut or a front-face shaft coupling is possible.
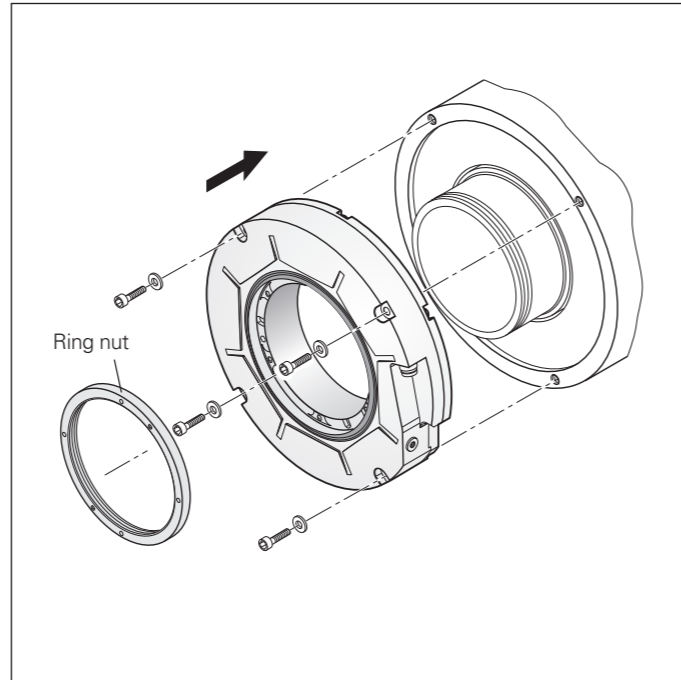
Ring nut

Example: mounting an angle encoder with a ring nut

ROC, ROD

The **ROC** and **ROD** angle encoders require a separate shaft coupling for the rotor-side coupling. The shaft coupling compensates for axial movement and misalignment between the shafts, preventing excessive load on the bearing of the angle encoder. For realizing high accuracies, it is necessary that the shaft of the angle encoder is optimally aligned with the shaft of the machine. The HEIDENHAIN product portfolio includes diaphragm couplings and flat couplings designed for rotor-side coupling of the ROC or ROD angle encoders.

Mounting
The ROC and ROD angle encoders feature a mounting flange with a centering collar. The encoder shaft is connected to the machine shaft by means of a diaphragm coupling or flat coupling.

Shaft couplings
The shaft coupling compensates for axial movement and misalignment between the encoder shaft and the measured shaft, thus preventing excessive loading on the bearing of the angle encoder.

Radial offset λ

Angular error α

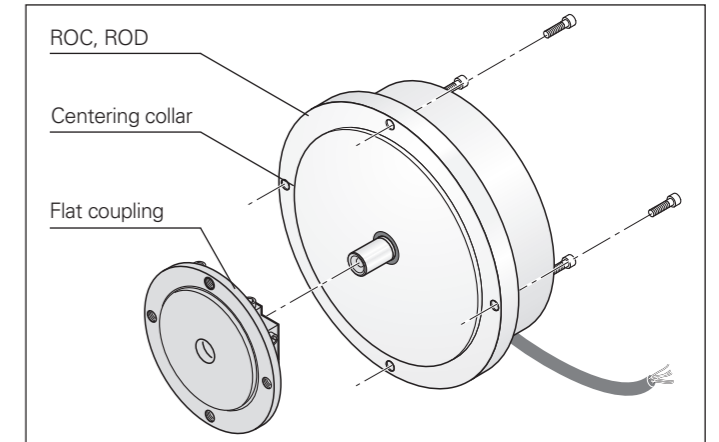Axial motion δ

Rotary table

Additional protection from dripping fluids

Mounting example ROC 7380

ROC 7380

Shaft coupling

ROC, ROD

Centering collar
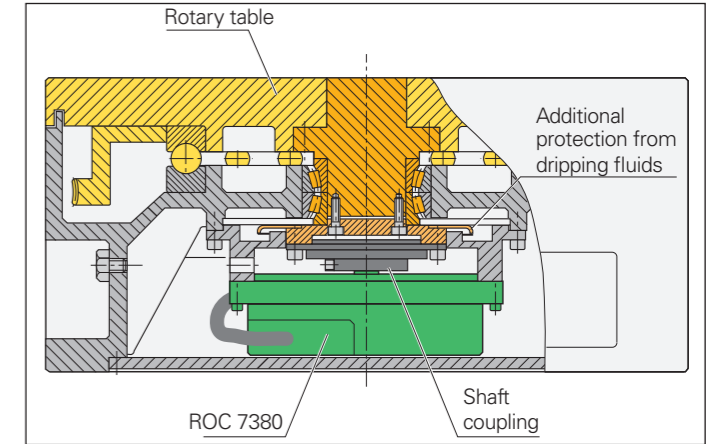
Flat coupling

Mounting an ROC or ROD with a flat coupling

Benefits of the RCN 2001, RCN 5001 and RCN 8001
The new standard: fast and smart

Angle encoders from HEIDENHAIN have long been the gold standard whenever angular measurement is needed on rotary tables and tilting axes. With the RCN 2001, RCN 5001 and RCN 8001 absolute angle encoders, for example, HEIDENHAIN offers the ideal solution for position measurement in the field of machine tools, including for safety-related applications.

High positioning accuracy
Proper encoder selection contributes significantly to the measurement of an axis position and thus to the machining accuracy. But when it comes to attaining optimal accuracy, it's important to consider not only the encoder-specific characteristics but also factors such as how well the encoder is mounted and adjusted. This is where the integrated bearing and stator coupling of the RCN series give them an important advantage over other encoders. Thus, along with encoder-specific error, such as the accuracy of the measuring standard or the interpolation accuracy, the error present in the coupling to the measured axis is included, and the system accuracy can be specified. The RCN 2001 and RCN 5001 series are specified with system accuracies of ±2″ and ±4″; the RCN 8001 series with ±1″ and ±2″.

High dynamic performance of the rotary axis
High encoder resolutions cause low noise in the motor current and smooth operating behavior, particularly in the case of direct-drive rotary axes. They also have a positive effect on control behavior and allow manufacturers to attain high surface quality combined with high productivity. The RCN 2001, RCN 5001 and RCN 8001 series feature very high resolution based on high line counts and high signal quality. The RCN 8001 series, for example, has a line count of 32 768 and provides absolute position values at a resolution of more than 536 million positions per revolution. For more information, see *Angle encoders for direct-drive motors in machine tools* on *Page 20*.

Easy mounting
Another key feature of the RCN series is their easy mounting. Very little effort is required. Unlike with other angle encoders, centering the graduation or electrically testing the signals prior to initial operation is not needed. And due to the way the RCN is designed, relatively large mounting tolerances are possible without limiting accuracy or functionality. Axial deviations of up to ±0.3 mm, for example, are permissible with the RCN 2001, RCN 5001 and RCN 8001.

High reliability
The scanning functionality of the RCN 2001, RCN 5001 and RCN 8001 series is so robust that liquid contamination and condensation droplets barely have an effect on the scanning signals or motor control. Droplet contamination on the circular scale, as seen in *Figure 1*, has almost no effect on the interpolation error *(Figure 2)*. The predecessor model, the RCN 8000, exhibited a low level of interpolation error. This broadly prevents interruptions to the machining process due to encoder contamination. A housing and a seal are also standard features of the RCN series, giving them an IP64 rating. As a result, sealing air is no longer needed in most applications, thus having a positive effect on energy and CO_2 conservation within the application.

In-situ processing of direct-drive motor temperatures
To prevent direct-drive motors from overheating during operation, their temperature is typically monitored. In conjunction with the HEIDENHAIN EIB 52x1 signal converter, the RCN 2001, RCN 5001 and RCN 8001 series enable simple evaluation of the winding temperatures of direct-drive motors. The EIB 5211 or EIB 5291S signal converters can be installed near the direct-drive motor, where they enable in-situ digitalization of the temperature information coming from the direct-drive motor. Along with the position data, the RCNs then transmit the processed temperature data to the controller via the purely digital interface.

This yields the following benefits:
- Reduced cabling
- Purely digital transmission technology
- Overload protection of the direct-drive motor through the monitoring of all three windings
- Precise temperature monitoring through compensation of the transmission timing behavior of the temperature measurement (with direct-drive motors from ETEL)
- Increased cost efficiency through use of the direct-drive motor up to its thermal load limit

RCN   **EIB 52x1**

Example of in-situ processing of direct-drive motor temperatures with an EIB 5211 and RCN 5311.
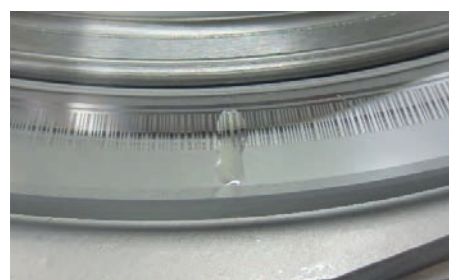

Figure 1:
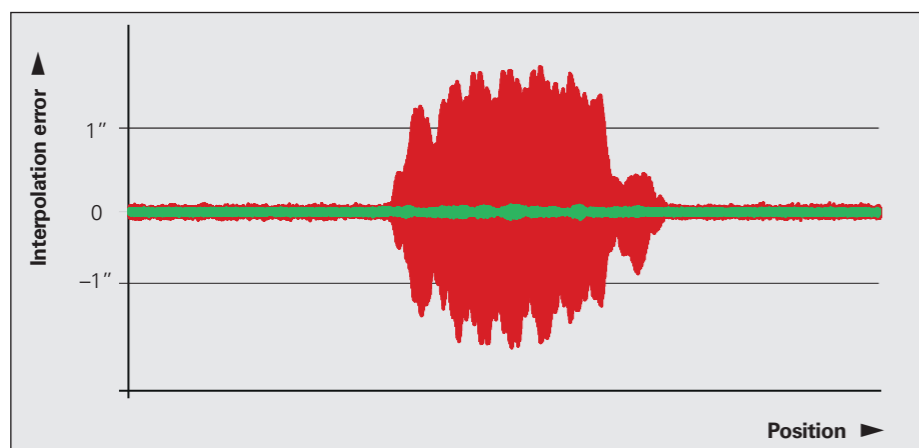Example of droplet-like contamination on a circular scale

Figure 2:
Effect of droplet-like contamination on the interpolation error (RCN 8001: green; RCN 8000: red)

Standardization and flexibility
It is not uncommon for rotary axes to be used on different models of controls. In this case, they must be able to communicate with the relevant interfaces. To avoid needing to create different rotary-axis variants, it is possible to take advantage of standardization. For this purpose, external signal converters such as the EIB 3392 S and EIB 3392 F signal converters in cable design are used. They convert the purely serial EnDat interface of the encoder to the DRIVE-CLiQ and FANUC interfaces, thus allowing the number of required variants for the angle encoders to be reduced. This has a positive effect on warehouse capacity and increases flexibility.

Example of a signal converter in cable design (EIB 3392 S)

DRIVE-CLiQ is a registered trademark of Siemens Aktiengesellschaft.

High productivity

In order to machine workpieces with maximum productivity, a machine tool's rotary axes must be operated at high shaft speeds. In particular, the purely serial interface of the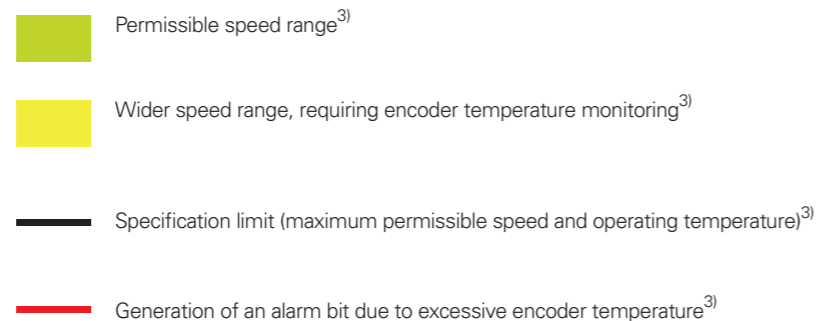 RCN supports this trend. With their purely serial interface, the RCN 2001 and RCN 5001 series achieve shaft speeds of up to 3000 rpm, with 1500 rpm possible for the RCN 8001. The permissible rotational speed is largely dependent on the internal encoder temperature, which is affected by the duration of operation and the operating temperature. The operating temperature is defined as the temperature in the immediate vicinity of the encoder but not at the encoder's surface. To protect the encoder from overheating, the RCN 2001, RCN 5001 and RCN 8001 are equipped with a temperature sensor. This sensor measures the temperature inside the encoder and transmits it to the downstream electronics. If the temperature inside the encoder is too high (90 °C), then an alarm is generated, and the machine controller initiates appropriate measures to protect the encoder from damage. When the EnDat interface is used and the temperature inside the encoder reaches 86 °C, a warning bit[1] is set in advance. This bit can be used to trigger individualized machine actions and avoid interruption of the machining process. Speed diagrams were created through analyzing the encoder temperatures from tests at different operating temperatures and shaft speeds. These diagrams show the permissible shaft speeds as a function of the operating temperature (valid for up to 90 minutes of uninterrupted operation). As a function of the operating temperature, the green areas represent the permissible shaft speeds at which temperatures inside the encoder are non-critical. In the yellow areas, the combination of speed and operating temperature already yield such a high encoder temperature that the EnDat interface generates a warning bit.[2] At the red lines, the encoder temperature is 90 °C, and an alarm bit is set for an excessive temperature.
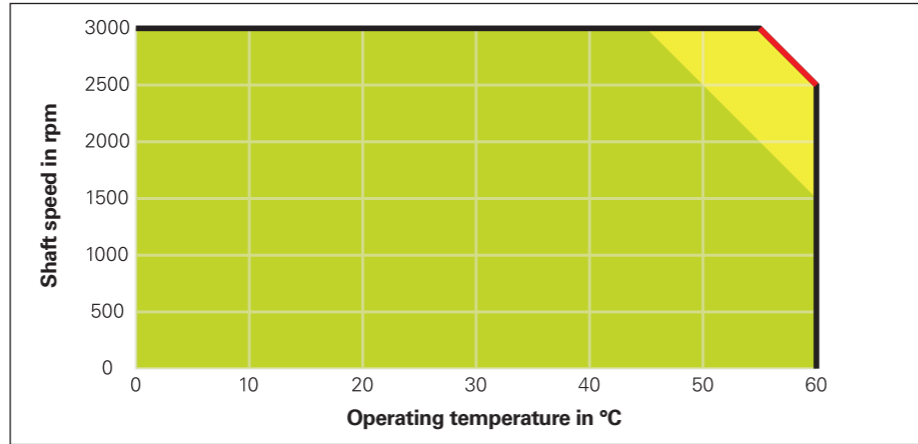
Shaft-speed diagram as an orientation aid for the RCN 2001 series with a purely serial interface

Shaft-speed graph as an orientation aid for the RCN 8001 with a hollow shaft (Ø 60 mm)
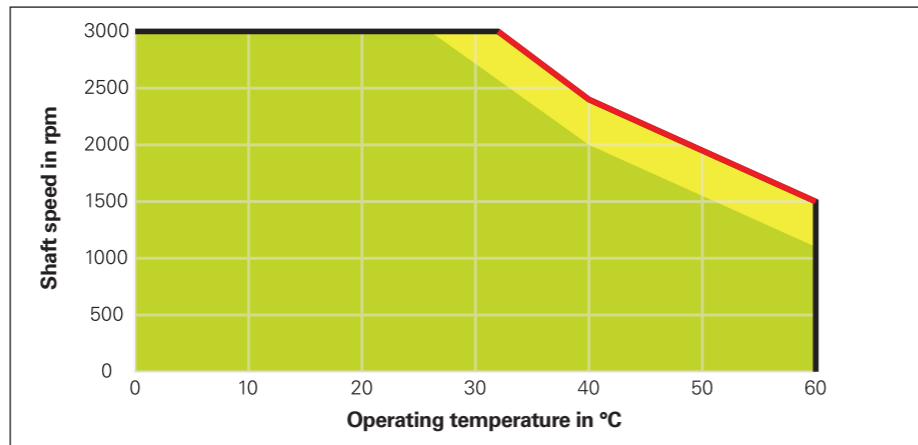
Shaft-speed diagram as an orientation aid for the RCN 5001 series with purely serial interface

Shaft-speed graph as an orientation aid for the RCN 8001 with a hollow shaft (Ø 100 mm)

Permissible speed range[3]

Wider speed range, requiring encoder temperature monitoring[3]

Specification limit (maximum permissible speed and operating temperature)[3]

Generation of an alarm bit due to excessive encoder temperature[3]

Permissible speed range[3]

Wider speed range, requiring encoder temperature monitoring[3]

Specification limit (maximum permissible speed and operating temperature)[3]

Generation of an alarm bit due to excessive encoder temperature[3]

[1] A preset operating parameter that can be changed
[2] At a preset temperature of 86 °C
[3] With a purely serial interface

[1] A preset operating parameter that can be changed
[2] At a preset temperature of 86 °C
[3] With a purely serial interface

Functional safety

Safe axes

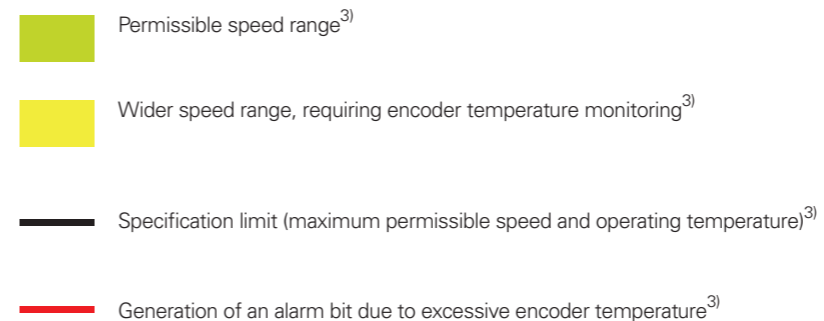Driven axes on machine tools usually represent a significant hazard for humans. It must be ensured that the machine does not make any uncontrolled movements, especially when a person is interacting with the machine (e.g., workpiece setup). This requires position information about the axes for proper implementation of safety function. As an evaluating safety module, the controller has the task of detecting faulty position information and reacting to it accordingly.

Various safety strategies can be pursued depending on the topology of the axis and the evaluation capabilities of the controller. In a single-encoder system, for example, only one encoder per axis is evaluated for the safety function. But on axes with two encoders, such as a rotational axis with a rotary encoder and an angle encoder, the two redundant position values can be compared with each other in the controller. Safe fault detection can be ensured only if the controller and the encoder are properly matched to each other. It must be noted that the safety designs of controller manufacturers differ from one another. As a result, the requirements to be fulfilled by the connected encoders may also differ to an extent.

Type-examined encoders

HEIDENHAIN angle encoders with an integral bearing are used successfully on different controls in a wide variety of safety designs. Particularly noteworthy in this context are the type-tested RCN 2001/ RCN 5001/RCN 8001 encoders with the EnDat interface. These encoders can be operated as single-encoder systems in conjunction with a suitable controller in applications with the controller category SIL 2 (as per EN 61508) or performance level "d" (as per EN ISO 13849). Unlike incremental encoders, the RCN 2001/ RCN 5001/RCN 8001 absolute angle encoders provide a safe absolute position value at all times, including immediately after switch-on or after a power outage. Reliable position transmission is based on two independently generated absolute position values and on error bits provided to the safe controller. The purely serial data transmission also provides other benefits, including greater reliability, improved accuracy, diagnostic capabilities, and reduced costs through simpler connection technology.

Standard encoders

In addition to those encoders explicitly qualified for safety applications, standard angle encoders (e.g., with a Fanuc interface or 1 V_{PP} signals) can be used in safe axes. In such cases, the characteristics of the encoders must be matched to the requirements of the given controller. For this purpose, HEIDENHAIN can provide additional data about the individual encoders (failure rate, fault model as per EN 61800-5-2).

Service life

Unless otherwise specified, HEIDENHAIN encoders are designed for a service life of 20 years (as per ISO 13849).

📖 **Further information:**

The safety-related characteristic values are listed in the encoder specifications. These characteristic values are explained in the Technical Information document *Safety-Related Position Encoders*.

For the use of standard encoders in safety-related applications, HEIDENHAIN can also provide additional information about individual products (failure rate, fault model as per EN 61800-5-2).
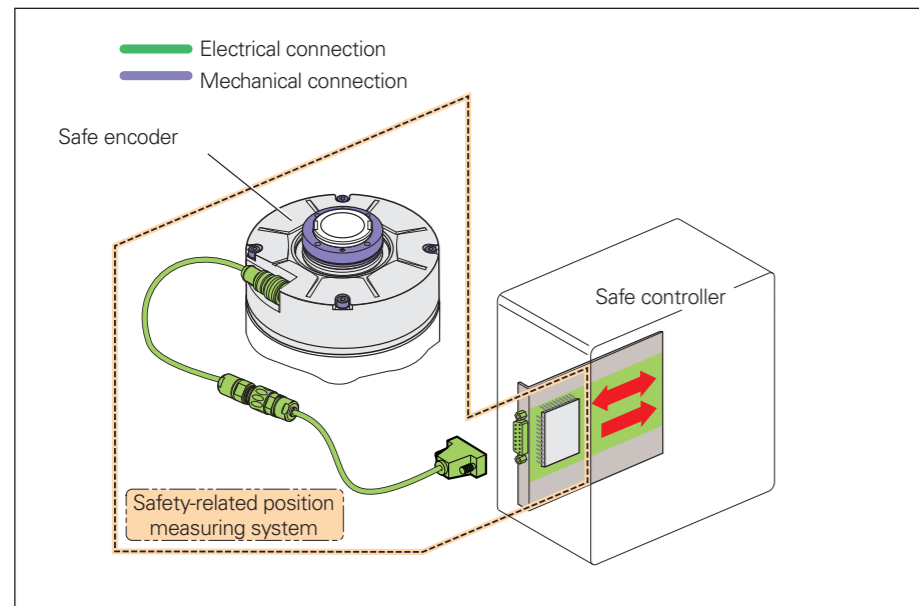
Safety-related position measuring system with mechanical connection and electrical interface

Fault exclusion for the loosening of the mechanical connection

Along with an encoder's data interface, its mechanical connection to the motor is also safety-relevant. In table D8 of the EN 61800-5-2 standard for electrical power drive systems, the loosening of the mechanical connection between the encoder and the motor is listed as a fault that requires consideration. Since it cannot be guaranteed that the controller will detect such errors, fault exclusion for the loosening of the mechanical connection is required in many cases.

There are various ways of connecting the RCN 2001, RCN 5001 and RCN 8001 series for providing this kind of fault exclusion. Whereas the housing or flange is normally fastened with screws, special factors must be considered for the hollow shaft connection. For more information on this topic and on deviating specifications, please refer to the following table.

Fault exclusion is thereby possible for the loosening of the mechanical connection between the encoder and the machine shaft or customer fastening components.

For designing the mechanical fault exclusion for other purely customer-side connections, the following encoder torque must be taken into account:

$$M_{Max} = J \cdot \alpha + M_{Friction}$$

J: Moment of inertia of the encoder (rotor or stator; see the specifications) and of the mechanical connection (e.g., ring nut and catch when acceleration is applied via the hollow shaft, and the shaft is coupled via these components)

α: Maximum angular acceleration in the application

$M_{Friction}$: RCN 2001/RCN 5001: 4.5 Nm
RCN 8001 (Ø 60 mm): 7.5 Nm
RCN 8001 (Ø 100 mm): 8.5 Nm

Mechanical connection	Fastening[1]	Safe position for the mechanical connection[2]	Limited specifications[3]
Housing/flange	*RCN 2001/5001:* M4 ISO 4762 8.8 screws *RCN 8001:* M5 ISO 4762 8.8 screws	±0°	See *Permissible angular accelerations* in *Mounting and accessories*
Hollow shaft Shaft coupling with ring nut	Ring nut and catch (see *Mounting*)	*RCN 2001:* ±0.55° *RCN 5001:* ±0.35° *RCN 8001:* Ø 60 mm: ±0.15° Ø 100 mm: ±0.10°	
Hollow shaft Front-face shaft coupling	*RCN 2001/5001:* ISO 4762 8.8 M3 screws ISO 8752 – 2.5x10 – St spring pins *RCN 8001:* M4 ISO 4762 8.8 screws ISO 8752 – 4x10 – St spring pins	*RCN 2001:* ±0.07° *RCN 5001:* ±0.06° *RCN 8001:* ±0.02°	

[1] A suitable anti-rotation lock must be used for the screw connections (mounting/servicing)
[2] Fault exclusion is granted only for the explicitly mentioned mounting options
[3] Unlike mounting without mechanical fault exclusion for the loosening of the mechanical connection

📖 **Further information:**

Adhere to the information in the following documents to ensure the correct and intended operation of the encoder:
- Mounting Instructions   *RCN 2xx1*   1307424 / 1307425
   RCN 5xx1   1307426 / 1307427
   RCN 8xx1   1307428 / 1307429 / 1307430 / 1307431
- Technical Information: *Safety-Related Position Measuring Systems*   596632

For implementation in a controller:
- Specification for the Safe Controller   533095

Mounting and accessories
RCN 2001, RCN 5001 and RCN 8001 with mechanical fault exclusion

The housing of the RCN is firmly connected to the mounting surface of the machine component via a mounting flange and centering collar.
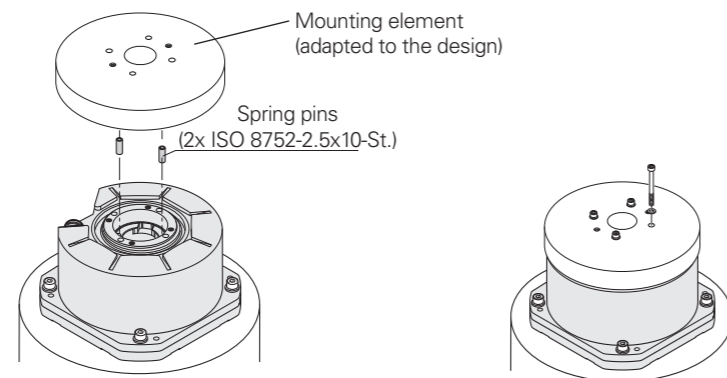
Shaft coupling with ring nut
During mounting, the hollow shaft of the angle encoder is press-fitted onto the machine shaft. The catch, which is added from above to the encoder face, implements the fault exclusion for the loosening of the mechanical connection between the encoder and the motor. Fastening is then performed with the ring nut, which can be easily tightened with the mounting aid. (for accessories and their moment of inertia, see *Accessories* on *Pages 33* to *35).*
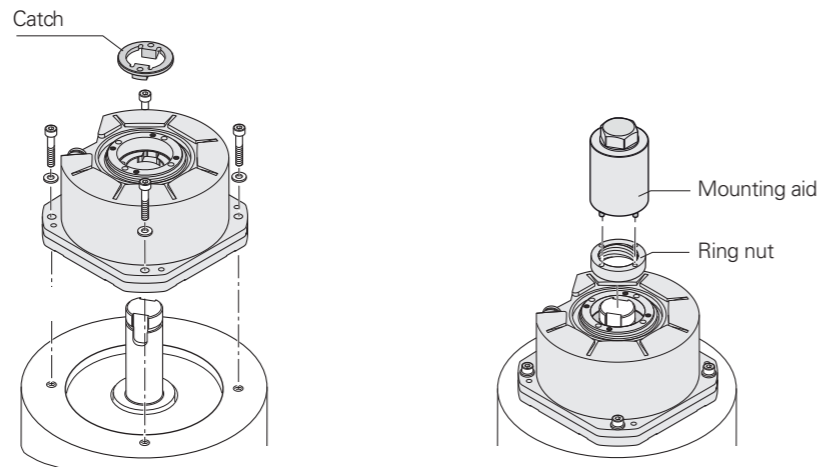
Shaft coupling with ring nut and catch (RCN 2001 as example)

Front-face shaft coupling
Particularly in the case of rotary tables, the angle encoder must be integrated into the table so as to be fully accessible when the rotor is lifted. The hollow shaft is connected through the front-face threaded holes by means of special mounting elements made for the given design (not included in delivery). For compliance with the radial runout and axial runout tolerances, the inside hole and the plane surfaces must be used as mounting surfaces for the front-face shaft coupling. Fault exclusion for the loosening of the mechanical connection between the encoder and the motor is achieved with additional spring pins.

Front-face shaft coupling (RCN 2001 as example)

Materials to be used
The materials stated in this table must be used for the machine shaft and fastening components.

Permissible angular accelerations for shaft coupling with mechanical fault exclusion
Based on where acceleration is applied and the type of mounting, the following values apply to angular acceleration:

- Permissible angular acceleration of the rotor when acceleration is applied via the hollow shaft, and the shaft is coupled with a ring nut and catch:

  RCN 2001 series: 20000 rad/s^2
  RCN 5001 series: 25000 rad/s^2
  RCN 8001 series:
  – Ø 60 mm: 4500 rad/s^2
  – Ø 100 mm: 3500 rad/s^2

- Permissible angular acceleration of the rotor when acceleration is applied via the hollow shaft, and the shaft is coupled to the front face with fastening screws and spring pins:

  RCN 2001 series: 5500 rad/s^2
  RCN 5001 series: 10000 rad/s^2
  RCN 8001 series:
  – Ø 60 mm: 3000 rad/s^2
  – Ø 100 mm: 3000 rad/s^2

- Permissible angular acceleration of the stator when acceleration is applied via the flange/housing:

  RCN 2001 series: 4000 rad/s^2
  RCN 5001 series: 2500 rad/s^2
  RCN 8001 series:
  – Ø 60 mm: 1000 rad/s^2
  – Ø 100 mm: 1000 rad/s^2

	Mating shaft	**Mating stator**
Material	Ferrous materials (steel/cast iron materials)	
Tensile strength R_m	≥ 600 N/mm^2	≥ 250 N/mm^2
Shear strength τ_B	≥ 390 N/mm^2	≥ 290 N/mm^2
Interface pressure p_G	≥ 660 N/mm^2	≥ 275 N/mm^2
Elastic modulus E	110000 N/mm^2 to 215000 N/mm^2	
Coefficient of expansion α_{therm} (at 20 °C)	$10 \cdot 10^{-6}$ K^{-1} to $17 \cdot 10^{-6}$ K^{-1}	
Mounting temperature	All information regarding screw connections is based on a mounting temperature of 15 °C to 35 °C	

RCN 2001, RCN 5001 and RCN 8001 series without mechanical fault exclusion

The housing of the RCN is firmly connected to the mounting surface of the machine component via a mounting flange and a centering collar.

Shaft coupling with ring nut

For installation, the hollow through shaft of the angle encoder is seated onto the machine shaft and fastened from the encoder's front face with a ring nut. The ring nut can be easily tightened by means of the mounting tool (see *Accessories*).
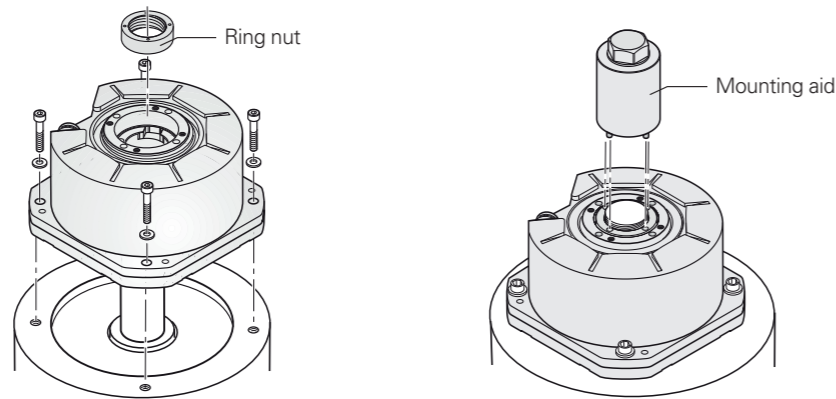
Shaft coupling with ring nut (RCN 2001 as example)

Front-face shaft coupling

The hollow shaft is connected through the front-face threaded holes by means of special mounting elements made for the given design (not included in delivery). For compliance with the radial runout and axial runout tolerances, the inside hole and plane surfaces must be used as mounting surfaces for the front-face shaft coupling.

Front-face shaft coupling (RCN 2001 as example)

Materials to be used

The materials stated in this table must be used for the machine shaft and fastening components.

Permissible angular accelerations

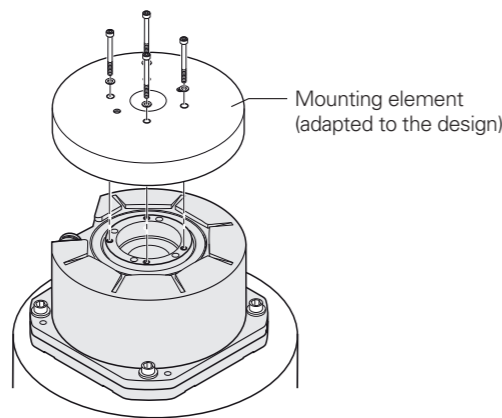The permissible angular acceleration of the rotor and stator is 1000 rad/s^2.

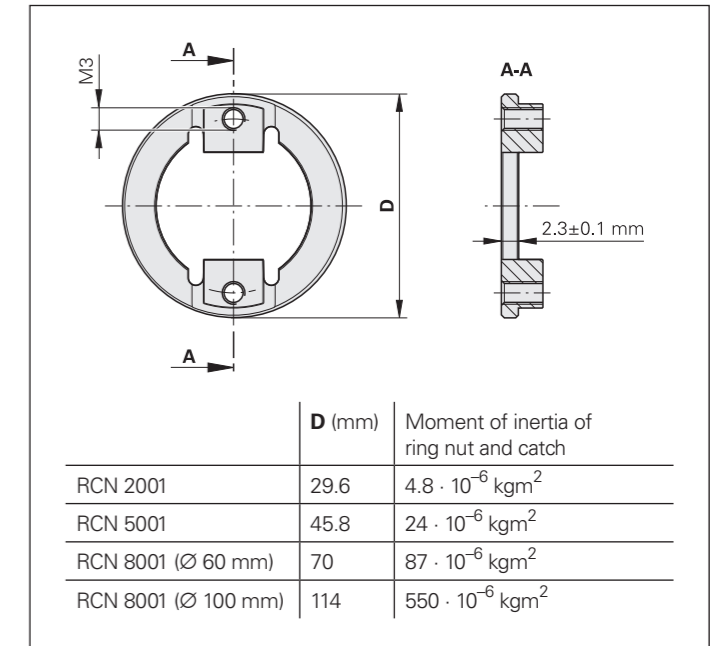|	Mating shaft	Mating stator
Material	Ferrous materials (steel/cast iron materials)	
Tensile strength R$_m$	≥ 600 N/mm^2	≥ 250 N/mm^2
Shear strength τ_B	≥ 390 N/mm^2	≥ 290 N/mm^2
Interface pressure p$_G$	≥ 660 N/mm^2	≥ 275 N/mm^2
Elastic modulus E	110 000 N/mm^2 to 215 000 N/mm^2	
Coefficient of expansion α_{therm} (at 20 °C)	$10 \cdot 10^{-6}$ K^{-1} to $17 \cdot 10^{-6}$ K^{-1}	
Mounting temperature	All information regarding screw connections is based on a mounting temperature of 15 °C to 35 °C	

Accessories

Catch

In order to ensure mechanical fault exclusion for the loosening of the mechanical connection between the encoder and the machine shaft, a catch must be used for the shaft coupling via ring nuts.

Catch for RCN 2001:   ID 817921-01
Catch for RCN 5001:   ID 817921-02
Catch for RCN 8001:
  – Hollow shaft (Ø 60 mm):   ID 817921-03
  – Hollow shaft (Ø 100 mm): ID 817921-04
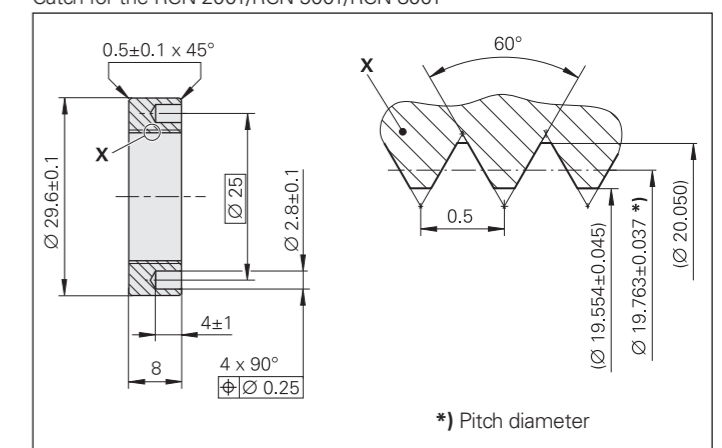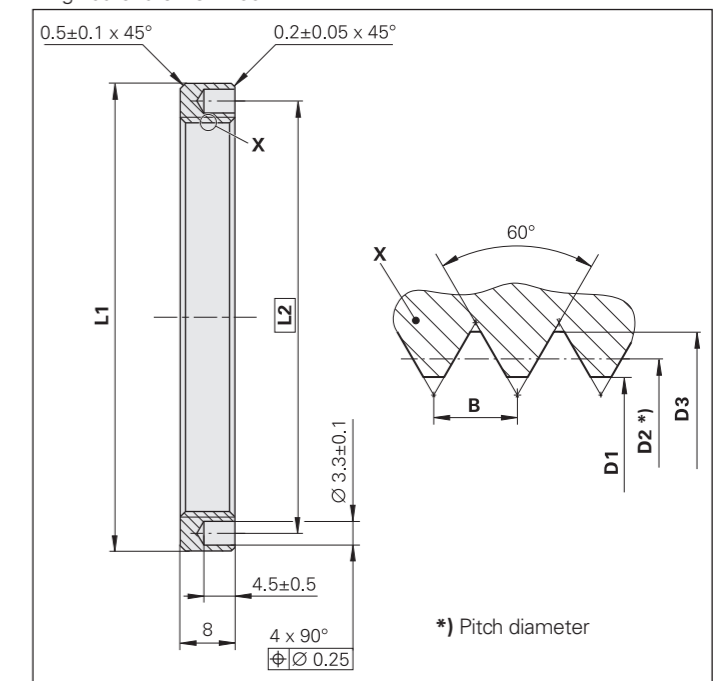
Ring nut

For fastening on the shaft side, HEIDENHAIN offers a special ring nut that, with low axial play, smoothly rotates along with the shaft thread. This ensures that the load is evenly distributed over the shaft connection and prevents adverse loading on the angular encoder's hollow shaft.

Ring nut for the RCN 2001:   ID 336669-03
Ring nut for the RCN 5001:   ID 336669-17
Ring nut for the RCN 8001:
  – Hollow shaft (Ø 60 mm):   ID 336669-11
  – Hollow shaft (Ø 100 mm): ID 336669-16

	D (mm)	Moment of inertia of ring nut and catch
RCN 2001	29.6	$4.8 \cdot 10^{-6}$ kgm^2
RCN 5001	45.8	$24 \cdot 10^{-6}$ kgm^2
RCN 8001 (Ø 60 mm)	70	$87 \cdot 10^{-6}$ kgm^2
RCN 8001 (Ø 100 mm)	114	$550 \cdot 10^{-6}$ kgm^2

Catch for the RCN 2001/RCN 5001/RCN 8001

*) Pitch diameter

Ring nut for the RCN 2001

Ring nut for	L1	L2	D1	D2	D3	B
RCN 5001	Ø 46±0.2	Ø 40	(Ø 34.052 ±0.075)	Ø 34.463 ±0.053	(Ø 35.24)	1
RCN 8001 Hollow shaft Ø 60	Ø 70±0.2	Ø 65	(Ø 59.052 ±0.075)	Ø 59.469 ±0.059	(Ø 60.06)	1
RCN 8001 Hollow shaft Ø 100	Ø 114±0.2	Ø 107	(Ø 98.538 ±0.095)	Ø 99.163 ±0.07	(Ø 100.067)	1.5

*) Pitch diameter

Mounting tool for HEIDENHAIN ring nuts

The mounting tool is used for tightening the ring nut. The tool's pins lock into the holes of the ring nut. A torque wrench allows the ring nuts to be tightened with the required tightening torque.

Mounting tool for
|	
RCN 2001:	ID 530334-03
RCN 5001:	ID 530334-17
RCN 8001:	
– Hollow shaft Ø 60 mm:	ID 530334-11
– Hollow shaft Ø 100 mm:	ID 530334-16

EIB 3392 S signal converter in cable design

The EIB 3392 S allows encoders with the "EnDat22" ordering designation to be connected to the DRIVE-CLiQ interface. With the EIB 3392 F, the Fanuc interface can be connected (resolution only as per operation with the Fanuc αi Interface).

115
77
61
Ø 10.5
EnDat22
DQ01/Fanuc05
Ø 4.5/Ø 6
Ø 20
DQ01: Ø 6.8
Fanuc05: Ø 6

Example of an EIB 3392 S
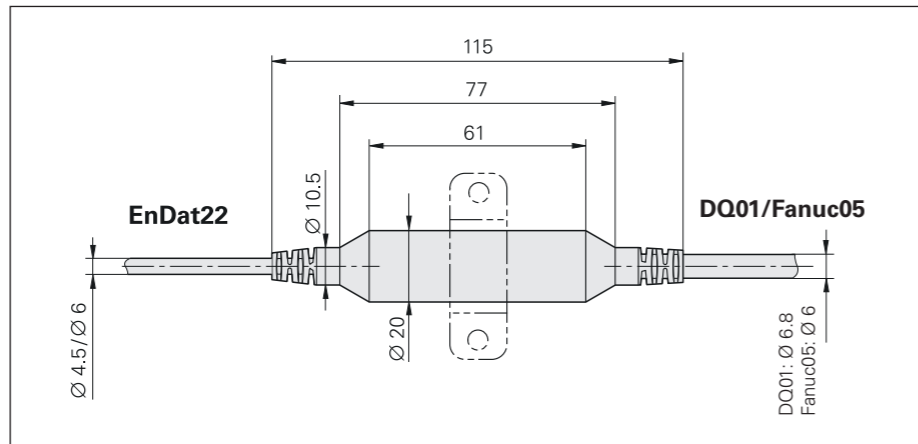
📖 **Further information:**

For a detailed description of the external interface boxes in cable design, refer to the *EIB 3392 S* and *EIB 3392 F* Product Information documents.

**EIB 5000 signal converter for measuring temperature at the direct-drive motor**

The EIB 5000 series enables the temperature measurement of direct drive motors. To do so, the EIB 5000 boxes process values from up to three temperature sensors and compensate for the transmission timing behavior of the temperature measurement (for direct-drive motors from ETEL). The maximum determined temperature is relayed to the upstream control. When the sensor box is used with a HEIDENHAIN encoder, the processed temperature values can be transmitted to the upstream control along with the position data. The control can use the temperature values to optimize the regulation of the direct-drive motor, thus ensuring rapid shutoff in the event of an overload.

The EIB 5000 series covers variants for use in an electrical cabinet (IP20) and for **in-situ** temperature measurement at the direct-drive motor (IP65).

Encoder interface	Downstream electronics interface	EIB 5000 version
EnDat22	EnDat22	EIB 5211 (IP64) EIB 5181 (IP20); only for the HEIDENHAIN control
EnDat22	DRIVE-CLiQ	EIB 5291 S (IP64); with a signal converter
Fanuc05	Fanuc05	EIB 5211 (IP64)
EnDat02	EnDat02	EIB 5281 (IP64) EIB 5181 (IP20)

In-situ measurement of a direct-drive motor   **Mounting in an electrical cabinet**

EIB 5211   EIB 5281   EIB 5291S

Control

EIB 5181

Temperature sensors
1 2 3

Direct-drive motors
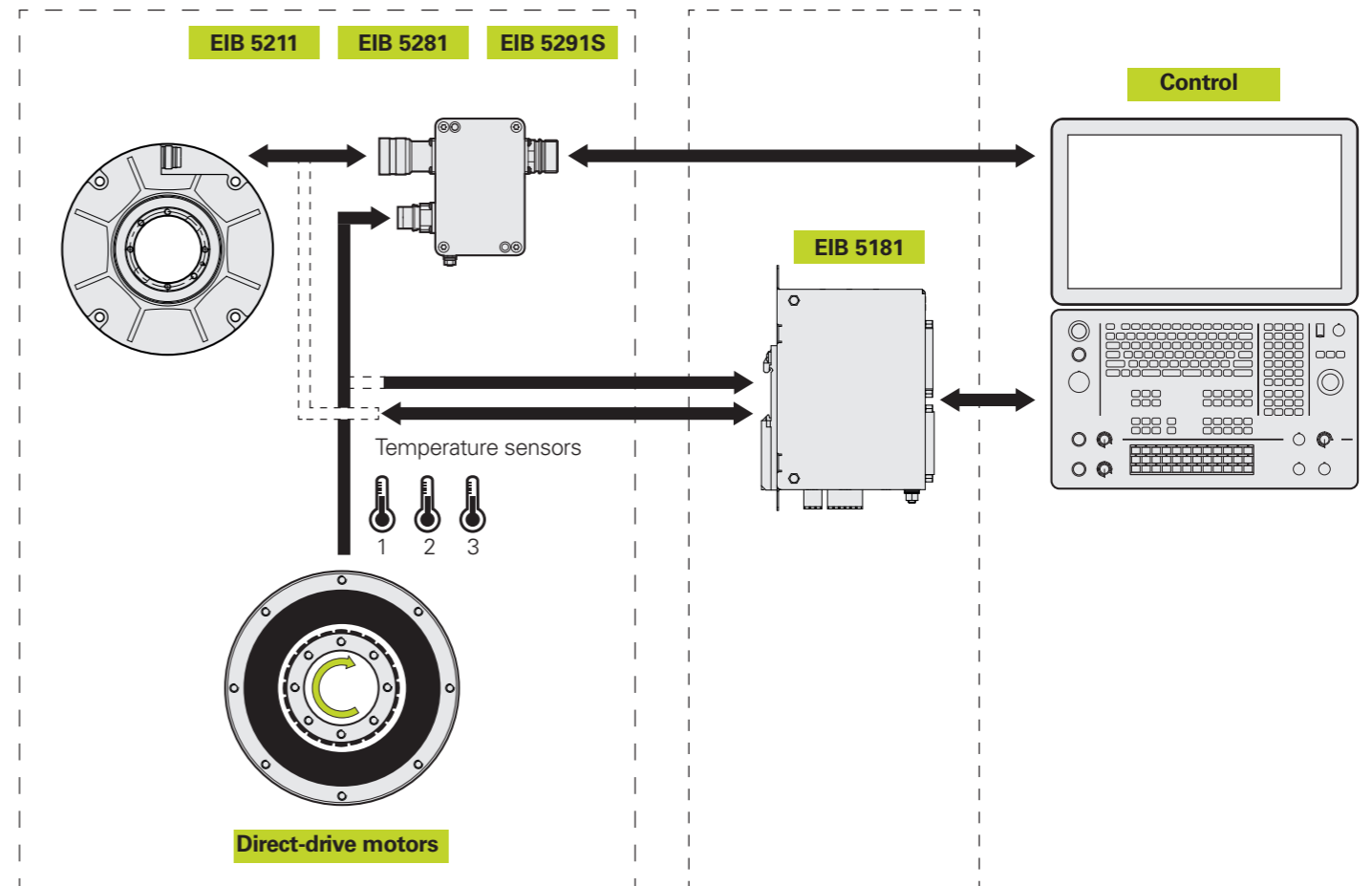
Adapter cable between the RCN 2001/RCN 5001/RCN 8001 and EIB 5211 or EIB 5291 S

PUR adapter cable Ø **6 mm;** $4 \times (2 \times 0.09\ mm^2) + (4 \times 0.16\ mm^2)$; $A_P = 2 \times 0.16\ mm^2$		
Adapter cable with 12-pin M12 quick connector and 12-pin M12 coupling (male)		1249072-xx[1]

[1] Maximum cable length: 6 m
A_P: Cross section of power supply lines
Ø: Cable diameter (for bend radii, see the *Interfaces of HEIDENHAIN Encoders* brochure)

DRIVE-CLiQ is a registered trademark of Siemens Aktiengesellschaft.

📖 **Further information:**

For a detailed description of the signal converters for temperature measurement on direct-drive motors, refer to the *EIB 5000* Product Information document.

General information
For the RCN, ECN, RON, RPN, ROC and ROD angle encoders

Protection rating
Unless otherwise stated, all RCN, ECN, RON, RPN, ROC and ROD encoders fulfill an IP64 protection rating in accordance with EN 60529 or IEC 60529.

Splash water must not contain any substances that would have harmful effects on the encoder's parts. If the standard IP64 protection rating is insufficient, such as for the shaft inlet when an angle encoder is installed vertically, then the devices should be protected by additional design measures such as labyrinth seals.

The RCN, RON, RPN, ROC and ROD angle encoders are provided with a compressed air connection. Connection to a source of compressed air slightly above atmospheric pressure generates **sealing air** and provides additional protection from contamination.

The compressed air introduced directly into the encoders must be cleaned by a microfilter and must comply with the following quality classes as per **ISO 8573-1** (2010 edition):
- Solid contaminants: **Class 1**
  Particle size: Number of particles per m^3

0.1 µm to 0.5 µm	≤ 20000
0.5 µm to 1.0 µm	≤ 400
1.0 µm to 5.0 µm	≤ 10
- Max. pressure dew point: **Class 4** (pressure dew point at 3 °C)
- Total oil content: **Class 1** (max. oil concentration 0.01 mg/m^3)

For an optimal supply of sealing air to the angular encoders with an integral bearing, the required air flow is 1 l/min to 4 l/min per encoder. Ideally, the air flow is regulated by the HEIDENHAIN connecting pieces with an integrated throttle. At an input pressure of ≈ 1 · 10^5 Pa (1 bar), the throttles ensure the required air flow rates.

Accessory:
DA 400 compressed air unit
ID 894602-01

DA 400
HEIDENHAIN offers the DA 400 compressed-air filter system for purifying the compressed air. It is designed specifically for conducting compressed air into encoders.

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

The compressed air introduced into the DA 400 must fulfill the requirements of the following purity classes as per ISO 8573-1 (2010 edition):
- Solid contaminants: **Class 5**
  Particle size: Number of particles per m^3

0.1 µm to 0.5 µm	Not specified
0.5 µm to 1.0 µm	Not specified
1.0 µm to 5.0 µm	≤ 100000
- Max. pressure dew point: **Class 6** (pressure dew point at 10 °C)
- Total oil content: **Class 4** (max. oil concentration: 5 mg/m^3)

DA 400

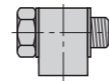Necessary for connection to angle encoders:

Connecting piece
For tubing 6 x 1
With throttle and gasket
For air-flow rate: 1 l/min to 4 l/min
ID 207835-04
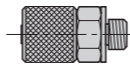
Also suitable:

Swiveling screw fitting (90°)
With seal
ID 207834-02

📖 **Further information:**
For more information, ask for our *DA 400* Product Information document

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 range** indicates the ambient temperature limits between which the angle encoders will function properly. The operating temperature is defined as the temperature in the immediate vicinity of the encoder but not at the encoder's surface.

The **storage temperature range** of –20 °C to 60 °C applies when the unit remains in its packaging. For the RPN 886 and RON 905, a storage temperature of –10 °C to 50 °C must not be exceeded.

Protection against contact
Rotating parts (e.g., shaft couplings with the ROC and ROD, ring nuts for the RCN, ECN, RON and RPN) must be sufficiently protected from unintended contact during operation.

Acceleration
Angle encoders are subject to various types of acceleration during operation and mounting.
- The **permissible angular acceleration** of the rotor and stator for the RCN/ECN/RON/RPN angle encoders is 1000 rad/s^2. To some extent, higher values apply to the RCN with fault exclusion for the loosening of the mechanical connection (see the chapters about mounting for each series).
  With the ROC and ROD angle encoders, the permissible angular acceleration varies depending on the shaft coupling and the mating shaft (more details upon request).
- The abovementioned extreme values for the **vibration resistance** apply to frequencies of 55 Hz to 2000 Hz (EN 60068-2-6), except when mechanical resonances occur.
- The maximum values for the permissible acceleration (sinusoidal shock) for **shock and impact loads** apply at 6 ms (EN 60068-2-27). During transport, they must not be higher than 1000 m/s^2 (ROD 780/880: 300 m/s^2). The corresponding values for operation are listed in the specifications.
  Under no circumstances should a hammer or similar implement be used to align the encoder.

Natural frequency f$_N$ of coupling
With the ROC and ROD angle encoders, the rotor and the shaft coupling together form an oscillation-capable spring-mass system. In the case of the RCN, ECN, RON and RPN angle encoders, this applies to the stator and stator coupling.

The **natural frequency f$_N$** should be as high as possible. For the RCN, ECN, RON and RPN angle encoders, the respective specifications state the frequency ranges at which the natural frequency of the encoder does not cause significant position deviations in the direction of measurement. Ensuring the highest possible natural frequency for **ROC and ROD angle encoders** requires the use of a **shaft coupling** with a high torsional rigidity C.

$$f_N = \frac{1}{2 \cdot \pi} \cdot \sqrt{\frac{C}{I}}$$

f$_N$: Natural frequency in Hz
C: Torsional rigidity of the shaft coupling in Nm/rad
I: Moment of inertia of the rotor in kgm^2

If radial and/or axial acceleration occurs during operation, the effect of the rigidity of the encoder bearing, the encoder stator and the coupling are also significant. If such loads occur in your application, HEIDENHAIN recommends consulting with the main office in Traunreut.

Conditions for longer storage periods
HEIDENHAIN recommends the following in order to make storage periods beyond 12 months possible:
- Leave the encoders in their original packaging.
- The storage location should be dry, free of dust, and temperature-regulated. It should not be exposed to vibrations, mechanical shock or chemical influences.
- Whenever encoders with an integral bearing have been unused for 12 months, rotate the shaft at low shaft speed and without axial or radial shaft loading so that the bearing lubrication becomes evenly redistributed (e.g., such as when first breaking in an encoder).

Compensating currents
Compensating currents conducted through the encoder bearing may negatively affect the functionality and are therefore not permissible.

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

Parts subject to wear
Encoders from HEIDENHAIN are designed for a long service life. Preventive maintenance is not required. However, they do contain components that are subject to wear, depending on the application and how they are deployed. These include in particular the following parts:
- LED light source
- Cables with frequent flexing
For encoders with an integral bearing, additionally:
- Bearing
- Shaft sealing rings for rotary encoders and angle encoders
- Sealing lips for sealed linear encoders

System tests
Encoders from HEIDENHAIN are usually integrated as components into complete systems. Applications of this type require **full-system, comprehensive testing**, regardless of the encoder's specifications. The specifications provided in this brochure apply only to the encoder and not to the entire system. Any operation of the encoder outside of the specified range or outside of its proper and intended use is solely at the user's own risk.

Mounting
The steps and dimensions that must be complied with during mounting are specified solely in the mounting instructions supplied with the device. All mounting-related information in this brochure is therefore provisional and non-binding; it does not become part of a contract.

📖 **Further information:**
Please also comply with the following planning and assembly documents:
- Brochure: *Cables and Connectors*
- Brochure: *Interfaces of HEIDENHAIN Encoders*
- Mounting Instructions of the encoder
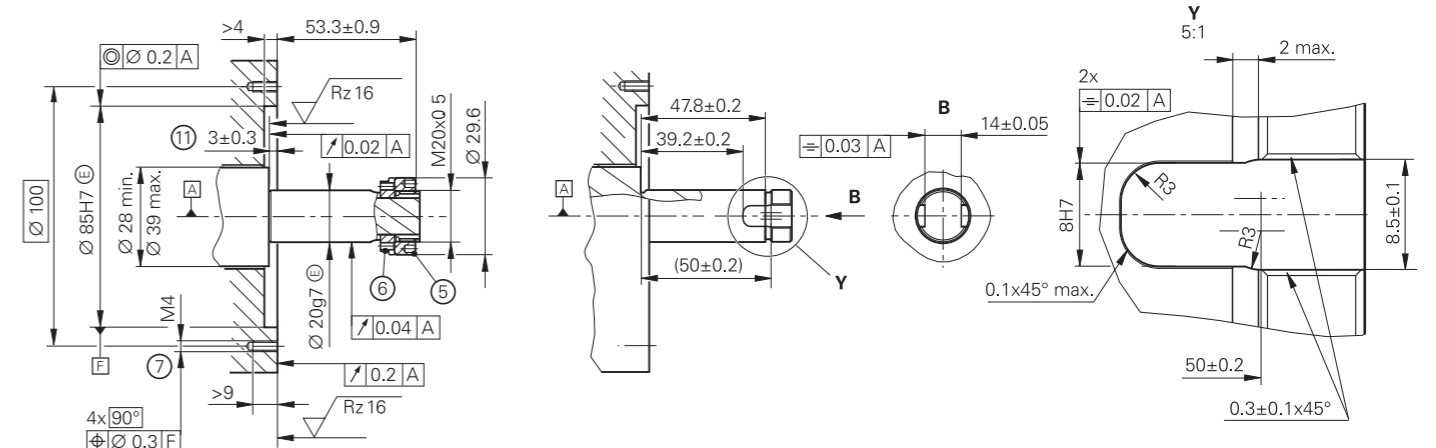- Mounting Instructions for the adapter cable

RCN 2001 series

Newest generation of absolute angle encoders
- System accuracies: ±2″ and ±4″
- Transmission of the direct-drive motor temperature
- Integrated temperature sensor
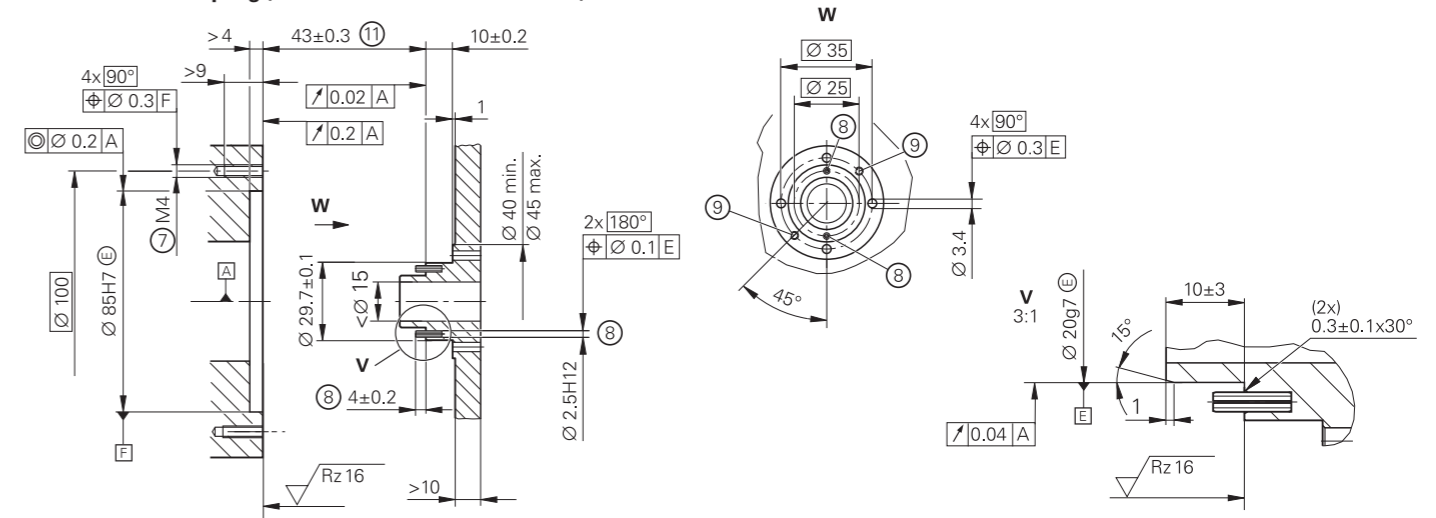- Suitability for high shaft speeds
- Hollow through shaft: Ø 20 mm

Functional Safety

mm
Tolerancing ISO 8015
ISO 2768 - m H
< 6 mm: ±0.2 mm
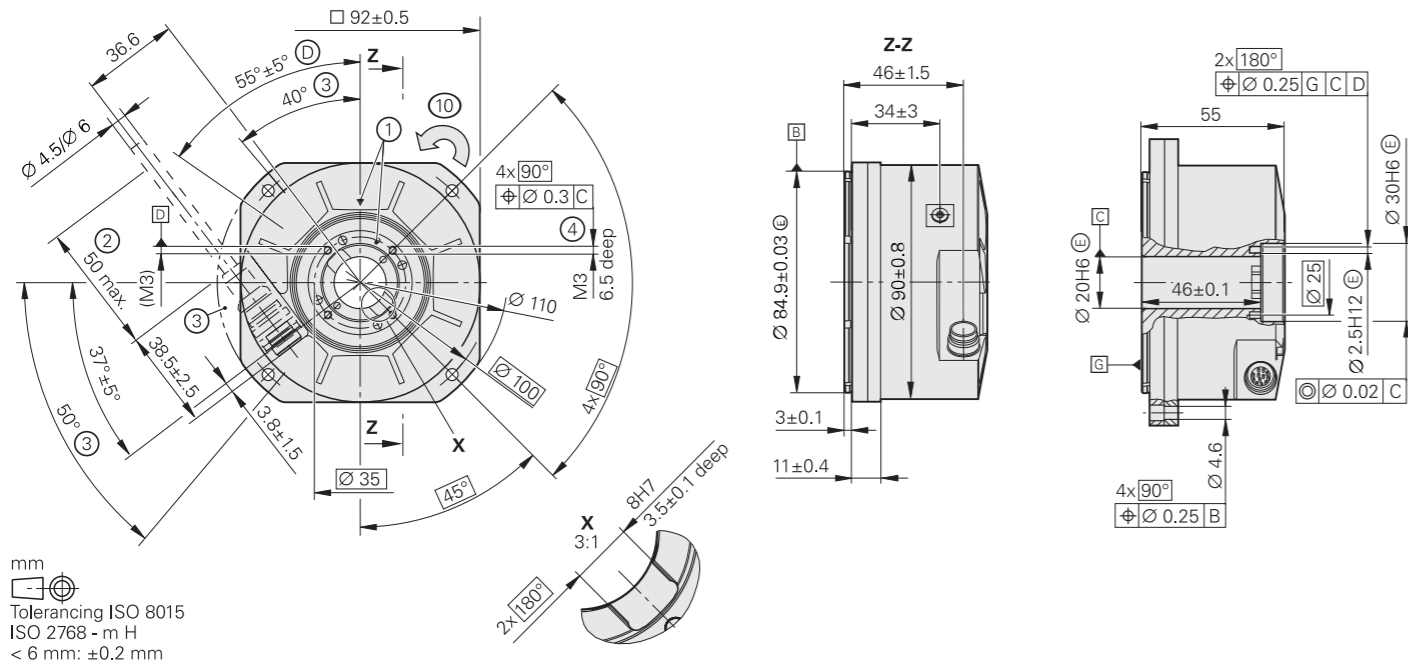
Ⓐ = Bearing of mating shaft
Ⓓ = Compressed air inlet
Ⓚ = Required mating dimensions
1 = Mark for 0° position ±5°
2 = Cable support
3 = Customer-side free space
4 = Thread engagement: 4.5 mm ±0.5 mm (for M3 cylinder head screws; for details, see the mounting instructions)
5 = Accessory: ring nut (ID 336669-03)
6 = Accessory: catch (ID 817921-01)
7 = Thread engagement: 8 mm ±1 mm (for M4x20 cylinder head screws; for details, see the mounting instructions)
8 = Two spring pins: ISO 8752 – 2.5x10 – St
9 = If spring pins are used, then provide additional M3 back-off threads
10 = Direction of shaft rotation for ascending position values
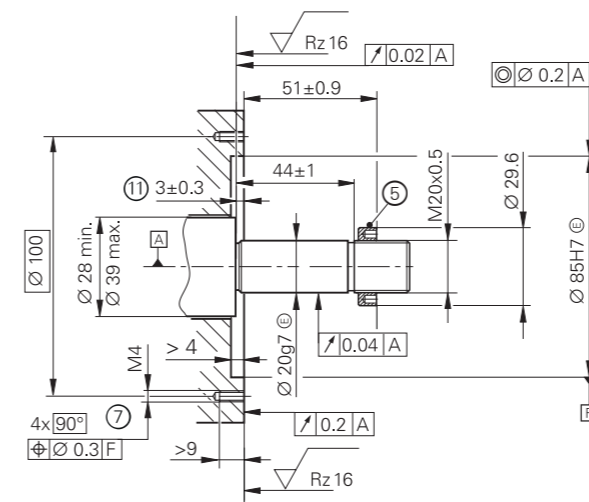11 = Stated tolerance includes mounting tolerances and thermal expansion; no dynamic movement permitted

Shaft coupling with ring nut and catch (with mechanical fault exclusion) Ⓚ
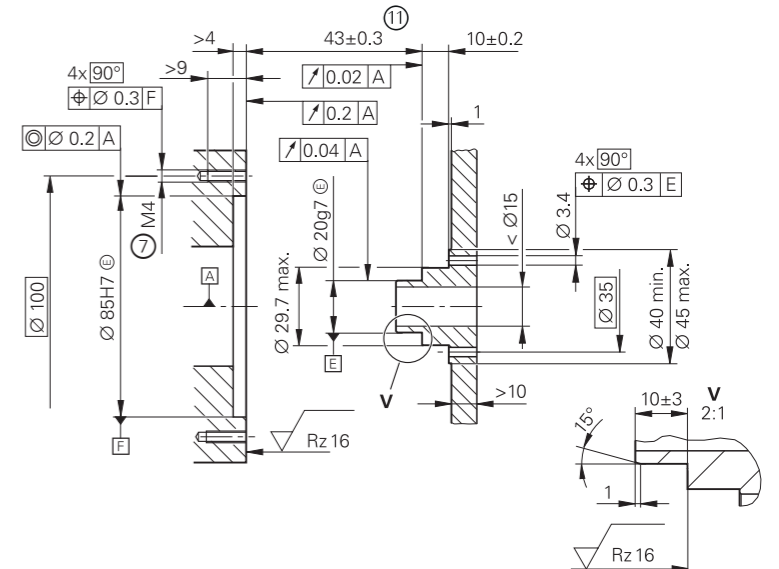

Front-face shaft coupling (with mechanical fault exclusion) Ⓚ

Shaft coupling with ring nut (without mechanical fault exclusion) Ⓚ

Front-face shaft coupling (without mechanical fault exclusion) Ⓚ

Specifications	Absolute RCN 2511 (Functional Safety)	RCN 2311 (Functional Safety)
Measuring standard	DIADUR circular scale with absolute track and incremental track (16384 lines)	
System accuracy	±2″	±4″
Position error per signal period	≤ ±0.3″	≤ ±0.4″
Functional safety for applications with up to	• SIL 2 as per EN 61508 (further basis for testing: EN 61800-5-2) • Category 3, PL d as per EN ISO 13849-1:2015	
PFH	≤ 25 · 10^{-9} (up to 2000 m above sea level)	
Safe position[1]	*Encoder:* ±0.22° (safety-related measuring step SM = 0.088°) *Mechanical coupling:* fault exclusion for the loosening of the housing/flange and hollow shaft (see *Functional safety* and *Mounting and accessories* on *Page 28/30*)	
Interface	EnDat 2.2	
Ordering designation	EnDat22	
Positions/revolution	268 435 456 (28 bits)	67 108 864 (26 bits)
Electrically permissible speed	≤ 3000 rpm for continuous position value	
Clock frequency Calculation time t_{cal}	≤ 16 MHz ≤ 5 µs	
Measurement of direct-drive motor temperature[2]	Possible with the HEIDENHAIN EIB 5000 signal converter (see *Page 34*)	
Electrical connection	Separate adapter cable connectable to encoder via quick connector	
Cable length	≤ 100 m (with HEIDENHAIN cable; clock frequency ≤ 8 MHz)	
Supply voltage	DC 3.6 V to 14 V	
Power consumption[3] (maximum)	*3.6 V:* ≤ 1.1 W *14 V:* ≤ 1.3 W	
Shaft	Hollow through shaft (Ø 20 mm)	
Mech. permiss. shaft speed (at constant speed for up to 90 min)	≤ 3000 rpm (at an operating temperature of 40 °C; for details, see the permissible shaft speeds on *Page 26*)	
Starting torque (at 20 °C)	≤ 0.08 Nm (typical)	
Moment of inertia	*Rotor (hollow shaft):* 180 · 10^{-6} kgm^2 *Stator (housing/flange):* 670 · 10^{-6} kgm^2	
Permissible axial motion of measured shaft	*Axial:* ±0.3 mm[4] *Radial:* Ø 0.2 mm for coaxially and, during operation, 0.04 mm for radial runout (each relative to the bearing axis of the mating shaft)	
Natural frequency	≥ 1000 Hz	
Vibration 55 Hz to 2000 Hz Shock 6 ms	≤ 200 m/s^2 (EN 60068-2-6) ≤ 200 m/s^2 (EN 60068-2-27)	
Operating temperature	0 °C to 60 °C	
Protection EN 60529	IP64	
Mass	≈ 1.1 kg	

[1] Further tolerances may arise in the downstream electronics after position value comparison (contact mfr. of the downstream electronics)
[2] For detailed descriptions of the signal converters for measuring the temperature of direct-drive motors, see the *EIB 5000* Product Information document
[3] See the *General electrical information* in the *Interfaces of HEIDENHAIN Encoders* brochure
[4] Range includes mounting tolerances and thermal expansion; no dynamic movement permitted
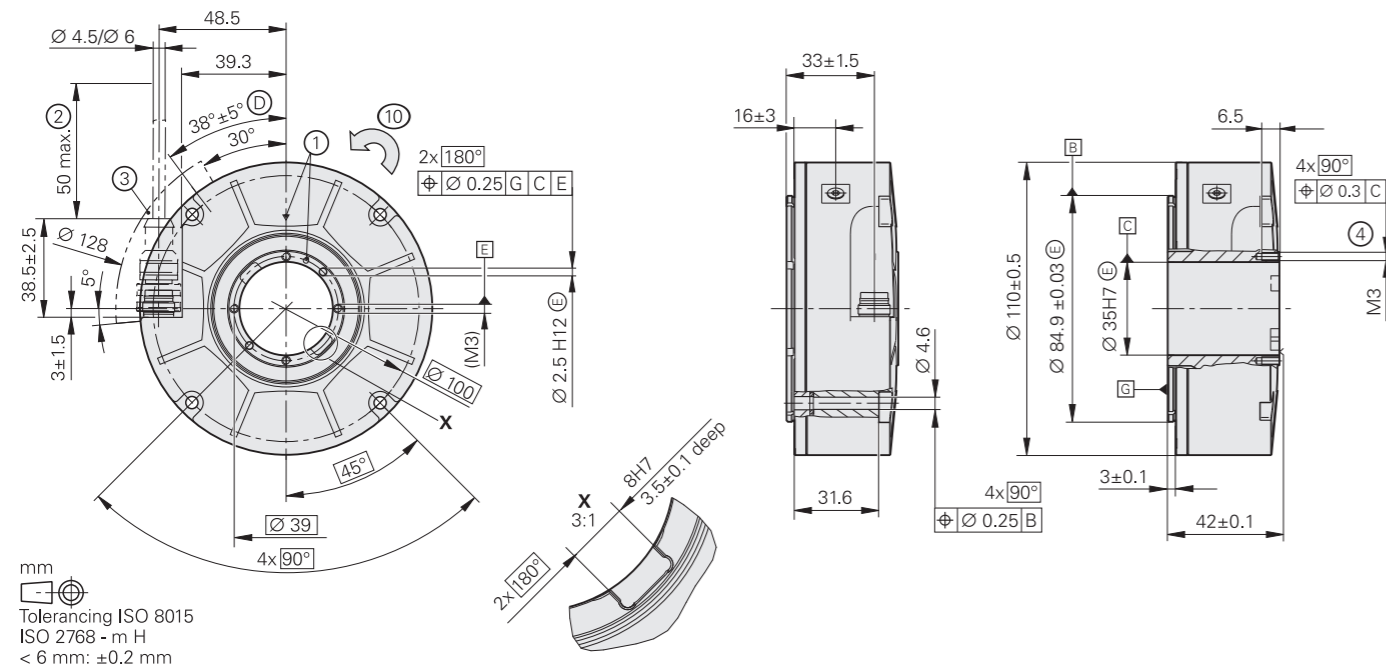
Specifications	Absolute RCN 2581 RCN 2381	RCN 2591 F RCN 2391 F	RCN 2591 M RCN 2391 M	RCN 2591 P RCN 2391 P
Measuring standard	DIADUR circular scale with absolute track and incremental track (16384 lines)			
System accuracy	*RCN 25x1:* ±2″ *RCN 23x1:* ±4″			
Position error per signal period	*RCN 2581:* ≤ ±0.4″ *RCN 2381:* ≤ ±0.4″	*RCN 25x1:* ≤ ±0.3″ *RCN 23x1:* ≤ ±0.4″		
Interface	EnDat 2.2	Fanuc Serial Interface αi interface[1]	Mitsubishi high speed interface	Panasonic Serial Interface
Ordering designation	EnDat02	Fanuc05	Mit03-4	Pana02
Position values/revolution[1]	*RCN 25x1:* 268 435 456 (28 bits) *RCN 23x1:* 67 108 864 (26 bits)			
Electrically permissible speed	≤ 1500 rpm for continuous position values	≤ 3000 rpm for continuous position value		
Clock frequency Calculation time t_{cal}	≤ 2 MHz ≤ 8 µs	–		
Incremental signals Cutoff frequency –3 dB	⎍ 1 V$_{PP}$ ≥ 400 kHz	–		
Measurement of direct-drive motor temperature[2]	Possible with the HEIDENHAIN EIB 5000 signal converter (see *Page 34*)	–		
Electrical connection	Separate adapter cable connectable to encoder via quick connector			
Cable length[3]	≤ 150 m	≤ 50 m		≤ 30 m
Supply voltage	DC 3.6 V to 14 V			
Power consumption[4] (maximum)	*3.6 V:* ≤ 1.1 W *14 V:* ≤ 1.3 W			
Shaft	Hollow through shaft (Ø 20 mm)			
Mech. permiss. shaft speed (at constant speed for up to 90 min)	*RCN 2x81:* ≤ 1500 rpm *RCN 2x91:* ≤ 3000 rpm (at an operating temperature of 40 °C; for more details, see the permissible shaft speeds on *Page 26*)			
Starting torque (at 20 °C)	Typically ≤ 0.08 Nm			
Moment of inertia	*Rotor (hollow shaft):* 180 · 10^{-6} kgm^2; *stator (housing/flange):* 670 · 10^{-6} kgm^2			
Permissible axial motion of measured shaft	*Axial:* ±0.3 mm[5] *Radial:* Ø 0.2 mm coaxiality and 0.04 mm runout during operation (each relative to the bearing axis of the mating shaft)			
Natural frequency	≥ 1000 Hz			
Vibration 55 Hz to 2000 Hz Shock 6 ms	≤ 200 m/s^2 (EN 60068-2-6) ≤ 200 m/s^2 (EN 60068-2-27)			
Operating temperature	0 °C to 60 °C			
Protection EN 60529	IP64			
Mass	≈ 1.1 kg			

[1] Reduced resolution during operation for the Fanuc α interface; *RCN 2591 F:* 134 217 728 (27 bits); *RCN 2391 F:* 8388608 (23 bits)
[2] For detailed descriptions of the signal converters for measuring the temperature of direct-drive motors, see the *EIB 5000* Product Information document
[3] With HEIDENHAIN cable ≤ 8 MHz
[4] See the *General electrical information* in the *Interfaces of HEIDENHAIN Encoders* brochure
[5] Range includes mounting tolerances and thermal expansion; no dynamic movement permitted

RCN 5001 series
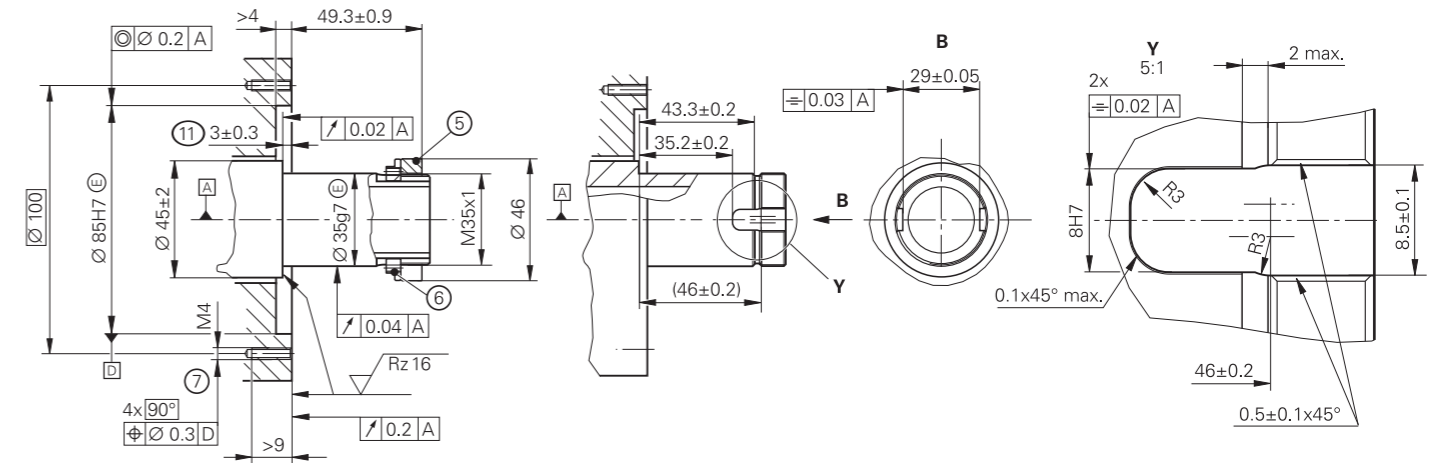
Newest generation of absolute angle encoders
- **System accuracies: ±2" and ±4"**
- **Transmission of the direct-drive motor temperature**
- **Integrated temperature sensor**
- **Suitability for high shaft speeds**
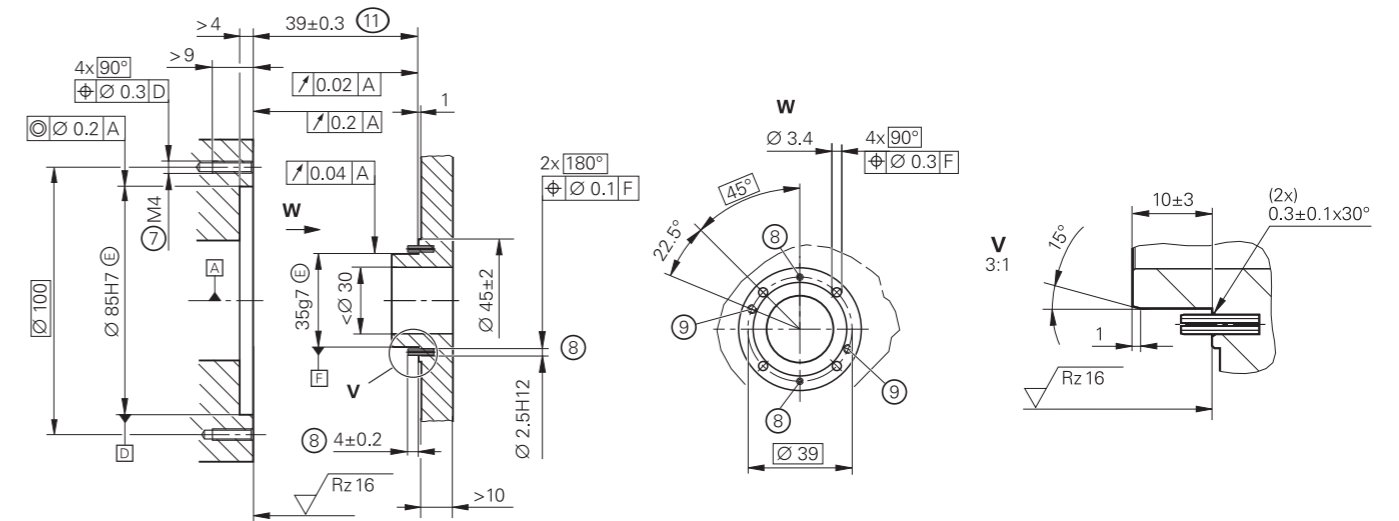- **Hollow through shaft: Ø 35 mm**

Functional Safety

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

Shaft coupling with ring nut and catch (with mechanical fault exclusion) Ⓚ

Front-face shaft coupling (with mechanical fault exclusion) Ⓚ

Shaft coupling with ring nut (without mechanical fault exclusion) Ⓚ

Front-face shaft coupling (without mechanical fault exclusion) Ⓚ

Ⓐ = Bearing of mating shaft
Ⓓ = Compressed air inlet
Ⓚ = Required mating dimensions
1 = Mark for 0° position ±5°
2 = Cable support
3 = Customer-side free space
4 = Thread engagement: 4.5 mm ±0.5 mm (for M3 cylinder head screws; for details, see the mounting instructions)
5 = Accessory: ring nut (ID 336669-17)
6 = Accessory: catch (ID 817921-02)
7 = Thread engagement: 8 mm ±1 mm (for M4x20 cylinder head screws; for details, see the mounting instructions)
8 = Two spring pins: ISO 8752 – 2.5x10 – St
9 = If spring pins are used, then provide additional M3 back-off threads
10 = Direction of shaft rotation for ascending position values
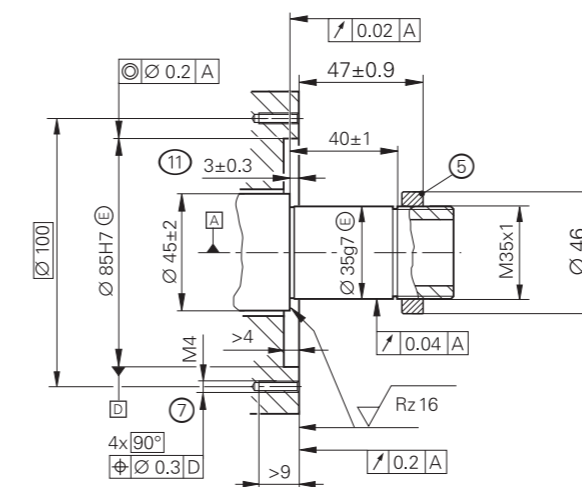11 = Stated tolerance includes mounting tolerances and thermal expansion; no dynamic movement permitted

Specifications	*Absolute* RCN 5511 [Functional Safety]	RCN 5311 [Functional Safety]
Measuring standard	DIADUR circular scale with absolute track and incremental track (16384 lines)	
System accuracy	±2″	±4″
Position error per signal period	≤ ±0.3″	≤ ±0.4″
Functional safety for applications with up to	• SIL 2 as per EN 61508 (further basis for testing: EN 61800-5-2) • Category 3, PL d as per EN ISO 13849-1:2015	
PFH	≤ 25 · 10^{-9} (up to 2000 m above sea level)	
Safe position[1]	*Encoder:* ±0.22° (safety-related measuring step SM = 0.088°) *Mechanical coupling:* fault exclusion for the loosening of the housing/flange and hollow shaft (see *Functional safety* and *Mounting and accessories* on *Page 28/30*)	
Interface	EnDat 2.2	
Ordering designation	EnDat22	
Positions per revolution	268435456 (28 bits)	67108864 (26 bits)
Electrically permissible speed	≤ 3000 rpm for continuous position value	
Clock frequency Calculation time t_{cal}	≤ 16 MHz ≤ 5 µs	
Measurement of direct-drive motor temperature[2]	Possible with the HEIDENHAIN EIB 5000 signal converter (see *Page 34*)	
Electrical connection	Separate adapter cable connectable to encoder via quick connector	
Cable length	≤ 100 m (with HEIDENHAIN cable; clock frequency ≤ 8 MHz)	
Supply voltage	DC 3.6 V to 14 V	
Power consumption[3] (maximum)	*3.6 V:* ≤ 1.1 W *14 V:* ≤ 1.3 W	
Shaft	Hollow through shaft (Ø 35 mm)	
Mech. permiss. shaft speed (at constant speed for up to 90 min)	≤ 2000 rpm (at an operating temperature of 40 °C; for more details, see the permissible shaft speeds on *Page 26*)	
Starting torque (at 20 °C)	≤ 0.2 Nm (typical)	
Moment of inertia	*Rotor (hollow shaft):* 130 · 10^{-6} kgm^2 *Stator (housing/flange):* 1010 · 10^{-6} kgm^2	
Permissible axial motion of measured shaft	*Axial:* ±0.3 mm[4] *Radial:* Ø 0.2 mm for coaxiality and, during operation, 0.04 mm for radial runout (each relative to the bearing axis of the mating shaft)	
Natural frequency	≥ 1000 Hz	
Vibration 55 Hz to 2000 Hz **Shock** 6 ms	≤ 200 m/s^2 (EN 60068-2-6) ≤ 200 m/s^2 (EN 60068-2-27)	
Operating temperature	0 °C to 60 °C	
Protection EN 60529	IP64	
Mass	≈ 0.9 kg	

[1] Further tolerances may arise in the downstream electronics after position value comparison (contact mfr. of the downstream electronics)
[2] For detailed descriptions about signal converters for measuring the temperature of direct-drive motors, see the *EIB 5000* Product Information document
[3] See the *General electrical information* in the *Interfaces of HEIDENHAIN Encoders* brochure
[4] Range includes mounting tolerances and thermal expansion; no dynamic movement permitted
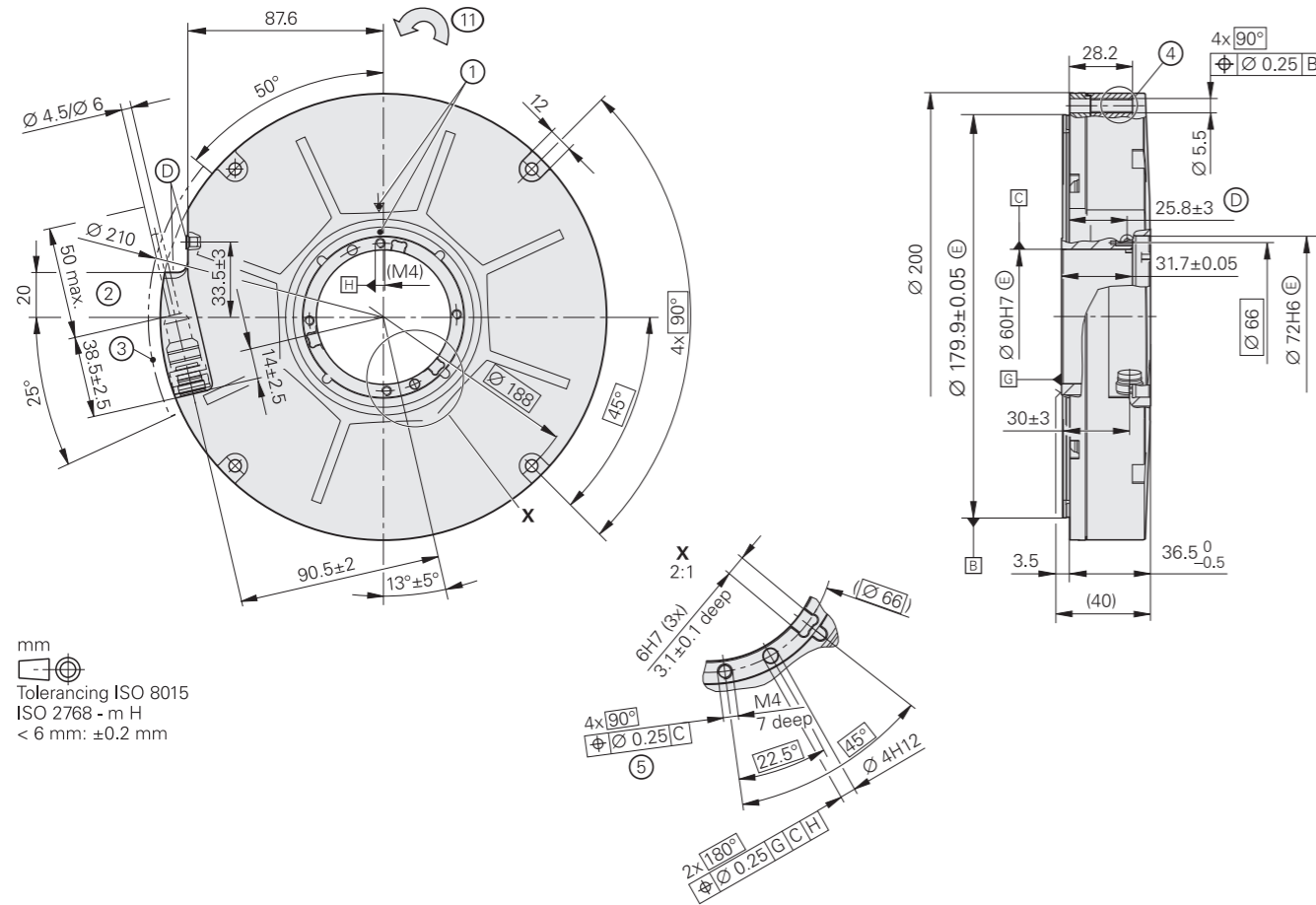
Specifications	*Absolute* RCN 5581 RCN 5381	RCN 5591 F RCN 5391 F	RCN 5591 M RCN 5391 M	RCN 5591 P RCN 5391 P
Measuring standard	DIADUR circular scale with absolute track and incremental track (16384 lines)			
System accuracy	*RCN 55x1:* ±2″ *RCN 53x1:* ±4″			
Position error per signal period	*RCN 5581:* ≤ ±0.4″ *RCN 5381:* ≤ ±0.4″	*RCN 55x1:* ≤ ±0.3″ *RCN 53x1:* ≤ ±0.4″		
Interface	EnDat 2.2	Fanuc Serial Interface αi interface[1]	Mitsubishi high speed interface	Panasonic Serial Interface
Ordering designation	EnDat02	Fanuc05	Mit03-4	Pana02
Positions per revolution[1]	*RCN 55x1:* 268435456 (28 bits) *RCN 53x1:* 67108864 (26 bits)			
Electrically permissible speed	≤ 1500 rpm for continuous position values	≤ 3000 rpm for continuous position values		
Clock frequency Calculation time t_{cal}	≤ 2 MHz ≤ 8 µs	–		
Incremental signals Cutoff frequency –3 dB	⌒ 1 V$_{PP}$ ≥ 400 kHz	–		
Measurement of direct-drive motor temperature[2]	Possible with the HEIDENHAIN EIB 5000 signal converter (see *Page 34*)	–		
Electrical connection	Separate adapter cable connectable to encoder via quick connector			
Cable length[3]	≤ 150 m	≤ 50 m		≤ 30 m
Supply voltage	DC 3.6 V to 14 V			
Power consumption[4] (maximum)	*3.6 V:* ≤ 1.1 W *14 V:* ≤ 1.3 W			
Shaft	Hollow through shaft (Ø 35 mm)			
Mech. permiss. shaft speed (at constant speed for up to 90 min)	*RCN 5x81:* ≤ 1500 rpm (operating temperature ≤ 50 °C) ≤ 1200 rpm (operating temperature > 50 °C) *RCN 5x91:* ≤ 2000 rpm (at an operating temperature of 40 °C; for more details, see the permissible shaft speeds on *Page 26*)			
Starting torque (at 20 °C)	Typically ≤ 0.2 Nm			
Moment of inertia	*Rotor (hollow shaft):* 130 · 10^{-6} kgm^2; *stator (housing/flange):* 1010 · 10^{-6} kgm^2			
Permissible axial motion of measured shaft	*Axial:* ±0.3 mm[5] *Radial:* Ø 0.2 mm coaxiality and 0.04 mm runout during operation (each relative to the bearing axis of the mating shaft)			
Natural frequency	≥ 1000 Hz			
Vibration 55 Hz to 2000 Hz **Shock** 6 ms	≤ 200 m/s^2 (EN 60068-2-6) ≤ 200 m/s^2 (EN 60068-2-27)			
Operating temperature	0 °C to 60 °C			
Protection EN 60529	IP64			
Mass	≈ 0.9 kg			

[1] Reduced resolution during operation with the Fanuc α interface; *RCN 5591 F:* 134217728 (27 bits); *RCN 5391 F:* 8388608 (23 bits)
[2] For detailed descriptions about signal converters for measuring the temperature of direct-drive motors, see the *EIB 5000* Product Information document
[3] With HEIDENHAIN cable ≤ 8 MHz
[4] See *General electrical information* in the *Interfaces of HEIDENHAIN Encoders* brochure
[5] Range includes mounting tolerances and thermal expansion; no dynamic movement permitted

RCN 8001 series

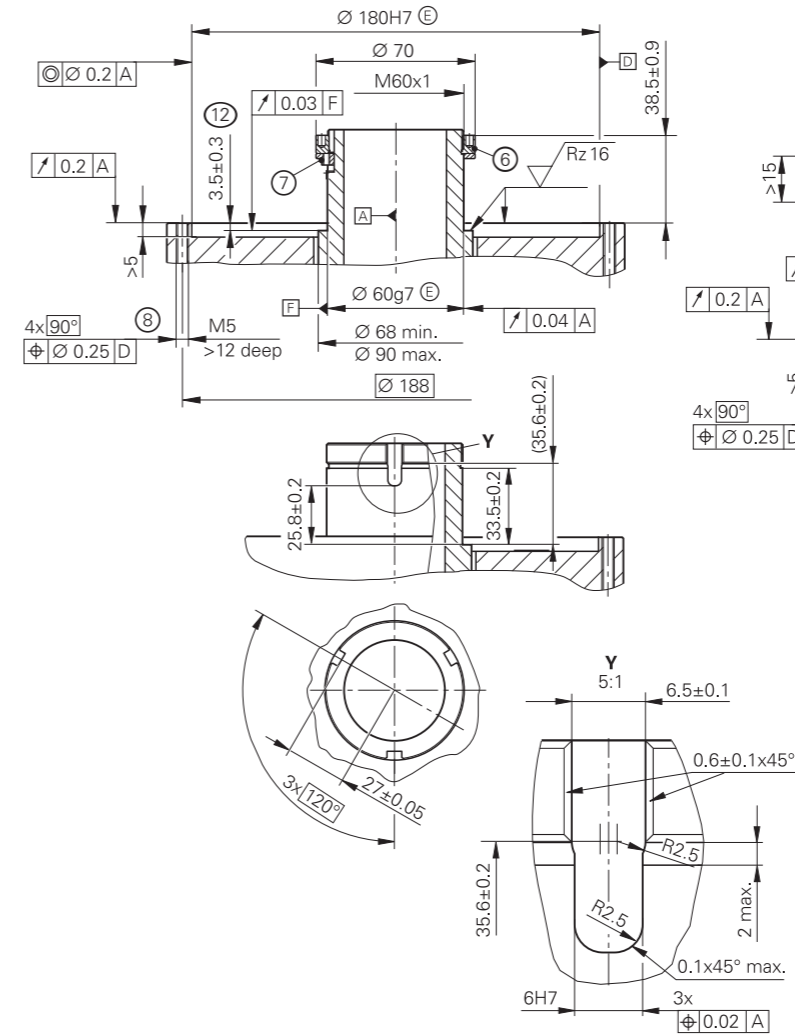**Newest generation of absolute angle encoders**
- **System accuracies: ±1" and ±2"**
- **Transmission of the direct-drive motor temperature**
- **Integrated temperature sensor**
- **Suitability for high shaft speeds**
- **Hollow through shaft: Ø 60 mm**

Functional Safety
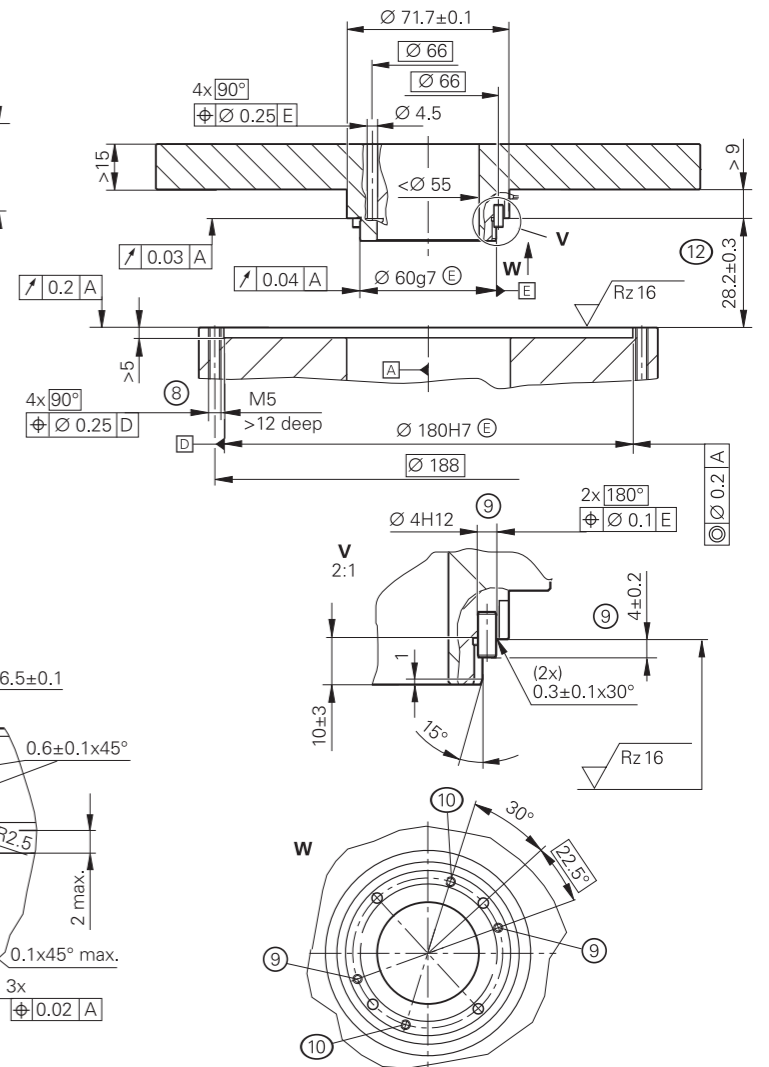
mm

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

Ⓐ = Bearing of mating shaft
Ⓓ = Compressed air inlet
Ⓚ = Required mating dimensions
1 = Mark for 0° position ±5°
2 = Cable support
3 = Customer-side free space
4 = Shown rotated by 45°
5 = Thread engagement: 5.5 mm ±0.5 mm (for M4 cylinder head screws; for details, see the mounting instructions)
6 = Accessory: ring nut (ID 336669-11)
7 = Accessory: catch (ID 817921-03)
8 = Thread engagement: 11 mm ±1 mm (for M5x40 cylinder head screws; for details, see mounting instructions)
9 = Two spring pins: ISO 8752 – 4x10 – St
10 = Provide additional M4 back-off thread if spring pins are used
11 = Direction of shaft rotation for ascending position values
12 = Stated tolerance includes mounting tolerances and thermal expansion; no dynamic movement permitted
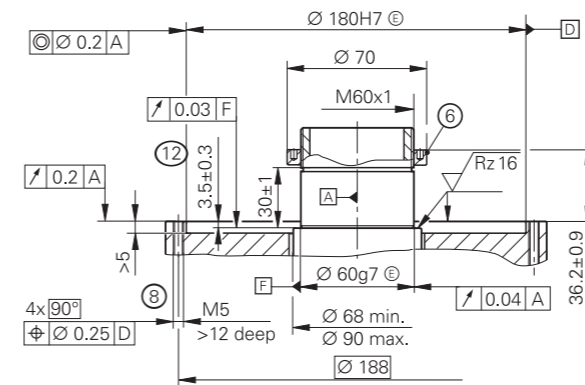
Shaft coupling with ring nut and catch
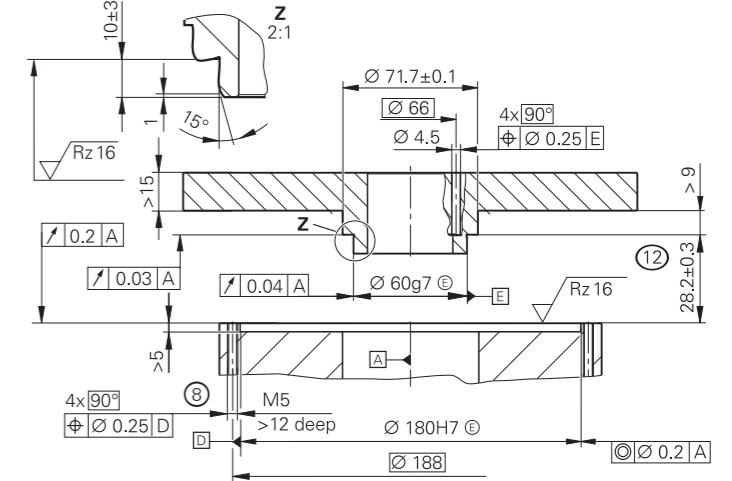**(with mechanical fault exclusion)** Ⓚ

Front-face shaft coupling
(with mechanical fault exclusion) Ⓚ

Shaft coupling with ring nut
(without mechanical fault exclusion) Ⓚ

**Front-face shaft coupling**
(without mechanical fault exclusion) Ⓚ

Specifications	Absolute RCN 8511 [Functional Safety]	RCN 8311 [Functional Safety]
Measuring standard	DIADUR circular scale with absolute track and incremental track (32 768 lines)	
System accuracy	±1″	±2″
Position error per signal period	≤ ±0.15″	≤ ±0.2″
Functional safety for applications with up to	• SIL 2 as per EN 61508 (further basis for testing: EN 61800-5-2) • Category 3, PL d as per EN ISO 13849-1:2015	
PFH	≤ 25 · 10^{-9} (up to 2000 m above sea level)	
Safe position[1]	*Encoder:* ±0.11° (safety-related measuring step SM = 0.044°) *Mechanical coupling:* fault exclusion for the loosening of the housing/flange and hollow shaft (see *Functional safety* and *Mounting and accessories* on *Page 28/30*)	
Interface	EnDat 2.2	
Ordering designation	EnDat22	
Positions per revolution	536 870 912 (29 bits)	
Electrically permissible speed	≤ 1500 rpm for continuous position values	
Clock frequency Calculation time t$_{cal}$	≤ 16 MHz ≤ 5 µs	
Measurement of direct-drive motor temperature[2]	Possible with the HEIDENHAIN EIB 5000 signal converter (see *Page 34*)	
Electrical connection	Separate adapter cable connectable to encoder via quick connector	
Cable length	≤ 100 m (with HEIDENHAIN cable; clock frequency ≤ 8 MHz)	
Supply voltage	DC 3.6 V to 14 V	
Power consumption[3] (maximum)	*3.6 V:* ≤ 1.1 W *14 V:* ≤ 1.3 W	
Shaft	Hollow through shaft (Ø 60 mm)	
Mech. permiss. shaft speed (at constant speed for up to 90 min)	≤ 1500 rpm (at an operating temperature of 40 °C; for more details, see the permissible shaft speeds on *Page 26*)	
Starting torque (at 20 °C)	≤ 0.7 Nm (typical)	
Moment of inertia	*Rotor (hollow shaft):* 1.22 · 10^{-3} kgm^2 *Stator (housing/flange):* 11 · 10^{-3} kgm^2	
Permissible axial motion of measured shaft	*Axial:* ±0.3 mm[4] *Radial:* Ø 0.2 mm for coaxiality and, during operation, 0.04 mm for radial runout (each relative to the bearing axis of the mating shaft)	
Natural frequency	≥ 900 Hz	
Vibration 55 Hz to 2000 Hz Shock 6 ms	≤ 200 m/s^2 (EN 60068-2-6) ≤ 200 m/s^2 (EN 60068-2-27)	
Operating temperature	0 °C to 50 °C	
Protection EN 60529	IP64	
Mass	≈ 2.8 kg	

[1] Further tolerances may arise in the downstream electronics after position value comparison (contact mfr. of the downstream electronics)
[2] For detailed descriptions about signal converters for measuring the temperature of direct-drive motors, see the *EIB 5000* Product Information document
[3] See *General electrical information* in the *Interfaces of HEIDENHAIN Encoders* brochure
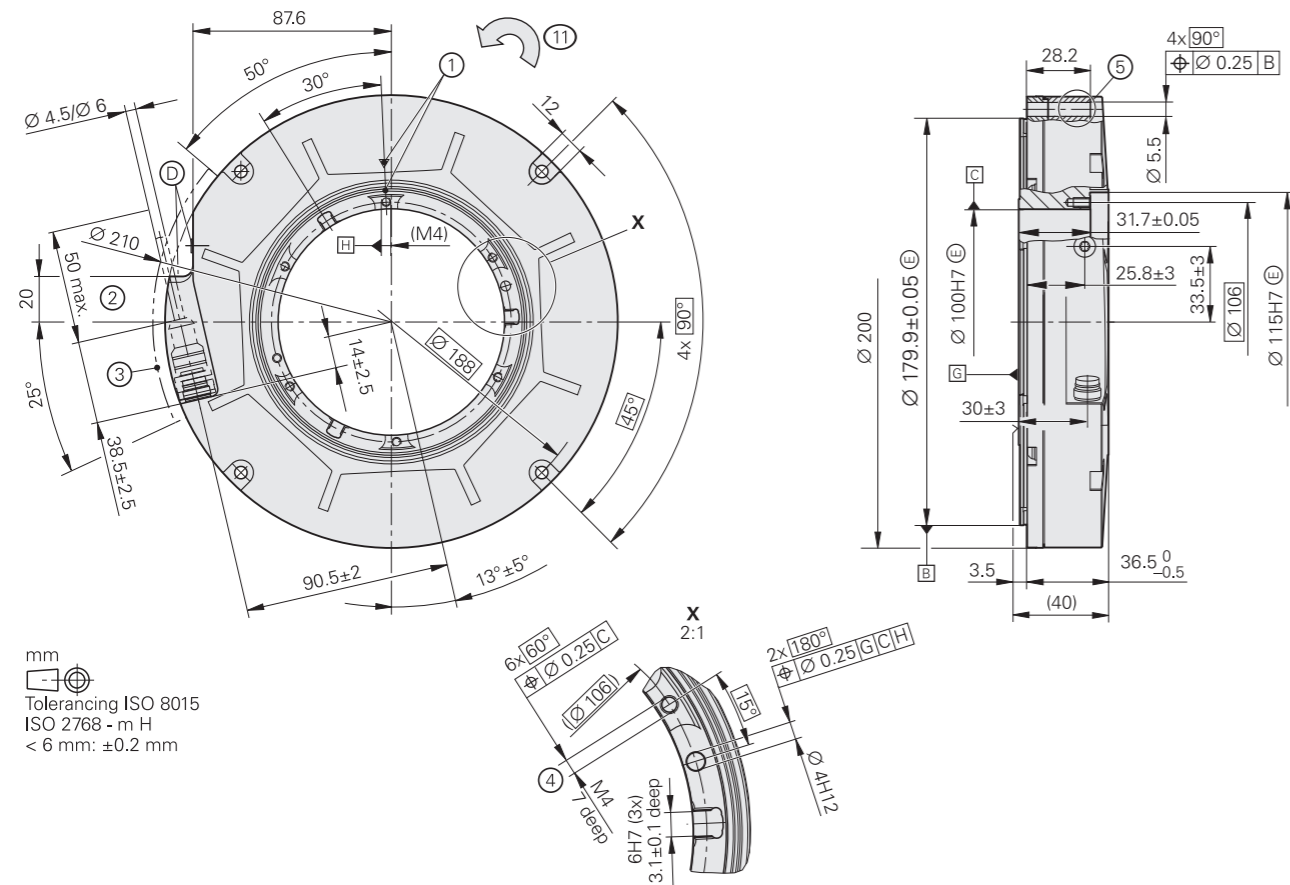[4] Range includes mounting tolerances and thermal expansion; no dynamic movement permitted

Specifications	Absolute RCN 8581 RCN 8381	RCN 8591 F RCN 8391 F	RCN 8591 M RCN 8391 M	RCN 8591 P RCN 8391 P
Measuring standard	DIADUR circular scale with absolute track and incremental track (32 768 lines)			
System accuracy	*RCN 85x1:* ±1″ *RCN 83x1:* ±2″			
Position error per signal period	*RCN 8581:* ≤ ±0.2″ *RCN 8381:* ≤ ±0.2″	*RCN 85x1:* ≤ ±0.15″ *RCN 83x1:* ≤ ±0.2″		
Interface	EnDat 2.2	Fanuc Serial Interface αi interface[1]	Mitsubishi high speed interface	Panasonic Serial Interface
Ordering designation	EnDat02	Fanuc05	Mit03-4	Pana02
Position values/revolution[1]	536 870 912 (29 bits)			
Electrically permissible speed	≤ 750 rpm for continuous position values	≤ 1500 rpm for continuous position values		
Clock frequency Calculation time t$_{cal}$	≤ 2 MHz ≤ 8 µs	–		
Incremental signals Cutoff frequency –3 dB	◠ 1 V$_{PP}$ ≥ 400 kHz	–		
Measurement of direct-drive motor temperature[2]	Possible with the HEIDENHAIN EIB 5000 signal converter (see *Page 34*)	–		
Electrical connection	Separate adapter cable connectable to encoder via quick connector			
Cable length[3]	≤ 150 m	≤ 50 m		≤ 30 m
Supply voltage	DC 3.6 V to 14 V			
Power consumption[4] (maximum)	*3.6 V:* ≤ 1.1 W *14 V:* ≤ 1.3 W			
Shaft	Hollow through shaft (Ø 60 mm)			
Mech. permiss. shaft speed (at constant speed for up to 90 min)	*RCN 8x81:* ≤ 750 rpm *RCN 8x91:* ≤ 3000 rpm (at an operating temperature of 40 °C; for more details, see the permissible shaft speeds on *Page 26*)			
Starting torque (at 20 °C)	Typically ≤ 0.7 Nm			
Moment of inertia	*Rotor (hollow shaft):* 1.22 · 10^{-3} kgm^2 *Stator (housing/flange):* 11 · 10^{-3} kgm^2			
Permissible axial motion of measured shaft	*Axial:* ±0.3 mm[5] *Radial:* Ø 0.2 mm coaxiality and 0.04 mm runout during operation (each relative to the bearing axis of the mating shaft)			
Natural frequency	≥ 900 Hz			
Vibration 55 Hz to 2000 Hz Shock 6 ms	≤ 200 m/s^2 (EN 60068-2-6) ≤ 200 m/s^2 (EN 60068-2-27)			
Operating temperature	0 °C to 50 °C			
Protection EN 60529	IP64			
Mass	≈ 2.8 kg			

[1] Reduced resolution during operation with the Fanuc α Interface; *RCN 8x91 F:* 134 217 728 (27 bits)
[2] For detailed descriptions about signal converters for measuring the temperature of direct-drive motors, see the *EIB 5000* Product Information document
[3] With HEIDENHAIN cable ≤ 8 MHz
[4] See *General electrical information* in the *Interfaces of HEIDENHAIN Encoders* brochure
[5] Range includes mounting tolerances and thermal expansion; no dynamic movement permitted

RCN 8001 series

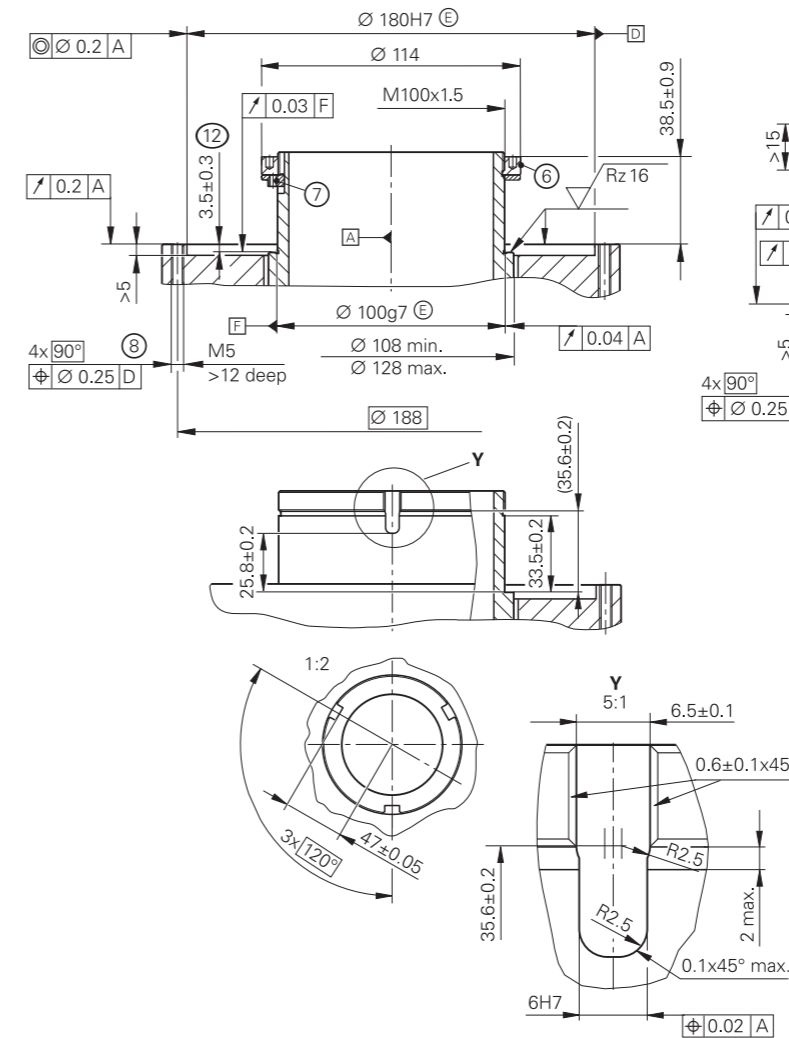**Newest generation of absolute angle encoders**
- System accuracies: ±1″ and ±2″
- Transmission of the direct-drive motor temperature
- Integrated temperature sensor
- Suitability for high shaft speeds
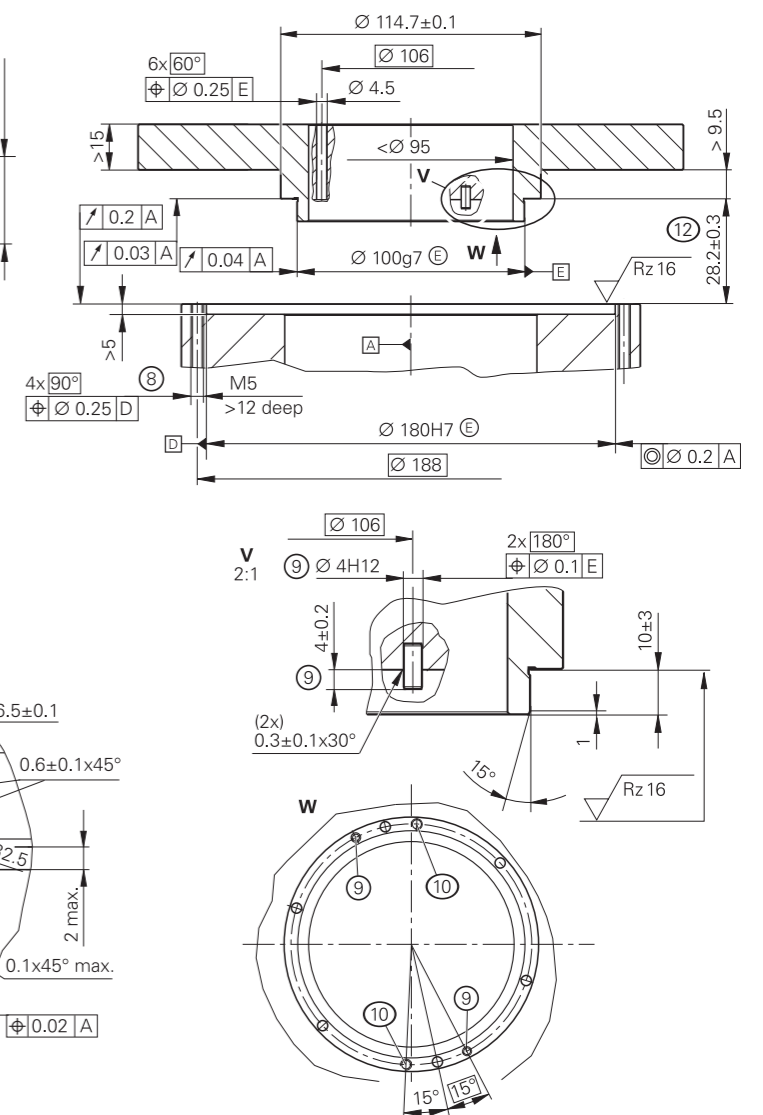- Hollow through shaft: Ø 100 mm

Functional Safety

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

Ⓐ = Bearing of mating shaft
Ⓓ = Compressed air inlet
Ⓚ = Required mating dimensions
1 = Mark for 0° position ±5°
2 = Cable support
3 = Customer-side free space
4 = Thread engagement: 5.5 mm ±0.5 mm (for M4 cylinder head screws; for details, see the mounting instructions)
5 = Shown rotated by 45°
6 = Accessory: ring nut (ID 336669-16)
7 = Accessory: catch (ID 817921-04)
8 = Thread engagement: 11 mm ±1 mm (for M5 cylinder head screws; for details, see the mounting instructions)
9 = Two spring pins: ISO 8752 – 4x10 – St
10 = Provide additional M4 back-off thread if spring pins are used
11 = Direction of shaft rotation for ascending position values
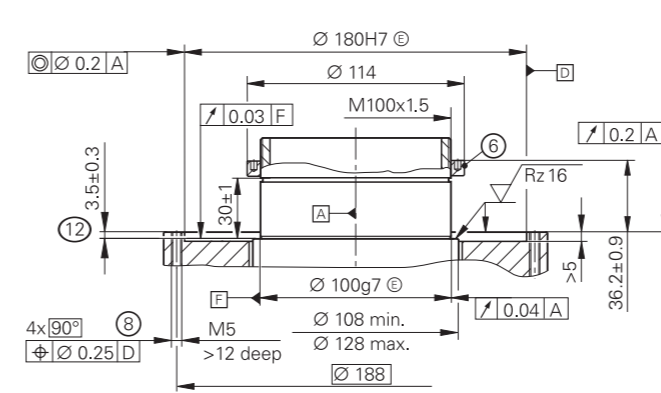12 = Stated tolerance includes mounting tolerances and thermal expansion; no dynamic movement permitted

Shaft coupling with ring nut and catch
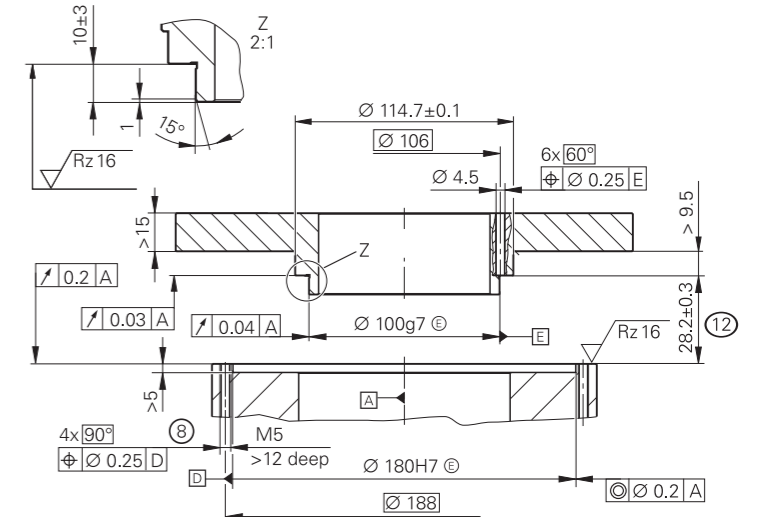**(with mechanical fault exclusion)** Ⓚ

Front-face shaft coupling
(with mechanical fault exclusion) Ⓚ

Shaft coupling with ring nut
(without mechanical fault exclusion) Ⓚ

Front-face shaft coupling
(without mechanical fault exclusion) Ⓚ

Left table

Specifications	Absolute RCN 8511 _Functional Safety_	RCN 8311 _Functional Safety_
Measuring standard	DIADUR circular scale with absolute track and incremental track (32 768 lines)	
System accuracy	±1″	±2″
Position error per signal period	≤ ±0.15″	≤ ±0.2″
Functional safety for applications with up to	• SIL 2 as per EN 61508 (further basis for testing: EN 61800-5-2) • Category 3, PL d as per EN ISO 13849-1:2015	
PFH	≤ 25 · 10^{-9} (up to 2000 m above sea level)	
Safe position[1]	_Encoder:_ ±0.11° (safety-related measuring step SM = 0.044°) _Mechanical coupling:_ fault exclusion for the loosening of the housing/flange and hollow shaft (see _Functional safety_ and _Mounting and accessories_ on _Page 28/30_)	
Interface	EnDat 2.2	
Ordering designation	EnDat22	
Positions per revolution	536 870 912 (29 bits)	
Electrically permissible speed	≤ 1500 rpm for continuous position values	
Clock frequency Calculation time t$_{cal}$	≤ 16 MHz ≤ 5 µs	
Measurement of direct-drive motor temperature[2]	Possible with the HEIDENHAIN EIB 5000 signal converter (see _Page 34_)	
Electrical connection	Separate adapter cable connectable to encoder via quick connector	
Cable length	≤ 100 m (with HEIDENHAIN cable; clock frequency ≤ 8 MHz)	
Supply voltage	DC 3.6 V to 14 V	
Power consumption[3] (maximum)	_3.6 V:_ ≤ 1.1 W _14 V:_ ≤ 1.3 W	
Shaft	Hollow through shaft (Ø 100 mm)	
Mech. permiss. shaft speed (at constant speed for up to 90 min)	≤ 1200 rpm (at an operating temperature of 40 °C; for details, see the permissible shaft speeds on _Page 26_)	
Starting torque (at 20 °C)	≤ 1.0 Nm (typical)	
Moment of inertia	_Rotor (hollow shaft):_ 3.2 · 10^{-3} kgm^2 _Stator (housing/flange):_ 10 · 10^{-3} kgm^2	
Permissible axial motion of measured shaft	_Axial:_ ±0.3 mm[4] _Radial:_ Ø 0.2 mm for coaxiality and, during operation, 0.04 mm for radial runout (each relative to the bearing axis of the mating shaft)	
Natural frequency	≥ 900 Hz	
Vibration 55 Hz to 2000 Hz Shock 6 ms	≤ 200 m/s^2 (EN 60068-2-6) ≤ 200 m/s^2 (EN 60068-2-27)	
Operating temperature	0 °C to 50 °C	
Protection EN 60529	IP64	
Mass	≈ 2.6 kg	

[1] Further tolerances may arise in the downstream electronics after position value comparison (contact mfr. of the downstream electronics)
[2] For detailed descriptions about signal converters for measuring the temperature of direct-drive motors, see the _EIB 5000_ Product Information document
[3] See the _General electrical information_ in the _Interfaces of HEIDENHAIN Encoders_ brochure
[4] Range includes mounting tolerances and thermal expansion; no dynamic movement permitted

Right table

Specifications	Absolute RCN 8581 RCN 8381	RCN 8591 F RCN 8391 F	RCN 8591 M RCN 8391 M	RCN 8591 P RCN 8391 P
Measuring standard	DIADUR circular scale with absolute track and incremental track (32 768 lines)			
System accuracy	_RCN 85x1:_ ±1″ _RCN 83x1:_ ±2″			
Position error per signal period	_RCN 8581:_ ≤ ±0.2″ _RCN 8381:_ ≤ ±0.2″	_RCN 85x1:_ ≤ ±0.15″ _RCN 83x1:_ ≤ ±0.2″		
Interface	EnDat 2.2	Fanuc Serial Interface αi interface[1]	Mitsubishi high speed interface	Panasonic Serial Interface
Ordering designation	EnDat02	Fanuc05	Mit03-4	Pana02
Position values/revolution[1]	536 870 912 (29 bits)			
Electrically permissible speed	≤ 750 rpm for continuous position values	≤ 1500 rpm for continuous position values		
Clock frequency Calculation time t$_{cal}$	≤ 2 MHz ≤ 8 µs	–		
Incremental signals Cutoff frequency –3 dB	1 V$_{PP}$ ≥ 400 kHz	–		
Measurement of direct-drive motor temperature[2]	Possible with the HEIDENHAIN EIB 5000 signal converter (see _Page 34_)	–		
Electrical connection	Separate adapter cable connectable to encoder via quick connector			
Cable length[3]	≤ 150 m	≤ 50 m		≤ 30 m
Supply voltage	DC 3.6 V to 14 V			
Power consumption[4] (maximum)	_3.6 V:_ ≤ 1.1 W _14 V:_ ≤ 1.3 W			
Shaft	Hollow through shaft (Ø 100 mm)			
Mech. permiss. shaft speed (at constant speed for up to 90 min)	_RCN 8x81:_ ≤ 750 rpm _RCN 8x91:_ ≤ 1200 rpm (at an operating temperature of 40 °C; for details, see the permissible shaft speeds on _Page 26_)			
Starting torque (at 20 °C)	Typically ≤ 1.0 Nm			
Moment of inertia	_Rotor (hollow shaft):_ 3.2 · 10^{-3} kgm^2 _Stator (housing/flange):_ 10 · 10^{-3} kgm^2			
Permissible axial motion of measured shaft	_Axial:_ ±0.3 mm[5] _Radial:_ Ø 0.2 mm coaxiality and 0.04 mm runout during operation (each relative to the bearing axis of the mating shaft)			
Natural frequency	≥ 900 Hz			
Vibration 55 Hz to 2000 Hz Shock 6 ms	≤ 200 m/s^2 (EN 60068-2-6) ≤ 200 m/s^2 (EN 60068-2-27)			
Operating temperature	0 °C to 50 °C			
Protection EN 60529	IP64			
Mass	≈ 2.6 kg			

[1] Reduced resolution during operation with Fanuc α Interface; _RCN 8x91 F:_ 134 217 728 (27 bits)
[2] For detailed descriptions about signal converters for measuring the temperature of direct-drive motors, see the _EIB 5000_ Product Information document
[3] With HEIDENHAIN cable ≤ 8 MHz
[4] See _General electrical information_ in the _Interfaces of HEIDENHAIN Encoders_ brochure
[5] Range includes mounting tolerances and thermal expansion; no dynamic movement permitted

Testing and inspection devices, and diagnostics

HEIDENHAIN encoders provide all of the information needed for initial setup, monitoring, and diagnostics. The type of available information depends on whether it is an absolute or incremental encoder and on which interface is used.

Absolute encoders use serial data transmission. Depending on the interface, additional 1 Vpp incremental signals can be output. The signals are extensively monitored within the encoder. The monitoring results (particularly valuation numbers) can be transmitted to the downstream electronics along with the position values via the serial interface (**digital diagnostics interface**). The following information is available:
- Error message: position value is not reliable
- Warning: an internal functional limit of the encoder has been reached
- Valuation numbers:
  – Detailed information on the encoder's function reserve
  – Identical scaling for all HEIDENHAIN encoders
  – Cyclic reading is possible

This enables the downstream electronics to evaluate the current status of the encoder with little effort, even in closed loop mode.

Incremental encoders have 1 Vpp TTL, or HTL interfaces. TTL and HTL encoders monitor their signal amplitudes internally and generate a simple fault detection signal. With 1 Vpp signals, an analysis of the output signals is possible only with external testing devices or through the use of computation resources in the downstream electronics (**analog diagnostics interface**).

For the analysis of these encoders, HEIDENHAIN offers the appropriate PWM inspection devices and PWT testing devices. Based on how these devices are integrated, a distinction is made between two types of diagnostics:
- Encoder diagnostics: the encoder is connected directly to the testing or inspection device, thereby enabling a detailed analysis of encoder functions.
- Monitoring mode: the PWM inspection device is inserted within the closed control loop (via suitable testing adapters as needed). This enables real-time diagnosis of the machine or equipment during operation. The available functions depend on the interface.
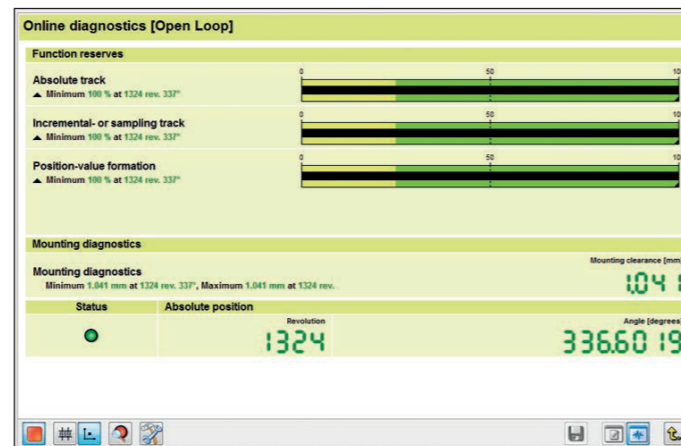
Diagnostics with the PWM 21 and ATS software

Initial setup with the PWM 21 and ATS software

Further information:

For detailed descriptions about diagnostics, and inspection devices and testing devices, please refer to the *Interfaces of HEIDENHAIN Encoders* brochure (ID 1078628-xx).

PWT 101

The PWT 101 is a testing device for the functional testing and adjustment of incremental and absolute HEIDENHAIN encoders. Thanks to its compact and rugged design, the PWT 101 is ideal for portable use.

Further information:

For a detailed description, refer to the *PWT 101* Product Information document.

PWM 21

The PWM 21 phase-angle measuring unit, in conjunction with the included ATS adjusting and testing software, serves as an adjusting and testing package for the diagnosis and adjustment of HEIDENHAIN encoders.

Further information:

For detailed descriptions, refer to the *PWM 21/ATS Software* Product Information document.

	PWT 101
Encoder input only for HEIDENHAIN encoders	• EnDat • Fanuc Serial Interface • Mitsubishi high speed interface • Panasonic Serial Interface • Yaskawa Serial Interface • 1 Vpp • 11 µApp • TTL
Display	4.3-inch color flat-panel display (touchscreen)
Supply voltage	DC 24 V Power consumption: max. 15 W
Operating temperature	0 °C to 40 °C
Protection EN 60529	IP20
Dimensions	≈ 145 mm × 85 mm × 35 mm

	PWM 21
Encoder input	• EnDat 2.1, EnDat 2.2, or EnDat 3 (absolute value with or without incremental signals) • DRIVE-CLiQ • Fanuc Serial Interface • Mitsubishi high speed interface • Yaskawa Serial Interface • Panasonic serial interface • SSI • 1 Vpp/TTL/11 µApp • HTL (via signal adapter)
Interface	USB 2.0
Supply voltage	AC 100 V to 240 V or DC 24 V
Dimensions	258 mm × 154 mm × 55 mm

	ATS
Languages	German or English (selectable)
Functions	• Position display • Connection dialog • Diagnostics • Mounting wizard for EBI/ECI/EQI, LIP 200, LIC 4000 and others • Additional functions (if supported by the encoder) • Memory contents
System requirements and recommendations	PC (dual-core processor > 2 GHz) RAM > 2 GB Operating systems: Windows 7, 8, and 10 (32-bit / 64-bit) 500 MB of free hard drive space

DRIVE-CLiQ is a registered trademark of Siemens Aktiengesellschaft.

HEIDENHAIN
Mastering nanometer accuracy