



Technical Information

Optimized Scanning in Absolute Rotary Encoders

Rotary encoders for electrical drives are subject to high requirements: they are expected to function reliably and provide dependable measurement data in spite of their often harsh environments. The optimized scanning principle—made possible by the serial-coded absolute track—meets these requirements. Absolute rotary encoders with optimized scanning are distinguished by the high quality of their scanning signals and their significantly reduced sensitivity to contamination. An innovative scanning and evaluation unit permits both high interpolation and optimized control loop performance. Interpolation and position value generation within the rotary encoder permit reliable, purely digital data transmission and relieves the higher-level electronics. Also, because their safety-related functions comply with IEC 61 508, the rotary encoders now are ready for use in SIL2 applications. These changes have no effect on the dimensions of the encoders; no mechanical changes of the motor dimensions are required.

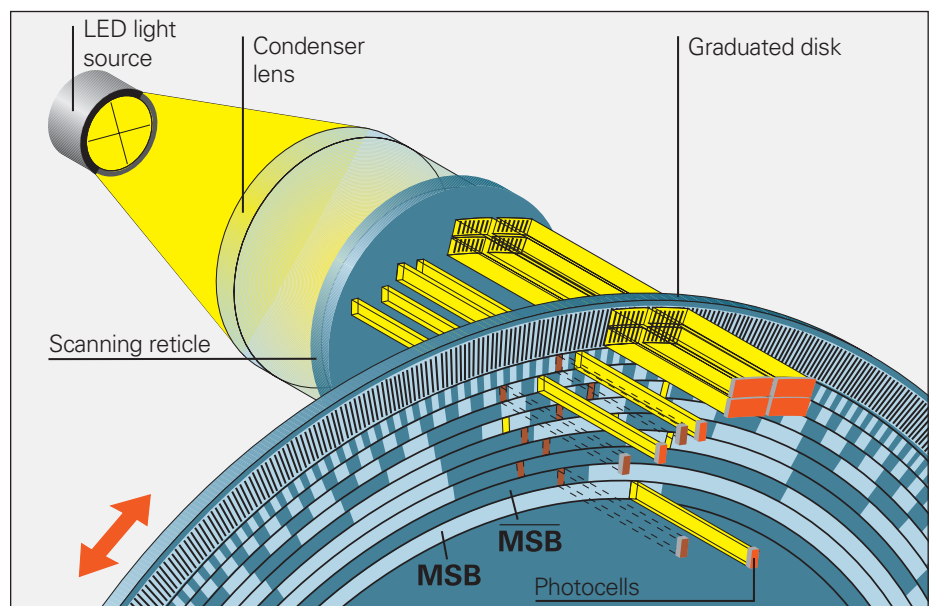
Controlled servo drives are used in many areas of automation technology, robotics and handling systems as well as in the drive technology of production machines and machine tools. The requirements regarding dynamics, speed stability and rigidity necessitate ever increasing gain factors in the control loops. The position encoders used have a decisive influence on important motor properties, such as:

- Positioning accuracy
- Speed stability
- Bandwidth, which determines drive command-signal response and disturbance rejection capability
- Power loss
- Size

The position resolution and the position error within one signal period are distinctly in the foreground. Decisive factors here are the scanning principle as well as the further processing of the scanning signals.

Encoders from HEIDENHAIN generally operate according to the principle of photoelectrically scanning a regularly structured measuring standard. In the imaging scanning procedure, as it is used by absolute rotary encoders, for example,

a structured graduated disk rotates relative to a scanning point. The incident light is converted into electrical signals by the photovoltaic cells. The absolute position information is determined from the graduation on the graduated disk.



Photoelectric scanning of a Gray-code graduation according to the imaging scanning principle

Scanning principle

The scanning principle of rotary encoders with optimized scanning generates the absolute position value from just two graduation tracks: the absolute information is encoded in just one track on the newly developed graduated disk. The pattern of this serial code structure is unique over one revolution. The incremental track is located next to it. It is interpolated for the position value and at the same time is used to generate an optional incremental signal. The information in the two tracks is processed in the new, highly integrated electronics to form an absolute position value with high resolution (approx. 33 million measuring steps per revolution).

An optical filter is used in the special scanning of the incremental track to produce very homogenous signals. Instead of the usual individual photovoltaic cells, one large-area, specially structured photosensor generates scanning signals with a good sinusoidal shape and high consistency, even at very different speeds, for each graduation track.

Higher resolution – better control

The consistently good quality of the sinusoidal scanning signals resulting from the optimized scanning significantly reduces the position errors within one signal period. This is why reliable 14-bit interpolation is now possible in the rotary encoder. The high resolution achieved by this results in finer measuring steps, which in turn are definitive for the high control quality and the finely tuned velocity control.

Consistently accurate

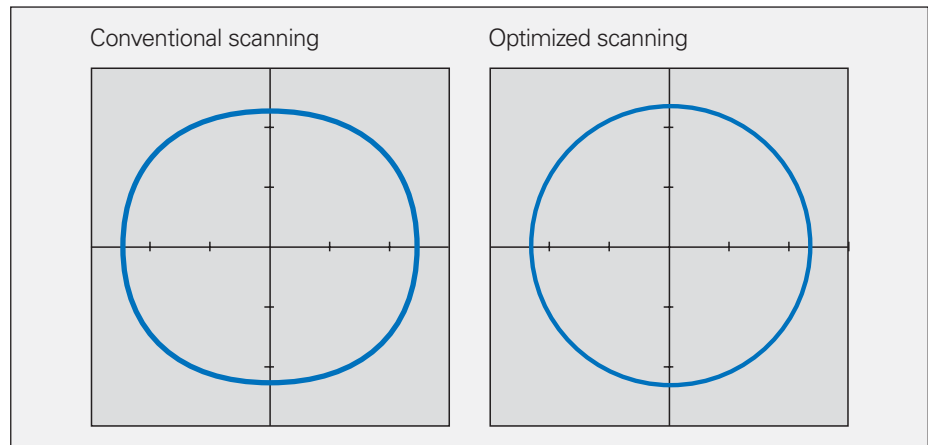
The serial code structure, located in just one track, combined with the optimized scanning principle, permits a high accuracy of the encoder, independent of the speed. This means that regardless of whether you are operating at the maximum speed or nearly at a standstill, the positioning accuracy is always consistently high.



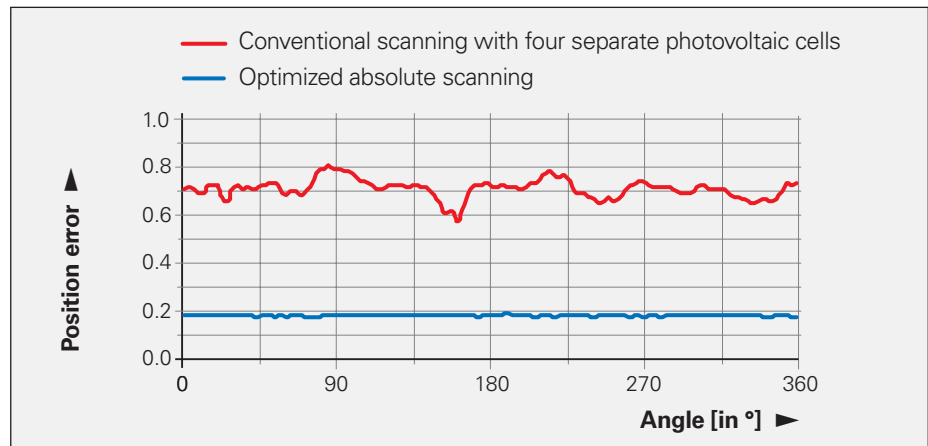
Conventional graduated disk with 13 Gray-code tracks



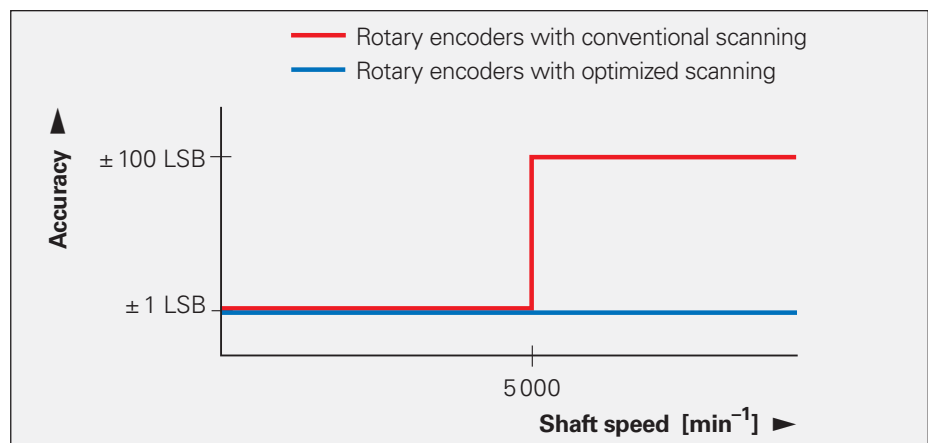
Graduated disk with serial code track and incremental track



Scanning signals shown as Lissajous figures



Position error within one signal period shown over one revolution



Accuracy relative to shaft speed

Tolerance to contamination

Theoretically, contamination is not an issue with sealed rotary encoders that are integrated in electrical motors. In practice, however, traces of oil from bearings, dust from the brakes and out-gassing from the motor coil can intrude into the rotary encoder. Due to the large scanning area over the entire width of the scale grating and the special arrangement of several scanning fields, encoders with optimized scanning are extremely insensitive to contamination.

Newly developed scanning and evaluation electronics

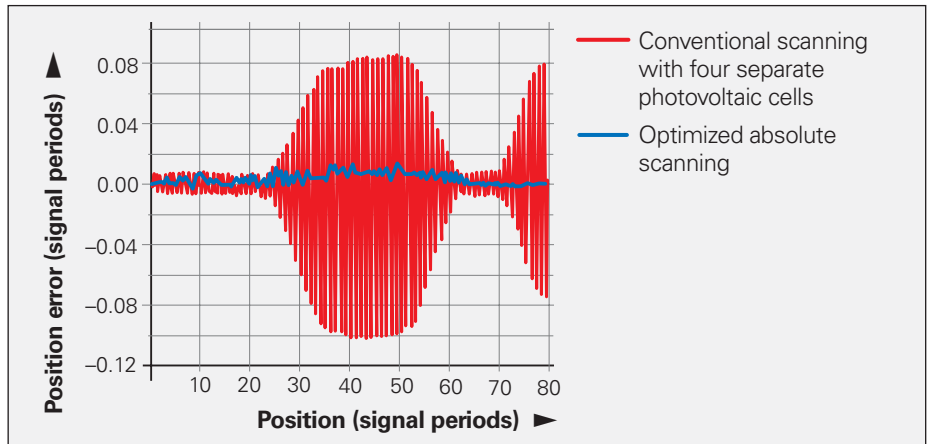
The significant reduction of individual components results in a decided improvement in **reliability** during manufacture and when in use. The most important factor here is the reduction of the scanning from 13 tracks to just two tracks, as well as the high degree of integration of the newly developed scanning and evaluation electronics.

These electronics also make it possible to increase the range for the **power supply voltage**, so that it is now from **3.6V to 14V**. This means that monitoring of the supply voltage in the encoder can be omitted, and so sensor lines and a controllable power supply in the subsequent electronics are no longer necessary.

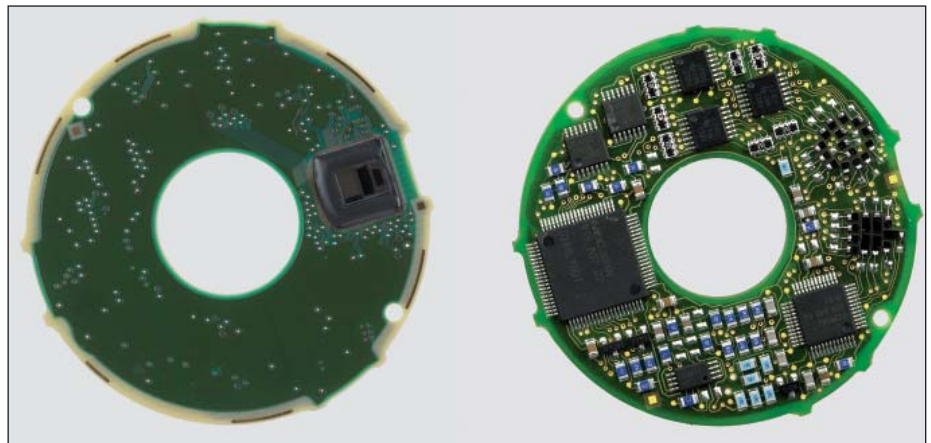
The combination of the new scanning and evaluation electronics with the EnDat interface offers important advantages. Since interpolation takes place within the rotary encoder, purely digital **data transmission**, which is less sensitive to noise, is possible. Since lines for the analog signals are no longer needed, the connection cables are less complex, meaning that simpler and thinner cables are possible, as well as smaller connecting elements. Since the **entire position value** is already available to the subsequent electronics, time-critical interrogations and calculation operations are avoided.

The EnDat interface makes extensive **monitoring and diagnosis** of an encoder possible without an additional line. The diagnostic system generates error messages and warnings, and is a significant prerequisite for the high level of availability of the complete system.

For encoders with purely serial interfaces, the valuation numbers provide the current state of the encoder and ascertain the encoder's "functional reserves." The valuation numbers can be read from the encoder cyclically via the EnDat 22 interface without influencing the quality of the axis control.



Influence of contamination on positioning accuracy (typical measured values)



PCB for absolute rotary encoders with optimized scanning (via opto-ASIC), and PCB with scanning via four photovoltaic cells

Online diagnostics [Open Loop]

Function reserves

Absolute track ▲ Minimum 91 % at 4096 rev. 45°	0 50 100
Incremental track ▲ Minimum 82 % at 4096 rev. 45°	0 50 100
Position-value formation ▲ Minimum 83 % at 4096 rev. 45°	0 50 100

Status	Absolute position				
● Absolute	<table border="1"> <tr> <th>Revolution</th> <th>Angle [degrees]</th> </tr> <tr> <td style="font-size: 2em;">4096</td> <td style="font-size: 2em;">45.14656</td> </tr> </table>	Revolution	Angle [degrees]	4096	45.14656
Revolution	Angle [degrees]				
4096	45.14656				

Screen showing the valuation numbers as functional reserves (e.g. with IK 215)

Rotary encoders for safety-oriented applications

For future-oriented applications, the question of safety standards is becoming increasingly important. That is why the **functional safety** as per IEC 61 508 was already taken into account when designing the new scanning and evaluation electronics. Scanning in the encoder simultaneously produces two independent position values that are transmitted using the EnDat 2.2 protocol to the EnDat master in the subsequent electronics. The EnDat master assumes various monitoring tasks, and provides both position values via two independent processor interfaces to the safe control. Safety-related position measuring systems from HEIDENHAIN are permitted as single-encoder systems in applications with control category SIL-2 (in accordance with IEC 61 508) or performance level "d" (ISO 13849).

Available rotary encoders with optimized scanning

HEIDENHAIN is gradually converting its absolute rotary encoders to optimized scanning. The following variants are available:

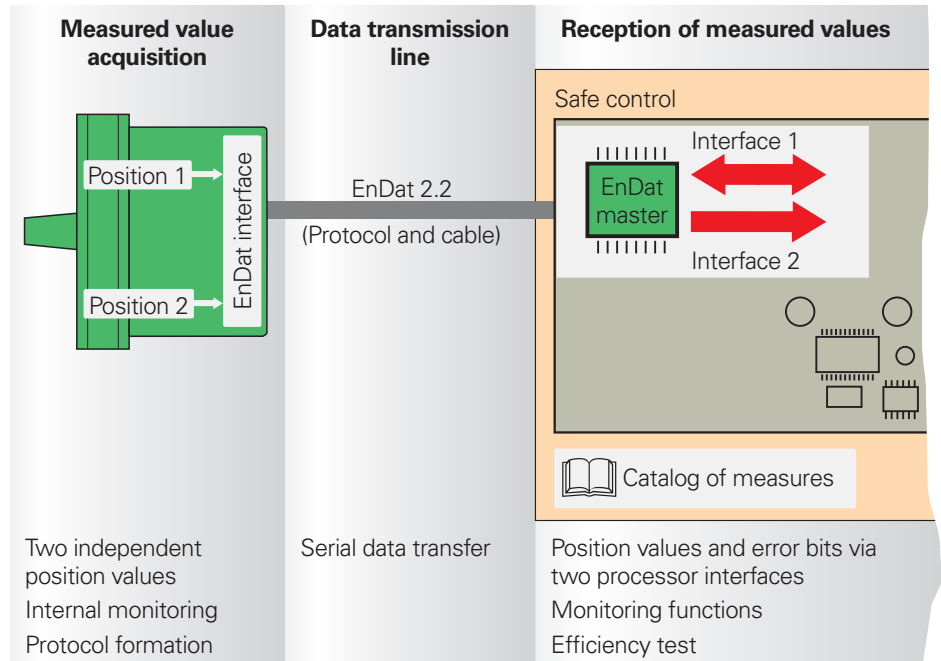
- ECN 1325/EQN 1337
- ECN 425/EQN 437
- ROC 425/ROQ 437
- ECN 1123/EQN 1135¹⁾
- ECN 1023/EQN 1035¹⁾
- ROC 1023/ROQ 1035¹⁾

Two rotary encoder models are already available for safety-related applications.

- ECN 1325 singleturn version
- ECN 1337 multiturn version

More absolute rotary, angular and linear encoders will follow.

¹⁾ Available in 2009



Safety-related position measuring system, consisting of an encoder, the data transmission line and the EnDat master

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For more information

- Brochure: *Encoders for Servo Drives*
- Technical Information: *Safety-Related Position Measuring Systems*

