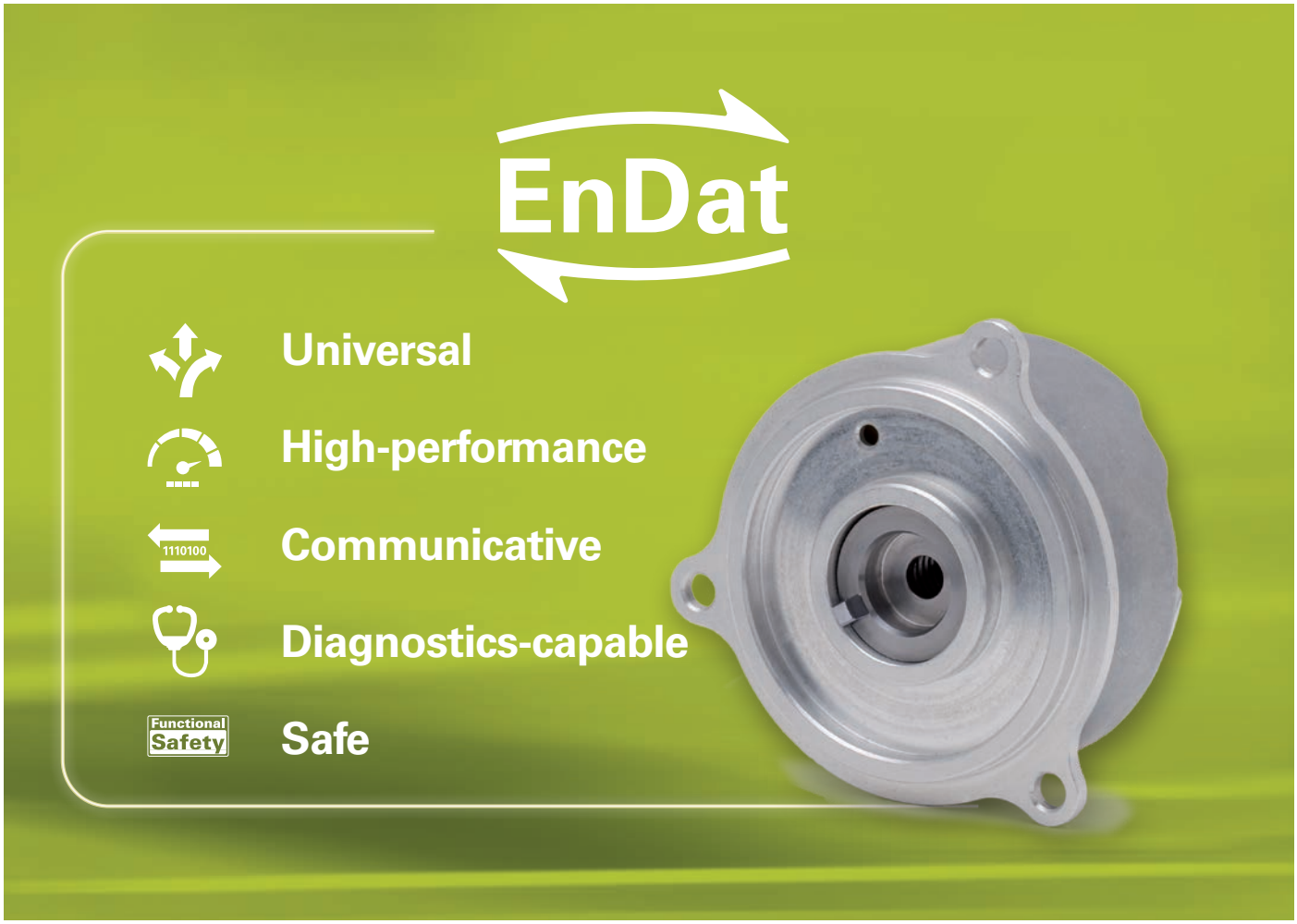
HEIDENHAIN

Technical Information

The EnDat 2.2 Bidirectional Interface for Position Encoders

Digital drive systems and feedback loops with position encoders for measured value acquisition require **fast data transfer** with **high transmission reliability from the encoders.** Further data such as **drive-specific parameters, compensation tables,** etc. must also be made available. For high system reliability, the encoders must be integrated in routines for error detection and have **diagnostic capabilities**.

The EnDat interface from HEIDENHAIN is a digital, bidirectional interface for encoders. It is capable both of transmitting position values from incremental and absolute encoders as well as transmitting or updating information stored in the encoder, or saving new information. Thanks to the serial transmission method, only four signal lines are required. The data are transmitted in synchronism with the clock signal from the subsequent electronics. The type of transmission (position values, parameters, diagnostics, etc.) is selected by mode commands that the subsequent electronics send to the encoder. The EnDat 2.2 interface, a purely serial interface, is also suited for safety-related applications with up to SIL 3.



EnDat 2.2: proven interface technology

Proven in daily operation
EnDat 2.2 is an established interface that enables flexible machine designs through a wide range of encoders together with its intrinsic properties:

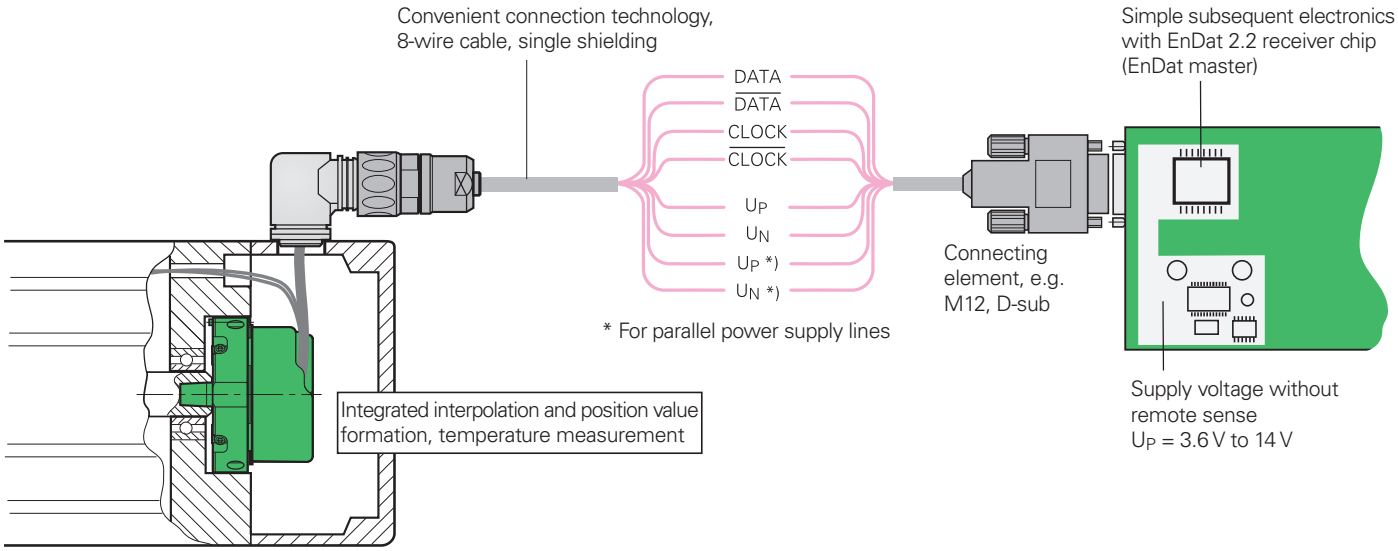
Universal
- Broad selection of encoders from various manufacturers
- Convenient cabling
  – HMC 6 hybrid cable technology
  – M12 connection technology
- Integration of additional sensors
  – Temperature sensors

High-performance
- Short cycle times
  – 15 µs attainable with low position-measurement jitter
- High transmission frequency and reliability
  – 8 MHz at 100 m cable length or 16 MHz at 20 m

Communicative
- Transmission of position values and sensor data
  – Rolling output of additional data
  – Access to encoder memory during closed loop operation
- Extensive system monitoring for Industry 4.0
  – Automatic system installation and diagnostics

Diagnostics-capable
- Electronic ID label for automatic system installation
  – Data for encoder, motor, and system
- Online encoder diagnostics
  – Together with the sensor data, forms the basis for condition monitoring and predictive maintenance
- Storage of operating status data
  – Storage via the subsequent electronics

Safe
- For safety-related applications with up to SIL 3
  – Can be implemented with EnDat Master Safe and EnDat Master Basic (according to the Black Channel principle)

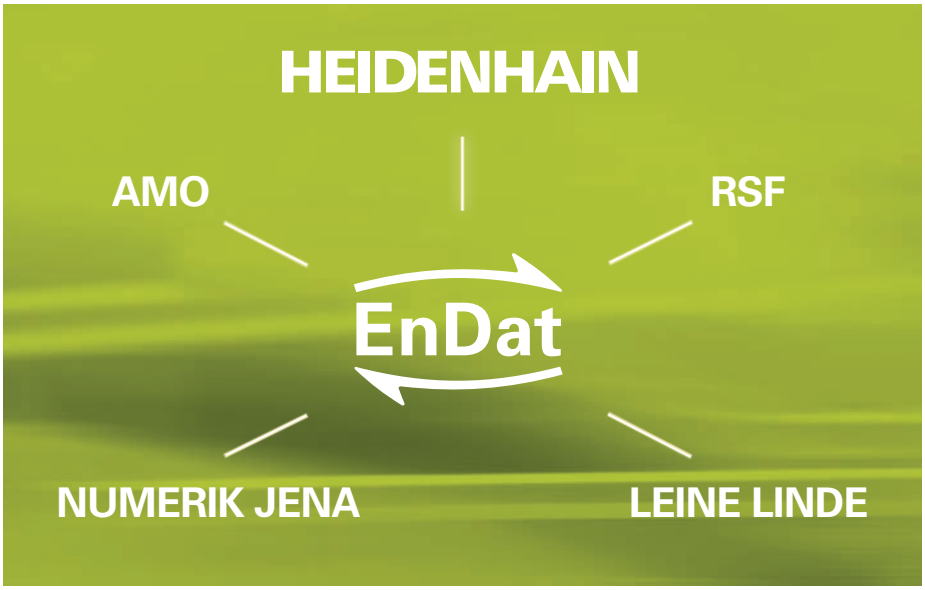


Thanks to the broad portfolio of EnDat 2.2 encoders, an optimal encoder is available for any given application:

- Encoders with different measuring and scanning methods
  – Absolute, incremental
  – Photoelectric, inductive, magnetic
  – Singleturn, multiturn with gears, multiturn with buffer battery backup
- Encoders with compatible mounting solutions

Further information:

For our entire range of encoders, visit *www.heidenhain.de*



Strong brands for your applications:
AMO, ACU-RITE, ETEL, LEINE LINDE, LTN, NUMERIK JENA, RENCO, RSF

The target industries for which EnDat was designed stand to benefit in particular from the following features:

Automation

- HMC 6 hybrid cable
- Sensor integration (e.g., easy connection of a temperature sensor in the servomotor)
- Storage of operating status data
- System information for automatic configuration
- Diagnostic capabilities
- Functional safety

Machine tool

- Mechanically robust cabling
- Integration of sensor boxes
- System information for automatic configuration
- Diagnostic capabilities
- Functional safety

Electronics industry

- System information for automatic configuration
- Diagnostic capabilities

The features of the EnDat interface and the wide range of available encoders permit the implementation of machine design flexibility with future-ready technology.

EnDat 2.2 The bidirectional interface

The EnDat interface is a digital, **bidirectional** interface for encoders. It is capable of outputting **position values**, reading and updating information stored in the encoder, and storing new information in the encoder. Thanks to the interface's **serial transmission method**, only **four signal lines** are required. The data are transmitted in **synchronism** with the clock signal from the subsequent electronics. The type of transmission (position values, parameters, diagnostics, etc.) is selected via mode commands sent to the encoder by the subsequent electronics. Some functions are available only in conjunction with EnDat 2.2 mode commands.

Interface	**EnDat** serial bidirectional
Data transmitted	Position values, parameters, and additional data
Data input	Differential line receiver in compliance with EIA standard RS-485 for the signals CLOCK, $\overline{\text{CLOCK}}$, DATA, and $\overline{\text{DATA}}$
Data output	Differential line driver in compliance with EIA standard RS-485 for DATA and $\overline{\text{DATA}}$ signals
Position values	Ascending during movement in the direction of the arrow (see mating dimensions of the encoders)
Incremental signals	Depends on encoder ~ 1 V_{PP}, TTL, HTL (see the respective incremental signals)

History and compatibility
The EnDat 2.1 interface, which has been available since the mid-1990s, has since been upgraded to EnDat 2.2 (recommended for new applications). In terms of its communication, command sets, and time conditions, EnDat 2.2 is compatible with EnDat 2.1 but also offers significant advantages. For example, EnDat 2.2 permits the transfer of additional data (sensor values, diagnostics, etc.) along with the position value without initiating a separate request. This allows the interface to support additional types of encoders (e.g., encoders with buffer battery backup, incremental encoders). The interface protocol has also been expanded, and the time conditions (clock frequency, calculation time, recovery time) have been optimized.

Supported encoder types
The following encoder types are currently supported with the EnDat 2.2 interface (readable from the memory area of the encoder):
- Incremental linear encoders
- Absolute linear encoders
- Incremental, singleturn rotational encoders
- Absolute, singleturn rotational encoders
- Multiturn rotary encoders
- Multiturn rotary encoders with buffer battery backup

For the various encoder types, some parameters must be interpreted differently (see the EnDat specifications), or EnDat additional data must be processed (e.g., incremental encoders or encoders with buffer battery backup).

Ordering designations
The ordering designations define the core specifications and provide the following information:
- Typical supply voltage range
- Command set
- Availability of incremental signals
- Maximum clock frequency

The second position in the ordering designation identifies the interface generation. With encoders of the current generation, the ordering designation can be read from the encoder memory.

Incremental signals
Some encoders also provide incremental signals. These signals are primarily used for increasing the resolution of the position value or for providing data to a second subsequent electronics unit. Current generations of encoders have a high internal resolution and therefore no longer need to provide incremental signals. The ordering designation indicates whether an encoder outputs incremental signals:
- EnDat01 With 1 V_{PP} incremental signals
- EnDatH With HTL incremental signals
- EnDatT With TTL incremental signals
- EnDat21 Without incremental signals
- EnDat02 With 1 V_{PP} incremental signals
- EnDat22 Without incremental signals

Note on EnDat01/02:
The signal period is stored in the encoder memory

Supply voltage
The typical supply voltage of the encoders depends on the interface:

EnDat01 EnDat21	5 V ±0.25 V
EnDat02 EnDat22	3.6 V to 5.25 V or 14 V
EnDatH	10 V to 30 V
EnDatT	4.75 V to 30 V

Exceptions are documented in the Specifications.

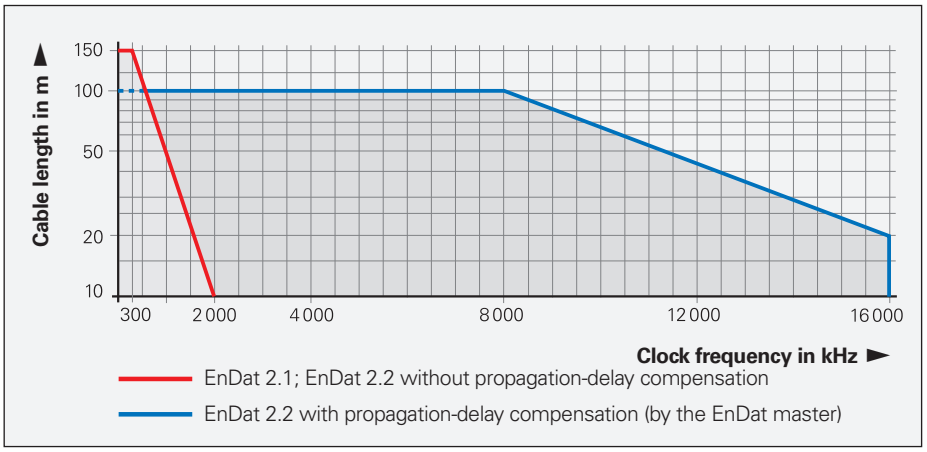
Command set
The command set describes the available mode commands, which define the information exchange between the encoder and the subsequent electronics. The EnDat 2.2 command set includes all EnDat 2.1 mode commands. In addition, EnDat 2.2 permits further mode commands for the selection of additional data and enables memory accesses even in a closed control loop. When a mode command from the EnDat 2.2 command set is sent to an encoder that supports only the EnDat 2.1 command set, an error message is triggered. The specific command set supported is identified in the encoder's memory area:
- EnDat01/21/H/T Command set 2.1 or 2.2
- EnDat02/22 Command set 2.2

Clock frequency
The clock frequency is variable between 100 kHz and 2 MHz depending on the cable length (maximum: 150 m). With propagation-delay compensation in the subsequent electronics, clock frequencies of up to 16 MHz or cable lengths of up to 100 m are possible. For EnDat encoders with the ordering designation EnDatx2, the maximum clock frequency is stored in the encoder memory. For all other encoders, the maximum clock frequency is 2 MHz. Propagation-delay compensation is intended only for the ordering designations EnDat21 and EnDat22; for EnDat02, see the note below.

EnDat01 EnDatT EnDatH	≤ 2 MHz (see *without propagation-delay compensation* in the diagram)
EnDat21	≤ 2 MHz
EnDat02	≤ 2 MHz or ≤ 8 MHz or 16 MHz (see note)
EnDat22	≤ 8 MHz or 16 MHz

In conjunction with long cable lengths, transmission frequencies of up to 16 MHz place high technological demands on the cable. For reasons concerning the transmission technology, the adapter cable connected directly to the encoder must not be longer than 20 m. Greater cable lengths can be realized with an adapter cable no longer than 6 m and an extension cable. As a rule, the entire transmission path must be designed for the respective clock frequency.

Note on EnDat02
EnDat02 encoders may have a pluggable cable assembly. In choosing the version of the adapter cable, the customer decides whether the encoder will be operated with or without incremental signals. This also influences the maximum possible clock frequency. For adapter cables with incremental signals, the clock frequency is limited to 2 MHz; see also EnDat01. For adapter cables without incremental signals, the clock frequency can be up to 16 MHz. The exact values are stored in the encoder memory.



Under certain conditions, cable lengths of up to 300 m are possible after consultation with HEIDENHAIN

Position values
The position value can be transmitted with or without additional data. At the earliest, the position value is transmitted to the subsequent electronics after the calculation time t_{cal} has elapsed or after 14.5 clock pulses. The calculation time is determined for the encoder's highest permitted clock frequency, but for no more than 8 MHz.

For the position value, only the required number of bits is transferred. The number of bits thus depends on the respective encoder and can be read from the encoder for automatic parameterization.

Typical operating modes
Operating mode EnDat 2.1: This mode is for encoders that provide additional incremental signals. For generation of the position value, the absolute position is read once simultaneously with the incremental position, and both are used in the calculation of the position value. The subsequent generation of the position value in the control loop is based on the incremental signals. Only EnDat 2.1 mode commands are used.

Operating mode EnDat 2.2: This mode is for purely serial encoders. For position value generation, the position value is read from the encoder during each control cycle. EnDat 2.2 mode commands are typically used to read the position value. EnDat 2.1 mode commands are typically used to read and write parameters after switch-on.
In a closed control loop, the EnDat 2.2 interface allows additional data to be queried along with the position, and it permits the execution of functions (e.g., read/write parameters, reset error messages, etc.).

Additional data
Depending on the type of transmission (selection via MRS code), one or two items of additional data can be appended to the position value. The types of additional data supported by the respective encoder are saved in the encoder's parameters. Additional data encompasses the following:

Status information, addresses, and data
- WRN: warnings
- RM: reference mark
- Busy: parameter request

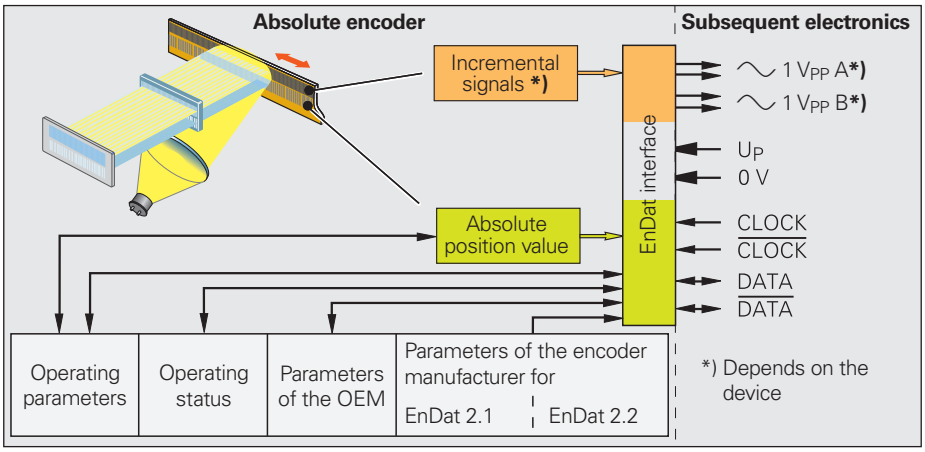
Additional data 1
- Diagnostics
- Position value 2
- Memory parameters
- MRS-code acknowledgment
- Test values
- Temperature
- Additional sensors

Additional data 2
- Commutation
- Acceleration
- Limit position signals
- Asynchronous position value
- Operating status error sources
- Timestamp

Memory areas
The encoder provides multiple memory areas for parameters. These memory areas can be read by the subsequent electronics, and some areas can be written to by the encoder manufacturer, the OEM, or the end user. The parameter data are stored in permanent memory. This memory allows only a limited number of write accesses and is not designed for the cyclic storage of data. Certain storage areas can be write-protected (resettable only by the encoder manufacturer).

Parameters are stored in various memory areas, e.g.:
- Encoder-specific information
- Information from the OEM (e.g., electronic ID label of the motor)
- Operating parameters (datum shift, instruction, etc.)
- Operating status (alarms or warnings)

Monitoring and diagnostic functions of the EnDat interface enable a detailed inspection of the encoder. These include the following:
- Error messages
- Warnings
- Online diagnostics based on valuation numbers for easily determining the function reserves of an encoder
- Parameters for mounting the encoder



System information
EnDat provides for the availability of system information about the encoder and the system (i.e., electronic ID label):
- Encoder parameters, which are all of the parameters needed for initial encoder configuration, are stored in the encoder.
- System parameters can be stored in the encoder's memory by the OEM or plant builder.
- System or process status data, referred to as operating status data, can be stored in the encoder during closed loop operation.

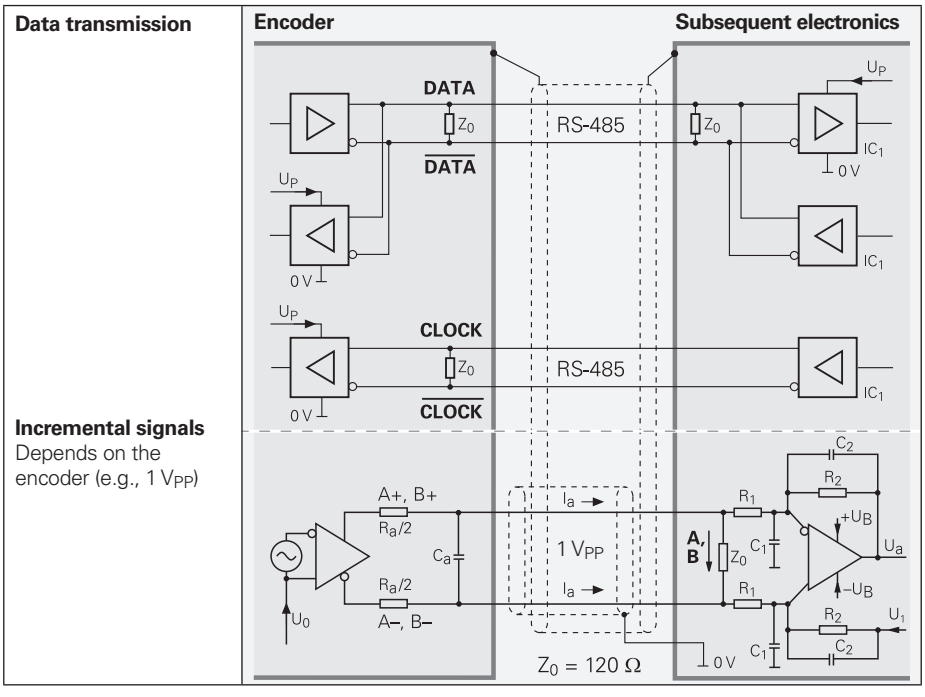
Basics of functional safety
EnDat 2.2 supports the use of encoders in safety-related applications. The standards DIN EN ISO 13849-1 (successor to EN 954-1), EN 61508, and EN 61800-5-2 are taken as the basis for this. These standards describe the assessment of safety-related systems based on the failure probabilities of integrated components and subsystems, for example. The modular approach helps manufacturers of safety-related systems in implementing their complete systems by allowing them to build upon already qualified subsystems.

Further information:
See *"Functional Safety"* at *www.endat.de*

Input circuit of the subsequent electronics

Dimensioning
IC_1 = RS-485 differential line receiver and driver

Z_0 = 120 Ω



Further information:
FAQ: RS-485 Transceiver at *www.endat.de*

Connection technology

Connecting elements
Encoders with EnDat 2.2 interface without incremental signals use mainly 8-pin M12 connecting elements, but also 9-pin M23. M12 connector technology is in wide use in industrial applications and has the following advantages:
- Cost-effective connection technology
- Smaller dimensions
- Simpler cable feed-through in machines
- Thinner connecting cables (Ø 6 mm instead of the previous 8 mm)
- Higher reliability thanks to injection-coated connection technology
- Integrated lock mechanism as vibration protection

Cables
In conjunction with long cable lengths, transmission frequencies of up to 16 MHz place high technological demands on the cable. HEIDENHAIN cables are equal to this task, not least because of a cable design conceived specifically for this application. We recommend using original HEIDENHAIN cables.

Further information:
Brochure: *Cables and Connectors*

HMC 6
Single-cable solution for servomotors
Servomotors normally require two separate cables:
- One cable for the motor encoder and
- One power cable for the motor supply

With its Hybrid Motor Cable HMC 6, HEIDENHAIN has integrated the encoder lines in the power cable. So now only one cable is needed between the motor and electrical cabinet.

Further information:
Product Information: *HMC 6*

Voltage supply
The correct supply voltage and power consumption are stated in each encoder's specifications. EnDat 2.2 encoders feature an expanded supply voltage range from 3.6 V to 5.25 V or from 3.6 V to 14 V.

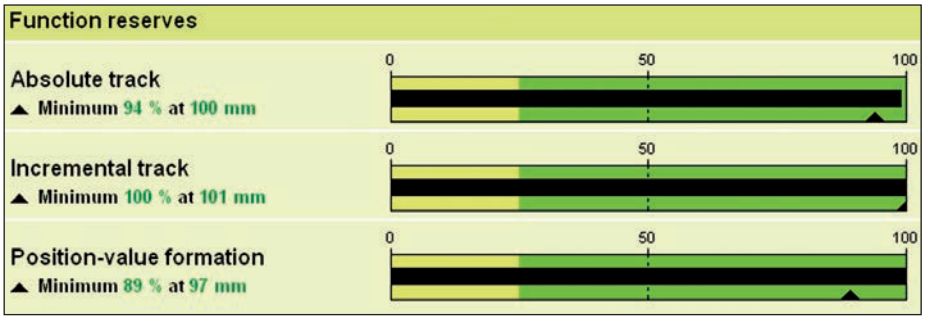
This makes it possible to design the voltage supply of the subsequent electronics so that the resulting voltage after attenuation through cable length, cable cross-section, and current consumption can be processed without correction (applies only for cable assemblies from HEIDENHAIN). This means that monitoring the voltage at the encoder with the encoder's sensor lines and adjusting the supply voltage through a controllable power supply unit (remote sense) are no longer necessary.

Diagnostics
EnDat enables extensive encoder monitoring and diagnostics without an additional line. Its diagnostics generate valuation numbers, error messages, and warnings, and are a key ingredient in attaining high availability in the complete system.

The important factors:
- Machine utilization planning
- On-site support for the service technician
- Easy evaluation of the encoder's function reserve
- Simplified troubleshooting for repairs
- Generation of useful quality statistics

For analysis of encoder functionality, valuation numbers can be read cyclically from the encoder. Valuation numbers provide information about the current status of the encoder and its function reserve. The identical scaling for all HEIDENHAIN encoders enables consistent analysis. The function reserves, combined with other sensor data, serve as the basis for condition monitoring and predictive maintenance in the higher-level subsequent electronics.

Further information:
Brochure: *Interfaces of HEIDENHAIN Encoders*



Sample display of the function reserve

Overview of encoders

Functional Safety

The comprehensive product program from HEIDENHAIN offers solutions for applications in which the highest possible accuracy, reliable reproducibility and repeatability, safe process management, high machine dynamics, simple operation, and maximum efficiency are required.

These products are therefore used mainly in the following areas:
- Machine tools
- Electronics production
- Automation facilities
- Elevators
- Medical technology

The product program from HEIDENHAIN also contains numerous encoders for safety-related applications.

Rotary encoders for servo drives, machines, and larger systems
HEIDENHAIN offers suitable rotary encoders for a wide variety of applications. The rotary encoders for safety-related applications are available in different versions with absolute position acquisition.

Angle encoders for rotary axes
Angle encoders are characterized by high accuracy values in the arc second range and better. The angle encoders for safety-related applications are available with and without integral bearing, and as sealed encoders for mounting or as modular encoders for integration.

Linear encoders for linear axes
HEIDENHAIN offers exposed and sealed linear encoders for safety-related applications. These linear encoders are available in various sizes, lengths, and accuracy grades.

Rotary encoders

ExI 1300 series

ECN 1100/ EQN 1100 series

ExN 1100/ ExN 1300 series

ExI 1100 series

ECN 400/ EQN 400 series

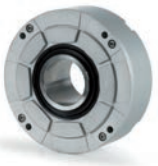
ECI/EBI 4000 series

Angle encoders

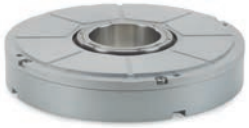
RCN 2000 series

ECA 4000 series

RCN 6000 series



RCN 5000 series



RCN 8000 series

Linear encoders

LC 400 series

LC 100 series

LIC 4000 series

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Further information on implementation:

The Implementation Guide provides an overview of which documents and their content are intended for which readers, and the available implementation aids.

We would be happy to send you the following EnDat 2.2 specifications upon request:
- EnDat 2.2 Interface Specification
- EnDat 2.2 Hardware Specification
- EnDat 2.2 Application Conditions for Functional Safety
- EnDat 2.2 Application Notes

To see the Implementation Guide and submit a query, please visit *www.endat.de*

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