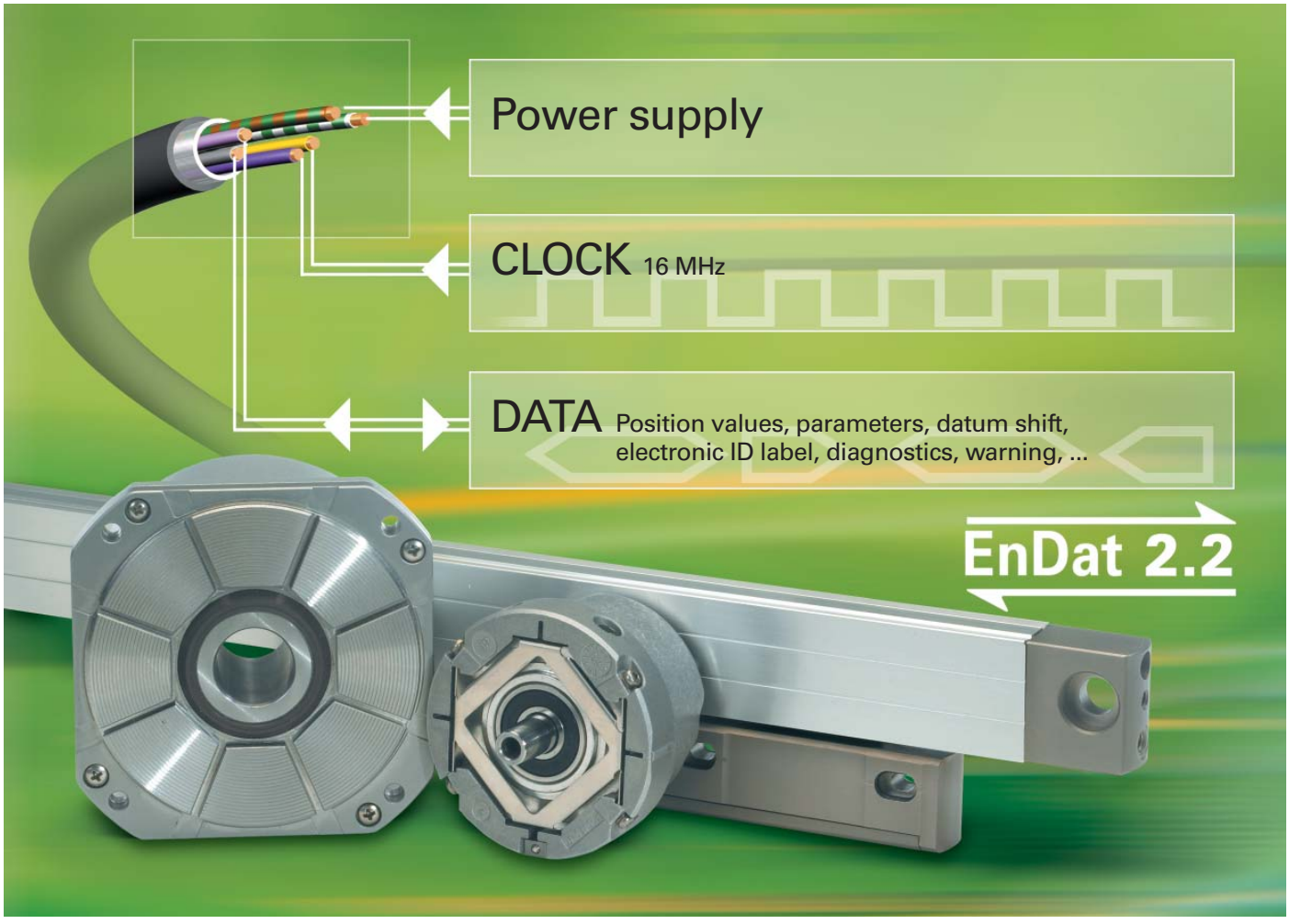
HEIDENHAIN

Technical Information

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 is 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 pure serial interface, is also suited for safety-related applications.



Benefits of the EnDat Interface

The EnDat interface provides everything needed to reduce system cost—per axis up to 50%—and at the same time improve the technical standard. The most significant benefits are:

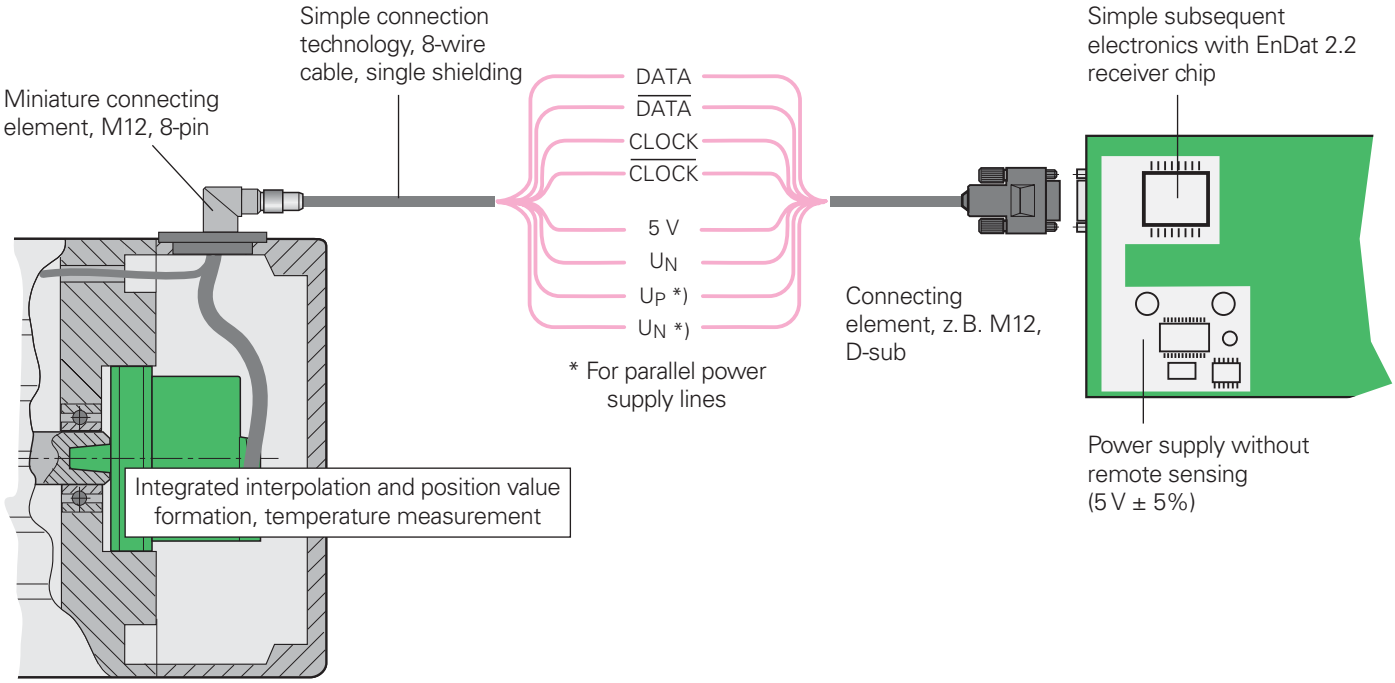
Cost optimization:
- A single interface for all absolute and incremental encoders
- Simple subsequent electronics with EnDat receiver chip and standard components
- Simpler, more economical power supply, since remote sensing is not required
- Simple connection technology: Standard connecting elements (M12 – 8-pin), single shielded standard cable and low wiring costs (see the Product Overview of *Connection Technology*)
- Small motor or system dimensions through compact connecting elements
- No expensive additional sensory analysis and wiring: EnDat 2.2 transmits additional information (limit switch/ temperature/acceleration)
- Faster configuration during installation: Datum shifting through offsetting by a value in the encoder

Improved quality
- Higher system accuracy through specific optimization in the encoder
- High contour accuracy, particularly for CNC machine tools: position value formation in the encoder permits shorter sampling intervals without influencing the computing time of the CNC

Higher availability
- Automatic configuration of the system axis: all necessary information can be saved in the encoder (electronic ID label).
- High system reliability through pure digital data transmission
- Diagnosis through monitoring messages and warnings that can be evaluated in the subsequent electronics
- High transmission reliability through cyclic redundancy checking

Safety system
- EnDat 2.2 was conceived for safety-related machine designs
- Two independent position information sources for error detection
- Two independent error messages
- Checksums and acknowledgments
- Forced dynamic sampling of error messages and CRC formation by subsequent electronics

Support for state-of-the-art machine designs
- Suitable for direct drive technology thanks to high resolution, short cycle times and commutation information
- Cyclic sampling every 25 µs with full "read and write" mode
- Position values available in the subsequent electronics after only approx. 10 µs



Compatibility of EnDat 2.2 > 2.1

The extended EnDat interface version 2.2 is compatible in its communication, command set and time conditions with the previous version 2.1, but also offers significant advantages. It makes it possible, for example, to transfer additional information with the position value without sending a separate request for it. The interface protocol was expanded and the time conditions were optimized as follows:

- Increased clock frequency (CLOCK) (16 MHz)
- Optimized calculating time (position value acquisition within 5 µs)
- Minimized dead time (recovery time) (1.25 to 3.75 µs)
- Expanded power supply range (3.6 V to 5.25 V or 14 V at the encoder)

EnDat 2.2 command set (includes EnDat 2.1 command set)

- Position values for incremental and absolute encoders
- Additional information on position value
  - Diagnostics, test values
  - Absolute position values after reference run of incremental encoders
  - Send and receive parameters
  - Commutation
  - Acceleration
  - Limit position signal

EnDat 2.1 command set

- Absolute position values
- Send and receive parameters
- Reset
- Test command
- Test values

Description of Function

The EnDat interface transmits position values or additional physical quantities in an unambiguous time sequence and serves to read out from and write to the encoder's internal memory.

1. **Position values** can be transmitted with or without additional information. The additional information types are selectable via the Memory Range Select (MRS) code. Other functions such as parameter reading and writing can also be called after the memory area has been selected. Through simultaneous transmission with the position value, additional information can also be requested of axes in the feedback loop, and functions executed with them.
2. **Parameter reading and writing** is possible both as a separate function and in connection with the position value. Parameters can be read or written after the memory area is selected.
3. **Reset functions** serve to reset the encoder in case of malfunction. Reset is possible instead of or during position value transmission.
4. **Test commands and values** are used for forced dynamic sampling in safety-related controls. The significance of the error message is inverted in order to monitor its generation.

Data Transfer

A **clock pulse (CLOCK)** is transmitted by the subsequent electronics to synchronize data transmission. When not transmitting, the clock signal is on high level.

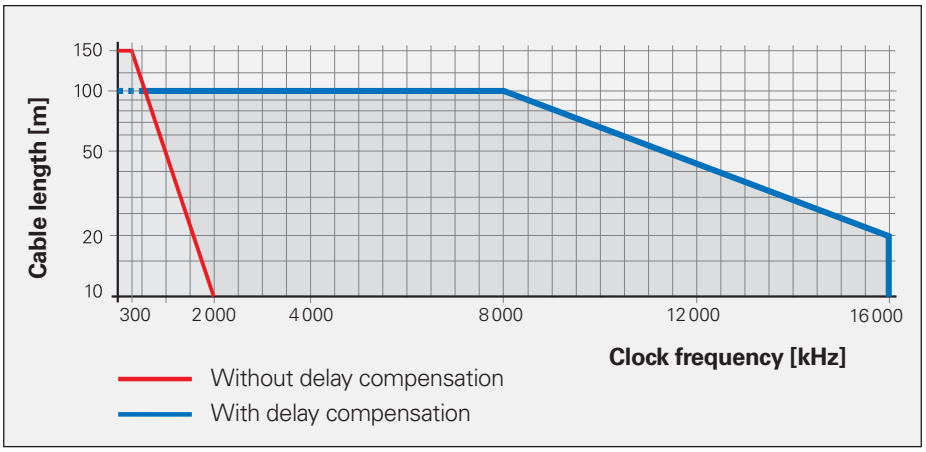
Clock frequency and cable length
Without propagation-delay compensation, the **clock frequency**—depending on the cable length—is variable between **100 kHz** and **2 MHz.** Because large cable lengths and high clock frequencies increase the signal run time to the point that they can disturb the unambiguous assignment of data, the delay can be measured in a test run and then compensated. With this **propagation-delay compensation** in the subsequent electronics, clock frequencies up to **16 MHz** at cable lengths up to a maximum of 100 m ($f_{CLK} \leq 8$ MHz) are possible. The maximum clock frequency is mainly determined by the cables and connecting elements used. To ensure proper function at clock frequencies above 2 MHz, use only original HEIDENHAIN cables.

The permissible clock frequencies shown in the diagrams apply for a **clock on-off ratio** of 1:1. This means that the HIGH and LOW levels of the clock are equally long. For other on-off ratios, the theoretical clock frequency is calculated as $fc = \frac{1}{2t_{min}}$.

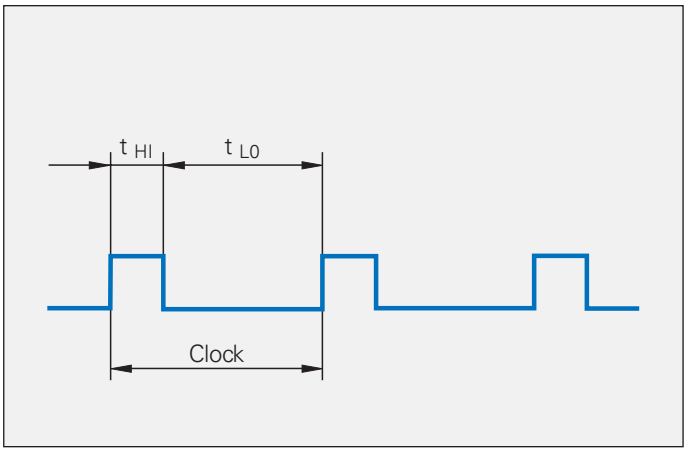
Determining the propagation time
After every change in the transmission line hardware, the propagation time must be ascertained—preferably automatically after every power interruption.

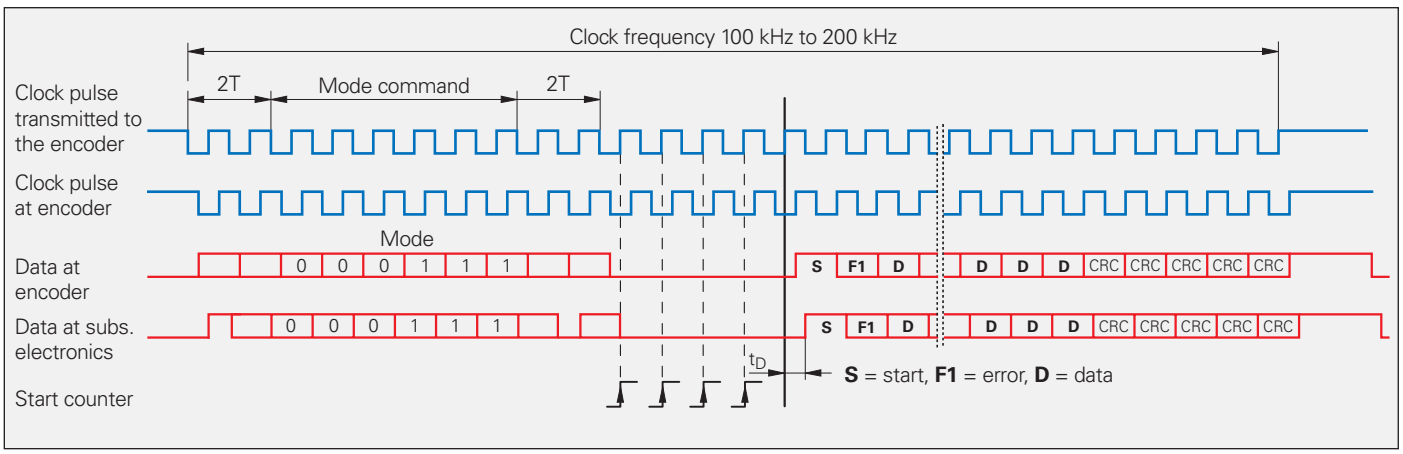
The subsequent electronics transmit the mode command *Encoder transmit position values without additional information* to the encoder. After the encoder has switched to transmission, i. e. after in total 10 clock periods, a counter in the subsequent electronics starts with every rising edge. The subsequent electronics measure the propagation time as the difference between the last rising clock pulse edge and the edge of the start bit. The process should be repeated at least three times in order to rule out any disturbances during the calculation of the propagation time and to test the value for consistency. The signal propagation time is measured at a reduced clock frequency (100 kHz to 200 kHz). To attain sufficient accuracy, however, the value must be sampled at an internal frequency that is at least eight times higher than the clock frequency to be used later for data transmission.

Clock frequency



Clock on-off ratio





Selecting the transmission type

Transmitted data are identified as either position values, position values with additional information, or parameters. The type of information to be transmitted is selected by mode commands. **Mode commands** define the content of the transmitted information. Every mode command consists of three bits. To ensure reliable transmission, every bit is transmitted redundantly (inverted or redundant). If the encoder detects an incorrect mode transmission, it transmits an error message. The EnDat 2.2 interface can also transfer parameter values in the additional information together with the position value. This makes the current position values constantly available for the control loop, even during a parameter request.

The time absolute linear encoders need for calculating the position values t_{cal} differs depending on whether EnDat 2.1 or EnDat 2.2 mode commands are transmitted (see *Specifications* in the *Linear Encoders for Numerically Controlled Machine Tools* brochure). If the incremental signals are evaluated for axis control, then the EnDat 2.1 mode commands should be used. Only in this manner can an active error message be transmitted synchronously with the currently requested position value. EnDat 2.1 mode commands should not be used for pure serial position value transfer for axis control.

				Mode bit					
No.	**Mode command**			**M2**	**M1**	**M0**	**(M2)**	**(M1)**	**(M0)**
1	Encoder transmit position values	**EnDat 2.1 command set**	**EnDat 2.2 command set**	0	0	0	1	1	1
2	Selection of memory area			0	0	1	1	1	0
3	Encoder receive parameters			0	1	1	1	0	0
4	Encoder transmit parameters			1	0	0	0	1	1
5	Encoder receive reset[1)]			1	0	1	0	1	0
6	Encoder transmit test values			0	1	0	1	0	1
7	Encoder receive test command			1	1	0	0	0	1
8	Encoder transmit position value with additional information			1	1	1	0	0	0
9	Encoder transmit position value and receive selection of memory area[2)]			0	0	1	0	0	1
10	Encoder transmit position value and receive parameters[2)]			0	1	1	0	1	1
11	Encoder transmit position value and transmit parameters[2)]			1	0	0	1	0	0
12	Encoder transmit position value and receive error reset[2)]			1	0	1	1	0	1
13	Encoder transmit position value and receive test command[2)]			1	1	0	1	1	0
14	Encoder receive communication command[3)]			0	1	0	0	1	0

[1)] Same reaction as switching the power supply off and on
[2)] Selected additional information is also transmitted
[3)] Reserved for encoders that do not support the safety system

Position Values

One data packet is sent in synchronism per data transmission. The transmission cycle begins with the first falling **clock edge.** The measured values are saved and the position value is calculated.

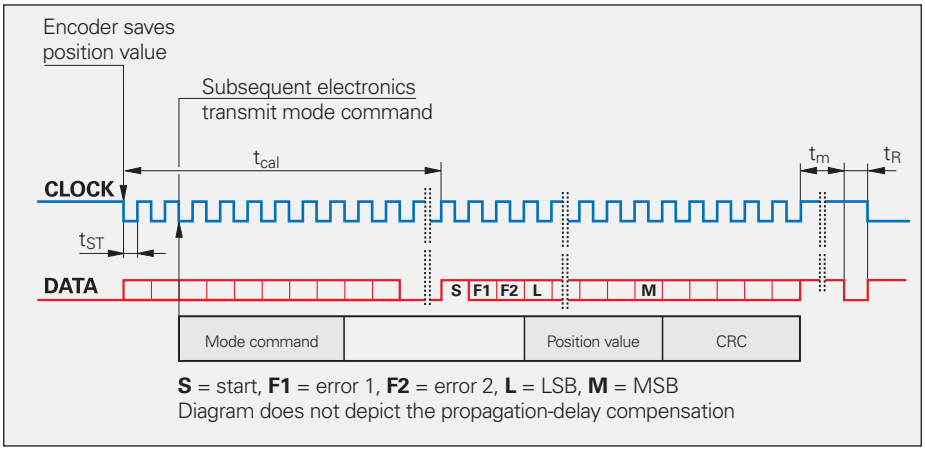
After two clock pulses (2T), the subsequent electronics transmits the **mode command** Encoder transmit position value (with/ without additional information).
After successful calculation of the absolute position value (t_{cal}—see table), the **start bit** begins the data transmission from the encoder to the subsequent electronics. The subsequent **error bits, error 1 and error 2** (only with EnDat 2.2 commands), are group signals for all monitored functions and serve for failure monitoring. They are generated separately from each other and indicate when a malfunction of the encoder can result in incorrect position values. The exact cause of the disturbance is saved in the "operating status" memory and can be interrogated in detail.

The encoder then transmits the **absolute position value,** beginning with the LSB. Its length varies depending on which encoder is being used. The number of required clock pulses for transmission of a position value is saved in the parameters of the encoder manufacturer.

The data transmission of the position value is completed with the **Cyclic Redundancy Check** (CRC). This is followed in EnDat 2.2 by the **additional information** 1 and 2, each also concluded with a CRC. The content of the additional information is determined by the selection of the memory area and is transmitted in the next sampling cycle for additional information. This information is then transmitted with every sampling until a selection of a new memory area changes the content.

With the end of the data word, the clock must be set to HIGH. After 10 to 30 µs or 1.25 to 3.75 µs (with EnDat 2.2 parameterizable recovery time t_m) the data line falls back to LOW. Then a new data transmission can begin by starting the clock.

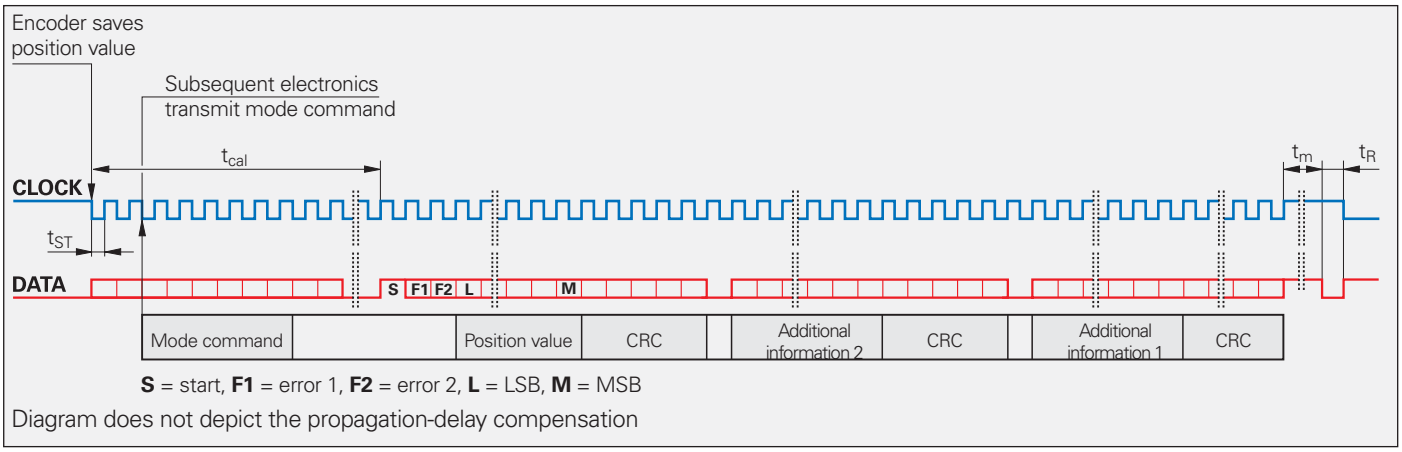
Position value packet without additional information



S = start, **F1** = error 1, **F2** = error 2, **L** = LSB, **M** = MSB
Diagram does not depict the propagation-delay compensation

		Without delay compensation	With delay compensation
Clock frequency	f_c	100 kHz ... 2 MHz	100 kHz ... 16 MHz
Calculation time for Position value Parameters	t_{cal} t_{ac}	Typical of EnDat 2.2 encoders: ≤ 5 µs Max. 12 ms	
Recovery time	t_m	*EnDat 2.1:* 10 to 30 µs *EnDat 2.2:* 10 to 30 µs or 1.25 to 3.75 µs (f_c ≥ 1 MHz) (parameterizable)	
	t_R	Max. 500 ns	
	t_{ST}	–	2 to 10 µs
Data delay time	t_D	(0.2 + 0.01 x cable length in m) µs	
Pulse width	t_{HI} t_{LO}	0.2 to 10 µs 0.2 to 50 ms to 30 µs (with LC)	Pulse width fluctuation HIGH to LOW max. 10%

Data packet with position value and additional information 1 and 2



S = start, **F1** = error 1, **F2** = error 2, **L** = LSB, **M** = MSB

Diagram does not depict the propagation-delay compensation

Typical command sequence when transmitting a position value with additional information:

	Subsequent electronics transmit	Encoder transmits		Subsequent electronics transmit	
Encoder transmit position value and receive selection of memory area (selection of the desired additional information)	Mode command 001 001	Position value		MRS	Random content
Encoder transmit position value and receive selection of memory area (acknowledgment of the MRS code)	Mode command 001 001	Position value		01000111 Acknowledg-ment request for MRS code	Random content
Encoder transmit position value with additional information (acknowledgment)	Mode command 111 000	Position value	Additional information 1MRS acknowledgment		

Content of the data packet

Error messages 1 and 2

The EnDat interface enables comprehensive monitoring of the encoder without requiring an additional transmission line. An error message becomes active if a malfunction of the encoder might result in incorrect position values. At the same time, the cause of error is saved in the encoder. Errors include:

- Light unit failure
- Signal amplitude too low
- Error in calculation of position value
- Power supply too high/low
- Current consumption is excessive

For reasons of security it is necessary to generate a second, independently acquired error message. This is transmitted with inverted level as error message 2.

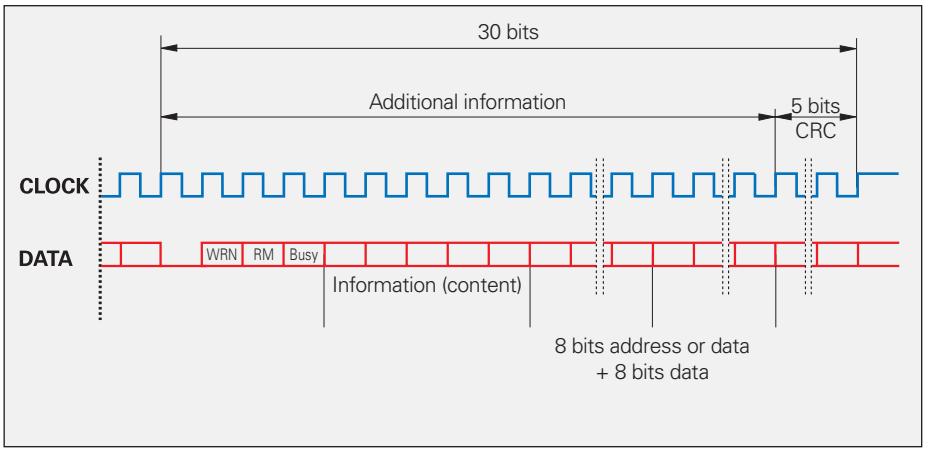
Position value

The position value is transmitted as a complete data word whose length depends on the resolution of the encoder. Transmission begins with the LSB (LSB first).

Additional information

One or two additional data can be appended to the position value, depending on the type of transmission (selection via MRS code). The additional data are each 30 bits in length, with LOW as first bit. Each additional data is concluded with a CRC that is formed from the respective additional information without the first bit or the CRC.

The additional information supported by the respective encoder is saved in the encoder parameters. The additional information includes status information, addresses, and data.



Status data

WRN – Warnings

This collective bit indicates whether certain tolerance limits of the encoder have been reached or exceeded, for example rotational speed or light source control reserve, without necessarily indicating an incorrect position value. This function makes it possible to issue preventive warnings in order to minimize idle time. The cause of the warning is stored in the encoder memory. The alarms and warnings supported by the respective encoder are saved in the "parameters of the encoder manufacturer" memory area.

RM – Reference mark

The RM bit indicates whether the reference run has been completed. In incremental systems, this is required in order to establish the absolute reference to the machine reference system. The absolute position value can then be read from the additional information 1. On absolute encoders the RM bit is always on HIGH.

Busy – Parameter request

When LOW, the busy bit indicates that a parameter request (read/write) is possible. If a request is being processed (HIGH), the encoder memory must not be accessed.

Content of the additional information

The content of the additional information is defined by the mode command for selection of a memory area. This content, updated with each clock pulse, is transmitted until there is a new request. The following contents are possible:

Additional information 1

- **Diagnosis**
  Cyclic information on encoder function and additional diagnostic values.
- **Position value 2**
  For incremental encoders: Relative position information (counter starts from zero at switch-on). Absolute position value is only available after the reference marks have been traversed (RM bit HIGH). *For absolute encoders:* Second absolute position value for safety-related applications.
- **Memory parameters**
  Parameters saved in the encoder can also be transmitted along with the position values. The request is defined via memory range selection, followed by the output of the parameters with the associated address.
- **MRS code – Acknowledgment**
  Acknowledgment of the requested memory range selection
- **Test values**
  Test values serve for inspection purposes, in service diagnostics, for example.
- **Temperature**
  Transmission of temperature in encoders with integrated evaluation of temperature sensors.
- **Additional sensors**
  The EnDat 2.2 protocol enables the connection of 16 additional sensors (4-bit address). The sensor values increase by x+1 for each request. The associated sensor is identified by the address supplied.

Additional information 2

- **Commutation**
  Incremental encoders provide "rough" position information for commutation in electric motors.
- **Acceleration**
  If the encoder has additional sensor systems for acceleration measurement, it can transmit the results.
- **Limit position signals**
  Limit position signals and homing information.
- **Asynchronous position value**
  Position formed by oversampling between two "regular" requests.
- **Operating status error sources**
  Detailed information about the cause of the present error message

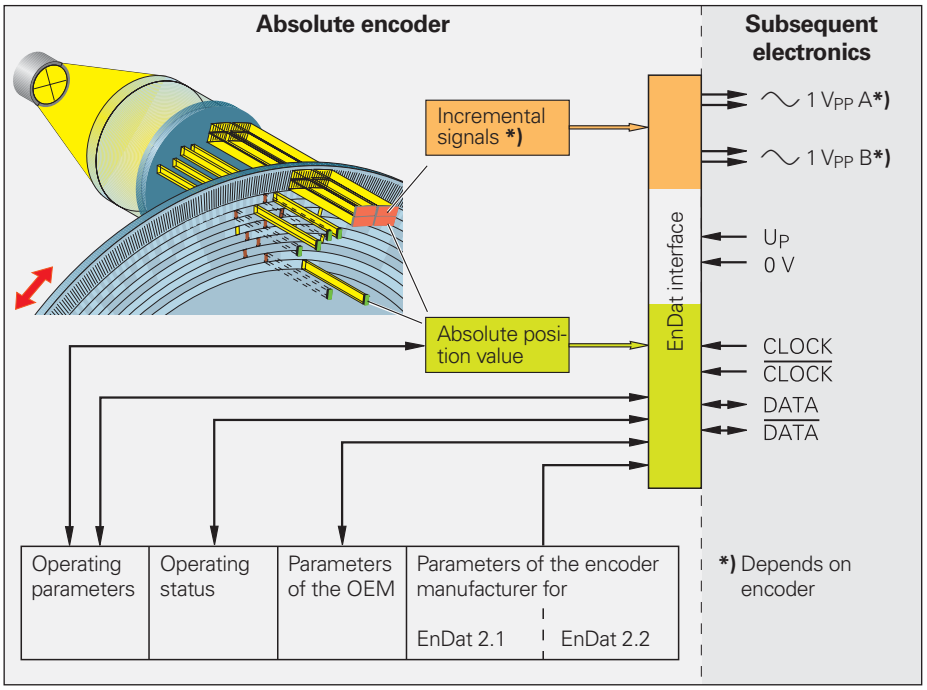
MRS code for selecting the additional information

	C7	C6	C5	C4	C3	C2	C1	C0	
Additional information 1	0	1	0	0	0	0	0	0	Transmit additional information 1 without data content (NOP)
	0	1	0	0	0	0	0	1	Transmit diagnosis
	0	1	0	0	0	0	1	0	Transmit position values 2 word 1 LSB
	0	1	0	0	0	0	1	1	Transmit position values 2 word 2
	0	1	0	0	0	1	0	0	Transmit position values 2 word 3 MSB
	0	1	0	0	0	1	0	1	Acknowledge memory content LSB
	0	1	0	0	0	1	1	0	Acknowledge memory content MSB
	0	1	0	0	0	1	1	1	Acknowledge MRS code
	0	1	0	0	1	0	0	0	Acknowledge test command
	0	1	0	0	1	0	0	1	Transmit test values word 1 LSB
	0	1	0	0	1	0	1	0	Transmit test values word 2
	0	1	0	0	1	0	1	1	Transmit test values word 3 MSB
	0	1	0	0	1	1	0	0	Transmit temperature 1
	0	1	0	0	1	1	0	1	Transmit temperature 2
	0	1	0	0	1	1	1	0	Additional sensors
	0	1	0	0	1	1	1	1	Transmit no more additional information 1
Additional information 2	0	1	0	1	0	0	0	0	Transmit additional information 2 without data content (NOP)
	0	1	0	1	0	0	0	1	Transmit commutation
	0	1	0	1	0	0	1	0	Transmit acceleration
	0	1	0	1	0	0	1	1	Transmit commutation and acceleration
	0	1	0	1	0	1	0	0	Transmit limit position signal
	0	1	0	1	0	1	0	1	Transmit limit position signal and acceleration
	0	1	0	1	0	1	1	0	Asynchronous position value word 1 LSB
	0	1	0	1	0	1	1	1	Asynchronous position value word 2
	0	1	0	1	1	0	0	0	Asynchronous position value word 3 MSB
	0	1	0	1	1	0	0	1	Operating status error sources
	.	.	.	.	.	.	.	.	(Not used at present)
	.	.	.	.	.	.	.	.	
	0	1	0	1	1	1	1	1	Transmit no more additional information 2

Parameters
Memory areas

The encoder provides several memory areas for parameters. These can be read from by the subsequent electronics, and some can be written to by the encoder manufacturer, the OEM, or even the end user. Certain memory areas can be write-protected.

The parameters, which in most cases are set by the OEM, largely define the function of the encoder and the EnDat interface. When the encoder is exchanged, it is therefore essential that its parameter settings are correct. Attempts to configure machines without including OEM data can result in malfunctions. If there is any doubt as to the correct parameter settings, the OEM should be consulted.



Block diagram of absolute encoder with EnDat 2.2 interface

Parameters of the encoder manufacturer
This write-protected memory area contains all **information specific to the encoder,** such as encoder type (linear/angular, singleturn/multiturn, etc.), signal periods, number of position values per revolution, transmission format of absolute position values, direction of rotation, maximum permissible speed, accuracy dependent on shaft speeds, support from warnings and alarms, ID number, and serial number. This information forms the basis for **automatic configuration.**

A separate memory area contains the parameters typical for EnDat 2.2: Status of additional information, temperature, acceleration, support of diagnostic and error messages, etc.

Parameters of the OEM
In this freely definable memory area, the OEM can store his information, e.g. the "electronic ID label" of the motor in which the encoder is integrated, indicating the motor model, maximum current rating, etc.

Operating parameters
This area is available to the customer for a **datum shift** and the configuration of diagnostics. Furthermore, a warning threshold can be defined for the temperature sensor integrated in the encoder. Other functions (cycle time, I/0) are reserved for future applications. The operating parameter area can be protected against overwriting.

Operating status
This memory area provides detailed alarms or warnings for diagnostic purposes. Here it is also possible to initialize certain encoder functions, to activate write protection for the OEM parameter and operating parameter memory areas, and to interrogate their status.
Once activated, **the write protection** cannot be reversed.

Parameters of the encoder manufacturer

The meaning of the information contained in the parameters of the encoder manufacturer depends on the encoder.

HEIDENHAIN encoders can be divided into six groups. They are differentiated by the type of encoder (word 14 of the EnDat 2.1 parameters).

Encoder types:

L Linear encoders
W Angle encoders (rotational)
D Rotary encoders (rotational)
E EIB external interface box for conversion of 1 V_{PP} to pure serial EnDat 2.2
iL Incremental linear encoder with integral conversion of 1 V_{PP} to pure serial EnDat 2.2
iR Incremental rotational encoder with integral conversion of 1 V_{PP} to pure serial EnDat 2.2

The meanings of parameters are divided into evaluation categories. On the basis of these categories, the user can make clear decisions on the use of parameters and their integration in the application software.

Evaluation categories:

- **Required:**
  It is essential for operation of the encoder that these parameters be considered.
- **Depends on application:**
  Whether these parameters are to be considered depends on the customer's application. If, for example, no OEM range is used, then the parameter regarding memory allocation for parameters of the OEM need not be considered.
- **Informative:**
  These parameters are not required for encoder operation, but they give the user additional information such as the model number.
- **Not relevant:**
  If no encoder types were assigned to any of the three other evaluation categories, then the parameter is not required for encoder operation and can be ignored.

The additional information for EnDat 2.2 contained in the parameters of the encoder manufacturer depends in part on the respective encoder.

EnDat 2.2 parameters can be read out only with EnDat 2.2 mode commands.

The types of additional information, additional functions, diagnostic values, and specifications that the respective encoder supports are saved in the assigned status words of these memory areas. Before interrogation of the additional information, HEIDENHAIN recommends reading out the supported information and functions (typically for every initialization of encoders). They are also shown in the encoders' specifications.

Parameters of the encoder manufacturer for EnDat 2.1

Word	Content	Unit for		Required	Depends on application	Informative	Remark
		Linear encoder	Rotary/ Angle encoder				
4	Mask 0	–	–	–	–	–	–
5	Mask 1	–	–	–	–	–	–
6	Mask 2	–	–	–	–	–	–
7	Mask 3	–	–	–	–	–	–
8	Version of the EnDat interface	–	–	–	–	All	"2" saved with EnDat 2.1 or 2.2
9	Memory allocation for parameters of the OEM	–	–	All	–	–	Depends on encoder; program flexibly. Memory pointer to first free address
10							
11	Memory allocation for compensation values	–	–	–	–	–	Reserved for encoder manufacturer
12							
13	Number of clock pulses for transfer of position value (transmission format)	–	–	All	–	–	Setting the correct clock number for position transmission
14	Type of encoder	–	–	All	–	–	Defines the units of the parameters
15	Signal period(s) per revolution for incremental output signals	nm	–	All	–	–	**E, iL, iR:** for calculating the smallest display step (LSB) or the correct display value for negative traverse direction **All:** for EnDat-compliant datum shift
16							
17	Distinguishable revolutions (only for multiturn encoders)	–	–	W D	–	–	Required for correct calculation of the position
18	(Nominal) increment of reference marks	mm	Signal periods	–	–	E iL iR	–
19	Position of first reference mark	mm	–	–	–	iL	Not supported by **EIB**

Parameters of the encoder manufacturer for EnDat 2.1 (continued)

Word	Content	Unit for		Required	Depends on application	Informative	Remark
		Linear encoder	Rotary/ Angle encoder				
20 21	Measuring step or steps per revolution with serial data transmission	nm	Measuring steps per revolution	All	–	–	–
22 23	Datum shift of the encoder manufacturer	Signal periods	Signal periods	All	–	–	To be accounted for by the user for datum shift
24 25 26	ID number	–	–	–	–	All	Safety technology
27 28 29	Serial number	–	–	–	All	–	Encoder exchange can be detected (may affect application—safety related)
30	Direction of rotation or traverse	–	–	All	–	–	–
31	Status of commissioning diagnosis	–	–	–	–	–	No longer supported since 1999
32	Maximum mechanically permissible linear velocity or shaft speed	m/min	min^{-1}	–	W L D iL iR	–	Required for cross checking of absolute position ⇔ incremental position
33	Accuracy depending on linear velocity or shaft speed, Area I	LSB [1]	LSB [1]	–	W L D	–	Comparison of absolute and incremental position not possible with **E iL iR,** because these encoders have only incremental information
34	Accuracy depending on linear velocity or shaft speed Area II	LSB [1]	LSB [1]	–	W L D	–	
35	Support of error messages 1	–	–	All	–	–	For definition of an "error mask" (safety related)
36	Support of warnings	–	–	–	–	All	For preventive maintenance
37	EnDat command set	–	–	All	–	–	Information whether EnDat 2.2 mode commands are supported
38	Reserved for measuring length [2]	–	–	–	–	L iL	Not supported by **EIB.**
39	Maximum processing time	–	–	All	–	–	For monitoring (time out)
40	EnDat ordering designation	–	–	–	All	–	Distinguishes between with/without incremental signals
41 42 43 44 45 46	HEIDENHAIN specifications	–	–	–	–	–	–
47	CHECKSUM	–	–	–	–	–	–

[1] The higher-valued byte contains the divisor with respect to the maximum permissible linear velocity or rotational shaft speed up to which this accuracy is valid.

[2] Not supported by all linear encoder models; initialized with default value 0.

Parameters of the encoder manufacturer for EnDat 2.2

Word	Content	Unit for		Required	Depends on application	Informative	Remark
		Linear encoder	Rotary/ Angle encoder				
0	Status of additional information 1	–	–	–	All	–	Can be safety related.Cross checking of "what is required" and "what does the encoder support"
1	Status of additional information 2	–	–	–	All	–	
2	Status of additional functions	–	–	–	All	–	
3	Acceleration	m/s^2	$1/s^2$	–	All	–	Consider the scaling factor
4	Temperature	K	K	–	All	–	Consider the scaling factor
5	Diagnostic status	–	–	–	–	All	–
6	Support of error message 2	–	–	All	–	–	For definition of an "error mask" (safety related)
7	Dynamic sampling status	–	–	–	All	–	Safety technology
8							
9	Measuring step or measuring steps per revolution for position value 2	nm	–	–	All	–	Safety technology or **EIB, iL, iR**
10							
11	Accuracy of position value 2 depending on linear velocity or shaft speed, Area I	LSB[1)]	LSB[1)]	–	All	–	Safety technology or **EIB, iL, iR**
12		LSB[1)]	LSB[1)]	–	All	–	Safety technology or **EIB, iL, iR**
13	Accuracy of position value 2 depending on linear velocity or shaft speed, Area II	LSB [1)]	LSB [1)]	–	All	–	Safety technology or **EIB, iL, iR**
14		LSB [1)]	LSB [1)]	–	All	–	Safety technology or **EIB, iL, iR**
15	Distinguishable revolutions Position value 2 (only for multiturn encoders)	–	–	W D	–	–	Required for correct calculation of the position
16	Direction of rotation of position value 2	–	–	All	–	–	–
17 to 20	Encoder designation	–	–	–	–	All	–
21	Support of instructions	–	–	–	–	–	Not yet supported. Not for safety technology
22	Max. permissible encoder temperature at measuring point	K	K	–	W L D iL iR	–	Not supported by **EIB**
23	Max. permissible acceleration	m/s^2	$1/s^2$	–	W L D iL iR	–	Not supported by **EIB**
24	Number of blocks for memory area Section 2	–	–	All	–	–	Depends on encoder; program flexibly
25	Maximum clock frequency	kHz	kHz	All	–	–	Depends on connector, cable lengths
26	Number of bits for position comparison	–	–	–	All	–	Safety technology
27	Scaling factor for resolution	–	–	All	–	–	For calculation of the smallest display step (LSB).
28	Measuring step, or measuring steps per revolution or subdivision values of a grating period	–	–	All	–	–	
29							
30	Max. velocity or rotational shaft speed for constant code value	m/min	min^{-1}	–	W L D iL iR	–	Specific to application. Applies for encoders that permit higher mechanical than electrical speed. Not supported by the EIB
31	Offset between position value and position value 2	–	–	–	All	–	Safety technology
32							
33							
34	"Number of distinguishable revolutions" with scaling factor	–	–	W D	–	–	Required for correct calculation of the position
35	Support of operating status error sources	–	–	–	All	–	Expanded EnDat error message, particularly for battery-buffered encoders
63	CHECKSUM	–	–	–	–	–	–

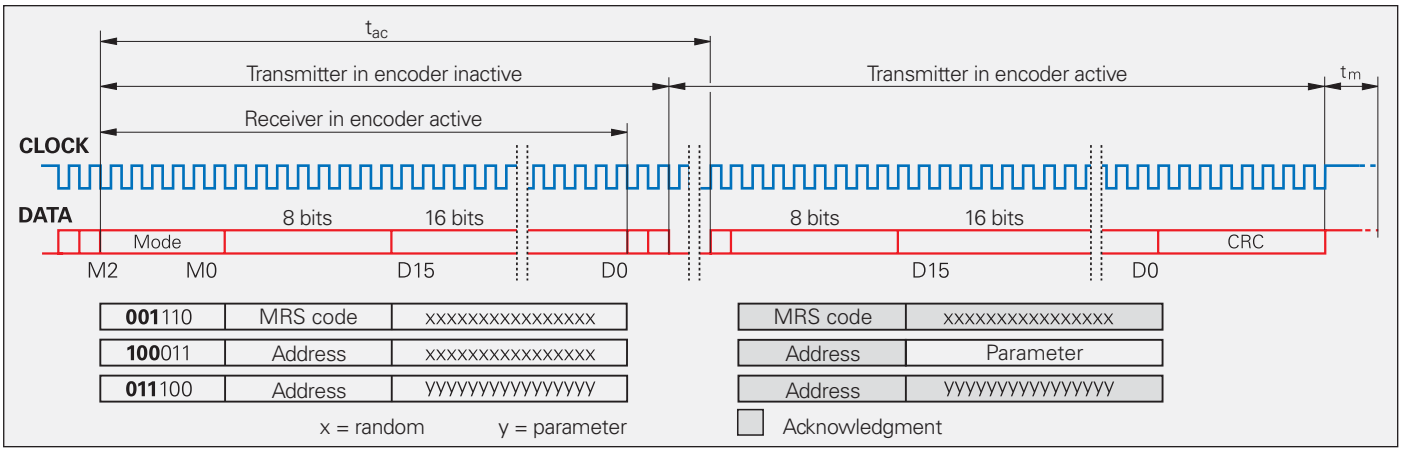
1) The higher-valued byte contains the divisor with respect to the maximum permissible linear velocity or rotational shaft speed up to which this accuracy is valid.

Transmission of parameters

Control cycles for transfer of parameters (EnDat 2.1 mode command 001110)
Before parameter transfer, the memory area is specified with the selection of memory area mode command. The possible memory areas are stored in the parameters of the encoder manufacturer. Due to internal access times to the individual memory areas, the time t_{ac} may reach 12 ms.

Reading parameters from the encoder (EnDat 2.1 mode command 100011)
After selecting the memory area, the subsequent electronics transmit a complete communications protocol beginning with the mode command Encoder transmit parameters, followed by an 8-bit address and 16 bits with random content. The encoder responds with the repetition of the address and 16 bits with the contents of the parameter. The transmission cycle is concluded with a CRC check.

Writing parameters to the encoder (EnDat 2.1 mode command 011100)
After selecting the memory area, the subsequent electronics transmit a complete communications protocol beginning with the mode command Encoder receive parameters, followed by an 8-bit address and a 16-bit parameter value. The encoder answers by repeating the address and the contents of the parameter. The CRC check concludes the cycle.



Typical EnDat 2.2 command sequence for transmitting a position value with parameter values in the additional information
(max. 12 ms access time by interrogating the integrated EEPROM)

	Subsequent electronics transmit	Encoder transmits		Subsequent electronics transmit	
Encoder transmit position value and receive selection of memory area (selection of the desired additional information)	Mode command 001 001	Position value		MRS	Random content
Encoder transmit position value and receive selection of memory area (acknowledgment of the MRS code)	Mode command 001 001	Position value		01000111 Acknowledgment request for MRS code	Random content
Encoder transmit position value with additional information (acknowledgment)	Mode command 111 000	Position value	Additional information 1 MRS acknowledgment		
Encoder transmit position value and transmit parameters	Mode command 100 100	Position value		Address	Random content
Encoder transmit position value with additional information	Mode command 111 000	Position value	Additional information 1 Busy = 1/no data		
Parameter value is not yet available, therefore the busy bit is at 1.					
Encoder transmit position value with additional information	Mode command 111 000	Position value	Additional information 1 Busy = 1/no data		
Encoder transmit position value with additional information	Mode command 111 000	Position value	Additional information 1 Busy = 1/no data		
Max. 12 ms					
Encoder transmit position value with additional information	Mode command 111 000	Position value	Additional information 1 Busy = 0/parameter		

This concludes the request. A new parameter value can be requested from a new address.

Diagnosis

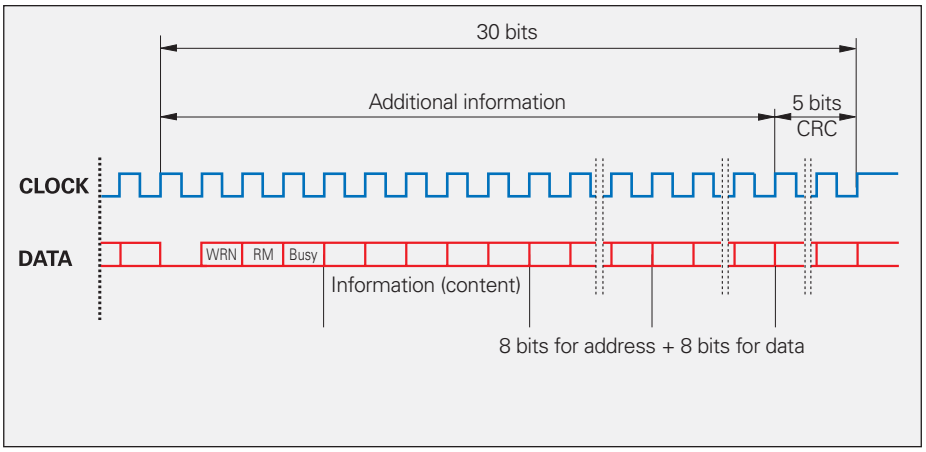
The EnDat interface makes extensive monitoring and diagnosis of an encoder possible without an additional line. The diagnostic system generates error messages and warnings (see *Position values*), and is a significant prerequisite for the high level of availability of the complete system.

Online diagnostics are growing in significance. Decisive points of emphasis are:
- Machine usage planning
- Support for the service technician on-site
- Simple evaluation of encoder function reserves
- Simplification of trouble-shooting for repair
- Generation of meaningful quality statistics

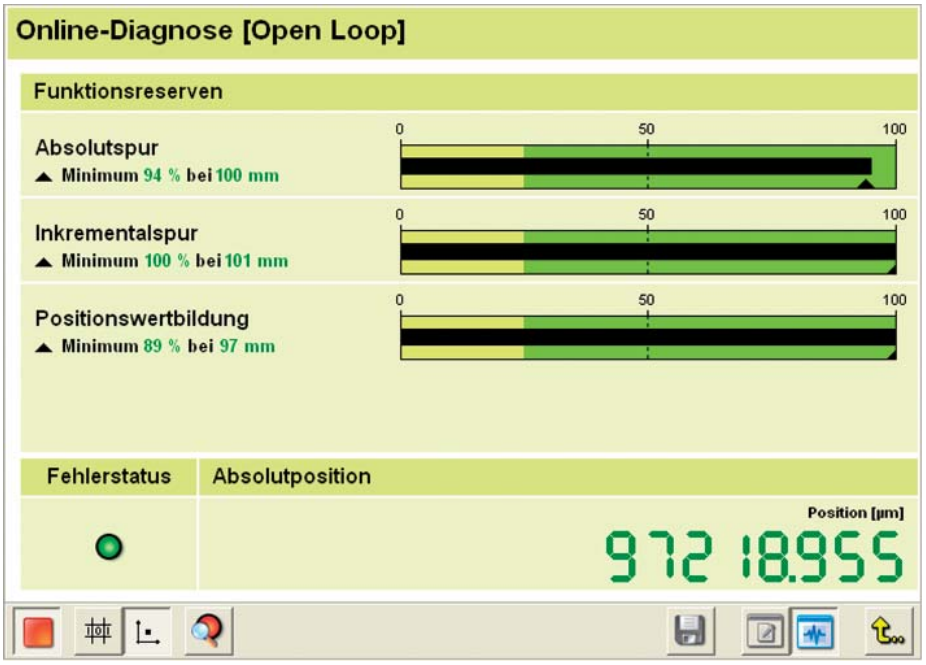
On encoders with incremental signals, it is possible to use Lissajous figures to analyze signal errors and what they mean for encoder function.

Encoders with pure serial interfaces do not provide incremental signals. Encoders with EnDat 2.2 can cyclically output the **valuation numbers** in order to evaluate the functions of the encoder. The valuation numbers provide the current state of the encoder and ascertain the encoder's "functional reserves." Their scaling is identical for all HEIDENHAIN encoders. This makes integrated evaluation possible. The valuation numbers supported by the respective encoder are saved in the EnDat 2.2 parameters.

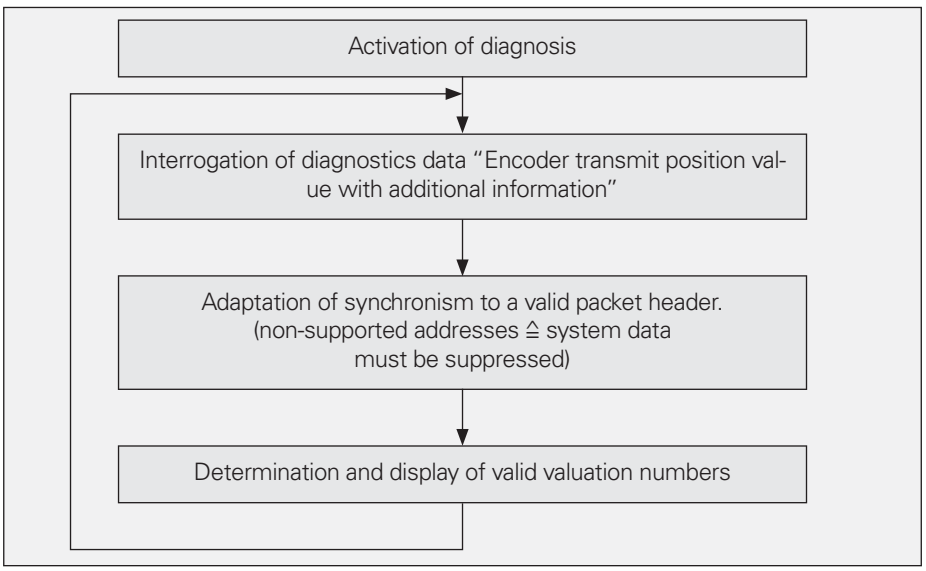
Composition and interrogation of the transmitted diagnostics data:
- The desired valuation numbers must be activated.
- The value (8 bits) is transmitted over the additional information 1.
- The values are output in a cyclic process; address and value.
- The information as to which valuation numbers are supported is saved in the EnDat 2.2 parameters.
- The diagnostics information can be transmitted in the closed-loop mode.
- The "border areas" should be suppressed in the display (definition of reserve areas is required).
- "Unknown addresses" (system data) must be ignored in the subsequent electronics.



The valuation numbers in EnDat 2.2 are provided in the additional information.



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



Flow chart for interrogation of diagnostics data

Configuration

Function initialization

In **word 3** of the operating status, the customer can define the **functions** of data transmission or special function modes of the encoder.

In the default setting, all additional information data are deactivated and the recovery time is programmed at $10\ \mu s \leq t_m \leq 30\ \mu s$. Recovery time can be changed to $1.25\ \mu s \leq t_m \leq 3.75\ \mu s$ only for the mode commands 8 to 14.

For clock pulse frequencies ≤ 1 MHz, recovery time must remain set to $10\ \mu s \leq t_m \leq 30\ \mu s$.

The *oversampling, diagnostics reset* and *EnDat-2.2 cyclic operation can be deactivated* functions are reserved for future applications, and cannot yet be activated.

In the future, the *multiturn* functions will enable connection of battery-buffered encoders.

Information	Condition upon delivery
Recovery time t_m	$10\ \mu s \leq t_m \leq 30\ \mu s$ Adjustable to $1.25\ \mu s \leq t_m \leq 3.75\ \mu s$ [1)]
Reference pulse initialization	Deactivated
Oversampling	Deactivated
EnDat 2.2 cyclic operation can be deactivated	Activated
Multiturn overflow alarm	Deactivated
Multiturn overflow latch	Deactivated
Multiturn position alarm	Deactivated
Multiturn counter reset	Deactivated
Diagnostics reset	Deactivated

[1)] Valid only for the mode commands 8 to 14 of the EnDat 2.2 command set

Configuration of diagnosis

In **word 3** of the operating status, the customer can define the **configuration** of the diagnosis for the "Encoder transmit position values with additional information mode" command.

Recommendation: All available valuation numbers should be activated to ensure the maximum depth of information on the encoder's function reserves.

	= 0	= 1
Valuation number 1	Deactivated	Activated
Valuation number 2	Deactivated	Activated
Valuation number 3	Deactivated	Activated
Valuation number 4	Deactivated	Activated
System-specific data	Deactivated	Activated

The configuration is not activated until the *encoder receive reset* mode command has been transmitted.

Interface
Power supply and switch-on

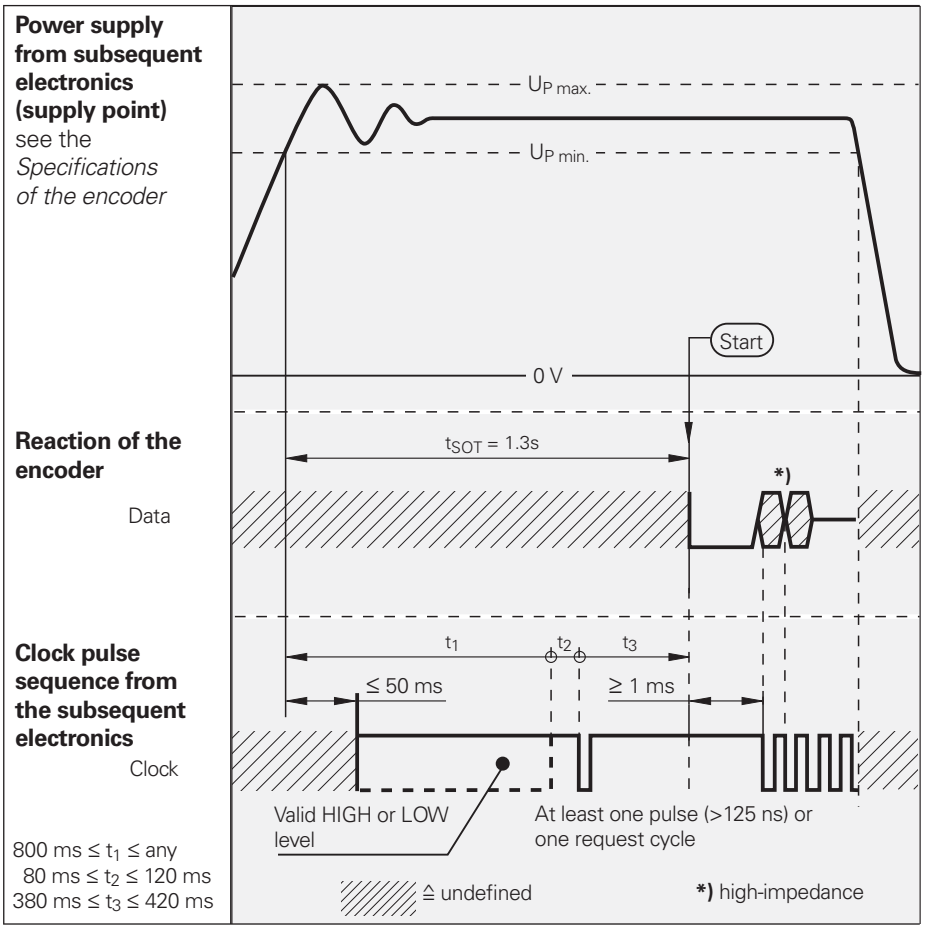
Power supply
The encoders require a **stabilized dc voltage U_P** as power supply. The required power supply and the current consumption are given in the respective specifications. The values apply as measured at the encoder.

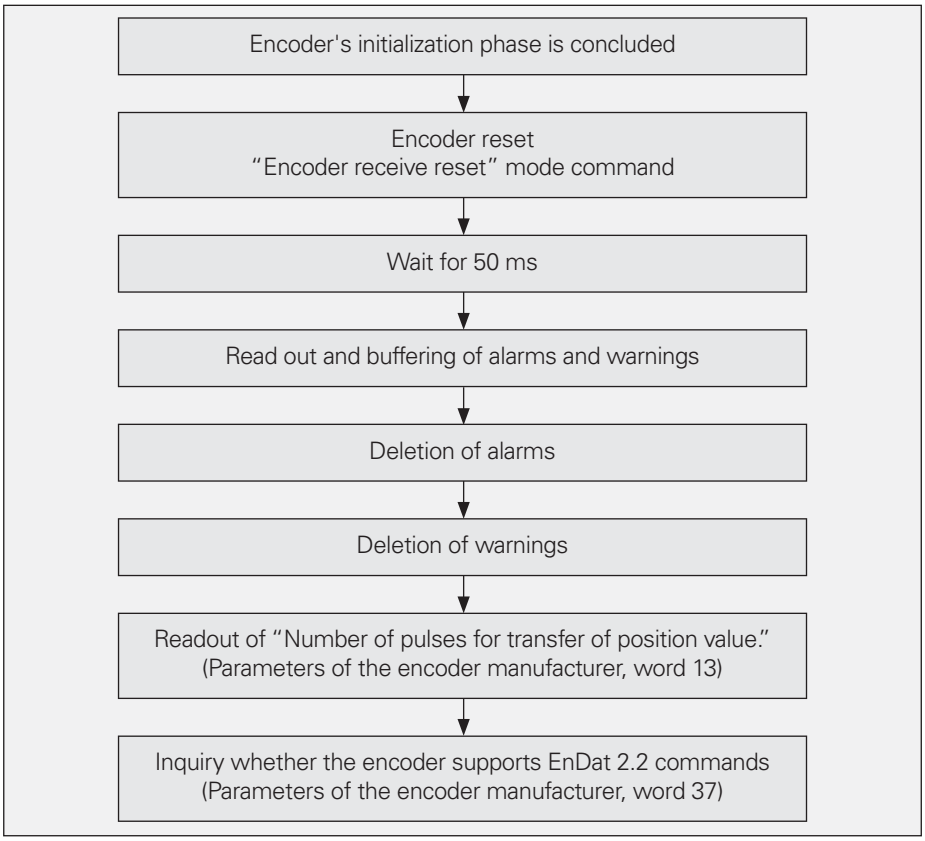
EnDat 2.2 encoders feature an expanded power supply range from 3.6 to 5.25 V or from 3.6 to 14 V. This makes it possible to design the power supply of the subsequent electronics so that the resulting voltage after attenuation through cable length, cable cross section and current consumption can be processed 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 (remote sense) are no longer necessary.

The permissible ripple content of the dc voltage is:
- High frequency interference U_{PP} < 250 mV with dU/dt > 5 V/µs
- Low frequency fundamental ripple U_{PP} < 100 mV

Starting behavior at the encoder
The integrated electronics require an initialization time of approx. 1.3 s, whereby the **initialization phase** should be taken into account (see "Clock pulse sequence from the subsequent electronics" at right).

After conclusion of the initialization phase, a certain **switch-on routine** is necessary. Only EnDat 2.1 mode commands can be used for this purpose.





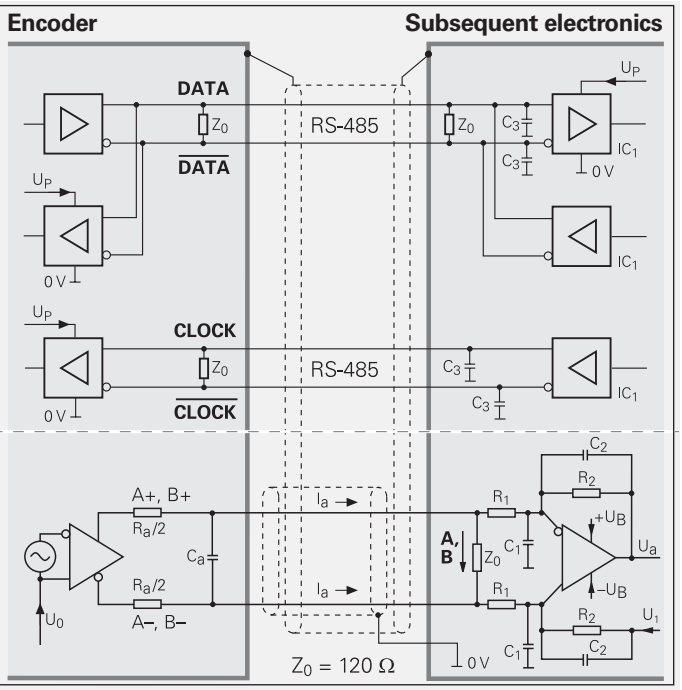
Input circuitry of the subsequent electronics

Data (measured values or parameters) can be transferred bidirectionally between position encoders and subsequent electronics with transceiver components in accordance with RS-485 (differential signals), in synchronism with the clock signal produced by the subsequent electronics.

Dimensioning
IC_1 = RS 485 differential line receiver and driver

C_3 = 330 pF
Z_0 = 120 Ω

Data transfer



Incremental signals
Depends on encoder

Safety System

Basic principle
EnDat 2.2 supports the use of encoders in safety-related applications. The ISO 13 849-1 (previously EN 954-1) and IEC 61 508 standards serve as the foundation for this. These standards describe the assessment of safety-related systems, for example based on the failure probabilities of integrated components and subsystems.

The modular approach helps manufacturers of safety-related systems to implement their complete systems, because they can begin with prequalified subsystems. Safety-related position encoders with pure serial data transmission via EnDat 2.2 accommodate this technique. The defined data interface to the subsequent electronics makes implementation in safety systems easier for the user.

In a safe drive, the safety-related position measuring system presents such a subsystem. The **safety-related position measuring system** consists of:

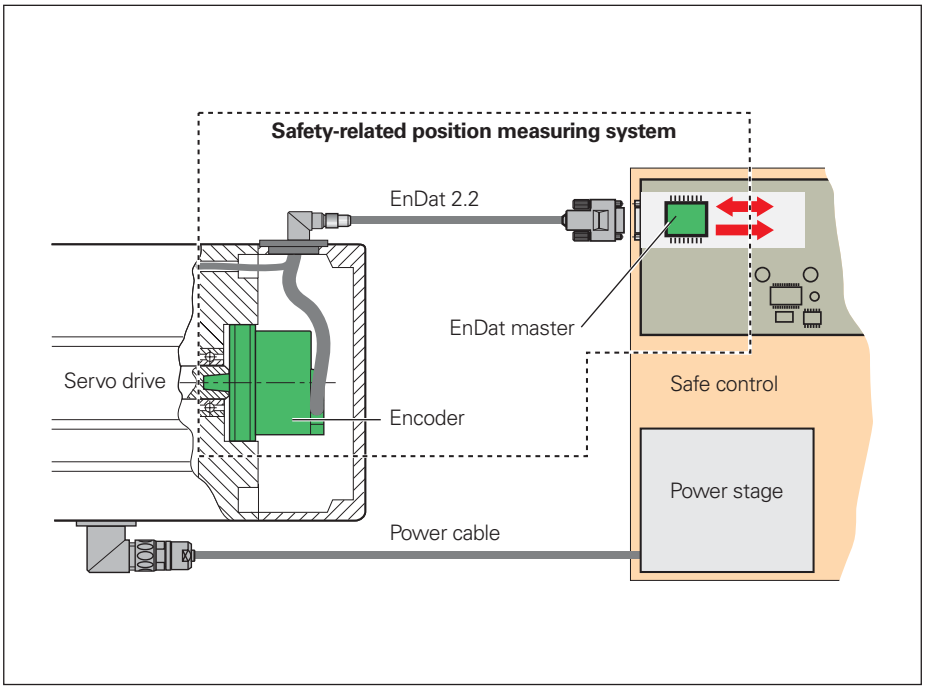
- Encoder with EnDat 2.2 transmission component
- Data transfer line with EnDat 2.2 communication and HEIDENHAIN cable
- EnDat 2.2 receiver component with monitoring function (EnDat master)

Integration of the position measuring system
The position measuring system is integrated via a physical and an electrical interface into the complete system. The physical coupling of the encoder to the drive is determined by the encoder's geometry. Including the EnDat master with its monitoring functions in the safe control ensures its electrical integration. The necessary measures have already been defined. The control manufacturer must only implement them. With regard to a safe complete system, the remaining components of the complete system must also be designed for safe technology.

Area of application
Safety-related position measuring systems from HEIDENHAIN are designed so that they can be used as single-encoder systems in applications with control category SIL-2 (in accordance with IEC 61 508). This corresponds to performance level "d" of ISO 13 849 or category 3 according to EN 954-1. Also, the functions of the safety-related position measuring system can be used for the following safety functions in the complete system
(also see IEC 61 800-5-2):
- Safe switch-off
- Safe stop
- Safe controlled stop
- Safe reduced linear velocity
- Safe reduced rotational speed
- Safe limited jog increment
- Safe limited absolute position

Function
The safety system of the position encoder is based on two mutually independent position values and additional error bits produced in the encoder and transmitted over the EnDat 2.2 protocol to the EnDat master. The EnDat master assumes various monitoring functions with which errors in the encoder and during transmission can be revealed. The two position values are then compared. The EnDat master then provides the two position values and mutually independent error bits to the safe control over two processor interfaces. The control monitors the correct operation of the safety-related position measuring system with periodic tests.

The architecture of the EnDat 2.2 protocol makes it possible to conduct all safety-oriented information or control mechanisms during unconstrained controller operation. The safety-related information is therefore saved in the additional information. According to IEC 61 508, the architecture of the position measuring system is regarded as a single-channel tested system.



Complete safe servo drive system

The EnDat 2.2 interface supports the following individual safety-relevant functions:

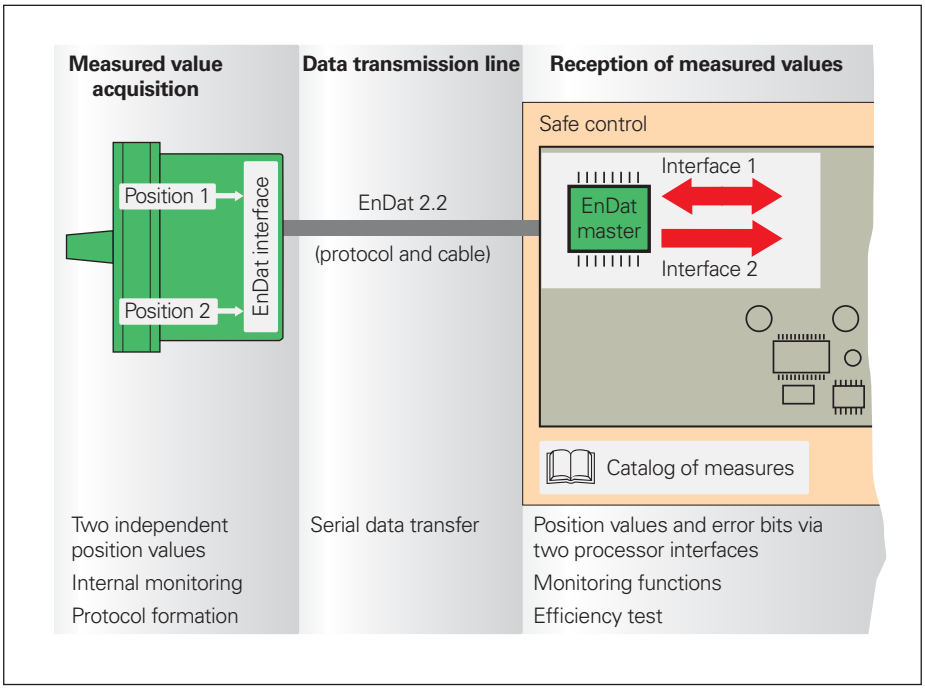
Two mutually independent position values for error detection
In addition to the position value, the additional information includes a separately generated position value to be used for comparison in the subsequent electronics.

Two mutually independent error messages
The error messages are generated independently of each other and are transmitted at different active levels.

Independent individual CRC generation for position values and additional information
Separate CRC values are generated for the individual data packets of a transmission (position value, additional information 1 and 2).

Highly dynamic data acquisition and transmission
Short cycle times for data acquisition including transmission make the necessary position-value comparisons and monitoring of transmission functions possible.

Reliable position value acquisition requires that the subsequent electronics initiate these functions and evaluate the data correctly. More detailed information can be found in the "Safety-Related Position Measuring Systems" Technical Information and the package of measures for the safe control.



Safety-related position measuring system

Overview of Encoders

EnDat is available in two versions, EnDat 2.1 and EnDat 2.2. Only EnDat 2.2 devices support functions such as short recovery time and additional information.

Absolute encoders		**Resolution**
Linear encoders	LC 183/LC 483 ± 5 µm ± 3 µm LIC 4000 ± 5 µm	0.01 µm 0.005 µm 0.01 µm
Angle encoders	RCN 226 RCN 228 RCN 729/RCN 829	26 bits 28 bits 29 bits
Rotary encoders	**Optical, singleturn** ROC/ECN 425, ECN 1325, ECN 125 ROC/ECN 10xx/11xx **Optical, multiturn** ROQ/EQN 437, EQN 1337, ROQ/EQN 10xx/11xx **Inductive, singleturn** ECI 13xx ECI 11xx **Inductive, multiturn** EQI 13xx EQI 11xx	 25 bits 23 bits 37 bits 35 bits 19 bits[1)] 18 bits[1)] 31 bits[1)] 30 bits[1)]
Incremental encoders		**Resolution**
Encoders with 1-V_{PP} output signals over EIB (**E**xternal **I**nterface **B**ox)		Integrated 14-bit interpolation

[1)] EnDat 2.1 available, EnDat 2.2 planned.

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For more information:
- HEIDENHAIN encoder brochures
- Description of the master component (www.mazet.de)
- Detailed interface specification (upon request)
- Product Overview: *Connection Technology*

383 942-24 · 5 · 11/2008 · F&W · Printed in Germany