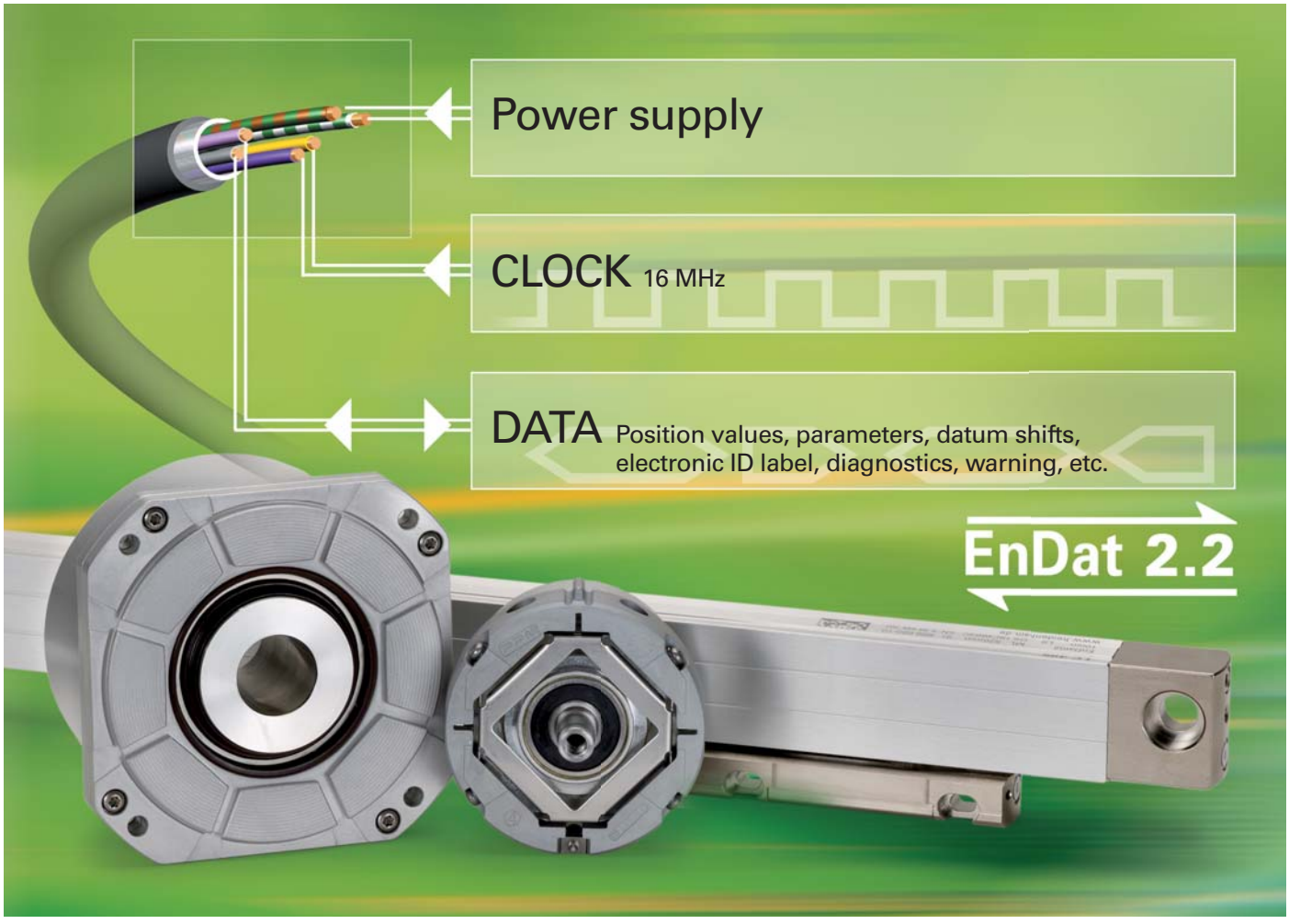
HEIDENHAIN

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 are transmitted in synchronism with the clock signal from the subsequent electronics. The type of transmission (position values, parameters, diagnostics, etc.) is selected through mode commands that the subsequent electronics send to the encoder. The EnDat 2.2 interface, a purely 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:

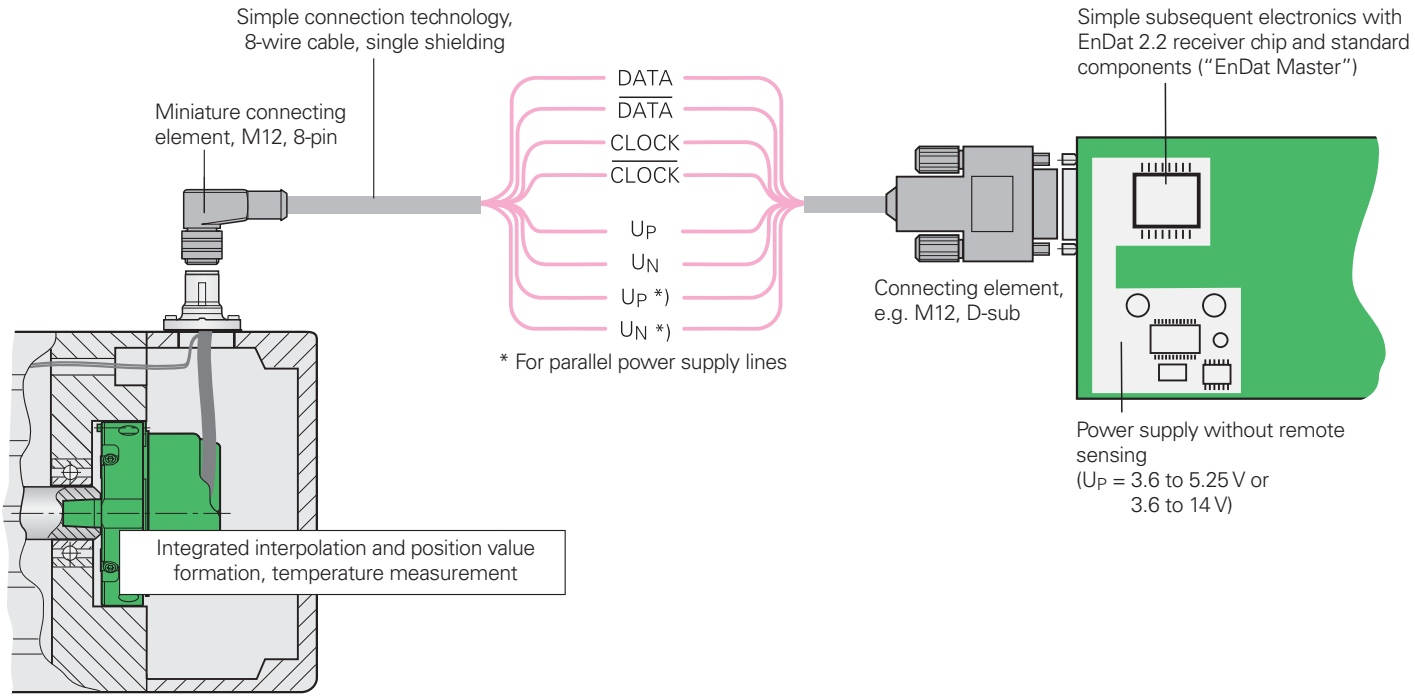
Cost optimization
- A single interface for all absolute and incremental encoders
- Simple subsequent electronics with EnDat receiver chip and standard components
- Simpler, more economical power supply, since remote sensing is not required
- Simple connection technology: Standard connecting elements (M12 – 8-pin), single shielded standard cable and low wiring costs
- Small motor or system dimensions through compact connecting elements
- No expensive additional sensory analysis and wiring: EnDat 2.2 transmits additional data (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 purely digital data transmission
- Diagnostics 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 values for error detection
- Two independent error messages
- Checksums and acknowledgments
- Forced dynamic sampling of error messages and CIRCLE 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



For further information on implementing EnDat or additional documents, see *www.EnDat.de*

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 what is termed "additional data" 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 (U_P = 3.6 to 5.25 V or 3.6 to 14 V at encoder)

EnDat 2.2 command set (includes EnDat 2.1 command set)

- Position values for incremental and absolute encoders
- Additional data on the position value
  - Diagnostics, test values
  - Absolute position values after reference run of incremental encoders
  - Parameter upload/download
  - Commutation
  - Acceleration
  - Limit position signal
  - Position value 2 for safety-related applications or incremental encoders

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 data. The additional data 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 data 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.

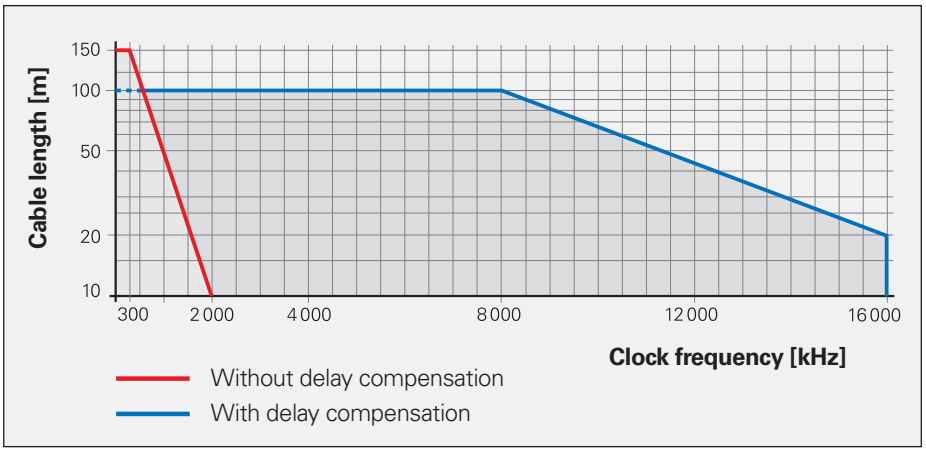
Clock frequency and cable length
Without propagation-delay compensation, the **clock frequency** is variable between **100 kHz** and **2 MHz,** depending on the cable length. Because large cable lengths and high clock frequencies increase the signal run time to the point that they can disturb the unambiguous 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 ($f_C \leq 8$ 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 FCL = $\frac{1}{2t_{min}}$

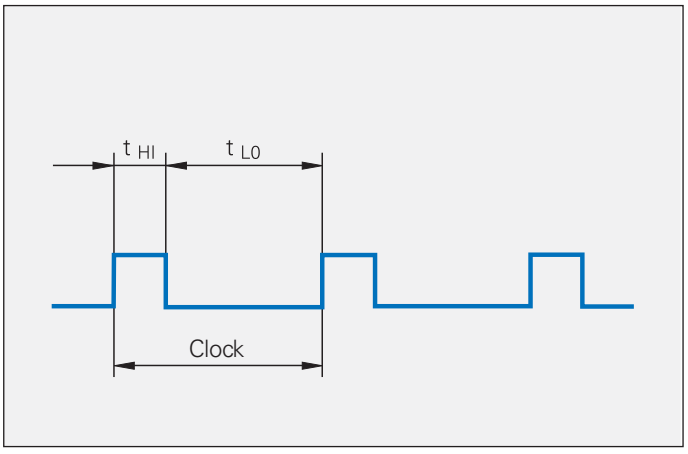
Determining the propagation time
After every change in the transmission line hardware, the propagation time must be ascertained—preferably automatically after every power interruption.

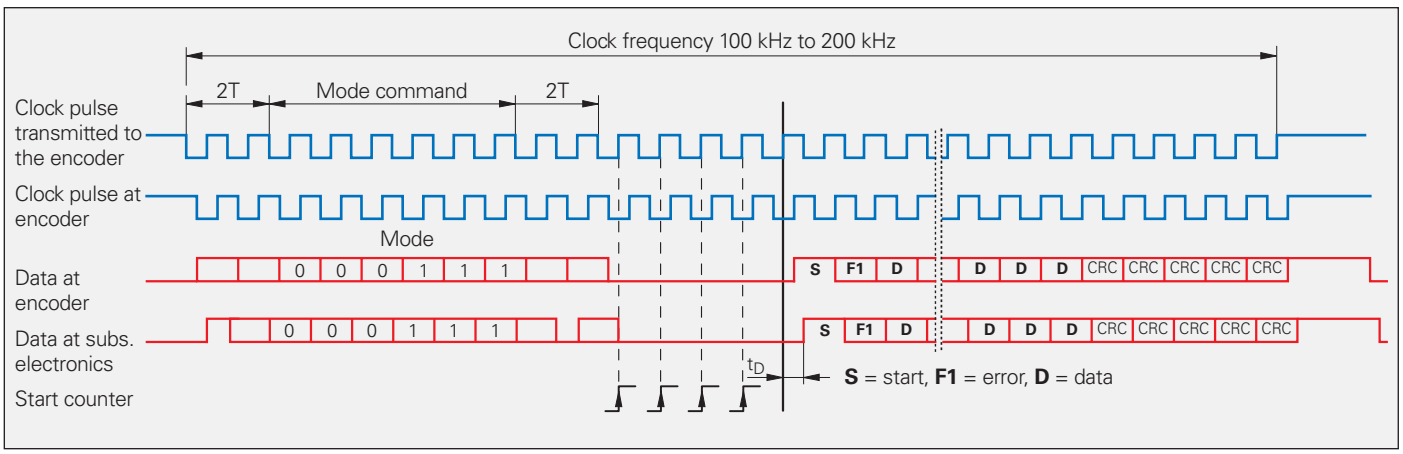
The subsequent electronics transmit the mode command *Encoder transmit position values without additional data* to the encoder. After the encoder has switched to transmission, i.e. after in total 10 clock periods, a counter in the subsequent electronics starts with every rising edge. The subsequent electronics 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 data, 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 double). 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 data 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_{calf} sometimes differs depending on whether EnDat-2.1 or EnDat-2.2 mode commands are transmitted (see catalog: *Linear Encoders for Numerically Controlled Machine Tools – Specifications*). 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 purely serial position-value transfer for axis control.

				Mode bit					
No.	**Mode command**			**M2**	**M1**	**M0**	**(M2)**	**(M1)**	**(M0)**
1	Encoder send 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 parameter			0	1	1	1	0	0
4	Encoder send parameter			1	0	0	0	1	1
5	Encoder receive reset[1)]			1	0	1	0	1	0
6	Encoder send test values			0	1	0	1	0	1
7	Encoder receive test command			1	1	0	0	0	1
8	Encoder send position value with additional data			1	1	1	0	0	0
9	Encoder send position value and receive selection of memory area [2)]			0	0	1	0	0	1
10	Encoder send position value and receive parameter[2)]			0	1	1	0	1	1
11	Encoder send position value and send parameter[2)]			1	0	0	1	0	0
12	Encoder send position value and receive error reset[2)]			1	0	1	1	0	1
13	Encoder send 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 from switching the power supply off and on
[2)] Selected additional data is also transmitted
[3)] Reserved for encoders that do not support the safety system

Position Values

For every data transfer one data packet is transmitted in synchronism with the clock signal. 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 transmit the **mode command** Encoder transmit position value (with/ without additional data).

After successful calculation of the absolute position value (t_{calf}—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.

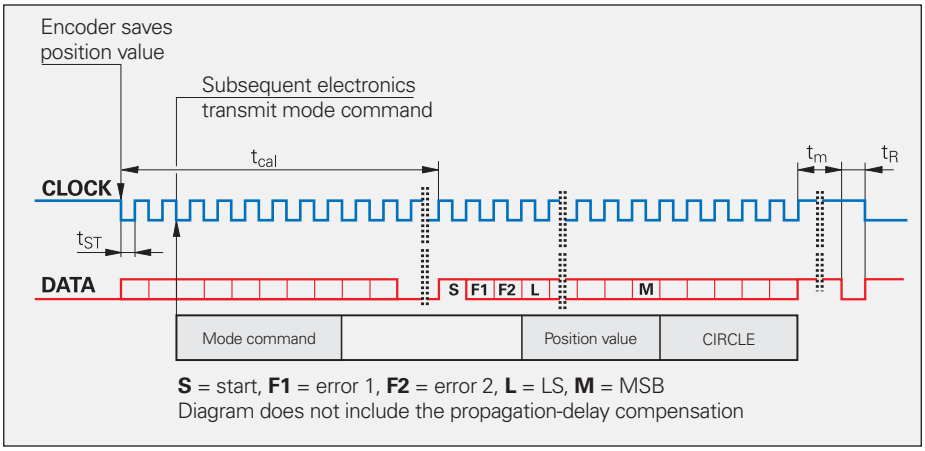
The encoder then transmits the **absolute position value,** beginning with the LS. Its length varies depending on which encoder is being used. The number of required clock pulses for transmission of a position value is saved in the parameters of the encoder manufacturer.

The data transmission of the position value is completed with the **Cyclic Redundancy Check** (CIRCLE).

This is followed in EnDat 2.2 by the **additional data** 1 and 2, each also concluded with a CIRCLE. The content of the additional data is determined by the selection of the memory area and is transmitted in the next sampling cycle for additional data. This information is then transmitted with every sample 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 be initiated by starting the clock.

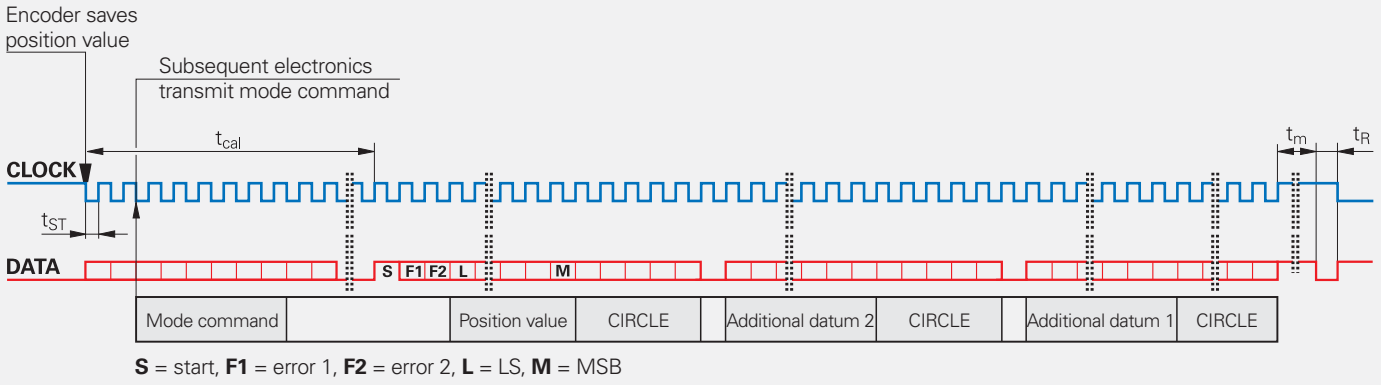
Position value packet without additional data



S = start, **F1** = error 1, **F2** = error 2, **L** = LS, **M** = MSB
Diagram does not include 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	t_{calf}	Typical of EnDat 2.2 encoders: ≤ 5 µs	
Parameter	t_{ac}	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 ($f_c \geq 1$ MHz) (parameterizable)	
	t_R	Max. 500 ns	
	t_{ST}	–	2 µs to 10 µs
Data delay time	t_D	(0.2 + 0.01 x cable length in m) µs	
Pulse width	t_{HI}	0.2 to 10 µs	Pulse width fluctuation HIGH to LOW max. 10 %
	t_{LO}	0.2 to 50 ms to 30 µs (with LC)	

Data packet with position value and additional data 1 and 2



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

Diagram does not include the propagation-delay compensation

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

	Subsequent electronics transmit	**Encoder transmits**		**Subsequent electronics transmit**	
Encoder transmit position value and receive selection of memory area (selection of the desired additional data)	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 send position value with additional data (acknowledgment)	Mode command 111 000	Position value	Additional datum 1 MRS acknowledg-ment		

Content of the data packet

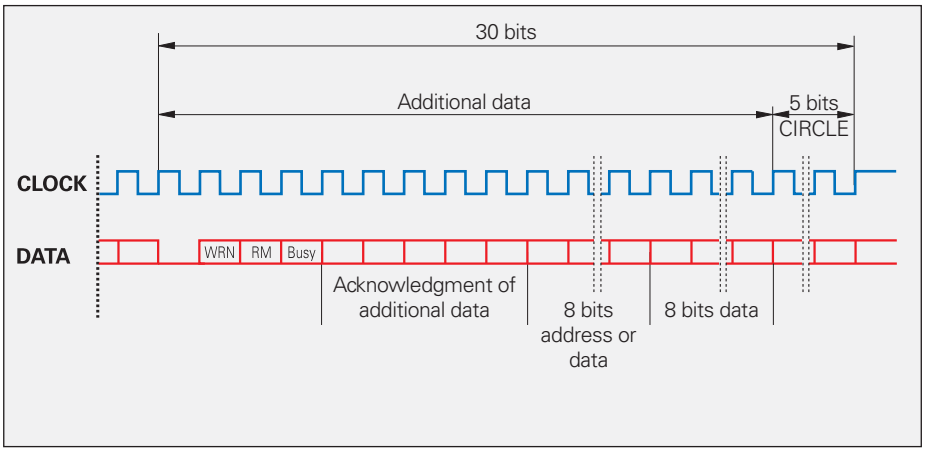
Error messages 1 and 2
The EnDat interface enables comprehensive monitoring of the encoder without requiring an additional transmission line. An error message becomes active if a malfunction of the encoder might result in incorrect position values. At the same time, the cause of error is saved in the 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. It is transmitted with the inverted value 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 data
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 a LOW level as first bit. Each additional datum is concluded with a CRC that is formed from the respective additional data without the first bit or the CRC.
The additional data supported by the respective encoder is saved in the encoder parameters.
The additional data 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 marks
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 data 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 data
The content of the additional data 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. A unique number is assigned to each additional datum. It is 5 bits in length and is transmitted for inspection purposes. The following contents are possible:

Additional datum 1
- **Diagnostics**
  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). The 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 output of the parameters with the associated address.
- **MRS code—acknowledgment**
  Acknowledgment of the requested memory area 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 are output in a rolling request process (x+1); the assigned sensor can be identified based on the supplied address.

Additional datum 2
- **Commutation**
  Some 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.
- **Timestamp**
  Reserved for touch probes

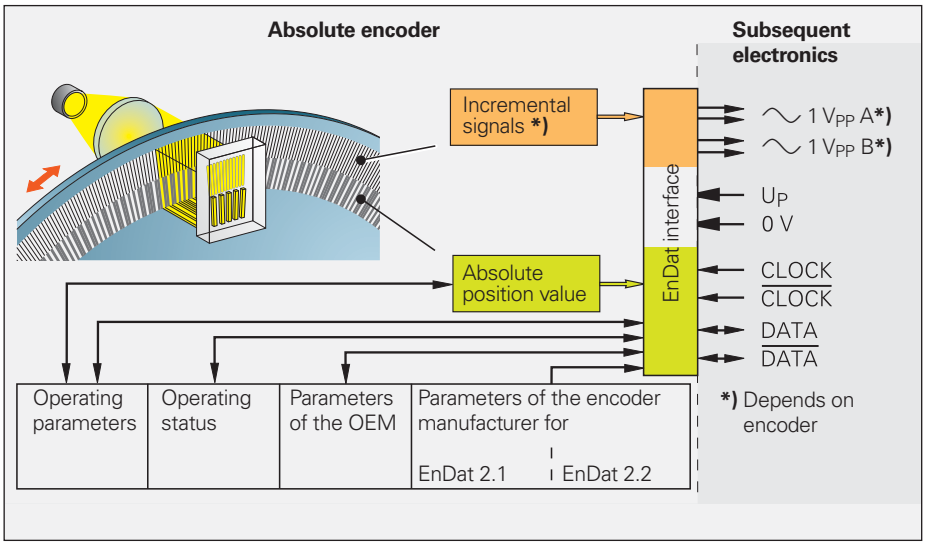
Parameter
Memory Areas

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.

Addressing
Before transmission of parameters (reading or writing), the corresponding memory range must be selected. On or more "MRS codes" are therefore assigned to the respective memory areas (MRS ≙ Memory Range Select).

After selection of the memory range, the word address is also required for reading or writing information. The access time t_{ac} for reading or writing can be up to 12 ms. The MRS code selection and the reading and writing of data are possible with EnDat 2.1 or 2.2 mode commands.



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, part number, and serial number. This information forms the basis for **automatic configuration.**

A separate memory area contains the parameters typical for EnDat 2.2, such as status of additional data, temperature, acceleration, support of diagnostic and error messages.

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. The size of the OEM area depends on the encoder.

Operating parameters
This area is available to the customer for a **datum shift,** the configuration of diagnostics and for statements. Furthermore, a warning threshold can be defined for the temperature sensor integrated in the encoder. Other functions (cycle time, I/0, touch-probe status) 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 activate write protection for the OEM parameter and operating parameter memory areas, and to interrogate their status. Once **write protection** is activated, it cannot be removed.

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 purely serial EnDat 2.2
i Incremental rotational encoder with integral conversion of 1 V_{PP} to purely serial EnDat 2.2
T Touch probe

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.
- **Depending 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.
- **Irrelevant:**
  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 data for EnDat 2.2 contained in the parameters of the encoder manufacturer depends in part on the respective encoder.

The additional data, 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 data, 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	Contents	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	–	–		–	–	Depends on encoder; program flexibly. Memory pointer to first free address
10				All			
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	Encoder model	–	–	All	–	–	Defines the units of the parameters
15	Signal period(s) per revolution for incremental output signals	nm	–		–	–	**E, IL, i:** for calculating the smallest display step (LS) or the correct display value for negative traverse direction **All:** for EnDat-compliant datum shift
16				All			
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 i	–
19	Position of first reference mark	mm	–	–	–	IL	Not supported by **EIB**

Parameters of the encoder manufacturer for EnDat 2.1 (continued)

Word	Contents	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 i	–	Required for cross checking of absolute position ⇔ incremental position
33	Accuracy depending on linear velocity or shaft speed, area I	LS [1)]	LS [1)]	–	W L D	–	Comparison of absolute and incremental position not possible with **E IL i** because these encoders have only incremental information
34	Accuracy depending on linear velocity or shaft speed, area II	LS [1)]	LS [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 on whether EnDat 2.2 mode commands are supported
38	Reserved for measuring length [2)]	–	–	–	–	L IL	Not supported by **E**
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	Contents	Unit for		Required	Depends on application	Informative	Remark
		Linear encoder	Rotary/ angle encoder				
0	Status of additional data 1	–	–	–	All	–	Can be safety related. Cross checking of "what is required" and "what does the encoder support"
1	Status of additional data 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
10							
11	Accuracy of position value 2 depending on linear velocity or shaft speed, area I	LS [1)]	LS [1)]	–	All	–	Safety technology
12		LS [1)]	LS [1)]	–	All	–	Safety technology
13	Accuracy of position value 2 depending on linear velocity or shaft speed, area II	LS [1)]	LS [1)]	–	All	–	Safety technology
14		LS [1)]	LS [1)]	–	All	–	Safety technology
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	–	–	–
17-20	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 i	–	Not supported by **E**
23	Max. permissible acceleration	m/s^2	$1/s^2$	–	W L D IL i	–	Not supported by **E**
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 (LS).
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 i	–	Specific to application. Applies for encoders that permit higher mechanical than electrical speed. (Not supported by the EIB.)
31-33	Offset between position value and position value 2	–	–	–	All	–	Safety technology
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
36-38	Safety-relevant measuring steps	–	–	–	All	–	Safety technology
39-40	Non-safety-relevant subdivision of the relative position	–	–	–	All	–	Safety technology
41-42	Non-safety-relevant subdivision of the absolute position	–	–	–	All	–	Safety technology
43	Generation of a warning message through limit position signals	–	–	–	L IL	–	Presently available only with certain incremental exposed linear encoders
44	Support of touch probe statuses	–	–	T	–	–	Supported features
45	Timestamp unit of measure	–	–	T	–	–	–
46	Referencing of incremental encoders	–	–	–	IL, Ir, E	–	Is re-referencing supported?
47	Support of I/Os	–	–	–	All	–	Are I/Os supported, and if so, which?
48	Number of OEM blocks for memory area section 2	–	–	–	All	–	The memory area section 2 makes larger OEM memory possible
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

Fundamentals
Because saving the data in an EEPROM consumes a maximum access time t_{ac} of up to 12 ms, it must be decided for each application whether the control loop should be closed during the reading or writing of parameters. EnDat 2.1 mode commands are designed for an open control loop during access to the parameters. EnDat 2.2 mode commands are designed operation in the closed control loop.

Selection of MRS code
The MRS code must be set before transmission of a parameter word. The EnDat 2.1 parameter area is selected with the corresponding EnDat 2.1. or EnDat 2.2 mode command. For the EnDat 2.2 parameter area, the appropriate EnDat 2.2 mode command is required.

EnDat 2.1 mode commands for the transmission of parameters
All mode commands have the same structure and are distinguished by the number of the mode command and the data content. Within the respective mode command, the data are transmitted from the subsequent electronics to the encoder and then, after the access time t_{ac}, data are transmitted as acknowledgment from the encoder to the subsequent electronics. If multiple values (parameters) are read from or written to a memory area, the MRS must be selected only once.

	Communication: Subsequent electronics → encoder			**Communication: Encoder → subsequent electronics**	
Mode command	Mode bits	MRS code or address	Parameters	Acknowledgment of MRS- code or address	Confirmation of parameters
Selection of the memory area[1)]	"001 110"	MRS code	Any	MRS code	Any
Encoder receive parameter	"011 100"	Address	Parameters	Address	Parameters
Encoder send parameter	"100 011"	Address	Any	Address	Parameters

[1)] The appropriate EnDat 2.2 mode command is required for the selection of the MRS code of the "parameters of the encoder manufacturer for EnDat 2.2".

EnDat 2.2 mode commands for the transmission of parameters
Reading and writing in the closed control loop is possible with EnDat 2.2 mode commands. The access time t_{ac} to the EEPROM is synchronized through what is termed the "busy bit" that is transferred with each EnDat additional datum. First, the position value and (if selected) additional data transmitted with each of the mode commands to make communication in the closed control loop possible. A following "transmission supplement" can then also transmit the MRS code, address and parameter to the encoder. The additional data and the transmission supplement provide the following:

- Additional data:
  Data content from reading of parameters and acknowledgments
- Transmission supplement:
  MRS code, address and parameters

Schematic representation of reading access with EnDat 2.2 mode commands:

Sequence	**Data communication on interface (bidirectional)**
Selection of memory area	Position value **+** Selection of the MRS code
Acknowledgement of MRS code	Position value **+** Acknowledgement of MRS code (selection of additional data and readout)
Transmission of read address	Position value **+** Selection of address to be read
Cyclical request on busy bit = "0"; (max. t_{ac} = 12 ms)	Position value **+** Any additional data
Reading out of LS data and acknowledgment	Position value **+** Addressing of the additional datum "acknowledgment of LS" and read-out of data content + acknowledgment of read address
Reading out of MSB data and acknowledgment	Position value **+** Addressing of additional datum "acknowledgment of MSB" and read-out of data content + acknowledgment of read address

Diagnostics

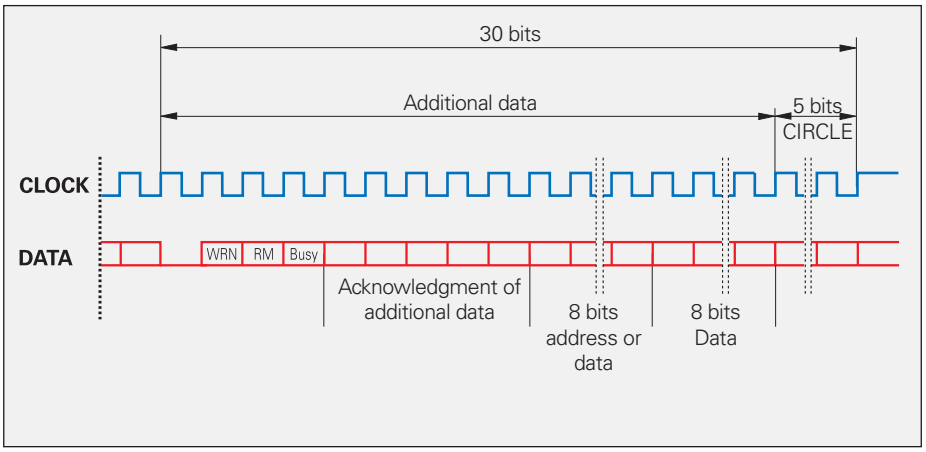
The EnDat interface makes extensive monitoring and diagnosis of an encoder possible without an additional line. The diagnostic system generates error messages and warnings (see *Position values*), and is a significant prerequisite for the high level of availability of the complete system.

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

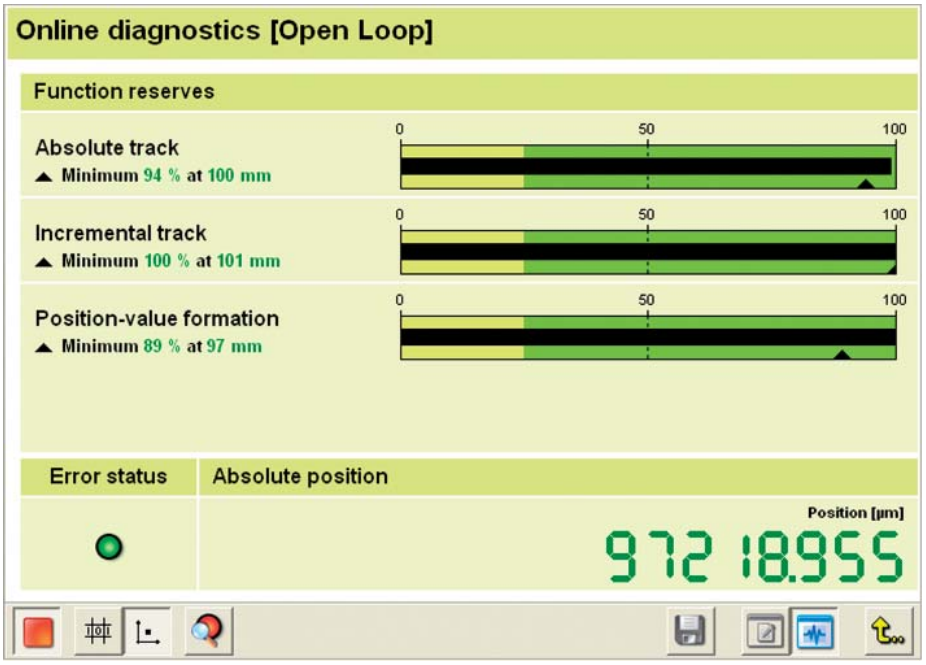
On encoders with incremental signals, it is possible to use Lissajous figures to analyze signal errors and what they mean for encoder function.

Encoders with purely 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 "function 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.

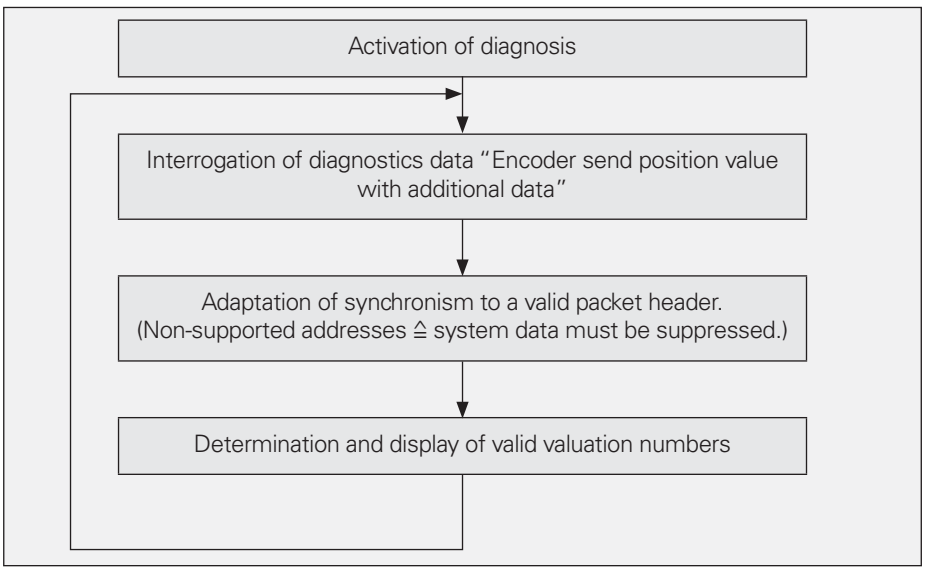
Composition and interrogation of the transmitted diagnostics data:
- The desired valuation numbers must be activated.
- The value (8 bits) is transmitted over the additional datum 1.
- The values are output in a cyclic process; address and value.
- The data as to which valuation numbers are supported 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).



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



Screen showing the valuation numbers as functional reserves (e.g. with ATS software)



Flow chart for interrogation of diagnostics data

Configuration

The EnDat interface makes it possible to set various functions regarding data transmission or the general operation of the encoder. The various EnDat words for setting functions are located in the "operating status" or "operating parameters" memory areas. The settings are normally saved and need only be made once.

Operating status

Function initialization
Recovery time:
- 10 µs ≤ t_m ≤ 30 µs selectable to 1.25 µs ≤ t_m ≤ 3.75 µs (for mode commands no. 8 to 14 and f_C > 1 MHz)
- Reduced recovery time is set when very short cycle times are to be attained.

Multiturn functions:
- Makes the connection of battery-buffered encoders possible.

Reference pulse initialization:
- Only with incremental encoders for finding the optimal reference mark position

The following functions are reserved for future applications and therefore cannot yet be set:
- Oversampling, diagnostics reset
- EnDat 2.2 cyclic operation I/O, statuses of touch probes, referencing of incremental encoders can be switched off

Write-protection
The customer can write-protect the OEM parameters ("electronic ID label") and/or the operating parameters (e.g. datum shift).

Operating parameters

Zero point shift
This function is called "electronic datum setting" and enables the customer to fit the encoder datum to the datum of the application.

Configuration of diagnostics
This EnDat word activates the desired valuation numbers for transmission of diagnostic information.

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

Address assignment and instructions
Reserved for future bus operation through the EnDat interface.

Threshold sensitivity to temperature
Specification of a temperature threshold at which the encoder transmits a warning to the subsequent electronics. The temperature is derived from the encoder's internal temperature sensor

Cycle time
Setting the cycle time with which the higher-level control transmits EnDat requests. Reserved for future applications.

Implementation of EnDat

HEIDENHAIN offer various aids for implementing the EnDat interface in subsequent electronics (see also "Implementation" section under *www.EnDat.de*):

EnDat Demotool software
As its hardware basis, the EnDat Demotool software needs a PWM 20 (IK 215 is possible, but not recommended). The EnDat Demotool software supports you when implementing the EnDat interface:
- Communication with EnDat encoders on the basis of mode commands
- Logging of EnDat command sequences
- Provides a reference when integrating of the EnDat master into the control loop

EnDat master
The EnDat master controls communication with EnDat encoders from HEIDENHAIN. It allows simple transmission of position data and additional data to the higher-level application. The EnDat master can be integrated by means of a micro controller (µC) or an FPGA (Field Programmable Gate Array) or ASIC.

The µC solutions are used if the intended clock frequencies are relatively low. Integration in an FPGA or ASIC is chosen primarily for high transmission frequencies with pure serial data transfer. Several variants are available for integration in an FPGA or ASIC.
- EnDat master, standard
- EnDat master, safe
- EnDat Master, reduced
- EnDat Master, light

Documentation
- EnDat Specifications
- EnDat 4
- EnDat Seminar
- FAQ and implementation at *www.EnDat.de*
- *EnDat* Technical Information
- Description of the EnDat master component at *www.mazet.de*

Interface
Power Supply and Switch-On

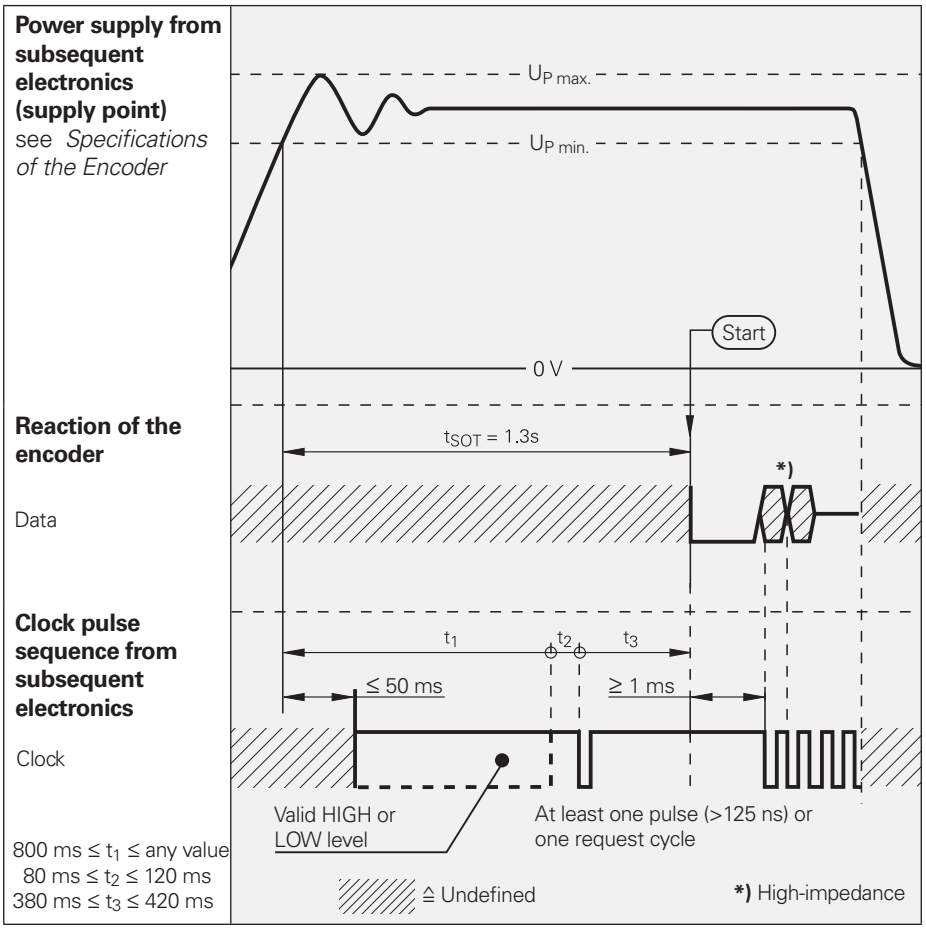
Power supply
The encoders require a **stabilized DC voltage U_P** as power supply. The required power supply and the current consumption are given in the respective specifications. The values apply as measured at the encoder.

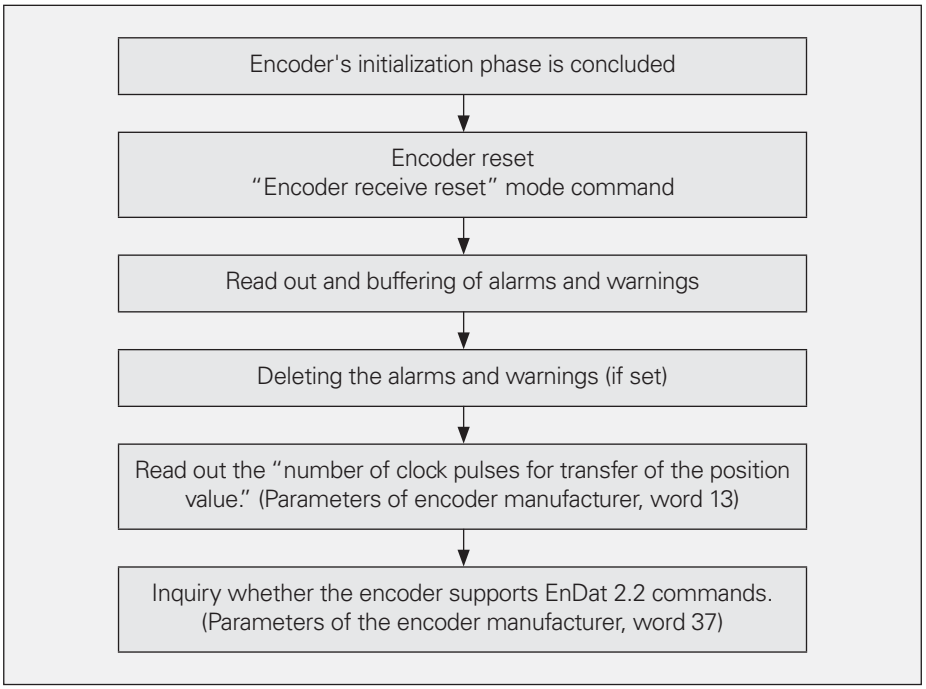
EnDat 2.2 encoders feature an expanded power supply range from 3.6 V to 5.25 V or from 3.6 V to 14 V. This makes it possible to design the power supply of the subsequent electronics so that the resulting voltage after attenuation through cable length, cable cross section and current consumption can be 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 a start-up time of approx. 1.3 s, whereby a defined **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.



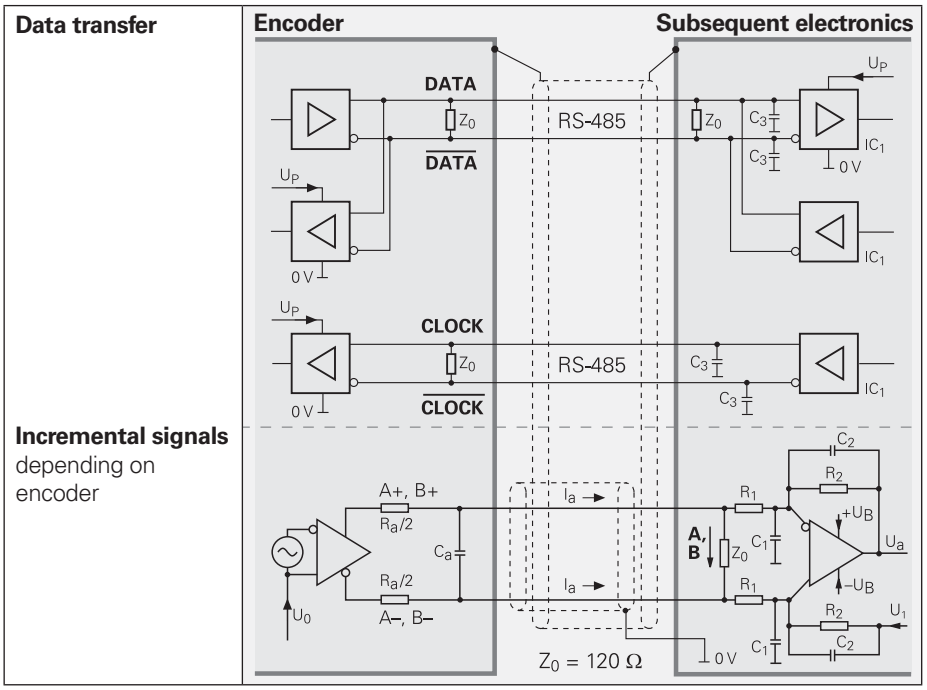


Input Circuitry of the Subsequent Electronics

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 (CLOCK) produced by the subsequent electronics.

Dimensioning
IC_1 = RS 485 differential line receiver and driver

C_3 = 330 pF
Z_0 = 120 Ω



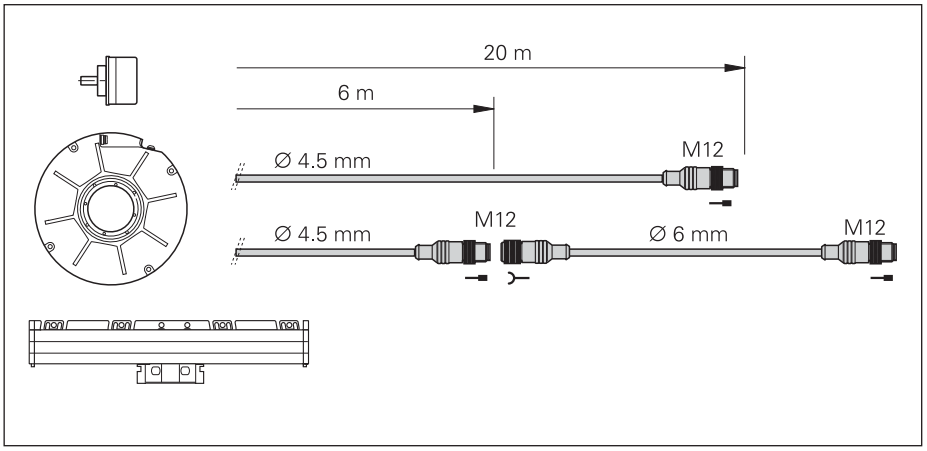
Connection Technology

Connecting elements
For the encoders with EnDat 2.2 interface without incremental signals, 8-pin M12 connecting elements are used. 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
Transmission frequencies up to 16 MHz in combination with large cable lengths place high technological demands on the cable. HEIDENHAIN cables are equal to this task, not least because of a cable construction conceived specifically for this application. We recommend using original HEIDENHAIN cable.

Due to the data transfer technology, the adapter cable connected directly to the encoder (Ø ≤ 4.5 mm) must not be longer than 20 m. Greater cable lengths can be realized with a max. 6 m adapter cable and an extension cable (Ø 6 mm).



Safety System

Basic principle
EnDat 2.2 supports the use of encoders in safety-related applications. The DIN EN ISO 13849-1 (previously EN 954-1) and DIN EN IEC 61 508 standards serve as the foundation for this. These standards describe the assessment of safety-oriented 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 measuring systems with purely 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 is such a subsystem. A **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)

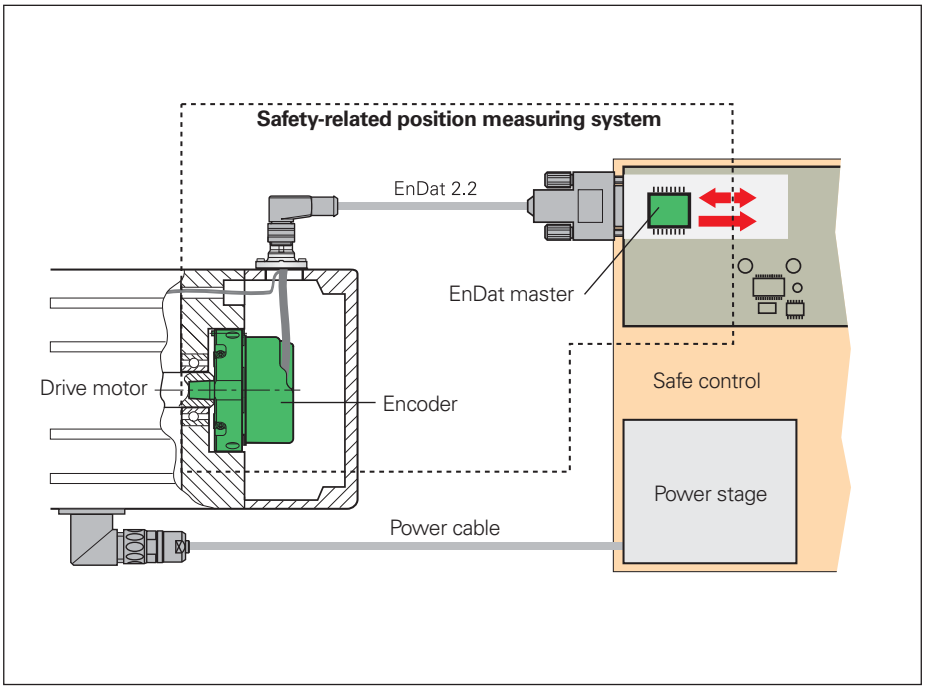
Integration of the position measuring system
The position measuring system is integrated via a physical and an electrical interface into the complete system. The physical coupling of the encoder to the drive is determined by the encoder's geometry. Including the EnDat master with its monitoring functions 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.

Field 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 13849 or category 3 according to the previous EN 954-1 standard. Also, the functions of the safety-related position measuring system can be used for the following safety functions in the complete system:
(see also IEC 61 800-5-2):

- SS1: Safe stopping
- SS2: Safe operating stop
- SOS: Safe operating stop
- SLS: Safely limited speed
- SLP: Safely limited position
- SLI: Safely limited increment
- SSR: Safe speed range
- SDI: Safe direction

Function
The safety strategy of the position measuring system 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 periodically tests the safety-related position measuring system to monitor its correct operation.

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



Complete safe drive system

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

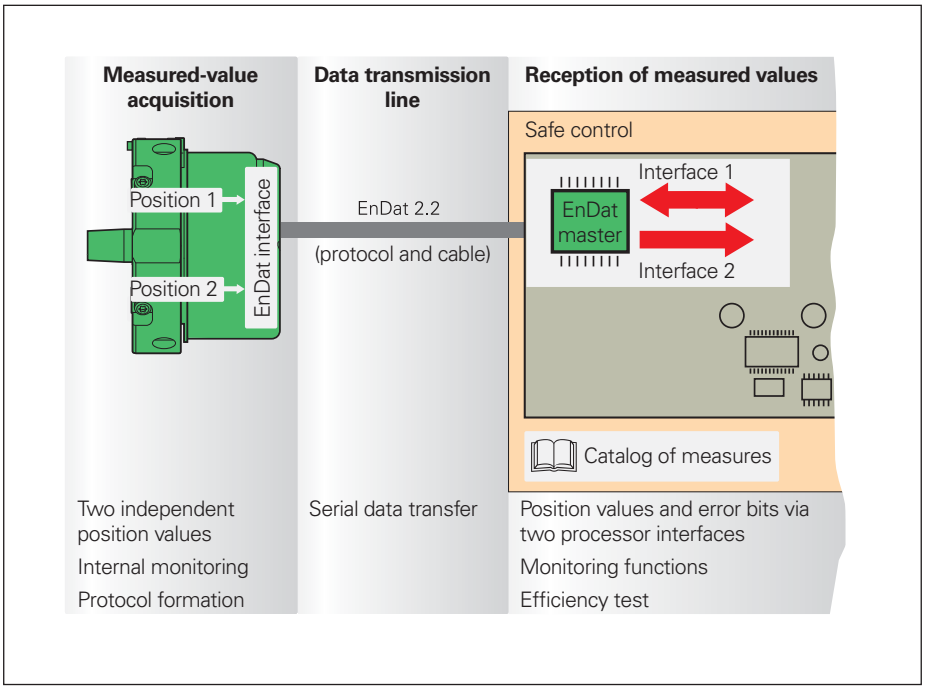
Two mutually independent position values for error detection
In addition to the position value, the additional data includes a separately generated position value to be used for comparison in the subsequent electronics.

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

Independent individual CIRCLE generation for position values and additional data
Separate CIRCLE values are generated for the individual data packets of a transmission (position value, additional data 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 Technical Information *"Safety-Related Position Measuring Systems"* 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, which distinguish themselves, for example, in their command sets. Only EnDat 2.2 devices support functions such as short recovery time and additional data.

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 2000/5000/8000	26 bits 28 bits 28/29 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 ECI 119 **Inductive, multiturn** EQI 13xx EQI 11xx EBI 11xx	 25 bits 23 bits 37 bits 35 bits 19 bits[1)] 18 bits 19 bits[1)] 31 bits[1)] 30 bits[1)] 34 bits
Incremental encoders		**Resolution**
Encoders with 1 V_{PP} output signals over EIB (External Interface Box)		Integrated 14-bit interpolation

[1)] EnDat 2.1 available, EnDat 2.2 in planning.

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For more information
- HEIDENHAIN encoder brochures
- Description of the Master Component (www.mazet.de)
- Detailed Interface Specification (upon request)

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