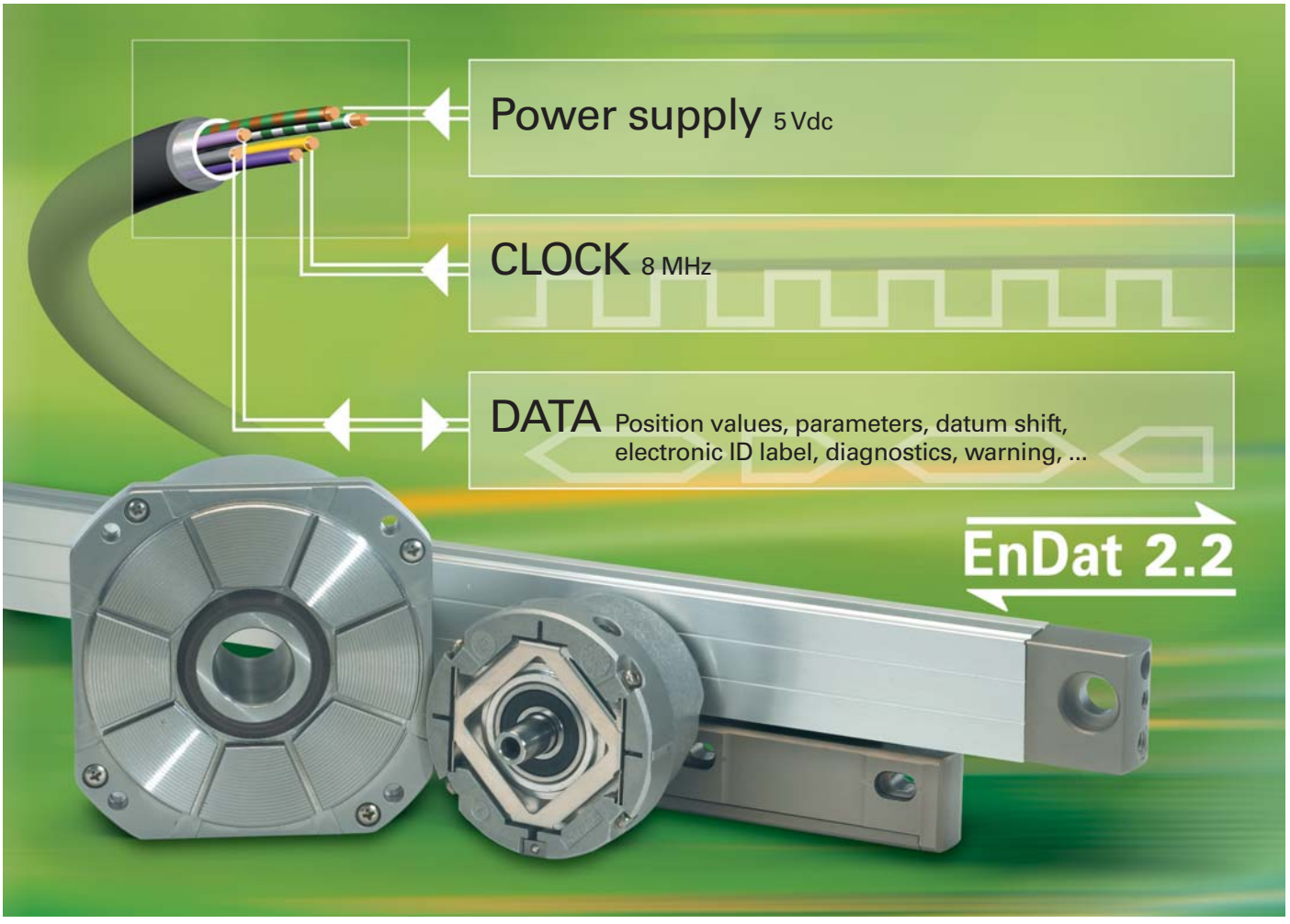
HEIDENHAIN

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 by mode commands that the subsequent electronics send to the encoder.



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:

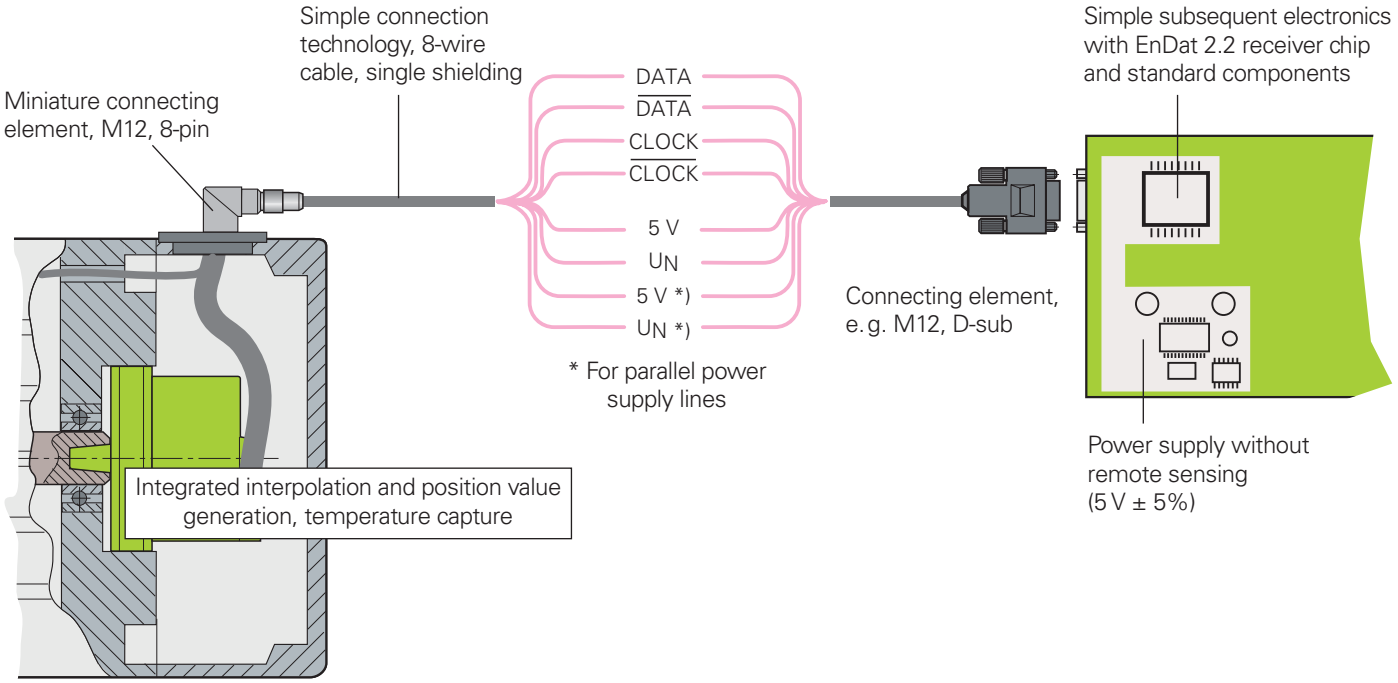
Cost optimization:
- A single interface for all absolute and incremental encoders
- Simple subsequent electronics with EnDat receiver chip and standard components
- Simpler, more economical power supply, since remote sensing is not required
- Simple connection technology: Standard connecting elements (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 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 purely 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 (in preparation)
- EnDat 2.2 was conceived for safety-oriented machine designs
- Two independent error messages
- Two independent position information sources for error detection
- 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) (8 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 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
  - Parameter upload/download
  - 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. **Servicing diagnostics** make it possible to inspect the position value even at a standstill. A test command has the encoder transmit the required test values.

Data Transfer

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

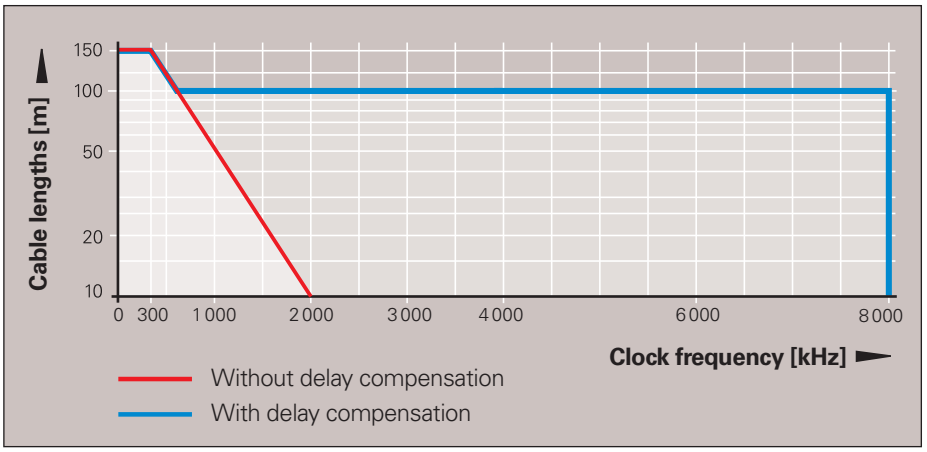
Clock frequency and cable length
Without propagation-delay compensation, the **clock frequency**—depending on the cable length—is variable between **100 kHz** and **2 MHz.** Because large cable lengths and high clock frequencies increase the signal run time to the point that they can disturb the unambiguous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

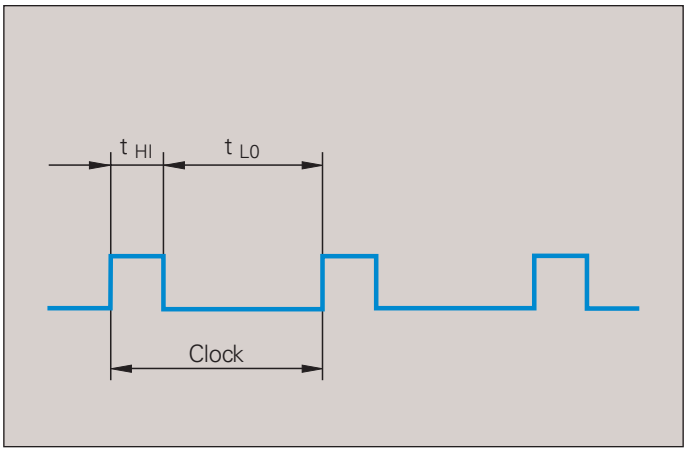
Determining the propagation time
After every change in the transmission line hardware, the propagation time must be ascertained—preferably automatically after every power interruption.

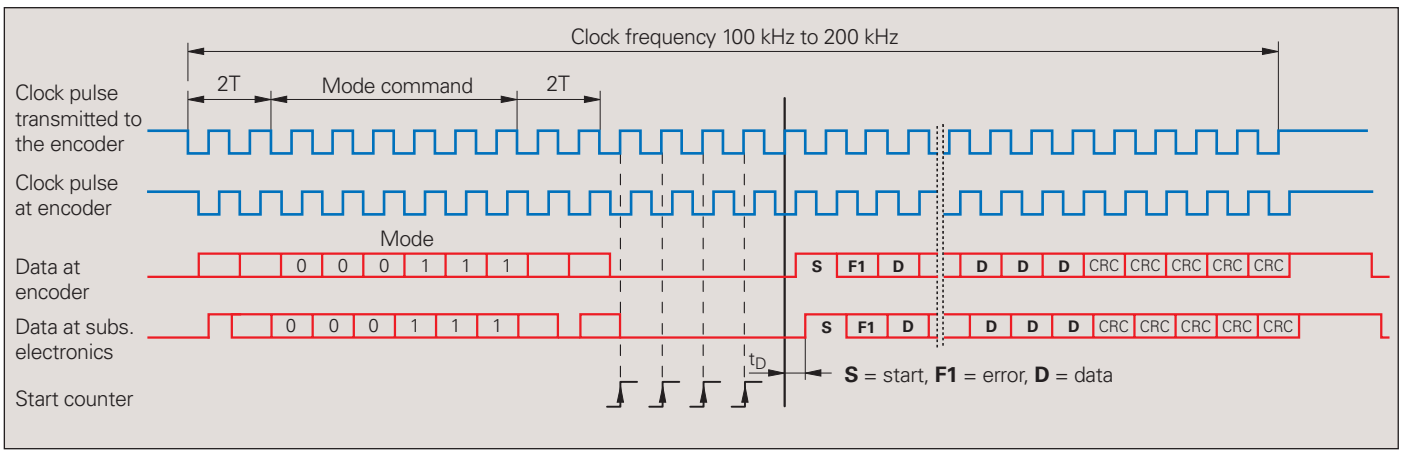
The subsequent electronics transmit the mode command *Encoder transmit position values without additional information* to the encoder. After the encoder has switched to transmission, i.e. after 10 clock periods in total, a counter in the subsequent electronics starts with every rising edge. The subsequent 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 run 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 double). If the encoder detects an erroneous 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.

Absolute linear encoders have different processing times t_{cal} for position values for EnDat 2.1 and EnDat 2.2 mode commands (see the *Specifications* in the *Linear Encoders for NC-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 to 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 transmit position values	**EnDat 2.1 command set**	**EnDat 2.2 command set**	0	0	0	1	1	1
2	Selection of the 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 commands			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 additional information is also transmitted
[3] Reserved for encoders that do not support the safety system

Position Values

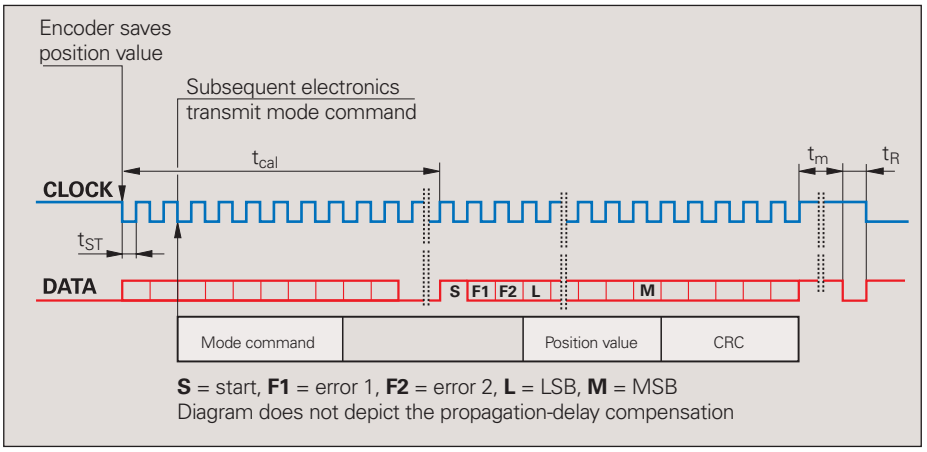
One data packet is sent in synchronism per data transmission. The transmission cycle begins with the first falling **clock edge.** The measured values are saved and the position value calculated. After two clock pulses (2T), the subsequent electronics transmit the **mode command** Encoder transmit position 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 **absolute position value** is then transmitted, beginning with the LSB. Its length depends on the encoder 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.

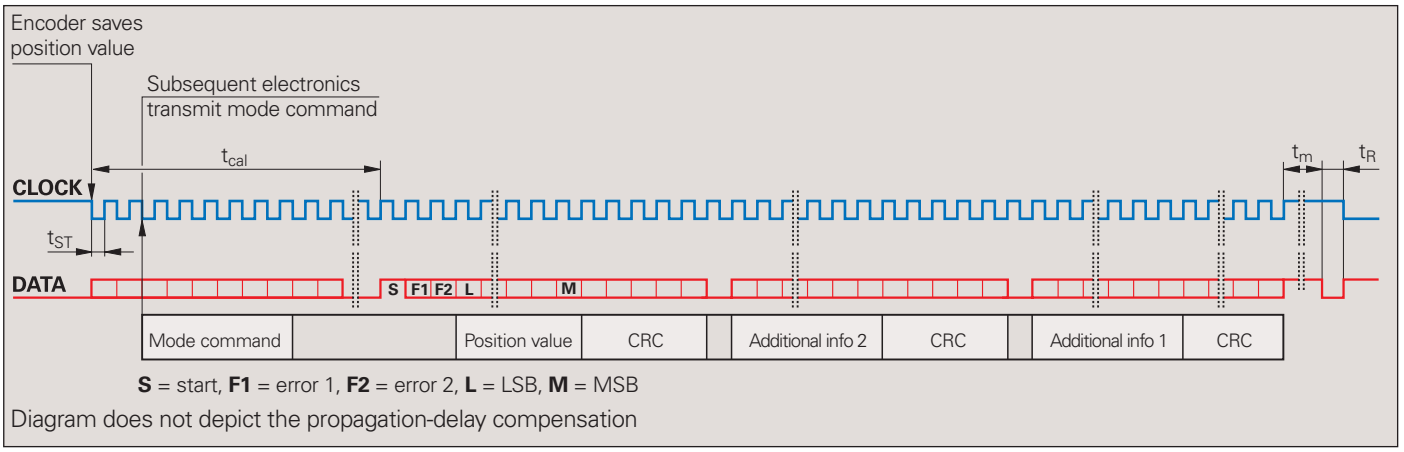
Position value package without additional information



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 ... 8 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



Typical command sequence when transmitting a positional 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 (acknowledgement of the MRS code)	Mode command 001 001	Position value		01000111 Acknowledgement request for MRS code	Random content
Encoder transmit position value with additional information (acknowledgement)	Mode command 111 000	Position value	Additional info 1 MRS acknowledgement		

Content of the data packet

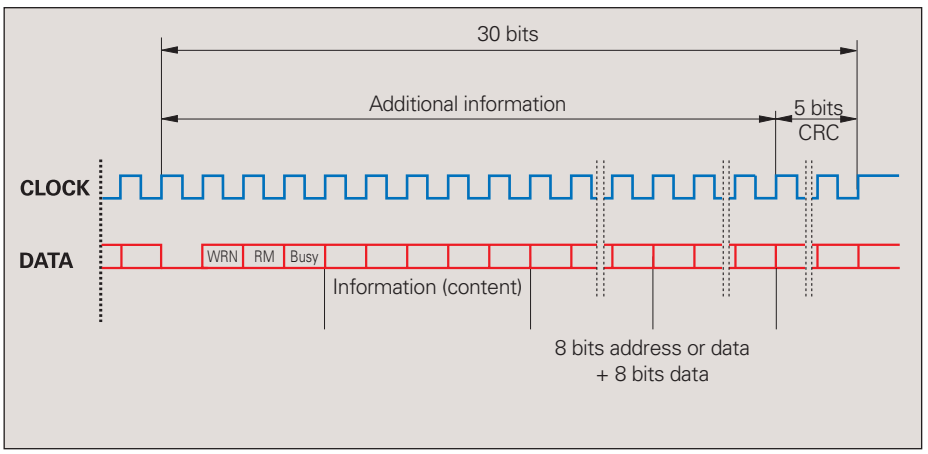
Error messages 1 and 2
The EnDat interface enables comprehensive monitoring of the encoder without requiring an additional transmission line. An error message becomes active if a malfunction of the encoder might result in incorrect position values. At the same time, the cause of error is saved in the 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 cannot 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**
  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.
- **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.
- **Memory Range Selection (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 increase by x+1 for each request. The associated sensor is identified by the address supplied.

Additional information 2

- **Commutation**
  Some incremental encoders provide "rough" position information for commutation in electric motors.
- **Acceleration**
  If the encoder has additional sensor systems for acceleration, 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, Operating status warning sources**
  Detailed information about the cause of the present error message or warning.

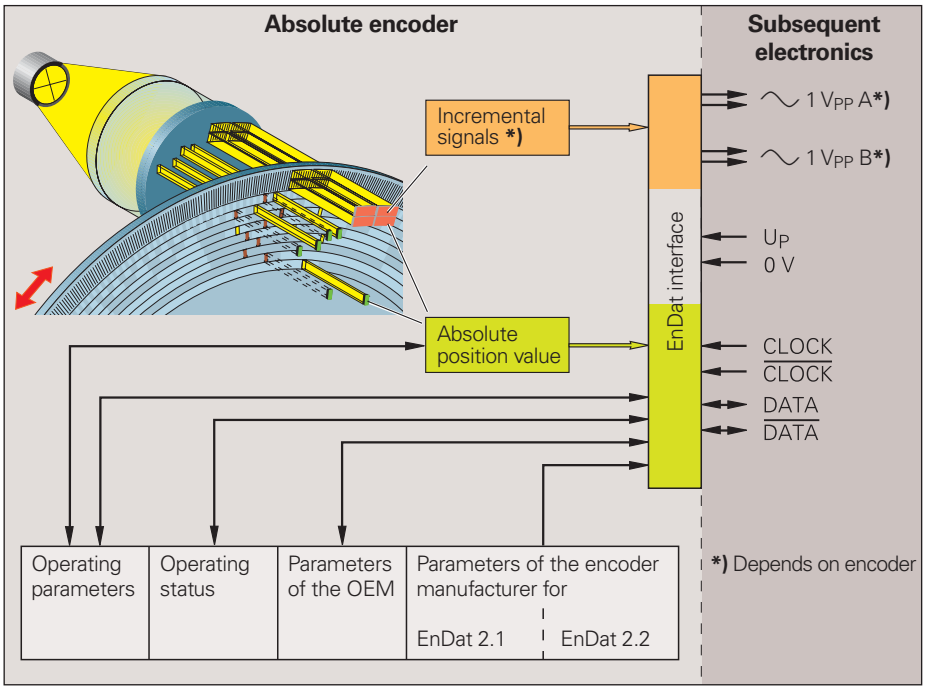
MRS code for selection of additional information

	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
	0	1	0	1	1	0	1	0	Operating status warning sources
	.	.	.	.	.	.	.	.	(Not used at present)
	.	.	.	.	.	.	.	.	
	0	1	0	1	1	1	1	1	Transmit no more additional information 2

Parameters

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 Interface

Memory areas

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 at 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: 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.

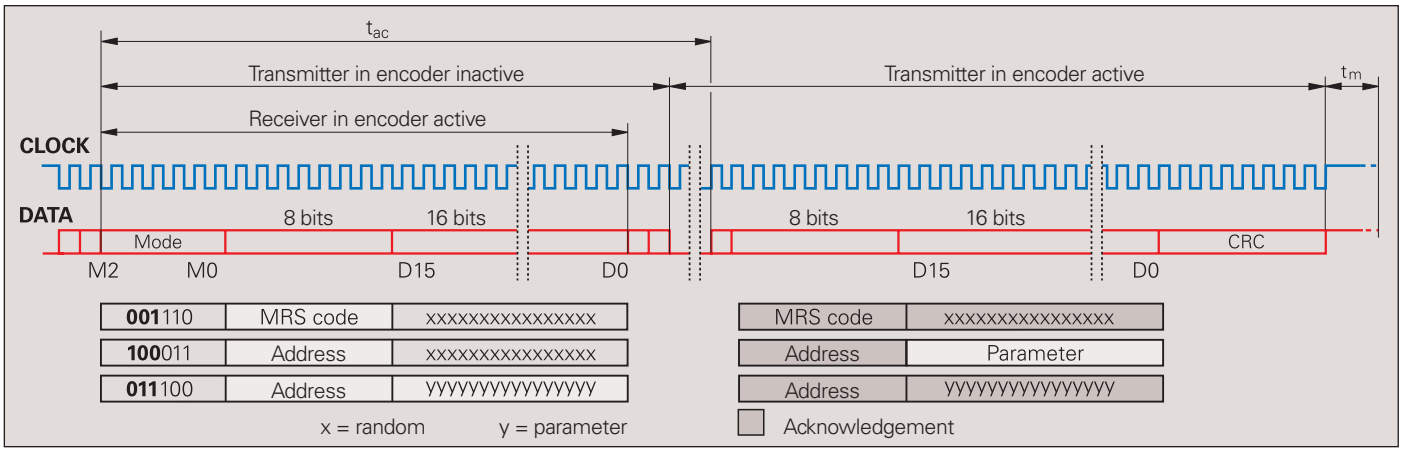
Operating parameters
This area is available to the customer for a **datum shift** and the configuration of diagnostics. It can be protected against overwriting.

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.

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 answers 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 (acknowledgement of the MRS code)	Mode command 001 001	Position value		01000111 Acknowledgement request for MRS code	Random content
Encoder transmit position value with additional information (acknowledgement)	Mode command 111 000	Position value	Additional info 1 MRS acknowledgement		
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 info 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 info 1 Busy = 1/no data		
Encoder transmit position value with additional information	Mode command 111 000	Position value	Additional info 1 Busy = 1/no data		
Max. 12 ms					
Encoder transmit position value with additional information	Mode command 111 000	Position value	Additional info 1 Busy = 0/parameter		

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

Parameters of the encoder manufacturer for EnDat 2.1

Word	Content	Unit for		MRS code								Address
		Linear encoder	Rotary encoder/ Angle encoder	C7	C6	C5	C4	C3	C2	C1	C0	HEX
4	Mask 0	–	–	1	0	1	0	0	0	0	1	04
5	Mask 1	–	–									05
6	Mask 2	–	–									06
7	Mask 3	–	–									07
8	Version of the EnDat Interface	–	–									08
9	Memory allocation for parameters of the OEM	–	–									09
10												0A
11	Memory allocation for compensation values	–	–									0B
12												0C
13	Number of pulses for transfer of position value (transmission format)	–	–									0D
14	Encoder type	–	–									0E
15	Signal period or signal periods per revolution for incremental output signals	nm	–									0F
16				1	0	1	0	0	0	1	1	00
17	Distinguishable revolutions (only for multiturn encoders)	–	–									01
18	(Nominal) increment of reference marks	mm	Signal periods									02
19	Position of first reference mark	mm	–									03
20	Measuring step or steps per revolution with serial data transmission	nm	Measuring steps per revolution									04
21												05
22	Datum shift of the encoder manufacturer	Signal periods	Signal periods									06
23												07
24	ID number	–	–									08
25												09
26												0A
27	Serial number	–	–									0B
28												0C
29												0D
30	Direction of rotation or traverse	–	–									0E
31	Status of commissioning diagnosis	–	–									0F
32	Maximum mechanically permissible linear velocity or shaft speed	m/min	rpm	1	0	1	0	0	1	0	1	00
33	Accuracy depending on linear velocity or shaft speed, Area I	LSB [1)]	LSB [1)]									01
34	Accuracy depending on linear velocity or shaft speed, Area II	LSB [1)]	LSB [1)]									02
35	Support of error messages 1	–	–									03
36	Support of warnings	–	–									04
37	EnDat command set	–	–									05
38	Reserved for measuring length [2)]	–	–									06
39	Maximum calculating time	–	–									07
40	HEIDENHAIN specifications	–	–									08
41												09
42												0A
43												0B
44												0C
45												0D
46												0E
47	CHECKSUM	–	–									0F

[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		MRS code								Address
		Linear encoder	Rotary encoder/ Angle encoder	C7	C6	C5	C4	C3	C2	C1	C0	HEX
0	Status of additional information 1	–	–									00
1	Status of additional information 2	–	–									01
2	Status of additional functions	–	–									02
3	Acceleration	m/s^2	$1/s^2$									03
4	Temperature	K	K									04
5	Diagnostic status	–	–									05
6	Support of error message 2	–	–									06
7	Forced speed-up status	–	–									07
8	Forced speed-up status	–	–									08
9	Measuring step or measuring steps per revolution for position value 2	~~n~~m	–									09
10												0A
11	Accuracy depending on linear velocity or shaft speed of position value 2, Area I	LSB [1)]	LSB [1)]									0B
12		LSB [1)]	LSB [1)]									0C
13	Accuracy depending on linear velocity or shaft speed of position value 2, Area II	LSB [1)]	LSB [1)]									0D
14		LSB [1)]	LSB [1)]									0E
15	Number of distinguishable revolutions for position value 2	–	–									0F
16	Direction of rotation of position value 2	–	–									10
17	Encoder designation	–	–									11
18												12
19				1	0	1	1	1	1	0	1	13
20												14
21	Support of instructions	–	–									15
22	Max. permissible encoder temperature at measuring point	K	K									16
23	Max. permissible acceleration	m/s^2	$1/s^2$									17
24	Number of blocks for memory area Section 2	–	–									18
25	Maximum clock frequency	kHz	kHz									19
26	Number of bits for position comparison	–	–									1A
27	Scaling factor for resolution	–	–									1B
28	Measuring step or measuring steps per revolution or subdivision values of a grating period	–	–									1C
29												1D
30	Max. velocity or shaft speed for continuous code value	m/min	rpm									1E
31	Offset between position value and position value 2	–	–									1F
32												20
33												21
34	"Number of distinguishable revolutions" with scaling factor	–	–									22
63	CHECKSUM	–	–									3F

[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.

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.

Safety System

Safety-oriented controls are the planned application for encoders with EnDat 2.2 interface. The ISO 13849-1 (previously EN 954-1) and IEC 61508 standards serve as the foundation for this. The safety-oriented position measuring system—consisting of the encoder, transmission path and EnDat 2.2 receiver chip (master) with monitoring functions—can assist in realizing a safety-oriented complete system when combined with a safety-oriented numeric control.

The position measuring system is only a part of the complete system. The appropriate steps for realizing a safety-oriented numeric control must also be taken. The calibration institutes must also approve it as part of the complete system.

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

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

- **Two independent error messages**
  The error messages are generated independently from each other and are transmitted at different active levels.

- **Inversion or repetition of mode commands**
  The mode commands consist of 3 bits that are transmitted redundantly either inverted or repeated. The consistency is monitored in the encoder and acknowledged with an error response.

- **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).

- **Quick-response data acquisition and transmission**
  Short cycle times for data acquisition including transmission make the necessary comparisons and monitoring of transmission functions possible.

The safety-oriented numeric control must of course also support the corresponding communication, and assume additional tasks as well.

- **Forced dynamization of error messages**
  Through the mode commands for requesting test values, the significance of the error messages are inverted and their generation is therefore monitored.

- **Force dynamization of CRC monitoring in the subsequent electronics**
  The CRC generation in the receiver chip (EnDat master) of the subsequent electronics must be ensured through a targeted execution of bit sequences with known result.

- **Multiple transmission of the position value during start-up**
  To avoid errors during initialization, the position value must be transmitted repeatedly during start-up and compared.

- **Monitoring of following error in the subsequent electronics**
  As a general additional check of the moving axes, the servo lag must be monitored in the subsequent electronics.

- **Assume safe status in case of error**

Configuration

Function initialization

In **word 3** of the operating status, the customer can define the **function** of the data transmission for the Encoder transmit position values with additional information mode command.

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 EnDat 2.2 command set. For clock pulse frequencies ≤ 1 MHz, the recovery time must be set to $10\ \mu s \leq t_m \leq 30\ \mu s$.

The *oversampling* and *EnDat 2.2 commands* are reserved for future applications, and cannot be activated yet.

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

Bit	Information	= 0
2^0	Recovery time t_m [1)]	$10\ \mu s \leq t_m \leq 30\ \mu s$
2^1	Recovery time t_m [1)]	$1.25\ \mu s \leq t_m \leq 3.75\ \mu s$
2^2	Reference pulse initialization	Deactivated
2^3	Reference pulse initialization	Activated
2^4	Oversampling	Deactivated
2^5	Oversampling	Activated
2^6	EnDat 2.2 commands	Deactivated
2^7	EnDat 2.2 commands	Activated
2^8	Multiturn overflow alarm	Deactivated
2^9	Multiturn overflow latch	Deactivated
2^{10}	Multiturn position alarm	Deactivated
2^{11}	Multiturn counter reset	Deactivated
2^{12}	Multiturn counter reset	Activated
2^{13}		
2^{14}		
2^{15}		

[1)] Only valid for EnDat 2.2 command set

Configuration of 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.

In addition, the diagnostics also permit evaluation of the **function reserves of the encoder.** The encoder can cyclically output the evaluation numbers in order to ascertain the function reserves.

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

Bit		= 0	= 1
20	Valuation number 1	Deactivated	Activated
21	Valuation number 2	Deactivated	Activated
22	Valuation number 3	Deactivated	Activated
23	Valuation number 4	Deactivated	Activated
24	Not used at present		
.	Not used at present		
.			
.			
215	System-specific data	Deactivated	Activated

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

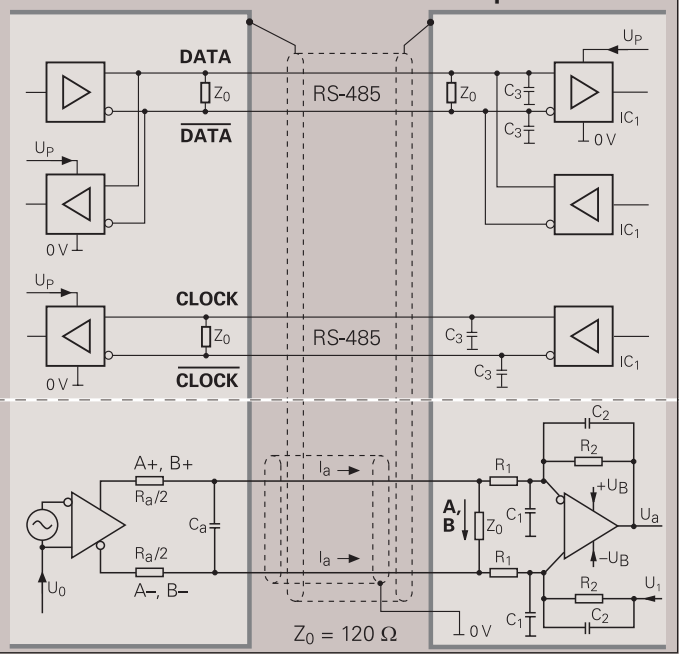
Hardware

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

Power supply
The encoders require a **stabilized dc voltage.** Voltage between 4.75 and 5.25 V must be available at the supply point (subsequent electronics). The encoders are designed 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).

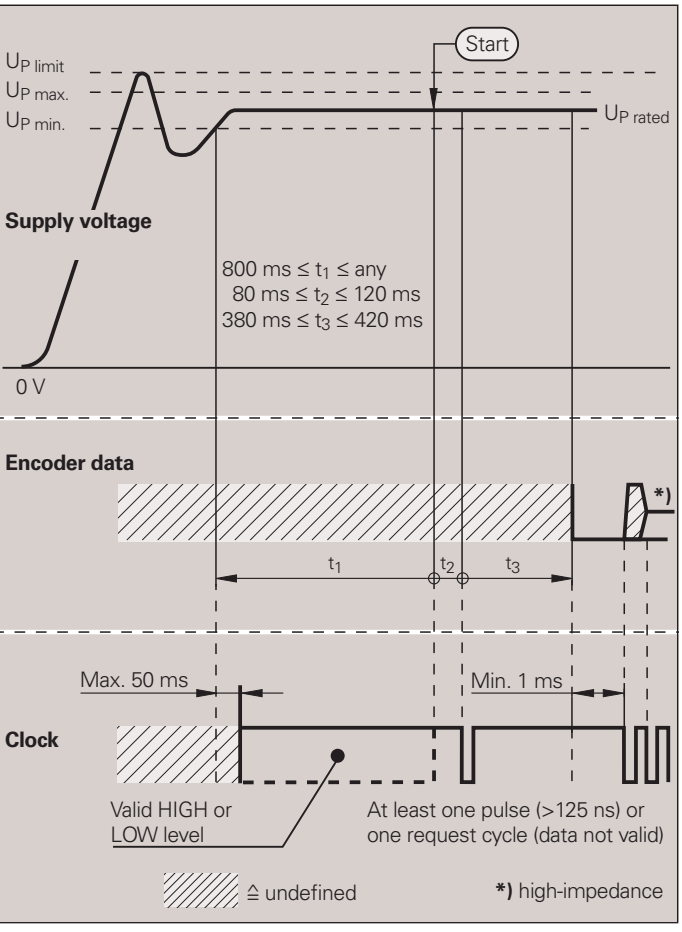
The permissible ripple content of the dc voltage is:
- High frequency interference
  U_{PP} < 250 mV with dU/dt > 5 V/µs
- Low frequency fundamental ripple
  U_{PP} < 100 mV

Starting behavior at the encoder
The integrated electronics require an initialization time of approx. 1 second. To attain a defined initialization procedure, the switch-on routine in the diagram should be taken into account.

Power supply from subsequent electronics (supply point)
see the *specifications of the encoder*

Reaction of the encoder

Clock pulse sequence from the subsequent electronics



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	0.01 µm 0.005 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 24 bits 37 bits 36 bits 19 bits 18 bits 31 bits 30 bits
Incremental encoders		**Resolution**
Encoders with 1-V_{PP} output signals via EIB (**E**xternal **I**nterface **B**ox)		Integrated 14-bit interpolation

HEIDENHAIN

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For more information:
- HEIDENHAIN encoder brochures
- Description of the master component (in preparation)
- Detailed interface specification (upon request)

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