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 up to SIL 3.

Voltage supply

CLOCK 16 MHz

DATA Position values, parameters, datum shifts, electronic ID label, diagnostics, warning, etc.

EnDat 2.2 – Bidirectional Interface for Position Encoders
The EnDat interface provides everything needed to reduce system cost and at the same time improve your 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 voltage supply, since remote sensing is not required
- Simple connection technology: Standard connecting elements (M12 – 8-pin), single shielded standard cables and low wiring costs
- Only one cable with HMC 6: the Hybrid Motor Cable contains the lines for the encoder, the motor and the brake
- 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, etc.)
- 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 of the encoders 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 up to SIL 3
- Two independent position values for error detection
- Two independent error messages
- Checksums and acknowledgments
- Forced dynamic sampling of error messages and CRC formation by subsequent electronics

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

---

For further information on implementing EnDat or additional documents, see [www.endat.de](http://www.endat.de)
The EnDat interface is a digital, bidirectional interface for encoders. It is capable both of transmitting position values as well as transmitting or updating information stored in the encoder, or saving new information. Thanks to the serial transmission method, only four signal lines are required. The data is transmitted in synchronism with the clock signal from the subsequent electronics. The type of transmission (position values, parameters, diagnostics, etc.) is selected through mode commands that the subsequent electronics send to the encoder. Some functions are available only with EnDat 2.2 mode commands.

History and compatibility
The EnDat 2.1 interface available since the mid-90s has since been upgraded to the EnDat 2.2 version (recommended for new applications). EnDat 2.2 is compatible in its communication, command set and time conditions with version 2.1, but also offers significant advantages. It makes it possible, for example, to transfer additional data (e.g. sensor values, diagnostics, etc.) with the position value without sending a separate request for it. This permits support of additional encoder types (e.g. with battery buffer, incremental encoders, etc.). The interface protocol was expanded and the time conditions (clock frequency, processing time, recovery time) were optimized.

Supported encoder types
The following encoder types are currently supported by the EnDat 2.2 interface (this information can be read out from the encoder’s memory area):
- Incremental linear encoder
- Absolute linear encoder
- Rotational incremental singleturn encoder
- Rotational absolute singleturn encoder
- Multiturn rotary encoder
- Multiturn rotary encoder with battery buffer
In some cases, parameters must be interpreted differently for the various encoder models (see EnDat Specifications) or EnDat additional data must be processed (e.g. incremental or battery-buffered encoders).

<table>
<thead>
<tr>
<th>Interface</th>
<th>EnDat serial bidirectional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data transfer</td>
<td>Position values, parameters and additional data</td>
</tr>
<tr>
<td>Data input</td>
<td>Differential line receiver according to EIA standard RS 485 for the signals CLOCK, CLOCK, DATA and DATA</td>
</tr>
<tr>
<td>Data output</td>
<td>Differential line driver according to EIA standard RS 485 for DATA and DATA signals</td>
</tr>
<tr>
<td>Position values</td>
<td>Ascending during traverse in direction of arrow (see dimensions of the encoders)</td>
</tr>
<tr>
<td>Incremental signals</td>
<td>Depends on encoder (1 Vpp, TTL, HTL (see the respective incremental signals))</td>
</tr>
</tbody>
</table>

Order designations
The order designations define the central specifications and give information about:
- Typical voltage supply range
- Command set
- Availability of incremental signals
- Maximum clock frequency
The second character of the order designation identifies the interface generation. For encoders of the current generation the order designation can be read out from the encoder memory.

Incremental signals
Some encoders also provide incremental signals. These are usually used to increase the resolution of the position value, or to serve a second subsequent electronics unit. Current generations of encoders have a high internal resolution, and therefore no longer need to provide incremental signals. The order designation indicates whether an encoder outputs incremental signals:
- EnDat01 With 1 Vpp incremental signals
- EnDatT With TTL incremental signals
- EnDat21 Without incremental signals
- EnDat02 With 1 Vpp incremental signals
- EnDat22 Without incremental signals

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

Voltage supply
The typical voltage supply of the encoders depends on the interface:
- EnDat01 5 V ± 0.25 V
- EnDat21
- EnDat02 3.6 V to 5.25 V or 14 V
- EnDat22
- EnDatH 10 V to 30 V
- EnDatT 4.75 V to 30 V

Exceptions are documented in the Specifications.

Command set
The command set describes the available mode commands, which define the exchange of information between the encoder and the subsequent electronics. The EnDat 2.2 command set includes all EnDat 2.1 mode commands. In addition, EnDat 2.2 permits further mode commands for the selection of additional data, and makes memory accesses possible even in a closed control loop. When a mode command from the EnDat 2.2 command set is transmitted to an encoder that only supports the EnDat 2.1 command set, an error message is generated. The supported command set is stored in the encoder’s memory area:
- EnDat01/21/H/T Command set 2.1 or 2.2
- EnDat02/22 Command set 2.2
Clock frequency
The clock frequency is variable—depending on the cable length (max. 150 m)—between 100 kHz and 2 MHz. With propagation-delay compensation in the subsequent electronics, either clock frequencies up to 16 MHz are possible or cable lengths up to 100 m. For EnDat encoders with order designation EnDat x2, the maximum clock frequency is stored in the encoder memory. For all other encoders the maximum clock frequency is 2 MHz. Propagation-delay compensation is provided only for order designations EnDat 21 and EnDat 22; for EnDat 02, see the note below.

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

Transmission frequencies up to 16 MHz in combination with large cable lengths place high technological demands on the cable. Due to the data transfer technology, the adapter cable connected directly to the encoder must not be longer than 20 m. Greater cable lengths can be realized with an adapter cable no longer than 6 m and an extension cable. As a rule, the entire transmission path must be designed for the respective clock frequency.

Position values
The position value can be transmitted with or without additional data. It is not transmitted to the subsequent electronics until after the calculation time \( t_{\text{calc}} \) has passed. The calculation time is ascertained at the highest clock frequency permissible for the encoder, but at no greater than 8 MHz.

Only the required number of bits is transferred for the position value. The bit number depends on the respective encoder and can be read out from the encoder for automatic parameterization.

Typical operating modes
Operating mode EnDat 2.1: This mode is for encoders that provide additional incremental signals. The absolute position is read out once simultaneously with the incremental position and both are used to calculate the position value. Otherwise, the position value in the control loop is formed on the basis of the incremental signals. Only EnDat 2.1 mode commands are used.

Operating mode EnDat 2.2: This mode is for purely serial encoders. The position value is read out from the encoder in each control cycle. EnDat 2.2 mode commands are typically used to read out the position value. EnDat 2.1 mode commands are typically used to read and write parameters after switch-on.

The EnDat 2.2 interface can interrogate the position and additional data, and also perform functions (e.g. read/write parameters, reset error messages, etc.), all within the closed loop.

Additional data
One or two items of additional data can be appended to the position value, depending on the type of transmission (selection via MRS code). The additional data supported by the respective encoder are saved in the encoder parameters. The additional data contains:

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

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

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

Note on EnDat02
EnDat02 encoders can feature a pluggable cable assembly. In choosing the version of the adapter cable, the customer also decides whether the encoder will be operated with incremental signals or without them. This also affects the maximum possible clock frequency. For adapter cables with incremental signals the clock frequency is limited to at most 2 MHz; see EnDat01. For adapter cables without incremental signals the clock frequency can be up to 16 MHz. The exact values are stored in the encoder’s memory.
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. The parameter data are stored in a permanent memory. This memory permits only a limited number of write access events and is not designed for cyclic data storage. Certain memory areas can be write-protected (this can only be reset by the encoder manufacturer).

Parameters are saved in various memory areas, e.g.:
- Encoder-specific information
- Information of the OEM (e.g. “electronic ID label” of the motor)
- Operating parameters (datum shift, instruction, etc.)
- Operating status (alarm or warning messages)

Monitoring and diagnostic functions of the EnDat interface make a detailed inspection of the encoder possible.
- Error messages
- Warnings
- Online diagnostics based on valuation numbers (EnDat 2.2)
- Mounting interface

Functional safety – Basic principle
EnDat 2.2 strictly supports the use of encoders in safety-related applications. The DIN EN ISO 13 849-1 (previously EN 954-1), EN 61 508 and EN 61 800-5-2 standards serve as the foundation. These standards describe the assessment of safety-related systems, for example based on the failure probabilities of integrated components and subsystems. The modular approach helps manufacturers of safety-related systems to implement their complete systems, because they can begin with prequalified subsystems.

For more information, see “Functional safety” at www.endat.de

Input circuitry of subsequent electronics
Dimensioning
IC1 = RS 485 differential line receiver and driver

\[ Z_0 = 120 \ \Omega \]
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 are possible at cable lengths up to a maximum of 100 m (fCLK ≤ 8 MHz). 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 \( f_c = \frac{1}{2t_{min}} \).

**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.
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 encoders need for calculating the position values \( t_{\text{cal}} \) 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 commands

<table>
<thead>
<tr>
<th>No.</th>
<th>Mode command</th>
<th>Mode bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Encoder send position values</td>
<td>M2: 0  M1: 0  M0: 1  (M2): 1  (M1): 1  (M0): 1</td>
</tr>
<tr>
<td>2</td>
<td>Selection of memory area</td>
<td>M2: 0  M1: 0  M0: 1  (M2): 1  (M1): 1  (M0): 0</td>
</tr>
<tr>
<td>3</td>
<td>Encoder receive parameters</td>
<td>M2: 0  M1: 1  M0: 1  (M2): 1  (M1): 1  (M0): 0</td>
</tr>
<tr>
<td>4</td>
<td>Encoder send parameters</td>
<td>M2: 1  M1: 0  M0: 0  (M2): 0  (M1): 1  (M0): 1</td>
</tr>
<tr>
<td>5</td>
<td>Encoder receive reset</td>
<td>M2: 1  M1: 0  M0: 1  (M2): 0  (M1): 1  (M0): 0</td>
</tr>
<tr>
<td>6</td>
<td>Encoder send test values</td>
<td>M2: 0  M1: 1  M0: 1  (M2): 0  (M1): 1  (M0): 0</td>
</tr>
<tr>
<td>7</td>
<td>Encoder receive test command</td>
<td>M2: 1  M1: 1  M0: 0  (M2): 0  (M1): 0  (M0): 1</td>
</tr>
<tr>
<td>8</td>
<td>Encoder send position value with additional data</td>
<td>M2: 1  M1: 1  M0: 1  (M2): 0  (M1): 0  (M0): 0</td>
</tr>
<tr>
<td>9</td>
<td>Encoder send position value and receive selection of memory area</td>
<td>M2: 0  M1: 1  M0: 0  (M2): 1  (M1): 0  (M0): 1</td>
</tr>
<tr>
<td>10</td>
<td>Encoder send position value and receive parameters</td>
<td>M2: 0  M1: 1  M0: 0  (M2): 1  (M1): 1  (M0): 1</td>
</tr>
<tr>
<td>11</td>
<td>Encoder send position value and send parameters</td>
<td>M2: 1  M1: 0  M0: 1  (M2): 0  (M1): 1  (M0): 0</td>
</tr>
<tr>
<td>12</td>
<td>Encoder send position value and receive error reset</td>
<td>M2: 1  M1: 1  M0: 1  (M2): 0  (M1): 0  (M0): 1</td>
</tr>
<tr>
<td>13</td>
<td>Encoder send position value and receive test command</td>
<td>M2: 1  M1: 0  M0: 1  (M2): 1  (M1): 1  (M0): 0</td>
</tr>
<tr>
<td>14</td>
<td>Encoder receive communication command 2)</td>
<td>M2: 0  M1: 0  M0: 1  (M2): 0  (M1): 1  (M0): 0</td>
</tr>
</tbody>
</table>

1) Selected additional data are also transmitted
2) Reserved for encoders that do not support the safety system
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 encoder saves the measured values and calculates the position value.

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_{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 of the encoder and can be interrogated in detail.

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

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

This is followed in EnDat 2.2 by the additional data 1 and 2, each also concluded with a CRC. 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_{R}) 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

**Diagram does not include the propagation-delay compensation**

### Parameters

<table>
<thead>
<tr>
<th>Clock frequency f_c</th>
<th>Without delay compensation</th>
<th>With delay compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 kHz ... 2 MHz</td>
<td>100 kHz ... 16 MHz</td>
<td></td>
</tr>
</tbody>
</table>

| Calculation time for Position value t_{cal} t_{ac} |
|-----------------------------------------------|----------|
| Typical of EnDat 2.2 encoders: ≤ 5 µs          |
| Max. 12 ms                                    |

<table>
<thead>
<tr>
<th>Recovery time t_{R}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. 500 ns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recovery time t_{ST}</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 µs to 10 µs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data delay time t_{D}</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.2 + 0.01 x cable length in m) µs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pulse width t_{HI}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 µs to 10 µs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pulse width t_{LO}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 ms to 50 ms</td>
</tr>
<tr>
<td>Up to 30 µs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pulse width fluctuation HIGH to LOW max. 10 %</th>
</tr>
</thead>
</table>

---

**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 encoder saves the measured values and calculates the position value.

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_{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 of the encoder and can be interrogated in detail.

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

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

This is followed in EnDat 2.2 by the additional data 1 and 2, each also concluded with a CRC. 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_{R}) the data line falls back to LOW. Then a new data transmission can be initiated by starting the clock.
Data packet with position value and additional data 1 and 2

Encoder saves position value

Subsequent electronics transmit mode command

Mode command

Position value

CRC

Additional datum 2

CRC

Additional datum 1

CRC

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

Diagram does not include the propagation-delay compensation

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
- Supply voltage 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. The two error messages must be evaluated separately from each other.

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).

The composition of the position value differs depending on the encoder model (see EnDat specifications). At this point, absolute encoders transmit the absolute position value while incremental encoders transmit the relative position value (see also “Position value 2” on the following page).

Additional data

An encoder with EnDat 2.2 interface can transmit the position value together with up to two additional data. Sixteen possible contents identified by unique numbers are assignable to each of the additional data 1 and 2. These numbers are used to select the additional data and are transmitted for acknowledgment (see next page). The additional data supported by the encoder is saved in the encoder memory.

The “Encoder transmit position value and receive selection of memory area” mode command selects the information to be transmitted, which is therefore possible in a closed loop. After the additional datum has been selected, it is transmitted with the next mode command (only no. 8 to 13). The additional datum is transmitted with each position value until it is deselected through the transmission of a special MRS code or until another additional datum is selected. When the encoder is switched on, at first no additional data is selected.

Example

Additional datum 1:
Rolling transmission of temperature 1 (Temp1: MRS code 0x4C) and temperature 2 (Temp2: MRS code 0x4D)

Additional datum 2: Transmission of the operating status error sources (BZFQ: MRS code 0x59)

Mode command 9 (001001): “Encoder transmit position value and receive selection of memory area”

Subsequent electronics ➔ encoder ➔ Encoder ➔ subsequent electronics

Mode command 9 + MRS code 0x59 ➔ Position
Mode command 9 + MRS code 0x4C ➔ Position + BZFQ
Mode command 9 + MRS code 0x4D ➔ Position + BZFQ + Temp1
Mode command 9 + MRS code 0x4C ➔ Position + BZFQ + Temp2
Mode command 9 + MRS code 0x4D ➔ Position + BZFQ + Temp1

etc.
Additional data

One or two items of 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 are saved in the encoder parameters. The additional data include 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 error messages 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 datum 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, such as mounting information
- **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 internal or external 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.
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. One 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 EnDat 2.2 mode commands.

**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 of error and warning messages, 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/O, touch-probe status) are reserved for future applications. The operating parameter area can be protected against overwriting.

**Operating status**

This memory area provides detailed error messages or warnings for diagnostic purposes. Here it is also possible to initialize certain encoder functions, activate write protection for the OEM parameters and operating parameters memory areas, and to interrogate their status. Once activated, the write protection cannot be reversed.
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 encoder
- **ST** Singleturn rotary encoder or angle encoder
- **MT** Multiturn encoder
- **iL** Incremental linear encoder with external (EIB) or integral conversion of 1 VPP to purely serial EnDat 2.2
- **iR** Incremental rotational encoder with external (EIB) or integral conversion of 1 VPP 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 depend 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

<table>
<thead>
<tr>
<th>Word</th>
<th>Contents</th>
<th>Linear encoder</th>
<th>Rotary/Angle encoder</th>
<th>Required</th>
<th>Depends on application</th>
<th>Informative</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Mask 0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>Mask 1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>6</td>
<td>Mask 2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>7</td>
<td>Mask 3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>8</td>
<td>Version of the EnDat interface</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>All</td>
<td>“2” saved with EnDat 2.1 or 2.2</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Memory allocation for parameters of the OEM</td>
<td>—</td>
<td>—</td>
<td>All</td>
<td>—</td>
<td>Depends on encoder; flexibly programmable. Memory pointer to first free address</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Memory allocation for compensation values</td>
<td>—</td>
<td>—</td>
<td>All</td>
<td>—</td>
<td>Reserved for encoder manufacturer</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Number of pulses for transmission of position value (transmission format)</td>
<td>—</td>
<td>—</td>
<td>All</td>
<td>—</td>
<td>Setting the correct clock number for position transmission</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Encoder type</td>
<td>—</td>
<td>—</td>
<td>All</td>
<td>—</td>
<td>Defines the units of the parameters</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Signal period(s) per revolution for incremental output signals</td>
<td>nm</td>
<td>—</td>
<td>All</td>
<td>—</td>
<td>iL, iR: For calculating the smallest display step (LSB) or the correct display value for negative traverse direction All: For EnDat-compliant datum shift</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Distinguishable revolutions (only for multiturn rotary encoders)</td>
<td>—</td>
<td>—</td>
<td>MT</td>
<td>—</td>
<td>Required for correct calculation of the position</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>(Nominal) increment of reference marks</td>
<td>mm</td>
<td>Signal periods</td>
<td>—</td>
<td>—</td>
<td>iL, iR</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Position of the first reference mark</td>
<td>mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>iL</td>
<td></td>
</tr>
</tbody>
</table>

1) Except touch probe
### Parameters of the encoder manufacturer for EnDat 2.1 (continued)

<table>
<thead>
<tr>
<th>Word</th>
<th>Contents</th>
<th>Linear encoder</th>
<th>Rotary/Angle encoder</th>
<th>Required</th>
<th>Depends on application</th>
<th>Informative</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Measuring step or steps per revolution with serial data transmission</td>
<td>nm</td>
<td>Measuring steps per revolution</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>21</td>
<td>Datum shift of the encoder manufacturer</td>
<td>Signal periods</td>
<td>Signal periods</td>
<td>All</td>
<td>–</td>
<td>–</td>
<td>To be accounted for by the user for datum shift</td>
</tr>
<tr>
<td>24</td>
<td>ID number</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>Safety technology</td>
</tr>
<tr>
<td>27</td>
<td>Serial number</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>Encoder exchange can be detected (may affect application—safety related)</td>
</tr>
<tr>
<td>30</td>
<td>Direction of rotation or traverse</td>
<td>–</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>32</td>
<td>Maximum mechanically permissible linear velocity or shaft speed</td>
<td>m/min</td>
<td>min⁻¹</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>Required for cross checking of absolute position → incremental position</td>
</tr>
<tr>
<td>33</td>
<td>Accuracy depending on linear velocity or shaft speed, area I</td>
<td>LSB ²</td>
<td>LSB ²</td>
<td>–</td>
<td>ST MT L</td>
<td>–</td>
<td>Comparison of absolute and incremental position not possible with E iL iR because these encoders have only incremental information</td>
</tr>
<tr>
<td>34</td>
<td>Accuracy depending on linear velocity or shaft speed, area II</td>
<td>LSB ²</td>
<td>LSB ²</td>
<td>–</td>
<td>ST MT L</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>36</td>
<td>Support of warnings</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>For definition of an “error mask” (safety related)</td>
</tr>
<tr>
<td>37</td>
<td>EnDat command set</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>–</td>
<td>Information on whether EnDat 2.2 mode commands are supported</td>
</tr>
<tr>
<td>39</td>
<td>Reserved for measuring length ³</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>L iL</td>
<td>–</td>
<td>Information on whether EnDat 2.2 mode commands are supported</td>
</tr>
<tr>
<td>40</td>
<td>Maximum processing time</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>–</td>
<td>For monitoring (time out)</td>
</tr>
<tr>
<td>41</td>
<td>HEIDENHAIN specifications</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Distinguishes between with/without incremental signals</td>
</tr>
</tbody>
</table>

¹ Except touch probe
² The highervalue byte contains the divisor with respect to the maximum permissible linear velocity or rotational shaft speed up to which this accuracy is valid.
³ Not supported by all linear encoder models; initialized with default value 0
<table>
<thead>
<tr>
<th>Word</th>
<th>Contents</th>
<th>Linear encoder</th>
<th>Rotary/Angle encoder</th>
<th>Required</th>
<th>Depends on application</th>
<th>Informative</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Status of additional datum 1</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1</td>
<td>Status of additional datum 2</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>Status of additional functions</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>Acceleration</td>
<td>m/s²</td>
<td>1/s²</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4</td>
<td>Temperature</td>
<td>K</td>
<td>K</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>Diagnostic status</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
</tr>
<tr>
<td>6</td>
<td>Support of error message 2</td>
<td>–</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>7</td>
<td>Dynamization status</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>8</td>
<td>Measuring step or measuring steps per revolution for position value 2</td>
<td>nm</td>
<td>–</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>9</td>
<td>Accuracy of position value 2 depending on linear velocity or shaft speed, area I</td>
<td>LSB²</td>
<td>LSB²</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>10</td>
<td>Max. permissible encoder temperature at measuring point</td>
<td>K</td>
<td>K</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>11</td>
<td>Max. permissible acceleration</td>
<td>m/s²</td>
<td>1/s²</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>12</td>
<td>Number of blocks for memory area section 2</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>–</td>
<td>Depends on encoder; program flexibly</td>
</tr>
<tr>
<td>13</td>
<td>Maximum clock frequency</td>
<td>kHz</td>
<td>kHz</td>
<td>All</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>14</td>
<td>Measuring step, or measuring steps per revolution or subdivision values of a grating period</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>15</td>
<td>Distinguishable revolutions for position value 2 (only for multturn encoders)</td>
<td>–</td>
<td>–</td>
<td>MT</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>16</td>
<td>Direction of rotation of position value 2</td>
<td>–</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>17-20</td>
<td>Encoder designation</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
</tr>
<tr>
<td>21</td>
<td>Support of instructions</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
</tr>
<tr>
<td>22</td>
<td>Support of operating status error sources</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>23</td>
<td>Safety-relevant measuring steps</td>
<td>–</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>24</td>
<td>Non-safety-relevant subdivision of the relative position</td>
<td>–</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>25</td>
<td>Generation of a warning message through limit position signals</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>26</td>
<td>Support of touch probe statuses</td>
<td>–</td>
<td>–</td>
<td>T</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>27</td>
<td>Timestamp for unit of measure</td>
<td>–</td>
<td>–</td>
<td>T</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>28</td>
<td>Referencing of incremental encoders</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>IL, Ir</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>29</td>
<td>Support of I/Os</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>All¹</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>30</td>
<td>Number of OEM blocks for memory area section 2</td>
<td>–</td>
<td>–</td>
<td>All</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

¹) Except touch probe
²) 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 for 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.

<table>
<thead>
<tr>
<th>Mode command</th>
<th>Communication: Subsequent electronics → encoder</th>
<th>Communication: Encoder → subsequent electronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection of the memory area $^1$</td>
<td>Mode bits</td>
<td>MRS code or address</td>
</tr>
<tr>
<td>Encoder receive parameters</td>
<td>“001 110”</td>
<td>MRS code</td>
</tr>
<tr>
<td>Encoder send parameters</td>
<td>“011 100”</td>
<td>Address</td>
</tr>
<tr>
<td>Encoder send parameters</td>
<td>“100 011”</td>
<td>Address</td>
</tr>
</tbody>
</table>

$^1$ 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 are 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 parameters 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:**

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Data communication on interface (bidirectional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection of memory area</td>
<td>Position value + Selection of the MRS code</td>
</tr>
<tr>
<td>Acknowledgment of MRS code</td>
<td>Position value + Acknowledgment of MRS code (selection of additional data and readout)</td>
</tr>
<tr>
<td>Transmission of read address</td>
<td>Position value + Selection of address to be read</td>
</tr>
<tr>
<td>Cyclical request on busy bit = “0”; (max. $t_{ac} = 12$ ms)</td>
<td>Position value + Any additional data</td>
</tr>
<tr>
<td>Reading out of LSB data and acknowledgment</td>
<td>Position value + Addressing of the additional datum “acknowledgment of LSB” and read-out of data content + acknowledgment of read address</td>
</tr>
<tr>
<td>Reading out of MSB data and acknowledgment</td>
<td>Position value + Addressing of additional datum “acknowledgment of MSB” and read-out of data content + acknowledgment of read address</td>
</tr>
</tbody>
</table>
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).

In addition to the online diagnostics, certain inductive rotary encoders provide special information over the diagnostics interface for mounting, for example the mounting dimensions. Output of the mounting information must be activated by the OEM and should also be deactivated after mounting is completed. For more information, see the EnDat Application Note.
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:*
- \(10 \mu s \leq t_m \leq 30 \mu s\) selectable to \(1.25 \mu s \leq t_m \leq 3.75 \mu s\) (for mode commands no. 8 to 14 and \(f_{\text{CLK}} > 1 \text{ MHz}\))
- Reduced recovery time is set when very short cycle times are to be attained.

**Multiturn functions:**
- Make it possible to connect encoders with a battery-buffered revolution counter.

**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**

**Datum 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.
Voltage supply

The encoders require a stabilized DC voltage $U_p$ as voltage supply. The required voltage 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 voltage 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 voltage supply of the subsequent electronics so that the resulting voltage after attenuation through cable length, cable cross section and current consumption can be processed without correction (applies only for cable assemblies from HEIDENHAIN). This means that monitoring the voltage at the encoder with the encoder’s sensor lines and adjusting the supply voltage through a controllable power supply unit (remote sense) are no longer necessary.

The permissible ripple content of the DC voltage is:
- High frequency interference $U_{pp} < 250 \text{ mV}$ with $\text{d}U/\text{d}t > 5 \text{ V/µs}$
- Low frequency fundamental ripple $U_{pp} < 100 \text{ mV}$

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.
Connection technology

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

Cable
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 cables.
Due to the data transfer technology, the adapter cable (Ø ≤ 4.5 mm) connected directly to the encoder must not be longer than 20 m. Greater cable lengths can be realized with an adapter cable no longer than 6 m and an extension cable (Ø 6 mm).

Implementation of EnDat

HEIDENHAIN offers various aids for implementing the EnDat interface in subsequent electronics (see also “Implementation” section at www.endat.de):

EnDat Demotool software
The EnDat Demotool software requires a PWM 20 as hardware basis. 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 purely 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

EnDat error injector
The simulation of a faulty data transmission can be useful for test purposes. The EnDat error injector enables manipulation of an EnDat transmission in a closed loop. A special PWM 20 version forms the basis for the error injector.

Documentation
• EnDat Specifications
• EnDat Application Note
• EnDat Seminar
• FAQ and implementation at www.endat.de
• Technical Information: EnDat
• Description of the EnDat master component at www.mazet.de
Another advantage of the EnDat interface is that it can be used with a wide variety of encoders. Rotary, linear and angle encoders with EnDat interface make it possible to cover very diverse applications in the machine tool, electronics and automation industries.

For more information about the encoders regarding the EnDat 2.2 interface, see "Encoder characteristics" at www.endat.de.

### Overview of encoders

<table>
<thead>
<tr>
<th>Absolute encoders</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear encoders</td>
<td>± 5 µm</td>
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<tr>
<td></td>
<td>± 3 µm</td>
</tr>
<tr>
<td>LC 115/LC 415</td>
<td>10 nm</td>
</tr>
<tr>
<td>LC 211</td>
<td>1 nm</td>
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<tr>
<td>LIC 4000</td>
<td>10 nm</td>
</tr>
<tr>
<td>LIC 4100</td>
<td>1 nm</td>
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<tr>
<td>LIC 2100</td>
<td>Down to 50 nm</td>
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<tr>
<td>Length gauges</td>
<td>0.023 µm</td>
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<tr>
<td></td>
<td>0.368 µm</td>
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<tr>
<td>Angle encoders</td>
<td>± 5 &quot;</td>
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<tr>
<td></td>
<td>± 2.5&quot;</td>
</tr>
<tr>
<td>RCN 2000/RCN 5000</td>
<td>26 bits</td>
</tr>
<tr>
<td>RCN 8000</td>
<td>28 bits</td>
</tr>
<tr>
<td>ECA 4000</td>
<td>29 bits</td>
</tr>
<tr>
<td>Rotary encoders, optical</td>
<td>13/25 bits</td>
</tr>
<tr>
<td>Singletum/multiturn</td>
<td>23/25 bits</td>
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<tr>
<td></td>
<td>13/25 bits</td>
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<tr>
<td></td>
<td>25/37 bits</td>
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<tr>
<td></td>
<td>13 bits</td>
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<td>25 bits</td>
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<td>13/25 bits</td>
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<td>25/37 bits</td>
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<td>13/25 bits</td>
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<td>23/35 bits</td>
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<tr>
<td>Rotary encoders, inductive</td>
<td>19/31 bits</td>
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<tr>
<td>Singletum/Multiturn</td>
<td>18/35 bits</td>
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<tr>
<td></td>
<td>19/31 bits</td>
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<tr>
<td></td>
<td>19/31 bits</td>
</tr>
<tr>
<td>Incremental encoders</td>
<td>Resolution</td>
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<tr>
<td>Linear encoders</td>
<td>LIP 211</td>
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<tr>
<td>Magnetic modular encoders</td>
<td>ERM 2410</td>
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<tr>
<td>HEIDENHAIN encoders with 1 Vpp output signals</td>
<td>Via EiB</td>
</tr>
</tbody>
</table>

1) Versions with functional safety available on request
2) Multiturn function via battery-buffered revolution counter

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This Technical Information supersedes all previous editions, which thereby become invalid. The basis for ordering from HEIDENHAIN is always the Technical Information valid when the contract is made.

More information:
- HEIDENHAIN encoder brochures
- www.endat.de
- Description of the Master Component (www.mazet.de)
- Detailed interface specifications (upon request)