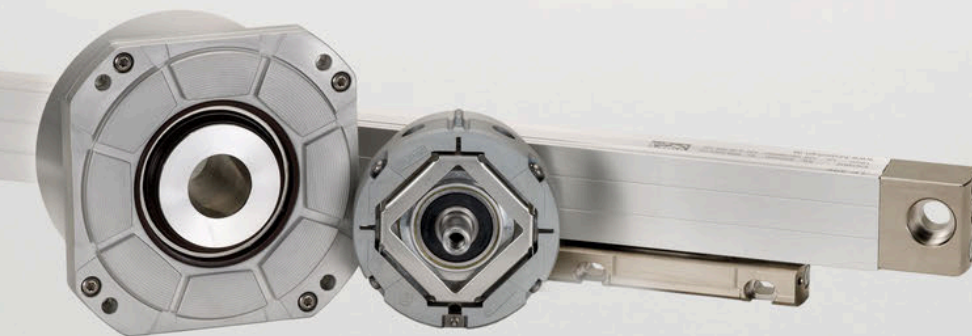




**Functional  
Safety**

## EnDat 2.2

## EnDat 2.2 Implementation Guide



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# 1 Fundamentals

## 1.1 About these instructions

These instructions are a guide for the implementation of the EnDat 2.2 interface. The implementation guide provides an overview of which documents, document contents, devices, and software can be used as an aid during the respective implementation stages.



For further information, please refer to: [www.endat.de](http://www.endat.de) ► EnDat 2.1 and 2.2



For individual advice on optimal implementation of the EnDat 2.2 interface, please consult with your HEIDENHAIN contact person.

## 1.2 Implementation in four stages

The EnDat 2.2 interface is implemented in four stages:

- Stage 1: Implementation of the physical layer: digital design, timing / "bits and bytes," etc.
- Stage 2: Communication on the basis of mode commands
- Stage 3: Implementation of complex processes, such as a memory access
- Stage 4: Integration of EnDat 2.2 communication into the controller structure, taking the various encoder profiles into account (absolute, incremental, linear, rotatory, etc.)

## 1.3 Various documents available as an aid

HEIDENHAIN provides a variety of aids and documents for the individual implementation stages.



For the implementation of Stage 1, HEIDENHAIN recommends that you use one of the available EnDat Masters.

**Further information:** "EnDat 2.2 Master", Page 10



For individual advice on optimal implementation of the EnDat interface, please consult with your HEIDENHAIN contact person.

## 1.4 Notes on reading the documentation

### Pertinent documentation

The table below lists the various parts of the documentation in their order of reading priority.

Documentation	Description
EnDat 2.2 Technical Information	This Technical Information document provides an overview of the interface. It is not an interface specification.
EnDat 2.2 Implementation Guide	The Implementation Guide provides an overview of which documents and document content are intended for which readers, and which aids are available for implementation.
EnDat 2.2 Interface Specification	The Interface Specification contains detailed and complete information regarding the physical interface, timing, and transmitted data contents. This information is required for implementation of the EnDat 2.2 interface.
EnDat 2.2 Master Instructions	The Master Instructions describe the EnDat 2.2 Master provided by HEIDENHAIN.
EnDat 2.2 Application Notes	The Application Notes describe the functionalities, processes, mechanisms, encoder functions, and other topics from the perspective of the application.
Electrical safety and electromagnetic compatibility	Information about electrical safety and electromagnetic compatibility can be found in the corresponding section of the "Interfaces of HEIDENHAIN Encoders" brochure. The documentation for the respective encoder must be observed as well.
EnDat Seminar	The EnDat Seminar provides detailed information surrounding the various aspects of the EnDat 2.2 interface, such as the EnDat 2.2 interface specification, information on cables and connecting elements, information about the EnDat Master, practical exercises for communicating with EnDat encoders via mode commands, and information on online diagnostics, datum shift, etc.
Functional safety	Documents for the implementation of functional safety with the EnDat 2.2 interface: Catalog of measures, requirements for position value comparison, supplementary catalog of measures for SIL 3, use of a non-functionally-safe EnDat 2.2 Master, etc.

**Further information on the pertinent documentation**

For further information, please refer to: **www.endat.de** ► EnDat 2.1 and 2.2  
To request the EnDat 2.2 documentation package, please use the contact form at  
**www.endat.de**  
The EnDat 2.2 Master Instructions are part of the items supplied with the corresponding  
EnDat Master.



If you have any questions, please contact your HEIDENHAIN contact person.

**Would you like to see any changes, or have you found any errors?**

We are continuously striving to improve our documentation for you. Please help us by sending your requests to the following e-mail address:

**userdoc@heidenhain.de**

## 2 Association of documentation and implementation stages

This chapter shows which documents can be used as an aid during the respective implementation stages of EnDat 2.2.

### 2.1 Documentation on the development of the hardware

Development of the hardware corresponds to Stage 1 of the implementation.

#### 2.1.1 Stage 1: physical layer, digital design, timing / "bits and bytes"

##### Physical layer

The following aids can be used for the implementation of the physical layer:

- EnDat 2.2 Interface Specification
- Chapter "Electrical safety" in "Interfaces of HEIDENHAIN Encoders"
- Chapter "Electromagnetic compatibility" in "Interfaces of HEIDENHAIN Encoders"

##### Digital design

The following aids can be used for the implementation of the digital design:

- EnDat 2.2 Interface Specification

##### Timing / "bits and bytes"

All of the information on the timing and "bits and bytes" that is required for the implementation of the EnDat 2.2 interface is provided in the following document:

- EnDat 2.2 Interface Specification



For the implementation of Stage 1, HEIDENHAIN recommends that you use one of the solutions described in the chapter "EnDat 2.2 Master".

**Further information:** "EnDat 2.2 Master", Page 10

Using one of these solutions reduces the time to market and ensures error-free communication.

It also minimizes the effort needed for testing.

### 2.2 Documentation on the development of the software

Software development corresponds to Stages 2 through 4 of the implementation.

You can use the following aids for the implementation of Stages 2 through 4:

- EnDat 2.2 Master Manual
- EnDat 2.2 Interface Specification
- EnDat 2.2 Application Notes
- PWM 21 with the EnDat Demotool software
- Sample programs

#### 2.2.1 Stage 2: Communication on the basis of mode commands

Communication between the control and the EnDat encoder is based on the mode commands. In Stage 2 of the implementation, the mode commands are used in order to establish basic communication with the encoder.

HEIDENHAIN offers the Demotool software, which makes it possible to send individual mode commands to the encoder. The customer can very simply add a "low-level" application software to test the mode commands together with the EnDat 2.2 Master Softmacro. Communication is based on simple register accesses.

### 2.2.2 Stage 3: Implementation of complex processes, such as a memory access

Stage 3 of the implementation requires processes that encompass the sending of multiple mode commands. With these processes, more complex tasks, such as a memory access, are handled.



**Further information:** "EnDat Application Notes", Page 8 and "Example programs", Page 11

### 2.2.3 Stage 4: Integration of EnDat 2.2 communication into the controller structure

In Stage 4 of the implementation, the processes must be integrated into the controller structure, taking the various encoder profiles into consideration (absolute, incremental, linear, rotatory, etc.).



**Further information:** "EnDat Application Notes", Page 8 and "Example programs", Page 11

## 2.3 Documentation on the implementation in functionally safe applications



For functionally safe applications, additional documents must be taken into consideration.  
**Further information:** "Notes on reading the documentation", Page 4



Regarding the EnDat 2.2 Master, in functionally safe applications, both the EnDat 2.2 Master Safe and the non-functionally safe versions can be used, of which the EnDat 2.2 Master Basic is specifically designed for this.



For further information, please refer to: [www.endat.de](http://www.endat.de) ► EnDat 2.1 and 2.2

## 2.4 EnDat Application Notes

The EnDat Application Notes describe the functionalities, processes, mechanisms, encoder functions, and other topics from the perspective of the application, also refer to the Chapter "How to get started." In addition to the information from the EnDat 2.2 interface specification, the implementation process is supported this way:

Implementation steps	EnDat Application Notes	Required actions / customer specifications
<b>Read-out and cycle times</b>	Calculation of readout time and cycle time	Definition of the configuration for the EnDat Master, e.g., clock frequency (with regard to the required cycle time), ...
<b>Basic communication</b>		
Power-up	"Sequences and data structures"	
Reading out parameters	"Position data formats"	
Cyclic reading of position	"Implementation examples, specifically the section on basic communication with purely serial absolute linear, singleturn and gear-based multiturn encoders from HEIDENHAIN"	Implementation of the basic communication (based on EnDat 2.1 mode commands) for the typical encoders
Evaluation of 1 V <sub>PP</sub>	"EnDat01 encoders"	Evaluation of 1 V <sub>PP</sub> required?
<b>Monitoring functions</b>	"EnDat monitoring functions"	Which monitoring functions are to be implemented?
<b>Advanced functions</b>		
OEM memory	"OEM memory area"	Which miscellaneous functions are to be supported?
Datum shift	"EnDat datum shift"	
Temperature	"Temperature sensor models"	
Diagnostics	"Online diagnostics"	
Memory access in the closed control loop	"Sequences and data structures"	
Mounting parameters	"Mounting parameters"	
<b>Further encoder profiles</b>		
Battery buffered multiturn	"Rotary encoders with battery-buffered revolution counter"	Which other encoder profiles are to be supported?
Incremental encoders	"Incremental encoders"	
Strain sensors	"Strain sensors"	
KCI 419 Dplus	"KCI 419 Dplus"	



Implementation steps	EnDat Application Notes	Required actions / customer specifications
<b>Functional safety</b>	Leading documents are the Catalog of Measures D533095 and Application Note D1128897, depending on which type of EnDat Master is to be used.	<ul style="list-style-type: none"> <li>■ Supported yes/no?</li> <li>■ Which EnDat Master is to be used?</li> <li>■ Implementation based on Master safe/non-safe decision</li> </ul>

## 2.5 FAQ

The Frequently Asked Questions (FAQ) are a collection of frequently asked questions and their answers regarding specific topics. FAQ can also be used as an aid for the implementation of the EnDat 2.2 interface, if needed.

HEIDENHAIN provides a comprehensive list of frequently asked questions in connection with the implementation of the EnDat 2.2 interface at [www.endat.de](http://www.endat.de).



The FAQ can be found at [www.endat.de](http://www.endat.de) ► EnDat 2.1 and 2.2

## 3 Aids for the implementation of hardware and software

### 3.1 EnDat 2.2 Master

#### 3.1.1 Overview

The EnDat 2.2 Master controls communication with the EnDat 2.2 encoders from HEIDENHAIN. This makes it easy to transfer the information transmitted via the EnDat 2.2 interface to the higher-level application. The EnDat 2.2 Master can be integrated via either a microcontroller ( $\mu$ C) or an FPGA (Field Programmable Gate Array) or ASIC.

The solutions with a  $\mu$ C are used when the desired clock frequencies are relatively low. For integration into a  $\mu$ C, HEIDENHAIN offers a sample code for the implementation of the EnDat mode commands. There are also  $\mu$ C-based solutions with an integrated EnDat 2.2 Master (e.g., from Texas Instruments, Renesas Electronics, or Hilscher).

Integration into an FPGA or ASIC is usually opted for when high transmission frequencies are desired with purely serial data transmission. Different versions are available for integration into an FPGA or ASIC.

#### 3.1.2 Versions from HEIDENHAIN

##### EnDat 2.2 Master Basic

For implementation of the EnDat 2.2 interface into the subsequent electronics, an FPGA or ASIC is sufficient as a master. This is due to the purely serial data transmission. To facilitate integration of the EnDat 2.2 Master into the subsequent electronics, HEIDENHAIN has developed an EnDat 2.2 Master Softmacro (EnDat 2.2 Master Basic) that exhibits the following key characteristics:

- Encapsulated, HEIDENHAIN-tested code block
- The implementation of the code block is secured through test vectors
- Designed for a short time to market
- All EnDat 2.2 encoders from HEIDENHAIN are supported

##### EnDat 2.2 Master Reduced

- Only the pure EnDat functionality (EnDat protocol machine) is integrated
- All EnDat encoders from HEIDENHAIN are supported
- Time to market: unfavorable in comparison with EnDat 2.2 Master Basic, because more extensive testing is required
- There is no further support regarding the convenient handling of the code, nor is there a microcontroller interface
- Due to the limited functionality, the code size is smaller compared with that of the EnDat 2.2 Master Basic
- The code was tested only in an example application
- Concise documentation is available

##### EnDat 2.2 Master Mini

- Specially designed for the FPGA Lattice MachXO2-1200 in order to take advantage of the special features of this FPGA
- Based on the EnDat 2.2 Master Reduced with an additional register interface and SPI interface
- Time-to-market: optimal, since, in the simplest case, the programming file provided with shipment is used

### EnDat 2.2 Master Light

- VHDL example code, which covers only a part of the EnDat 2.2 functionality
- Only absolute EnDat 2.2 encoders are supported; no incremental encoders or encoders with battery buffer backup are supported
- Time to market: unfavorable in comparison with EnDat 2.2 Master Basic, because more extensive testing is required
- In purely serial operation, only the position is transferred without any EnDat 2.2 additional data. Thus, only a part of the functionality of the EnDat 2.2 interface is modelled
- There is no further support regarding the convenient handling of the code, nor is there a micro-controller interface
- The code size is considerably smaller than of the Basic and Reduced variants
- The code was tested only in an example application
- Concise documentation is available (in English only)



For further information, please refer to: [www.endat.de](http://www.endat.de) ► EnDat 2.1 and 2.2

## 3.2 Example programs

### EnDat 2.2 Master

For the EnDat 2.2 Master Basic and EnDat 2.2 Master Safe from HEIDENHAIN, example programs for driving the master are included in delivery.

### EnDat 2.2 Master based on a $\mu$ C

For integration into a  $\mu$ C, HEIDENHAIN offers an example code for the implementation of the EnDat 2.1 mode commands.

Examples for the implementation of the EnDat 2.2 communication are additionally available, as well as an example for demonstration of fundamental processes of functional safety.

### EIB 700

The EIB 700 series are external signal converters for precise position measurement, especially for inspection stations and multipoint inspection apparatuses, as well as for mobile data acquisition, such as during machine calibration. For the sake of processing measured values on a PC, the items supplied include driver software for Windows, Linux and LabVIEW, as well as example programs and the EIB application software. The driver software enables customers to easily program their own applications. For the EIB 700, an example program is available that demonstrates how various EnDat 2.2 features can be implemented from the perspective of the subsequent electronics.

### EnDat 2.2 Application Note

The EnDat 2.2 Application Note contains implementation examples that show how communication with the encoder is established and how certain features are implemented.

### 3.3 PWM 21 and EnDat 2.2 Demotool software

The communication between the encoder and the subsequent electronics via the EnDat 2.2 interface is based on mode commands sent to the encoder by the subsequent electronics. The mode commands determine the specific data content to be transmitted, such as the position value, parameters, diagnostics, etc.

The EnDat 2.2 Demotool software can run on the PWM 21 and enables easy communication with the encoder based on the mode commands:

- Display of the values returned by the encoder (position data and additional data)
- Entry of the parameters to be transmitted to the encoder for each mode command
- Display of communication error conditions
- Adjustment of the transmission frequency
- The communication is recorded on a log page for later analysis
- EnDat 2.1 and EnDat 2.2 mode commands are supported

These features support the design process in the following manner:

- In the first step, communication can be tested with mode commands outside of the control loop
- Provides a reference when integrating the EnDat 2.2 Master into the control loop
- Servicing of encoders by means of the ATS software and the PWM 21



For further information, please visit: [www.heidenhain.com](http://www.heidenhain.com)

Downloads ► Software ► Category PC Software



Figure 1: PWM 21 with the EnDat 2.2 Demotool software

### 3.4 The PWM 21 and ATS software

HEIDENHAIN encoders provide all of the information needed for commissioning, monitoring, and diagnostics.

For analysis of its encoders, HEIDENHAIN offers the PWM inspection devices and the PWT testing devices. The PWM inspection devices are universally deployable, feature low measuring tolerances, and can be calibrated. In conjunction with the ATS software, the PWM 21 enables an analysis of an EnDat 2.2 encoder in the event of servicing.



Figure 2: The PWM 21 and ATS software



For further information, please visit: [www.heidenhain.com](http://www.heidenhain.com)

Downloads ► Software ► Category Inspection and Testing Equipment

### 3.5 EnDat 2.2 error injector

For manipulating the EnDat 2.2 communication during continuous operation (error injector), HEIDENHAIN offers a solution based on the PWM 21.



If you require more information on the error injector, please consult with your HEIDENHAIN contact person.

## 4 Overview of encoder characteristics

The extensive HEIDENHAIN product portfolio of linear encoders, angle encoders, and rotary encoders covers applications in the fields of machine tools, the electronics industry, and automation technology.

The requirements arising within these applications and industries are reflected by the different characteristics of the various encoder types. These characteristics are modelled by the EnDat 2.2 interface and are reflected in the memory contents or functions of the encoder.



For further information, please refer to: [www.endat.de](http://www.endat.de) ► EnDat 2.1 and 2.2

## 5 References

### References

<b>Title</b>	<b>Document no.</b>
EnDat 2.2 Interface Specification	297403-xx
EnDat 2.2 Application Notes	722024-xx
EnDat 2.2 Application Conditions for Functional Safety	533095-xx
Safety with EnDat 2.2 and Non-Safe EnDat Master	1128897-xx

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