



Technical Information

Safety-Related Position Measuring Systems

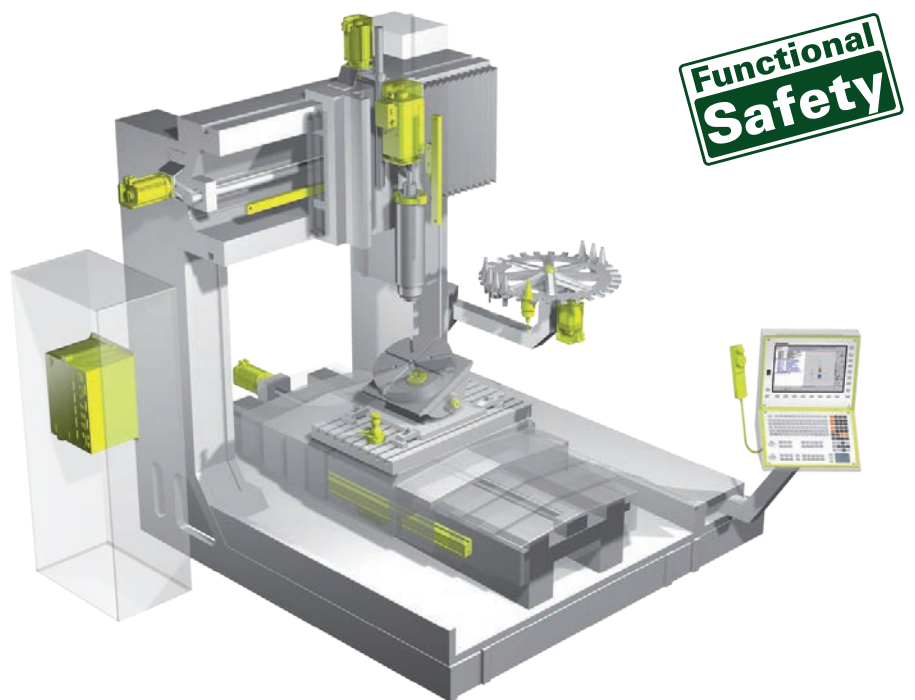
with purely serial EnDat 2.2 interface for safety-related applications with up to control category SIL 3 (according to EN 61508) or performance level PL e (according to EN ISO 13849)

HEIDENHAIN offers encoders that can be used in safety-related applications. These encoders operate as single-encoder systems with purely serial data transmission via EnDat 2.2. Reliable transmission of the position is based on two independently generated absolute position values and on error bits, which are then provided to the safe control.

In addition to rotary encoders with different mounting options, absolute sealed linear encoders are also available. Absolute angle encoders round out HEIDENHAIN's product program for functional safety.

Safety is becoming increasingly important in machine and plant construction. Proof of this can be seen in new legislation and in the heightened safety regulations of national and international standards. These high requirements mainly serve to protect human beings, but material assets and the environment are also receiving more consideration.

The aim of functional safety is to minimize or remove hazards that may arise during both undisturbed and disturbed operation of machine tools and systems. This is achieved primarily with redundant systems. For example, axes that are moved in safety-related applications require redundant position information in order to perform the corresponding safety functions. Various system configurations can be realized in order to acquire independent position values. One possibility is the use of two encoders per axis. In many cases, however, a more economical solution requiring only one position encoder is preferred. Until now, analog encoders with sine and cosine signals were used for this. HEIDENHAIN offers a purely serial, single-encoder solution for safety-related position measuring systems in safety-oriented applications in accordance with EN 61508 and EN 13849. This means that safety applications can now take advantage of all the benefits of serial data transfer, such as optimization of costs, diagnostic possibilities, automatic commissioning, and rapid formation of the position value.



HEIDENHAIN measuring systems for safety-related applications are tested for compliance with EN ISO 13849-1 (successor to EN 954-1) as well as EN 61508 and EN 61800-5-2. In these standards, the assessment of safety-related systems is based on, among other things, the failure probabilities of integrated components and subsystems. This modular approach helps manufacturers of safety-oriented

systems to implement their complete systems, because they can begin with subsystems that have already been qualified. Safety-related position measuring systems with purely serial data transmission via EnDat 2.2 accommodate this technique. In a safe drive, the safety-related position measuring system is such a subsystem.

Safety-related position measuring systems

A **safety-related position measuring system** consists of:

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

In practice, the **complete “safe servo drive” system** consists of:

- Safety-related position measuring system
- A safety-related control (including the EnDat master with monitoring functions)
- Power stage with motor power cable and drive
- Physical connection between encoder and drive (e.g. rotor/stator connection)

Area of application

Safety-related position measuring systems from HEIDENHAIN are designed to be usable as single-encoder systems in applications with control category SIL 2 (as per EN 61508), PL d, Category 3 (as per EN ISO 13849).

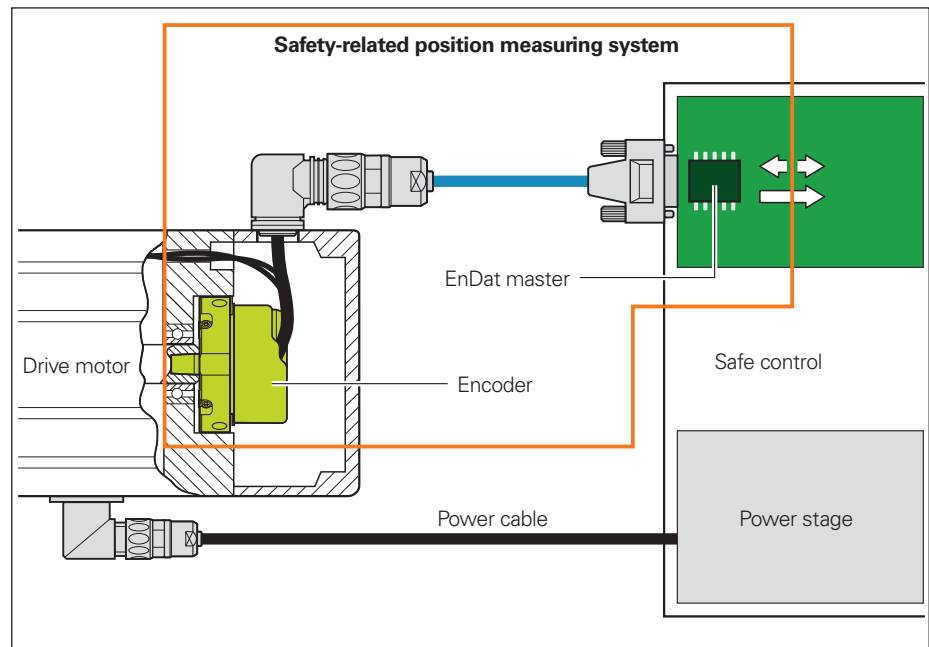
Additional measures in the control make it possible to use certain encoders for applications with up to SIL 3, PL e, Category 4. The suitability of these encoders is indicated appropriately in the documentation (brochures / Product Information documents).

The functions of the safety-related position measuring system can be used for numerous safety tasks of the complete system (see also EN 61800-5-2).

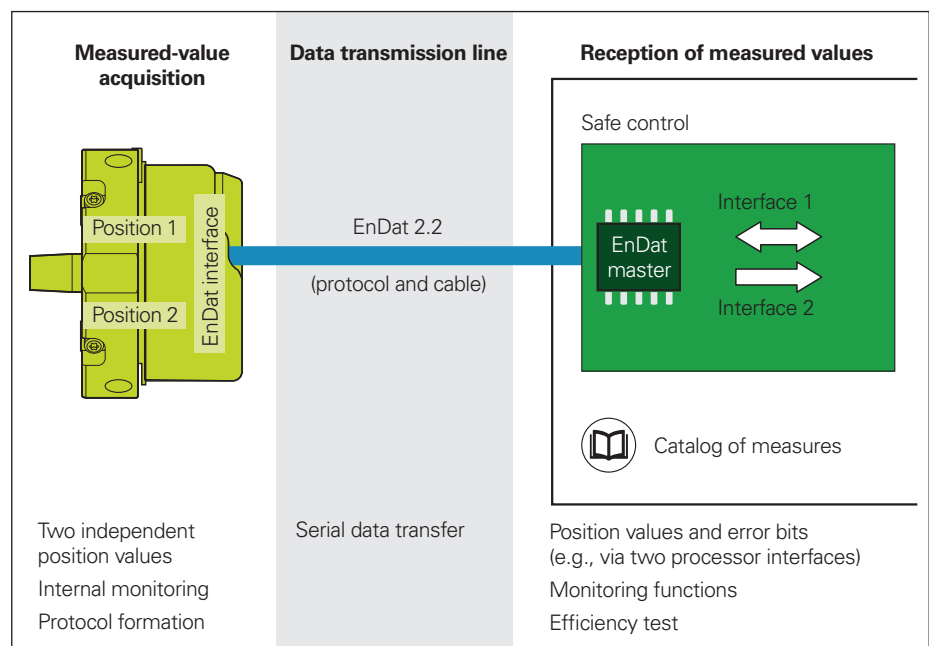
Function

The safety strategy of the position measuring system is based on two mutually independent position values and additional error bits produced in the encoder and transmitted over the EnDat 2.2 protocol to the EnDat master. The EnDat master assumes various monitoring functions with which errors in the encoder and during transmission can be revealed. A comparison is made, for example, between the two position values. The EnDat master then makes the data available to the safe control.

The control monitors the functionality of the safety-related position measuring system through periodically triggered tests. The architecture of the EnDat 2.2 protocol makes it possible to process all safety-relevant information and control mechanisms during unconstrained controller operation. This is possible because the safety-relevant information is saved in the additional information. According to EN 61508, the architecture of the position measuring system is regarded as a single-channel tested system.



Complete safe drive system



Safety-related position measuring system

In addition to the safety-related position measuring systems with EnDat 2.2 interface, HEIDENHAIN also offers safety-related encoder solutions for applications with DRIVE-CLiQ¹⁾ interface. For details, please refer to the respective product documentation. Upon request, HEIDENHAIN can provide additional data about the individual products (failure rate, fault model as per EN 61800-5-2, D16) for the use of standard encoders (e.g., with 1 V_{PP} output signals) in safety-related applications.

¹⁾ DRIVE-CLiQ is a registered trademark of Siemens Aktiengesellschaft

Documentation regarding integration of the position measuring system

The proper use of a position measuring system places demands on the control, the machine designer, the installation technician, servicing personnel, etc. The needed information is provided in the documentation for the position measuring systems.

In order to be able to implement a position measuring system in a safety-related application, a suitable control is required. The control assumes the fundamental task of communicating with the encoder and safely evaluating the encoder data.

The requirements for integrating the EnDat master with monitoring functions into the safe control are described in HEIDENHAIN document 533095. It contains, for example, specifications on the evaluation and

processing of position values and error bits, and on electrical connection and cyclic tests of position measuring systems.

Supplementing this, document 1000344 describes measures that enable the use of suitable encoders in applications with up to SIL 3, PL e, Category 4.

Machine and equipment manufacturers need not attend to these details themselves. This functionality must be provided by the control. Product Information documents, brochures, and mounting instructions provide information to aid in the selection of a suitable encoder. **Product Information documents** and **brochures** contain general information on the function and application of encoders, as well as specifications and permissible ambient conditions. The **mounting instructions** provide detailed information about installing the encoders.

The architecture of the safety system and the diagnostic possibilities of the control may call for further requirements. For example, the operating instructions of the control must explicitly state whether fault exclusion is required for the loosening of the mechanical connection between the encoder and the drive. Any resulting requirements must be relayed by the machine designer to the installation technician and the servicing staff, for example (also see the information under "Safety-related characteristic values").

Safety-related characteristic values

Additional parameters, as described below, become relevant for the use of position measuring systems in safety-oriented applications. These parameters are to be complied with when designing the safety system of a machine.

The **Probability of Dangerous Failure per Hour value** (PFH) indicates the probability of a hazardous encoder failure per hour. The failure rate of the encoder is included in the calculation of the PFH value for the complete system.

The **error reaction time** in the application depends mainly on the cycle times of the safety module in the control and the connected actuators (brake, contactors, etc.). In addition, application-specific settings (e.g. EnDat clock frequency) can influence this value. For this reason, the error reaction time indicated in the control documentation should be referred to.

The **safe position** describes the maximum possible position offset of the encoder until safe fault detection is ensured. The characteristic value refers to the position value 1 in fault-free operation and is given in the encoder's unit of measure. It significantly

influences the minimum distance required to provide protection from pinching (e.g. of fingers). The safe position is divided into the values for the encoder and for the mechanical coupling.

The value for the **encoder** describes the maximum position offset including the influence of the position value comparison in the control (algorithm according to document 536402). Besides quantization errors, it also includes any position deviations occurring in the encoder. Depending on the control and the application, the characteristic value **safety-relevant measuring step** (SM) may also be relevant for the parameterization of the safety function. The control documentation includes a corresponding note in such cases.

The characteristic value **mechanical coupling** provides information in case of the "loosening of the mechanical connection" fault. Table D16 of the EN 61800-5-2 standard for electrical drives defines the loss or loosening of the mechanical connection between the encoder and motor as a fault that requires consideration. Since it cannot be guaranteed that the control will detect such errors, fault exclusion is

required for this in many cases. If fault exclusion is required in the control's operating instructions, the information for the safe mechanical connection is to be taken into account. Otherwise it can be ignored.

For a friction-type connection with fault exclusion there is no additional mechanical offset that would need to be considered for the safe position.

If the fault exclusion is fulfilled only by a mechanical stop with backlash, this maximum possible offset is to be calculated into the safe position. This is done by adding the values for the encoder and for the mechanical coupling.

Important! Fault exclusion can be connected with constraints on the permissible specifications. This is to be considered for the selection of a suitable encoder or type of mounting. In addition, fault exclusions for the loss or loosening of the mechanical coupling usually require additional measures when mounting the encoders or in the event of servicing (e.g. anti-rotation lock for screws) that are not necessary in standard applications. The design engineer of a machine must strictly adhere to these additional measures.

Encoders for safety-related applications



The comprehensive product program from HEIDENHAIN offers solutions for applications in which the highest possible accuracy, reliable reproducibility and repeatability, safe process management, high machine dynamics, simple operation, and maximum efficiency are required.

These products are therefore used mainly in the following areas:

- Machine tools
- Electronics production
- Automation facilities
- Elevators
- Medical technology

The product program from HEIDENHAIN also contains numerous encoders for safety-related applications.

Rotary encoders for servo drives, machines, and larger systems

HEIDENHAIN offers suitable rotary encoders for a wide variety of applications. The rotary encoders for safety-related applications are available in different versions with absolute position acquisition.

Angle encoders for rotary axes

Angle encoders are characterized by high accuracy values in the arc second range and better. The angle encoders for safety-related applications are available with and without integral bearing, and as sealed encoders for mounting or as modular encoders for integration.

Linear encoders for linear axes

HEIDENHAIN offers exposed and sealed linear encoders for safety-related applications. These linear encoders are available in various sizes, lengths, and accuracy grades.

Rotary encoders



ExI 1300 Series



ECN 1100/
EQN 1100 series



ExN 1100/
ExN 1300 series



ExI 1100 series



ECN 400/
EQN 400 series



ECI/EBI 4000 series

Angle encoders



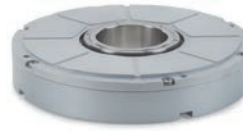
RCN 2000 series



ECA 4000 series



RCN 5000 series



RCN 8000 series



RCN 6000 series

Linear encoders

LC 400 series



LC 100 series



LIC 4000 series



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Further information:

Adhere to the information in the following documents to ensure the correct and intended operation of an encoder:

- Product Information / brochure and mounting instructions of safety-related position measuring systems

For implementation in a control:

- Specification for Safe Control 533095
- Supplementary Specification for SIL 3, PL e, Cat. 4 1000344
- EnDat Interface Description 297403
- Electrical Connection Directive 231929
- Requirements for Position Value Comparison 536402