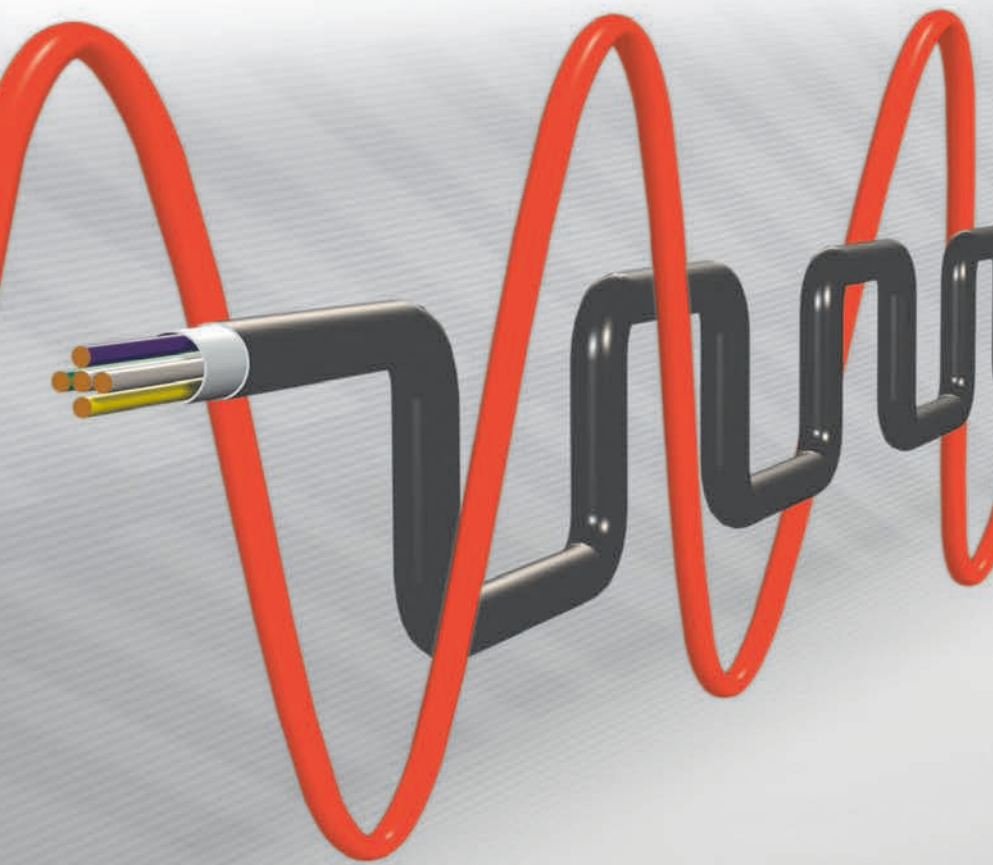




HEIDENHAIN



Interfaces
of HEIDENHAIN Encoders

Interfaces

As the defined junctions between encoders and subsequent electronics, interfaces ensure the reliable exchange of information.

HEIDENHAIN offers encoders with interfaces for many common subsequent electronics. The interface possible in each individual case depends on, among other things, the measuring method used by the encoder.

Measurement methods

With the **incremental measuring method**, the position information is obtained **by counting** the individual increments (measuring steps) starting from some point of origin. Since an absolute reference point is necessary for determining the positions, a reference-mark signal is output as well. As a general rule, encoders that operate with the incremental measuring method provide **incremental signals**. Some incremental encoders with integrated interface electronics have a counting function: once the reference mark is traversed, an absolute position value is generated and transmitted via a serial interface.

Note:

Specialized encoders can have other interface characteristics (e.g., with regard to shielding).

With the **absolute measuring method** the absolute position information is acquired directly **from the grating of the measuring standard**. The position value is available from the encoder immediately upon switch-on and can be requested at any time by the subsequent electronics.

Encoders that use the absolute measuring method output **position values**. Some interfaces provide incremental signals as well.

Since absolute encoders do not require a reference run, they are particularly advantageous in concatenated manufacturing systems, transfer lines, and multi-axis machines. They are also highly immune to EMC interference.

Interface electronics

Interface electronics from HEIDENHAIN adapt the encoder signals to the interface of the subsequent electronics. They are used when the subsequent electronics cannot directly process the output signals from HEIDENHAIN encoders or when additional interpolation of the signals is necessary.



Further information:

- *Interface Electronics* product overview
- *Cables and Connectors* brochure

This brochure supersedes all previous editions, which thereby become invalid. The basis for ordering from HEIDENHAIN is always the brochure edition valid when the order is made.

Standards (ISO, EN, etc.) apply only where explicitly stated in the brochure.

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EnDat 2.2 **The bidirectional interface**

The EnDat interface is a digital, **bidirectional** interface for encoders. It is capable of outputting **position values**, reading and updating information stored in the encoder, and storing new information in the encoder. Thanks to the interface's **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 via mode commands sent to the encoder by the subsequent electronics. Some functions are available only in conjunction with EnDat 2.2 mode commands.

History and compatibility

The EnDat 2.1 interface, which has been available since the mid-1990s, has since been upgraded to EnDat 2.2 (recommended for new applications). In terms of its communication, command sets, and time conditions, EnDat 2.2 is compatible with EnDat 2.1 but also offers significant advantages. For example, EnDat 2.2 permits the transfer of additional data (sensor values, diagnostics, etc.) along with the position value without initiating a separate request. This allows the interface to support additional types of encoders (e.g., encoders with buffer battery backup, incremental encoders). The interface protocol has also been expanded, and the time conditions (clock frequency, calculation time, recovery time) have been optimized.

Supported encoder types

The following encoder types are currently supported with the EnDat 2.2 interface (readable from the memory area of the encoder):

- Incremental linear encoders
- Absolute linear encoders
- Incremental, singleturn rotational encoders
- Absolute, singleturn rotational encoders
- Multiturn rotary encoders
- Multiturn rotary encoders with buffer battery backup

For the various encoder types, some parameters must be interpreted differently (see the EnDat specifications), or EnDat additional data must be processed (e.g., incremental encoders or encoders with buffer battery backup).

Interface	EnDat serial bidirectional
Data transmitted	Position values, parameters, and additional data
Data input	Differential line receiver in compliance with EIA standard RS-485 for the signals $\overline{\text{CLOCK}}$, $\overline{\text{CLOCK}}$, $\overline{\text{DATA}}$, and $\overline{\text{DATA}}$
Data output	Differential line driver in compliance with EIA standard RS-485 for $\overline{\text{DATA}}$ and $\overline{\text{DATA}}$ signals
Position values	Ascending during movement in the direction of the arrow (see mating dimensions of the encoders)
Incremental signals	Depends on the encoder $\sim 1 V_{PP}$ TTL, HTL (see respective <i>Incremental signals</i>)

Ordering designations

The ordering designations define the core specifications and provide the following information:

- Typical power supply range
- Command set
- Availability of incremental signals
- Maximum clock frequency

The second position in the ordering designation identifies the interface generation. With encoders of the current generation, the ordering designation can be read from the encoder memory.

Incremental signals

Some encoders also provide incremental signals. These signals are primarily used for increasing the resolution of the position value or for servicing a second subsequent electronics unit. Current generations of encoders have a high internal resolution and therefore no longer need to provide incremental signals. The ordering designation indicates whether an encoder outputs incremental signals:

- EnDat01 With $1 V_{PP}$ incremental signals
- EnDatH With HTL incremental signals
- EnDatT With TTL incremental signals
- EnDat21 Without incremental signals
- EnDat02 With $1 V_{PP}$ incremental signals
- EnDat22 Without incremental signals

Note on EnDat01/02:

The signal period is stored in the encoder memory

Notes on EnDatH/EnDatT:

The interpolation factor with which the internal incremental signals are output is indicated by a single letter added to the ordering designation:

- *a* 2-fold interpolation
- *b* Without interpolation
- *c* 0.5-fold interpolation (incremental signals/2)

Supply voltage

The typical supply voltage of the encoders depends on the interface:

EnDat01 EnDat21	5 V \pm 0.25 V
EnDat02 EnDat22	3.6 V to 5.25 V or 14 V
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 information exchange 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 enables memory accesses even in a closed control loop. When a mode command from the EnDat 2.2 command set is sent to an encoder that supports only the EnDat 2.1 command set, an error message is triggered. The specific command set supported is identified 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

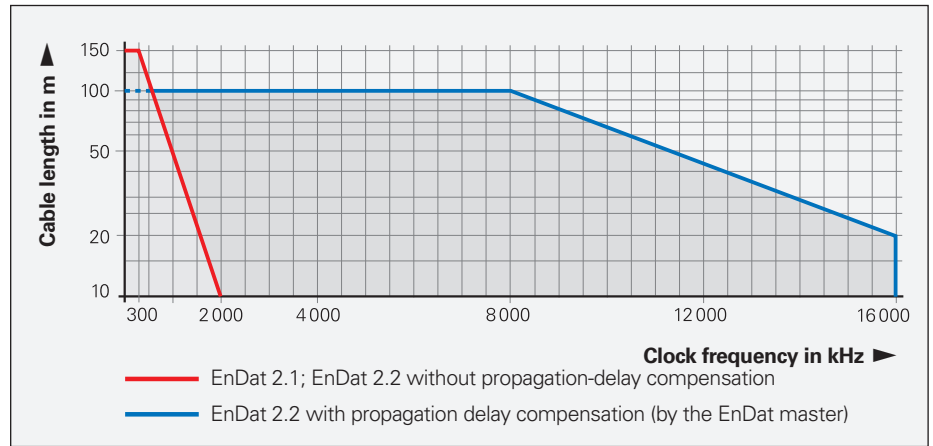
The clock frequency is variable between 100 kHz and 2 MHz depending on the cable length (max. 150 m). With propagation-delay compensation in the subsequent electronics, clock frequencies of up to 16 MHz or cable lengths of up to 100 m are possible. For EnDat encoders with the ordering designation EnDatx2, 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 intended only for the ordering designations EnDat21 and EnDat22; for EnDat02, see the note below.

EnDat01 EnDatT EnDatH	≤ 2 MHz (see “without propagation-delay compensation” in diagram)
EnDat21	≤ 2 MHz
EnDat02	≤ 2 MHz or ≤ 8 MHz or 16 MHz (see note)
EnDat22	≤ 8 MHz or 16 MHz

In conjunction with large cable lengths, transmission frequencies of up to 16 MHz place high technological demands on the cable. For reasons concerning the transmission 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.

Note on EnDat02

EnDat02 encoders may have a pluggable cable assembly. In choosing the version of the adapter cable, the customer decides whether the encoder will be operated with or without incremental signals. This also influences the maximum possible clock frequency. For adapter cables with incremental signals, the clock frequency is limited to 2 MHz; see also EnDat01. For adapter cables without incremental signals, the clock frequency can be up to 16 MHz. The exact values are stored in the encoder memory.



Under certain conditions, cable lengths of up to 300 m are possible after consultation with HEIDENHAIN

Position values

The position value can be transmitted with or without additional data. At the earliest, the position value is transmitted to the subsequent electronics after the calculation time t_{cal} has elapsed. The calculation time is determined for the encoder's highest permitted clock frequency, but for no more than 8 MHz.

For the position value, only the required number of bits is transferred. The number of bits thus depends on the respective encoder and can be read from the encoder for automatic parameterization.

Typical operating modes

Operating mode EnDat 2.1: This mode is for encoders that provide additional incremental signals. For generation of the position value, the absolute position is read once simultaneously with the incremental position, and both are used in the calculation of the position value. The subsequent generation of the position value in the control loop is based on the incremental signals. Only EnDat 2.1 mode commands are used.

Operating mode EnDat 2.2: This mode is for purely serial encoders. For position value generation, the position value is read from the encoder during each control cycle. EnDat 2.2 mode commands are typically used to read the position value. EnDat 2.1 mode commands are typically used to read and write parameters after switch-on. In the closed control loop, the EnDat 2.2 interface allows additional data to be requested along with the position, and it permits the execution of functions (e.g., read/write parameters, reset error messages).

Additional data

Depending on the type of transmission (selection via MRS code), one or two items of additional data can be appended to the position value. The types of additional data supported by the respective encoder are saved in the encoder's parameters. Additional data encompasses the following:

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

Memory areas

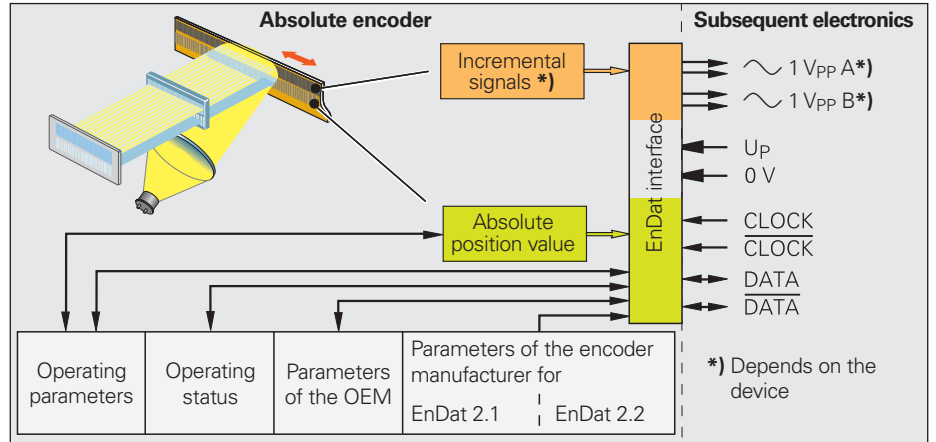
The encoder provides multiple memory areas for parameters. These memory areas can be read by the subsequent electronics, and some areas can be written to by the encoder manufacturer, the OEM, or the end user. The parameter data are stored in permanent memory. This memory allows only a limited number of write accesses and is not designed for the cyclic storage of data. Certain storage areas can be write-protected (resettable only by the encoder manufacturer).

Parameters are stored in various memory areas, e.g.:

- Encoder-specific information
- Information from the OEM (e.g., electronic ID label of the motor)
- Operating parameters (datum shift, instruction, etc.)
- Operating status (alarms or warnings)

Monitoring and diagnostic functions of the EnDat interface enable a detailed inspection of the encoder. These include the following:

- Error messages
- Warnings
- Online diagnostics based on valuation numbers (EnDat 2.2)
- Mounting interface



Basics of functional safety

EnDat 2.2 can support the use of encoders in safety-related applications. To this end, the following standards are taken as a basis: DIN EN ISO 13849-1 (successor to EN 954-1), as well as EN 61508 and EN 61800-5-2. In these standards, safety-related systems are assessed based on criteria such as the failure probabilities of integrated components and subsystems. The modular approach helps manufacturers of safety-related systems in implementing their complete systems by allowing them to build upon already qualified subsystems.



Further information:

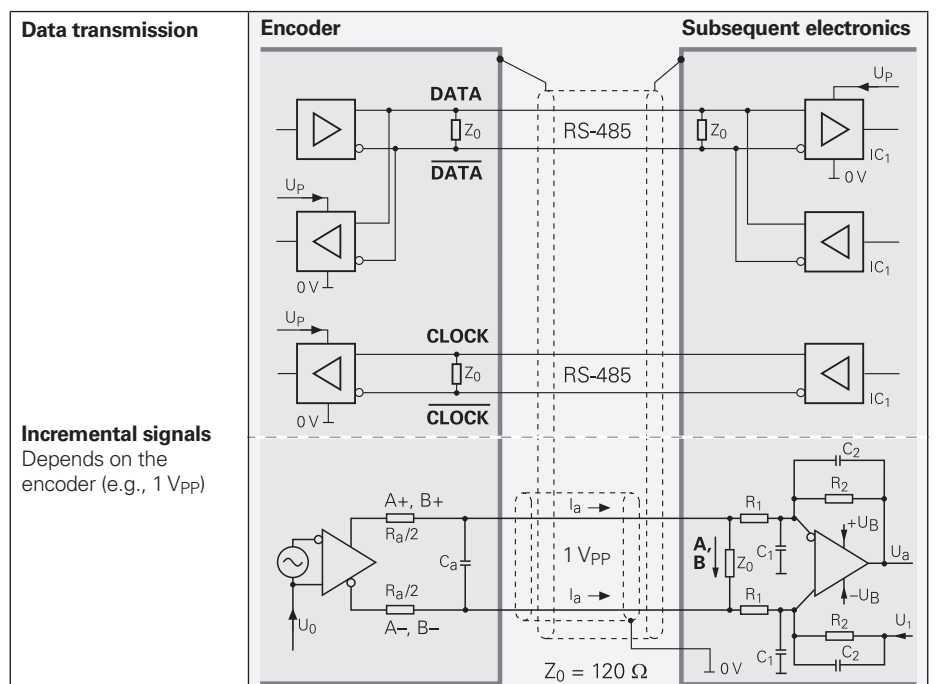
See "Functional Safety" at www.endat.de

Input circuit of the subsequent electronics

Dimensioning

IC₁ = RS-485 differential line receiver and driver

$$Z_0 = 120 \Omega$$



Further information:

FAQ: RS-485 Transceiver at www.endat.de

Proprietary serial interfaces

Control manufacturer ¹⁾	Interface	Designation in brochure	Ordering designation	Code letter ²⁾	Comment
Siemens	Siemens DRIVE CLiQ	DRIVE-CLiQ	DQ01	S	
Fanuc	Fanuc Serial Interface α	Fanuc α	Fanuc02	F	Normal and high speed, two-pair transmission
	Fanuc Serial Interface α i	Fanuc α i	Fanuc05		High-speed, one-pair transmission, includes the α interface (normal and high speed, two-pair transmission)
			Fanuc06		High-speed, one-pair transmission
Mitsubishi	Mitsubishi high speed interface	Mitsubishi	Mitsu01 Mit02-4 Mit02-2 Mit03-4 Mit03-2	M	Two-pair transmission Generation 1, two-pair transmission Generation 1, one-pair transmission Generation 2, two-pair transmission Generation 2, one-pair transmission
Yaskawa	Yaskawa Serial Interface	Yaskawa	YEC02	Y	–
			YEC07		Compatible with YEC02
Panasonic	Panasonic Serial Interface	Panasonic	Pana01	P	–
			Pana02		Compatible with Pana01

¹⁾ For more information on the combination of an encoder and control, please contact the control manufacturer

²⁾ The code letter is an add-on to the model designation of HEIDENHAIN encoders, such as "LC 495 S."

Position values

PROFIBUS DP serial interface



PROFIBUS DP

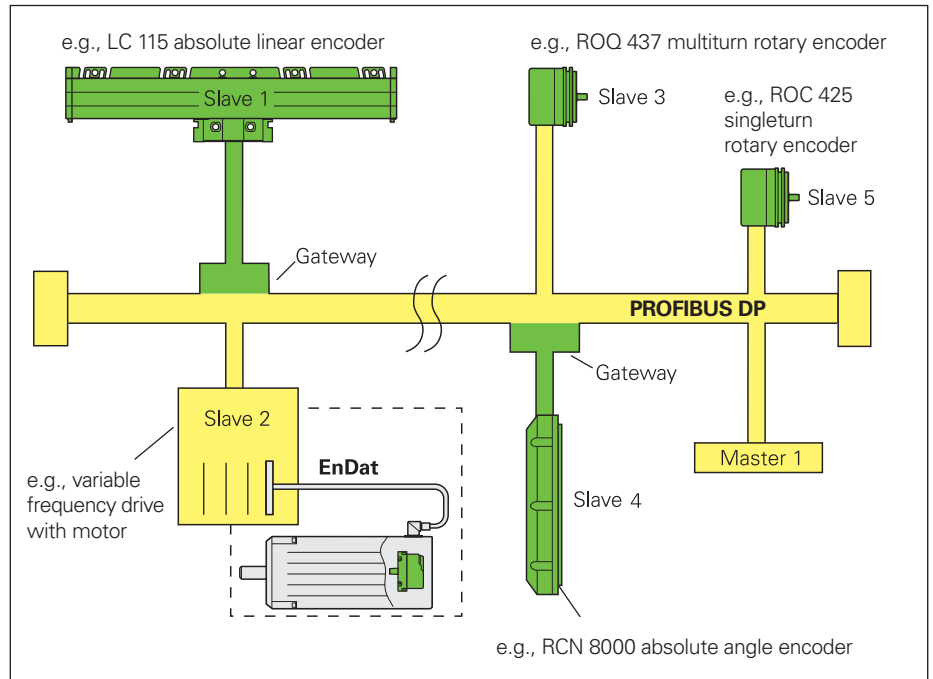
PROFIBUS is a non-proprietary, open fieldbus that complies with the international standard EN 50170. The connection of sensors through fieldbus systems minimizes cabling and reduces the number of lines between the encoder and the subsequent electronics.

Topology and bus assignment

The PROFIBUS DP has a linear topology. Transfer rates of up to 12 Mbit/s are possible. Both single-master and multi-master systems can be implemented. Each master can serve only its own slaves (polling). The slaves are polled cyclically by the master. Slaves can be sensors such as absolute rotary encoders and linear encoders, or they can also be control devices such as variable-frequency drives.

Physical-layer characteristics

The electrical characteristics of PROFIBUS DP comply with the RS-485 standard. The bus connection is a shielded, twisted-pair cable with active bus terminations at both ends.



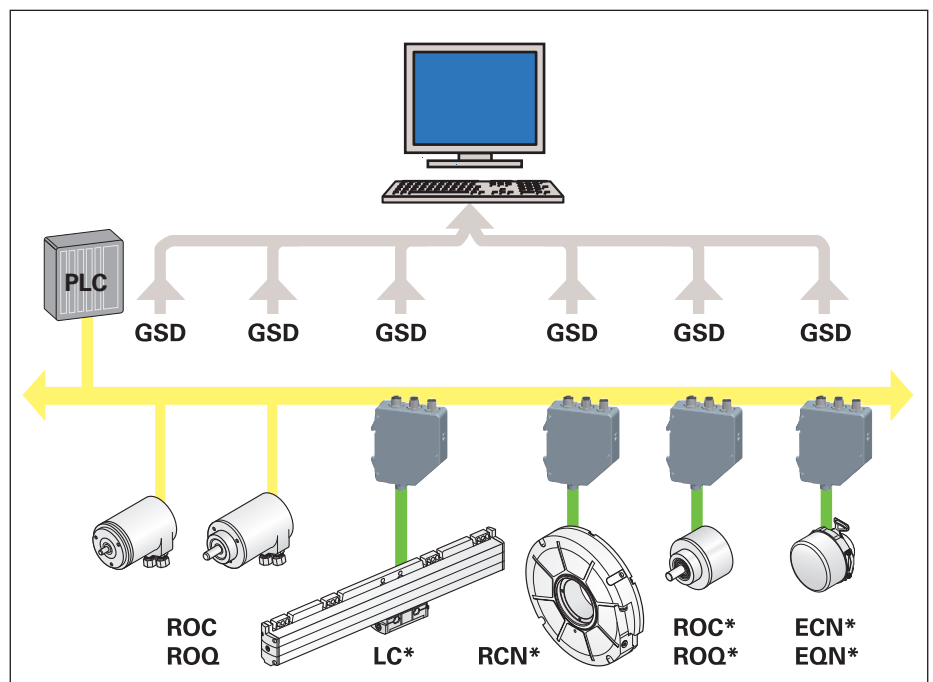
Bus topology of PROFIBUS DP

Commissioning

The data of the connectable HEIDENHAIN encoders required for system configuration are available for each encoder in the form of electronic device data sheets, commonly referred to as general station description files (GSD). These general station description files completely and unambiguously describe the characteristics of a device in a precisely defined format, thereby enabling the convenient and application-friendly integration of the devices into the bus system.

Configuration

PROFIBUS DP devices can be configured and parameterized in accordance with the requirements of the user. These settings are saved in the master once they have been selected in the configuration tool with the help of the GSD file. As a result, the PROFIBUS devices are configured upon every network start-up. This simplifies device replacement by eliminating the need for editing or re-entry of the configuration data.



* With EnDat interface

There are two GSD files to choose from:

- GSD file for the DP-V0 profile
- GSD file for the DP-V1 and DP-V2 profiles

PROFIBUS DP profile

The PNO (PROFIBUS user organization) has defined standardized, non-proprietary profiles for the connection of absolute encoders to the PROFIBUS DP fieldbus. High flexibility and simple configuration are thereby ensured for all equipment using these standardized profiles.

DP-V0 profile

This profile can be requested from the PNO in Karlsruhe, Germany (ordering number: 3.062). There are two classes defined in this profile: class 1 is equivalent to the minimum range of functions, and class 2 contains additional functions, some of which are optional.

DP-V1 and DP-V2 profile

This profile can be obtained from the PNO in Karlsruhe, Germany (ordering number: 3.162). This profile likewise distinguishes between two device classes:

- Class 3 with the basic functions and
- Class 4 with the full range of scaling and preset functions.

In addition to the mandatory functions of classes 3 and 4, optional functions are defined as well.

Supported functions

Of particular importance in decentralized fieldbus systems are **diagnostic functions** (e.g., warnings and alarms) and the **electronic ID label**, which contains information about the encoder model, resolution, and measuring range. Yet programming functions are possible as well, such as reversal of counting direction, **preset/datum shift**, and **changing the resolution (scaling)**. The **operating time** and the speed of the encoder can also be recorded.

Encoders with PROFIBUS DP

Absolute encoders with an **integrated PROFIBUS DP interface** are connected directly to the PROFIBUS fieldbus. The rear side of these encoders is equipped with LEDs for indicating the **operating status**, supply voltage, and bus status.

The coding switches for addressing (0 to 99) and for activating the terminating resistor are easily accessible under the bus cover. The terminating resistor must be activated if the rotary encoder is the final participant on the PROFIBUS DP fieldbus and if the external terminating resistor is not in use.

Functions of the DP-V0 classes

Characteristic <i>Data word width</i>	Class	Rotational encoders		Linear encoders
		≤ 16 bits	≤ 31 bits ¹⁾	≤ 31 bits ¹⁾
Pos. value in pure binary code	1,2	✓	✓	✓
Data word length	1,2	16	32	32
Scaling function Measuring steps/rev. Total resolution	2 2	✓ ✓	✓ ✓	– –
Reversal of counting direction	1,2	✓	✓	–
Preset (output data: 16 bits or 32 bits)	2	✓	✓	✓
Diagnostic functions Warnings and alarms	2	✓	✓	✓
Operating time recording	2	✓	✓	✓
Speed	2	✓ ²⁾	✓ ²⁾	–
Profile version	2	✓	✓	✓
Serial number	2	✓	✓	✓

¹⁾ With a data word width > 31 bits, only the upper 31 bits are transferred

²⁾ Requires a 32-bit configuration of the output data and a 32+16-bit configuration of the input data

Functions of the DP-V1 and DP-V2 classes

Characteristic <i>Data word width</i>	Class	Rotational encoders		Linear encoders
		≤ 32 bits	> 32 bits	
Telegram	3,4	81-84	84	81-84
Scaling function	4	✓	✓	–
Reversal of counting direction	4	✓	✓	–
Preset / datum shift	4	✓	✓	✓
Acyclic parameters	3,4	✓	✓	✓
Channel-dependent diagnosis via alarm channel	3,4	✓	✓	✓
Operating time recording	3,4	✓ ¹⁾	✓ ¹⁾	✓ ¹⁾
Speed	3,4	✓ ¹⁾	✓ ¹⁾	–
Profile version	3,4	✓	✓	✓
Serial number	3,4	✓	✓	✓

¹⁾ Not supported by DP-V2

Position values

PROFINET IO serial interface



PROFINET IO

PROFINET IO is the open Industrial Ethernet standard for industrial communication. It builds on the field-proven functional model of PROFIBUS DP but employs fast Ethernet technology as its physical transmission medium, thereby tailoring it to the fast transmission of I/O data. At the same time, this standard provides the option of transmitting demand data, parameters, and IT functions.

PROFINET enables the connection of decentralized field devices to a controller. It also describes parameterization, diagnostics, and the exchange of data between the controller and field devices. The PROFINET design is modular. Cascading functions can be selected by the user himself. In order for the high speed requirements to be met, these functions primarily differ in terms of their data exchange type.

Topology and bus assignment

A PROFINET IO system is made up of the following elements:

- **IO controller** (control/PLC; controls the automation task)
- **IO device** (decentralized field device such as a rotary encoder)
- **IO supervisor** (development or diagnostic tool such as a PC or programming device)

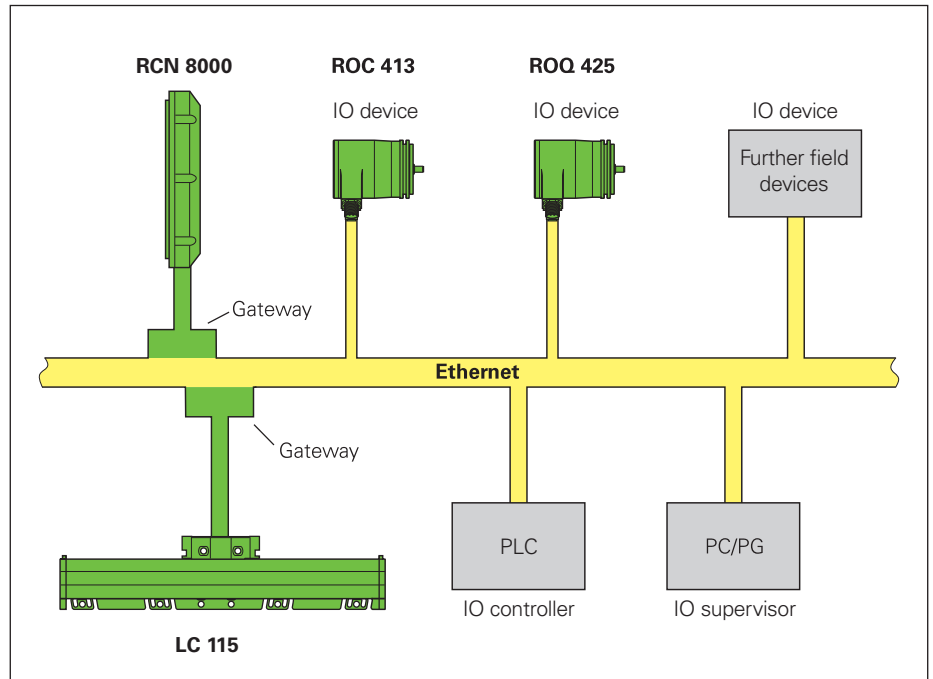
PROFINET IO follows the provider-consumer model, which supports communication between Ethernet peers. This has the advantage that the provider transmits its data without any prompting by the communication partner.

Physical-layer characteristics

HEIDENHAIN encoders are connected to PROFINET in accordance with 100BASE-TX (IEEE 802.3, Clause 25) over one shielded, twisted wire pair in each direction. The data transfer rate is 100 Mbit/s (Fast Ethernet).

PROFINET profile

HEIDENHAIN encoders generally satisfy the definition as per Profile 3.162, Version 4.1. This device profile describes the functionality of the rotary encoder. Class 4 functions are supported (full scaling and preset functionality). More information about PROFINET can be obtained from the PROFIBUS user organization (PNO).



Supported functions (Profile 3.162, V4.1)	Class	Rotary encoders	
		Singletum	Multitum
Position value	3,4	✓	✓
Isochronous mode	3,4	✓	✓
Functions of class 4	4	✓	✓
Scaling function	4	✓	✓
Measuring units per revolution	4	✓	✓
Total measuring range	4	✓	✓
Cyclic operation (binary scaling)	4	✓	✓
Acyclic operation	4	✓	✓
Preset	4	✓	✓
Code sequence	4	✓	✓
Preset control G1_XIST1	4	✓	✓
Compatibility mode (encoder profile V.3.1)	3,4	✓	✓
Operating time	3,4	✓	✓
Speed	3,4	✓	✓
Profile version	3,4	✓	✓
Continuous storage of the offset value	4	✓	✓
Identification & maintenance (I & M)		✓	✓
External firmware upgrade		✓	✓

Commissioning

In order for an encoder with PROFINET interface to be put into operation, a general station description (GSD) must be downloaded and imported to the configuration software. The GSD file contains the execution parameters required for a PROFINET IO device.

Configuration

Profiles are predefined configurations of the functions and performance characteristics available from PROFINET for use in certain devices or applications, such as in rotary encoders. They are defined and published by the workgroups of PROFIBUS & PROFINET International (PI).

Profiles are important for openness, interoperability, and exchangeability, assuring the end user that similar devices from different manufacturers operate in a standardized manner.

Encoders with PROFINET

Absolute encoders with an integrated PROFINET interface are incorporated directly into the network. Addresses are assigned automatically via a protocol integrated into the PROFINET network. Within a network, a PROFINET IO field device is addressed via its physical device MAC address.

The rear side of the encoders features two double-color LEDs for bus and device diagnostics.

A terminating resistor for the final participant is not needed.

Position values

SSI serial interface

Starting with the most significant bit (MSB), the **absolute position value** is transmitted over the data lines (DATA) in synchronism with a clock signal (CLOCK) provided by the control. The SSI standard data word length for singleturn encoders is 13 bits, and for multiturn encoders 25 bits. In addition to the absolute position values, **incremental signals** can be transmitted as well. For a signal description, see *Incremental signals*.

The following **functions** can be activated via the programming inputs of the interface through application of the supply voltage U_P :

- **Direction of rotation**

The continuous application of a HIGH level on PIN 2 ($t_{\min} > 1$ ms) reverses the direction of rotation for ascending position values.

- **Zeroing** (setting to zero)

Application of a positive edge ($t_{\min} > 12$ ms) to pin 5 sets the current position value to zero.

Warning: The programming inputs must always be terminated with a resistor (see *Input circuit of the subsequent electronics*).

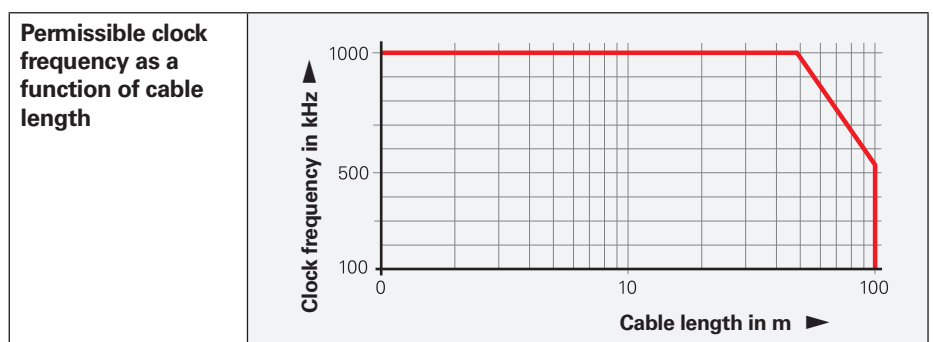
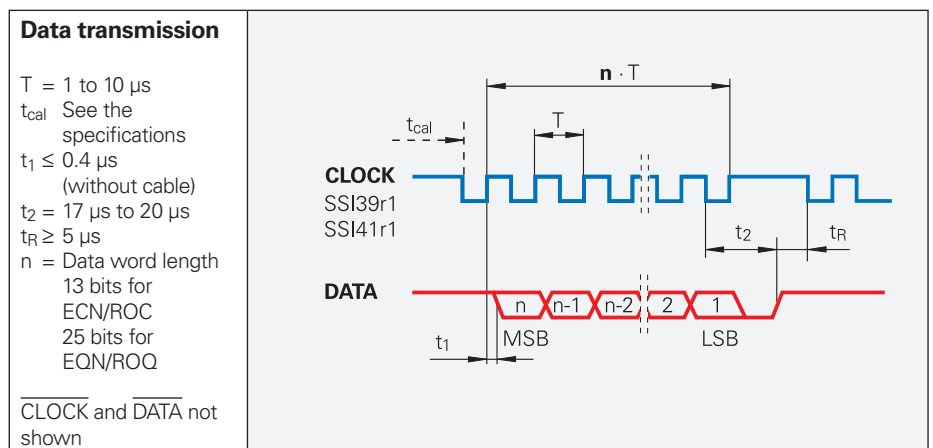
Interface	SSI serial
Ordering designation	<i>Singleturn:</i> SSI 39r1 <i>Multiturn:</i> SSI 41r1
Data transmitted	Absolute position values
Data input	Differential line receiver in compliance with EIA standard RS-485 for CLOCK and $\overline{\text{CLOCK}}$ signals
Data output	Differential line driver in compliance with EIA standard RS-485 for DATA and $\overline{\text{DATA}}$ signals
Code	Gray code
Ascending position values	With clockwise rotation as viewed from the flange side (switchable via interface)
Incremental signals	Depends on the encoder $\sim 1 V_{PP}$ TTL, HTL (see respective <i>Incremental signals</i>)
Programming inputs	Direction of rotation and zeroing; for availability, see encoder documentation
Inactive	LOW $< 0.25 \cdot U_P$
Active	HIGH $> 0.6 \cdot U_P$
Connecting cable	HEIDENHAIN shielded cables; e.g., PUR [(4 x 0.14 mm ²) + 4(2 x 0.14 mm ²) + (4 x 0.5 mm ²)]
Cable length	Max. 100 m
Propagation time	6 ns/m

Control cycle for a complete data format

When not transmitting, the clock and data lines are held at HIGH level. The internally and cyclically generated position value is stored on the first falling clock edge. The data are transmitted on the first rising clock edge.

After transmission of a complete data word, the data output line remains at LOW level until the encoder is ready for a new measured-value request (t_2). Encoders with the SSI 39r1 or SSI 41r1 interfaces additionally require a subsequent clock pause (t_R). If another data-output request (CLOCK) is received within this time (t_2 or t_2+t_R), then the same data will be output again.

If the data output is interrupted (CLOCK = HIGH for $t \geq t_2$), then a new position value will be stored on the next falling clock edge. The data are read in by the subsequent electronics on the next rising clock edge.



Incremental signals

Some encoders also provide incremental signals. These signals are primarily used to increase the resolution of the position value or to service a second subsequent electronics unit. The signals are almost always $1 V_{PP}$ incremental signals. Exceptions are identifiable based on the ordering designation:

- SSI41H With HTL incremental signals
- SSI41T With TTL incremental signals

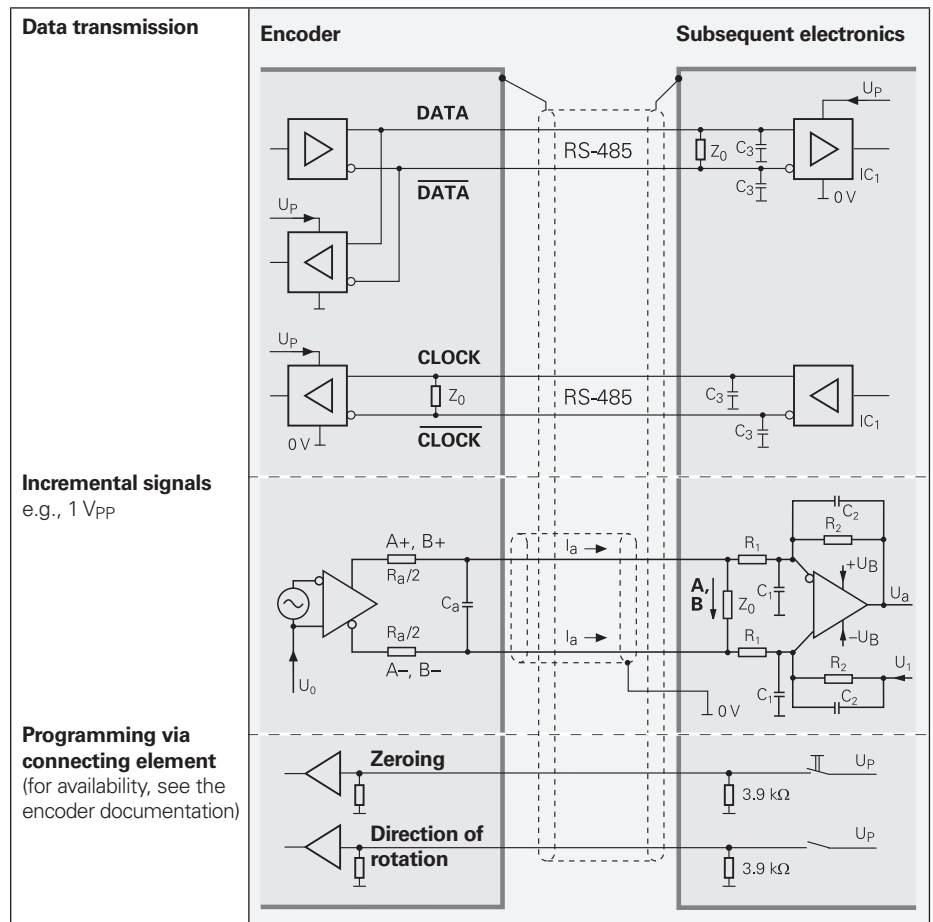
Input circuit of the subsequent electronics

Dimensioning

IC₁ = Differential line receiver and driver
 e.g., SN 65 LBC 176
 LT 485

Z₀ = 120 Ω

C₃ = 330 pF (for improved noise immunity)



Incremental signals

~ 1 V_{PP} sinusoidal signals

HEIDENHAIN encoders with the ~ 1 V_{PP} interface provide voltage signals that are highly interpolatable.

The sinusoidal **incremental signals** A and B are phase-shifted by 90° elec. and have a typical amplitude of 1 V_{PP}. The illustrated sequence of output signals—with B lagging A—applies to the direction of motion shown in the dimension drawing.

The **reference mark signal** R has a usable component G of approx. 0.5 V. Adjacent to the reference mark, the output signal can drop by up to 1.7 V to a quiescent value H. The subsequent electronics must not be allowed to overdrive on account of this. Even at the low quiescent level, signal peaks with amplitude G can appear.

The **signal amplitude** is valid when the supply voltage stated in the specifications is applied at the encoder. The signal amplitude is based on a differential measurement between the associated outputs at the 120 ohm terminating resistor. The signal amplitude decreases when the frequency increases. The **cutoff frequency** is the frequency up to which a certain percentage of the original signal amplitude is maintained:

- -3 dB ≅ 70 % of the signal amplitude
- -6 dB ≅ 50 % of the signal amplitude

The parameters in the signal description apply to motion at up to 20 % of the -3 dB cutoff frequency.

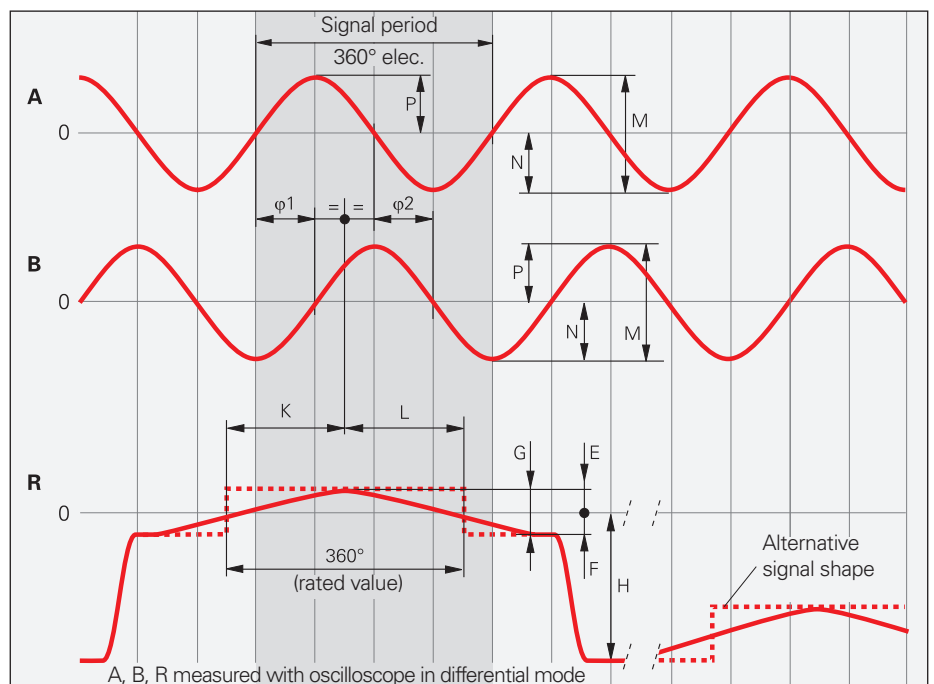
Interpolation/resolution/measuring step

The output signals of the 1 V_{PP} interface are usually interpolated in the subsequent electronics for the purpose of attaining sufficiently high resolutions. For **speed control**, interpolation factors of greater than 1000 are normally used for providing usable data even at low shaft speeds or traversing speeds.

Measuring steps for **position measurement** are recommended in the specifications. Other resolutions are also possible for special applications.

Interface	~ 1 V _{PP} sinusoidal voltage signals
Incremental signals	Two nearly sinusoidal signals A and B Signal amplitude M: 0.6 to 1.2 V _{PP} ; typ. 1 V _{PP} Asymmetry P - N /2M: ≤ 0.065 (equivalent to 15°) Amplitude ratio M _A /M _B : 0.8 to 1.25 Phase angle φ ₁ + φ ₂ /2: 90° ± 10° elec.
Reference mark signal	One or more signal peaks R Usable component G: ≥ 0.2 V Quiescent value H: ≤ 1.7 V Signal-to-noise ratio E, F: 0.04 V to 0.68 V Zero crossovers K, L: 180° ± 90° elec.
Connecting cable	HEIDENHAIN shielded cables; e.g., PUR [4(2 × 0.14 mm ²) + (4 × 0.5 mm ²)]
Cable length	Max. 150 m
Propagation time	6 ns/m

These values can be used for the dimensioning of the subsequent electronics. Any encoder tolerances that are subject to constraints are listed in the specifications. For encoders without an integral bearing, reduced tolerances are recommended for commissioning (see mounting instructions).



Short-circuit stability

The shorting of outputs is not a permissible operating condition. Excepted from this are encoders with a supply voltage of DC 5V ±5 %, which do not fail if an output briefly shorts to 0V or U_P

Short circuit at	20 °C	125 °C
One output	< 3 min	< 1 min
All outputs	< 20 s	< 5 s

Monitoring of the incremental signals

The following sensitivity levels are recommended for monitoring the signal amplitude M:

Lower threshold:	0.30 V _{PP}
Upper threshold:	1.35 V _{PP}

The amplitude of the incremental signals can be monitored based on the resulting length of the position indicator, for example. The oscilloscope shows the output signals A and B as a Lissajous figure in the XY graph. Ideal sinusoidal signals produce a circle with a diameter M. In this case, the position indicator r (shown) is equivalent to ½M.

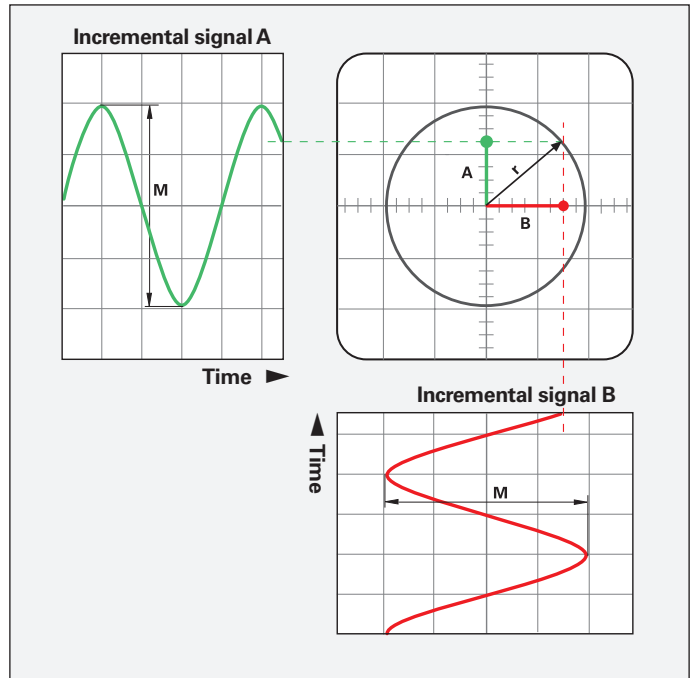
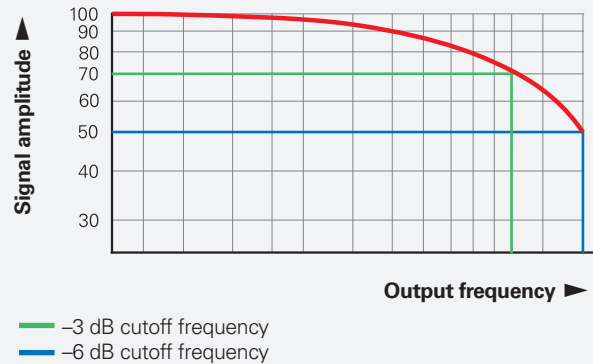
The following formula applies:

$$r = \sqrt{(A^2 + B^2)}$$

where $0.3V < 2r < 1.35V$.

Cutoff frequency

Typical signal amplitude curve as a function of the output frequency (depends on the encoder)



Input circuit of the subsequent electronics

Dimensioning

Operational amplifier (e.g., MC 34074)

Z₀ = 120 Ω

R₁ = 10 kΩ and C₁ = 100 pF

R₂ = 34.8 kΩ and C₂ = 10 pF

U_B = ±15V

U₁ ≈ U₀

-3 dB cutoff frequency of the circuit

≈ 450 kHz

≈ 50 kHz with C₁ = 1000 pF
and C₂ = 82 pF

The circuit variant for 50 kHz does reduce the bandwidth of the circuit but also improves its immunity to interference.

Output signals of the circuit

U_a = typ. 3.48 V_{PP}

Gain: 3.48-fold

Incremental signals Reference mark signal

R_a < 100 Ω, typ. 24 Ω

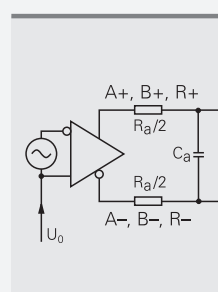
C_a < 50 pF

ΣI_a < 1 mA

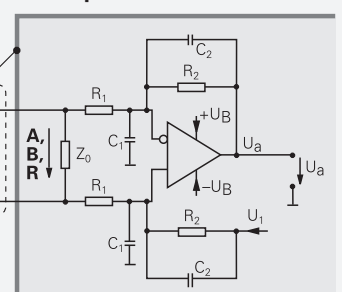
U₀ = 2.5V ±0.5V

(referenced to 0V of the power supply)

Encoder



Subsequent electronics



Input circuit of the subsequent electronics for high signal frequencies

For high-accuracy encoders with a high signal frequency, a special input circuit is necessary.

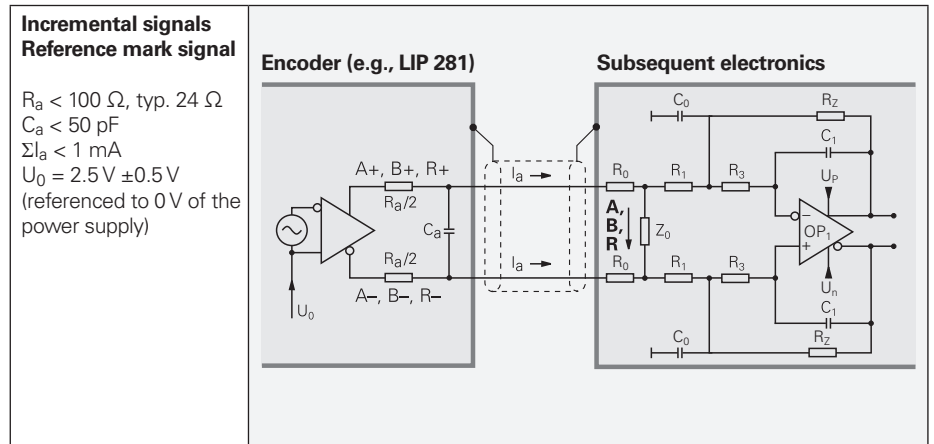
-3 dB cutoff frequency of the circuit

Various circuit variants are possible for the input circuit, thereby allowing various cutoff frequencies to be implemented. Depending on the application and the encoder being used, the receiver circuit may need to be adapted in order to achieve maximum performance from the overall system.

Output signals of the circuit

The input circuit has been optimized for a downstream A/D converter with an input range of $2 V_{PP}$

This yields a signal gain factor of 1.21, resulting in an output voltage $U_a = 1.21 V_{PP}$ for the A and B signals. The signal gain factor for the R signal is 0.58.



	Cutoff frequency -3 dB							
	500 kHz		2.5 MHz		5 MHz		10 MHz	
Signal	A, B	R	A, B	R	A, B	R	A, B	R
U_a	0 V		0 V		0 V		0 V	
U_p	+5 V		+5 V		+5 V		+5 V	
U_n	0 V		0 V		0 V		0 V or -5 V	
Z_0^*	127 Ω	59.0 Ω	133 Ω	59.0 Ω	133 Ω	59.0 Ω	133 Ω	59.0 Ω
R_0	0 Ω	31.6 Ω	0 Ω	31.6 Ω	0 Ω	31.6 Ω	0 Ω	31.6 Ω
R_1	1.21 k Ω		681 Ω		681 Ω		681 Ω	
R_2	1.47 k Ω		825 Ω		825 Ω		825 Ω	
R_3	1.82 k Ω		464 Ω		464 Ω		464 Ω	
C_0	220 pF		100 pF		47 pF		22 pF	
C_1	68 pF		47 pF		22 pF		10 pF	
OP_1	e.g., THS452x						e.g., AD8138	

* The resulting effective terminating resistance of the circuit is $\sim 120 \Omega$ for A, B, and R

Incremental signals

~ 11 μA_{PP} sinusoidal signals

HEIDENHAIN encoders with the ~11 μA_{PP} interface provide current signals. These encoders are intended for connection to ND position display units or EXE pulse-shaping electronics from HEIDENHAIN.

The sinusoidal **incremental signals** I_1 and I_2 are phase-shifted by 90° elec. and typically have a signal level of 11 μA_{PP} . The illustrated sequence of output signals—with I_2 lagging I_1 —applies to the direction of motion indicated in the dimension drawing (or to plunger retraction in the case of length gauges).

The **reference mark signal** I_0 has a usable component G of approx. 5.5 μA .

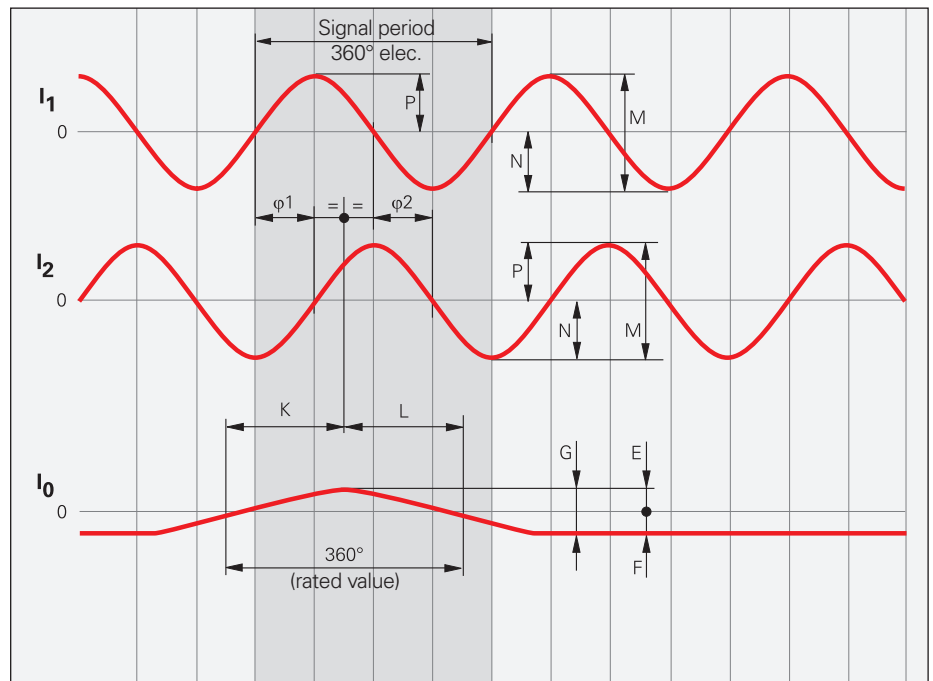
The **signal amplitude** is valid when the supply voltage stated in the specifications is applied at the encoder. It is based on a differential measurement between the associated outputs. The signal amplitude decreases when the frequency increases. The **cutoff frequency** is the frequency up to which a certain percentage of the original signal amplitude is maintained:

- -3 dB cutoff frequency: 70 % of the signal amplitude
- -6 dB cutoff frequency: 50 % of the signal amplitude

Interpolation/resolution/measuring step

The output signals of the 11 μA_{PP} interface are usually interpolated in the subsequent electronics (ND position displays or EXE pulse-shaping electronics from HEIDENHAIN) in order to attain sufficiently high resolutions.

Interface	~ 11 μA_{SS} sinusoidal current signals
Incremental signals	Two approximately sinusoidal signals I_1 and I_2 Signal amplitude M: 7 to 16 μA_{PP} ; typ. 11 μA_{PP} Asymmetry IP – NI/2M: ≤ 0.065 (equivalent to 15°) Amplitude ratio M_A/M_B : 0.8 to 1.25 Phase angle $ \varphi_1 + \varphi_2 /2$: $90^\circ \pm 10^\circ$ elec.
Reference mark signal	One or more signal peaks I_0 Usable component G: 2 μA to 8.5 μA Signal-to-noise ratio E, F: $\geq 0.4 \mu\text{A}$ Zero crossovers K, L: $180^\circ \pm 90^\circ$ elec.
Connecting cable	HEIDENHAIN shielded cable PUR $[3(2 \times 0.14 \text{ mm}^2) + (2 \times 1 \text{ mm}^2)]$
Cable length	Max. 30 m
Propagation time	6 ns/m



□TTL square-wave signals

HEIDENHAIN encoders with the □TTL interface contain electronics that digitalize sinusoidal scanning signals either with or without interpolation.

The **incremental signals** are output as the square-wave pulse trains U_{a1} and U_{a2} , phase-shifted by 90° elec. The **reference mark signal** consists of one or more reference pulses U_{a0} , which are gated with the incremental signals. In addition, the integrated electronics generate the **inverted signals** $\overline{U_{a1}}$, $\overline{U_{a2}}$, and $\overline{U_{a0}}$ for noise-immune transmission. The illustrated sequence of output signals—with U_{a2} lagging U_{a1} —applies to the direction of motion shown in the dimension drawing.

The **fault-detection signal** $\overline{U_{aS}}$ indicates malfunctions such as breakage of the power lines or failure of the light source. In automated manufacturing, for example, it can be used for machine switch-off.

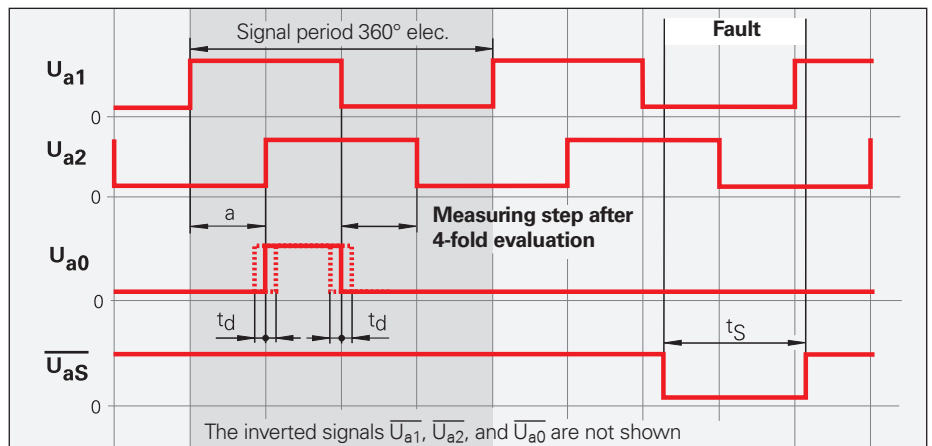
The distance between two successive edges of the incremental signals U_{a1} and U_{a2} through 1-fold, 2-fold, or 4-fold evaluation is one **measuring step**.

The subsequent electronics must be designed to detect each edge of the square-wave pulse. The minimum **edge separation a** stated in the specifications is valid for the input circuit shown in conjunction with a cable length of 1 m, and is based on a measurement at the output of the differential line receiver.

Note:

Not all encoders output a reference-mark signal, fault-detection signal, and inverted signals. Please see the pin layout for this.

Interface	□TTL square-wave signals
Incremental signals	Two TTL square-wave signals U_{a1} , U_{a2} , and their inverted signals $\overline{U_{a1}}$, $\overline{U_{a2}}$
Reference mark signal Pulse width Delay time	One or more TTL square-wave pulses U_{a0} and their inverted pulses $\overline{U_{a0}}$ 90° elec. (other widths upon request) $ t_d \leq 50$ ns
Fault-detection signal Pulse width	One TTL square-wave pulse $\overline{U_{aS}}$ Fault detection: LOW (upon request: high-impedance U_{a1}/U_{a2}) Proper functioning: HIGH $t_s \geq 20$ ms
Signal amplitude	Differential line driver as per EIA standard RS-422
Permissible load	$Z_0 \geq 100 \Omega$ Between associated outputs $ I_L \leq 20$ mA Max. load per output $C_{load} \leq 1000$ pF To 0 V Outputs are protected against a short to 0 V
Switching times (10% to 90%)	$t_+/t_- \leq 30$ ns (typ. 10 ns) with 1 m cable and specified input circuit
Connecting cable Cable length Propagation time	HEIDENHAIN shielded cables; e.g., PUR [4(2 × 0.14 mm ²) + (4 × 0.5 mm ²)] Max. 100 m ($\overline{U_{aS}}$ max. 50 m) Typ. 6 ns/m



Clocked output signals are typical of encoders and interpolation electronics with 5-fold interpolation (or higher). The edge separation a of these signals is derived from an internal clock source. At the same time, the clock frequency determines the permissible input frequency of the incremental signals (1 V_{PP} or 11 μA_{PP}) and thus the resulting maximum permissible shaft speed or traversing speed:

$$a_{nom} = \frac{1}{4 \cdot IPF \cdot fe_{nom}}$$

a_{nom} Nominal edge separation
 IPF Interpolation factor
 fe_{nom} Nominal input frequency

The tolerances of the internal clock source have an influence on the edge separation a of the output signal and the input frequency f_e , thereby influencing the traversing speed or shaft speed.

For the stated edge separation, these tolerances are already taken into account at 5%; in each case, it is not the nominal edge separation that is stated, but rather the minimum edge separation a_{min} .

For the maximum permissible input frequency, however, a tolerance of at least 5% must be taken into account. This means that the maximum permissible traversing speed or shaft speed is also reduced accordingly.

As a rule, encoders and interpolation electronics without interpolation have **unlocked output signals**. The minimum edge separation a_{min} at the maximum permissible input frequency is stated in the specifications. If the input frequency is reduced, then the edge separation correspondingly increases.

Cable-dependent differences in the propagation time additionally reduce the edge separation by 0.2 ns per meter of cable. In order to avoid counting errors, a safety margin of 10% must be taken into account. The subsequent electronics must also be designed to process 90% of the resulting edge separation.

Please note:

The maximum permissible **shaft speed** or **traversing speed** must not be exceeded—even temporarily—because this will cause irreversible counting errors.

Example calculation 1

LIDA 400 linear encoder

Requirements: display step: 0.5 μm ; traversing speed: 1 m/s;
 output signals: TTL; cable length to subsequent electronics: 25 m.

What is the minimum edge separation that the subsequent electronics must be able to process?

Selection of the interpolation factor

20 μm grating period : 0.5 μm display step = 40-fold subdivision
 Evaluation in the subsequent electronics 4-fold

Interpolation

10-fold

Selection of the edge separation

Traversing speed 60 m/min (equivalent to 1 m/s)
 + tolerance value: 5% 63 m/min

Select in the specifications:

Next LIDA 400 version 120 m/min (from the specifications)

Minimum edge separation

0.22 μs (from the specifications)

Determining the edge separation that the subsequent electronics must process

Subtract cable-dependent differences in propagation time 0.2 ns per meter

For cable length of 25 m 5 ns

Resulting edge separation 0.215 μs

Subtract 10% safety margin 0.022 μs

Minimum edge separation for the subsequent electronics

0.193 μs

Example calculation 2

ERA 4000 angle encoder with 32 768 lines

Requirements: measuring step of 0.1"; TTL output signals (IBV external interface required);
 cable length from IBV to subsequent electronics: 20 m;
 minimum edge separation that the subsequent electronics can process: 0.5 μs (input frequency: 2 MHz).

What shaft speed is possible?

Selection of the interpolation factor

32 768 lines corresponds to a signal period of 40"

Signal period of 40": measuring step of 0.1" = 400-fold subdivision

Evaluation in the subsequent electronics 4-fold

Interpolation in the IBV **100-fold**

Calculation of the edge separation

Permissible edge separation of the subsequent electronics 0.5 μs

This corresponds to 90% of the resulting edge separation

Therefore: resulting edge separation 0.556 μs

Subtract cable-dependent differences in the propagation time 0.2 ns per meter

For cable length of 20 m 4 ns

Minimum edge separation IBV 102

$\geq 0.56 \mu s$

Selecting the input frequency

With the IBV 102, the input frequencies and thus the edge separation a are adjustable as per the Production Information document.

Next suitable edge separation 0.585 μs

Input frequency at 100-fold interpolation

4 kHz

Calculating the permissible shaft speed

Subtract 5% tolerance 3.8 kHz

This is 3800 signals per second, or 228 000 signals per minute.

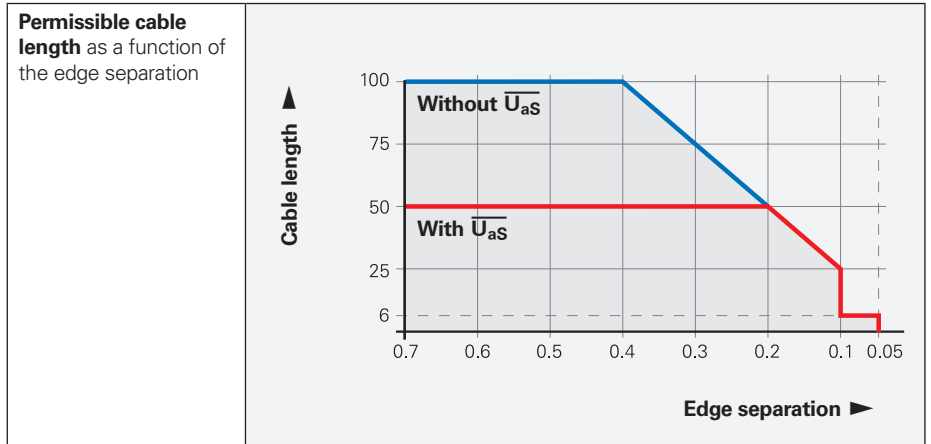
With the 32 768 lines of the ERA 4000, the following applies:

Maximum permissible shaft speed

6.95 rpm

The permissible **cable length** for transmission of the TTL square-wave signals to the subsequent electronics is dependent on the edge separation a . The maximum cable length is 100 m, or 50 m for the fault detection signal. The required supply voltage must be applied at the encoder (see the specifications). Over the sense lines, the voltage at the encoder can be monitored and adjusted as needed by a suitable regulating device (remote sense power supply).

Greater cable lengths can be provided upon consultation with HEIDENHAIN.



Input circuit of the subsequent electronics

Dimensioning

IC₁ = Recommended differential line receiver:

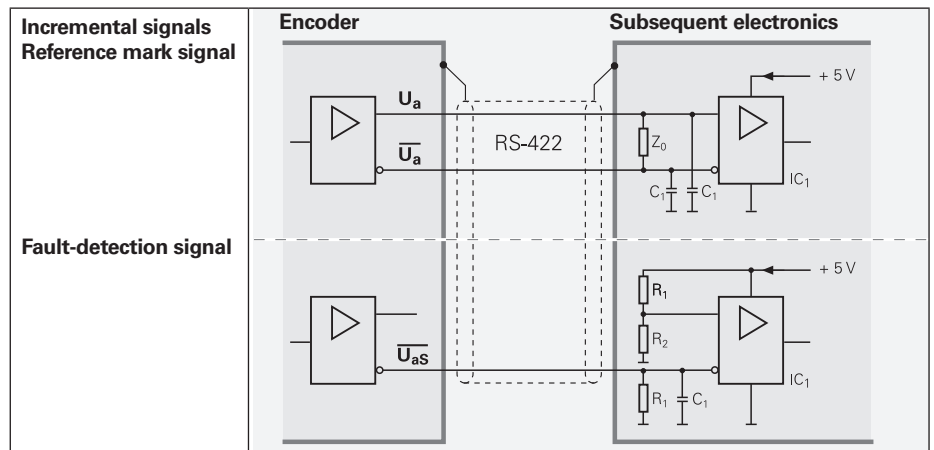
- DS 26 C 32 AT
- Only for $a > 0.1 \mu\text{s}$:
- AM 26 LS 32
- MC 3486
- SN 75 ALS 193

$R_1 = 4.7 \text{ k}\Omega$

$R_2 = 1.8 \text{ k}\Omega$

$Z_0 = 120 \Omega$

$C_1 = 220 \text{ pF}$ (serves to improve noise immunity)



Incremental signals

HTL square-wave signals

HEIDENHAIN encoders with the HTL interface contain electronics that digitalize sinusoidal scanning signals with or without interpolation.

The **incremental signals** are output as the square-wave pulse trains U_{a1} and U_{a2} , phase-shifted by 90° elec. The **reference mark signal** consists of one or more reference pulses U_{a0} , which are gated with the incremental signals. In addition, the integrated electronics generate the **inverted signals** $\overline{U_{a1}}$, $\overline{U_{a2}}$, and $\overline{U_{a0}}$ for noise-immune transmission (not with HTLs). The illustrated sequence of output signals—with U_{a2} lagging U_{a1} —applies to the direction of motion shown in the dimension drawing.

The **fault-detection signal** $\overline{U_{aS}}$ indicates malfunctions such as a failure of the light source. In automated manufacturing, for example, it can be used for machine switch-off.

The distance between two successive edges of the incremental signals U_{a1} and U_{a2} through 1-fold, 2-fold, or 4-fold evaluation is one **measuring step**.

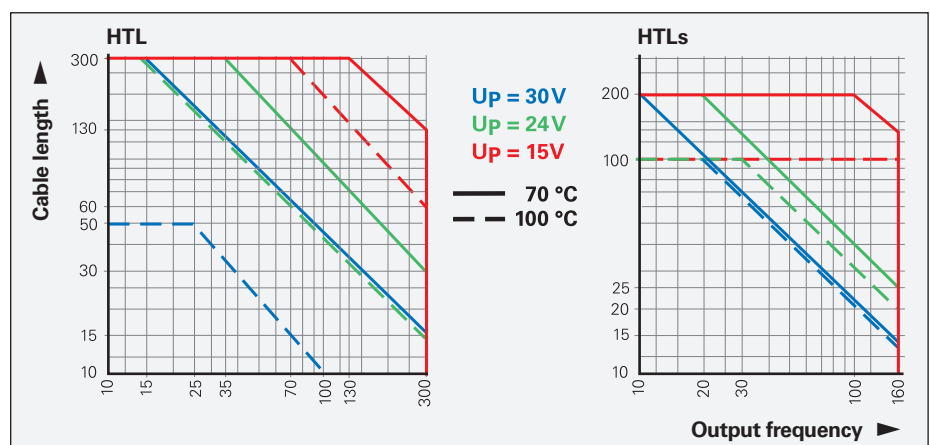
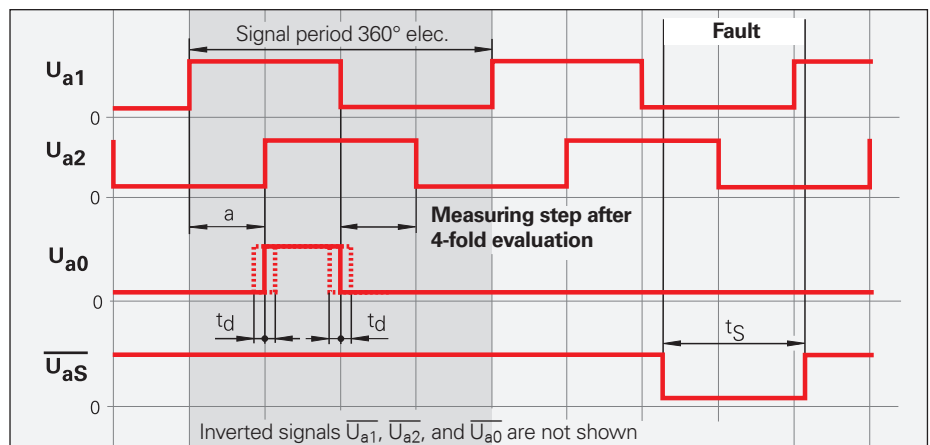
The subsequent electronics must be designed to detect each edge of the square-wave pulse. The minimum **edge separation a** stated in the specifications is based on a measurement at the output of the specified differential input circuit. To prevent counting errors, the subsequent electronics should be designed to still be able to process 90 % of the edge separation a .

The maximum permissible **shaft speed** or **traversing speed** must never be exceeded.

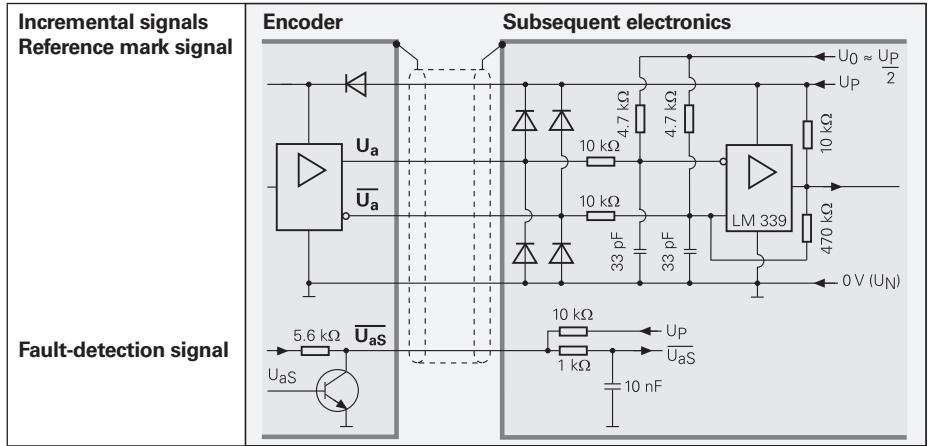
The permissible **cable length** for incremental encoders with HTL signals is dependent on the output frequency, the supply voltage being applied, and the operating temperature of the encoder.

The **current consumption** of encoders with HTL output signals is dependent on the output frequency and the cable length to the subsequent electronics.

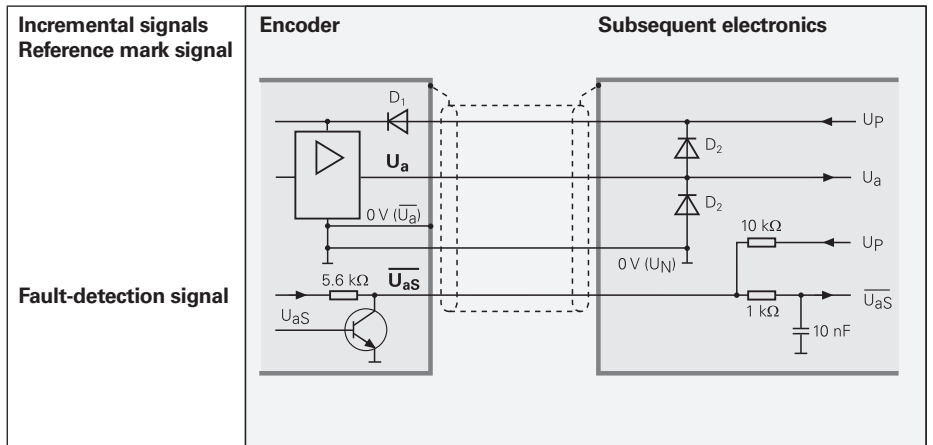
Interface	HTL, HTLs square-wave signals	
Incremental signals	Two HTL square-wave signals U_{a1} , U_{a2} and their inverted signals $\overline{U_{a1}}$ and $\overline{U_{a2}}$ (HTLs without U_{a1} and U_{a2})	
Reference mark signal	One or more HTL square-wave pulses U_{a0} and their inverse pulses $\overline{U_{a0}}$ (HTLs without U_{a0})	
Pulse width	90° elec. (other widths upon request)	
Delay time	$ t_d \leq 50$ ns	
Fault-detection signal	One HTL square-wave pulse $\overline{U_{aS}}$	
	Malfunction: LOW Proper functioning: HIGH	
Pulse width	$t_S \geq 20$ ms	
Signal level	$U_H \geq 21$ V at $-I_H = 20$ mA $U_L \leq 2.8$ V at $I_L = 20$ mA	With supply voltage $U_P = 24$ V, without cable
Permissible load	$ I_L \leq 100$ mA $C_{load} \leq 10$ nF	Max. load per output, (except $\overline{U_{aS}}$) To 0 V
	Outputs can tolerate a short to 0 V and U_P for a maximum of 1 min (except $\overline{U_{aS}}$)	
Switching times (10 % to 90 %)	$t_+/t_- \leq 200$ ns (except $\overline{U_{aS}}$) with 1 m cable and specified input circuit	
Connecting cable	HEIDENHAIN shielded cables; e.g., PUR [4(2 × 0.14 mm ²) + (4 × 0.5 mm ²)]	
Cable length	Max. 300 m (HTLs max. 100 m)	
Propagation time	6 ns/m	



Input circuit of the subsequent electronics
HTL



HTLs



Other signals

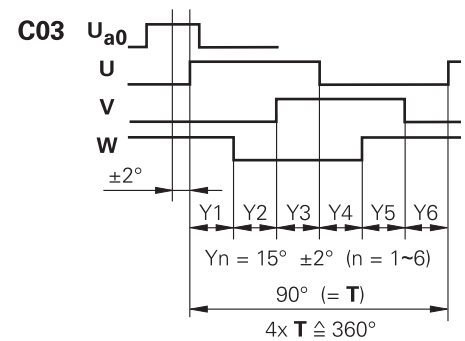
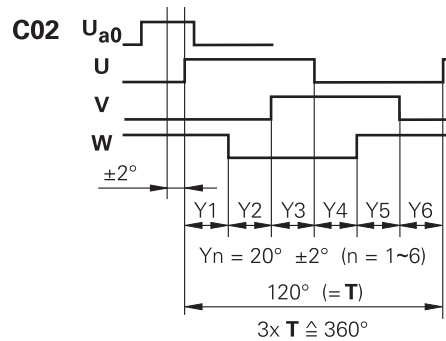
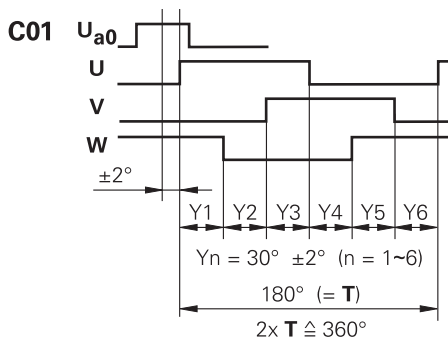
Commutation signals for block commutation

The **block commutation signals U, V, and W** are obtained from three separate tracks. They are transmitted as square-wave signals in TTL levels.

Interface	□ TTL square-wave signals
Commutation signals	Three square-wave signals U, V, W and their inverted signals $\bar{U}, \bar{V}, \bar{W}$
Width	2x180° mech., 3x120° mech., or 4x90° mech. (others upon request)
Signal level	See <i>Incremental signals</i> □ TTL
Incremental signals	See <i>Incremental signals</i> □ TTL
Connecting cable	HEIDENHAIN shielded cables; e.g., PUR [6(2 x 0.14 mm ²) + (4 x 0.5 mm ²)]
Cable length	Max. 100 m
Propagation time	6 ns/m

Commutation signals

(values in mechanical degrees)



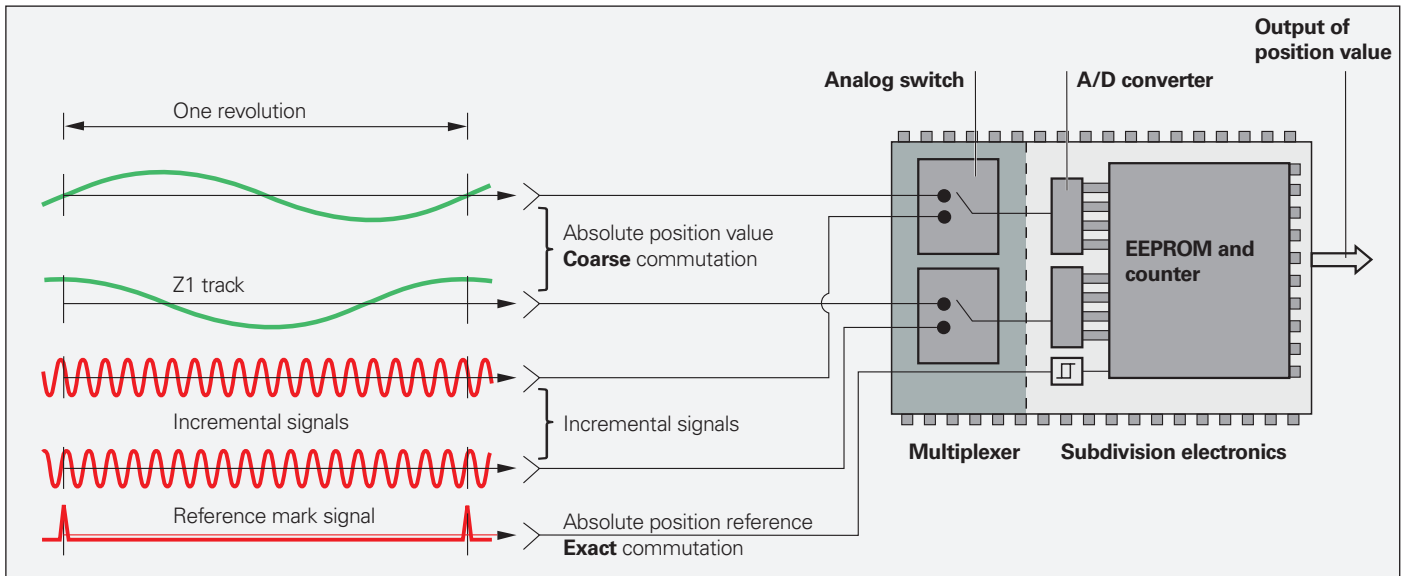
Commutation signals for sine commutation

The **commutation signals C and D** are obtained from the Z1 track and are equivalent to one sine or cosine period per revolution. They have a signal amplitude of typically 1 V_{PP} at 1 kΩ.

The input circuit of the subsequent electronics is the same as that of the ~ 1 V_{PP} interface. However, the required terminating impedance Z₀ is 1 kΩ instead of 120 Ω.

Interface	~ 1 V _{PP} sinusoidal voltage signals
Commutation signals	Two nearly sinusoidal signals C and D For signal levels, see <i>Incremental signals</i> ~ 1 V _{PP}
Incremental signals	See <i>Incremental signals</i> ~ 1 V _{PP}
Connecting cable	HEIDENHAIN shielded cables; e.g., PUR [4(2 × 0.14 mm ²) + (4 × 0.14 mm ²) + (4 × 0.5 mm ²)] Cable length Max. 150 m Propagation time 6 ns/m

Electronic commutation with Z1 track




Other signals

Limit switches

Encoders with limit switches, such as the LIDA 400, are equipped with two limit switches that permit limit-position detection or the creation of a homing track. The limit switches are activated by differing adhesive magnets, thereby permitting precise switching of the right or left limit switches. The magnets can be configured in series for the creation of homing tracks.

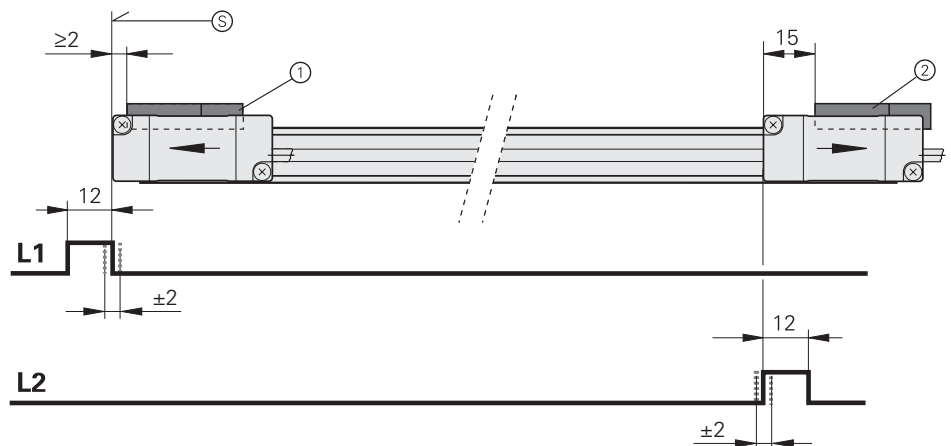
The signals from the limit switches are output over separate lines and are thus directly available.

		LIDA 4xx
Output signals		HIGH/LOW level for each TTL square-wave pulse for limit switches L1 and L2
Signal amplitude		Collector stage with load resistance of 10 kΩ against 5 V
Permissible load		$I_{aL} \leq 4 \text{ mA}$ $I_{aH} \leq 4 \text{ mA}$
Switching times (10 % to 90 %)	Rise time Fall time	$t_r \leq 10 \mu\text{s}$ $t_f \leq 3 \mu\text{s}$ Measured with 3 m cable and recommended input circuit
Permissible cable length		Max. 20 m

mm

 Tolerancing ISO 8015
 ISO 2768 - m H
 $\leq 6 \text{ mm}$: $\pm 0.2 \text{ mm}$

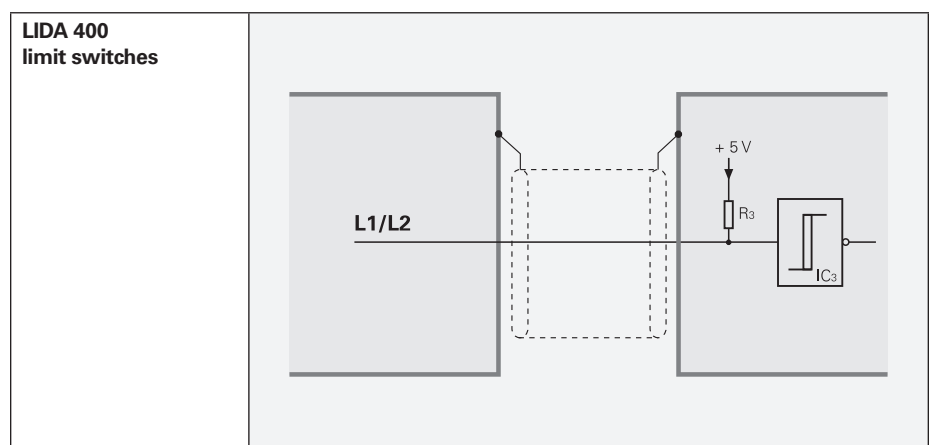
L1/L2 = Output signals of limit switches 1 and 2
 Tolerance of the switching edge: $\pm 2 \text{ mm}$

Ⓢ = Beginning of measuring length ML
 1 = Magnet N for limit switch 1
 2 = Magnet S for limit switch 2



Input circuit of the subsequent electronics

Dimensioning
 IC_3 (e.g., 74AC14)
 $R_3 = 1.5 \text{ k}\Omega$



Position detection

In addition to having an incremental graduation, encoders with position detection, such as the LIF 4x1/LIP 60x1, feature a homing track and limit switches for limit position detection.


The signals are output in TTL levels over the separate lines H and L, and are therefore directly available.

With the LIP 60x1, fine adjustment of the limit/homing position can also be performed with the PWM 21.

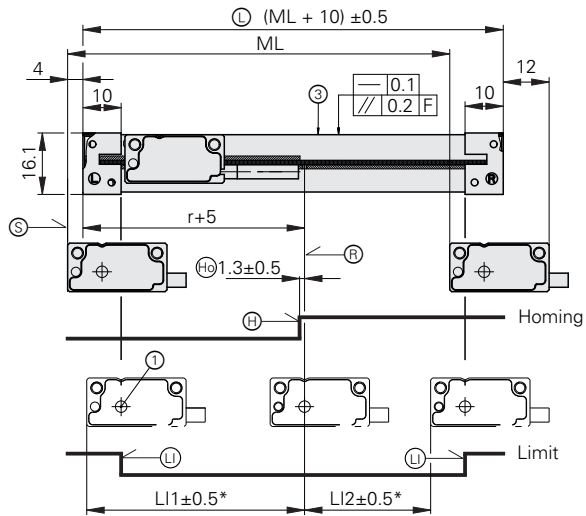
LIF 4x1/LIP 60x1

Output signals	One TTL pulse each for homing track H and limit switch L
Signal amplitude	TTL $U_H \geq 3.8 \text{ V}$ at $-I_H = 8 \text{ mA}$ $U_L \leq 0.45 \text{ V}$ at $I_L = 8 \text{ mA}$
Permissible load	$R \geq 680 \Omega$ $ I_L \leq 8 \text{ mA}$
Permissible cable length	Max. 10 m; for LIP 60x1 during adjustment with PWM 21: max. 3 m


LIP 60x1

mm

 Tolerancing ISO 8015
 ISO 2768 - m H
 $\leq 6 \text{ mm}$: $\pm 0.2 \text{ mm}$

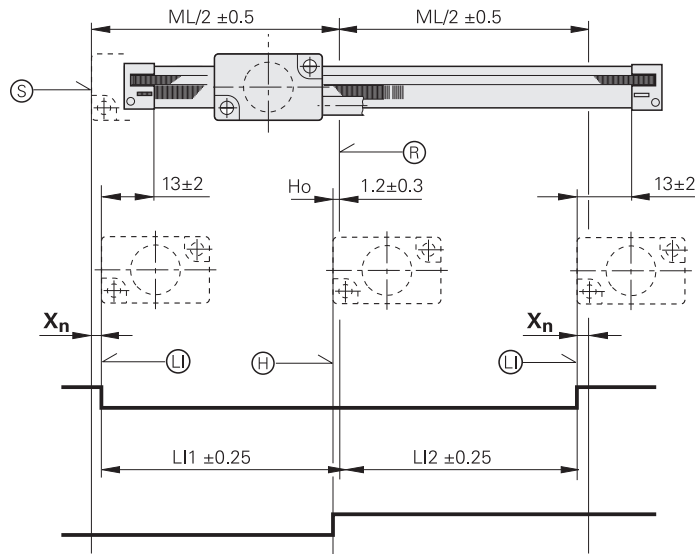
- Ⓜ = Reference mark position
- Ⓢ = Beginning of measuring length ML
- Ⓛ = Limit mark, adjustable
- Ⓟ = Switch for homing track
- Ho = Trigger point for homing



LIF 4x1

mm

 Tolerancing ISO 8015
 ISO 2768 - m H
 ≤ 6 mm: ±0.2 mm

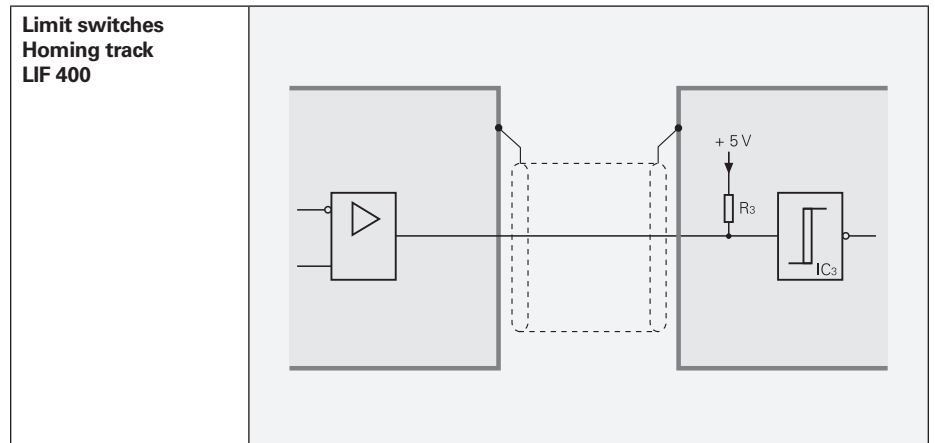
- Ⓜ = Reference mark position
- Ⓢ = Beginning of measuring length ML
- Ⓛ = Limit mark, adjustable
- Ⓜ = Switch for homing track
- Ho = Trigger point for homing



X_n =
 Var. 01 **X₁** = 2 mm
 Var. 02 **X₂** = 14 mm
 Var. 03 **X₃** = 22 mm

Input circuit of the subsequent electronics

Dimensioning
 IC₃ (e.g., 74AC14)
 R₃ = 4.7 kΩ



Further information

Interface electronics

Interface electronics from HEIDENHAIN adapt the encoder signals to the interface of the subsequent electronics. They are used when the subsequent electronics cannot directly process the output signals from HEIDENHAIN encoders or when additional interpolation of the signals is necessary.

Input signals of the interface electronics

HEIDENHAIN interface electronics can be connected to encoders with 1 V_{PP} sinusoidal signals (voltage signals) or 11 μA_{PP} sinusoidal signals (current signals). Encoders with the EnDat or SSI serial interfaces can also be connected to various interface electronics.

Output signals of the interface electronics

The interface electronics are available with the following interfaces to the subsequent electronics:

- TTL square-wave pulse trains
- EnDat 2.2
- DRIVE-CLiQ
- Fanuc Serial Interface
- Mitsubishi high speed interface
- Yaskawa Serial Interface
- PROFIBUS

Interpolation of the sinusoidal input signals

The interface electronics perform signal conversion and interpolate the sinusoidal encoder signals. This permits finer measuring steps and thus higher control quality and superior positioning behavior.

Position value generation

Various interface electronics feature an integrated counting function. Beginning from the last set reference point, an absolute position value is generated and output to the subsequent electronics when the reference mark is traversed.

Box design



Plug design



Cable design



Top-hat rail design



Outputs		Inputs		Design – IP rating	Interpolation ¹⁾ or subdivision	Model
Interface	Quantity	Interface	Quantity			
□TTL	1	~ 1 V _{PP}	1	Box design – IP65	5/10-fold	IBV 101
					20/25/50/100-fold	IBV 102
					Without interpolation	IBV 600
					25/50/100/200/400-fold	IBV 660B
				Plug design – IP40	5/10-fold	IBV 3171
					20/25/50/100-fold	IBV 3271
		~ 11 μA _{PP}	1	Box design – IP65	5/10-fold	EXE 101
					20/25/50/100-fold	EXE 102
□TTL/ ~ 1 V _{PP} (adjustable)	2	~ 1 V _{PP}	1	Box design – IP65	2-fold	IBV 6072
					5/10-fold	IBV 6172
					5/10-fold and 20/25/50/100-fold	IBV 6272
EnDat 2.2	1	~ 1 V _{PP}	1	Box design – IP65	≤ 16384-fold subdivision	EIB 192
				Plug design – IP40	≤ 16384-fold subdivision	EIB 392
			2	Box design – IP65	≤ 16384-fold subdivision	EIB 1512
DRIVE-CLiQ	1	EnDat 2.2	1	Box design – IP65	–	EIB 2391 S
				Cable design – IP65	–	EIB 3392 S
Fanuc Serial Interface	1	~ 1 V _{PP}	1	Box design – IP65	≤ 16384-fold subdivision	EIB 192 F
				Plug design – IP40	≤ 16384-fold subdivision	EIB 392 F
			2	Box design – IP65	≤ 16384-fold subdivision	EIB 1592 F
Mitsubishi high speed interface	1	~ 1 V _{PP}	1	Box design – IP65	≤ 16384-fold subdivision	EIB 192 M
				Plug design – IP40	≤ 16384-fold subdivision	EIB 392 M
			2	Box design – IP65	≤ 16384-fold subdivision	EIB 1592 M
Yaskawa Serial Interface	1	EnDat 2.2	1	Plug design – IP40	–	EIB 3391 Y
PROFIBUS DP	1	EnDat 2.2	1	Top-hat rail design	–	PROFIBUS Gateway
PROFINET IO	1	EnDat 2.2	1	Top-hat rail design	–	PROFINET Gateway

¹⁾ Switchable

Diagnostic, inspection, and testing equipment

HEIDENHAIN encoders provide all of the information necessary for commissioning, monitoring, and diagnostics. The type of information available depends on whether the encoder is incremental or absolute and on which interface is in use.

Incremental encoders primarily have 1 V_{PP}, TTL, or HTL interfaces. TTL and HTL encoders monitor their signal amplitudes internally and generate a purely digital fault detection signal. With 1 V_{PP} signals, an analysis of the output signals is possible only with external testing devices or through the use of computation resources in the subsequent electronics (**analog diagnostic interface**).

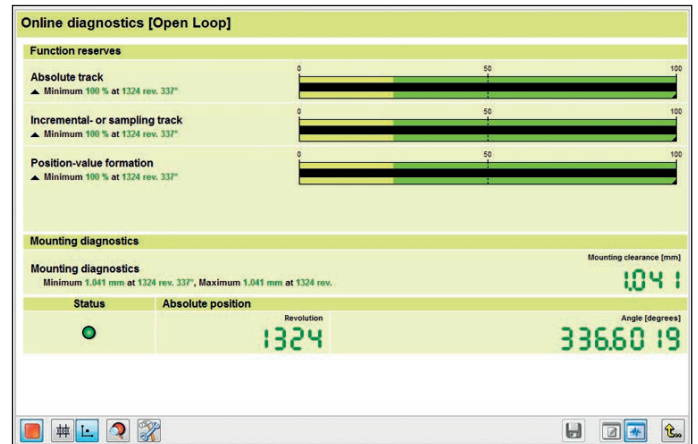
Absolute encoders employ serial data transmission. Depending on the interface, additional 1 V_{PP} incremental signals can be output. The signals are comprehensively monitored within the encoder. The result from monitoring (particularly in the case of valuation numbers) can be transmitted to the subsequent electronics along with the position values via the serial interface (**digital diagnostics interface**). The following information is available:

- Error message: position value is not reliable
- Warning: an internal functional limit of the encoder has been reached
- Valuation numbers:
 - Detailed information about the encoder's functional reserve
 - Identical scaling for all HEIDENHAIN encoders
 - Cyclic reading is possible

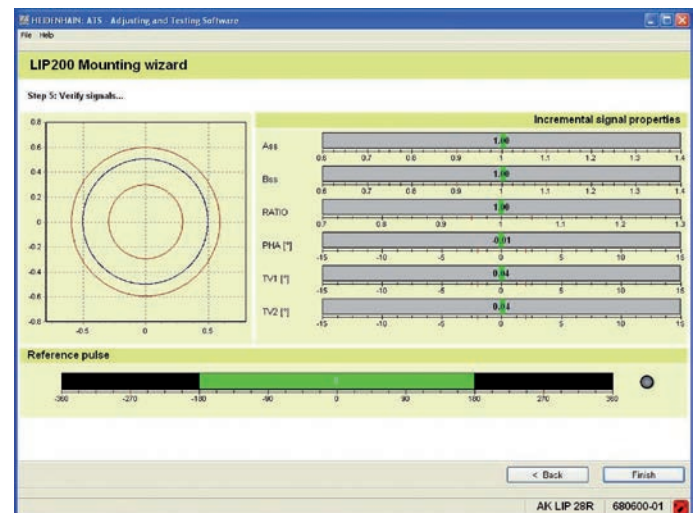
The subsequent electronics are able to evaluate the current status of the encoder with little resource expenditure, including in closed-loop operation.

For the analysis of these encoders, HEIDENHAIN offers the suitable PWM inspection devices and PWT testing devices. Depending on how these devices are integrated, a distinction is made between two types of diagnostics:

- Encoder diagnostics: The encoder is connected directly to the testing or inspection device, thereby enabling a detailed analysis of the encoder functions.
- Monitoring mode: The PWM inspection device is inserted into the closed control loop (via suitable testing adapters if needed). This enables real-time diagnosis of the machine or equipment during operation. The available functions depend on the interface.



Diagnostics with the PWM 21 and ATS software



Commissioning with the PWM 21 and ATS software

Overview		PWM 21		PWT 101
Interface	Output signals	Encoder diagnostics	Monitoring mode	Encoder diagnostics
EnDat 2.1	Position value Incremental signals	Yes Yes	No Yes	Yes Yes
EnDat 2.2	Position value Valuation numbers	Yes Yes	Yes Yes ¹⁾	Yes Yes
DRIVE-CLiQ	Position value Valuation numbers	Yes Yes	No No	No ⁷⁾ No ⁷⁾
Fanuc	Position value Valuation numbers	Yes Yes	Yes Yes	Yes ⁸⁾ Yes ⁸⁾
Mitsubishi	Position value Valuation numbers	Yes Yes ⁵⁾	Yes Yes ^{1) 5)}	Yes ⁸⁾ Yes ⁸⁾
Panasonic	Position value Valuation numbers	Yes Yes	Yes Yes ¹⁾	Yes ⁸⁾ Yes ⁸⁾
Yaskawa	Position value Valuation numbers	Yes Yes ⁶⁾	No ⁷⁾ No ⁷⁾	Yes ⁸⁾ Yes ⁸⁾
SSI	Position value Incremental signals	Yes Yes	No Yes	No No
1 V_{PP}	Incremental signals	Yes	Yes	Yes
11 μA_{PP}	Incremental signals	Yes	Yes	Yes
TTL	Incremental signals Scanning signals	Yes Yes ⁴⁾	Yes No	Yes Yes ⁴⁾
HTL	Incremental signals	Yes ²⁾	No	No ⁷⁾
Commutation	Block commutation Sinusoidal commutation	Yes ²⁾ Yes	No Yes	Yes ³⁾ Yes

¹⁾ Information must be requested and transferred by the control

²⁾ Via appropriate signal adapter

³⁾ Only for encoders with block commutation (see encoder documentation)

⁴⁾ If supported by the encoder (PWT function)

⁵⁾ Not usable for encoders with the Mitsu01 ordering designation

⁶⁾ Not available for EIB 3391Y

⁷⁾ Function not available yet

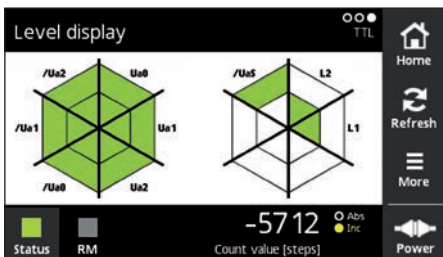
⁸⁾ Two-pair transmission is required (for more information, see the documentation for the *PWT 100/PWT 101*)

PWT 101

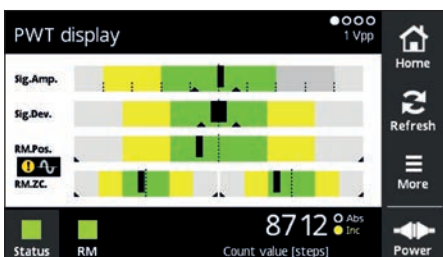
The PWT 101 is a testing device for the functional testing and adjustment of incremental and absolute HEIDENHAIN encoders. Thanks to its compact dimensions and rugged design, the PWT 101 is ideal for portable use.



PWT 101	
Encoder input only for HEIDENHAIN encoders	<ul style="list-style-type: none"> • EnDat • Fanuc Serial Interface • Mitsubishi high speed interface • Panasonic Serial Interface • Yaskawa Serial Interface • 1 V_{PP} • 11 μA_{PP} • TTL
Display	4.3-inch color flat-panel display (touchscreen)
Supply voltage	DC 24 V Power consumption: max. 15 W
Operating temperature	0 °C to 40 °C
Protection class EN 60529	IP20
Dimensions	Approx. 145 mm x 85 mm x 35 mm



Level display



PWT display

PWM 21

The PWM 21 phase-angle measuring unit, together with the ATS adjusting and testing software, serves as an adjusting and testing package for the diagnosis and adjustment of HEIDENHAIN encoders.



For more information, please refer to the *PWM 21/ATS Software Product Information* document.

	PWM 21
Encoder input	<ul style="list-style-type: none"> • EnDat 2.1 or EnDat 2.2 (absolute value with or without incremental signals) • DRIVE-CLiQ • Fanuc Serial Interface • Mitsubishi high speed interface • Yaskawa Serial Interface • Panasonic serial interface • SSI • 1 V_{PP}/TTL/11 μA_{PP} • HTL (via signal adapter)
Interface	USB 2.0
Supply voltage	AC 100 V to 240 V or DC 24 V
Dimensions	258 mm × 154 mm × 55 mm

	ATS
Languages	Choice between German and English
Functions	<ul style="list-style-type: none"> • Position display • Connection dialog • Diagnostics • Mounting wizard for EBI/ECI/EQI, LIP 200, LIC 4000, and others • Additional functions (if supported by the encoder) • Memory contents
System requirements and recommendations	PC (dual-core processor > 2 GHz) RAM > 2 GB Operating systems: Windows 7, 8, and 10 (32-bit/64-bit) 500 MB of free hard drive space

DRIVE-CLiQ is a registered trademark of Siemens AG.

General electrical information

Scope

The general electrical information applies to encoders from HEIDENHAIN as well as to cables. Any supplementary information is provided in the specifications.

Supply voltage

Connect HEIDENHAIN encoders only to subsequent electronics whose supply voltage comes from PELV systems (for a definition, see EN 50178).

HEIDENHAIN encoders meet the requirements of the IEC 61010-1 standard if power is supplied from a secondary circuit with limited energy as per IEC 61010-1^{3rd Ed.}, Section 9.4, or with limited power as per IEC 60950-1^{2nd Ed.}, Section 2.5, or from a Class 2 secondary circuit as per UL1310.¹⁾

A **stabilized DC voltage U_p** is required for powering the encoders. Information on voltage and current consumption or power consumption can be obtained from the respective specifications. Regarding the ripple voltage of the DC power, the following parameters apply:

- High-frequency interference
 $U_{PP} < 250 \text{ mV}$ with $dU/dt > 5 \text{ V}/\mu\text{s}$
- Low-frequency fundamental ripple
 $U_{PP} < 100 \text{ mV}$

However, the limits of the supply voltage must not be violated by the ripple content.

The required supply voltage depends on the encoder interface. A distinction is made between encoders without an extended supply voltage range (e.g., DC 5.0 V ± 0.25 V) and those with an extended supply voltage range (e.g., DC 3.6 V to 14 V).

Encoders with extended supply voltage range

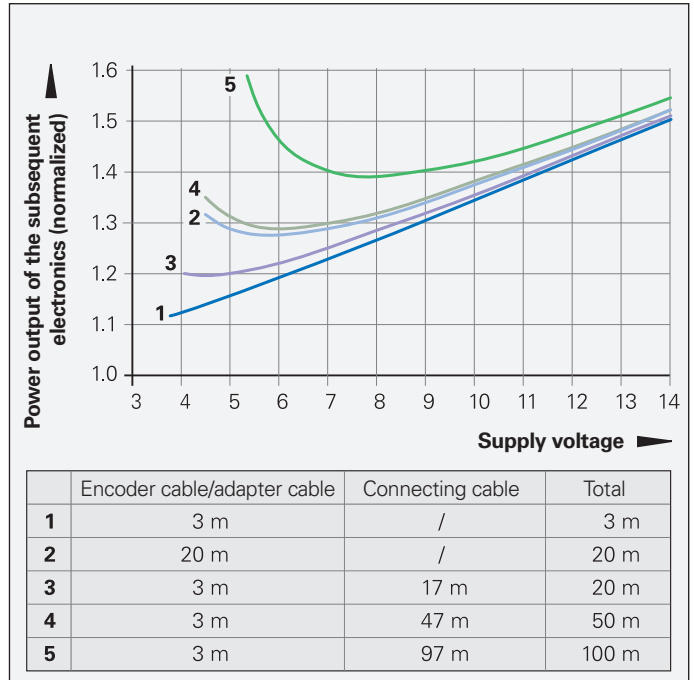
For encoders with an extended supply voltage range, the relationship between the current consumption and the supply voltage is non-linear. However, the power consumption of the encoder exhibits a nearly linear curve (see *Power consumption and current consumption graph*).

For this reason, the specifications provide the maximum power consumption at the minimum and maximum supply voltage. The maximum power consumption takes the following factors into account:

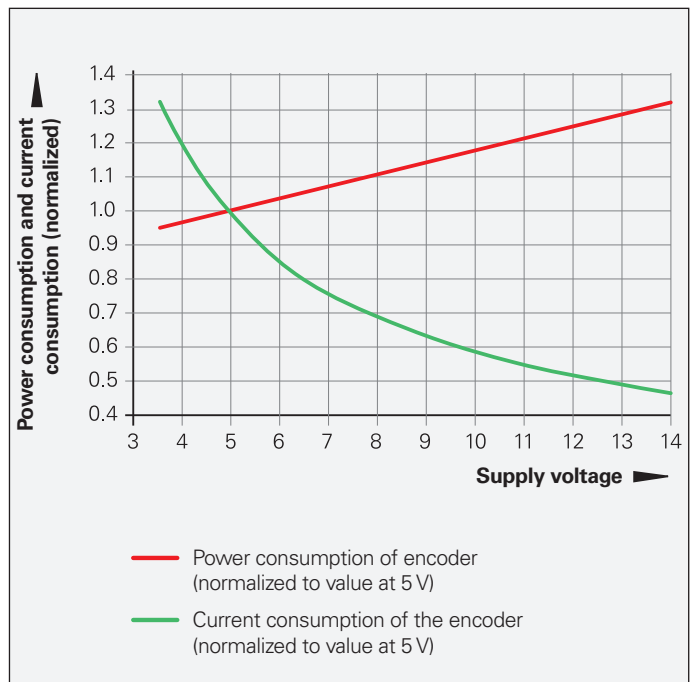
- The recommended receiver circuit
- A cable length of 1 m
- The effects of aging and temperature
- Proper use of the encoder with respect to the clock frequency and cycle time

For the sake of comparison and for inspection purposes, the typical current consumption and power consumption at typical ambient and operating conditions without load (only supply voltage connected) are specified for the typical supply voltage or rated voltage.

This information is non-binding and subject to change without notice. For dimensioning of the power supply, the maximum power consumption is to be used.



Influence of the cable length on the power output of the subsequent electronics (example)



The current consumption and power consumption as a function of the supply voltage (example)

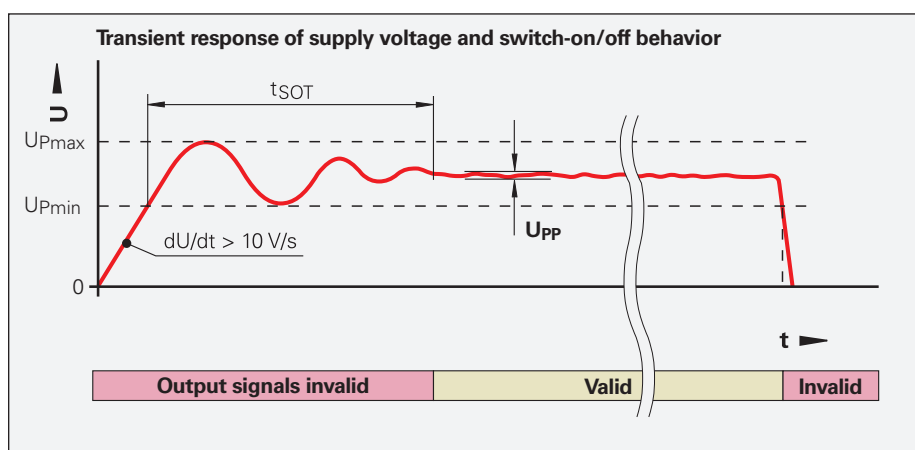
¹⁾ In place of IEC 61010-1^{3rd Ed.}, Section 9.4, the corresponding sections of the following standards can be used: DIN EN 61010-1, EN 61010-1, UL 61010-1, and CAN/CSA-C22.2 No. 61010-1. In place of IEC 60950-1^{2nd Ed.}, Section 2.5, the corresponding sections of the following standards can be used: DIN EN 60950-1, EN 60950-1, UL 60950-1, and CAN/CSA-C22.2 No. 60950-1.

The voltage values must be maintained at the encoder. The voltage applied at the encoder can be monitored and regulated over the **sense lines**, if available. If no variable power pack is available, then the sense lines should be switched in parallel with the respective supply lines in order to reduce the voltage drop (see *Cable lengths* in the *Cables and Connectors* brochure).

Switch-on/off behavior of the encoders

Valid output signals are available after the switch-on time t_{SOT} . During the time t_{SOT} , the output signals reach the maximum voltage values stated in the table. The duration of switch-on time t_{SOT} depends on the interface.

Interface	Switch-on time	Maximum voltage
1 V _{PP}	1.3 s	5.5 V
11 μA _{PP}		
TTL		
HTL		
EnDat		
SSI	U_{Pmax}	
PROFIBUS DP	2 s	5.5 V
PROFINET	10 s	U_{Pmax}



If the power supply is switched off, or if the supply voltage falls below U_{Pmin} , then the output signals are invalid as well. Furthermore, the interface-specific switch-on/off characteristics must be taken into account. If the encoder is operated via

interposed interface electronics, then the switch-on/off behavior of the interface electronics must be considered as well.

Other proprietary interfaces supported by HEIDENHAIN are not dealt with here.

Design information regarding the power pack of the subsequent electronics

Selection of the power supply of the subsequent electronics

Select a power supply that is as close as possible to the upper tolerance limit. Consider the voltage drop ΔU resulting from the cable length. The power supply should lie within the upper tolerance range, particularly in the case of encoders with a supply voltage of DC 5 V \pm 0.25 V and DC 5 V \pm 0.5 V. For encoders with a supply voltage of DC 3.6 V to 14 V and functional safety, a supply voltage of DC 12 V is recommended.

Power output of the subsequent electronics

For encoders with an extended supply voltage range, the maximum power consumption stated in the specifications must be taken into account. Particularly in the case of encoders with a supply voltage of DC 5 V, be sure to note that the power for the current consumption is indicated **without load**. Therefore, keep in mind that the current consumption values will be higher depending on the design of the receiver circuit. The voltage drops in the adapter cables and connecting cables must be taken into account as well (for the calculations, see *Power supply* in the *Cables and Connectors* brochure).

Maximum current consumption at the moment of switch-on

The increased current consumption must be considered for the dimensioning of the power pack. HEIDENHAIN therefore recommends that the power pack be equipped with a current limit. The recommended value for the limit is 400 mA, but at least 1.2 times the value of the maximum current consumption of the encoder in steady state.

When dimensioning the current monitor with switch-off (especially trigger threshold and trigger speed), ensure that the increased current consumption can be tolerated at the moment of switch-on.

Scope

For HEIDENHAIN encoders with a proprietary interface, the general electrical information is applicable along with the sections below. For supplementary information, see the specifications.

Encoders with the DRIVE-CLiQ interface

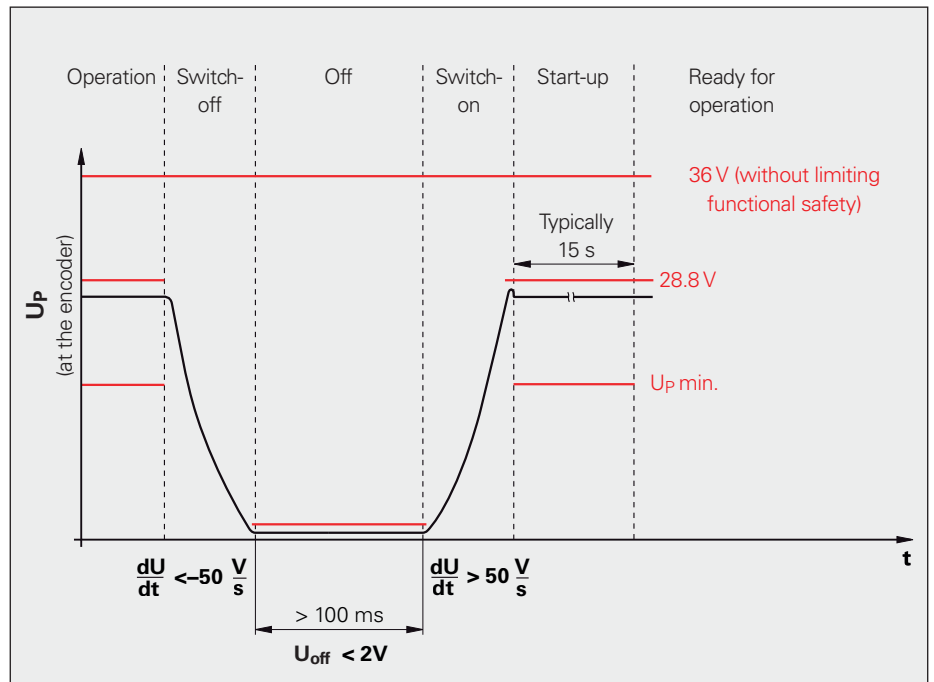
Power supply

Encoders with the DRIVE-CLiQ interface are designed for a rated voltage of DC 24 V. The manufacturer of the subsequent electronics specifies DC 20.4 V to 28.8 V as the tolerance for the supply voltage.

HEIDENHAIN encoders with the DRIVE-CLiQ interface permit a larger voltage range (see the specifications). Operation at up to DC 36.0 V is briefly permissible. In the range of DC 28.8 V to 36.0 V, higher power consumption is to be expected.

Switch-on/off behavior

HEIDENHAIN encoders with the DRIVE-CLiQ interface are designed for the switch-on/switch-off behavior shown to the right.



Depiction of the switch-on and switch-off conditions

Electrically permissible shaft speed or traversing speed

The maximum permissible shaft speed or traversing speed of an encoder is derived from:

- the **mechanically** permissible shaft speed or traversing speed and
- the **electrically** permissible shaft speed or traversing speed.

In the case of incremental encoders with **sinusoidal output signals**, the electrically permissible shaft speed or traversing speed is limited by the -3dB/-6dB cutoff frequency or the permissible input frequency of the subsequent electronics.

For incremental encoders with **square-wave signals**, the electrically permissible shaft speed or traversing speed is limited by:

- the maximum permissible scanning/output frequency f_{\max} of the encoder and
- the minimum permissible edge separation a for the subsequent electronics.

For angle or rotary encoders

$$n_{\max} = \frac{f_{\max}}{z} \cdot 60 \cdot 10^3$$

For linear encoders

$$v_{\max} = f_{\max} \cdot SP \cdot 60 \cdot 10^{-3}$$

Where:

- n_{\max} Electrically permissible speed in rpm
- v_{\max} Electrically permissible traversing speed in m/min
- f_{\max} Maximum scanning/output frequency of the encoder or input frequency of the subsequent electronics in kHz
- z Signal periods of the angle encoder or rotary encoder per 360°
- SP Signal period of the linear encoder in μm

Electrical safety

HEIDENHAIN encoders must be powered through PELV systems (for a definition, see EN 50178). The housings of HEIDENHAIN encoders are insulated from internal circuits. The impulse withstand voltage of the insulation is 500 V in accordance with EN 60664-1. In addition, contamination level 2 must be complied with in the micro-environment (see EN 60664-1).

Electromagnetic compatibility

Sources of electrical interference

Electrical interference is primarily caused by capacitive or inductive couplings. Interference can arise over wires and at input and output terminals on devices.

Typical sources of electrical interference include the following:

- Strong magnetic fields from transformers, brakes, and electric motors
- Relays, contactors, and solenoid valves
- High-frequency equipment, pulse devices, and stray magnetic fields from switching power supplies
- Power cables and supply lines to the abovementioned devices

Conformity

When the measures described below are implemented, HEIDENHAIN encoders comply with **EMC Directive 2014/30/EU** with regard to the generic standards for the following phenomena:

• Noise immunity (EN 61000-6-2)

Specifically, the following standards:

- ESD EN 61000-4-2
- Electromagnetic fields EN 61000-4-3
- Burst EN 61000-4-4
- Surge EN 61000-4-5
- Conducted disturbances EN 61000-4-6
- Power frequency magnetic fields EN 61000-4-8
- Voltage dips, short interruptions EN 61000-4-11

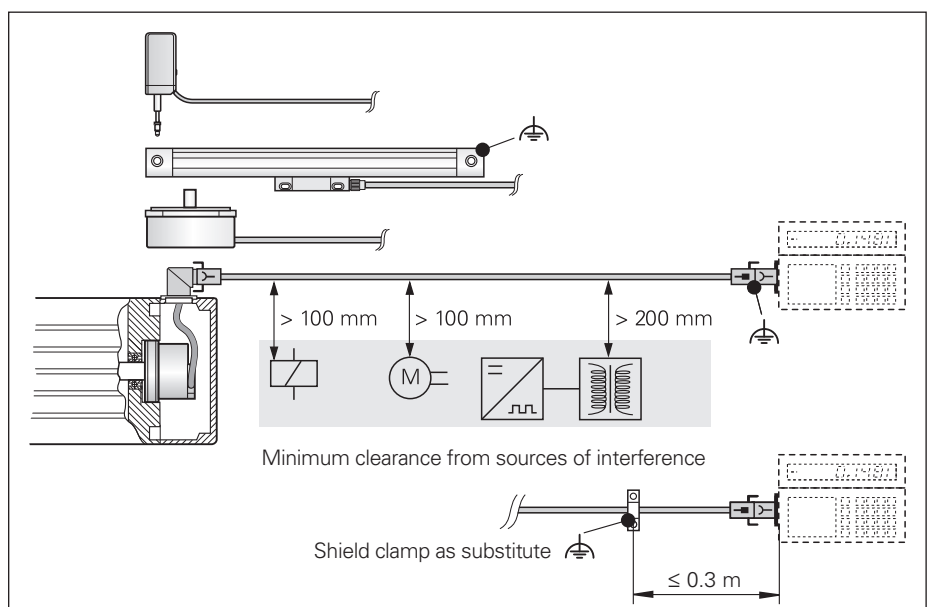
• Noise emission (EN 61000-6-4)

Measures

The EMC Directive requires the attainment of interference-free operation without the need for EMC expertise. The following measures serve to ensure this level of interference-free operation (please consult with HEIDENHAIN as needed):

- Properly install or mount HEIDENHAIN encoders in accordance with the mounting instructions
- Use only original HEIDENHAIN cables. Comply with the maximum permissible cable lengths for the respective interface. For usage that deviates from standard usage (assignment of signals and connectors), the manufacturer of the complete system must ensure conformity

- Do not install signal cables in the direct vicinity of sources of interference (inductive consumers such as contactors, motors, frequency inverters, solenoids, etc.)
 - Sufficient decoupling from interference-signal-conducting cables can usually be achieved by an air clearance of 100 mm or, when cables are routed in metal ducts, by a grounded partition
 - A minimum clearance of 200 mm from storage reactors in switching power supplies is required
- Prevent accidental contact between the shield (e.g., connector) and other metal parts
- For cables with an internal shield and external shield, connect the internal shield to 0 V on the subsequent electronics (exception: the hybrid motor cable from HEIDENHAIN; see the documentation on the hybrid motor cable). Do not connect the internal shield with the external shield
- Use connecting elements (e.g., connectors or terminal boxes) with metal housings. These connecting elements may be used only for the signals and supply voltage of the connected encoder (exception: the hybrid motor cable from HEIDENHAIN)
- Connect the encoder housing, connecting elements, and subsequent electronics with each other by means of the cable shield. Connect the shield over a large area along the complete circumference (360°). For encoders with more than one electrical connection, refer to the documentation of the respective product
- Install encoders and interface electronics with exposed electronics or a plastic housing in an enclosed metal housing. If other signals and sources of interference will pass through the housing, then EMC expertise is required, and the manufacturer of the complete system must ensure conformity
- Connect the (external) shield with functional earth in accordance with the mounting instructions
- For devices and cable assemblies with plastic connectors or connectors without a large-area shield connection, connect the (external) shield with functional earth over a large area just a short distance before the connector (shield clamp; see figure). There must be no source of interference in the immediate vicinity
- For encoders that optionally enable the connection of an external sensor (e.g., a temperature sensor), conformity with the EMC Directive applies only to operation without an external sensor. For operation with an external sensor (e.g., temperature sensor), EMC expertise is required for interference-free operation, and the manufacturer of the complete system must ensure conformity
 - In most applications, interference-free operation is possible because the disturbances acting on the sensor are low
 - In addition, the requirements for the electrical isolation of the sensor must be considered, because electrical hazards can arise in such systems
- If compensating currents are to be expected within the complete system, then a separate equipotential bonding conductor must be provided. The shield is not meant to serve as an equipotential bonding conductor
- For HEIDENHAIN encoders, provide high-frequency, low-resistance grounding (see the EMC chapter in EN 60204-01)



Related documents

Length measurement



Brochure
Linear Encoders
For Numerically Controlled Machine Tools

Contents:
Absolute linear encoders
LC
Incremental linear encoders
LB, LF, LS



Brochure
Length Gauges

Contents:
HEIDENHAIN-ACANTO
HEIDENHAIN-SPECTO
HEIDENHAIN-METRO
HEIDENHAIN-CERTO



Brochure
Exposed Linear Encoders

Contents:
Absolute linear encoders
LIC
Incremental linear encoders
LIP, PP, LIF, LIDA

Angle measurement



Brochure
Rotary Encoders

Contents:
Absolute rotary encoders
ECN, EQN, ROC, ROQ
Incremental rotary encoders
ERN, ROD



Brochure
Angle Encoders with Integral Bearing

Contents:
Absolute angle encoders
RCN, ECN
Incremental angle encoders
RON, RPN, ROD



Brochure
Encoders for Servo Drives

Contents:
Rotary encoders
Angle encoders
Linear encoders



Brochure
Modular Angle Encoders
With Optical Scanning

Contents:
Incremental angle encoders
ERP, ERO, ERA



Brochure
Modular Angle Encoders
With Magnetic Scanning

Contents:
Incremental encoders
ERM



Brochure
Angle Encoder Modules

Contents:
Angle Encoder Modules
MRP 2000/MRP 5000/MRP 8000
Angle encoder modules
with integrated torque motor
SRP 5000, AccurET

Measured value acquisition and display



Brochure
Evaluation Electronics
For Metrology Applications

Contents:
ND, QUADRA-CHEK, MSE, EIB, IK



Product Overview
Interface Electronics



Brochure
Digital Readouts/Linear Encoders
For Manually Operated Machine Tools

Contents:
Digital readouts
ND, POSITIP
Linear encoders
LS

Setup and measurement



Brochure
Measuring Devices For Machine Tool
Inspection and Acceptance Testing

Contents:
Incremental linear encoders
KGM, VM



Brochure
Cables and Connectors

Contents:
Technical characteristics, cable overviews,
and cable lists

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