Safety over EtherCAT®

Original

Absolute Encoder CD_582 EtherCAT/FSoE

CDV582

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DIN EN 61508: **SIL CL2 / SIL CL3**
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_Safety information
_Device-specific characteristics
_Installation/Commissioning
_Parameterization
_Error causes and solutions

User Manual Interface

TR-ECE-BA-GB-0177 v05 05/05/2025

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First release	05/29/2024	02
“Address correction”	08/14/2024	03
Correction in status byte: “Coupled actual value” bit 2^6 -> bit 2^5	04/17/2025	04
- Commissioning via Beckhof and Berghof control system added - New device description file for Berghof control system	05/05/2025	05

1 General information

This interface-specific user manual contains the following topics:

- Safety information
- Device-specific characteristics
- Installation/Commissioning
- Parameterization
- Error causes and solutions

As the documentation is arranged in a modular structure, this User Manual is supplementary to other documentation, such as product data sheets, dimensional drawings, brochures and safety manual etc.

The User Manual may be included in the customer's specific delivery package or it may be requested separately.

1.1 Applicability

This User Manual applies exclusively for measuring system series in accordance with the following type code with EtherCAT interface und FSoE protocol:

* 1	* 2	* 3	* 4	* 5	-	* 6	* 6	* 6	* 6	* 6

Position	Designation	Description
* 1	A C	Explosion-proof enclosure (ATEX); Absolute encoder, programmable
* 2	D	Redundant dual scanning
* 3	V H S W	Solid shaft Hollow shaft Blind shaft Draw-wire box
* 4	582	Outer diameter ∅ 58 mm, 2. generation
* 5	M S	Multi-turn Single-turn
* 6	-	Consecutive number

* = placeholder

The products are labeled with affixed nameplates and are components of a system.

The following documentation therefore also applies:

- see chapter "Applicable documents" in the safety manual https://www.tr-electronic.de/f/TR-ECE-BA-GB-0142
- Product data sheets https://www.tr-electronic.com/s/S026079

1.2 References

1.	ETG.1000.1 – 6	EtherCAT Technology Group (ETG): EtherCAT specification
2.	ETG.1600, V1.0.4	EtherCAT Technology Group (ETG): Installation guideline
3.	ETG.5100, V1.2.0	EtherCAT Technology Group (ETG): Safety over EtherCAT, protocol specification
4.	ETG.5120, V1.3.0	EtherCAT Technology Group (ETG): Safety over EtherCAT, protocol extensions
5.	EN 50325:4	Industrial Communication Systems, based on ISO 11898 (CAN) for Controller Device Interfaces. Part 4: CANopen
6.	CiA DS-301	CANopen communication profile based on CAL
7.	CiA DS-406	CANopen profile for encoders
8.	IEC 61158-1 - 6	Digital data communications for measurement and control - Fieldbus for use in industrial control systems - Protocols and services, type 12 = EtherCAT
9.	IEC 61784-2	Digital data communications for measurement and control - Additional profiles for ISO/IEC 8802-3 based communication networks in real-time applications, 12 = EtherCAT
10.	IEC 61784-3	Industrial communication networks - Profiles - Part 3: Functional safety fieldbuses- General rules and profile definitions
11.	IEC 61784-5-12	Industrial communication networks - Profiles - Part 5-12: Installation of fieldbuses - Installation profiles for CPF 12
12.	IEC 61918	Industrial communication networks - Installation of communication networks in industrial premises
13.	ISO/IEC 8802-3	Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications
14.	ISO 15745-4 AMD 2	Industrial automation systems and integration - Open systems application integration framework - Part 4: Reference description for Ethernet-based control systems; Amendment 2: Profiles for Modbus TCP, EtherCAT and ETHERNET Powerlink
15.	IEEE 1588-2002	IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

1.3 Abbreviations and terms used

0x	Hexadecimal representation
A**582*	Explosion-proof enclosure ∅ 58 mm with integrated measuring system, all variants
CAN	Controller Area Network. Data Layer Protocol for serial communication, described in ISO 11898.
CAT	Category: Classification of cables which are also used for Ethernet.
CD_	Absolute encoder with redundant dual scanning, all designs
CiA	CAN in Automation. “Internationale Anwender- und Herstellervereinigung e.V.”: non-profit organization for the Controller Area Network (CAN).
CoE	CANopen over EtherCAT
DC_{avg}	***D***iagnostic ***C***overage Average diagnostic coverage
EU	***E***uropean ***U***nion
EMV	***E***lectro ***M***agnetic ***C***ompatibility
ESM	***E***therCAT ***S***tate ***M***achine
ETG	"***E***therCAT ***T***echnology ***G***roup" user association
FSoE	Safety over EtherCAT
IEC	International Electrotechnical Commission
IP	***I***nternet ***P***rotocol
ISO	***I***nternational ***S***tandard ***O***rganisation
$MTTF_d$	***M***ean ***T***ime ***T***o ***F***ailure (dangerous) Mean time until dangerous failure
NMT	Network Management. One of the service elements in the application layer in the CAN reference model. Executes initialization, configuration and troubleshooting in bus traffic.
PDO	Process Data Object. Object for data exchange between several devices.
PDU	***P***rotocol ***D***ata ***U***nit. Contains protocol information such as source and destination address, checksum and service parameter information
PFD_{av}	***Av***erage ***P***robability of ***F***ailure on ***D***emand Average probability of failure of a safety function with low demand
Safe-Data (FailSafeData)	In the case of a safety-oriented periphery with outputs, the safety-oriented system transmits substitute values (e.g. 0) to the fail-safe outputs in the case of error instead of the output values provided in the process image by the safety program.

Continued

PFH	Probability of Failure per Hour Operating mode with high requirement rate or continuous demand. Probability of dangerous failure per hour.
SDO	Service Data Object. Point to point communication with access to the object data list of a device.
SIL	***S***afety ***I***ntegrity ***L***evel: Four discrete levels (SIL1 to SIL4). The higher the SIL of a safety-related system, the lower the probability that the system cannot execute the required safety functions.
STP	***S***hielded ***T***wisted ***P***air
Repeat test (proof test)	Repetitive test to detect hidden dangerous failures in a safety-related system.
XML	E**x**tensible **M**arkup **L**anguage, description file for commissioning the measuring system.

1.4 Main features

- EtherCAT - Interface with FSoE protocol, for transfer of a safe position and speed
- Fast process data channel over EtherCAT, not safety-oriented
- Only for variant 1:
  Additional incremental - / SIN/COS - or SSI - interface, not safety-oriented
- Two-channel scanning system, for generation of safe measured data through internal channel comparison
  - Variant 1:
    Channel 1, master system:
    optical single-turn scanning via code disk with transmitted light and magnetic multi-turn scanning

    Channel 2, inspection system:
    magnetic single- and multi-turn scanning
  - Variant 2:
    Channel 1, master system:
    magnetic single- and multi-turn scanning

    Channel 2, inspection system:
    magnetic single- and multi-turn scanning
- A common drive shaft

The data of the [1)] “leading scanning system” is provided unverified in the non-safety-related process data channel in the standard EtherCAT frame, but with a short cycle time.

The inspection system serves for the internal safety check. The "safe data" obtained through two-channel data comparison are embedded in the process data of the cyclical communication as a safety container and also made available over EtherCAT. Initiated via an FSoE master frame, the measuring system responds with an FSoE slave frame and transmits the safe input data to the FSoE master.

The SSI interface and the incremental interface, or the optionally available SIN/COS interface, are provided with a single channel and are not evaluated in terms of safety.

[1)] optical/magnetic variant: Actual value of the optical system
magnetic/magnetic variant: Actual value of the second channel

1.5 Principle of the safety function

System safety results when:

- Each of the two scanning channels is largely fail-safe thanks to individual diagnostic measures
- The measuring system internally compares the positions detected by both channels in two channels, also determines the speed in two channels and transfers the safe data in the FSoE frame via EtherCAT to the FSoE master
- In the event of a failed channel comparison or other errors detected through internal diagnostic mechanisms, the measuring system switches the Safety channel into error state
- The measuring system initialization and execution of the preset adjustment function are appropriately verified
- The control additionally checks whether the obtained position data lie in the position window expected by the control. Unexpected position data are e.g. position jumps, tracking error deviations and incorrect direction of travel
- When errors are detected the control introduces appropriate safety measures defined by the system manufacturer
- The system manufacturer ensures, through correct mounting of the measuring system, that the measuring system is always driven by the axis to be measured and is not overloaded
- The system manufacturer performs a verified test during commissioning and in the event of any parameter modification

2 Safety information

2.1 Definition of symbols and notes

⚠ DANGER	means that death or serious injury will occur if the required precautions are not met.
⚠ WARNING	means that death or serious injury can occur if the required precautions are not met.
⚠ CAUTION	means that minor injuries can occur if the required precautions are not met.
NOTICE	means that damage to property can occur if the required precautions are not met.
	indicates important information or features and application tips for the product used.

2.2 Safety functions of the fail-safe processing unit

The measuring system does not make any decisions about valid states of motion of the system in which it is used. The system must check the consistency between the position information of the measuring system and the expected movement of the system.
The **FSoE master**, to which the measuring system is connected, must perform the following safety checks.

To enable the correct measures to be taken in the case of error, the following applies:

If no safe position can be output due to an error detected by the measuring system, the safety channel is set to `FailSafeData` state and automatically put into fail-safe state, safety status LED = red. In this state so-called "safe data" are output via the safety channel. Also see the chapter “Output of safe data (substitute values)” on page 72.

Fail-safe state from the viewpoint of the measuring system:

- Safety state: FailSafeData
- Safety frame: Data are set to 0

Upon receipt of safe data the FSoE master must put the system into a safe state. You can only leave this error state by eliminating and then acknowledging the error, see chapter “Error acknowledgement – flow diagram“ on page 75.

The process data channel addressable via EtherCAT standard is not necessarily affected by this. If the internal diagnosis in the leading channel does not detect an error, the process data are still output.

2.2.1 Mandatory safety checks / measures

Measures for commissioning, changes	Error reaction
Application-dependent parameterization of safety parameters, see chapter “Object 8000h: FSoE parameter settings” on page 62.	–
In the event of parameter changes, check that the measure is performed as desired.	STOPP

Check by FSoE master	Error reaction
Cyclical consistency check of the current safety-related safety data to the previous data.	STOPP
Consistency check between the safety position information of the measuring system and the movement of the system.	STOPP
Monitoring of cyclical safety data.	PDU-Command = FailSafeData -> STOPP
FSoE watchdog time: Monitoring of the measuring system response time. For checking e.g. cable breakage, power failure, etc. The maximum permitted value for the FSoE watchdog is 65535 ms.	STOPP

3 Installation / Preparation for Commissioning

3.1 Basic rules

⚠ WARNING ***Deactivation of the safety function through conducted interference sources!***

- All EtherCAT FSoE devices used on the bus must have an EtherCAT- and an FSoE-certificate.
- All safety-oriented devices must also have a certificate from a "Notified Body" (e.g. TÜV, BIA, HSE, INRS, UL, etc.).
- The 24V power supplies used must fulfil the requirements according to IEC 60364-4-41 SELV/PELV.
- The shielding effect of cables must also be guaranteed after installation (bending radii/tensile strength!) and after connector changes. In cases of doubt, use more flexible cables with a higher current carrying capacity.
- For connecting the measuring system only use M12 connectors, which guarantee good contact between the cable shield and connector housing. The cable shield must be connected to the connector housing over a large area.
- Compensating currents due to potential differences across the shield to the measuring system must be avoided.
- A shielded and stranded data cable must be used to ensure high electromagnetic interference stability of the system. The shielding should be connected with low resistance to protective ground using large shield clips **at both ends**. The shielding should be grounded **in the switch cabinet only** if the machine ground is heavily contaminated with interference towards the switch cabinet ground.
- Equipotential bonding measures must be provided for the complete processing chain of the system.
- Power and signal cables must be laid separately. During installation the national safety and installation directives for data and energy cables must be observed.
- Observe the manufacturer's instructions for the installation of converters and for shielding power cables between frequency converter and motor.
- Ensure adequate dimensioning of the energy supply.

Upon completion of installation, a visual inspection with report should be carried out. Wherever possible, the quality of the network should be verified using a suitable bus analysis tool.

To ensure safe and fault-free operation,

- *ETG.1600 EtherCAT Installation guideline*
- *IEC 60204-1*
- *and the standards and directives referenced therein must be observed!*

In particular the EMC directive in its valid version must be observed!

3.2 EtherCAT transmission technology, cable specification

The safety-oriented FSoE communication is embedded in the standard protocol of EtherCAT and transmitted over the same network.

EtherCAT supports linear, tree or star structures. The bus or linear structure used in the field buses is thus also available for Ethernet. This is particularly practical for system wiring, as a combination of line and stubs is possible.

For transmission according to the 100Base-TX Fast Ethernet standard, patch cables in category STP CAT5 must be used (2 x 2 shielded twisted pair copper wire cables). The cables are designed for bit rates of up to 100 MBit/s. Because the measuring system supports the “auto-crossover-function”, it can be used crossover cables as well as uncrossed cables. The transmission speed is automatically detected by the measuring system and does not have to be set by means of a switch.

EtherCAT addressing by switch is also not necessary; this is done automatically using the addressing options of the EtherCAT master.

The cable length between two nodes may be max. 100 m; a total of 65535 nodes are possible in the EtherCAT network.

3.3 Connection instructions

The pin assignment depends on the device version and is therefore noted on every connector as a pin assignment number. When the measuring system is delivered, a printed device-specific pin assignment form is enclosed.

Download
https://www.tr-electronic.com/service/downloads/pin-assignments.html

⚠ WARNING

NOTICE

The measuring system may be destroyed or damaged or its function be impaired by ingress of moisture!

- Connector plugs of the measuring system that are unused during storage and/or operation of the system have to be provided either with a mating connector or a protective cap. The IP degree of protection is to be selected according to requirements.
- Protective cap with O-ring:
  When re-closing, check that the O-ring is present and seated properly.
- For suitable protective caps, see the Chapter on Accessories in the Safety Manual.

3.3.1 Supply voltage

NOTICE

The internal electronics may be damaged by impermissible overvoltages and this damage go unnoticed!

- The power supply used must meet the requirements of
  – SELV/PELV (IEC 60364-4-41:2005)
  – and be designed according to NEC Class 2,
  see also Chapter “UL/CSA Approval” in the safety manual

Cable specification: min. 0.34 mm^2 (recommended 0.5 mm^2). Generally, the cable cross-section must be harmonized with the cable length. At use in particularly sensitive EMC environments, the use of a shielded cable is recommended.

3.3.2 Optional additional interfaces (Incremental, SSI)

Cable specification: min. 0.25 mm^2 and shielded.
To guarantee the signal quality and minimization of possible environmental influences, we urgently recommend to use a shielded twisted pair cable.

3.4 Setting the FSoE address

Each FSoE slave device is addressed via a system-wide unique 16-bit safety address. However, the measuring system only supports an adjustable address range of eight bits: 1 to 255.

The set safety address can be read out via “Object F980h: Safe address”.

⚠ WARNING

The measuring system may be destroyed or damaged or its function be impaired by penetration of foreign bodies and ingress of moisture!

NOTICE

- Firmly close the access to the address switches with the screw plug after the settings have been made.

The safety address is set via two HEX rotary switches (B) which are only read at the moment of switch-on. Subsequent settings during operation are therefore not recognized.

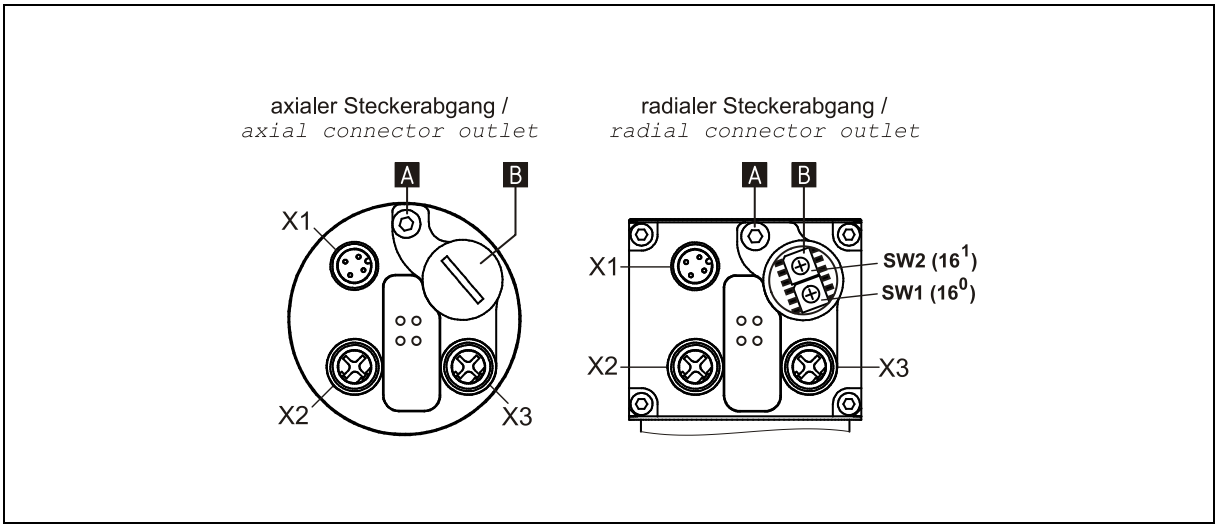


Figure 1: FSoE address, switch assignment

3.5 Incremental interface / SIN/COS interface (optional)

In addition to the EtherCAT – interface for outputting the absolute position, the measuring system can be equipped with an additional incremental interface.
Adjustable parameter, see chapter “Object 2520h: ITF2_Incr_Parameter” on page 52.

Alternatively, this interface can also be designed as a SIN/COS interface. This interface cannot be parameterized.

⚠ WARNING ***This additional interface is not evaluated in relation to safety and may not be used for safety instrumented purposes!***

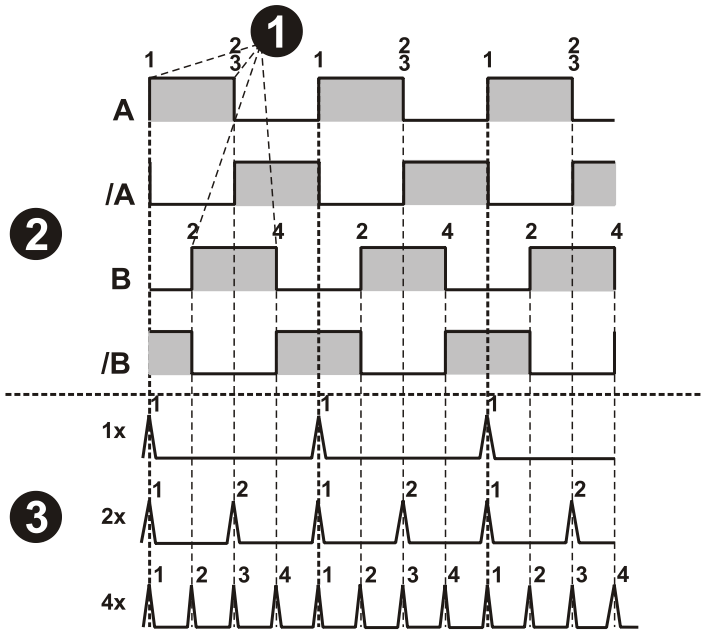
- ➢ In motor control applications, the interface is generally used as position feedback.

NOTICE ***In the event of overvoltage, caused by a missing ground reference point, there is a danger of damage to the downstream electronic devices!***

- If the ground reference point is completely missing, e.g., 0 V of the power supply are not connected, voltages equal to the supply voltage can occur at the outputs of this interface.
  - ➢ Ensure that a ground reference point is present at all times,
  - ➢ or the organization responsible for the system must provide appropriate protective measures for downstream electronic devices.

The signal characteristics of the two possible interfaces are shown below.

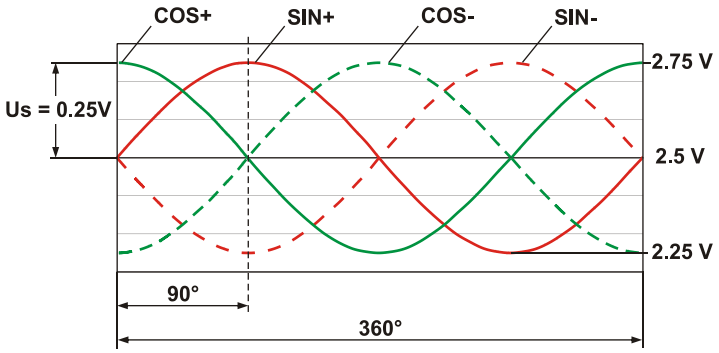
3.5.1 Signal characteristics



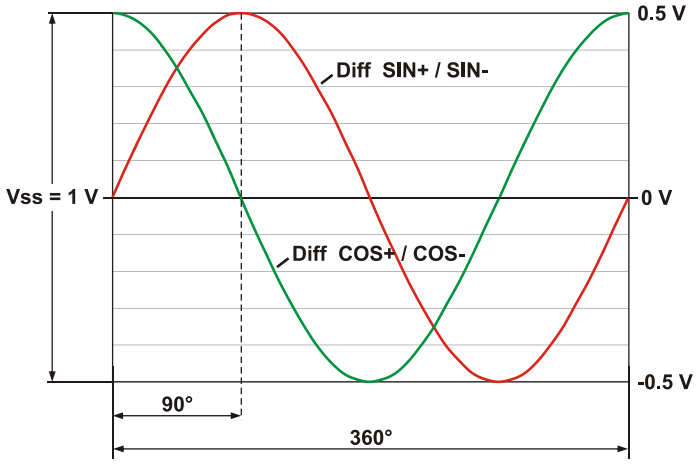
1: Edge evaluation
2: Measuring system with 1024 pulses/revol.
3: Counter evaluation

1x: 1024 counter pulses/rev.
2x: 2048 counter pulses/rev.
4x: 4096 counter pulses/rev.

Figure 2: Counter evaluation, incremental interface



Measurement of signals tending to 0 V



Differential measurement

Figure 3: Level definition, SIN/COS interface

3.5.2 HTL/TTL Level (optional)

Optionally, the incremental interface is also available with HTL and TTL levels. For technical reasons, the user using this version has to take the following general conditions into account: ambient temperature, cable length, cable capacitance, supply voltage, and output frequency.

In this case, the maximum output frequencies that can be reached via the incremental interface are a function of the cable capacitance, the supply voltage and the ambient temperature. Therefore, the use of this interface is reasonable only if the interface characteristics meet the technical requirements.

From the view of the measuring system, the transmission cable represents a capacitive load which must be reloaded with each impulse. The load quantity required varies strongly depending on the cable capacitance. It is this reloading of the cable capacitances that is responsible for the high power dissipation and heat, which result in the measuring system.

The following diagrams show, separated by TTL and HTL version, the different dependencies with respect to three different supply voltages.

TR's own hybrid cable (part number: 64-200-021) was used for the measurements.

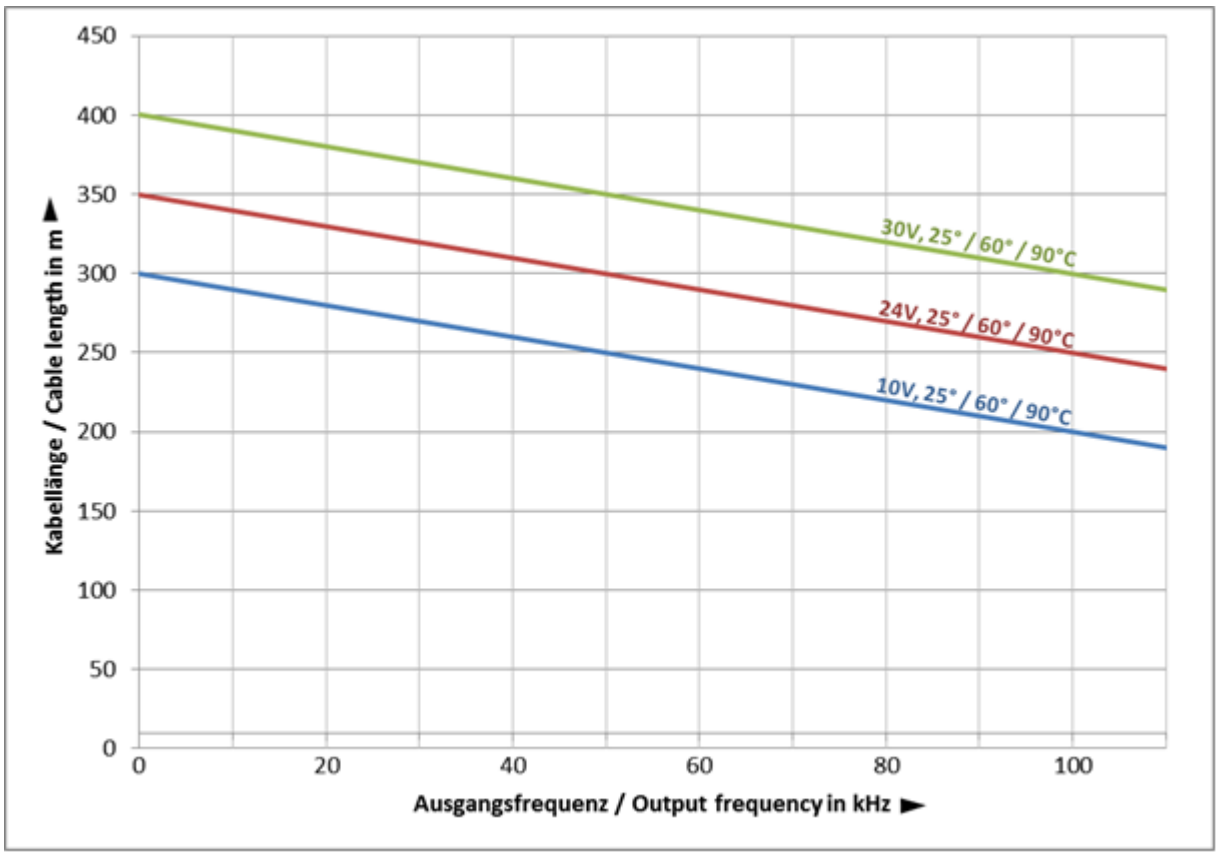


Figure 4: Cable lengths / limit frequencies, TTL version

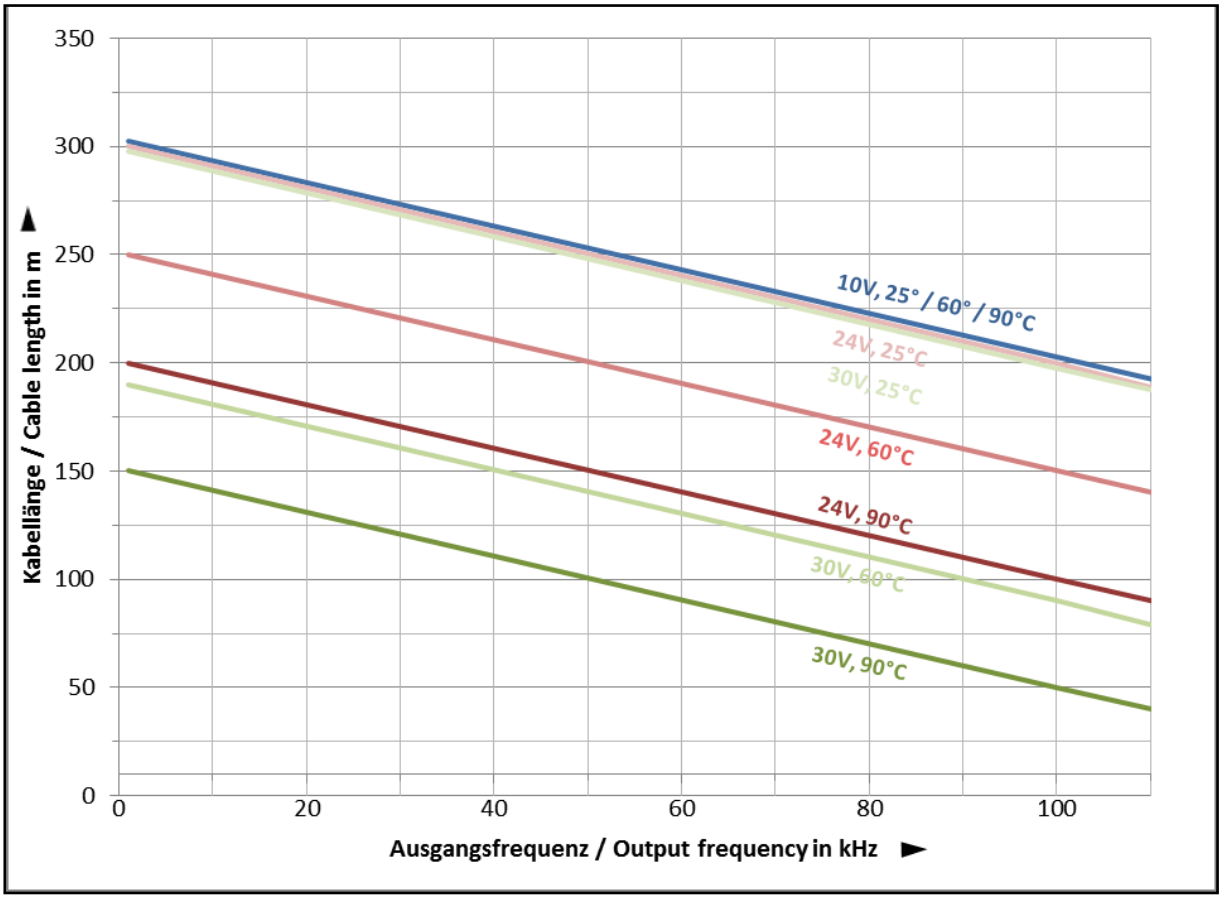


Figure 5: Cable lengths / limit frequencies, HTL version

Other cable parameters, frequencies and ambient temperatures as well as bearing heat and temperature increase via the shaft and flange, can yield a considerably poorer result in practice.

Therefore, the fault-free function of the incremental interface with the application-dependent parameters has to be checked prior to productive operation.

3.6 SSI interface (optional)

Instead of the incremental interface, the measuring system can be optionally equipped with a synchronous serial absolute SSI interface in addition to the EtherCAT – interface.

Adjustable parameters, see chapter “Object 2500h: ITF2_SSI_Parameter” on page 49.

⚠ WARNING ***This additional interface is not evaluated in relation to safety and may not be used for safety instrumented purposes!***

- The interface is typically used for control purposes when transferring absolute value data to a second non-safety instrumented controller.

3.6.1 Signal characteristics

In power-down mode, Data+ and Clock+ are set to high. In the diagram below, this corresponds to the Time before point **(1)**.

When the clock signal changes from High to Low **(1)** for the first time, the device-internal re-triggerable monoflop is set to monoflop time t_M.
The time t_M determines the lowest transmission frequency ($T = t_M / 2$). The upper limit frequency results from the sum of all signal propagation times and is additionally limited by the built-in filter circuits.

With each further falling clock edge, the active state of the monoflop is extended by the time t_M – this happens last at point **(4)**.
Setting the monoflop **(1)** causes the bit-parallel data pending at the internal parallel-to-serial converter to be stored by an internally generated signal in an input latch of the shift register. This ensures that the data does not change during the transmission of an actual position value.

When the clock signal changes from Low to High **(2)** for the first time, the most significant device information bit (MSB) is applied to the serial data output. With each further rising edge, the next lower-order bit is pushed to the data output.
When the clock rate has ended, the data lines are kept at 0 V (low) for the duration of the monoflop time t_M **(4)**. This also results in the minimum pause time t_p, which must be maintained between two consecutive clock sequences and is $2 * t_M$.

The evaluation electronics read the data already at the first rising clock edge. Various factors result in a delay time t_V >100 ns, without cables. The measuring system data push to the output is thus delayed by the time t_V. Therefore, a “Pause-1” is read at time **(2)**. This must be discarded or used for line break monitoring in conjunction with a “0” after the LSB data bit. The MSB data bit is read only at time **(3)**. Therefore, the clock number must always be one higher (n+1) than the number of data bits to be transmitted.

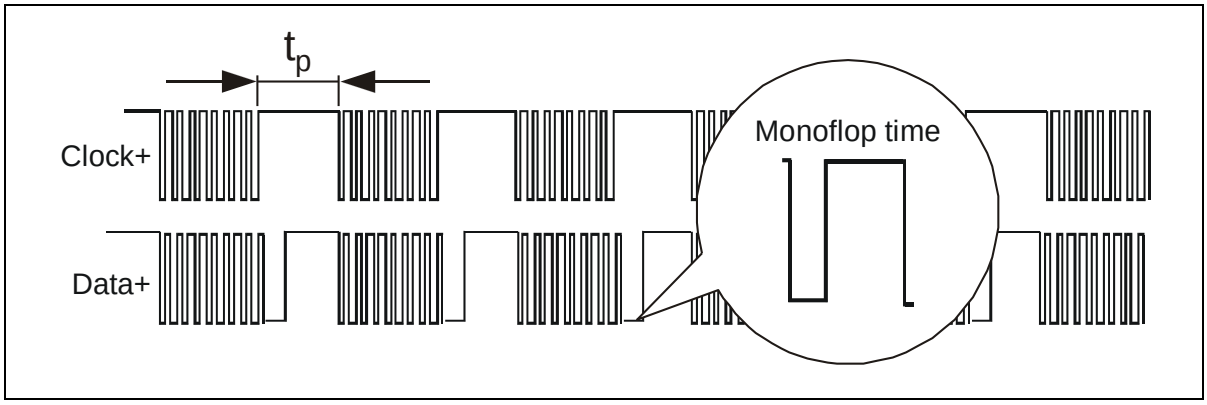


Figure 6: Typical SSI transmission sequences

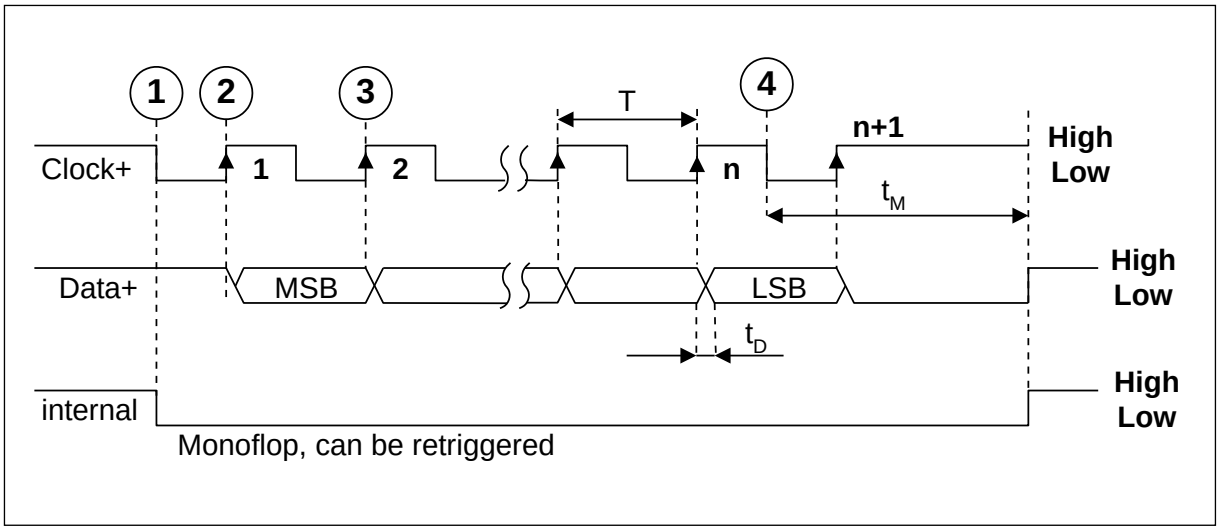


Figure 7: SSI transmission format

3.6.2 Cable length

The maximum cable length depends on the SSI clock frequency and cable quality.

TR's own hybrid cable (part number: 64-200-021) was used for the measurements.

SSI clock frequency [kHz]	2000	1000	500	250	125	125	125
Cable length [m]	ca.12,5	ca. 25	ca. 50	ca. 100	ca. 150	ca. 200	ca. 250

Table 1: SSI clock frequency / Cable lengths

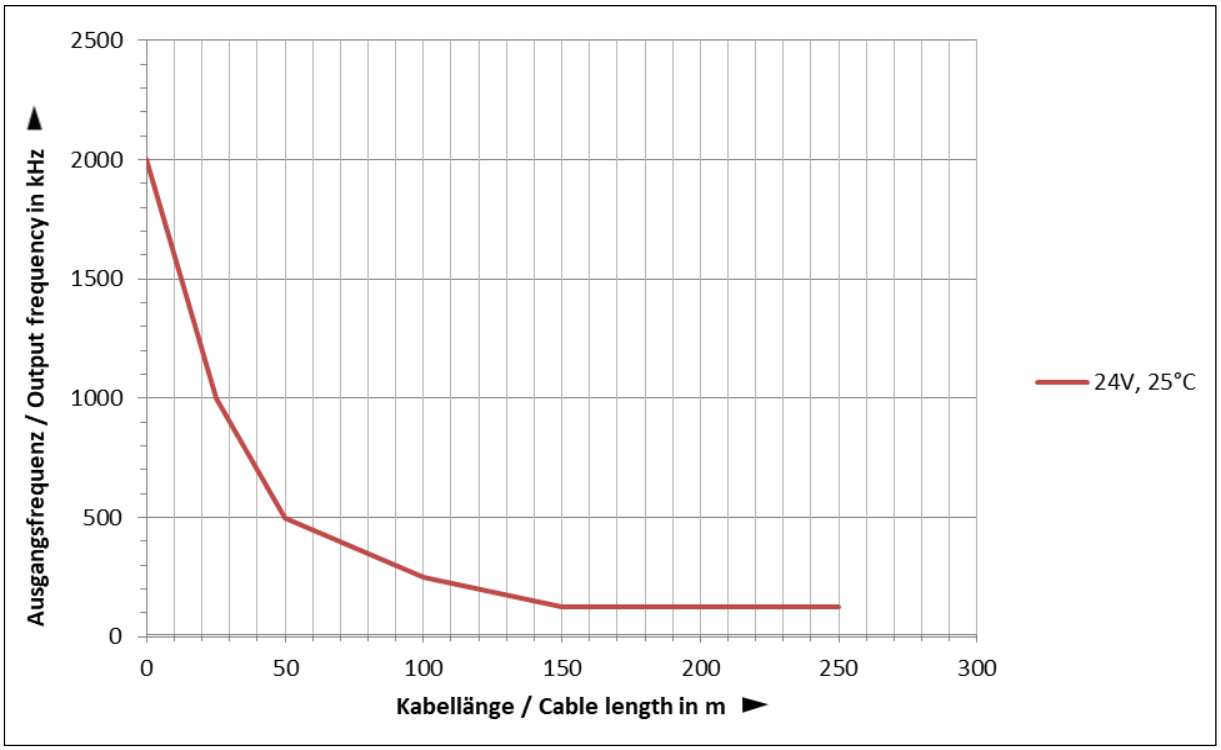


Figure 8: SSI clock frequency / Cable lengths

Other cable parameters, frequencies and ambient temperatures as well as bearing heat and temperature increase via the shaft and flange, can yield a considerably poorer result in practice.

Therefore, the fault-free function of the ssi interface with the application-dependent parameters has to be checked prior to productive operation.

4 Commissioning

4.1 EtherCAT / FSoE

The EtherCAT functional principle and the general communication process are described in the ETG specifications *ETG.1000.1 to ETG.1000.6 EtherCAT Specification - Part 1 to Part 6.*

Especially for planning, assembly and commissioning, the ETG guideline
ETG.1600 Guideline for Planning, Assembling and Commissioning of EtherCAT Networks is provided.

The safety protocol *Safety over EtherCAT (FSoE)* is described in the ETG specification
ETG.5100 Protocol Specification, important extensions are contained in the
ETG.5120 Protocol Enhancements.

This and further information on EtherCAT FSoE is available on request from the ***EtherCAT Technology Group*** (ETG) at the address below:

ETG Headquarter
Ostendstraße 196
90482 Nuremberg
Germany
Phone: + 49 (0) 9 11 / 5 40 5620
Fax: + 49 (0) 9 11 / 5 40 5629
Email: info@ethercat.org
Internet: www.ethercat.org

4.2 Device description file (XML)

A device description file, the so-called "EtherCAT Slave Information" file (ESI), must be supplied with each EtherCAT device. This file, written in XML, contains all information about the measuring system-specific parameters and operating modes of the measuring system.

The XML file is integrated by the EtherCAT network configuration tool in order to properly configure and commission the measuring system.

Download, standard

- www.tr-electronic.de/f/TR-ECE-ID-MUL-0081

Download, Berghof control system

- www.tr-electronic.de/f/TR-ECE-ID-MUL-0085

Observe Readme.txt - file

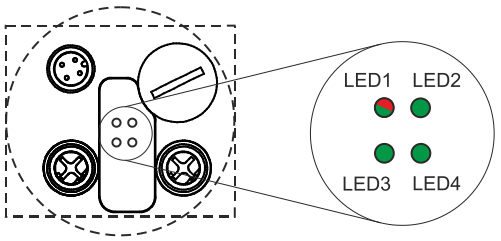
4.3 Bus status display

⚠ WARNING

Destruction, damage and malfunction of the measuring system due to penetration of foreign bodies and moisture!

NOTICE

- Securely seal the access to the LEDs again with the screw plug after completing the settings.



LED1: FSoE Status (green/red)
LED2: Net Run (green)
LED3: EtherCAT IN, Link/Activity (green)
LED4: EtherCAT OUT, Link/Activity (green)

Figure 9: Bus status display

4.3.1 Display states and flashing frequency

LED	Description
ON	Continuously ON
OFF	Continuously OFF
Flickering	Same ON and OFF times with a frequency of around 10 Hz: ON = 50 ms, OFF = 50 ms.
Blinking	Same ON and OFF times with a frequency of around 2.5 Hz: ON = 200 ms, OFF = 200 ms.
Single flash	Single short flash, ON around 200 ms, followed by a long OFF time, around 1000 ms
Double flash	Double short flash, ON/OFF around 200 ms, followed by a long OFF time, around 1000 ms
Triple flash	Triple short flash, ON/OFF around 200 ms, followed by a long OFF time, around 1000 ms

4.3.2 LED1, FSoE Status

green	Description
OFF	Initialization, device off
Single flash	INIT state, booting
Double flash	Data state – output of safe data
ON	Data state – output of process data
rot	**Description**
Single flash	Error acknowledgement required by the user
ON	System or safety error

For appropriate measures in case of error, see chapter “Troubleshooting and Diagnosis Options”, page 73.

4.3.3 LED2, Net Run

green	Description
OFF	Device is in *INIT* state
Blinking	Device is in *PRE-OPERATIONAL* state
Single flash	Device is in *SAFE-OPERATIONAL* state
ON	Device is in *OPERATIONAL* state
Flickering	Bootstrap: A firmware update can be performed in this status

4.3.4 LED3/4, EtherCAT IN/OUT – Link/Activity

green	Description
OFF	No Ethernet connection
ON	Ethernet connection established
Flickering	Data transmission

For appropriate measures in case of error, see chapter “Troubleshooting and Diagnosis Options”, page 73.

4.4 Commissioning via Beckhoff control system

Download
Technical information: www.tr-electronic.de/f/TR-ECE-TI-DGB-0416

4.5 Commissioning via Berghof control system

Download
Technical information: www.tr-electronic.de/f/TR-ECE-TI-DGB-0420

5 Structure of Process Data

5.1 Safety-oriented process data

Via the FSoE master, the safety-related process data can optionally be mapped or hidden in the input and output process data (mapping objects 0x1A00/0x1600).

- There are two modules for the safety slot:
  - Standard `FSoE` module
  - `FSoE 16bit` module for transmission of 16-bit values.
  This selection option is intended for FSoE masters that cannot process 32-bit values in the FSoE protocol.
- If the `FSoE 16bit` module is selected, the application program must ensure that the input data or output data with 32-bit data format can be read or written contiguously.

Structure of the input data

Byte	Bit	Input data	Data type	Object description
X+0	2^0-2^7	SafeStatus	UNSIGNED16	0x6801, see page 60
X+1	2^8-2^{15}			
X+2	2^0-2^7	Safe absolute position	UNSIGNED32	0x6801, see page 60
X+3	2^8-2^{15}			
X+4	2^{16}-2^{23}			
X+5	2^{24}-2^{31}			
X+6	2^0-2^7	Safe speed value	INTEGER32	0x6801, see page 60
X+7	2^8-2^{15}			
X+8	2^{16}-2^{23}			
X+9	2^{24}-2^{31}			

Structure of the output data

Byte	Bit	Output data	Data type	Object description
X+0	2^0-2^7	SafeControl	UNSIGNED16	0x7001, see page 61
X+1	2^8-2^{15}			
X+2	2^0-2^7	Safe preset value	UNSIGNED32	0x7001, see page 61
X+3	2^8-2^{15}			
X+4	2^{16}-2^{23}			
X+5	2^{24}-2^{31}			

5.1.1 Input data

5.1.1.1 SafeStatus

⚠ WARNING

NOTICE

- **Danger of death, serious physical injuries and/or damage to property due to uncontrolled start-up of the drive system, in the event of NON-evaluation of `Safe state` bit 2^4!**
  - ➢ The output actual values are only valid if `Safe state` bit $2^4 = 1$.

UNSIGNED16

Bit	Description
2^0	`Safe speed error` Bit = 1, if the speed value is outside the range of –2147483648…+2147483647.
2^1	`Error acknowledge requested` Bit = 1, if the measuring system is in a safe state and is waiting for an error acknowledgement.
2^2	`Safe preset OK` Bit = 1, if a preset request was executed successfully.
2^3	`Safe preset error` Bit = 1, if a preset request could not be executed due to an error. The bit can be reset via the preset control bits `Safe preset request` and `Safe preset preparation`, see also page 33.
2^4	`Safe state` Bit = 0, - in the initialization phase, or if the initialization could not be completed successfully - if a preset request is initiated via the `Safe preset preparation` control bit - if an exception error occurs during preset execution - if the measuring system is in the safe state Bit = 1, - if the initialization was successfully completed - if a preset request could be successfully executed and the preset control bits `Safe preset request` and `Safe preset preparation` were reset again
2^5	`Safe preset active` Bit = 1, if preset execution is triggered via the `Safe preset request` control bit. The bit is automatically reset after preset execution has finished, see also page 33.
2^6	reserved
2^7	`Safe scaling error` Bit = 1, if the measuring system was moved in a de-energized state. As it is not possible to check whether a zero transition has been generated, the output position must first be verified with the desired mechanical position before the application is started. After positive verification, the bit can be deleted by executing the preset adjustment function, see chapter 5.1.3 on page 33.
2^8…2^{15}	reserved

5.1.1.2 Safe absolute position

Actual value scaled, UNSIGNED32

Byte	X+2	X+3	X+4	X+5
Bit	7 – 0	15 – 8	23 – 16	31 – 24
Data	$2^7 – 2^0$	$2^{15} – 2^8$	$2^{23} – 2^{16}$	$2^{31} – 2^{24}$

The current scaled actual position is output via the `Safe absolute position` register.

The output position is not signed.

5.1.1.3 Safe speed value

Speed, INTEGER32

Byte	X+6	X+7	X+8	X+9
Bit	7 – 0	15 – 8	23 – 16	31 – 24
Data	$2^7 – 2^0$	$2^{15} – 2^8$	$2^{23} – 2^{16}$	$2^{31} – 2^{24}$

The speed is output as a signed two's complement value.

Setting the direction of rotation = `True`

– With view of the flange, turn the shaft clockwise:
--> Positive speed output

Setting the direction of rotation = `False`

– With view of the flange, turn the shaft clockwise:
--> Negative speed output

If the measured speed exceeds the display range of –2147483648…+2147483647, this results in an overflow, which is reported in the status register via bit 2^0. At the time of the overflow, the speed remains at the respective +/- maximum value until the speed returns to the display range. In this case, the message in the status register is also deleted.
The speed is output in the parameterized unit.

5.1.2 Output data

5.1.2.1 SafeControl

UNSIGNED16

Byte	X+0	X+1
Bit	7 – 0	15 – 8
Data	2^7 – 2^0	2^{15} – 2^8

Bit	Description
2^0	`Safe preset preparation` The bit is used to prepare the preset adjustment function. The actual preset can only be executed via the `Safe preset request` control bit if this bit is set. A strict sequence must be followed to execute the function, see chapter “Preset adjustment function” on page 33.
2^1	`Safe preset request` The bit is used to control the preset adjustment function. When this function is executed, the measuring system is set to the position value stored in the `Safe preset value` register. A strict procedure must be followed to execute the function, see chapter „Preset adjustment function“ on page 33.
2^2…2^5	reserved
2^6	`Error acknowledge` The bit is used for error acknowledgement by the user if the input bit 2^1 `Error acknowledge requested` has been set to “1” by the measuring system, see chapter „SafeStatus“ on page 30.
2^7…2^{15}	reserved

5.1.2.2 Safe preset value

Preset setpoint, UNSIGNED32

Byte	X+2	X+3	X+4	X+5
Bit	7 – 0	15 – 8	23 – 16	31 – 24
Data	2^7 – 2^0	2^{15} – 2^8	2^{23} – 2^{16}	2^{31} – 2^{24}

The desired preset value must be within the programmed measuring length –1,
max. 536870911 (29 bits).
The preset value is set as the new position when the preset adjustment function is executed, see chapter “Preset adjustment function” on page 33.

5.1.3 Preset adjustment function

⚠ WARNING

NOTICE

- **Danger of death, serious physical injury and/or damage to property due to uncontrolled start-up of the drive system during execution of the preset adjustment function!**
  - ➢ The relevant drive systems must be locked to prevent automatic start-up
  - ➢ It is advisable to protect the preset triggering via the FSoE master by means of additional protective measures, such as e.g. key-operated switch, password etc.
  - ➢ The procedure specified below must be observed; in particular, the status bits must be evaluated by the FSoE master, in order to check successful or incorrect execution
  - ➢ The new position must be checked after execution of the preset adjustment function

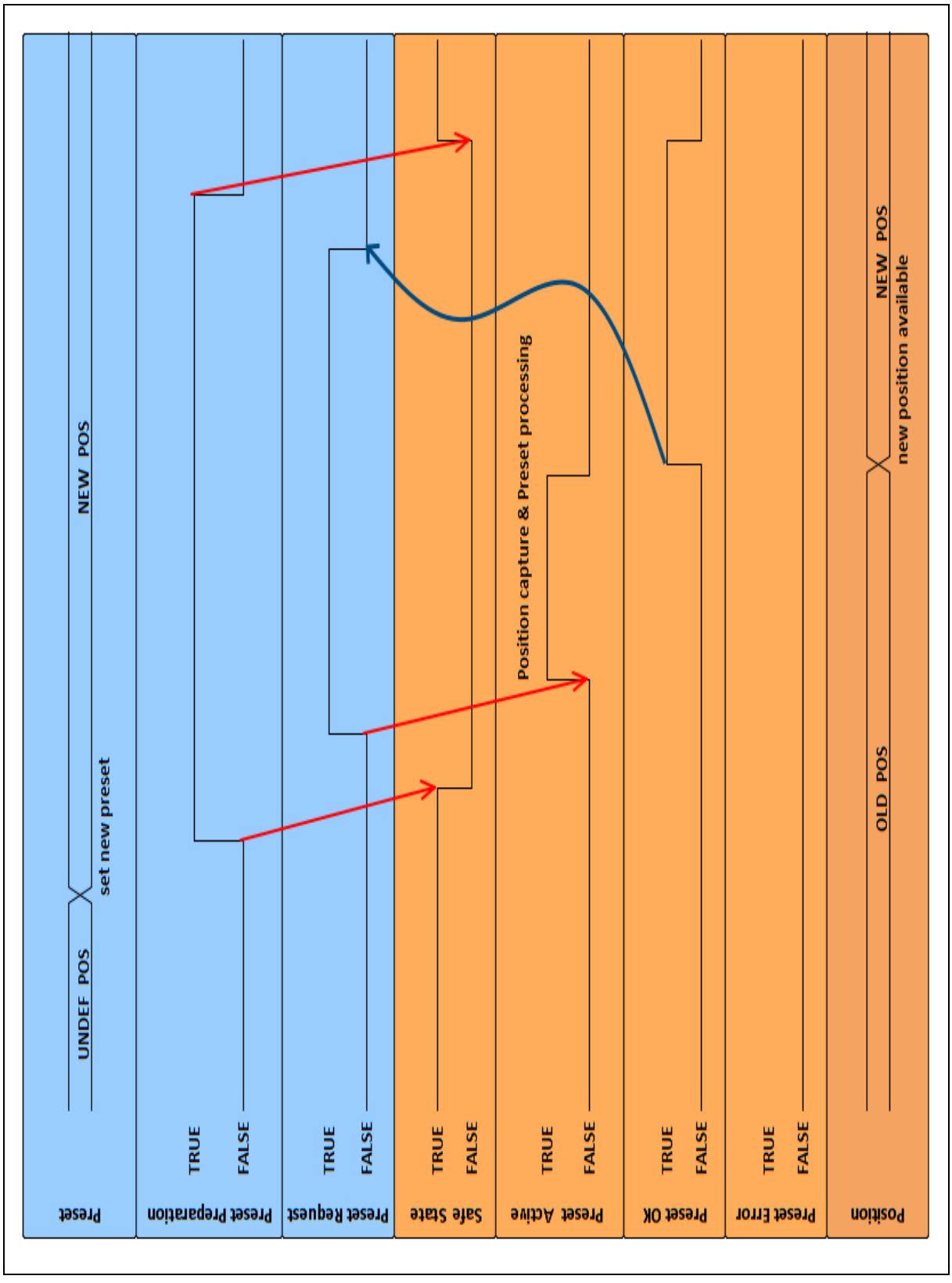
The preset adjustment function is used to set the currently output position value to any position value within the measuring range. The displayed position can thus be set to a machine reference position purely electronically.

Procedure with the FSoE-Master

- ➢ Prerequisite: The measuring system is in cyclical data exchange.
- ➢ Write the desired preset value to the `Safe preset value` register in the output data of the FSoE master.
- ➢ Set `Safe preset preparation` and `Safe preset request` control bits to 0.
- ➢ Set `Safe preset preparation` control bit to 1. As a result the `Safe state` status bit is to 0, and the FSoE master must then switch the system to a safe state. The output position value is no longer safe!
- ➢ With a rising edge of the `Safe preset request` control bit, the preset value is accepted. Receipt of the preset value is acknowledged by setting (=1) the `Safe preset active` status bit. When the preset has been executed, the `Safe preset active` status bit is reset to 0.
- ➢ After receipt of the preset value, the measuring system checks that all prerequisites for execution of the preset adjustment function are fulfilled. If so, the preset value is written as the new position value. In case of error, the execution is rejected and an error message is output by setting the `Safe preset error` status bit.
- ➢ After successful execution of the preset adjustment function, the measuring system sets the `Safe preset OK` status bit to 1 to indicate to the FSoE master that the preset execution is complete.
- ➢ Reset the `Safe preset request` control bit to 0.
- ➢ Reset the `Safe preset preparation` control bit to 0. As a result, the `Safe state` status bit is reset to 1.
- ➢ Finally, the FSoE master must check that the new position corresponds to the new set position.

5.1.3.1 Timing diagram

blue area: Output signals FSoE Master -> measuring system
orange area: input signals measuring system -> FSoE master



5.2 NON-safety-related process data

The FSoE master can be used to display or remove the NON-safety-related process data in the input and output process data (mapping objects 0x1A01/0x1601).

Structure of the input data

Byte	Bit	Input data	Data type	Object description
X+0	2^0-2^7	Status Bits	UNSIGNED8	0x3010, see page 54
X+1	2^0-2^7	Position	UNSIGNED32	0x3012, see page 55 / 0x6004, see page 58
X+2	2^8-2^{15}			
X+3	2^{16}-2^{23}			
X+4	2^{24}-2^{31}			
X+5	2^0-2^7	Speed	INTEGER32	0x3011, see page 55
X+6	2^8-2^{15}			
X+7	2^{16}-2^{23}			
X+8	2^{24}-2^{31}			

Structure of the output data

Byte	Bit	Output data	Data type	Object description
X+0	2^0-2^7	Control Bits	UNSIGNED8	0x3100, see page 56
X+1	2^0-2^7	Preset	UNSIGNED32	0x3101, see page 56
X+2	2^8-2^{15}			
X+3	2^{16}-2^{23}			
X+4	2^{24}-2^{31}			

5.2.1 Input data

5.2.1.1 Status Bits (status byte)

UNSIGNED8

Byte	X+0
Bit	7 – 0
Data	2^7 – 2^0

Bit	Description
2^0	Adjustment OK 1: Adjustment has been executed
2^1	Output of the original position 0: own channel **A** [1)] or **B** [1)] in error state 1: Output of the original position, either -> by channel 1 (master system) or -> by channel 2 (test system), depending on how the submodule configuration was assigned
2^2	Output of the substitute position 0: No output of the substitute position 1: Output of the substitute position, either -> by channel 2 (test system) in the case of the error constellation **A** or -> by channel 1 (master system) in the case of the error constellation **B** The substitute position must be configured accordingly, see chapter 6.2.1.8: Setting in subindex 10 = `on`
2^3	reserved
2^4	Speed overflow 0: No speed overflow 1: Speed overflow present
2^5	Coupled actual value 0: No channel coupling 1: Channel coupling activated The channel coupling must be configured as required, see chapter 6.2.1.9: Setting in subindex 11 = `on`
2^6	reserved
2^7	Adjustment error 1: Error, adjustment was not executed

1)
A : Channel 1 (Master system)
B : Channel 2 (Test system)

5.2.1.2 Position

Actual value scaled, UNSIGNED32

Byte	X+1	X+2	X+3	X+4
Bit	7 – 0	15 – 8	23 – 16	31 – 24
Data	$2^7 – 2^0$	$2^{15} – 2^8$	$2^{23} – 2^{16}$	$2^{31} – 2^{24}$

The current scaled actual position is output via the `Position` register.

The output position is not signed.

5.2.1.3 Speed

Speed, INTEGER32

Byte	X+5	X+6	X+7	X+8
Bit	7 – 0	15 – 8	23 – 16	31 – 24
Data	$2^7 – 2^0$	$2^{15} – 2^8$	$2^{23} – 2^{16}$	$2^{31} – 2^{24}$

The speed is output as a signed two's complement value.

Setting the direction of rotation = `True`

With view of the flange, rotate the shaft clockwise:
--> positive speed output

Setting the direction of rotation = `False`

With view of the flange, rotate the shaft clockwise:
--> negative speed output

If the measured speed exceeds the display range of –2147483648…+2147483647, this results in an overflow, which is reported in the status register via bit 2^4. At the time of the overflow, the speed remains at the respective +/- maximum value until the speed returns to the display range. In this case, the message in the status register is also deleted.
The speed is output in the parameterized unit.

5.2.2 Output data

5.2.2.1 Control Bits (control byte) / Preset adjustment function

⚠ WARNING

NOTICE

Danger of physical injury and damage to property due to an actual value jump during execution of the preset adjustment function!

- The adjustment function should only be executed when the measuring system is at a standstill, or the resulting actual value jump must be permitted by the program and the application!

UNSIGNED8

Byte	X+0
Bit	7 – 0
Data	2^7 – 2^0

Bit	Description
2^0	Execute adjustment (edge 0 -> 1)
2^1…2^7	reserved

The `Preset` register can be used to transfer a 32-bit adjustment value via the process output data and set it as the new position value. The adjustment value must be within the programmed measuring length –1. If an invalid adjustment value is transferred, the adjustment is not accepted and error bit 2^7 `Adjustment error` is set in the status byte. With control byte = 0x00, error bit 2^7 `Adjustment error` in the status byte is deleted again.

The adjustment value is set with rising edge 0->1 of bit 2^0 `Execute adjustment` (0x01) in the control byte. The execution of the adjustment is acknowledged in the status byte by setting bit 2^0 `Adjustment OK` (0x01). When bit 2^0 `Execute adjustment` (0x00) in the control byte is reset, bit 2^0 `Adjustment OK` (0x00) in the status byte is also automatically reset.

5.2.2.2 Preset

Adjustment setpoint, UNSIGNED32

Byte	X+1	X+2	X+3	X+4
Bit	7 – 0	15 – 8	23 – 16	31 – 24
Data	2^7 – 2^0	2^{15} – 2^8	2^{23} – 2^{16}	2^{31} – 2^{24}

The desired adjustment value must be within the programmed measuring length –1.

The adjustment value is set as the new position when the adjustment function is executed via the control byte.

6 EtherCAT – Object Directory

Both NON-safety-oriented and the safety-oriented data packed in safety frames are transferred via the objects in the EtherCAT directory. However, the use of safety-oriented data in the non-safety-oriented control is not safe for the purposes of a safety standard.
The overall management occurs via the NON-safety-oriented control section.

6.1 CoE communication-specific objects (CiA DS-301)

References, ETG specifications:
- *ETG.1000.6 Application Layer Protocol Specification*
- *ETG.1020 Protocol Enhancements*

Supported communication-specific objects:

Index (h)	Name
1000	Device Type
1008	Manufacturer Device Name
1009	Manufacturer Hardware Version
100A	Manufacturer Software Version
1018	Identity Object
10E0	Device Identification Reload Object
1600	1st Receive PDO Mapping, for the safety-related output data
1601	2nd Receive PDO Mapping, for the NON-safety-related output data
1A00	1st Transmit PDO Mapping, for the safety-related input data
1A01	2nd Transmit PDO Mapping, for the NON-safety-related input data
1C00	Sync Manager Communication Type
1C12	Sync Manager 2 PDO Assignment
1C13	Sync Manager 3 PDO Assignment
1C32	Sync Manager 2 Synchronization
1C33	Sync Manager 3 Synchronization

6.2 Manufacturer-specific objects

Index (h)	Object	Name	Data length	Attr.	Page
2040	RECORD	Parameter grey (NON-safety-oriented)	UNSIGNED16	rw	41
2200	ARRAY	TRDiagV2 (internal purposes)	OCTET STRING	ro	76
2220	VAR	Failsafe Simulation	UNSIGNED8	rw	48
2500	RECORD	ITF2_SSI_Parameter	UNSIGNED8	rw	49
2520	RECORD	ITF2_Incr_Parameter	UNSIGNED8	rw	52
2707	ARRAY	Firmware-Info	OCTET STRING	ro	52
2736	VAR	Update Time	UNSIGNED32	rw	53
2738	ARRAY	Update History	OCTET STRING	ro	53
2739	VAR	Customer Date	STRING(10)	rw	53
3000	VAR	Status Universal	UNSIGNED8	ro	53
3001	VAR	Cycle Time Bus	UNSIGNED32	ro	54
3002	VAR	Cycle Time Encoder	UNSIGNED32	ro	54
[1)] 3010	VAR	Status byte	UNSIGNED8	ro	54
[1)] 3011	VAR	Speed output	INTEGER32	ro	55
[1)] 3012	VAR	Absolute position	UNSIGNED32	ro	55
[1)] 3100	VAR	Control byte	UNSIGNED8	rw	56
[1)] 3101	VAR	Preset (adjustment setpoint)	UNSIGNED32	rw	56

Table 2: Manufacturer profile area

[1)] Access only possible via the NON-safety-related process data (mapping objects 0x1A01/0x1601)

6.2.1 Object 2040h: Parameter grey

The object contains all NON-safety-related configuration parameters.

Index	Sub	Comment	Default [Unit]	Type	Attr.	Page
2040h	0	Max. Subindex	11	UNSIGNED8	ro	-
	1	Rotational direction grey	True [increasing]	BOOL	rw	41
	2	Measuring range grey	536870912 [Steps]	UNSIGNED32	rw	42
	3	Revolutions numerator grey	65536 [Revol. Numerator]	UNSIGNED32	rw	42
	4	Revolutions denominator grey	1 [Revol. Denominator]	UNSIGNED32	rw	42
	5	Speed format grey	1 [revol./min]	UNSIGNED8	rw	45
	6	Speed factor grey	1 [Factor]	UNSIGNED16	rw	45
	7	Speed integration time grey	100 [ms]	UNSIGNED16	rw	46
	8	Speed filter intensity grey	0 [Filter strength]	UNSIGNED8	rw	47
	9	Speed filter type grey	0 [static]	UNSIGNED8	rw	47
	10	Position replacement grey	True [Substitute position ON]	BOOL	rw	47
	11	Parameter coupled to safe	False [Coupled channel OFF]	BOOL	rw	48

6.2.1.1 Subindex 1: Rotational direction grey

⚠ WARNING

Risk of death, serious injury and/or damage to property due to a jump in the absolute value when the direction of rotation function is changed!

NOTICE

- The internal calculation algorithm results in different absolute positions for the `decreasing` and `increasing` counting direction settings. After changing the direction of rotation, the correct function must therefore first be checked by means of a validated test run. It may be necessary to adjust the output position using the preset function.

BOOL

Value	Description	Default
0 = False	Measuring system – position clockwise decreasing (view of shaft, flange)	
1 = True	Measuring system – position clockwise increasing (view of shaft, flange)	X

6.2.1.2 Subindex 2, 3, 4: Scaling parameters

Risk of physical injury and material damage due to shifting of the zero point when the measuring system is switched on again after positioning in de-energized state!

⚠ WARNING

If more than 32767 revolutions are executed in de-energized state, the zero point of the multiturn measuring system may be lost!

⚠ CAUTION

- Make sure that positioning operations in de-energized state take place within 32767 revolutions on a multiturn measuring system.
- If this cannot be ensured, the output position must be verified with the desired mechanical position before starting the application.

Via the scaling parameters

- Subindex 2 - Measuring range grey
- Subindex 3 - Revolutions numerator grey
- Subindex 4 - Revolutions denominator grey

the physical resolution of the measuring system can be changed. The measuring system supports the gear function for round axes.

This means that the ***number of steps per revolution*** and the quotient of `revolutions numerator/revolutions denominator` can be a decimal number.

The position value output is calculated with a zero point correction, the counting direction set and the gearbox parameter entered.

Subindex 2: **MEASURING RANGE**

Defines the ***total number of steps*** of the measuring system, before the measuring system starts at zero again.

UNSIGNED32

Lower limit	2 steps
Upper limit	536 870 912 steps (30 bit)
Default	**536870912**

The actual upper limit value to be entered for the `measuring length` depends on the measuring system design and can be calculated using the formula below. As the value "0" is already counted as a step, the end value = measuring range in steps - 1.

Measuring range = steps per revolution * number of revolutions

For the purposes of calculation the parameters ***Steps/revolution*** and ***Number of revolutions*** can be taken from the measuring system type plate.

Subindex 3: **REVOLUTIONS NUMBERATOR /** Subindex 4: **REVOLUTIONS DENOMINATOR**

These two parameters together define the ***number of revolutions***, before the measuring system starts at 0 again.

As decimal numbers are not always finite (as is e.g. 3.4), but they may have an infinite number of digits after the decimal point (e.g. 3.43535355358774...) the number of revolutions is entered as a fraction.

UNSIGNED32

Numerator lower limit	1
Numerator upper limit	256000
Numerator default	65536

UNSIGNED32

Denominator lower limit	1
Denominator upper limit	16384
Denominator default	**1**

Formula for gearbox calculation:

$$\text{Measuring range in steps} = \text{number of steps per rev.} * \frac{\text{Number of numerator revolutions}}{\text{Number of denominator revolutions}}$$

If it is not possible to enter parameter data in the permitted ranges of numerator and denominator, the attempt must be made to reduce these accordingly. If this is not possible, it may only be possible to represent the relevant decimal number approximately. The resulting minor inaccuracy accumulates for real round axis applications (infinite applications with motion in one direction).
A solution is, for example, to perform adjustment after each revolution or to adapt the mechanics or gear ratio accordingly.

The parameter **Number of steps per revolution** may also be a decimal number, however the `measuring length` may not. The result of the above formula must be rounded up or down. The resulting error is distributed over the total number of revolutions programmed and is therefore negligible.

Preferably for linear axes (forward and backward motion):

The parameter `denominator revolutions` can be programmed as a fixed value of "1" for linear axes. The parameter `numerator revolutions` is programmed slightly higher than the required number of revolutions. This ensures that the measuring system does not generate an actual value jump (zero transition) if the travel is slightly exceeded. For the sake of simplicity the full revolution range of the measuring system can also be programmed.

The following example serves to illustrate the approach.

Given:

- Measuring system with 4096 steps/rev. and max. 4096 revolutions
- Resolution 1/100 mm

- Make sure that the measuring system is programmed in its full resolution and measuring range (4096x4096):
  Measuring range in steps = 16777216,
  Revolutions numerator = 4096
  Revolutions denominator = 1
  Set the mechanics to be measured to the left stop position
- Set measuring system to "0" by adjustment
- Set the mechanics to be measured to the end position
- Measure the mechanical distance covered in mm
- Read off the actual position of the measuring system on the connected control

Assumed:

- Distance covered = 2000 mm
- Measuring system actual position after 2000 mm = 607682 steps

Derived:

Number of revolutions covered = 607682 steps / 4096 steps/rev.
= **148.3598633 revolutions**

Number of mm / revolution = 2000 mm / 148.3598633 revs. = **13.48073499mm / rev.**

For 1/100mm resolution this equates to a **number of steps / revolution** of **1348.073499**

required programming:

Number of numerator revolutions = ***4096***
Number of denominator revolutions = ***1***

$$\text{Measuring range in steps} = \text{number of steps per revolution} * \frac{\text{Number of numerator revolutions}}{\text{Number of denominator revolutions}}$$

$$= 1348.073499 \text{ steps / rev.} * \frac{4096 \text{ numerator revolutions}}{1 \text{ denominator revolution}}$$

= ***5521709 steps*** *(rounded off)*

6.2.1.3 Subindex 5: Speed format grey

Subindex 5 indicates the resolution at which the speed is calculated and output.

The speed is output signed, as a two's complement:

- Counting direction setting = increasing
  - Output positive, with clockwise rotation (looking at flange connection)

- Counting direction setting = decreasing
  - Output negative, with clockwise rotation (looking at flange connection)

UNSIGNED8

Value	Assignment	Description	Default
0	rev/sec * factor	Output in [rev./second], multiplied by the factor set under the *Speed factor grey* parameter, see Subindex 6.	
1	rev/min * factor	Output in [rev./minute], multiplied by the factor set under the *Speed factor grey* parameter, see Subindex 6.	X
2	rev/hour * factor	Output in [rev./hour], multiplied by the factor set under the *Speed factor grey* parameter, see Subindex 6.	
3	steps/integration time	Integration time in [ms]	

6.2.1.4 Subindex 6: Speed factor grey

Subindex 6 indicates the factor value for the parameter `Subindex 5: Speed format grey`.

UNSIGNED16

Lower limit	1
Upper limit	1000
Default	**1**

6.2.1.5 Subindex 7: Speed integration time grey

Subindex 7 indicates the integration time in [ms] for the parameter `Subindex 5: Speed format grey`, see page 45.

The parameter serves to calculate the speed, which is output via the cyclic process data. The speed is specified in `Steps/Integration time`. High integration times enable high-resolution measurements at low speeds. Low integration times show speed changes more quickly and are suitable for high speeds and high dynamics.

If the `Dynamic integration time` function is set to a value exceeding 0, the integration time is adjusted dynamically to the speed. The integration time increases at low speed and decreases at high speed.
The integration time is always set so that the speed deviation is less than 1 per thousand (0.001). The integration time never exceeds 219 ms

UNSIGNED16

Dynamic integration time	0
Lower limit	1 ms
Upper limit	1000 ms
Default	**100 ms**

Example

Given:
- Programmed resolution = 8192 steps per revolution
- Speed = 4800 revolutions per minute
- Integration time t_i = 50 ms = 0.05 s

Find:
- Output value in steps/integration time

$$\text{Number of steps / s} = \frac{8192 \text{ steps} * 4800 \cancel{\text{rev.}}}{\cancel{\text{rev.}} * 60 \text{ s}} = \frac{655360 \text{ steps}}{1 \text{ s}}$$

$$\text{Number of steps / } t_i = \frac{655360 \text{ steps}}{1 \text{ s}} * 0.05 \text{ s} = 32768 \text{ steps}$$

Steps/integration time = 32768 steps / 50 ms

6.2.1.6 Subindex 8: Speed filter intensity grey

The output speed can be averaged using the `Speed filter intensity grey` parameter. The averaging strength can be preset. You can also select whether the filtering is dynamically switched off in acceleration phases, see `Speed filter type grey` parameter described below. This means that the speed signal can quickly follow the actual course in the event of changes and is stable in the stationary range.

UNSIGNED8

Lower limit	0
Upper limit	10
Default	**0**

0: no filtering

1: weak filtering, high limit frequency

. . .

10: strong filtering, low limit frequency

6.2.1.7 Subindex 9: Speed filter type grey

Also see the parameter `Subindex 8: Speed filter intensity grey` on page 47.

UNSIGNED8

Value	Assignment	Description	Default
0	static	The low-pass filter characteristic influences the speed actual value output, independently of the current movement or acceleration status of the drive.	X
1	dynamic	The low-pass filter characteristic is deactivated, as soon as the measuring system detects a significant change in acceleration in the speed signal. The low-pass filter is reactivated, as soon as the measuring system detects a uniform movement.	

6.2.1.8 Subindex 10: Position replacement grey

BOOL

Value	Assignment	Description	Default
0 = false	off	Function switched off	
1 = true	on	Output of the substitute position, if the position channel is in error state, also see parameter in chapter 5.2.1.1 bit 2^2 on page 36.	X

6.2.1.9 Subindex 11: Parameter coupled to safe

BOOL

Value	Assignment	Description	Default
0 = false	off	Function switched off	X
1 = true	on	The setting `Parameter coupled to safe = on` can be used to specify whether the NON-safety-related process data channel `Grey` should be coupled with the safety-related process data channel `FSoE`. In this case, the settings for the position and speed of the safety-related process data channel `FSoE` are used and the existing settings in the NON-safety-related process data channel `Grey` for the position and speed are ignored. The preset function can only be performed in the safety-related process data channel `FSoE`, while the preset function in the NON-safety-related channel `Grey` is disabled.	

6.2.2 Object 2220h: TR safe state simulation

During the commissioning phase or for test purposes, the measuring system can be set to fail-safe status by writing the value 2Ch. The measuring system then behaves in exactly the same way as if a safety-relevant error had occurred: So-called "safe data" is output via the safety channel, see chapter “Output of safe data (substitute values)” on page 72.

To restart the measuring system, an OFF/ON cycle of the supply voltage must be executed.

UNSIGNED8

Lower limit	0
Upper limit	255
Default	**0**

6.2.3 OPTION: Second interface

6.2.3.1 Object 2500h: ITF2_SSI_Parameter

The measuring system can optionally be equipped with a synchronous-serial absolute SSI interface, in addition to the fieldbus interface.

SSI data transmission format:

MSB LSB

Position	Status	Sign of life	Checksum
max. 8…29 bits	max. 0…2 bits	max. 0…5 bits	max. 0…8 bits

Index	Subindex	Comment	Default	Type	Attr.
2500h	0	Largest subindex supported	7	UNSIGNED8	ro
	1	SSI_Source	0: channel 1	UNSIGNED8	rw
	2	SSI_Code	0: binary code	UNSIGNED8	rw
	3	SSI_Databits	29: 29 data bits	UNSIGNED8	rw
	4	SSI_Monotime	1: 20 µs	UNSIGNED8	rw
	5	SSI_Statusbits	0: no status bits	UNSIGNED8	rw
	6	SSI_Livecounterbits	0: no sign of life bits	UNSIGNED8	rw
	7	SSI_CRC_Length	0: no checksum	UNSIGNED8	rw

6.2.3.1.1 Subindex 1: SSI_Source

UNSIGNED8

Value	Description	Default
0	Channel 1: SSI output: Actual position of master system	X
1	Channel 2: SSI output: Actual position of test system	

6.2.3.1.2 Subindex 2: SSI_Code

UNSIGNED8

Value	Description	Default
0	SSI output is binary-coded	X
1	SSI output is gray-coded	

6.2.3.1.3 Subindex 3: SSI_Databits

The `SSI_Databits` subindex defines the number of reserved bits for the measuring system position, and the number of required SSI clock pulses to the LSB of the data is also specified. Special bits such as status bits, sign-of-life bits or checksum bits are not included and are output in this order after the data bits.

UNSIGNED8

Lower limit	8
Upper limit	29
Default	**29**

6.2.3.1.4 Subindex 4: SSI_Monotime

UNSIGNED8

Value	Description	Default
0	SSI monoflop time = 15 µs	
1	SSI monoflop time = 20 µs	X
2	SSI monoflop time = 35 µs	
3	SSI monoflop time = 50 µs	
4	SSI monoflop time = 500 µs	

6.2.3.1.5 Subindex 5: SSI_Statusbits

UNSIGNED8

Value	Description	Default
0	No status bits output	X
1	One-bit status output 0: No errors 1: Error in master system or test system; depending on the source	
2	Two-bit status output MSB bit = 0: No errors MSB bit = 1: Error in master system LSB bit = 0: No errors LSB bit = 1: Error in test system	

6.2.3.1.6 Subindex 6: SSI_Lifecounterbits

The `SSI_Lifecounterbits` subindex defines the number of reserved bits for the sign-of-life output.

The sign-of-life counter is incremented depending on the scanning processes and inserted into the SSI telegram. Monitoring of this incrementation by the control ensures that the newly transferred position value originates from a current scanning process.

UNSIGNED8

Value	Description	Default
0	No sign-of-life bits output	X
1	1 bit sign-of-life (toggle bit)	
2	2 bit sign-of-life	
3	3 bit sign-of-life	
4	4 bit sign-of-life	
5	5 bit sign-of-life	

6.2.3.1.7 Subindex 7: SSI_CRC_Length

The type of checksum is set in SSI data transmission format via the `SSI_CRC_Length` subindex.

The checksum is generally calculated over all useful data (position, status and sign-of-life) in the SSI telegram and is always inserted in the SSI telegram in the last position (LSB).

An incorrect checksum does not indicate a measuring system error, but a communication problem. The cause may be an EMC fault, for example. However, communication problems in SSI interfaces can also be caused by excessively long cables or excessively high SSI scanning frequencies.

UNSIGNED8

Value	Description	Default
0	No checksum output	X
1	Even parity: The parity represents the checksum of the bits in the SSI data word. If the SSI data word contains an odd number of ones, the bit is = "1" and changes the checksum to even parity.	
2	Odd parity: The parity represents the checksum of the bits in the SSI data word. If the SSI data word contains an even number of ones, the bit is = "1" and changes the checksum to odd parity.	
3	8-bit CRC checksum: Polynomial: $X^8 + X^5 + X^4 + 1$ (Maxim/Dallas) Start value 0xFF Min. Hamming distance: 4	

6.2.3.2 Object 2520h: ITF2_Incr_Parameter

The measuring system can optionally be equipped with an incremental interface, in addition to the fieldbus interface.

Index	Subindex	Comment	Default	Type	Attr.
2520h	0	Largest subindex supported	1	UNSIGNED8	ro
	1	Pulses per revolution	0: 1024 pulses	UNSIGNED8	rw

6.2.3.2.1 Subindex 1: Incr_Steps

The `Incr_Steps` subindex defines the number of pulses per revolution.

UNSIGNED8

Value	Description	Default
0	The number of pulses is set to 1024	X
1	The number of pulses is set to 2048	
2	The number of pulses is set to 3072	
3	The number of pulses is set to 4096	
4	The number of pulses is set to 5120	

6.2.4 Object 2707h: Firmware info

The object contains the current firmware version of the measuring system

Index	Subindex	Comment	Type	Attr.
2707h	0	No. of entries	UNSIGNED8	ro
	1	Firmware data_01	OCTET STRING	ro
	2	Firmware data_02	OCTET STRING	ro
	3	Firmware data_03	OCTET STRING	ro
	4	Firmware data_04	OCTET STRING	ro

The OCTET STRINGs are simple UNSIGNED8 arrays, each with a length of 32 bytes.

6.2.5 Object 2736h: Update time

The object contains the update time of the measuring system.

Index	0x2736
Description	Update time
Data type	UNSIGNED32
Access	ro
PDO mapping	no
Value	contains the seconds since Jan. 1. 1970 (UNIX time)

6.2.6 Object 2738h: Update history

The object contains the update history of the measuring system.

Index	0x2738
Description	Update history
Data type	UNSIGNED8
Access	ro
PDO mapping	no
Value	contains the number of updates carried out

6.2.7 Object 2739h: Customer date

If the measuring system receives a new firmware update, the implementation date should be entered here.

Index	0x2739
Description	Implementation date - Firmware update
Data type	STRING10
Access	rw
PDO mapping	no
Value	YYYY-MM-DD

6.2.8 Object 3000h: Status universal

The initialization status is output via the object.

Index	0x3000
Description	Status
Data type	UNSIGNED8
Access	ro
PDO mapping	no
Value	Bit 1 = 0: Device in operation Bit 1 = 1: Device in initialization state for calculation of the bus cycle --> no valid output data

6.2.9 Object 3001h: Cycle time bus

The current EtherCAT bus cycle time is output via the object.

Index	0x3001
Description	Cycle time bus
Data type	UNSIGNED32
Access	ro
PDO mapping	no
Unit	µs

6.2.10 Object 3002h: Cycle time encoder

The current internal measuring system cycle time is output via the object.

Index	0x3002
Description	Cycle time encoder
Data type	UNSIGNED32
Access	ro
PDO mapping	no
Unit	µs

6.2.11 Object 3010h: Status bits

The object contains the measuring system-related status bits and is part of the NON-safety-related process data, see from page 35.

Index	0x3010
Description	Status byte
Data type	UNSIGNED8
Access	ro
PDO mapping	yes

Can only be accessed via the process data.

6.2.12 Object 3011h: Speed

The current speed is output via the object and is part of the NON-safety-related process data, see from page 35.

Index	0x3011
Description	Speed
Data type	INTEGER32
Access	ro
PDO mapping	yes
Lower limit	–2147483648
Upper limit	+2147483647
Unit	Increments / Integration time unsafe

Can only be accessed via the process data.

6.2.13 Object 3012h: Position

The current scaled actual position is output via the object and is part of the NON-safety-related process data, see from page 35.

Index	0x3012
Description	Position
Data type	UNSIGNED32
Access	ro
PDO mapping	yes
Lower limit	0
Upper limit	268 435 456
Unit	Steps

Can only be accessed via the process data.

6.2.14 Object 3100h: Control bits

The object contains the control byte for the preset adjustment function and is part of the NON- safety-related process data, see from page 35.

Index	0x3100
Description	Control byte
Data type	UNSIGNED8
Access	rw
PDO mapping	yes

Can only be accessed via the process data.

6.2.15 Object 3101h: Preset

The object contains the adjustment setpoint for the preset adjustment function and is part of the NON-safety-related process data, see from page 35.

The `Preset` register can be used to transfer a 32-bit adjustment value via the process output data and set it as the new position value. The adjustment value must be within the programmed measuring length –1.
The adjustment value is set as the new position when the adjustment function is executed via the control byte.

Index	0x3101
Description	Preset value
Data type	UNSIGNED32
Access	rw
PDO mapping	yes
Lower limit	0
Upper limit	536 870 912
Unit	Steps

Can only be accessed via the process data.

6.3 Profile specific objects

Index (h)	Object	Name	Attr.	Page
6000	VAR	Operating parameters	rw	58
6004	VAR	Position value	ro	58
6500	VAR	Operating status	ro	59
6501	VAR	Single turn resolution	ro	59
6502	VAR	Number of distinguishable revolution	ro	59
6800	RECORD	FSoE Slave Frame Elements	ro	58
6801	RECORD	FSoE Slave Frame Data	ro	58
7000	RECORD	FSoE Master Frame Elements	ro	61
7001	RECORD	FSoE Master Frame Data	ro	61
8000	RECORD	FSoE Parameter adjustments	rw	62
F980	RECORD	Safe address	ro	62

Table 3: Device profile area

6.3.1 Object 6000h: Operating parameters

The object with index 6000h only contains the measuring system operating parameter for the switching of the counting direction.

Index	**0x6000**
Description	Operating parameters
Data type	UNSIGNED16
Object code	VARIABLE
Access	rw
PDO mapping	no
Default	**0**

Bit	**Function**	**Bit = 0**	**Bit = 1**
0	Counting direction	Position increasing	Position decreasing
1 – 15	reserved		

Bit 0, Counting direction:
The counting direction defines whether increasing or decreasing position values are output via the two objects 3012h and 6004h when the measuring system shaft is rotating clockwise or counterclockwise (viewing direction of the shaft).

6.3.2 Object 6004h: Position value

Object 6004h is used to output the current NON-safety-related scaled position value. The scaling is defined by the settings of the scaling parameters

- Measuring length
- Revolutions Numerator
- Revolutions Denominator

out of the `Object 2040h: Parameter grey`, see from page 42. The object is not intended for PDO mapping. However, the cyclical output of the NON-safety-related position via the process data is generally carried out via the mapping object 0x1A01, see from page 35.

Index	**0x6004**
Description	Position value (scaled)
Data type	UNSIGNED32
Object code	VARIABLE
Access	ro
PDO mapping	no

Position value (scaled)			
Byte 0	Byte 1	Byte 2	Byte 3
2^7 to 2^0	2^{15} to 2^8	2^{23} to 2^{16}	2^{31} to 2^{24}

6.3.3 Object 6500h: Operating status

This object provides the operating status of the measuring system functions configured in `Object 6000h: Operating` parameters. However, only the function for switching the counting direction is supported.

Index	0x6500
Description	Operating status
Data type	UNSIGNED16
Object code	VARIABLE
Access	ro
PDO mapping	no

Bit	Function	Bit = 0	Bit = 1
0	Counting direction	Position increasing	Position decreasing
1 – 15	reserved		

6.3.4 Object 6501h: Single-turn resolution

This object contains the maximum number of measuring steps per revolution that can be output by the measuring system.

Index	0x6501
Description	Single turn resolution
Data type	UNSIGNED32
Object code	VARIABLE
Access	ro
PDO mapping	no
Default	Output in steps per revolution, device-specific

6.3.5 Object 6502h: Number of distinguishable revolutions

This object contains the maximum number of revolutions that the measuring system can output.

Index	0x6502
Description	Number of revolutions
Data type	UNSIGNED32
Object code	VARIABLE
Access	ro
PDO mapping	no
Default	Output in revolutions, device-specific

6.3.6 Object 6800h: FSoE Slave Frame Elements

The object is required to describe the complete FSoE slave frame in the TxPDO mapping object 0x1A00 together with “Object 6801h: FSoE Slave Frame Data (16 bit/32 bit)”.

Index	Subindex	Comment	Type	Attr.
6800h	0	Number of entries = 7	UNSIGNED8	ro
	1	FSoE Slave Command	UNSIGNED8	ro
	2	FSoE Slave Connection ID	UNSIGNED16	ro
	3	FSoE Slave CRC_0	UNSIGNED16	ro
	4	FSoE Slave CRC_1	UNSIGNED16	ro
	5	FSoE Slave CRC_2	UNSIGNED16	ro
	6	FSoE Slave CRC_3	UNSIGNED16	ro
	7	FSoE Slave CRC_4	UNSIGNED16	ro

6.3.7 Object 6801h: FSoE Slave Frame Data (16 bit/32 bit)

The object contains the cyclical safety-related user input data for the two module variants `FSoE 16bit` and 32 bit `FSoE`, for structure see from page 29.

Index	Subindex	Comment	16 bit	32 bit	Type	Attr.
6801h	0	Number of entries = 13	x	x	UNSIGNED8	ro
	1	Safe speed error	x	x	BOOL	ro
	2	Error acknowledge requested	x	x	BOOL	ro
	3	Safe preset OK	x	x	BOOL	ro
	4	Safe preset error	x	x	BOOL	ro
	5	Safe state	x	x	BOOL	ro
	6	Safe preset active	x	x	BOOL	ro
	7	Safe scaling error	x	x	BOOL	ro
	8	Safe absolute position	–	x	UNSIGNED32	ro
	9	Safe speed value	–	x	INTEGER32	ro
	10	Safe absolute position low word	x	–	UNSIGNED16	ro
	11	Safe absolute position high word	x	–	UNSIGNED16	ro
	12	Safe speed value low word	x	–	INTEGER16	ro
	13	Safe speed value high word	x	–	INTEGER16	ro

6.3.8 Object 7000h: FSoE Master Frame Elements

The object is required to describe the complete FSoE master frame in the RxPDO mapping object 0x1600 together with “Object 7001h: FSoE Master Frame Data (16 bit/32 bit)”.

Index	Subindex	Comment	Type	Attr.
7000h	0	Number of entries = 5	UNSIGNED8	ro
	1	FSoE Master Command	UNSIGNED8	ro
	2	FSoE Master Connection ID	UNSIGNED16	ro
	3	FSoE Master CRC_0	UNSIGNED16	ro
	4	FSoE Master CRC_1	UNSIGNED16	ro
	5	FSoE Master CRC_2	UNSIGNED16	ro

6.3.9 Object 7001h: FSoE Master Frame Data (16 bit/32 bit)

The object contains the cyclical safety-related user output data for the two module variants 16 bit `FSoE 16bit` and 32 bit `FSoE`, for structure see from page 29.

Index	Subindex	Comment	16 bit	32 bit	Type	Attr.
7001h	0	Number of entries = 6	x	x	UNSIGNED8	ro
	1	Safe preset preparation	x	x	BOOL	ro
	2	Safe preset request	x	x	BOOL	ro
	3	Error acknowledge	x	x	BOOL	ro
	4	Safe preset value	–	x	UNSIGNED32	ro
	5	Safe preset value low word	x	–	UNSIGNED16	ro
	6	Safe preset value high word	x	–	UNSIGNED16	ro

6.3.10 Object 8000h: FSoE parameter settings

The object contains all safety-related configuration parameters.

Index	Sub	Comment	Default [Unit]	Type	Attr.	Page
8000h	0	Number of entries	11	UNSIGNED8	ro	-
	1	SIL Level	2	UNSIGNED8	rw	62
	2	Rotational direction	true [increasing]	BOOL	rw	63
	3	Measuring range	536870912 [Steps]	UNSIGNED32	rw	63
	4	Revolutions numerator	65536 [Rev. Numerator]	UNSIGNED32	rw	63
	5	Revolutions denominator	1 [Rev. Denominator]	UNSIGNED32	rw	63
	6	Speed format	1 [Rev./min]	UNSIGNED8	rw	67
	7	Speed factor	1 [Factor]	UNSIGNED16	rw	67
	8	Speed integration time	100 [ms]	UNSIGNED16	rw	68
	9	Speed filter intensity	0 [Filter strength]	UNSIGNED8	rw	68
	10	Speed filter type	0 [static]	UNSIGNED8	rw	69
	11	Window increments	1000 [Increments]	UNSIGNED16	rw	70

6.3.10.1 Subindex 1: SIL level

Subindex 1 specifies the SIL level that the user expects from the respective safety-related device. It is compared with the manufacturer's locally stored specification. The measuring system supports safety classes SIL2 and SIL3

UNSIGNED8

Lower limit	2
Upper limit	3
Default	**2**

Value	Description
2	SIL level = 2
3	SIL level = 3

6.3.10.2 Subindex 2: Rotational direction

⚠ WARNING

Danger of death, serious physical injury and/or damage to property due to a jump of the absolute value following a change in the rotational direction function!

NOTICE

- The internal calculation algorithm produces different absolute positions for the counting direction settings `decreasing` or `rising`. After a change of rotational direction, the correct function must therefore be ensured by means of a protected test run. It may be necessary to adapt the output position using the preset function.

UNSIGNED8

Lower limit	0
Upper limit	1
Default	**1**

Value	Description
0	Measuring system – position descending clockwise (looking at shaft, flange connection)
1	Measuring system – position ascending clockwise (looking at shaft, flange connection)

6.3.10.3 Subindex 3, 4, 5: Scaling parameters

Risk of physical injury and material damage due to shifting of the zero point when the measuring system is switched on again after positioning in de-energized state!

If the settings of the scaling parameters specified below deviate from the default settings, the zero point of the multiturn measuring system may be lost if more than the permissible number of revolutions are executed in de-energized state!

⚠ WARNING

NOTICE

- SIL2 – measuring system: Make sure that positioning operations in de-energized state take place within 3200 revolutions on a multiturn measuring system.
- SIL3 – measuring system: Make sure that positioning operations in de-energized state take place within 320 revolutions on a multiturn measuring system.
- If this cannot be ensured, the output position must be verified with the desired mechanical position before starting the application.
  If the permissible number of revolutions have been exceeded, this is indicated when the system restarts via object 6801h `FSoE Slave Frame Data`, bit 7 `Scaling Error` = 1. After positive verification the `Scaling Error` bit can be deleted by executing the preset adjustment function, see chapter 5.1.3 on page 33.

Via the scaling parameters

- Subindex 3 - Measuring range
- Subindex 4 - Revolutions numerator
- Subindex 5 - Revolutions denominator

the physical resolution of the measuring system can be changed. The measuring system supports the gear function for round axes.

This means that the ***number of steps per revolution*** and the quotient of `revolutions numerator/revolutions denominator` can be a decimal number.

The position value output is calculated with a zero point correction, the counting direction set and the gearbox parameter entered.

Subindex 2: **MEASURING RANGE**

Defines the ***total number of steps*** of the measuring system, before the measuring system starts at zero again.

UNSIGNED32

Lower limit	2 steps
Upper limit	536 870 912 Steps (30 Bit)
Default	**536870912**

The actual upper limit value to be entered for the `measuring length` depends on the measuring system design and can be calculated using the formula below. As the value "0" is already counted as a step, the end value = measuring range in steps - 1.

Measuring range = steps per revolution * number of revolutions

For the purposes of calculation the parameters ***Steps/revolution*** and ***Number of revolutions*** can be taken from the measuring system type plate.

Subindex 3: **REVOLUTIONS NUMBERATOR /** Subindex 4: **REVOLUTIONS DENOMINATOR**

These two parameters together define the ***number of revolutions***, before the measuring system starts at 0 again.

As decimal numbers are not always finite (as is e.g. 3.4), but they may have an infinite number of digits after the decimal point (e.g. 3.43535355358774...) the number of revolutions is entered as a fraction.

UNSIGNED32

Numerator lower limit	1
Numerator upper limit	256000
Numerator default	65536

UNSIGNED32

Denominator lower limit	1
Denominator upper limit	16384
Denominator default	**1**

Formula for gearbox calculation:

$$\text{Measuring range in steps} = \text{number of steps per revolution} * \frac{\text{Number of numerator revolutions}}{\text{Number of denominator revolutions}}$$

If it is not possible to enter parameter data in the permitted ranges of numerator and denominator, the attempt must be made to reduce these accordingly. If this is not possible, it may only be possible to represent the relevant decimal number approximately. The resulting minor inaccuracy accumulates for real round axis applications (infinite applications with motion in one direction).
A solution is, for example, to perform adjustment after each revolution or to adapt the mechanics or gear ratio accordingly.

The parameter **Number of steps per revolution** may also be a decimal number, however the `measuring length` may not. The result of the above formula must be rounded up or down. The resulting error is distributed over the total number of revolutions programmed and is therefore negligible.

Preferably for linear axes (forward and backward motion):

The parameter `denominator revolutions` can be programmed as a fixed value of "1" for linear axes. The parameter `numerator revolutions` is programmed slightly higher than the required number of revolutions. This ensures that the measuring system does not generate an actual value jump (zero transition) if the travel is slightly exceeded. For the sake of simplicity the full revolution range of the measuring system can also be programmed.

The following example serves to illustrate the approach.

Given:

- Measuring system with 4096 steps/rev. and max. 4096 revolutions
- Resolution 1/100 mm

- Make sure that the measuring system is programmed in its full resolution and measuring range (4096x4096):
  Measuring range in steps = 16777216,
  Revolutions numerator = 4096
  Revolutions denominator = 1
  Set the mechanics to be measured to the left stop position
- Set measuring system to "0" by adjustment
- Set the mechanics to be measured to the end position
- Measure the mechanical distance covered in mm
- Read off the actual position of the measuring system on the connected control

Assumed:

- Distance covered = 2000 mm
- Measuring system actual position after 2000 mm = 607682 steps

Derived:

Number of revolutions covered = 607682 steps / 4096 steps/rev.
= **148.3598633 revolutions**

Number of mm / revolution = 2000 mm / 148.3598633 revs. = **13.48073499mm / rev.**

For 1/100mm resolution this equates to a **number of steps / revolution** of **1348.073499**

required programming:

Number of numerator revolutions = ***4096***
Number of denominator revolutions = ***1***

$$\text{Measuring range in steps} = \text{number of steps per revolution} * \frac{\text{Number of numerator revolutions}}{\text{Number of denominator revolutions}}$$

$$= 1348.073499 \text{ steps / rev.} * \frac{4096 \text{ numerator revolutions}}{1 \text{ denominator revolution}}$$

= ***5521709 steps*** *(rounded off)*

6.3.10.4 Subindex 6: Speed format

Subindex 6 indicates the resolution at which the speed is calculated and output.

The speed is output signed, as a two's complement:

- Counting direction setting = ascending
  - Output positive, with clockwise rotation (looking at flange connection)

- Counting direction setting = descending
  - Output negative, with clockwise rotation (looking at flange connection)

UNSIGNED8

Value	Assignment	Description	Default
0	rev/sec * factor	Output in [rev./second], multiplied by the factor set under the *Speed factor* parameter, see Subindex 7.	
1	rev/min * factor	Output in [rev./minute], multiplied by the factor set under the *Speed factor* parameter, see Subindex 7.	X
2	rev/hour * factor	Output in [rev./hour], multiplied by the factor set under the *Speed factor* parameter, see Subindex 7.	
3	steps/integration time	Output in [steps/ms]	

6.3.10.5 Subindex 7: Speed factor

Subindex 7 indicates the factor value for the parameter `Subindex 6: Speed format`.

UNSIGNED16

Lower limit	1
Upper limit	1000
Default	**1**

6.3.10.6 Subindex 8: Speed integration time

Subindex 8 indicates the integration time in [ms] for the parameter `Subindex 6: Speed format`, see page 67.

The parameter serves to calculate the speed, which is output via the cyclic process data. The speed is specified in `steps/integration time`. High integration times enable high-resolution measurements at low speeds. Low integration times show speed changes more quickly and are suitable for high speeds and high dynamics.

If the `Dynamic integration time` function is set to a value exceeding 0, the integration time adjusts dynamically to the speed. The integration time increases at low speed and decreases at high speed.
The integration time is always set so that the speed deviation is less than 1 per thousand (0.001). The integration time never exceeds 219 ms

UNSIGNED16

Dynamic integration time	0
Lower limit	1 ms
Upper limit	1000 ms
Default	**100 ms**

Example

Given:
- Programmed resolution = 8192 steps per revolution
- Speed = 4800 revolutions per minute
- Integration time t_i = 50 ms = 0.05 s

Find:
- Output value in steps/integration time

$$\text{Number of steps / s} = \frac{8192 \text{ steps} * 4800 \ \cancel{\text{rev.}}}{\cancel{\text{rev.}} * 60 \text{ s}} = \frac{655360 \text{ steps}}{1 \text{ s}}$$

$$\text{Number of steps / } t_i = \frac{655360 \text{ steps}}{1 \text{ s}} * 0.05 \text{ s} = 32768 \text{ steps}$$

Steps/integration time = 32768 steps / 50 ms

6.3.10.7 Subindex 9: Speed filter intensity

The output speed can be averaged using the `Speed filter intensity` parameter. The averaging strength can be preset. You can also select whether the filtering is dynamically switched off in acceleration phases, see `Speed filter type` parameter described below. This means that the speed signal can quickly follow the actual course in the event of changes and is stable in the stationary range.

UNSIGNED8

Lower limit	0
Upper limit	10
Default	**0**

0: no filtering

1: weak filtering, high limit frequency

. . .

10: strong filtering, low limit frequency

6.3.10.8 Subindex 10: Speed filter type

Also see the parameter `Subindex 9: Speed filter intensity` on page 69.

UNSIGNED8

Value	Assignment	Description	Default
0	static	The low-pass filter characteristic influences the speed actual value output, independently of the current movement or acceleration status of the drive.	X
1	dynamic	The low-pass filter characteristic is deactivated, as soon as the measuring system detects a significant change in acceleration in the speed signal. The low-pass filter is reactivated, as soon as the measuring system detects a uniform movement.	

6.3.10.9 Subindex 11: Window increments

This parameter defines the maximum permissible position deviation in increments of the master / slave scanning systems integrated into the measuring system. The permissible tolerance window is basically dependent on the maximum speed occurring in the system and must first be determined by the system operator. Higher speeds require a larger tolerance window.

If the `Dynamic window increments` function is set to a value exceeding 0, the set value adjusts dynamically to the speed. A small window applies at low speeds and a correspondingly large window at high speeds.

The following applies:
Dynamic window increments = 0.0675 * 1/min + 20
If the calculated value is less than 50, it is set to 50.

UNSIGNED16

Dynamic window increments	0
Lower limit	50
Upper limit	4000
Default	**1000**

The larger the window increments the greater the angle, until an error is detected.

For the position deviation in increments, the unscaled resolution of 13 bit = 8192 steps/revolution is always used as the basis.

6.3.11 Object F980h: Safe address

Subindex 1 of the object contains the safety address set via the HEX rotary switches, see chapter „Setting the FSoE address“ on page 18. The serial number of the measuring system is noted under subindex two.

Index	Subindex	Comment	Default	Type	Attr.
F980h	0	Number of entries	2	UNSIGNED8	ro
	1	FSoE Address	18	UNSIGNED16	ro
	2	Serial Number	Serial-No.	UNSIGNED32	ro

7 Resetting the device parameters

⚠ WARNING

NOTICE

Destruction, damage and malfunction of the measuring system due to penetration of foreign bodies and moisture!

- Make sure that the screw plug is securely closed again after accessing the address switches to make settings.

Resetting of the device parameters is carried out using two HEX rotary switches SW1 (16^0) and SW2 (16^1). The position and assignment of the HEX rotary switches can be found in the accompanying pin assignment.

Procedure:

1. Loosen screw plug
2. Exit `OPERATIONAL` state
3. Switch SW1 / SW2 ≠ 0
4. Switch SW1 / SW2 = 0
5. Wait until LED2 flashes orange 4 times
6. Switch SW1 = 2 / SW2 = 5, corresponds to 0x52 = 'R' (RESET)
7. Wait until LED2 flashes orange at 2 Hz
8. Switch SW1 / SW2 = 0
9. LED2 lights up statically for 3 s
10. RESET was performed successfully
11. The process is complete, the screw plug can be screwed in again

8 Output of safe data (substitute values)

The safety function requires, that in the case of an error in the safety-oriented safety channel, instead of the cyclically output values the **safe data (0)** are used in the following cases (FailSafeData).

- On start-up of the safety-oriented system
- In the case of errors in the safety-oriented communication between FSoE master and measuring system via the FSoE protocol
- If the value set for the `Window increments` under the safety-oriented parameters is exceeded and/or the internally calculated safety telegram is defective
- if the permissible ambient temperature range specified under the corresponding article number is not reached or is exceeded
- Technical hardware faults in the measuring system
- Double magnetic scanning system: if the electrically permissible speed defined in the safety manual has been exceeded.
  As error-free operation is guaranteed up to this limit value, the actual output of safe data only occurs considerably above the specified limit value.
- if the value 2Ch is written via the `Object 2220h: TR safe state simulation`, see page 48

The process data channel addressable via EtherCAT Standard is not necessarily affected by this. If the internal diagnosis in the master channel does not detect an error, the process data are still output. However, these data are not safe for the purposes of a safety standard.

If the internal diagnosis in the master channel detects an error, **safe data (1)** are also used for the NON-safety-oriented channel.

9 Troubleshooting and Diagnosis Options

9.1 Optical displays

For assignment and position of the status LEDs, see chapter “Bus status display” on page 27.

9.1.1 Link / Activity LEDs

green LED	Cause	Solution
OFF	Voltage supply absent or too low	- Check power supply, wiring - Is the voltage supply in the permissible range?
	No Ethernet connection	Check cable
	Hardware error, measuring system defective	Replace measuring system
ON	Measuring system ready for operation, Ethernet connection established	-

9.1.2 FSoE Status LED

green LED	Cause	Solution
OFF	Measuring system is in initialization or is switched off	-
	Power supply is missing or has fallen below	- Check power supply, wiring - Is the power supply within the permissible range?
	Hardware error, measuring system defective	Replace measuring system
Single flash (permanent)	Measuring system remains in the initialization phase due to the following causes: - No connection to the FSoE master - EtherCAT master is not in "RUN mode" - Incorrect FSoE address - Incorrect or not adjusted FSoE parameters	- Check the entire cabling between the measuring system and FSoE master - Check EtherCAT master project planning - Check whether the EtherCAT master is in RUN mode - Check FSoE address, this must be unique system-wide - Check FSoE parameter, see from page 62
Double flash (permanent)	Measuring system remains in the output of safe data due to the following causes: - FSoE communication was interrupted and restored - FSoE Time Out	- Check whether the set timeout times are suitable for the automation task - Check whether the connection between the FSoE master and the measuring system is faulty - Check whether the FSoE master requires an error acknowledgement
ON	OPERATIONAL	Normal operating status, `Safe state` bit = 1

red LED	Cause	Solution
Single flash (green = OFF)	Measuring system waits for an error acknowledgement. `SafeStatus` bits: - `Error acknowledge requested` = 1 - `Safe state` = 0	Reset the error via bit 2^6 `Error acknowledge` in the `SafeControl` control word, see page 32.
ON (green = OFF)	**A safety-relevant error was detected, the measuring system was put into fail-safe status and is outputting its passivated data:**	**To be able to restart the measuring system after a safety relevant error, the error must generally be eliminated first of all. The** `Safe State` bit **can then change back to 1 by** **1. Error acknowledgement by means of** `Error acknowledge`**, if** `Error acknowledge request` **= 1** (red LED flashes after error elimination) **2. Supply voltage OFF/ON** (red LED constantly lit after error elimination)
	– Error in the safety-oriented communication	– Try to localize the error with the aid of diagnostic mechanisms (control-dependent)
	– The set value for the `Window increments` parameter was exceeded	– Check that the set value for the `Window increments` parameter is suitable for the automation task, see chapter Subindex 11: Window increments" on page 70
	– The permissible ambient temperature range specified under the corresponding article number is not reached or is exceeded	– Suitable measures must be taken to ensure that the permissible ambient temperature range can be observed at all times
	– Double magnetic scanning system: The electrically permissible speed defined in the Safety Manual was exceeded	– Bring speed into the permissible range. Acknowledge error via Supply voltage OFF/ON

9.2 Error acknowledgement – flow diagram

When the measuring system detects a safety-relevant error, it automatically switches from process data output to the `FailSafeData` state. If the error is eliminated and the error type permits restarting, the measuring system automatically switches back to process data output. However, the `Safe State` bit remains at "0" and with the bit `Error acknowledge request` = 1 the measuring system indicates any required error acknowledgement via the `Error acknowledge` bit. Once the error has been acknowledged, the `Safe State` bit is reset to "1", and the process data can be used again.

Areas: red = error occurrence / blue = measuring system / yellow = FSoE application on FSoE master

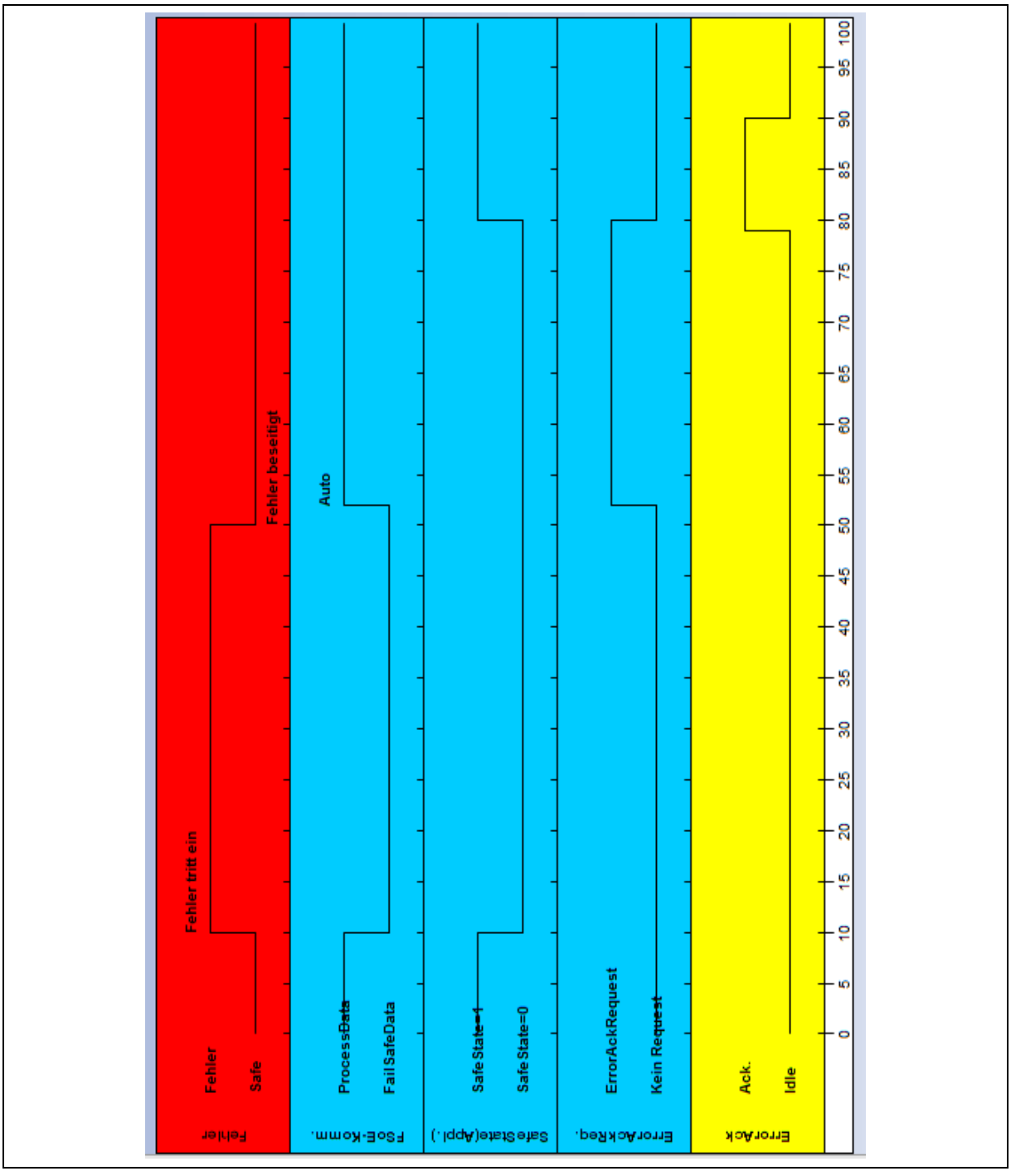


Figure 10: Error acknowledgement - flow chart

9.3 Manufacturer-specific diagnosis EtherCAT (object)

The measuring system supports the following manufacturer-specific diagnosis object:

Index	Subindex	Comment	Type	Attr.
2200h	0	No. of entries	UNSIGNED8	ro
	1	Manufacturer-specific diagnosis	OCTET STRING	ro
	2	Manufacturer-specific diagnosis	OCTET STRING	ro
	3	Manufacturer-specific diagnosis	OCTET STRING	ro
	…	…	…	…
	38	Manufacturer-specific diagnosis	OCTET STRING	ro

Octet Strings are simple UNSIGNED8 arrays with a length of 32 bytes.

The error must be eliminated as described in chapter “Optical displays” If the error cannot be eliminated, the diagnostic codes can be sent to TR Electronic for evaluation, stating the article number.

10 Checklist, Part 2 of 2

We recommend that you print out and work through the Checklist for commissioning, when replacing the measuring system and when changing the parameterization of a previously accepted system and store it as part of the overall system documentation.

Documentation basis	Date	Edited	Checked

Sub-item	To note	Can be found under	yes
Present user manual has been read and understood	–	Document no.: TR-ECE-BA-GB-0177	☐
Check that the measuring system can be used for the present automation task on the basis of the specified safety requirements	• Safety functions of the fail-safe processing unit • Compliance with all technical data	• Chapter Safety functions of the fail-safe processing unit, page 14 • Product data sheets https://www.tr-electronic.com/s/S026079	☐
Voltage supply requirement	• The power supply used must meet the requirements of SELV/PELV (IEC 60364-4-41:2005)	• Chapter Supply voltage, page 17	☐
Correct - electrical installation (shielding) - network installation	• Observance of basic rules for installation • Observance of wiring standards and directives specified by EtherCAT the User Organization	• Chapter Installation / Preparation for Commissioning, from page 15 • Chapter Commissioning, page 26	☐
System test after commissioning and parameterization	• During commissioning and after each parameter change all affected safety functions must be checked	• Chapter Object 8000h: FSoE parameter settings from page 62	☐
Preset Adjustment Function	• It must be ensured that the Preset adjustment function cannot be inadvertently triggered • After execution of the preset adjustment function the new position must be checked before restarting	• Chapter Preset adjustment function, page 33	☐
Device replacement	• It must be ensured that the new device corresponds to the replaced device • All affected safety functions must be checked	• Safety Manual (Checklist, Part 1 of 2) • Chapter Object 8000h: FSoE parameter settings from page 62	☐

11 Appendix

11.1 TÜV certificate

Download, CD_582M +FS02
www.tr-electronic.de/f/TR-ECE-TI-DGB-0344

Download, CD_582M +FS03
www.tr-electronic.de/f/TR-ECE-TI-DGB-0350

11.2 EtherCAT certificate

Download
www.tr-electronic.de/f/TR-ECE-TI-GB-0414

11.3 Safety over EtherCAT certificate

Download
www.tr-electronic.de/f/TR-ECE-TI-GB-0413

11.4 EU Declaration of Conformity

Download, FS02
www.tr-electronic.de/f/TR-ECE-KE-DGB-0354

Download, FS03
www.tr-electronic.de/f/TR-ECE-KE-DGB-0358