Operating manual

# ELX3351

## 1-channel analog input terminal for strain gauge, 16 bit, Ex i

Version: 1.3.1
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BECKHOFF

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# 1 Foreword

## 1.1 Notes on the documentation

**Intended audience**

This description is only intended for the use of trained specialists in control and automation engineering who are familiar with the applicable national standards.
It is essential that the documentation and the following notes and explanations are followed when installing and commissioning these components.
It is the duty of the technical personnel to use the documentation published at the respective time of each installation and commissioning.

The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations, guidelines and standards.

**Disclaimer**

The documentation has been prepared with care. The products described are, however, constantly under development.

We reserve the right to revise and change the documentation at any time and without prior announcement.

No claims for the modification of products that have already been supplied may be made on the basis of the data, diagrams and descriptions in this documentation.

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**Patent Pending**

The EtherCAT Technology is covered, including but not limited to the following patent applications and patents: EP1590927, EP1789857, DE102004044764, DE102007017835 with corresponding applications or registrations in various other countries.

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## 1.2 Safety instructions

**Safety regulations**

Please note the following safety instructions and explanations!
Product-specific safety instructions can be found on following pages or in the areas mounting, wiring, commissioning etc.

**Exclusion of liability**

All the components are supplied in particular hardware and software configurations appropriate for the application. Modifications to hardware or software configurations other than those described in the documentation are not permitted, and nullify the liability of Beckhoff Automation GmbH & Co. KG.

**Personnel qualification**

This description is only intended for trained specialists in control, automation and drive engineering who are familiar with the applicable national standards.

**Description of instructions**

In this documentation the following instructions are used.
These instructions must be read carefully and followed without fail!

| | |
|---|---|
| DANGER | **Serious risk of injury!**<br>Failure to follow this safety instruction directly endangers the life and health of persons. |
| WARNING | **Risk of injury!**<br>Failure to follow this safety instruction endangers the life and health of persons. |
| CAUTION | **Personal injuries!**<br>Failure to follow this safety instruction can lead to injuries to persons. |
| Attention | **Damage to environment/equipment or data loss**<br>Failure to follow this instruction can lead to environmental damage, equipment damage or data loss. |
| Note | **Tip or pointer**<br>This symbol indicates information that contributes to better understanding. |

## 1.3 Documentation Issue Status

| Version | Comment |
|---|---|
| 1.3.1 | • Minor corrections at chapter *Basic function principles* and *Parameterization and programming* during translation |
| 1.3.0 | • Chapter *Basic function principles* added<br>• Chapter *Parameterization and programming* added |
| 1.2.0 | • Connection extended with sensor display<br>• Chapter *Configuration of ELX terminals in Bus Terminal block* updated<br>• Chapter *Identification of ELX terminals* updated<br>• Technical data updated |
| 1.1.0 | • Chapter *Configuration of ELX terminals in Bus Terminal block* updated |
| 1.0.1 | • Layout updated |
| 1.0 | • Technical data updated<br>• Chapter *Mounting and wiring* updated |
| 0.2 | • Technical data updated<br>• Chapter *Mounting and wiring* updated |
| 0.1 | • First preliminary version (for internal use only) |

## 1.4 Marking of ELX terminals

### Name

An ELX terminal has a 15-digit technical designation, composed of

- family key
- type
- software variant
- revision

| example | family | type | software variant | revision |
|---|---|---|---|---|
| ELX1052-0000-0000 | ELX terminal | 1052: two-channel digital input terminal for NAMUR sensors, Ex i | 0000: basic type | 0001 |
| ELX9650-0000-0000 | ELX terminal | 9650: power supply terminal | 0000: basic type | 0001 |

### Notes

- The elements mentioned above result in the **technical designation**. ELX1052-0000-0001 is used in the example below.
- Of these, ELX1052-0000 is the order identifier, commonly called just ELX1052 in the "-0000" revision. “-0001” is the EtherCAT revision.
- The **order identifier** is made up of
  - family key (ELX)
  - type (1052)
  - software version (-0000)
- The **Revision** -0001 shows the technical progress, such as the extension of features with regard to the EtherCAT communication, and is managed by Beckhoff.
  In principle, a device with a higher revision can replace a device with a lower revision, unless specified otherwise, e.g. in the documentation.
  Associated and synonymous with each revision there is usually a description (ESI, EtherCAT Slave Information) in the form of an XML file, which is available for download from the Beckhoff website.
  The revision has been applied to the terminals on the outside, see *ELX1052 with date code 3218FMFM, BTN 10000100 and Ex marking.*
- The hyphen is omitted in the labeling on the side of the terminal. Example:
  Name: ELX1052-0000
  Label: ELX1052 $_{0000}$
- The type, software version and revision are read as decimal numbers, even if they are technically saved in hexadecimal.

### Identification numbers

ELX terminals have two different identification numbers:

- date code (batch number)
- **B**eckhoff **T**raceability **N**umber, or BTN for short (as a serial number it clearly identifies each terminal)

### Date code

The date code is an eight-digit number given by Beckhoff and printed on the ELX terminal. The date code indicates the build version in the delivery state and thus identifies an entire production batch, but does not distinguish between the terminals in a batch.

Structure of the date code: **WW YY FF HH**

WW - week of production (calendar week)
YY - year of production
FF - firmware version
HH - hardware version

Example with date code: 02180100:
02 - week of production 02
18 - year of production 2018
01 - firmware version 01
00 - hardware version 00

### Beckhoff Traceability Number (BTN)

In addition, each ELX terminal has a unique **B**eckhoff **T**raceability **N**umber (BTN).

### Ex marking

The Ex marking can be found at the top left on the terminal:

II 3 (1) G Ex ec [ia Ga] IIC T4 Gc
II (1) D [Ex ia Da] IIIC
I (M1) [Ex ia Ma] I
IECEx BVS 18.0005X
BVS 18 ATEX E 005 X

### Examples

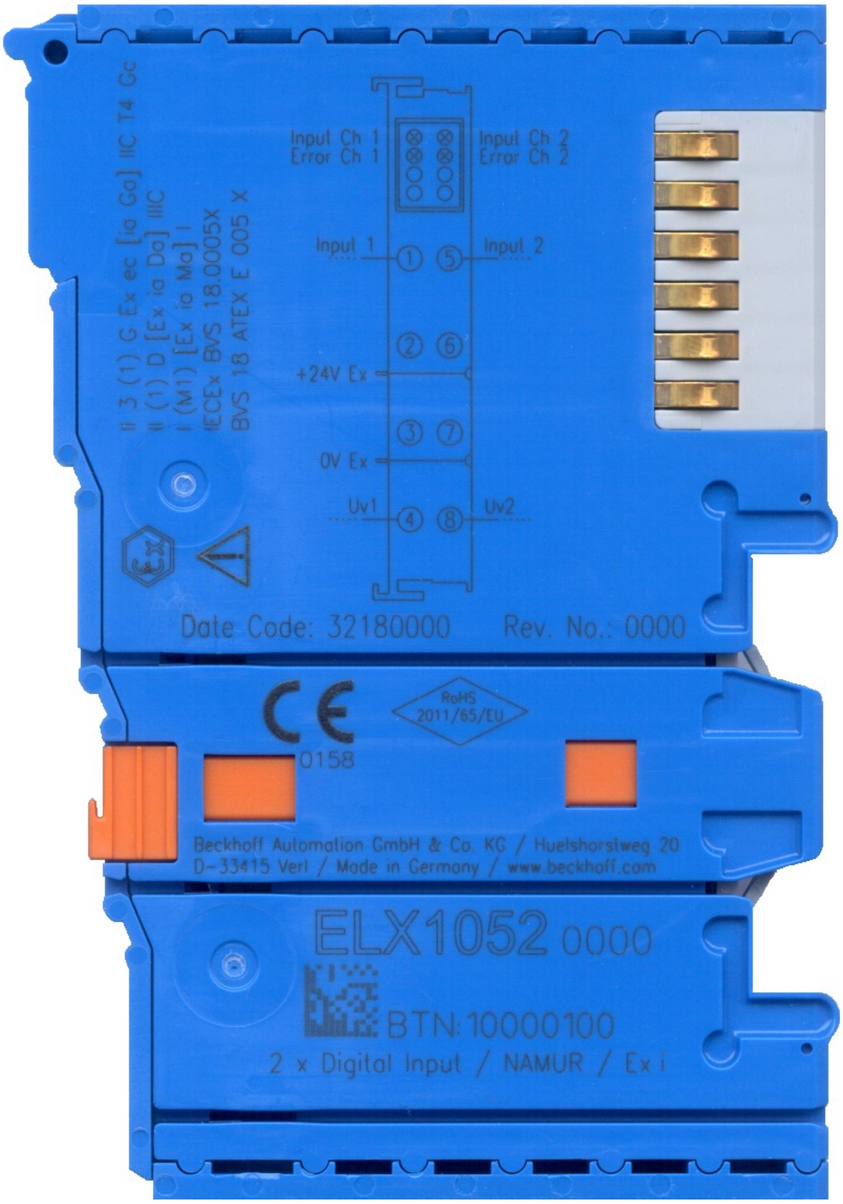


Fig. 1: ELX1052-0000 with date code 32180000, BTN 10000100 and Ex marking


Fig. 2: ELX9012 with date code 32180005 and Ex marking

# 2 Product overview

## 2.1 ELX3351 - Introduction

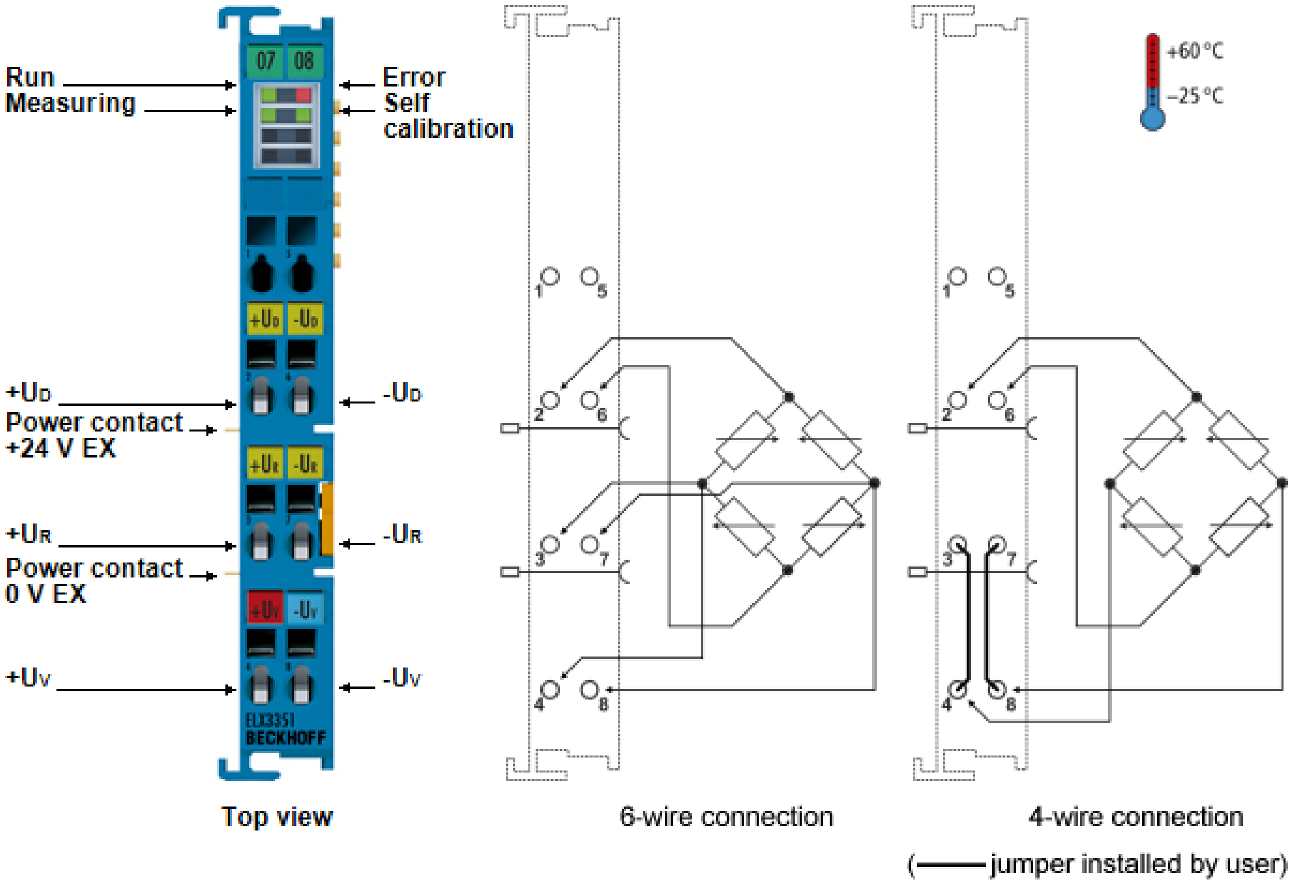


Fig. 3: 1-channel analog input terminal for strain gauge, 16 bit, Ex i

The analog ELX3351 input terminal enables direct connection of a resistor bridge or load cell from hazardous areas, Zone 0/20 and 1/21. The terminal can be connected in 4- or 6-wire technology. The ratio between the bridge voltage $U_D$ and the supply voltage $U_R$ is determined in 24-bit resolution, and the load value is calculated as a process value. Apart from automatic self-calibration (can be deactivated), additional functions such as Tara and Freeze as well as dynamic filters are integrated.

## 2.2 Technical data

| Technical data | ELX3351-0000 |
|---|---|
| Sensor types | resistor bridge, strain gauge |
| Number of inputs | 1, for 1 resistor bridge in full bridge technology |
| Connection method | 4-wire, 6-wire |
| Bridge input resistance | 300 Ω…1.5 kΩ |
| Measuring range $U_D$ | max. -18…+18 mV |
| Measuring range $U_{REF}$ | max. -12…+12 V |
| Internal resistance | > 25 kΩ ($U_R$, differential), > 1 MΩ ($U_D$, differential) |
| Resolution | 24 Bit, 32 bit presentation |
| Measuring error | < ±0,5 % (relative to full scale value), self-calibration active |
| Input filter limit frequency | typ. 3.6 kHz (-3 dB, low pass) |
| Conversion time | typ. 1.6 ms |
| Filter | 50 Hz, configurable |
| Supply voltage electronics | via E-Bus (5 $V_{DC}$) and Power Contacts (24 $V_{DC}$ Ex, feeding by ELX9560) |
| Current consumption from E-Bus | typ. 85 mA |
| Power supply $U_V$ | up to 10 $V_{DC}$, dependent on sensor |
| Current consumption power contacts | min. 20 mA, dependent on sensor |
| Special features | self-calibration, dynamic filters, freeze |
| Bit width in the process image | 32 bit |
| Electrical isolation | 1500 V (E-Bus / field voltage) |
| Weight | app. 60 g |
| Permissible ambient temperature range during operation | -25°C ... + 60°C |
| Permissible ambient temperature range during storage | -40°C ... + 85°C |
| Permissible relative humidity | 95%, no condensation |
| Permissible air pressure (operation, storage, transport) | 800 hPa to 1100 hPa (this corresponds to a height of approx. -690 m to 2000 m over sea level assuming an international standard atmosphere) |
| Dimensions (W x H x D) | app. 15 mm x 100 mm x 70 mm (width aligned: 12 mm) |
| Mounting | on 35 mm mounting rail conforms to EN 60715 |
| Vibration / shock resistance | conforms to EN 60068-2-6 / EN 60068-2-27 |
| EMC immunity / emission | conforms to EN 61000-6-2 / EN 61000-6-4 |
| Protect. class | IP20 |
| Permissible installation position | See chapter Installation position and minimum distances [▸ 19] |
| Approvals | CE, ATEX, IECEx |

| Technical data for explosion protection | ELX3351-0000 | |
|---|---|---|
| Ex marking | II 3 (1) G Ex ec [ia Ga] IIC T4 Gc<br>II (1) D [Ex ia Da] IIIC<br>I (M1) [Ex ia Ma] I | |
| Certificate numbers | IECEx BVS 18.0005X<br>BVS 18 ATEX E 005 X | |
| Power supply | Invariable in connection with ELX9560 | |
| Field interfaces | $U_O$ = 11.76 V<br>$I_O$ = 146 mA<br>$P_O$ = 214 mW<br>Characteristic curve: linear | |

| Reactance (without consideration of the simultaneousness) | | $L_0$ | $C_0$ |
|---|---|---|---|
| | Ex ia I | 20 mH | 40 µF |
| | Ex ia IIA | 13.3 mH | 39 µF |
| | Ex ia IIB | 6.6 mH | 9.9 µF |
| | Ex ia IIC | 1.7 mH | 1.5 µF |
| | Ex ia IIIC | 6.6 mH | 9.9 µF |

## 2.3 Intended use

**WARNING**

**Endangering the safety of persons and equipment!**

The ELX components may only be used for the purposes described below!

**CAUTION**

**Observe ATEX and IECEx!**

The ELX components may only be used in accordance with the ATEX directive and the IECEx scheme!

The ELX terminals extend the field of application of the Beckhoff bus terminal system with functions for integrating intrinsically safe field devices from hazardous areas. The intended field of application is data acquisition and control tasks in discrete and process engineering automation, taking into account explosion protection requirements.

The ELX terminals are protected by the type of protection "Increased safety" (Ex e) according to IEC 60079-7 and must only be operated in hazardous areas of Zone 2 or in non-hazardous areas.

The field interfaces of the ELX terminals achieve explosion protection through the type of protection "intrinsic safety" (Ex i) according to IEC 60079-11. For this reason, only appropriately certified, intrinsically safe devices may be connected to the ELX terminals. Observe the maximum permissible connection values for voltages, currents and reactances. Any infringement can damage the ELX terminals and thus eliminate the explosion protection.

The ELX terminals are open, electrical equipment for installation in lockable cabinets, enclosures or operating rooms. Make sure that access to the equipment is only possible for authorized personnel.

**CAUTION**

**Ensure traceability!**

The buyer has to ensure the traceability of the device via the Beckhoff Traceability Number (BTN) [▸ 9].

# 3 Mounting and wiring

## 3.1 Special conditions of use for ELX terminals

WARNING

**Observe the special conditions of use for the intended use of Beckhoff ELX terminals in potentially explosive areas (ATEX directive 2014/34/EU)!**

- The certified components are to be installed in a suitable housing that guarantees an ingress protection of at least IP54 in accordance with EN 60079-0 and EN 60529! The prescribed environmental conditions during installation, operation and maintenance are thereby to be taken into account! Inside the housing, pollution degree 1 and 2 are permissible.
- If the temperatures during rated operation are higher than 70°C at the feed-in points of cables, lines or pipes, or higher than 80°C at the wire branching points, then cables must be selected whose temperature data correspond to the actual measured temperature values!
- Observe the permissible ambient temperature range of -25 to +60°C of Beckhoff ELX terminals!
- Measures must be taken to protect against the rated operating voltage being exceeded by more than 40% due to short-term interference voltages! The power supply of the ELX9560 power supply terminal must correspond to overvoltage category II according to EN 60664-1
- The individual terminals may only be unplugged or removed from the bus terminal system if all supply voltages have been switched off or if a non-explosive atmosphere is ensured!
- The connections of the ELX9560 power supply terminal may only be connected or disconnected if all supply voltages have been switched off or if a non-explosive atmosphere is ensured!
- The fuses of the EL92xx power feed terminals may only be exchanged if all supply voltages have been switched off or if a non-explosive atmosphere is ensured!
- Address selectors and switches may only be adjusted if all supply voltages have been switched off or if a non-explosive atmosphere is ensured!

## 3.2 Installation notes for ELX terminals

Attention

**Storage, transport and mounting**

- Transport and storage are permitted only in the original packaging!
- Store in a dry place, free from vibrations.
- A brand new ELX terminal with a certified build version is delivered only in a sealed carton. Therefore, check that the carton and all seals are intact before unpacking.
- Do not use the ELX terminal if
  - its packaging is damaged
  - the terminal is visibly damaged or
  - you cannot be sure of the origin of the terminal.
- ELX terminals with a damaged packaging seal are regarded as used.

WARNING

**Observe the accident prevention regulations**

During mounting, commissioning, operation and maintenance, adhere to the safety regulations, accident prevention regulations and general technical rules applicable to your devices, machines and plants.

| | |
|---|---|
| CAUTION | **Observe the erection regulations**<br>Observe the applicable erection regulations. |

| | |
|---|---|
| Attention | **Protect the terminals against electrostatic discharge (ESD)**<br>Electronic components can be destroyed by electrostatic discharge. Therefore, take the safety measures to protect against electrostatic discharge as described in DIN EN 61340-5-1 among others. In conjunction with this, ensure that the personnel and surroundings are suitably earthed. |

| | |
|---|---|
| Attention | **Do not place terminals on E-bus contacts**<br>Do not place the ELX terminals on the E-bus contacts located on the right-hand side. The function of the E-bus contacts can be negatively affected by damage caused by this, e.g. scratches. |

| | |
|---|---|
| Attention | **Protect the terminals against dirt**<br>To ensure the functionality of the ELX terminals they must be protected against dirt, especially on the contact points. For this reason use only clean tools and materials. |

| | |
|---|---|
| Attention | **Handling**<br>• It is forbidden to insert conductive or non-conductive objects of any kind into the interior of the housing (e.g. through the ventilation slots in the housing).<br>• Use only the openings provided in the housing front and appropriate tools to actuate the spring-loaded terminal contacts on the front side for attaching connection cables to the terminal; see chapter Wiring [▶ 22].<br>• The opening of the housing, the removal of parts and any mechanical deformation or machining of an ELX terminal are not permitted! |

If an ELX terminal is defective or damaged it must be replaced by an equivalent terminal. Do not carry out any repairs to the devices. For safety reasons repairs may only be carried out by the manufacturer.

| | |
|---|---|
| Attention | **Contact marking and pin assignment**<br>The colored inscription labels above the front connection contacts shown in the illustrations in the introduction chapter are only examples and are not part of the scope of delivery!<br>A clear assignment of channel and terminal designation according to the chapter contact assignment to the actual terminal point can be made via the lasered channel numbers 1 to 8 on the left above the respective terminal point as well as via the laser image.<br>Observe any possible polarity dependency of connected intrinsically safe circuits! |

# 3.3 Arrangement of ELX terminals within a bus terminal block

| WARNING | **Observe the following instructions for the arrangement of ELX terminals!**<br>• ELX signal terminals must always be installed behind an ELX9560 power supply terminal, without exception!<br>• Only signal terminals of the ELX series may be installed behind an ELX9560 power supply terminal!<br>• Multiple ELX9560 power supply terminals may be set in one terminal block as long as one ELX9410 is placed before each additional ELX9560!<br>• An ELX9410 power supply terminal must not be mounted to the right of an ELX9560 nor to the left of any ELX signal terminal!<br>• The last terminal of each ELX segment is to be covered by an ELX9012 bus end cover, unless two ELX9410 power supply terminals are installed in direct succession for continuing the same terminal segment with standard Beckhoff EtherCAT terminals (e.g. EL/ES/EK)! |
|---|---|

**Examples for the arrangement of ELX terminals**

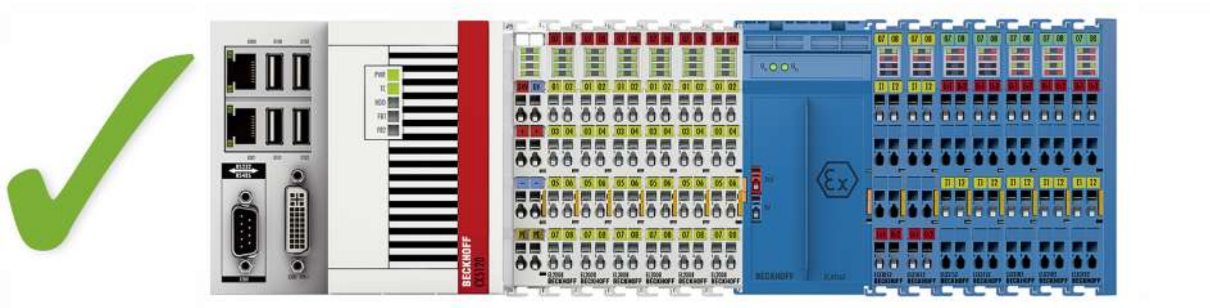

Fig. 4: Valid arrangement of the ELX terminals (right terminal block).

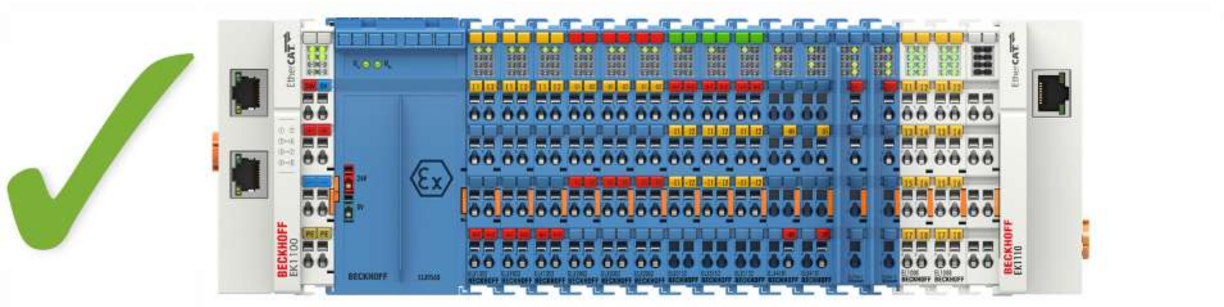

Fig. 5: Valid arrangement - terminals that do not belong to the ELX series are set before and after the ELX terminal segment. The separation is realized by the ELX9560 at the beginning of the ELX terminal segment and two ELX9410 at the end of the ELX terminal segment.

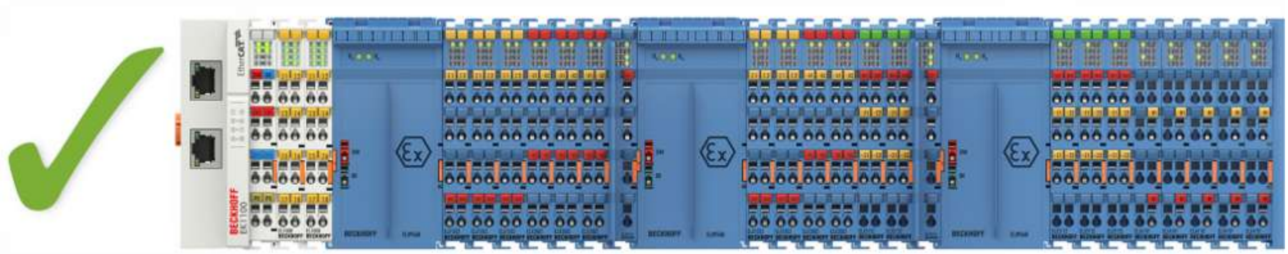

Fig. 6: Valid arrangement - multiple power supplies by ELX9560, each with an upstream ELX9410.

Fig. 7: Valid arrangement - ELX9410 in front of an ELX9560 power supply terminal.

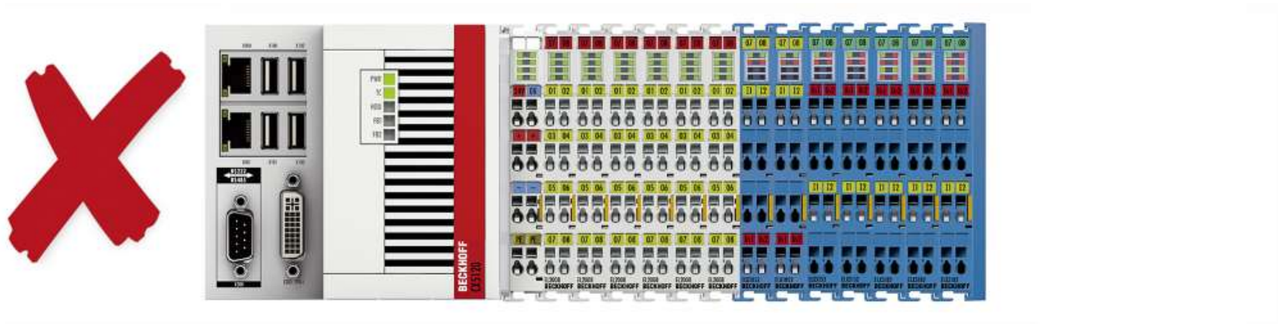

Fig. 8: Invalid arrangement - missing ELX9560 power supply terminal.

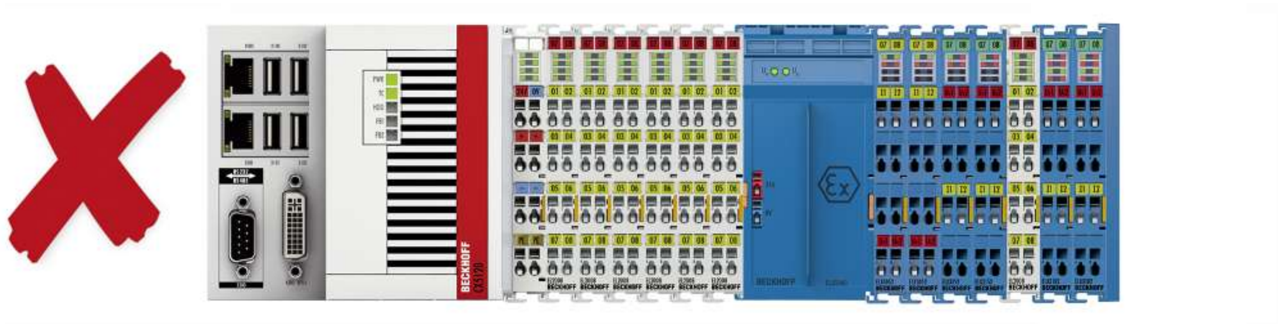

Fig. 9: Invalid arrangement - terminal that does not belong to the ELX series within the ELX terminal segment.

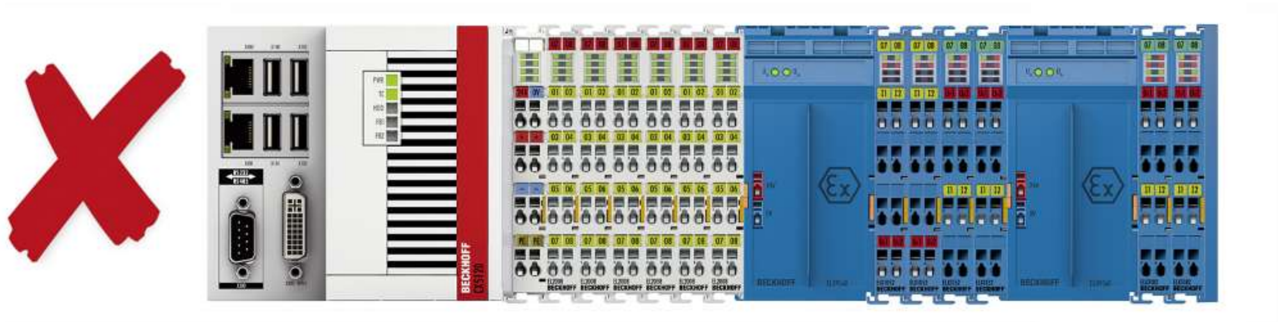

Fig. 10: Invalid arrangement - second ELX9560 power supply terminal within the ELX terminal segment without an upstream ELX9410.

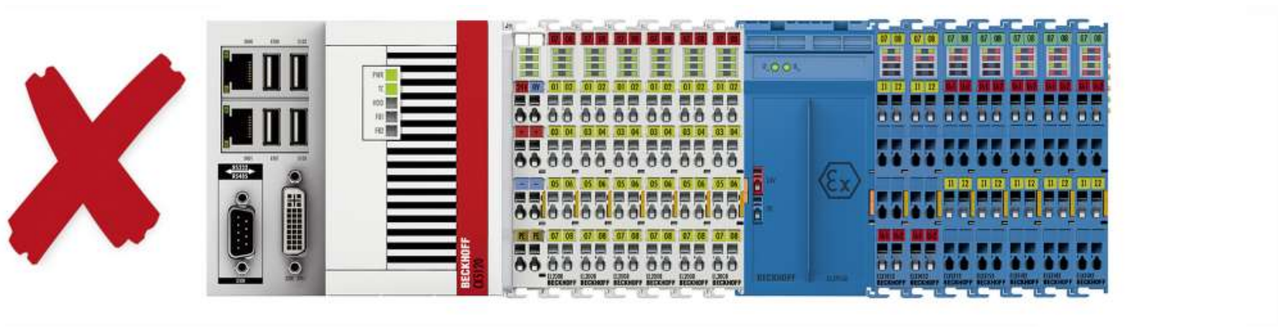

Fig. 11: Invalid arrangement - missing ELX9012 bus end cover.

| | |
|---|---|
| **Attention** | **Observe the maximum output current of the ELX9560**<br>When configuring the ELX terminal segment, please note the maximum available output current of the ELX9560 power supply terminal in accordance with the specified technical data.<br>If required, an additional power supply terminal ELX9560 with an upstream ELX9410 connected (see mounting examples) must be installed or a completely new terminal block must be assembled. |

# 3.4 Installation position and minimum distances

### Installation position

For the prescribed installation position the mounting rail is installed horizontally and the mating surfaces of the ELX terminals point toward the front (see illustration below). The terminals are ventilated from below, which enables optimum cooling of the electronics through convection. The direction indication “down” corresponds to the direction of positive acceleration due to gravity.

### Minimum distances

Observe the following minimum distances to ensure optimum convection cooling:

- above and below the ELX terminals: 35 mm (required!)
- besides the bus terminal block: 20 mm (recommended)

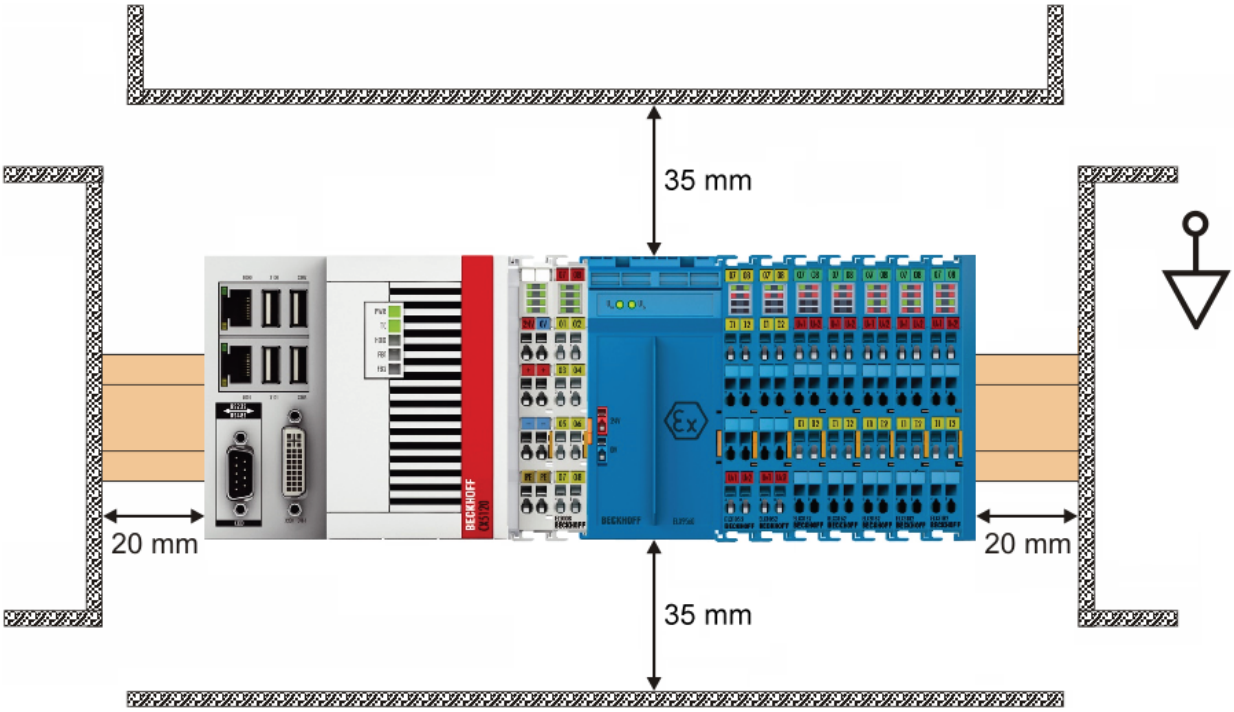


Fig. 12: Installation position and minimum distances

| WARNING | **Observe the minimum separation distances according to IEC 60079-14!**<br>Observe the prescribed minimum separation distances between intrinsically safe and non-intrinsically safe circuits according to IEC 60079-14. |
| --- | --- |

## 3.5 Installation of ELX terminals on mounting rails

| WARNING | **Risk of electric shock and damage of device!**<br>Bring the bus terminal system into a safe, powered down state before starting installation, disassembly or wiring of the bus terminals! |
|---|---|

| CAUTION | **Danger of injury due to power contacts!**<br>For your own protection, pay attention to careful and careful handling of the ELX terminals. In particular, the left side mounted, sharp-edged blade contacts pose a potential risk of injury. |
|---|---|

**Assembly**

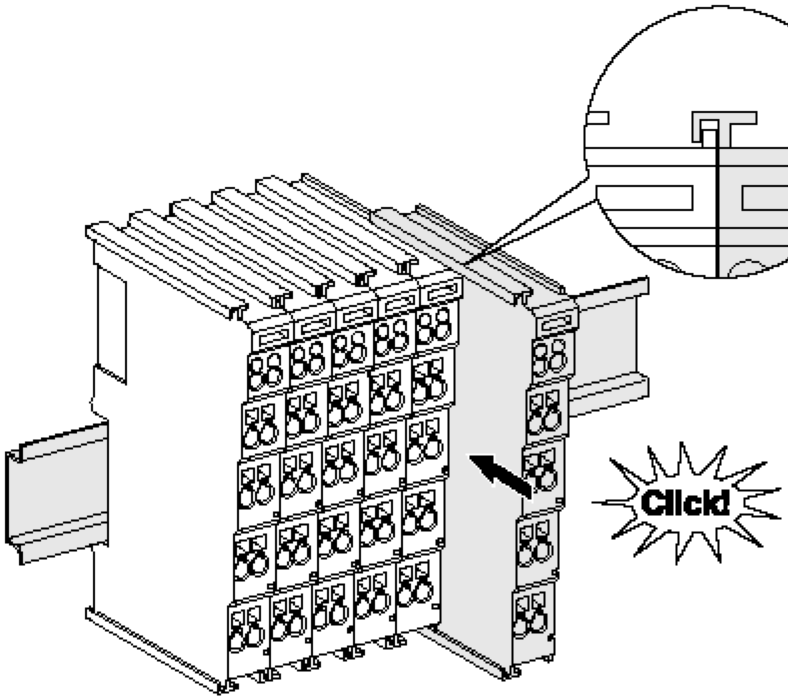


Fig. 13: Attaching on mounting rail

The bus coupler and bus terminals are attached to commercially available 35 mm mounting rails (DIN rails according to EN 60715) by applying slight pressure:

1. First attach the fieldbus coupler to the mounting rail.
2. The bus terminals are now attached on the right-hand side of the fieldbus coupler. Join the components with tongue and groove and push the terminals against the mounting rail, until the lock clicks onto the mounting rail.
   If the terminals are clipped onto the mounting rail first and then pushed together without tongue and groove, the connection will not be operational! When correctly assembled, no significant gap should be visible between the housings.

| Note | **Fixing of mounting rails**<br>The locking mechanism of the terminals and couplers extends to the profile of the mounting rail. At the installation, the locking mechanism of the components must not come into conflict with the fixing bolts of the mounting rail. To mount the mounting rails with a height of 7.5 mm under the terminals and couplers, you should use flat mounting connections (e.g. countersunk screws or blind rivets). |
|---|---|

**Disassembly**

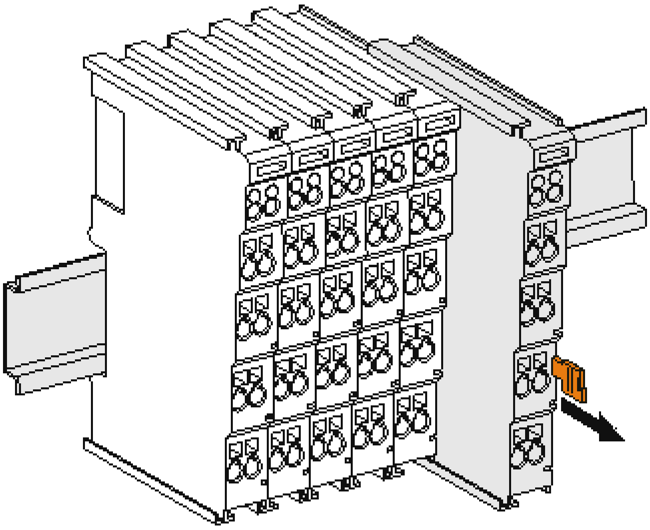

Fig. 14: Disassembling of terminal

Each terminal is secured by a lock on the mounting rail, which must be released for disassembly:

1. Pull the terminal by its orange-colored lugs approximately 1 cm away from the mounting rail. In doing so for this terminal the mounting rail lock is released automatically and you can pull the terminal out of the bus terminal block easily without excessive force.
2. Grasp the released terminal with thumb and index finger simultaneous at the upper and lower grooved housing surfaces and pull the terminal out of the bus terminal block.

**Connections within a bus terminal block**

The electric connections between the Bus Coupler and the Bus Terminals are automatically realized by joining the components:

- The six spring contacts of the E-Bus deal with the transfer of the data and the supply of the Bus Terminal electronics.
- The power contacts deal with the supply for the field electronics and thus represent a supply rail within the bus terminal block.
  The power contacts of the ELX terminals are supplied by the ELX9560 power terminal. This interrupts the power contacts and thus represents the beginning of a new supply rail.

| | |
|---|---|
| **Note** | **Power Contacts**<br>During the design of a bus terminal block, the pin assignment of the individual Bus Terminals must be taken account of, since some types (e.g. analog Bus Terminals or digital 4-channel Bus Terminals) do not or not fully loop through the power contacts. |

# 3.6 Connection

## 3.6.1 Connection system

| | |
|---|---|
| **WARNING** | **Risk of electric shock and damage of device!**<br>Bring the bus terminal system into a safe, powered down state before starting installation, disassembly or wiring of the bus terminals! |

**Overview**

The terminals of ELXxxxx series with standard wiring include electronics and connection level in a single enclosure.

**Standard wiring (ELXxxxx)**

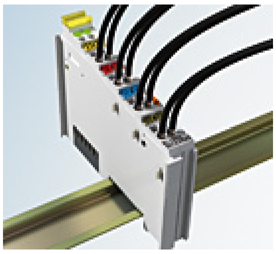

Fig. 15: Standard wiring

The terminals of ELXxxxx series feature integrated screwless spring force technology for fast and simple assembly.

**Ultrasonically "bonded" (ultrasonically welded) conductors**

| | |
|---|---|
| **Note** | **Ultrasonically “bonded" conductors**<br>It is also possible to connect the Standard Terminals with ultrasonically "bonded" (ultrasonically welded) conductors. In this case, please note the tables concerning the wire-size width below! |

## 3.6.2 Wiring

| | |
|---|---|
| **WARNING** | **Risk of electric shock and damage of device!**<br>Bring the bus terminal system into a safe, powered down state before starting installation, disassembly or wiring of the Bus Terminals! |

**Terminals for standard wiring ELXxxxx**

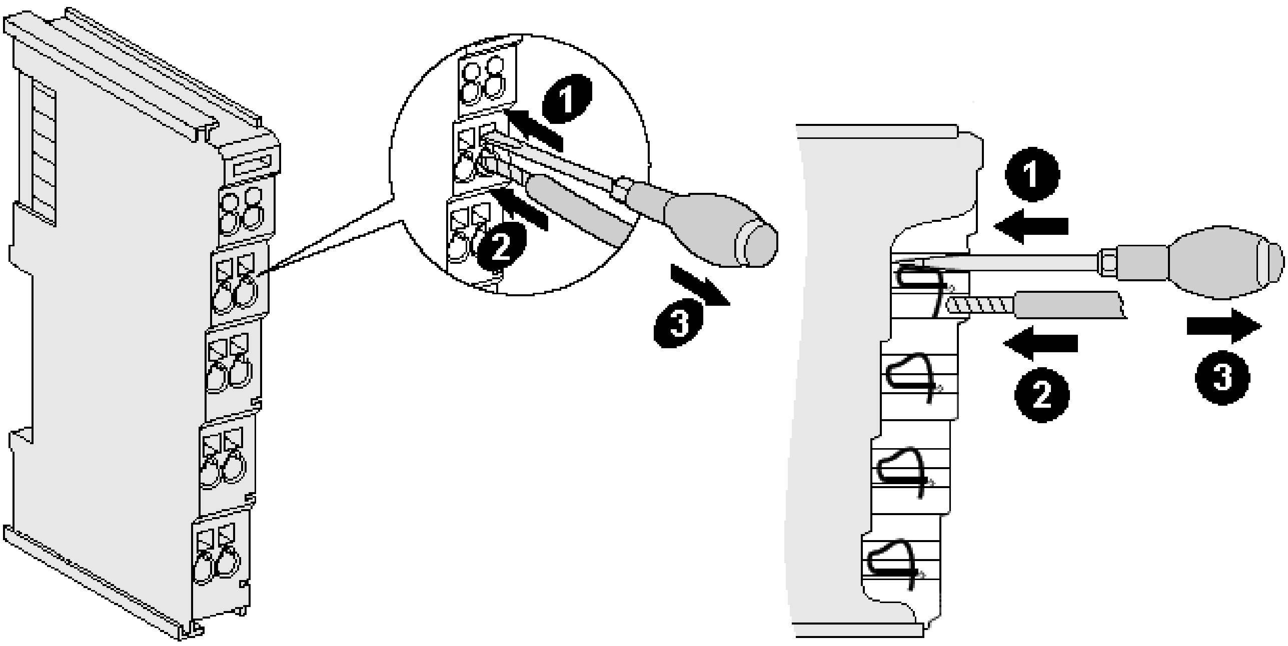


Fig. 16: Connecting a cable on a terminal point

Up to eight terminal points enable the connection of solid or finely stranded cables to the Bus Terminal. The terminal points are implemented in spring force technology. Connect the cables as follows:

1. Open a terminal point by pushing a screwdriver straight against the stop into the square opening above the terminal point. Do not turn the screwdriver or move it alternately (don't toggle).
2. The wire can now be inserted into the round terminal opening without any force.
3. The terminal point closes automatically when the pressure is released, holding the wire securely and permanently.

Observe the requirements for connecting cables and cross sections according to IEC 60079-7 and IEC 60079-11. See the following tables for the suitable wire size width.

| **Power supply terminal** | **ELX9560** |
|---|---|
| **Wire size width (single core wires)** | 0.14 ... 1.5 mm$^2$ |
| **Wire size width (fine-wire conductors)** | 0.14 ... 1.5 mm$^2$ |
| **Wire size width (conductors with a wire end sleeve)** | 0.14 ... 1.0 mm$^2$ |
| **Wire stripping length** | 8 ... 9 mm |

**Attention**

**Maximum screwdriver width for ELX9560**

Use a screwdriver with a maximum width of 2 mm to wire the ELX9560 power supply terminal. Wider screwdrivers can damage the terminal points.

| **All other ELX terminals** | **ELXxxxx** |
|---|---|
| **Wire size width (single core wires)** | 0.08 ... 2.5 mm$^2$ |
| **Wire size width (fine-wire conductors)** | 0.08 ... 2.5 mm$^2$ |
| **Wire size width (conductors with a wire end sleeve)** | 0.14 ... 1.5 mm$^2$ |
| **Wire stripping length** | 8 ... 9 mm |

## 3.6.3 Proper line connection

Always connect only one wire per terminal point.

When using fine-wire conductors it is recommended to connect them with wire end sleeves in order to establish a safe, conductive connection.

In addition, make sure that the pin assignment is correct to prevent damage to the ELX terminals and the connected devices.

## 3.6.4 Shielding and potential separation

**Note**

**Shielding**

Encoder, analog sensors and actors should always be connected with shielded, twisted paired wires.

**CAUTION**

**Observe installation requirements in areas of potentially explosive atmospheres!**

During installation, observe the requirements for cables, shielding and earth potential equalization in areas of potentially explosive atmospheres according to IEC 60079-11, IEC 60079-14 and IEC 60079-25.

**WARNING**

**Ensure potential separation of the 24 V Ex busbar!**

In any case, make sure that the galvanic isolation made by the ELX9560 between the 24 V Ex busbar (power contacts +24 V Ex and 0 V Ex) and other system potentials (if applicable also functional or protective earths) is not removed.

## 3.6.5 ELX3351 - Contact assignment

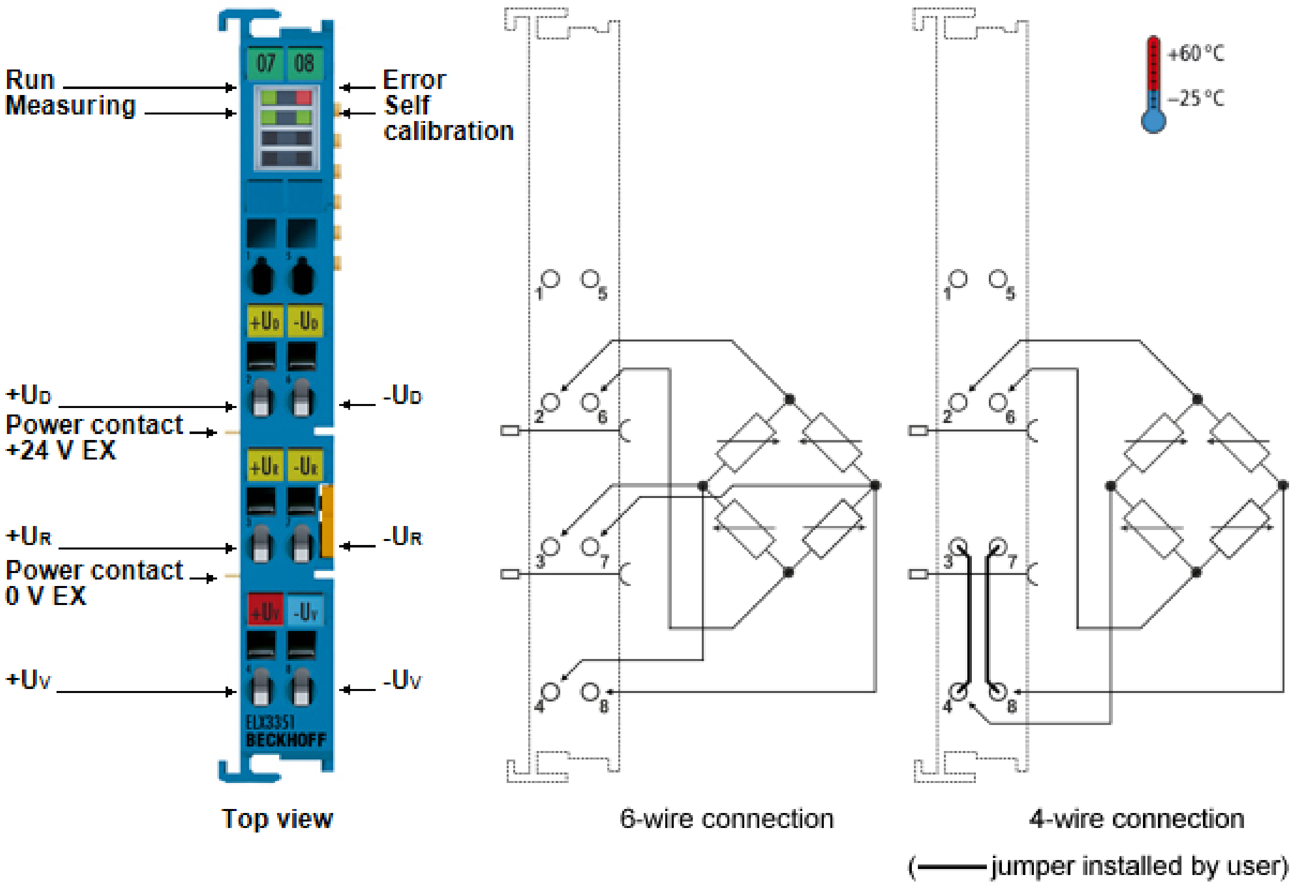


Fig. 17: ELX3351 - Contact assignment

| Terminal point | | Description |
|---|---|---|
| Name | No. | |
| | 1 | not implemented |
| $+U_D$ | 2 | + input measuring voltage (difference voltage of bridge) |
| $+ U_R$ | 3 | + input reference voltage (supply voltage at bridge) |
| $+U_V$ | 4 | + output supply voltage for bridge |
| | 5 | not implemented |
| $-U_D$ | 6 | - input measuring voltage (difference voltage of bridge) |
| $- U_R$ | 7 | - input reference voltage (supply voltage at bridge) |
| $- U_V$ | 8 | - output supply voltage for bridge |

### Wiring the bridge

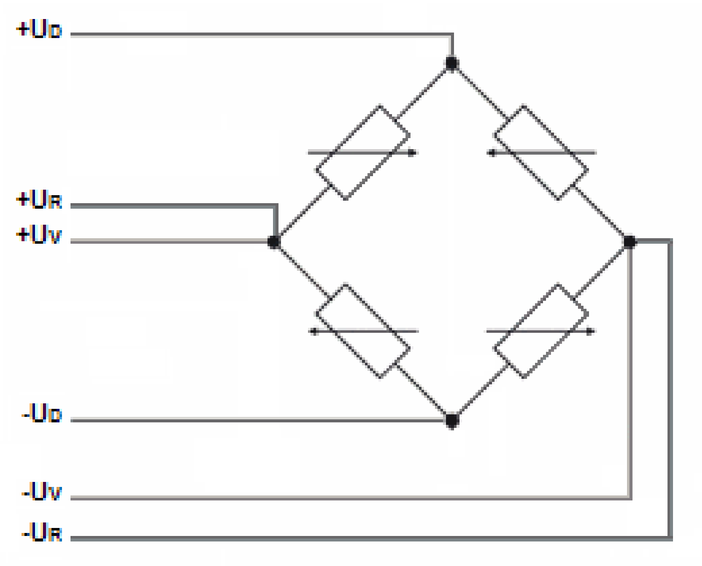


Fig. 18: ELX3351 - Connection of a full bridge in 6-wire technology

The ELX3351 is standardly designed for a sensor connection in 6-wire technology.
In the event that a sensor is to be operated in 4-wire technology, the contacts $+U_V$ and $+U_R$ as well as the contacts $-U_V$ and $-U_R$ are to be bridged manually, a software-side switching within the terminal is not possible.

The terminal supplies 10 $V_{DC}$ bridge supply voltage $U_V$ in not loaded state. This voltage is still limited to $U_O$ in accordance with the Technical Data for Explosion Protection [▶ 13].

The maximum measuring input voltage $U_{REF}$ is limited to 12 $V_{DC}$, the input measuring voltage is limited to 18 $mV_{DC}$.

### LED Display

| LED | Color | Meaning | |
|---|---|---|---|
| Run | green | These LED indicates the terminal's operating state: | |
| | | off | State of the EtherCAT State Machine: **INIT** = initialization of the terminal |
| | | flashing | State of the EtherCAT State Machine: **PREOP** = function for mailbox communication and different standard-settings set |
| | | single flash | State of the EtherCAT State Machine: **SAFEOP** = verification of the Sync Manager channels and the distributed clocks.<br>Outputs remain in safe state |
| | | on | State of the EtherCAT State Machine: **OP** = normal operating state; mailbox and process data communication is possible |
| | | flickering | State of the EtherCAT State Machine: **BOOTSTRAP** = function for firmware updates of the terminal |
| Error | red | on | There is a fault (eg. undershooting or exceeding the measured value range)<br>Note: Wire break detection is only for the +Uv and -Uv connections |
| Measuring | green | on | The terminal is in normal operating mode (measurement) |
| Self calibration | green | on | Self-calibration in operation |

# 4 Basic function principles

## 4.1 EtherCAT basics

Please refer to the EtherCAT System Documentation for the EtherCAT fieldbus basics, also available as PDF file from www.beckhoff.com.

## 4.2 Basic principles of strain gauge technology

Basic information on the technological field of strain gauges/load cells as metrological instruments is to be given below. The information is of general nature; it is up to the user to check the extent to which it applies to his application.

- Strain gauges serve either to directly measure the static (0 to a few Hz) or dynamic (up to several KHz) elongations, compressions or torsions of a body by being directly fixed to it, or to measure various forces or movements as part of a sensor (e.g. load cells/force transducers, displacement sensor, vibration sensors).
- In the case of the optical strain gauge (e.g. Bragg grating), an application of force causes a proportional change in the optical characteristics of a fiber used as a sensor. Light with a certain wavelength is fed into the sensor. Depending upon the deformation of the grating, which is laser-cut into the sensor, due to the mechanical load, part of the light is reflected and evaluated using a suitable measuring transducer (interrogator).

The commonest principle in the industrial environment is the electrical strain gauge. There are many common terms for this type of sensor: load cell, weighbridge, etc.

**Structure of electrical strain gauges**

A strain gauge consists of a carrier material (e.g. stretchable plastic film) with an applied metal film from which a lattice of electrically conductive resistive material is worked in very different geometrical forms, depending on the requirements.

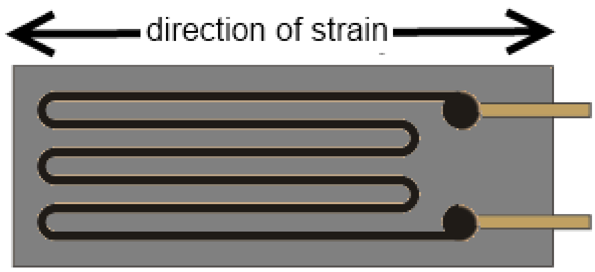


Fig. 19: Strain gauge

This utilizes a behavior whereby, for example in the case of strain, the length of a metallic resistance network increases and its diameter decreases, as a result of which its electrical resistance increases proportionally.

**$\Delta R/R = k*\varepsilon$**

$\varepsilon = \Delta l/l$ thereby corresponds to the elongation; the strain sensitivity is called the k-factor. This also gives rise to the typical track layout inside the strain gauge: the resistor track or course is laid in a meandering pattern in order to expose the longest possible length to the strain.

**Example**

The elongation $\varepsilon$ = 0.1% of a strain gauge with k-factor 2 causes an increase in the resistance of 0.2%. Typical resistive materials are constantan (k~2) or platinum tungsten (92PT, 8W with k ~4). In the case of semiconductor strain gauges a silicon structure is glued to a carrier material. The conductivity is changed primarily by deformation of the crystal lattice (piezo-resistive effect). k-factors of up to 200 can be achieved.

**Measurement of signals**

The change in resistance of an individual strain gauge can be determined in principle by resistance measurement (current/voltage measurement) using a 2/3/4-wire measurement technique.

Usually 1/2/4 strain gauges are arranged in a Wheatstone bridge (-> quarter/half/full bridge); the nominal resistance/impedance $R_0$ of all strain gauges (and the auxiliary resistors used if necessary) is usually equivalent to $R1=R2=R3=R4=R_0$. Typical values in the non-loaded state are $R_0$ = 120 Ω, 350 Ω, 700 Ω and 1 kΩ.

The full bridge possesses the best characteristics such as linearity in the feeding of current/voltage, four times the sensitivity of the quarter-bridge as well as systematic compensation of disturbing influences such as temperature drift and creeping. In order to achieve high sensitivity, the 4 individual strain gauges are arranged on the carrier in such a way that 2 are elongated and 2 are compressed in each case.

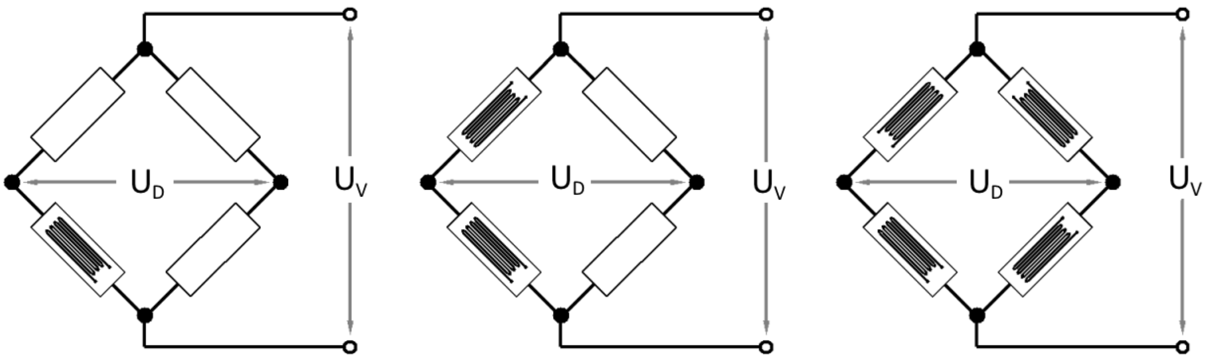


Fig. 20: quarter, half, and full bridge

The measuring bridges can be operated with constant current, constant voltage, or also with AC voltage using the carrier frequency method.

**Full bridge strain gauge at constant voltage (ratiometric measurement)**

Since the relative resistance change ΔR is low in relation to the nominal resistance $R_0$, a simplified equation is given for the strain gauge in the Wheatstone bridge arrangement:

**$U_D/U_V$= ¼ * (ΔR1-ΔR2+ΔR3-ΔR4)/$R_0$.**

ΔR usually has a positive sign in the case of elongation and a minus sign in the case of compression.

A suitable measuring instrument measures the bridge supply voltage $U_V$ and the resulting bridge voltage $U_D$, and forms the quotients from both voltages, i.e. the ratio. After further calculation and scaling the measured value is output, e.g. in kg.

If the voltages $U_V$ and $U_D$ are measured simultaneously, i.e. at the same moment, and placed in relation to each other, then this is referred to as a ratiometric measurement.

The advantage of this is that (with simultaneous measurement!) brief changes in the supply voltage (e.g. EMC effects) or a generally inaccurate or unstable supply voltage likewise have no effect on the measurement.

A change in $U_V$ by e.g. 1% creates the same percentage change in $U_D$ according to the above equation. Due to the simultaneous measurement of $U_D$ and $U_V$ the error cancels itself out completely during the division.

**4-wire vs. 6-wire connection**

With a constant voltage supply, the magnitude of the current can be quite considerable, e.g. 12 V / 350 Ω = 34.3 mA. This leads not only to dissipated heat, wherein the specification of the strain gauge employed must not be exceeded, but possibly also to measuring errors in the case of inadequate wiring due to line losses not being taken into account or compensated.

In principle a full bridge can be operated with a 4-conductor connection (2 conductors for the supply $U_V$ and 2 for the measurement of the bridge voltage $U_D$).

If, for example, a 25 m copper cable (feed + return = 50 m) with a cross section q of 0.25 mm² is used, this results in a line resistance of

**$R_L$= l/ (κ * q) = 50 m / (58 S*m/mm²* 0.25 mm²) = 3.5 Ω**

If this value remains constant, then the error resulting from it can be calibrated out. However, assuming a realistic temperature change of, for example, 30° the line resistance $R_L$ changes by

**ΔRL =30° * 3.9 * 10-4 * 3.5 Ω = 0.41 Ω**

In relation to a 350 Ω measuring bridge this means a measuring error of > 0.1%.

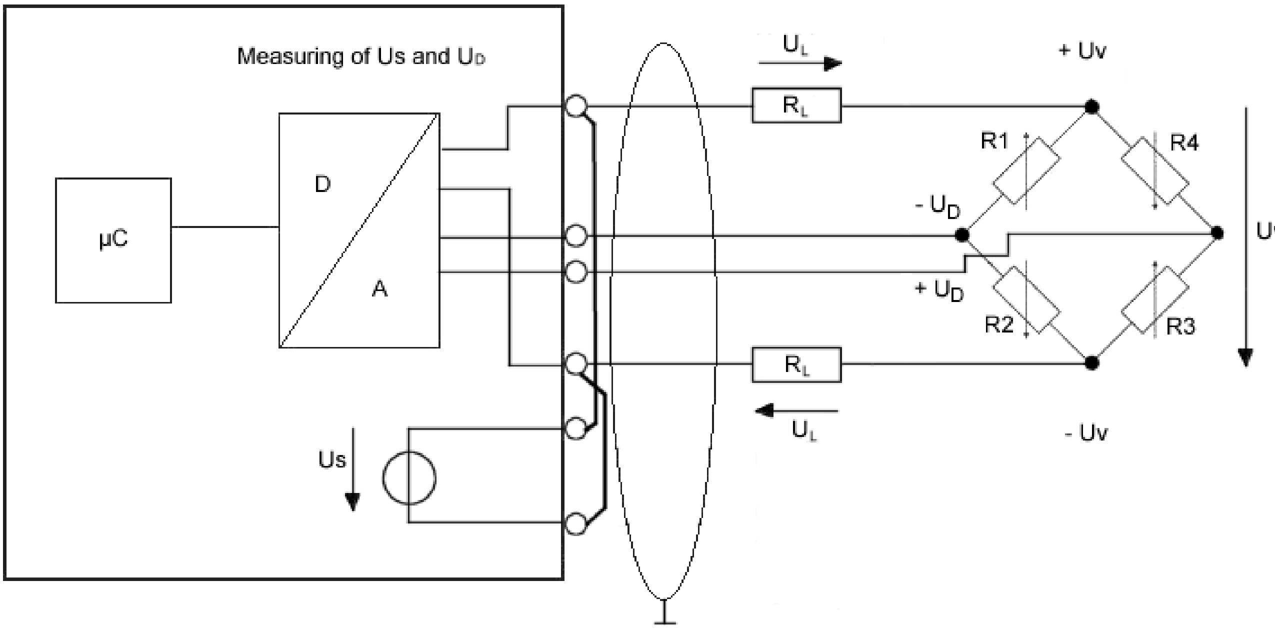


Fig. 21: 4-wire connection

This can be remedied by a 6-wire connection, in particular for precision applications.

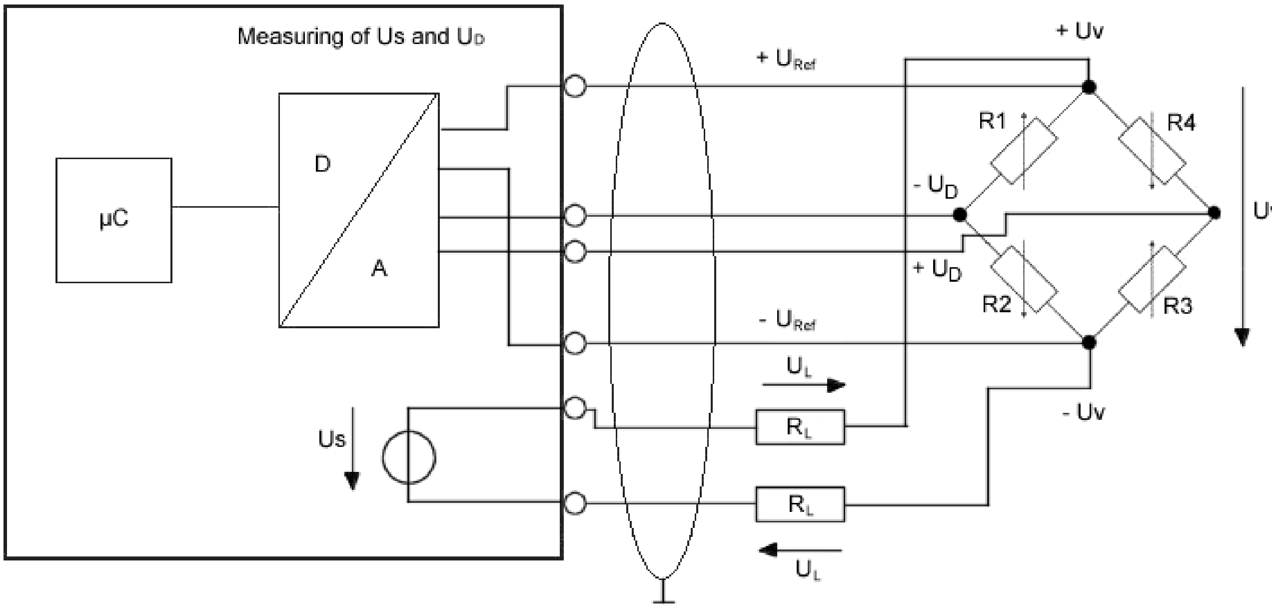


Fig. 22: *6-wire connection*

The supply voltage $U_V$ is thereby fed to the strain gauge (= current carrying conductor). The incoming supply voltage $U_{Ref}$ is only measured with high impedance directly at the measuring bridge in exactly the same way as the bridge voltage $U_D$ with two currentless return conductors in each case. The conductor-related errors are hence omitted.

Since these are very small voltage levels of the order of mV and µV, all conductors should be screened.

### Structure of a load cell with a strain gauge

One application of the strain gauge is the construction of load cells.

This involves gluing strain gauges (full bridges as a rule) to an elastic mechanical carrier, e.g. a double-bending beam spring element, and additionally covered to protect against environmental influences.

The individual strain gauges are aligned for maximum output signals according to the load direction (2 strain gauges in the elongation direction and 2 in the compression direction).

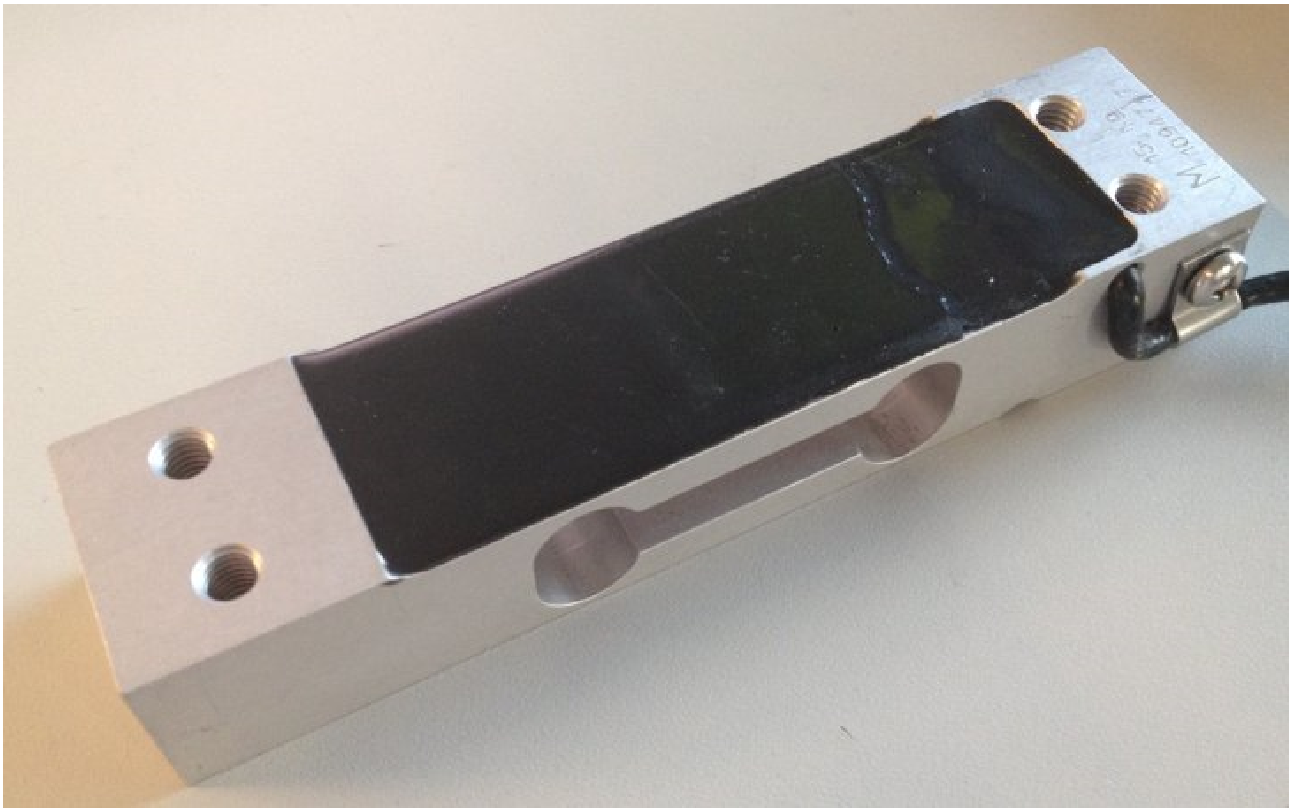

Fig. 23: Example of a load cell

### The most important characteristic data of a load cell

| Note | **Characteristic data**<br>Please enquire to the sensor manufacturer regarding the exact characteristic data! |
|---|---|

#### Nominal load $E_{max}$

Maximum permissible load for normal operation, e.g. 10 kg

#### Nominal characteristic value mV/V

The nominal characteristic value 2mV/V means that, with a supply of $U_S$ =10 V and at the full load $E_{max}$ of the load cell, the maximum output voltage $U_D$ = 10 V  * 2 mV/V = 20 mV. The nominal characteristic value is always a nominal value – a manufacturer’s test report is included with good load cells stating the characteristic value determined for the individual load cell, e.g. 2.0782 mV/V.

#### Minimum calibration value $V_{min}$

This indicates the smallest mass that can be measured without the maximum permissible error of the load cell being exceeded [RevT].

This value is represented either by the equation $V_{min} = E_{max} / n$ (where n is an integer, e.g. 10000), or in % of $E_{max}$ (e.g. 0.01).

This means that a load cell with $E_{max}$ = 10 kg has a maximum resolution of

$V_{min}$ = 10 kg / 10000 = 1 g or $V_{min}$ = 10 kg * 0.01% = 1 g.

**Accuracy class according to OIML R60**

The accuracy class is indicated by a letter (A, B, C or D) and an additional number, which encodes the **scale interval d with a maximum number $n_{max}$** (*1000); e.g. C4 means Class C with maximally 4000d scale intervals.

The classes specify a maximum and minimum limit for **scale intervals d**:

- A: 50,000 – unlimited
- B: 5000 – 100,000
- C: 500 – 10,000
- D: 500 – 1000,

The scale interval $n_{max}$ = 4000d states that, with a load cell with a resolution of $V_{min}$ = 1 g, a calibratable set of scales can be built that has a maximum measuring range of 4000d * $V_{min}$ = 4 kg. Since $V_{min}$ is thereby a minimum specification, an 8 kg set of scales could be built – if the application allows – with the same load cell, wherein the calibratable resolution would then fall to 8 kg/4000d = 2 g. From another point of view the scale interval $n_{max}$ is a maximum specification; hence, the above load cell could be used to build a set of scales with a measuring range of 4 kg, but a resolution of only 2000 divisions = 2 g, if this is adequate for the respective application. Also the classes differ in certain error limits related to non-repeatability/creep/TC.

**Accuracy class according to PTB**

The European accuracy classes are defined in an almost identical way (source: PTB).

| Class | Calibration value e | Minimum load | Max/e | |
|---|---|---|---|---|
| | | | Minimum value | Maximum value |
| I<br>Fine scales | 0.001 g <= e | 100 e | 50000 | - |
| II<br>Precision scales | 0,001 g <= e <= 0,05 g<br>0,1 g <= e | 20 e<br>50 e | 100<br>5000 | 100000<br>100000 |
| III<br>Commercial scales | 0.1 g <= e <= 2 g<br>5 g <= e | 20 e<br>20 e | 100<br>500 | 10000<br>10000 |
| IIII<br>Coarse scales | 5 g <= e | 10 e | 100 | 1000 |

**Minimum application range or minimum measuring range in % of rated load**

This is the minimum measuring range/measuring range interval, which a calibratable load cell/set of scales must cover.

Example: above load cell $E_{max}$ = 10 kg; minimum application range e.g. 40% $E_{max}$

The used measuring range of the load cell must be at least 4 kg. The minimum application range can lie in any range between $E_{min}$ and $E_{max}$, e.g. between 2 kg and 6 kg if a tare mass of 2 kg already exists for structural reasons. A relationship between $n_{max}$ and $V_{min}$ is thereby likewise apparent:
4000 * 1 g = 4 kg .

There are further important characteristic values, which are for the most part self-explanatory and need not be discussed further here, such as nominal characteristic value tolerance, input/output resistance, recommended supply voltage, nominal temperature range etc.

**Parallel connection of strain gauges**

It is usual to distribute a load mechanically to several strain gauge load cells at the same time. Hence, for example, the 3-point bearing of a silo container on 3 load cells can be realized. Taking into account wind loads and loading dynamics, the total loading of the silo including the dead weight of the container can thus be measured. The mechanically parallel-connected load cells are usually also electrically connected in parallel and to one measuring transducer, e.g. the ELX3351. To this end the following must be observed:

- The load cells must be matched to each other and approved by the manufacturer for this mode of operation.
- The impedance of the load cells must be such that the current feed capability of the transducer electronics is not overloaded.
- For parallel connection, the minimum permissible connection resistance to the ELX3351 must be observed (bridge input resistance according to chapter Technical data [▶ 12]). To ensure explosion protection, the parallel connection of the individual bridge resistors must not fall below the minimum value of 300 Ω. The individual strain gage bridges do not require safe isolation in accordance with the requirements of IEC 60079-11 and must be regarded as an intrinsically safe circuit (e.g. for the design of connection cables in accordance with IEC 60079-25).

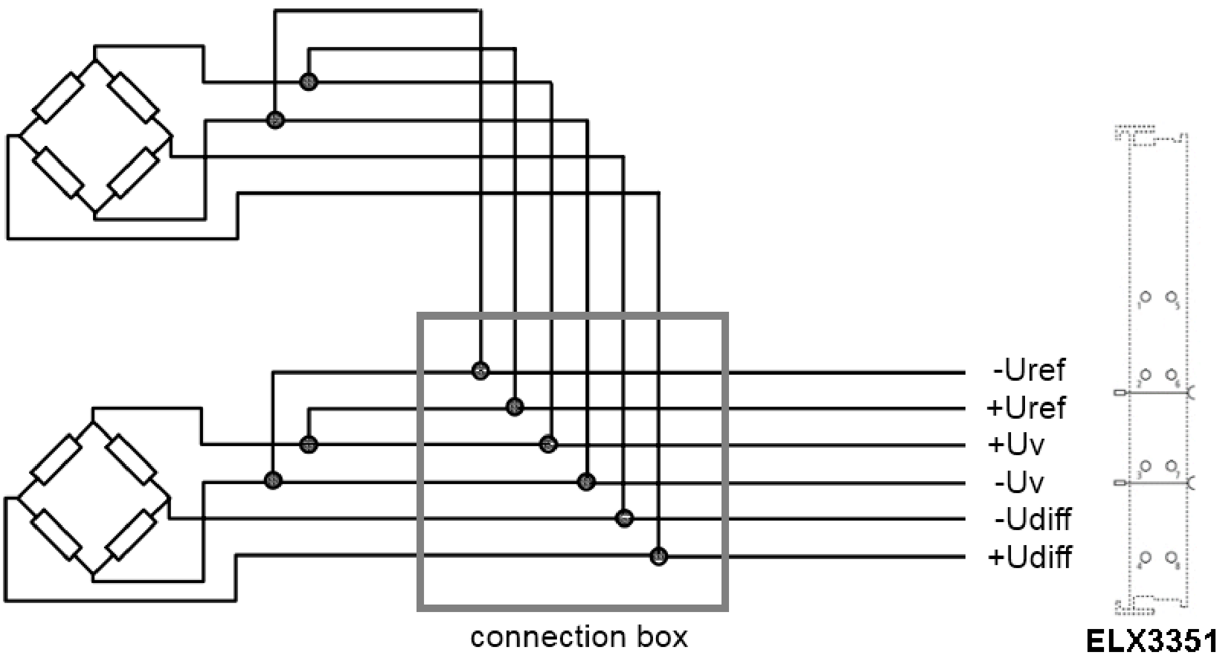


Fig. 24: Parallel strain gauge

**Sources of error/disturbance variables**

**Inherent electrical noise of the load cell**

Electrical conductors exhibit so-called thermal noise (thermal/Johnson noise), which is caused by irregular temperature-dependent movements of the electrons in the conductor material. The resolution of the bridge signal is already limited by this physical effect. The rms value $e_n$ of the noise can be calculated by $e_n = \sqrt{4kTRB}$.

In the case of a load cell with $R_0$ = 350 Ω at an ambient temperature T = 20°C (= 293K) and a bandwidth of the measuring transducer of 50 Hz (and Boltzmann constant k = 1.38 * $10^{-23}$ J/K), the rms $e_n$ = 16.8 nV. The peak-peak noise $e_{pp}$ is thus approx. $e_{pp}$ ~ 6.6* $e_n$ = 111 nV.

**Example**

In relation to the maximum output voltage $U_{out\_max}$ of a bridge with 2 mV/V and $U_s$ = 5 V, this corresponds to $U_{out\_max}$ = 5 V * 2 mV/V = 10 mV. (For the nominal load) this results in a maximum resolution of 10 mV / 111 nV = 90090 digits. Converted into bit resolution: ln(90090)/ln(2) ~ 16 bits.

Interpretation: a higher digital measuring resolution than 16 bits is thus inappropriate for such an analog signal in the first step. If a higher measuring resolution is used, then additional measures may need to be taken in the evaluation chain in order to obtain the higher information content from the signal, e.g. hardware low-pass filter or software algorithms.

This resolution applies alone to the measuring bridge without any further interferences. The resolution of the measuring signal can be increased by reducing the bandwidth of the measuring unit.

If the strain gauge is glued to a carrier (load cell) and wired up, both external electrical disturbances (e.g. thermovoltage at connection points) and mechanical vibrations in the vicinity (machines, drives, transformers (mechanical and audible 50 Hz vibration due to magnetostriction etc.)) can additionally impair the result of measurement.

**Creep**

Under a constant load, spring materials can further deform in the load direction. This process is reversible, but it generates a slowly changing measured value during the static measurement. In an ideal case the error can be compensated by constructive measures (geometry, adhesives).

**Hysteresis**

If even elongation and compression of the load cell take place, then the output voltage does not follow exactly the same curve, since the deformation of the strain gauge and the carrier may be different due to the adhesive and its layer thickness.

**Temperature drift (inherent heating, ambient temperature)**

Relatively large currents can flow in strain gauge applications, e.g. $I = U_s/R_0$ = 10 V / 350 Ω = 26 mA. The power dissipation at the sensor is thus $P_v = U * I$ = 10 V * 26 mA = 260 mW. Depending on application/carrier material (= cooling) and ambient temperature, a not insignificant error can arise that is termed apparent elongation. The sensor manufacturers integrate suitable compensation elements in their strain gauges.

**Inadequate circuit technology**

As already shown, a full bridge may be able (due to the system) to fully compensate non-linearity, creep and temperature drift. Wiring-related measuring errors are avoided by the 6-conductor connection.

**References**

Some organizations are listed below that provide the specifications or documents for the technological field of weighing technology:

- OIML (ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE) www.oiml.org
- PTB - Physikalisch-Technischen Bundesanstalt www.ptb.de
- www.eichamt.de
- WELMEC - European cooperation in legal metrology www.welmec.org
- DKD - Deutscher Kalibrierdienst www.dkd.eu
- Fachgemeinschaft Waagen (AWA) im Verband Deutscher Maschinen- und Anlagenbau VDMA www.vdma.org

# 5 Parameterization and programming

## 5.1 Basics of the measurement functions

The measuring functions of the ELX3351 can be described as follows:

- The ELX3356 Analog Input Terminal is used to acquire the supply voltage to a load cell as a reference voltage, and the differential voltage that is proportional to the force acting on the cell.
- A full bridge must be connected. If only a quarter or half bridge is available, external auxiliary bridges should be added. In this case, the nominal characteristic value should be modified accordingly.
- The reference and differential voltages are measured simultaneously.
- Since the two voltages are measured at the same time, there is basically no need for a high-precision reference voltage with respect to the level.
  The bridge supply and reference voltages are provided by the ELX3351 for the full bridge. A connection of other, externally supplied circuits (e.g. an external bridge supply) is not permitted!
- The change of the quotient of the differential and reference voltages corresponds to the relative force acting on the load cell.
- The quotient is converted into a weight and is output as process data.
- The data processing is subject to the following filtering procedures:
  - software filter IIR/FIR (if activated)
- The ELX3351 has an automatic compensation/self-calibration function.
  - Default state: self-calibration activated, execution every 3 minutes
  - Errors in the analog input stages (temperature drift, long-term drift etc.) are checked by regular automatic calibration, and compensated to bring the measurement within the permitted tolerance range.
  - The automatic function can be deactivated or activated in a controlled manner.

### 5.1.1 General notes

**General notes**

- The measuring ranges of both channels (supply voltage and bridge voltage) should always be used as widely as possible in order to achieve a high measuring accuracy.
  We recommended a load cell that has such a sensitivity (e.g. 2 mV/V) that the largest possible bridge voltage (ideally ±20 mV) is generated.
  Note the input voltages (see Technical data [▶ 12]).

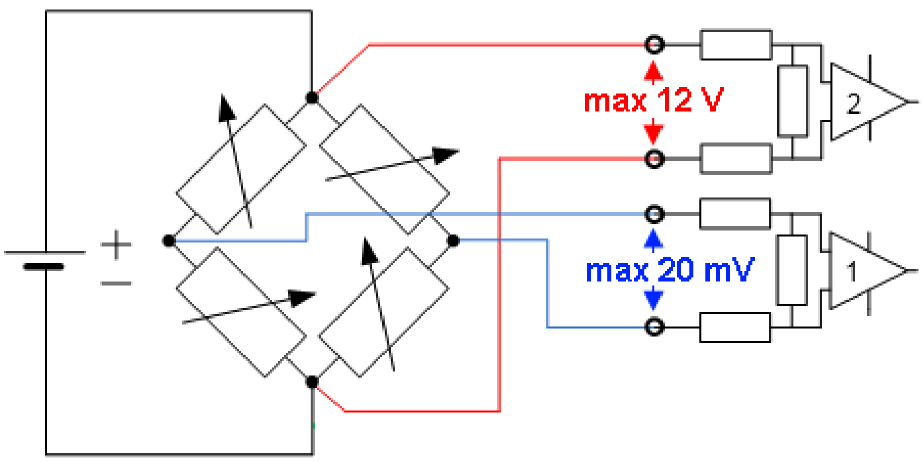


Fig. 25: Max. input voltages

- Parallel operation of load cells is possible with the ELX3351. Please note:
  - Load cells approved and calibrated by the load cell manufacturer for parallel operation should be used. The nominal characteristic values [mV/V], zero offset [mV/V] and impedance [Ω, ohm] are then usually adjusted accordingly.
  - A 6-wire connection is expressly recommended.
  - All the relevant operating parameters (e.g. the minimum bridge input resistance) must be observed.

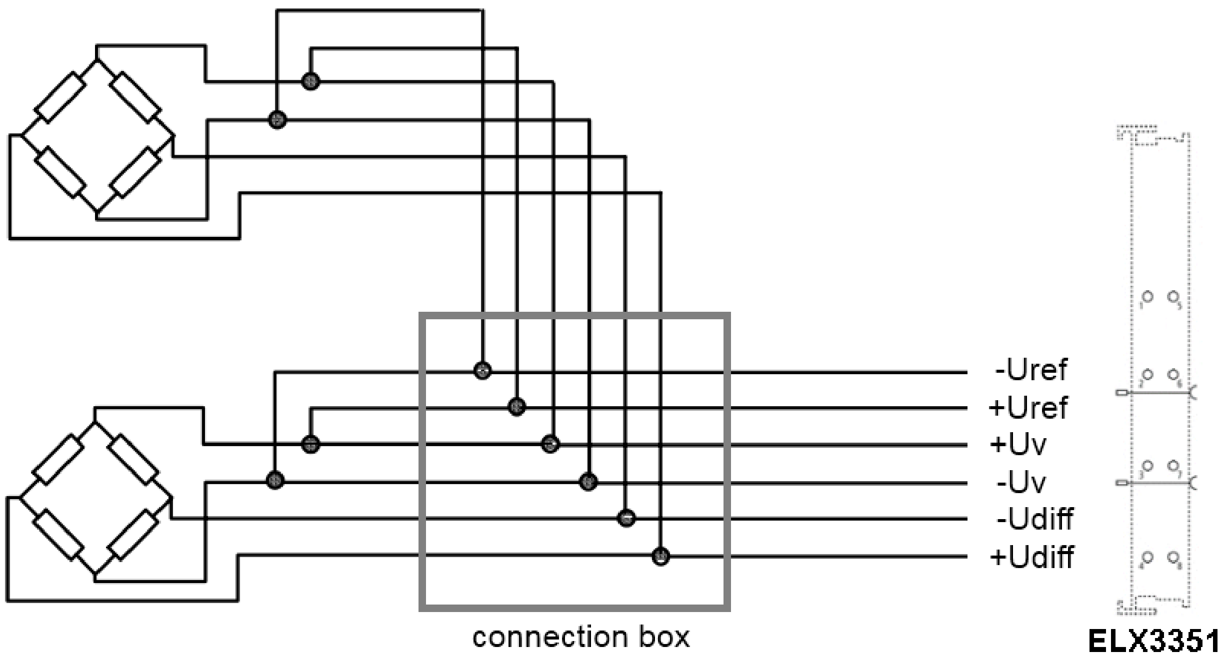


Fig. 26: Parallel connection with ELX3351

  - Load cell signals have a low amplitude and are occasionally very sensitive to electromagnetic interference. Considering the typical system characteristics and taking into account the technical possibilities, purposeful state-of-the-art EMC protective measures are to be taken. If shielded cables are used, the installation measures and, if necessary, the Separation distances in accordance with IEC 60079-11 and IEC 60079-25 must be taken into account. Under high EMC interference loads, it can be helpful to remove the cable shield in front of the terminal additionally with suitable shielding material.

## 5.1.2 Block diagram

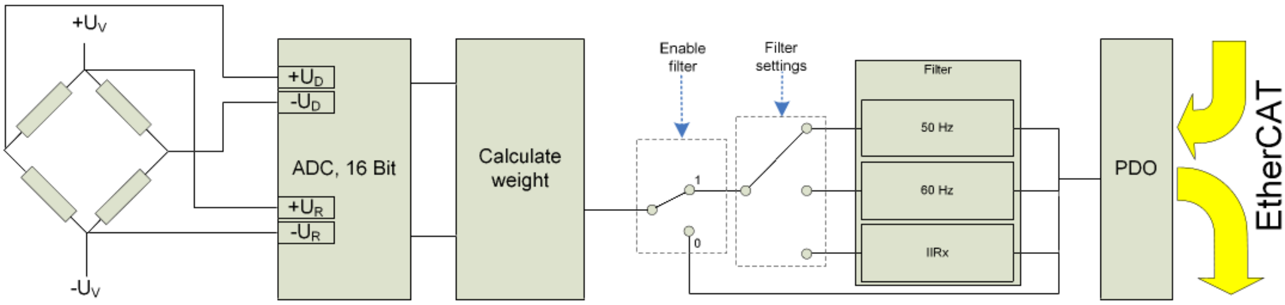


Fig. 27: ELX3351 - Block diagramm

The ELX3351 processes the data in the following order

1. Hardware low-pass 3.6 KHz
2. 2-channel simultaneous sampling by delta-sigma (ΔΣ) converter and internal prefiltration
3. Software filter (can be deactivated)
4. Calculating the weight

| Note | **Measurement principle of delta-sigma (ΔΣ) converter**<br>The measurement principle employed in the ELX3351, with real sampling in the MHz range, shifts aliasing effects into a very high frequency range, so that normally no such effects are to be expected in the KHz range. |
|---|---|

## 5.1.3 Software filter

The ELX3351 is equipped with a digital software filter which, depending on its settings, can adopt the characteristics of a *F*inite *I*mpulse *R*esponse filter (*FIR filter*), or an *I*nfinite *I*mpulse *R*esponse filter (*IIR filter*). The filter is activated by default as *50Hz-FIR*.

In the respective measuring mode the filter can be activated (0x8000:01 [▸ 60], 0x8000:02 [▸ 60]) and parameterized (0x8000:11 [▸ 60], 0x8000:12 [▸ 60]) (the ELX3351 supports only mode 0).

- **FIR 50/60 Hz**
  The filter performs a notch filter function and determines the conversion time of the terminal. The higher the filter frequency, the faster the conversion time. A 50 Hz and a 60 Hz filter are available. Notch filter means that the filter has zeros (notches) in the frequency response at the filter frequency and multiples thereof, i.e. it attenuates the amplitude at these frequencies. The FIR filter operates as a non-recursive filter.

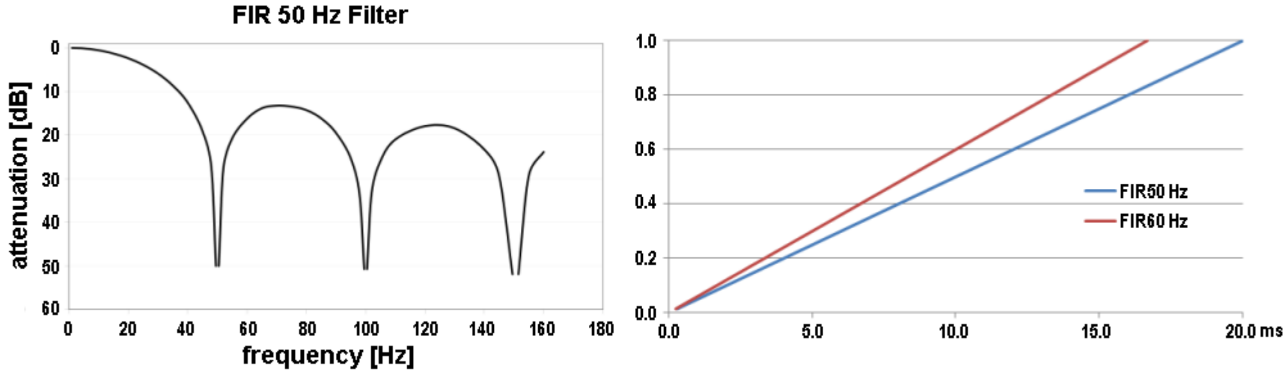


Fig. 28: Notch characteristic/amplitude curve and step response of the FIR filter

- **IIR-Filter 1 to 8**
  The filter with IIR characteristics is a discrete time, linear, time invariant filter that can be set to eight levels (level 1 = weak recursive filter, up to level 8 = strong recursive filter).
  The IIR can be understood to be a moving average value calculation after a low-pass filter.

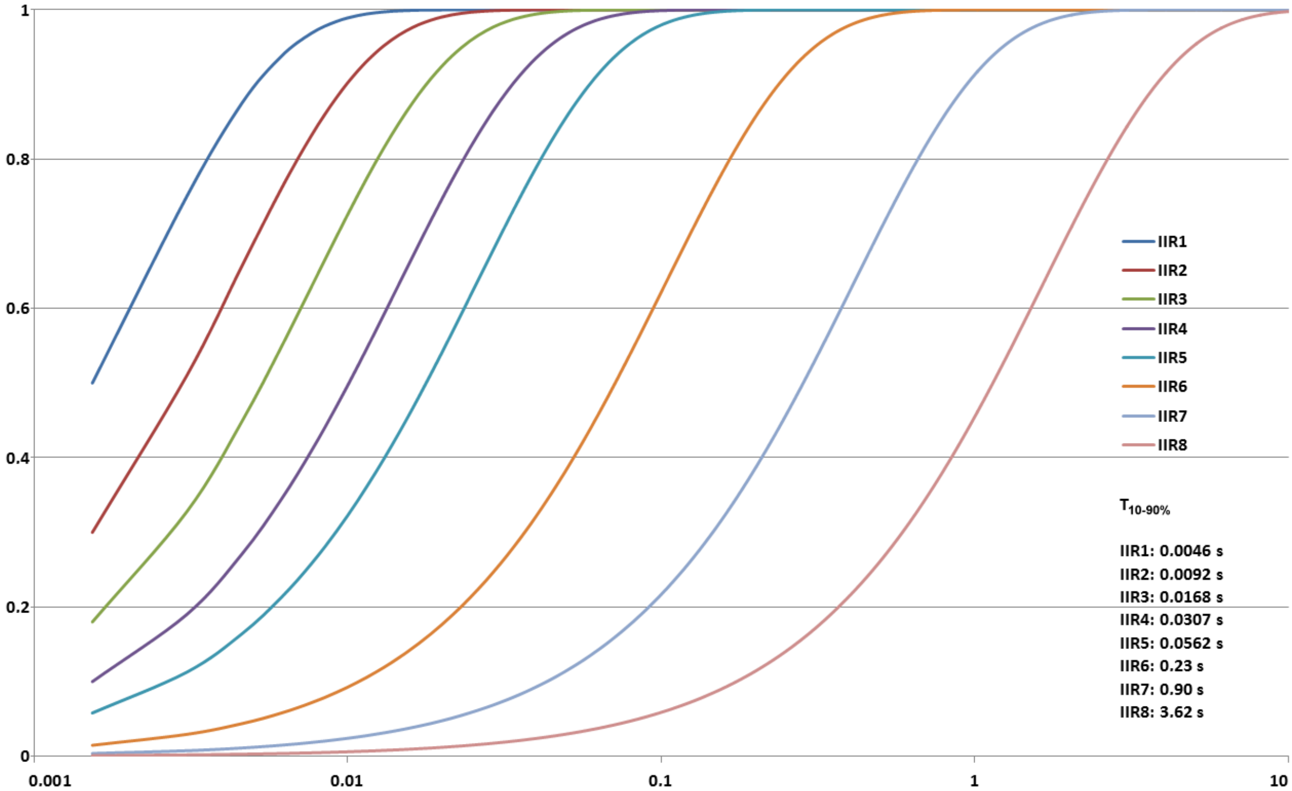


Fig. 29: Step response of the IIR filter

| | |
|---|---|
| Note | **Filter and cycle time**<br>If the FIR filters (50 Hz or 60 Hz) are switched on, the process data are updated maximally with the specified conversion time. (see table) The IIR filter works cycle-synchronously. Hence, a new measured value is available in each PLC cycle. |

| | |
|---|---|
| Note | **IIR filter**<br>Differential equation: $Y_n = X_n * a_0 + Y_{n-1} * b_1$<br>with $a_0 + b_1 = 1$<br>$a_0$ = (see table)<br>b1 = 1 - $a_0$ |

## 5.1.4 Dynamic filter

The dynamic IIR filter automatically switches through the 8 different IIR filters depending on the weight change. The idea:

- The target state is always the IIR8-Filter, i.e. the greatest possible damping and hence a very calm measured value.
- In the input variable changes rapidly the filter is opened, i.e. switched to the next lower filter (if still possible). This gives the signal edge more weight and the measured value curve can follow the load quickly.
- If the measured value changes very little the filter is closed, i.e. switched to the next higher filter (if still possible). Hence the static state is mapped with a high accuracy.
- The evaluation as to whether a downward change of filter is required or whether an upward change is possible takes place continuously at fixed time intervals.

Parameterization takes place via the CoE entries 0x8000:13 [▸ 60] and 0x8000:14 [▸ 60]. Evaluation takes place according to 2 parameters:

- The "Dynamic filter change time" object (0x8000:13 [▸ 60]) is used to set the time interval at which the existing signal is re-evaluated.
- Object 0x8000:14 [▸ 60] is used to specify the maximum deviation that is permissible during this time without filter switching occurring.

**Example:**

The dynamic filter is to be adjusted in such a manner that a maximum slope of 0.5 digits per 100 ms (5 digits per second) is possible without the filter being opened. This results in a "calm" measured value. In the case of a faster change, however, it should be possible to immediately follow the load.

- Dynamic filter change time (0x8000:13 [▸ 60]) = 10 (equivalent to 100 ms)
- Dynamic filter delta (0x8000:14 [▸ 60]) = 0.5 (related to the calculated load value)

The measured value curve is shown below for a slower (left) and faster (right) change.

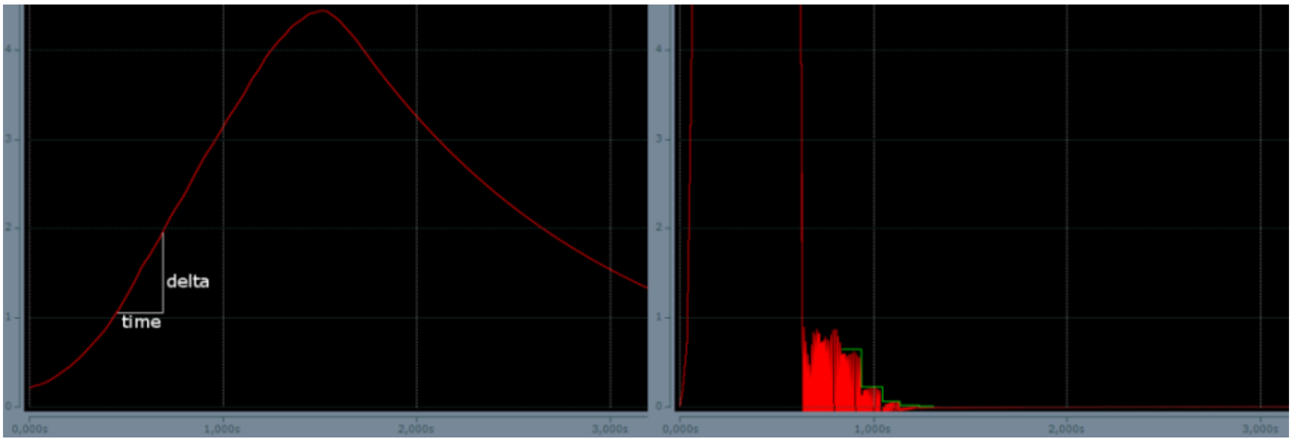


Fig. 30: Effect of dynamic IIR filters

- Links: The scales are slowly loaded. The change in the weight (delta/time) remains below the mark of 0.5 digits per 100 ms. The filter therefore remains unchanged at the strongest level (IIR8), resulting in a low-fluctuation measured value.
- Right: The scales are suddenly loaded. The change in the weight immediately exceeds the limit value of 0.5 digits per 100 ms. The filter is opened every 100 ms by one level (IIR8 --> IIR7 --> IIR6 etc.) and the display value immediately follows the jump. After the removal of the weight the signal quickly falls again. If the change in the weight is less than 0.5 digit per 100 ms, the filter is set one level stronger every 100 ms until IIR8 is reached. The green line is intended to clarify the decreasing "noise level"

### 5.1.5 Calculating the weight

Each measurement of the analog inputs is followed by the calculation of the resulting weight or the resulting force, which is made up of the ratio of the measuring signal to the reference signal and of several calibrations.

| | | |
|---|---|---|
| $Y_R = (U_{Diff} / U_{Ref}) \times A_i$ | (1.0) | Calculation of the raw value in mV/V |
| $Y_L = ( (Y_R - C_{ZB}) / (C_n - C_{ZB}) ) * E_{max}$ | (1.1) | Calculation of the weight |
| $Y_S = Y_L * A_S$ | (1.2) | Scaling factor (e.g. factor 1000 for rescaling from kg to g) |
| $Y_G = Y_S * (G / 9.80665)$ | (1.3) | Influence of acceleration of gravity |
| $Y_{AUS} = Y_G \times Gain - Tare$ | (1.4) | Gain and Tare |

| Name | Description | CoE Index |
|---|---|---|
| $U_{Diff}$ | Bridge voltage/differential voltage of the sensor element, after filter | |
| $U_{Ref}$ | Bridge supply voltage/reference signal of the sensor element, after filter | |
| $A_i$ | Internal gain, not changeable. This factor accounts for the unit standardization from mV to V and the different full-scale deflections of the input channels | |
| $C_n$ | Nominal characteristic value of the sensor element (unit mV/V, e.g. nominally 2 mV/V or 2.0234 mV/V according to calibration protocol) | 0x8000:23 [▶ 60] |
| $C_{ZB}$ | Zero balance of the sensor element (unit mV/V, e.g. -0.0142 according to calibration protocol) | 0x8000:25 [▶ 60] |
| $E_{max}$ | Nominal load of the sensor element | 0x8000:24 [▶ 60] |
| $A_S$ | Scaling factor (e.g. factor 1000 for rescaling from kg to g) | 0x8000:27 [▶ 60] |
| G | Acceleration of gravity in m/s^2 (default: 9.80665 ms/s^2) | 0x8000:26 [▶ 60] |
| Gain | | 0x8000:21 [▶ 60] |
| Tare | | 0x8000:22 [▶ 60] |

## 5.2 Application notes

### 5.2.1 Wiring fail indication

The ELX3351 has no express open-circuit recognition facility. If one of the bridge wires is broken, however, the voltage measured there generally moves towards the final value, thus displaying an error in the status word. Over/underrange of the supply voltage is likewise indicated.

### 5.2.2 InputFreeze

If the terminal is placed in the freeze state by *InputFreeze* in the control word, no further analog measured values are relayed to the internal filter. This function is usable, for example, if a filling surge is expected from the application that would unnecessarily overdrive the filters due to the force load. This would result in a certain amount of time elapsing until the filter had settled again. The user himself must determine a sensible *InputFreeze* time for his filling procedure.

For clarification: temporal control of the *InputFreeze* and the decision regarding its use must be realized by the user in the PLC, they are not components of the ELX3351.

In the following example (recorded with Scope2) impulses on a 15 kg load cell are recorded; the filter is wide open at IIR1 so that steep edges occur in the signal.


Fig. 31: InputFreeze example

Explanation: The weight (A) is shown in blue; the state of the *InputFreeze* variable, which can be controlled by the PLC program and can be TRUE/FALSE, is shown in red (B). The first two impulses (C) lead to large peak deflections in the signal. After that the following is activated in the PLC program (see example program):

- if the measured value for the last cycle (cycle time 100 µs) has changed by more than 10 g (indicating a sudden load),
- *bInputFreeze* is set to TRUE for 50 ms by a TOF block on the ELX3351

The effect can be seen in (D): The peak load is no longer acknowledged by the ELX3351. If it is optimally adapted to the expected force impulse, the ELX3351 can measure the current load value without overshoot.

## 5.2.3 Gravity adaptation

The calculation of the weight depends on the gravitation/the Earth's gravitational force/acceleration due to gravity at the place of installation of the scales. In general, acceleration due to the gravitational pull of the earth at the place of installation is not equal to the defined standard value of g = 9.80665 m/s². For example, 4 zones of acceleration due to gravity are defined in Germany, in which a local acceleration due to gravity of 9.807 to 9.813 m/s² is to be assumed. Hence, within Germany alone there is a clear dispersion of the order of parts per thousand for acceleration due to gravity, which has a direct effect on the measured weight in accordance with the equation $F_G = m*g$!

If

- load cells are used in the theoretical calibration with characteristic values according to the sensor certificate
- calibration weights are used whose weight at the place of installation of the scales is by nature different to that at the place of origin
- scales of the accuracy class I to III are to be realized
- scales that are generally independent of acceleration due to gravity are to be realized

then one should check whether the gravity correction needs to be adapted via object 0x8000:26 [▶ 60].

### 5.2.4 Idling recognition

Weighing is a dynamic procedure that can lead to large jumps in the bridge voltage and thus to the calculation of the value. Following a change in load, the measured value must first "settle" so that the process value is evaluable in the controller. The evaluation of the measured value and the decision over the degree of calmness can be done in the controller; however, the ELX3351 also offers this function, which is activated by default. The result is output in the status word.

- If the load value remains within a range of values y for longer than time x, then the *SteadyState* is activated in the *StatusWord*.
- *SteadyState* is set to FALSE as soon as this condition no longer applies.
- The parameters x and y can be specified in the CoE
- The evaluation is naturally considerably affected by the filter setting

In the following example (recorded with TwinCAT Scope2), a 15 kg load cell is suddenly unloaded and loaded with 547 g. *SteadyState* is subject to a window time from 100 ms and a tolerance of 8 g (15 kg nominal value, scaling 1000; see CoE).

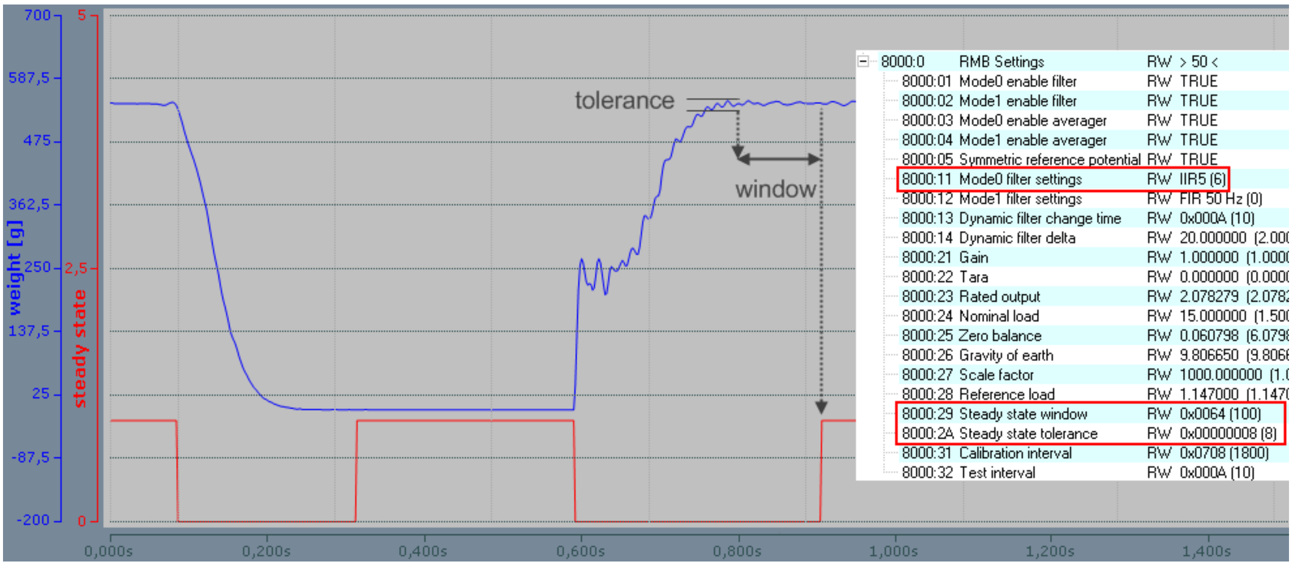


Fig. 32: Idling recognition example

### 5.2.5 Official calibration capability

"Official calibration" is a special kind of calibration that is accomplished according to special regulations with the involvement of trained personnel using prescribed aids. The use of "officially calibrated" scales is mandatory in the Central European region, in particular for the filling of foodstuffs. This ensures the correctness of the weighed quantities in a particular way.

The ELX3351 terminals cannot be officially calibrated as individual devices. However, they can be integrated as elements in applications that can then be equipped by the integrator with the required characteristics for official calibration capability using appropriate means.

## 5.3 Calibration and compensation

The term "calibration" can be applied in 3 different ways to the ELX3351:

- Sensor calibration: once-only calibration of the employed sensor (strain gauge) during commissioning of the system

- Self-calibration: continuously repeated self-calibration of the terminal for the improvement of the measuring accuracy
- Tare: repeated gross/net compensation by taring

## 5.3.1 Sensor calibration

The ELX3351 is matched to the characteristic curve of the sensor element by means of the calibration. Two values are required for this procedure: the initial value without a load (zero balance) and fully loaded (rated output). These values can be determined by a calibration protocol or by a calibration using calibration weights.

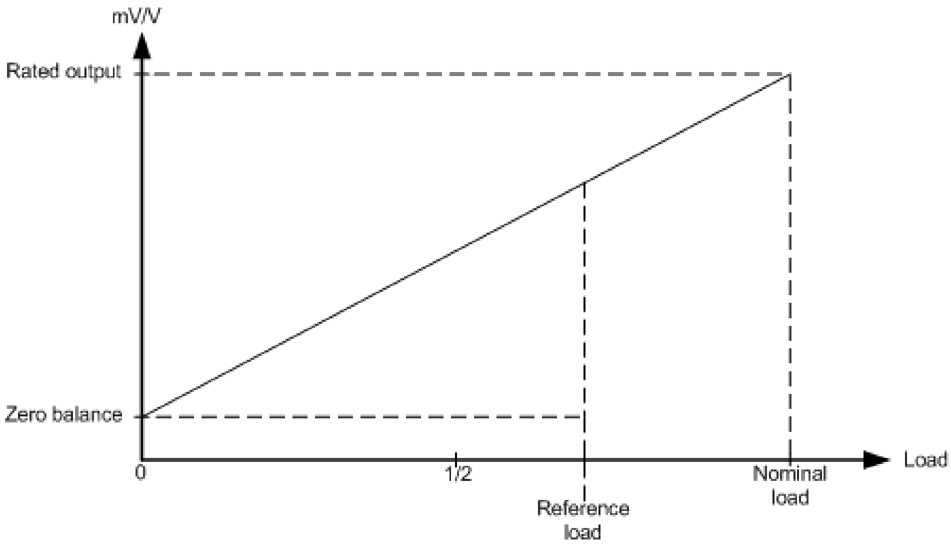


Fig. 33: Adaptation to the sensor curve

**Calibration by means of compensation in the system**

In the practical calibration, measurement takes place first with the scales unloaded, then with a defined load on the scales. The ELX3351 automatically calculates the existing sensor characteristic values from the measured values.

Sequence:

1. Perform a CoE reset with object 0x1011:01
   see Restoring the delivery state
2. Activate mode 0 via the control word
3. Set scale factor to 1 (0x8000:27 [▶ 60])
4. Set gravity of earth (0x8000:26) [▶ 60] if necessary (default: 9.806650)
5. Ste gain to (0x8000:21 [▶ 60]) = 1
6. Set tare to 0 (0x8000:22 [▶ 60])
7. Set the filter (0x8000:11 [▶ 60]) to the strongest level: IIR8
8. Specify the nominal load of the sensor in 0x8000:24 [▶ 60] ("Nominal load")
9. Zero balance: Do not load the scales
   As soon as the measured value indicates a constant value for at least 10 seconds, execute the command 0x0101 ($257_{dec}$) on CoE object 0xFB00:01.
   This command causes the current mV/V value(0x9000:11 [▶ 62]) to be entered in the "Zero balance" object.
   Check: CoE objects FB00:02 and FB00:03 must contain "0" after execution

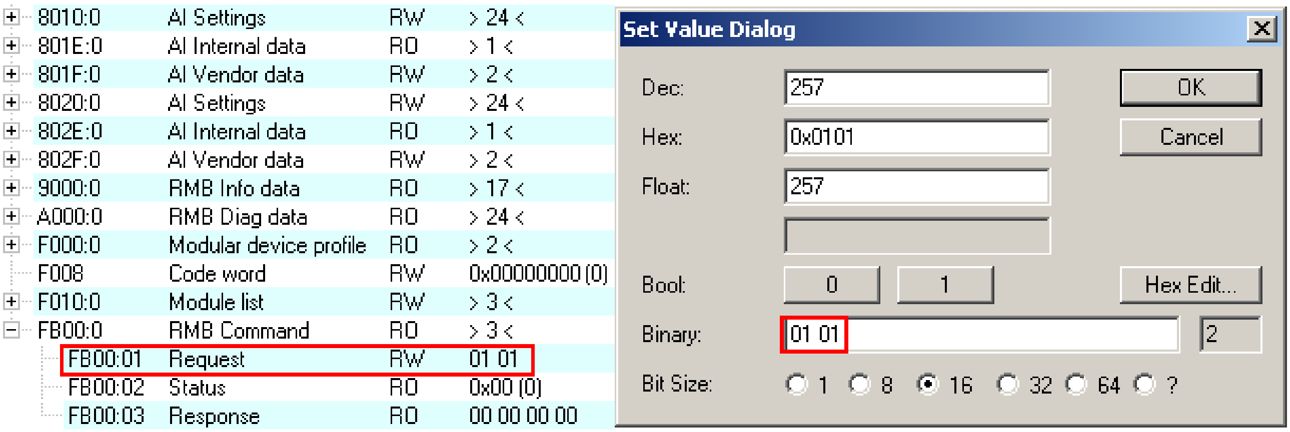


Fig. 34: Zero calibration with command 0x0101 in CoE object 0xFB00:01

10. Load the scales with a reference load. This should be at least 20% of the rated load. The larger the reference load, the better the sensor values can be calculated.
    In object 0x8000:28 [▶ 60] ("Reference load"), enter the load in the same unit as the rated load (0x8000:24 [▶ 60]).
    As soon as the measured value indicates a constant value for at least 10 seconds, execute the command "0x0102" ($258_{dec}$) on CoE object 0xFB00:01.
    By means of this command the ELX3351 determines the output value for the nominal weight ("Rated output")
    Check: CoE objects FB00:02 and FB00:03 must contain "0" after execution

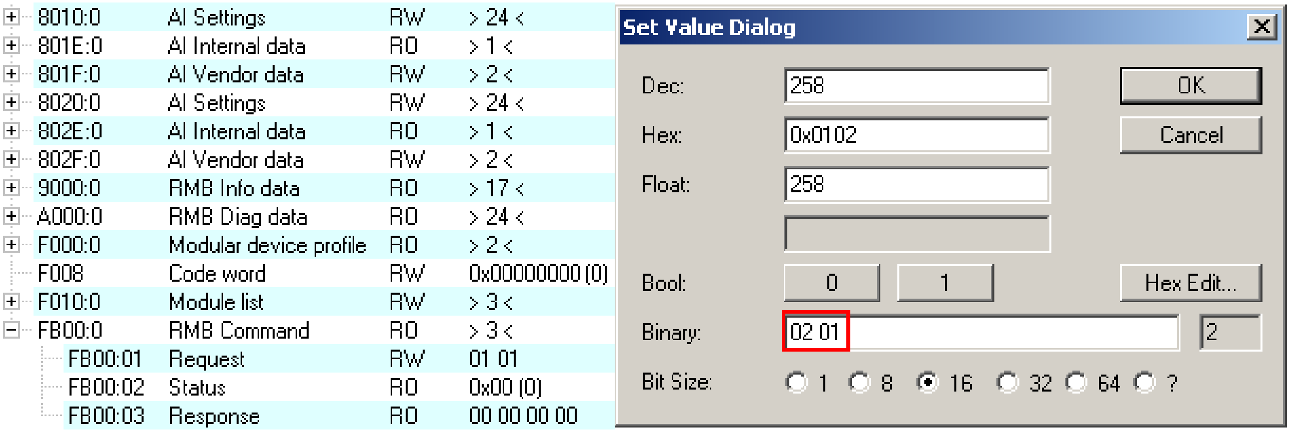


Fig. 35: Loading with reference load, command 0x0102 in CoE object 0xFB00:01

11. Reset: execute the command 0x0000 ($0_{dec}$) on CoE object 0xFB00:01.
12. Set the filter to a lower stage.

**Calibration according to the sensor calibration protocol (theoretical calibration)**

The sensor characteristic values according to the manufacturer's certificate are communicated here directly to the ELX3351, so that it can calculate the load.

1. Execute a CoE reset
2. Set scale factor to 1 (0x8000:27 [▶ 60])
3. Set gravity of earth (0x8000:26) [▶ 60] if necessary (default: 9.806650)
4. Ste gain to (0x8000:21 [▶ 60]) = 1
5. Set tare to 0 (0x8000:22 [▶ 60])
6. Specify the nominal load of the sensor in 0x8000:24 [▶ 60] (Nominal load)
7. Adopt the "Rated output" (mV/V value 0x8000:23 [▶ 60]) from the calibration protocol
8. Adopt the "Zero balance" (0x8000:25 [▶ 60]) from the calibration protocol

| | |
|---|---|
| Note | **Calibration**<br>The calibration is of great importance for the accuracy of the system. In order to increase this, the filter should be set as strong as possible over the entire calibration phase. It may take several seconds before a static value is obtained. |

| | |
|---|---|
| Note | **Local storage**<br>The values modified during the theoretical and practical calibration are stored in a local EEPROM. This can be written to up to 1 million time. In order to prolong the life of the EEPROM, therefore, the commands should not be executed cyclically. |

## 5.3.2 Self-calibration

### Self-calibration of the measuring amplifiers

The measuring amplifiers are periodically subjected to examination and self-calibration. Several analog switches are provided for this purpose, so that the various calibration signals can be connected. It is important for this process that the entire signal path, including all passive components, is examined at every phase of the calibration. Only the interference suppression elements (L/C combination) and the analog switches themselves cannot be examined. In addition, a self-test is carried out at longer intervals.

The self-calibration is carried out every 3 minutes in the default setting.

- **Self-calibration**
  The time interval is set in 100 ms steps with object 0x8000:31 [▶ 60]; default: 3 min.
  Duration approx. 150 ms

By means of the self-calibration of the input stages at the two operating points (zero point and final value), the two measuring channels are calibrated to each other.

### Interface for controller

The self-calibration takes place automatically at the defined intervals. In order to prevent calibration during a time-critical measurement, the automatic calibration can be disabled permanently via the *Disable calibration* bit in *ControlWord*. If it should be additional necessary to carry out a manual test, this is started by a rising edge of the *Start manual calibration* bit in the process image.

While the terminal is performing a self-calibration, the *Calibration in progress* bit is set in the process image. Once started, a self-calibration cannot be aborted.

If the self-calibration has been disabled by *Disable calibration*, it can nevertheless be started by the *Start calibration* process data bit.

| | |
|---|---|
| Note | **Self-calibration**<br>The self-calibration takes place for the first time directly after starting up the terminal. At this point the supply voltage must already be applied. If the supply voltage is only applied later, the self-calibration must be manually initiated (process data bit: *Start calibration*).<br>The self-calibration must be executed at least once after each start-up.<br>A lower measuring accuracy is expected if the self-calibration is disabled for a longer period or permanently. |

After a change in the CoE settings (section x80nn), a self-calibration is always performed (even if *DisabledCalibration* = TRUE), since the settings affect the measurement. Changing the CoE settings during an ongoing measurement should therefore be avoided, if possible.

## 5.3.3 Taring

When taring, the scales are zeroed using an arbitrary applied load; i.e. an offset correction is performed. This is necessary for the gross/net compensation of goods that cannot be weighed without a container that has a mass of its own.

The ELX3351 supports 2 tarings; it is recommended to set a strong filter when taring.

- **Temporary tare**
  The correction value is NOT stored in the terminal and is lost in the event of a power failure.
  To this end the command 0x0001 is executed on CoE object 0xFB00:01 (binary dialog in the System Manager: 01 00). This sets the tare object (0x8000:22 [▶ 60]) such that the display value is 0.
  Note: in the case of a device restart (INIT->OP) the tare is not deleted.
  In addition this tare can be executed via the control word:

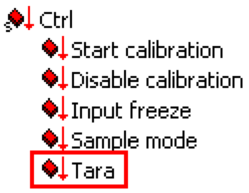


Fig. 36: Control word, tare

- **Permanent tare**
  The correction value is stored locally in the terminal's EEPROM and is not lost in the event of a power failure.
  To this end the command 0x0002 is executed on CoE object 0xFB00:01 (binary dialog in the System Manager: 02 00). This sets the tare object (0x8000:22 [▶ 60]) such that the display value is 0.

| | |
|---|---|
| **Note** | **Local storage**<br>The values modified during the theoretical and practical calibration are stored in a local EEPROM. This can be written to up to 1 million time. In order to prolong the life of the EEP-ROM, therefore, the commands should not be executed cyclically. |

## 5.3.4 Overview of commands

The functions described above are carried out by means of commands in the standardized object 0xFB00.

| Index | Name | Comment |
|---|---|---|
| FB00:01 | Request | Entry of the command to be executed |
| FB00:02 | Status | Status of the command currently being executed<br>0: Command executed without error.<br>255: Command is being executed |
| FB00:03 | Response | Optional response value of the command |

The function blocks *FB_EcCoESdoWrite* and *FB_EcCoESdoRead* from the *TcEtherCAT.lib* (contained in the standard TwinCAT installation) can be used in order to execute the commands from the PLC.

**Commands of the ELX3351**

The following commands can be transferred to the terminal via the CoE entry 0xFB00:01.

| Command | Comment |
|---|---|
| 0x0101 | Execute zero balance |
| 0x0102 | Execute calibration |
| 0x0001 | Execute tare procedure (value is NOT saved in the terminal's EEprom) |
| 0x0002 | Execute tare procedure (value is saved in the terminal's EEprom) |

## 5.4 Notices on analog specifications

Beckhoff I/O devices (terminals, boxes, modules) with analog inputs are characterized by a number of technical characteristic data; refer to the technical data in the respective documents.

Some explanations are given below for the correct interpretation of these characteristic data.

### 5.4.1 Full scale value (FSV)

An I/O device with an analog input measures over a nominal measuring range that is limited by an upper and a lower limit (initial value and end value); these can usually be taken from the device designation.
The range between the two limits is called the measuring span and corresponds to the equation (end value - initial value). Analogous to pointing devices this is the measuring scale (see IEC 61131) or also the dynamic range.

For analog I/O devices from Beckhoff the rule is that the limit with the largest value is chosen as the full scale value of the respective product (also called the reference value) and is given a positive sign. This applies to both symmetrical and asymmetrical measuring spans.

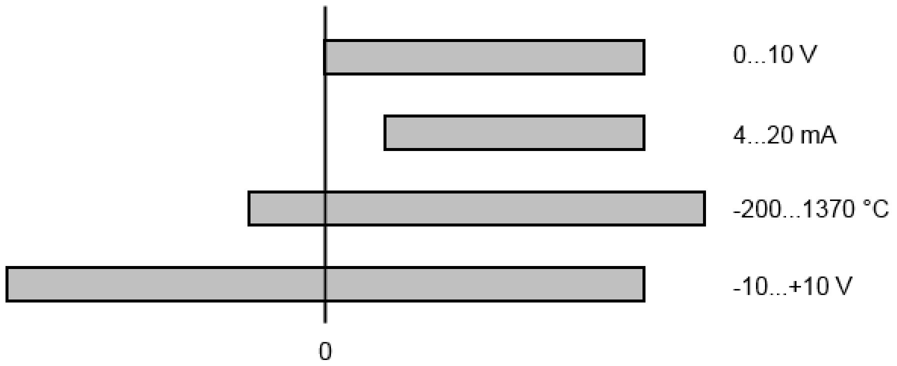


Fig. 37: Full scale value, measuring span

For the above **examples** this means:

- Measuring range 0...10 V: asymmetric unipolar, full scale value = 10 V, measuring span = 10 V
- Measuring range 4...20 mA: asymmetric unipolar, full scale value = 20 mA, measuring span = 16 mA
- Measuring range -200...1370°C: asymmetric bipolar, full scale value = 1370°C, measuring span = 1570°C
- Measuring range -10...+10 V: symmetric bipolar, full scale value = 10 V, measuring span = 20 V

This applies to analog output terminals/ boxes (and related Beckhoff product groups).

### 5.4.2 Measuring error/ measurement deviation

The relative measuring error (% of the full scale value) is referenced to the full scale value and is calculated as the quotient of the largest numerical deviation from the true value (‘measuring error’) referenced to the full scale value.

$$\text{Measuring error} = \frac{|\text{max. deviation}|}{\text{full scale value}}$$

The measuring error is generally valid for the entire permitted operating temperature range, also called the ‘usage error limit’ and contains random and systematic portions of the referred device (i.e. ‘all’ influences such as temperature, inherent noise, aging, etc.).

It is always to be regarded as a positive/negative span with ±, even if it is specified without ± in some cases.

The maximum deviation can also be specified directly.

**Example**: Measuring range 0...10 V and measuring error < ± 0.3 % full scale value → maximum deviation ± 30 mV in the permissible operating temperature range.

| | |
|---|---|
| **Note** | **Lower measuring error**<br>Since this specification also includes the temperature drift, a significantly lower measuring error can usually be assumed in case of a constant ambient temperature of the device and thermal stabilization after a user calibration.<br>This applies to analog output devices. |

## 5.4.3 Temperature coefficient tK [ppm/K]

An electronic circuit is usually temperature dependent to a greater or lesser degree. In analog measurement technology this means that when a measured value is determined by means of an electronic circuit, its deviation from the "true" value is reproducibly dependent on the ambient/operating temperature.

A manufacturer can alleviate this by using components of a higher quality or by software means.

The temperature coefficient, when indicated, specified by Beckhoff allows the user to calculate the expected measuring error outside the basic accuracy at 23 °C.

Due to the extensive uncertainty considerations that are incorporated in the determination of the basic accuracy (at 23 °C), Beckhoff recommends a quadratic summation.

**Example:** Let the basic accuracy at 23 °C be ±0.01% typ. (full scale value), tK = 20 ppm/K typ.; the accuracy A35 at 35 °C is wanted, hence ΔT = 12 K

$$G35 = \sqrt{(0.01\%)^2 + (12K \cdot 20\,\frac{ppm}{K})^2} = 0.026\%\ \text{full scale value, typ}$$

Remarks: ppm $\triangleq 10^{-6}$ % $\triangleq 10^{-2}$

## 5.4.4 Single-ended/differential typification

For analog inputs Beckhoff makes a basic distinction between two types: *single-ended* (SE) and *differential (DIFF)*, referring to the difference in electrical connection with regard to the potential difference.

The diagram shows two-channel versions of an SE module and a DIFF module as examples for all multi-channel versions.

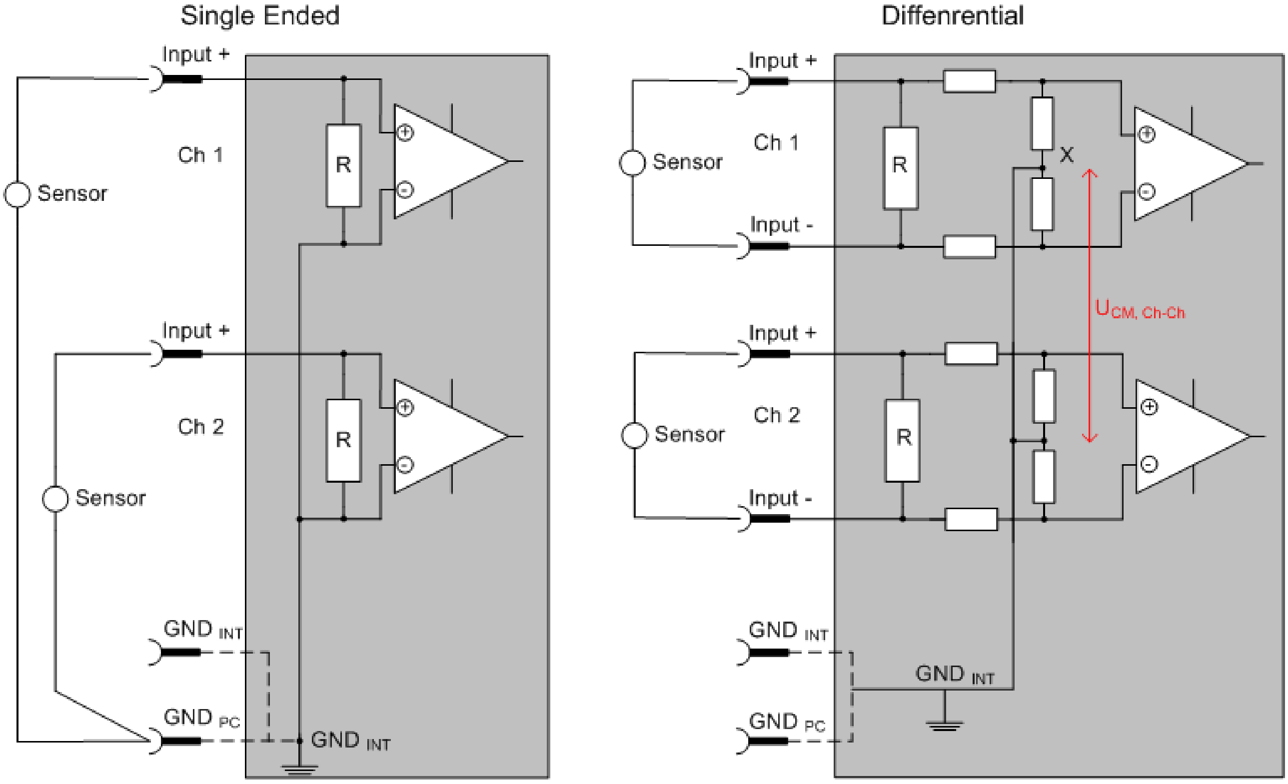


Fig. 38: SE and DIFF module as 2-channel version

Note: Dashed lines indicate that the respective connection may not necessarily be present in each SE or DIFF module. Electrical isolated channels are operating as differential type in general, hence there is no direct relation (voltaic) to ground within the module established at all. Indeed, specified information to recommended and maximum voltage levels have to be taken into account.

The basic rule:

- Analog measurements always take the form of voltage measurements between two potential points. For voltage measurements a large R is used, in order to ensure a high impedance. For current measurements a small R is used as shunt. If the purpose is resistance measurement, corresponding considerations are applied.
  - Beckhoff generally refers to these two points as input+/signal potential and input-/reference potential.
  - For measurements between two potential points two potentials have to be supplied.
  - Regarding the terms "single-wire connection" or "three-wire connection", please note the following for pure analog measurements: three- or four-wire connections can be used for sensor supply, but are not involved in the actual analog measurement, which always takes place between two potentials/wires.
    In particular this also applies to SE, even though the term suggest that only one wire is required.
- The term "electrical isolation" should be clarified in advance.
  Beckhoff IO modules feature 1..8 or more analog channels; with regard to the channel connection a distinction is made in terms of:
  - how the channels WITHIN a module relate to each other, or
  - how the channels of SEVERAL modules relate to each other.

The property of electrical isolation indicates whether the channels are directly connected to each other.

- Beckhoff terminals/ boxes (and related product groups) always feature electrical isolation between the field/analog side and the bus/EtherCAT side. In other words, if two analog terminals/ boxes are not connected via the power contacts (cable), the modules are effectively electrically isolated.
- If channels within a module are electrically isolated, or if a single-channel module has no power contacts, the channels are effectively always differential. See also explanatory notes below. Differential channels are not necessarily electrically isolated.

- Analog measuring channels are subject to technical limits, both in terms of the recommended operating range (continuous operation) and the destruction limit. Please refer to the respective terminal/ box documentation for further details.

**Explanation**

- **differential (DIFF)**
  - Differential measurement is the most flexible concept. The user can freely choose both connection points, input+/signal potential and input-/reference potential, within the framework of the technical specification.
  - A differential channel can also be operated as SE, if the reference potential of several sensors is linked. This interconnection may take place via the system GND.
  - Since a differential channel is configured symmetrically internally (cf. Fig. SE and DIFF module as 2-channel variant), there will be a mid-potential (X) between the two supplied potentials that is the same as the internal ground/reference ground for this channel. If several DIFF channels are used in a module without electrical isolation, the technical property $V_{CM}$ (common-mode voltage) indicates the degree to which the mean voltage of the channels may differ.
  - The internal reference ground may be accessible as connection point at the terminal/ box, in order to stabilize a defined GND potential in the terminal/ box. In this case it is particularly important to pay attention to the quality of this potential (noiselessness, voltage stability). At this GND point a wire may be connected to make sure that $V_{CM,max}$ is not exceeded in the differential sensor cable.
    If differential channels are not electrically isolated, usually only one $V_{CM, max}$ is permitted. If the channels are electrically isolated this limit should not apply, and the channels voltages may differ up to the specified separation limit.
  - Differential measurement in combination with correct sensor wiring has the special advantage that any interference affecting the sensor cable (ideally the feed and return line are arranged side by side, so that interference signals have the same effect on both wires) has very little effect on the measurement, since the potential of both lines varies jointly (hence the term common mode). In simple terms: Common-mode interference has the same effect on both wires in terms of amplitude and phasing.
  - Nevertheless, the suppression of common-mode interference within a channel or between channels is subject to technical limits, which are specified in the technical data.
  - Further helpfully information on this topic can be found on the documentation page *Configuration of 0/4..20 mA differential inputs* (see documentation for the EL30xx terminals, for example).
- **Single Ended (SE)**
  - If the analog circuit is designed as SE, the input/reference wire is internally fixed to a certain potential that cannot be changed. This potential must be accessible from outside on at least one point for connecting the reference potential, e.g. via the power contacts (cable).
  - In other words, in situations with several channels SE offers users the option to avoid returning at least one of the two sensor cables to the terminal/ box (in contrast to DIFF). Instead, the reference wire can be consolidated at the sensors, e.g. in the system GND.
  - A disadvantage of this approach is that the separate feed and return line can result in voltage/ current variations, which a SE channel may no longer be able to handle. See common-mode interference. A $V_{CM}$ effect cannot occur, since the module channels are internally always 'hard-wired' through the input/reference potential.

### Typification of the 2/3/4-wire connection of current sensors

Current transducers/sensors/field devices (referred to in the following simply as 'sensor') with the industrial 0/4-20 mA interface typically have internal transformation electronics for the physical measured variable (temperature, current, etc.) at the current control output. These internal electronics must be supplied with energy (voltage, current). The type of cable for this supply thus separates the sensors into *self-supplied* or *externally supplied* sensors:

### Self-supplied sensors

- The sensor draws the energy for its own operation via the sensor/signal cable + and -.
  So that enough energy is always available for the sensor's own operation and open-circuit detection is possible, a lower limit of 4 mA has been specified for the 4-20 mA interface; i.e. the sensor allows a minimum current of 4 mA and a maximum current of 20 mA to pass.
- 2-wire connection see Fig. *2-wire connection*, cf. IEC60381-1
- Such current transducers generally represent a current sink and thus like to sit between + and – as a 'variable load'. Refer also to the sensor manufacturer's information.

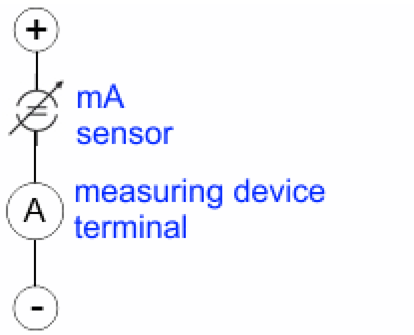


Fig. 39: 2-wire connection

Therefore, they are to be connected according to the Beckhoff terminology as follows:

preferably to **'single-ended' inputs** if the +Supply connections of the terminal/ box are also to be used - connect to +Supply and Signal

they can, however, also be connected to **'differential' inputs**, if the termination to GND is then manufactured on the application side – to be connected with the right polarity to +Signal and –Signal
It is important to refer to the information page *Configuration of 0/4..20 mA differential inputs* (see documentation for the EL30xx terminals, for example)!

### Externally supplied sensors

| WARNING | **An external supply of sensors / actuators, which are connected to signal terminals of the ELX series is not permitted!**<br>In terms of intrinsic safety, all signal terminals of the ELX series are energy-supplying, associated equipment. For this reason, connected sensors or actuators are supplied exclusively via the respective channel of the terminal and must not be externally supplied in any form (e.g. via an additional, external supply voltage).<br>This limitation is also independent of whether the additional, external supply is energy limited in the sense of IEC 60079-11.<br>Connecting any externally powered, intrinsically safe circuits to a ELX signal terminal contradicts the intended use and the specified technical data for explosion protection [▶ 13]. The explosion protection provided by the specified type of protection thus automatically expires. |
|---|---|

## 5.4.5 Common-mode voltage and reference ground (based on differential inputs)

Common-mode voltage ($V_{cm}$) is defined as the average value of the voltages of the individual connections/ inputs and is measured/specified against reference ground.

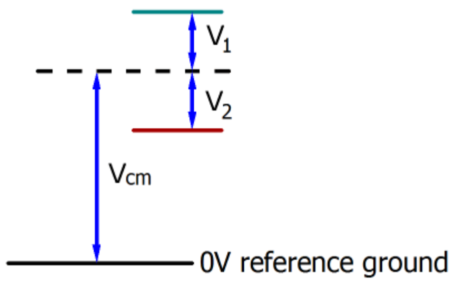


Fig. 40: Common-mode voltage ($V_{cm}$)

The definition of the reference ground is important for the definition of the permitted common-mode voltage range and for measurement of the common-mode rejection ratio (CMRR) for differential inputs.

The reference ground is also the potential against which the input resistance and the input impedance for single-ended inputs or the common-mode resistance and the common-mode impedance for differential inputs is measured.

The reference ground is usually accessible at or near the terminal/ box, e.g. at the terminal contacts, power contacts (cable) or a mounting rail. Please refer to the documentation regarding positioning. The reference ground should be specified for the device under consideration.

For multi-channel terminals/ boxes with resistive (=direct, ohmic, galvanic) or capacitive connection between the channels, the reference ground should preferably be the symmetry point of all channels, taking into account the connection resistances.

**Reference ground samples for Beckhoff IO devices:**

1. Internal AGND fed out: EL3102/EL3112, resistive connection between the channels
2. 0V power contact: EL3104/EL3114, resistive connection between the channels and AGND; AGND connected to 0V power contact with low-resistance
3. Earth or SGND (shield GND):
    - EL3174-0002: Channels have no resistive connection between each other, although they are capacitively coupled to SGND via leakage capacitors
    - EL3314: No internal ground fed out to the terminal points, although capacitive coupling to SGND

## 5.4.6 Dielectric strength

A distinction should be made between:

- Dielectric strength (destruction limit): Exceedance can result in irreversible changes to the electronics
    - Against a specified reference ground
    - Differential
- Recommended operating voltage range: If the range is exceeded, it can no longer be assumed that the system operates as specified
    - Against a specified reference ground
    - Differential

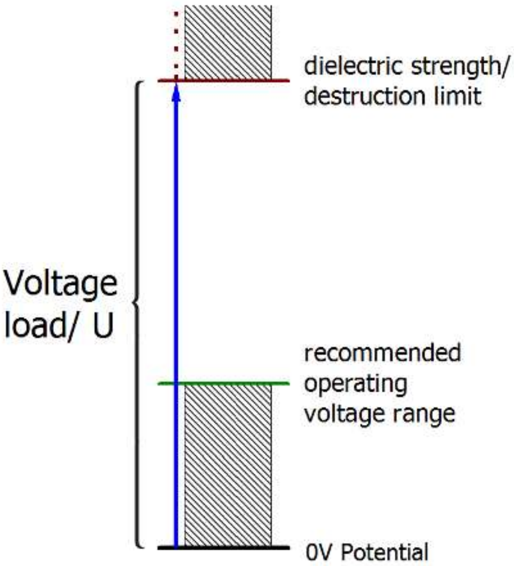


Fig. 41: Recommended operating voltage range

The device documentation may contain particular specifications and timings, taking into account:

- Self-heating
- Rated voltage
- Insulating strength
- Edge steepness of the applied voltage or holding periods
- Normative environment (e.g. PELV)

## 5.4.7 Temporal aspects of analog/digital conversion

The conversion of the constant electrical input signal to a value-discrete digital and machine-readable form takes place in the analog Beckhoff EL/KL/EP input modules with ADC (analog digital converter). Although different ADC technologies are in use, from a user perspective they all have a common characteristic: after the conversion a certain digital value is available in the controller for further processing. This digital value, the so-called analog process data, has a fixed temporal relationship with the “original parameter”, i.e. the electrical input value. Therefore, corresponding temporal characteristic data can be determined and specified for Beckhoff analogue input devices.

This process involves several functional components, which act more or less strongly in every AI (analog input) module:

- the electrical input circuit
- the analog/digital conversion
- the digital further processing
- the final provision of the process and diagnostic data for collection at the fieldbus (EtherCAT, K-bus, etc.)

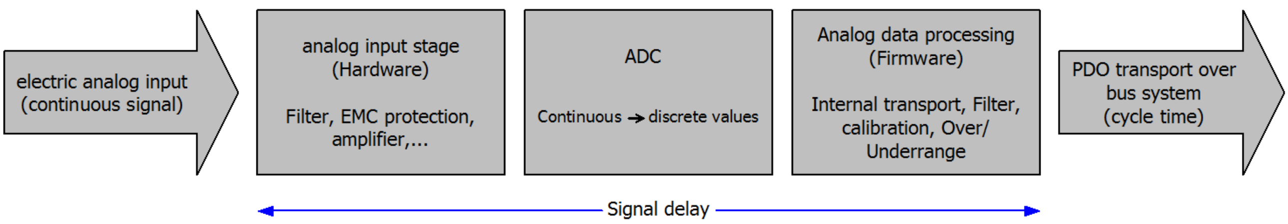


Fig. 42: Signal processing analog input

Two aspects are crucial from a user perspective:

- “How often do I receive new values?”, i.e. a sampling rate in terms of speed with regard to the device/channel
- What delay does the (whole) AD conversion of the device/channel cause?
  - i.e. the hardware and firmware components in its entirety. For technological reasons, the signal characteristics must be taken into account when determining this information: the run times through the system differ, depending on the signal frequency.

This is the “external” view of the “Beckhoff AI channel” system – internally the signal delay in particular is composed of different components: hardware, amplifier, conversion itself, data transport and processing. Internally a higher sampling rate may be used (e.g. in the deltaSigma converters) than is offered “externally” from the user perspective. From a user perspective of the “Beckhoff AI channel” component this is usually irrelevant or is specified accordingly, if it is relevant for the function.

For Beckhoff AI devices the following specification parameters for the AI channel are available for the user from a temporal perspective:

**1. Minimum conversion time [ms, µs]**
= the reciprocal value of the maximum **sampling rate** [sps, samples per second]:
Indicates how often the analog channel makes a newly detected process data value available for collection by the fieldbus. Whether the fieldbus (EtherCAT, K-bus) fetches the value with the same speed (i.e. synchronous), or more quickly (if the AI channel operates in slow FreeRun mode) or more slowly (e.g. with oversampling), is then a question of the fieldbus setting and which modes the AI device supports.
For EtherCAT devices the so-called toggle bit indicates (by toggling) for the diagnostic PDOs when a newly determined analog value is available.
Accordingly, a maximum conversion time, i.e. a smallest sampling rate supported by the AI device, can be specified.
Corresponds to IEC 61131-2, section 7.10.2 2, “Sampling repeat time”

**2. Typical signal delay**
Corresponds to IEC 61131-2, section 7.10.2 1, “Sampling duration”. From this perspective it includes all internal hardware and firmware components, but not “external” delay components from the fieldbus or the controller (TwinCAT).
This delay is particularly relevant for absolute time considerations, if AI channels also provide a time stamp that corresponds to the amplitude value – which can be assumed to match the physically prevailing amplitude value at the time.
Due to the frequency-dependent signal delay time, a dedicated value can only be specified for a given signal. The value also depends on potentially variable filter settings of the channel.
A typical characterization in the device documentation may be:

**2.1 Signal delay (step response)**
Keywords: Settling time
The square wave signal can be generated externally with a frequency generator (note impedance!)
The 90 % limit is used as detection threshold.
The signal delay [ms, µs] is then the time interval between the (ideal) electrical square wave signal and the time at which the analog process value has reached the 90 % amplitude.

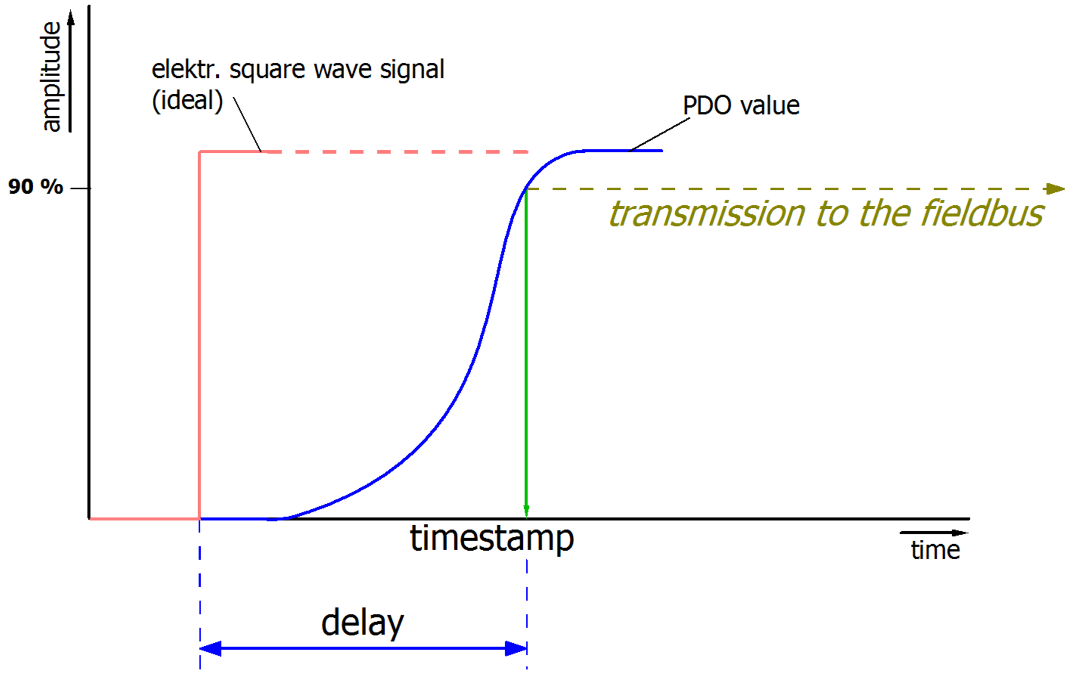


Fig. 43: Diagram signal delay (step response)

**2.2 Signal delay (linear)**
Keyword: Group delay
Describes the delay of a signal with constant frequency
A test signal can be generated externally with a frequency generator, e.g. as sawtooth or sine. A simultaneous square wave signal would be used as reference.
The signal delay [ms, µs] is then the interval between the applied electrical signal with a particular amplitude and the moment at which the analog process value reaches the same value.
A meaningful range must be selected for the test frequency, e.g. 1/20 of the maximum sampling rate.

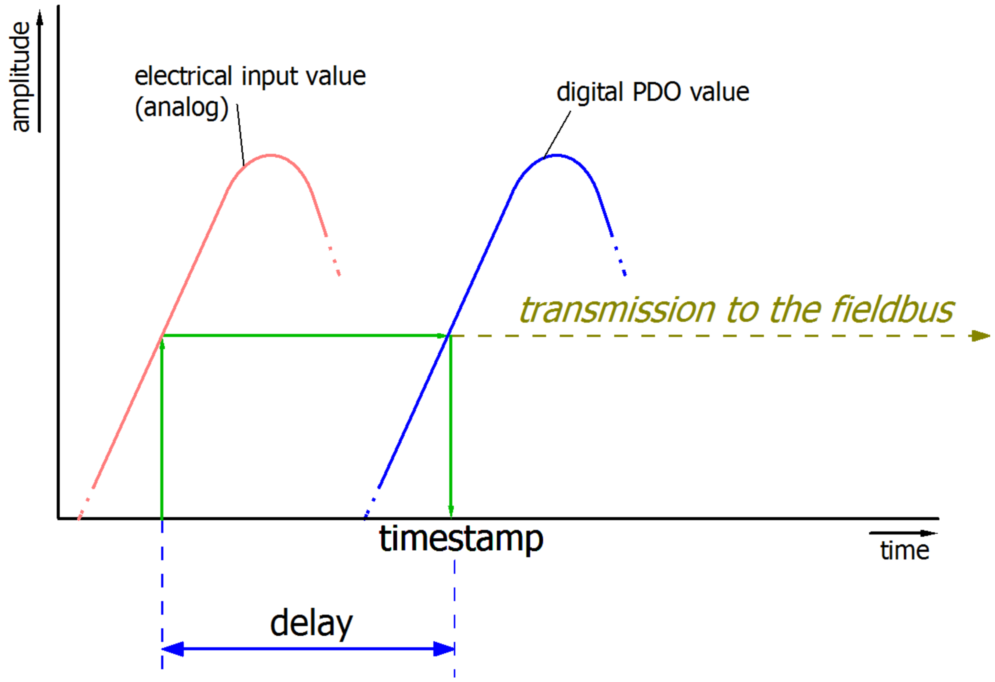


Fig. 44: Diagram signal delay (linear)

**3. Additional information:**
may be provided in the specification, e.g.
3.1 Actual sampling rate of the ADC (if different from the channel sampling rate)
3.2 Time correction values for run times with different filter settings
…

# 5.5 Process data

This section describes the individual PDOs and their content. A PDO (Process Data Object) is a unit on cyclically transmitted process values. Such a unit can be an individual variable (e.g. the weight as a 32-bit value) or a group/structure of variables. The individual PDOs can be activated or deactivated separately in the TwinCAT System Manager. The ‘Process data’ tab is used for this (visible only if the terminal is selected on the left). A change in the composition of the process data in the TwinCAT System Manager becomes effective only after restarting the EtherCAT system.

## 5.5.1 Selection of process data

The process data of the ELX3351 are set up in the TwinCAT System Manager. The PDOs can be activated or deactivated separately. The ‘Process data’ tab is used for this (visible only if the terminal is selected on the left).

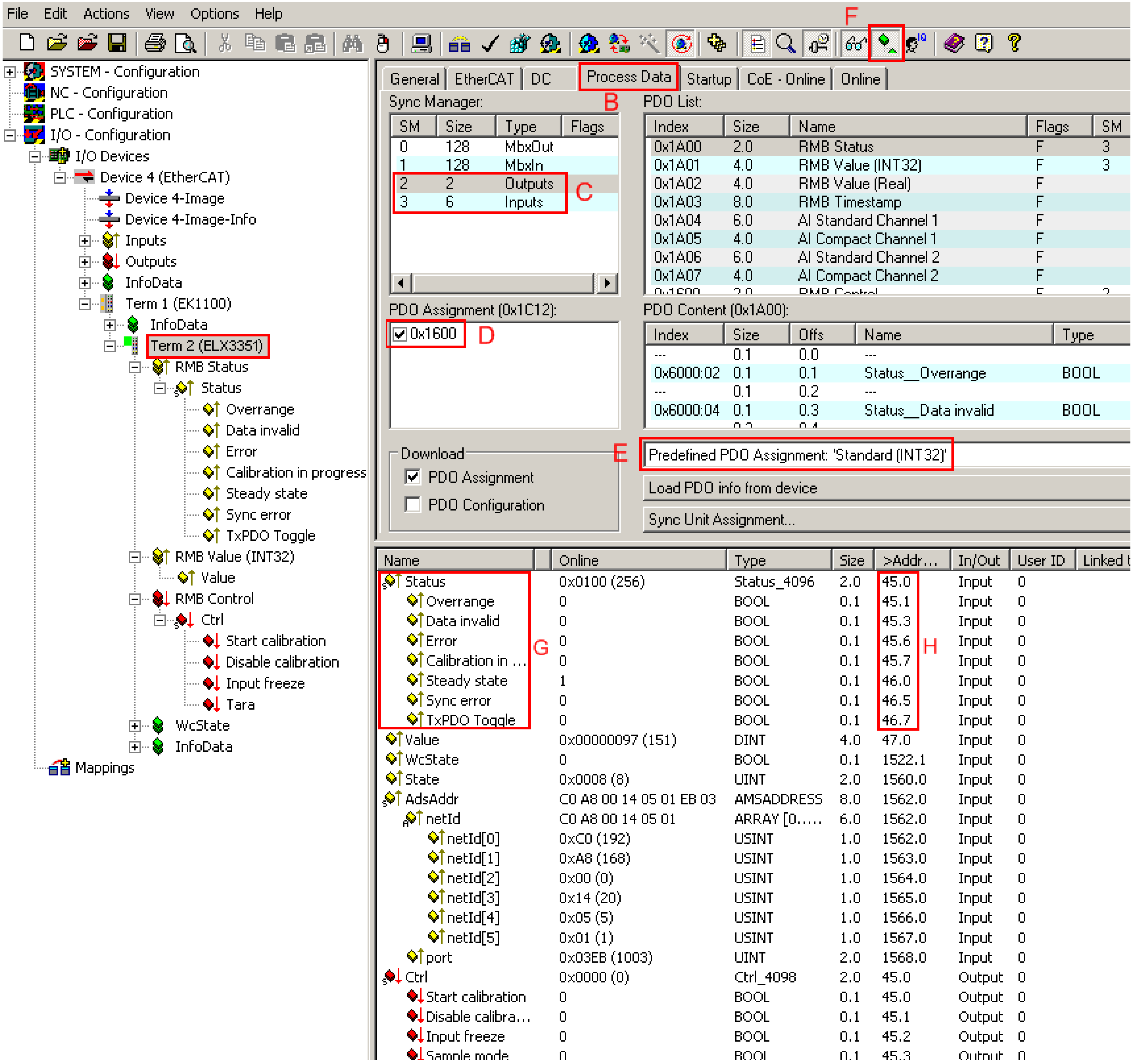


Fig. 45: ELX3351 – process data selection in the TwinCAT System Manager

If the terminal is selected in the System Manager (A), the *Process data* tab (B) shows the PDO selection. The two SyncManagers of the inputs (SM3) and outputs (SM2) can be changed (C). If one of the two is clicked on, the PDO possible for this SyncManager appears underneath it (D). PDOs that are already activated have an activated checkbox in front of them; this is activated by clicking on it.

The process data which then belong to the device are listed underneath it (G). So that the individual bit meanings are visible, e.g. in the *Status* status word, and can be separately linked (G), *ShowSubVariables* must be activated in the System Manager (F). The bit position at which the subvariables are located in the status or control word *Ctrl*) can be taken from the address overview (H) or the following information.

**Predefined PDO Assignment**

In order to simplify the configuration, typical configuration combinations of process data are stored in the device description. The predefined configurations can be selected in the process data overview. Therefore the function is available only if the ESI/XML files are saved in the system (downloadable from the Beckhoff website).

The following combinations are possible (see also Fig. *ELX3351 process data selection in the TwinCAT System Manager*, E):

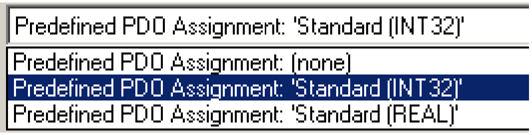


Fig. 46: ELX3351 - selection Predefined PDO Assignment

- Standard (INT32): [Default setting] load calculation; 32-bit integer load value as final value according to the calculation specifications in the CoE, no further conversion necessary in the PLC.
- Standard (REAL): Load calculation; 32-bit floating-point load value as final value according to the calculation specifications in the CoE, no further conversion necessary in the PLC.

## 5.5.2 Default process image

The default process image is standard (INT32).

| Name | Online | Type | Size | >Addr... | In/Out | User ID |
|---|---|---|---|---|---|---|
| Status | 0x8100 (33024) | Status_4096 | 2.0 | 45.0 | Input | 0 |
| Overrange | 0 | BOOL | 0.1 | 45.1 | Input | 0 |
| Data invalid | 0 | BOOL | 0.1 | 45.3 | Input | 0 |
| Error | 0 | BOOL | 0.1 | 45.6 | Input | 0 |
| Calibration in progress | 0 | BOOL | 0.1 | 45.7 | Input | 0 |
| Steady state | 1 | BOOL | 0.1 | 46.0 | Input | 0 |
| Sync error | 0 | BOOL | 0.1 | 46.5 | Input | 0 |
| TxPDO Toggle | 1 | BOOL | 0.1 | 46.7 | Input | 0 |
| Value | 0x00000097 (151) | DINT | 4.0 | 47.0 | Input | 0 |
| WcState | 0 | BOOL | 0.1 | 1522.1 | Input | 0 |
| State | 0x0008 (8) | UINT | 2.0 | 1560.0 | Input | 0 |
| AdsAddr | C0 A8 00 14 05 01 EB 03 | AMSADDRESS | 8.0 | 1562.0 | Input | 0 |
| netId | C0 A8 00 14 05 01 | ARRAY [0..... | 6.0 | 1562.0 | Input | 0 |
| netId[0] | 0xC0 (192) | USINT | 1.0 | 1562.0 | Input | 0 |
| netId[1] | 0xA8 (168) | USINT | 1.0 | 1563.0 | Input | 0 |
| netId[2] | 0x00 (0) | USINT | 1.0 | 1564.0 | Input | 0 |
| netId[3] | 0x14 (20) | USINT | 1.0 | 1565.0 | Input | 0 |
| netId[4] | 0x05 (5) | USINT | 1.0 | 1566.0 | Input | 0 |
| netId[5] | 0x01 (1) | USINT | 1.0 | 1567.0 | Input | 0 |
| port | 0x03EB (1003) | UINT | 2.0 | 1568.0 | Input | 0 |
| Ctrl | 0x0000 (0) | Ctrl_4098 | 2.0 | 45.0 | Output | 0 |
| Start calibration | 0 | BOOL | 0.1 | 45.0 | Output | 0 |
| Disable calibration | 0 | BOOL | 0.1 | 45.1 | Output | 0 |
| Input freeze | 0 | BOOL | 0.1 | 45.2 | Output | 0 |
| Sample mode | 0 | BOOL | 0.1 | 45.3 | Output | 0 |
| Tara | 0 | BOOL | 0.1 | 45.4 | Output | 0 |

Fig. 47: ELX3351 - Default process image

Note regarding ELX3351: No switching of *SampleMode* in the Ctrl word

### Function of the variables

| Variable | Meaning |
|---|---|
| Status | The status word (SW) is located in the input process image, and is transmitted from terminal to the controller. For explanation see the entries in the object overview, index 0x6000 [▶ 61] see "Bit - meaning of the status word [▶ 57]" |
| Value | calculated 32-bit DINT load value in unit [1], with sign |
| Value (Real) | calculated 32-bit floating point REAL load value with mantissa and exponent in unit [1]<br>The format matches the REAL format of IEC 61131-3, which in turn is based on the REAL format of IEC 559. A REAL number (single precision) is defined as follows (See also Beckhoff InfoSys: TwinCAT PLC Control: standard data types). According to IEC 61131, this 32-bit variable can be linked directly with a FLOAT variable of the PLC, see "Bit - meaning of the variable value (REAL) [▶ 57]" |
| WcState | cyclic diagnostic variable; "0" indicates correct data transmission |
| Status | State of the EtherCAT device; *State*.3 = TRUE indicates correct operation in OP |
| AdsAddr | AmsNet address of the EtherCAT device from AmsNetId (in this case: 192.168.0.20.5.1) and port (in this case: 1003) |
| Ctrl | The control word (CW) is located in the output process image, and is transmitted from the controller to the terminal. For explanation see the entries in the object overview, index 0x7000 [▶ 61] see "Bit - meaning of the control word [▶ 57]" |

See also the example program for the dissection of the Status and CTRL variable.

### Bit - meaning of the Status Word

| Bit | SW.15 | SW.14 | SW.13 | SW.12 - SW.9 | SW.8 | SW.7 | SW.6 | SW.5 - SW.4 | SW.3 | SW. 2 | SW.1 | SW. 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Name** | TxPDO Toggle | - | - | - | Steady State | Calibration in progress | Error | - | Data invalid | - | Over - range | - |
| **Meaning** | toggles 0->1->0 with each updated data set | - | - | - | Idling recognition | Calibration in progress | Collective error display | - | Input data are invalid | - | Measuring range exceeded | - |

### Bit - purpose of the variable *Value (Real)*

| **Bit position (from left)** | 1 | 8 | 23 (+1 "hidden bit", see IE559) |
|---|---|---|---|
| **Function** | Sign | Exponent | Mantissa |

### Bit - meaning of the Control Word

| Bit | CW.15 - CW.5 | CW.4 | CW.3 | CW.2 | CW.1 | CW.0 |
|---|---|---|---|---|---|---|
| **Name** | - | Tare | - | Input Freeze | Disable Calibration | Start Calibration |
| **Meaning** | - | starts tare | - | stops the measurement | switches the automatic self-calibration off | starts the self-calibration immediately |

## 5.5.3 Variants Predefined PDO

### Floating-point representation of the load

The display of the load value can also be converted already in the terminal into a point representation. To do this the input PDOs are to be changed as follows:

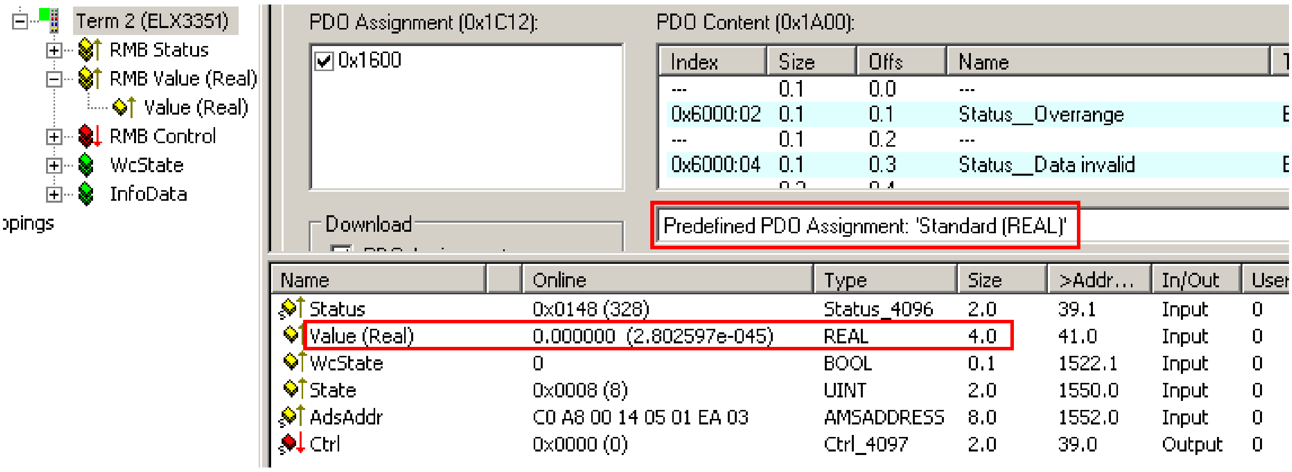


Fig. 48: Load value in floating-point representation

| Variable | Meaning |
|---|---|
| Value (Real) | calculated 32-bit floating point REAL load value with mantissa and exponent in unit [1]<br>The format matches the REAL format of IEC 61131-3, which in turn is based on the REAL format of IEC 559. A REAL number (single precision) is defined as follows (See also Beckhoff InfoSys: TwinCAT PLC Control: standard data types). According to IEC61131, this 32-bit variable can be linked directly with a FLOAT variable of the PLC, see "Bit – meaning of the variable value (REAL)" |

## 5.5.4 Sync Manager

### PDO Assignment

| Inputs: SM3, PDO Assignment 0x1C13 | | | | |
|---|---|---|---|---|
| **Index** | **Index of excluded PDOs** | **Size (byte.bit)** | **Name** | **PDO content** |
| 0x1A00 (default) | - | 2.0 | RMB Status (Resistor Measurement Bridge) | Index 0x6000:02 [▸ 61] - Overrange<br>Index 0x6000:04 [▸ 61] - Data invalid<br>Index 0x6000:07 [▸ 61] - Error<br>Index 0x6000:08 [▸ 61] - Calibration in progress<br>Index 0x6000:09 [▸ 61] - Steady State<br>Index 0x6000:10 [▸ 61] - TxPDO Toggle |
| 0x1A01(default) | 0x1A02<br>0x1A04<br>0x1A05<br>0x1A06<br>0x1A07 | 4.0 | RMB Value (INT32) | Index 0x6000:11 [▸ 61] - Value |
| 0x1A02 | 0x1A01<br>0x1A04<br>0x1A05<br>0x1A06<br>0x1A07 | 4.0 | RMB Value (Real) | Index 0x6000:12 [▸ 61] - Value (Real) |

| Outputs: SM2, PDO assignment 0x1C12 | | | | |
|---|---|---|---|---|
| **Index** | **Index of excluded PDOs** | **Size (byte.bit)** | **Name** | **PDO content** |
| 0x1600 (default) | - | 2.0 | RMB Control (Resistor Measurement bridge) | Index 0x7000:01 [▸ 61] - Start calibration<br>Index 0x7000:02 [▸ 61] - Disable calibration<br>Index 0x7000:03 [▸ 61] - Input freeze<br>Index 0x7000:05 [▸ 61] - Tare |

# 5.6 ELX3351 - Object description and parameterization

| | |
|---|---|
| Note | **EtherCAT XML Device Description**<br>The display matches that of the CoE objects from the EtherCAT XML Device Description. We recommend downloading the latest XML file from the download area of the Beckhoff website and installing it according to installation instructions. |

| | |
|---|---|
| Note | **Parameterization via the CoE list (CAN over EtherCAT)**<br>The EtherCAT device is parameterized via the CoE-Online tab (double-click on the respective object) or via the Process Data tab (allocation of PDOs). Please note the following general CoE notes when using/manipulating the CoE parameters:<br>• Keep a startup list if components have to be replaced<br>• Differentiation between online/offline dictionary, existence of current XML description<br>• use “CoE reload” for resetting changes |

## 5.6.1 Restore object

**Index 1011 Restore default parameters**

| Index | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1011:0 | Restore default parameters | Restore default parameters | UINT8 | RO | 0x01 ($1_{dec}$) |
| 1011:01 | SubIndex 001 | If this object is set to “**0x64616F6C**” in the set value dialog, all backup objects are reset to their delivery state. | UINT32 | RW | 0x00000000 ($0_{dec}$) |

## 5.6.2 Configuration data

### Index 8000 RMB Settings

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 8000:0 | RMB Settings | Max. subindex | UINT8 | RO | 0x32 ($50_{dec}$) |
| 8000:01 | Enable filter | 0: No filters active. The terminal operates cycle-synchronous<br>1: The filter settings selected in subindex 0x8000:11 or 0x8000:12 are active. | BOOLEAN | RW | 0x01 ($1_{dec}$) |
| 8000:03 | Enable averager | Activate hardware mean value filter | BOOLEAN | RW | 0x01 ($1_{dec}$) |
| 8000:05 | Symmetric reference potential | Activate symmetric measurement | BOOLEAN | RW | 0x01 ($1_{dec}$) |
| 8000:11 | Mode0 filter settings | 0: FIR 50 Hz<br>1: FIR 60 Hz<br>2: IIR 1<br>3: IIR 2<br>4: IIR 3<br>5: IIR 4<br>6: IIR 5<br>7: IIR 6<br>8: IIR 7<br>9: IIR 8<br>10: Dynamic IIR | UINT16 | RW | 0x0000 ($0_{dec}$) |
| 8000:13 | Dynamic filter change time | Sampling rate for dynamic filter switching.<br>Scaling in 0.01 ms (100 = 1 s)<br>(only if the filters are active and "dynamic IIR" is selected as filter) | UINT16 | RW | 0x000A ($10_{dec}$) |
| 8000:14 | Dynamic filter delta | Limit value for dynamic filter switching.<br>(only if the filters are active and "dynamic IIR" is selected as filter) | REAL32 | RW | 0x41A00000 ($1101004800_{dec}$) = 20.0 |
| 8000:21 | Gain | Scale factor | REAL32 | RW | 0x3F800000 ($1065353216_{dec}$) = 1.0 |
| 8000:22 | Tare | Process data value offset | REAL32 | RW | 0x00000000 ($0_{dec}$) = 0.0 |
| 8000:23 | Rated output | Nominal characteristic value of the sensor element in mV/V | REAL32 | RW | 0x40000000 ($1073741824_{dec}$) = 2.0 |
| 8000:24 | Nominal load | Nominal load of the force transducer/load cell/etc. (e.g. in kg, N or ...) | REAL32 | RW | 0x40A00000 ($1084227584_{dec}$) = 5.0 |
| 8000:25 | Zero balance | Zero point offset in mV/V | REAL32 | RW | 0x00000000 ($0_{dec}$) = 0.0 |
| 8000:26 | Gravity of earth | Current acceleration of gravity (default 9.806650) | REAL32 | RW | 0x411CE80A ($1092413450_{dec}$) = 9.806650 |
| 8000:27 | Scale factor | This factor can be used to re-scale the process data. In order to change the display from kg to g, for example, the factor 1000 can be entered here. | REAL32 | RW | 0x447A0000 ($1148846080_{dec}$) = 1000.0 |
| 8000:28 | Reference load | Reference weight for manual calibration | REAL32 | RW | 0x40A00000 ($1084227584_{dec}$) = 5.0 |
| 8000:29 | Steady state window | Time constant for the "steady state" bit (used for idle recognition) | UINT16 | RW | 0x03E8 ($1000_{dec}$) |
| 8000:2A | Steady state tolerance | Tolerance window for the "steady state" bit | UINT32 | RW | 0x00000005 ($5_{dec}$) |
| 8000:31 | Calibration interval | Calibration interval for automatic calibration of the terminal.<br>The unit is 100 ms.<br>The smallest possible value is 5 (500 ms). A value of 0 deactivates automatic self-calibration. This is also possible via the process data bit "Disable calibration". | UINT16 | RW | 0x0708 ($1800_{dec}$) |

## 5.6.3 Command object

### Index FB00 RMB Command

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| FB00:0 | RMB Command | Max. subindex | UINT8 | RO | 0x03 ($3_{dec}$) |
| FB00:01 | Request | Commands can be sent to the terminal via the request object. Command:<br>• 0x0101: Zero balance<br>• 0x0102: Calibration<br>• 0x0001 Taring<br>• 0x0002 Taring (data are stored in the EEPROM)<br>see commands | OCTET-STRING[2] | RW | {0} |
| FB00:02 | Status | Status of the command currently being executed<br>0: Command executed without error.<br>255: Command is being executed | UINT8 | RO | 0x00 ($0_{dec}$) |
| FB00:03 | Response | Optional response value of the command | OCTET-STRING[4] | RO | {0} |

## 5.6.4 Input data

### Index 6000 RMB Inputs

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 6000:0 | RMB Inputs | Max. Subindex | UINT8 | RO | 0x13 ($19_{dec}$) |
| 6000:02 | Overrange | The measured value has reached its end value | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| 6000:04 | Data invalid | The displayed process data are invalid. e.g. during calibration. | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| 6000:07 | Error | An error has occurred. | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| 6000:08 | Calibration in progress | Calibration is running. The process data show the last valid measured value. | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| 6000:09 | Steady state | | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| 6000:10 | TxPDO Toggle | The TxPDO toggle is toggled by the slave when the data of the associated TxPDO is updated. | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| 6000:11 | Value | Measured value as 32 bit signed integer | INT32 | RO | 0x61746144 ($1635017028_{dec}$) |
| 6000:12 | Value (Real) | Measured value as real | REAL32 | RO | 0x00000000 ($0_{dec}$) |

## 5.6.5 Output data

### Index 7000 RMB Outputs

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 7000:0 | RMB Outputs | Max. subindex | UINT8 | RO | 0x05 ($5_{dec}$) |
| 7000:01 | Start calibration | The calibration can be started manually with a rising edge. This can be used to prevent the calibration from starting automatically at an unsuitable time. | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| 7000:02 | Disable calibration | 0: Automatic calibration is active.<br>1: Automatic calibration is switched off. | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| 7000:03 | Input freeze | The process data and the digital filters are frozen. | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| 7000:05 | Tare | The process record can be set to 0 with a rising edge. The tare value is not stored in the EEPROM and is therefore no longer available after a terminal reset. | BOOLEAN | RO | 0x00 ($0_{dec}$) |

## 5.6.6 Information / diagnostic data

### Index 9000 RMB Info data

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 9000:0 | RMB Info data | Max. subindex | UINT8 | RO | 0x11 ($17_{dec}$) |
| 9000:11 | mV/V | Current mV/V value | REAL32 | RO | 0x00000000 ($0_{dec}$) |

### Index A000 RMB Diag data

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| A000:13 | No external reference supply | The external reference voltage is less than ±1 V. | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| A000:15 | Overrange bridge | Measuring range exceeded in the bridge junction | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| A000:16 | Underrange bridge | Value below measuring range in the bridge junction | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| A000:17 | Overrange supply | Measuring range of the reference voltage exceeded | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| A000:18 | Underrange supply | Value below measuring range for the reference voltage | BOOLEAN | RO | 0x00 ($0_{dec}$) |
| A000:21 | ADC raw value supply | ADC raw value bridge supply voltage | INT32 | RO | 0x00 ($0_{dec}$) |
| A000:22 | ADC raw value bridge | ADC raw value bridge voltage | INT32 | RO | 0x00 ($0_{dec}$) |

## 5.6.7 Standard objects

### Index 1000 Device type

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1000:0 | Device type | Device type of the EtherCAT slave: the Lo-Word contains the CoE profile used (5001). The Hi-Word contains the module profile according to the modular device profile. | UINT32 | RO | 0x01681389 ($23597961_{dec}$) |

### Index 1008 Device name

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1008:0 | Device name | Device name of the EtherCAT slave | STRING | RO | ELX3351 |

### Index 1009 Hardware version

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1009:0 | Hardware version | Hardware version of the EtherCAT slave | STRING | RO | 00 |

### Index 100A Software version

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 100A:0 | Software version | Firmware version of the EtherCAT slave | STRING | RO | 01 |

### Index 1018 Identity

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1018:0 | Identity | Information for identifying the slave | UINT8 | RO | 0x04 ($4_{dec}$) |
| 1018:01 | Vendor ID | Vendor ID of the EtherCAT slave | UINT32 | RO | 0x00000002 ($2_{dec}$) |
| 1018:02 | Product code | Product code of the EtherCAT slave | UINT32 | RO | 0x0D1C3052 ($219951186_{dec}$) |
| 1018:03 | Revision | Revision number of the EtherCAT slave; the low word (bit 0-15) indicates the special terminal number, the high word (bit 16-31) refers to the device description | UINT32 | RO | 0x00100000 ($1048576_{dec}$) |
| 1018:04 | Serial number | Serial number of the EtherCAT slave; the low byte (bit 0-7) of the low word contains the year of production, the high byte (bit 8-15) of the low word contains the week of production, the high word (bit 16-31) is 0 | UINT32 | RO | 0x00000000 ($0_{dec}$) |

### Index 10F0 Backup parameter handling

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 10F0:0 | Backup parameter handling | Information for standardized loading and saving of backup entries | UINT8 | RO | 0x01 ($1_{dec}$) |
| 10F0:01 | Checksum | Checksum across all backup entries of the EtherCAT slave | UINT32 | RO | 0x00000000 ($0_{dec}$) |

### Index 1600 RMB RxPDO-Map Control

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1600:0 | RMB RxPDO-Map Control | PDO Mapping RxPDO-Map control | UINT8 | RO | 0x07 ($7_{dec}$) |
| 1600:01 | Subindex 001 | 1. PDO Mapping entry (object 0x7000 (RMB outputs), entry 0x01 (Start calibration)) | OCTET-STRING[10] | RO | 0x7000:01, 1 |
| 1600:02 | Subindex 002 | 2. PDO Mapping entry (object 0x7000 (RMB outputs), entry 0x02 (Disable calibration)) | OCTET-STRING[10] | RO | 0x7000:02, 1 |
| 1600:03 | Subindex 003 | 3. PDO Mapping entry (object 0x7000 (RMB outputs), entry 0x03 (Input freeze)) | OCTET-STRING[10] | RO | 0x7000:03, 1 |
| 1600:04 | Subindex 004 | 4. PDO Mapping entry (4 bits align) | OCTET-STRING[10] | RO | 0x0000:00, 1 |
| 1600:05 | Subindex 005 | 5. PDO Mapping entry (object 0x7000 (RMB outputs), entry 0x05 (Tara)) | OCTET-STRING[10] | RO | 0x7000:05, 1 |
| 1600:06 | Subindex 006 | 6. PDO Mapping entry (3 bits align) | OCTET-STRING[10] | RO | 0x0000:00, 3 |
| 1600:07 | Subindex 007 | 7. PDO Mapping entry (8 bits align) | OCTET-STRING[10] | RO | 0x0000:00, 8 |

### Index 1800 RMB TxPDO-Par Status

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1800:0 | RMB TxPDO-Par Status | PDO Parameter TxPDO 1 | UINT8 | RO | 0x06 ($6_{dec}$) |
| 1800:06 | Exclude TxPDOs | Specifies the TxPDOs (index of TxPDO mapping objects) that must not be transferred together with TxPDO 1 | OCTET-STRING[10] | RO | 04 1A 05 1A 06 1A 07 1A 00 00 |

### Index 1801 RMB TxPDO-Par Value (INT32)

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1801:0 | RMB TxPDO-Par Value (INT32) | PDO Parameter TxPDO 2 | UINT8 | RO | 0x06 ($6_{dec}$) |
| 1801:06 | Exclude TxPDOs | Specifies the TxPDOs (index of TxPDO mapping objects) that must not be transferred together with TxPDO 2 | OCTET-STRING[10] | RO | 02 1A 04 1A 05 1A 06 1A 07 1A |

### Index 1802 RMB TxPDO-Par Value (Real)

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1802:0 | RMB TxPDO-Par Value (Real) | PDO Parameter TxPDO 3 | UINT8 | RO | 0x06 ($6_{dec}$) |
| 1802:06 | Exclude TxPDOs | Specifies the TxPDOs (index of TxPDO mapping objects) that must not be transferred together with TxPDO 3 | OCTET-STRING[10] | RO | 01 1A 04 1A 05 1A 06 1A 07 1A |

### Index 1A00 RMB TxPDO-Map Status

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1A00:0 | RMB TxPDO-Map Status | PDO Mapping RxPDO-Map Status | UINT8 | RO | 0x0A ($10_{dec}$) |
| 1A00:01 | Subindex 001 | 1. PDO Mapping entry (1 bits align) | OCTET-STRING[10] | RO | 0x0000:00, 1 |
| 1A00:02 | Subindex 002 | 2. PDO Mapping entry (object 0x6000 (RMB inputs), entry 0x02 (Overrange)) | OCTET-STRING[10] | RO | 0x6000:02, 1 |
| 1A00:03 | Subindex 003 | 3. PDO Mapping entry (1 bits align) | OCTET-STRING[10] | RO | 0x0000:00, 1 |
| 1A00:04 | Subindex 004 | 4. PDO Mapping entry (object 0x6000 (RMB inputs), entry 0x04 (Data invalid)) | OCTET-STRING[10] | RO | 0x6000:04, 1 |
| 1A00:05 | Subindex 005 | 5. PDO Mapping entry (2 bits align) | OCTET-STRING[10] | RO | 0x0000:00, 2 |
| 1A00:06 | Subindex 006 | 6. PDO Mapping entry (object 0x6000 (RMB inputs), entry 0x07 (Error)) | OCTET-STRING[10] | RO | 0x6000:07, 1 |
| 1A00:07 | Subindex 007 | 7. PDO Mapping entry (object 0x6000 (RMB inputs), entry 0x08 (Calibration in progress)) | OCTET-STRING[10] | RO | 0x6000:08, 1 |
| 1A00:08 | Subindex 008 | 8. PDO Mapping entry (object 0x6000 (RMB inputs), entry 0x09 (Steady state)) | OCTET-STRING[10] | RO | 0x6000:09, 1 |
| 1A00:09 | Subindex 009 | 9. PDO Mapping entry (4 bits align) | OCTET-STRING[10] | RO | 0x0000:00, 6 |
| 1A00:0A | Subindex 010 | 10. PDO Mapping entry (object 0x6000 (RMB inputs), entry 0x0E (Sync error)) | OCTET-STRING[10] | RO | 0x6000:10, 1 |

### Index 1A01 RMB TxPDO-Map Value (INT32)

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1A01:0 | RMB TxPDO-Map Value (INT32) | PDO Mapping Value (INT32) | UINT8 | RW | 0x01 ($1_{dec}$) |
| 1A01:01 | SubIndex 001 | 1. PDO Mapping entry (object 0x6000 (RMB inputs), entry 0x11 (Value)) | UINT32 | RW | 0x6000:11, 32 |

### Index 1A02 RMB TxPDO-Map Value (Real)

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1A02:0 | RMB TxPDO-Map Value (real) | PDO Mapping Value (real) | UINT8 | RW | 0x01 ($1_{dec}$) |
| 1A02:01 | SubIndex 001 | 1. PDO Mapping entry (object 0x6000 (RMB inputs), entry 0x12 (Value (real))) | UINT32 | RW | 0x6000:12, 32 |

### Index 1C00 Sync manager type

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1C00:0 | Sync manager type | Using the sync managers | UINT8 | RO | 0x04 ($4_{dec}$) |
| 1C00:01 | SubIndex 001 | Sync-Manager Type Channel 1: Mailbox Write | UINT8 | RO | 0x01 ($1_{dec}$) |
| 1C00:02 | SubIndex 002 | Sync-Manager Type Channel 2: Mailbox Read | UINT8 | RO | 0x02 ($2_{dec}$) |
| 1C00:03 | SubIndex 003 | Sync-Manager Type Channel 3: Process Data Write (Outputs) | UINT8 | RO | 0x03 ($3_{dec}$) |
| 1C00:04 | SubIndex 004 | Sync-Manager Type Channel 4: Process Data Read (Inputs) | UINT8 | RO | 0x04 ($4_{dec}$) |

### Index 1C12 RxPDO assign

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1C12:0 | RxPDO assign | PDO Assign Outputs | UINT8 | RW | 0x02 ($2_{dec}$) |
| 1C12:01 | Subindex 001 | 1. allocated RxPDO (contains the index of the associated RxPDO mapping object) | UINT16 | RW | 0x1600 ($5632_{dec}$) |
| 1C12:02 | Subindex 002 | 2. allocated RxPDO (contains the index of the associated RxPDO mapping object) | UINT16 | RW | - |

### Index 1C13 TxPDO assign

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1C13:0 | TxPDO assign | PDO Assign Inputs | UINT8 | RW | 0x03 ($3_{dec}$) |
| 1C13:01 | Subindex 001 | 1. allocated TxPDO (contains the index of the associated TxPDO mapping object) | UINT16 | RW | 0x1A00 ($6656_{dec}$) |
| 1C13:02 | Subindex 002 | 2. allocated TxPDO (contains the index of the associated TxPDO mapping object) | UINT16 | RW | 0x1A01 ($6657_{dec}$) |
| 1C13:03 | Subindex 003 | 3. allocated TxPDO (contains the index of the associated TxPDO mapping object) | UINT16 | RW | - |

### Index 1C32 SM output parameter

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1C32:0 | SM output parameter | Synchronization parameters for the outputs | UINT8 | RO | 0x20 ($32_{dec}$) |
| 1C32:01 | Sync mode | Current synchronization mode:<br>• 0: Free Run<br>• 1: Synchron with SM 2 Event<br>• 2: DC-Mode - Synchron with SYNC0 Event<br>• 3: DC-Mode - Synchron with SYNC1 Event | UINT16 | RW | 0x0000 ($0_{dec}$) |
| 1C32:02 | Cycle time | Cycle time (in ns):<br>• Free Run: Cycle time of the local timer<br>• Synchronous with SM 2 event: Master cycle time<br>• DC mode: SYNC0/SYNC1 Cycle Time | UINT32 | RW | 0x001E8480 ($2000000_{dec}$) |
| 1C32:03 | Shift time | Time between SYNC0 event and output of the outputs (in ns, DC mode only) | UINT32 | RO | 0x00000000 ($0_{dec}$) |
| 1C32:04 | Sync modes supported | Supported synchronization modes:<br>• Bit 0 = 1: free run is supported<br>• Bit 1 = 1: Synchronous with SM 2 event is supported<br>• Bit 2-3 = 01: DC mode is supported<br>• Bit 4-5 = 10: Output shift with SYNC1 event (only DC mode)<br>• Bit 14 = 1: dynamic times (measurement through writing of 0x1C32:08) | UINT16 | RO | 0x0001 ($1_{dec}$) |
| 1C32:05 | Minimum cycle time | Minimum cycle time (in ns) | UINT32 | RO | 0x000186A0 ($100000_{dec}$) |
| 1C32:06 | Calc and copy time | Minimum time between SYNC0 and SYNC1 event (in ns, DC mode only) | UINT32 | RO | 0x00000000 ($0_{dec}$) |
| 1C32:07 | Minimum delay time | | UINT32 | RO | 0x00000000 ($0_{dec}$) |
| 1C32:08 | Command | • 0: Measurement of the local cycle time is stopped<br>• 1: Measurement of the local cycle time is started<br>The entries 0x1C32:03, 0x1C32:05, 0x1C32:06, 0x1C32:09, 0x1C33:03, 0x1C33:06, 0x1C33:09 [▸ 65] are updated with the maximum measured values. For a subsequent measurement the measured values are reset | UINT16 | RW | 0x0000 ($0_{dec}$) |
| 1C32:09 | Maximum Delay time | Time between SYNC1 event and output of the outputs (in ns, DC mode only) | UINT32 | RO | 0x00000000 ($0_{dec}$) |
| 1C32:0B | SM event missed counter | Number of missed SM events in OPERATIONAL (DC mode only) | UINT16 | RO | 0x0000 ($0_{dec}$) |
| 1C32:0C | Cycle exceeded counter | Number of occasions the cycle time was exceeded in OPERATIONAL (cycle was not completed in time or the next cycle began too early) | UINT16 | RO | 0x0000 ($0_{dec}$) |
| 1C32:0D | Shift too short counter | Number of occasions that the interval between SYNC0 and SYNC1 event was too short (DC mode only) | UINT16 | RO | 0x0000 ($0_{dec}$) |
| 1C32:20 | Sync error | The synchronization was not correct in the last cycle (outputs were output too late; DC mode only) | BOOLEAN | RO | 0x00 ($0_{dec}$) |

### Index 1C33 SM input parameter

| Index | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| 1C33:0 | SM input parameter | Synchronization parameters for the inputs | UINT8 | RO | 0x20 ($32_{dec}$) |
| 1C33:01 | Sync mode | Current synchronization mode:<br>• 0: Free Run<br>• 1: Synchronous with SM 3 event (no outputs available)<br>• 2: DC - Synchronous with SYNC0 Event<br>• 3: DC - Synchronous with SYNC1 Event<br>• 34: Synchronous with SM 2 event (outputs available) | UINT16 | RW | 0x0000 ($0_{dec}$) |
| 1C33:02 | Cycle time | as 0x1C32:02 | UINT32 | RW | 0x001E8480 ($2000000_{dec}$) |
| 1C33:03 | Shift time | Time between SYNC0 event and reading of the inputs (in ns, only DC mode) | UINT32 | RO | 0x00000000 ($0_{dec}$) |
| 1C33:04 | Sync modes supported | Supported synchronization modes:<br>• Bit 0: free run is supported<br>• Bit 1: synchronous with SM 2 event is supported (outputs available)<br>• Bit 1: synchronous with SM 3 event is supported (no outputs available)<br>• Bit 2-3 = 01: DC mode is supported<br>• Bit 4-5 = 01: input shift through local event (outputs available)<br>• Bit 4-5 = 10: input shift with SYNC1 event (no outputs available)<br>• Bit 14 = 1: dynamic times (measurement through writing of 0x1C32:08 or 0x1C33:08) | UINT16 | RO | 0x0001 ($1_{dec}$) |
| 1C33:05 | Minimum cycle time | as 0x1C32:05 | UINT32 | RO | 0x000186A0 ($100000_{dec}$) |
| 1C33:06 | Calc and copy time | Time between reading of the inputs and availability of the inputs for the master (in ns, only DC mode) | UINT32 | RO | 0x00000000 ($0_{dec}$) |
| 1C33:07 | Minimum delay time | | UINT32 | RO | 0x00000000 ($0_{dec}$) |
| 1C33:08 | Command | as 0x1C32:08 | UINT16 | RW | 0x0000 ($0_{dec}$) |
| 1C33:09 | Maximum Delay time | Time between SYNC1 event and reading of the inputs (in ns, only DC mode) | UINT32 | RO | 0x00000000 ($0_{dec}$) |
| 1C33:0B | SM event missed counter | as 0x1C32:11 | UINT16 | RO | 0x0000 ($0_{dec}$) |
| 1C33:0C | Cycle exceeded counter | as 0x1C32:12 | UINT16 | RO | 0x0000 ($0_{dec}$) |
| 1C33:0D | Shift too short counter | as 0x1C32:13 | UINT16 | RO | 0x0000 ($0_{dec}$) |
| 1C33:20 | Sync error | as 0x1C32:32 | BOOLEAN | RO | 0x00 ($0_{dec}$) |

### Index F000 Modular device profile

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| F000:0 | Modular device profile | General information for the modular device profile | UINT8 | RO | 0x02 ($2_{dec}$) |
| F000:01 | Module index distance | Index spacing of the objects of the individual channels | UINT16 | RO | 0x0010 ($16_{dec}$) |
| F000:02 | Maximum number of modules | Number of channels | UINT16 | RO | EL3351-0000: 0x0001 ($1_{dec}$)<br>EL3351-0090: 0x0002 ($2_{dec}$) |

### Index F008 Code word

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| F008:0 | Code word | reserved | UINT32 | RW | 0x00000000 ($0_{dec}$) |

### Index F010 Module list

| Index (hex) | Name | Meaning | Data type | Flags | Default |
|---|---|---|---|---|---|
| F010:0 | Module list | Max. subindex | UINT8 | RW | 0x02 ($2_{dec}$) |
| F010:01 | SubIndex 001 | RMB | UINT32 | RW | 0x00000172 ($370_{dec}$) |
| F010:02* | SubIndex 002 | TSC | UINT32 | RW | 0x000003B6 ($950_{dec}$) |

*) ELX3351-0090 only

# 6 Appendix

## 6.1 EtherCAT AL Status Codes

For detailed information please refer to the EtherCAT system description.

## 6.2 UL notice

| | |
|---|---|
| | **Application**<br>Beckhoff EtherCAT modules are intended for use with Beckhoff's UL Listed EtherCAT System only. |
| | **Examination**<br>For cULus examination, the Beckhoff I/O System has only been investigated for risk of fire and electrical shock (in accordance with UL508 and CSA C22.2 No. 142). |
| | **For devices with Ethernet connectors**<br>Not for connection to telecommunication circuits. |

**Basic principles**

Two UL certificates are met in the Beckhoff EtherCAT product range, depending upon the components:

1. UL certification according to UL508. Devices with this kind of certification are marked by this sign:

2. UL certification according to UL508 with limited power consumption. The current consumed by the device is limited to a max. possible current consumption of 4 A. Devices with this kind of certification are marked by this sign:

US LISTED
Ind. Cont. Eq.: 24TB
Use 4 Amp. fuse or
Class 2 power supply.
See instructions.

Almost all current EtherCAT products (as at 2010/05) are UL certified without restrictions.

**Application**

If terminals certified *with restrictions* are used, then the current consumption at 24 $V_{DC}$ must be limited accordingly by means of supply

- from an isolated source protected by a fuse of max. 4 A (according to UL248) or
- from a voltage supply complying with *NEC class 2*.
  A voltage source complying with *NEC class 2* may not be connected in series or parallel with another *NEC class 2*compliant voltage supply!

These requirements apply to the supply of all EtherCAT bus couplers, power adaptor terminals, Bus Terminals and their power contacts.

## 6.3 Support and Service

Beckhoff and their partners around the world offer comprehensive support and service, making available fast and competent assistance with all questions related to Beckhoff products and system solutions.

**Beckhoff's branch offices and representatives**

Please contact your Beckhoff branch office or representative for local support and service on Beckhoff products!

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http://www.beckhoff.com

You will also find further documentation for Beckhoff components there.

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| e-mail: | info@beckhoff.com |

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- design, programming and commissioning of complex automation systems
- and extensive training program for Beckhoff system components

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|---|---|
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| e-mail: | support@beckhoff.com |

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