BECKHOFF New Automation Technology

Documentation | EN
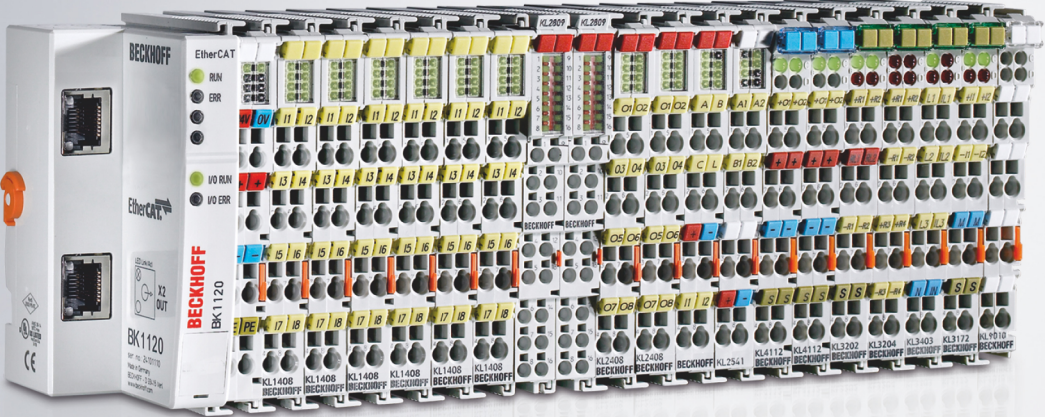
KL3681/KS3681

Multimeter Terminals

2021-11-12 | Version: 2.5.0

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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.

Trademarks

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Patent Pending

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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!
Failure to follow this safety instruction directly endangers the life and health of persons.

⚠ **WARNING**
Risk of injury!
Failure to follow this safety instruction endangers the life and health of persons.

⚠ **CAUTION**
Personal injuries!
Failure to follow this safety instruction can lead to injuries to persons.

NOTE
Damage to environment/equipment or data loss
Failure to follow this instruction can lead to environmental damage, equipment damage or data loss.

● Tip or pointer

i This symbol indicates information that contributes to better understanding.

1.3 Documentation Issue Status

Version	Comment
2.5.0	• Chapter *Process image* corrected • Chapter *Disposal* added • Approvals/markings updated
2.4.0	• Chapter *Technology* added • New title page
2.3.0	• Chapter *Instructions for ESD protection* updated • Chapter *Beckhoff Identification Code (BIC)* added
2.2.0	• Design of the safety instructions adapted to IEC 82079-1 • Chapter *Instructions for ESD protection* added • Example program added to chapter *KS2000 Configuration software*
2.1.0	• Chapter *Notes on the documentation* updated • Chapter *connection* updated
2.0.0	• Migration (complete Document) • LED Display: meaning of K-bus run led exchanged (off/on)
1.0.0	• Technical data updated • Description of parameterization via KS2000 configuration software extended • Description of control and status byte corrected • Description of process image added
0.5	• Preliminary version (German only)

Firm and hardware versions

Documentation Version	KL3681-0000, KS3681-0000	
	Firmware	Hardware
2.5.0	1C	04
2.4.0	1C	04
2.3.0	1C	02
2.2.0	1C	02
2.1.0	1C	02
2.0.0	1C	01
1.0.0	1C	01
0.5	1C	01

The firmware and hardware version (delivery state) can be found in the serial number printed at the side of the terminal.

Syntax of the serial number

Structure of the serial number: WW YY FF HH

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

Example with serial number 02 13 00 01:

02 - week of production 02
13 - year of production 2013
00 - firmware version 09
01 - hardware version 01

1.4   Beckhoff Identification Code (BIC)

The Beckhoff Identification Code (BIC) is increasingly being applied to Beckhoff products to uniquely identify the product. The BIC is represented as a Data Matrix Code (DMC, code scheme ECC200), the content is based on the ANSI standard MH10.8.2-2016.
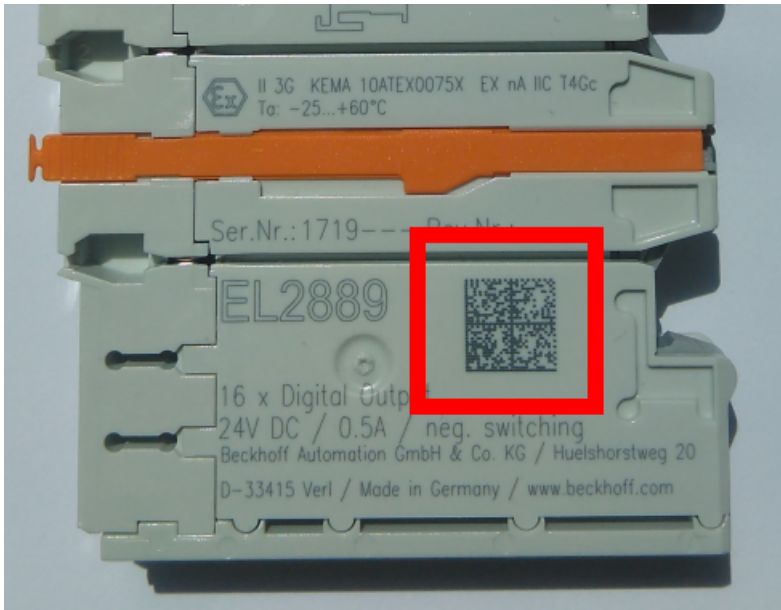
Fig. 1: BIC as data matrix code (DMC, code scheme ECC200)

The BIC will be introduced step by step across all product groups.

Depending on the product, it can be found in the following places:

- on the packaging unit
- directly on the product (if space suffices)
- on the packaging unit and the product

The BIC is machine-readable and contains information that can also be used by the customer for handling and product management.

Each piece of information can be uniquely identified using the so-called data identifier (ANSI MH10.8.2-2016). The data identifier is followed by a character string. Both together have a maximum length according to the table below. If the information is shorter, spaces are added to it. The data under positions 1 to 4 are always available.

The following information is contained:

Item no.	Type of information	Explanation	Data identifier	Number of digits incl. data identifier	Example
1	Beckhoff order number	**Beckhoff order number**	1P	8	1P072222
2	Beckhoff Traceability Number (BTN**)**	**Unique serial number, see note below**	S	12	SBTNk4p562d7
3	Article description	**Beckhoff article description, e.g. EL1008**	1K	32	1KEL1809
4	Quantity	**Quantity in packaging unit, e.g. 1, 10, etc.**	Q	6	Q1
5	Batch number	Optional: Year and week of production	2P	14	2P401503180016
6	ID/serial number	Optional: Present-day serial number system, e.g. with safety products or calibrated terminals	51S	12	51S678294104
7	Variant number	Optional: Product variant number on the basis of standard products	30P	32	30PF971, 2*K183
...					

Further types of information and data identifiers are used by Beckhoff and serve internal processes.

Structure of the BIC

Example of composite information from item 1 to 4 and 6. The data identifiers are marked in red for better display:

BTN

An important component of the BIC is the Beckhoff Traceability Number (BTN, item no. 2). The BTN is a unique serial number consisting of eight characters that will replace all other serial number systems at Beckhoff in the long term (e.g. batch designations on IO components, previous serial number range for safety products, etc.). The BTN will also be introduced step by step, so it may happen that the BTN is not yet coded in the BIC.

NOTE
This information has been carefully prepared. However, the procedure described is constantly being further developed. We reserve the right to revise and change procedures and documentation at any time and without prior notice. No claims for changes can be made from the information, illustrations and descriptions in this information.

2 Product overview

2.1 Introduction
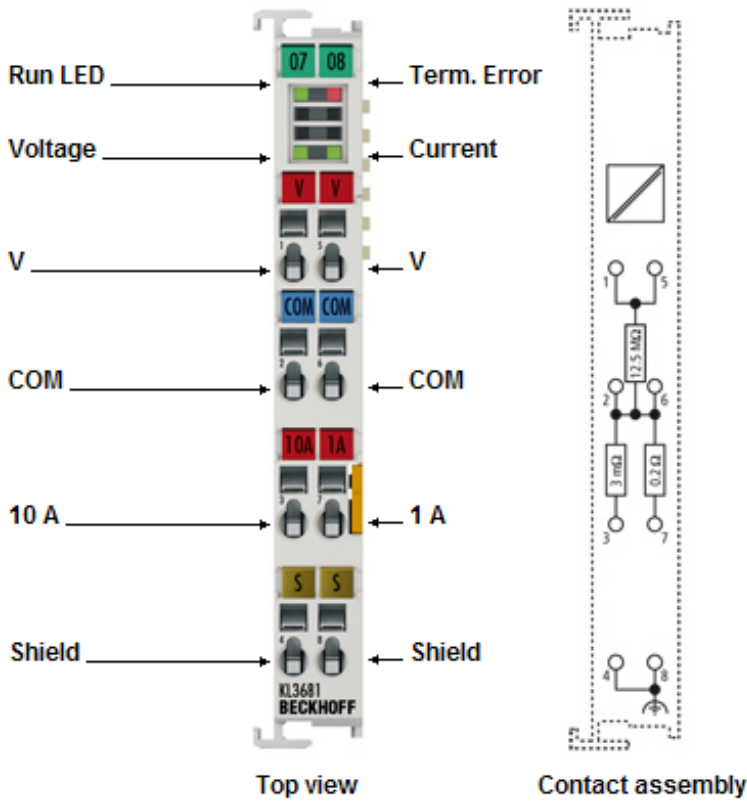
Fig. 2: KL3681-0000 - Digital multimeter terminal

The KL3681 Bus Terminal enables measurement of currents and voltages in a wide input range. The measuring ranges are switched automatically, as usual in advanced digital multimeters. For current measurements, two current paths are available, one of which is a high-current path for up to 10 A. The current and the voltage measurement facility can be used for DC and AC. The alternating parameters are output as true RMS values. The measurement readings can be read and processed with commercially available fieldbus systems. At the same time, the KL3681 enables the measuring type and range to be set via the bus.

Excellent interference immunity is achieved through the fully electrically isolated design of the electronic measuring system and the dual-slope conversion system. High precision and simple, high-impedance measurement from 300 mV to 300 V allow the Bus Terminal to be used like a digital multimeter.

In measuring applications in particular, the voltage to be expected is often not yet known during the planning phase. Automatic adjustment of the measurement range simplifies use and reduces stock levels. The selected measuring type and overload are indicated by LEDs.

2.2 Technical data

Technical data	KL3681-0000	KS3681-0000
Number of inputs	1, voltage or current (1 A / 10 A)	
Technology	digital multimeter with automatic range selection	
Measured values	current, voltage (AC/DC)	
Measuring voltage	300 mV, 3 V, 30 V, 300 V	
Measuring current	100 mA, 1 A and 10 A via high-current path	
Resolution	18 bit + sign in each measurement range	
Internal resistance	Measuring range DC 300 mV - 300 V: 12.5 MΩ	
	Measuring range DC 100 mA - 1 A: 0.2 Ω	
	Measuring range DC 10 A: 3 mΩ	
	Measuring range AC 300 mV - 300 V: 1 MΩ, approx. 33 pF	
	Measuring rangeAC 100 mA - 1 A: 0.2 Ω	
	Measuring range AC 10 A: 3 mΩ	
Measuring error	see table at chapter Accuracy [▶ 12]	
Measuring procedure	DC with arithmetic averaging, AC with true RMS value calculation TrueRMS, 0...1 kHz input signal, Crest factor < 3 allowed	
Update time	0.5 s, 1 s for measuring range selection	
Electrical isolation	1500 V (terminal / E-bus)	
Supply voltage for internal circuit	via K-Bus	
Current consumption from via E-bus	typically 100 mA	
Configuration	via KS2000 Configuration Software	
Pluggable wiring	no	yes
Weight	approx. 70 g	
Permissible ambient temperature for operation	0°C ... + 55°C	
Permissible ambient temperature for storage	-25°C ... + 85°C	
Permissible Relative humidity	95 %, no condensation	
Dimensions	approx. 15 mm x 100 mm x 70 mm (width aligned: 12 mm)	
Mounting [▶ 34]	on 35 mm mounting rail conforms to EN 60715	
Vibration / shock resistance	conforms to EN 60068-2-6 / EN 60068-2-27	
EMC resistance burst / ESD	conforms to EN 61000-6-2 / EN 61000-6-4	
Protection class	IP20	
Installation position	variable	
Approvals/markings*	CE, UKCA, EAC	

*) Real applicable approvals/markings see type plate on the side (product marking).

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2.3 Technology

General description

The functionality of the KL3681 is similar to that of a commercial digital multimeter. The terminal offers the following features:

- Single-channel measurement
- AC/DC voltage measurement, range selection automatic through Autorange function or through the controller; measuring ranges 300 mV, 3 V, 30 V, 300 V
- AC/DC current measurement in the 1 A path (internal fuse: 1.25 A) or 10 A path (no internal fuse), measuring ranges: 100 mA, 1 A, 10 A
- Formation of measured values:
  AC current/voltage is calculated as a true RMS value without DC component, an integration of the signal waveform in the ADC takes place
  DC current/voltage is calculated as an arithmetic mean value, an integration of the signal waveform in the ADC takes place
- Electrical isolation from the fieldbus
- Very good interference immunity through dual-slope conversion technique
- Display of measurement type (current/voltage) and overload through LED
- Typical update rate approx. 2/s, after measuring range change up to approx. 1/s, with deactivated filter approx. 16/s.

The data collection is shown in fig. *KL3681 - Data flow*.
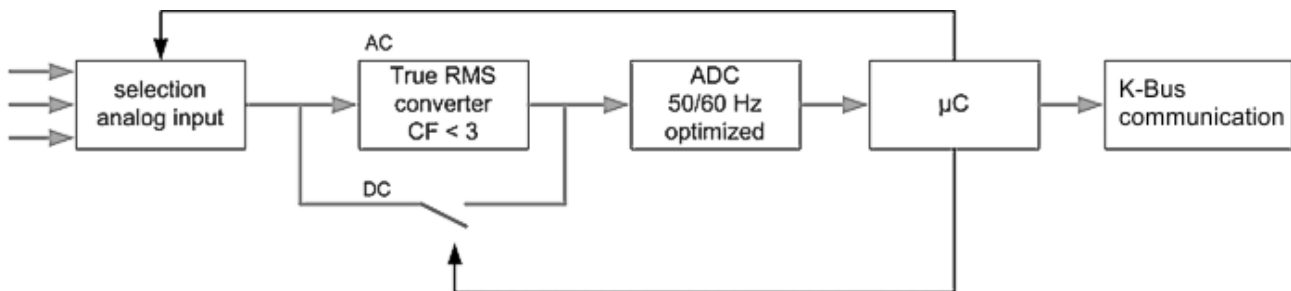
Fig. 3: KL3681 - Data flow

Application note

For the measurement of a 60 Hz signal, the register R32.7 should be set accordingly. For all other signal frequencies the 50 Hz preset is valid, because of the longer integration time. The accuracy information shown below refer to a input signal of a frequency range of > 0 ... 1 kHz. With higher frequencies the measurement accuracy decreases (-3 dB > 500 kHz).

It is possible to measure a non-sinus AC input signal if the Crest factor is < 3. The accuracy information below refers to a Crest factor of max. 2.

The simultaneous electrical connection of both current paths (10, 1 A) and the voltage path for a following alternating measurement of values is possible, but not recommended. In case of AC components in the signal, a parasitic crosstalk from path to path can occur. After switching over, the process data update time can be up to 1 second.

Specifications

Accuracy

The unused measurement input should be connected to the COM port of the terminal in order to make the analysis as accurate as possible and minimize interference.

- Possible measuring inputs at the terminal:
  - Voltage measurement 300 mV – 300 V (connection points 1 + 5)

  ◦ Current measurement 100 mA – 1 A (connection point 7)
  ◦ Current measurement 10 A (connection point 3)

The measuring accuracy depends on the type of signal to be measures and on the terminal settings.
The accuracy values specified in the following table apply to the default settings for the terminal parameters:

- Enable vendor calibration: true
- Enable filter: true
- Frequency: 50 Hz
- Zero compensation interval: Off (0)
- Presentation: Scaled (1Bit/1µV) (2)

Measuring tolerances depending on temperatures. MBE = full scale value

Signal to be measured		Typical max. tolerance in % of full scale value[1]		Typical temperature drift[2][6]
Measure-ment type	Measuring range	40°C [3]	0 ... 55°C	ppm/°C
DC	3 V - 300 V [8]	0.01	0.2	35
	300 mV [8]	0.05	0.2	35
	100 mA [7]	0.1	0.5	50
	1 A	0.1	0.5	50
	10 A	0.2	1.2	170
AC [4][5]	3 V - 300 V	0.25	0.75	130
	300 mV	0.25	0.5	50
	100 mA	0.5	1	50
	1 A	0.5	0.7	50
	10 A	0.5	1.2	150

1) In 60 Hz mode of ADC 0.02 should be added to the specified tolerance
2) The values apply to a minimum terminal warm-up time of 30 minutes
3) The compensation temperature is 40 °C
4) All AC voltage and current ranges are specified for a range of 5% to 100%
5) Crest factor < 2
6) In 60 Hz mode an additional temperature drift of 20 ppm/°C is to be expected.
7) The maximum deviation under EMC test conditions according to IEC 61131 is 1 %
8) The maximum deviation under EMC test conditions according to IEC 61131 is 0.2 %

Measuring procedure

The measuring technique in the terminal is based on the dual-slope technique.
The Zero Offset Compensation function reads the internal ADC offset and corrects the analog value
accordingly. The additional temperature drift can thus be partly compensated, either cyclically or through
external control.

Operating conditions

  • To avoid interference shielded cables must be used for the analog signals. The maximum cable length
    is 30 m.
  • For DC voltage measurements may the AC component may not exceed 150 V_{pp}.
  • For AC voltage measurements may the DC component may not exceed 150 V (sine voltage).
  • The peak voltage (relative to the COM terminal) may not exceed 600 V.

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Internal resistances

Measurement type	Measuring range	Internal resistance
DC	300 mV - 300 V	12.5 MΩ
	100 mA - 1 A	0.2 Ω
	10 A	3 mΩ
AC [4] [5]	300 mV - 300 V	1 MΩ, approx. 33 pF
	100 mA - 1 A	0.2 Ω
	10 A	3 mΩ

Default Setting

The factory setting for the multimeter terminal enables voltages up to 300 V_{DC} to be measured directly without additional settings. The Autorange function is active and selects the measuring range automatically. The measured value is displayed with 1 bit/µV, i.e. no adjustment is required.

2.4 Basic function principles

Features

The functionality of the KL3681 is similar to that of a commercial digital multimeter. The terminal offers the following features:

- Single-channel measurement
- AC/DC voltage measurement, automatic range selection: "Autorange" or specified via the controller
  Measurement ranges: 300 mV, 3 V, 30 V, 300 V
- AC/DC current measurement in the 1 A path (internal fuse: 1.25 A) or 10 A path (no internal fuse)
  Measurement ranges: 100 mA, 1 A, 10 A
- Formation of measured values:
  Alternating current and alternating voltage are calculated as true RMS values, no DC component
  Direct current and direct voltage are calculated as arithmetic average value
- Electrical isolation from the fieldbus
- Very good interference immunity through dual-slope conversion technique
- Display of measurement type (current/voltage) and overload through LED
- Typical update rate approx. two seconds, after measuring range change approx. one second

Quick start

The factory setting for the multimeter terminal enables voltages up to 300 V_{DC} to be measured directly without additional settings. The Autorange function is active and selects the measuring range automatically.

The measured value is displayed with 1 bit per microvolt, i.e. no adjustment is required.

Functional description

Measuring ranges and output

The terminal starts measuring automatically. New measurement readings will be put out as soon as the calculation is complete. If the last used and the requested measuring range do not match, the bit "Data invalid" is set. In the event of an error (generally measuring range exceeded) the respective error bits are set. New measurement values are provided approx. every 0.5 seconds. The filter time is reset if the measuring range is changed via Autorange or by the user during the filter period. If the value fluctuates too much in Autorange mode, it may not be possible to determine a new measured value. As a remedy the filter can be deactivated.

The terminal has an extended measuring range, if a larger measuring range is available (Example: 30 V range, extended measuring range is 300 V). In Autorange mode the extended measuring range is used as a hysteresis range. In the extended measuring range overflow and underflow bits and the error bit are set at 115 % of the normal measuring range.

● **Please note**

i
- In AC mode only the RMS value of AC voltage is shown (no DC component).
- Error bits are under-range, over-range and data invalid. The error bit is set together with these bits. In some cases several bits may be set simultaneously in the event of an error (e.g.: Over-range and Data invalid).
- Since the terminal integrates the input value over an interval of 20 ms (16.66 ms in 60 Hz mode), superimposed interferences of the input values from the supply network can largely be compensated.

Measuring range selection

The measuring range is selected in process data mode via the control byte [▶ 51].

The Autorange function selects the best measuring range for the selected measurement type. In Autorange mode the 10 A measuring ranges are distinct types of measurement, i.e. it is not possible to switch from 1 A and 10 A or back (Causes: different input contacts as like fuse protection of the1 A range with 1.25 A).

The limits for changing the measuring ranges range are 10 % above the full scale value (extended measuring range, larger range) and 10 % of the full scale value (smaller range). If "Left aligned" view is selected, the limits are 100 % and 5 % of the full scale value.

Filter

The built-in filter averages the values for the last half second. If the measuring range is changed the filter is reset. The filter is active by default. If the filter is switched off the terminal supplies approx. 16 measured values per second.

Mains frequency

The integration times are adapted to the mains frequency (50, 60 Hz). The default is 50 Hz.

Presentation

The presentation of the values in the process data can be changed.

left aligned (0)
Left-justified presentation, full-scale value corresponds to 0x7FFFE000 (0x7FFFFFFF) or 0x80000000.

right aligned (1)
Right-aligned presentation: 18 bit resolution of the measuring range, end value corresponds to 0x0003FFFF (262143_{dec}) or 0xFFFC0000 (-262144_{dec}).
In the extended measuring range these limits are exceeded!

scaled (2)
Scaled presentation: this presentation corresponds to 1 bit per µV / µA. Examples:
- Mode 0, Autorange, 2.5 V: 2500000_{dec}
- Mode 2, 800 mA: 800000_{dec}

float (5)
Scaled presentation in floating-point format

Scaled presentation (2) is set as default.

Please note

- Only in scaled presentation the factors 0.1/1/10/100 are taken into account between the measuring ranges.

- In left aligned presentation the extended measuring range is not available.

Zero Compenzation Interval

The compensation function compensates the internal offset drift of the ADC. The interval length is selectable.

If setting 4 "Triggered by PDO" is used, the time for reading the internal offset can be selected manually via the "Start Calibration" process data bit.

50 Hz mode

In 50 Hz mode this function should not be used (0: off).

Calibration

The terminal features manufacturer and user calibration options, which can be switched on and off independently. The calibration always applies to all measuring ranges. Adaptation in 60 Hz mode and compensation of the AC system offset cannot be switched off.

2.5   Process data

Calculation of process data

The process data are calculated in up to seven steps between reading of the ADC and the process data output.

Designation	Calculation formula	not active
Offset correction	$Y_Z = X_{ADC} - (B_Z - B_{ZCal})$	$Y_Z = X_{ADC}$
Filter for averaging over 8 values	$Y_F = \frac{1}{8} \cdot \sum_{i=0}^{8} Y_{Zi}$	$Y_F = Y_Z$
60 Hz mode adaptation	$Y_{60} = (Y_F - B_F) \cdot \frac{7}{8} + (Y_F - B_F) \cdot A_F$	$Y_{60} = Y_F$
Calibration active	$Y_H = (Y_{60} - B_K) \cdot \frac{7}{8} + (Y_{60} - B_K) \cdot A_K$	$Y_H = Y_{60}$
	$Y_A = (Y_H - B_A) \cdot \frac{7}{8} + (Y_H - B_A) \cdot A_A$	$Y_A = Y_H$
AC system offset	$Y = (Y_A - X_{SO}) \cdot 2$ for $0 < Y_A < 2 \cdot X_{SO}$	$Y = Y_A$ (condition not met)
Scaling	$Y_{Scal} = Y \cdot \frac{F_{Scal}}{2^{18}} \cdot 10^{Range}$	-

The scaling includes the powers of ten selected in the range.
All gain factors should therefore correspond to 1/8 in order to obtain a total factor of 1. The value 8192 (0x2000) results in a total factor of 1.

Designation	Meaning	Register	Designation	Meaning	Register
X_{ADC}	Output value of the A/D converter	R0 [▶ 55]			
Y_Z	Measured value after ADC offset correction		B_Z	Current ADC Zero value	
			B_{ZCal}	ADC Zero at the time of calibration	
Y_F	Measured value after averaging				
Y_{60}	Measured value after adaptation of the 60 Hz integration time		B_F	60 Hz offset	
			A_F	60 Hz gain	
Y_H	Measured value after manufacturer calibration		B_K	Manufacturer offset	
			A_K	Manufacturer gain	
Y_A	Measured value after user calibration		B_A	User offset	
			A_A	User gain	
Y	Measured value after AC system offset		X_{SO}	AC system offset	
Y_{Scal}	Measured value after scaling		F_{Scal}	End value in 1 bit per 1µV / 1µA	

Determining (user) gain values

The terminal has one user compensation value pair for each measuring range and measurement type, i.e. 14 pairs in total. "+1" (0x4000) is not used in order to increase the resolution of the gain value.
Since the gain values may be less than 1, a factor of 1/8 is multiplied to the gain value. For a gain of 1 the gain value must be 0x2000.

For gain G = 1 the following applies:

$$A_A = \left(G - \frac{7}{8}\right) \cdot 2^{16}$$

$$A_A = 0x2000$$

For other values G must be replaced with the required gain factor.

Before the compensation the value display option should be set to "right-aligned": Register R32.12 to R32.15 [▶ 57] value assignment of 1_{dec}.

2.6 LED Display
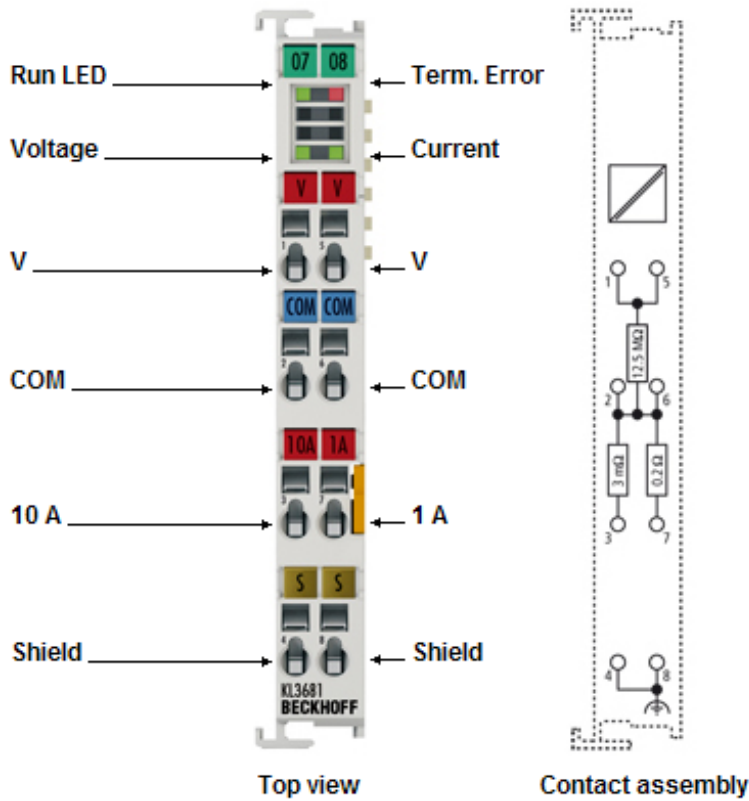
Fig. 4: KL3681-0000 - LED display

LED	Color	Meaning	
RUN	green	off	K-Bus data transfer not active
		on	K-Bus data transfer active
Term. Error	red	on	An error has occurred (see status byte [▶ 51])
Voltage	green	on	Indicates voltage measurement
Current	green	on	Indicates current measurement

3 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.

3.1 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.
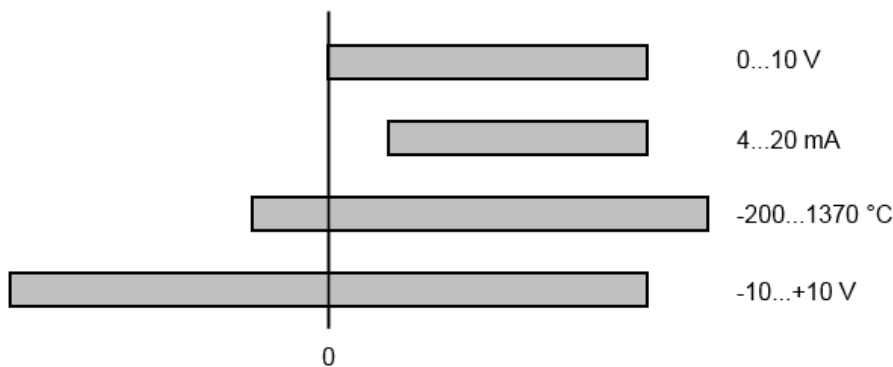

Fig. 5: Full scale value, measuring span

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).

3.2 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.

● **i** **Lower measuring error**

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.

This applies to analog output devices.

3.3 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

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

Remarks: ppm ≙ 10^{-6} % ≙ 10^{-2}

3.4 Long-term use

Analog devices (inputs, outputs) are subject to constant environmental influences during operation (temperature, temperature change, shock/vibration, irradiation, etc.) This can affect the function, in particular the analog accuracy (also: measurement or output uncertainty).

As industrial products, Beckhoff analog devices are designed for 24h/7d continuous operation.

The devices show that they generally comply with the accuracy specification, even in long-term use. However, as is usual for technical devices, an unlimited functional assurance (also applies to accuracy) cannot be given.

Beckhoff recommends checking the usability in relation to the application target within the scope of normal system maintenance, e.g. every 12-24 months.

3.5 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.
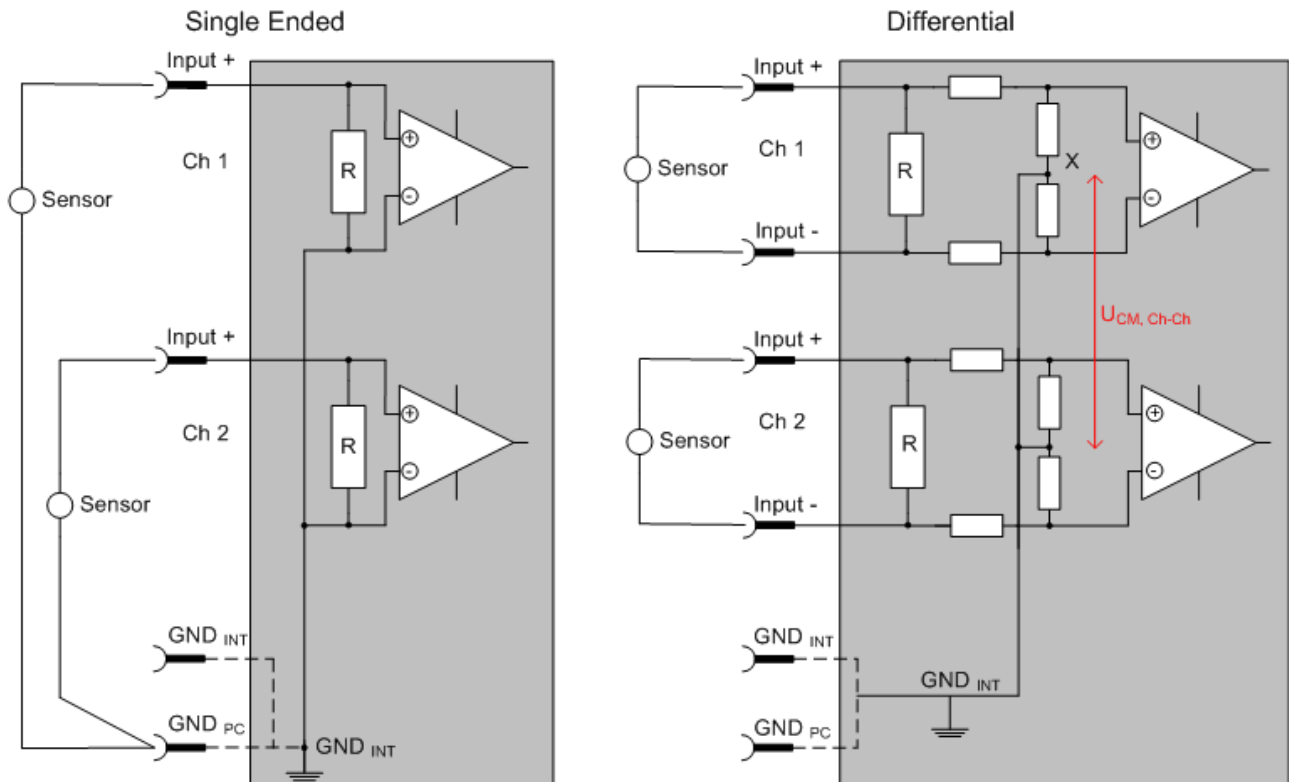

Fig. 6: SE and DIFF module as 2-channel version

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.
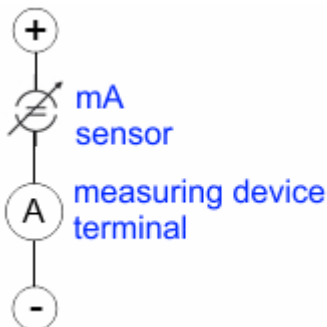

Fig. 7: 2-wire connection

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

• 3- and 4-wire connection see Fig. *Connection of externally supplied sensors*, cf. IEC60381-1

• the sensor draws the energy/operating voltage for its own operation from two supply cables of its own. One or two further sensor cables are used for the signal transmission of the current loop:

◦ 1 sensor cable: according to the Beckhoff terminology such sensors are to be connected to **'single-ended' inputs** in 3 cables with +/-/Signal lines and if necessary FE/shield

◦ 2 sensor cables: for sensors with 4-wire connection based on +supply/-supply/+signal/-signal, check whether +signal can be connected to +supply or –signal to –supply.

- Yes: then you can connect accordingly to a Beckhoff **'single-ended' input**.

- No: the Beckhoff **'differential' input** for +Signal and −Signal is to be selected; +Supply and −Supply are to be connected via additional cables.
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)!

Note: expert organizations such as NAMUR demand a usable measuring range <4 mA/>20 mA for error detection and adjustment, see also NAMUR NE043.
The Beckhoff device documentation must be consulted in order to see whether the respective device supports such an extended signal range.
Usually there is an internal diode existing within unipolar terminals/ boxes (and related product groups), in this case the polarity/direction of current have to be observed.
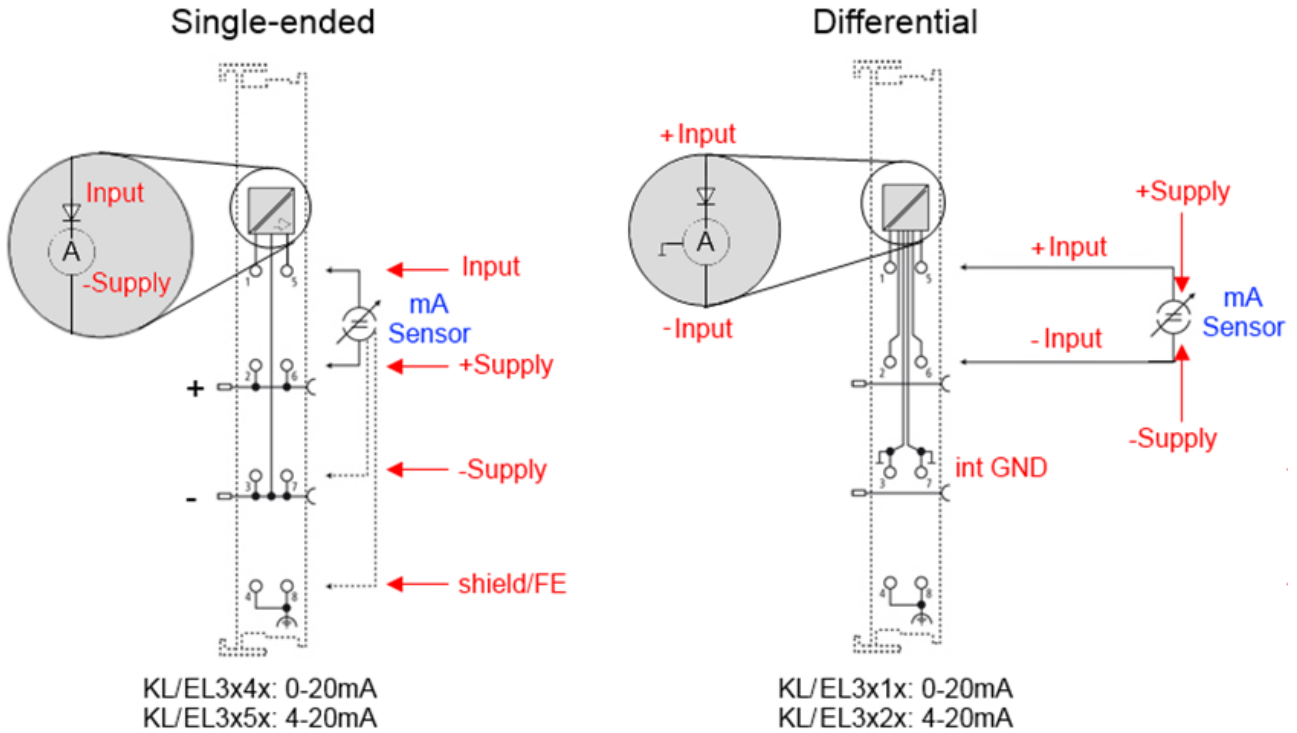

Fig. 8: Connection of externally supplied sensors

Classification of the Beckhoff terminals/ boxes - Beckhoff 0/4-20 mA terminals/ boxes (and related product groups) are available as **differential** and **single-ended** terminals/ boxes (and related product groups):

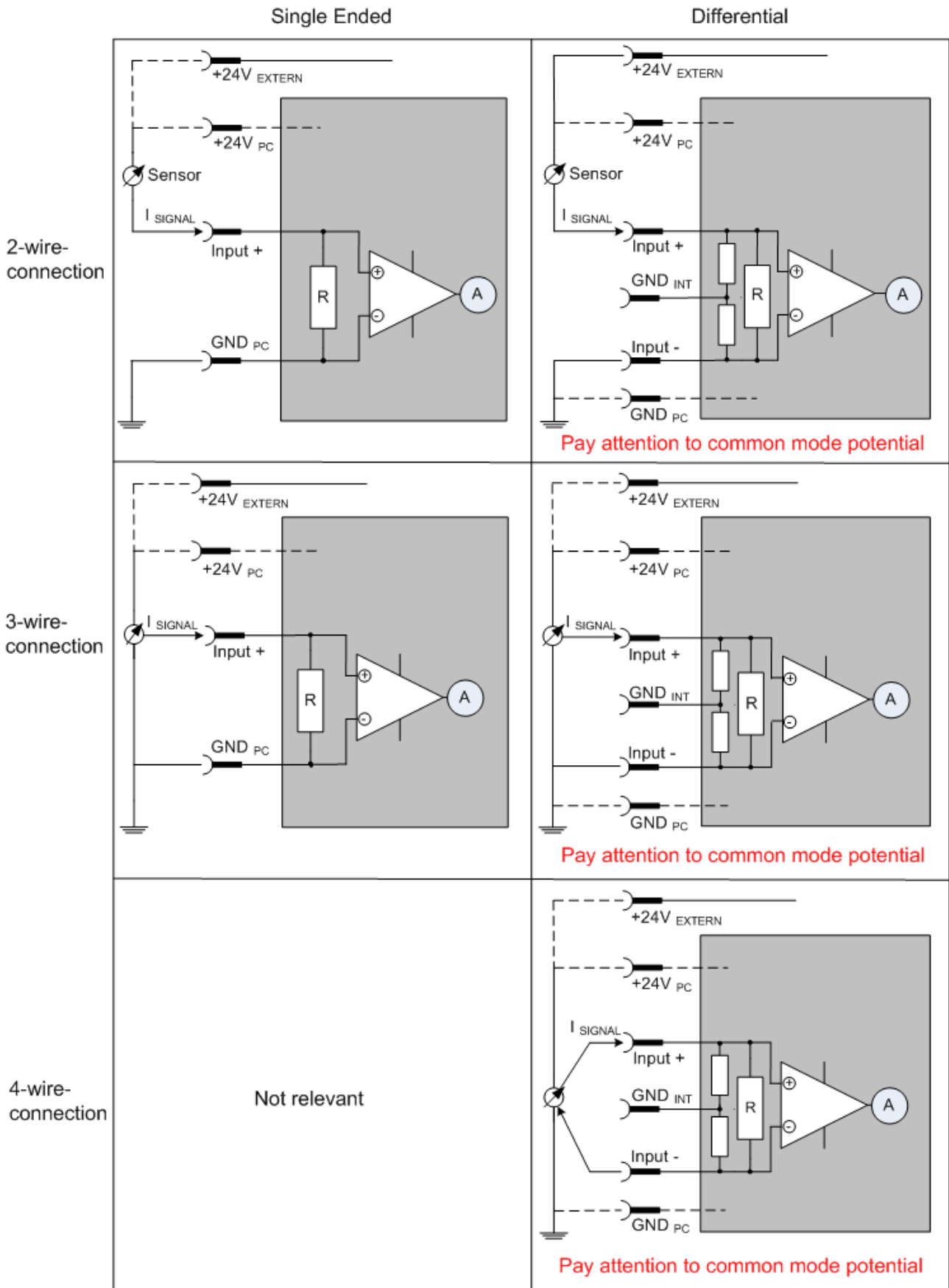| **Single-ended**	**Differential**
EL3x4x: 0-20 mA, EL3x5x: 4-20 mA; KL and related product groups exactly the same	EL3x1x: 0-20 mA, EL3x2x: 4-20 mA; KL and related product groups exactly the same
Preferred current direction because of internal diode	Preferred current direction because of internal diode
Designed for the connection of externally-supplied sensors with a 3/4-wire connection	The terminal/ box is a passive differential current measuring device; passive means that the sensor is not supplied with power.
Designed for the connection of self-supplied sensors with a 2-wire connection	

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Fig. 9: 2-, 3- and 4-wire connection at single-ended and differential inputs

3.6 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.
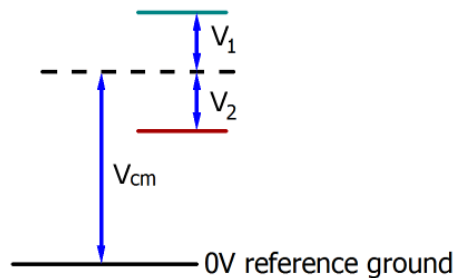

Fig. 10: Common-mode voltage (V_{cm})

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

3.7 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
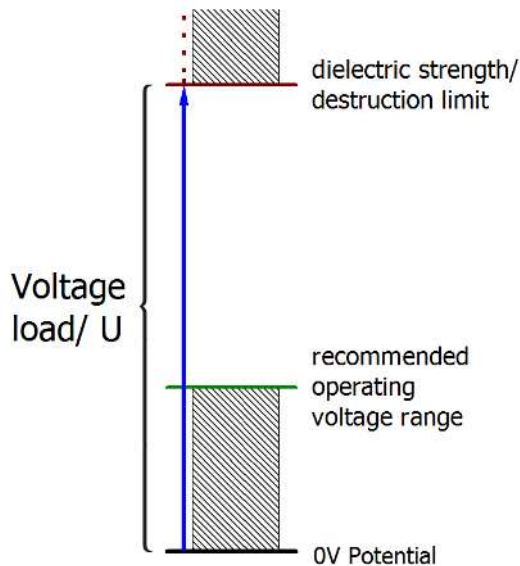   ◦ Differential

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Fig. 11: 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)

3.8 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.)
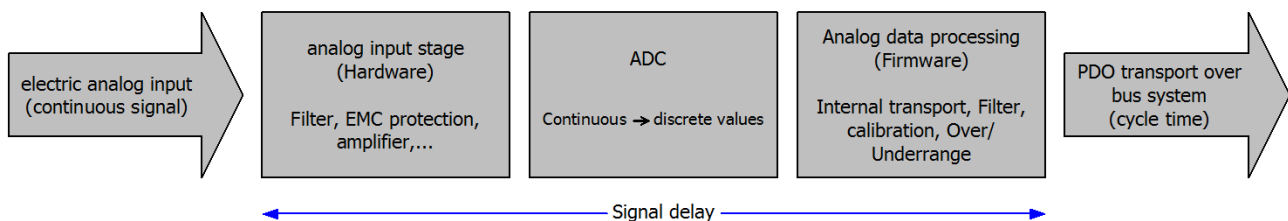

Fig. 12: Signal processing analog input

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]

This is 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.
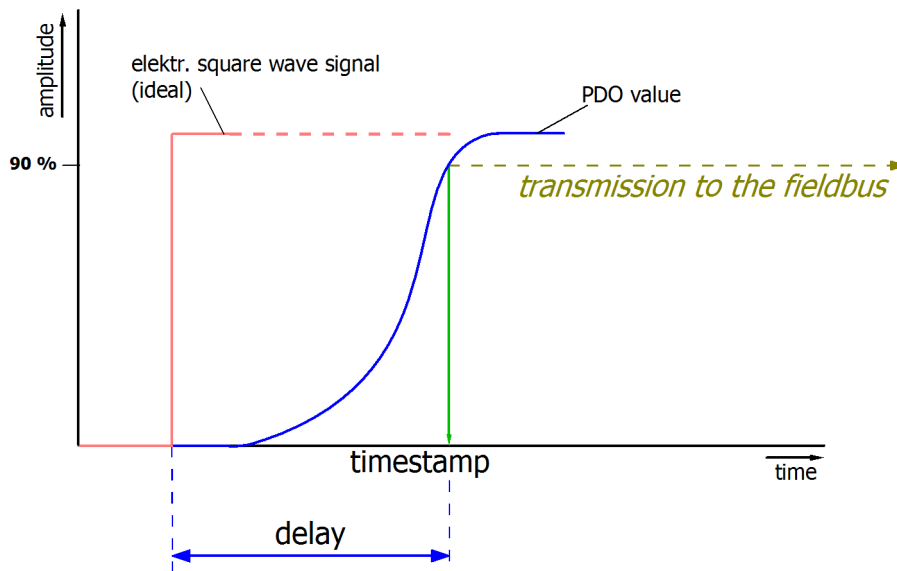
Fig. 13: Diagram signal delay (step response)

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. 14: Diagram signal delay (linear)

3. Additional Information

May be provided in the specification, e.g.

- Actual sampling rate of the ADC (if different from the channel sampling rate)
- Time correction values for run times with different filter settings
- etc.

3.9 Explanation of the term GND/Ground

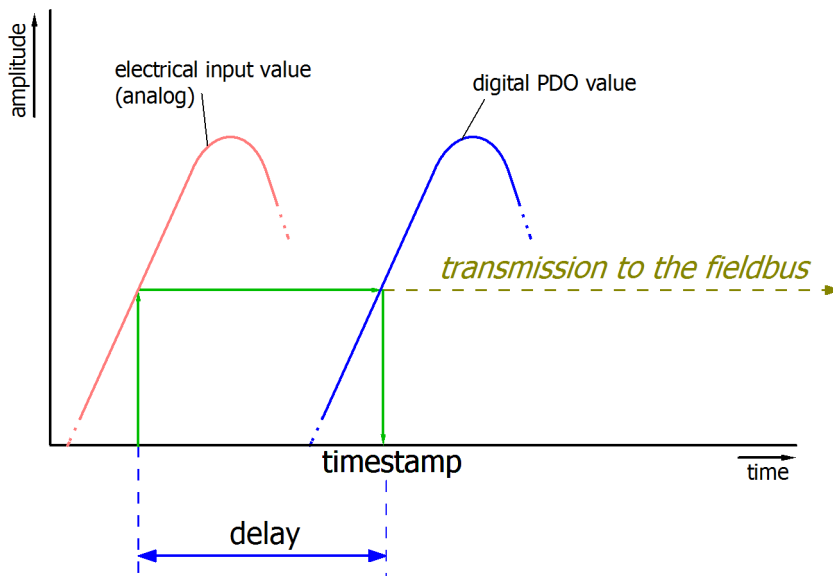I/O devices always have a reference potential somewhere. After all, the working voltage is only created by two points having different potentials – one of these points is then called the reference potential.

In the Beckhoff I/O area and in particular with the analog products, various reference potentials are used and named. These are defined, named and explained here.

Note: for historical reasons, different names are used with various Beckhoff I/O products. The following explanations place them on a uniform foundation.

SGND

- Also called: FE, Functional Earth, Shield GND, Shield.

- Use: Dissipation of interference and radiation, predominantly currentless.

- Symbol: .

- Notes and recommendations on SGND/FE can be found in the separate chapter Notes regarding analog equipment - shielding and earth.

- SGND usually ends at the structural earth star point.

- In order to be usable for its intended purpose, SGND itself should be a low noise/noise-free "clean" current and voltage sink.

PE

- Also called: Protective Earth.

- Use: Protective measure to prevent the occurrence of hazardous touch voltages by dissipating these touch voltages and then tripping upstream protective devices. If installed correctly, the PE conductor is currentless, but according to specification it must be capable of conducting for the protection case.

- Symbol: .

- PE usually ends at the structural earth star point.

- For specifications and notes on PE, please refer to the relevant rules.

PGND, AGND

- Use: Reference ground or return line of analog or digital signals.

- Depending on use, nominally currentless as reference potential or conducting as return line.

- In the analog area, the so-called standard signals can be 0...10 V and 4...20 mA, measuring bridge signals and thermocouples can be in the range of a few mV and resistance measurement in any Ohm range, and voltages can be from µV to a few thousand Volts.

- In the digital area they can be, for example, 0/24 V, -5/+5 V etc.

- Symbols:

  preferred: ;

  hardly used any more, but actually means earth potential: .

- There may be several PGND/AGND networks in a system that are electrically isolated from one another.

- If a device has several AGNDs, due to isolation by channel, these can be numbered: AGND1, AGND2, …

- PGND

  ◦ also called: GND_{PC}, 0 V, power contact 0 V, GND.

  ◦ Version: PGND is a structural description of the "negative" power contact rail of the Bus Terminal system.

- ◦ Can be connected to the device electronics, for example for supplying power to the device or as a signal feedback (see chapter Single-ended/differential typification [▶ 22]). Refer to the respective device documentation.
- ◦ Example: PGND is not connected to the device electronics:
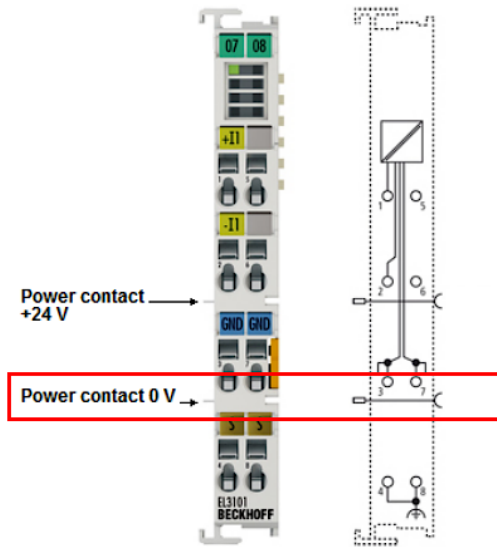
- • AGND
    - ◦ Also called: GND_{int}, GND, analog ground, GND_{analog}.
    - ◦ AGND electrically designates the device's analog reference ground.
    - ◦ AGND can, for example, be internally connected to PGND or to a connection point so that it can be connected externally to a desired potential. Electrical restrictions according to the device documentation must be observed, e.g. common mode limits.
    - ◦ AGND is usually a currentless reference potential. The action of interference on AGND must be avoided.
    - ◦ Example: AGND is fed out on the device plug:
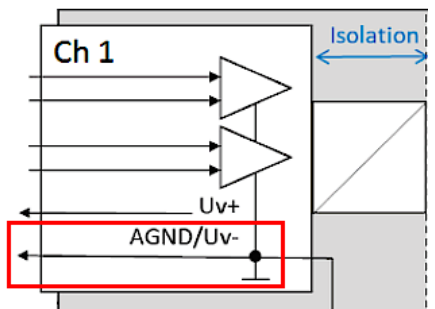
4   Mounting and wiring

4.1   Instructions for ESD protection

NOTE

Destruction of the devices by electrostatic discharge possible!

The devices contain components at risk from electrostatic discharge caused by improper handling.

- Please ensure you are electrostatically discharged and avoid touching the contacts of the device directly.
- Avoid contact with highly insulating materials (synthetic fibers, plastic film etc.).
- Surroundings (working place, packaging and personnel) should by grounded probably, when handling with the devices.
- Each assembly must be terminated at the right hand end with a KL9010 bus end terminal, to ensure the protection class and ESD protection.
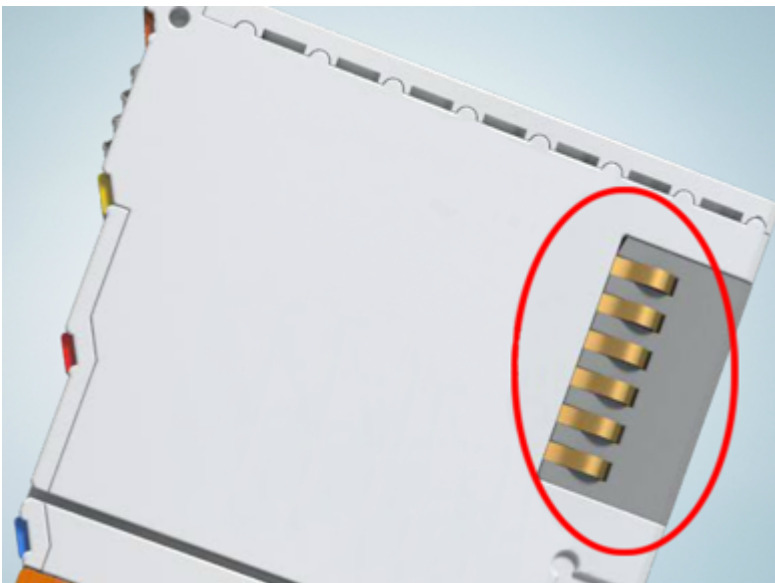
Fig. 15: Spring contacts of the Beckhoff I/O components

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4.2 Installation on mounting rails

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

Assembly
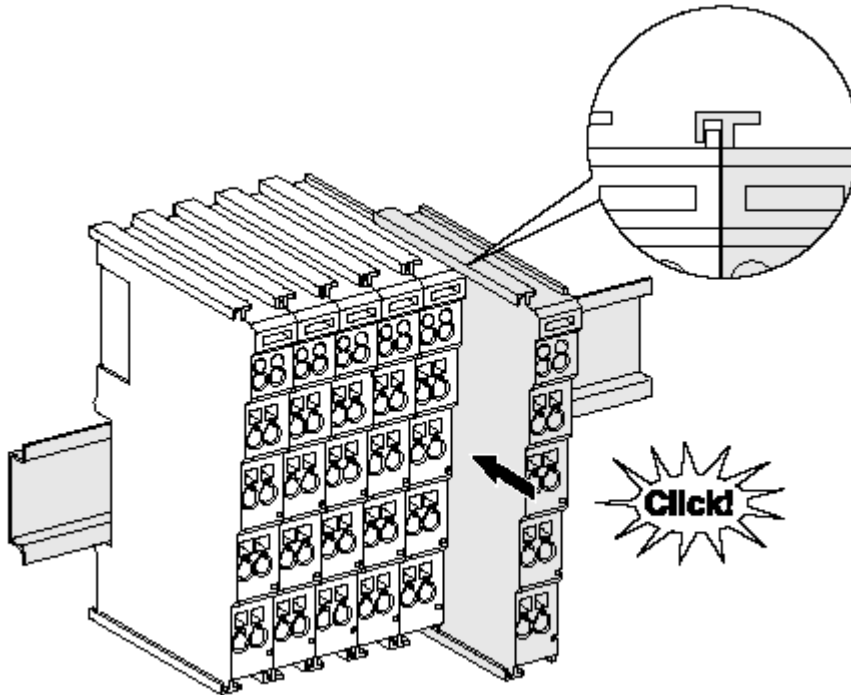
Fig. 16: Attaching on mounting rail

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.

> ℹ **Fixing of mounting rails**
>
> 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
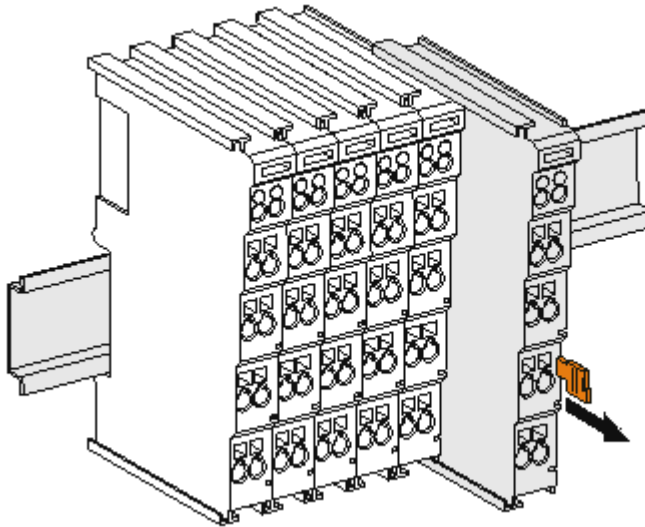
Fig. 17: Disassembling of terminal

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 K-Bus/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 are supplied via terminals on the Bus Coupler (up to 24 V) or for higher voltages via power feed terminals.

● **Power Contacts**

i 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. Power Feed Terminals (KL91xx, KL92xx or EL91xx, EL92xx) interrupt the power contacts and thus represent the start of a new supply rail.

PE power contact

The power contact labeled PE can be used as a protective earth. For safety reasons this contact mates first when plugging together, and can ground short-circuit currents of up to 125 A.

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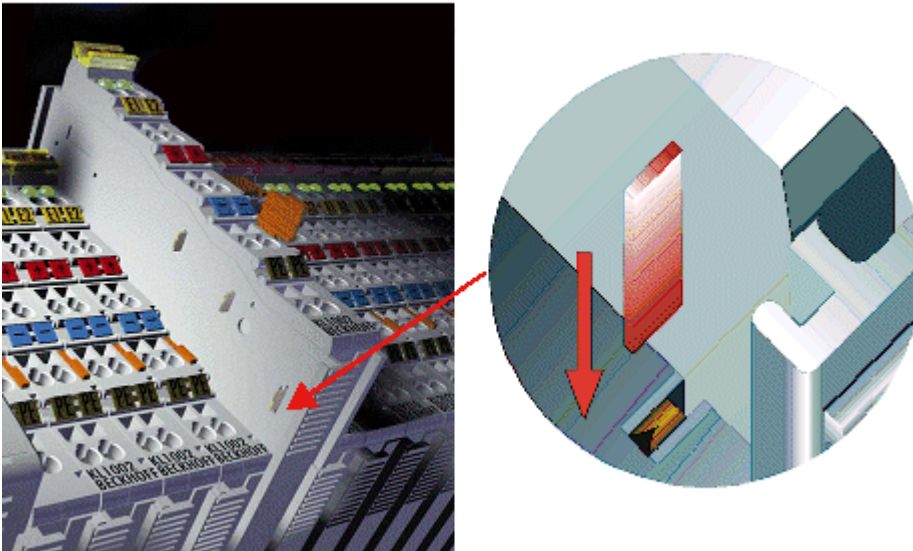
Fig. 18: Power contact on left side

NOTE
Possible damage of the device
Note that, for reasons of electromagnetic compatibility, the PE contacts are capacitatively coupled to the mounting rail. This may lead to incorrect results during insulation testing or to damage on the terminal (e.g. disruptive discharge to the PE line during insulation testing of a consumer with a nominal voltage of 230 V). For insulation testing, disconnect the PE supply line at the Bus Coupler or the Power Feed Terminal! In order to decouple further feed points for testing, these Power Feed Terminals can be released and pulled at least 10 mm from the group of terminals.

⚠ **WARNING**
Risk of electric shock!
The PE power contact must not be used for other potentials!

4.3 Connection

4.3.1 Connection system

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

Overview

The bus terminal system offers different connection options for optimum adaptation to the respective application:

- The terminals of ELxxxx and KLxxxx series with standard wiring include electronics and connection level in a single enclosure.
- The terminals of ESxxxx and KSxxxx series feature a pluggable connection level and enable steady wiring while replacing.
- The High Density Terminals (HD Terminals) include electronics and connection level in a single enclosure and have advanced packaging density.

Standard wiring (ELxxxx / KLxxxx)

Fig. 19: Standard wiring

The terminals of ELxxxx and KLxxxx series have been tried and tested for years.
They feature integrated screwless spring force technology for fast and simple assembly.

Pluggable wiring (ESxxxx / KSxxxx)

Fig. 20: Pluggable wiring

The terminals of ESxxxx and KSxxxx series feature a pluggable connection level.
The assembly and wiring procedure is the same as for the ELxxxx and KLxxxx series.
The pluggable connection level enables the complete wiring to be removed as a plug connector from the top of the housing for servicing.
The lower section can be removed from the terminal block by pulling the unlocking tab.
Insert the new component and plug in the connector with the wiring. This reduces the installation time and eliminates the risk of wires being mixed up.

The familiar dimensions of the terminal only had to be changed slightly. The new connector adds about 3 mm. The maximum height of the terminal remains unchanged.

A tab for strain relief of the cable simplifies assembly in many applications and prevents tangling of individual connection wires when the connector is removed.

Conductor cross sections between 0.08 mm^2 and 2.5 mm^2 can continue to be used with the proven spring force technology.

The overview and nomenclature of the product names for ESxxxx and KSxxxx series has been retained as known from ELxxxx and KLxxxx series.

High Density Terminals (HD Terminals)

Fig. 21: High Density Terminals

The terminals from these series with 16 terminal points are distinguished by a particularly compact design, as the packaging density is twice as large as that of the standard 12 mm bus terminals. Massive conductors and conductors with a wire end sleeve can be inserted directly into the spring loaded terminal point without tools.

> **ℹ Wiring HD Terminals**
>
> The High Density Terminals of the ELx8xx and KLx8xx series doesn't support pluggable wiring.

Ultrasonically "bonded" (ultrasonically welded) conductors

> **ℹ Ultrasonically "bonded" conductors**
>
> It is also possible to connect the Standard and High Density Terminals with ultrasonically "bonded" (ultrasonically welded) conductors. In this case, please note the tables concerning the wire-size width [▶ 39]!

4.3.2 Wiring

⚠ WARNING
Risk of electric shock and damage of device! 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 ELxxxx/KLxxxx and for pluggable wiring ESxxxx/KSxxxx
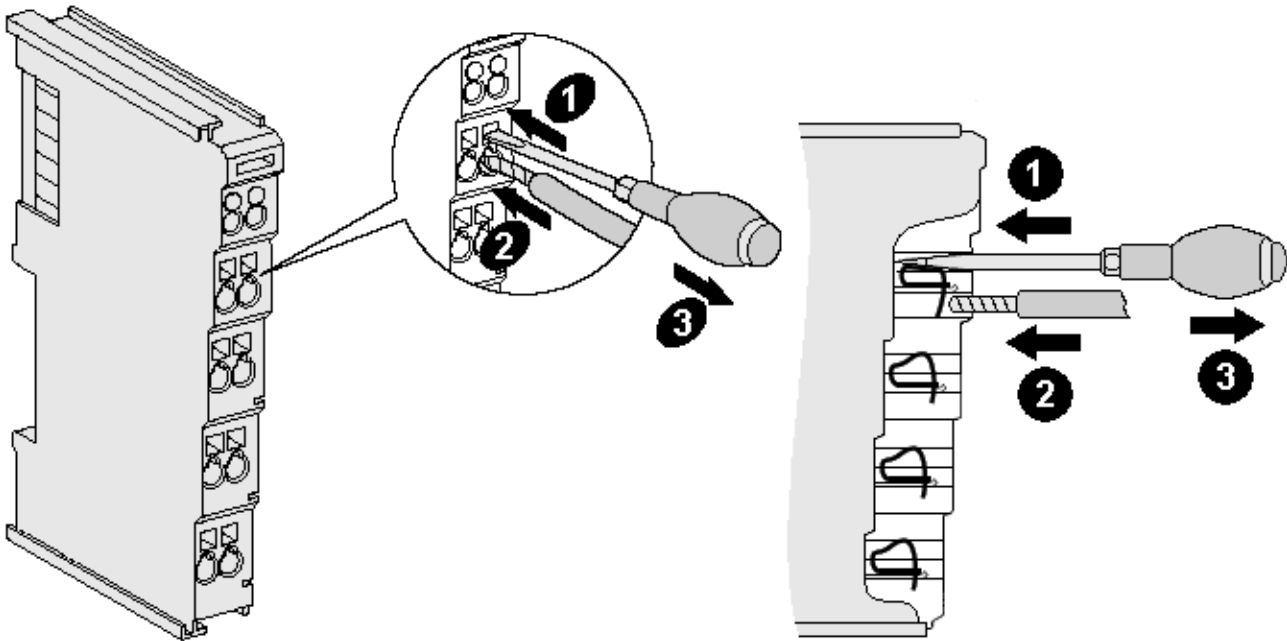
Fig. 22: Connecting a cable on a terminal point

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.

See the following table for the suitable wire size width.

Terminal housing	ELxxxx, KLxxxx	ESxxxx, KSxxxx
Wire size width (single core wires)	0.08 ... 2.5 mm^2	0.08 ... 2.5 mm^2
Wire size width (fine-wire conductors)	0.08 ... 2.5 mm^2	0.08 ... 2.5 mm^2
Wire size width (conductors with a wire end sleeve)	0.14 ... 1.5 mm^2	0.14 ... 1.5 mm^2
Wire stripping length	8 ... 9 mm	9 ... 10 mm

High Density Terminals (HD Terminals [▶ 38]) with 16 terminal points

The conductors of the HD Terminals are connected without tools for single-wire conductors using the direct plug-in technique, i.e. after stripping the wire is simply plugged into the terminal point. The cables are released, as usual, using the contact release with the aid of a screwdriver. See the following table for the suitable wire size width.

Terminal housing	High Density Housing
Wire size width (single core wires)	0.08 ... 1.5 mm^2
Wire size width (fine-wire conductors)	0.25 ... 1.5 mm^2
Wire size width (conductors with a wire end sleeve)	0.14 ... 0.75 mm^2
Wire size width (ultrasonically "bonded" conductors)	only 1.5 mm^2 (see notice [▶ 38])
Wire stripping length	8 ... 9 mm

4.3.3   Shielding

Shielding

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

4.3.4   Disposal

Products marked with a crossed-out wheeled bin shall not be discarded with the normal waste stream. The device is considered as waste electrical and electronic equipment. The national regulations for the disposal of waste electrical and electronic equipment must be observed.

4.4 Contact assignment

⚠ **WARNING**
Risk of electric shock and damage of device!
Bring the bus terminal system into a safe, powered down state before starting installation, disassembly or wiring of the Bus Terminals!
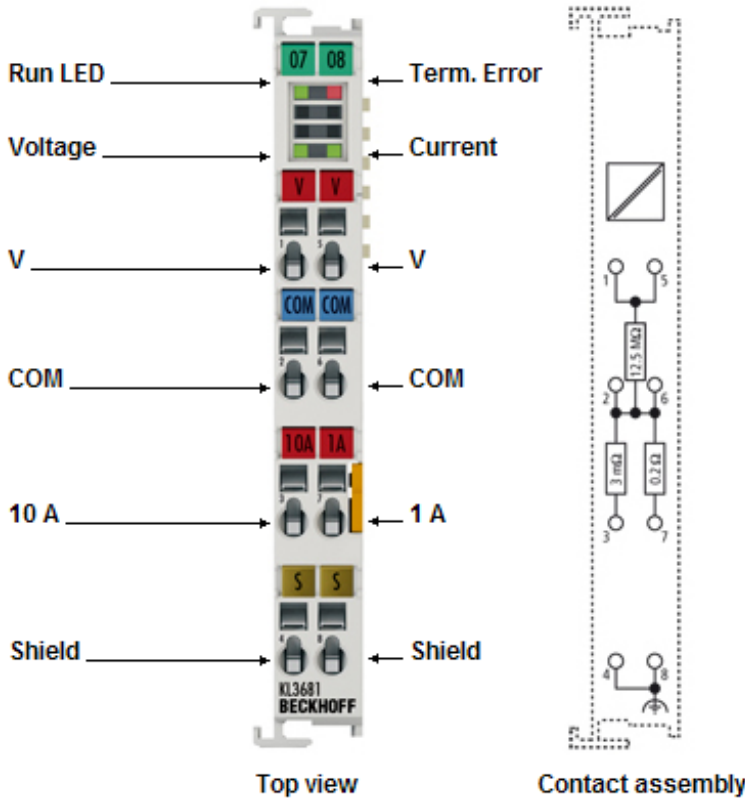
Fig. 23: KL3681 - Contact assignment

Terminal point	No.	Comment
V	1	Terminal point for voltage measurement (internally connected with terminal point 5)
COM	2	Ground (internally connected with terminal point 6)
10 A	3	Terminal point for current measurement, 10 A range
Shield	4	Shield (internally connected with terminal point 8)
V	5	Terminal point for voltage measurement (internally connected with terminal point 1)
COM	6	Ground (internally connected with terminal point 2)
1 A	7	Terminal point for current measurement, 1 A range
Shield	8	Shield (internally connected with terminal point 4)

⚠ **WARNING**
Danger for persons through electric shock!
For voltages greater than 25 V_{AC} (42 V peak) or 60 V_{DC} the fuse opening must be covered by an additional terminal or the EL9011 end terminal. Risk of electric shock!

NOTE
10 A branch is not fuse-protected
The current branch for 10 A is not fuse-protected. The device may be damaged if the current in the 10 A branch exceeds 10 A.

5   KS2000 Configuration software

5.1   KS2000 - Introduction

The KS2000 configuration software permits configuration, commissioning and parameterization of bus couplers, of the affiliated bus terminals and of Fieldbus Box Modules. The connection between bus coupler / Fieldbus Box Module and the PC is established by means of the serial configuration cable or the fieldbus.

Fig. 24: KS2000 configuration software

Configuration

You can configure the Fieldbus stations with the Configuration Software KS2000 offline. That means, setting up a terminal station with all settings on the couplers and terminals resp. the Fieldbus Box Modules can be prepared before the commissioning phase. Later on, this configuration can be transferred to the terminal station in the commissioning phase by means of a download. For documentation purposes, you are provided with the breakdown of the terminal station, a parts list of modules used and a list of the parameters you have modified. After an upload, existing fieldbus stations are at your disposal for further editing.

Parameterization

KS2000 offers simple access to the parameters of a fieldbus station: specific high-level dialogs are available for all bus couplers, all intelligent bus terminals and Fieldbus Box modules with the aid of which settings can be modified easily. Alternatively, you have full access to all internal registers of the bus couplers and intelligent terminals. Refer to the register description for the meanings of the registers.

Commissioning

The KS2000 software facilitates commissioning of machine components or their fieldbus stations: Configured settings can be transferred to the fieldbus modules by means of a download. After a *login* to the terminal station, it is possible to define settings in couplers, terminals and Fieldbus Box modules directly *online*. The same high-level dialogs and register access are available for this purpose as in the configuration phase.

The KS2000 offers access to the process images of the bus couplers and Fieldbus Box modules.

- Thus, the coupler's input and output images can be observed by monitoring.
- Process values can be specified in the output image for commissioning of the output modules.

All possibilities in the *online mode* can be used in parallel with the actual fieldbus mode of the terminal station. The fieldbus protocol always has the higher priority in this case.

5.2 Parameterization with KS2000

Connect the configuration interface of your Fieldbus Coupler with the serial interface of your PC via the configuration cable and start the *KS2000* configuration software.

Click on the *Login* button. The configuration software will now load the information for the connected fieldbus station. In the example shown, this is

- a BK9000: Bus Coupler for Ethernet
- a KL1xx2: Digital Input Terminal
- a KL3681: Multimeter Terminal
- a KL9010: Bus End Terminal
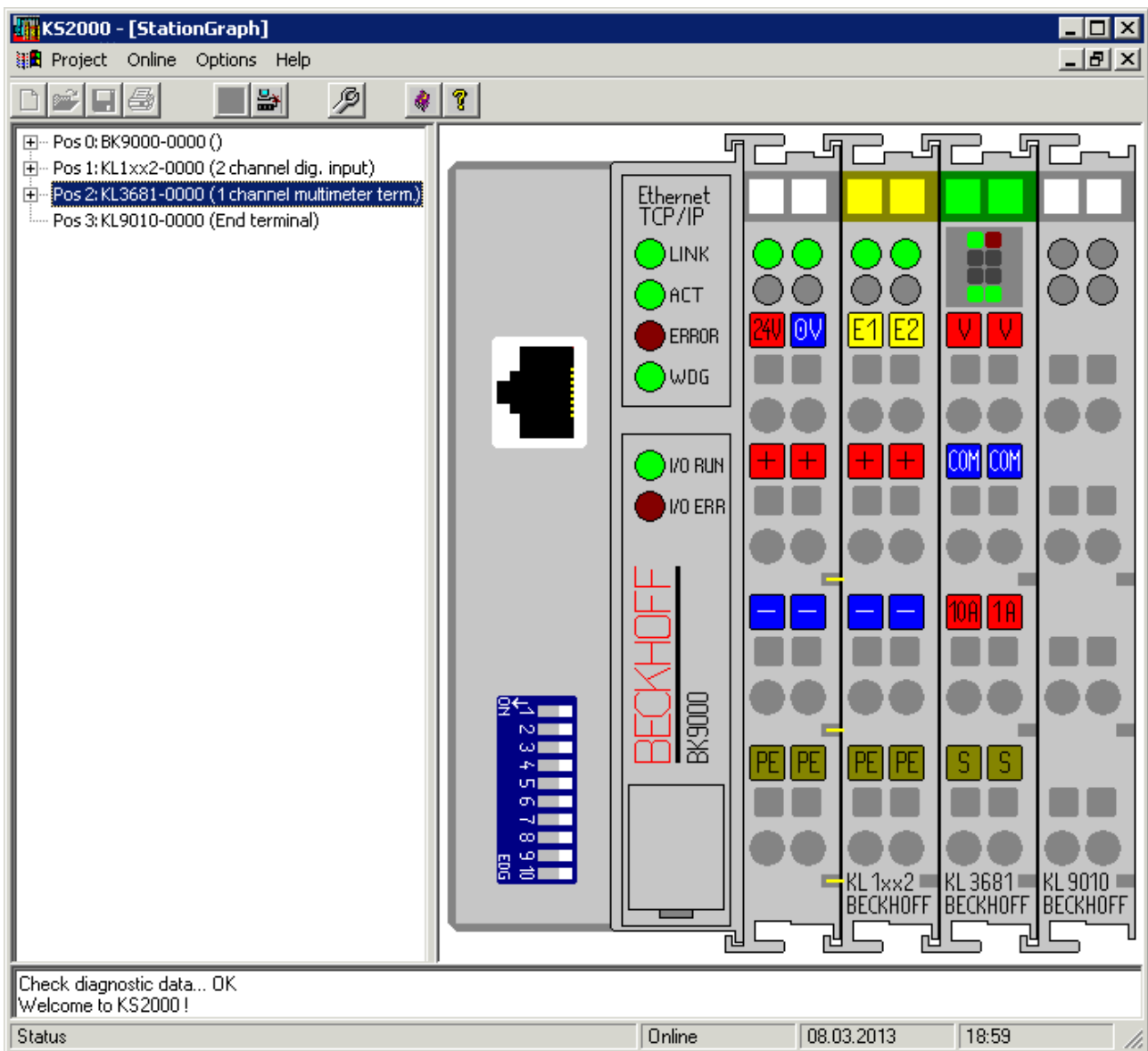
Fig. 25: View of fieldbus station within KS2000

The left-hand KS2000 window displays the terminals of the fieldbus station in a tree structure.
The right-hand KS2000 window contains a graphic display of the fieldbus station terminals.

In the tree structure of the left-hand window, click on the plus-sign next to the terminal whose parameters you wish to change (item 2 in the example).
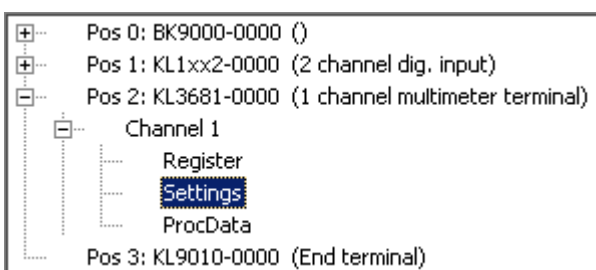
Fig. 26: KS2000 branch for channel 1 of KL3681

For the KL3404, the branches *Register*, *Settings* and *ProcData* are displayed:

- Register [▶ 45] enables direct access to the KL3681 registers.

- A dialog mask for the parameterization of the KL3681 can be found under Settings [▶ 46].

- ProcData displays the KL3681 process data.

5.3 Register

You can access the registers of the KL3681 directly under *Register*. The meaning of the register is explained in the register overview [▶ 53].
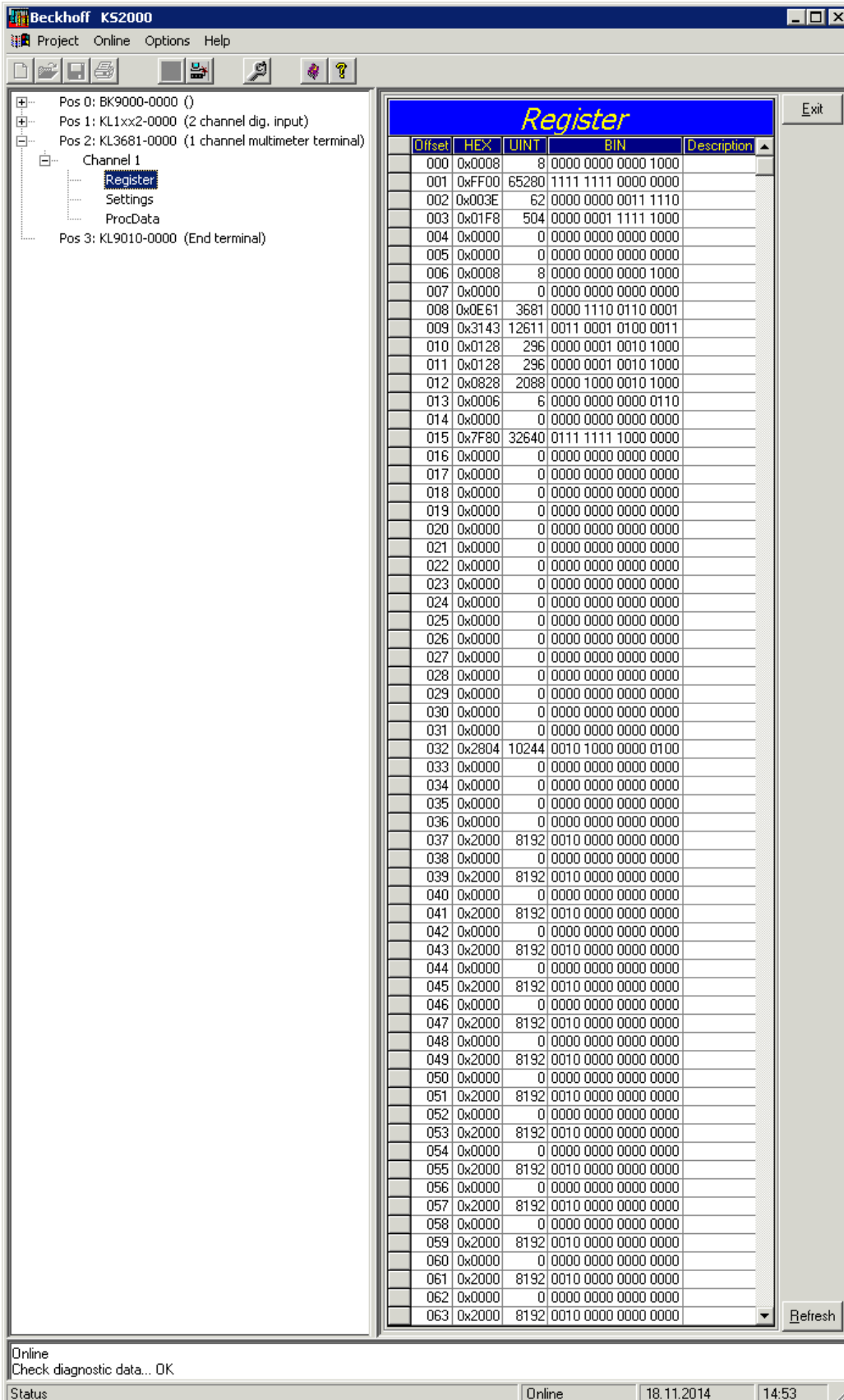
Fig. 27: Register view within KS2000

5.4 Settings

The dialog mask for the parameterization of the KL3681 can be found under *Settings*.

Fig. 28: Settings via KS2000

Operating mode

- **Watchdog timer active (register page 0, register** R32.2 [▶ 57]**)**
  Here you can deactivate the watchdog timer (default: active).

- **Frequency 60 Hz (register page 0, register** R32.7 [▶ 57]**)**
  Here you can switch the terminal to a mains frequency of 60 Hz (default: 50 Hz).

- **User calibration active (register page 0, register** R32.8 [▶ 57]**)**
  Here you can activate user calibration (default: inactive)

- **Filter enable (register page 0, register** R32.11 [▶ 57]**)**
  Here you can disable the watchdog (default: enable).

Presentation

Here you can select the presentation format for the process data (default: scaled).

- **Options (register page 0, registers** R32.15 to R32.12 [▶ 57]**)**
  - Left aligned*
  - Right aligned
  - Scaled
  - Real

    *) In left aligned presentation the extended measuring range is not available.

Zero Compensation Interval

Here you can specify the interval for zero compensation (default: deactivated).

- **Options (register page 0, register** R33 [▶ 57]**)**

○ deactivated

○ 10 seconds

○ 1 minute

○ 10 minutes

○ automatic correction

5.5 Sample program for KL register communication via EtherCAT on KL3314 exemplary

Using the sample programs

This document contains sample applications of our products for certain areas of application. The application notes provided here are based on typical features of our products and only serve as examples. The notes contained in this document explicitly do not refer to specific applications. The customer is therefore responsible for assessing and deciding whether the product is suitable for a particular application. We accept no responsibility for the completeness and correctness of the source code contained in this document. We reserve the right to modify the content of this document at any time and accept no responsibility for errors and missing information.

Program description / function

This example program (TwinCAT 3) provides change of single register values of the KL3314 as selection of the element type, characteristical settings of the feature register R32 and user scaling offset and gain (R33/R34) similar as per KS2000.
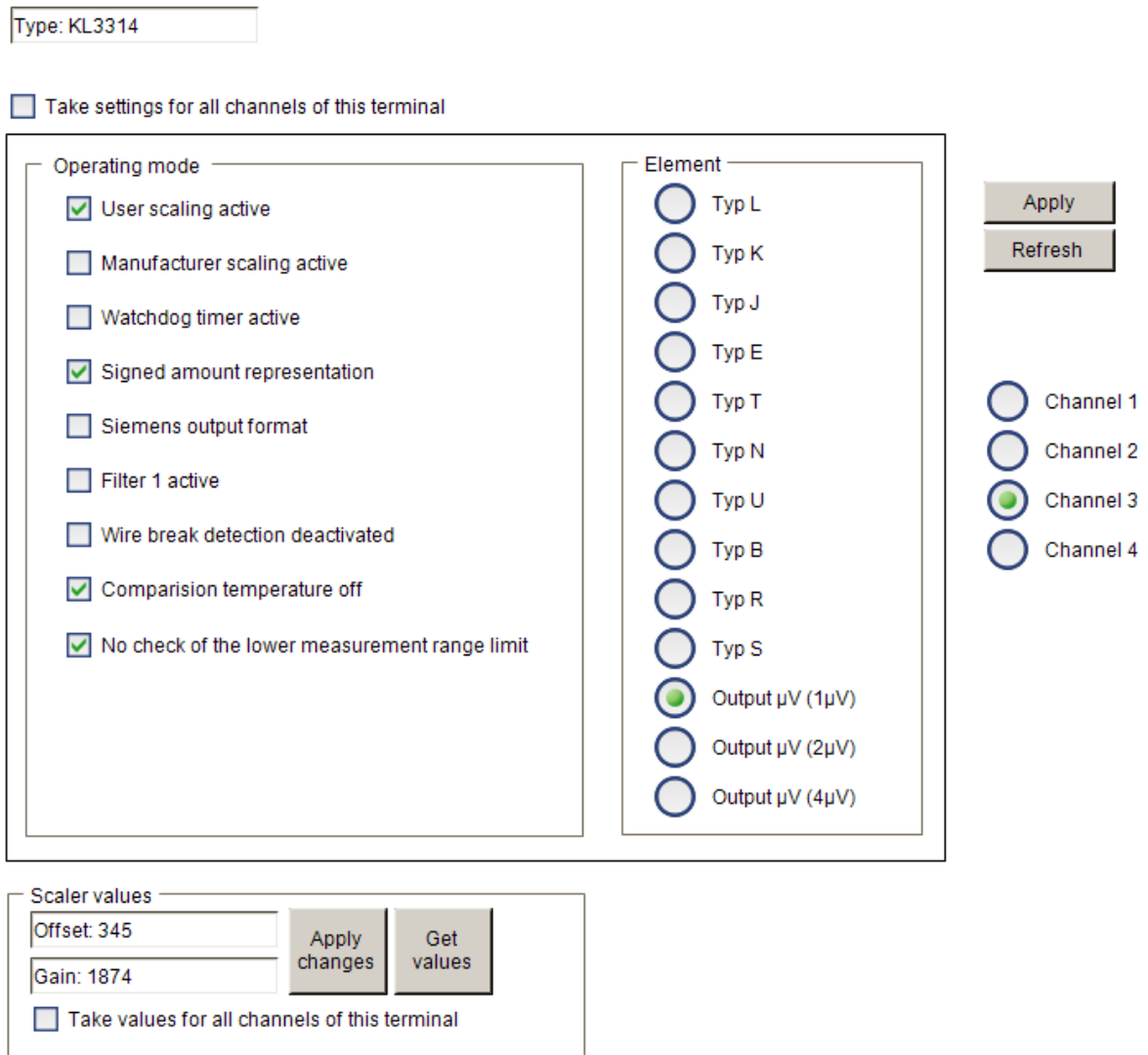
Fig. 29: Settings of KL3314 via visualisation of TwinCAT 3

At least following configuration setup shall be present:

[coupler (e.g. BK1120) or embedded PC] + KL3314 + KL9010.

Download:
https://infosys.beckhoff.com/content/1033/KL3681/Resources/zip/5996114571.zip

Preparations for starting the sample programs (tnzip file / TwinCAT 3)

- Click on the download button to save the Zip archive locally on your hard disk, then unzip the *.tnzip archive file in a temporary folder.
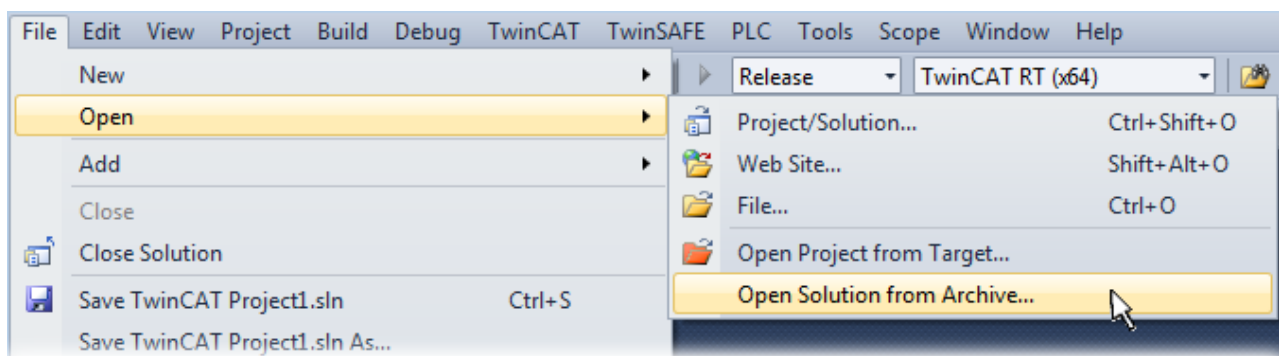
Fig. 30: Opening the *. tnzip archive

- Select the .tnzip file (sample program).
- A further selection window opens. Select the destination directory for storing the project.
- For a description of the general PLC commissioning procedure and starting the program please refer to the terminal documentation or the EtherCAT system documentation.
- The EtherCAT device of the example should usually be declared your present system. After selection of the EtherCAT device in the "Solutionexplorer" select the "Adapter" tab and click on "Search...":
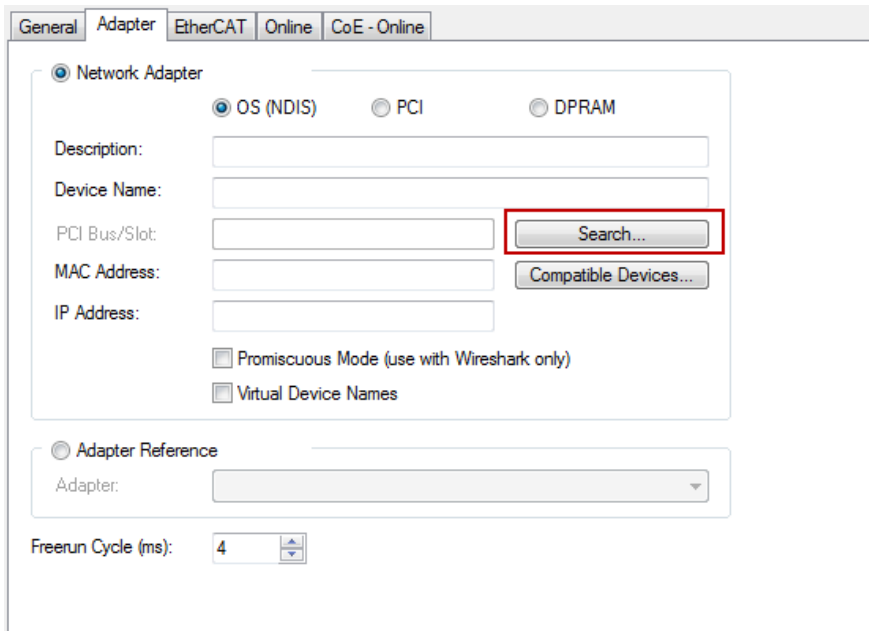
Fig. 31: Search of the existing HW configuration for the EtherCAT configuration of the example

- Checking NetId: the "EtherCAT" tab of the EtherCAT device shows the configured NetId:
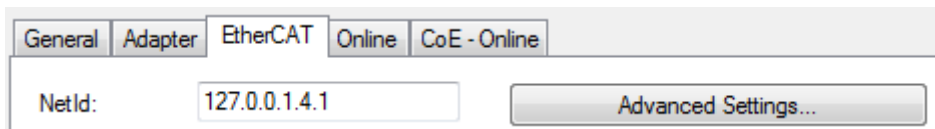
The first 4 numbers have to be identical with the project NetId of the target system. The project NetId can be viewed within the TwinCAT environment above, where a pull down menu can be opened to choose a target system (by clicking right in the text field). The number blocks are placed in brackets there next to each computer name of a target system.

- Modify the NetId: By right clicking on "EtherCAT device" within the solution explorer a context menu opens where "Change NetId..." have to be selected. The first four numbers of the NetId of the target computer have to be entered; the both last values are 4.1 usually.
  Example:
  - NetId of project: myComputer (123.45.67.89.1.1)
  - Entry via „Change NetId...":   123.45.67.89.4.1

6 Access from the user programm

6.1 Process image

Complex mapping

The following 5 bytes are transferred bi-directionally between KL3681 and control:

Byte offset (without word alignment*)	Byte offset (with word alignment*)	Format	Input data	Output data
0	0	Byte	Status byte (SB [▶ 51])	Control byte (CB [▶ 51])
1	2	Word	DataIN0	DataOUT0
3	4	Word	DataIN1	DataOUT1

*) Word alignment: The Bus Coupler places values on even byte addresses

Compact mapping (from firmware version 1C)

The following 4 bytes are transferred bi-directionally between KL3681 and control:

Byte offset (with and without word alignment*)	Format	Input data	Output data
0	Word	DataIN0	DataOUT0
2	Word	DataIN1	DataOUT1

*) word alignment has no effect with compact mapping

6.2 Control and status byte

Process data mode

Control byte (in process data mode)

The control byte (CB) is located in the <u>output image [▶ 50]</u> and is transmitted from the controller to the terminal.

Bit	CB.7	CB.6	CB.5	CB.4	CB.3	CB.2	CB.1	CB.0
Name	RegAccess	StartCalibration	StartCalibration	disAutorange	Voltage/ Current	DC/ AC	Range	

Bit	Name	Description	
CB.7	RegAccess	0_{bin}	Register communication off (process data mode)
CB.6	R/W	0_{bin}	Read access
		1_{bin}	Write access
CB.5	StartCalibration	1_{bin}	initiates an automatic correction of the internal measuring range (only if register R33 = 4)
CB.4	disAutorange	0_{bin}	auto range enabled
		1_{bin}	auto range disabled
CB.3	Voltage/ Current	0_{bin}	Voltage
		1_{bin}	Current
CB.2	DC/AC	0_{bin}	DC
		1_{bin}	AC
CB.1, CB.0	Range	Measuring range (see also CB.2)	
		00_{bin}	3 V or 1 A
		01_{bin}	30 V or 10 A
		10_{bin}	300 V
		11_{bin}	300 mV or 100 mA

Status byte (in process data mode)

The status byte (SB) is located in the <u>input image [▶ 50]</u> and is transmitted from terminal to the controller.

Bit	SB.7	SB.6	SB.5	SB.4	SB.3	SB.2	SB.1	SB.0
Name	RegAccess	Error	-	noAutorange	data Invalid	extended range	overrange	underrange

Bit	Name	Description	
SB.7	RegAccess	0_{bin}	Acknowledge for process data mode
SB.6	Error	1_{bin}	measuring range exceeded, over or under range, the error LED shines or converting error or invalid measuring range
SB.5	reserved	0_{bin}	reserved
SB.4	-	0_{bin}	auto range is enabled
		1_{bin}	auto range is disabled
SB.3	data invalid	1_{bin}	invalidprocess data, e.g. invalid value, e.g. filter latency, start up
SB.2	extended range*	1_{bin}	The extended measuring range (~10% of upper range value) is used (hysteresis area of auto range functionality).
SB.1	overrange	1_{bin}	Exceeding of the electrical measuring range
SB.0	underrange	1_{bin}	Undershooting of the electrical measuring range at DC mode (not displayed in AC mode

*) The extended range is only available for the measuring ranges 300 mV, 3 V, 30 V and 100 mA.

BECKHOFF

Register communication

Control byte (at register communication)

The control byte (CB) is located in the output image [▶ 50] and is transmitted from the controller to the terminal.

Bit	CB.7	CB.6	CB.5	CB.4	CB.3	CB.2	CB.1	CB.0
Name	RegAccess	R/W	Register no.					

Bit	Name	Description	
CB.7	RegAccess	1_{bin}	Register communication switched on
CB.6	R/W	0_{bin}	Read access
		1_{bin}	Write access
CB.5 to CB.0	Register no.	Register number: Enter here the number of the register [▶ 53] that you wish - to read with input data word DataIN [▶ 50], or - to write with output data word DataOUT [▶ 50].	

Status byte (at register communication)

The status byte (SB) is located in the input image [▶ 50] and is transmitted from terminal to the controller.

Bit	SB.7	SB.6	SB.5	SB.4	SB.3	SB.2	SB.1	SB.0
Name	RegAccess	R/W	Register no.					

Bit	Name	Description	
SB.7	RegAccess	1_{bin}	Acknowledge for register access
SB.6	R	0_{bin}	Read access
SB.5 to SB.0	Register no.	Number of the register that was read or written.	

6.3   Register overview

All registers can be read or written via <u>register communication</u> [▶ 59].

Registers R0 to R31 (direct access)

These registers are used to parameterize the terminal KL3681.

Register no.	Comment	Default value		R/W	Memory
<u>R0 [</u>▶ <u>55]</u>	Raw value of the A/D converter	0x0000	0_{dec}	R	RAM
<u>R1 [</u>▶ <u>55]</u>	Current measuring range / mode	0x0000	0_{dec}	R	RAM
<u>R2 [</u>▶ <u>55]</u>	Internal calibration value	0x0000	0_{dec}	R	RAM
<u>R3 [</u>▶ <u>55]</u>	Sampling duration in milliseconds	0x0000	0_{dec}	R	RAM
<u>R4 [</u>▶ <u>55]</u>	Register page selection register	0x0000	0_{dec}	R/W	RAM
<u>R5 [</u>▶ <u>58]</u>	reserved	-	-	-	-
<u>R6 [</u>▶ <u>55]</u>	Diagnostic register	0x0000	0_{dec}	R	RAM
<u>R7 [</u>▶ <u>55]</u>	Command register	0x0000	0_{dec}	R/W	RAM
<u>R8 [</u>▶ <u>55]</u>	Terminal type	0x0E61	3681_{dec}	R	ROM
<u>R9 [</u>▶ <u>55]</u>	Firmware version	e.g.	e.g. $1A_{ASCI}$	R	ROM
R10	Multiplex shift register, data length	0x0130	304_{dec}	R	ROM
R11	Signal channels			R	ROM
R12	Minimum data length			R	ROM
R13	Data structure			R	ROM
R14	reserved	-	-	-	-
R15	Alignment register	typically	typically	R/W	RAM
<u>R16 [</u>▶ <u>56]</u>	Hardware version number			R/W	SEEPROM
R17	reserved	-	-	-	-
...	reserved	-	-	-	-
R28	reserved	-	-	-	-
R29	Terminal type, version	0x0000	0_{dec}	R	ROM
R30	reserved	-	-	-	-
<u>R31 [</u>▶ <u>56]</u>	Code word register	0x0000	0_{dec}	R/W	RAM

Register page 0

These registers are also used for parameterization of the KL3681 (access selectable via register <u>R4 [</u>▶ <u>55]</u>).

Register no.	Comment	Default value		R/W	Memory
R32 [▶ 57]	Feature register	0x2804	10244$_{dec}$	R/W	SEEPROM
R33 [▶ 57]	Zero Comp Interval	0x0000	0$_{dec}$	R/W	SEEPROM
R34	reserved	-	-	-	-
R35	reserved	-	-	-	-
R36 [▶ 57]	User scaling, measuring range 300 mV$_{DC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R37 [▶ 57]	User scaling, measuring range 300 mV$_{DC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R38 [▶ 57]	User scaling, measuring range 3 V$_{DC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R39 [▶ 57]	User scaling, measuring range 3 V$_{DC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R40 [▶ 58]	User scaling, measuring range 30 V$_{DC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R41 [▶ 58]	User scaling, measuring range 30 V$_{DC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R42 [▶ 58]	User scaling, measuring range 300 V$_{DC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R43 [▶ 58]	User scaling, measuring range 300 V$_{DC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R44 [▶ 58]	User scaling, measuring range 300 mV$_{AC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R45 [▶ 58]	User scaling, measuring range 300 mV$_{AC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R46 [▶ 58]	User scaling, measuring range 3 V$_{AC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R47 [▶ 58]	User scaling, measuring range 3 V$_{AC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R48 [▶ 58]	User scaling, measuring range 30 V$_{AC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R49 [▶ 58]	User scaling, measuring range 30 V$_{AC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R50 [▶ 58]	User scaling, measuring range 300 V$_{AC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R51 [▶ 58]	User scaling, measuring range 300 V$_{AC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R52 [▶ 58]	User scaling, measuring range 100 mA$_{DC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R53 [▶ 58]	User scaling, measuring range 100 mA$_{DC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R54 [▶ 58]	User scaling, measuring range 1 A$_{DC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R55 [▶ 58]	User scaling, measuring range 1 A$_{DC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R56 [▶ 58]	User scaling, measuring range 10 A$_{DC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R57 [▶ 58]	User scaling, measuring range 10 A$_{DC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R58 [▶ 58]	User scaling, measuring range 100 mA$_{AC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R59 [▶ 58]	User scaling, measuring range 100 mA$_{AC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R60 [▶ 58]	User scaling, measuring range 1 A$_{AC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R61 [▶ 58]	User scaling, measuring range 1 A$_{AC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM
R62 [▶ 58]	User scaling, measuring range 10 A$_{AC}$, offset	0x0000	0$_{dec}$	R/W	SEEPROM
R63 [▶ 58]	User scaling, measuring range 10 A$_{AC}$, gain	0x2000	8192$_{dec}$	R/W	SEEPROM

Register page 1

These registers are used for calibration of the KL3681 (access selectable via register R4 [▶ 55]).

Register no.	Comment	Default value		R/W	Memory
R32 [▶ 58]	Internal calibration data			R	SEEPROM
...	...			...	...
R35 [▶ 58]	Internal calibration data			R	SEEPROM
R36 [▶ 59]	Manufacturer calibration			R	SEEPROM
...	...			...	...
R63 [▶ 59]	Manufacturer calibration			R	SEEPROM

6.4 Register description

The following registers are used for parameterization of the KL3681. They can be read or written via the register communication [▶ 52] with the aid of control [▶ 52], status [▶ 52] and data bytes [▶ 50].

- **R0: Raw value A/D-C**
  Raw value of the A/D converter (X_R)
- **R1: Current measuring range / mode**
- **R2: Internal calibration value**
- **R3: Sampling duration**
  In milliseconds
- **R4: Register page selection register**
  This register defines which register page is displayed in registers R32 to R63 [▶ 57] (default: 0x0000). The terminal supports two register pages.
  - Register page 0 is used to save the configuration data (see from register RP0.R32 [▶ 57])
  - Register page 1 is used for internal calibration data and manufacturer calibration and must not be changed by the user!
- **R6: Diagnostic register**
  The status byte [▶ 51] is mapped to the low-order byte (bit 7 to bit 0) of register R6.
  The high-order byte (bit 15 to bit 8) of register R6 is reserved.
- **R7: Command register**

ℹ **User code word**

For the following commands to be executed, it is first necessary for the user code word, 0x1235, to be entered into register R31 [▶ 56].

- **Command 0x7000: Restore Factory Settings**
  An entry of 0X7000 in register R7 sets the following registers for the two channels to the following default values:
  - RP0.R32 [▶ 57]: 0x2804 (10244_{dec})
  - RP0.R33 [▶ 57]: 0x0000 (0_{dec})
  - RP0.R34: 0x0000 (0_{dec})
  - RP0.R35: 0x0000 (0_{dec})
  - RP0.R36 [▶ 57], RP0.R38 ... RP0.R62: 0x0000 (0_{dec})
  - RP0.R37 [▶ 57], RP0.R39 ... RP0.R63: 0x2000 (8192_{dec})
- **R8: Terminal description**
  The terminal identifier is contained in register R8: KL3681: 0x0E61 (3681_{dec}).
- **R9: Firmware version**
  Register R9 contains the ASCII coding of the terminal's firmware revision level, e.g. **0x3141 (1A)**$_{ASCII}$. **'0x31'** corresponds to the ASCII character **'1'** and **'0x41'** to the ASCII character **'A'**. This value cannot be changed.
- **R10: Data length (multiplex shift register)**
  R10 contains the number of multiplexed shift registers and their length in bits.
- **R11: Signal channels**
  Unlike R10, this contains the number of channels that are logically present. Thus for example a shift register that is physically present can perfectly well consist of several signal channels.
- **R12: Minimum data length**
  The particular byte contains the minimum data length for a channel that is to be transferred. If the MSB is set, the control and status byte is not necessarily required for the terminal function and is not transferred to the control, if the Bus Coupler is configured accordingly.

- **R13: Data structure (data type register)**

Data type register	Meaning
0x00	Terminal with no valid data type
0x01	Byte array
0x02	Structure: 1 byte, n bytes
0x03	Word array
0x04	Structure: 1 byte, n words
0x05	Double word array
0x06	Structure: 1 byte, n double words
0x07	Structure: 1 byte, 1 double word
0x08	Structure: 1 byte, 1 double word
0x11	Byte array with variable logical channel length
0x12	Structure: 1 byte, n bytes with variable logical channel length (e.g. 60xx)
0x13	Word array with variable logical channel length
0x14	Structure: 1 byte, n words with variable logical channel length
0x15	Double word array with variable logical channel length
0x16	Structure: 1 byte, n double words with variable logical channel length

- **R15: Alignment register**
  Via the alignment register bits, the Bus Coupler arranges the address range of an analog terminal such that it starts at a byte boundary.

- **R16: Hardware version number**
  Register R16 contains the hardware revision level of the terminal; this value cannot be changed.

- **R29: Terminal type, special version**
  The special terminal identifier is contained in register R8: KL3681-0000: 0x0000 (0)$_{dec)}$.

- **R31: Code word register**

  ○ If you write values into the user registers without first entering the user code word (0x1235) into the code word register, the terminal will not accept the supplied data.

  ○ If you write values into the user registers and have previously entered the user code word (0x1235) in the code word register, these values are stored in the RAM registers and in the SEEPROM registers and are therefore retained if the terminal is restarted.

  The code word is reset with each restart of the terminal.

Register page 0

If register page 0 was selected with register R4 [▶ 55], registers R32 to R63 have the following meaning.

- **R32: Feature register**
  The feature register specifies the terminal's configuration. Default: 0x2804 (10244_{dec})

Bit	R32.15	R32.14	R32.13	R32.12	R32.11	R32.10	R32.9	R32.8
Name	presentation				enFilter	-	-	enUserCalli

Bit	R32.7	R32.6	R32.5	R32.4	R32.3	R32.2	R32.1	R32.0
Name	frequency	-	-	-	-	enWdTimer	-	-

Bit	Name	Description		Default
R32.15 to R32.12	presentation	0_{dec}	Left aligned (In left aligned presentation the extended measuring range is not available!)	2_{dec}
		1_{dec}	right aligned	
		2_{dec}	scaled: 1 bit per µV/µA	
		3_{dec}	reserved	
		4_{dec}	reserved	
		5_{dec}	float: Scaled presentation in floating-point format	
		6_{dec}	reserved	
		7_{dec}	reserved	
R32.12	-	reserved		0_{bin}
R32.11	enFilter	0_{bin}	Filter not active	1_{bin}
		1_{bin}	filter active	
R32.10	enLimit2	0_{bin}	Threshold 2 is not active	0_{bin}
		1_{bin}	Threshold 2 is active	
R32.9	enLimit1	0_{bin}	Threshold 1 is not active	0_{bin}
		1_{bin}	Threshold 1 is active	
R32.8	enUserCalli	0_{bin}	User calibration not active	0_{bin}
		1_{bin}	User calibration active	
R32.7	frequency	0_{bin}	50 Hz mains frequency	0_{bin}
		1_{bin}	60 Hz mains frequency	
R32.6	-	reserved		0_{bin}
...	...	...		...
R32.3	-	reserved		0_{bin}
R32.2	enWdTimer	0_{bin}	Watchdog timer is not active	1_{bin}
		1_{bin}	Watchdog timer is active (the watchdog is triggered if no process data are received for 100 ms)	
R32.1	-	reserved		0_{bin}
R32.0	-	reserved		0_{bin}

- **R33: Zero Comp Interval**
- **R36: User scaling, measuring range 300 mV DC, offset**
  (Default: 0x0000)
- **R37: User scaling, measuring range 300 mV DC, gain**
  (Default: 0x2000)
- **R38: User scaling, measuring range 3 V DC, offset**
  (Default: 0x0000)
- **R39: User scaling, measuring range 3 V DC, gain**
  (Default: 0x2000)

- **R40: User scaling, measuring range 30 V DC, offset**
  (Default: 0x0000)
- **R41: User scaling, measuring range 30 V DC, gain**
  (Default: 0x2000)
- **R42: User scaling, measuring range 300 V DC, offset**
  (Default: 0x0000)
- **R43: User scaling, measuring range 300 V DC, gain**
  (Default: 0x2000)
- **R44: User scaling, measuring range 300 mV AC, offset**
  (Default: 0x0000)
- **R45: User scaling, measuring range 300 mV AC, gain**
  (Default: 0x2000)
- **R46: User scaling, measuring range 3 V AC, offset**
  (Default: 0x0000)
- **R47: User scaling, measuring range 3 V AC, gain**
  (Default: 0x2000)
- **R48: User scaling, measuring range 30 V AC, offset**
  (Default: 0x0000)
- **R49: User scaling, measuring range 30 V AC, gain**
  (Default: 0x2000)
- **R50: User scaling, measuring range 300 V AC, offset**
  (Default: 0x0000)
- **R51: User scaling, measuring range 300 V AC, gain**
  (Default: 0x2000)
- **R52: User scaling, measuring range 100 mA DC, offset**
  (Default: 0x0000)
- **R53: User scaling, measuring range 100 mA DC, gain**
  (Default: 0x2000)
- **R54: User scaling, measuring range 1 A DC, offset**
  (Default: 0x0000)
- **R55: User scaling, measuring range 1 A DC, gain**
  (Default: 0x2000)
- **R56: User scaling, measuring range 10 A DC, offset**
  (Default: 0x0000)
- **R57: User scaling, measuring range 10 A DC, gain**
  (Default: 0x2000)
- **R58: User scaling, measuring range 100 mA AC, offset**
  (Default: 0x0000)
- **R59: User scaling, measuring range 100 mA AC, gain**
  (Default: 0x2000)
- **R60: User scaling, measuring range 1 A AC, offset**
  (Default: 0x0000)
- **R61: User scaling, measuring range 1 A AC, gain**
  (Default: 0x2000)
- **R62: User scaling, measuring range 10 A AC, offset**
  (Default: 0x0000)
- **R63: User scaling, measuring range 10 A AC, gain**
  (Default: 0x2000)

Register page 1

If register page 1 was selected with register R4 [▶ 55], registers R32 to R63 have the following meaning.

- **R32 to R35: Internal calibration data**
  These registers contain internal calibration data and must not be changed by the user!

- **R36 to R63: Manufacturer calibration**
  These registers are used for manufacturer calibration and must not be changed by the user!

6.5 Examples of Register Communication

The numbering of the bytes in the examples corresponds to the display without word alignment.

6.5.1 Example 1: reading the firmware version from Register 9

Output Data

Byte 0: Control byte	Byte 1: DataOUT1, high byte	Byte 2: DataOUT1, low byte
0x89 (1000 1001$_{bin}$)	0xXX	0xXX

Explanation:

- Bit 0.7 set means: Register communication switched on.
- Bit 0.6 not set means: reading the register.
- Bits 0.5 to 0.0 specify the register number 9 with 00 1001$_{bin}$.
- The output data word (byte 1 and byte 2) has no meaning during read access. To change a register, write the required value into the output word.

Input Data (answer of the Bus Terminal)

Byte 0: Status byte	Byte 1: DataIN1, high byte	Byte 2: DataIN1, low byte
0x89	0x33	0x41

Explanation:

- The terminal returns the value of the control byte as a receipt in the status byte.
- The terminal returns the firmware version 0x3341 in the input data word (byte 1 and byte 2). This is to be interpreted as an ASCII code:
  - ASCII code 0x33 represents the digit 3
  - ASCII code 0x41 represents the letter A
    The firmware version is thus 3A.

6.5.2 Example 2: Writing to an user register

ℹ Code word

In normal mode all user registers are read-only with the exception of Register 31. In order to deactivate this write protection you must write the code word (0x1235) into Register 31. If a value other than 0x1235 is written into Register 31, write protection is reactivated. Please note that changes to a register only become effective after restarting the terminal (power-off/power-on).

I. Write the code word (0x1235) into Register 31.

Output Data

Byte 0: Control byte	Byte 1: DataOUT1, high byte	Byte 2: DataOUT1, low byte
0xDF (1101 1111$_{bin}$)	0x12	0x35

Explanation:

- Bit 0.7 set means: Register communication switched on.

BECKHOFF

- Bit 0.6 set means: writing to the register.
- Bits 0.5 to 0.0 specify the register number 31 with 01 1111$_{bin}$.
- The output data word (byte 1 and byte 2) contains the code word (0x1235) for deactivating write protection.

Input Data (answer of the Bus Terminal)

Byte 0: Status byte	Byte 1: DataIN1, high byte	Byte 2: DataIN1, low byte
0x9F (1001 1111$_{bin}$)	0xXX	0xXX

Explanation:

- The terminal returns a value as a receipt in the status byte that differs only in bit 0.6 from the value of the control byte.
- The input data word (byte 1 and byte 2) is of no importance after the write access. Any values still displayed are invalid!

II. Read Register 31 (check the set code word)

Output Data

Byte 0: Control byte	Byte 1: DataOUT1, high byte	Byte 2: DataOUT1, low byte
0x9F (1001 1111$_{bin}$)	0xXX	0xXX

Explanation:

- Bit 0.7 set means: Register communication switched on.
- Bit 0.6 not set means: reading the register.
- Bits 0.5 to 0.0 specify the register number 31 with 01 1111$_{bin}$.
- The output data word (byte 1 and byte 2) has no meaning during read access.

Input Data (answer of the Bus Terminal)

Byte 0: Status byte	Byte 1: DataIN1, high byte	Byte 2: DataIN1, low byte
0x9F (1001 1111$_{bin}$)	0x12	0x35

Explanation:

- The terminal returns the value of the control byte as a receipt in the status byte.
- The terminal returns the current value of the code word register in the input data word (byte 1 and byte 2).

III. Write to Register 32 (change contents of the feature register)

Output data

Byte 0: Control byte	Byte 1: DataIN1, high byte	Byte 2: DataIN1, low byte
0xE0 (1110 0000$_{bin}$)	0x00	0x02

Explanation:

- Bit 0.7 set means: Register communication switched on.
- Bit 0.6 set means: writing to the register.
- Bits 0.5 to 0.0 indicate register number 32 with 10 0000$_{bin}$.
- The output data word (byte 1 and byte 2) contains the new value for the feature register.

<table>
<tr><td colspan="3" style="background:yellow">⚠ CAUTION</td></tr>
</table>

⚠ CAUTION
Observe the register description!
The value of 0x0002 given here is just an example!
The bits of the feature register change the properties of the terminal and have a different meaning, depending on the type of terminal. Refer to the description of the feature register of your terminal (chapter *Register description*) regarding the meaning of the individual bits before changing the values.

Input data (response from the Bus Terminal)

Byte 0: Status byte	Byte 1: DataIN1, high byte	Byte 2: DataIN1, low byte
0xA0 (1010 0000$_{bin}$)	0xXX	0xXX

Explanation:

- The terminal returns a value as a receipt in the status byte that differs only in bit 0.6 from the value of the control byte.
- The input data word (byte 1 and byte 2) is of no importance after the write access. Any values still displayed are invalid!

IV. Read Register 32 (check changed feature register)

Output Data

Byte 0: Control byte	Byte 1: DataOUT1, high byte	Byte 2: DataOUT1, low byte
0xA0 (1010 0000$_{bin}$)	0xXX	0xXX

Explanation:

- Bit 0.7 set means: Register communication switched on.
- Bit 0.6 not set means: reading the register.
- Bits 0.5 to 0.0 indicate register number 32 with 10 0000$_{bin}$.
- The output data word (byte 1 and byte 2) has no meaning during read access.

Input Data (answer of the Bus Terminal)

Byte 0: Status byte	Byte 1: DataIN1, high byte	Byte 2: DataIN1, low byte
0xA0 (1010 0000$_{bin}$)	0x00	0x02

Explanation:

- The terminal returns the value of the control byte as a receipt in the status byte.
- The terminal returns the current value of the feature register in the input data word (byte 1 and byte 2).

V. Write Register 31 (reset code word)

Output Data

Byte 0: Control byte	Byte 1: DataOUT1, high byte	Byte 2: DataOUT1, low byte
0xDF (1101 1111$_{bin}$)	0x00	0x00

Explanation:

- Bit 0.7 set means: Register communication switched on.
- Bit 0.6 set means: writing to the register.
- Bits 0.5 to 0.0 specify the register number 31 with 01 1111$_{bin}$.
- The output data word (byte 1 and byte 2) contains 0x0000 for reactivating write protection.

Input Data (answer of the Bus Terminal)

Byte 0: Status byte	Byte 1: DataIN1, high byte	Byte 2: DataIN1, low byte
0x9F (1001 1111$_{bin}$)	0xXX	0xXX

Explanation:

- The terminal returns a value as a receipt in the status byte that differs only in bit 0.6 from the value of the control byte.
- The input data word (byte 1 and byte 2) is of no importance after the write access. Any values still displayed are invalid!

7   Appendix

7.1   Accessories

Fuse

Spare fuses are available as accessories. The *upper* of the two built-in fuses in the EL3681 is designated as a spare fuse.

⚠ WARNING
Danger for persons through electric shock!
The fuse may only be changed if the Bus Terminal is in a safe, de-energized state.

The fuse can be removed with pliers by pulling it upwards from its sockets (see Figure).

Fig. 32: Replacing the fuse

NOTE
Pull the fuse evenly to avoid damaging the sockets!
An improper taking out of the fuses can result in damage to the sockets!

Order number for the fuse

ZB8000-0001, pack of 10 fuses, 1.25 A

7.2 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.

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Table of figures

More Information:
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