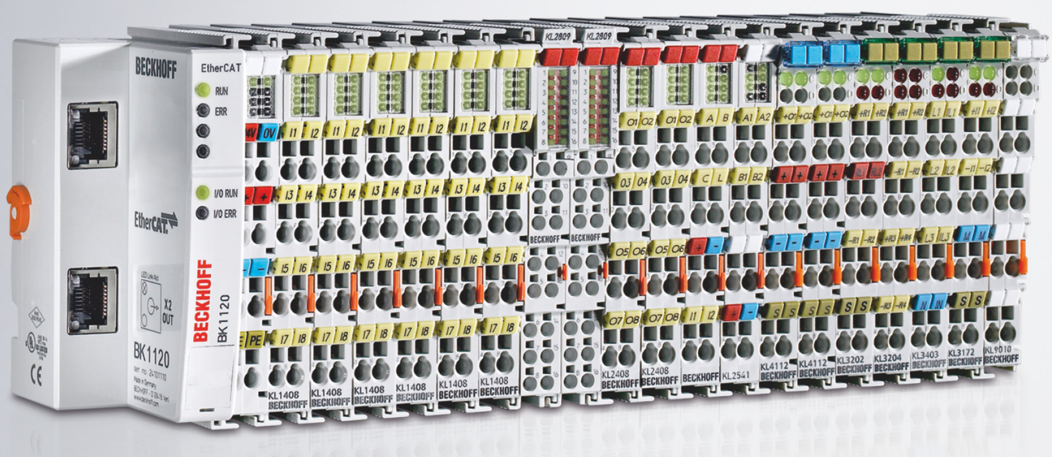
BECKHOFF New Automation Technology

Documentation | EN

KL3224

Four channel analog input terminal for PT1000, Ni1000



2021-07-07 | Version: 2.0.0

Table of contents

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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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

This symbol indicates information that contributes to better understanding.

1.3 Documentation issue status

Version	Comment
2.0.0	• Migration • Document structure updated • Chapter *Beckhoff Identification Code (BIC)* added • Chapter *Notes on ESD protection* added • Safety instructions adapted to IEC 82079-1 • New title page
1.0	• First release

Firmware and hardware versions

Documentation Version	KL3224-0000	
	Firmware	Hardware
2.0.0	1B	06
1.0	1B	03

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

Syntax of the serial number

Structure of the serial number: WW YY FF HH

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

Example with serial number 35 04 1B 01:

35 - week of production 35
04 - year of production 2004
1B - firmware version 1B
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.

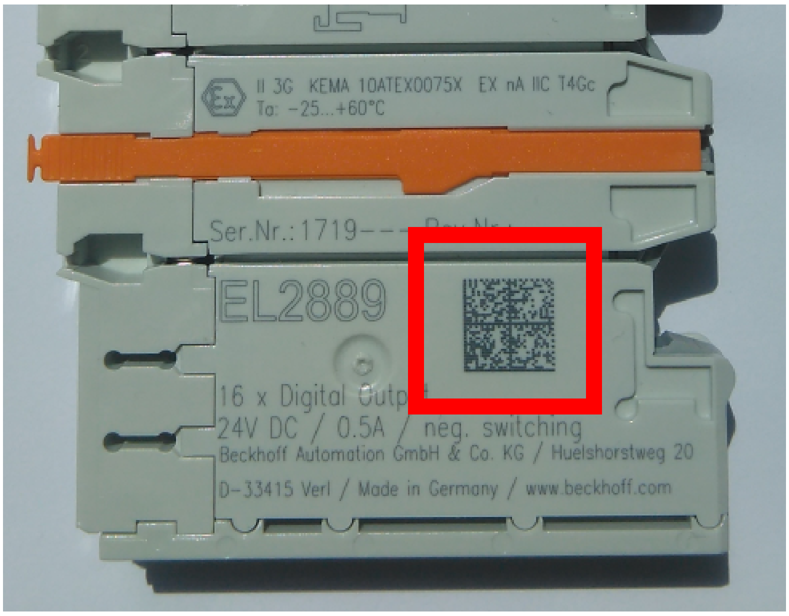

Fig. 1: BIC as data matrix code (DMC, code scheme ECC200)

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 KL3224 - Introduction

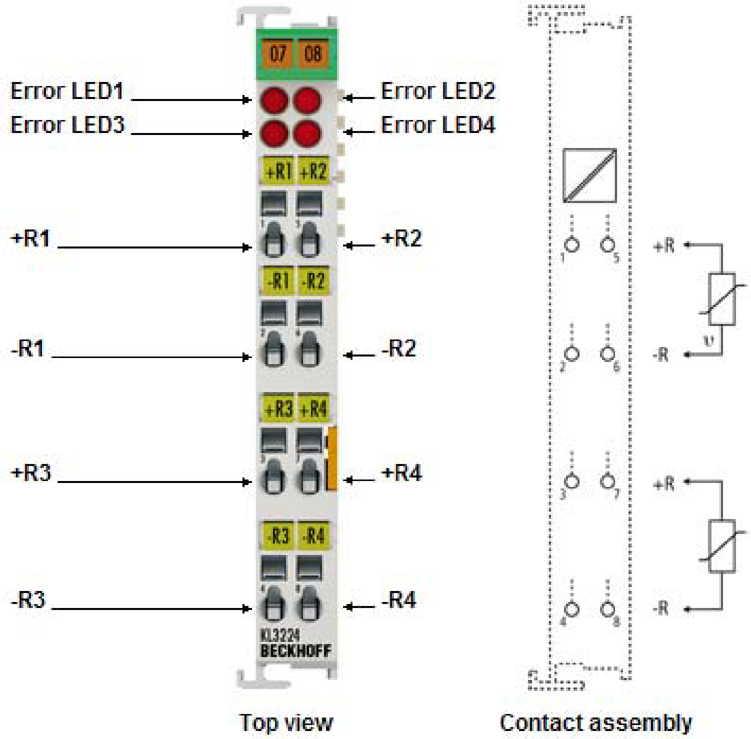

Fig. 2: KL3224 - 4-channel analog input terminal PT1000, Ni1000

The KL3224 analog input terminal allows resistance sensors to be connected directly. A micro-controller within the terminal is used for converting and linearizing the resistance value to a temperature value. The temperatures are displayed as follows:

1/10 °C (1 digit = 0.1 °C)

In addition to this, a broken wire or short circuit is reported to the Bus Coupler or to the controller, and indicated by the ERROR LED.

NI1000 and PT1000 elements are implemented as resistance sensors. The terminal can be fully configured over a fieldbus. A self-defined scaling of the output can, for instance, be performed, or the temperature conversion can be switched off. In the latter case, the measurement is output in the range from 10 Ω up to 1.2 kΩ with a resolution of 1/16 Ω (the internal resolution of the resistance value is 1/255 Ω).

2.2 Technical data

Technical data	KL3224
Number of inputs	4
Power supply	via the K-bus
Sensor types	PT1000, Ni1000
Connection technology	2-wire
Temperature range	0 °C ... +40 °C
Resolution	0.1 °C per digit
Electrical isolation	500 V (K-bus / signal voltage)
Conversion time	approx. 250 ms
Measuring current	typically 0.5 mA.
Measuring error (total meas. range)	< ± 1 °C (at 0 °C ... +55 °C)
Bit width in process image	Input: 4 x 16 bits of data (4 x 8 bit control/status optional)
Current consumption via K-bus	typically 60 mA
Configuration	no address setting, configuration via bus coupler or controller
Special features	Open-circuit recognition
Weight	approx. 70 g
Permissible ambient temperature during operation	0 °C ... +55 °C
Permissible ambient temperature during storage	-25 °C ... +85 °C
Permissible relative humidity	95% no condensation
Vibration / shock resistance	conforms to EN 60068-2-6 / EN 60068-2-27
EMC immunity / emission	conforms to EN 61000-6-2 / EN 61000-6-4
Installation position	variable
Protection class	IP20
Approval / identification	CE

2.3 Basic function principles

Process data output format

In the delivery state, the measured value is displayed in increments of 1/10 °C in two's complement format (integer). The complete measuring range is output for each resistance sensor. Other presentation types can be selected via the feature register (e.g., signed amount representation, Siemens output format).

Measured value	Hexadecimal output	Signed integer output
-250.0 °C	0xF63C	-2500
-200.0 °C	0xF830	-2000
-100.0 °C	0xFC18	-1000
-0.1 °C	0xFFFF	-1
0.0 °C	0x0000	0
0.1 °C	0x0001	1
100.0 °C	0x03E8	1000
200.0 °C	0x07D0	2000
500.0 °C	0x1388	5000
850.0 °C	0x2134	8500

Resistance limit values

R > 400 Ω: Bits 1 and 6 (overrange and error bits) in the status byte are set. The linearization of the characteristic curve is continued with the coefficients of the upper range limit up to the limit stop of the A/D converter (approx. 500 Ω for PT100).
R<18 Ω: Bits 0 and 6 (underrange and error bits) in the status byte are set. The smallest negative number is displayed (0x8001 corresponds to -32767).
For overrange or underrange the red error LED is switched on.

LED display

The LEDs indicate the operating state of the associated terminal channels.

Red LEDs: ERROR

- On: Short circuit or wire breakage. The resistance value is in the invalid range of the characteristic curve.
- Off: The resistance is in the valid range of the characteristic curve.

Calculation of process data

The process data that are transferred to the terminal bus are calculated using the following equations:

X_RL:		ADC value of the supply line
X_RTD:		ADC value of the temperature sensor, including one supply line
X_R:		ADC value of the temperature sensor
A_a, B_a:		Manufacturer gain and offset compensation (R17, R18)
A_h, B_h:		Manufacturer scaling
A_w, B_w:		User scaling
Y_R:		Temperature sensor resistance value
Y_T:		measured temperature in 1/16 °C
Y_THS:		Temperature after manufacturer scaling (1/10 °C)
Y_TAS:		Temperature after user scaling
Y_AUS:		Process data to PLC
X_R = X_RTD-X_RL	(1.0)	Calculating the resistance value
Y_R = A_a * (X_R - B_a)	(1.1)	
Y_T = a_1 * Y_R^2 + b_1* Y_R + c_1	(1.2)	Linearization of the characteristic curve
Y_T = Y_R if output in Ω	(1.3)	
Y_AUS = Y_T	(1.4)	Neither user nor manufacturer scaling is active
Y_THS = A_h * Y_T + B_h Y_AUS = Y_THS	(1.5)	Manufacturer scaling active (factory setting)
Y_TAS = A_w * Y_T + B_w Y_AUS = Y_TAS	(1.6)	User scaling active
Y_1 = A_h * Y_T + B_h Y_2 = A_w * Y_1 + B_w Y_AUS = Y_2	(1.7)	Manufacturer and user scaling active

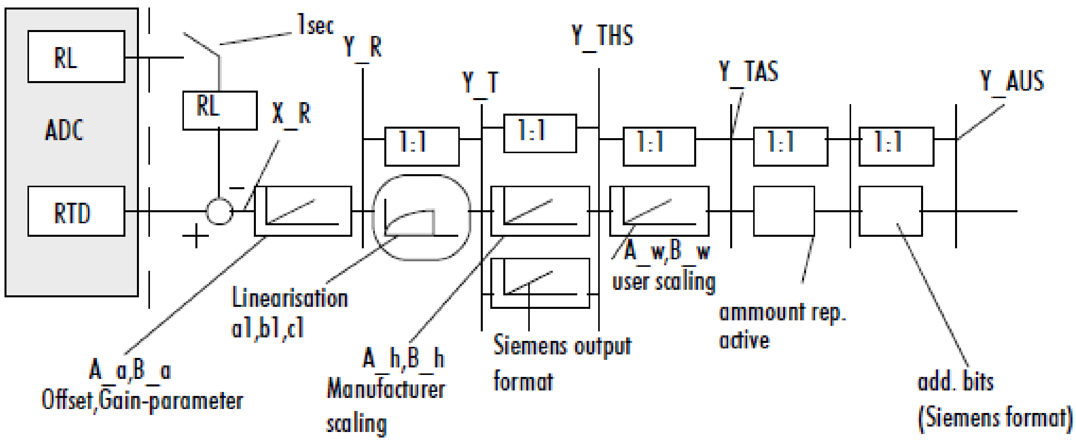

Fig. 3: KL3224x - Data flow

3 Mounting and wiring

3.1 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.

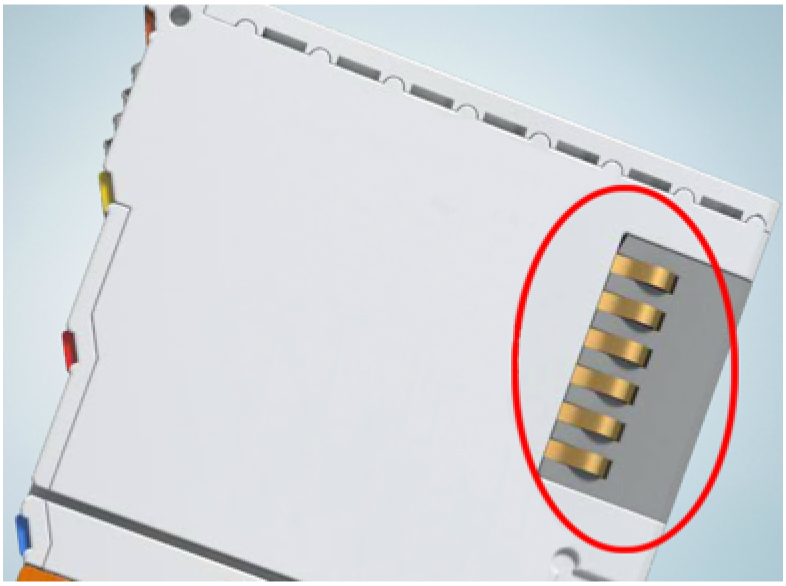

Fig. 4: Spring contacts of the Beckhoff I/O components

3.2 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

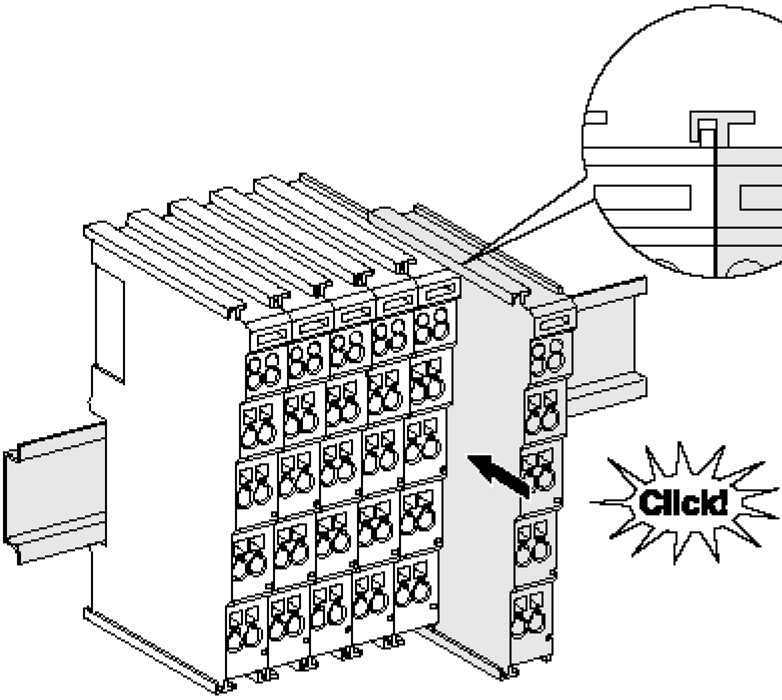

Fig. 5: Attaching on mounting rail

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.

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

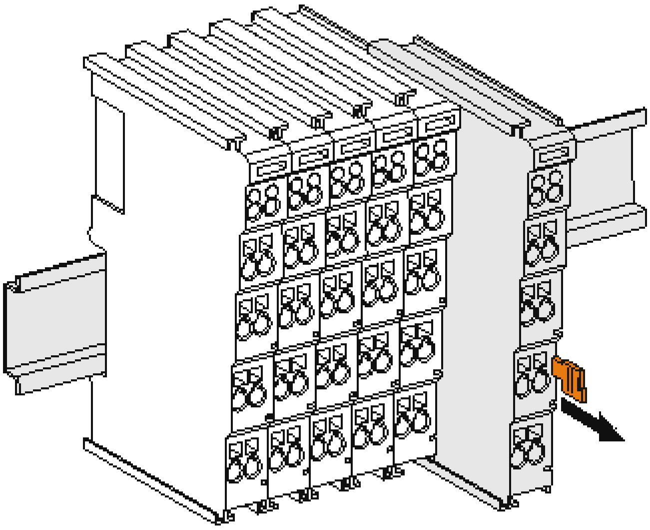

Fig. 6: Disassembling of terminal

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

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.

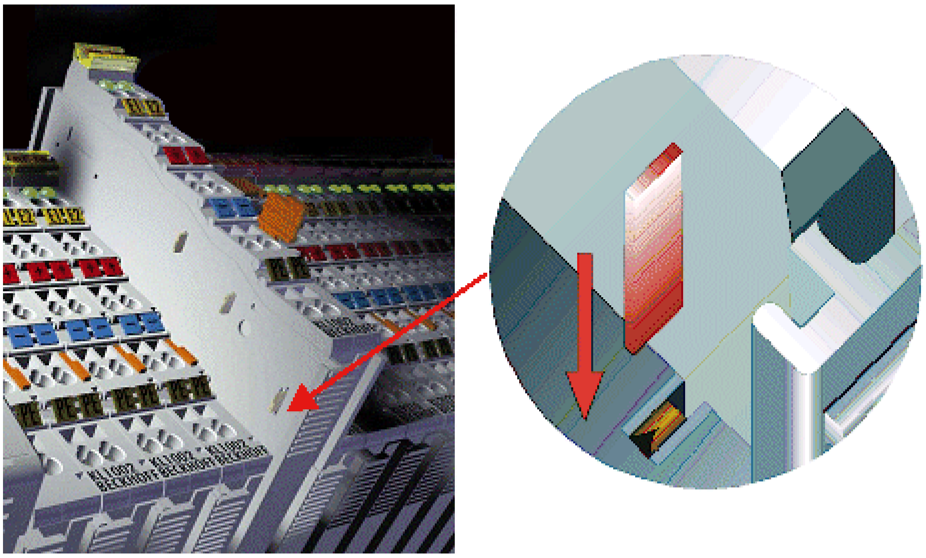

Fig. 7: Power contact on left side

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!

3.3 Connection

3.3.1 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)

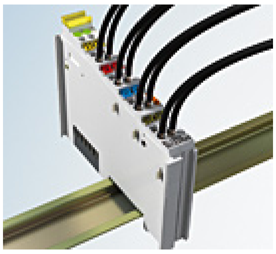

Fig. 8: Standard wiring

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)

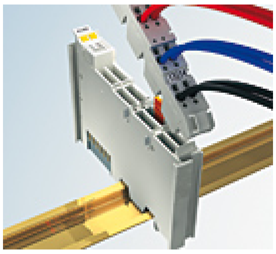

Fig. 9: Pluggable wiring

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)

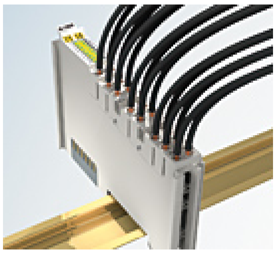

Fig. 10: High Density Terminals

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.

Wiring HD Terminals

The High Density Terminals of the ELx8xx and KLx8xx series doesn't support pluggable wiring.

Ultrasonically “bonded” (ultrasonically welded) conductors

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!

3.3.2 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

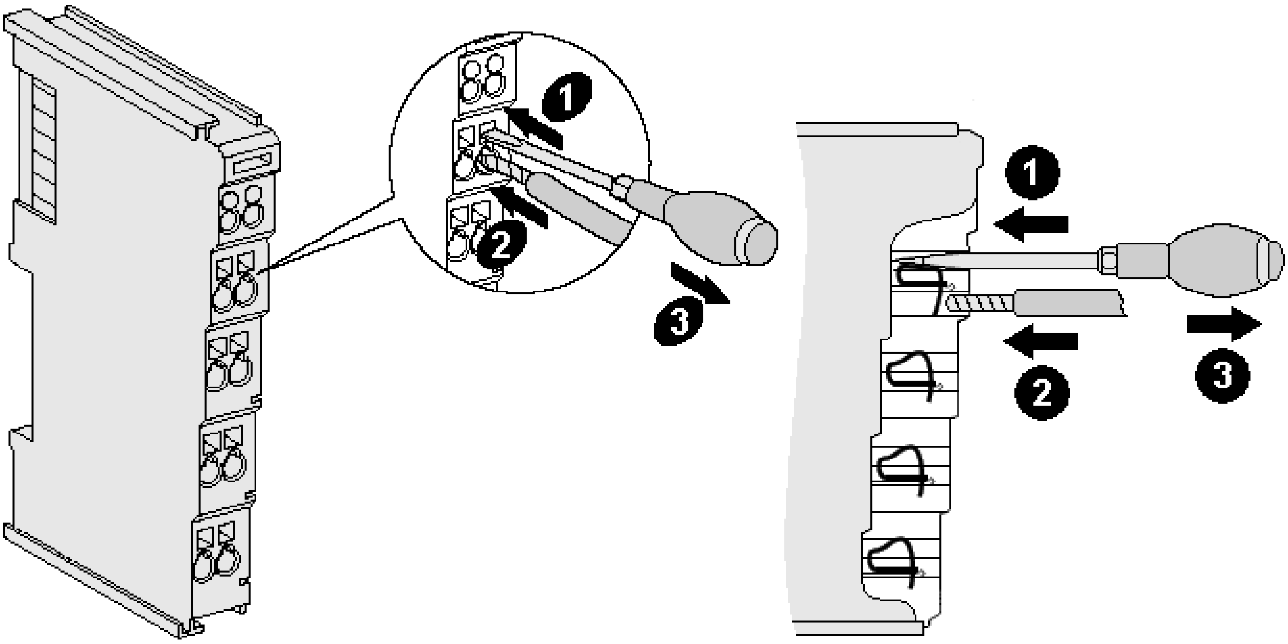

Fig. 11: Connecting a cable on a terminal point

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 [▶ 19]) 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
Wire stripping length	8 ... 9 mm

3.3.3 Shielding

Shielding

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

3.3.4 Connection

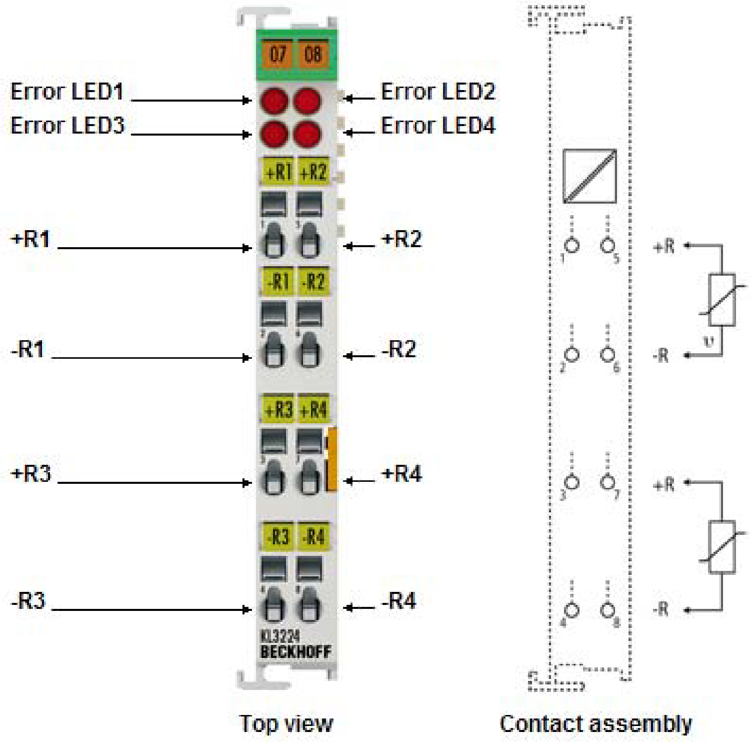

Fig. 12: KL3224 - connection and LEDs

Connection

Terminal point	No.	Comment
+R1	1	Input +R1
- R1	2	Input –R1
+R3	3	Input +R3
-R3	4	Input -R3
+R2	5	Input +R2
-R2	6	Input –R2
+R4	7	Input +R4
-R4	8	Input -R4

KL3224 - LED Displays

LED	Color	Description	
Error	red	On	The respective channel is affected by a short circuit or broken wire. The resistance value is in the invalid range of the characteristic curve.
		Off	The resistance is in the valid range of the characteristic curve.

4 Configuration Software KS2000

4.1 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. 13: 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 Access from the user program

5.1 Terminal configuration

The terminal can be configured and parameterized via the internal register structure. Each terminal channel is mapped in the Bus Coupler. Depending on the type of the Bus Coupler and the mapping configuration (e.g. Motorola/Intel format, word alignment etc.) the terminal data are mapped in different ways to the Bus Coupler memory. For parameterizing a terminal, the control and status byte also has to be mapped.

BK2000 Lightbus Coupler

In the BK2000 Lightbus coupler, the control and status byte is mapped in addition to the data bytes. This is always located in the low byte at the offset address of the terminal channel.

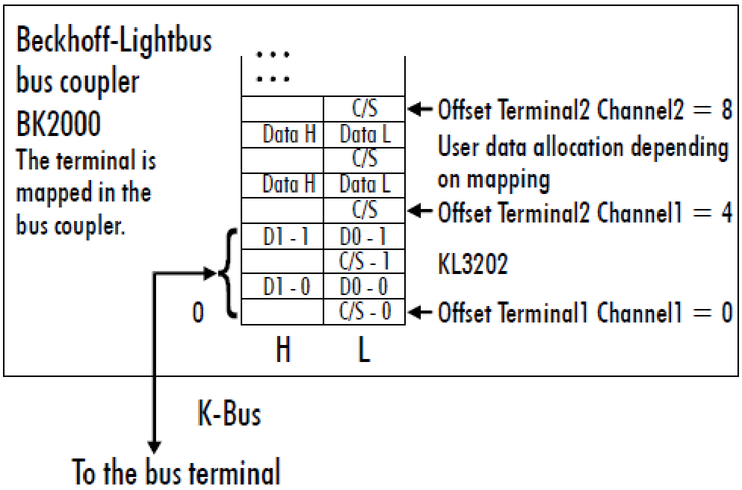

Fig. 14: Mapping in the Lightbus Coupler_KL3202

BK3000 Profibus Coupler

For the BK3000 PROFIBUS coupler, the master configuration should specify for which terminal channels the control and status byte is to be inserted. If the control and status byte are not evaluated, the terminals occupy 2 bytes per channel:

- KL3202: 4 bytes of input data
- KL3224: 8 bytes of input data

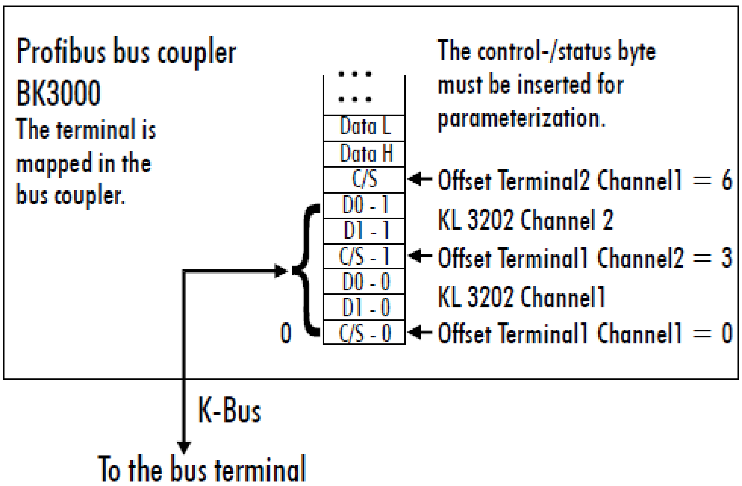

Fig. 15: Mapping in the Profibus coupler – example for KL3202

BK4000 Interbus Coupler

The BK4000 Interbus Coupler maps the terminals in the delivery state with 2 bytes per channel:

- KL3202: 4 bytes of input data
- KL3224: 8 bytes of input data

Parameterization via the fieldbus is not possible. If the control and status byte is to be used, the KS2000 configuration software is required.

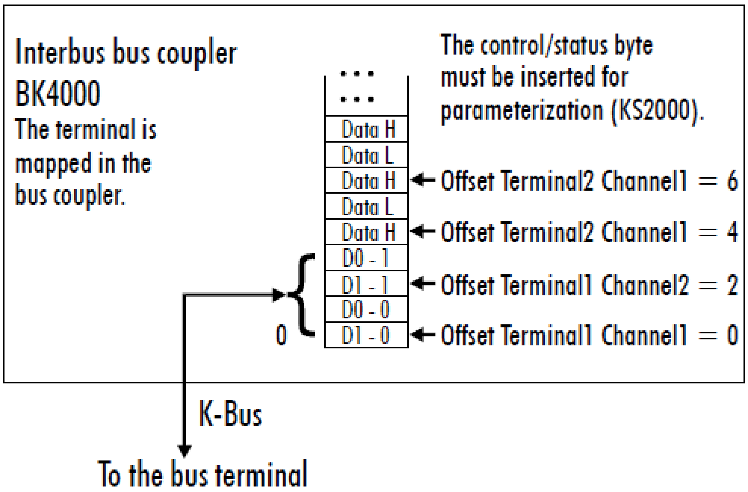

Fig. 16: Mapping in the Interbus coupler – example for KL3202

Further information about the mapping configuration of Bus Couplers can be found in the Appendix of the respective Bus Coupler manual under Master configuration.

The Appendix contains an overview of possible mapping configurations depending on the parameters that can be set.

NOTE

Parameterization with KS2000

The parameterizations can be carried out independently of the fieldbus system with the KS2000 configuration software via the serial configuration interface in the Bus Coupler.

5.2 Mapping in the Bus Coupler

As already described in the *Terminal Configuration* section, each Bus Terminal is mapped in the Bus Coupler. This mapping is usually done with the default setting in the Bus Coupler / Bus Terminal. The KS2000 configuration software or a master configuration software (e.g. ComProfibus or TwinCAT System Manager) can be used to change this default setting.
If the terminals are fully evaluated, they occupy memory space in the input and output process image.
The following tables provide information about how the terminals map themselves in the Bus Coupler, depending on the parameters set.

Default mapping for: CANopen, CANCAL, DeviceNet, ControlNet, Modbus, RS232 and RS485 Coupler

Conditions	Word offset	High byte	Low byte
Complete evaluation: no Motorola format: no Word alignment: any	0	Ch0 D1	Ch0 D0
	1	Ch1 D1	Ch1 D0
	2	Ch2 D1	Ch2 D0
	3	Ch3 D1	Ch3 D0

Default mapping for: PROFIBUS and Interbus

Conditions	Word offset	High byte	Low byte
Complete evaluation: no Motorola format: yes Word alignment: any	0	Ch0 D0	Ch0 D1
	1	Ch1 D0	Ch1 D1
	2	Ch2 D0	Ch2 D1
	3	Ch3 D0	Ch3 D1

Conditions	Word offset	High byte	Low byte
Complete evaluation: yes Motorola format: no Word alignment: no	0	Ch0 D0	Ch0 CB/SB
	1	Ch1 CB/SB	Ch0 D1
	2	Ch1 D1	Ch1 D0
	3	Ch2 D0	Ch2 CB/SB
	4	Ch3 CB/SB	Ch2 D1
	5	Ch3 D1	Ch3 D0

Conditions	Word offset	High byte	Low byte
Complete evaluation: yes Motorola format: yes Word alignment: no	0	Ch0 D1	Ch0 CB/SB
	1	Ch1 CB/SB	Ch0 D0
	2	Ch1 D0	Ch1 D1
	3	Ch2 D1	Ch2 CB/SB
	4	Ch3 CB/SB	Ch2 D0
	5	Ch3 D0	Ch3 D1

Default mapping for: Lightbus, EtherCAT & Ethernet coupler and Bus Terminal Controller (BCxxxx, BXxxxx)

Conditions	Word offset	High byte	Low byte
Complete evaluation: yes Motorola format: no Word alignment: yes	0	Res.	Ch0 CB/SB
	1	Ch0 D1	Ch0 D0
	2	Res.	Ch1 CB/SB
	3	Ch1 D1	Ch1 D0
	4	Res.	Ch2 CB/SB
	5	Ch2 D1	Ch2 D0
	6	Res.	Ch3 CB/SB
	7	Ch3 D1	Ch3 D0

Conditions	Word offset	High byte	Low byte
Complete evaluation: yes Motorola format: yes Word alignment: yes	0	Res.	Ch0 CB/SB
	1	Ch0 D0	Ch0 D1
	2	Res.	Ch1 CB/SB
	3	Ch1 D0	Ch1 D1
	4	Res.	Ch2 CB/SB
	5	Ch2 D0	Ch2 D1
	6	Res.	Ch3 CB/SB
	7	Ch3 D0	Ch3 D1

Key

Complete evaluation	The terminal is mapped with control and status byte.
Motorola format	Motorola or Intel format can be set.
Word alignment	The terminal is positioned on a word boundary in the Bus Coupler.
Ch n CB	Control byte for channel n (appears in the process image of the outputs).
Ch n SB	Status byte for channel n (appears in the process image of the inputs).
Ch n D0	Channel n, data byte 0 (byte with the lowest value)
Ch n D1	Channel n, data byte 1 (byte with the highest value)
"-"	This byte is not used or occupied by the terminal.
Res.	Reserved: This byte occupies process data memory, although it is not used.

5.3 Control and status byte

The control and status byte is transmitted from the controller to the terminal. It can be used

- in register mode [▸ 34] (REG = 1_{bin}) or
- in process data exchange [▸ 27] (REG = 0_{bin}).

5.3.1 Process data exchange

Control byte in process data exchange (REG=0)

A gain and offset calibration of the terminal can be carried out with the control byte. The code word must be entered in R31 so that the terminal calibration can be carried out. The gain and offset of the terminal can then be calibrated. The parameter will only be saved permanently once the code word is reset!

5.3.2 Compensation

Implemented linear equation

Y[Ω] = (X_Adc * G + B_h) * A_h + 100 Ω

Hence:

B_h consists of a component that depends on the gain of the A/D converter and a constant for calculating the axis offset of 100 Ω. The gain-dependent component calculates the offset of the external components (the offset of the component can be varied via adjustable amplification). This procedure is necessary, because compensation at 0 Ω is technically not possible. The line is therefore compensated around the point 100 Ω (offset to the point and rotated around this point).

B_h: (B_off * G + B_100)

- Offset compensation should therefore be carried out for PT100 at 100 Ω (or PT1000 at 1000 Ω).
- Gain compensation is then carried out independently of the offset, e.g., at 300 Ω. 300 Ω corresponds to 557.7 °C = 0x15C9

5.3.3 Default setting of the registers

R17: 0xED68 corresponds to -90.8 Ω
R18: 0x4E20 corresponds to 2000 * 16-5 = 0,01907 Ω/digit
R19: 0x0000
R20: 0x00A0

R32: 0x0106
R33: 0x0000
R34: 0x0100

The gain and offset compensation only has to be carried out once, i.e. it does not have to be repeated or corrected for any of the other implemented elements

For the two-wire connection, with short-circuited line resistance (+R1-Rl1) the raw ADC value of the line resistance (contained in R1) has to be entered in register R21.

5.4 Register overview

These registers exist once for each channel

Address	Name	Default value	R/W	Storage medium
R0 [▸ 30]	Raw ADC value	variable	R	RAM
R1 [▸ 30]	Unprocessed ADC value for the leads	variable	R	
R2	reserved	0x0000	R	
R3	...	...	...	...
R5	reserved	0x0000	R	
R6 [▸ 30]	Diagnostic register	variable	R	RAM
R7 [▸ 30]	Command register not used	0x0000	R	
R8 [▸ 30]	Terminal type	e.g., KL3224	R	ROM
R9 [▸ 30]	Software version number	0x????	R	ROM
R10 [▸ 30]	Multiplex shift register	0x0218/0130	R	ROM
R11 [▸ 31]	Signal channels	0x0218	R	ROM
R12 [▸ 31]	Minimum data length	0x0098	R	ROM
R13 [▸ 31]	Data structure	0x0000	R	ROM
R14 [▸ 31]	reserved	0x0000	R	
R15 [▸ 31]	Alignment register	variable	R/W	RAM
R16	Hardware version number	0x????	R/W	SEEROM
R17 [▸ 31]	Hardware compensation: Offset	specific	R/W	SEEROM
R18 [▸ 31]	Hardware compensation: Gain	specific	R/W	SEEROM
R19 [▸ 32]	Manufacturer scaling: Offset	0x0000	R/W	SEEROM
R20 [▸ 32]	Manufacturer scaling: Gain	0x00A0	R/W	SEEROM
R21 [▸ 32]	Offset register two-wire connection method	specific	R/W	SEEROM
R22	reserved	0x0000	R/W	SEEROM
R3	...	...	...	...
R30	reserved	0x0000	R/W	SEEROM
R31 [▸ 32]	Code word register	variable	R/W	RAM
R32 [▸ 32]	Feature register	0x0106	R/W	SEEROM
R33 [▸ 33]	User scaling: Offset	0x0000	R/W	SEEROM
R34 [▸ 33]	User scaling: Gain	0x0100	R/W	SEEROM
R35 [▸ 33]	reserved	0x0000	R/W	SEEROM
R36 [▸ 33]	reserved	0x0000	R/W	SEEROM
R37 [▸ 33]	Filter constant	0x0138	R/W	SEEROM
R38	reserved	0x0000	R/W	SEEROM
R3	...	...	...	...
R63	reserved	0x0000	R/W	SEEROM

5.5 Register description

The registers can be read or written via the register communication. They are used for the parameterization of the terminal.

R0 to R7: Registers in the internal RAM of the terminal

The process variables can be used in addition to the actual process image. Their function is specific to the terminal.

R0 to R5: Terminal-specific registers

The function of these registers depend on the respective terminal type (see terminal-specific register description).

R0: Raw ADC value X_R

This register contains the raw ADC value.

R1: Raw ADC value of the line resistance between +R1 - RL1 or +R2 - RL2

R2 to R5: Reserved

R6: Diagnostic register

The diagnostic register can contain additional diagnostic information. Parity errors, for instance, that occur in serial interface terminals during data transmission are indicated here.

R6: Diagnostic register

High byte: not used
Low byte: Status byte

R7: Command register

High-Byte_Write = function parameter
Low-Byte_Write = function number
High-Byte_Read = function result
Low-Byte_Read = function number

R8 to R15: Registers in the internal ROM of the terminal

The type and system parameters are hard programmed by the manufacturer, and the user can read them but cannot change them.

R8: Terminal type

The terminal type in register R8 is needed to identify the terminal.

R9: Software version (X.y)

The software version can be read as a string of ASCII characters.

R10: Data length

R10 contains the number of multiplexed shift registers and their length in bits.
The Bus Coupler sees this structure.

R11: Signal channels

Related to 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 type register

Value	Data type
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 word
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

R14: Reserved

R15: Alignment bits (RAM)

The alignment bits are used to place the analog terminal in the Bus Coupler on a byte boundary.

R16 to R30: Manufacturer parameter area (SEEROM)

The manufacturer parameters are specific for each type of terminal. They are programmed by the manufacturer, but can also be modified by the controller. The manufacturer parameters are stored in a serial EEPROM in the terminal, and are retained in the event of voltage drop-out.

These registers can only be altered after a code word has been set in R31.

R17: Hardware compensation – offset (B_a)

16-bit signed integer
This register is used for offset compensation of the terminal (Eq. 1.1).
Register value approx. 0xEDXX

R18: Hardware compensation – gain (A_a)

16 bits * 16^{-5} (approx. 0,01907 Ω/digit)
This register is used for gain compensation of the terminal (Eq. 1.1).
Register value approx. 0x27XX

R19: Manufacturer scaling – offset (B_h)

16-bit signed integer [0x0000]
This register contains the offset of the manufacturer's straight-line equation (1.5). The linear equation is enabled via register R32.

R20: Manufacturer scaling – gain (A_h)

16 bits signed integer *2^{-8} [0x00A0]
This register contains the scaling factor of the manufacturer's straight-line equation (1.5). The linear equation is enabled via register R32.

R21: Additional offset register for two-wire connection

The value of register 1 at short circuit +R1-RL1 or +R2-RL2 [approx. 0x01AX]

R31 to R47: User parameter area (SEEROM)

The user parameters are specific for each type of terminal. They can be modified by the programmer. The user parameters are stored in a serial EEPROM in the terminal, and are retained in the event of voltage drop-out. The user area is read-only by a code word.

R31: Code word register in RAM

The code word 0x1235 must be entered here so that parameters in the user area can be modified. If any other value is entered into this register, the write protection is active. When write protection is not active, the code word is returned when the register is read. If the write protection is active, the register contains a zero value.

R32: Feature register

This register specifies the operation modes of the terminal. Thus, for instance, a user-specific scaling can be enabled for the analog I/Os.

The feature register specifies the terminal's operation mode. [0x0106]

Feature bit no.		Description of the operation mode
Bit 0	1	User scaling (R33, R44) active [0]
Bit 1	1	Manufacturer scaling (R19, R20) active [1]
Bit 2	1	Watchdog timer active [1] In the delivery state, the watchdog timer is switched on.
Bit 3	1	Signed amount representation [0] Signed amount representation is active instead of two's-complement representation (-1 = 0x8001).
Bit 4	1	Siemens output format [0] This bit is used for inserting status information on the lowest 3 bits (see below).
Bit 5, 6	-	reserved, do not change
Bit 7	1	activates filter constant in R37 [0]
Bit 8	1	Overrange Protection [1] If the temperature exceeds 850 °C the status bits are correspondingly set and the output value is restricted to 850 °C.
Bit 9	-	reserved, do not change
Bit 10	1	Two-wire connection [0]
Bit 11	-	reserved, do not change
Bit 12, 13, 14, 15	Element	Valid measuring range
0 0 1 0	PT1000	0 °C ... 40 °C
0 1 0 1	NI1000	0 °C ... 40 °C

Output format

If only manufacturer scaling via the feature register is active, the output format is as follows:
1 digit is equivalent to 1/10 °C or
1 digit is equivalent to 1/10 Ω

If no scaling is active, the output format is as follows:
1 digit is equivalent to 1/16 °C or
1 digit is equivalent to 1/16 Ω

If the Siemens output format is selected, the lowest three bits are used for status evaluation. The process data is mapped in bits 3 to 15, with bit 15 representing the sign bit. Scaling of the measurement reading according to the Siemens standard has to be done via user scaling.

Measured value	Bit 15-3	Bit 2 X	Bit 1 Error	Bit 0 Overflow
out of range		0	0	1
in range	Process data	0	0	0

R33 to R47: Terminal-specific registers

The function of these registers depend on the respective terminal type (see terminal-specific register description).

R33: User scaling – offset (B_w)

16-bit signed integer
This register contains the offset of the user straight-line equation (1.6). The linear equation is enabled via register R32.

R34: User scaling (A_w)

16-bit signed integer * 2^{-8}. This register contains the scaling factor of the user straight-line equation (1.6). The linear equation is enabled via register R32.

R35 and R36: reserved

R37: Filter constant

[0x0000]
This documentation applies to all terminals from firmware version 3x. The version number can be found within the serial number on the right-hand side face of the terminal: xxxx3xxx

Example: 5298**3A**2A = the firmware version is 3A.

Filter constant	First notch [Hz]	Conversion time [ms]
0x0000	25	250
0x50	100	65
0xA0	50	125
0x140	25	250
0x280	12.5	500

5.6 Register communication

Register access via process data exchange

- **Bit 7=1bin: Register mode**
  If bit 7 of the control byte is set, the first two bytes of the user data are not used for process data exchange but written into the register set of the terminal or read from it.
- **Bit 6=0bin: read, bit 6=1bin: write**
  Bit 6 of the control bytes is used to specify whether a register should be read or written. If bit 6 is not set, then a register is read out without modifying it. The value can be found in the input process image. If bit 6 is set, then the user data is written into a register. As soon as the status byte has supplied an acknowledgement in the input process image, the procedure is completed (see example).
  - **Bit 6=0**: A register is read without changing it. The value can be found in the input process image.
  - **Bit 6=1**: The user data are written into a register. The process is complete once the status byte in the input process image has returned an acknowledgment (see example).
- **Bit 0 to 5: Address**
  The address of the register to be addressed is entered in bits 0 to 5 of the control byte

Control byte in register mode (REG=1)

MSB

REG=1	W/R	A5	A4	A3	A2	A1	A0

REG = 0_{bin}: Process data exchange
REG = 1_{bin}: Access to register structure

W/R = 0_{bin}: Read register
W/R = 1_{bin}: Write register

A5..A0 = register address
Addresses A5...A0 can be used to address a total of 64 registers.

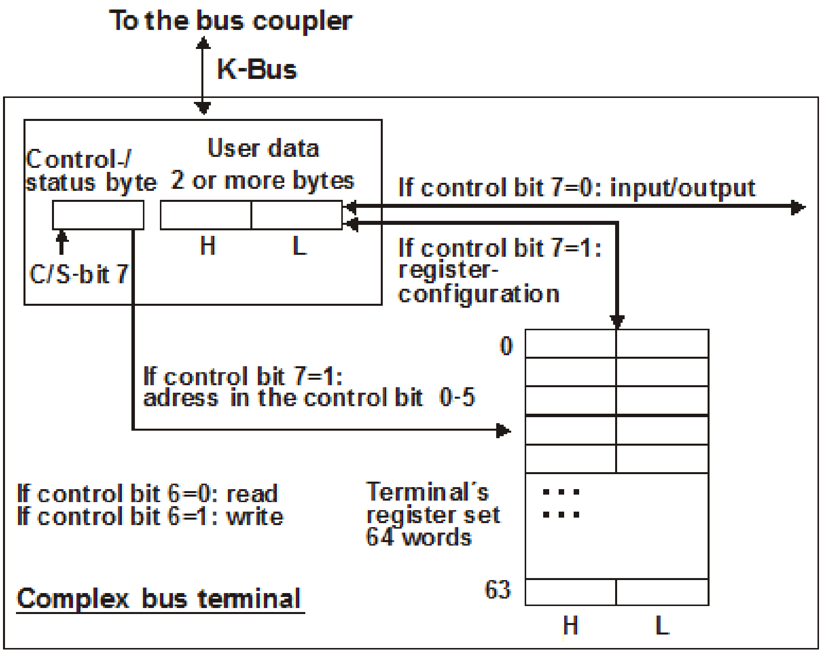

Fig. 17: ControByte_RegisterMode

The control or status byte occupies the lowest address of a logical channel. The corresponding register values are located in the following 2 data bytes. (The BK2000 is an exception: here, an unused data byte is inserted after the control or status byte, and the register value is therefore placed on a word boundary).

Sample 1:
Reading of register 8 in the BK2000 with a KL3202 and the end terminal:

If the following bytes are transferred from the controller to the terminal,

Byte	Byte 3	Byte 2	Byte 1	Byte 0
Name	DataOUT 1	DataOUT 0	Not used	Control byte
Value	0xXX	0xXX	0xXX	0x88

The terminal returns the following type identifier (0x0CF82 corresponds to unsigned integer 3202)

Byte	Byte 3	Byte 2	Byte 1	Byte 0
Name	DataIN 1	DataIN 0	Not used	Status byte
Value	0x0C	0x82	0x00	0x88

Sample 2:
Writing of register 31 in the BK2000 with an intelligent terminal and the end terminal:

If the following bytes (code word) are transferred from the controller to the terminal,

Byte	Byte 3	Byte 2	Byte 1	Byte 0
Name	DataOUT 1	DataOUT 0	Not used	Control byte
Value	0x12	0x35	0xXX	0xDF

The code word is set, and the terminal returns the register address with bit 7 for register access as acknowledgment.

Byte	Byte 3	Byte 2	Byte 1	Byte 0
Name	DataIN 1	DataIN 0	Not used	Status byte
Value	0x00	0x00	0x00	0x9F

5.7 Examples of Register Communication

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

5.7.1 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.

5.7.2 Example 2: Writing to an user register

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.
- 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.

⚠ 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!

6 Appendix

6.1 Support and Service

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

Beckhoff's branch offices and representatives

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

The addresses of Beckhoff's branch offices and representatives round the world can be found on her internet pages: https://www.beckhoff.com

You will also find further documentation for Beckhoff components there.

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e-mail:	support@beckhoff.com

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The Beckhoff Service Center supports you in all matters of after-sales service:

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