KL-33x2

Technical Documentation
2-Channel Input Terminal
Thermocouple

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Author:	KOH

TRSystemtechnik GmbH
Eglishalde 6
D-78647 Trossingen
Germany
Tel. +49 - (0) 7425 / 228-0
Fax +49 - (0) 7425 / 228-34

Imprint

TRSystemtechnik GmbH
D-78647 Trossingen
Eglishalde 6
Tel.: (++49) 07425/228-0
Fax: (++49) 07425/228-34

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Revision History

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Note:
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Revision	Date

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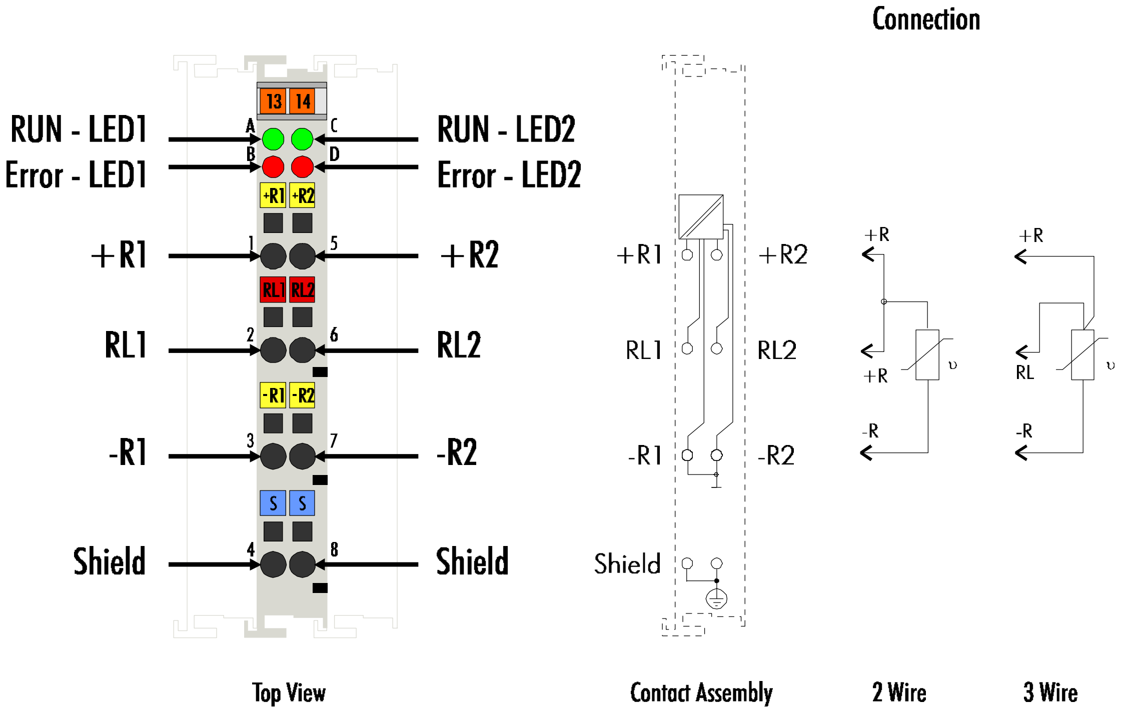
TR - Systemtechnik GmbH, Eglishalde 6, 78647 Trossingen, Tel. +49 - (0) 7425-228-0, Fax +49 - (0) 7425-228-34

2-Channel Thermocouple Input Terminal KL3302/KL3312



Technical data	KL3302	KL3312
Number of inputs	2	
Power supply	via the T-Bus	
Thermocoupler sensor types	Type J, K, L, B, E, N, R, S, T, U (Default; Type K), mV measurement	
Connection	2-wire	
Temperature range	within the defined range of each sensor (default: Type K; -100° ... 1370°C)	
Resolution	0.1°C per bit, for mV measurement < 25 µV, typ.15 µV	
Wiring fail indication	No	Yes
Electrical isolation	500 Vrms (T-Bus / signal voltage)	
Current consumption from T-Bus	65 mA typ.	
Bit width in the process image	I: 2 x 16 bits data (2 x 8 bits control/status can be optionally inserted))	
Configuration	no address setting, configuration via the bus coupler or the controller	
Weight approx..	75 g	
Operating temperature	0°C ... +55°C	
Storage temperature	-25°C ... +85°C	
Relative humidity	95%, no condensation	
Vibration/shock resistance	conforms to IEC 68-2-6 / IEC 68-2-27	
EMC resistance Burst / ESD	conforms to EN 61000-4-4 / EN 61000-4-2, limit EN 50082-2	
Installation position	any	
Type of protection	IP20	

Description of functions

The thermocouple terminal KL3302 or KL3312 (with wire breakage detection) is capable of evaluating thermocouple types J, K, B, E, N, R, S, T, U and L. Linearisation of the characteristics and determination of the comparison temperature take place directly in the terminal. Temperaturs are output in 1/10 °C. The terminal can be configured completely via the bus coupler or the controller. In doing so, it is possible to choose between various output formats and user-defined scalings can also be activated. Linearisation of the characteristic and determination and ofsetting of the comparison temperature (temperature at the terminal's terminal contacts) can also be deactivated.

Operating principle

Thermocouples belong to the category of active sensors. Here, the thermoelectric effect (Seebeck, Peltier, Thomson) is exploited. At the contact points of two electrical conductors made of different materials (e.g. iron and constantan), a charge shift takes place. A contact voltage comes into being that is a unique function of the temperature. This thermal voltage is both a function of the measured temperature T and also of the comparison temperature Tv at the terminal contacts of the thermocouple. As the coefficient is determined at a comparison temperature of 0°C, the influence of the comparison temperature must be compensated. To do this, the comparison temperature is converted to a comparison voltage that depends on the thermocouple type and this is added to the measured thermal voltage. The temperature is determined on the basis of the resulting voltage and the corresponding characteristic.

Uk = Umeas+ Ucomp

Taus = f(Uk)

Output format
of the process data

By default, the measured value is output in 1/10 °C increments in 2's complement notation. Other notations can be selected by way of the feature register (e.g. signed integer, Siemens output format).

Measured value	hexadecimal output	Signed integer output
-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
1000,0°C	0x2710	10000

Voltage limits

Uk>Ukmax: bit1 and bit6 (overrange and error bits) in the status byte are set. Linearisation of the characteristic is continued with the coefficients of the top range limit up to the end stop of the AD converter or up to the maximum value 0x7FFF.

Uk<Ukmin: bit0 and bit6 (underrange and error bits) in the status byte are set. Linearisation of the characteristic is continued with the coefficients of the low range limit down to the end stop of the AD converter or to a minium of 0x8000.

The red error LED is activated in the event of overrange or underrange.

LED indication

The four LEDs indicate the operating state of the affiliated temrinal channel.
Green LEDs: RUN
On – normal operation

Off – watchdog timer overflow has occurred. The green LEDs go off if no process data is transferred by the bus coupler for 100 ms.

Red LEDs: ERROR
On: a wire breakage has occurred (KL3312 only). The resistance value is in the invalid range of the respective thermocouple's characteristic.

Off: the resistance value is within the valid range of the characteristic.

Process data

The process data that is transferred to the terminal bus is computed on the basis of the following equations:

X_vgl:	ADC value of the comparison point
Tvgl:	Temperature of the comparison point
Uvgl:	Voltage value of the comparison point
X_R:	ADC value of the temperature sensor
Um1	Voltage value of the temperature sensor
A_a, B_a:	Manufacturer gain and offset adjustment (R17,R18)
A_h, B_h:	Manufacturer scaling
A_w, B_w:	User scaling
Uk:	Total of Uvgl and Um1
T:	Measured temperature in 1/16 °C
Th:	Temperature according to manufacturer scaling (1/10 °C)
Ta:	Temperature according to user scaling
T_AUS:	Process data to the PLC

a) Voltage value of the comparison point:
Tvgl = A00 * X_ (1.0)
Uvgl = a1 * Tvgl^2 + b1 * Tvgl + c1 (1.1)

b) Measured temperature in 1/16°C:
Um1 = A_a * X_m + B_a (1.2)
Uk = Uvgl + Um1 (1.3)
T = a0 * Uk^2 + b0 * Uk + c0 (1.4)

c) Neither user nor manufacturer scaling active:
T_AUS = T (1.5)

d) Manufacturer scaling active (works setting):

$$Th = A_h * T + B_h \qquad (1.6)$$

$$Y_{AUS} = Th$$

e) User scaling active:

$$Ta = A_w * T + B_w \qquad (1.7)$$

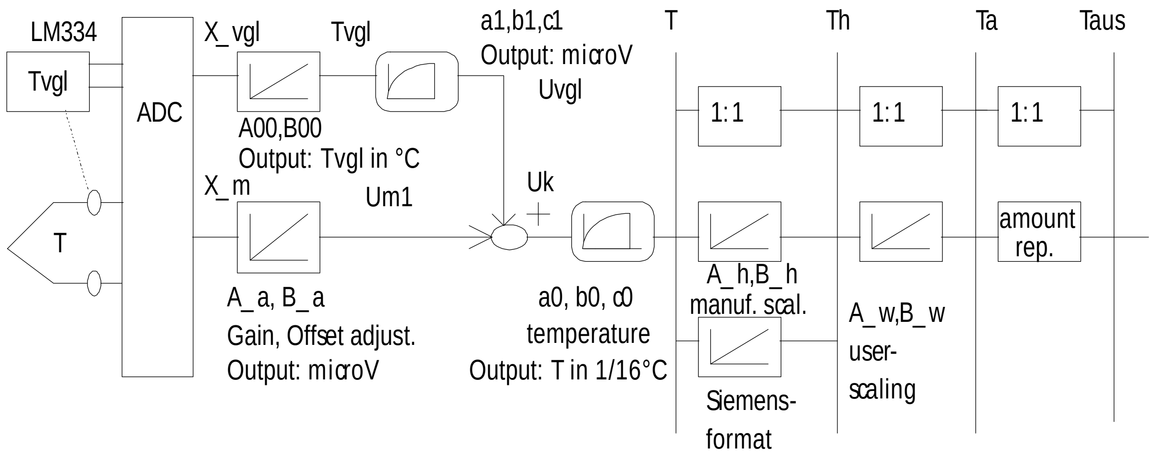
$$Y_{AUS} = Ta$$

f) Manufacturer and user scaling active: (1.8)

$$Y_1 = A_h * T + B_h$$

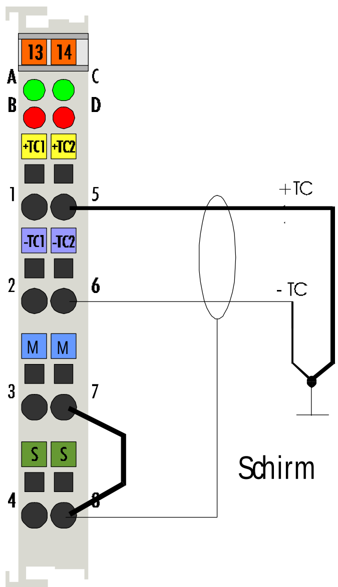
$$Y_2 = A_w * Y_1 + B_w$$

$$Y_{AUS} = Y_2$$

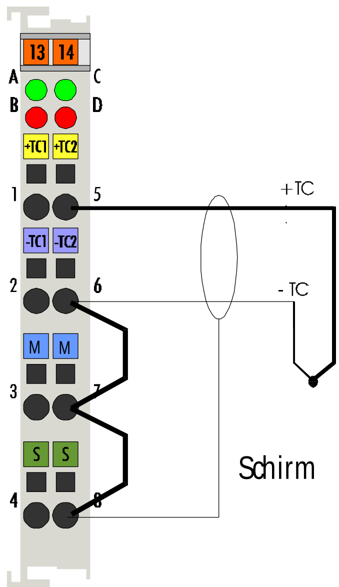


Connection

Owing to the difference inputs of the terminals, different connection techniques are recommended depending on the thermocouple design.
In the case of earthed thermocouples, the earth is connected to the screen.
If the thermocouple does not have an earth connection, the earth, screen and –TC1 or –TC2 contacts are connected to one another.



earth thermocouple



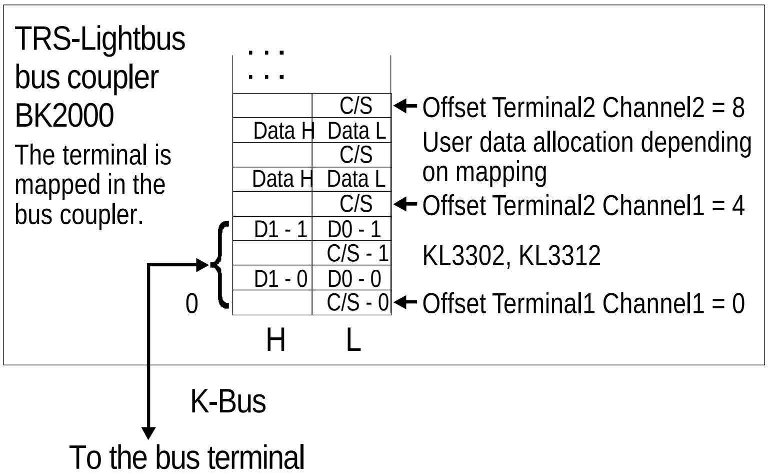
earth-free thermocouple

Terminal configuration

The terminal can be configured and parametrized by way of the internal register structure.
Each terminal channel is mapped in the bus coupler. The terminal's data is mapped differently in the bus coupler's memory depending on the type of the bus coupler and on the set mapping configuration (eg.Motorola / Intel format, word alignment,...). For parametrization of a terminal, the control /status byte must also be mapped.

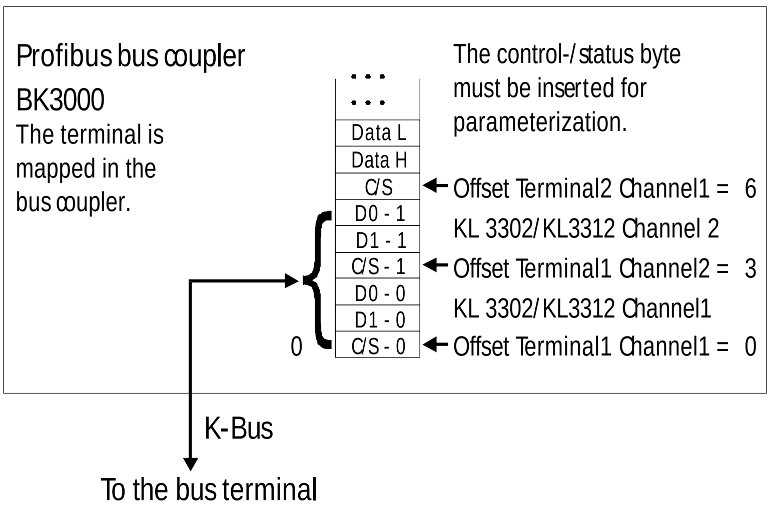
TRS Lightbus Coupler BK2000

In the case of the TRS Lightbus coupler BK2000, the control /status byte is always mapped besides the data bytes. It is always in the low byte at the offset address of the terminal channel.



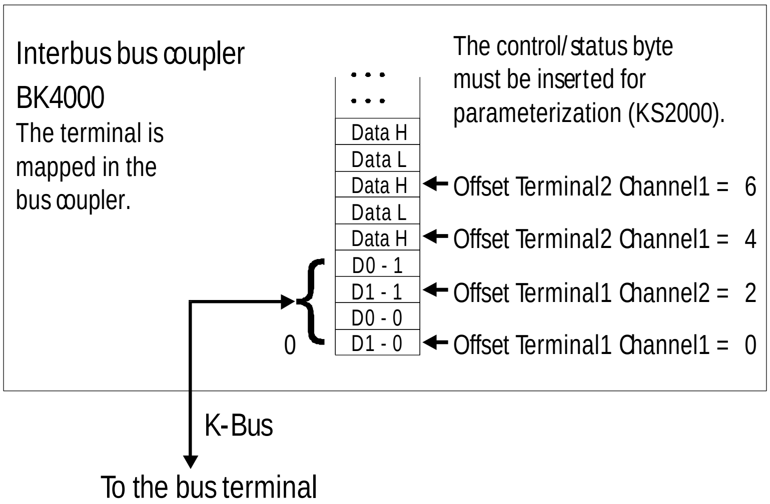
Profibus Coupler BK3000

In the case of the Profibus coupler BK3000, for which terminal channels the control /status byte is also to be inserted must be defined in the master configuration .If the control /status byte is not evaluated, the KL3302/KL3312 occupies 4 bytes of input data (2 bytes of user data per channel).



Interbus Coupler BK4000

By default, the Interbus coupler BK4000 maps the KL3302/KL3312 with 4 bytes of input data (2 bytes of user data per channel). Parametrization via the field bus is not possible. The KS2000 software is required for configuration if use is to be made of the control /status byte.



Other bus couplers and further information

You will find further information on the mapping configuration of bus couplers in the annex of the respective bus coupler manual under the heading of "Configuration of masters".

Reference

The annex contains an overview of the possible mapping configurations depending on the adjustable parameters.

Parametrization with the KS2000 software

Parametrization operations can be carried out independantly of the field bus system using the TRS KS2000 configuration software via the serial configuration interface in the bus coupler.

Register communication KL3302/3312

General register description

Complex terminals that possess a processor are capable of bidirectionally exchanging data with the higher-level control system. Below, these terminals are referred to as intelligent bus terminals. They include the analog inputs (0-10V, -10-10V, 0-20mA, 4-20mA), the analog outputs (0-10V, -10-10V, 0-20mA, 4-20mA), serial interface terminals (RS485, RS232, TTY, data transfer terminals), counter terminals, the encoder interface, the SSI interface, the PWM terminal and all other parametrizable terminals.

Internally, all intelligent terminals possess a data structure that is identical in terms of its essential characteristics. This data area is organized in words and embraces 64 memory locations. The essential data and parameters of the terminal can be read and adjusted by way of this structure. Function calls with corresponding parameters are also possible. Each logical channel of an intelligent terminal has such a structure (therefore, 4-channel analog terminals have 4 register sets).

This structure is broken down into the following areas:
(You will find a list of all registers at the end of this documentation).

Area	Address
Process variables	0-7
Type registers	8-15
Manufacturer parameters	16-31
User parameters	32-47
Extended user area	48-63

Process variables

R0 - R7 Registers in the terminal's internal RAM:

The process variables can be used in addition to the actual process image and their functions are specific to the terminal.

R0 - R5: These registers have a function that depends on the terminal type.

R6: Diagnostic register

The diagnostic register may contain additional diagnostic information. In the case of serial interface terminals, for example, parity errors that have occurred during data transfer are indicated.

R7: Command register

High-Byte_Write = function parameter
Low-Byte _Write = function number
High-Byte _Read = function result
Low-Byte_ Read = function number

Type registers

R8 - R15 Registers in the terminal's internal ROM

The type and system parameters are programmed permanently by the manufacturer and can only be read by the user, but cannot be modified.

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 an ASCII character string.

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

In comparison with R10, the number of logically existing channels is located here. For example, one physically existing shift register may consist of several signal channels.

R12: Minimum data length

The respective byte contains the minimum data length of a channel to be transferred. The status byte is omitted if the MSB is set.

R13: Data type register

Data type register	
0x00	Terminal without valid data type
0x01	Byte array
0x02	1 byte n bytes structure
0x03	Word array
0x04	1 byte n words structure
0x05	Double word array
0x06	1 byte n double words structure
0x07	1 byte 1 double word structure
0x08	1 byte 1 double word structure
0x11	Byte array with a variable logical channel length
0x12	1 byte n bytes structure with a variable logical channel length (eg 60xx)
0x13	Word array with a variable logical channel length
0x14	1 byte n words structure with a variable logical channel length.
0x15	Double word array with a variable logical channel length
0x16	1 byte n double words structure with a variable logical channel length

R14: not used

R15: Alignment bits (RAM)

The analog terminal is set to a byte limit in the terminal bus with the alignment bits.

Manufacturer Parameters

R16 - R30 is the area of the "Manufacturer Parameters" (SEEROM)

The manufacturer parameters are specific to each terminal type. They are programmed by the manufacturer, but can also be modified from the control system. The manufacturer parameters are stored permanently in a serial EEPROM in the terminal and are therefore not destroyed by power failures.
These registers can only be modified after setting a code word in R31.

User Parameters

R31 - R47 " Application Parameters" area (SEEROM)

The application parameters are specific to each terminal type. They can be modified by the programmer. The application parameters are stored permanently in a serial EEPROM in the terminal and cannot be destroyed by power failures. From software version 2.A, the user area is write-protected by way of a code word.

R31: Code word register in the RAM

The code word 0x1235 must be entered here to enable modification of parameters in the user area. Write protection is set if a different value is entered in this register. When write protection is inactive, the code word is returned during reading of the register. The register contains the value zero when write protection is active.

R32: Feature register

This register defines the operating modes of the terminal. For example, a user-specific scaling can be activated for the Analog I/O`s.

R33 - R47

Registers that depend on the terminal type.

Extended application area

R47 - R63

These registers have not yet been implemented.

Register access via process data transfer.

bit 7=1: register mode

When bit 7 of the control byte is set, the first two bytes of the user data are not used for process data transfer, but are written into or read out of the terminal's register set.

bit 6=0: read
bit 6=1: write

In bit 6 of the control byte, you define whether a register is to be read or written. When bit 6 is not set, a register is read without modification. The value can be taken from the input process image.
When bit 6 is set, the user data is written into a register. The operation is concluded as soon as the status byte in the input process image has assumed the same value as the control byte in the output process image.

bits 0 to 5: address

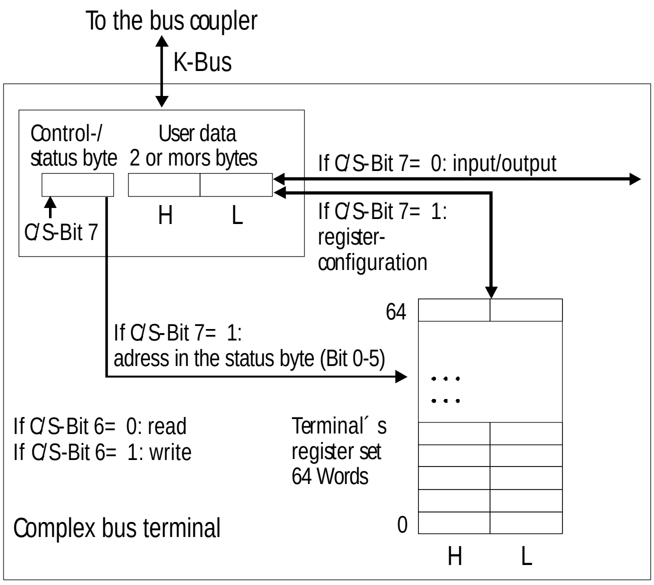
The address of the register to be addressed is entered in bits 0 to 5 of the control byte.

Control byte in the register mode

MSB

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

REG = 0 : Process data transfer
REG = 1 : Access to register structure
W/NR = 0 : Read register
W/NR = 1 : Write register
A5..A0 = Register address
A total of 64 registers can be addressed with the addresses A5...A0.



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 to this rule: here, an unused data byte is inserted after the control or status byte, thus setting the register value to a word limit.)

Example

Reading register 8 in the BK2000 with a Kl3022 and the end terminal.

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

Byte0	Byte1	Byte2	Byte3
0x88	0xXX	0xXX	0xXX

the terminal returns the following type designation (0xBCE corresponds to the unsigned integer 3022)

Byte0	Byte1	Byte2	Byte3
0x88	0x00	0xCE	0x0B

A further example

Writing register 31 in the BK2000 with an intelligent terminal and the end terminal.

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

Byte0	Byte1	Byte2	Byte3
0xDF	0xXX	0x12	0x35

the user code word is set and the terminal returns the register address with the bit 7 for register access as the acknowledgement.

Byte0	Byte1	Byte2	Byte3
0x9F	0x00	0x00	0x00

Terminal-specific register description Process variables

R0: ADC raw value X_R
This register contains the ADC raw value of the connected thermocouple in accordance with (Eq. 0.1)
(0x0000 corresponds to approximately -125mV, 0x8000 to approximately 0V, 0xFFFF to approximately 125mV, i.e. gain and offset errors are included)

R1-R5: no function

R6: diagnostic register
High byte: not used
Low byte: status byte

Manufacturer parameters

R16: hardware version number
The hardware version number of the terminal is stored in this register.

R17: offset – hardware B_a
16 bit signed integer
The offset of the terminal is adjusted via this register (Eq. 1.2).
Register value approximately 0x0000

R18: gain-hardware A_a
The gain of the terminal is adjusted via this register (Eq. 1.2).
Register value approximately 0x3D4X

R19: manufacturer offset B_h
16 bit signed integer [0x0000]
This register contains the offset of the manufacturer's linear equation (1.6). The linear equation is activated via R32.

R20: manufacturer scaling A_h
16 bit signed integer *2^-8 [0x00A0]
This register contains the scaling factor of the manufacturer's linear equation (1.6). The linear equation is activated via R32.

R21: manufacturer gain adjustment for comparison voltage
[approximately 0x01XX]

Application parameters

R32: feature register:
[0x1006]

Feature bit No.		Description of the operating 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] By default, the watchdog timer is on.
Bit 3	1	Signed integer [0] Instead of 2's complement notation, the signed integer format is active. (-1 = 0x8001)
Bit 4	1	Siemens output format [0] With this bit, status flags are inserted in the three least significant bits (see below).
Bit 7-5	-	Not used
Bit 8	1	Comparison temperature off [0]
Bit 9	-	Not used
Bit 10	1	No check of the low measurement range limit. [0]
Bit 15 14 13 12	Thermocouple used	Valid measurement range
0 0 0 0	Type:L	-25°C - 900°C
0 0 0 1	Type: K	-100°C - 1370°C
0 0 1 0	Type: J	-100°C - 1200°C
0 0 1 1	Type: E	-100°C - 1000°C
0 1 0 0	Type: T	-100°C - 400°C
0 1 0 1	Type: N	-100°C - 1300°C
0 1 1 0	Type: U	-25°C - 600°C
0 1 1 1	Type: B	600°C - 1800°C
1 0 0 0	Type: R	0°C - 1700°C
1 0 0 1	Type: S	0°C - 1700°C
1 1 1 1	Output in µV (4 or 6.4 µV resolution)	-120 to +120 mV

Output format

If only manufacturer scaling is active via the feature register, the output format is as follows:

1Digit <=> 1/10 °C
or 1Digit <=> 6.4 µV

If no scaling is active, the otuput format is as follows:

1Digit <=> 1/16 °C
or 1Digit <=> 4 µV

If the Siemens output format is selected, the three least significnt bits are used for status evaluation. The process data item is mapped in the bits 3-15, and bit 15 is the sign bit. The scaling of the measured value in accordance with the Siemens standard must be achieved via user scaling.

Measured value	Bit 3-15	Bit 2	Bit 1	Bit0
		X	ERROR	Overflow
out of range		0	0	1
in range	Process data item	0	0	0

R33: user offset B_w

16 bit signed integer
This register contains the offset of the user linear equation (1.7). The linear equation is activated via R32.

R34: user scaling A_w

16 bit signed integer * 2^-8
This register contains the scaling factor of the user linear equation (1.7). The linear equation is activated via R32.

CONTROL byte during process data exchange

The control byte is transferred from the controller to the temrinal. In the case of the KL3302/KL3312, the control byte has no function.

STATUS byte during process data exchange

The status byte is transferred from the terminal to the controller. The status byte contains various status bits of the analog input terminals KL3002 and KL3312. In the case of the KL3312, the Error bit and the Overrange bit are set in the event of a wire breakage.

Status byte:

Bit 7 = 0
Bit6= 1: ERROR – General error bit
Bit5- Bit2: not used
Bit1= 1: overrange
Bit0= 1: underrange

KL3302 adjustment

The terminal KL3302 is adjusted when delivered.

To compensate for tolerances of the external components, gain and offset registers are implemented for adjusted of each channel's thermocouple voltage. These are R17 (thermocouple voltage offset) and R18 (thermocouple voltage gain) and, for adjustment of the comparison point temperature (temperature of the transition point from the thermocouple to the terminal contacts), a gain register R21 that is identical for both register sets.

As from software version "1A", adjustment can be carried out as follows:

First of all adjust the offset with 0V input voltage with the comparison temperature and linearisation off. To do this, enter 0xF100 in the feature register. This is followed by gain adjustment with a voltage that must not exceed 125 mV (typical value: 70 mV). With this setting of the terminal, and with manufacturer scaling deactivated, the voltage output is 4 microvolts per digit.

Gain and offset adjustment of the thermocouple voltage is carried separately for each channel.

Then adjust the temperature of the comparison point. To enable this, you must select a thermocouple via the feature register and offset of the comparison point temperature must be active (R32 0x1006 Type K) with the inputs shorted (0V), the temperature of the contacts is determined and the temperature output by the terminal (recorded via an internal temperature sensor) is set accordingly (by means of R21).

The compariosn point temperature must be adjusted once for each terminal, i.e. R21 is identical for both channels.

Annex

As already described in the chapter on terminal configuration, each bus terminal is mapped in the bus coupler. In the standard case, this mapping is done with the default setting in the bus coupler / bus terminal. This default setting can be modified with the TRS Configuration software KS2000 or using Master Configuration (eg ComProfibus). The following tables provide information on how the KL3302/3312 maps itself in the bus coupler depending on the set parameters.

Mapping in the bus coupler

The KL3302/3312 is mapped in the bus coupler depending on the set parameters. If the terminal is evaluated completely, the terminal occupies memory space in the process image of the inputs and outputs.

Parameters	I/O Offset	High Byte	Low Byte
Complete evaluation = 0 MOTOROLA format = 0 Word alignment = X	3		
	2		
	1	D1 – 1	D0 - 1
	0	D1 – 0	D0 - 0

Parameters	I/O Offset	High Byte	Low Byte
Complete evaluation = 0 MOTOROLA format = 1 Word alignment = X	3		
	2		
	1	D0 - 1	D1 – 1
	0	D0 - 0	D1 – 0

Parameters	I/O Offset	High Byte	Low Byte
Complete evaluation = 1 MOTOROLA format = 0 Word alignment = 0	4		
	3	D1 - 1	D0 – 1
	2	CT/ST - 1	D1 - 0
	1	D0 – 0	CT/ST - 0

Parameters	I/O Offset	High Byte	Low Byte
Complete evaluation = 1 MOTOROLA format = 1 Word alignment = 0	4		
	3	D0 – 1	D1 - 1
	2	CT/ST - 1	D0 – 0
	1	D1 - 0	CT/ST - 0

Parameters	I/O Offset	High Byte	Low Byte
Complete evaluation = 1 MOTOROLA format = 0 Word alignment = 1	4	D1 - 1	D0 – 1
	3		CT/ST - 1
	2	D1 - 0	D0 – 0
	1		CT/ST - 0

Parameters	I/O Offset	High Byte	Low Byte
Complete evaluation = 1 MOTOROLA format = 1 Word alignment = 1	4	D0 – 1	D1 - 1
	3		CT/ST - 1
	2	D0 – 0	D1 - 0
	1		CT/ST - 0

Legend

Complete evaluation: the terminal is mapped with control / status byte.
Motorola format: The Motorola or Intel format can be set.
Word alignment: The terminal is at a word limit in the bus coupler.
CT: Control Byte (appears in the PI of the outputs).
ST: Status Byte (appears in the PI of the inputs).
D0 - 0 : D0 = Data-Low-Byte, 0 = Channel 0
D1 – 1 : D1 = Data-High-Byte, 1 = Channel 1

Table of the KL3302/3312 register set

Address	Description	Default	R/W	Storage medium
R0	Raw ADC value	variable	R	RAM
R1	not used	0x0000	R	
R2	not used	0x0000	R	
R3	not used	0x0000	R	
R4	not used	0x0000	R	
R5	not used	0x0000	R	
R6	Diagnostic register	variable	R	RAM
R7	Command register - not used	0x0000	R	
R8	Terminal type	3302/ 3312	R	ROM
R9	Software version number	0x????	R	ROM
R10	Multiplex-shift register	0x0218	R	ROM
R11	Signal channels	0x0218	R	ROM
R12	minimum data length	0x0098	R	ROM
R13	Data structure	0x0000	R	ROM
R14	not used	0x0000	R	
R15	Alignment-register	variable	R/W	RAM
R16	Hardware version number	0x????	R/W	SEEROM
R17	Hardware offset adjustment	specific	R/W	SEEROM
R18	Hardware gain adjustment	specific	R/W	SEEROM
R19	Manufacturer scaling: offset	0x0000	R/W	SEEROM
R20	Manufacturer scaling: gain	0x00A0	R/W	SEEROM
R21	Hardware adjustment compare temperature	specific	R/W	SEEROM
R22	not used	0x0000	R/W	SEEROM
R23	not used	0x0000	R/W	SEEROM
R24	not used	0x0000	R/W	SEEROM
R25	not used	0x0000	R/W	SEEROM
R26	not used	0x0000	R/W	SEEROM
R27	not used	0x0000	R/W	SEEROM
R28	not used	0x0000	R/W	SEEROM
R29	not used	0x0000	R/W	SEEROM
R30	not used	0x0000	R/W	SEEROM
R31	Code word register	variable	R/W	RAM
R32	Feature register	0x1006	R/W	SEEROM
R33	User offset	0x0000	R/W	SEEROM
R34	User gain	0x0100	R/W	SEEROM
R35	not used	0x0000	R/W	SEEROM
R36	not used	0x0000	R/W	SEEROM
R37	not used	0x0000	R/W	SEEROM
R38	not used	0x0000	R/W	SEEROM
R39	not used	0x0000	R/W	SEEROM
R40	not used	0x0000	R/W	SEEROM
R41	not used	0x0000	R/W	SEEROM
R42	not used	0x0000	R/W	SEEROM
R43	not used	0x0000	R/W	SEEROM
R44	not used	0x0000	R/W	SEEROM
R45	not used	0x0000	R/W	SEEROM
R46	not used	0x0000	R/W	SEEROM
R47	not used	0x0000	R/W	SEEROM