MODBUS
Bus Terminal Controller
BC7300

Version: 1.5
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BECKHOFF

Please note the following

Target group

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

Safety requirements

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.

The documentation has been prepared with care. The products described are, however, constantly under development. For that reason the documentation is not in every case checked for consistency with performance data, standards or other characteristics, and does not represent an assurance of characteristics in the sense of § 459, Para. 2 of the German Civil Code. In the event that it contains technical or editorial errors, we retain the right to make alterations at any time and without warning. No claims for the modification of products that have already been supplied may be made on the basis of the data, diagrams and descriptions in this documentation.

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Foreword

Notes on the documentation

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Liability Conditions

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Delivery conditions

In addition, the general delivery conditions of the company Beckhoff Automation GmbH apply.

Copyright

Safety Instructions

State at Delivery

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.

Description of safety symbols

The following safety symbols are used in this documentation. They are intended to alert the reader to the associated safety instructions..

Danger	This symbol is intended to highlight risks for the life or health of personnel.
Attention	This symbol is intended to highlight risks for equipment, materials or the environment.
Note	This symbol indicates information that contributes to better understanding.

Basic Principles

Device Description of the BC7300

The BC7300 Bus Terminal Controller is a Bus Coupler with integrated PLC functionality and a MODBUS slave interface.
The controller is programmed in IEC 1131-3. Up to 64 terminals belonging to the Beckhoff Bus Terminal System can be connected to the BC7300. These include analog signal types for current and voltage, as well as PT100 and thermocouples, in addition to digital input and output terminals. The Bus Terminal Controller's MODBUS interface allows a MODBUS master to be connected.

The Beckhoff Bus Terminal System

Up to 64 Bus Terminals

Each having 2 I/O channels for each signal form

The Bus Terminal system is the universal interface between a fieldbus system and the sensor / actuator level. A unit consists of a Bus Coupler as the head station, and up to 64 electronic series terminals, the last one being an end terminal. For each technical signal form, terminals are available each having two I/O channels, and these can be mixed in any order. All the terminal types have the same mechanical construction, so that difficulties of planning and design are minimised. The height and depth match the dimensions of compact terminal boxes.

De-centralised wiring of each I/O level

IPC as controller

Fieldbus technology allows more compact forms of controller to be used. The I/O level does not have to be brought to the controller. The sensors and actuators can be wired de-centrally, using minimum cable lengths. You can locate the controller installation anywhere within the plant. The use of an Industrial PC as the controller means that the operating and observing element can be implemented in the controller’s hardware. The controller can therefore be located at an operating panel, in a control room, or at some similar place. The Bus Terminals form the de-centralised input/output level of the controller in the control cabinet and the subsidiary terminal boxes. The power sector of the plant is also controlled over the bus system in addition to the sensor/actuator level. The Bus Terminal replaces the conventional series terminal as the wiring level in the control cabinet. The control cabinet can have smaller dimensions.

Bus Couplers for all usual bus systems

The Beckhoff Bus Terminal system unites the advantages of a bus system with the possibilities of the compact series terminal. Bus Terminals can be driven within all the usual bus systems, thus reducing the controller parts count. The Bus Terminals then behave like conventional connections for that bus system. All the performance features of the particular bus system are supported.

Standard C - rail assembly

The easy, space-saving assembly on a standard C-rail, and the direct wiring of actuators and sensors without cross-connections between the terminals standardises the installation. The consistent labelling scheme also contributes.

The small physical size and the great flexibility of the Bus Terminal system allows it to be used wherever a series terminal is also used. Every type of connection, such as analog, digital, serial or the direct connection of sensors can be implemented.

Modularity

The modular assembly of the terminal strip with Bus Terminals of various functions limits the number of unused channels to a maximum of one per function. The presence of two channels in one terminal is the optimum compromise of unused channels and the cost of each channel. The possibility of galvanic isolation through potential feed terminals also helps to keep the number of unused channels low.

Display of the channel state The integrated LEDs show the state of each channel at a location close to the sensors and actuators.

K-Bus

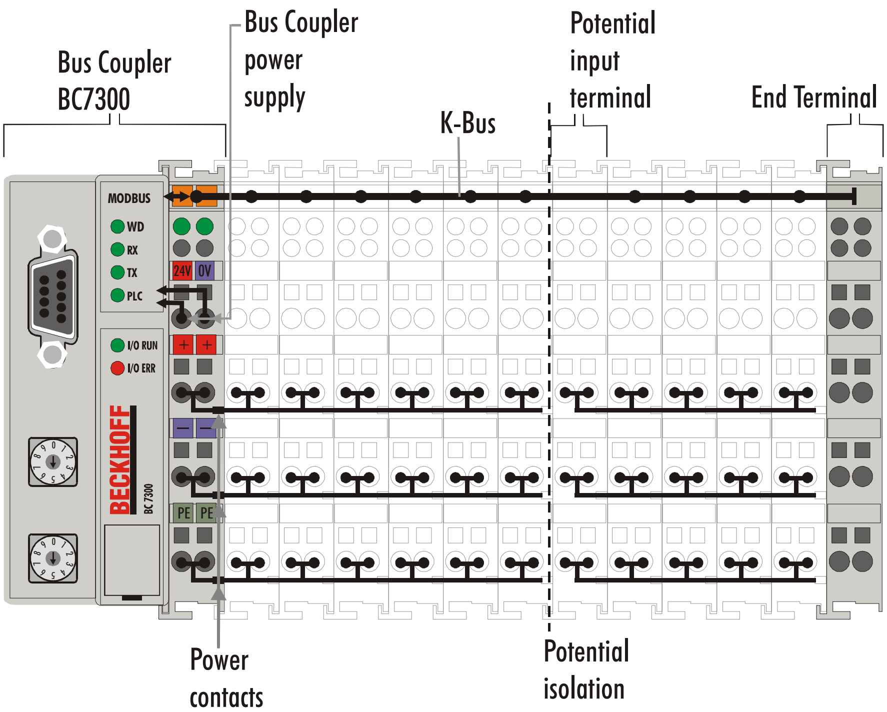
End terminal

The K-Bus is the data path within a terminal strip. The K-Bus is led through from the Bus Coupler through all the terminals via six contacts on the terminals‘ side walls. The end terminal terminates the K-Bus. The user does not have to learn anything about the function of the K-Bus or about the internal workings of the terminals and the Bus Coupler. Many software tools that can be supplied make project planning, configuration and operation easy.

Potential feed terminals for galvanically isolated groups The operating voltage is passed on to following terminals via three power contacts. You can divide the terminal strip into arbitrary galvanically isolated groups by means of potential feed terminals. The feed terminals play no part in the control of the terminals, and can be inserted at any points within the terminal strip.

Up to 64 terminals may be located in a terminal strip, including the potential feed terminals and end terminal.

The principle of the Bus Terminal



Additional characteristics of the Bus Terminal Controllers Bus Terminal Controllers (BC) differ from Bus Couplers (BK) in that, in addition to K-Bus processing, a real-time PLC task is also running. Unlike Bus Couplers, the signals from the terminals are processed by the PLC task, while the fieldbus carries the in- and outputs of the PLC task. It is possible, however, to subdivide the Bus Terminals to that some Bus Terminals are pre-processed by the PLC task, while others are sent directly over the fieldbus to a supervising system.

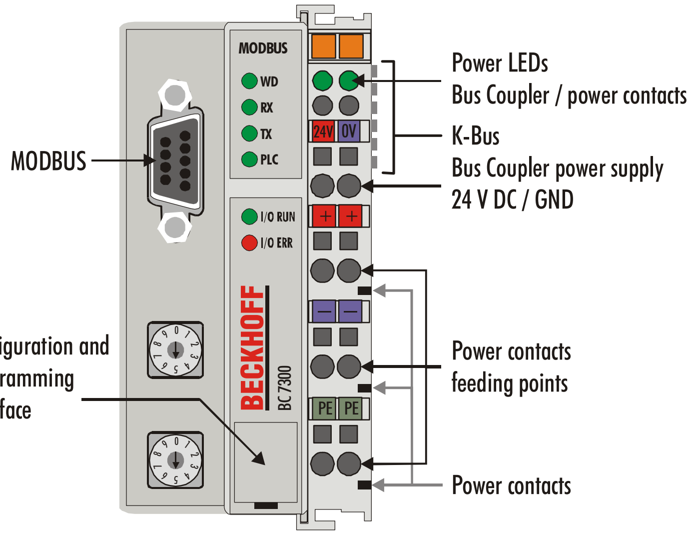
Bus Terminal Controllers for various fieldbus systems Various Bus Terminal Controllers can be used to couple the electronic terminal strip with integrated PLC task quickly and easily to different fieldbus systems. It is also possible to convert to another fieldbus system at a later time. The Bus Terminal Controller performs all the monitoring and control tasks that are necessary for operation of the connected Bus Terminals. The operation and configuration of the Bus Terminals is carried out exclusively by the Bus Terminal Controller. Fieldbus, K-Bus and I/O level are galvanically isolated.

If data exchange over the fieldbus fails, the PLC task continues to run as an autonomous system.

The interfaces

A Bus Terminal Controller has six different methods of connection. These interfaces are designed as plug connectors and as spring-loaded terminals.

The MODBUS – Bus Terminal Controller BC7300



Electrical power supply

24 V DC to the topmost terminals "24 V" and "0 V"

The Bus Terminal Controllers require a 24 V DC supply for their operation. The connection is made by means of the upper spring-loaded terminals labelled "24 V" and "0 V". This supply voltage feeds not only the Bus Coupler electronics via the K-Bus, but also the Bus Terminals. The power supply for the Bus Coupler electronics and that of the K-Bus are electrically separated from the potential of the field level.

Power contacts feeding points

Lower 3 terminal pairs for power feed

Maximum 24 V

Maximum 10 A

The bottom six connections with spring-loaded terminals can be used to feed the supply for the peripherals. The spring-loaded terminals are joined in pairs to a power contact. The feed for the power contacts has no connection to the voltage supply for the Bus Coupler. The design of the feed permits voltages of up to 24 V. The assignment in pairs and the electrical connection between feed terminal contacts allows the connection wires to be looped through to various terminal points. The current drawn from the power contact must not exceed 10 A for long periods. The current rating between two spring-loaded terminals is identical to that of the connecting wires.

Power contacts

Spring contacts on the side

On the right hand face of the Bus Terminal Controller there are three spring contacts for the power contact connections. The spring contacts are hidden in slots so that they can not be accidentally touched. By attaching a Bus Terminal the blade contacts on the left hand side of the Bus Terminal are connected to the spring contacts. The tongue and groove guides on the top and bottom of the Bus Terminal Controllers and of the Bus Terminals guarantees that the power contacts mate securely.

Fieldbus connection

9 pin sub-D socket strip

There is a recessed front face on the left hand side. The MODBUS connection plug can be inserted here. A full description of the fieldbus interfaces is found elsewhere in this manual. (In the section on The Medium: Plugs and Cables)

Configuration and programming interface

Serial interface under the front cover

The standard Bus Terminal Controllers have an RS232 interface at the bottom of the front face. The miniature connector can be joined to a PC with the aid of a connecting cable and either the KS2000 configuration software or TwinCAT BC. The interface allows the analog channels to be configured with the KS2000 software. The BC7300 is programmed via the same interface.

KS2000 Software

In order to link the MODBUS BK7300 Bus Terminal Controller and the KS2000 configuration software, the coupler's address selection switch must be set to "00", and it must be restarted (i.e. the coupler must be switched off and then on again). The MODBUS must not be connected.

TwinCAT BC

In order to link the MODBUS BK7300 Bus Terminal Controller and the TwinCAT BC programming software, the coupler's address selection switch must be set to "00", and it must be restarted (i.e. the coupler must be switched off and then on again). The MODBUS must not be connected.

K-Bus Contacts

6 contacts on the side

In order to connect the Bus Coupler and Bus Terminals the Bus Coupler has gold contacts on the right hand side. When the Bus Terminals are pushed together the gold contacts automatically make the connection between the Bus Terminals. The voltage supply to the K-Bus electronics in the Bus Terminals and the data exchange between the Bus Coupler and the Bus Terminals is carried out by the K-Bus. A part of the data exchange takes place via a ring structure within the K-Bus. Opening the K-Bus, e.g. by pulling out one of the Bus Terminals, opens the ring. Data exchange is no longer possible. Special mechanisms nevertheless allow the Bus Coupler to identify the location of the interruption and to report it.

Electrical isolation

3 potential groups:
Fieldbus
K-Bus
Peripheral level

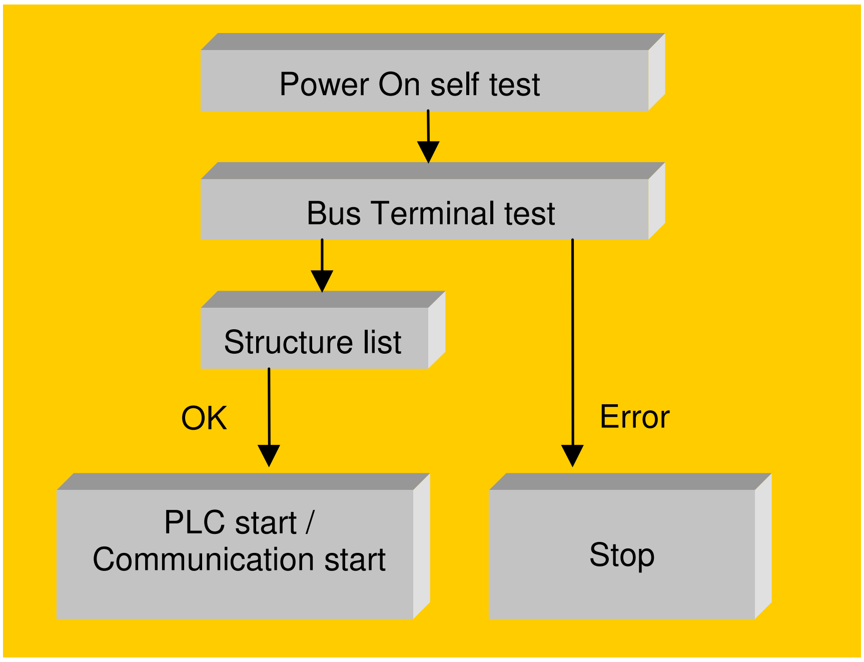
The Bus Terminal Controllers operate by means of three independent potential groups. The supply voltage feeds the K-Bus electronics in the Bus Terminal Controller and the K-Bus itself, which is electrically separate. The supply voltage is also used to generate the operating voltage for the fieldbus.

Remark: All the Bus Terminals are galvanically isolated from the K-Bus. The K-Bus is thus galvanically isolated from everything else.

Operating Modes of the Bus Terminal Controller

Immediately after being switched on, the Bus Terminal Controller checks, in the course of a “self test”, all the functions of its components and the communication of the K-Bus. The red I/O LED blinks while this is happening. After completion of the self-test, the Bus Terminal Controller starts to test the attached Bus Terminals (in a "Bus Terminal test"), and reads in the configuration. An internal structure list is created from the Bus Terminal configuration. In case of an error, the Bus Terminal Controller enters the „STOP“ state. Once the start-up has completed without error, the Bus Terminal Controller enters the "fieldbus start" state.

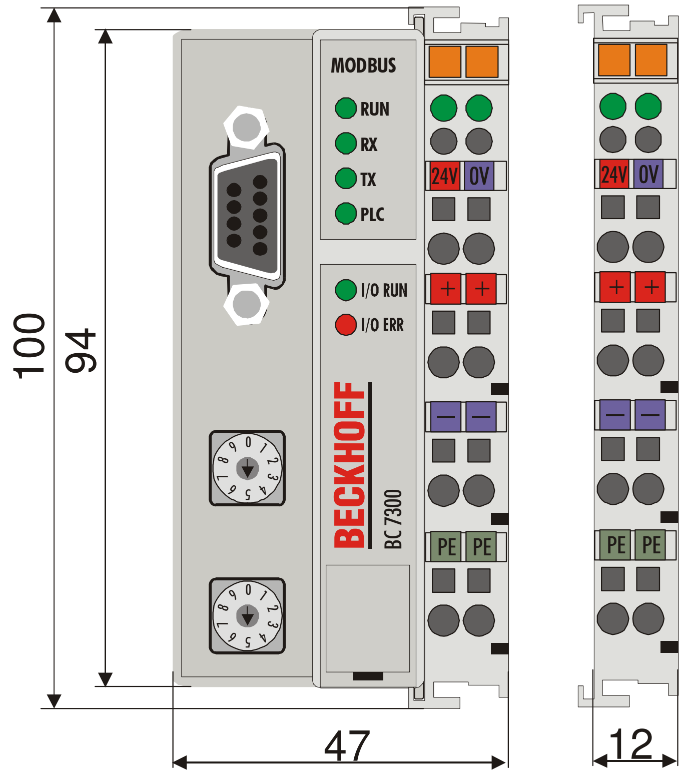
Start-up behaviour of the Bus Terminal Controller



Mechanical structure

The system of the Beckhoff Bus Terminals is characterised by low physical volume and high modularity. When planning a project it must be assumed that at least one Bus Coupler and a number of Bus Terminals will be used. The mechanical dimensions of the Bus Couplers are independent of the fieldbus system. If large plugs are used, such as, for example, certain bus plugs for the Profibus, the maximum height of the housing can be exceeded.

Dimensions of a Bus Coupler in mm



The total width in practical cases is composed of the width of the Bus Coupler with the bus end terminal and the width of the Bus Terminals in use. Depending on function, the Bus Terminals are 12 or 24 mm wide. The front wiring increases the total height of 68 mm by about 5 to 10 mm, depending on the wire thickness.

Assembly and connection

The Bus Coupler and all the Bus Terminals can be clipped by light pressure onto a 35 mm C-mounting rail. A locking mechanism prevents the individual housings from being pulled off again. For removal from the mounting rail the orange coloured tension strap releases the latching mechanism, allowing the housing to be pulled off the rail without any force. Work should only be carried out on the Bus Terminals and the Bus Coupler when switched off. Pulling out and inserting under power can cause undefined states to be temporarily caused. (A reset of the Bus Coupler, for example).

Maximum number of terminals

Up to 64 Bus Terminals can be attached to the Bus Coupler on the right hand side. When plugging the components together, be sure to assemble the housings with groove and tongue against each other. A properly working connection can not be made by pushing the housings together on the mounting rail. When correctly assembled, no significant gap can be seen between the attached housings.

The right hand part of the Bus Coupler can be compared to a Bus Terminal. Eight connections on the top permit connection with solid or fine wires. The connection is implemented with the aid of a spring device. The spring-loaded terminal is opened with a screwdriver or rod, by exerting gentle pressure in the opening above the terminal. The wire can be inserted into the terminal without any force. The terminal closes automatically when the pressure is released, holding the wire securely and permanently.

The connection between the bus coupler and the bus terminals is automatically realised by pushing the components together. The transfer of the data and the supply voltage for the intelligent electronics in the Bus Terminals is performed by the K-Bus. The supply of the field electronics is performed for the digital Bus Terminals through the power contacts.

Plugging together the power contacts creates a supply rail. Note the circuit diagrams for the Bus Terminals, since some Bus Terminals do not loop these power contacts through, or only do so partially (e.g. analog Bus Terminals or 4 channel digital Bus Terminals). The potential feed terminals interrupt the power contacts, and represent the start of a new supply rail. The Bus Coupler can also be made use of to feed the power contacts.

Insulation testing

The power contact labelled “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. Note that, for reasons of electromagnetic compatibility, the PE contacts are capacitatively coupled to the mounting rail. This can both lead to misleading results and to damaging the terminal during insulation testing. (e.g.: breakdown of the insulation from a 230 V power user to the PE conductor.) The PE conductor to the Bus Coupler must be disconnected for the insulation testing. In order to uncouple further feed locations for the purposes of testing, the feed terminals can be pulled at least 10 mm out from the connected group of other terminals. In that case, the PE conductors do not have to be disconnected.

PE power contacts

The “PE” power contact must not be used for other potentials.

Technical data

The MODBUS – the fieldbus-specific electrical data is listed in this section. The following table gives an overview of all the data:

Technical data	BC7300
Supply voltage	24 V DC
Input current	70mA + (total K-Bus current)/4 500 mA max.
Power-on surge	2.5 x steady operating current
K Bus supply current up to	1750 mA max.
Configuration facility	via KS2000 or the controller
Number of Bus Terminals	64
Digital peripheral signals	256 inputs/outputs
Analog peripheral signals	128 inputs/outputs
Baud rate	From 150 baud to 38400 baud
Protocol	RTU and ASCII
Bus connection	D-Sub RS 485 9-pin
Voltage of the power contact	24 V DC / AC max.
Power contacts current drawn	10 A max.
Electric strength	500 Veff (power contact / supply voltage / fieldbus) none
Typical weight	170 g
Operating temperature	0°C ... +55°C
Storage temperature	-20°C ... +85°C
Relative humidity	95% without dew formation
Vibrations/Shock resistance	conforms to IEC 68-2-6 / IEC 68-2-27
EMC resistance burst / ESD	conforms to EN 50082 (ESD, Burst) / EN 50081
Installation position	any
Type of protection	IP20
PLC data	
Programmability	via programming interface (TwinCAT BC/TwinCAT)
Program size	approx. 3000 PLC statements
Program memory	32 kbytes / 96 kbytes
Data memory	32 kbytes / 64 kbytes
Remanent flags	512 bytes
Runtime system	1 PLC task
PLC cycle time	approx. 3 ms for 1000 instructions (including K-Bus I/O cycle)
Programming languages	IL, LD, FBD, SFC, ST
Station addresses	selectable to 99 via DIP switch 0 Programming mode and configuration mode 1 – 99 Slave address
Baud rate in programming mode	19,200 baud, 8 data bits, even parity, one stop bit

Current consumption on the K-Bus

The Bus Terminals require energy for the operation of the K-Bus electronics, and this is supplied by the Bus Coupler. Find the current consumption of the K-Bus from the catalogue, or from the appropriate data sheets for the Bus Terminals. Consider the maximum output current of the Bus Coupler that is available for supply of the Bus Terminals. A special power supply terminal (KL9400) can be inserted at any location to insert more power into the K-Bus. Refer to Beckhoff's technical support department regarding the use of a power supply terminal.

Peripheral Data in the Process Image

After being switched on, the Bus Coupler determines the configuration of the inserted input/output terminals. The assignment of the physical slots for the input/output channels and the addresses in the process image is carried out automatically by the Bus Coupler.

The Bus Coupler creates an internal assignment list, in which the input/output channels have a specific position in the process image. A distinction is made here according to inputs and outputs, and according to bit-oriented (digital) and byte-oriented (analog or complex) signal processing.

Two groups are created, one for inputs and the other for outputs. Each group has the byte-oriented channels in ascending sequence starting from the lowest address. The bit-oriented channels are placed after this block.

Digital signals (bit-oriented)

The digital signals are bit-oriented. This means that one bit in the process image is assigned to each channel. The Bus Coupler creates a memory area containing the current input bits, and ensures that the bits in a second memory area dedicated to the output channels are written out immediately.

The details of the assignment of the input and output channels to the controller's process image is explained fully with the aid of an example in the appendix.

Analog signals (byte-oriented)

The processing of all analog signals is always byte-oriented. Analog input and output values are represented in memory by two bytes each. Values are represented in SIGNED INTEGER or two‘s complement format. The number "0" stands for the input/output value "0 V", "0 mA" or "4 mA". The maximum value of an output or input value is represented, according to the standard settings, by "7FFF" (hex). Negative input or output values, e.g. -10 V, are represented from "8000" (hex). The intermediate values are correspondingly proportional. A range with a resolution of 15 bits is not achieved for all inputs and outputs. If the actual resolution is 12 bits, the last three bits have no effect in outputs, while as inputs they are read as "0". Each channel also has a control and status byte. The control and status byte is the lowest value byte. The master configuration software must specify whether the control/status byte is also mapped into the controller. An analog channel is represented in the process image by 2 bytes of user data.

Special signals and interface

A Bus Coupler supports Bus Terminals with other interfaces such as RS232, RS485, incremental encoder and others. These signals can be considered similarly to the analog signals named above. For some special signals the bit width of 16 is not sufficient. The Bus Coupler can support any byte width.

Default assignment of inputs/outputs to the process image

Once it has been switched on, the Bus Coupler finds out how many Bus Terminals are inserted, and creates an assignment list. The analog and digital channels, divided into inputs and outputs, are assembled into separate parts of this list. The assignment starts on the left next to the Bus Coupler. The software in the Bus Coupler collects the individual entries for each of the channels in order to create the assignment list counting from left to right.

Four groups are distinguished in the assignment:

	Functional type of the channel	Assignment level
1.	Analog outputs	assignment by bytes
2.	Digital outputs	assignment by bits
3.	Analog inputs	assignment by bytes
4	Digital inputs	assignment by bits

Analog inputs and outputs here also represent other Bus Terminals with complex multi-byte signals (RS232, SSI sensor interface, ...)

Data consistency

Items of data are said to be consistent if their content all belongs together, and if they are transmitted as a single block. Examples of data items that belong together are: 1. the high and low bytes of an analog value (word consistency), and 2. a control/status byte and the associated parameter word for access to the registers. Data consistency in the interaction of peripheral devices and their controllers is, in a basic sense, only assured for a single byte. In other words, the bits of a byte are output or read in together. Byte consistency is sufficient for handling digital signals. Whenever values have a length of more than 8 bits, analog values for instance, the consistency must be extended. The different bus systems guarantee consistency up to the required length. Correct transfer of the consistent data from the bus system master to the controller is important. The corresponding manual for the bus system will provide a detailed description of the correct procedure, in particular the description of the used master interfaces. Those chapters of this manual that deal with the fieldbus refer to the most widespread interfaces.

Complex signal processing

All the byte-oriented signal channels such as RS232, RS485 or incremental encoders operate to some extent with byte lengths of more than two. Apart from the difference in length, they are always handled similarly to the analog signals.

Start-up procedure and Diagnostics

After switching on, the Bus Coupler immediately checks the connected configuration. Error-free start-up is signalled by extinction of the red LED "I/O ERR". If the "I/O ERR" LED blinks, an error in the area of the terminals is indicated. The error code can be determined from the frequency and number of blinks. This permits rapid rectification of the error.

The diagnostic LEDs

The Bus Coupler has two groups of LEDs for the display of status. The upper group with four LEDs indicates the status of the respective fieldbus. The significance of the "fieldbus status" LED is explained in the relevant sections of this manual - it conforms to conventional fieldbus displays.

On the upper right hand side of the Bus Couplers are two more green LEDs that indicate the supply voltage. The left hand LED indicates the 24 V supply of the Bus Coupler. The right hand LED signals the supply to the power contacts.

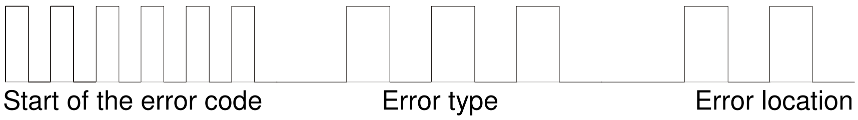
Local errors

Two LEDs, the "I/O LEDs", in the area below the field bus status LEDs referred to above, serve to indicate the operating status of the Bus Terminals and the connections to these terminals. The green LED lights up in order to indicate fault-free operation. The red LED blinks with two different frequencies in order to indicate an error.

The error is encoded in the blinks as follows:

Blink code

Fast blinking	Start of the error code
First slow sequence	Error code
Second slow sequence	Error code argument



Error code	Error argument	Description	Remedy
Persistent, continuous blinking		EMC problems	- Check power supply for overvoltage or undervoltage peaks - Implement EMC measures - If a K-Bus error is present, it can be localised by a restart of the coupler (by switching it off and then on again)
1 pulse	0 1 2	EEPROM checksum error Inline code buffer overflow Unknown data type	- Set manufacturer's setting with the KS2000 - Connect fewer Bus Terminals; too many entries in the table for the programmed configuration - Software update required for the coupler
2 pulses	0 n (n > 0)	Programmed configuration Incorrect table entry / Bus Coupler Incorrect table comparison (Bus Terminal n)	- Check programmed configuration for correctness - Incorrect table entry / Bus Coupler
3 pulses	0	K-Bus command error	- No Bus Terminal connected; attach Bus Terminals. - One of the Bus Terminals is defective; halve the number of Bus Terminals attached and check whether the error is still present with the remaining Bus Terminals. Repeat until the defective Bus Terminal is located.
4 pulses	0 n	K-Bus data error Break behind Bus Terminal n (0: coupler)	- Check whether the n+1 Bus Terminal is correctly connected; replace if necessary. – Check whether the Bus End Terminal 9010 is connected.
5 pulses	n	K-Bus error with register communication with Bus Terminal n	Exchange Bus Terminals
9 pulses	0 n (n>0)	Checksum error in program flash memory Bus Terminal n is not consistent with the configuration that existed at boot image entry	Transmit program to the BC7300 again Check the n^{th} Bus Terminal. If a new Bus Terminal is to be inserted, delete the boot project (manufacturer's setting)
14 pulses	n	Bus Terminal n has the wrong format	- Start the coupler again, and if the error occurs again then exchange the Bus Terminal
15 pulses	n	Number of Bus Terminals is no longer correct	- Start the coupler again, and if the error occurs again after this, use the KS2000 software to set manufacturer's settings
16 pulses	n	Length of the K-Bus data is no longer correct	- Start the coupler again, and if the error occurs again after this, use the KS2000 software to set manufacturer's settings

The number of pulses (n) indicates the position of the last Bus Terminal before the fault. Passive Bus Terminals, such as a power feed terminal, are not included in the count.

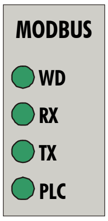
In the case of some errors, rectification does not cause the Bus Coupler to leave the blink sequence. The Bus Coupler stays in the "Stop" state. The Bus Coupler can only be re-started either by switching the power supply off and on again, or by a software reset.
Insertion and removal of Bus Terminals is only permitted when switched

off. The electronics in the Bus Terminals and in the Bus Coupler are protected to a large measure against damage, but incorrect function and damage cannot be ruled out if they are plugged in under power.

The occurrence of a fault in the course of operation does not immediately trigger the display of error codes by the LEDs. The Bus Coupler must be requested to diagnose the Bus Terminals. The diagnostic request is generated after switching on.

MODBUS LEDs

LED:	on	off
WD	Watchdog is active	Watchdog is not yet running or the watchdog time has elapsed
RX	Receive Data	
		Data is being received
TX	Transmit Data	
		Data is being transmitted
PLC	Program running LED flashes while a boot project is being created	



If a K-Bus error occurs during operation, the procedures for reaction to a K-Bus error are executed in accordance with the parameterisation. If the K-Bus error occurs during booting, the slave is not included in the data exchange.

Fieldbus errors

WD

A fieldbus error only occurs when the watchdog (WD) period has elapsed. The watchdog is preset to 1000 ms. The WD is activated as soon as a "write" access has been made to the coupler's process data (WD LED goes on). After this, another "write" command must be sent to the process data within the set WD time, in order to start the WD from zero again.

Once a WD error has occurred, data communication can only be restarted by resetting the coupler (see "Coupler Reset", under Diagnostics).

The maximum watchdog time is 65000 ms, and it can be set by rotary switch or via the KS2000 software.

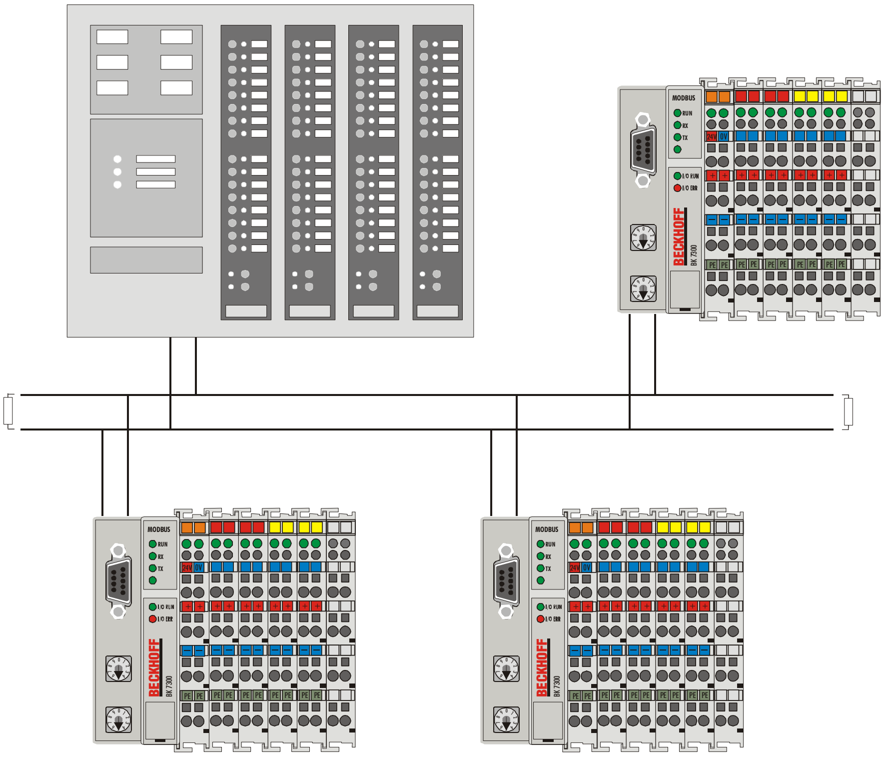
MODBUS

Basic Principles

The MODBUS is a master-slave bus system in which only one device (the master) actively starts a transaction (queries). The passive device (the slave) then sends an answer (response) if the telegram was directly addressed to it and provided that it has no errors.

Bus Topology

The BK7300 uses the RS485 physical data transmission. This means that a two-wire cable is needed for the data transmission. The communication structure corresponds to the linear topology. At the beginning and end of the lines the bus requires termination resistors. The structure of the Modbus network is similar to that of PROFIBUS.



Broadcast function

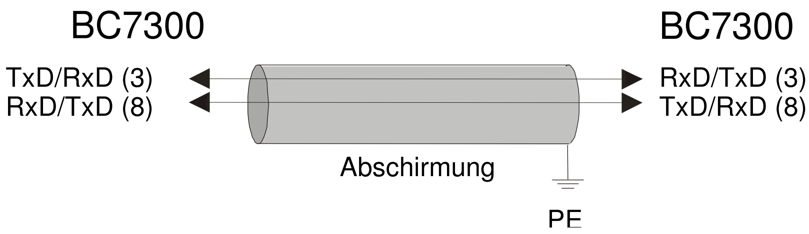
Beckhoff Bus Terminal Controllers support the broadcast function. For this purpose the slave address in the telegram must be set to "00". Slaves do not answer a broadcast. Not all functions are supported.
Functions that support a broadcast:

- 5 Force single coil
- 6 Preset single register
- 15 Force multiple coils
- 16 Preset multiple register

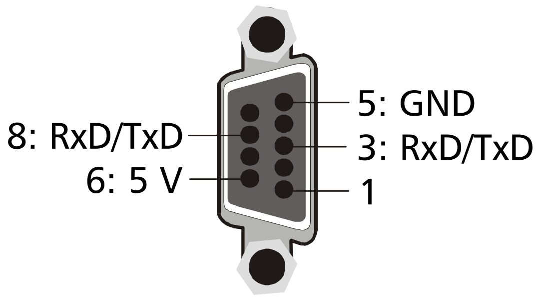
PIN assignment

The BC7300 uses RS485 for the data transmission. A screened two-wire cable is sufficient. The connection to the coupler is a 9-pin sub-D socket. The data line is connected to PIN 3 and PIN 8.

Cable

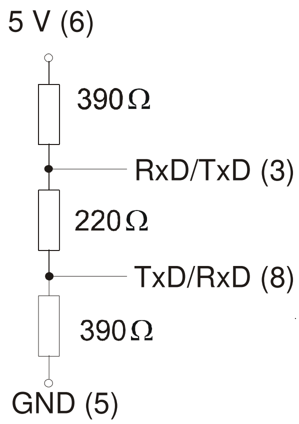


Sub-D socket



Bus termination

The MODBUS requires termination resistors at the beginning and end of the bus lines.



Process Data and Memory Map

The following example illustrates how the process image is constructed in the Bus Terminal Controller, and the functions of the MODBUS telegram with which digital and analog values can be read.

The Bus Terminal Controller has two process images. One is the fieldbus interface and the other is the process image on the Bus Terminal Controller. Bus Terminals can be assigned to one or the other process image. The PLC variables offer an interface between these two process images.

MODBUS
The input process image of the BC7300 starts from address 0x0000. All the byte-oriented Bus Terminals (see Appendix) are entered here into the process image first. The bit-oriented Bus Terminals them follow, and each word (16 bit) is filled before starting a new one. The PLC variables are entered into the process image last.

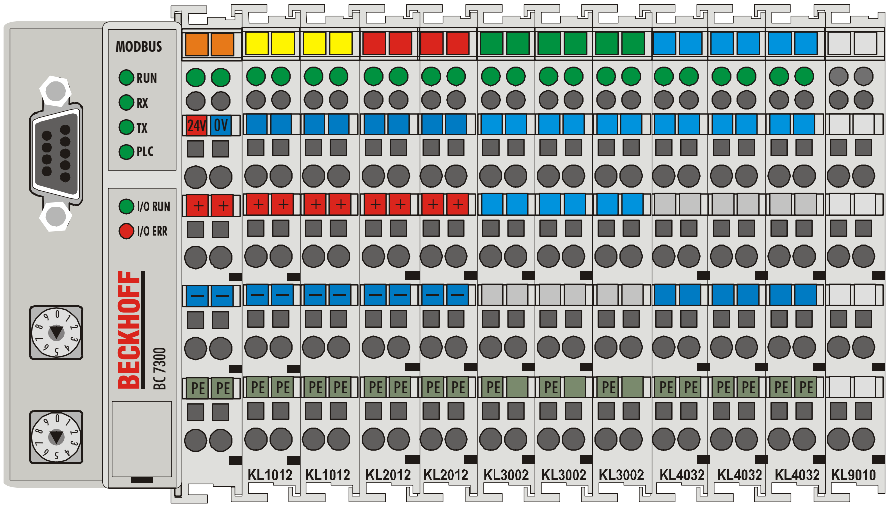
The output process image starts at address 0x0800. The entry begins again here with the byte-oriented Bus Terminals, continues with the bit-oriented Bus Terminals and finally the PLC variables.

All the digital signals can be directly addressed with functions 1, 2, 5 and 15.

Bus Terminal Controller

Example

The process image in the Bus Terminal Controller ignores all the Bus Terminals that have been assigned to the MODBUS process image. The controller first enters all the byte-oriented Bus Terminals, following the sequence with which they are plugged in. The digital Bus Terminals come next. The PLC variables are positioned from addresses %I128 and %Q128.



POS 1	*KL1012 MODBUS terminal*
POS 2	KL1012 BC7300 terminal
POS 3	*KL2012 MODBUS terminal*
POS 4	KL2012 BC7300 terminal
POS 5	*KL3002 MODBUS terminal*
POS 6	KL3002 BC7300 complex terminal
POS 7	KL3002 BC7300 compact terminal
POS 8	*KL4032 MODBUS terminal*
POS 9	KL4032 BC7300 complex terminal
POS 10	KL4002 BC7300 compact terminal
KL9010	
PLC Variables	
POS 11	16 bytes INPUT
POS 12	16 bytes OUTPUT

MODBUS Process Image

MODBUS example

Terminals	Functions	Offset	Length
POS 1. Terminal 2 digital inputs	4, 23	0x0802	16 bit
	2	0x0000 0x0001	1 bit 1 bit
POS 3. Terminal 2 digital outputs	3, 6, 16, 23	0x0002	16 bit
	1, 5, 15	0x0000 0x0001	1 bit 1 bit
POS 5. Terminal 2 analog inputs	4, 23	0x0800 0x0801	16 bit 16 bit
POS 8. Terminal 2 analog outputs	3, 6, 16, 23	0x0000 0x0001	16 bit 16 bit
PLC variables 16 byte inputs	4, 23	0x0803 0x0804 0x0805 0x0806 0x0807 0x0808 0x0809 0x080A	16 bit 16 bit 16 bit 16 bit 16 bit 16 bit 16 bit 16 bit
PLC variables 16 byte outputs	3, 6, 16, 23	0x0003 0x0004 0x0005 0x0006 0x0007 0x0008 0x0009 0x000A	16 bit 16 bit 16 bit 16 bit 16 bit 16 bit 16 bit 16 bit

BC7300 Process Image

Example for the BC7300

Byte address	Terminal	Inputs	Terminal	Outputs
0	KL3002 (POS 6)	Status	KL3002 (POS 6)	Control
1		-		-
2		Data 0		Data 0
3		Data 1		Data 1
4		Status		Control
5		-		-
6		Data 0		Data 0
7		Data 1		Data 1
8	KL3002 (POS 7)	Data 0	KL4032 (POS 9)	Control
9		Data 1		-
10		Data 0		Data 0
11		Data 1		Data 1
12	KL4032 (POS 9)	Status		Control
13		-		-
14		Data 0		Data 0
15		Data 1		Data 1
16		Status	KL4032 (POS 10)	Data 0
17		-		Data 1
18		Data 0		Data 0
19		Data 1		Data 1
20	KL1012 (POS 2)	Bit 0/1	KL2112 (POS 4)	Bit 0/1
21		-		-
128..143	PLC Variables		PLC Variables	

Assignment of the Bus Terminals

In the default setting, all the Bus Terminals are assigned to the Bus Terminal Controller. This can be changed with the KS2000 software. The assignment of the terminals is specified in Table 1 of the BC7300.

Hex	Bin	Description
0	00	The Bus Terminal is assigned to the MODBUS, and byte-oriented Bus Terminals are given compact mapping (user data only)
1	01	No function
2	10	The Bus Terminal is assigned to the BC, and byte-oriented Bus Terminals are given compact mapping (user data only)
3	11	The Bus Terminal is assigned to the BC, and byte-oriented Bus Terminals are given complex mapping (with control and status)

Compact

Compact evaluation of a byte-oriented Bus Terminal means that only the user data is transmitted.
Example: a KL3xx2 has 2 input words, and a KL4xx2 has 2 output words.

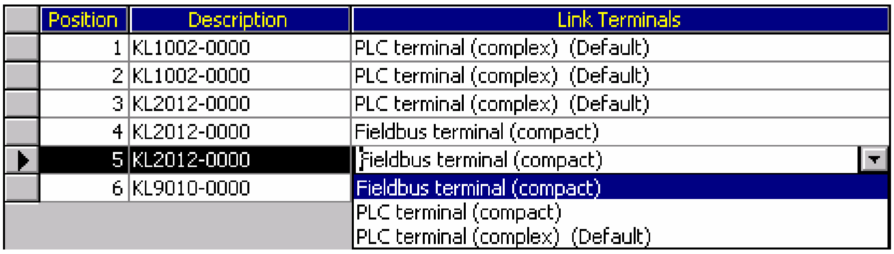
Complex

Complex evaluation of a byte-oriented Bus Terminal means that the user data and the control and status byte are transmitted.
Example: a KL3xx2 has 4 input words and 4 output words; the same applies to a KL4xx2.
You will find further information in the documentation for the Bus Terminals.

Table 1	Default	Description
Offset 4	0xFFFF	1.-8. terminal
Offset 5	0xFFFF	9.-16. terminal
Offset 6	0xFFFF	17.-24. terminal
Offset 7	0xFFFF	25.-32. terminal
Offset 8	0xFFFF	33.-40. terminal
Offset 9	0xFFFF	41.-48. terminal
Offset 10	0xFFFF	49.-56. terminal
Offset 11	0xFFFF	57.-64. terminal

KS2000 example

As from Version 2.3.2, the KS2000 software permits the adaptation of the Bus Terminals to be set via a dialogue. You can update your KS2000 software at www.Beckhoff.de.



Setting and Parameterisation of the MODBUS

The MODBUS is parameterised by means of the rotary switch on the BC7300. Only the Bus Terminal Controller's end terminal may be inserted for this.

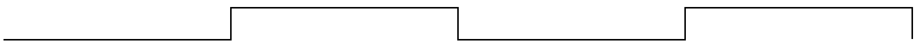
Only plug the KL9010 into the BC7300. Use the rotary switch to select the parameters. The x10 address switch is used to select the parameter, while the x1 address switch is used for the associated setting. The settings can be found in the table. Connect the Bus Coupler's 24 V supply, and the Modbus coupler will now start up in parameterisation mode. The LEDs WD, RX, TX and ERROR are now toggled, and the LEDs I/O RUN and I/O ERR give the function value.

Example

You want to check whether the correct baud rate has been set.

1. Switch off the Bus Coupler's 24 V supply
2. Remove all the terminals except the KL9010 end terminal
3. Set the x10 address selection switch to 0 and the x1 switch to 3
4. Switch on the Bus Coupler's 24 V supply again

The coupler indicates the set baud rate via the LEDs.
3 x flashes of the I/O RUN and I/O ERR LEDs means 9600 baud



WD,RX,TX,ERROR LEDs

I/O Run, I/O ERR

Now you want to set a new rate of 1200 baud

5. Switch off the Bus Coupler's 24 V supply
6. Set the x10 address selection switch to 3 and the x1 switch to 6
7. Switch on the Bus Coupler's 24 V supply again

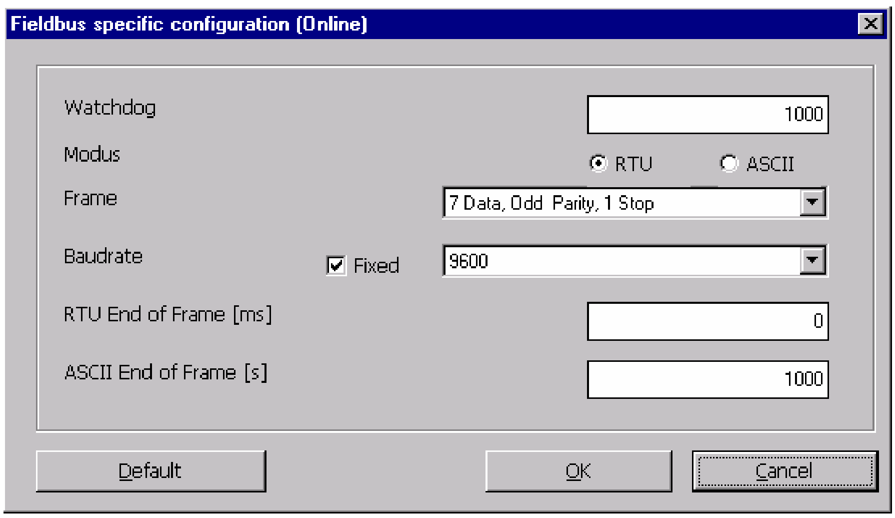
The Bus Coupler indicates the new set baud rate via the LEDs.
6 x flashes of the I/O RUN and I/O ERR LEDs means 1200 baud

Incorrect Entry

If a parameter is set that the MODBUS Bus Terminal Controller does not recognise, this is indicated by a constant even flashing of the I/O RUN and I/O ERR LEDs, while all the other LEDs remain off.

KS2000

The parameter settings can also be carried out with the KS2000 software.



Parameterisation Table

Parameter	x 10	x 1	Default	Parameter value	
	0	1..9	-	Indicates the parameter of the x 10 function	
Modbus	1	1	1	RTU mode	
		2		ASCII mode	
Frame	2	1	1	8 data bits, no parity	one stop bit
		2		8 data bits even Parity	one stop bit
		3		8 data bits odd Parity	one stop bit
		4		7 data bits even Parity	one stop bit
		5		7 data bits odd Parity	one stop bit
		6		one stop bit	
		7		2 stop bits	
		8		8 data bits, no parity	two stop bits
		9		8 data bits even Parity	two stop bits
		10		8 data bits odd Parity	two stop bits
		11		7 data bits even Parity	two stop bits
		12		7 data bits odd Parity	two stop bits
Baud rate	3	1	3	38400 baud	
		2		19200 baud	
		3		9600 baud	
		4		4800 baud	
		5		2400 baud	
		6		1200 baud	
		7		600 baud	
		8		300 baud	
		9		150 baud	
End of Frame Time	4	0..9	0	In ms for RTU mode (0 dependent on the baud rate) In seconds for ASCII mode (0 EOF time switched off)	
Watchdog 100 ms	5	0..9	0	Watchdog x 100 ms	
Watchdog 1000 ms	6	0..9	1	Watchdog x 1000 ms	
Factory setting	9	9			

The MODBUS Protocol

ASCII

In ASCII mode the telegram starts with a colon (:) character (0x3A), and ends with a carriage return and a line feed (CRLF) (0x0D, 0x0A). The characters transferred are represented in the ASCII code.

ASCII frame

Start	Address	Function	Data	LRC	END
1 character :	2 characters	2 characters	n characters	2 characters	2 characters CRLF

RTU

In RTU mode the protocol starts with a pause of 3.5 characters, and finishes in the same way (illustrated in the diagram with T1-T2-T3-T4). The characters permitted for transmission in all fields are hexadecimal 0... 9, A..., F.

RTU frame

Start	Address	Function	Data	CRC Check	END
T1-T2-T3-T4	1 character	1 character	n characters	2 characters	T1-T2-T3-T4

Functions

In the MODBUS protocol, the functions determine whether data are to be read or written, and what kind of data is involved. In the ASCII protocol the fourth and fifth bytes are function bytes, while in the RTU protocol it is the second byte.

The Beckhoff MODBUS Bus Terminal Controller supports the following functions:

Function	Code	Description
Read coil status	1	Read digital outputs
Read input status	2	Read digital inputs
Read holding registers	3	Read analog outputs / GPR
Read input registers	4	Read analog inputs / GPR
Force single coil	5	Write one digital output
Preset single register	6	Write one analog output / GPR
Diagnostics	8	Read the MODBUS diagnostic register
Force multiple coils	15	Write a number of digital outputs
Preset multiple registers	16	Write a number of analog outputs / GPR
Read / Write Registers	23	Write and read a number of process data outputs / GPRs

GPR – General Preset Register (see Modbus Interface)

The functions are briefly described in the next section and clarified with the aid of an example.

Read Digital Outputs (Function 1)

READ COIL STATUS

Function 1 can be used to read the settings of the digital outputs.

In this example the first 10 digital outputs of slave number 11 are read. The start address is zero. If an offset is to be entered, this is done in the "Start address" field.

Query

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	1	0x01	„01“	0x30, 0x31
Start address high	0	0x00	„00“	0x30, 0x30
Start address low	0	0x00	„00“	0x30, 0x30
Count high	0	0x00	„00“	0x30, 0x30
Count low	10	0x0A	„10“	0x31, 0x30
Error Check LRC / CRC		0xBC 0xA7	„E4“	0x45, 0x34
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Response

The Bus Terminal Controller answers with byte count 2, i.e. 2 bytes of data are returned. The query was for 10 bits, and these are now distributed over 2 bytes. The third bit in the output process image of the BC7300 is set, and the Bus Coupler returns a "4" in the first data byte.

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	1	0x01	„01“	0x30, 0x31
Byte Count	2	0x02	„02“	0x30, 0x32
Data bits 0..7	4	0x04	„04“	0x30, 0x34
Data bits 8..15	0	0x00	„00“	0x30, 0x30
Error Check LRC / CRC		0x23 0x3D	„EE“	0x45, 0x45
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Read Digital Inputs (Function 2)

READ INPUT STATUS

Function 2 can be used to read the digital input data.
In this example the first 10 digital inputs of slave number 11 are read. The start address is zero. If an offset is to be entered, this is done in the "Start address" field.

Query

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	2	0x02	„02“	0x30, 0x32
Start address high	0	0x00	„00“	0x30, 0x30
Start address low	0	0x00	„00“	0x30, 0x30
Count high	0	0x00	„00“	0x30, 0x30
Count low	10	0x0A	„10“	0x31, 0x30
Error Check LRC / CRC		0xF8 0xA7	„E3“	0x45, 0x33
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Response

The Bus Terminal Controller answers with byte count 2, i.e. 2 bytes of data are returned. The query was for 10 bits, and these are now distributed over 2 bytes. The first bit in the input process image of the BC7300 is set, and the Bus Coupler returns a "1" in the first data byte.

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	2	0x02	„02“	0x30, 0x32
Byte Count	2	0x02	„02“	0x30, 0x32
Data 0..7	1	0x01	„01“	0x30, 0x31
Data 8..15	0	0x00	„00“	0x30, 0x30
Error Check LRC / CRC		0x20 0x29	„F0“	0x46, 0x30
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Read Analog In/Outputs (Function 3) [1]

READ HOLDING REGISTERS

Function 3 can be used to read the input and output words and the registers.

In this example the first two analog outputs of slave number 11 are read. The analog outputs begin at offset 0x800 (hex). The length indicates the number of channels to be read.

[1] From Firmware B4 reading with function 3 is allowed.

Query

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	3	0x03	„03“	0x30, 0x33
Start address high	8	0x08	„08“	0x30, 0x38
Start address low	0	0x00	„00“	0x30, 0x30
Count high	0	0x00	„00“	0x30, 0x30
Count low	2	0x02	„02“	0x30, 0x32
Error Check LRC / CRC		0xC6 0xC1	„E8“	0x45, 0x38
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Response

The Bus Terminal Controller answers with byte count 4, i.e. 4 bytes of data are returned. The query was for 2 analog channels, and these are now distributed over 2 words. In the analog output process image, the first channel has the value 0x3FFF, while the second channel has the value 0x0.

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	3	0x03	„03“	0x30, 0x31
Count byte	4	0x04	„04“	0x30, 0x30
Data 1 high byte	63	0x3F	„3F“	0x33, 0x46
Data 1 low byte	255	0xFF	„FF“	0x46, 0x46
Data 2 high byte	0	0x00	„00“	0x30, 0x30
Data 2 low byte	0	0x00	„00“	0x30, 0x30
Error Check LRC / CRC		0xC6 0xC1	„B0“	0x42, 0x30
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Read Analog Inputs (Function 4)

READ INPUT REGISTER

Function 4 is used to read the analog inputs.

In this example the first two analog inputs of slave number 11 are read. The analog outputs begin at offset 0x0000 (hex). The length indicates the number of words to be read. A KL3002 has 2 words of input data, which is why the value to be entered in "Count low" is two.

Query

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	4	0x04	„04“	0x30, 0x34
Start address high	0	0x00	„00“	0x30, 0x30
Start address low	0	0x00	„00“	0x30, 0x30
Count high	0	0x00	„00“	0x30, 0x30
Count low	2	0x02	„02“	0x30, 0x32
Error Check LRC / CRC		0x71 0x61	„EF“	0x45, 0x46
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Response

The Bus Terminal Controller answers with byte count 4, i.e. 4 bytes of data are returned. The query was for 2 analog channels, and these will now be distributed over 2 words. In the analog input process image, the first channel has the value 0x0038, while the second channel has the value 0x3F1B.

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	4	0x04	„04“	0x30, 0x34
Count byte	4	0x04	„04“	0x30, 0x30
Data 1 high byte	0	0x00	„00“	0x30, 0x30
Data 1 low byte	56	0x38	„38“	0x33, 0x38
Data 2 high byte	63	0x3F	„3F“	0x33, 0x46
Data 2 low byte	11	0x0B	„0B“	0x30, 0x42
Error Check LRC / CRC		0x80 0x7E	„6A“	0x36, 0x41
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Writing a Digital Output (Function 5)

FORCE SINGLE COIL

Function 5 can be used to write a digital output. In this example the third digital output of slave number 11 is written. The digital outputs begin at offset 0x0000 (hex). The digital value is located in the high byte of the data. To switch the output on, "Data high" must contain 0xFF (hex), while 0x00 (hex) is used to switch the output off again. "Data low" must contain 0x00 (hex).

Query

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	5	0x05	„05“	0x30, 0x35
Start address high	0	0x00	„00“	0x30, 0x30
Start address low	2	0x02	„02“	0x30, 0x32
Data high	255	0xFF	„FF“	0x46, 0x46
Data low	0	0x00	„00“	0x30, 0x32
Error Check LRC / CRC		0x2D 0x50	„EF“	0x45, 0x46
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Response

The Bus Terminal Controller answers with the same telegram.

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	5	0x05	„05“	0x30, 0x35
Start address high	0	0x00	„00“	0x30, 0x30
Start address low	2	0x02	„02“	0x30, 0x32
Data high	255	0xFF	„FF“	0x46, 0x46
Data low	0	0x00	„00“	0x30, 0x32
Error Check LRC / CRC		0x2D 0x50	„EF“	0x45, 0x46
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Writing an Analog Output (Function 6)

PRESET SINGLE REGISTER

Function 6 can be used to access the output process image and the interface.

The first analog output of slave number 11 is written with function 6. The analog outputs begin at offset 0x0800 (hex). Here again the offset always describes a word. This means offset 0x0803 refers to the fourth word in the output process image.

Query

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	6	0x06	„06“	0x30, 0x36
Start address high	8	0x08	„08“	0x30, 0x38
Start address low	0	0x00	„00“	0x30, 0x30
Data high	63	0x3F	„3F“	0x33, 0x46
Data low	255	0xFF	„FF“	0x46, 0x46
Error Check LRC / CRC		0xDA 0xB0	„A9“	0x41, 0x39
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Response

The Bus Terminal Controller answers with the same telegram.

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	6	0x06	„06“	0x30, 0x36
Start address high	8	0x08	„08“	0x30, 0x38
Start address low	0	0x00	„00“	0x30, 0x30
Data high	63	0x3F	„3F“	0x33, 0x46
Data low	255	0xFF	„FF“	0x46, 0x46
Error Check LRC / CRC		0xDA 0xB0	„A9“	0x41, 0x39
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Writing a Number of Digital Outputs (Function 15)

FORCE MULTIPLE COILS

Function 15 can be used to set or reset a number of digital outputs at the same time.

In this example the first 20 digital outputs of slave number 11 are written. The digital outputs begin at offset 0x0000 (hex). Here the offset always describes a bit. Offset 0x0003 writes to the fourth bit in the output process image. The length indicates the number of bits, and the "Byte count" is composed from the combination all the bytes that are to be written.

Example: 20 bits – corresponds to 24 bits – count is 3 bytes (round up to the nearest byte)

The data bytes contain the values for the individual bits.

In this example, the first 16 bits are set to "TRUE", while bits 17 to 20 are "FALSE".

Query

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	15	0x0F	„0F“	0x30, 0x46
Start address high	0	0x00	„00“	0x30, 0x30
Start address low	0	0x00	„00“	0x30, 0x30
Length high	0	0x00	„00“	0x30, 0x30
Length low	20	0x14	„14“	0x31, 0x34
Byte Count	3	0x03	„03“	0x30, 0x33
Data 1 bit 0..7	255	0xFF	„FF“	0x46, 0x46
Data 2 bit 8..15	255	0xFF	„FF“	0x46, 0x46
Data 3 bit 16..19	0	0x00	„00“	0x30, 0x30
Error Check LRC / CRC		0x01 0x95	„D1“	0x44, 0x31
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Response

The Bus Terminal Controller answers with the same telegram.

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	15	0x0F	„0F“	0x30, 0x46
Start address high	0	0x00	„00“	0x30, 0x30
Start address low	0	0x00	„00“	0x30, 0x30
Data high	0	0x00	„00“	0x30, 0x30
Data low	20	0x14	„14“	0x30, 0x34
Error Check LRC / CRC		0xDA 0xB0	„D2“	0x44, 0x32
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Writing a Number of Analog Outputs (Function 16)

PRESET MULTIPLE REGISTERS

Function 16 can be used to write a number of analog outputs. In this example the first 2 analog output words of slave number 11 are written. The analog outputs begin at offset 0x0800 (hex). Here the offset always describes a word. Offset 0x0003 writes to the fourth word in the output process image. The length indicates the number of words, and the "Byte count" is composed from the combination all the bytes that are to be written.

Example: 4 words – correspond to a byte count of 8

The data bytes contain the values for the analog outputs. In this example, two words are to be written. The first word is to receive the value 0x7FFF (hex), and the second word is to receive the value 0x3FFF.

Query

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	16	0x10	„10“	0x31, 0x30
Start address high	8	0x08	„08“	0x30, 0x38
Start address low	0	0x00	„00“	0x30, 0x30
Length high	0	0x00	„00“	0x30, 0x30
Length low	2	0x02	„02“	0x30, 0x32
Byte Count	4	0x04	„04“	0x30, 0x34
Data 1 byte 1	127	0x7F	„7F“	0x37, 0x46
Data 1 byte 2	255	0xFF	„FF“	0x46, 0x46
Data 2 byte 1	63	0x3F	„3F“	0x33, 0x46
Data 2 byte 2	255	0xFF	„FF“	0x46, 0x46
Error Check LRC / CRC		0xCD 0xE3	„1B“	0x31, 0x42
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Response

The Bus Terminal Controller replies with the start address and the length of the transmitted words.

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	16	0x10	„10“	0x31, 0x30
Start address high	8	0x08	„08“	0x30, 0x38
Start address low	0	0x00	„00“	0x30, 0x30
Length high	0	0x00	„00“	0x30, 0x30
Length low	2	0x02	„02“	0x30, 0x32
Error Check LRC / CRC		0x43 0x02	„DB“	0x44, 0x42
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Writing and Reading Analog Outputs and Inputs (Function 23)

READ / WRITE REGISTERS

A number of analog outputs can be written and a number of analog inputs read with one telegram using function 23. In this example the first 2 analog output words of slave number 11 are written, and the first two analog inputs are read. The analog outputs start at offset 0x0800 (hex), while the inputs start at offset 0x0000 (hex). Here the offset always describes a word. Offset 0x0003 writes to the fourth word in the output process image. The length indicates the number of words, and the "Byte count" is composed from the combination all the bytes that are to be written.

Example: 4 words – correspond to a byte count of 8

The data bytes contain the values for the analog outputs. In this example, two words are to be written. The first word is to receive the value 0x3FFF (hex), and the second word is to receive the value 0x7FFF.

Query

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	23	0x17	„17“	0x31, 0x37
Read start address high	0	0x00	„00“	0x30, 0x30
Read start address low	0	0x00	„00“	0x30, 0x30
Read length high	0	0x00	„00“	0x30, 0x30
Read length low	2	0x02	„02“	0x30, 0x32
Write start address high	8	0x08	„08“	0x30, 0x38
Write start address low	0	0x00	„00“	0x30, 0x30
Write length high	0	0x00	„00“	0x30, 0x30
Write length low	2	0x02	„02“	0x30, 0x32
Byte Count	4	0x04	„04“	0x30, 0x34
Data 1 high	63	0x3F	„3F“	0x33, 0x46
Data1 low	255	0xFF	„FF“	0x46, 0x46
Data 2 high	127	0x7F	„7F“	0x37, 0x46
Data 2 low	255	0xFF	„FF“	0x46, 0x46
Error Check LRC / CRC		0x76 0xD3	„12“	0x31, 0x32
End of frame		T1-t2-t3	CRLF	0xD, 0xA

Response

The Bus Terminal Controller replies with the start address and the length of the bytes to be transferred in "Byte count". The data information follows. In this example the first word contains 0x0038 (hex) while the second word contains 0x3F0B.

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	23	0x17	„17“	0x31, 0x37
Byte Count	4	0x04	„04“	0x30, 0x34
Data 1 high	0	0x00	„00“	0x30, 0x30
Data 1 low	56	0x38	„38“	0x33, 0x38
Data 2 high	63	0x3F	„3F“	0x33, 0x46
Data 2 low	11	0x0B	„0B“	0x30, 0x42
Error Check LRC / CRC		0x82 0xDD	„58“	0x35, 0x38
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Diagnostics

In the MODBUS, function 08 provides a series of tests for examination of the communication system between the master and the slave and for inspection of a variety of internal error states within the slave. A broadcast telegram is not supported.

The function uses a two-byte sub-function code field in the query to define the test that is to be carried out. The slave outputs the function code and the sub-function code as an answer.

The diagnostic queries use a two-byte data field to send diagnostics data or control information to the slave.

EXAMPLE

Query

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	8	0x08	„08“	0x30, 0x38
Subfunction high	0	0x00	„00“	0x30, 0x30
Subfunction low	0	0x00	„00“	0x30, 0x30
Data high	2	0x02	„02“	0x30, 0x32
Data low	3	0x03	„03“	0x30, 0x33
Error Check LRC / CRC		0xA1 0xC0	„E8“	0x45, 0x38
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Response

Byte Name	Example	RTU	ASCII	
Start frame			„:“	0x3A
Slave address	11	0x0B	„0B“	0x30, 0x42
Function code	8	0x08	„08“	0x30, 0x38
Subfunction high	0	0x00	„00“	0x30, 0x30
Subfunction low	0	0x00	„00“	0x30, 0x30
Data high	2	0x02	„02“	0x30, 0x32
Data low	3	0x03	„03“	0x30, 0x33
Error Check LRC / CRC		0xA1 0xC0	„E8“	0x45, 0x38
End of frame		t1-t2-t3	CRLF	0xD, 0xA

Echoes a query (Sub-Function 0)

Sub-function 0 causes the data that is sent to the slave by the master to be returned.

Bus Coupler Reset (Sub-Function 1)

Sub-function 1 re-initialises the BC7300. Error counters are reset, and the coupler executes a self-test. No telegrams are either received or sent while the coupler is being reset.

Sub-function	Data field (query)	Data field (response)
00 01	00 00	00 00

Delete All Counter Contents (Sub-Function 10)

Calling this sub-function deletes the contents of all error counters in the coupler.

Sub-function	Data field (query)	Data field (response)
00 0B	00 00	Echo Query Data

Bus Communication Error Counter (Sub-Function 11)

Returns the number of faulty communications.

Sub-function	Data field (query)	Data field (response)
00 0C	00 00	CRC error counter

Error Answer Counter (Sub-Function 13)

This counter contains the number of error answer telegrams that the coupler has sent.

Sub-function	Data field (query)	Data field (response)
00 0D	00 00	Error Answer Counter

Slave Answers (Sub-Function 14)
Contains the number of answers that the slave has sent.

Sub-function	Data field (query)	Data field (response)
00 0E	00 00	Slave Message Count

Unsent Slave Answers (Sub-Function 15)
Contains the number of answers that the slave has not sent. For example, the slave does not send an answer to a broadcast message.

Sub-function	Data field (query)	Data field (response)
00 0F	00 00	Slave No Response Count

Number of Error Answers (Sub-Function 16)
Contains the number of error answers that the slave has sent.

Sub-function	Data field (query)	Data field (response)
00 10	00 00	Number of error answers

BC7300 Error Answers

EXCEPTION RESPONSE

When the user sends the slave either a request or information that the Bus Coupler does not understand, the BC7300 responds with an error report. This answer contains the function and the error code. 0x80 is added to the value returned by the function.

Code	Name	Meaning
1	ILLEGAL FUNCTION	Function not implemented
2	ILLEGAL DATA ADDRESS	Invalid address or length
3	ILLEGAL DATA VALUE	Invalid parameter • Diagnostic functions • Incorrect number of read/write accesses to the register
4	SLAVE DEVICE ERROR	Watchdog or K-Bus error

Example

The following example contains an invalid "Start address".

Query

BYTE	Contents	Example
1	Slave address	0B
2	Function	01
3	Start address high	0D
4	Start address low	FF
5	Data high	FF
6	Data low	01
7	LRC	

The slave's answer contains the function plus 0x80, together with error code "02", i.e. an invalid address.

Response

BYTE	Contents	Example
1	Slave address	0B
2	Function	81
3	Error code	02
4	LRC	

Bus Terminal Controller

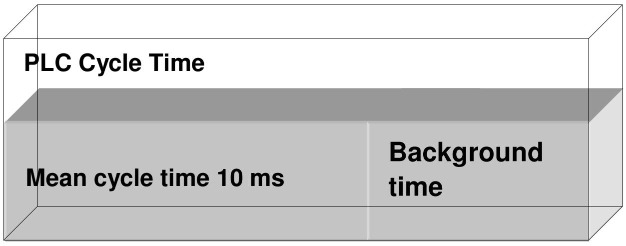
PLC Cycle Time

PLC Cycle Time

The PLC cycle time determines the program's repetition frequency. This time is not deterministic. This means that when the program in the Bus Terminal Controller needs more time, the PLC cycle time rises. If the program needs less than the cycle time, it is repeated at intervals of the set cycle time.
The processing of the MODBUS and the serial interfaces is executed in the background time. This should be set to approx. 20 % of the PLC cycle time.

The „mean cycle time“ is measured in order to optimise the system. You will find this item in PLC Control under Online\Coupler. About 20% – 30% is added to this, and the result entered as the PLC cycle time. The background time is then set to 20% of the PLC cycle time.

Example of cycle time optimisation



PLC cycle time = mean cycle time + 20% = 10 ms + 20% = 12 ms
Background time = PLC cycle time * 0.2 = 12 ms * 0.2 = 2.4 ms ≈ 2 ms

Mean cycle time

The measured cycle time also includes that required for the K-Bus update. This results in a connection between the number of terminals that are inserted and the cycle time. Before initiating the program, the Bus Terminal Controller executes a K-Bus update, in order to interrogate the inputs. After the program has been executed, the BC7300 carries out another K-Bus update, in order to write the current outputs. The background time follows this.

PLC Variables

PLC variables are variables that are situated in the BC7300 from addresses %IB128 and %QB128. This offset can be shifted. These addresses are not assigned to any terminal, so that signals or data can be transmitted to or received from the master via the PLC variables. The default setting is for 16 words of input and output. These can be changed with the KS2000.

Remanent Variables

Retained or remanent variables are data that retain their value when voltage is not present. In PLC Control this data is placed in the allocated flags area. Following the default setting, this means that all the variables from %MB0 - %MB63 are RETAIN data. The maximum setting is for 512 bytes, which can be set using the KS2000 software.

Persistent Data[2]

The Persistent Data remain intact, even after a new program download and a reset. Like the Retain Variables, they are stored in the flags area of the Bus Terminal Controller.
Example: VarP1 AT %MB0: INT;
The Persistent Data are in the same area as the Retain Variables and also start at %MB0. You first have to enable Retain Variables in order to achieve a storage increase through the Persistent Data. By default, no Persistent Variables are declared.
The Persistent Variable memory area must always be smaller or equal than that of the Retain Variables.
The KS2000 software allows this area to be increased to a maximum of 512 bytes (Table 1, Register 18).
These data are deleted by a general reset.

[2] From Firmware B4

Allocated flags area

The allocated flags area offers a variety of further additional functions and diagnostic facilities.

Cycle tick counter

The cycle tick counter starts at address %MB504. Each tick corresponds to about 1 ms. The counter has 32 bits, and can also be written from the PLC in order to set it to zero or to some other particular value.

Fieldbus diagnostics

Fieldbus diagnostics are located at flag words 508 and 509.
%MX508.0 "TRUE" watchdog time elapsed
The bit is set to "1" if a write telegram has been processed and no new write telegram is sent to the Bus Terminal Controller within the watchdog time.
No other bits have any function.

K-Bus diagnostics

K-Bus diagnostics are located at flag words 510 and 511.
%MX510.0 "TRUE" K-Bus error
%MX510.1 "TRUE" configuration error

Flag byte	Meaning
%MW508	Bit 0: Fieldbus error Bits 1-15: reserved
%MW510	Bit 0: K-Bus error Bit 1: Configuration error Bits 2-15: reserved

Data acces via Modbus

From the firmware B4 is it as well possible to access directly reading and writing on the flag area. This access does not trigger the watchdog. That means values which are written in this range, remain as well after a watchdog error set.

Appendix

MODBUS Interface

Address		Description		
0x0000 0x00FF		Process data interface Inputs (%QBx)		
0x0800 0x08FF		Process data interface Outputs (%IBx)		
0x1000- 0x1006	Only Read	Bus Coupler identification		
0x100A	Only Read	2 byte PLC interface		
0x100B	Only Read	Terminal diagnostics		
0x100C	Only Read	Bus Coupler status		
0x1010	Only Read	Process image length in bits	Analog outputs	
0x1011	Only Read	Process image length in bits	Analog inputs	
0x1012	Only Read	Process image length in bits	Digital outputs	
0x1013	Only Read	Process image length in bits	Digital inputs	
0x1020	Only Read	Watchdog	Current time in [ms]	1000
0x110A	Read/Write	2 byte PLC interface		
0x110B	Read/Write	Terminal diagnostics		
0x1120	Read/Write	Watchdog	Pre-defined time in [ms]	1000
0x400 0x40FF	Read/Write	Flag range[3] %MB0 - %MB511		

Bus Coupler status 0x100C	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	FB														CNF	KB

FB: Fieldbus error, watchdog time elapsed
KB: Terminal Bus error
CNF: BK configuration window

2 byte PLC interface/
2 byte diagnostic interface

Registers in the complex terminals and Bus Coupler registers can both be read or written using the 2 byte PLC interface. The complex terminal registers are described in the associated terminal documentation. The Bus Coupler registers can be used, for example, to read terminal bus diagnostics data, the terminal composition or the cycle times, and the programmed configuration can be written. It is also possible for a manual terminal bus reset to be carried out. The 2-byte PLC interface requires two bytes each of output and input data. They are handled using a special protocol. A description of the 2 byte PLC interface, the registers available in the Bus Couplers and of function blocks for various PLCs that implement the 2 byte PLC interface can be supplied on request.

The terminals' error messages can be sent over the 2-byte diagnostic interface. Terminal bus diagnostics must however be activated for this purpose. The 2-byte diagnostic interface occupies two bytes each of output and input data. They are handled using a special protocol. A description of the 2 byte-diagnostic interface can be supplied on request.

[3] From Firmware B4

Mapping the Bus Terminals

The precise assignment of the byte-oriented Bus Terminals may be found in the Bus Terminal configuration guide.

The documentation is available on the product CD or on the Internet under www.beckhoff.de.

Byte oriented Bus Terminals	Bit oriented Bus Terminals
KL1501	KL10XX, KL11XX, KL12XX, KL17XX
KL2502	KL20XX, KL21XX, KL22XX, KL26XX KL27XX
KL3XXX	
KL4XXX	
KL5XXX	
KL6XXX	
	KL9110, KL9160, KL9210, KL9260

List of references

Modicon: „MODBUS Protocol Reference Guide“
http://www.modicon.com

Software – Win-TECH
http://www.win-tech.com

Firmware

The label under the coupler will tell you which firmware is installed in the Bus Coupler. (Fifth and sixth positions)

Example

3200**B2**020000
The current Firmware version is B2.

To update your firmware you need the KS2000 software and the appropriate serial cable, supplied along with KS2000. You may find the firmware under www.Beckhoff.de.

Table

Firmware	Description
B1	Released version
B2	PLC optimized
B3	Internal version
B4	Modbus access to flag range

Example Program

This example program makes use of the basic settings for the BC7300. This makes it very easy to quickly include this Bus Terminal Controller in the data exchange for the first time. The procedure is explained step by step with the aid of a small example.

Explanation of the Program

The following very simple example should clarify the function and type of data transmission with the aid of the PLC variables. The blinker block is called in the MAIN program when the first input of the input terminal has reached the value zero. The blinker block contains a pulse generator that is fed to two counters. One of the counters increments output word 130, while the other counts output word 128 downwards. Both of these output words are what are known as PLC variables, and they are read by the MODBUS master.

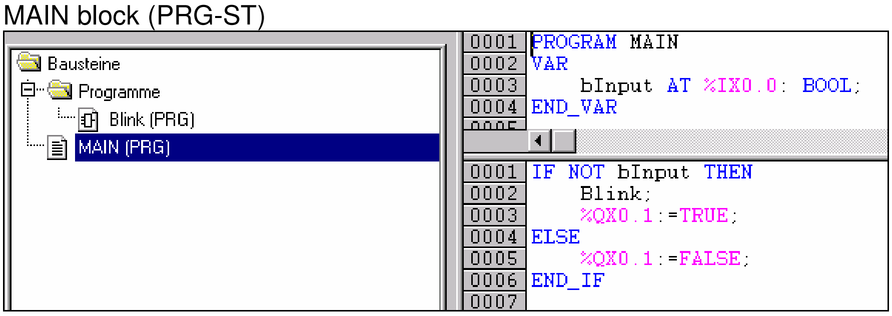
The Program in the Bus Terminal Controller

In order to generate this example program you need a BC7300, 2 x KL2012, 2 x KL1002, 1 x KL9010 and a 24V DC mains power supply unit (2A) with a cable and a connection on your MODBUS master to the BC7300. The software you require is TwinCAT / TwinCAT BC and a programming cable. This is included when TwinCAT BC or KS2000 is supplied.

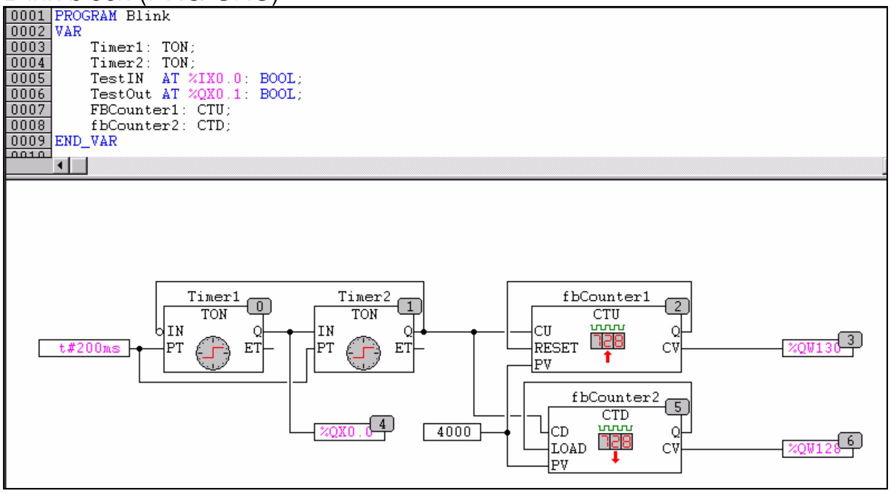
The first step is to create a program in the BC7300. For this purpose the address selection switch is set to "00". This it the programming mode for the Bus Terminal Controller. The MODBUS cannot be operated at the same time, which means that the fieldbus connection must not be connected. Connect the supply voltage and the supply to the power contacts. The Bus Terminal Controller now boots. When booting is complete the "I/O RUN" LED lights up on the BC7300. Insert the programming cable into your PC's serial interface and into the programming interface of the BC7300. Open the flap under the Beckhoff logo to do this. Start TwinCAT or TwinCAT BC, and under File/New select the item "BC serial". Confirm with "OK". Then select "ST" as the language, and confirm with "OK". Now test communication with the BC by executing a reset under Online/Coupler/K-Bus reset. If a message box then appears with the number of Bus Terminals inserted (not counting the end terminal), the communication has been successful. If, after about 15 seconds, a "Communication error" message appears, check the cable, the address on the BC7300 and the settings of the serial interface. You will find these under Online/Communication parameters. The necessary setting is 19200 baud, 1 start bit, even parity.

Example program on the BC7300

MAIN block (PRG-ST)



Blink block (PRG-CRC)



Creating the BOOT Program

The next step is the creation of a boot project. To achieve this, select, when you are logged in, Online/Create boot project. The PLC LED flashes while the boot project is being created. Now set the MODBUS slave address and switch the Bus Terminal Controller off and then on again. Remove the programming cable, and connect the MODBUS cable.

MODBUS Communication

Function 4 is used in order to obtain the states of the counters in the two 16-bit output words in the MODBUS master.

Query

Byte Name	Example	RTU	Description
Slave address	11	0x0B	
Function code	4	0x04	
Start address high	0	0x00	
Start address low	0	0x00	
Count high	0	0x00	
Count low	2	0x02	Number of data words
Error Check LRC / CRC		0x71 0x61	
End of frame		t1-t2-t3	

Response

The Bus Terminal Controller answers with byte count 4, i.e. 4 bytes of data are returned. The query was for 2 input words, and these are now distributed over 4 bytes.

Byte Name	Example	RTU	Description
Start frame			
Slave address	11	0x0B	
Function code	4	0x04	
Count byte	4	0x04	Number of data bytes
Data 1 high byte	0	0x00	Address %QB129
Data 1 low byte	56	0x38	Address %QB128
Data 2 high byte	63	0x3F	Address %QB131
Data 2 low byte	11	0x0B	Address %QB130
Error Check LRC / CRC		0x80 0x7E	
End of frame		t1-t2-t3	

Questions and Answers

General

No communication with the BC7300

Problem You cannot log in with either KS2000 nor TwinCAT (BC).

Solution Set the address selection switch to "00" and start the Bus Terminal Controller again.

Mapping of the digital and the byte-oriented Bus Terminals onto a fixed address

Problem You want a constant start address for the digital inputs and outputs.

Solution With the KS2000 software, you can enter an offset start value for the digital inputs and outputs in table 0. The byte-oriented Bus Terminals should not jut into this process image, i.e. no overlap should occur.
Table 0:
Register 19 offset for digital outputs
Register 20 offset for digital inputs
"0" is the default setting (automatic Bus Terminal mapping)

Example You have a KL3002 and a KL2012. In the default case, the KL3002 maps onto %IB0- %IB7 and %QB0-QB7 in the memory. The digital output terminal would now map to %QX8.0 and %QX8.1. As soon as you now plug another byte-oriented Bus Terminal, the process image of the digital Bus Terminal is moved to a higher memory. You can now pre-empt this by entering 20 in register 19. This means that KL2012 now maps onto %QX20.0 and %QX20.1.

Drop of the digital outputs

Problem Your digital outputs drop away.

Solution Your program takes longer than 100 ms. Because the internal K-Bus runs synchronous with your PLC program, it is no longer triggered early enough, and the Bus Terminal watchdog becomes active. This can be rectified by triggering a short refresh of the K-Bus. The setting can be carried out with the KS2000 software.
Table 1 register 17
LowByte cycle time to K-Bus refresh (<= 80 ms)
HighByte Retries

Recommendation Enter 0x0350 in table 1, register 17, i.e. three retries, all at 80 ms.
Note that this causes the Bus Terminal watchdog to increase to 240 ms during a fault condition (this is not true in case of a K-Bus error, where the watchdog will remain at 100 ms).

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