Operating Instructions for

EL2904

TwinSAFE Terminal with 4 digital fail-safe outputs

Version:	**2.1.1**
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1 Foreword

1.1 Notes on the documentation

Intended audience

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

It is essential that the following notes and explanations are followed when installing and commissioning these components.

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.

Origin of the document

This documentation was originally written in German. All other languages are derived from the German original.

Currentness

Please check whether you are using the current and valid version of this document. The current version can be downloaded from the Beckhoff homepage at http://www.beckhoff.com/english/download/twinsafe.htm. In case of doubt, please contact Technical Support [▶ 44].

Product features

Only the product features specified in the current user documentation are valid. Further information given on the product pages of the Beckhoff homepage, in emails or in other publications is not authoritative.

Disclaimer

The documentation has been prepared with care. The products described are subject to cyclical revision. For that reason the documentation is not in every case checked for consistency with performance data, standards or other characteristics. We reserve the right to revise and change the documentation at any time and without prior announcement. No claims for the modification of products that have already been supplied may be made on the basis of the data, diagrams and descriptions in this documentation.

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Patent Pending

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

The TwinCAT Technology is covered, including but not limited to the following patent applications and patents: EP0851348, US6167425 with corresponding applications or registrations in various other countries.

EtherCAT® is registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany

Delivery conditions

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

1.2   Safety instructions

1.2.1   Delivery state

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

1.2.2   Operator's obligation to exercise diligence

The operator must ensure that

- the TwinSAFE products are only used as intended (see chapter Product description);
- the TwinSAFE products are only operated in sound condition and in working order.
- the TwinSAFE products are operated only by suitably qualified and authorized personnel.
- the personnel is instructed regularly about relevant occupational safety and environmental protection aspects, and is familiar with the operating instructions and in particular the safety instructions contained herein.
- the operating instructions are in good condition and complete, and always available for reference at the location where the TwinSAFE products are used.
- none of the safety and warning notes attached to the TwinSAFE products are removed, and all notes remain legible.

1.2.3 Description of safety symbols

In these operating instructions the following symbols are used with an accompanying safety instruction or note. The safety instructions must be read carefully and followed without fail!

DANGER	**Serious risk of injury!** **Failure** to follow the safety instructions associated with this symbol directly endangers the life and health of persons.
WARNING	**Risk of injury!** **Failure** to follow the safety instructions associated with this symbol endangers the life and health of persons.
CAUTION	**Personal injuries!** **Failure** to follow the safety instructions associated with this symbol can lead to injuries to persons.
Attention	**Damage to the environment or devices** **Failure** to follow the instructions associated with this symbol can lead to damage to the environment or equipment.
Note	**Tip or pointer** This symbol indicates information that contributes to better understanding.

1.3   Documentation issue status

Version	Comment
2.1.1	• Technical data *permissible air pressure* expanded
2.1.0	• Chapter *Address settings on TwinSAFE terminals with 1023 possible addresses* updated • Links in technical data corrected
2.0.1	• Links at chapter *Diagnostic LEDs* corrected
2.0.0	• Migration and structural adaptation • Reliability document updated • Safety parameters updated • Foreword revised
1.6.2	• Block diagram updated • Numbering/table of contents changed • Description of the reaction times added • Reliability document updated
1.6.1	• Certificate updated
1.6.0	• Company address amended • Safety parameters extended
1.5.0	• Extended temperature range amended • Notes regarding temperature measurement and EMC added • Description of date code extended
1.4.1	• Document origin added
1.4.0	• Note regarding cable length and signal routing extended • Table listing causes for diagnostic messages amended
1.3.0	• Block diagram for EL2904 added
1.2.1	• Reference to EN 60068-2-29 removed
1.2.0	• ATEX notes amended • Installation position / minimum distances extended • Notes regarding overvoltage protection amended • Notes regarding cable length and clocked signals extended • EN954 wiring example removed • Diagnostics for CoE object 0x800E described
1.1.0	• Minor amendments for EtherCAT • Copyright / disclaimer modified • Support / service addresses updated
1.0.0	• First released version

2 System description

2.1 The Beckhoff Bus Terminal system

The Beckhoff Bus Terminal system is used for decentralized connection of sensors and actuators to a control system. The Beckhoff Bus Terminal system components are mainly used in industrial automation and building management applications. In its minimum configuration, a bus station consists of a Bus Coupler or a Bus Terminal Controller and Bus Terminals connected to it. The Bus Coupler forms the communication interface to the higher-level controller, and the terminals are the interface to sensors and actuators. The whole bus station is clipped onto a 35 mm DIN mounting rail (EN 60715). The mechanical cross connection of the bus station is established via a slot and key system at the Bus Coupler and the Bus Terminals.

The sensors and actuators are connected with the terminals via the screwless (spring-loaded) connection system.

Fig. 1: Slot and key system and screwless (spring-loaded) connection system.

In order to accommodate the wide range of different communication standards encountered in industrial automation, Beckhoff offers Bus Couplers for a number of common bus systems (e.g. EK1100 for EtherCAT).

2.1.1   Bus Coupler

Mechanical data	Bus Coupler
Material	polycarbonate, polyamide (PA6.6).
Dimensions (W x H x D)	44 mm x 100 mm x 68 mm
Mounting	on 35 mm mounting rail (EN 60715) with locking
Attachable by	double slot and key connection

Fig. 2: Bus Coupler (EtherCAT)

Connection technology	Bus Coupler
Wiring	spring-loaded system
Connection cross-section	0.08 mm² ... 2.5 mm², stranded wire, solid wire
Fieldbus connection	depending on fieldbus
Power contacts	3 spring contacts
Current load	10 A
Rated voltage	24 V_{DC}

2.1.2 Bus Terminals

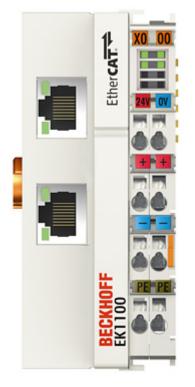| Mechanical data	Bus Terminal
Material	polycarbonate, polyamide (PA6.6).
Dimensions (W x H x D)	12 mm x 100 mm x 68 mm or 24 mm x 100 mm x 68 mm
Mounting	on 35 mm mounting rail (EN 60715) with locking
Attachable by	double slot and key connection

Fig. 3: TwinSAFE Terminals (EtherCAT)

Connection technology	Bus Terminal
Wiring	spring-loaded system
Connection cross-section	0.08 mm² ... 2.5 mm², stranded wire, solid wire
Fieldbus connection	E-bus
Power contacts	up to 3 blade/spring contacts
Current load	10 A
Rated voltage	depends on Bus Terminal type

2.1.3 E-bus

The E-bus is the data path within a terminal strip. The E-bus is led through from the Bus Coupler through all the terminals via six contacts on the terminals' side walls.

2.1.4 Power contacts

The operating voltage is passed on to following terminals via three power contacts. Terminal strip can be split into galvanically isolated groups by means of potential feed terminals as required. The power feed terminals play no part in the control of the terminals, and can be inserted at any locations within the terminal strip.

2.2   TwinSAFE

2.2.1   The I/O construction kit is extended safely

With the TwinSAFE Terminals, Beckhoff offers the option of simply expanding the proven Bus Terminal system, and to transfer the complete cabling for the safety circuit into the already existing fieldbus cable. Safe signals can be mixed with standard signals without restriction. This saves design effort, installation and material. Maintenance is simplified significantly through faster diagnosis and simple replacement of only a few components.

The new ELx9xx series Bus Terminals only include three basic functionalities: digital inputs EL19xx, digital outputs EL29xx and a logic unit EL6900. For a large number of applications, all sensors and actuators can be wired on these Bus Terminals. The required logical link of the inputs and the outputs is handled by the EL6900. For small to medium-sized configurations, the tasks of a fail-safe PLC can thus be handled within the Bus Terminal system.

2.2.2   Safety concept

TwinSAFE: Safety and I/O technology in one system
- Extension of the familiar Beckhoff I/O system with TwinSAFE terminals
- Freely selectable mix of safe and standard signals
- Logical link of the I/Os in the EL6900 TwinSAFE logic terminal
- Safety-relevant networking of machines via bus systems

TwinSAFE protocol (FSoE)
- Transfer of safety-relevant data via any media ("genuine black channel")
- TwinSAFE communication via fieldbus systems such as EtherCAT, Lightbus, PROFIBUS or Ethernet
- IEC 61508:2010 SIL 3 compliant

Configuring instead of wiring: the TwinSAFE configurator
- Configuration of the TwinSAFE system via the TwinCAT System Manager
- System Manager for editing and displaying all bus parameters
- Certified function blocks such as emergency stop, operation mode, etc.
- Simple handling
- Typical function blocks for machine safety
- any bus connection with the EL6900 TwinSAFE logic terminal

TwinSAFE logic Bus Terminal EL6900
- Link unit between TwinSAFE input and output terminals
- Configuration of a simple, flexible, cost-effective, decentralized safety controller
- No safety requirements for higher-level control system
- TwinSAFE enables networks with up to 65535 TwinSAFE devices
- TwinSAFE logic terminal can establish up to 128 connections (TwinSAFE connections).
- Several TwinSAFE logic terminals are cascadable in a network
- Safety functions such as emergency stop, protective door, etc. are already included
- Suitable for applications up to SIL 3 according to IEC 61508:2010 and
  DIN EN ISO 13849-1:2006 (Cat 4, PL e).

TwinSAFE digital input (EL1904) and output terminal (EL2904)
- All current safety sensors can be connected

- Operation with a TwinSAFE logic terminal
- EL1904 with 4 fail-safe inputs for sensors (24 VDC) with floating contacts
- EL2904 with four safe channels for actuators (24 VDC, 0.5 A per channel)
- Conforming to IEC 61508:2010 SIL 3 and DIN EN ISO 13849-1:2006 (Cat 4, PL e) requirements.

2.2.3   EL1904, EL2904 - Bus Terminals with 4 fail-safe inputs or outputs

The EL1904 and EL2904 Bus Terminals enable connection of common safety sensors and actuators. They are operated with the EL6900 TwinSAFE logic terminal. The TwinSAFE logic terminal is the link unit between the TwinSAFE input and output terminals. It enables the configuration of a simple, flexible and cost-effective decentralized safety control system.

Therefore, there are no safety requirements for the higher-level controller! The typical safety functions required for the automation of machines, such as emergency stop, protective door, two-hand etc., are already permanently programmed in the EL6900. The user configures the EL6900 terminal according to the safety requirements of his application.

2.2.4   EL6900 - TwinSAFE logic terminal

The TwinSAFE logic terminal is the link unit between the TwinSAFE input and output terminals. The EL6900 meets the requirements of IEC 61508:2010 SIL 3, EN 954 Cat. 4 and DIN EN ISO 13849-1:2006 (Cat 4, PL e).

2.2.5   The fail-safe principle (Fail Stop)

The basic rule for a safety system such as TwinSAFE is that failure of a part, a system component or the overall system must never lead to a dangerous condition. The safe state is always the switched off and wattless state.

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3 Product description

3.1 EL2904 – TwinSAFE terminal with 4 digital fail-safe outputs

The EL2904 is a safe output terminal with digital outputs for connecting actuators (contactors, relays, etc.) with a maximum current 0.5 A (24 V_{DC}). The Bus Terminal has 4 fail-safe outputs.

The EL2904 meets the requirements of IEC 61508:2010 SIL 3, DIN EN ISO 13849-1:2006 (Cat 4, PL e), NRTL, UL508, UL1998 and UL991.

The TwinSAFE terminal has the typical design of an EtherCAT terminal.
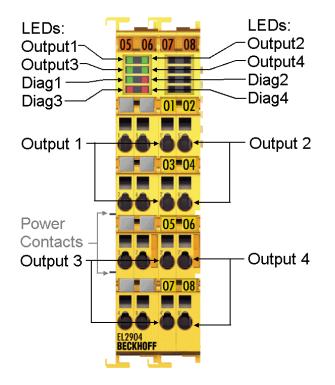

Fig. 4: EL2904 – TwinSAFE terminal with 4 digital fail-safe outputs

3.2 Intended use

⚠️ **WARNING**	**Caution - Risk of injury!** TwinSAFE components may only be used for the purposes described below!

The TwinSAFE terminals expand the application range of Beckhoff Bus Terminal system with functions that enable them to be used for machine safety applications. The TwinSAFE terminals are designed for machine safety functions and directly associated industrial automation tasks. They are therefore only approved for applications with a defined fail-safe state. This safe state is the wattless state. Fail-safety according to the relevant standards is required.

The TwinSAFE Terminals enable connection of:

- 24 V_{DC} sensors (EL1904) such as
  emergency off pushbutton switches, pull cord switches, position switches, two-hand switches, safety mats, light curtains, light barriers, laser scanner, etc.

- 24 V_{DC} actuators (EL2904) such as
contactors, protection door switches with tumbler, signal lamps, servo drives, etc.

	Test pulses
i **Note**	When selecting actuators please ensure that the EL2904 test pulses do not lead to actuator switching or diagnostic message from the EL2904.

The following TwinSAFE components have been developed for these tasks:

- The EL1904 is an EtherCAT Terminal with 4 digital fail-safe inputs.
- The EL2904 is an EtherCAT Terminal with 4 digital fail-safe outputs.
- The EL6900 is an EtherCAT Terminal with integrated TwinSAFE logic.

These TwinSAFE components are suitable for operation on the

- Beckhoff EKxxxx series Bus Couplers
- Beckhoff CXxxxx series Embedded PCs with E-bus connection

	Power supply from SELV/PELV power supply unit!
⚠ **WARNING**	The TwinSAFE components must be supplied with 24 V_{DC} by an SELV/PELV power supply unit with an output voltage limit U_{max} of 36 V_{DC}. Failure to observe this can result in a loss of safety.

	Follow the machinery directive!
⚠ **CAUTION**	The TwinSAFE components may only be used in machines as defined in the machinery directive.

	Ensure traceability!
⚠ **CAUTION**	The buyer has to ensure the traceability of the device via the serial number.

3.3   Technical data

Product designation	EL2904
Number of outputs	4
Status display	4 (one green LED per output)
Error reaction time	≤ watchdog times
Output current per channel	max. 500 mA, min. 20 mA with parameter *current measurement active* set
Actuators	When selecting actuators please ensure that the EL2904 test pulses do not lead to actuator switching.
Cable length between actuator and terminal	unshielded max. 100 m shielded max. 100 m
Wire cross section	min. 0.75 mm^2
Input process image	6 bytes
Output process image	6 bytes
EL2904 supply voltage (PELV)	24 V_{DC} (–15%/+20%)
Current consumption via E-bus	approx. 221 mA
Power dissipation of the terminal	typically 2 W
Electrical isolation (between the channels)	no
Electrical isolation (between the channels and the E-bus)	yes
Insulation voltage (between the channels and the E-bus, under common operating conditions)	insulation tested with 500 V_{DC}
Dimensions (W x H x D)	24mm x 100mm x 68mm
Weight	approx. 100 g
Permissible ambient temperature (operation) up to SW 03	0°C to +55°C (see notes in chapter Example configuration for temperature measurement [▶ 22])
Permissible ambient temperature (operation) from SW 04 (week 02/2014)	-25°C to +55 °C (see notes in chapter Example configuration for temperature measurement [▶ 22])
Permissible ambient temperature (transport/storage)	-40°C to +70°C
Permissible air humidity	5% to 95%, non-condensing
Permissible air pressure (operation/storage/transport)	750 hPa to 1100 hPa (this corresponds to a height of approx. -690 m to 2450 m over sea level assuming an international standard atmosphere)
Climate category according to EN 60721-3-3	3K3 (the deviation from 3K3 is possible only with optimal environmental conditions and also applies only to the technical data which are specified differently in this documentation)
Permissible level of contamination according to EN 60664-1	level of contamination 2 (comply with the chapter Maintenance [▶ 41])
Impermissible operating conditions	TwinSAFE terminals must not be used under the following operating conditions: • under the influence of ionizing radiation (that exceeds the level of the natural environmental radiation) • in corrosive environments • in an environment that leads to unacceptable soiling of the Bus Terminal
EMC immunity/emission	conforms to EN 61000-6-2 / EN 61000-6-4
Vibration/shock resistance	conforms to EN 60068-2-6 / EN 60068-2-27
Shocks	15 g with pulse duration 11 ms in all three axes
Protection class	IP20
Permitted operating environment	In the control cabinet or terminal box, with minimum protection class IP54 according to IEC 60529
Permissible installation position	see chapter Installation position and minimum distances [▶ 21]
Approvals	CE, cULus, ATEX, TÜV SÜD

3.4   Safety parameters

Key figures	EL2904
Lifetime [a]	20
Prooftest Interval [a]	not required [1]
PFH_D	1.25E-09
%SIL3	1,25 %
PFD	8.45E-05
%SIL3	8,45 %
$MTTF_d$	high
DC	high
Performance level	PL e
Category	4
HFT	1
Element classification [2]	Type B

1. Special proof tests are not required during the entire service life of the EL2904 EtherCAT terminal.
2. Classification according to IEC 61508-2:2010 (chapter 7.4.4.1.2 and 7.4.4.1.3)

The EL2904 EtherCAT Terminal can be used for safety-related applications within the meaning of
IEC 61508:2010 up to SIL3 and EN ISO 13849-1 up to PL e (Cat4).

For the calculation or estimation of the $MTTF_d$ value from the PFH_D value, further information can be found in the TwinSAFE application manual or in ISO 13849-1:2015 Table K.1.
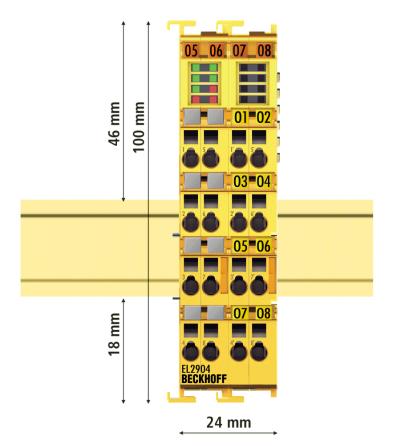
3.5   Dimensions

Fig. 5: Dimensions of the EL2904

Width: 24 mm (side-by-side installation)
Height: 100 mm
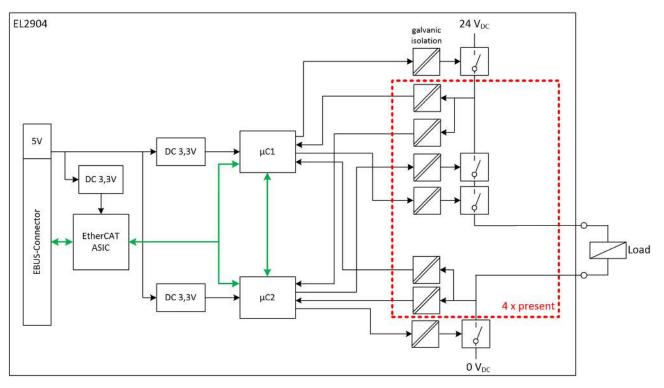Depth: 68 mm

3.6   Block diagram of the EL2904

Fig. 6: Block diagram of the EL2904

The block diagram shows the basic configuration of a channel in the EL2904. The part with a red border is present four times in the terminal. The high-side and low-side switches only exist once for all channels. This means that each channel has a total of four stop paths.

4 Operation

4.1 Environmental conditions

Please ensure that the TwinSAFE components are only transported, stored and operated under the specified conditions (see technical data)!

⚠️ **WARNING**	**Risk of injury!**
	The TwinSAFE components must not be used under the following operating conditions.
	• under the influence of ionizing radiation (that exceeds the level of the natural environmental radiation)
	• in corrosive environments
	• in an environment that leads to unacceptable soiling of the TwinSAFE component

❗ **Attention**	**Electromagnetic compatibility**
	The TwinSAFE components comply with the current standards on electromagnetic compatibility with regard to spurious radiation and immunity to interference in particular. However, in cases where devices such as mobile phones, radio equipment, transmitters or high-frequency systems that exceed the interference emissions limits specified in the standards are operated near TwinSAFE components, the function of the TwinSAFE components may be impaired.

4.2 Installation

4.2.1 Safety instructions

Before installing and commissioning the TwinSAFE components please read the safety instructions in the foreword of this documentation.

4.2.2 Transport / storage

Use the original packaging in which the components were delivered for transporting and storing the TwinSAFE components.

⚠️ **CAUTION**	**Note the specified environmental conditions**
	Please ensure that the digital TwinSAFE components are only transported and stored under the specified environmental conditions (see technical data).

4.2.3 Mechanical installation

⚠️ **DANGER**	**Risk of injury!**
	Bring the bus system into a safe, de-energized state before starting installation, disassembly or wiring of the devices!

4.2.3.1 Control cabinet / terminal box

The TwinSAFE terminals must be installed in a control cabinet or terminal box with IP54 protection class according to IEC 60529 as a minimum.

4.2.3.2   Installation position and minimum distances

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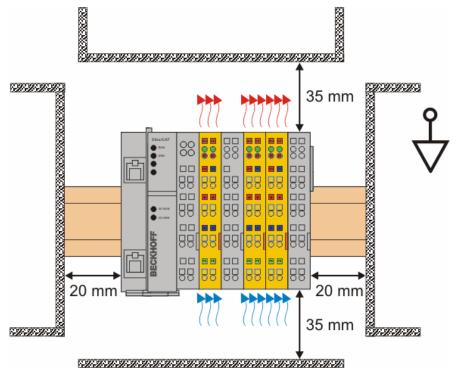

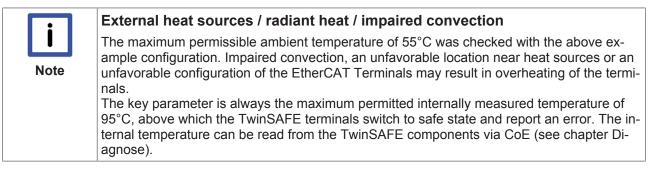Fig. 7: Installation position and minimum distances

In order to ensure optimum convection cooling, the distances to neighboring devices and to control cabinet walls must not be smaller than those shown in the diagram.

4.2.3.3   Example configuration for temperature measurement

Fig. 8: Example configuration for temperature measurement

The example configuration for the temperature measurement consists of an EK1100 EtherCAT coupler with connected terminals that match the typical distribution of digital and analog signal types at a machine. On the EL6900 a safety project is active, which reads safe inputs and enables all 4 safe outputs during the measurement.

i **Note**	**External heat sources / radiant heat / impaired convection**
	The maximum permissible ambient temperature of 55°C was checked with the above example configuration. Impaired convection, an unfavorable location near heat sources or an unfavorable configuration of the EtherCAT Terminals may result in overheating of the terminals.
	The key parameter is always the maximum permitted internally measured temperature of 95°C, above which the TwinSAFE terminals switch to safe state and report an error. The internal temperature can be read from the TwinSAFE components via CoE (see chapter Diagnose).

4.2.3.4 Installation on mounting rails

Mounting

The Bus Couplers and Bus Terminals are attached to commercially available 35 mm mounting rails (according to EN 60715) by applying slight pressure:
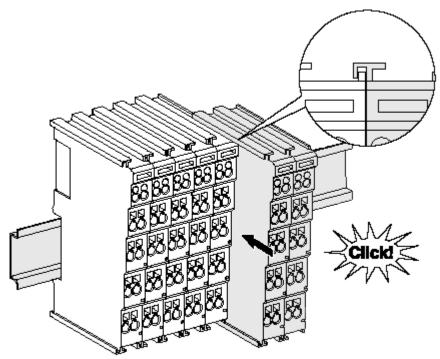

Fig. 9: Installation on the mounting rail

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

![i] **Note**	**Fastening of mounting rails** The locking mechanism of the terminals and couplers protrudes into the profile of the mounting rail. When installing the components, make sure that the locking mechanism doesn't come into conflict with the fixing bolts of the mounting rail. For fastening mounting rails with a height of 7.5 mm under the terminals and couplers, use flat fastening components such as countersunk head screws or blind rivets.

Removal

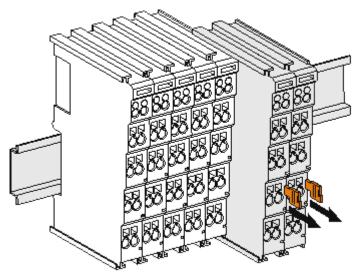

Fig. 10: Removal of mounting rails

1. Carefully pull the orange-colored lugs approximately 1 cm out of the disassembled terminal, until they protrude loosely. The lock with the mounting rail is now released for this terminal, and the terminal can be pulled from the mounting rail without excessive force.
2. Grasp the released terminal with thumb and index finger simultaneous at the upper and lower grooved housing surfaces and pull the terminal away from the mounting rail.

4.2.4 Electrical installation

4.2.4.1 Connections within a Bus Terminal block

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

Spring contacts (E-bus)

The six spring contacts of the E-bus deal with the transfer of the data and the supply of the Bus Terminal electronics.

i **Note**	**Observe the E-bus current** Observe the maximum current that your Bus Coupler can supply to the E-bus! Use the EL9410 Power Supply Terminal if the current consumption of your terminals exceeds the maximum current that your Bus Coupler can feed to the E-bus supply.

Power contacts

The power contacts deal with the supply for the field electronics and thus represent a supply rail within the Bus Terminal block. The power contacts are supplied via terminals on the Bus Coupler.
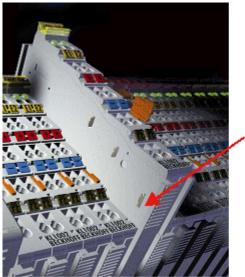
i **Note**	**Note the connection of the power contacts** During the design of a Bus Terminal block, the pin assignment of the individual Bus Terminals must be taken account of, since some types (e.g. analog Bus Terminals or digital 4-channel Bus Terminals) do not or not fully loop through the power contacts. Power Feed Terminals (EL91xx, EL92xx) interrupt the power contacts and thus represent the start of a new supply rail.

PE power contact

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.
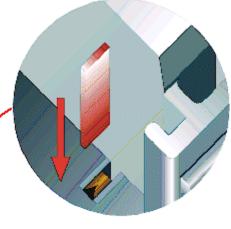

Fig. 11: PE power contact

⚠️ **CAUTION**	**Insulation tests** Note that, for reasons of electromagnetic compatibility, the PE contacts are capacitatively coupled to the mounting rail. This may lead to incorrect results during insulation testing or to damage on the terminal (e.g. disruptive discharge to the PE line during insulation testing of a consumer with a rated voltage of 230 V). For insulation testing, disconnect the PE supply line at the Bus Coupler or the Power Feed Terminal! In order to decouple further feed points for testing, these Power Feed Terminals can be released and pulled at least 10 mm from the group of terminals.
⚠️ **DANGER**	**Serious risk of injury!** The PE power contact must not be used for other potentials!

4.2.4.2   Overvoltage protection

If protection against overvoltage is necessary in your plant, provide a surge filter for the voltage supply to the Bus Terminal blocks and the TwinSAFE terminals.
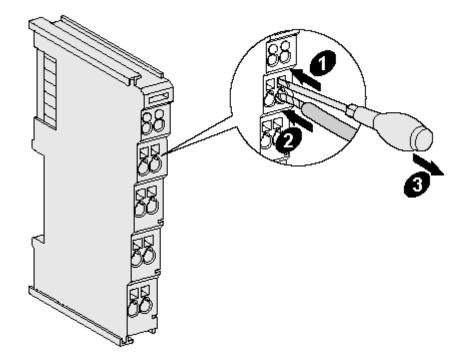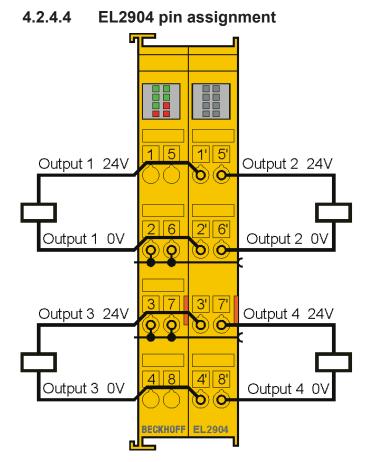
4.2.4.3 Wiring

Fig. 12: Connection of a cable to a terminal point

Up to eight connections enable the connection of solid or finely stranded cables to the Bus Terminals. The connections are implemented in spring-loaded technology. Connect the cables as follows:

1. Open a spring-loaded terminal by slightly pushing with a screwdriver or a rod into the square opening above the terminal.
2. The wire can now be inserted into the round terminal opening without any force.
3. The terminal closes automatically when the pressure is released, holding the wire safely and permanently.

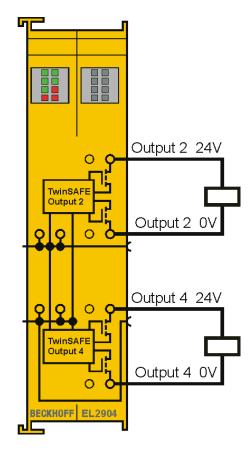| Wire cross section	0,08 ... 2.5 mm^2
Strip length	8 ... 9 mm

4.2.4.4 EL2904 pin assignment

Fig. 13: EL2904 pin assignment

Terminal point	Output	Signal
1	-	not used, no function
2		positive power contact
3	-	negative power contact
4		not used, no function
5	-	not used, no function
6		positive power contact
7	-	negative power contact
8		not used, no function
1'	1	Output 1+
2'		Output 1-
3'	3	Output 3+
4'		Output 3-
5'	2	Output 2+
6'		Output 2-
7'	4	Output 4+
8'		Output 4-

ℹ️ **Note**	**Test pulses**
	When selecting actuators please ensure that the EL2904 test pulses do not lead to actuator switching or diagnostic message from the EL2904.

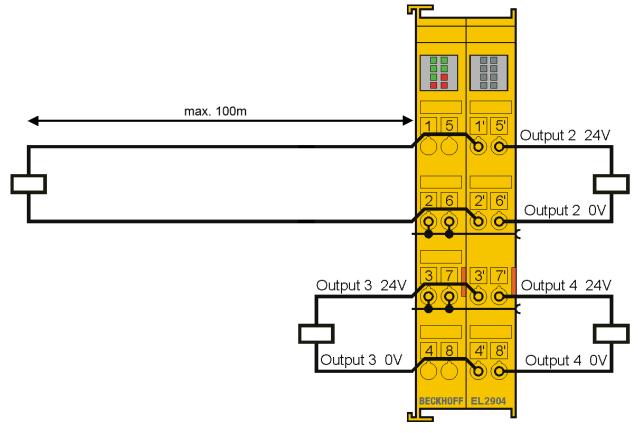### 4.2.4.5   Signal cables

Permitted cable length

Fig. 14: Permitted cable length

When connecting a single actuator via its own continuous cabling (or via a sheathed cable), the maximum permitted cable length is 100 m.

The use of contact points, connectors or additional actuators in the cabling reduces the maximum propagation.
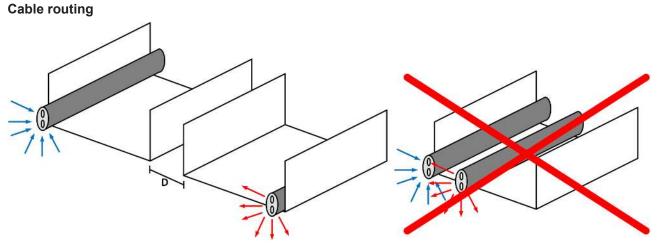
Cable routing

Fig. 15: Cable routing

! **Attention**	**Route the signal cable separately**
	The signal cable must be routed separately from potential sources of interference, such as motor supply cables, 230 V_{AC} power cables etc.!
	Interference caused by cables routed in parallel can influence the signal form of the test pulses and thus cause diagnostic messages (e.g. sensor errors or OpenLoad errors).
	D: Distance between the cable ducts should be as large as possible
	blue arrows: signal line
	red arrows: potential source of interference

The common routing of signals together with other clocked signals in a common cable also reduces the maximum propagation, since crosstalk of the signals can occur over long cable lengths and cause diagnostic messages.

If connection via a bus cable is unavoidable, the test pulses can be switched off (parameters *Testing of outputs active* and *Current measurement active*). However, this then leads to a reduction in the degree of diagnostic cover when calculating the performance level.

Test pulses

The typical length of test pulse (switching from 24 V to 0 V and back to 24 V) is 300 µs to 800 µs. Testing usually takes place 5 to 7 times per second.

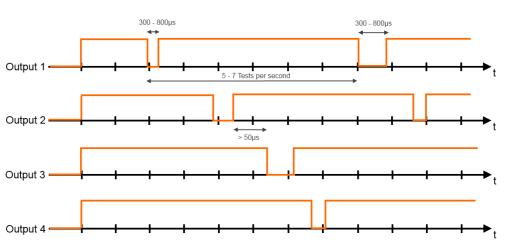| i **Note**	**Test pulses for the outputs**
	The following diagram shows a typical test pulse curve for the four outputs of an EL2904. The parameters *Current measurement active* and *Testing of outputs active* are enabled.

Fig. 16: Typical course of test pulses of the outputs

4.2.5   TwinSAFE reaction times

The TwinSAFE terminals form a modular safety system that exchanges safety-oriented data via the Safety-over-EtherCAT protocol. This chapter is intended to help you determine the system's reaction time from the change of signal at the sensor to the reaction at the actuator.

Typical reaction time

The typical reaction time is the time that is required to transmit information from the sensor to the actuator, if the overall system is working without error in normal operation.
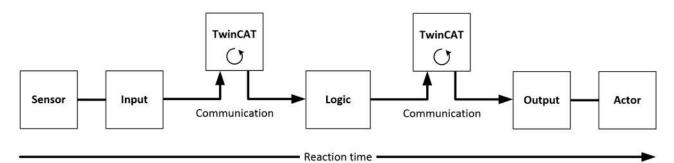

Fig. 17: Typical reaction time

Definition	Description
RTSensor	Reaction time of the sensor until the signal is provided at the interface. Typically supplied by the sensor manufacturer.
RTInput	Reaction time of the safe input, such as EL1904 or EP1908. This time can be found in the technical data. In the case of the EL1904 it is 4 ms.
RTComm	Reaction time of the communication This is typically 3x the EtherCAT cycle time, because new data can only be sent in a new Safety-over-EtherCAT telegram. These times depend directly on the higher-level standard controller (cycle time of the PLC/NC).
RTLogic	Reaction time of the logic terminal. This is the cycle time of the logic terminal and typically ranges from 500 µs to 10 ms for the EL6900, depending on the size of the safety project. The actual cycle time can be read from the terminal.
RTOutput	Reaction time of the output terminal. This typically lies within the range of 2 to 3 ms.
RTActor	Reaction time of the actuator. This information is typically supplied by the actuator manufacturer
WDComm	Watchdog time of the communication

This results in the following equation for the typical reaction time:

$$ReactionTime_{typ} = RT_{Sensor} + RT_{Input} + 3 * RT_{Comm} + RT_{Logic} + 3 * RT_{Comm} + RT_{output} + RT_{Actor}$$

with, for example

$$ReactionTime_{typ} = 5ms + 4ms + 3 * 1ms + 10ms + 3 * 1ms + 3ms + 20ms = 48ms$$

Worst-case reaction time

The worst case reaction time is the maximum time required to switch off the actuator in the case of an error.
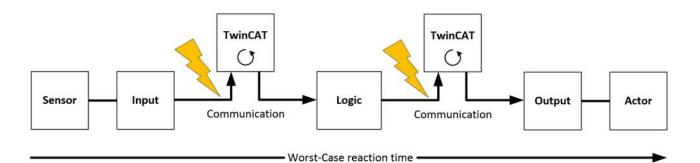
Fig. 18: Worst-case reaction time

This assumes that a signal change occurs at the sensor and is transmitted to the input. A communication error occurs at precisely the moment when the signal is to be transferred to the communication interface. This is detected by the logic following the watchdog time of the communication link. This information should then be transferred to the output, but a further communication error occurs here. This error is detected at the output following the expiry of the watchdog time and leads to the switch-off.

This results in the following equation for the worst-case reaction:

$$ReactionTime_{max} = WD_{Comm} + WD_{Comm} + RT_{Actor}$$

with, for example

$$ReactionTime_{max} = 2 * 15ms + 20ms = 50ms$$

4.2.6   Tested EL2904 devices

The following list contains devices that were tested together with the EL2904 TwinSAFE terminal. The results only apply for the current device hardware version at the time of testing. The tests were carried out in a laboratory environment. Modifications of these products cannot be considered here. If you are unsure please test the hardware together with the TwinSAFE terminal.

Manufacturer	Type	Comment
Beckhoff	AX5801	TwinSAFE Drive option card: safe restart lock
Beckhoff	AX2000 AS option	safe restart lock
Siemens	SIRIUS series S00 3RT1016-1BB42	Contactor
Telemecanique	LP1K09	Contactor

The tests were carried out as function tests only. The information provided in the respective manufacturer documentation remains valid.

	Recommended protective circuits
i **Note**	We recommend R/C or diode-based protective circuits for these devices. Varistor-based protective circuits should not be used.

4.3 Operation in potentially explosive atmospheres (ATEX)

4.3.1 Special conditions

⚠️ **WARNING**	**Observe the special conditions for the intended use of Beckhoff fieldbus components in potentially explosive areas (directive 94/9/EU)!**
	The certified components are to be installed in a suitable housing that guarantees a protection class of at least IP54 in accordance with EN 60529! The environmental conditions during use are thereby to be taken into account!
	If the temperatures during rated operation are higher than 70 °C at the feed-in points of cables, lines or pipes, or higher than 80°C at the wire branching points, then cables must be selected whose temperature data correspond to the actual measured temperature values!
	Observe the permissible ambient temperature range of 0 to 55 °C when using Beckhoff fieldbus components in potentially explosive atmospheres!
	Measures must be taken to protect against the rated operating voltage being exceeded by more than 40% due to short-term interference voltages!
	The individual terminals may only be unplugged or removed from the Bus Terminal system if the supply voltage has been switched off or if a non-explosive atmosphere is ensured!
	The connections of the certified components may only be connected or disconnected if the supply voltage has been switched off or if a non-explosive atmosphere is ensured!
	The fuses of the EL92xx power feed terminals may only be exchanged if the supply voltage has been switched off or if a non-explosive atmosphere is ensured!
	Address selectors and ID switches may only be adjusted if the supply voltage has been switched off or if a non-explosive atmosphere is ensured!

The fundamental health and safety requirements are fulfilled by compliance with the following standards:

- EN 60079-0: 2006
- EN 60079-15: 2005

4.3.2   Identification

Beckhoff fieldbus components that are certified for use in potentially explosive atmospheres bear one of the following markings:

II 3 G Ex nA II T4   KEMA 10ATEX0075 X Ta: 0 - 55°C

or

II 3 G Ex nA nC IIC T4   KEMA 10ATEX0075 X Ta: 0 - 55°C

4.3.3   Date code and serial number

The TwinSAFE terminals bear a date code, which is composed as follows:

Date code: CW YY SW HW

Legend:	Sample: Date code 29 10 02 01
CW: Calendar week of manufacture	Calendar week: 29
YY: Year of manufacture	Year: 2010
SW: Software version	Software version: 02
HW: Hardware version	Hardware version: 01

In addition the TwinSAFE terminals bear a unique serial number.

4.3.4   Further ATEX documentation

i Note	**Please also refer to the further documentation** Notes regarding application of the Bus Terminal system in areas potentially explosive atmosphere are available in the Download section of the Beckhoff website at http://www.beckhoff.de.

4.4   Configuration of the terminal in TwinCAT

⚠ CAUTION	**Do not change CoE objects!** Do not change any of the CoE objects in the TwinSAFE terminals. Any modifications (e.g. via TwinCAT) of the CoE objects will permanently set the terminals to the Fail-Stop state or lead to unexpected behavior of the terminals!

4.4.1   Inserting a Bus Coupler

See TwinCAT automation software documentation.

4.4.2   Inserting a Bus Terminal

See TwinCAT automation software documentation.

4.4.3   Inserting an EL2904

An EL2904 is inserted in the same way as any other Beckhoff Bus Terminal. In the list open *Safety Terminals (ELx9xx)* and select the EL2904.

Fig. 19: Inserting an EL2904

4.4.4 Address settings on TwinSAFE terminals with 1023 possible addresses
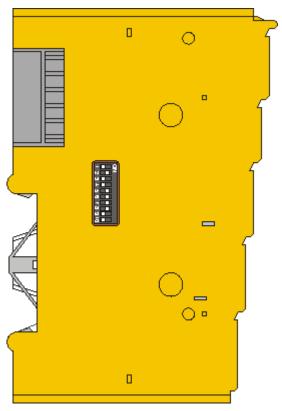

Fig. 20: Address settings on TwinSAFE terminals with 1023 possible addresses

The TwinSAFE address of the terminal is set via the 10-way DIP switch on the left-hand side of the TwinSAFE terminal. TwinSAFE addresses between 1 and 1023 are available.

DIP switch										Address
1	2	3	4	5	6	7	8	9	10	
ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	1
OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	2
ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	3
OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	4
ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	5
OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	6
ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	7
...	...	...	...	...	...	...	...	...	...	...
ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	1023

⚠ **WARNING**	**TwinSAFE address** Each TwinSAFE address may only be used once within a network / a configuration! The address 0 is not a valid TwinSAFE address!

4.4.5 Entering a TwinSAFE address and parameters in the System Manager

The FSoE address set at the DIP switch must also be entered under the *FSoE* tab (*FSoE_Address* entry).

Fig. 21: Entering the FSoE address

The EL2904 parameters are set under the respective TwinSAFE connection in the *Connection* and *Parameter* tabs.

Fig. 22: Setting the connection of the TwinSAFE connection

Fig. 23: Setting the parameters of the TwinSAFE connection

Parameter overview

PrmName	Meaning	Values
Standard outputs active	In addition the output can be switched off from the standard PLC. The safe output is linked with the standard logic signal AND.	true / false
Current measurement active	Current measurement for the outputs is activated	true / false
Testing of outputs active	Test pulses for the outputs are activated	true / false
Error acknowledge active	True: Terminal errors lead to a reset of the TwinSAFE connection (error code 14 (0x0E)). This error code is shown in the diagnostic data for the connection until the user acknowledges it via ErrAck in the TwinSAFE group. False (Default): Terminal errors can only be reset by switching the power supply off and back on again.	true / false
Store Code	This parameter is required for the TwinSAFE Restore Mode	0x0000
Project CRC	This parameter is required for the TwinSAFE Restore Mode	0x0000

i **Note**	**Test pulses** If the parameters Current Measurement active or Testing of outputs active are set to TRUE, the terminal generates test pulses at the outputs. To avoid generating test pulses at the channel outputs, Testing of outputs active and Current measurement active must be set to FALSE. Please note that deactivating of Current measurement active and/or Testing of outputs active may reduce the achievable performance level. A calculation example for the performance level can be found in the TwinSAFE application manual. There are no known application for which it would make sense to set Testing of outputs active to FALSE, while Current measurement active is set to TRUE.

4.5 Diagnostics

4.5.1 Diagnostic LEDs

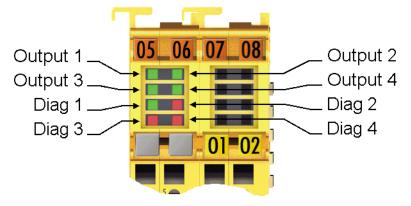The LEDs Diag 1 to Diag 4 display diagnostic information for the EL2904.

Fig. 24: Diagnostic LEDs

Diag 1 (green)

The *Diag 1* LED indicates the state of the TwinSAFE interface (in preparation).

Flashing Code	Meaning
LED illuminated continuously	Diagnostic flashing code in preparation

Diag 2 (red)

The *Diag 2* LED indicates the state of the digital outputs.

Flashing Code	Meaning (see chapterPossible causes of diagnostic messages [▶ 41])
rapid flickering, alternating with 1 flash pulse	Error at output 1
rapid flickering, alternating with 2 flash pulses	Error at output 2
rapid flickering, alternating with 3 flash pulses	Error at output 3
rapid flickering, alternating with 4 flash pulses	Error at output 4
rapid flickering, alternating with 5 flash pulses	Field voltage too low
rapid flickering, alternating with 6 flash pulses	Field voltage too high
rapid flickering, alternating with 7 flash pulses	Internal terminal temperature too low
rapid flickering, alternating with 8 flash pulses	Internal terminal temperature too high
rapid flickering, alternating with 9 flash pulses	Temperature difference error
rapid flickering, alternating with 10 flash pulses	Error in output circuit

These errors can only be reset by switching the power supply for the TwinSAFE terminal off and back on again.

Diag 3 (red) and Diag 4 (red)

If the Diag 3 LED is lit, the Diag 4 LED indicates internal terminal errors.

These errors lead to shutdown of the terminal. The terminal must be checked by Beckhoff Automation GmbH & Co. KG.

Flashing Code

In the case of such an error, the *Diag 4* LED on the EL2904 displays flashing codes that describe the error in more detail.

A flashing code consists of four sequences, which are interrupted in each case by a short break. After the four sequences there is a long break, following which the flashing code is displayed again.

Count the individual sequences of the flashing code.

	Note the flashing codes and return the terminal
Note	Note the flashing code displayed and include this information with the terminal when you return it.

4.5.2 Diagnostic objects

	Do not change CoE objects!
CAUTION	Do not make any modifications to the CoE objects in the TwinSAFE components! Any modifications (e.g. using TwinCAT) of the CoE objects will permanently set the TwinSAFE components to the Fail-Stop state.

Index FA80$_{hex}$: Internal temperature values

The CoE objects FA80$_{hex}$ indicate the current internal temperature values of the EL2904.

Index	Name	Meaning	Flags	Default
FA80:01	Temperature 1	Temperature measurement 1 (left board)	RO	0$_{bin}$
FA80:02	Temperature 2	Temperature measurement 2 (left board)	RO	0$_{bin}$
FA80:03	Temperature Outputs	Temperature measurement (right board)	RO	0$_{bin}$

Index 800E$_{hex}$: Diagnostic objects

The CoE objects 800E$_{hex}$ display further diagnostic information.

Index	Name	Meaning		Flags	Default
800E:0	Diag	The following sub-indices contain detailed diagnostic information.		RO	
800E:0C	Error at the output	Bit	External supply or cross-circuit*	RO	
		0	1_{bin}: Output 1		0_{bin}
		1	1_{bin}: Output 2		0_{bin}
		2	1_{bin}: Output 3		0_{bin}
		3	1_{bin}: Output 4		0_{bin}
		Bit	Open load or current below minimum value of 20 mA or current above maximum value of 500 mA**		0_{bin}
		4	1_{bin}: Output 1		
		5	1_{bin}: Output 2		0_{bin}
		6	1_{bin}: Output 3		0_{bin}
		7	1_{bin}: Output 4		0_{bin}
800E:0D	Supply error	Bit	Field voltage (power contacts) outside the specification	RO	
		0	1_{bin}: Field voltage too high		0_{bin}
		1	1_{bin}: Field voltage too low		0_{bin}
800E:0E	Temperature error	Bit	Terminal temperature outside the specification.	RO	
		0	1_{bin}: Overtemperature µC1		0_{bin}
		1	1_{bin}: Overtemperature µC2		0_{bin}
		2	1_{bin}: Overtemperature of the output board		0_{bin}
		3	1_{bin}: Temperature too low µC1		0_{bin}
		4	1_{bin}: Temperature too low µC2		0_{bin}
		5	1_{bin}: Temperature of the output board too low		0_{bin}
		6	1_{bin}: Temperature difference on the processor board too large		0_{bin}
		7	1_{bin}: Temperature difference between the boards is too large		0_{bin}

*) These diagnostic messages are displayed only if Current Measurement active = false.

**) These diagnostic messages are displayed only if Current Measurement active = true. If no channel-specific diagnostic is possible, all bits (4...7) are set. This is independent of the parameter settings.

i **Note**	**Differing diagnostic messages possible** Due to the variable order or execution of the test series, diagnostic messages differing from those given in the table above are possible.

4.5.3 Possible causes of diagnostic messages

Diagnostics	Possible cause	Remedial actions
Diag 2 LED Flash code 1 to 4 or 10	If parameters "Testing of outputs active" and/or "Current measurement active" are enabled:	
	Faulty test pulses. Cause: external supply or cross-circuit.	Eliminate cross-circuit or external supply.
	Faulty test pulses. Cause: parallel routed cables with high capacitive coupling and dynamized signals, possibly also in common cables	Isolate lines and lay in separate non-metallic sheathed cable. Create a distance between the non-metallic sheathed cables.
	Cause: Current is below the limit of 20 mA or above the limit of 500 mA.	Select actuator accordingly. Current > 20mA and < 500mA
	Regardless of whether the parameters "Testing of outputs active" and/or "Current measurement active" are enabled:	
	The output voltage lies below the permissible voltage range (24V -15%/+20%). A possible cause is a short-circuit at the output or e.g. a voltage drop at the instant of switching.	Eliminate short-circuit. Design power supply accordingly. Check supply lines for voltage drop.
	EMC faults	Take suitable EMC measures
	Internal defect	Replace terminal
Diag 2 LED Flash code 5	Voltage at the power contacts not switched on.	Switch on voltage at the power contacts and reset the error display through PowerOn Reset of the terminal
	Voltage at the power contacts was switched on after the terminal supply	Switch on voltage at the power contacts before or at the same time as the terminal supply and reset the error display through PowerOn Reset of the terminal
	Voltage on the power contacts too low.	Increase the voltage at the power contacts and reset the error display through PowerOn Reset of the terminal
	EMC faults	Take suitable EMC measures
	Internal defect	Replace terminal
Diag 2 LED Flash code 6	Field voltage too high. Voltage on the power contacts too high.	Reduce the voltage at the power contacts and reset the error display through PowerOn Reset of the terminal
	Voltage briefly too high due to external influences, such as switching contactors off.	Use an R/C or diode-based protective circuit on the actuators
	EMC faults	Take suitable EMC measures
	Internal defect	Replace terminal
Diag 2 LED Flash code 7	Terminal temperature too low	Comply with the specified temperature range
	EMC faults	Take suitable EMC measures
	Internal defect	Replace terminal
Diag 2 LED Flash code 8	Terminal temperature too high	Comply with the specified temperature range
	EMC faults	Take suitable EMC measures
	Internal defect	Replace terminal
Diag 2 LED Flash code 9	Terminal temperature difference too large: one of the 3 internal measuring points is faulty	Replace terminal
	Terminal temperature difference too large: An internal measuring point shows an elevated temperature due to inadequate convection.	Check the installation position of the terminal and modify it according to the specifications in section *Mechanical installation*, if required
	EMC faults	Take suitable EMC measures
	Internal defect	Replace terminal

4.6 Maintenance

Maintenance

The TwinSAFE components are maintenance-free!

Environmental conditions

⚠️ **WARNING**	**Observe the specified environmental conditions!** Please ensure that the TwinSAFE components are only stored and operated under the specified conditions (see technical data).

If the TwinSAFE component is operated outside the permitted temperature range it will switch to *Global Shutdown* state.

Cleaning

Protect the TwinSAFE component from unacceptable soling during operation and storage!

If the TwinSAFE component was subjected to unacceptable soiling it may no longer be operated!

⚠️ **WARNING**	**Have soiled terminals checked!** Cleaning of the TwinSAFE component by the user is not permitted! Please send soiled terminals to the manufacturer for inspection and cleaning!

4.7   Service life

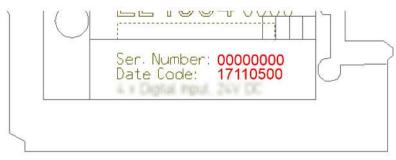The TwinSAFE terminals are designed for a service life of 20 years.

Due to the high diagnostic coverage within the lifecycle no special proof tests are required.

The TwinSAFE terminals bear a date code, which is composed as follows:

Date code: CW YY SW HW

Legend: Sample: Date Code 17 11 05 00

CW: Calendar week of manufacture   Calendar week: 17

YY: Year of manufacture   Year: 2011

SW: Software version   Software version: 05

HW: Hardware version   Hardware version: 00

In addition the TwinSAFE terminals bear a unique serial number.

Fig. 25: Unique serial number of a TwinSAFE terminal

4.8   Decommissioning

⚠️ **DANGER**	**Serious risk of injury!** Bring the bus system into a safe, de-energized state before starting disassembly of the devices!

Disposal

In order to dispose of the device, it must be removed and fully dismantled.

- Housing components (polycarbonate, polyamide (PA6.6)) are suitable for plastic recycling.
- Metal parts can be sent for metal recycling.
- Electronic parts such as disk drives and circuit boards must be disposed of in accordance with national electronics scrap regulations.

5 Appendix

5.1 Support and Service

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

Beckhoff's branch offices and representatives

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

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

You will also find further documentation for Beckhoff components there.

Beckhoff Headquarters

Beckhoff Automation GmbH & Co. KG

Huelshorstweg 20
33415 Verl
Germany

Phone:	+49(0)5246/963-0
Fax:	+49(0)5246/963-198
e-mail:	info@beckhoff.com

Beckhoff Support

Support offers you comprehensive technical assistance, helping you not only with the application of individual Beckhoff products, but also with other, wide-ranging services:

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

Hotline:	+49(0)5246/963-157
Fax:	+49(0)5246/963-9157
e-mail:	support@beckhoff.com

Beckhoff Service

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

- on-site service
- repair service
- spare parts service
- hotline service

Hotline:	+49(0)5246/963-460
Fax:	+49(0)5246/963-479
e-mail:	service@beckhoff.com

5.2 Certificates

Reliability of EL2904

Test and Certification body

TÜV SÜD Rail GmbH
Rail Automation - IQSE
Barthstraße 16
D-80339 Munich

Manufacturer

Beckhoff Automation GmbH & Co. KG
Huelshorstweg 20
D-33415 Verl

Safety parameters EL2904

Key figures	EL2904
Lifetime [a]	20
Prooftest Intervall [a]	not required [1]
PFH_D	1.25E-09
%SIL3	1.25%
PFD	8.45E-05
%SIL3	8.45%
$MTTF_d$	High
B10d (cycles)	-
DC	High
Performance level	PL e
Category	4
HFT	1
Element classification*	Type B

*) Classification according to IEC 61508-2:2010 (see chapters 7.4.4.1.2 and 7.4.4.1.3)

The EL2904 EtherCAT Terminal can be used for safety-related applications within the meaning of IEC 61508:2010 up to SIL3 and EN ISO 13849-1 up to PL e (Cat4).

[1] Special proof tests for the product are not required during the lifetime of the EL2904 EtherCAT terminal as a result of the high diagnostic coverage of the system.

Munich, 2016-03-07

Günter Greil

Digital unterschrieben von
Guenter Greil
DN: c=DE, o=TUEV SUED
Rail GmbH, ou=Rail &
Automation, cn=Guenter
Greil,
email=guenter.greil@tuev
-sued.de
Datum: 2016.03.07
17:51:11 +01'00'

TwinSAFE Reliability

7

BECKHOFF

Product Service

CERTIFICATE

No.   Z10 14 12 62386 022

Holder of Certificate: **Beckhoff Automation GmbH & Co. KG**
Hülshorstweg 20
33415 Verl
GERMANY

Factory(ies):   62386

Certification Mark:

Product: **Safety components**

Model(s):   **KL 2904, EL 2904**

Parameters:

Supply voltage:	24VDC (-15%/+20%)
Power dissipation:	2W
Protection class:	IP 20

Tested according to:
2006/42/EC
EN 61508-1:2010 (SIL 1-3)
EN 61508-2:2010 (SIL 1-3)
EN 61508-3:2010 (SIL 1-3)
DIN EN ISO 13849-1:2008 (Cat 4, PL e)
DIN EN 81-1:2000
EN 13243:2004
DIN EN 61000-6-2:2006
DIN EN 61000-6-4:2007

The product was tested on a voluntary basis and complies with the essential requirements. The certification mark shown above can be affixed on the product. It is not permitted to alter the certification mark in any way. In addition the certification holder must not transfer the certificate to third parties. See also notes overleaf.

Test report no.:   BV82168T

Valid until: 2019-12-17

Date,   2014-12-18   (Günter Greil)
Page 1 of 1

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TÜV®

A1 / 04.11

ZERTIFIKAT ◆ CERTIFICATE ◆ СЕРТИФИКАТ ◆ 証明書 ◆ 认证证书 ◆ CERTIFICADO ◆ CERTIFICAT ◆ CERTIFICAT

List of illustrations