Design Guide to

EJ Backplane for TwinSAFE Modules

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BECKHOFF

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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 [▶ 38].

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
1.5.1	• Changes after Review
1.5.0	• Maximum voltage increased to 60 V and selection of clearances and creepage distances adjusted accordingly
1.4.0	• Appendix updated • Notes to pinouts of non-certified products removed
1.3.0	• EJ1914 / EJ2914 pinout added • Note to pinouts of non-certified products added
1.2.0	• Reference to standards updated
1.1.0	• Chapter Specifications expanded
1.0.0	• first released version

2 General description

2.1 Purpose and area of application

This document is meant for developers who would like to create a backplane or an EJ distribution board upon which secure EJ modules should be used along with standard EJ modules.

The document [R1] gives information about the general design of an EJ distribution board for standard EJ components. This design guide must be expanded accordingly for secure EJ components. This document contains only the expansion to [R1]. All requirements from [R1] must likewise be met.

2.2 Applicability

This document an expansion to the document mentioned under [R1]. The requirements from [R1] and this document must be met in order to develop an EJ distribution board.

2.3 Terms and definitions

n/a	not applicable
PCB	Printed-Circuit-Board

2.4 Reference documents

The reference documents are listed with their current revision of the date of this document creation. The user must ensure that always the most current standard is used for the development. All named references must be used by the developer in the original. This document can not be used as a substitute for the below-mentioned references.

[R1]	**EJxxxx | EtherCAT plug-in modules Design Guide** Version 4.2 from 02/03/2016 or newer
[R2]	**DIN EN ISO 13849-2:2013** *„Safety of machinery – Safety-related parts of control systems – Part 2: Validation“*
[R3]	**EN 60664-1:2007** *„Insulation coordination for electrical equipment in low-voltage systems – Part 1: Principles, requirements and tests”*
[R4]	**DIN EN ISO 13849-1:2016-06** *“Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design”*
[R5]	**-**
[R6]	**EN 60664-5:2007** *“Insulation coordination for electrical equipment in low-voltage systems – Part 5: Comprehensive method for determining clearances and creepage distances equal to or less than 2 mm”*
[R7]	**IPC-A-600H** *Acceptability of Printed Boards*
[R8]	**IPC-2221B** *Generic Standard on Printed Board Design*

Note	**EN 60664-5** The clearances and creepage distances according to EN 60664-5 (listed under [R6]) are only valid for distances below 2mm. For this reason, EN 60664-1 (listed under [R3]) is taken as the general standard in this analysis.

2.5 Specifications

The power supply on the EJ distribution board for the safety EJ module can only be provided by an SELV/PELV power supply unit with a nominal voltage of 24 V.

For other standard modules, e.g. ServoDrive modules, a higher voltage may be necessary. This supply may be made with a SELV / PELV power supply with a nominal voltage of 48 VDC.

 WARNING	**Power supply 24 V_{DC}** An SELV/PELV power supply unit with a voltage limit of U_{max}= 36 V_{DC} on the output side must be used to supply power for the TwinSAFE EJ modules with 24 V_{DC}. Failure to observe this can result in a loss of safety.
 WARNING	**Power supply 48 V_{DC}** An SELV/PELV power supply unit with a voltage limit of U_{max}= 60 V_{DC} on the output side must be used to supply power for the standard EJ modules with 48 V_{DC}. Failure to observe this can result in a loss of safety.
 Attention	**Overvoltage protection** If protection against overvoltage is necessary in your plant, provide a surge filter for the voltage supply to the EJ Distributionboard and the TwinSAFE EJ modules. This surge filter can be realized on the EJ-distribution board or as an external filter module and is intended to limit transients above 36 volts.
 WARNING	**Voltages max. 60 V** The selection of the rated surge voltage only applies if no higher voltages than the 60 V presumed here are present or used on the printed circuit board.
 Note	**Voltages higher than 60 V** This document can NOT be used to design clearances and creepage distances if voltages greater than 60 V are present on the EJ distribution board.

2.6 Environmental conditions safety EJ modules

Please consult the respective user documentation for information about the environmental conditions in which the safety EJ modules may be operated.

2.7 Further considerations

The EJ distribution board has to be a printed circuit board (PCB). In addition, the assumption is made that there are no other components on the EJ distribution board with the exception of connectors.

 Note	**Additional components on the EJ distribution board** If e.g. additional electronic components are used on the EJ distribution board, the user must perform a separate assessment of these circuits.

2.8 TwinSAFE EJ modules

2.8.1 TwinSAFE logic EJ module

The TwinSAFE logic EJ module does not have any inputs and outputs for sensors or actuators, but instead uses only E-bus communication, in order to exchange secure data with other TwinSAFE components via Safety-over-EtherCAT. EtherCAT communication is located in the black channel of the EJ module. Corresponding error detection mechanisms are defined in the Safety-over-EtherCAT specification, so that communication errors are detected. There are therefore no special requirements for the board design.

2.8.2 TwinSAFE input or output EJ module

The safe input and output EJ modules likewise use Safety-over-EtherCAT communication for exchange of secure data with the TwinSAFE logic. This part is located in the black channel of the respective module and is separate from the inputs and outputs according to [R1]. The signals to the sensors and actuators can have test pulses assigned and thus errors can be detected in the cable routing. The activation of the test pulses has an influence on the achievable performance level of the respective safety functions.

In addition, the following comments regarding clearances and creepage distances must be observed, in order to rule out a cross-circuit between two adjacent conductor paths or contact points.

3 Requirements for the EJ distribution board

This chapter describes the requirements for an EJ distribution board when using a safety EJ module.

The consideration must be made for 3 different parts of the distribution board.

- SAMTEC connector between EJ module and distribution board
- Tracks on the distribution board
- Customized connectors from the distribution board into the field

For all 3 areas, the definition of clearances and creepage distances is carried out in the following chapters and the derivation is also shown.

3.1 Requirements from DIN EN ISO 13849-2:2013

3.1.1 Table D.1: Basic safety principles

The following table with Columns 1 and 2 was taken from [R2]. The last column contains comments for the developer of the PCB, which are not normatively set.

Basic safety principle	Comments	Comments, not normative: To be considered by the PCB developer
Application of suitable materials and production methods	Selection of material, production and treatment methods taking into consideration e.g. voltage, durability, elasticity, friction, wear and tear, corrosion, temperature, conductivity, mechanical strength of the insulation materials.	Specification from Table D.5: As a base material at least EP GC in accordance with IEC 60893-1 is used.
Correct dimensioning and shaping	Consideration e.g. of tension, strain, fatigue, surface roughness, tolerance limits, production methods.	Design e.g. according to [R8] and examination corresponding to [R7] class 3
Suitable selection, combination, arrangements, assembly and installation of the components/ of the system	Consideration of operating instructions of manufacturer, e.g. catalogue sheets, installation information, requirements, as well as the application of proven technical experiences.	see user documentation of safety components
Correct protective conductor connection	One side of the control circuit, a terminal of any electromagnetically operated device or a terminal of other electrical devices is connected to a protective conductor (see IEC 60204-1:2005, 9.4.3.1).	must be performed by user
Insulation monitoring	A device for insulation monitoring is to be used which either displays an earth leakage or automatically breaks the circuit after an earth leakage (see IEC 60204-1:2005, 6.3.3.)	must be performed by user
Application of the principle of energy separation	A safe state is achieved by separating all important devices from the energy source, e.g. by application of a normally closed contact (NC) for inputs (pushbutton and position switch) and a normally opened contact (NO) for relay (see also ISO 12100:2010, 6.2.11.3). In some cases exceptions are possible, e.g. whenever the power failure constitutes an additional hazard. Time delaying functions may be necessary to achieve a secure state of the system (see IEC 60204-1:2005, 9.2.2).	must be performed by user
Suppression of voltage peaks	A device for the suppression of voltage peaks (RC element, diode, varistor) should be used parallel to the applied load, however not parallel to the contacts. NOTE: Using a diode increases the switch-off time.	typically used only outside of the printed circuit board
Reduction of the response time	Minimization of the delay in switching off the components used for switching.	to be considered by the user
Compatibility	Application of components that are suitable for the applied voltages and currents.	see user documentation of safety components
Resistance to ambient loads	Design of the devices so that they can work in all environments expected for use and under all unfavorable conditions, e.g. temperature, humidity, vibration and electromagnetic interference (EMI) (see Section 10).	see user documentation of safety components
Secure fastening of the input devices	The input devices are to be secured in such a way, e.g. by locking switches, position switches, limit switches, proximity switches, that position, orientation and switch tolerances can be maintained under all expected conditions, e.g. vibration, normal wear and tear, penetration of foreign bodies, temperature. See ISO 14119:1998, Section 5.	n/a
Protection from unexpected start-up	Prevention of unexpected start-up, e.g. after restoration of power (see ISO 12100:2010, 6.2.11.4, ISO 14118, IEC 60204-1).	n/a
Protection of the control circuit	The control circuit should be protected in accordance with IEC 60204-1:2005, 7.2 and 9.1.1.	n/a
Successive switching in the case of circuits with serial connections of redundant signals	For the prevention of the common-cause failures by two welded contacts simultaneous activation and deactivation does not take place, so that one contact always switches without current.	n/a

3.1.2 Table D.2: Proven safety principles

The following table with Columns 1 and 2 was taken from [R2]. The last column contains comments for the developer of the PCB, which are not normatively set.

Proven safety principle	Comments	Comments, not normative: To be considered by the PCB developer
Positively mechanically linked contacts	Application of positively mechanically linked contacts, e.g. for monitoring function in systems of category 2, 3 and 4 (see EN 50205, IEC 60947-4-1:2001, Annex F, IEC 60947-5-1:2003 + A1:2009, Annex L).	n/a
Fault prevention in cables	To prevent short circuits between two adjacent lines, either • at each individual line use cable, whose shielding is connected to the protective conductor system, or • in flat cables, use a protective conductor between all signal lines.	to be considered by the user
Distances between conductors	Use of sufficient distance between connection terminals, components and lines so that unintentional connections are prevented.	according to Table D.5
Energy limitation	Use a capacitor for supply of a limited quantity of energy, e.g. using a time controller.	n/a
Limitation of electrical parameters	Limitation of voltage, current, power or frequency, in order to restrict the movement, e.g. through torque control, staggered/time limited running and reduced speed, in order to prevent an unsafe state	n/a
Preventing undefined states	Undefined states in the control system should be avoided. The control system should be designed such that during normal operation and under all expected operating conditions the state of the control system, e.g. output/outputs, can be predetermined.	n/a
Positive actuation mode	A direct actuation is transferred by positive locking (not by force locking) without elastic elements, i.e. no use of springs between actuator and contacts (see ISO 14119:1998, 5.1, ISO 12100:2010, 6.2.5).	n/a
State alignment in the event of breakdowns	If possible, in the event of a breakdown all devices/circuits should change to a secure state or to secure conditions.	is implemented by the safety EJ module
Directed breakdown	If feasible, components or systems should be used for which the type of breakdown is known in advance (see ISO 12100:2010, 6.2.12.3).	is implemented by the safety EJ module
Overdimensioning	Components, that are used in protective circuitry, must be derated, e.g. by • the current, which is conducted through the switching contacts, and which should be less than half of the current nominal value, • the switching frequency of the components, which should be less than half of the switching frequency nominal value, and • the total number of the expected switching operations, which should be no more than 10 % of the number of switching operations, for which this electrical device is designed. NOTE: Derating may depend on sensible design.	Requires design by user.
Reduction of potential failures	Separation of safety-related functions from other functions	is implemented by the safety EJ module
Balance between complexity/simplification	A balance should be established between: • the complexity of the devices, in order to achieve better control and • the simplification of the devices, in order to improve their reliability	n/a

3.1.3 Table D.3 - Proven components

This table does not apply, since no “proven” components are used.

3.1.4 Section D2 Fault exclusions

Section D2 of [R2] covers fault exclusions.

Regarding D.2.1 General Remarks from [R2]:

The environmental conditions under which the safety EJ modules may be operated are described and specified in the user documentation.

Regarding D.2.2 “Tin Whiskers” from [R2]:

NOTE 3: Whiskers have not yet been detected on printed circuit boards. The conducting paths generally consist of copper without tin coating. While contact points can be coated with tin alloy, the production process does not seem to promote the susceptibility to whisker formation.

In spite of NOTE 3 the user should take this issue into consideration in the design.

Regarding D.2.3 Short Circuits on PCB-mounted Parts from [R2]:

“Short circuit between two adjacent conductor paths/contact points” as in Table D.5 (see Chapter Table D.5 - Errors and fault exclusions - printed circuit boards / assembled PCBs [▶ 15]) must be taken into consideration.

Regarding D.2.4 Fault Exclusions and Integrated Circuits from [R2]:

Since no integrated circuits are used on the EJ distribution board, this item does not apply.

3.1.5 Table D.4 - Errors and fault exclusions – lines / cables

Table D.4 does not apply, since no lines and cables are used in the EJ distribution board.

Note	**External wiring** For external wiring from the custom connector into the field, Table D.4 must be considered by the user.

3.1.6 Table D.5 - Errors and fault exclusions - printed circuit boards / assembled PCBs

The following table has been adopted from [R2] in its entirety.

Observed error	Fault exclusion	Comments
Short circuit between adjacent conducting paths / contact points	Short circuits between adjacent conductors, if the observations are correct.	As a base material at least EP GC in accordance with IEC 60893-1 is used. The clearances and creepage distances are dimensioned at least in accordance with IEC 60664-5 (for distances of more than 2 mm IEC 60664-1) with degree of contamination 2 / overvoltage category III; if both conducting paths are supplied with power via an SELV/ PELV power supply unit, then the degree of contamination 2 / overvoltage category II with a minimum distance of 0.1 mm applies. The mounted board is installed in a border which protects it from conductive contamination, e.g. a border with a degree of protection of at least IP 54, and the printed side(s) of the assembled board is/are furnished with an age-resistant paint or protective coating so that all conducting paths are covered.
Interruption in all conductor paths	No	—

3.1.7 Table D.6 Errors and fault exclusions terminal points

Table D.6 does not apply, since no terminal points are used on the EJ distribution board.

3.1.8 Table D.7 Errors and fault exclusions - Multi-pole connectors

The following table has been adopted from [R2] in its entirety.

Observed error	Fault exclusion	Comments
Short circuit between two random adjacent connector pins	Short circuit between adjacent connector pins, if the observation is correct. If the conductor is mounted on a PCB, the considerations on failure exclusion from Table D.5 apply.	For multi-core wires through the use of wire end ferrules or other suitable means. Creepage distances and clearances and all distances should be dimensioned at least in accordance with IEC 60664-1, overvoltage category III.
Pin transposed or incorrectly plugged in, when no mechanical possibility for prevention is provided	No	—
Short circuit between a random conductor (see comment) and the ground or a conducting part or the protective conductor	No	The wire conductors of the cable are considered part of the multi-pole connector.
Interruption of individual connector pins	No	—

3.1.9 Tables D.8 through D.21

If additional electrical / electronic components are used on the EJ distribution board along with a pure signal distribution, the user must also consider the respective associated Tables D.8 through D.21.

4 Specification pollution degree and overvoltage category

In Tables D.5 and D.7 from [R2] the degree of pollution and the overvoltage category are specified.

4.1 Samtec connector

The Samtec female connector on the distribution board and the post connector on the EJ module are both soldered on the PCB side.

Refer to Table D.7 (Fault Exclusion - Multipole Connectors) in [R2] for connectors mounted on the PCB side for fault exclusion considerations in D.5 of [R2]. Accordingly, a pollution degree 2 / overvoltage category III applies.

Since a SELV/PELV power supply is required, the overvoltage category can be reduced to II.

Note	**Result Samtec connector** For the Samtec connection pollution degree 2 / overvoltage category II applies.

4.2 EJ Distribution Board

For the Distribution Board, Table D.5 from [R2] Errors and Fault Exclusions - Printed Circuit Boards / assembled Printed Circuit Boards is applicable.

According to Table D.5 from [R2], a pollution degree 2 / overvoltage category III applies.

Since a SELV/PELV power supply is required, the overvoltage category can be reduced to II.

Note	**Result Distribution Board** For the Distribution Board pollution degree 2 / overvoltage category II applies.

4.3 Customer-specific connector

Typically, the custom connector is soldered on the PCB side. On the connector side, a custom wiring takes place.

Refering to Table D.7 (Fault Exclusion - Multipole Connectors) in [R2] for connectors mounted on the PCB side, the fault exclusion considerations in D.5 of [R2] applies. Accordingly, a pollution degree 2 / overvoltage category III applies.

Since a SELV/PELV power supply is required, the overvoltage category can be reduced to II.

For the connector side, this reduction can not be applied. All distances must be at least rated according to overvoltage category III.

Note	**Result customer-specific connection** Pollution degree 2 / overvoltage category II for the PCB side and pollution degree 2 / overvoltage category III for the connector side apply to the customer-specific connection.

4.4 Determination rated surge voltage

The rated surge voltage is determined from Table F.1 in [R3]. This value is the parameter with which the clearance and creepage distances can be measured.

The nominal voltage of a 48 V_{DC} SELV/PELV power supply is typically between 48 V_{DC} and 56 V_{DC}. The maximum voltage is 60 V_{DC}, so in table F.1 the voltage between conductor and neutral is assumed to be 100 V.

Voltage conductor to neutral conductor, derived from nominal or nominal DC voltage up to and including (in V)	Reated surge voltage			
	Overvoltage category			
	I (in V)	II (in V)	III (in V)	IV (in V)
50	330	500	800	1500
100	500	**800**	**1500**	2500

Note

Rated surge voltage

Overvoltage category II: 800 V

Overvoltage category III: 1500 V

5 Clearances and creepage distances (EJ board)

The following ratings apply to the EJ Distribution Board and the PCB-sided multipole connectors.

Note	**Connector** For PCB-mounted connectors, the mechanical structure of the connector must be taken into account.

The clearances are determined for transient overvoltages.

Assuming the rated surge voltages determined in the previous chapter, results in the following minimum clearances.

Clearances for transient overvoltages of [R3] Tabelle F.2

The following table is a section of table F.2 from [R3]. You can find the complete table and the comments on it in the standard.

Required standing surge voltage (in kV)	Minimum clearances at altitudes up to 2000 m above sea level (NN)					
	Condition A - inhomogenous field (in mm)			Condition B - homogenous field (in mm)		
	Pollution degree			Pollution degree		
	1	2	3	1	2	3
0,33	0,01	**0,20**	0,80	0,01	**0,20**	0,80
0,40	0,02			0,02		
0,50	0,04			0,04		
0,60	0,06			0,06		
0,80	**0,10**			**0,10**		
1,0	0,15			0,15		
1,2	0,25	0,25		0,20		
1,5	0,50	0,5		0,30	0,30	
2,0	1,0	1,0	1,0	0,45	0,45	

With printed circuit boards, the values of pollution degree 1 apply, with the exception that an clearance of 0.04 mm must not be underexceeded..

Note	**Clearance for the EJ-Board** The clearance is 0.10 mm for a homogeneous and inhomogeneous field. This also corresponds to the minimum clearance of 0.1 mm from D.5 [R2]. These clearances are valid only up to a height of 2000 m above sea level.

Note	**Clearance for the PCB-side connector** The clearance is 0.20 mm for a homogeneous and inhomogeneous field. These clearances are valid only up to a height of 2000 m above sea level.

Creepage distances according to [R3] table F.4

The voltage to be used for table F.4 is determined from table F.3a.

The nominal voltage of a 48 V_{DC} SELV/PELV power supply is typically between 48 V_{DC} and 56 V_{DC}. The maximum voltage is 60 V_{DC}, so in Table F.4 the voltage of 63 V determined from Table F.3a is used.

Voltage (RMS value in V)	Minimum creepage								
	printed circuits								
	Pollution degree								
	1	2	1	2			3		
	All ISG*	All ISG except IIIb	All ISG	ISG I	ISG II	ISG III	ISG I	ISG II	ISG III
40	0,025	0,040	0,16	0,56	0,80	1,10	1,40	1,60	1,80
50	0,025	0,040	0,18	0,60	0,85	1,20	1,50	1,70	1,90
63	**0,040**	0,063	0,20	**0,63**	**0,90**	**1,25**	1,60	1,80	2,00
80	0,063	0,100	0,22	0,67	0,95	1,30	1,70	1,90	2,10

* ISG - Insulating group (see chapter 4.8.1.3 in [R3])

Note

Minimum creepage

The minimum creepage distance of the printed circuit board is 0.04 mm (63 V, printed circuits, pollution degree 1). Thus, the minimum creepage distance of 0.1 mm applies according to D.5 [R2].

The minimum creepage distance of the PCB-side connector is 1.25 mm for the insulating group III. Depending on the group of insulating materials, this distance can be reduced. For the distances of the Samtec female connector see Connection EJ modules (Samtec female connector) [▶ 23].

6 Clearances and creepage distances (customer-specific connector)

A custom connector forms the connection level between the EJ Distribution Board and the cabling to the sensor or actuator. This plug must be selected according to the voltage and current carrying capacity.

If a connector with single-core or multi-core wires is used, Table D.7 in [R2] applies. The overvoltage category III is used for the clearances and creepage distances. This does not take into account the PCB-side connection of the plug. This is considered according to Table D.5 [R2].

Note	**Non-interchangeable connectors** It must be used reverse polarity protected and interchange-proofed plug-in connectors. If this is not the case, the user must take alternative measures in order to be able to rule out reverse polarity or interchanging of the plug connectors.

Note	**Clearances and creepage distances (connector side)** The following ratings apply to the male side of the multipole connectors. The ratings for the PCB-side part of the connectors can be found under Clearances and creepage distances (EJ board) [▶ 19]. The selection of the plug must be made according to the determined minimum clearances and creepage distances. For the connection of multi-core wires, appropriate distances must be maintained, or e.g. the specification of ferrules with plastic collar are provided. The creepage distances with pollution degree 2 for non-printed circuits depend on the groups of insulating materials. Please clarify with the manufacturer of the plug the appropriate characteristics and necessary distances.

The clearances are determined for transient overvoltages.

The rated surge voltage used can be found in the chapter Determination rated surge voltage [▶ 18].

Clearances for transient overvoltages according to [R3] table F.2

The following table is a section of table F.2 from [R3]. The complete table and the notes can be found in the standard.

Required standing surge voltage (in kV)	Minimum clearances at altitudes up to 2000 m above sea level (NN)					
	Condition A - inhomogenous field (in mm)			Condition B - homogenous field (in mm)		
	Pollution degree			Pollution degree		
	1	2	3	1	2	3
0,33	0,01	0,20	0,80	0,01	0,20	0,80
0,40	0,02			0,02		
0,50	0,04			0,04		
0,60	0,06			0,06		
0,80	0,10			0,10		
1,0	0,15			0,15		
1,2	0,25	0,25		0,20		
1,5	0,50	**0,5**		0,30	**0,30**	
2,0	1,0	1,0	1,0	0,45	0,45	

Note	**Clearance for the connector** The clearance is 0.50 mm for an inhomogeneous field. A homogeneous field is more likely to be excluded in a connector, therefore, the minimum clearances applies to an inhomogeneous field. These clearances are valid only up to a height of 2000 m above sea level

Creepage distances according to [R3] table F.4

The voltage to be used for table F.4 is determined from table F.3a.

The nominal voltage of a 48 V_{DC} SELV/PELV power supply is typically between 48 V_{DC} and 56 V_{DC}. The maximum voltage is 60 V_{DC}, so in Table F.4 the voltage of 63 V determined from Table F.3a is used.

Voltage (RMS value in V)	Minimum creepage								
	printed circuits								
	Pollution degree								
	1	2	1	2			3		
	All ISG*	All ISG except IIIb	All ISG	ISG I	ISG II	ISG III	ISG I	ISG II	ISG III
40	0,025	0,040	0,16	0,56	0,80	1,10	1,40	1,60	1,80
50	0,025	0,040	0,18	0,60	0,85	1,20	1,50	1,70	1,90
63	0,040	0,063	0,20	**0,63**	**0,90**	**1,25**	1,60	1,80	2,00
80	0,063	0,100	0,22	0,67	0,95	1,30	1,70	1,90	2,10

* ISG - Insulating group (see chapter 4.8.1.3 in [R3])

Note	**Minimum creepage** For the connector there is a minimum creepage distance of 1.25 mm (63 V, pollution degree 2, group of insulating material III). For other groups of insulating materials, the minimum creepage distance can be reduced according to the above table.

7 Connection EJ modules (Samtec female connector)

The socket strip used for the contacting of the EJ modules comes from Samtec and has the designation SSQ-120-01-L-D. This socket strip must be installed according to the manufacturer's specifications. The specified distance from soldering pad to soldering pad is 2.54 mm. The soldering pad should have a diameter of 1.02 mm. Hence one would have a distance of 1.52 mm.

Distance between the socket connectors 2.54mm – 1.02mm = 1.52mm (typical)

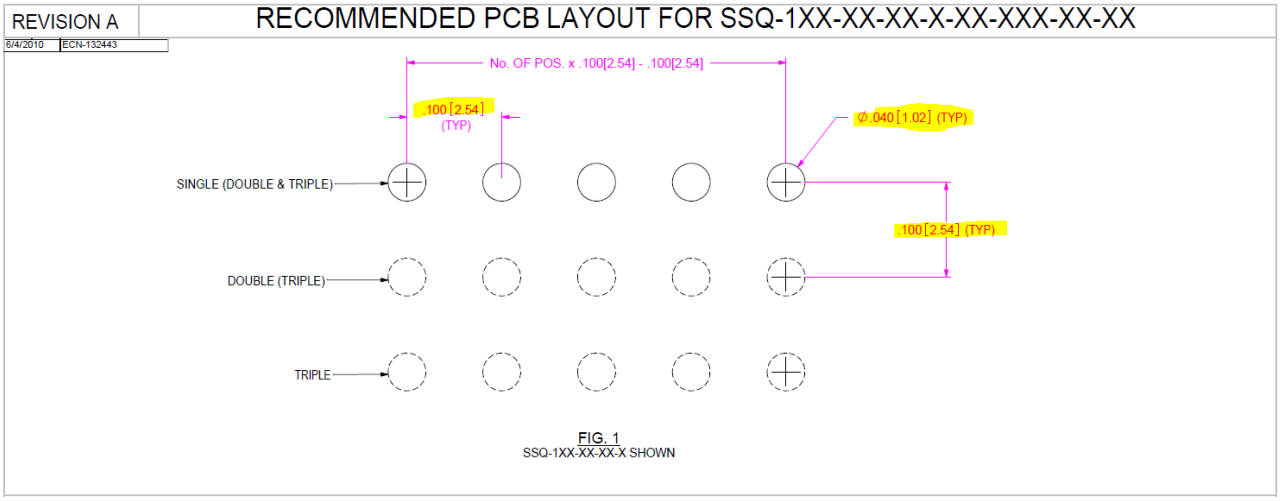

Fig. 1: Layout SSQ-120-01-L-D

8 Conclusions

Checklist for the PCB developers

Requirement	Description	Result
PCB design	Table D.5 according to [R2]: “As base material at least EP GC in accordance with IEC 60893-1 is used.” (see Table D.5 - Errors and fault exclusions - printed circuit boards / assembled PCBs [▶ 15]) The design should be created in accordance with the specifications in [R8]. For safety-related components an examination according to [R7] class 3 is recommended.	
Power supply	24 V_{DC} SELV/PELV power supply with a voltage limit of U_{max}= 36 V_{DC} on the output side 48 V_{DC} SELV/PELV power supply with a voltage limit of U_{max}= 60 V_{DC} on the output side (see Table D.5 - Errors and fault exclusions - printed circuit boards / assembled PCBs [▶ 15])	
Conducting path distances	Clearance of at least 0.13 mm for printed circuits and 0.2 mm for PCB-side connectors. Creepage distances: 0.10 mm for printed circuits and 1.25 mm (or less, depending on the group of insulating materials) for PCB-side connectors. (see Clearances and creepage distances (EJ board) [▶ 19])	
Distances customer-specific connectors	Clearance of at least 0.50 mm. Creepage distances: 1.25 mm (or less, depending on the group of insulating materials). (see Clearances and creepage distances (customer-specific connector) [▶ 21]) Note: For PCB-mounted connectors, the mechanical structure of the plug must be taken into account.	
Soldering pads of Samtec socket strip	Soldering pads of Samtec socket strip must be created according to the manufacturer’s specifications (see Connection EJ modules (Samtec female connector) [▶ 23])	
Installation	The mounted board is installed in a border or cabinet with a protection class of at least IP 54. (see Table D.5 - Errors and fault exclusions - printed circuit boards / assembled PCBs [▶ 15])	
Protective coating	The printed side(s) of the assembled board is/are furnished with an age-resistant paint or protective coating so that all conducting paths are covered. (see Table D.5 - Errors and fault exclusions - printed circuit boards / assembled PCBs [▶ 15]) Note 1 from EN ISO 13849-2 Table D.5: Experience has shown that solder masks as a protective layer are sufficient. Note 2 from EN ISO 13849-2 Table D.5: Another protective layer, which covers according to IEC 60664-3, can reduce the creepage and clearance distances.	

9 Appendix

9.1 PinOuts

9.1.1 EJ1918 PinOut

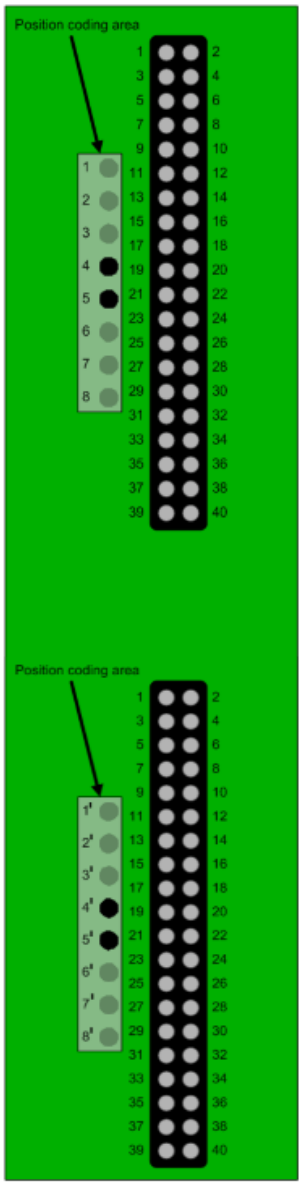

Fig. 2: EJ1918 - PinOut

The graphic of the PinOut of the EJ module also show the coding of the respective EJ module.

Presentation	Meaning
	At this position, **no** coding pin is present on the EJ module and there must be no hole in the distribution board.
	At this position, **a** coding pin is present on the EJ module and there must be a hole in the distribution board so that the EJ module can be plugged into this slot.

Pin assignment of the EJ1918

Pin # (upper socket strip)		Signal	
1	2	U_{EBUS}	U_{EBUS}
3	4	GND	GND
5	6	RX0+	TX1+
7	8	RX0-	TX1-
9	10	GND	GND
11	12	TX0+	RX1+
13	14	TX0-	RX1-
15	16	GND	GND
17	18	SDI1-	SDI1+
19	20	SDI2-	SDI2+
21	22	SDI3-	SDI3+
23	24	SDI4-	SDI4+
25	26	SDI5-	SDI5+
27	28	SDI6-	SDI6+
29	30	SDI7-	SDI7+
31	32	SDI8-	SDI8+
33	34	NC	NC
35	36	NC	NC
37	38	NC	NC
39	40	SGND	SGND

Pin # (lower socket strip)		Signal	
1	2	U_{EBUS}	U_{EBUS}
3	4	GND	GND
5	6	RX0+	TX1+
7	8	RX0-	TX1-
9	10	GND	GND
11	12	TX0+	RX1+
13	14	TX0-	RX1-
15	16	GND	GND
17	18	NC	NC
19	20	NC	NC
21	22	NC	NC
23	24	NC	NC
25	26	NC	NC
27	28	NC	NC
29	30	NC	NC
31	32	NC	NC
33	34	0V U_P	0V U_P
35	36	0V U_P	U_P (24 V_{DC})
37	38	U_P (24 V_{DC})	U_P (24 V_{DC})
39	40	SGND	SGND

Legend

Label	Description
U_{EBUS}	Power supply of E-BUS (here 3,3 V)
GND	0 V to power supply E-BUS
RX0+ / RX0- / TX0+ / TX0-	EtherCAT-Input of EJ1918
TX1+ / TX1- / RX1+ / RX1-	EtherCAT-Output of EJ1918
NC	contact not used
SDI1+ - SDI8+	Clock outputs for safe inputs 1 to 8
SDI1- - SDI8-	Safe inputs 1 to 8
U_P (24 V_{DC})	24 V power supply U_P
0V U_P	GND to power supply U_P
SGND	Signal GND

Coding pins of the EJ1918

Each EJ module has two coding pins to prevent any confusion of the scheduled modules. For each pin a corresponding hole in the EJ backplane must be created. The following table shows the position of the hole or the position of the coding pins of EJ1918 with an X.

Module	1	2	3	4	5	6	7	8	1‘	2‘	3‘	4‘	5‘	6‘	7‘	8‘
EJ1918				X	X							X	X			

9.1.2 EJ1957 PinOut

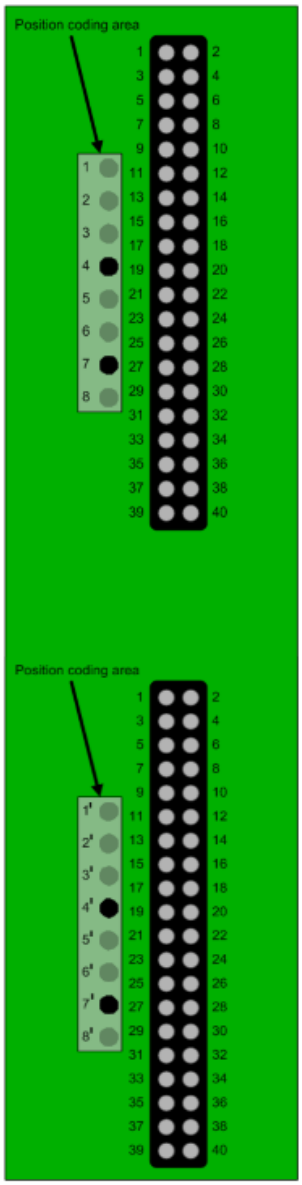

Fig. 3: EJ1957 - PinOut

The graphic of the PinOut of the EJ module also show the coding of the respective EJ module.

Presentation	Meaning
	At this position, **no** coding pin is present on the EJ module and there must be no hole in the distribution board.
	At this position, **a** coding pin is present on the EJ module and there must be a hole in the distribution board so that the EJ module can be plugged into this slot.

Pin assignment of the EJ1957

Pin # (upper socket strip)		Signal	
1	2	U_{EBUS}	U_{EBUS}
3	4	GND	GND
5	6	RX0+	TX1+
7	8	RX0-	TX1-
9	10	GND	GND
11	12	TX0+	RX1+
13	14	TX0-	RX1-
15	16	GND	GND
17	18	SDI1-	SDI1+
19	20	SDI2-	SDI2+
21	22	SDI3-	SDI3+
23	24	SDI4-	SDI4+
25	26	SDI5-	SDI5+
27	28	SDI6-	SDI6+
29	30	SDI7-	SDI7+
31	32	SDI8-	SDI8+
33	34	NC	NC
35	36	NC	NC
37	38	NC	NC
39	40	SGND	SGND

Pin # (lower socket strip)		Signal	
1	2	U_{EBUS}	U_{EBUS}
3	4	GND	GND
5	6	RX0+	TX1+
7	8	RX0-	TX1-
9	10	GND	GND
11	12	TX0+	RX1+
13	14	TX0-	RX1-
15	16	GND	GND
17	18	0V U_P	SDO1
19	20	0V U_P	SDO2
21	22	0V U_P	SDO3
23	24	0V U_P	SDO4
25	26	NC	NC
27	28	NC	NC
29	30	NC	NC
31	32	NC	NC
33	34	0V U_P	0V U_P
35	36	0V U_P	U_P (24 V_{DC})
37	38	U_P (24 V_{DC})	U_P (24 V_{DC})
39	40	SGND	SGND

Legend

Label	Description
U_{EBUS}	Power supply of E-BUS (here 3,3 V)
GND	0 V to power supply E-BUS
RX0+ / RX0- / TX0+ / TX0-	EtherCAT-Input of EJ1957
TX1+ / TX1- / RX1+ / RX1-	EtherCAT-Output of EJ1957
SDI1+ - SDI8+	Clock outputs for safe inputs 1 to 8
SDI1- - SDI8-	Safe inputs 1 to 8
SDO1 - SDO4	Safe outputs 1 to 4
NC	contact not used
U_P (24 V_{DC})	24 V power supply U_P
0V U_P	GND to power supply U_P
SGND	Signal GND

Coding pins of the EJ1957

Each EJ module has two coding pins to prevent any confusion of the scheduled modules. For each pin a corresponding hole in the EJ backplane must be created. The following table shows the position of the hole or the position of the coding pins of EJ1957 with an X.

Module	1	2	3	4	5	6	7	8	1‘	2‘	3‘	4‘	5‘	6‘	7‘	8‘
EJ1957				X			X					X			X	

9.1.3 EJ2918 PinOut

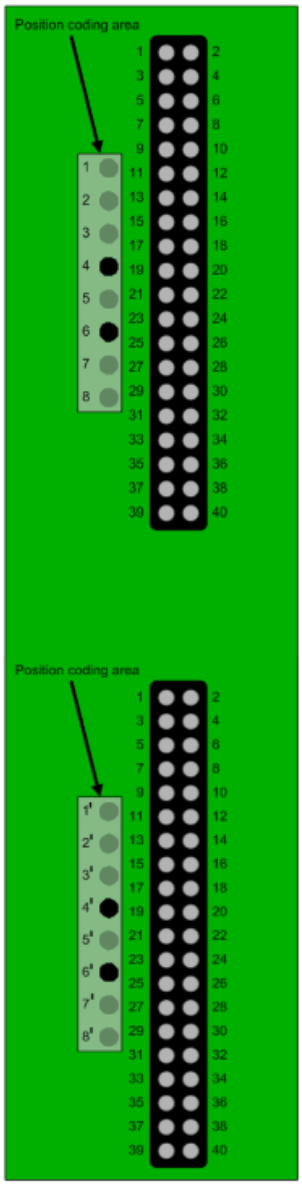

Fig. 4: EJ2918 - PinOut

The graphic of the PinOut of the EJ module also show the coding of the respective EJ module.

Presentation	Meaning
	At this position, **no** coding pin is present on the EJ module and there must be no hole in the distribution board.
	At this position, **a** coding pin is present on the EJ module and there must be a hole in the distribution board so that the EJ module can be plugged into this slot.

Pin assignment of the EJ2918

Pin # (upper socket strip)		Signal	
1	2	U_{EBUS}	U_{EBUS}
3	4	GND	GND
5	6	RX0+	TX1+
7	8	RX0-	TX1-
9	10	GND	GND
11	12	TX0+	RX1+
13	14	TX0-	RX1-
15	16	GND	GND
17	18	0V U_P	SDO1
19	20	0V U_P	SDO2
21	22	0V U_P	SDO3
23	24	0V U_P	SDO4
25	26	0V U_P	SDO5
27	28	0V U_P	SDO6
29	30	0V U_P	SDO7
31	32	0V U_P	SDO8
33	34	NC	NC
35	36	NC	NC
37	38	NC	NC
39	40	SGND	SGND

Pin # (lower socket strip)		Signal	
1	2	U_{EBUS}	U_{EBUS}
3	4	GND	GND
5	6	RX0+	TX1+
7	8	RX0-	TX1-
9	10	GND	GND
11	12	TX0+	RX1+
13	14	TX0-	RX1-
15	16	GND	GND
17	18	NC	NC
19	20	NC	NC
21	22	NC	NC
23	24	NC	NC
25	26	NC	NC
27	28	NC	NC
29	30	NC	NC
31	32	NC	NC
33	34	0V U_P	0V U_P
35	36	0V U_P	U_P (24 V_{DC})
37	38	U_P (24 V_{DC})	U_P (24 V_{DC})
39	40	SGND	SGND

Legend

Label	Description
U_{EBUS}	Power supply of E-BUS (here 3,3 V)
GND	0 V to power supply E-BUS
RX0+ / RX0- / TX0+ / TX0-	EtherCAT-input of EJ2918
TX1+ / TX1- / RX1+ / RX1-	EtherCAT-output of EJ2918
SDO1 - SDO8	Safe outputs 1 to 8
NC	Contact not used
U_P (24 V_{DC})	24 V power supply U_P
0V U_P	GND to power supply U_P
SGND	Signal GND

Coding pins of the EJ2918

Each EJ module has two coding pins to prevent any confusion of the scheduled modules. For each pin a corresponding hole in the EJ backplane must be created. The following table shows the position of the hole or the position of the coding pins of EJ2918 with an X.

Module	1	2	3	4	5	6	7	8	1‘	2‘	3‘	4‘	5‘	6‘	7‘	8‘
EJ2918				X		X						X		X		

9.1.4 EJ6910 PinOut

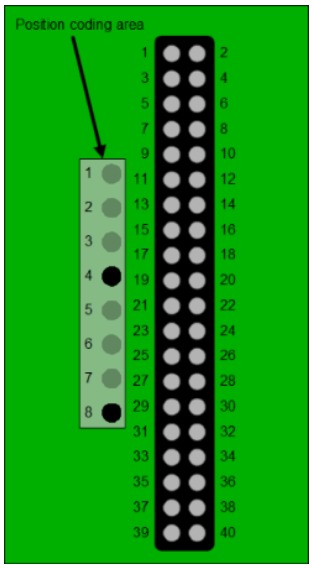

Fig. 5: EJ6910 - PinOut

The graphic of the PinOut of the EJ module also show the coding of the respective EJ module.

Presentation	Meaning
	At this position, **no** coding pin is present on the EJ module and there must be no hole in the distribution board.
	At this position, **a** coding pin is present on the EJ module and there must be a hole in the distribution board so that the EJ module can be plugged into this slot.

Pin assignment of the EJ6910

Pin #		Signal	
1	2	U_{EBUS}	U_{EBUS}
3	4	GND	GND
5	6	RX0+	TX1+
7	8	RX0-	TX1-
9	10	GND	GND
11	12	TX0+	RX1+
13	14	TX0-	RX1-
15	16	GND	GND
17	18	NC	NC
19	20	NC	NC
21	22	NC	NC
23	24	NC	NC
25	26	NC	NC
27	28	NC	NC
29	30	NC	NC
31	32	NC	NC
33	34	NC	NC
35	36	NC	NC
37	38	NC	NC
39	40	SGND	SGND

Legend

Label	Description
U_{EBUS}	Power supply of E-BUS (here 3,3 V)
GND	0 V to power supply E-BUS
RX0+ / RX0- / TX0+ / TX0-	EtherCAT-input of EJ6910
TX1+ / TX1- / RX1+ / RX1-	EtherCAT-output of EJ6910
NC	Contact not used
SGND	Signal GND

Coding pins of the EJ6910

Each EJ module has two coding pins to prevent any confusion of the scheduled modules. For each pin a corresponding hole in the EJ backplane must be created. The following table shows the position of the hole or the position of the coding pins of EJ6910 with an X.

Module	1	2	3	4	5	6	7	8
EJ6910				X				X

9.1.5 EJ1914 PinOut

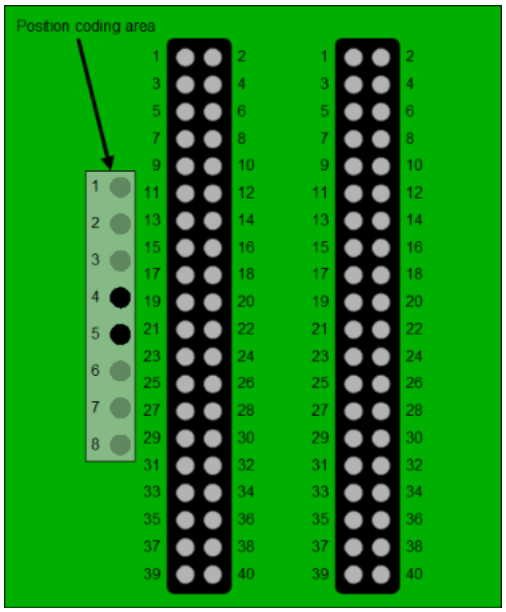

Fig. 6: EJ1914 - PinOut

The graphic of the PinOut of the EJ module also show the coding of the respective EJ module.

Presentation	Meaning
	At this position, **no** coding pin is present on the EJ module and there must be no hole in the distribution board.
	At this position, **a** coding pin is present on the EJ module and there must be a hole in the distribution board so that the EJ module can be plugged into this slot.

Pin assignment of the EJ1914

Pin #		Signal (left socket strip)		Signal (right socket strip)	
1	2	U_{EBUS}	U_{EBUS}	U_{EBUS}	U_{EBUS}
3	4	GND	GND	GND	GND
5	6	RX0+	TX1+	NC	NC
7	8	RX0-	TX1-	NC	NC
9	10	GND	GND	GND	GND
11	12	TX0+	RX1+	NC	NC
13	14	TX0-	RX1-	NC	NC
15	16	GND	GND	GND	GND
17	18	NC	NC	SDI1-	SDI1+
19	20	NC	NC	SDI2-	SDI2+
21	22	NC	NC	SDI3-	SDI3+
23	24	NC	NC	SDI4-	SDI4+
25	26	NC	NC	NC	NC
27	28	NC	NC	NC	NC
29	30	NC	NC	NC	NC
31	32	NC	NC	NC	NC
33	34	NC	NC	0V U_P	0V U_P
35	36	NC	NC	0V U_P	U_P (24 V_{DC})
37	38	NC	NC	U_P (24 V_{DC})	U_P (24 V_{DC})
39	40	SGND	SGND	SGND	SGND

Legend

Label	Description
U_{EBUS}	Power supply of E-BUS (here 3,3 V)
GND	0 V to power supply E-BUS
RX0+ / RX0- / TX0+ / TX0-	EtherCAT-Input of EJ1914
TX1+ / TX1- / RX1+ / RX1-	EtherCAT-Output of EJ1914
NC	contact not used
SDI1+ - SDI4+	Clock outputs for safe inputs 1 to 4
SDI1- - SDI4-	Safe inputs 1 to 8
U_P (24 V_{DC})	24 V power supply U_P
0V U_P	GND to power supply U_P
SGND	Signal GND

Coding pins of the EJ1914

Each EJ module has two coding pins to prevent any confusion of the scheduled modules. For each pin a corresponding hole in the EJ backplane must be created. The following table shows the position of the hole or the position of the coding pins of EJ1914 with an X.

Module	1	2	3	4	5	6	7	8
EJ1914				X	X			

9.1.6 EJ2914 PinOut

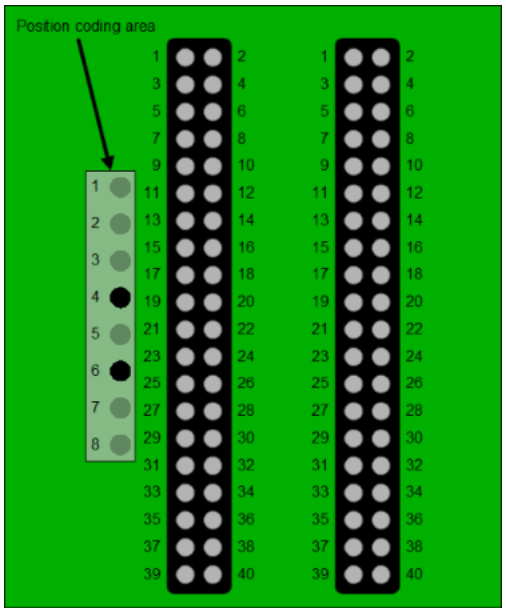

Fig. 7: EJ2914 - PinOut

The graphic of the PinOut of the EJ module also show the coding of the respective EJ module.

Presentation	Meaning
	At this position, **no** coding pin is present on the EJ module and there must be no hole in the distribution board.
	At this position, **a** coding pin is present on the EJ module and there must be a hole in the distribution board so that the EJ module can be plugged into this slot.

Pin assignment of the EJ2914

Pin #		Signal (left socket strip)		Signal (right socket strip)	
1	2	U_{EBUS}	U_{EBUS}	U_{EBUS}	U_{EBUS}
3	4	GND	GND	GND	GND
5	6	RX0+	TX1+	NC	NC
7	8	RX0-	TX1-	NC	NC
9	10	GND	GND	GND	GND
11	12	TX0+	RX1+	NC	NC
13	14	TX0-	RX1-	NC	NC
15	16	GND	GND	GND	GND
17	18	NC	NC	0V U_P	SDO1
19	20	NC	NC	0V U_P	SDO2
21	22	NC	NC	0V U_P	SDO3
23	24	NC	NC	0V U_P	SDO4
25	26	NC	NC	NC	NC
27	28	NC	NC	NC	NC
29	30	NC	NC	NC	NC
31	32	NC	NC	NC	NC
33	34	NC	NC	0V U_P	0V U_P
35	36	NC	NC	0V U_P	U_P (24 V_{DC})
37	38	NC	NC	U_P (24 V_{DC})	U_P (24 V_{DC})
39	40	SGND	SGND	SGND	SGND

Legend

Label	Description
U_{EBUS}	Power supply of E-BUS (here 3,3 V)
GND	0 V to power supply E-BUS
RX0+ / RX0- / TX0+ / TX0-	EtherCAT-input of EJ2914
TX1+ / TX1- / RX1+ / RX1-	EtherCAT-output of EJ2914
SDO1 - SDO4	Safe outputs 1 to 4
NC	Contact not used
U_P (24 V_{DC})	24 V power supply U_P
0V U_P	GND to power supply U_P
SGND	Signal GND

Coding pins of the EJ2914

Each EJ module has two coding pins to prevent any confusion of the scheduled modules. For each pin a corresponding hole in the EJ backplane must be created. The following table shows the position of the hole or the position of the coding pins of EJ2914 with an X.

Module	1	2	3	4	5	6	7	8
EJ2914				X		X		

9.2 Support and Service

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

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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

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