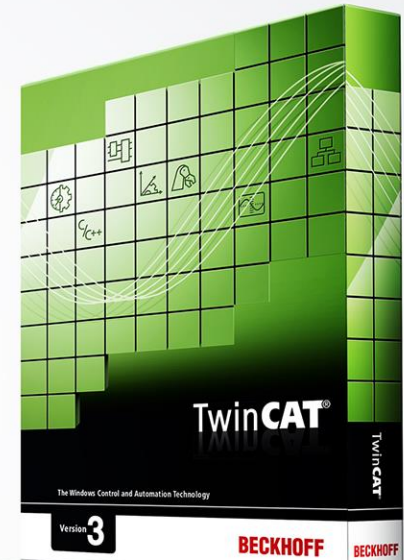
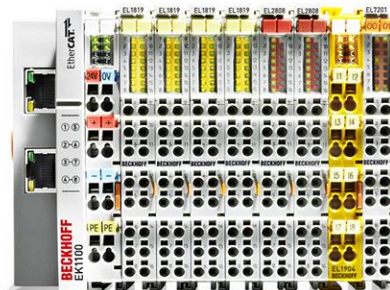


New Automation Technology

Beckhoff Automation

BECKHOFF



The TwinSAFE System

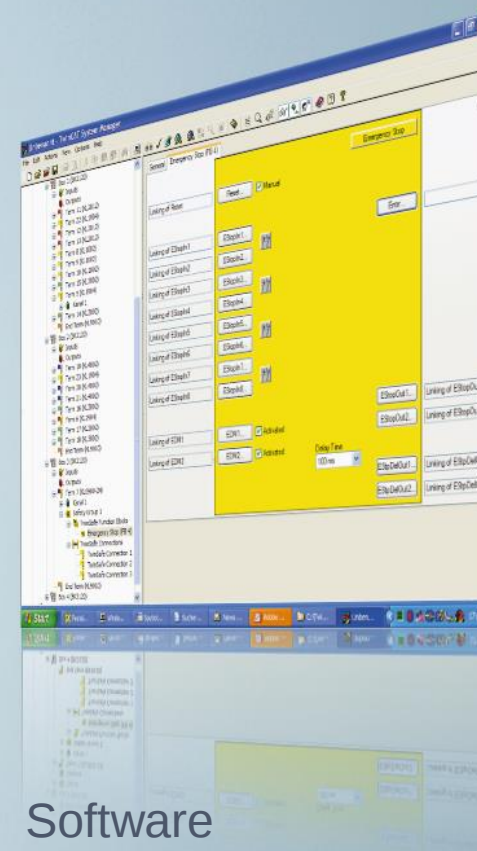
BECKHOFF



Drives with
TwinSAFE option card



TwinSAFE
I/O Terminals



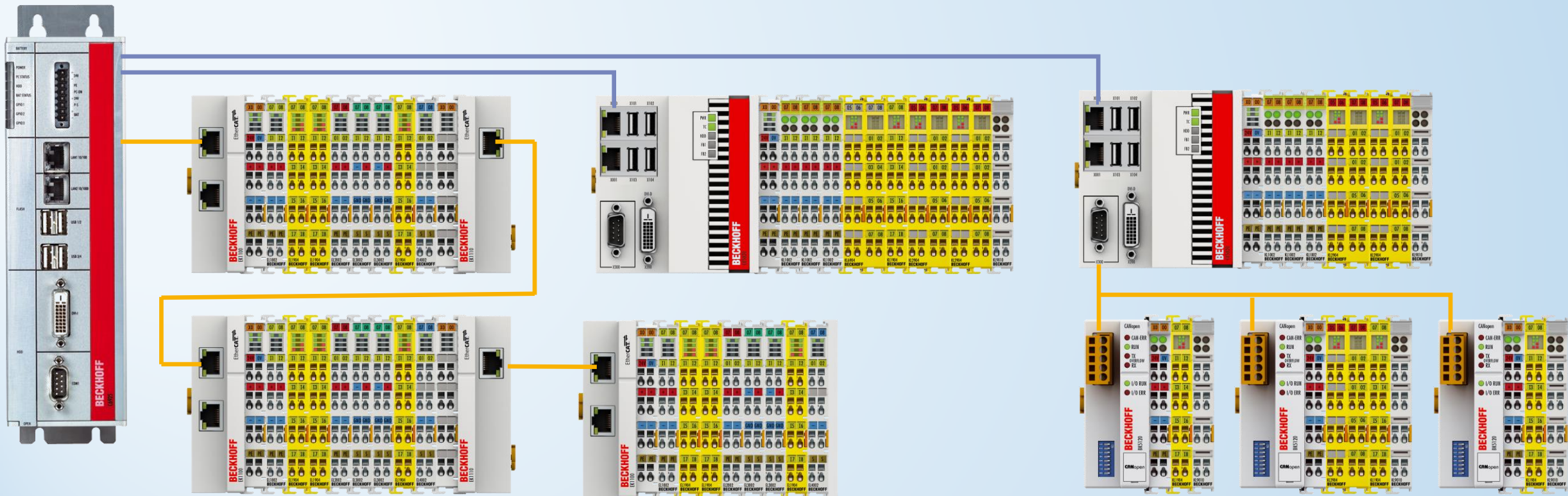
Software



Safety Engineering in Modern Automation

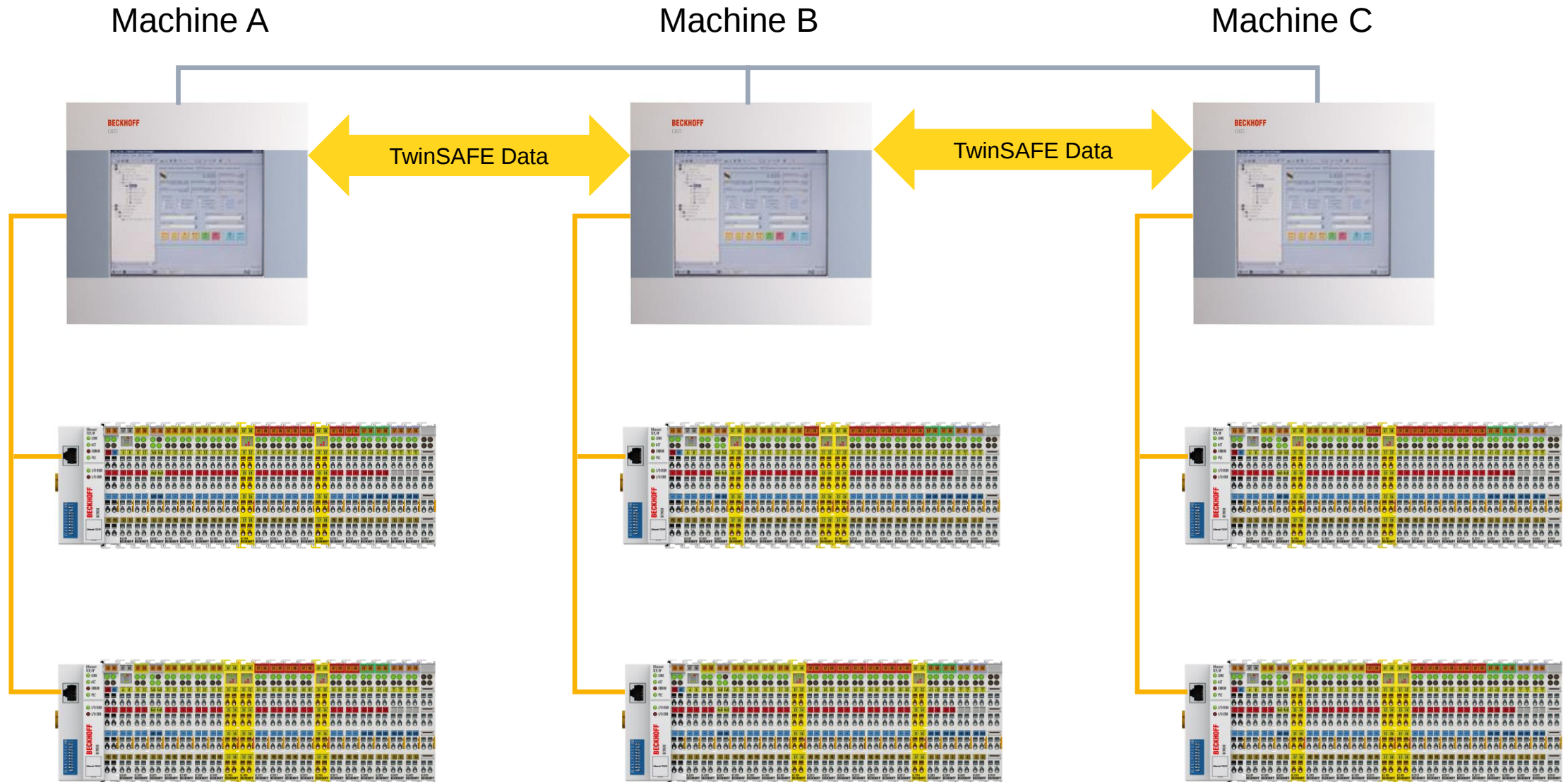
BECKHOFF

1. Mixed network for standard and safety functions (EtherCAT in below example)
2. Standard network with a decentralized safety island (CX controller in below example)
3. Separated network for standard and safety functions (CX with underlying CAN Bus for example)



Plant Interlinking with TwinSAFE

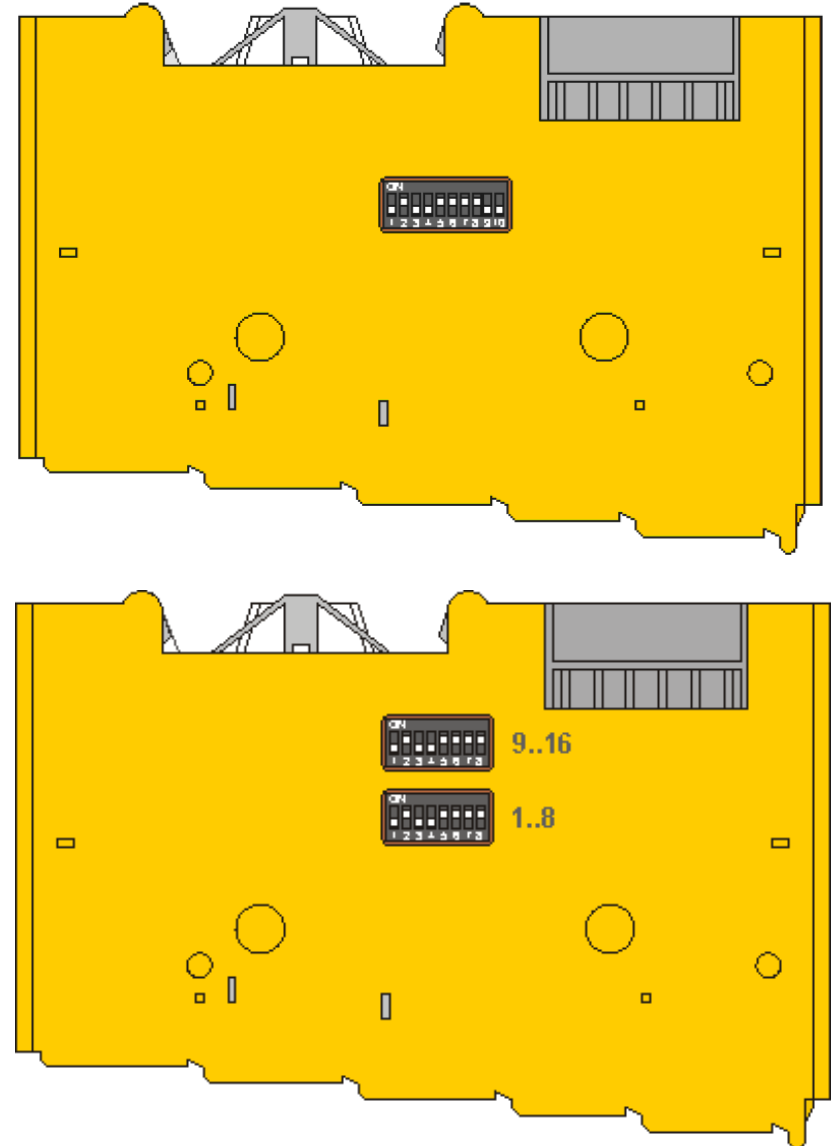
BECKHOFF



S-Address of KL/ELx90x

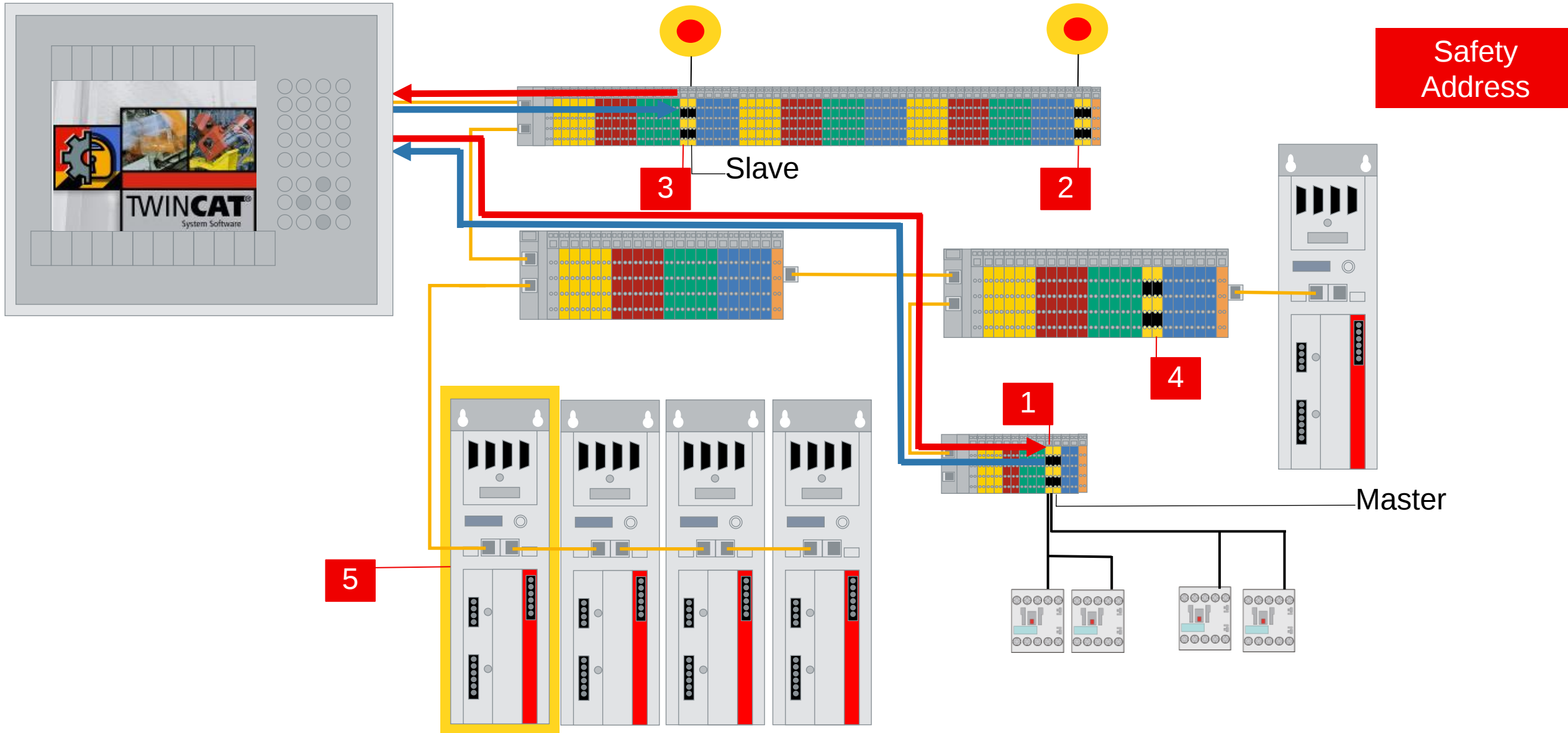
BECKHOFF

- The S-address has to be set for each terminal
- The S address has to be unique within one system manager configuration
- S-address is binary coded
 - Range 1-1023
for KL terminals and EL6900 and EL2904
 - Range 1-65534
for EL1904



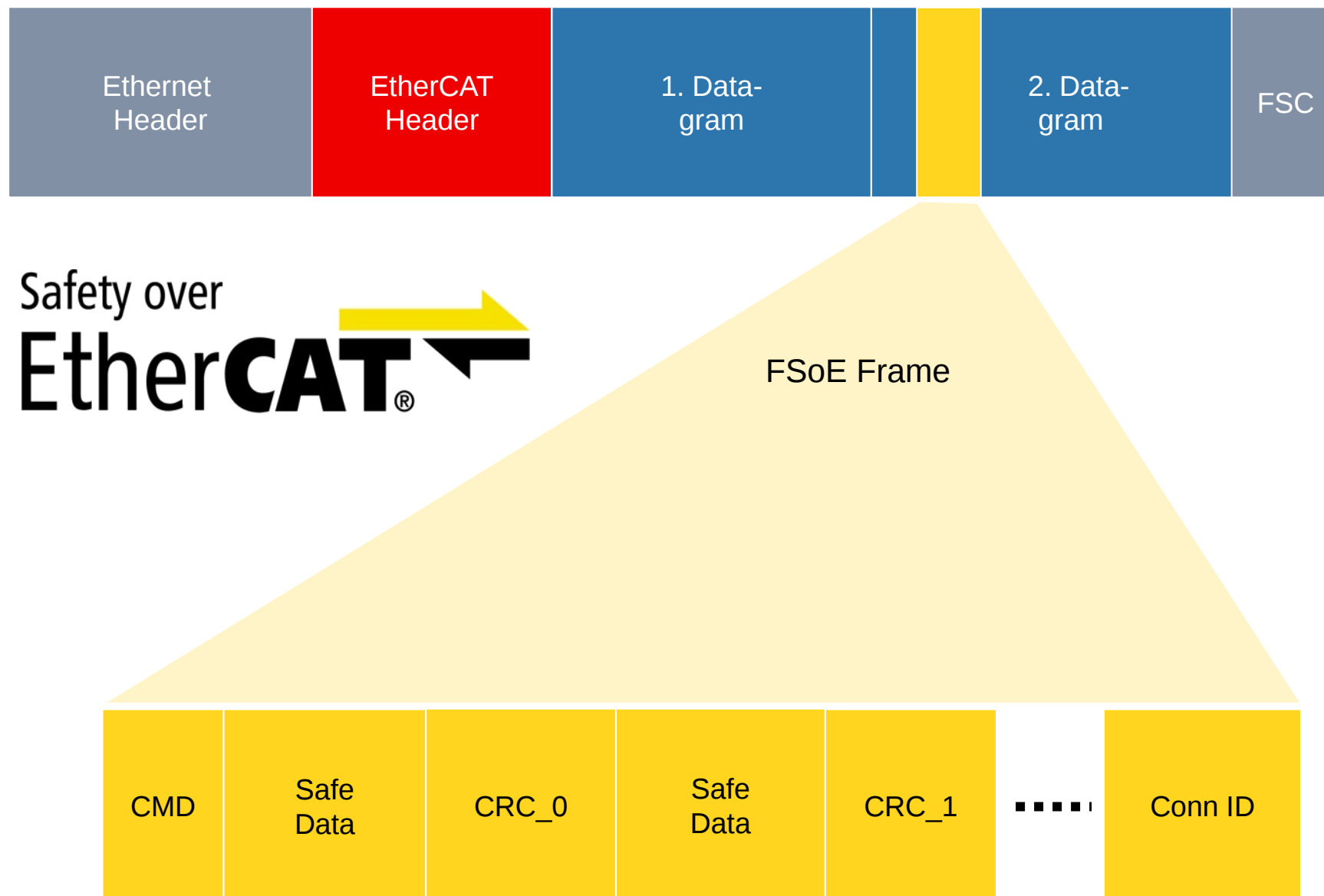
Safe Data Exchange

BECKHOFF



FSoE Frame

- The FSoE Frame is a data container mapped in the process data of the devices.
- A new FSoE Frame is recognized if at least one bit has changed according to the last frame.
- For every 2 Byte SafeData a 2 Byte CRC is calculated.
- Up to 14 Byte SafeData can be transmitted.



CMD

- In normal data exchange the CMD is set to 0x36 or 0x08.
- During startup or in case of an error the CMD is set to 0x2A, 0x4E, 0x64 or 0x52 and the SafeData DOES NOT contain the safety input or output signals.
- Command 0x78 means that the connection is shutdown.

Safety over EtherCAT®



Command

0x36
0x2A
0x4E
0x64
0x52
0x08
0x78

Description

ProcessData
Reset
Session
Connection
Parameter
FailSafeData
Connection shutdown

The TwinSAFE Components

BECKHOFF



KL/EL1904: Safety Input Terminal, 24 V DC

BECKHOFF

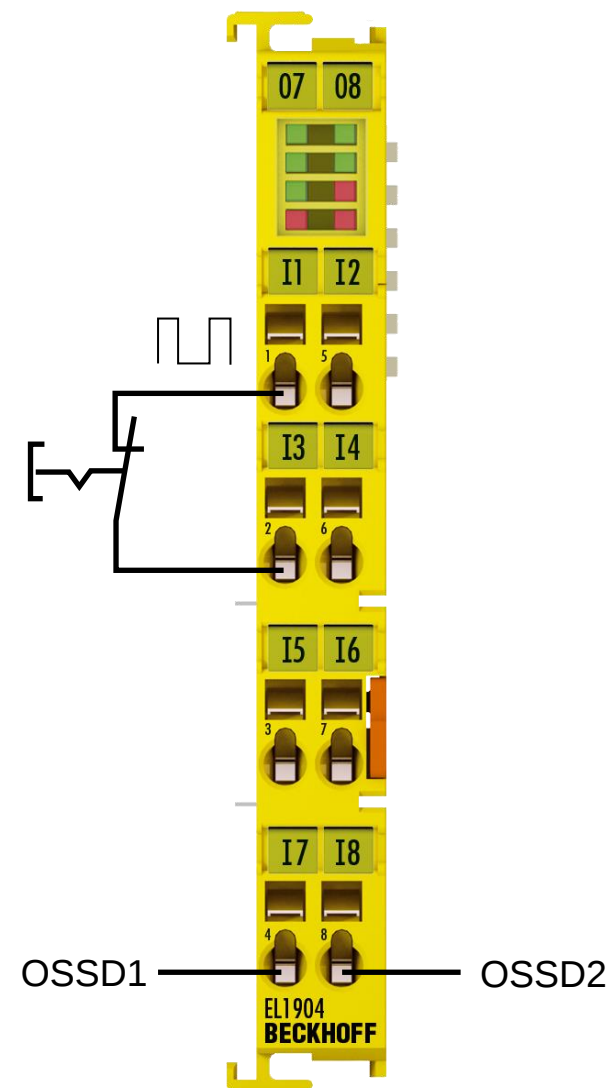
Input terminal (4 clock outputs and 4 digital inputs)

Certified in accordance to

- EN 61508 SIL3
- EN 954-1 Cat. 4
- DIN EN ISO 13849-1 PL e
- NRTL, UL508, UL1998, UL991
- EN 81 (as applicable)
- EN 13243 (as applicable)
- 98/37/EC Machinery Directive

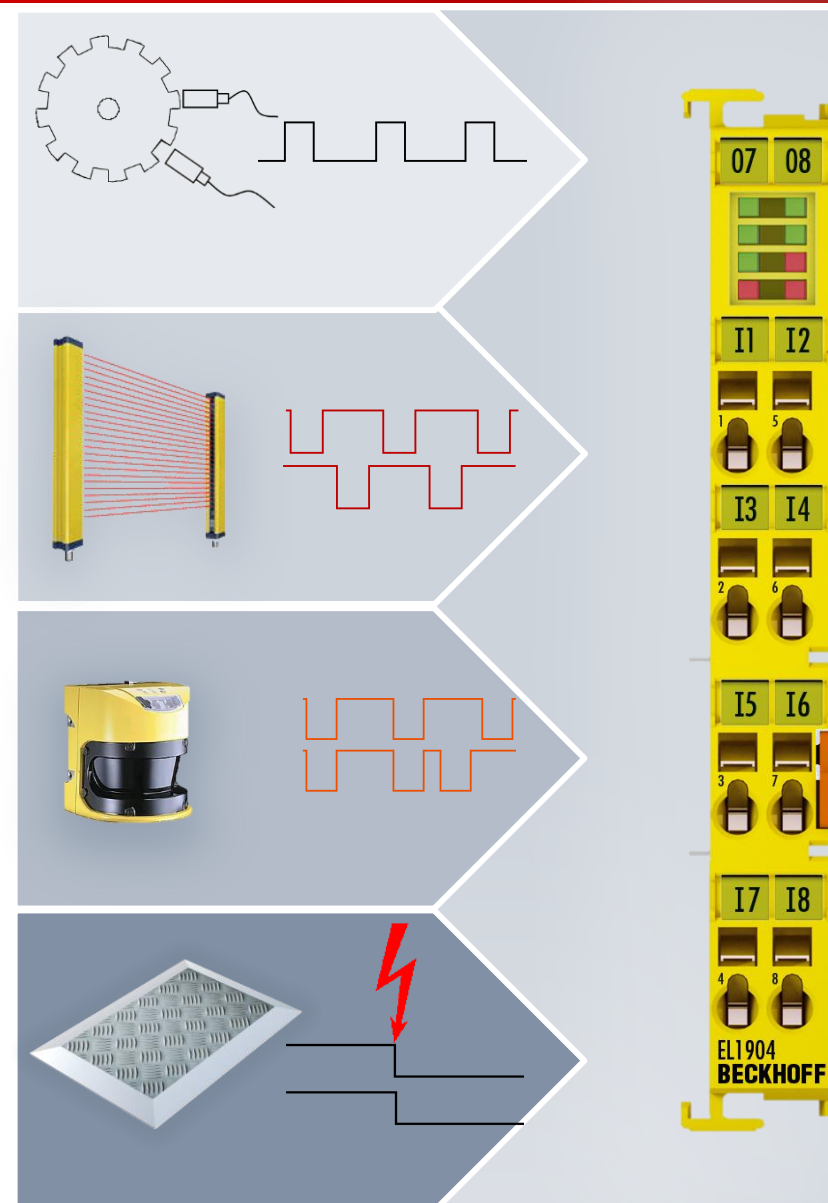
High diagnosis

- Communication error
- Processor error
- Sensor error
 - External supply
 - Cross-circuit detection



EL1904 configuration

- Operating modes
 - Digital
 - Standstill monitoring 1
 - Standstill monitoring 2
- Logic of channels
 - Single logic
 - OSSD asynchronous analysis (no sensortest)
 - OSSD any pulse repetition (no sensortest)
 - Short cut is no module fault



EL1904 Operating Modes

BECKHOFF

- Parameters are set on an own tab Parameter under the TwinSAFE connection.
- 8000:1 Operating Mode
 - Digital
 - Standstill monitoring 1+2
- 8001:1-4 Sensortest active
 - True/False
- 8002:1+3 Logic of Channel
 - Single logic
 - OSSD asynchronous
 - OSSD any pulse repetition
 - Short cut is no module fault
- 10E0:1+2
Required for Backup/Restore mode (can not be changed by the user)

The screenshot displays the Beckhoff TwinCAT software interface. The top pane, 'Solution Explorer', shows a project tree with 'Device 2 (EtherCAT) - Term 3 (EL1904).sds' selected. The bottom pane, 'Parameter Editor', shows the 'Safety Parameters' tab. It contains three sections: '8000 FS Operating Mode', '8001 FS Sensor Test', and '8002 FS Logic of Input pairs'. The '8000 FS Operating Mode' section shows '8000:00 SubIndex 000' set to '1' and '8000:01 Operating Mode' set to 'digital'. The '8001 FS Sensor Test' section shows '8001:00 SubIndex 000' set to '5' and four sensor test channels (1-4) all set to 'True'. The '8002 FS Logic of Input pairs' section shows '8002:00 SubIndex 000' set to '5' and two logic channel pairs (1/2 and 3/4) both set to 'single logic channel'.

Parameter	Value
8000:00 SubIndex 000	1
8000:01 Operating Mode	digital
8001:00 SubIndex 000	5
8001:01 Sensor test Channel 1 active	True
8001:02 Sensor test Channel 2 active	True
8001:03 Sensor test Channel 3 active	True
8001:04 Sensor test Channel 4 active	True
8002:00 SubIndex 000	5
8002:01 Logic of Channel 1 and 2	single logic channel 1/2
8002:03 Logic of Channel 3 and 4	single logic channel 3/4

KL/EL2904: Safety Output Terminal 0,5 A 24 V DC

BECKHOFF

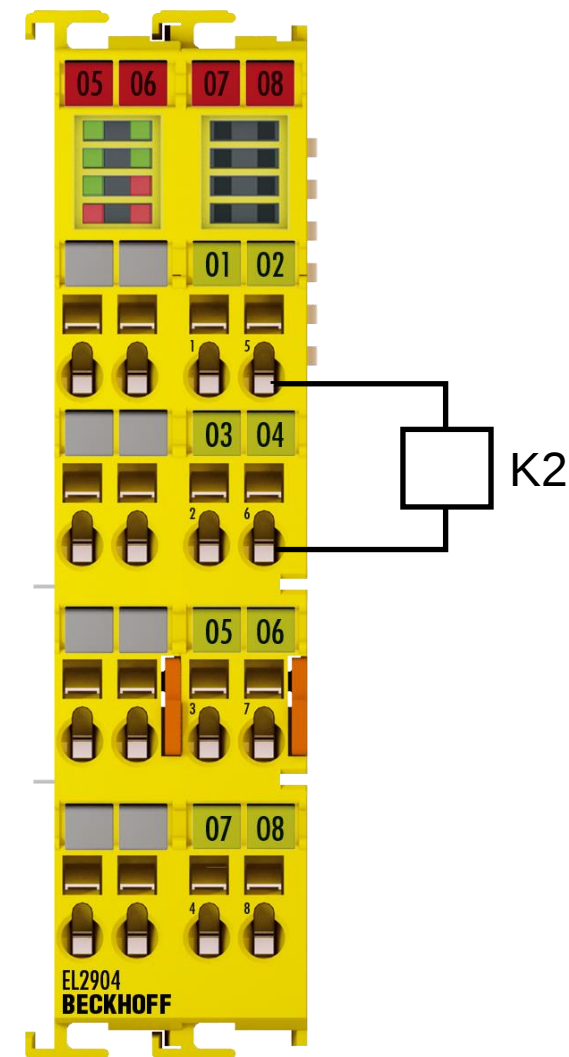
Output terminal (4 safety outputs)

Certified in accordance to

- EN 61508 SIL3
- EN 954-1 Cat. 4
- DIN EN ISO 13849-1 PL e
- NRTL, UL508, UL1998, UL991
- EN 81 (as applicable)
- EN 13243 (as applicable)
- 98/37/EC Machinery Directive

High diagnosis

- Communication error
- Terminal error
 - Processor error
 - Under-/overvoltage
 - Temperature monitoring
- Actor error
 - External supply
 - Short circuit
 - Wire break



KL/EL2904: Safety Output Terminal 0.5 A 24 V DC

BECKHOFF

EL2904 Configuration

Standard outputs active:

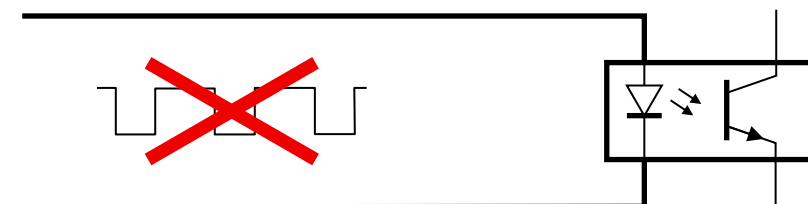
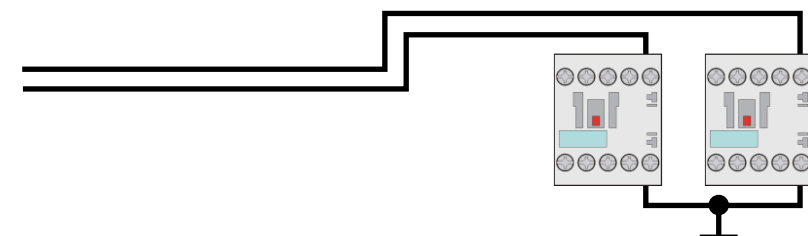
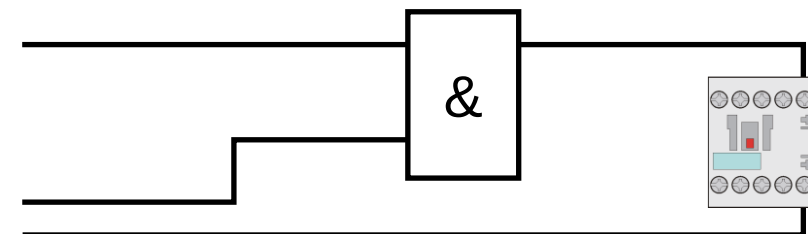
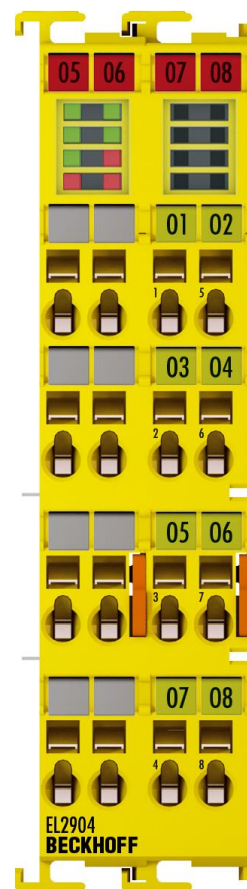
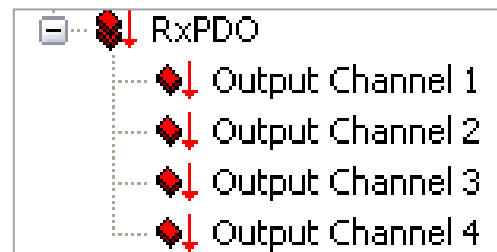
- Standard outputs and safety outputs are logically AND connected.

Current measurement active:

- When deactivating the current measurement a common ground can be used.

Testing of outputs active:

- The test pulses of the output signals can be deactivated with this setting.



EL2904 Operating Modes

BECKHOFF

- Parameters are set on an own tab “Safety Parameter” under the TwinSAFE connection.
- 8000:1 standard outputs active
 - True/False
- 8000:2 current measurement active
 - True/False
- 8000:3 testing of outputs active
 - True/False
- 8000:4 error acknowledge active
 - True/False
- 10E0:1+2
Required for Backup/Restore mode (can not be changed by the user)

The screenshot shows the Beckhoff TwinCAT software interface. The top part is the 'Solution Explorer' showing a project tree with 'SAFETY' expanded, leading to 'Untitled1 Project' and 'TwinSafeGroup1'. Under 'Alias Devices', 'Device 2 (EtherCAT) - Term 4 (EL2904).sds' is highlighted with a red box. Below this is the 'Safety Parameters' configuration window. It has two tabs: 'Safety Parameters' (selected and highlighted with a red box) and 'TwinSAFE Connection'. The 'Safety Parameters' tab shows '8000 FSOE Settings' with a table of parameters.

Parameter	Value
8000:00 SubIndex: 000	5
8000:01 Standard outputs active	False
8000:02 Current measurement active	True
8000:03 Testing of outputs active	True
8000:04 Error acknowledge active	False

EL6900: Safety Logic Terminal

BECKHOFF

Logic terminal (no local outputs)

Certified in accordance to

- EN 61508 SIL3
- EN 954-1 Cat. 4
- DIN EN ISO 13849-1 PL e
- NRTL, UL508, UL1998, UL991

- EN 81 (as applicable)
- EN 13243 (as applicable)
- 98/37/EC Machinery Directive

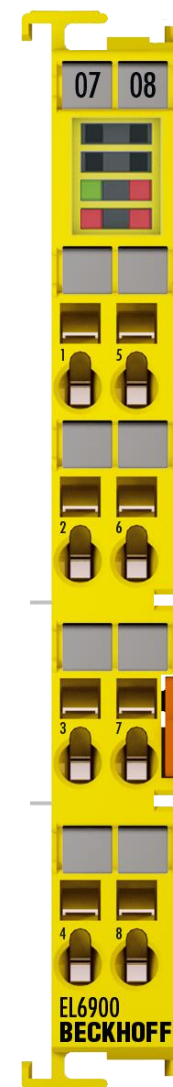
TwinSAFE Configuration

- 255 function blocks
- 128 connections
- 14 FB types
- Min. WD Time 1ms

- Complete Diagnosis available on EtherCAT
- High performance
- Short reaction time

High diagnosis

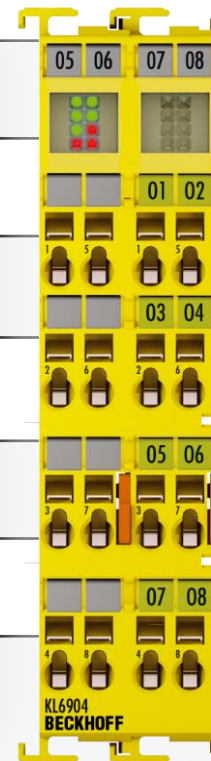
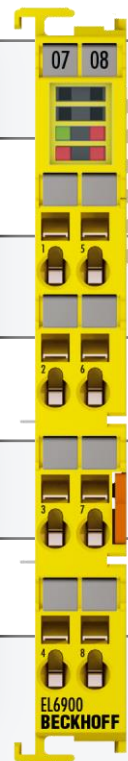
- Communication error
- Terminal error
 - Processor error
 - Under-/overvoltage
 - Temperature monitoring



Comparison EL6900/KL6904

BECKHOFF

	EL6900	KL6904
Width	12 mm	24 mm
Output	No local outputs	4 outputs 24 V DC
Max. number of connections	128	7 - 15
Max. number of FBs	255 FB	48 FB
Min. WD time	1 ms	100 ms
Available FB types	14	6
Diagnostic data	in the Process data	asynchronous
Data trans-mission rate interface	100 MBit	1.6 MBit



Certified Safety Functions

Validation & Calculation done and already approved by the TÜV!

- Choose the function appropriate to your necessary PL
- Wiring notes
- Terminal parameters
- Setting of the FB

<http://www.beckhoff.com/english/download/twinsafe.htm?id=71003127100377>



Application guide

TwinSAFE

Version: 1.3.1
Date: 2012-02-01



BECKHOFF

Date: 2012-05-01
Version: 1.3.1



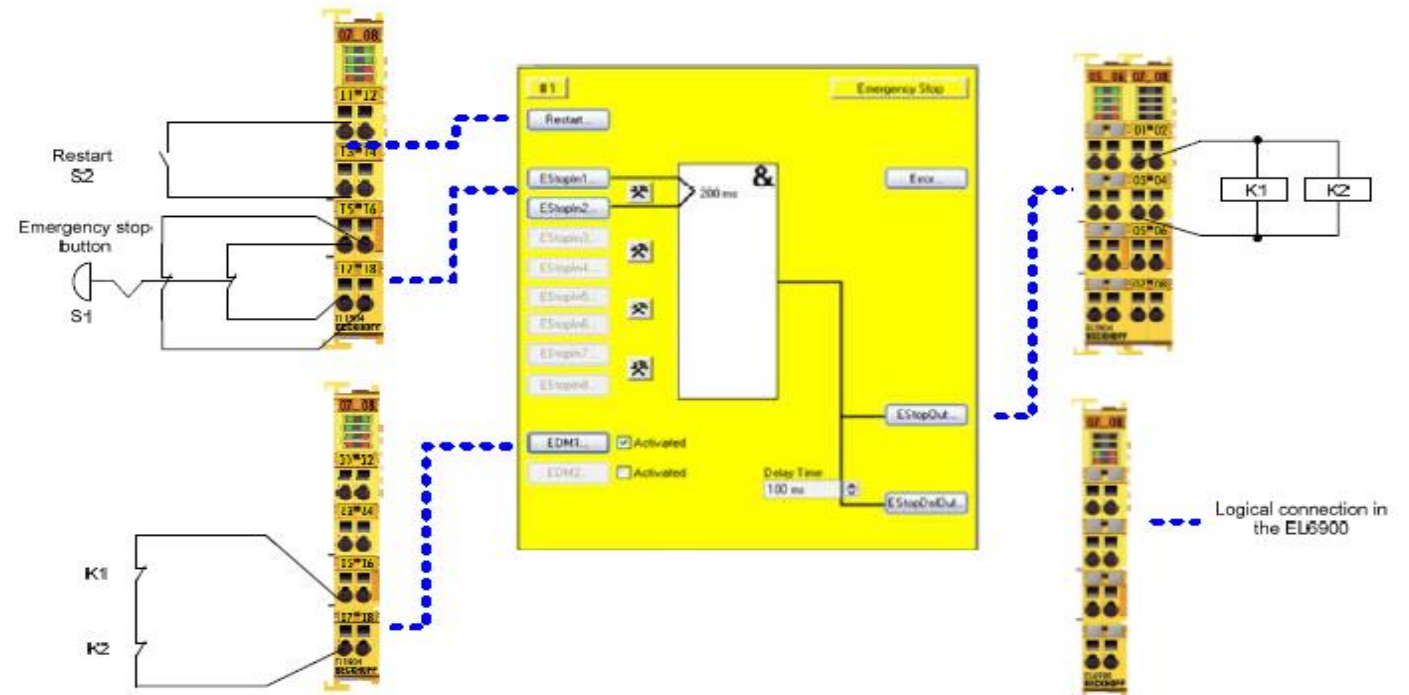
BECKHOFF

ESTOP

- Required: PL e
- The hardware is done according to chapter 2.4 Application Guide

→ Assign the settings to TwinSAFE.

2.4 ESTOP function variant 4 (Category 4, PL e)

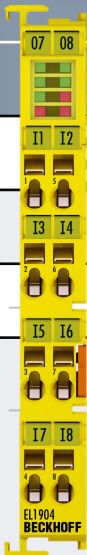


First Project Step-by-Step

BECKHOFF

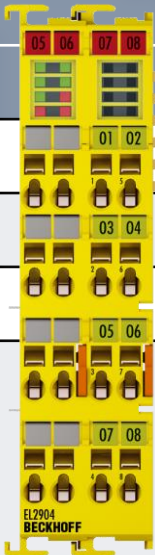
Input EL1904

Channel	Signal
1	ESTOP Channel 1
2	ESTOP Channel 2
3	Restart
4	EDM



Output EL2904

Channel	Signal
1	Relay
2	
3	
4	



- Safety parameters are settings (depend on the terminal):
 - TwinSAFE terminal (e.g. operation mode)
 - single channel (e.g. sensor test)

See Application Guide –
in this case application in
chapter 2.4

EL1904 (applies to all EL1904 used)

Parameter	Value
Sensor test channel 1 active	Yes
Sensor test channel 2 active	Yes
Sensor test channel 3 active	Yes
Sensor test channel 4 active	Yes
Logic channel 1 and 2	Single Logic
Logic channel 3 and 4	Single Logic

EL2904

Parameter	Value
Current measurement active	Yes
Output test pulses active	Yes

- The combination **of all** safety parameters defines the safety level of the function → **it is important to set all safety parameters properly!**
- They are similarly necessary for faultless operation.

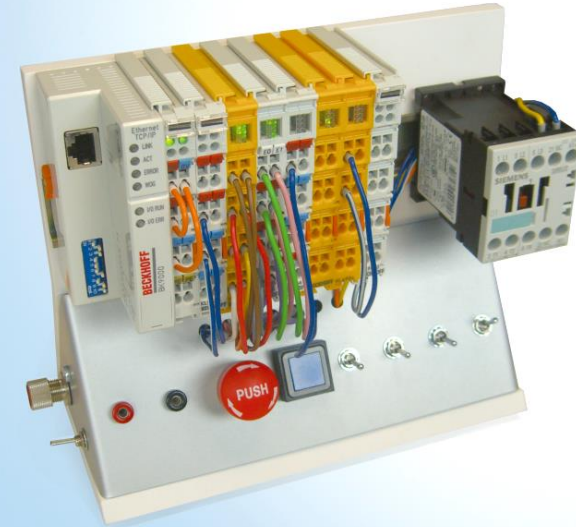


The screenshot displays the TwinCAT Project2 configuration environment. On the left, the 'Solution Explorer' shows the project structure, with 'Device 3 (EtherCAT)' selected under the 'I/O' folder. The right pane shows the 'General' tab for this device, with the following configuration:

- Name: Device 3 (EtherCAT)
- Object Id: 0x03010030
- Type: EtherCAT Master
- Comment: (empty text area)
- Disabled: ☐
- Create symbols: ☐

Below the configuration fields is a table listing the device's terms and their addresses:

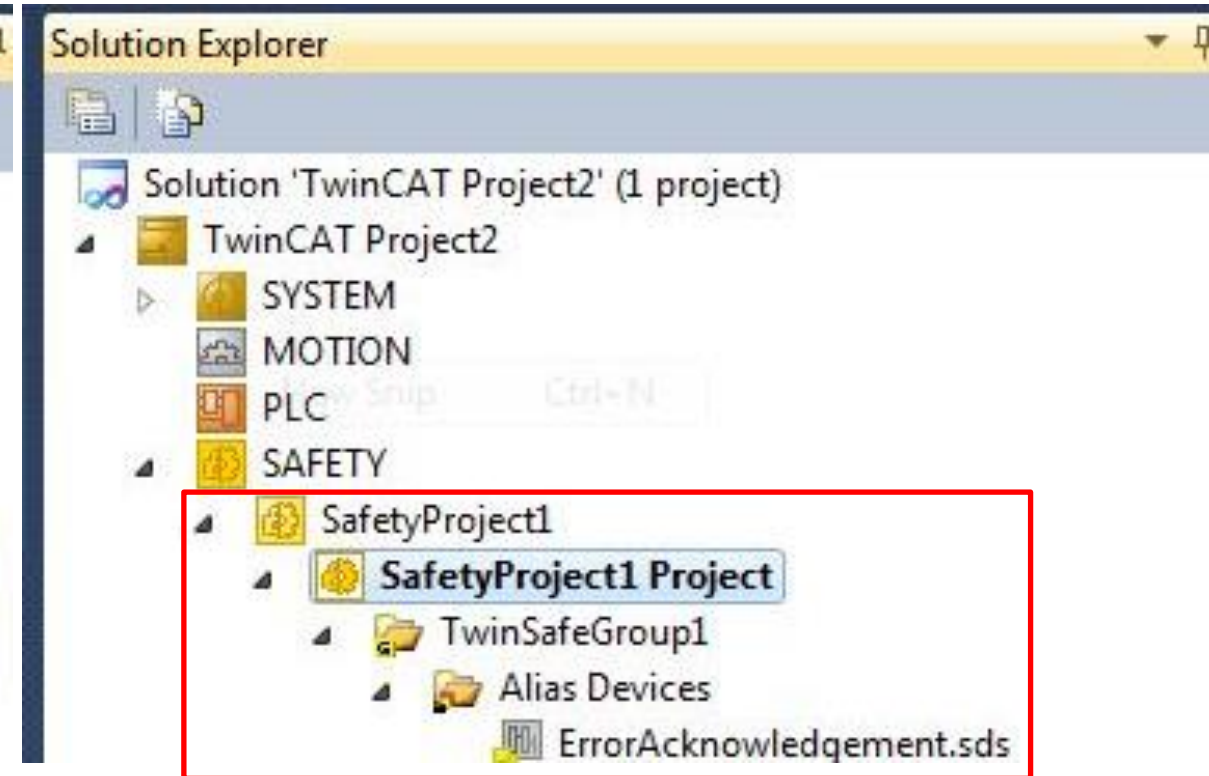
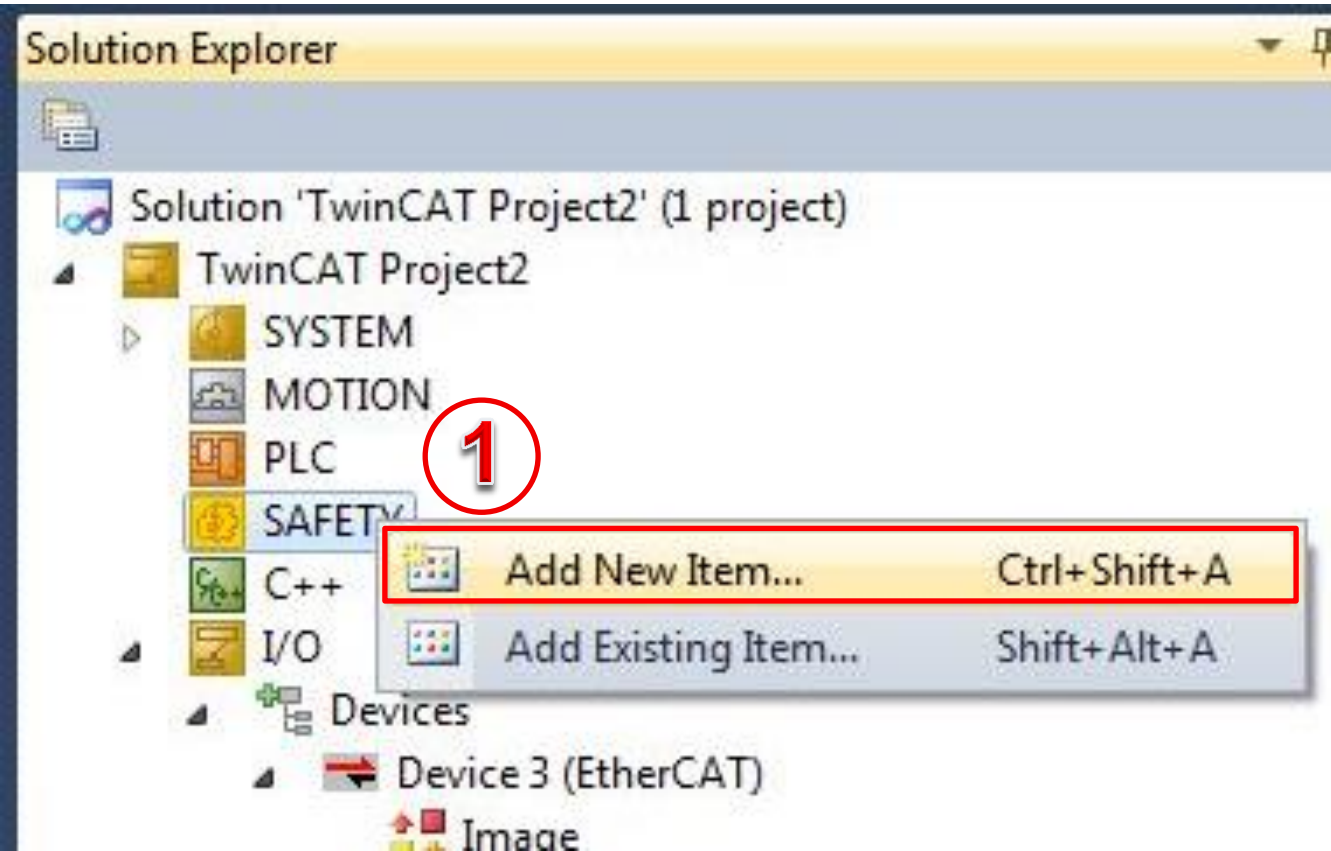
Number	Box Name	Address	Type	In Size	Out Size	E-Bus (m...)
1	Term 1 (EK1100)	1001	EK1100			
2	Term 2 (EL6900)	1002	EL6900	2.0	2.0	1810
3	Term 3 (EL1904)	1003	EL1904	6.0	6.0	1610
4	Term 4 (EL2904)	1004	EL2904	6.0	8.0	1389
5	Term 5 (EL1014)	1005	EL1014	0.4		1299
6	Term 6 (EL2004)	1006	EL2004		0.4	1199
7	Term 7 (EL9011)		EL9011			



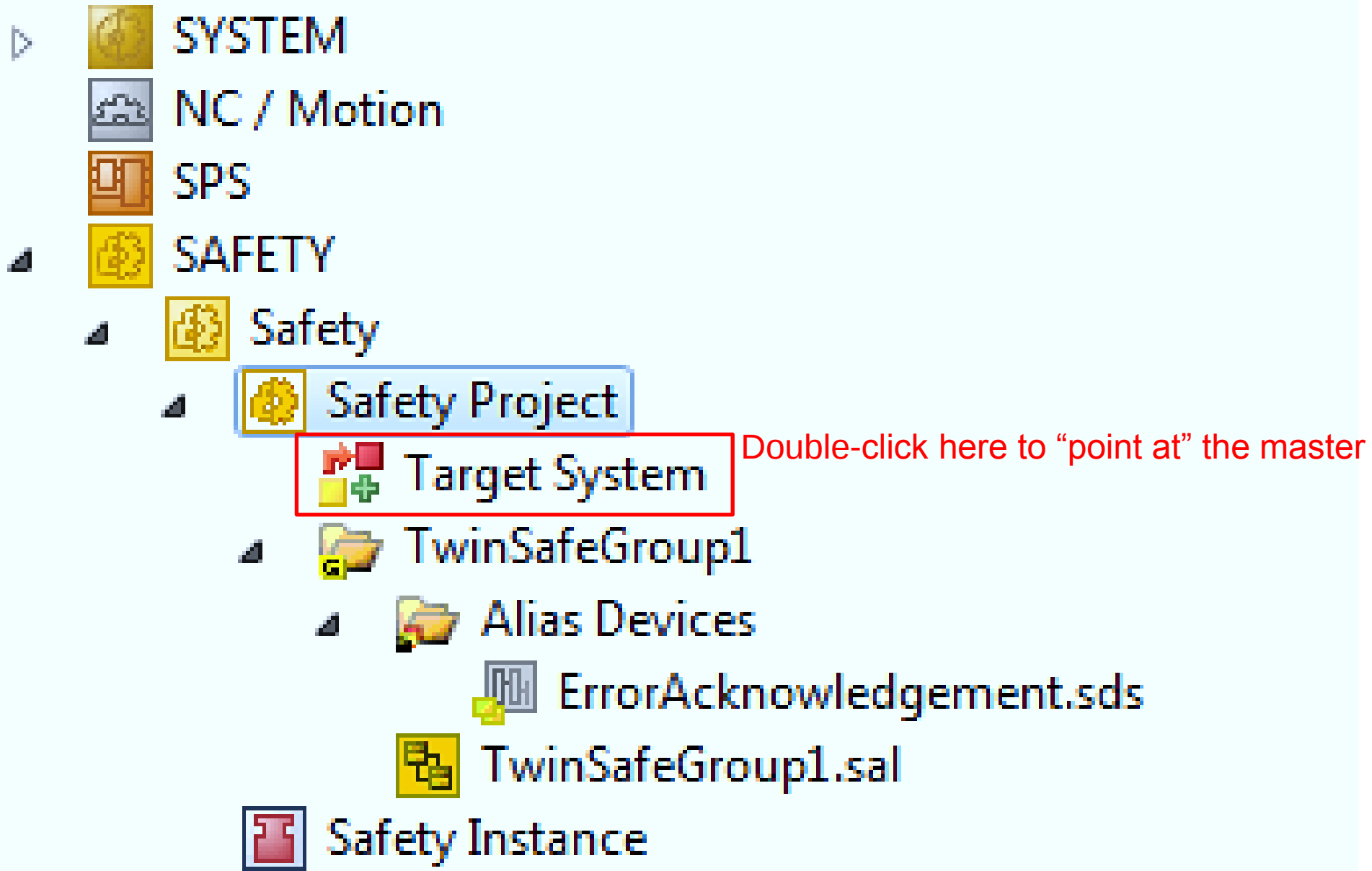
Create a TwinSafe Project

BECKHOFF

1. SAFETY: Add New Item



Results in this “default” structure

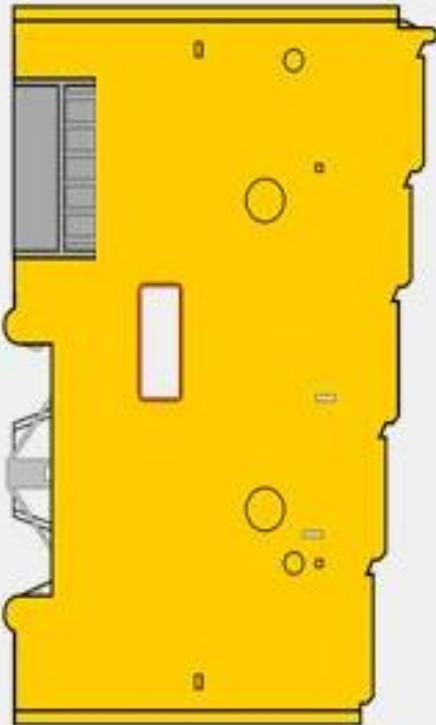


- Select the master

Target System*

User Administration

Configuration: N/A Platform: N/A



Target System: EL69XX

Physical Device: not available

☐ Device is an external device

Software Version: not available

Serial Number: not available

Project CRC: not available

Map Serial Number: ☐ Map Project CRC: ☐

Version Number: 1

FSoE-Address: 2

Dip-Switch: not available

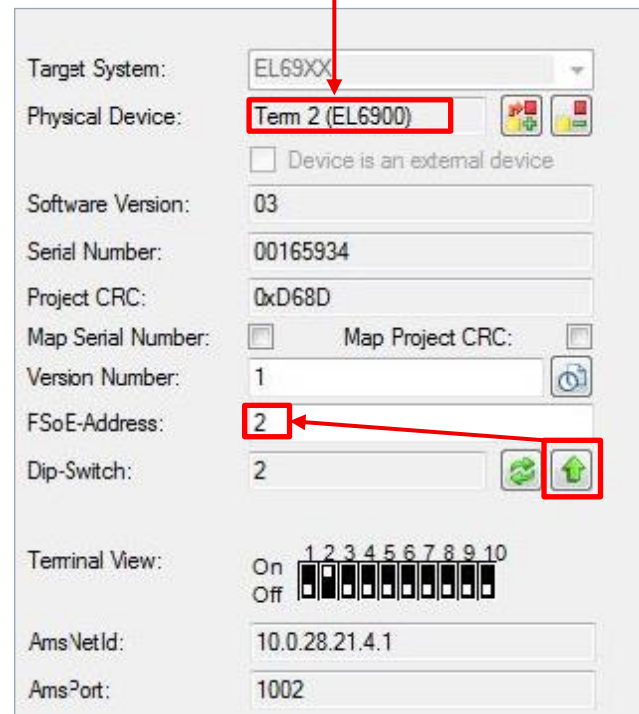
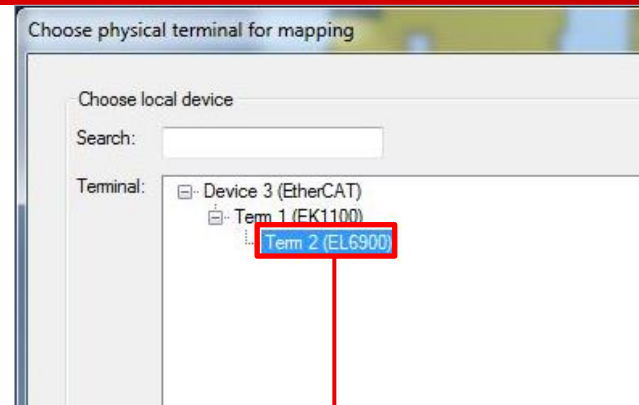
Terminal View:

On Off 1 2 3 4 5 6 7 8 9 10

AmsNetId: not available

AmsPort: not available

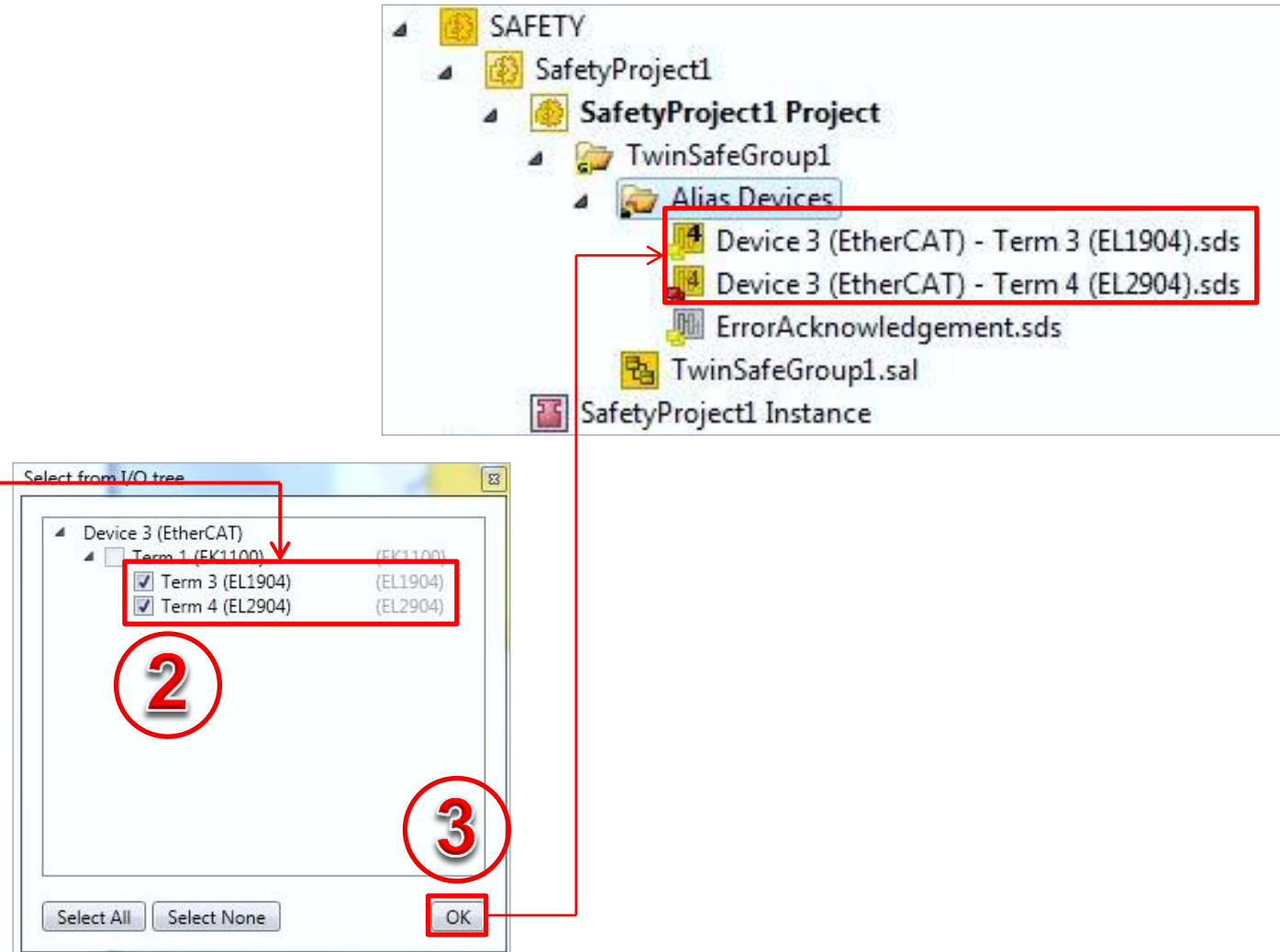
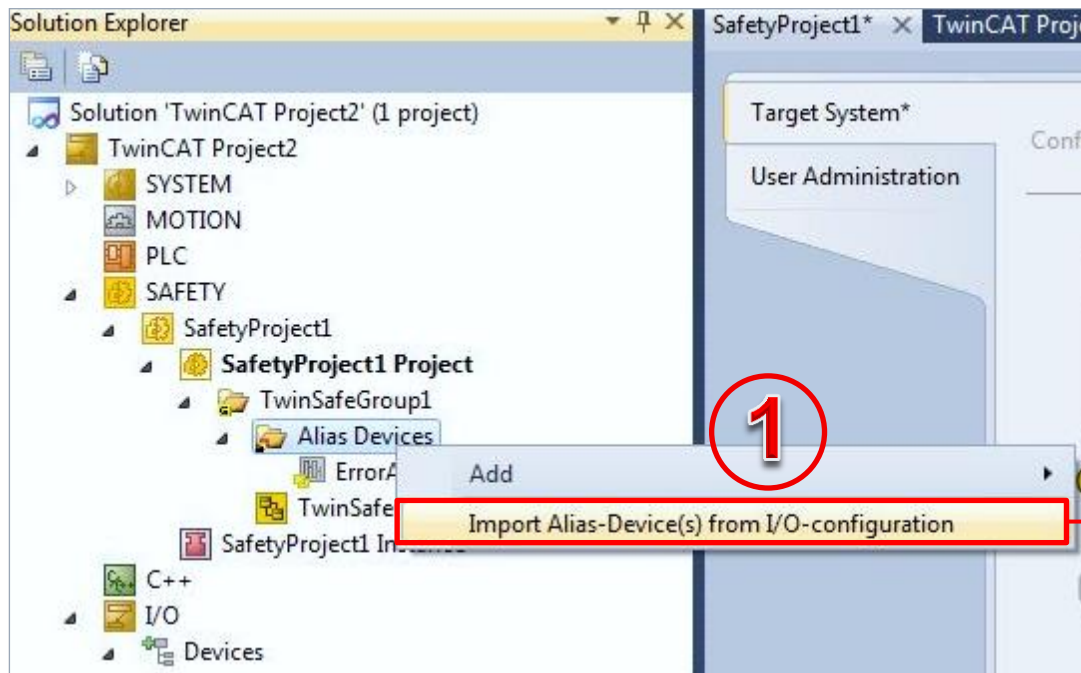
- Select the master
- Confirm the FSoE address



Select I/O Terminals

BECKHOFF

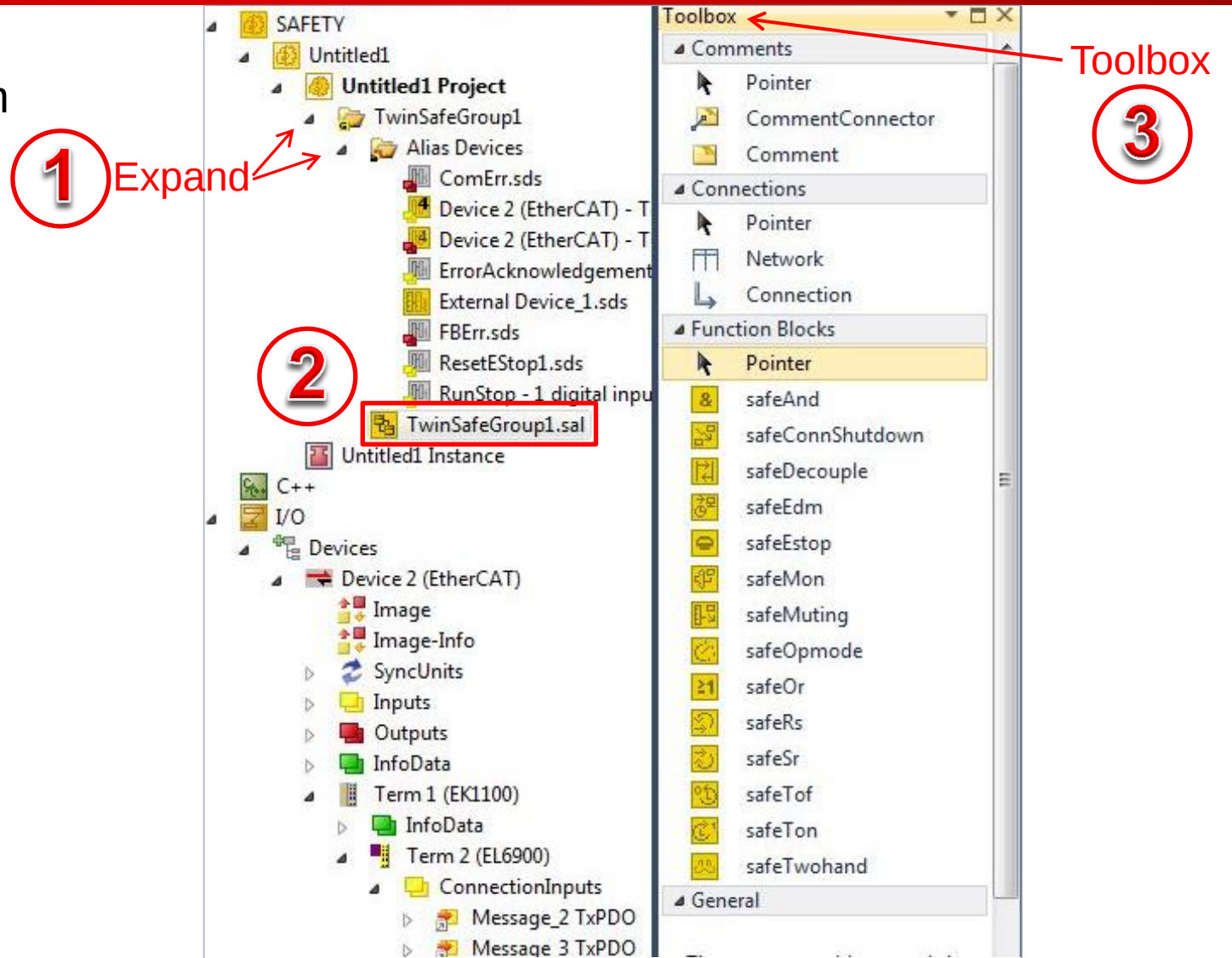
■ Import of I/O Terminals



Select Safety FB

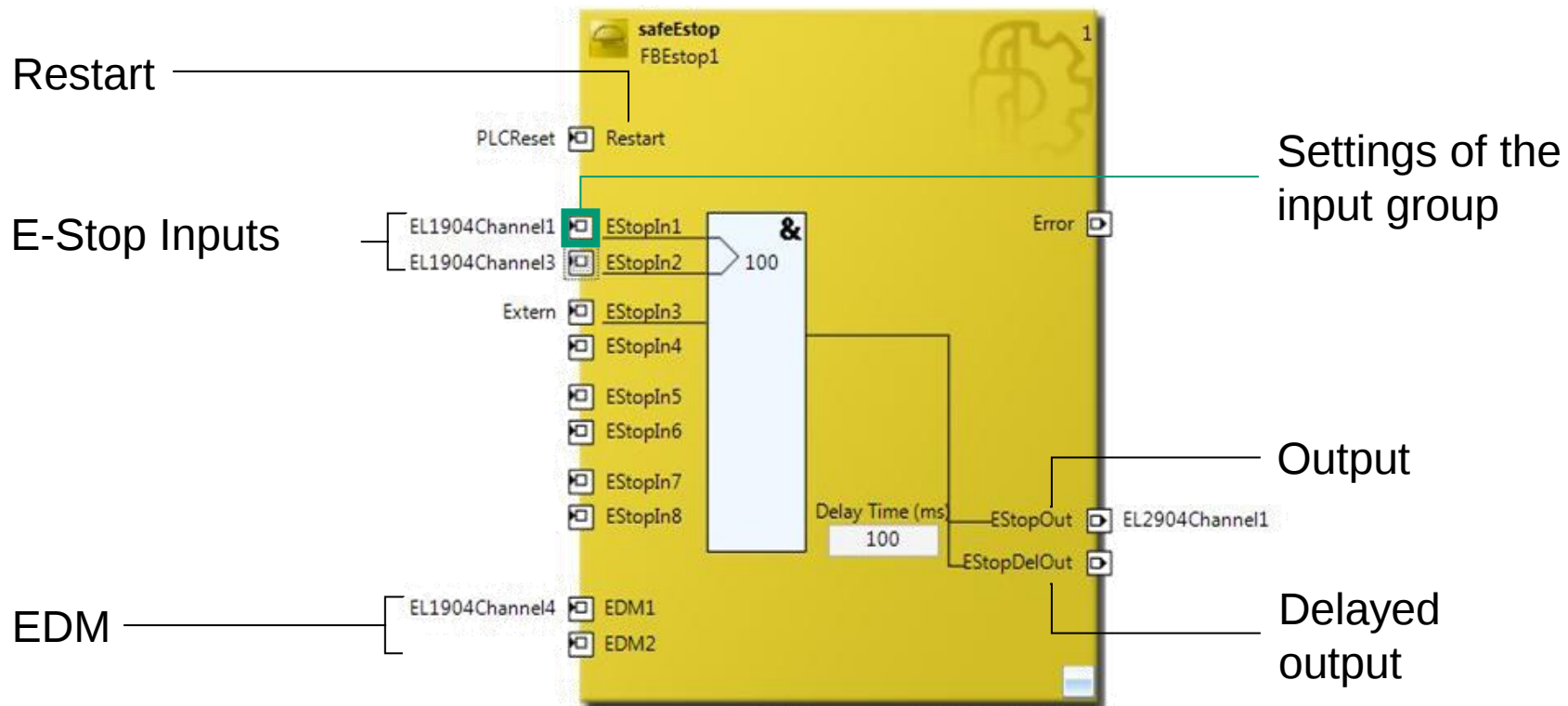
BECKHOFF

- Open the group and select a FB from the toolbox.



Example: Emergency Stop

- Further FBs: machine monitoring, operation mode, AND, OR, etc.



Settings of the FB Inputs

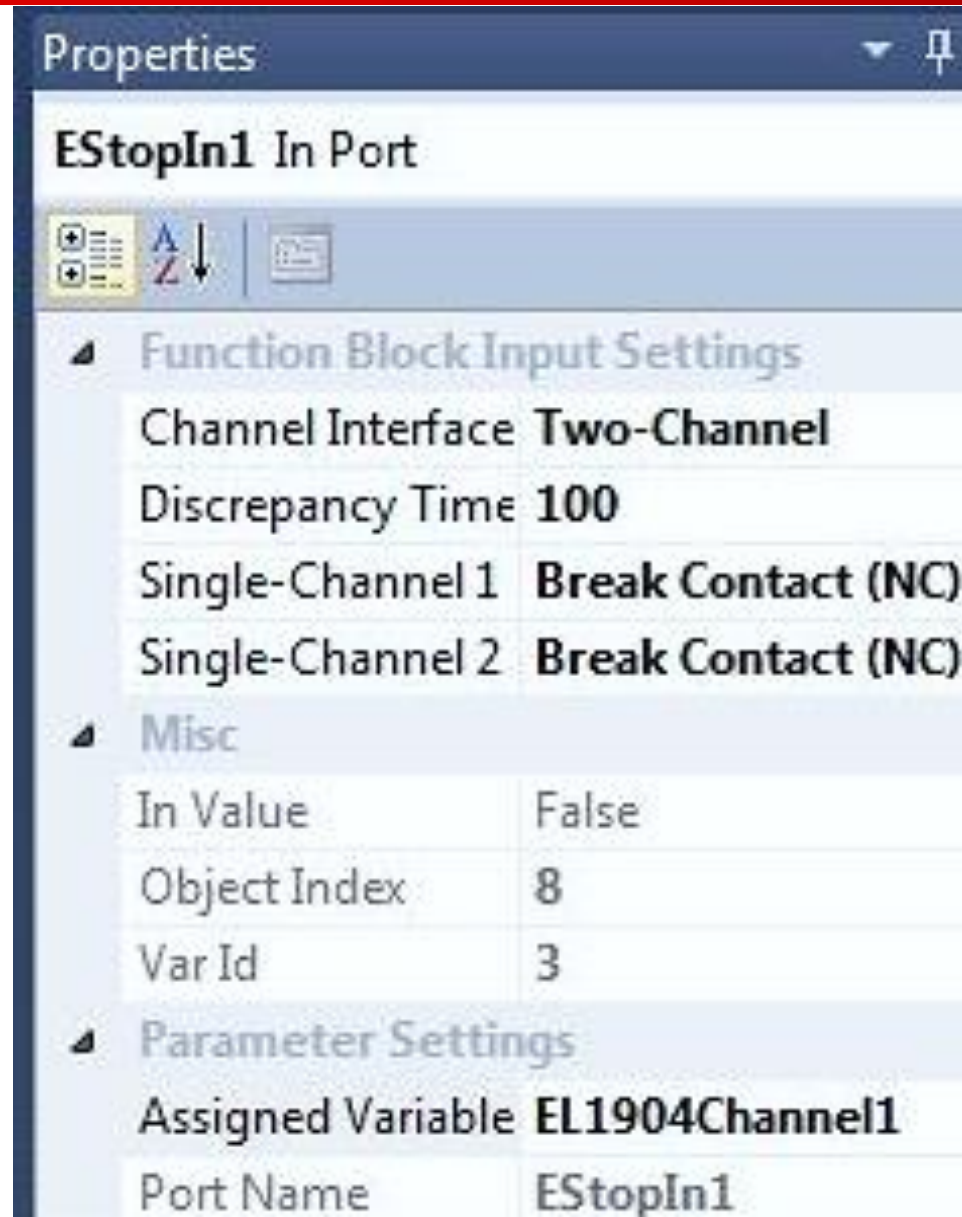
BECKHOFF

Break contact:

- The direct signal will be used.
- Input signal logically 1 →
FB input logically 1

Make contact:

- The inverted signal will be used.
- Input signal logically 1 →
FB input logically 0



Settings of the FB Diagnostic

BECKHOFF

Activate FB diagnostic data

- Map Diag
- Map State

Properties

FBStop1 FBStop

Info Data

Map Diag	True
Map State	True

Misc

Graph Level	0
Order Of Execution	1
State	
Type	11

Parameter Setting

Safe Inputs After Disc E	False
--------------------------	-------

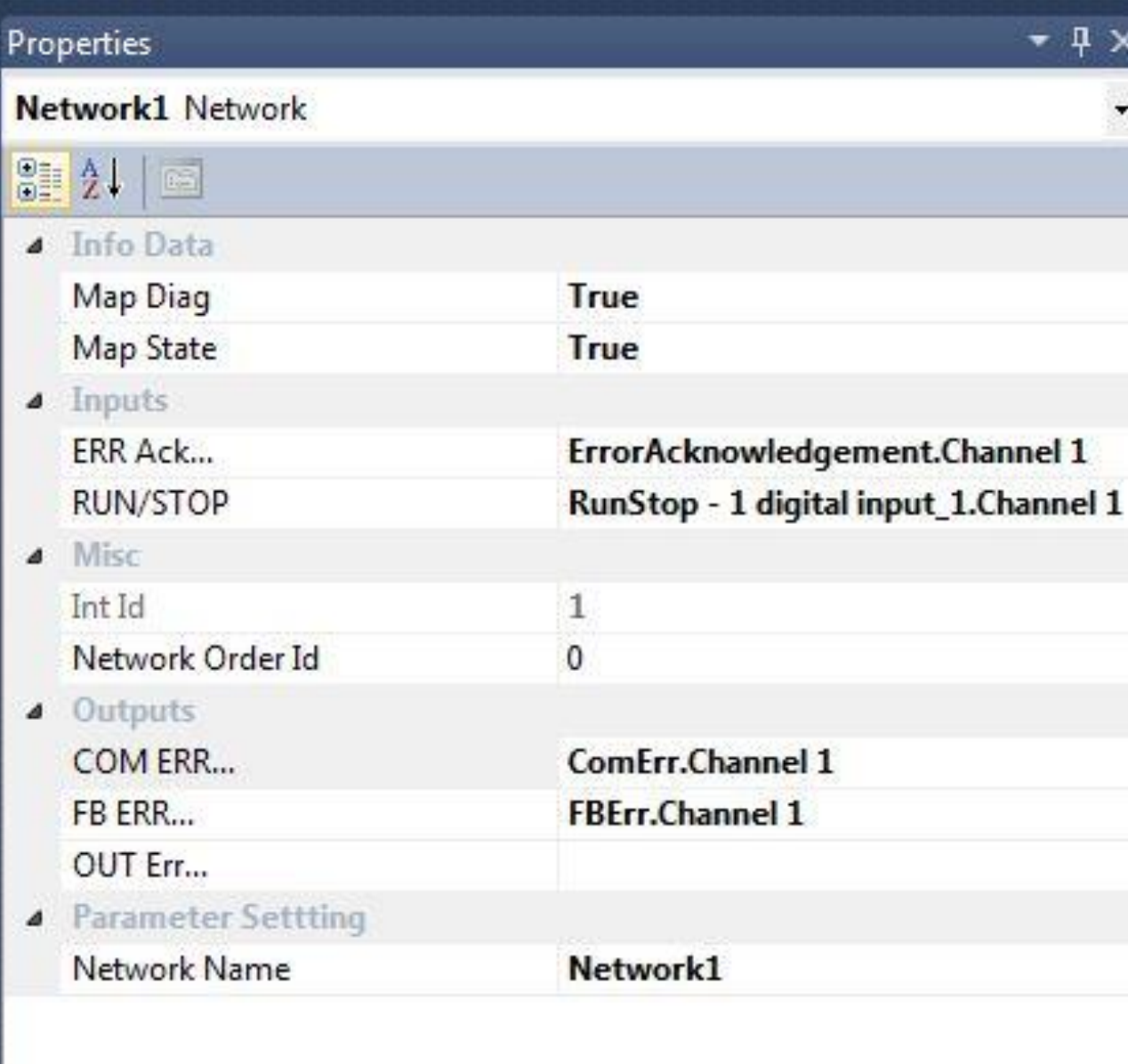
Properties

Function Name	safeEstop
Instance Name	FBStop1

Toggle these from False (the default value) to True

Activate group diagnostic data

- Map Diag
- Map State
- Group signals:
 - ERR Ack
 - Run/Stop (assumes RUN if not connected)
 - Com Err
 - FB Err
 - Out Err (not used: no local safety outputs on the EL6900)



Properties	
Network1 Network	
Info Data	
Map Diag	True
Map State	True
Inputs	
ERR Ack...	ErrorAcknowledgement.Channel 1
RUN/STOP	RunStop - 1 digital input_1.Channel 1
Misc	
Int Id	1
Network Order Id	0
Outputs	
COM ERR...	ComErr.Channel 1
FB ERR...	FBErr.Channel 1
OUT Err...	
Parameter Setting	
Network Name	Network1

Mapping of the Signals (alias abstraction layer)

BECKHOFF

The screenshot displays the TwinCAT environment with three main components:

- Function Block Diagram:** A yellow function block named `safeEstop` (instance `FBStop1`) is shown. Its inputs include `PLCReset` (Restart), `EL1904Channel1` (EStopIn1), `EL1904Channel3` (EStopIn2), and `Extern` (EStopIn3). A logic gate (AND) combines `EStopIn1` and `EStopIn2` to produce `EStopOut`. A delay block (100 ms) is connected to `EStopOut`. The output is `EL2904Channel1`.
- Solution Explorer:** The project structure shows `SAFETY` > `Untitled1` > `Alias Devices`. Under `Alias Devices`, `ComErr.sds` is expanded, showing `Device 2 (EtherCAT) - Term 3 (EL1904).sds` and `Device 2 (EtherCAT) - Term 4 (EL2904).sds`.
- Variable Mapping Table:** This table maps the function block ports to their assigned variables and alias ports.

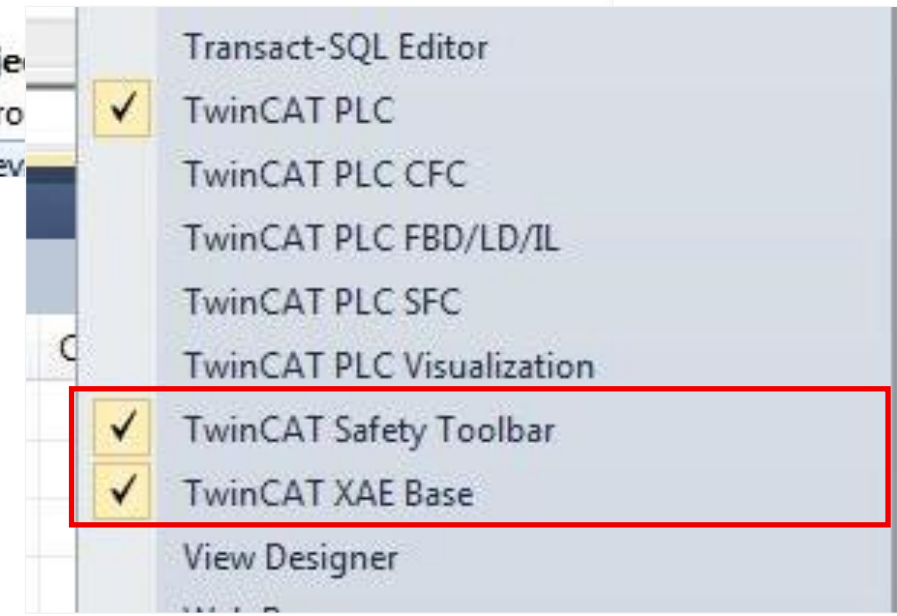
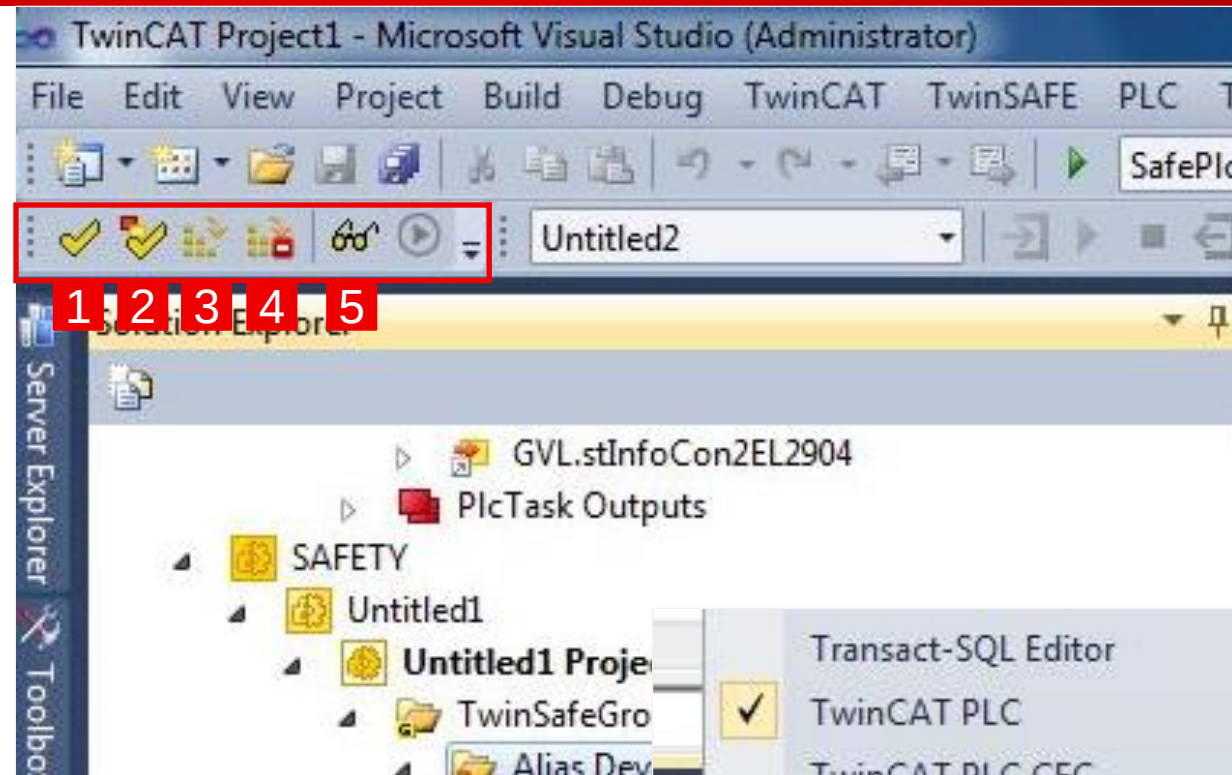
Function Name	Instance Name	Port Name	Direction	Assigned Variable	Data Type	Alias Port
safeEstop	FBStop1	Restart	input	PLCReset	Bool	ResetEStop1.Channel 1
safeEstop	FBStop1	EStopIn1	input	EL1904Channel1	safeBool	Device 2 (EtherCAT) - Term 3 (EL1904).Channel 1
safeEstop	FBStop1	EStopIn2	input	EL1904Channel3	safeBool	Device 2 (EtherCAT) - Term 3 (EL1904).Channel 3
safeEstop	FBStop1	EStopIn3	input	Extern	safeBool	External Device_1.FSoE Data 0[0]
safeEstop	FBStop1	EDM1	input	EL1904Channel4	safeBool	Device 2 (EtherCAT) - Term 3 (EL1904).Channel 4
safeEstop	FBStop1	EStopOut	output	EL2904Channel1	safeBool	Device 2 (EtherCAT) - Term 4 (EL2904).Channel 1

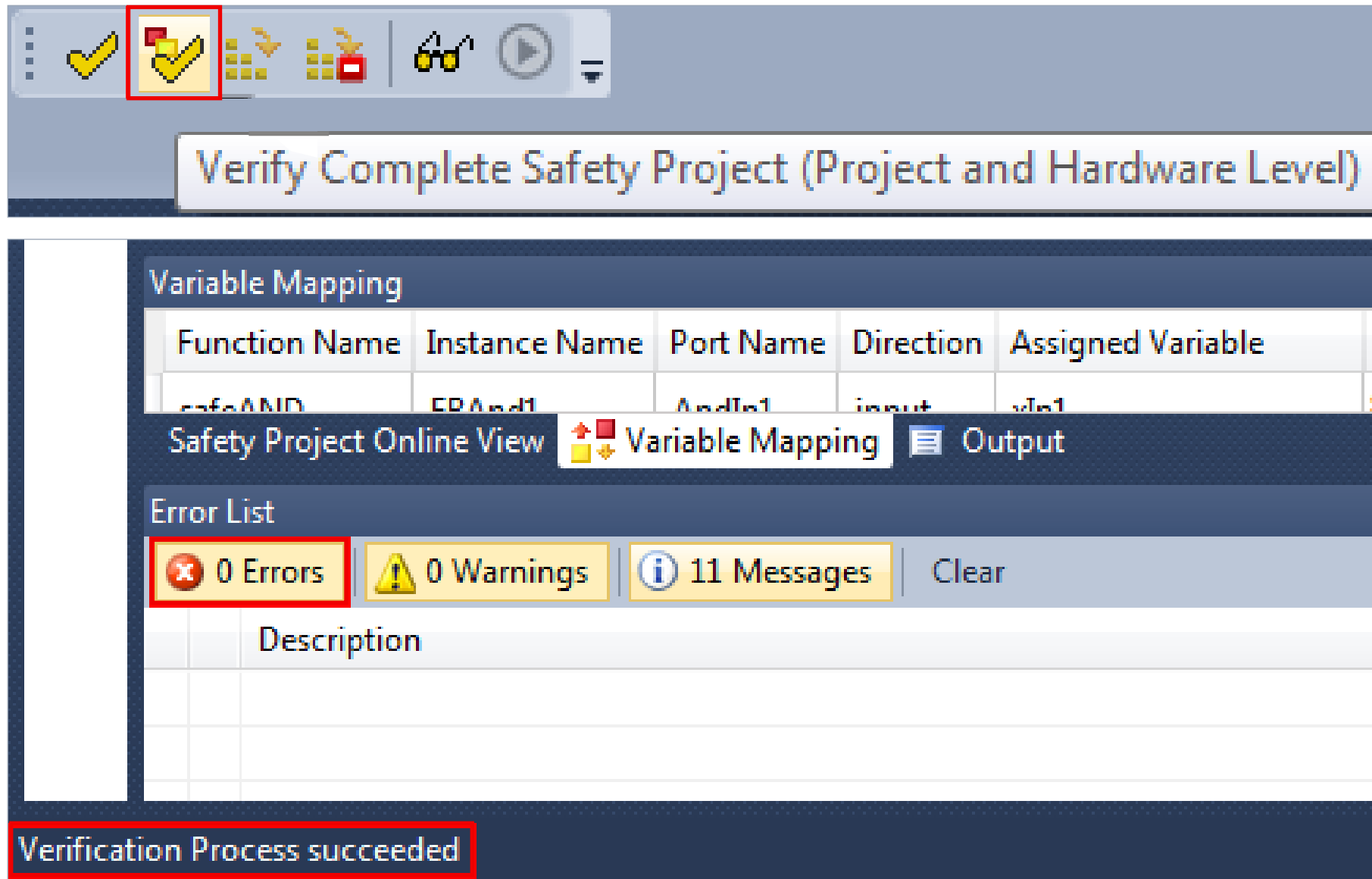
The bottom of the window shows the **Safety Project Online View** tabs: `Variable Mapping` (active), `Error List`, and `Output`.

Safety Toolbar

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- Display the safety toolbar
- 1 Verify Safety Project (Project Level)
 - 2 Verify Complete Safety Project (Project and Hardware Level)
 - 3 Download Safety Project
 - 4 Delete Safety Project
 - 5 Show Online Data of Safety Project





The screenshot displays the Beckhoff Safety Project Online View interface. At the top, a toolbar contains several icons, with the 'Verify Complete Safety Project' icon (a yellow checkmark with a red square) highlighted by a red box. Below the toolbar, a button labeled 'Verify Complete Safety Project (Project and Hardware Level)' is visible. The main content area is divided into three sections: 'Variable Mapping', 'Error List', and a status bar at the bottom.

Variable Mapping

Function Name	Instance Name	Port Name	Direction	Assigned Variable
safeAND	EPAnd1	AndIn1	input	vin1

Error List

The Error List section shows a summary of the verification results: 0 Errors, 0 Warnings, and 11 Messages. The '0 Errors' button is highlighted with a red box. Below this summary is a table with a 'Description' header.

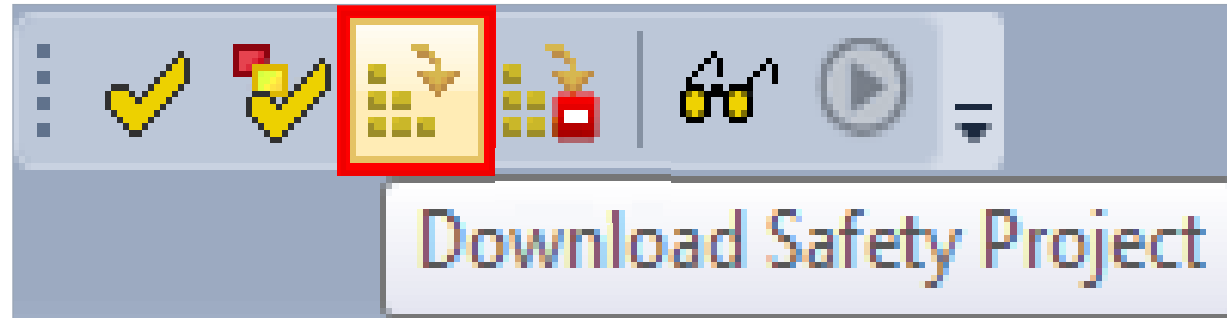
Description

Verification Process succeeded

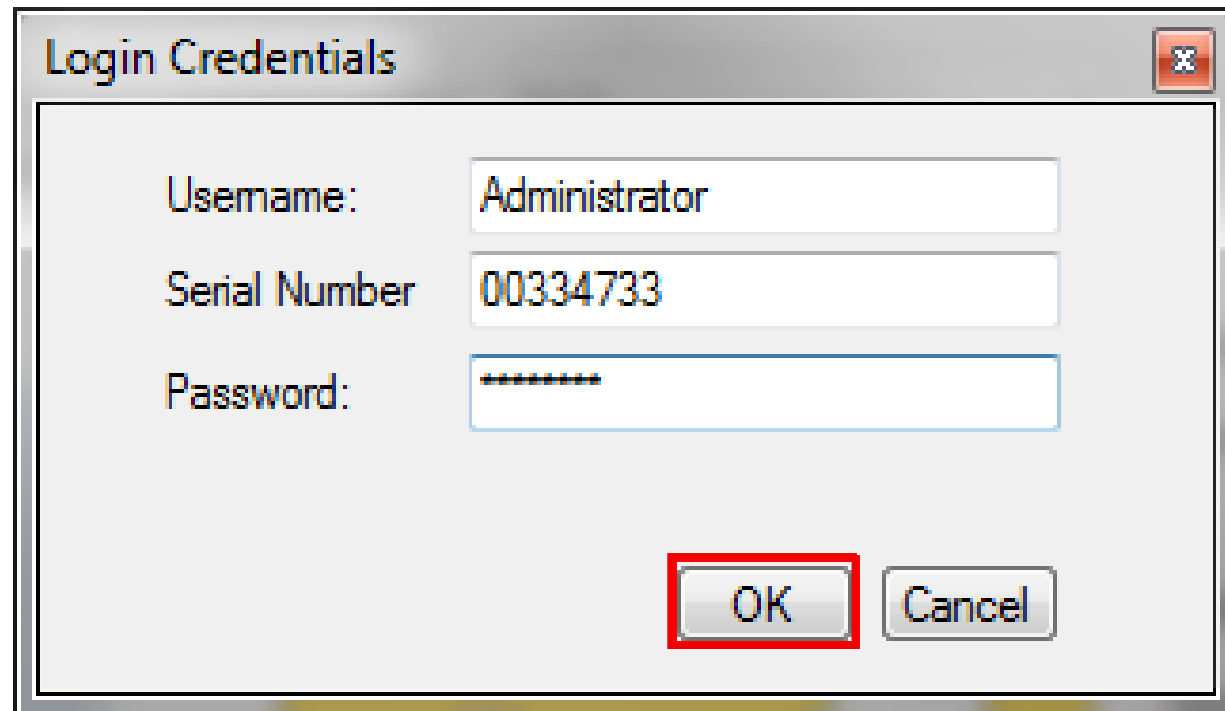
Download to the Safety Controller

BECKHOFF

- Choose download ICON



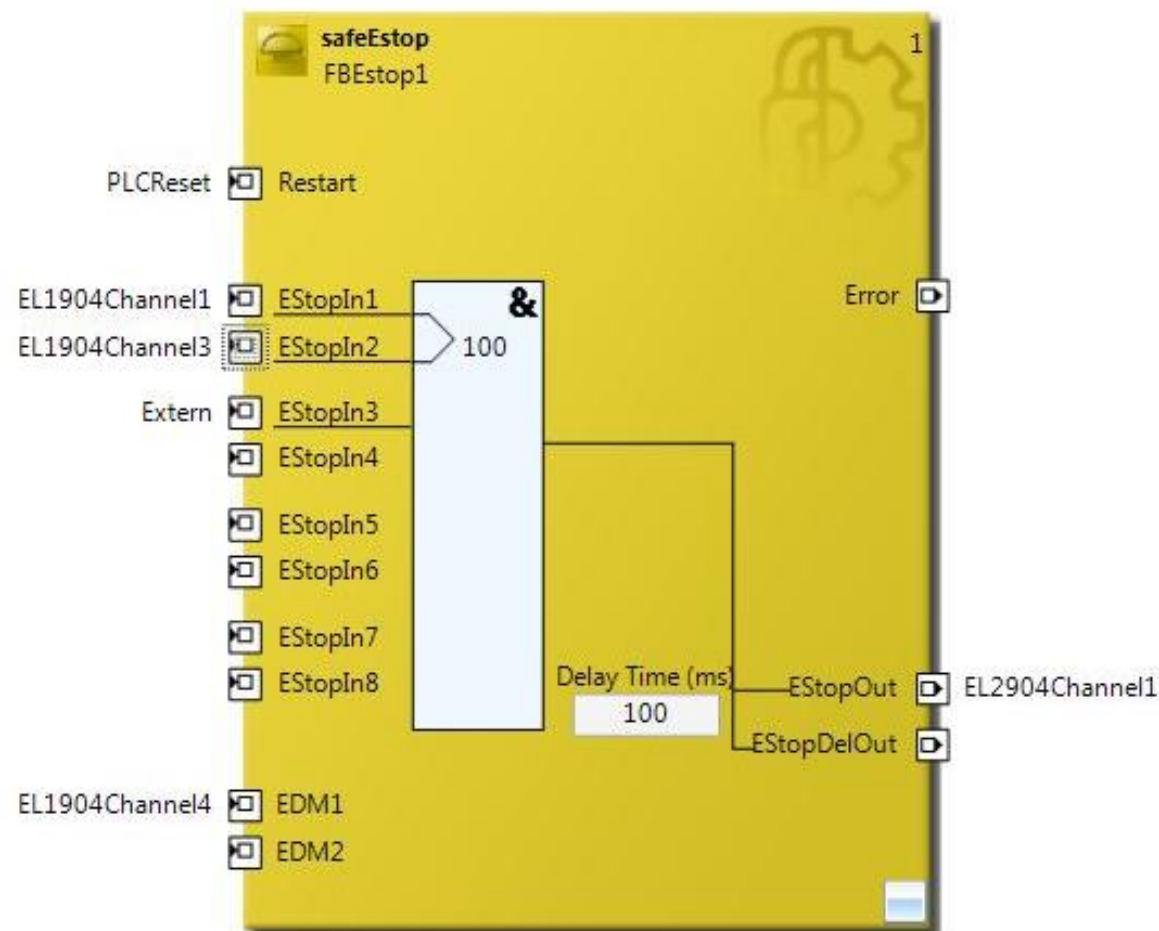
- Username: Administrator
- Serial number: 00334733
- Password: TwinSAFE

A screenshot of a 'Login Credentials' dialog box. It contains three input fields: 'Username' with the text 'Administrator', 'Serial Number' with the text '00334733', and 'Password' with masked characters (dots). At the bottom right, there are two buttons: 'OK' and 'Cancel'. The 'OK' button is highlighted with a red rectangular box.



Function Block Emergency Stop

- Only manual restart
- Up to four 2-channel E-Stop buttons can be used.
- Direct and delayed switching outputs with up to 30 seconds delay time
- Checkbox “Safe Inputs after Discrepancy error” forces that after a discrepancy error the reporting input group must give on both channels a logical 0. Otherwise a restart is not possible.



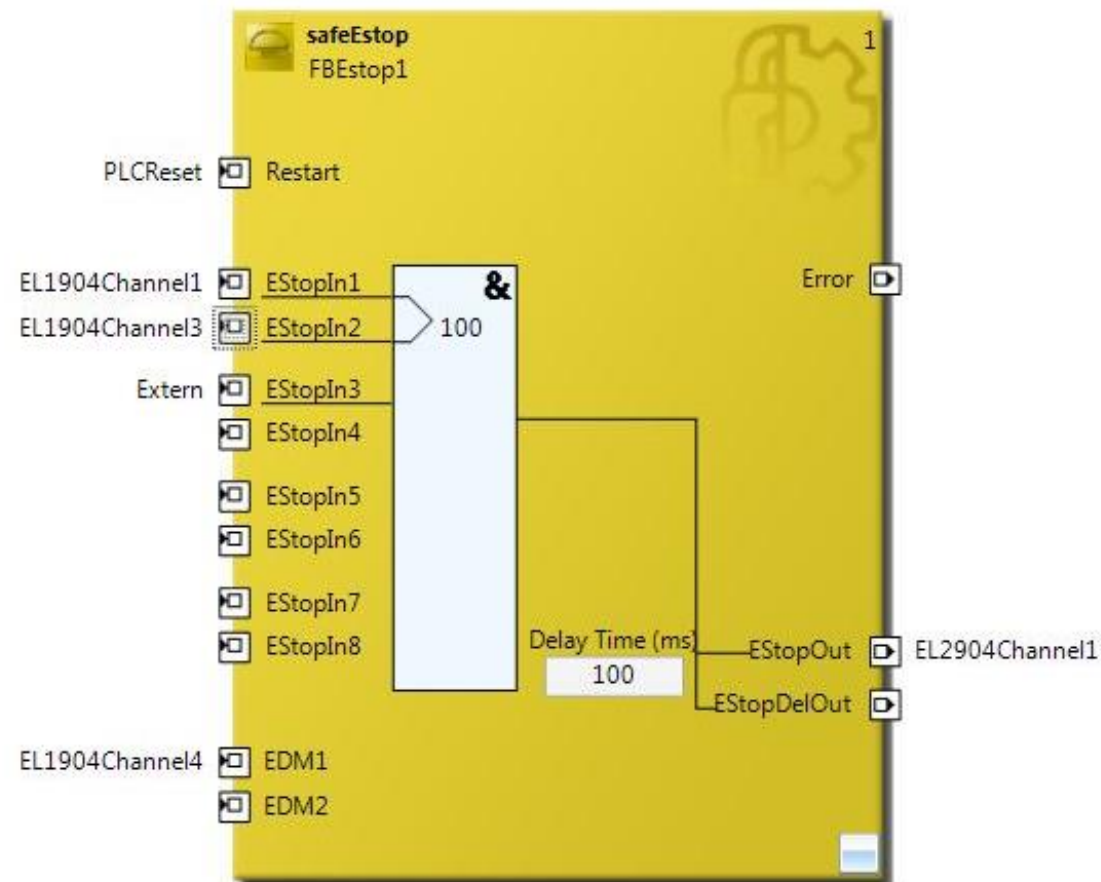
Function Block Emergency Stop state and diagnosis

State:

- 0 undefined
- 1 RUN
- 2 STOP
- 3 SAFE
- 4 ERROR
- 5 RESET
- 6 START
- 8 DELAYOUT

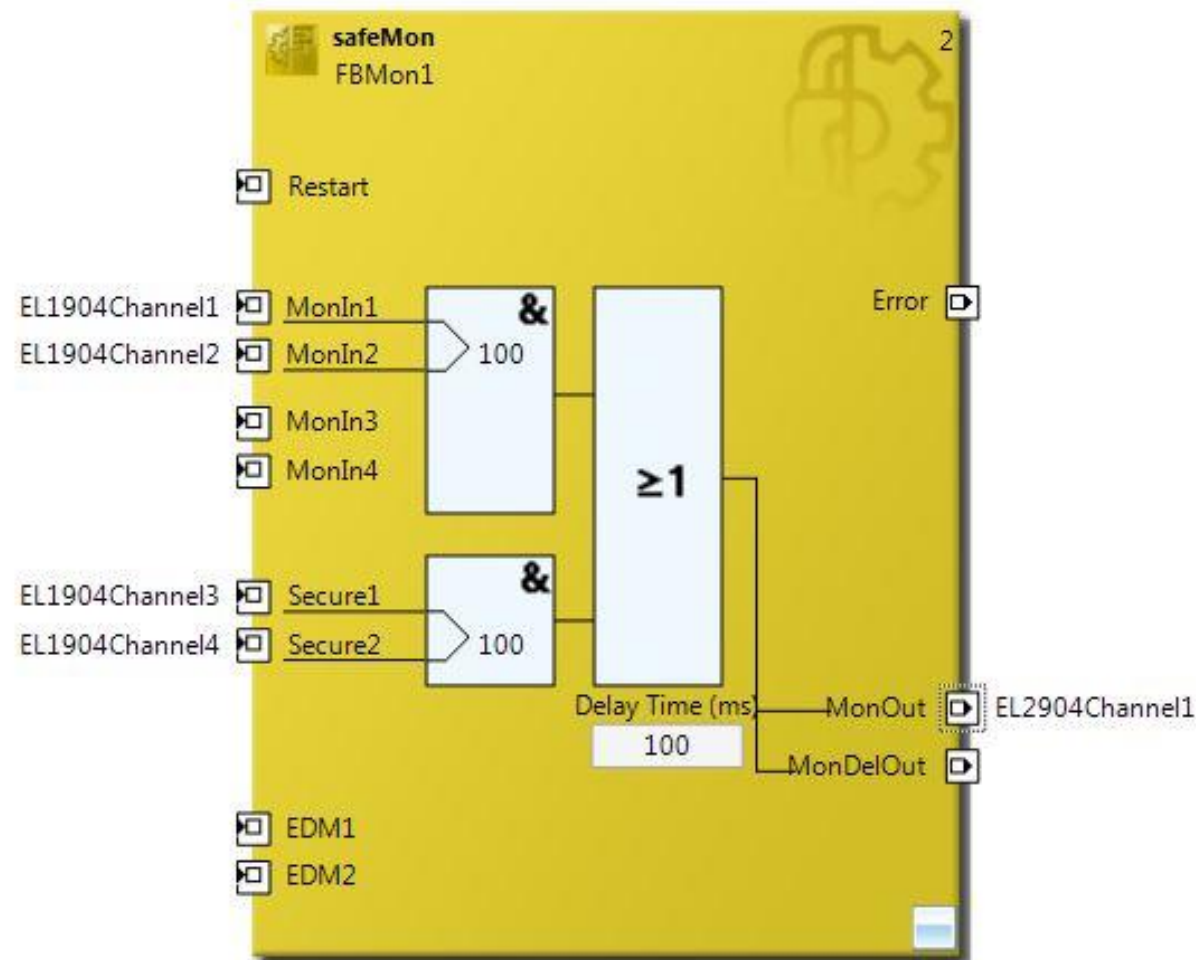
DIAG:

- Bit 0 Discrepancy error input group 1
- Bit 1 Discrepancy error input group 2
- Bit 2 Discrepancy error input group 3
- Bit 3 Discrepancy error input group 4
- Bit 4 EDM error EDM 1
- Bit 5 EDM error EDM 2



Function Block Machine Monitor

- Manual and automatic restart configurable
- Up to two 2-channel guard door switches usable
- Direct and delayed switching outputs with up to 30 seconds delay time
- Checkbox “Safe Inputs after Discrepancy error” forces that after a discrepancy error the reporting input group must give on both channels a logical 0. Otherwise a restart is not possible.



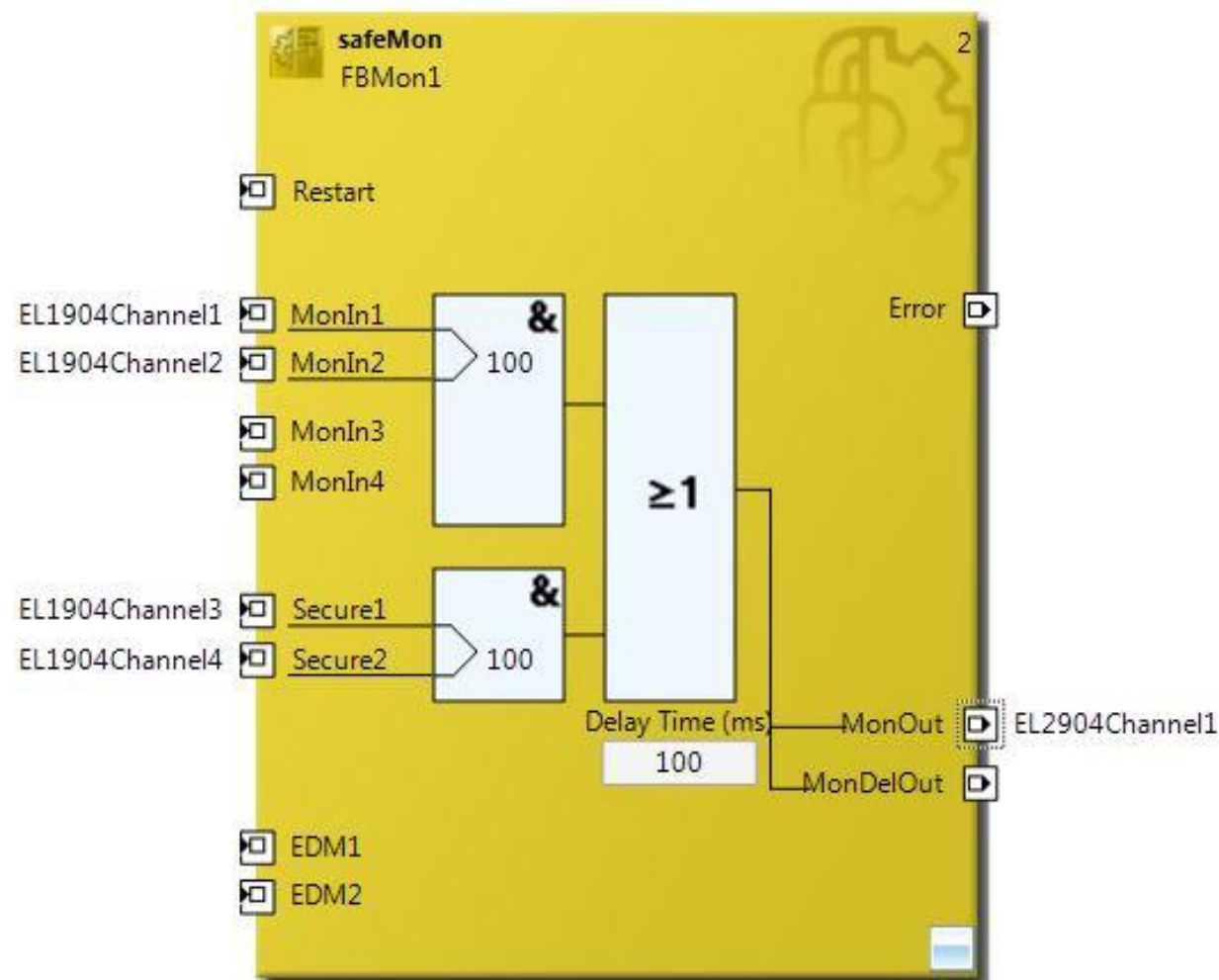
Function Block Machine Monitor state and diagnosis

State:

- | | |
|-------------|--------------|
| 0 undefined | 5 RESET |
| 1 RUN | 6 START |
| 2 STOP | 7 ERRORDELAY |
| 3 SAFE | 8 DELAYOUT |
| 4 ERROR | 9 FUNCTEST |

DIAG:

- Bit 0 Discrepancy error input group 1
- Bit 1 Discrepancy error input group 2
- Bit 2 Discrepancy error secure inputs
- Bit 4 EDM error EDM 1
- Bit 5 EDM error EDM 2



Function Block AND

- AndIn1 is allowed to be a standard input.
- At least 2 input signals must be connected to the function block.

State:

0 undefined

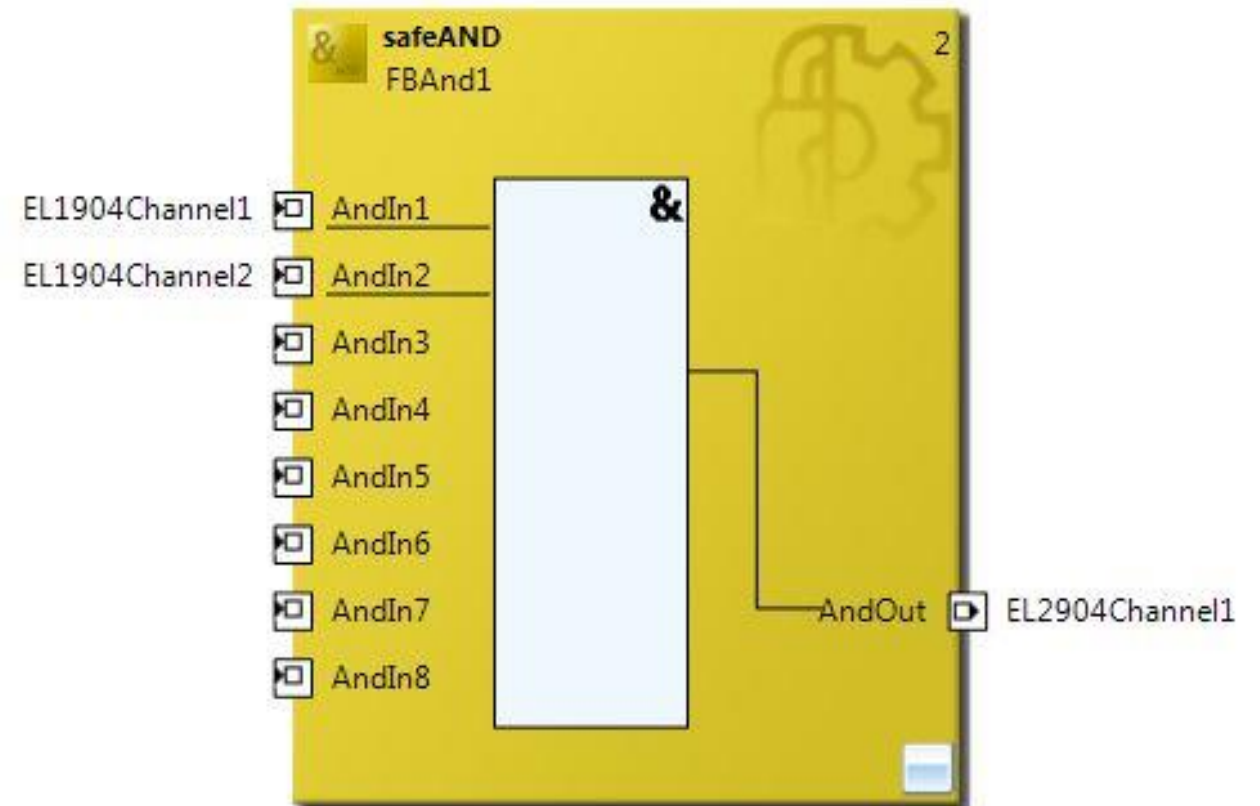
1 RUN

2 STOP

3 SAFE

DIAG:

Always 0



Function Block OR

- Logical OR
- At least 2 input signals must be connected to the function block.
- All inputs must be SAFE inputs

State:

0 undefined

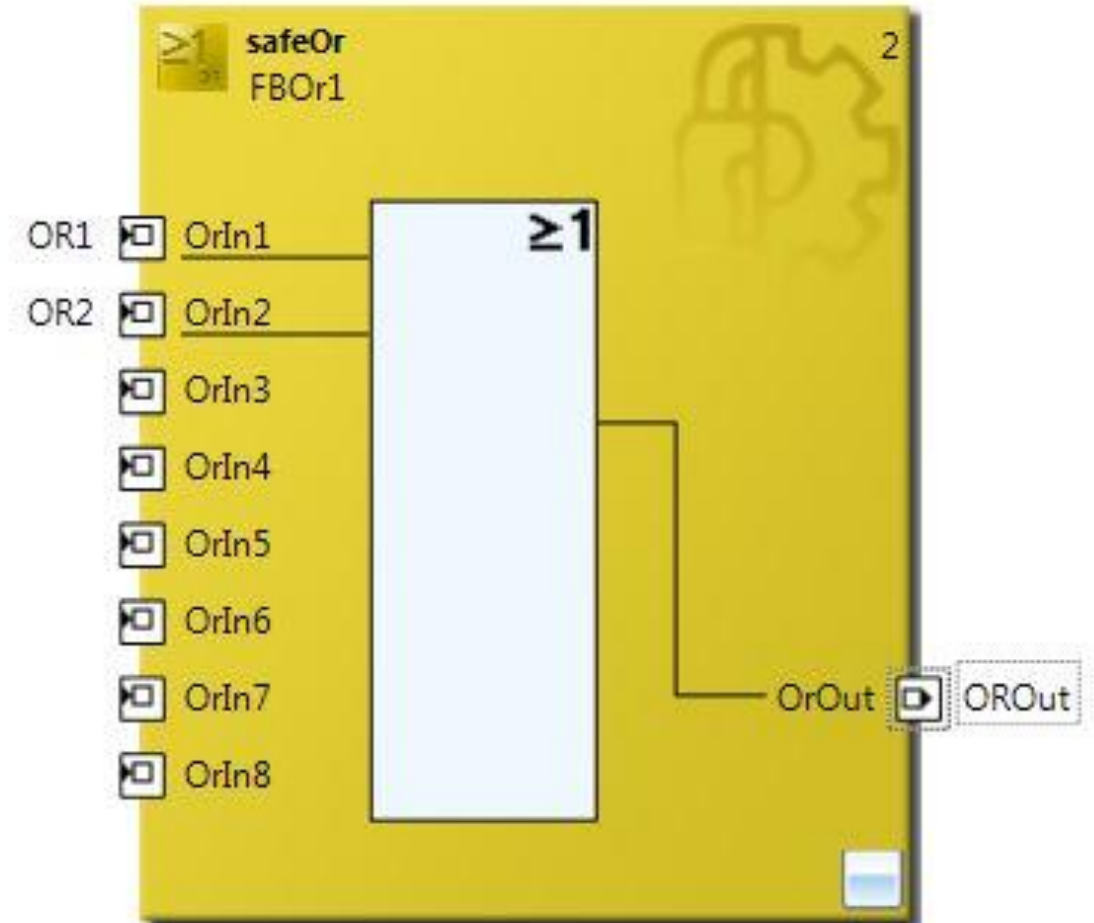
1 RUN

2 STOP

3 SAFE

DIAG:

Always 0



Function Block Decoupler

- The Decouple function block is used if it is necessary for other groups to access the safe input and safe output connections of this group
- The associated output must be linked if the input is linked and vice versa

State:

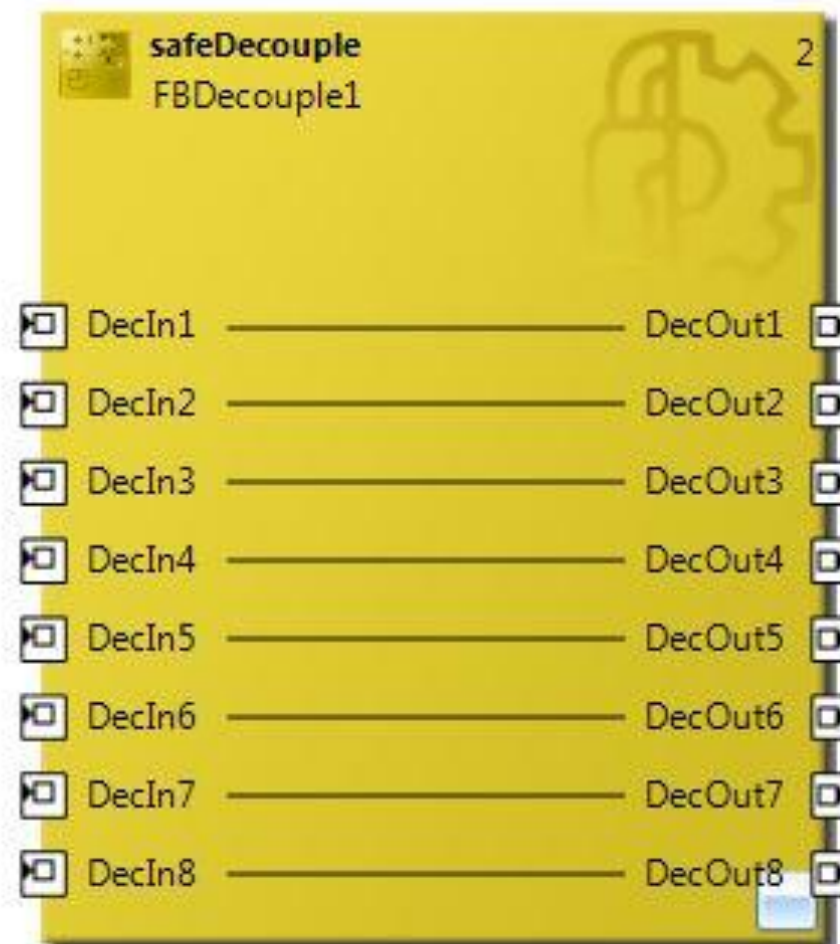
0 undefined

1 RUN

2 STOP

DIAG:

Always 0



Function Block Operation Mode

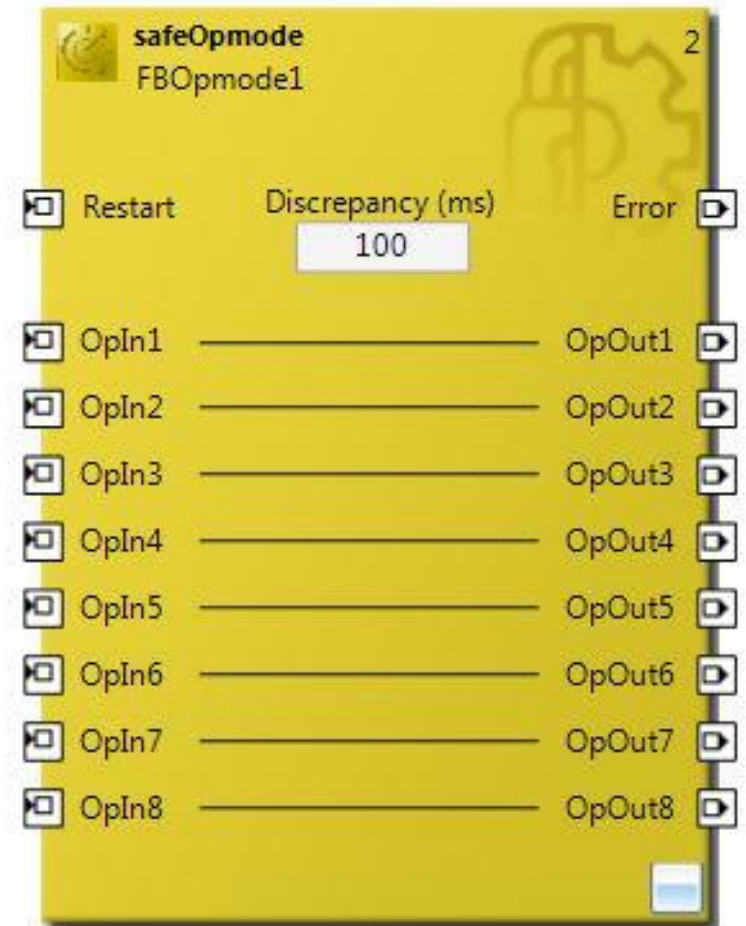
1. Manual restart can be configured for switching from one mode to another.
2. Discrepancy time can be configured while no signal is logically 1.

State:

0 undefined
1 RUN
2 STOP
3 SAFE
4 ERROR
5 RESET
6 START

DIAG:

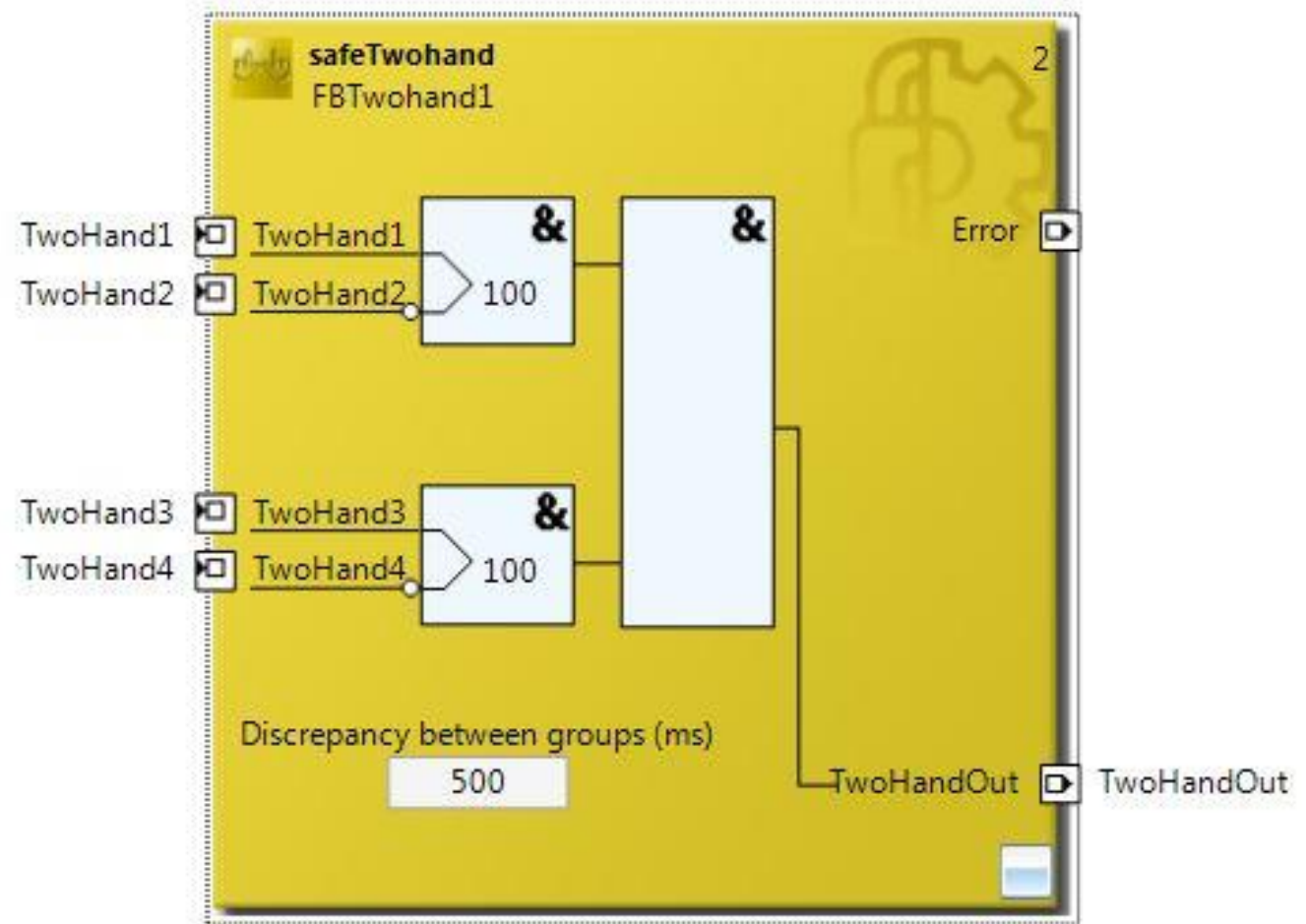
Bit 0 Discrepancy error



Function Block Two hand control

Configuration for the following type possible:

- EN 574 Typ I
- EN 574 Typ II
- EN 574 Typ IIIA
- EN 574 Typ IIIC



Two hand control state and diagnosis

State:

0 undefined

1 RUN

2 STOP

3 SAFE

4 ERROR

5 RESET

6 START

11 1BUTTON

12 2BUTTON

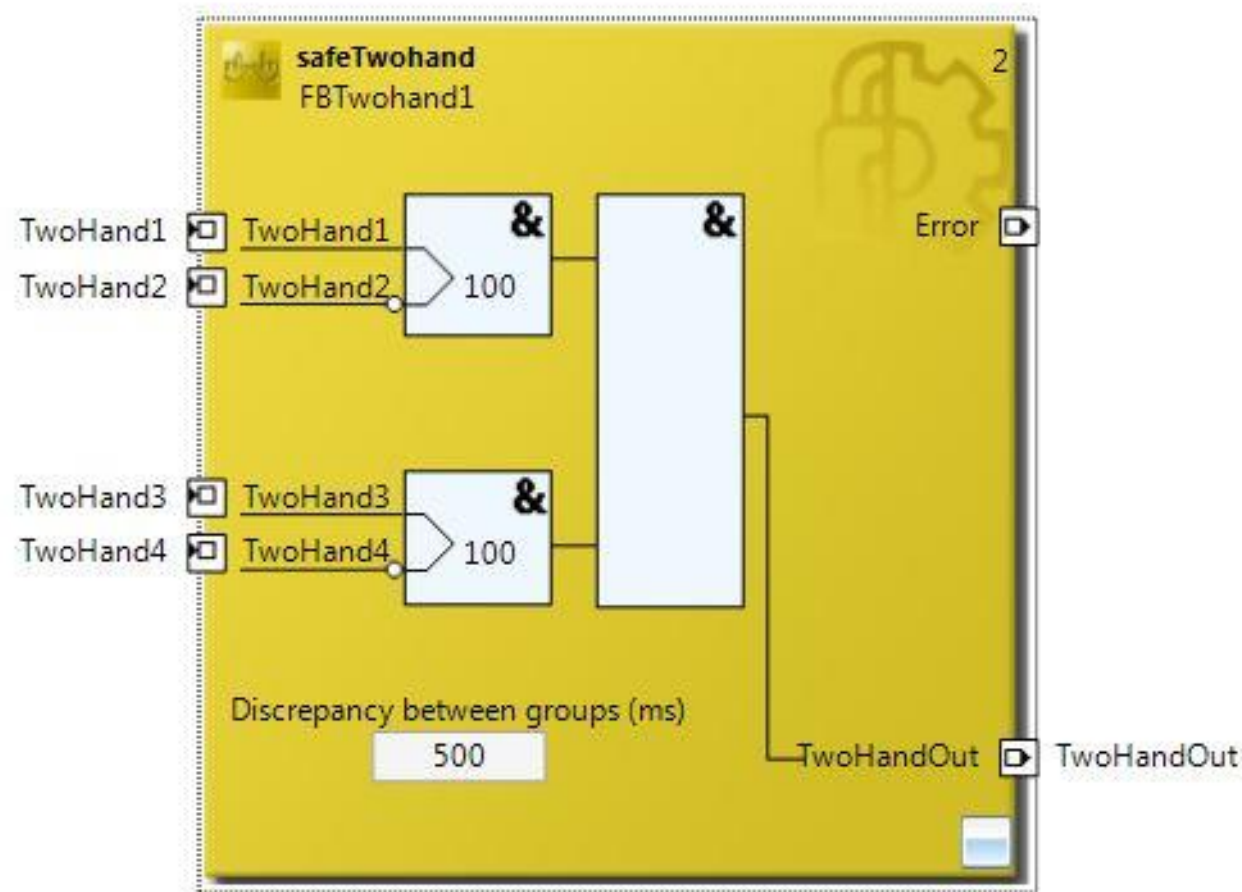
13 RELEASE

DIAG:

Bit 0 Discrepancy error input group 1

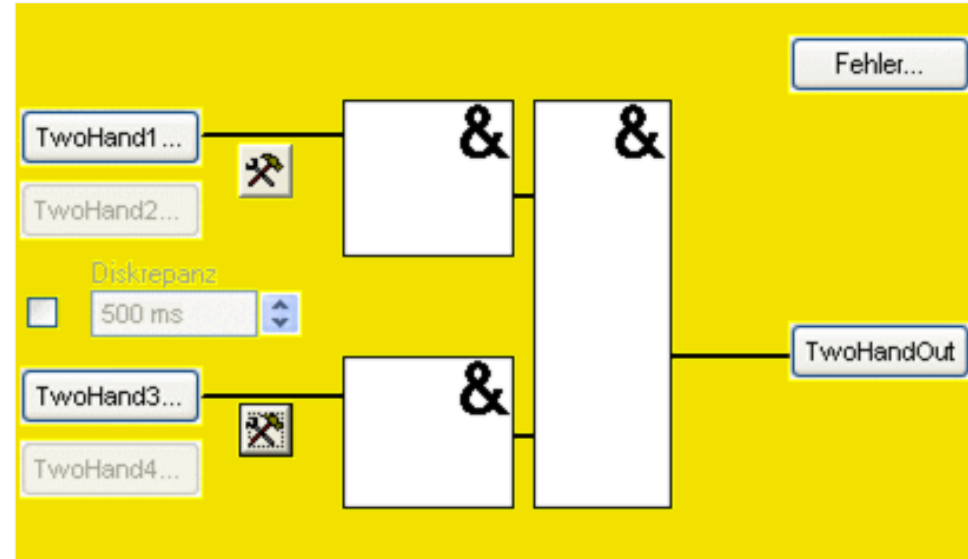
Bit 1 Discrepancy error input group 2

Bit 2 Discrepancy error between the input groups

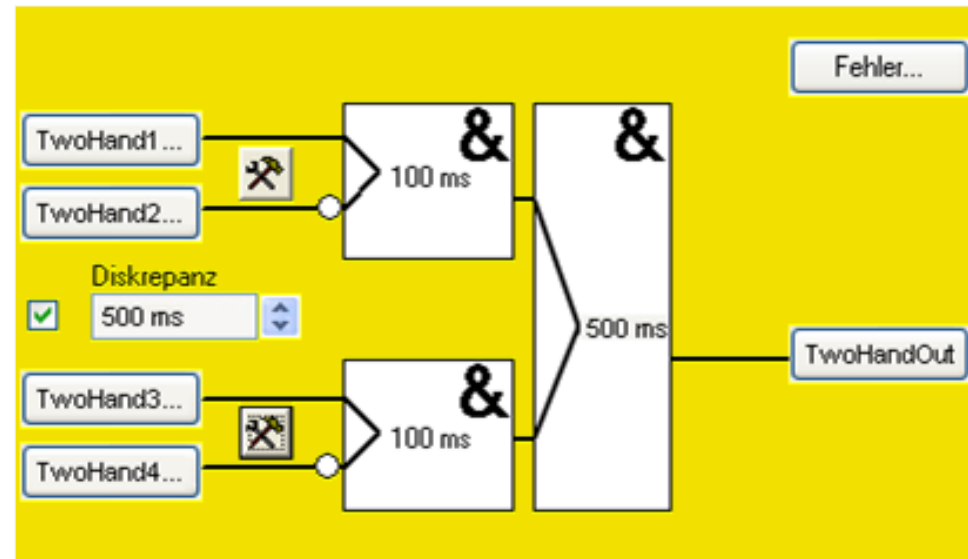


Function Block Two hand control

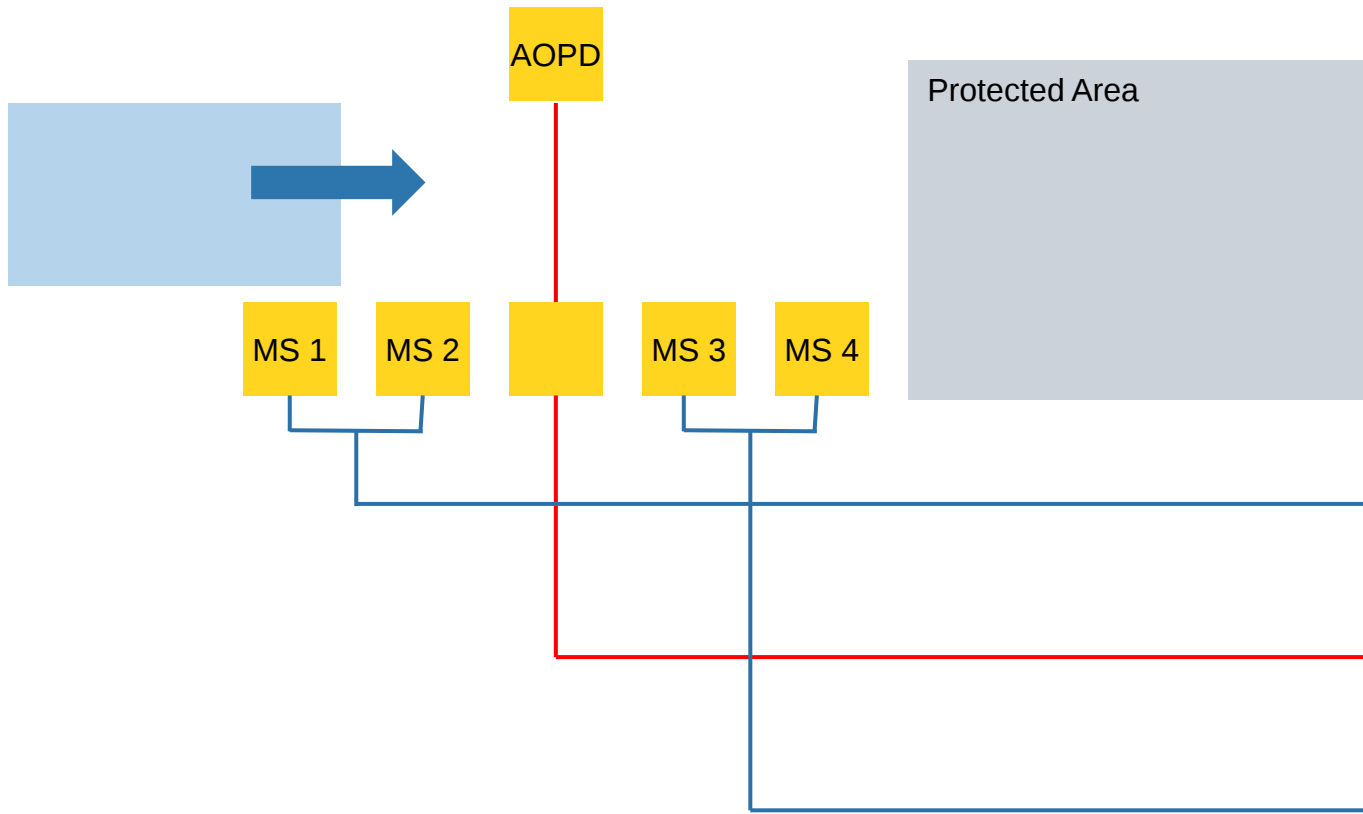
1. EN 574 Typ I



2. EN 574 Typ IIIC

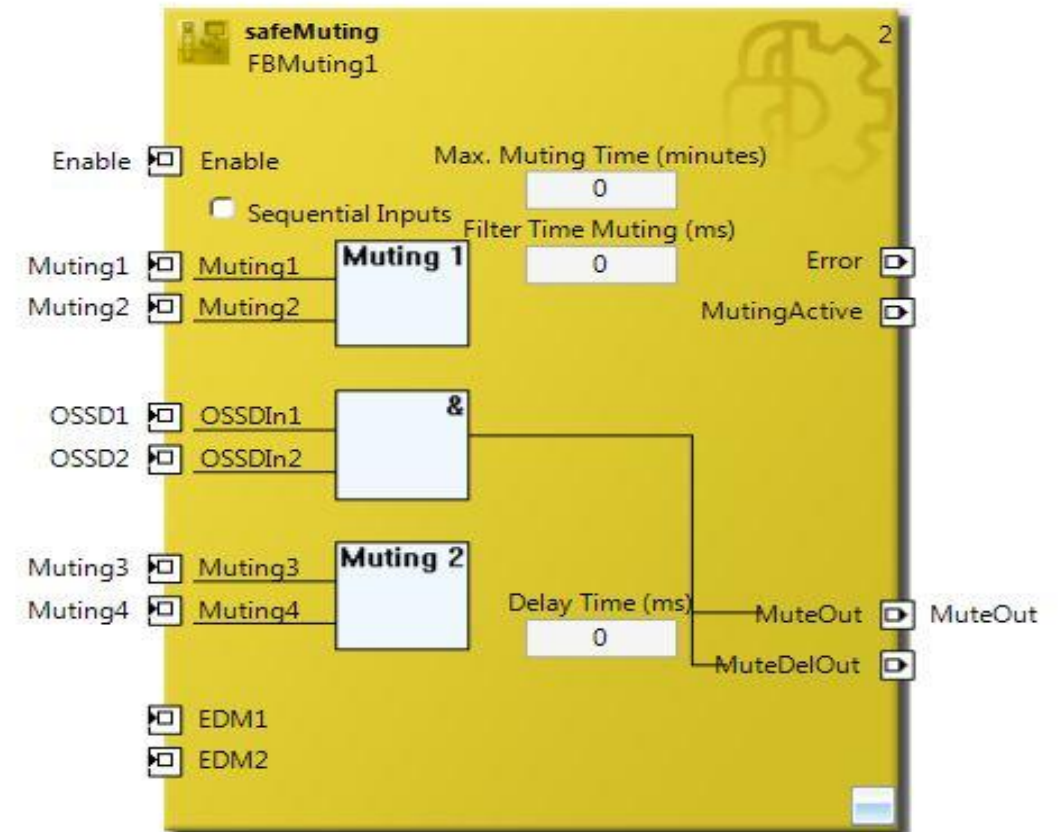


Function Block Muting – Intended suppression of safety function



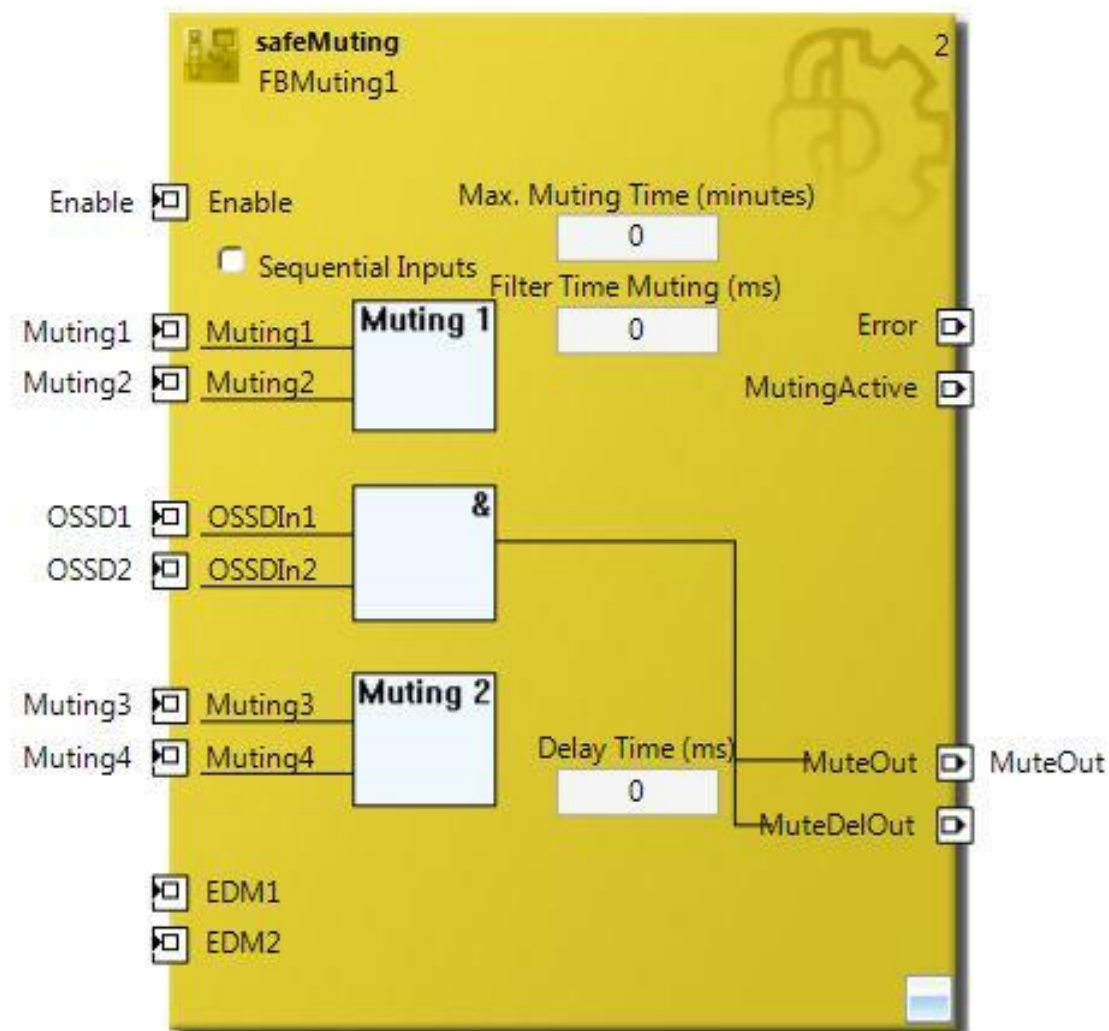
MSx Muting Switch

AOPD Active Opto-electronic Protective Device



Function Block Muting

- Sequential and parallel muting possible
- Filter time for inputs
- Maximum muting time
- Discrepancy time for parallel muting
- Enable input activates the muting.
- Output MutingActive can be used for diagnosis or muting lamps.



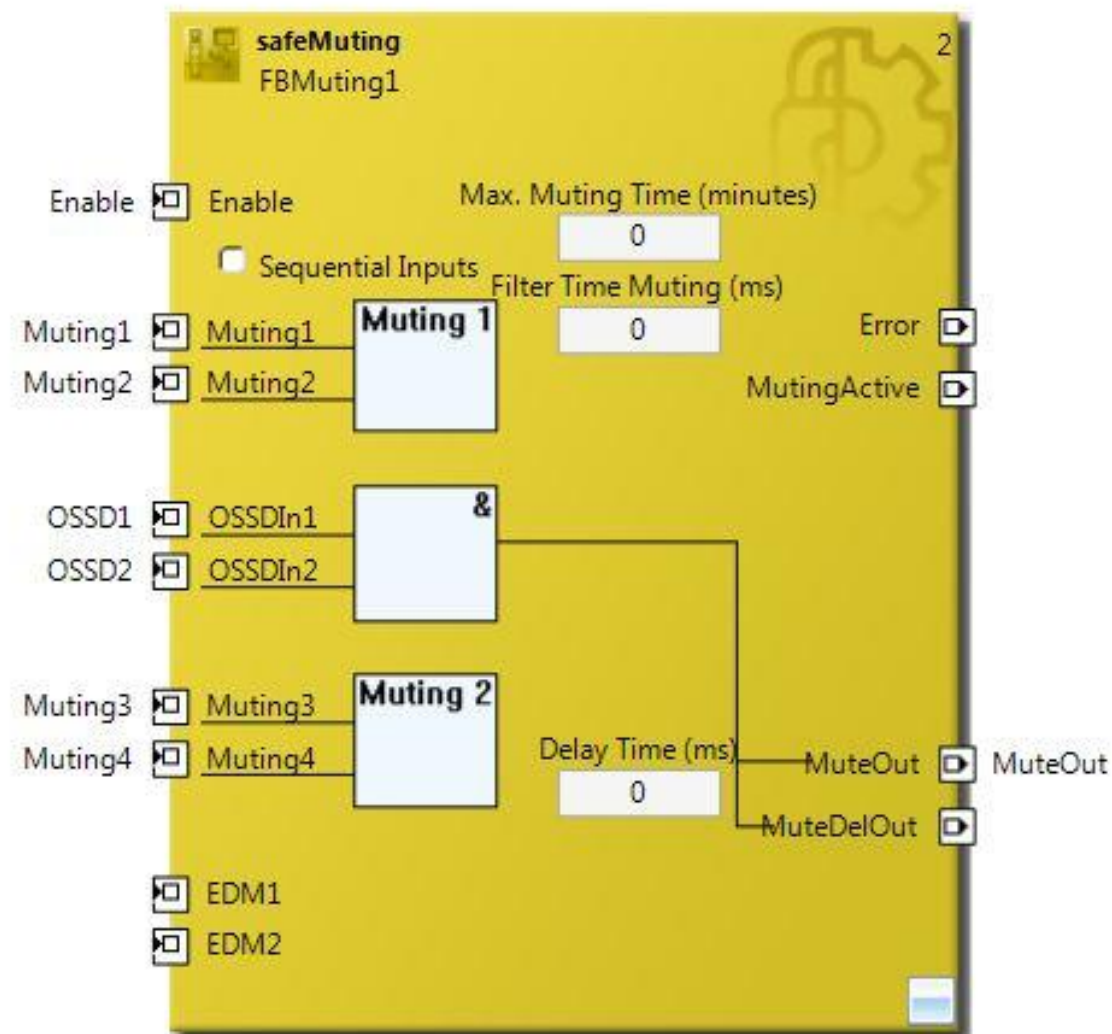
FB Muting state and diagnosis

State:

0 undefiniert	10 MUTING2
1 RUN	11 MUTING3
2 STOP	12 MUTING4
3 SAFE	13 MUTING5
4 ERROR	14 MUTING6
5 RESET	15 MUTING7
8 DELAYOUT	16 MUTING8
9 MUTING1	17 MUTING9

DIAG:

- Bit 0 Discrepancy error MUTING input gr. 1
- Bit 1 Discrepancy error OSSD input group
- Bit 2 Discrepancy error MUTING input gr. 2
- Bit 4 EDM error EDM 1
- Bit 5 EDM error EDM 2
- Bit 6 Muting sequence harmed
- Bit 7 Max. muting time exceeded



Function Block Set/Reset

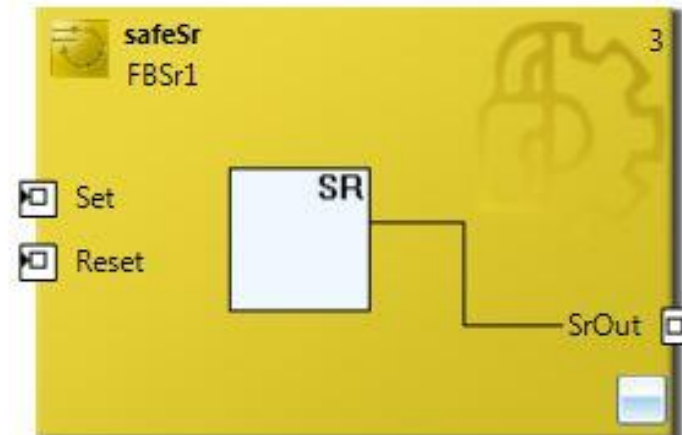
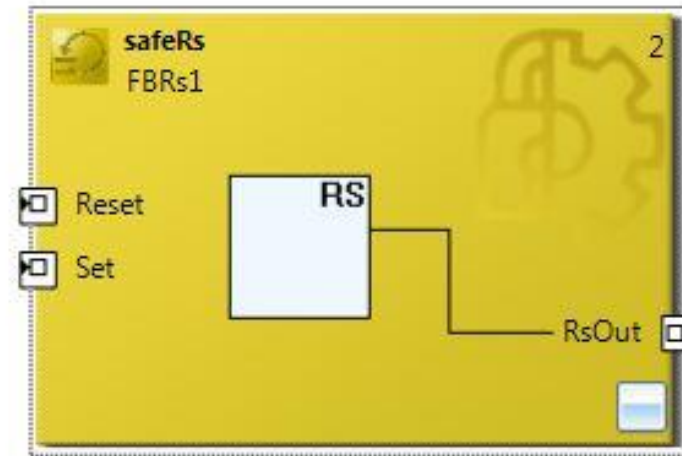
- **SR:** Set is dominant
- **RS:** Reset is dominant

State:

0 undefined
 2 STOP
 3 SAFE
 9 Set

DIAG:

Always 0



Function BlockTON/TOF

- **TON:** switch on delay
- **TOF:** switch off delay
- Function blocks can be retriggered.

State:

0 undefined

1 RUN

2 STOP

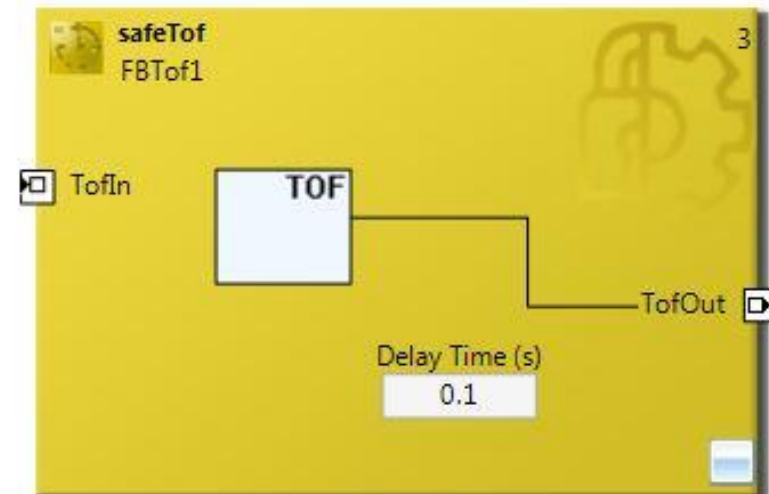
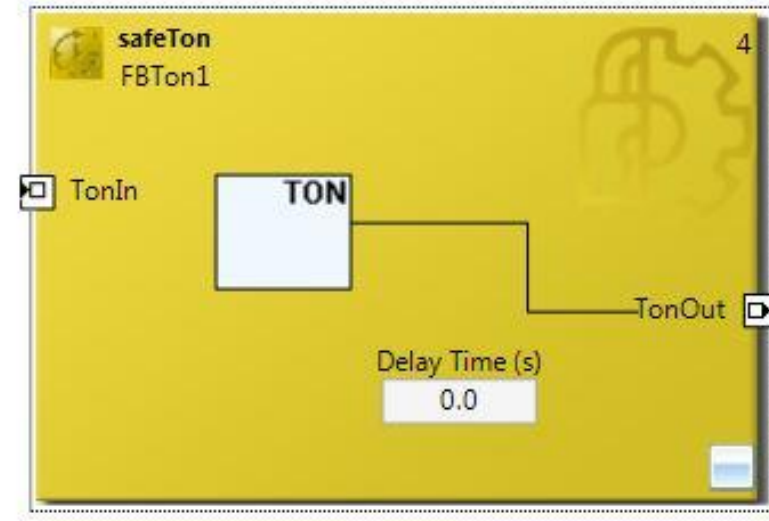
3 SAFE

8 DELAY_OUT (nur TOF)

9 DELAY_IN (nur TON)

DIAG:

Always 0



Function Block EDM – External device monitor (checking the feedback circuit)

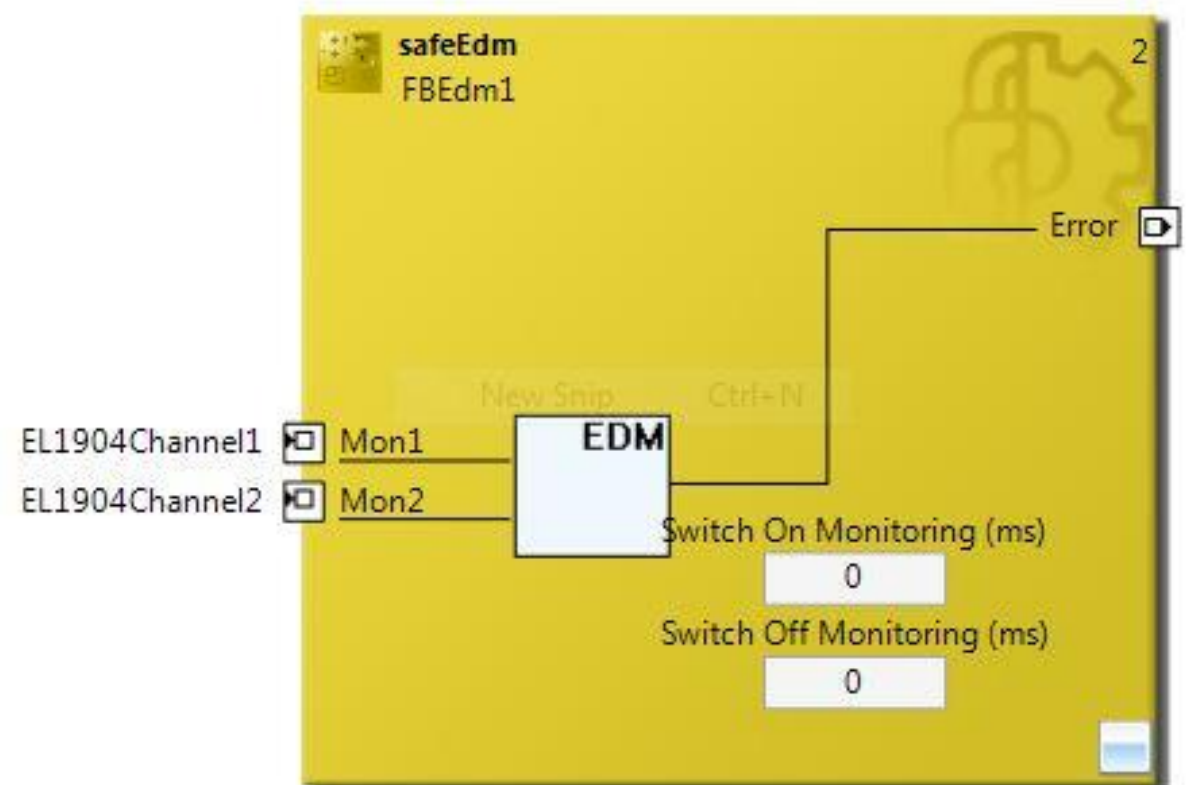
1. Switch on monitoring
Mon1 0 → 1
Mon2 1 → 0
within the SwitchOn time
2. Switch off monitoring
Mon1 1 → 0
Mon2 0 → 1
within the SwitchOff time

State:

0 undefined	5 RESET
2 STOP	14 MON_OFF
4 ERROR	15 MON_ON

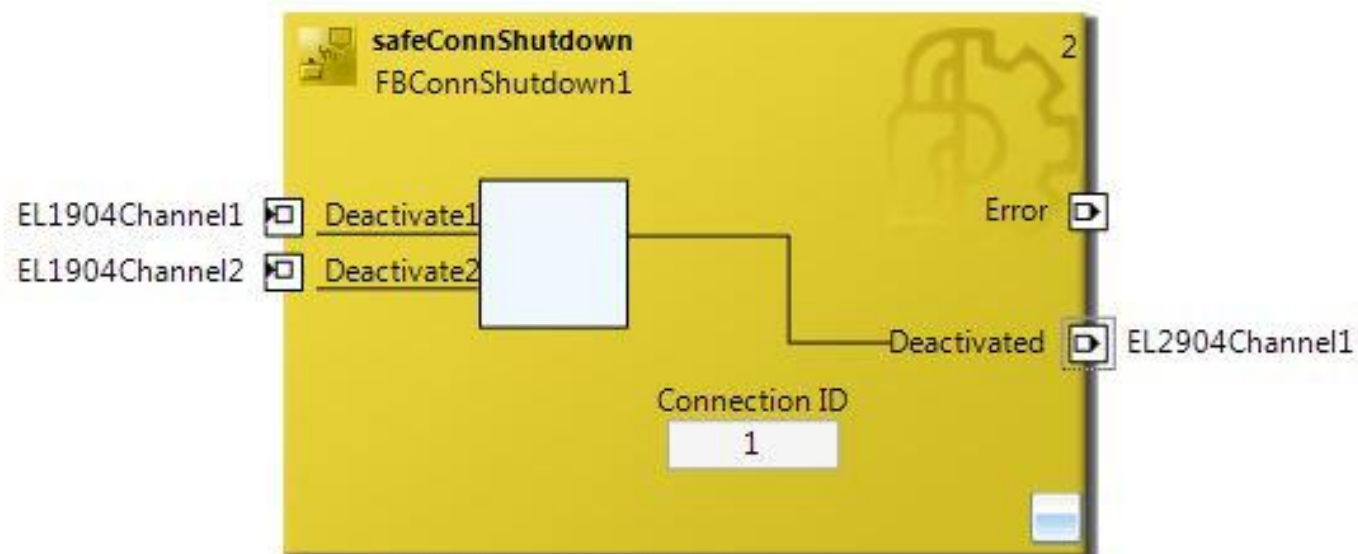
DIAG:

Bit 0 Switch OFF timer expired
Bit 1 Switch ON timer expired



Deactivating a TwinSAFE connection from within the TwinSAFE application

- The configured connection under “Connection ID” will be shut down and the output “Deactivated” will be set in case that the FB input is set.
- When the connection is shut down from the communication partner the output “Deactivated” will be set.
- The output will be 0 when the connection is in state DATA again.



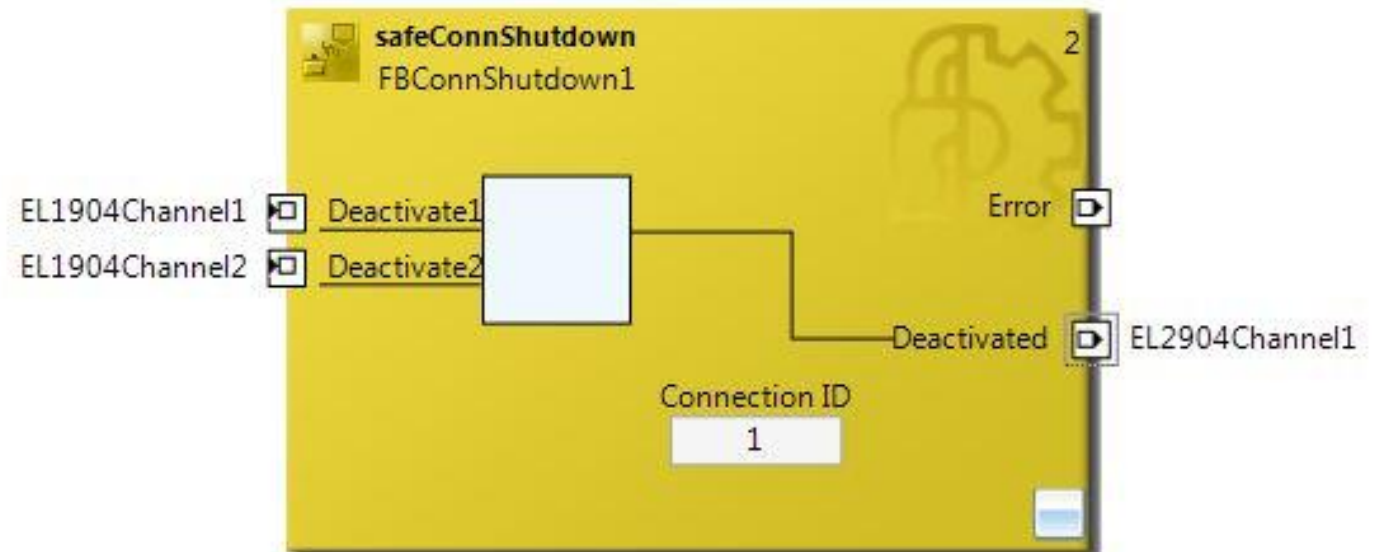
Function Block Connection Shutdown state and diagnosis

State:

- 0 undefined
- 2 STOP
- 3 SAFE
- 4 ERROR
- 5 RESET
- 10 ACTIVE
- 11 DEACTIVATE

DIAG:

- Bit 0 Discrepancy error input group 1



Questions?

