



Chapter 6

ESC – Electronic Safety Circuit

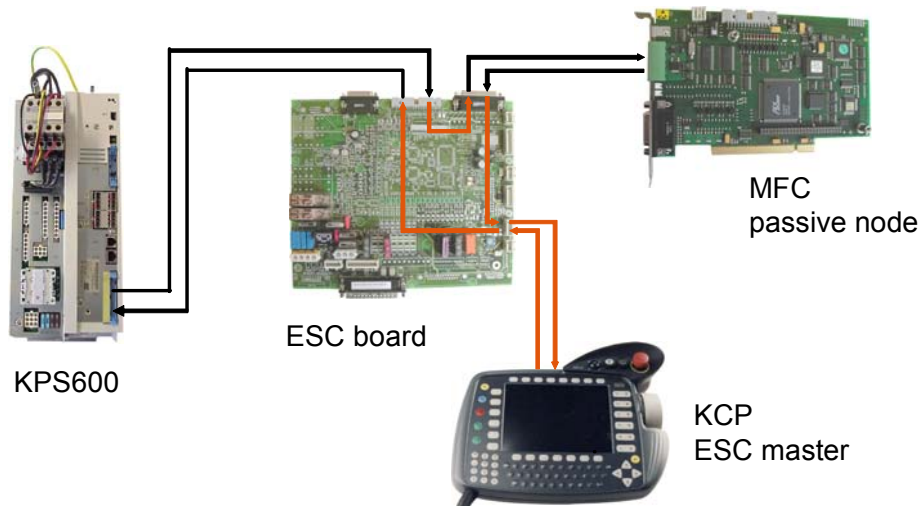
Table of contents

1. ESC – Electronic Safety Circuit.....	3
2. Fault detection ESC	15
3. X11 Jumper plug	21
4. ESC Gateway	23
5. Wiring diagrams ESC.....	31



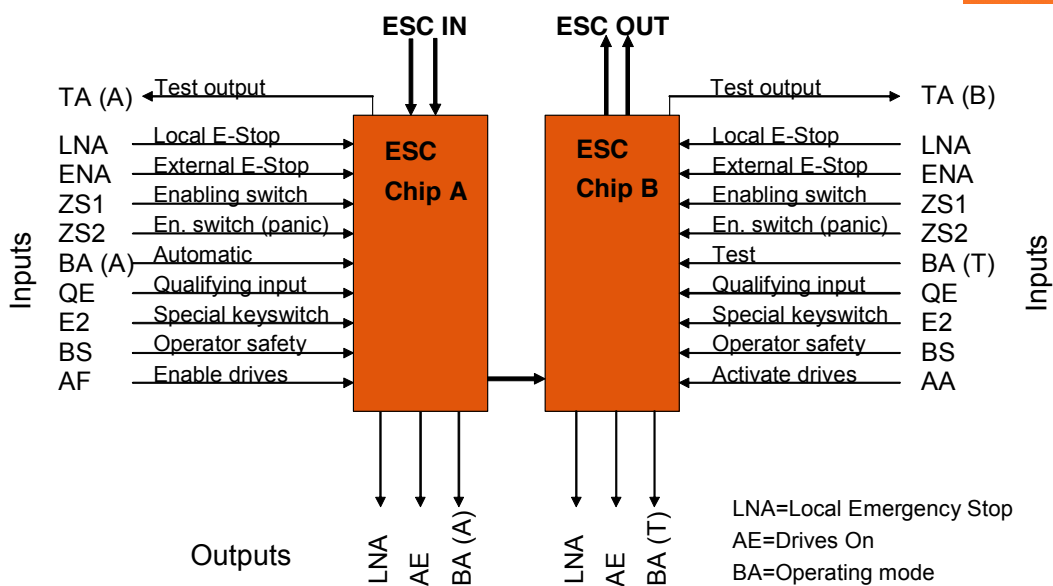
1. ESC – Electronic Safety Circuit

Electronic Safety Circuit (ESC)



The Electronic Safety Circuit (**ESC**) is a **dual-channel, computer-aided safety system**, that functions with a **closed ring bus**.
 The ESC devices are **nodes** that are connected to each other via power supply and communication lines.

ESC circuit nodes



ESC nodes, inputs and outputs



Failsafe inputs

NA	Local Emergency Stop
ENA	External Emergency Stop
ZS1	Enabling switch
ZS2	Enabling, panic position
BA	Operating mode (Test / Auto)
QE	Qualifying input (loading stations, range limitation)
BS	Operator safety (safety gates)

Controller inputs

AA	Activate drives (Drives ON)
AF	Drives enable (Drives OFF)

Failsafe outputs

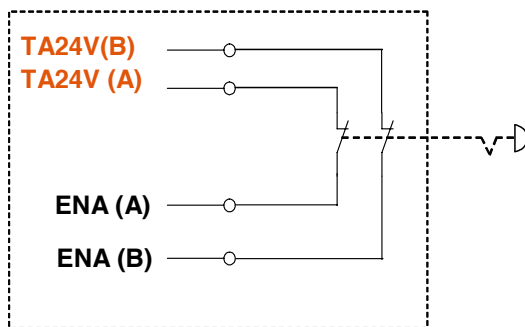
AE	Drives ON (drives contactor)
LNA	Local Emergency Stop
BA	Operating mode (Test / Auto)

Errors recognized by the ESC circuit



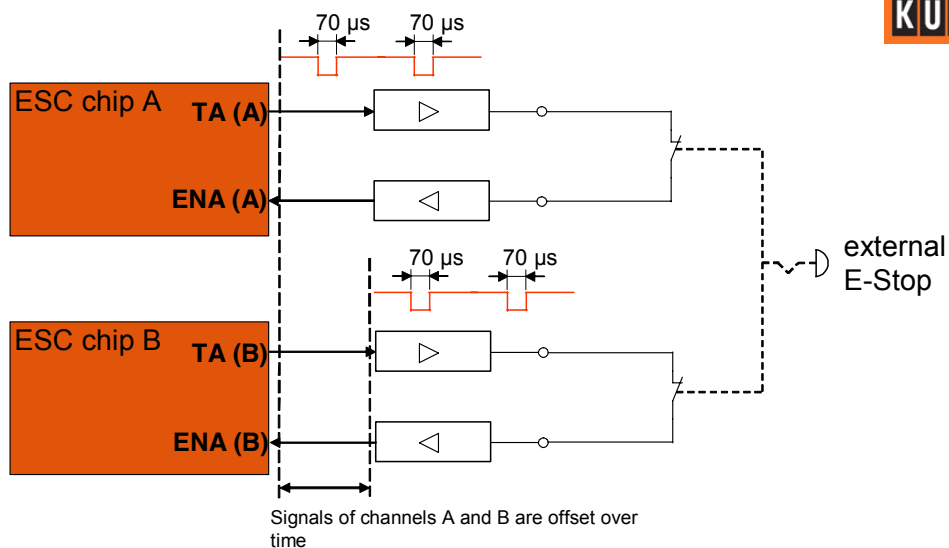
- Cross-connection between the two channels of an input signal
- Cross-connection between one input channel and the supply voltage
- Communication error (e.g. bus cable discontinuity)
- Hardware fault (e.g. defective relay contacts of the failsafe outputs)
- Defective ESC chip

ESC - Wiring of the 2-channel inputs



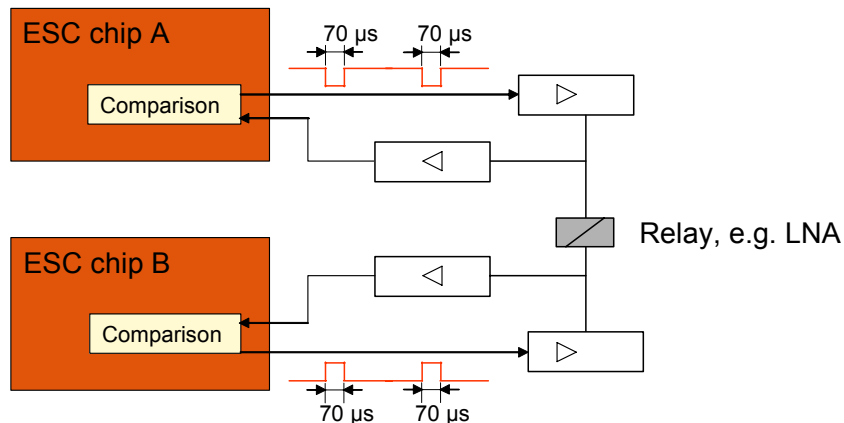
ENA = External EMERGENCY STOP

ESC - Monitoring of the failsafe inputs



The maximum cable length for the input signals is about 100 m due to the monitored time period for the return signals of max. 2 ms.

ESC - Monitoring of the failsafe outputs



Each ESC chip sends a bit pattern to its outputs and compares the return signals with this pattern.

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ESC board variants



For the KR C2edition2005, different ESC boards can be installed for a variety of configurations and in accordance with customer requirements.

The assignment of the individual connectors, relays and fuses remains the same, however.

The fuses are rated for up to 35 V. On the boards there is a red LED for each fuse, which lights up if the fuse is defective.

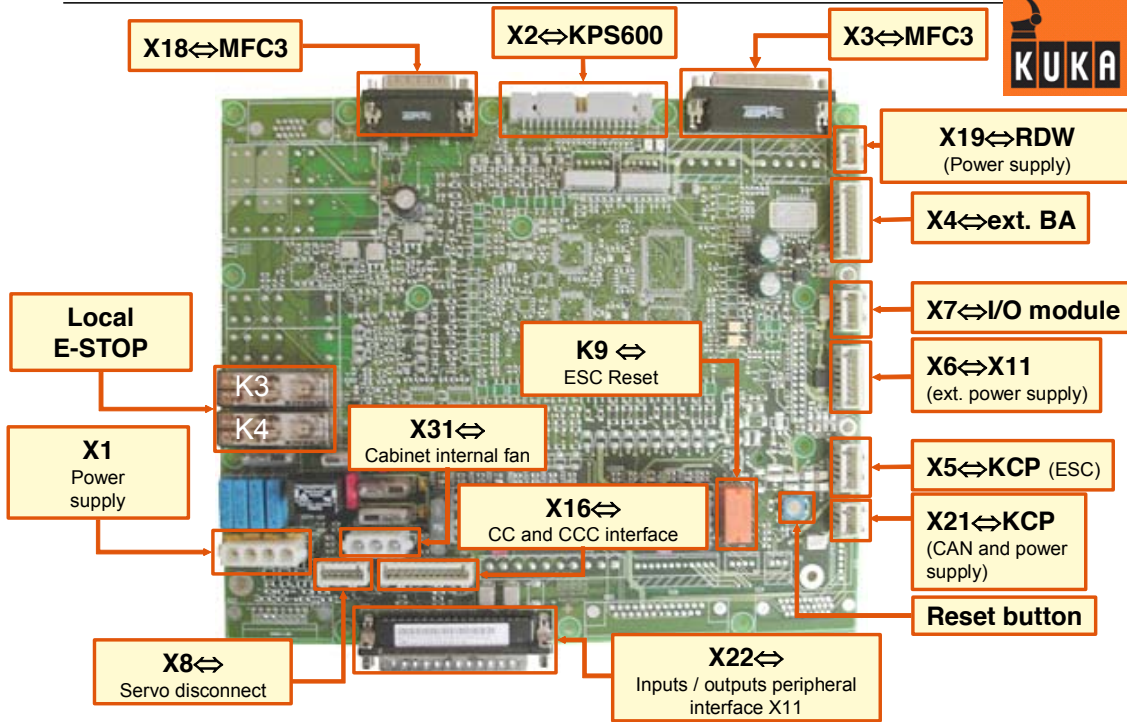
The following variants of the ESC boards are in use:

- [CI3 Standard](#) ESC board without node
- [CI3 Extended](#) ESC board with node
- [CI3 Bus](#) ESC board for connection to SafetyBus p
- [CI3 Tech](#) ESC board for RoboTeam, shared pendant, SafeRobot

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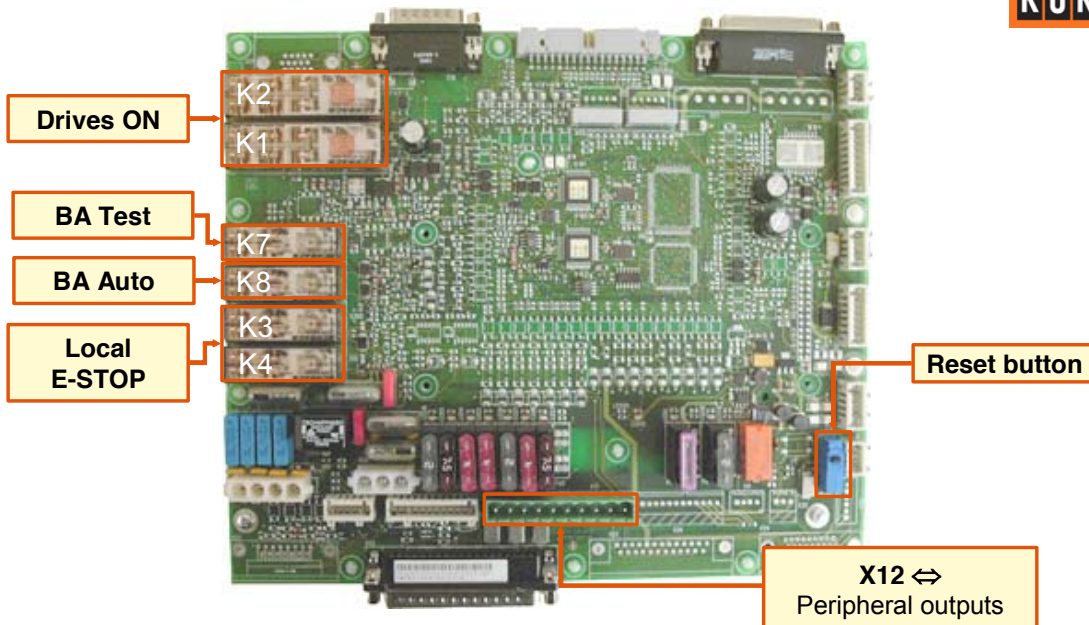
CI3 Standard



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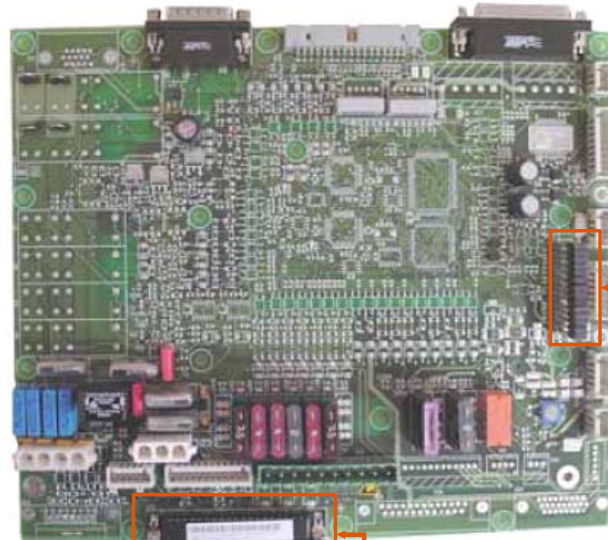
CI3 Extended



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C13 Bus



X13↔
Gateway / bus coupler
interface

X22↔
Inputs / outputs peripheral
interface X11

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C13 Tech



X18↔MFC (RoboTeam option)

X19↔
RoboTeam lamp

**Local
E-STOP**

**K3
K4**

**X26 ↔ KUKA
Guiding Device**

X23 ↔ Safe RDW

X25 ↔ RoboTeam IN

X24 ↔ RoboTeam OUT

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CI3 board interface assignment - Part 1



Interface	Assignment
X1	Power supply with/without battery backup
X2	Ribbon cable to KPS 600
X3	Connection to MFC3 via Connector Print
X4	Inputs to the MFC3, stationary operating mode switch
X5	KCP, ESC bus
X6	Customer interface X11, internal / external power supply
X7	User I/Os to peripheral interface, 16 inputs / 20 outputs via CAN bus (optional)
X8	Servo Disconnect, E-STOP from KGD (optional)
X11	E7 special keyswitch (VW option), RoboTeam test outputs
X12	Customer interface X11, outputs: internal E-Stop, operating mode, Drives ON
X13	Jumper / interface to other safety bus systems
X16	Interface for CC (Cobra Control) and CCC (Common Control Cabinet)
X17	Control and return signals for external main contactor (optional)
X18	Interface to MFC3, ESC Reset, fan monitoring, RoboTeam (optional)

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CI3 board interface assignment - Part 2



Interface	Assignment
X19	Interface to lamp for RoboTeam (optional)
X20	Selection Switch on Shared Pendant (RoboTeam option)
X21	Interface to KCP, CAN bus and buffered 27 V power supply
X22	Connection to customer interface X11, inputs: ENA, BS, ext. enabling
X23	Interface to SafeRDC (optional)
X24	RoboTeam functionalities
X25	RoboTeam functionalities
X26	KUKA Guiding Device KGD interface (optional)
X27	MultiPowerTap MPT DeviceNet from MFC3
X28	MultiPowerTap MPT DeviceNet OUT1
X29	MultiPowerTap MPT DeviceNet OUT2
X30	Ext. ESC reset relay
X31	Internal cabinet fan connection

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CI3 board assignment of fuses



Fuse	Value	Function
F1	2 A	AE output at X12
F2	2 A	Cabinet fan monitoring
F3	2 A	Power supply, contactor control AE
F10	3 A	Power supply, ESC circuit
F12	4 A	27 V without battery backup at X12
F13	4 A	27 V without battery backup at X6 for internal ESC supply
F14	4 A	Output AE
F15	7.5 A	Output AE
F16	7.5 A	27 V without battery backup at X12
F21	2 A	RoboTeam lamp (optional)
F23	2 A	RDC supply
F24	2 A	Supply, multipower tap MPT

CI3 board relay functionality



Relay	Function
K1	Drives ON
K2	Drives ON
K3	Local Emergency Stop
K4	Local Emergency Stop
K7	Operating mode TEST / AUTO
K8	Operating mode TEST / AUTO
K9	ESC Reset

CI3-Board diagnosis LEDs for supply voltage and fusing



LED	Color	Description
1	Red	Voltage monitoring F10 3A, supply voltage for ESC
2	Red	Voltage monitoring F13 4A, 27 Volt unbuffered at X6 for the internal supply of the ESC
3	Red	Voltage monitoring F3 2A, Supply of the relay control (Output AE)
4	Red	Voltage monitoring F12 4A, 27Volt unbuffered at X12
5	Red	Voltage monitoring F16 7,5A, 24 Volt unbuffered at X12
6	Red	Fuse monitoring F1 2A, Output AE at X12
7	Red	Fuse monitoring F14 4A, Output AE at X12
8	Red	Fuse monitoring F15 7,5A Output AE at X12
9	Green	Voltage monitoring VCC buffered
10	Red	Fuse monitoring F7 2A, 24 Volt buffered MPT
11	Red	Fuse monitoring F4 2A, switching lamp RoboTeam
12	Red	Fuse monitoring F6 2A, 24 Volt buffered RDW
14	Green	Voltage monitoring VCC unbuffered
15	Green	Voltage monitoring 5V ESC-node
16	Red	Fuse monitoring F8 2A, 24 Volt unbuffered inside fan

CI3-Board diagnosis LEDs for ESC-nodes (Low-level-diagnosis)



LED	Color	Description
17	Green	ESC-Output KCP OK
18	Red	ESC-Output KCP NOK
19	Red	ESC-Output KPS NOK
20	Green	ESC-Output KPS OK
21	Green	ESC-Output local ESC node OK
22	Red	ESC-Output local ESC node NOK
23	Red	ESC-Output Safetybus Gateway NOK
24	Green	ESC-Output Safetybus Gateway OK
25	Green	ESC-Output X6 OK
26	Red	ESC-Output X6 NOK
27	Red	ESC-Output MFC NOK
28	Green	ESC-Output MFC OK
29	Green	Voltage monitoring 3,3 Volt for RoboTeam PLDs

KR C2 braking reactions



	Test (T1 or T2)	Auto (Automatic or automatic external)
E-STOP	Path-oriented braking	Path-maintaining braking
Enabling switch	Path-oriented braking	----
Operator safety	----	Path-maintaining braking
Drives OFF	Path-oriented braking	
Op. mode change	Path-oriented braking	
Encoder error	Short-circuit braking	
Motion enable	Ramp-down braking	
Stop key	Ramp-down braking	

KR C2 braking reactions

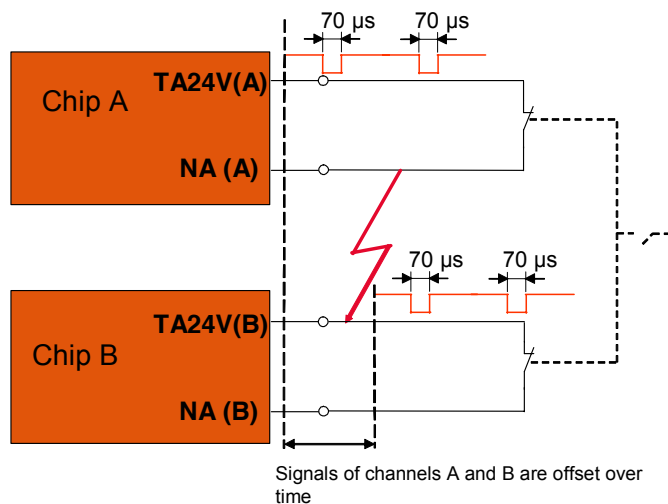


	Drives contactor	Intermediate circuit voltage	Short-circuit braking relays	Brakes	Software
Ramp- down braking	Remains switched on	Remains charged	Not applied	Remain open	Robot is stopped along a normal braking ramp
Path- maintaining braking	Opened with a delay of 1 s	Remains charged for 1 s and is then continuously discharged	Not applied	Applied after 1 s	In the 1 s time interval the KRC2 brakes the robot with a steeper braking ramp
Path-oriented braking	Switched off immediately	Discharged immediately	Not applied	Applied immediately	The controller attempts to brake the robot on the path with the remaining intermediate circuit voltage. When the intermediate circuit voltage is no longer sufficient for doing so, short-circuit braking is activated.
Short-circuit braking	Switched off immediately	High-speed discharge	Applied immediately	Applied immediately	----



2. Fault detection ESC

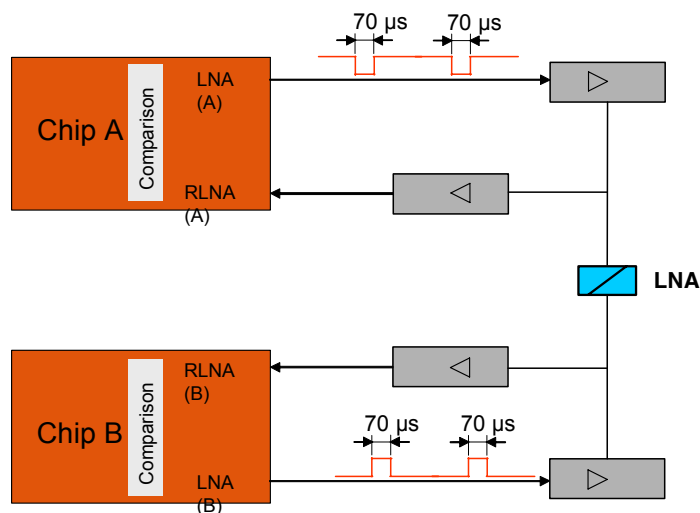
Testing the failsafe inputs



Each chip sends a bit pattern to its outputs and compares the return signals with this pattern.

In the event of disparity, the outputs are set to a safe state.

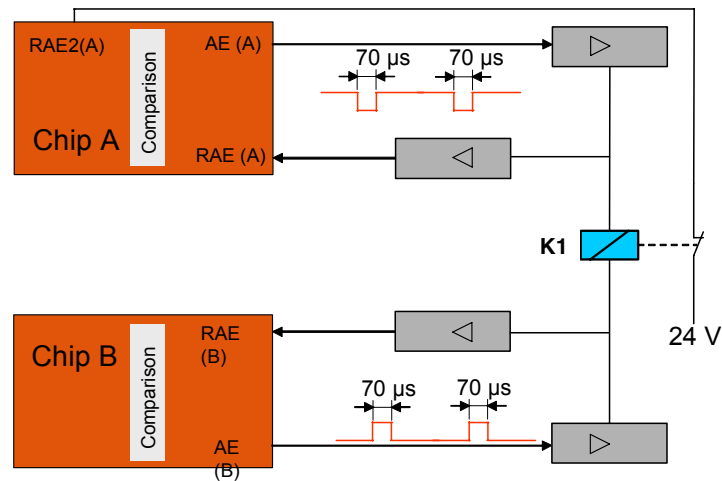
Testing the failsafe outputs



Each chip sends a bit pattern to its outputs and compares the return signals with this pattern.

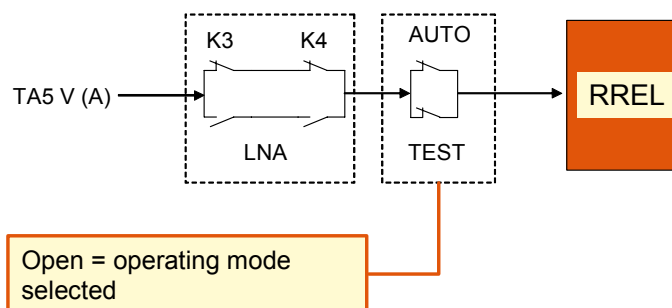
In the event of disparity, the outputs are set to a safe state.

Drives contactor return signal



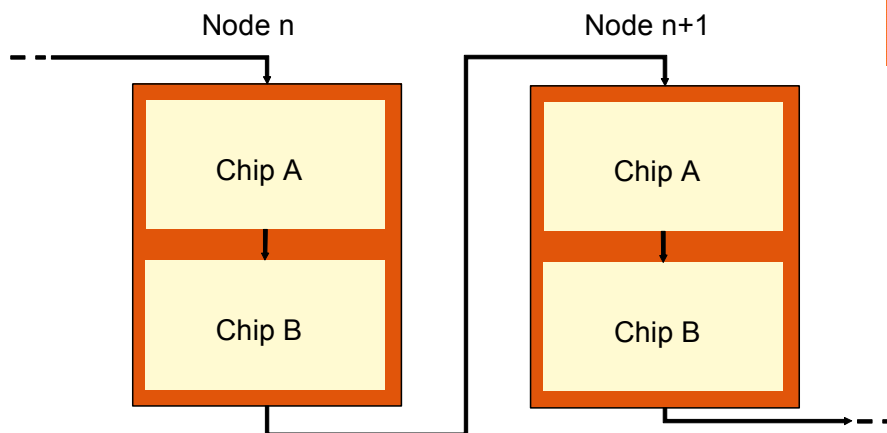
Each chip compares the state of the outputs with the state of the return signals. In the event of disparity, the outputs are set to a safe state.

Relay test



The signal sent from the TA must be applied once more to the input of the RREL (return relay).
In the event of disparity, the outputs are set to a safe state.

Reciprocal monitoring of the nodes



Chip A compares the input signals with the protocol of the previous **node**, sets the outputs and the sends on the protocol

Chip B compares the input signals with the protocol of the previous **chip**, sets the outputs and the sends on the protocol

CI3-Board diagnosis LEDs for supply voltage and fusing

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1	Red	Voltage monitoring F10 3A, supply voltage for ESC
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18	Red	ESC-Output KCP NOK
19	Red	ESC-Output KPS NOK
20	Green	ESC-Output KPS OK
21	Green	ESC-Output local ESC node OK
22	Red	ESC-Output local ESC node NOK
23	Red	ESC-Output Safetybus Gateway NOK
24	Green	ESC-Output Safetybus Gateway OK
25	Green	ESC-Output X6 OK
26	Red	ESC-Output X6 NOK
27	Red	ESC-Output MFC NOK
28	Green	ESC-Output MFC OK
29	Green	Voltage monitoring 3,3 Volt for RoboTeam PLDs



3. X11 Jumper plug

X11 Jumper plug



The external safety circuit of the robot can be short-circuited using the X11 jumper plug.

When troubleshooting in the safety circuit it then becomes possible to establish whether the source of the fault is in the control cabinet or in the periphery.



The jumper plug detailed in this documentation relates only to the KUKA standard X11.

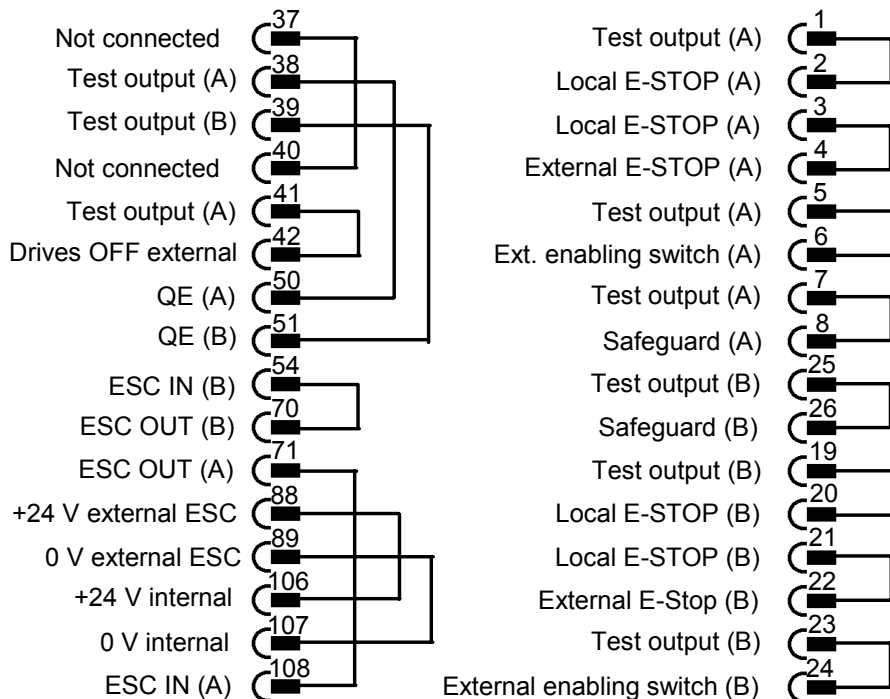


All other assignments (resulting from previously defined standards) are to be taken from the appropriate wiring diagrams.



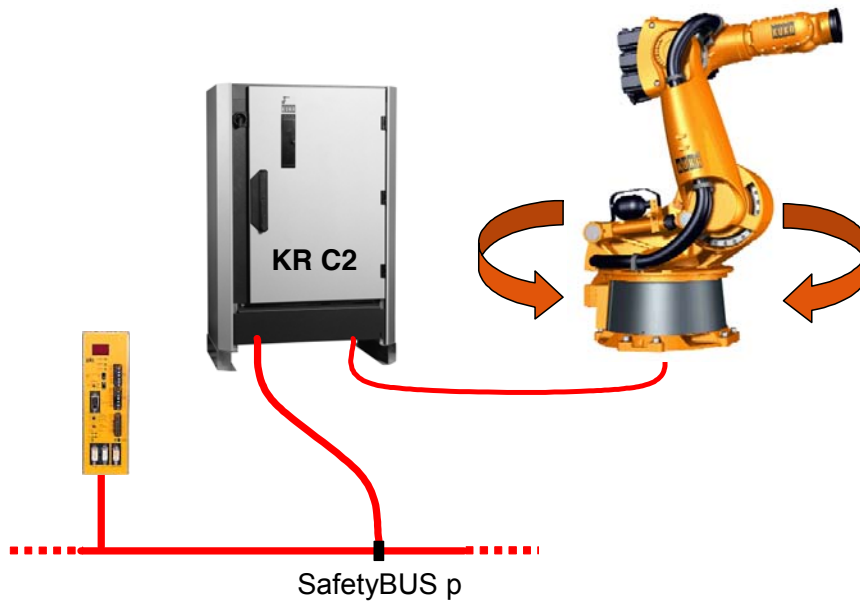
When using the SafetyBUS p Gateway the ESC circuit of the robot can be started by means of a HIGH signal to both of the start-up pins (INB(A) and INB(B)), without a connection to the PSS.

X11 KUKA standard jumper plug



4. ESC Gateway

KUKA safety systems



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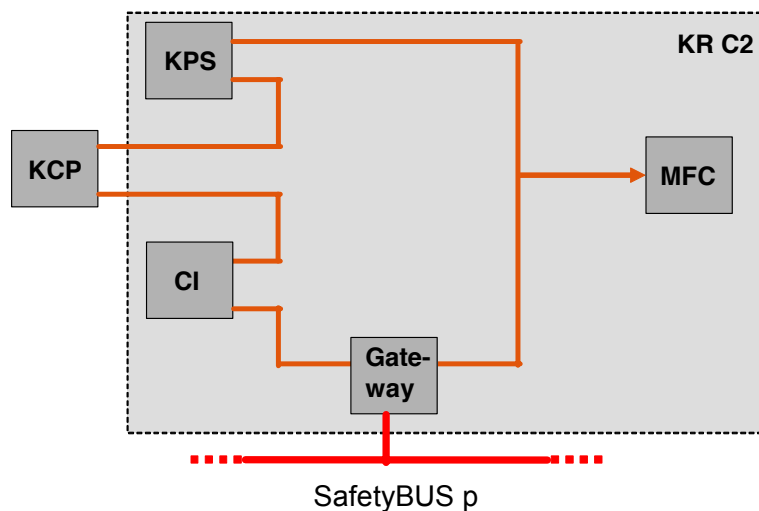
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KUKA safety technology



Advantages of KUKA safety technology on KR C2:

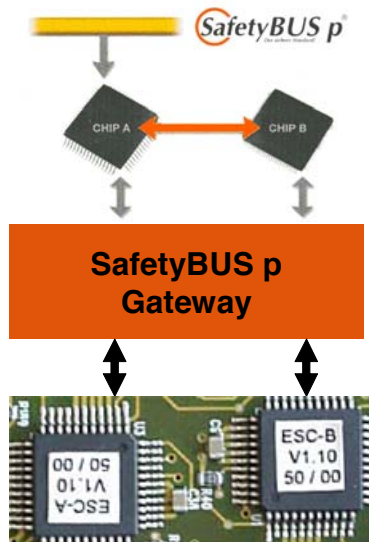
- Electronic safety logic
- Open to other standards
- Decentralized structure is possible



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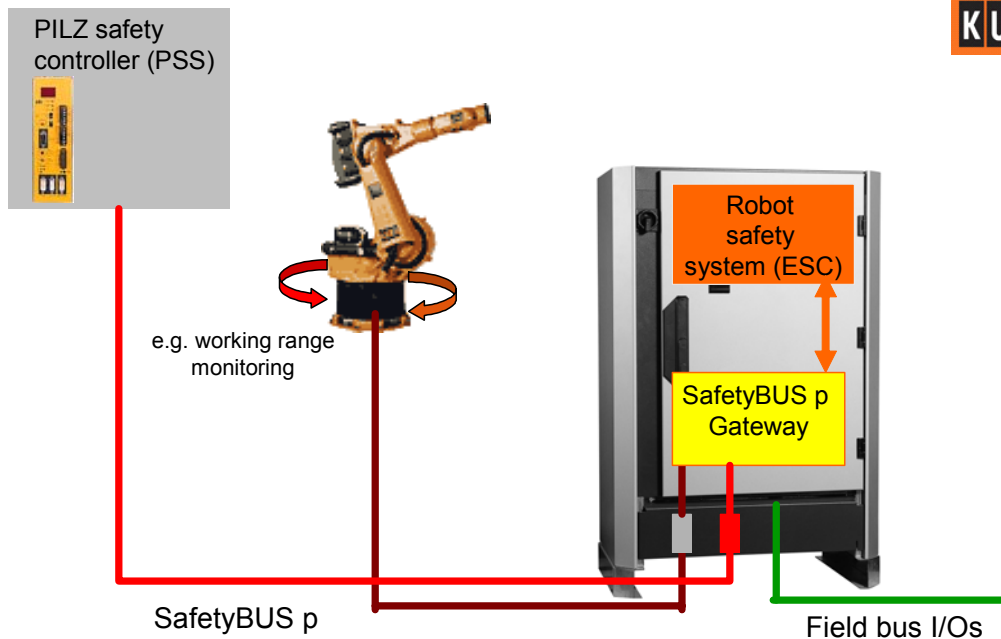
SafetyBUS p connection



The use of the SafetyBUS p Gateway enables:

- Electronic coupling of the ESC circuit to SafetyBUS p
- Dual-channel link
- Safety category 3

SafetyBUS p connection



Variants of the SafetyBUS p Gateway



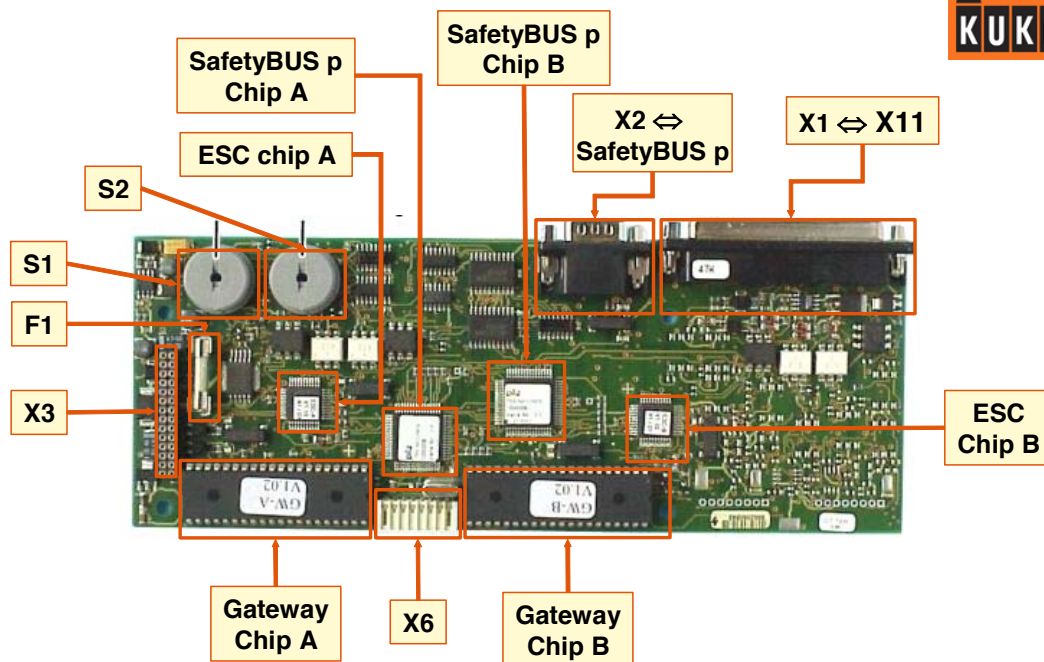
Two different variants of the SafetyBUS p Gateway are currently used by KUKA:

- SafetyBUS p Gateway and
- SafetyBUS p Gateway A



When replacing or ordering the SafetyBUS p Gateway, always pay attention to the correct article number!

SafetyBUS p Gateway



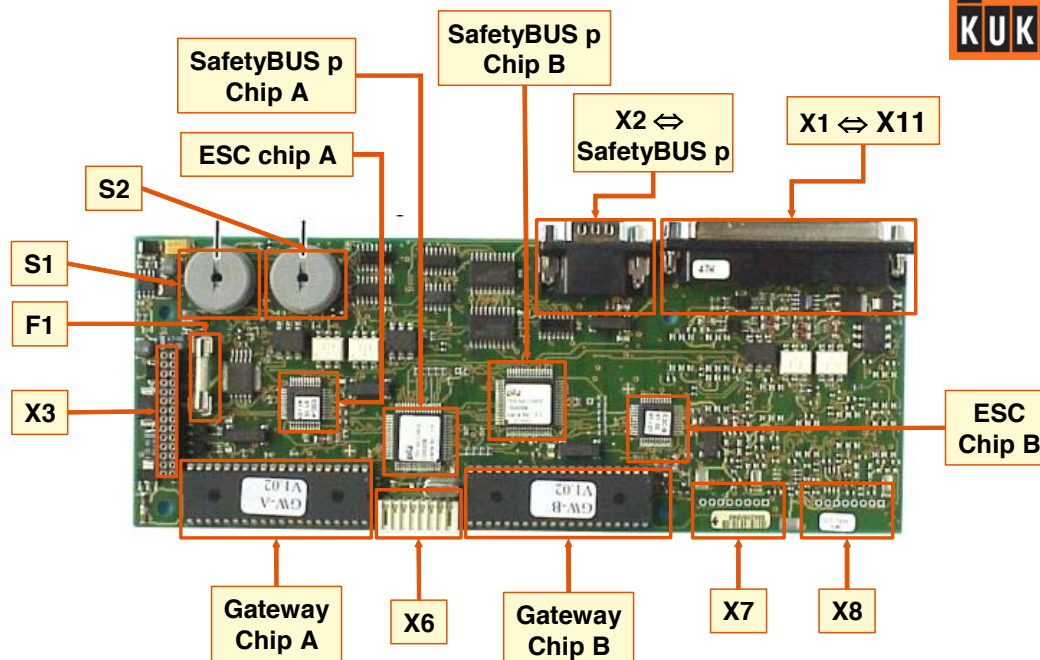
SafetyBUS p Gateway technical data



SafetyBUS p Gateway technical data:

Supply voltage:	24 V DC (permissible range: 20 V – 33 V DC)
Inputs/outputs:	14 digital inputs 24 V DC pulsed (resistive load only) 4 digital inputs 24 V DC, unpulsed (resistive load only) 2 digital outputs (channel A) 24 V DC (resistive / inductive load) 2 digital outputs (channel B) GND DC (resistive / inductive load) 1 A each (short-circuit proof)
Temperature ranges:	Operating temperature +20 °C to +70 °C Storage temperature +5 °C to +80 °C
SafetyBUS p connection:	Via PILZ SafetyBUS p connector D0, D1, D2, or D3

SafetyBUS p Gateway A



SafetyBUS p Gateway technical data



SafetyBUS p Gateway A technical data:

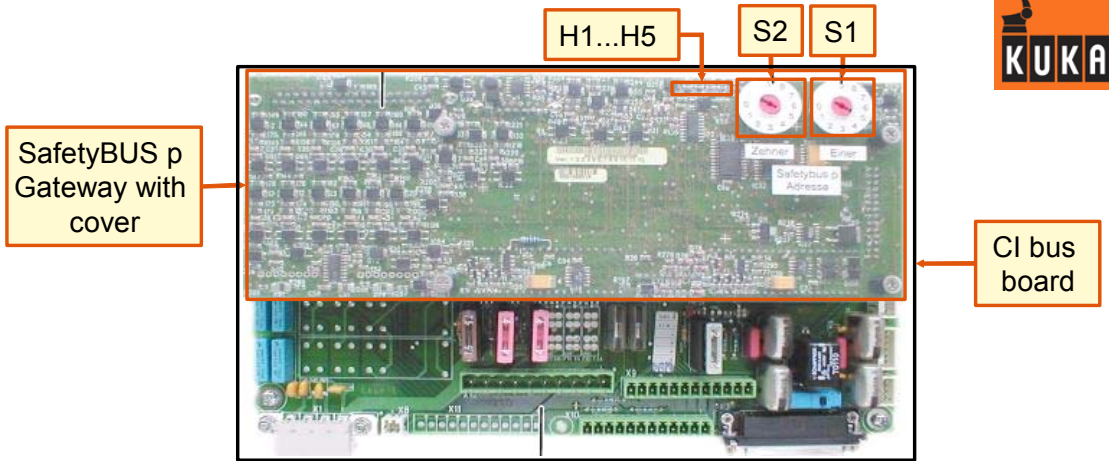
Supply voltage:	24 V DC (permissible range: 20 V – 33 V DC)
Inputs/outputs:	16 digital inputs 24 V DC pulsed (resistive load only) 4 digital inputs 24 V DC, unpulsed (resistive load only) 4 digital outputs (channel A) 24 V DC (resistive / inductive load) 4 digital outputs (channel B) GND DC (resistive / inductive load) 1 A each (short-circuit proof)
Temperature ranges:	Operating temperature +20 °C to +70 °C Storage temperature +5 °C to +80 °C
SafetyBUS p connection:	Via PILZ SafetyBUS p connector D0, D1, D2, or D3; 5 V for the supply of the Cu / fiber-optic converters

SafetyBUS p Gateway - Interfaces



Designation	Meaning
X1:	Peripheral connector inputs and outputs
X2:	SafetyBUS p connection
X3:	Connector to CI bus board
X6	Connector for wiring output A1 and return signals
X7	Connector for wiring output A2 and return signals
X8	Connector for wiring output A3 and return signals
S1:	Rotary selector for setting the SafetyBUS p address (tens selector)
S2	Rotary selector for setting the SafetyBUS p address (units selector)
F1	Supply voltage fuse, 2A mT

SafetyBUS p Gateway

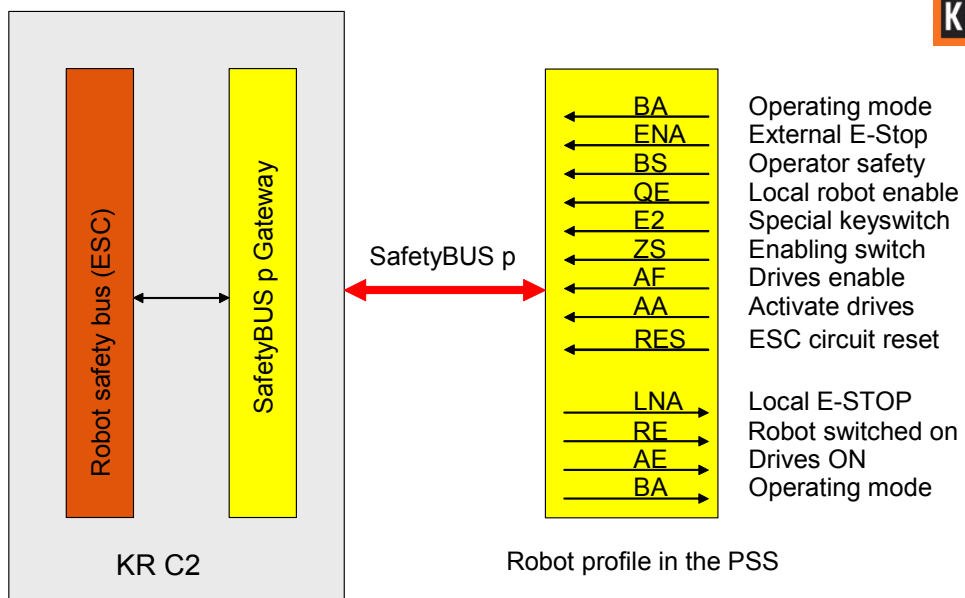


LED	Designation	Color	Function
H1	LED BUS	green	Status of SafetyBUS p (lit = OK)
H2	LED Device_R	red	Device status (lit = fault, H3 is off)
H3	LED Device_G	green	Device status (lit = OK, H2 is off)
H4	LED GR_A	green	Group status, group A (lit = A started)
H5	LED GR_B	green	Group status, group B (lit = B started)

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SafetyBUS p connection



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SafetyBUS p - I/O description

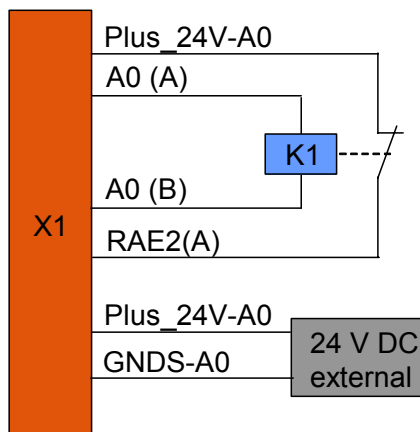
Inputs		
BA	Operating mode	Always 0; reserved for later use
ENA	External E-STOP	System E-STOP; directed to the ESC of the robot
BS	Operator safety	Safety signal from safety gate or light barrier
QE	Local robot enable	Interlock of the robot, independent of the operating mode (does not affect other devices in the safety bus)
E2	Special keyswitch	Customer-specific signal
ZS	Enabling switch	Enabling signal in manual mode via PSS
AF	Drives enable	Drives OFF
AA	Activate drives	0? 1 edge in auto mode switches drives on
RES	Reset ESC circuit	Reset ESC circuit
Outputs		
LNA	Local E-STOP	Robot in E-STOP
RE	Robot switched on	Robot is switched on (voltage on)
AE	Drives ON	Robot drives are ON (drives contactor energized)
BA	Operating mode	Selected operating mode (AUTO/ TEST)
INB	Start-up	Overriding the external safety circuit. The drives contactor can only pick up in TEST mode

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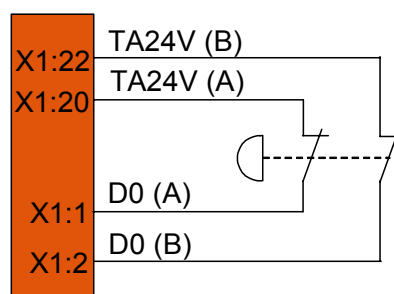
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Connection examples

Connection of a contactor with external power supply



Connection of a pushbutton with external power supply



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5. Wiring diagrams ESC



