Circuit Examples

kapitel 7
7.1 Safety-Related Low-Voltage Switchgear and Sensors
7.2 Controllers: Fail-safe controls
7.3 Motion Control Systems: Safe Motion Control
7.1 Safety-Related Low-Voltage Switchgear and Sensors

7.1.1 Switch safely

The following circuit examples have been checked with the German Trade Association (BG) and have been approved.

- Contactor circuits
- SIGUARD safety combinations

suitable for:
- EMERGENCY STOP
- Protective door monitoring functions
- Press controls

EMERGENCY STOP circuits for extremely simple machines

EMERGENCY STOP switch

The EMERGENCY STOP function may only be routed through an EMERGENCY STOP switch for extremely simple machines, depending on the result of the risk analysis. In this particular case, only Stop Category 0 is possible. Such an EMERGENCY STOP switch, contrary to usual EMERGENCY STOP pushbutton, interrupts the main circuit (Fig. 7/1).

An EMERGENCY STOP switch must be configured so that:
- There is only one EMERGENCY STOP switch;
- The EMERGENCY STOP switch is located in the supply to those circuits which can result in hazardous motion in the system. The complete power supply to all of the circuits does not have to be interrupted;
- The EMERGENCY STOP switch must be able to interrupt the current of the largest motor when the motor stalls;
- The sum of the currents of all of the loads, which must be disconnected using the EMERGENCY STOP switch, must be able to be safely interrupted.

An EMERGENCY STOP switch may:
- be manually actuated;
- act on an undervoltage release via one or several EMERGENCY STOP control devices (circuit diagram 7/1);
- be provided with overload and/or short-circuit releases (version as circuit-breaker);
- be simultaneously used as main switch if it additionally fulfills the requirements for a main switch (however, a main switch must disconnect all circuits).

An example for such an EMERGENCY STOP switch for extremely simple machines is illustrated in Fig. 7/2.

Fig. 7/1
EMERGENCY STOP switch with manual actuation or remote actuation via under-voltage release

- Contactor circuits
- SIGUARD safety combinations

suitable for:
- EMERGENCY STOP
- Protective door monitoring functions
- Press controls
EMERGENCY STOP contactor

Generally, a so-called EMERGENCY STOP contactor is not permitted. Such a contactor is only permissible in precisely defined exceptional cases: This contactor may only be used as an EMERGENCY STOP contactor in the branch to be shutdown. Additional contactors in series are not permitted. This means that this concept is restricted for applications on extremely simple machines (refer to circuit diagram 7/2).

An EMERGENCY STOP contactor must be configured so that

- each EMERGENCY STOP contactor must be immediately de-energized by the EMERGENCY STOP control device;
- there are no additional contactors in series.

Safety circuits using individual contactors

Configured using two auxiliary contactors

Safety circuits of any complexity can be configured using auxiliary contactors. Several years ago, the circuit with two auxiliary contactors and overlapping auxiliary contacts (Fig. 7/3) was considered to be state-of-the-art.

This circuit offers redundancy. However, due to the fact that the contacts are not positively driven, the two auxiliary contactors do not mutually monitor each other for correct functioning. This means that if a contact welds, this fault is not detected and the circuit still continues to function.

A subsequent fault in the second contactor could completely disable the combination. This would mean that the level of safety would no longer be guaranteed. Thus, today, this circuit is no longer used (Fig. 7/3).

Fig. 7/2
Example of a machine control with 2 power contactors, only permitted with some restrictions

Fig. 7/3
This contactor combination consists of two auxiliary contactors with overlapping contacts (Category 2 according to EN 954-1)
Configured using three auxiliary contactors

Today, circuits with three auxiliary contactors represent state-of-the-art technology. Three auxiliary contactors with positively driven contacts are used, as shown in circuit diagram 7/4. The three auxiliary contacts guarantee redundancy and function monitoring. The positively driven contacts guarantee that the auxiliary contactors mutually monitor themselves. Faults are therefore detected and the circuit can no longer be closed after shut-down, therefore eliminating subsequent faults.

With this circuit, using today’s state-of-the-art technology, it can be assumed that if the auxiliary contactors incorrectly function, this will not cause the system to go into a hazardous condition.

Connecting several EMERGENCY STOP control devices

In the previous circuit diagrams, only one EMERGENCY STOP device was shown. Generally, there are several EMERGENCY STOP control devices (e.g. at different locations) on a machine. The contacts of these EMERGENCY STOP control devices are then connected in series.

In the 3TK28 contactor safety combinations, which are complete devices, several auxiliary contactors are connected to form a safety circuit. These circuits can also be implemented using individual contactors.

Circuit examples to monitor protective devices

Circuits to monitor protective devices use position switches. Various possibilities of the different devices are shown in the examples for EMERGENCY STOP. These circuit examples will not be repeated here as the EMERGENCY STOP control device is only replaced by one or two position switches per protective device. The number of position switches which are required for each protective door can be taken from Section 3 of the Manual.
7.1.2 SIGUARD 3TK28 Safety Combinations

Function description

- Power on:
  Connect the power;
  The “Power” LED is lit, EMERGENCY STOP closed, C1 is charged, press ON;
  C1 starts to charge K1, V1 is energized, K2 starts, K1 + K2 latch, “Channel 1” and “Channel 2” LED’s are lit.

- ON monitoring:
  ON is pressed → fault!
  EMERGENCY STOP is closed;
  V1 immediately starts K2, C1 is not charged
  → K1 does not start.
  Only LED “Channel 2” is lit.

- Cross-circuit:
  If EMERGENCY STOP 1 and EMERGENCY STOP 2 are short-circuited, a current flows through the PTC fuse.
  The PTC goes into a high-ohmic state.
  None of the LED’s are lit.
The following circuit diagrams have been checked with the German Trade Association (BG) and approved. The connection designations are in compliance with DIN EN 50042.

**EMERGENCY SWITCHING-OFF (EMERGENCY STOP) circuits**

Circuit diagrams

*Fig. 7/10*
3TK28 21/24 for EMERGENCY STOP, Category 2, single channel, with feedback circuit

*Fig. 7/11*
3TK28 21/24 EMERGENCY STOP, Category 3 (4), two-channel with feedback circuit

*Fig. 7/12*
3TK28 23 for EMERGENCY STOP, Category 4, two-channel, with feedback circuit, monitored start
Fig. 7/13 3TK28 25 EMERGENCY STOP, Category 2, single-channel, according to EN 954-1, monitored start

Fig. 7/14 3TK28 25 EMERGENCY STOP, Category 4, two-channel, according to EN 954-1, monitored start

Fig. 7/15 3TK28 27 EMERGENCY STOP, Category 2, single-channel, according to EN 954-1, monitored start
Fig. 7/16
3TK28 27 EMERGENCY STOP with shutdown, Stop Category 1, for Category 3 according to EN 954-1, two-channel, with feedback circuit, monitored start

Fig. 7/17
3TK28 23 expanded with 3TK28 30 for EMERGENCY STOP, Category 4 acc. to EN 954-1, two-channel, with feedback circuit
Fig. 7/18
3TK28 25 expanded by 3TK28 30 for EMERGENCY STOP, Category 4 acc. to EN 954-1, two-channel cc. to EN 954-1, monitored start

Fig. 7/19
3TK28 27 expanded by 3TK28 30 for EMERGENCY STOP, Category 4 (Category 3 for delayed contacts), two-channel, monitored start
Fig. 7/20
EMERGENCY STOP, Category 4 acc. to EN954-1, 3TK2823(25) in conjunction with operational control of a standard PLC (SIMATIC S7-300/ET200M), load current for each enable circuit, max. 5 A. When using 3TK285.--. max. 10 A for each enable circuit.

Fig. 7/21
EMERGENCY OFF, Category 2 acc. to EN954-1, 3TK2821 in conjunction with operational control of a standard PLC (SIMATIC S7-300/ET200M), load current, max. 5 A per output group (8 digital outputs).
Fig. 7/22
3TK28 21/24 for protective door monitoring
(2 protective doors are cascaded
each with 1 SIGUARD position switch),
Category 2 acc. to EN 954-1,
single-channel, with feedback circuit, autostart

Fig. 7/23
3TK28 21/24 for protective door monitoring
with tumbler (2 protective doors are cascaded
each with 2 SIGUARD position switches
with tumbler) Category 2 acc. to EN 954-1,
single-channel, with feedback circuit, autostart
Fig. 7/24
3TK28 21/24 for protective door monitoring (2 protective doors are cascaded, each with 2 SIGUARD position switches), Category 3 (4) acc. to EN 954-1, two-channel, with feedback circuit, autostart, (∞ for Category 4 - the cable has to be routed so that it is well protected). Sensors must be fail-safe.

Fig. 7/25
3TK28 22 for protective door monitoring (protective doors, each with 2 SIGUARD position switches), Category 4 acc. to EN 954-1, two-channel, with feedback circuit, autostart
Fig. 7/26
3TK28 25 for protective door monitoring (2 protective doors are cascaded, each with 1 SIGUARD position switch), autostart, Category 2 acc. to EN 954-1, single-channel, with feedback circuit

Fig. 7/27
3TK28 25 for protective door monitoring with 2 SIGUARD position switches, autostart, Category 4 acc. to EN 954-1, two-channel, with feedback circuit
3TK28 28 for protective door monitoring (2 protective doors are cascaded, each with 1 SIGUARD position switch), Stop Category 1, Category 2 acc. to EN 954-1, single-channel, with feedback circuit, autostart

3TK28 28 for protective door monitoring with 2 SIGUARD position switches, stop Category 1, Category 3 acc. to EN 954-1, two-channel, with feedback circuit, autostart
Fig. 7/30
3TK28 25 expanded by 3TK28 30 for protective door monitoring with 2 SIGUARD position switches, Category 4 acc. to EN 954-1, two-channel, with feedback circuit, autostart

Fig. 7/31
Protective door monitoring with magnetically-operated switch, Category 3 acc. to EN 954-1, two-channel, with feedback circuit, autostart
Protective door monitoring with contactless SIGUARD magnetically-operated switches

Protective doors are monitored using an evaluation unit up to Cat. 3 acc. to EN 954-1 (Fig. 7/32).

The evaluation unit can be operated, both with automatic restart as well as with monitored start. The start button is not necessarily required.

Monitoring several protective doors with evaluation unit up to Cat. 3 acc. to EN 954-1

A maximum of eight SIGUARD magnetically-operated switches can be connected to the 3SE6808-6DB evaluation unit. If one of the eight magnetically-operated switches is actuated (the protective door is opened), then the unit shuts down.

There is a PLC signaling output (switching to p) for each input. The fail-safe shutdown is realized using two relay safety outputs.

If an input is not used, then the appropriate terminals of the NO contact must be bridged.

For limited safety requirements, the evaluation unit can also be used without a start button. For this particular application, contacts X1 and Y1 must be permanently bridged.

Fig. 7/32
SIGUARD magnetically-operated switch with 3SE6801-1CC evaluation unit for Category 3 acc. to EN 954-1
Fig. 7/33
A maximum of 8 protective doors can be monitored using SIGUARD magnetically-operated switches and evaluation unit 3SE6808-6DB for Category 3 acc. to EN 954-1
Press control devices

For press control devices with contactors also refer to Pages 7/14 and 7/15.

**Fig. 7/34**
Internal circuit diagram of the 3TK28 34 two-hand control device

**Fig. 7/35**
3TK28 34 two-hand control device, Category 4 acc. to EN 954-1
Fig. 7/36
Internal circuit diagram of the 3TK28 35 overtravel tester

Fig. 7/37
3TK28 34 two-hand control device in conjunction with a 3TK28 35 overtravel tester to monitor the overtravel on linear hydraulic, pneumatic and spindle presses acc. to VBG 7 n 5.2 § 11, Category 4 acc. to EN 954-1
Sequence after the press has been powered-up:

1. The hydraulic pump is powered-up with S5, the ram is moved up to the upper dead center, if required, using S6.
2. Depress S1, S2 at the two-hand operating console until the position switch for the test cams (S4) opens.
3. Release S1, S2.
4. Depress S1, S2 again: Signal lamp H1 lights up (bright) if the overtravel is OK.
5. Release S1, S2: The ram returns to the upper dead center.
6. If the overtravel is OK, all of the outputs remain active until the control voltage is disconnected.

Fault situation

If the cam actuates position switch S4, then the signal lamp H1 is not lit up. The machine part, which is potentially hazardous, can then only be moved to the upper dead center using S6.

This press can then no longer be used. Contact the technician to check the press.

A more detailed description of the function of the 3TK28 34 two-hand control devices is provided in the Instruction Manual, Order No. 3ZX1012-0TK28-7CA1, for the overtravel tester 3ZX1012-0TK28-6CA1.

Fig. 7/38

Fault situation

If the cam actuates position switch S4, then the signal lamp H1 is not lit up. The machine part, which is potentially hazardous, can then only be moved to the upper dead center using S6.

This press can then no longer be used. Contact the technician to check the press.

A more detailed description of the function of the 3TK28 34 two-hand control devices is provided in the Instruction Manual, Order No. 3ZX1012-0TK28-7CA1, for the overtravel tester 3ZX1012-0TK28-6CA1.

Fig. 7/39
Function schematic of the press control.

The permissible overtravel \(s\) corresponds to the length of the cam which actuates position switch S4. According to ZV 1/456, the press manufacturer must define \(s\).

**Overtravel too long**

1. Power \(V_G\) on.
2. S5 is pressed, K1 pulls in (latches).
3. S6 is pressed, K2 pulls in (the ram moves upwards in the manual mode).
4. The upper dead center is reached, S3 is actuated.
5. S6 is released, K2 drops out.
6. S1 and S2 on the two-hand operating console are pressed, the 3TK2834 two-hand control device outputs enable signals, K3 and K4 pull in.
7. The ram moves downwards, S3 is no longer actuated.
8. Test cams are reached, S4 is depressed, K3 drops out.
9. **The ram does not remain stationary**, S4 is no longer actuated (is passed over), K3 pulls in.
10. S1 and S2 are released, K3 and K4 drop out.
11. S1, S2 are actuated, K4 pulls in again. Overtravel tester is inhibited.

Fig. 7/40

Fig. 7/41

Function schematic of the press control.
Circuit examples SIGUARD electronic safety combinations

Fig. 7/42
SIGUARD 3TK28 41, internal circuit diagram, standard electronic device

Fig. 7/43
SIGUARD 3TK28 40, basic electronic device, EMERGENCY STOP, 2-channel, Category 3 acc. to EN 954-1
Fig. 7/44
SIGUARD 3TK2840, EMERGENCY STOP, Category 2 acc. to EN 954-1, single-channel, with feedback circuit

Fig. 7/45
SIGUARD 3TK2840, protective door monitoring, Category 3 acc. to EN 954-1, two-channel with feedback circuit
**Fig. 7/46**
*SIGUARD 3TK2841, protective door monitoring, Category 4 acc. to EN 954-1, two-channel with feedback circuit, autostart*

**Fig. 7/47**
*SIGUARD 3TK2841, EMERGENCY STOP, Category 2 acc. to EN 954-1, one-channel, with feedback circuit, monitored start*
Fig. 7/48
SIGUARD 3TK2841, EMERGENCY STOP, Category 4 acc. to EN 954-1, two-channel, with feedback circuit, monitored start with “ON” button.

Fig. 7/49
SIGUARD 3TK2841, light grid monitoring, Category 4 acc. to EN 954-1, 2-channel, with feedback circuit, autostart.
Fig. 7/50
SIGUARD 3TK2841, EMERGENCY STOP, 2-channel, monitored start, with additional on button and protective door monitoring, 2-channel, autostart, Category 4 acc. to EN 954-1

Fig. 7/51
SIGUARD 3TK2841, contact mat, Category 3 acc. to EN 954-1, 2-channel, autostart
Fig. 7/52
SIGUARD 3TK2841, EMERGENCY STOP, Category 4 acc. to EN 954-1, in conjunction with operational control of a standard PLC (SIMATIC S7 300/ET200M) load current for each enable circuit, max. 2 A

Fig. 7/53
SIGUARD 3TK2841, EMERGENCY STOP and light grid, Category 4 acc. to EN 954-1, cascaded with operational control of a standard PLC (SIMATIC S7 300/ET200M)
Fig. 7/54
SIGUARD 3TK2842, protective door monitoring, Category 4 acc. to EN 954-1, 2-channel, with feedback circuit with AC drive inverter and delayed shutdown, Stop Category 1

Fig. 7/55
SIGUARD 3TK2842, EMERGENCY STOP Category 2 acc. to EN 954-1, 1-channel, monitored start with ON button with checkback circuit, with AC drive inverter and delayed shutdown, Stop Category 1
Fig. 7/56
SIGUARD 3TK2842, EMERGENCY STOP Category 4 acc. to EN 954-1, 2-channel, monitored start with ON button, with AC drive and delayed shutdown, Stop Category 1

Fig. 7/57
SIGUARD 3TK2842, EMERGENCY STOP and protective door monitoring, Category 4 acc. to EN 954-1, 2-channel, with tumbler, monitored start
Fig. 7/58
SIGUARD 3TK2841, cascaded with 3TK2842 for EMERGENCY STOP,
2-channel, monitored start with ON button and protective door monitoring,
2-channel, autostart, Category 4 acc. to EN 954-1

Fig. 7/59
SIGUARD 3TK2842, light grid monitoring, 2-channel,
autostart, Category 4 acc. to EN 954-1
Fig. 7/60
SIGUARD 3TK2842, contact mat, Category 3 acc. to EN 954-1, 2-channel, autostart

Fig. 7/61
SIGUARD 3TK2850, 51, 52, internal circuit diagram, electronic basic unit with auxiliary contactors, Category 3 acc. to EN 954-1
Fig. 7/62
The electronic basic 3TK2850 device with auxiliary contactors, protective door monitoring, 2-channel, autostart, Category 3 acc. to EN 954-1

Fig. 7/63
The electronic basic 3TK2850 device with auxiliary contactors, protective door monitoring, 1-channel, autostart, Category 2 acc. to EN 954-1
Fig. 7/64
The electronic basic 3TK2850 device with auxiliary contactors, EMERGENCY STOP, 1-channel, with additional ON button, Category 2 acc. to EN 954-1

Fig. 7/65
The electronic basic 3TK2850 device with auxiliary contactors, EMERGENCY STOP, 2-channel, Category 3 acc. to EN 954-1
Fig. 7/66
The electronic basic 3TK2850 device with auxiliary contactors, EMERGENCY STOP, 2-channel, Category 4 acc. to EN 954-1 SIL 3

Fig. 7/67
3TK285-.., EMERGENCY STOP, Category 4 acc. to EN 954-1, P-M switching in conjunction with operational control of a standard PLC (SIMATIC S7 300/ET200M), load current per enable circuit, 10 A
Fig. 7/68
3TK2853, internal circuit diagram, electronic basic device with auxiliary contactors, Category 4 acc. to EN 954-1

Fig. 7/69
The electronic basic 3TK2853 device with auxiliary contactors, protective door monitoring, 2-channel, autostart, Category 4 acc. to EN 954-1, SIL 3
Fig. 7/70
The electronic basic 3TK2853 device with auxiliary contactors, protective door monitoring, 1-channel, autostart, Category 2 acc. to EN 954-1, SIL 3

Fig. 7/71
The electronic basic 3TK2853 device with auxiliary contactors, EMERGENCY STOP, 1-channel, with additional EN button, Cat. 2 acc. to EN 954-1, SIL 3
Fig. 7/72
The electronic basic 3TK2853 device with auxiliary contactors, light curtain/grid, 2-channel, autostart, Category 4 acc. to EN 954-1

Fig. 7/73
The electronic basic 3TK2853 device with auxiliary contactors, cascading EMERGENCY STOP and protective door monitoring, 2-channel, Cat. 4 acc. to EN 954-1, SIL 3
Load feeders with Integrated Safety Technology

Typical application for load feeder outgoing cables
- Six actuation units are monitored by two EMERGENCY STOP switches
- The actuation equipment can either be individual de-activated or in groups using the protective doors
- During operation, the equipment is switched-over using a PLC or a pushbutton.

Conventional solution
- Conventional wiring => approx. 160 different solutions
- Complex installation => high costs => increased space requirement
- Frequent faults
- No overload or short-circuit protection
Solution with 3RA7

- Combination of 3RA7 and 3TK28 (cascading)
- Approx. 80 connections
- Simpler installation => lower costs => compact design
- Few faults due to the "single wire connection"
- Motor protection using a protection circuit-breaker

Typical applications for safe combinations

- 3TK2840 electronic basic device
- Protective door monitoring
- Category 3 acc. to EN 954-1
- 2 channels with feedback circuit
• 3TK2840 electronic basic device
• EMERGENCY STOP
• Category 2 acc. to EN 954-1
• 1 channel with feedback circuit

24 V DC (+)
Y33 Y34
L1 L2 L3
3SB3
3TK2840

A1 Y11 Y12
Y20
M
Y21 Y22 A2 14 24
K1

EMERGENCY STOP
3SB3

• 3TK2840 electronic basic device
• EMERGENCY STOP
• Category 3 acc. to EN 954-1
• 2 channels with feedback circuit

24 V DC (+)
Y33 Y34
L1 L2 L3
3SB3
3TK2840

A1 Y11 Y12
Y20
M
Y21 Y22 A2 14 24
K1

K2
7.1.3 Contactless Protective Devices

Circuit examples for SIGUARD light curtains

Connection example, light curtain Category 4 connected to a standard evaluation unit 3RG7847-4BB

Light curtain or light grid 3RG7842 connected through 2 channels to the evaluation unit 3RG7847-4BB:

- Category 4 acc. to EN 954-1
- Manual start with monitored start button
- Contactor monitoring

Connection example, light curtain Category 4 connected to an evaluation unit with muting function

A light curtain or light grid 3RG7842 connected to the evaluation unit with muting function 3RG7847-4BF:

- Category 4 acc. to EN 954-1
- Integrated muting function (e.g. with light barriers as muting sensors)
- Manual start with dynamically monitored start button
- Dynamic contactor monitoring
Connection example, light curtain Category 2 connected to a standard evaluation unit 3RG7847-4BD

A light curtain 3RG7841 connected to the evaluation unit 3RG7847-4BD:
- Category 2 acc. to EN 954-1
- Cyclic testing of the light curtain
- Manual start with dynamically monitored start button
- Dynamic contactor monitoring

Connection example, light curtain Category 4 connected to an evaluation unit with cycle control

A light curtain or grid 3RG7842/44 connected through 2 channels to the evaluation unit 3RG7847-4BH:
- Category 4 acc. to EN 954-1
- Automatic single or two-cycle control
- Manual start with dynamically monitored start button
- Dynamic contactor monitoring
Circuit examples for SIGUARD light barriers

![Circuit Diagram](image)

Fig. 7/78
Fig. 7/79
- Start button for a manual restart directly at the scanner (connection 2)
- Alarm output at connection 5 (e.g. alarm lamp)
- The protective field is changed-over at connections 4, 6, 7 and 8
- The safe outputs are safely processed (connections 11 and 12) when using an evaluation unit or fail-safe PLC
Connection example, LS4 SIGUARD laser scanner
Connected to a standard 3RG7847-4BB evaluation unit

- Start button for a manual restart directly at the scanner (connection 2)
- Fixed protective field pair 1 (24 V always present at connection 4)

* A suitable arc quenching device must be provided.
7.1.4 SIGUARD Switching Strips

Circuit examples with evaluation unit

SIGUARD switching strips, together with the 3RG78 57-1BD evaluation unit, can be used as a safety system up to Category 4 acc. to EN 954-1. The evaluation electronics in the 22.5 mm enclosure is used to evaluate the transmitter/receiver signal and to monitor the complete system for faults and errors.

The power supply voltage of the evaluation unit is 24 V DC. Two relay outputs are available as safety-related outputs. A semiconductor output can be used to issue a signal to a PLC. After the switching strip has been actuated, the device must be enabled using a manual start button, so that the system can restart.

![Diagram of SIGUARD Switching Strips](image_url)
7.1.5 Circuit examples, ET 200S SIGUARD

Fig. 7/81
EMERGENCY STOP circuit with monitored start, Category 4 acc. to EN 954-1

Fig. 7/82
EMERGENCY STOP circuit with monitored start, Category 2 acc. to EN 954-1
Fig. 7/83
EMERGENCY STOP circuit in two groups

Fig. 7/84
EMERGENCY STOP circuit arranged in a cascade
Fig. 7/85
EMERGENCY STOP circuit arranged in a cascade with delayed shutdown (Stop Category 1)
Fig. 7/86
EMERGENCY STOP combined with protective door
Fig. 7/87
One EMERGENCY STOP circuit for several ET 200S rails

Fig. 7/88
Integrated in an external EMERGENCY STOP circuit, Category 4 acc. to EN 954-1
Fig. 7/89
Integrated in an external EMERGENCY STOP circuit, Category 2 acc. to EN 954-1

Category 4 (EN 954-1) – separate shutdown groups are also possible

Fig. 7/90
SIMATIC ET 200S SIGUARD and AS-i Safety at Work
Fig. 7/91
EMERGENCY STOP circuit with integrated pneumatic valves

Fig. 7/92
EMERGENCY STOP circuit with integrated external actuators
This section shows you the possibilities of achieving Safety Classes AK4/SIL2/Cat.3 and AK6/SIL3/Cat.4 using the F I/O in S7-300F and S7-400F/FH. This information refers to the F I/O of the SIMATIC S7 range - this means F-SMs S7-300 and F modules ET 200S.

How is the safety class achieved for F inputs?

For F inputs, the required Safety Class is achieved by the type of transmitter evaluation. This means that Safety Class AK4/SIL2/Cat.3 or AK6/SIL3/Cat.4 is defined by how the transmitter is connected-up.

How is the Safety Class achieved with F outputs?

For F outputs, the required Safety Class is achieved by the way in which the test signals are connected to the F I/O.

Evaluating transmitters for F digital inputs

For F digital inputs, the required Safety Class is achieved by the type of transmitter evaluation.

<table>
<thead>
<tr>
<th>Safety Classes</th>
<th>Achieved by</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIL2 AK4 Cat. 3</td>
<td>1-from-1 evaluation</td>
</tr>
<tr>
<td>SIL3 AK5,6 Cat. 4</td>
<td>2-from-2 evaluation</td>
</tr>
</tbody>
</table>

Table: Safety Classes which can be achieved for F digital inputs
Example: A transmitter connected to an F-DI through 1 channel (AK4/SIL2/Cat.3)
The connection schematic for an SM 326, DI 24 x 24V DC for a 1-from-1 evaluation of the transmitter is shown in the following diagram. The transmitter is supplied from the F I/O. AK4/SIL2/Cat.3 can be achieved using this connection.

Example: A transmitter connected to an F-DI through 1 channel (AK6/SIL3/Cat.4)
The connection schematic for an SM 326, DI 24 x 24V DC for a 2-from-2 evaluation of the transmitter is shown in the following diagram. The transmitter is supplied from the F I/O. AK6/SIL3/Cat.4 can be achieved using this connection as long as a suitably qualified transmitter is used.

Example: A transmitter connected to an F-DI through 2 channels (AK6/SIL3/Cat.4)
The connection schematic for an SM 326, DI 24 x 24V DC for a 2-from-2 evaluation of the transmitter is shown in the following diagram. AK6/SIL3/Cat.4 can be achieved using this connection.

Example: An antivalent transmitter (2-channel) connected to an F-DI (AK6/SIL3/Cat.4)
The connection schematic for an SM 326, DI 24 x 24V DC with antivalent transmitter (2-from-2 evaluation) is shown in the following diagram. AK6/SIL3/Cat.4 can be achieved with this connection.
7.2.2 Function block for the S7-300F muting function

Mode of operation

Light curtains can be operated in the muting mode so that products or objects can be brought into the hazardous area, monitored by the light curtain, without stopping the machine. It must be ensured that personnel cannot enter the hazardous area while the light curtain is bypassed by using two or four muting sensors as well as the correct integration into the production sequence.

It is extremely important to note that the interval in which the safety program is called (e.g. OB 35) must be less than the selected discrepancy time.

Schematic sequence of an error-free muting operation using 4 muting sensors (MS_11, MS_12, MS_21, MS_22)

1. If the inputs for the muting sensors MS_11 and MS_12 are activated by the product within DISCTIM1, then the F application block switches to MUTING. The enable signal Q remains at 1, also if the input FREE = 0 (the product interrupts the light curtain). The output MUTING goes to 1 to control the muting lamp.

2. As long as the two inputs MS_11 and MS_12 are still activated by the product, Q remains at 1 and MUTING remains at 1 as a result of the MUTING function of the F application block (so that the product may pass through the light curtain without the machine stopping).

3. The inputs for the muting sensors MS_21 and MS_22 must have been activated within DISCTIM2 and before the inputs for the muting sensors MS_11 and MS_12 are switched into an inactive state. This means that the F application block maintains the MUTING. (Q = 1, MUTING = 1).

4. After one of the inputs for the muting sensors MS_21 and MS_22 = 0 (the product enables the sensors), the MUTING function is exited (Q = 1, MUTING = 0). The MUTING function may be active for a maximum time parameterized at the input TIME_MAX.
Timing diagram for error-free muting using 4 muting sensors

DISCTIM1 and DISCTIM2 are discrepancy times for sensor pairs 1 and 2.
7.3 Motion Control Systems: Safe Motion Control

This section describes the circuit examples using the drive systems SIMOVERT MASTERDRIVES and SIMODRIVE 611 universal for applications involving variable-speed drives with AC motors.

These examples show possibilities of implementing the various solutions. The solution required for the machine must be aligned to the particular machine function. This results in individual parameter assignments or control commands for applications associated with stop Category 1.

Using the “safe standstill” function, the drive pulses are cancelled thus preventing the drive from undesirably starting.

The solutions which are shown can, from the actual principle, also be implemented using other drive systems. However, the appropriate information/instructions in the documentation describing the various products must be carefully observed (also refer to the Certificate in Section 8.6.3).

7.3.1 Application examples for EMERGENCY STOP Category 0

Fig. 7/93
Stop Category 0, 2-channel, with feedback circuit; Category 3 acc. to EN 954-1;
Function with a motor coasting down

SIMOVERT MASTERDRIVES
Vector Control Catalog DA 65.10
SIMOVERT MASTERDRIVES
Motion Control Catalog DA 65.11
SIMODRIVE 611
Catalog NC 60.1 and NC 60.2
7.3.2 Application examples for EMERGENCY STOP Category 1

Fig. 7/94
Stop Category 1, 2-channel, with feedback circuit, Category 3 acc. to EN 954-1;
Function where the motor is shut down along the torque limit in a controlled fashion.
7.3.3 Application examples for EMERGENCY SWITCHING-OFF and EMERGENCY STOP Category 1

Structure acc. to EN 954-1 control category 3 and EN1037

The drive is shut down according to the stop function, Category 1 acc. to EN 60204-1.

By implementing as a higher-level circuit using contacts, the “Safe standstill” function is even guaranteed for erroneous behavior or if the PLC fails. For an EMERGENCY SWITCHING-OFF, the drive is electrically isolated from the line supply.

For this type of connection, the internal line contactor of the supply unit only drops-out if the internal safety relay functions erroneously.

Fig. 7/95
EMERGENCY SWITCHING-OFF and EMERGENCY STOP, Stop Category 1 acc. to EN 60204, 2-channel with feedback circuit, control Category 3 acc. to EN 954-1
7.3.4 Application example for EMERGENCY STOP, Category 1 for several drives

With this particular circuit principle, the internal line contactor of the supply unit only drops-out if one of the two internal safety relays has an erroneous function. This circuit principle is suitable if individual drive groups must be selectively shut down. The circuit principle can be expanded to several drive groups.

Structure/design in accordance with EN 954-1 control Category 3 and EN1037

The drive is shut down in accordance with stop function Category 1 acc. to EN 60204-1.

Fig. 7/96
Emergency Stop, Stop Category 1 acc. to EN 60204, 2-channel with feedback circuit, control Category 3 acc. to EN 954-1