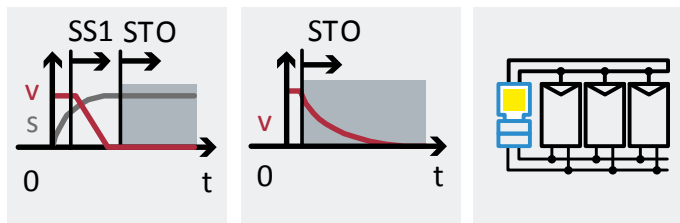


### Safety Sub-Functions SS1-t, STO Servo Drive CMMT-AS-...-S1 Cross Wiring of Servo Drives



Application Note  
CMMT-AS-...-S1,  
SS1-t, STO, Cross  
Wiring

Title .....Application Note CMMT-AS-....S1, SS1-t, STO, Cross Wiring  
Version ..... 1.1  
Document number ..... TSHQ 100241  
Original ..... German  
Author ..... Festo  
Last date of saving ..... 17/07/2019

## Legal Notice

In the following, the “Festo AG & Co.KG” is designated as “Festo”.

This Example circuit is not binding. This example circuit outlines a possible solution for a sample application and makes no claim of completeness, especially with regard to configuration and equipment, as well as any eventualities for your actual application. The Example circuit is not a customised solution, it merely offers assistance with typical task assignments.

The values stated in the Example circuit are partly assumptions and assessments which do not replace a detailed examination based on EN ISO 13849 part 1 and 2.

The actual characteristic values that can be obtained (especially PL, PFH<sub>D</sub>, category, DC, MTT<sub>D</sub>, CCF) depend on the components used, as well as their conditions of use in the actual application.

The example circuit does not relieve you of the obligation to carry out a risk assessment and a validation of the specific application and to ensure the adherence to all specifications, especially the EC Machinery Directive 2006/42/EG. As the user, you are responsible for your specific application and for the correct operation of the described products.

Festo does not accept any liability for damages arising from the use of any incorrect or incomplete information contained in this documentation or any information missing therefrom. This equally applies to defects resulting from improper handling of devices and modules. In addition, all liability, with the exception of intent or gross negligence on the part of Festo, for damages arising due to non-adherence of the specifications of the EC Machinery Directive 2006/42/EG is also rejected.

The information in this document is in no way intended as a substitute for the operating instructions of the respective manufacturers or the design and testing of the application by the user. The operating instructions for products from Festo can be found at [www.festo.com](http://www.festo.com). Users of this document must themselves verify that all the functions described herein also work correctly in the application. Even after examining this document and using the specifications contained herein, users are nevertheless solely responsible for their own application.

Otherwise, all stipulations concerning liability included in the terms and conditions of delivery, payment and use of software from Festo, which can be found at [www.festo.com](http://www.festo.com) and can be supplied on request, apply.

This document is only suitable for persons with sufficient expertise for machine safety based on EN ISO 12100 and EN ISO 13849. In addition, the following qualifications are required in the project team:

- Specialist in electrical engineering
- Specialist for the programming of control systems and safety switching devices

## Copyright Notice

This documentation is the intellectual property of Festo, which also holds the exclusive copyright. Any modification of the content, duplication or reprinting of this documentation, as well as distribution to third parties, is only permissible with the express consent of Festo.

Festo reserves the right to make modifications to this document in whole or in part. All brand and product names are trademarks or registered trademarks of their respective owners.

© (Festo AG & Co.KG, D - 73734 Esslingen, 2019)

Internet: [www.festo.com](http://www.festo.com)

E-Mail: [service\\_international@festo.com](mailto:service_international@festo.com)

# Table of Content

<b>1</b>	<b>Example Circuits .....</b>	<b>4</b>
1.1	Selection Guide for the Circuits .....	4
1.2	SS1-t, STO with CMMT-AS-...-S1, contact outputs, without STA evaluation.....	5
1.2.1	Circuit Diagram .....	5
1.2.2	Components.....	6
1.2.3	Description.....	6
1.2.4	Safety Considerations .....	7
1.3	SS1-t, STO with CMMT-AS-...-S1, contact outputs, with STA evaluation .....	8
1.3.1	Circuit Diagram .....	8
1.3.2	Components.....	9
1.3.3	Description.....	9
1.3.4	Safety Considerations .....	10
1.4	SS1-t, STO with CMMT-AS-...-S1, electronic outputs, without STA evaluation .....	11
1.4.1	Circuit Diagram .....	11
1.4.2	Components.....	12
1.4.3	Description.....	12
1.4.4	Safety Considerations .....	13
1.5	SS1-t, STO with CMMT-AS-...-S1, electronic outputs, with STA evaluation .....	14
1.5.1	Circuit Diagram .....	14
1.5.2	Components.....	15
1.5.3	Description.....	15
1.5.4	Safety Considerations .....	16
1.6	SS1-t, STO with CMMT-AS-...-S1, safety PLC, with STA evaluation .....	17
1.6.1	Circuit Diagram .....	17
1.6.2	Components.....	18
1.6.3	Description.....	18
1.6.4	Safety Considerations .....	19
<b>2</b>	<b>Glossary.....</b>	<b>20</b>
	Low Test Pulses.....	20
	High Test Pulses.....	21
<b>3</b>	<b>Literature .....</b>	<b>21</b>

# 1 Example Circuits

- The circuits specified in this document are principle circuits which cannot be complete due to their clarity and scope. Safety commanding device and safety switching device are not part of this document and are given for information only.
- The abbreviations used for the safety sub-functions refer to the definitions in EN 61800-5-2 [1] for electrical power drive systems:
  - SS1-t: Safe stop 1 time controlled
  - STO: Safe Torque Off
- Category and PL according EN ISO 13849-1 [2].
- To understand this application note, are following documents necessary:
  - Description “Servo drive CMMT-AS-C2/C4-3A-...”. This description is available on the Internet [https://www.festo.com/net/en-gb\\_gb/SupportPortal/Downloads/466851/573769/CMMT-AS-C2\\_C4-3A\\_2018-10a\\_8095049g1.pdf](https://www.festo.com/net/en-gb_gb/SupportPortal/Downloads/466851/573769/CMMT-AS-C2_C4-3A_2018-10a_8095049g1.pdf)
  - Description “Safety sub-function STO, SBC, SS1” for servo drive CMMT-AS-...-S1. This description is available on the Internet [https://www.festo.com/net/en-gb\\_gb/SupportPortal/Downloads/466859/573777/CMMT-AS-S1\\_2018-10a\\_8096257g1.pdf](https://www.festo.com/net/en-gb_gb/SupportPortal/Downloads/466859/573777/CMMT-AS-S1_2018-10a_8096257g1.pdf)
- The circuits and the procedure described are recommendations which do not exclude other possibilities.

## 1.1 Selection Guide for the Circuits

The circuits specified in this application note differ in the following points:

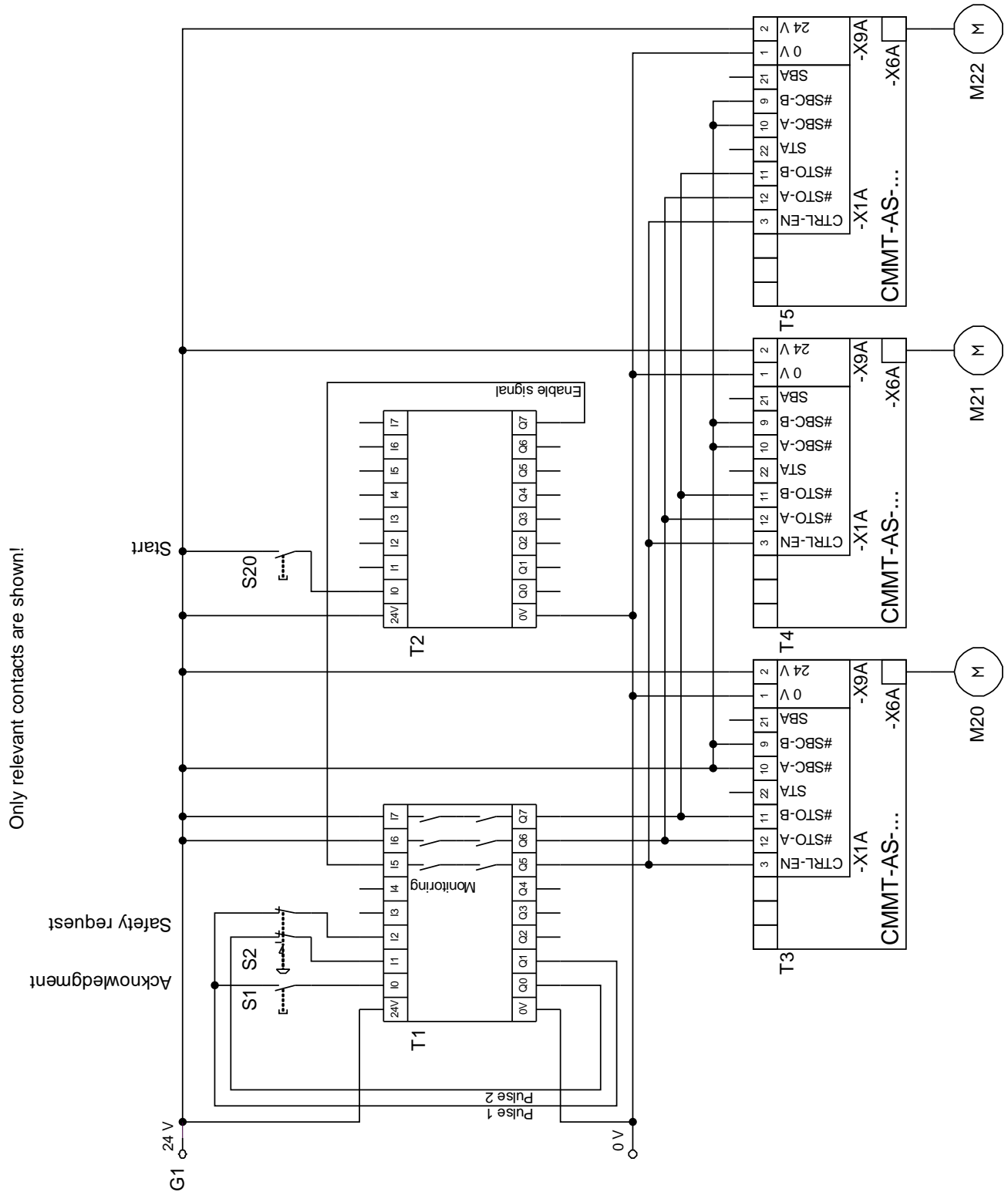
- Use of safe outputs of the safety switching device (T1) with contact outputs without short-circuit and cross-circuit detection or electronic outputs with short-circuit and cross-circuit detection
- With or without evaluation of the diagnostic signal of the servo drive (T3) by the safety switching device (T1).

Section	Safety Switching Device (T1)	Possible Category and PL	Remarks
1.2	Safety relay or safety PLC Contact outputs Without short-circuit and cross-circuit detection Without evaluation STA Suitable for PL e, category 4	Category 4 up to PL e	Fault exclusions for wiring in control cabinet required
1.3	Safety relay or safety PLC Contact outputs Without short-circuit and cross-circuit detection With evaluation STA Suitable for PL e, category 4	Category 4 up to PL e	Fault exclusions for wiring in control cabinet required
1.4	Safety relay or safety PLC Electronic outputs With short circuit and cross circuit detection Without evaluation STA Suitable for PL e, category 4	Category 3 up to PL d	
1.5	Safety relay or safety PLC Electronic outputs With short circuit and cross circuit detection With evaluation STA Suitable for PL e, category 4	Category 3 up to PL d	
1.6	Safety PLC Electronic outputs With short circuit and cross circuit detection With high test pulses With evaluation STA Suitable for PL e, category 4	Category 4 up to PL e	

## 1.2 SS1-t, STO with CMMT-AS-...-S1, contact outputs, without STA evaluation

- SS1-t, STO, category 4, up to PL e
- Safety switching device with contact outputs
- Without evaluation STA
- Fault exclusion for wiring control cabinet necessary

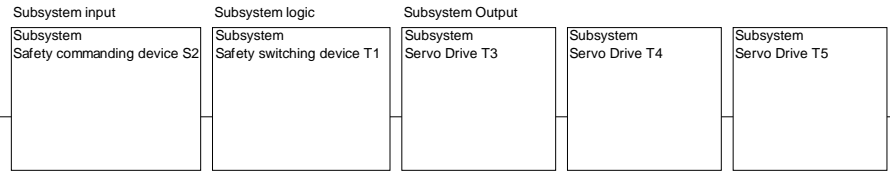
### 1.2.1 Circuit Diagram



### 1.2.2 Components

Component	Type (Part Number)	Description / Remarks	Qty.	Mssr.
M20, M21, M22	EMM...-AS	Servo motor	3	Festo
S1		Acknowledge push button	1	
S2		Safety commanding device, e.g. emergency stop switch	1	
S20		Start push button	1	
T1		Safety switching device	1	
T2		Functional PLC	1	
T3, T4, T5	CMMT-AS-...-S1	Servo drive	3	Festo

### 1.2.3 Description

Application	Servo drives with servo motors without external forces, e.g. horizontal axis
Triggering event	Safety request (S2), e.g. by emergency stop switch, safety gate
Reaction (Safety function)	<p><b>Stopping at safety request using the safety sub-function “safe stop 1 time controlled (SS1-t)” with the safe state “safe torque off (STO)”, category 4, up to PL e</b></p> 
Safe state	<p>The servo motors (M20, M21, M22) are functionally stopped and after an application-specific time no energy is supplied to the servo motors (M20, M21, M22) that can generate a force and a movement. It is presumed that this state of the servo motors (M20, M21, M22) is the safe state.</p> <p>Notes:</p> <ul style="list-style-type: none"> <li>Stopping the servo motors (M20, M21, M22) is functional and is not safety-rated, i.e. if the movement is not stopped in the event of a fault, additional measures may be required, e.g. end position damping for linear axes.</li> <li>If external forces act on the servomotor, e.g. in the case of vertical axes, the request for the safety sub-function STO can result in a dangerous movement. Then additional measures may be necessary, e.g. a holding brake.</li> <li>For the wiring between safety switching device (T2) and servo drives (T3, T4, T5), fault exclusions on short circuits and cross circuits, e.g. according to ISO 13849-2 [4], Table D.4, are required. The preconditions for these are that the safety switching device (T2) and the servo drives (T3, T4, T5) are located in the same control cabinet and that the control cabinet meets the requirements of EN 60204-1 [3].</li> </ul>
Function of the circuit	<p>Due to the safety request (S2):</p> <ol style="list-style-type: none"> <li>The input circuit of the safety switching device (T1) is interrupted.</li> <li>The output (Q5) of the safety switching device (T1) is then switched off.</li> <li>The input “output stage enable (CTRL-EN)” of the servo drives (T3, T4, T5) is no longer controlled. This causes the servo drives (T3, T4, T5) to functionally deaccelerate the motor with the braking ramp. This corresponds to a behaviour of stop category 1 according to EN 60204-1 [3]. After the end of the braking ramp, the output stage is functionally switched off.</li> <li>The outputs (Q6, Q7) of the safety switching device (T1) are then switched off with a time delay. The required time delay must be determined depending on the specific application.</li> <li>The inputs “Safe torque off, channel A and B (#STO-A, #STO-B)” of the servo drives (T3, T4, T5) are no longer controlled. This switch off the control of the output stage and requests the safety sub-function STO.</li> </ol>

Manual reset function	<ol style="list-style-type: none"> <li>1. After resetting the safety request (S2), e.g. by mechanically unlocking the emergency stop switch or closing the safety gate, the start or restart can be made possible by actuating the acknowledgement button (S1).</li> <li>2. The safety switching device (T1) controls via the outputs (Q6, Q7) the servo drives (T3, T4, T5). This makes it possible to control the power output stage again and the STO safety sub-function is no longer active.</li> <li>3. The safety switching device (T1) permits the control of the “output stage enable (CRTL-EN)” via the functional control (T2) again via the output (Q5). Normal operation is then possible by pressing the start push button (S20).</li> </ol>
Diagnosis	The diagnostic outputs (STA) must not be evaluated for the specified category and PL.

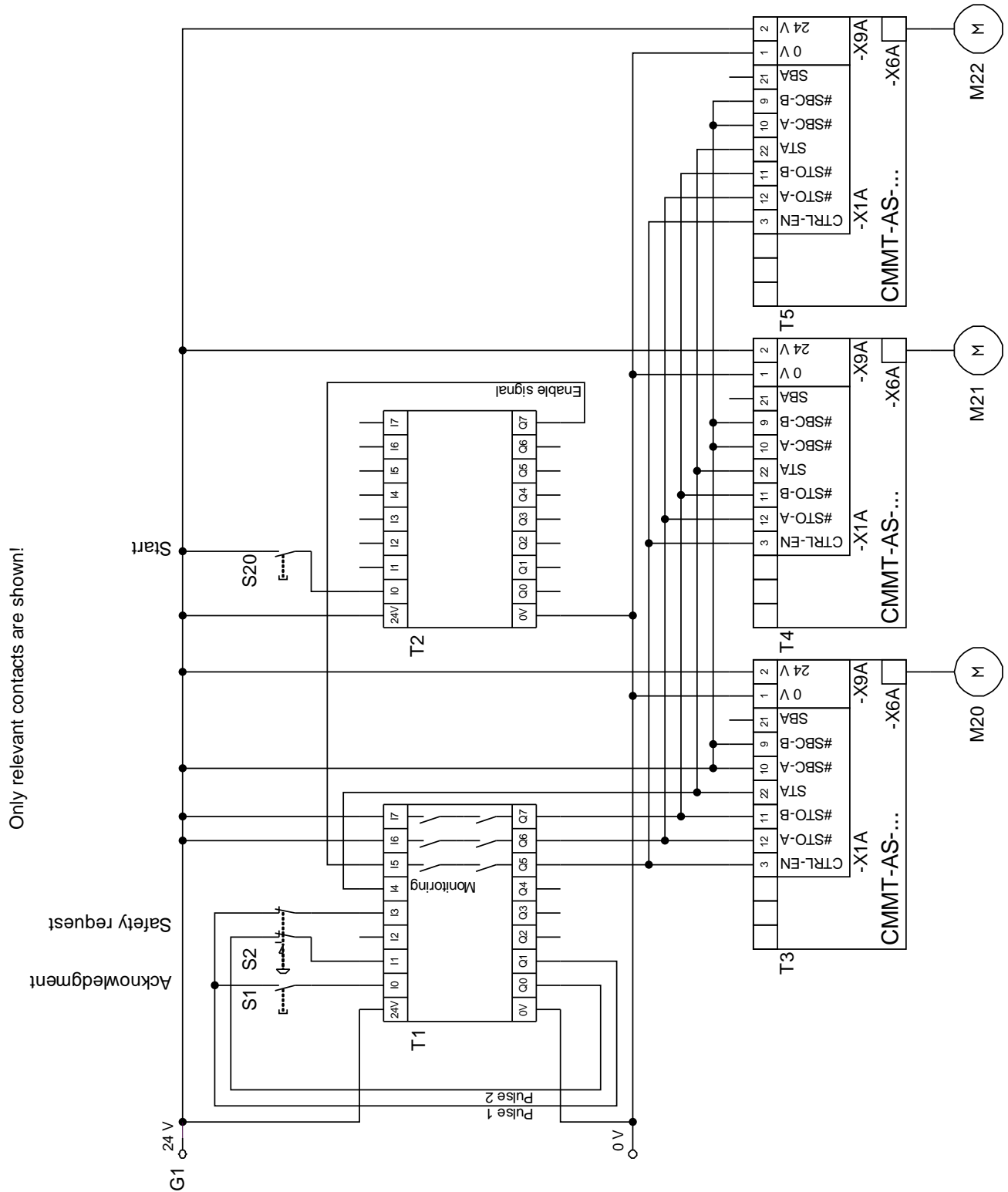
#### 1.2.4 Safety Considerations

Input	Safety considerations must be carried out in accordance with the selected safety commanding device (S2).
Logic	<p>Safety considerations must be carried out in accordance with the selected safety switching device (T1).</p> <p>Notes:</p> <ul style="list-style-type: none"> <li>• The outputs (Q6, Q7) of the safety switching device (T1) for switching the signals for the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5) are contact outputs without short-circuit and cross-circuit detection.</li> <li>• The outputs (Q6, Q7) of the safety switching device (T1) including the necessary time delay must be suitable for PL e, category 4.</li> </ul>
Output	<p>The intended use of the servo drives (T3, T4, T5) includes the safety sub-function STO with category 4, up to PL e, with cross wiring. The PL, category and PFH<sub>D</sub> values of the servo drive (T3) required to determine the reliability of the overall circuit must be available.</p> <p>Note:</p> <ul style="list-style-type: none"> <li>• For the circuit shown in this document, the safety reference data of the servo drive (T3) “without high test pulses, without or with STA evaluation” can be selected.</li> </ul>

### 1.3 SS1-t, STO with CMMT-AS-...-S1, contact outputs, with STA evaluation

- SS1-t, STO, category 4, up to PL e
- Safety switching device with contact outputs
- With evaluation STA
- Fault exclusion for wiring control cabinet necessary

#### 1.3.1 Circuit Diagram

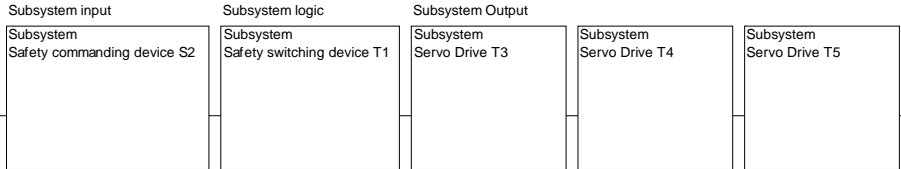




### 1.3.2 Components

Component	Type (Part Number)	Description / Remarks	Qty.	Mssr.
M20, M21, M22	EMM...-AS	Servo motor	3	Festo
S1		Acknowledge push button	1	
S2		Safety commanding device, e.g. emergency stop switch	1	
S20		Start push button	1	
T1		Safety switching device	1	
T2		Functional PLC	1	
T3, T4, T5	CMMT-AS-...-S1	Servo drive	3	Festo

### 1.3.3 Description

Application	Servo drive with servo motor without external forces, e.g. horizontal axis
Triggering event	Safety request (S2), e.g. by emergency stop switch, safety gate
Reaction (Safety function)	<p><b>Stopping at safety request using the safety sub-function “safe stop 1 time controlled (SS1-t)” with the safe state “safe torque off (STO)”, category 4, up to PL e</b></p> 
Safe state	<p>The servo motors (M20, M21, M22) are functionally stopped and after an application-specific time no energy is supplied to the servo motors (M20, M21, M22) that can generate a force and a movement. It is presumed that this state of the servo motors (M20, M21, M22) is the safe state.</p> <p>Notes:</p> <ul style="list-style-type: none"> <li>Stopping the servo motors (M20, M21, M22) is functional and is not safety-rated, i.e. if the movement is not stopped in the event of a fault, additional measures may be required, e.g. end position damping for linear axes.</li> <li>If external forces act on the servomotor, e.g. in the case of vertical axes, the request for the safety sub-function STO can result in a dangerous movement. Then additional measures may be necessary, e.g. a holding brake.</li> <li>For the wiring between safety switching device (T2) and servo drives (T3, T4, T5), fault exclusions on short circuits and cross circuits, e.g. according to ISO 13849-2 [4], Table D.4, are required. The preconditions for these are that the safety switching device (T2) and the servo drives (T3, T4, T5) are located in the same control cabinet and that the control cabinet meets the requirements of EN 60204-1 [3].</li> </ul>
Function of the circuit	<p>Due to the safety request (S2):</p> <ol style="list-style-type: none"> <li>The input circuit of the safety switching device (T1) is interrupted.</li> <li>The output (Q5) of the safety switching device (T1) is then switched off.</li> <li>The input “output stage enable (CTRL-EN)” of the servo drives (T3, T4, T5) is no longer controlled. This causes the servo drives (T3, T4, T5) to functionally deaccelerate the motor with the braking ramp. This corresponds to a behaviour of stop category 1 according to EN 60204-1 [3]. After the end of the braking ramp, the output stage is functionally switched off.</li> <li>The outputs (Q6, Q7) of the safety switching device (T1) are then switched off with a time delay. The required time delay must be determined depending on the specific application.</li> <li>The inputs “Safe torque off, channel A and B (#STO-A, #STO-B)” of the servo drive (T3) are no longer controlled. This switch off the control of the output stage and requests the safety sub-function STO.</li> </ol>

Manual reset function	<ol style="list-style-type: none"> <li>1. After resetting the safety request (S2), e.g. by mechanically unlocking the emergency stop switch or closing the safety gate, the start or restart can be made possible by actuating the acknowledgement button (S1).</li> <li>2. The safety switching device (T1) controls via the outputs (Q6, Q7) the servo drive (T3). This makes it possible to control the power output stage again and the STO safety sub-function is no longer active.</li> <li>3. The safety switching device (T1) permits the control of the “output stage enable (CTRL-EN)” via the functional control (T2) again via the output (Q5). Normal operation is then possible by pressing the start push button (S20).</li> </ol>
Diagnosis	<p>The diagnostic outputs STA reports the status of the safety sub-function STO to the safety switching device (T1). Diagnosis is performed via the safety switching device (T1):</p> <ul style="list-style-type: none"> <li>• If the outputs (Q6, Q7) of the safety switching device (T1) are switched off with a time delay, the safety sub-function STO is requested via the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5). After the typical time for the servo drive, the output (STA) is switched on. This diagnostic feedback delay can be monitored for a minimum permissible time and must be monitored for a maximum permissible time by the safety switching device (T1).</li> <li>• If the outputs (Q6, Q7) of the safety switching device (T1) are switched on, the safety sub-function STO is disabled via the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5). After the typical time for the servo drive, the output (STA) is switched off. This diagnostic feedback delay can be monitored for a minimum permissible time and must be monitored for a maximum permissible time by the safety switching device (T1).</li> </ul> <p>If a fault is detected by the diagnosis, a suitable fault reaction must be carried out by the safety switching device (T1). It is common that the machine is brought into a safe state and further operation is prevented.</p>

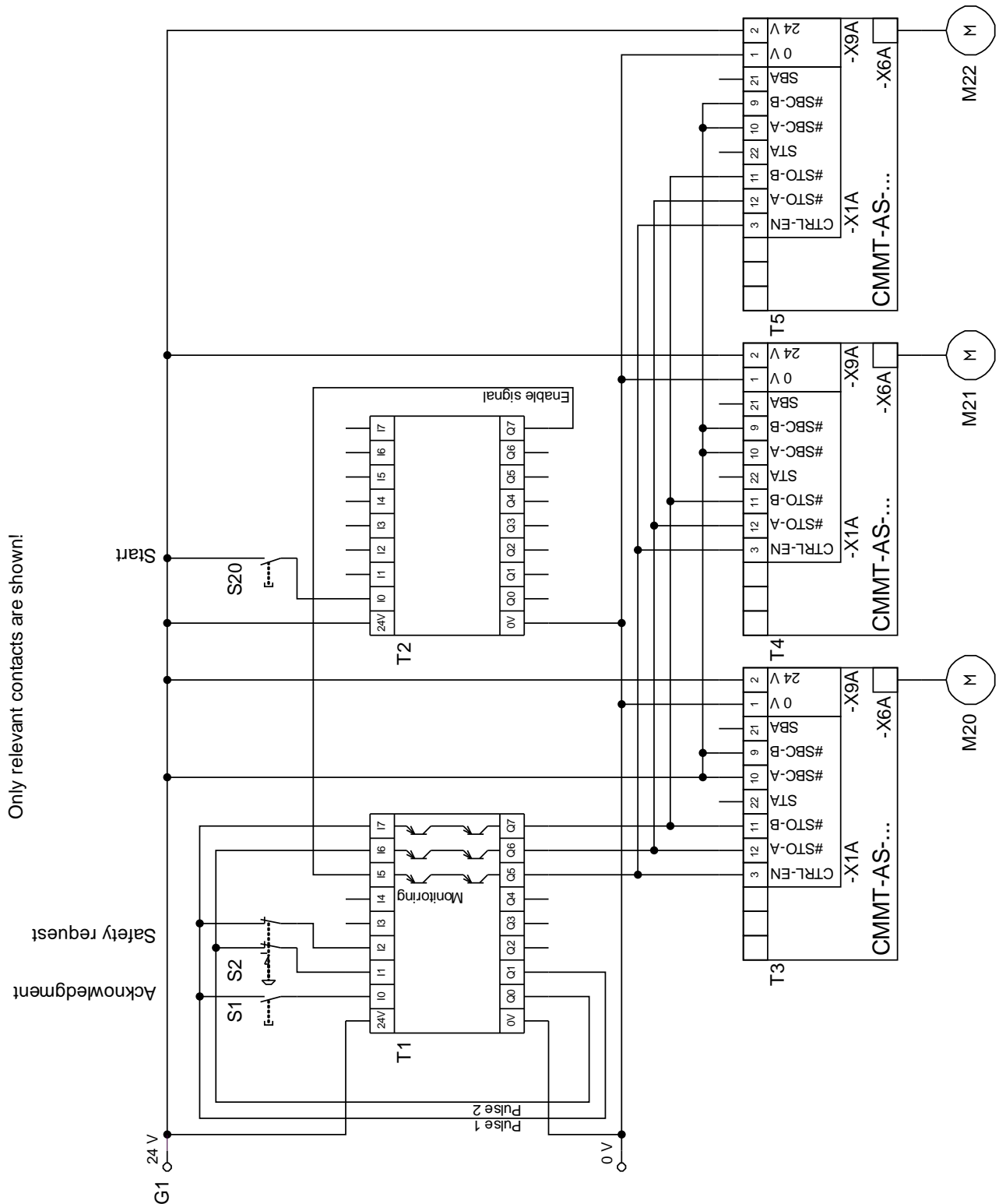
#### 1.3.4 Safety Considerations

Input	Safety considerations must be carried out in accordance with the selected safety commanding device (S2).
Logic	<p>Safety considerations must be carried out in accordance with the selected safety switching device (T1).</p> <p>Notes:</p> <ul style="list-style-type: none"> <li>• The outputs (Q6, Q7) of the safety switching device (T1) for switching the signals for the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5) are contact outputs without short-circuit and cross-circuit detection.</li> <li>• The outputs (Q6, Q7) of the safety switching device (T1) including the necessary time delay must be suitable for PL e, category 4.</li> </ul>
Output	<p>The intended use of the servo drives (T3, T4, T5) includes the safety sub-function STO with category 4, up to PL e, with cross wiring. The PL, category and PFH<sub>D</sub> values of the servo drive (T3) required to determine the reliability of the overall circuit must be available.</p> <p>Note:</p> <ul style="list-style-type: none"> <li>• For the circuit shown in this document, the safety reference data of the servo drive (T3) “without high test pulses, without or with STA evaluation” can be selected.</li> </ul>

## 1.4 SS1-t, STO with CMMT-AS-...-S1, electronic outputs, without STA evaluation

- SS1-t, STO, category 3, up to PL d
- Safety switching device with electronic outputs
- Without evaluation STA

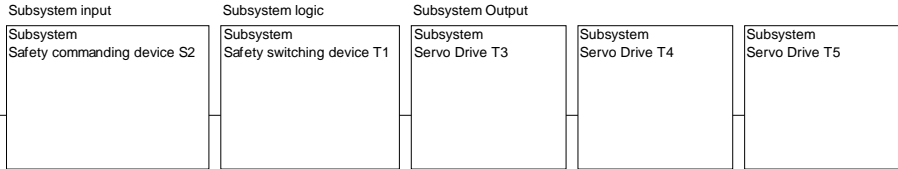
### 1.4.1 Circuit Diagram



### 1.4.2 Components

Component	Type (Part Number)	Description / Remarks	Qty.	Mssr.
M20, M21, M22	EMM...-AS	Servo motor	3	Festo
S1		Acknowledge push button	1	
S2		Safety commanding device, e.g. emergency stop switch	1	
S20		Start push button	1	
T1		Safety switching device	1	
T2		Functional PLC	1	
T3, T4, T5	CMMT-AS-...-S1	Servo drive	3	Festo

### 1.4.3 Description

Application	Servo drives with servo motors without external forces, e.g. horizontal axis
Triggering event	Safety request (S2), e.g. by emergency stop switch, safety gate
Reaction (Safety function)	<p><b>Stopping at safety request using the safety sub-function “safe stop 1 time controlled (SS1-t)” with the safe state “safe torque off (STO)”, category 3, up to PL d</b></p> 
Safe state	<p>The servo motors (M20, M21, M22) are functionally stopped and after an application-specific time no energy is supplied to the servo motors (M20, M21, M22) that can generate a force and a movement. It is presumed that this state of the servo motors (M20, M21, M22) is the safe state.</p> <p>Notes:</p> <ul style="list-style-type: none"> <li>Stopping the servo motors (M20, M21, M22) is functional and is not safety-rated, i.e. if the movement is not stopped in the event of a fault, additional measures may be required, e.g. end position damping for linear axes.</li> <li>If external forces act on the servomotor, e.g. in the case of vertical axes, the request for the safety sub-function STO can result in a dangerous movement. Then additional measures may be necessary, e.g. a holding brake.</li> </ul>
Function of the circuit	<p>Due to the safety request (S2):</p> <ol style="list-style-type: none"> <li>The input circuit of the safety switching device (T1) is interrupted.</li> <li>The output (Q5) of the safety switching device (T1) is then switched off.</li> <li>The input “output stage enable (CTRL-EN)” of the servo drives (T3, T4, T5) is no longer controlled. This causes the servo drives (T3, T4, T5) to functionally decelerate the motor with the braking ramp. This corresponds to a behaviour of stop category 1 according to EN 60204-1 [3]. After the end of the braking ramp, the output stage is functionally switched off.</li> <li>The outputs (Q6, Q7) of the safety switching device (T1) are then switched off with a time delay. The required time delay must be determined depending on the specific application.</li> <li>The inputs “Safe torque off, channel A and B (#STO-A, #STO-B)” of the servo drives (T3, T4, T5) are no longer controlled. This switch off the control of the output stage and requests the safety sub-function STO.</li> </ol>
Manual reset function	<ol style="list-style-type: none"> <li>After resetting the safety request (S2), e.g. by mechanically unlocking the emergency stop switch or closing the safety gate, the start or restart can be made possible by actuating the acknowledgement button (S1).</li> </ol>

	<ol style="list-style-type: none"> <li>2. The safety switching device (T1) controls via the outputs (Q6, Q7) the servo drives (T3, T4, T5). This makes it possible to control the power output stage again and the STO safety sub-function is no longer active.</li> <li>3. The safety switching device (T1) permits the control of the “output stage enable (CRTL-EN)” via the functional control (T2) again via the output (Q5). Normal operation is then possible by pressing the start push button (S20).</li> </ol>
Diagnosis	The diagnostic outputs (STA) must not be evaluated for the specified category and PL.

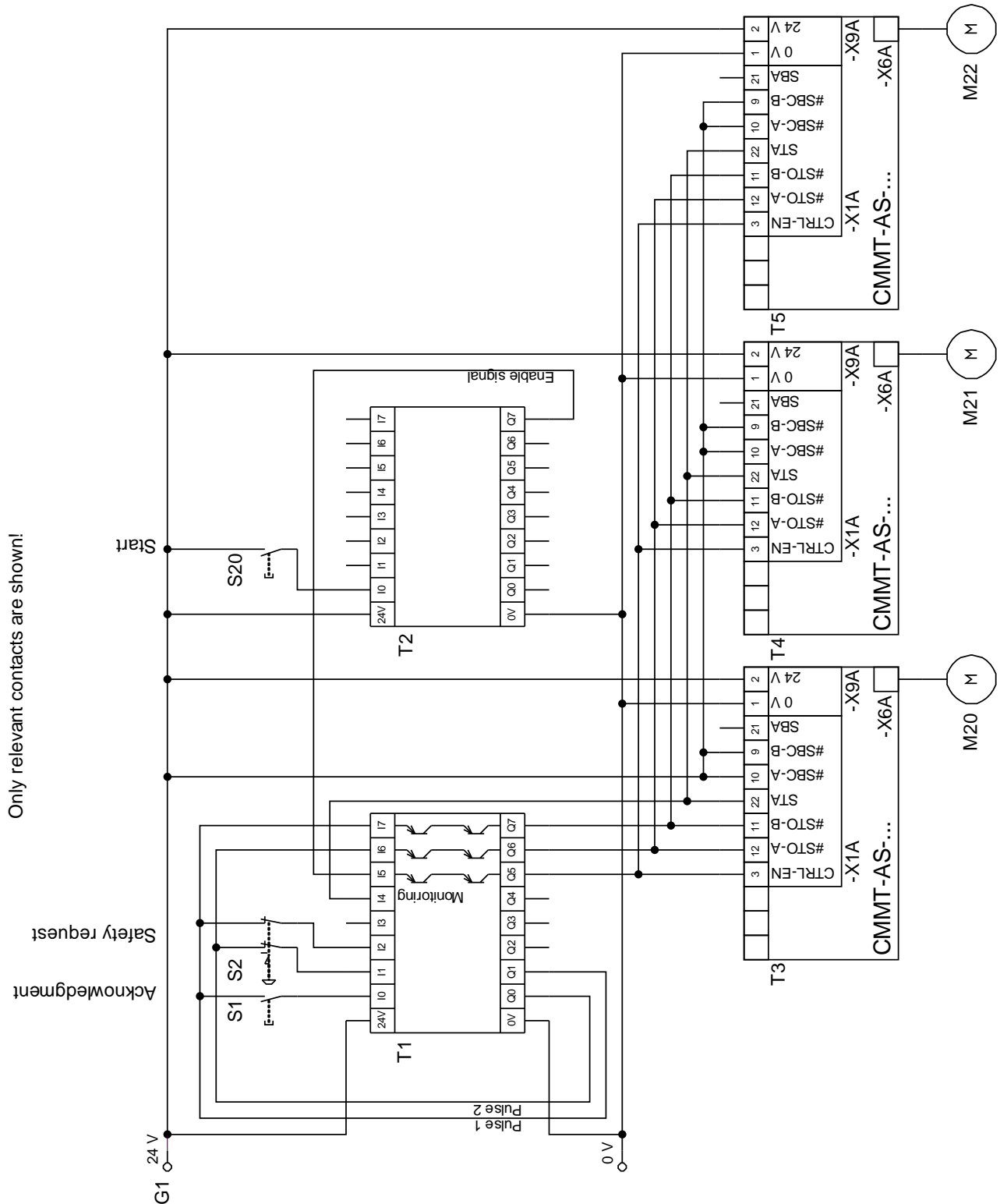
#### 1.4.4 Safety Considerations

Input	Safety considerations must be carried out in accordance with the selected safety commanding device (S2).
Logic	<p>Safety considerations must be carried out in accordance with the selected safety switching device (T1).</p> <p>Notes:</p> <ul style="list-style-type: none"> <li>• The outputs (Q6, Q7) of the safety switching device (T1) for switching the signals for the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5) are electronic outputs with short-circuit and cross-circuit detection with low test pulses. It is presumed that no high test pulses are configured for the safety switching device (T1).</li> <li>• The outputs (Q6, Q7) of the safety switching device (T1) including the necessary time delay must be suitable for PL d, category 3.</li> </ul>
Output	<p>The intended use of the servo drive (T3) includes the safety sub-function STO with category 3, up to PL d, with cross wiring. The PL, category and PFH<sub>D</sub> values of the servo drives (T3, T4, T5) required to determine the reliability of the overall circuit must be available.</p> <p>Note:</p> <ul style="list-style-type: none"> <li>• For the circuit shown in this document, the safety reference data of the servo drive (T3, T4, T5) “without high test pulses and without STA evaluation” can be selected.</li> <li>• This proposal deviates from the highly recommended circuit in the operating instructions for wiring of the diagnostic outputs. As a result, only 1-fault safety is possible, so that STO can only be implemented with category 3 and up to PL d.</li> </ul>

## 1.5 SS1-t, STO with CMMT-AS-...-S1, electronic outputs, with STA evaluation

- SS1-t, STO, category 3, up to PL d
- Safety switching device with electronic outputs
- With evaluation STA

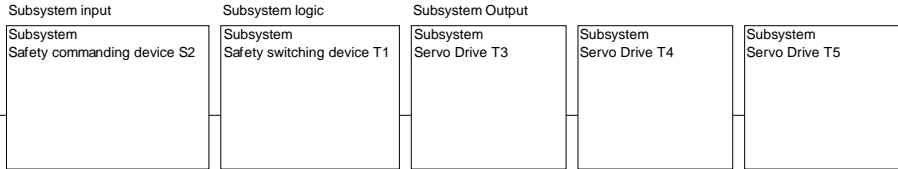
### 1.5.1 Circuit Diagram



### 1.5.2 Components

Component	Type (Part Number)	Description / Remarks	Qty.	Mssr.
M20, M21, M22	EMM...-AS	Servo motor	3	Festo
S1		Acknowledge push button	1	
S2		Safety commanding device, e.g. emergency stop switch	1	
S20		Start push button	1	
T1		Safety switching device	1	
T2		Functional PLC	1	
T3, T4, T5	CMMT-AS-...-S1	Servo drive	3	Festo

### 1.5.3 Description

Application	Servo drives with servo motors without external forces, e.g. horizontal axis
Triggering event	Safety request (S2), e.g. by emergency stop switch, safety gate
Reaction (Safety function)	<p><b>Stopping at safety request using the safety sub-function “safe stop 1 time controlled (SS1-t)” with the safe state “safe torque off (STO)”, category 3, up to PL d</b></p> 
Safe state	<p>The servo motors (M20, M21, M22) are functionally stopped and after an application-specific time no energy is supplied to the servo motors (M20, M21, M22) that can generate a force and a movement. It is presumed that this state of the servo motors (M20, M21, M22) is the safe state.</p> <p>Notes:</p> <ul style="list-style-type: none"> <li>Stopping the servo motors (M20, M21, M22) is functional and is not safety-rated, i.e. if the movement is not stopped in the event of a fault, additional measures may be required, e.g. end position damping for linear axes.</li> <li>If external forces act on the servomotor, e.g. in the case of vertical axes, the request for the safety sub-function STO can result in a dangerous movement. Then additional measures may be necessary, e.g. a holding brake.</li> </ul>
Function of the circuit	<p>Due to the safety request (S2):</p> <ol style="list-style-type: none"> <li>The input circuit of the safety switching device (T1) is interrupted.</li> <li>The output (Q5) of the safety switching device (T1) is then switched off.</li> <li>The input “output stage enable (CTRL-EN)” of the servo drives (T3, T4, T5) is no longer controlled. This causes the servo drives (T3, T4, T5) to functionally deaccelerate the motor with the braking ramp. This corresponds to a behaviour of stop category 1 according to EN 60204-1 [3]. After the end of the braking ramp, the output stage is functionally switched off.</li> <li>The outputs (Q6, Q7) of the safety switching device (T1) are then switched off with a time delay. The required time delay must be determined depending on the specific application.</li> <li>The inputs “Safe torque off, channel A and B (#STO-A, #STO-B)” of the servo drives (T3, T4, T5) are no longer controlled. This switch off the control of the output stage and requests the safety sub-function STO.</li> </ol>
Manual reset function	<ol style="list-style-type: none"> <li>After resetting the safety request (S2), e.g. by mechanically unlocking the emergency stop switch or closing the safety gate, the start or restart can be made possible by actuating the acknowledgement button (S1).</li> </ol>

	<ol style="list-style-type: none"> <li>The safety switching device (T1) controls via the outputs (Q6, Q7) the servo drives (T3, T4, T5). This makes it possible to control the power output stage again and the STO safety sub-function is no longer active.</li> <li>The safety switching device (T1) permits the control of the “output stage enable (CRTL-EN)” via the functional control (T2) again via the output (Q5). Normal operation is then possible by pressing the start push button (S20).</li> </ol>
Diagnosis	<p>The diagnostic output STA reports the status of the safety sub-function STO to the safety switching device (T1). Diagnosis is performed via the safety switching device (T1):</p> <ul style="list-style-type: none"> <li>If the outputs (Q6, Q7) of the safety switching device (T1) are switched off, the safety sub-function STO is requested via the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5). After the typical time for the servo drive, the output (STA) is switched on. This diagnostic feedback delay can be monitored for a minimum permissible time and must be monitored for a maximum permissible time by the safety switching device (T1).</li> <li>If the outputs (Q6, Q7) of the safety switching device (T1) are switched on, the safety sub-function STO is disabled via the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5). After the typical time for the servo drive, the output (STA) is switched off. This diagnostic feedback delay can be monitored for a minimum permissible time and must be monitored for a maximum permissible time by the safety switching device (T1).</li> </ul> <p>If a fault is detected by the diagnosis, a suitable fault reaction must be carried out by the safety switching device (T1). It is common that the machine is brought into a safe state and further operation is prevented.</p>

#### 1.5.4 Safety Considerations

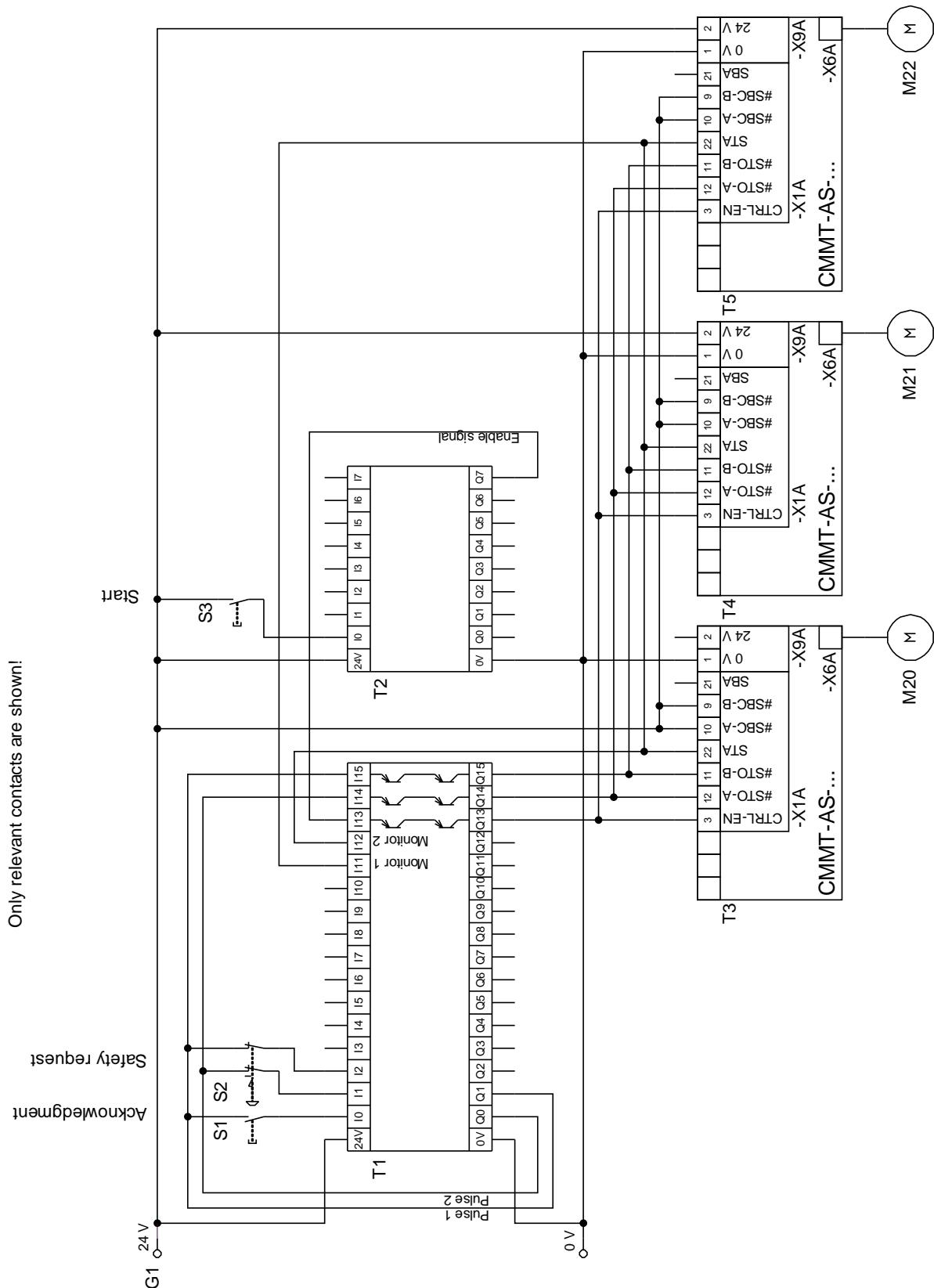
Input	Safety considerations must be carried out in accordance with the selected safety commanding device (S2).
Logic	<p>Safety considerations must be carried out in accordance with the selected safety switching device (T1).</p> <p>Notes:</p> <ul style="list-style-type: none"> <li>The outputs (Q6, Q7) of the safety switching device (T1) for switching the signals for the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5) are electronic outputs with short-circuit and cross-circuit detection with low test pulses. It is presumed that no high test pulses are configured for the safety switching device (T1).</li> <li>The outputs (Q6, Q7) of the safety switching device (T1) including the necessary time delay must be suitable for PL d, category 3.</li> </ul>
Output	<p>The intended use of the servo drive (T3) includes the safety sub-function STO with category 3, up to PL d, with cross wiring. The PL, category and PFH<sub>0</sub> values of the servo drives (T3, T4, T5) required to determine the reliability of the overall circuit must be available.</p> <p>Note:</p> <ul style="list-style-type: none"> <li>For the circuit shown in this document, the safety reference data of the servo drive (T3, T4, T5) “without high test pulses and without STA evaluation” can be selected.</li> <li>This proposal deviates from the highly recommended circuit in the operating instructions for wiring of the diagnostic outputs. As a result, only 1-fault safety is possible, so that STO can only be implemented with category 3 and up to PL d.</li> </ul>



## 1.6 SS1-t, STO with CMMT-AS-...-S1, safety PLC, with STA evaluation

- SS1-t, STO, category 4, up to PL e
- Safety PLC with electronic outputs
- With high test pulses (see glossary)
- With evaluation STA

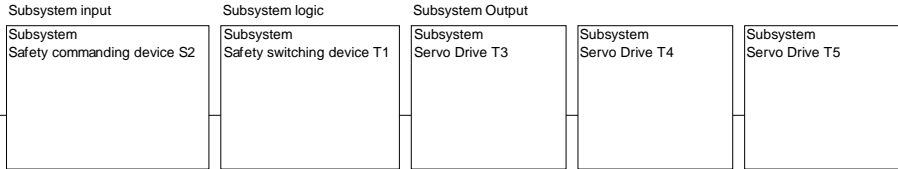
### 1.6.1 Circuit Diagram



### 1.6.2 Components

Component	Type (Part Number)	Description / Remarks	Qty.	Mssr.
M20, M21, M22	EMM...-AS	Servo motor	3	Festo
S1		Acknowledge push button	1	
S2		Safety commanding device, e.g. emergency stop switch	1	
S20		Start push button	1	
T1		Safety PLC	1	
T2		Functional PLC	1	
T3, T4, T5	CMMT-AS-...-S1	Servo drive	3	Festo

### 1.6.3 Description

Application	Servo drives with servo motors without external forces, e.g. horizontal axis
Triggering event	Safety request (S2), e.g. by emergency stop switch, safety gate
Reaction (Safety function)	<p><b>Stopping at safety request using the safety sub-function “safe stop 1 time controlled (SS1-t)” with the safe state “safe torque off (STO)”, category 4, up to PL e</b></p> 
Safe state	<p>The servo motors (M20, M21, M22) are functionally stopped and after an application-specific time no energy is supplied to the servo motors (M20, M21, M22) that can generate a force and a movement. It is presumed that this state of the servo motors (M20, M21, M22) is the safe state.</p> <p>Notes:</p> <ul style="list-style-type: none"> <li>Stopping the servo motors (M20, M21, M22) is functional and is not safety-rated, i.e. if the movement is not stopped in the event of a fault, additional measures may be required, e.g. end position damping for linear axes.</li> <li>If external forces act on the servomotor, e.g. in the case of vertical axes, the request for the safety sub-function STO can result in a dangerous movement. Then additional measures may be necessary, e.g. a holding brake.</li> </ul>
Function of the circuit	<p>Due to the safety request (S2):</p> <ol style="list-style-type: none"> <li>The input circuit of the safety PLC (T1) is interrupted.</li> <li>The output (Q5) of the safety PLC (T1) is then switched off.</li> <li>The input “output stage enable (CTRL-EN)” of the servo drives (T3, T4, T5) is no longer controlled. This causes the servo drives (T3, T4, T5) to functionally decelerate the motor with the braking ramp. This corresponds to a behaviour of stop category 1 according to EN 60204-1 [3]. After the end of the braking ramp, the output stage is functionally switched off.</li> <li>The outputs (Q6, Q7) of the safety PLC (T1) are then switched off with a time delay. The required time delay must be determined depending on the specific application.</li> <li>The inputs “Safe torque off, channel A and B (#STO-A, #STO-B)” of the servo drives (T3, T4, T5) are no longer controlled. This switches off the control of the output stage and requests the safety sub-function STO.</li> </ol>
Manual reset function	<ol style="list-style-type: none"> <li>After resetting the safety request (S2), e.g. by mechanically unlocking the emergency stop switch or closing the safety gate, the start or restart can be made possible by actuating the acknowledgement button (S1).</li> <li>The safety PLC (T1) controls via the outputs (Q6, Q7) the servo drives (T3, T4, T5). This makes it possible to control the power output stage again and the STO safety sub-function is no longer active.</li> </ol>

	3. The safety PLC (T1) permits the control of the “output stage enable (CTRL-EN)” via the functional control (T2) again via the output (Q5). Normal operation is then possible by pressing the start push button (S20).
Diagnosis	<p>The diagnostic output STA reports the status of the safety sub-function STO to the safety PLC (T1). All STA diagnostic outputs of the servo drive controllers (T3, T4, T5) are connected via a ring line so that category 4 requirements can be met. Diagnosis is performed via a safe input of the safety PLC (T1), which fulfils the requirements for category 4, PL e.</p> <ul style="list-style-type: none"> <li>• If the outputs (Q6, Q7) of the safety PLC (T1) are switched off, the safety sub-function STO is requested via the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5). After the typical time for the servo drive, the output (STA) is switched on. This diagnostic feedback delay can be monitored for a minimum permissible time and must be monitored for a maximum permissible time by the safety PLC (T1) with the Inputs (I11, I12).</li> <li>• If the outputs (Q6, Q7) of the safety PLC (T1) are switched on, the safety sub-function STO is disabled via the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5). After the typical time for the servo drive, the output (STA) is switched off. This diagnostic feedback delay can be monitored for a minimum permissible time and must be monitored for a maximum permissible time by the safety PLC (T1) with the Inputs (I11, I12).</li> <li>• The inputs (I11, I12) of the safety PLC (T1) for monitoring must be monitored for signal change discrepancy.</li> </ul> <p>If a fault is detected by the diagnosis, a suitable fault reaction must be carried out by the safety PLC (T1). It is common that the machine is brought into a safe state and further operation is prevented.</p>

#### 1.6.4 Safety Considerations

Input	Safety considerations must be carried out in accordance with the selected safety commanding device (S2).
Logic	<p>Safety considerations must be carried out in accordance with the selected safety PLC (T1).</p> <p>Notes:</p> <ul style="list-style-type: none"> <li>• The inputs (I11, I12) of the safety PLC (T1) are the monitoring of the ring line of the diagnostic signal STA of the servo drives (T3, T4, T5).</li> <li>• The inputs (I11, I12) of the safety PLC (T1) must be suitable for PL e, category 4.</li> <li>• The outputs (Q6, Q7) of the safety PLC (T1) for switching the signals for the inputs (#STO-A, #STO-B) of the servo drives (T3, T4, T5) are electronic outputs with short-circuit and cross-circuit detection with low and high test pulses.</li> <li>• The outputs (Q6, Q7) of the safety PLC (T1) including the necessary time delay must be suitable for PL e, category 4.</li> </ul>
Output	<p>The intended use of the servo drive (T3) includes the safety sub-function STO with category 4, up to PL e, with cross wiring. The PL, category and PFH<sub>D</sub> values of the servo drive (T3) required to determine the reliability of the overall circuit must be available.</p> <p>Note:</p> <ul style="list-style-type: none"> <li>• For the circuit shown in this document, the safety reference data of the servo drive (T3) “with high test pulses and with STA evaluation” can be selected.</li> </ul>

## 2 Glossary

### Low Test Pulses

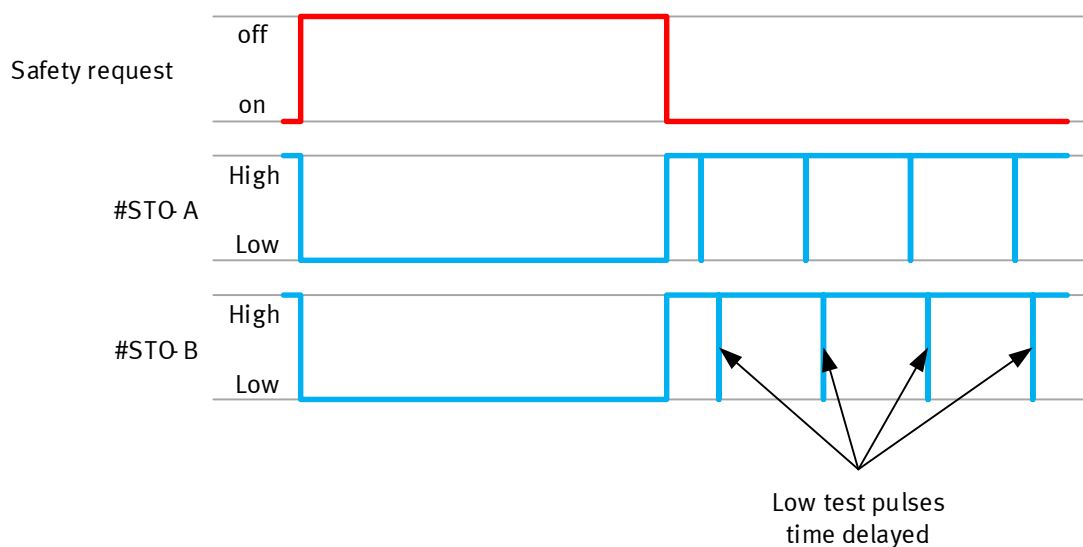
Low test pulses use a safety switching device to test its safe electronic outputs for their functionality. These low-test pulses are also used to detect short circuits and cross-circuits.

The safety switching device (T1) can cyclically test its outputs for the signals #STO-A and #STO-B at high level with low test pulses.

If the safety requirement is switched off (high level), the safety switching device regularly checks whether it can switch off any electronic outputs. To do this, the high level is lowered to the low level and after a certain time the safety switching device checks whether the electronic output has actually switched off. Then the low level is raised again to the high level.

If an error occurs during this functional test, the safety switching device issues an fault message and usually brings the application into a safe state.

The low test pulses are output by the safety switching device for the outputs of the signals #STO-A and #STO-B time-delayed.



#### Notes:

- The electronic outputs of safety switching devices usually have these low-test pulses.
- With safety relays, the low-test pulses usually have a duration of up to 1 ms.
- With safety PLCs, the duration of the low-test pulses is usually configurable.
- Depending on the manufacturer of the safety switching device, low-test pulses may also have other designations, e.g. shutdown test, dark test, etc.
- It is recommended that low-resistance and low-capacitance wiring be used.

## High Test Pulses

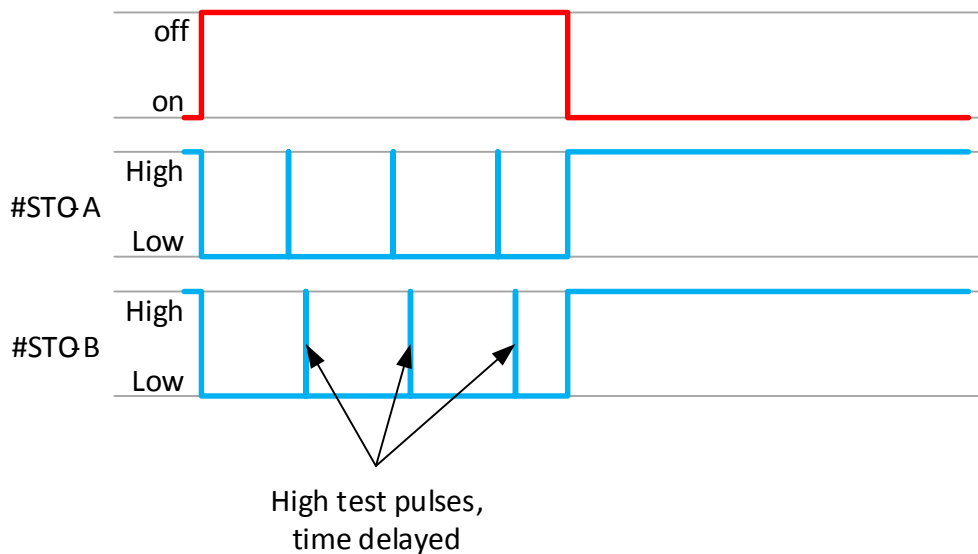
High test pulses can use some safety controllers to test their safe electronic outputs for certain functions.

The safety switching device (T1) can cyclically test the signals #STO-A and #STO-B at low levels with high test pulses.

If the safety sub-function STO is switched on (low signal), the safety switching device checks whether it can switch on its electronic outputs. For this purpose, the low level is raised to the high level and after a certain time it is checked whether the electronic output has actually been switched on. Then the high level is lowered again to the low level.

If an error occurs during this functional test, the safety switching device issues a fault message and usually brings the application into a safe state.

The high test pulses are output by the safety switching device for the outputs of the signals #STO-A and #STO-B time-delayed.



Notes:

- The safety relays usually have no high test pulses.
- Safety PLCs can have electronic outputs with high test pulses.
- With safety PLCs, the duration of the high test pulses is usually configurable.
- Depending on the manufacturer of the safety switching device, high test pulses can also have other designations, e.g. bright test.
- It is recommended to ensure low-resistance and low-capacitance wiring.

## 3 Literature

- [1] DIN EN 61800-5-2:2017-11 - Adjustable speed electrical power drive systems - Part 5-2: Safety requirements - Functional (IEC 61800-5-2:2016); German version EN 61800-5-2:2017
- [2] DIN EN ISO 13849-1:2016-06 - Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design (ISO 13849-1:2015); German version EN ISO 13849-1:2015
- [3] DIN EN 60204-1:2007-06 - Safety of machinery - Electrical equipment of machines - Part 1: General requirements (IEC 60204-1:2005, modified); German version EN 60204-1:2006
- [4] DIN EN ISO 13849-2:2013-02 - Safety of machinery - Safety-related parts of control systems - Part 2: Validation (ISO 13849-2:2012); German version EN ISO 13849-2:2012