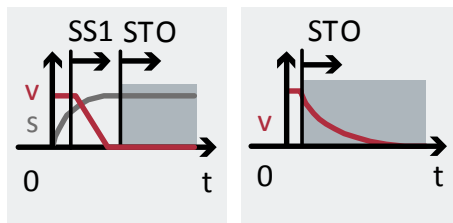


Safety Sub-Functions SS1-t, STO Servo Drive CMMT-ST-...-S0



Application Note
CMMT-ST-...-S0,
SS1-t, STO

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The actual characteristic values that can be obtained (especially PL, PFH_D, category, DC, MTT_D, CCF) depend on the components used, as well as their conditions of use in the actual application.

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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

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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-ST-C8-1C-...-S0”. This description is available on the Internet http://ademsp00.de.festo.net/net/de_de/SupportPortal/Downloads/544124/629414/CMMT-ST-C8-1C-_-S0_description_2019-01_8097120g1.pdf
 - Description “Safety sub-function STO, SS1-t” for servo drive CMMT-ST-C8-1C-...-S0. This description is available on the Internet http://ademsp00.de.festo.net/net/de_de/SupportPortal/Downloads/544132/629421/CMMT-ST-C8-1C-_-S0_description_2019-01_8097129g1.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:

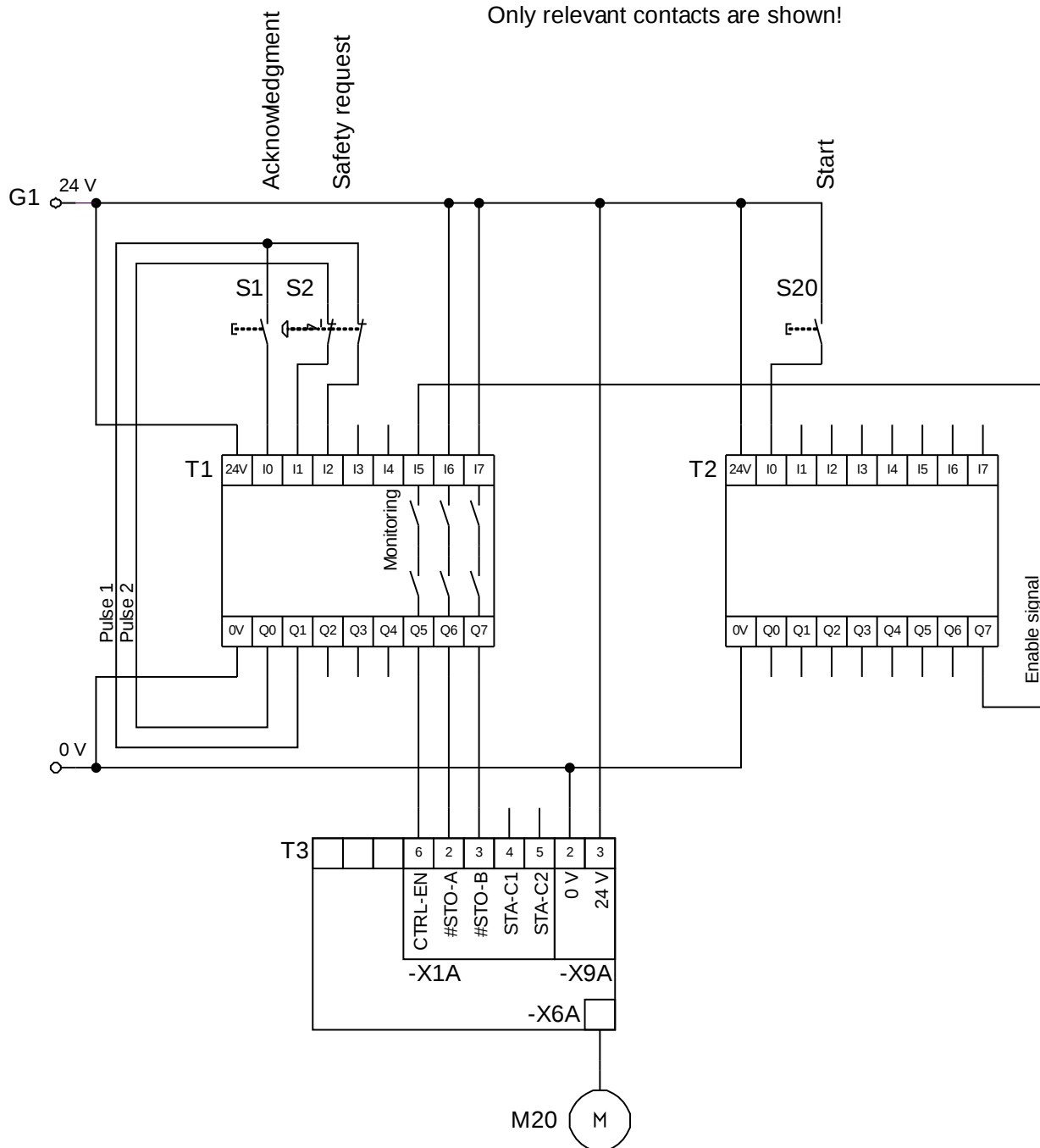
- Use of safe outputs of the safety switching device (T1) with contact outputs without short-circuit and cross-circuit detection or electronic outputs with short-circuit and cross-circuit detection.
- With or without evaluation of the diagnostic signal of the servo drive (T3) by the safety switching 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 3	Stepper motor: Category 3, up to PL e EC motor: Category 3, up to PL d	Fault exclusions for wiring in the 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 3	Category 3, up to PL e	Fault exclusions for wiring in the 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 3	Stepper motor: Category 3, up to PL e EC motor: 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 3	Category 3, up to PL e	

1.2 SS1-t, STO with CMMT-ST-...-S0, contact outputs, without STA evaluation

- With stepper motors: SS1-t, STO, category 3, up to PL e
- With EC motors: SS1-t, STO, category 3, up to PL d
- Safety switching device with contact outputs
- Without evaluation STA
- Fault exclusion control cabinet necessary

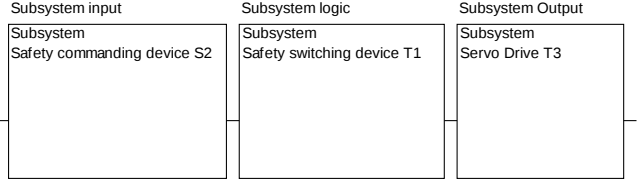
1.2.1 Circuit Diagram



1.2.2 Components

Component	Type (Part Number)	Description / Remarks	Qty.	Mssr.
M20	EMM...-ST	Stepper motor (or EC motor)	1	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	CMMT-ST-...-S0	Servo drive	1	Festo

1.2.3 Description

Application	Servo drive with stepper motor or EC motor without external forces, e.g. horizontal axis
Triggering event	Safety request (S2), e.g. by emergency stop switch, safety gate
Reaction (Safety function)	Stopping at safety request by using safety sub-function “safe stop 1 time controlled (SS1-t)” with the safe state “safe torque off (STO)”, With stepper motors: category 3, up to PL e With EC motors: category 3, up to PL d 
Safe state	The electric motor (M20) is functionally stopped and after an application-specific time no energy is supplied to the electric motor (M20) that can generate a force and a movement. It is presumed that this state of the electric motor (M20) is the safe state. Notes: - Stopping the electric motor (M20) 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. - If external forces act on the electric motor, 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. - For the wiring between safety switching device (T2) and servo drive (T3), 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 drive (T3) are located in the same control cabinet and that the control cabinet meets the requirements of EN 60204-1 [3].
Function of the circuit	Due to the safety request (S2): - The input circuit of the safety switching device (T1) is interrupted. - The output (Q5) of the safety switching device (T1) is then switched off. - The input “output stage enable (CTRL-EN)” of the servo drive (T3) is no longer controlled. This causes the servo drive (T3) 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. - 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. - 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.

Manual reset function	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). 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. 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).
Diagnosis	The diagnostic output (STA) does not have to be evaluated for the specified category and PL.

1.2.4 Safety Considerations

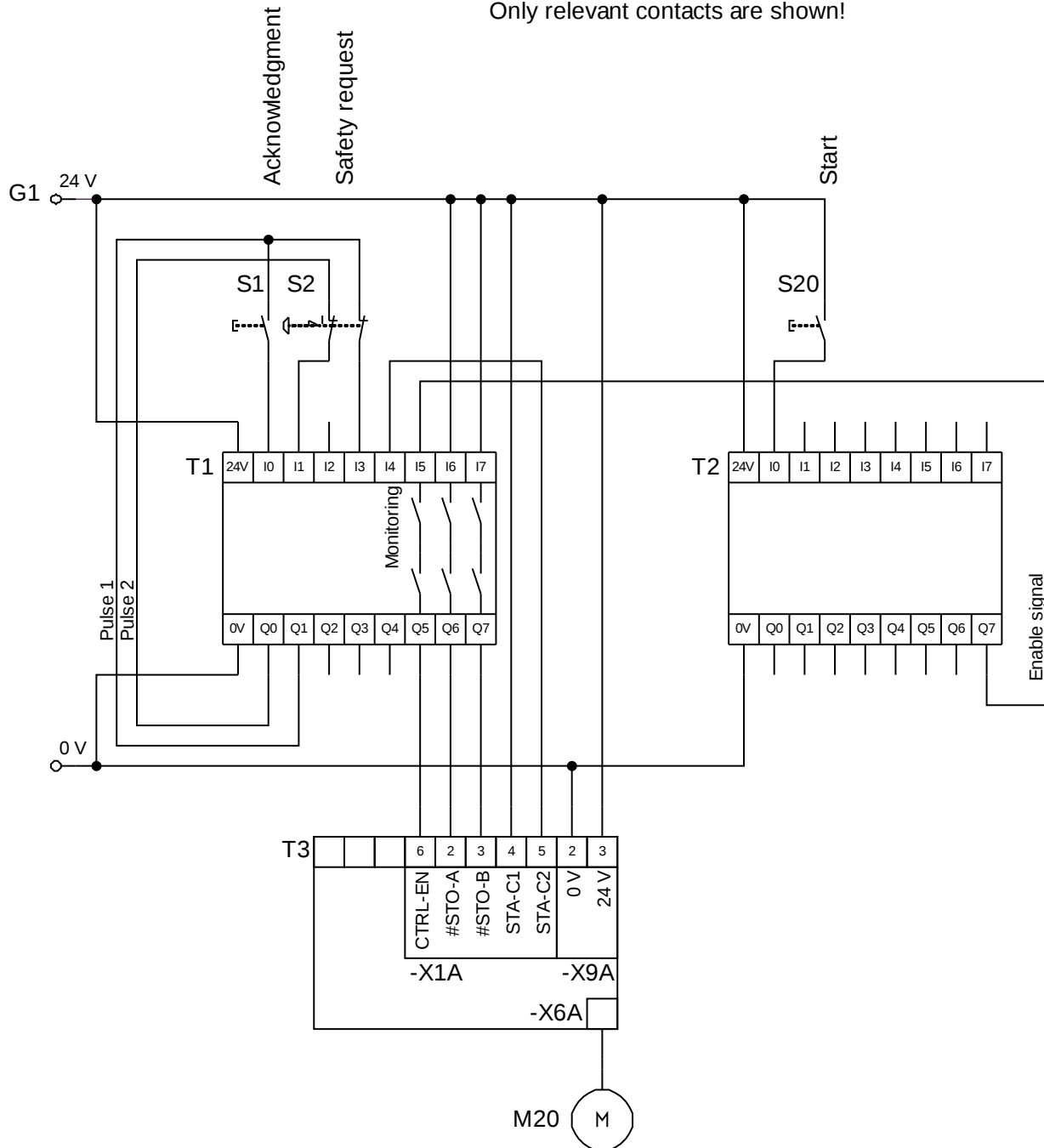
Input	Safety considerations must be carried out in accordance with the selected safety commanding device (S2).
Logic	Safety considerations must be carried out in accordance with the selected safety switching device (T1). Notes: • The outputs (Q6, Q7) of the safety switching device (T1) for switching the signals for the inputs (#STO-A, #STO-B) of the servo drive (T3) are contact outputs without short-circuit and cross-circuit detection. • The outputs (Q6, Q7) of the safety switching device (T1) including the necessary time delay must be suitable for PL e, category 3 when using a stepper motor or PL d, category 3 when using an EC motor.
Output	The intended use of the servo drive (T3) includes the safety sub-function STO with category 3, up to PL e when using a stepper motor or PL d, category 3 when using an EC motor. The PL, category and PFH_D values of the servo drive (T3) required to determine the reliability of the overall circuit must be available. Note: • Depending on the electric motor used, the corresponding safety reference data of the servo drive (T3) must be selected: Either the safety reference data for “stepper motor” or “EC motors without evaluation of STA”.

1.3 SS1-t, STO with CMMT-ST-...-S0, contact outputs, with STA evaluation

- SS1-t, STO, category 3, up to PL e
- Safety switching device with contact outputs
- With evaluation STA
- Fault exclusion control cabinet necessary

1.3.1 Circuit Diagram

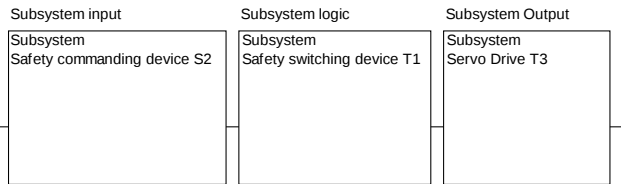
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1.3.2 Components

Component	Type (Part Number)	Description / Remarks	Qty.	Mssr.
M20	EMM...-ST	Stepper motor (or EC motor)	1	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	CMMT-ST-...-S0	Servo drive	1	Festo

1.3.3 Description

Application	Servo drive with stepper motor or EC motor without external forces, e.g. horizontal axis
Triggering event	Safety request (S2), e.g. by emergency stop switch, safety gate
Reaction (Safety function)	Stopping at safety request by using safety sub-function “safe stop 1 time controlled (SS1-t)” with the safe state “safe torque off (STO)”, category 3, up to PL e 
Safe state	The electric motor (M20) is functionally stopped and after an application-specific time no energy is supplied to the electric motor (M20) that can generate a force and a movement. It is presumed that this state of the electric motor (M20) is the safe state. Notes: - Stopping the electric motor (M20) 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. - If external forces act on the electric motor, 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. - For the wiring between safety switching device (T2) and servo drive (T3), 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 drive (T3) are located in the same control cabinet and that the control cabinet meets the requirements of EN 60204-1 [3].
Function of the circuit	Due to the safety request (S2): - The input circuit of the safety switching device (T1) is interrupted. - The output (Q5) of the safety switching device (T1) is then switched off. - The input “output stage enable (CTRL-EN)” of the servo drive (T3) is no longer controlled. This causes the servo drive (T3) 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. - 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. - 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.
Manual reset function	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).

	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. 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).
Diagnosis	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): • 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 drive (T3). 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). • 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 drive (T3). 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). 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.

1.3.4 Safety Considerations

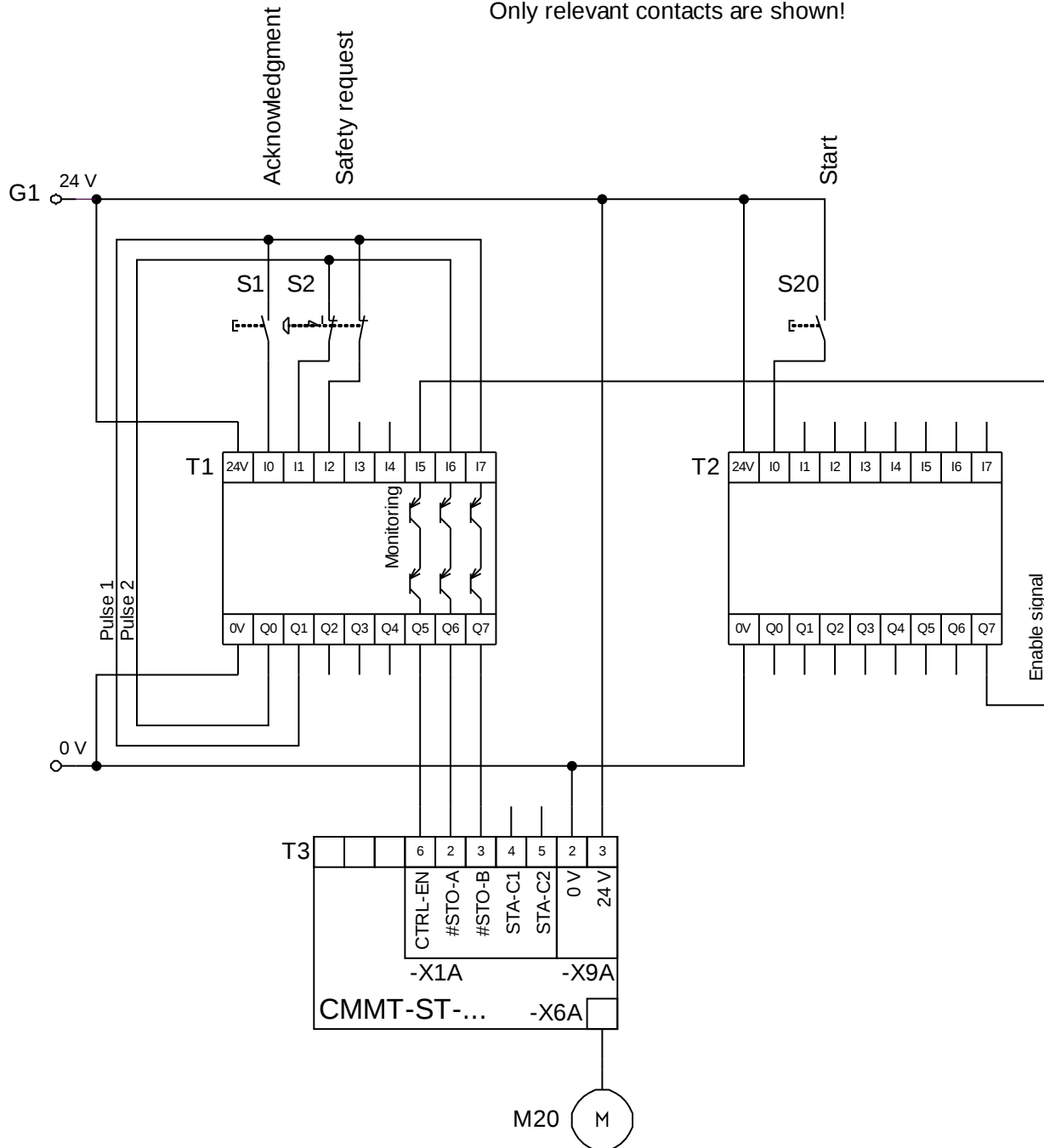
Input	Safety considerations must be carried out in accordance with the selected safety commanding device (S2).
Logic	Safety considerations must be carried out in accordance with the selected safety switching device (T1). Notes: • The outputs (Q6, Q7) of the safety switching device (T1) for switching the signals for the inputs (#STO-A, #STO-B) of the servo drive (T3) are contact outputs without short-circuit and cross-circuit detection. • The outputs (Q6, Q7) of the safety switching device (T1) including the necessary time delay must be suitable for PL e, category.
Output	The intended use of the servo drive (T3) includes the safety sub-function STO with category 3, up to PL e. The PL, category and PFH_D values of the servo drive (T3) required to determine the reliability of the overall circuit must be available. Note: • Depending on the electric motor used, the corresponding safety reference data of the servo drive (T3) must be selected: Either the safety reference data for “stepper motor” or “EC motors with evaluation of STA”.

1.4 SS1-t, STO with CMMT-ST-...-S0, electronic outputs, without STA evaluation

- With stepper motors: SS1-t, STO, category 3, up to PL e
- With EC motors: SS1-t, STO, category 3, up to PL d
- Safety switching device with electronic outputs
- Without evaluation STA

1.4.1 Circuit Diagram

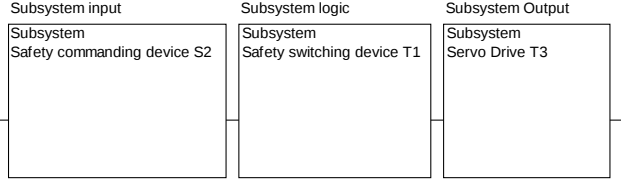
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1.4.2 Components

Component	Type (Part Number)	Description / Remarks	Qty.	Mssr.
M20	EMM...-ST	Stepper motor (or EC motor)	1	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	CMMT-ST-...-S0	Servo drive	1	Festo

1.4.3 Description

Application	Servo drive with stepper motor or EC motor without external forces, e.g. horizontal axis
Triggering event	Safety request (S2), e.g. by emergency stop switch, safety gate
Reaction (Safety function)	Stopping at safety request by using safety sub-function “safe stop 1 time controlled (SS1-t)” with the safe state “safe torque off (STO)”, With stepper motors: category 3, up to PL e With EC motors: category 3, up to PL d 
Safe state	The electric motor (M20) is functionally stopped and after an application-specific time no energy is supplied to the electric motor (M20) that can generate a force and a movement. It is presumed that this state of the stepper motor (M20) is the safe state. Notes: - Stopping the electric motor (M20) 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. - If external forces act on the electric motor, 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.
Function of the circuit	Due to the safety request (S2): - The input circuit of the safety switching device (T1) is interrupted. - The output (Q5) of the safety switching device (T1) is then switched off. - The input “output stage enable (CTRL-EN)” of the servo drive (T3) is no longer controlled. This causes the servo drive (T3) 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. - 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. - The inputs “Safe torque off, channel A and B (#STO-A, #STO-B)” of the servo drive (T3) are no longer controlled. This switches off the control of the output stage and requests the safety sub-function STO.
Manual reset function	- 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). - 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.

	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).
Diagnosis	The diagnostic output (STA) does not have to be evaluated for the specified category and PL.

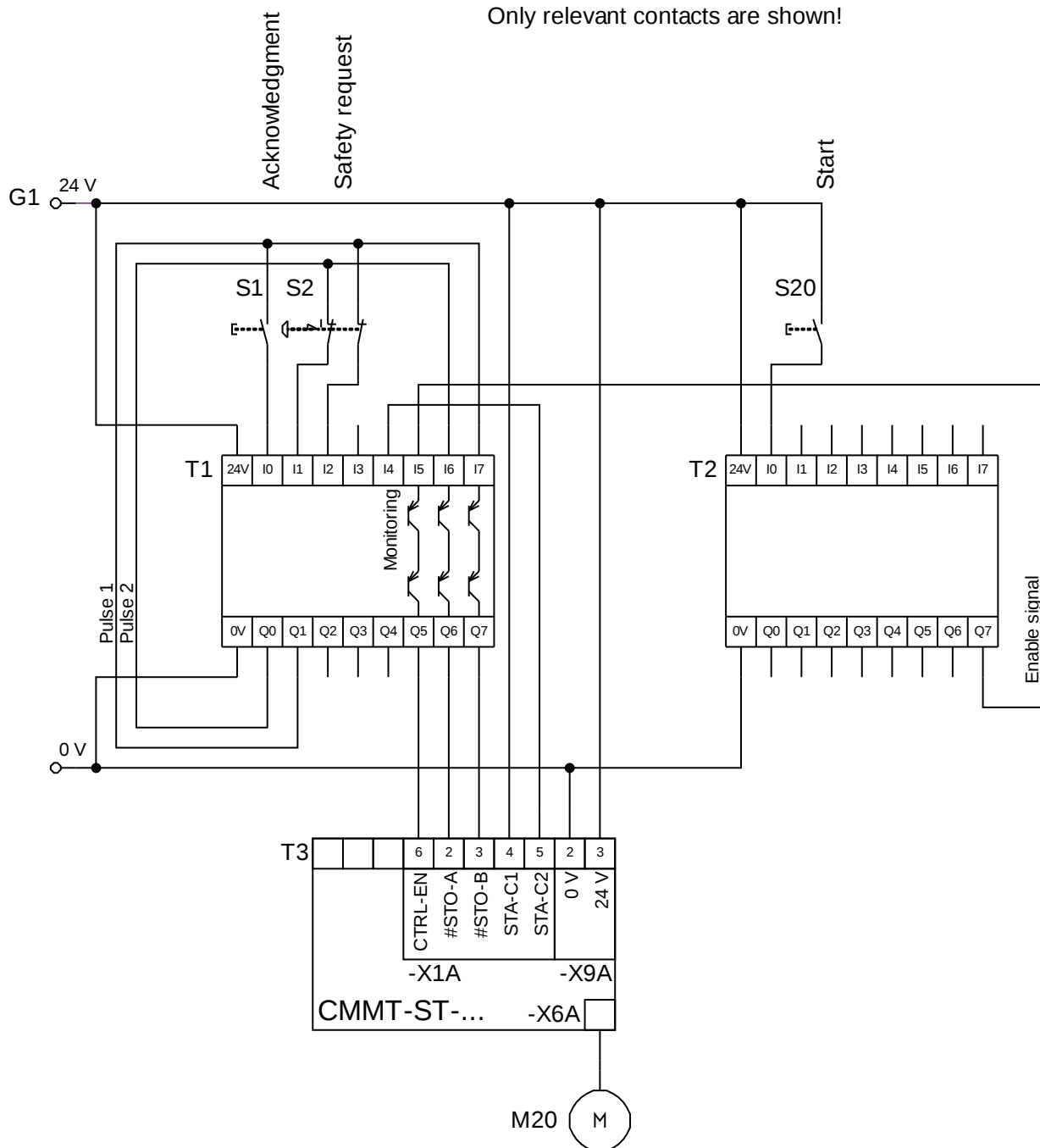
1.4.4 Safety Considerations

Input	Safety considerations must be carried out in accordance with the selected safety commanding device (S2).
Logic	Safety considerations must be carried out in accordance with the selected safety switching device (T1). Notes: • The outputs (Q6, Q7) of the safety switching device (T1) for switching the signals for the inputs (#STO-A, #STO-B) of the servo drive (T3) are electronic outputs without short-circuit and cross-circuit detection. • The outputs (Q6, Q7) of the safety switching device (T1) including the necessary time delay must be suitable for PL e, category 3 when using a stepper motor or PL d, category 3 when using an EC motor.
Output	The intended use of the servo drive (T3) includes the safety sub-function STO with category 3, up to PL e when using a stepper motor or PL d, category 3 when using an EC motor. The PL, category and PFH_D values of the servo drive (T3) required to determine the reliability of the overall circuit must be available. Note: • Depending on the electric motor used, the corresponding safety reference data of the servo drive (T3) must be selected: Either the safety reference data for “stepper motor” or “EC motors without evaluation of STA”.

1.5 SS1-t, STO with CMMT-ST-...-S0, electronic outputs, with STA evaluation

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

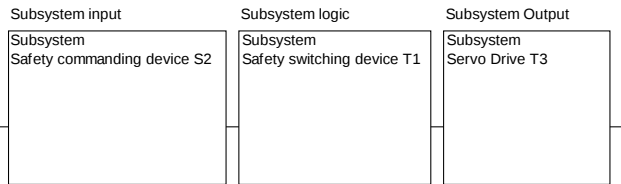
1.5.1 Circuit Diagram



1.5.2 Components

Component	Type (Part Number)	Description / Remarks	Qty.	Mssr.
M20	EMM...-ST	Stepper motor (or EC motor)	1	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	CMMT-ST-...-S0	Servo drive	1	Festo

1.5.3 Description

Application	Servo drive with stepper motor or EC motor without external forces, e.g. horizontal axis
Triggering event	Safety request (S2), e.g. by emergency stop switch, safety gate
Reaction (Safety function)	Stopping at safety request by using safety sub-function “safe stop 1 time controlled (SS1-t)” with the safe state “safe torque off (STO)”, category 3, up to PL e 
Safe state	The electric motor (M20) is functionally stopped and after an application-specific time no energy is supplied to the electric motor (M20) that can generate a force and a movement. It is presumed that this state of the electric motor (M20) is the safe state. Notes: - Stopping the electric motor (M20) 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. - If external forces act on the electric motor, 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.
Function of the circuit	Due to the safety request (S2): - The input circuit of the safety switching device (T1) is interrupted. - The output (Q5) of the safety switching device (T1) is then switched off. - The input “output stage enable (CTRL-EN)” of the servo drive (T3) is no longer controlled. This causes the servo drive (T3) 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. - 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. - The inputs “Safe torque off, channel A and B (#STO-A, #STO-B)” of the servo drive (T3) are no longer controlled. This switches off the control of the output stage and requests the safety sub-function STO.
Manual reset function	- 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). - 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.

	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).
Diagnosis	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): • 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 drive (T3). 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). • 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 drive (T3). 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). 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.

1.5.4 Safety Considerations

Input	Safety considerations must be carried out in accordance with the selected safety commanding device (S2).
Logic	Safety considerations must be carried out in accordance with the selected safety switching device (T1). Notes: • The outputs (Q6, Q7) of the safety switching device (T1) for switching the signals for the inputs (#STO-A, #STO-B) of the servo drive (T3) are electronic outputs with short-circuit and cross-circuit detection. • The outputs (Q6, Q7) of the safety switching device (T1) including the necessary time delay must be suitable for PL e, category 3.
Output	The intended use of the servo drive (T3) includes the safety sub-function STO with category 3, up to PL e. The PL, category and PFH_D values of the servo drive (T3) required to determine the reliability of the overall circuit must be available. Note: • Depending on the electric motor used, the corresponding safety reference data of the servo drive (T3) must be selected: Either the safety reference data for “stepper motor” or “EC motors with evaluation of STA”.

2 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