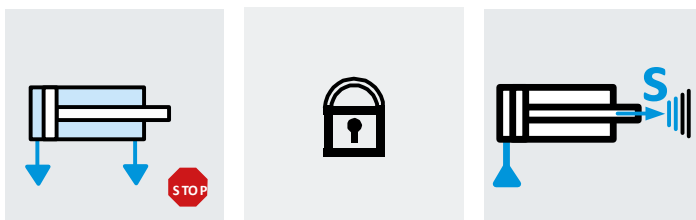


Safety Sub-functions
STO Category 1, up to PL c
PUS Category 1, up to PL c
SLS Category 1, up to PL c



Application Note
STO, PUS, SLS,
Category 1, up to PL
c

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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_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 pneumatics
- 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.
- The abbreviations used for the safety sub-functions refer to the definitions in VDMA 24584 [1] for pneumatics:
 - STO: Safe Torque Off
 - PUS: Prevention of Unexpected Start-up
 - SLS: Safely-Limited Speed
- Category and PL according EN ISO 13849-1 [2]
- The circuits and the procedure described are recommendations which do not exclude other possibilities.
- Due to the wide variety of possible valves, no valve type and part numbers can be given in this document. When selecting valves, make sure that the selected valves have the following characteristics:
 - Valve function: 5/3 exhausted (3/2 closed)
 - Type of actuation: electrical
 - Type of reset: mechanical spring
 - Sealing principle: soft
 - Type of piloting: piloted
 - Pilot air supply: internal or external
 - Duty cycle: 100%.
 - Well-tried components according to EN ISO 13849-1 and the relevant basic and well-tried safety principles have been observed.
 - B10 value required for the calculation of the $MTTF_D$ value must be available.

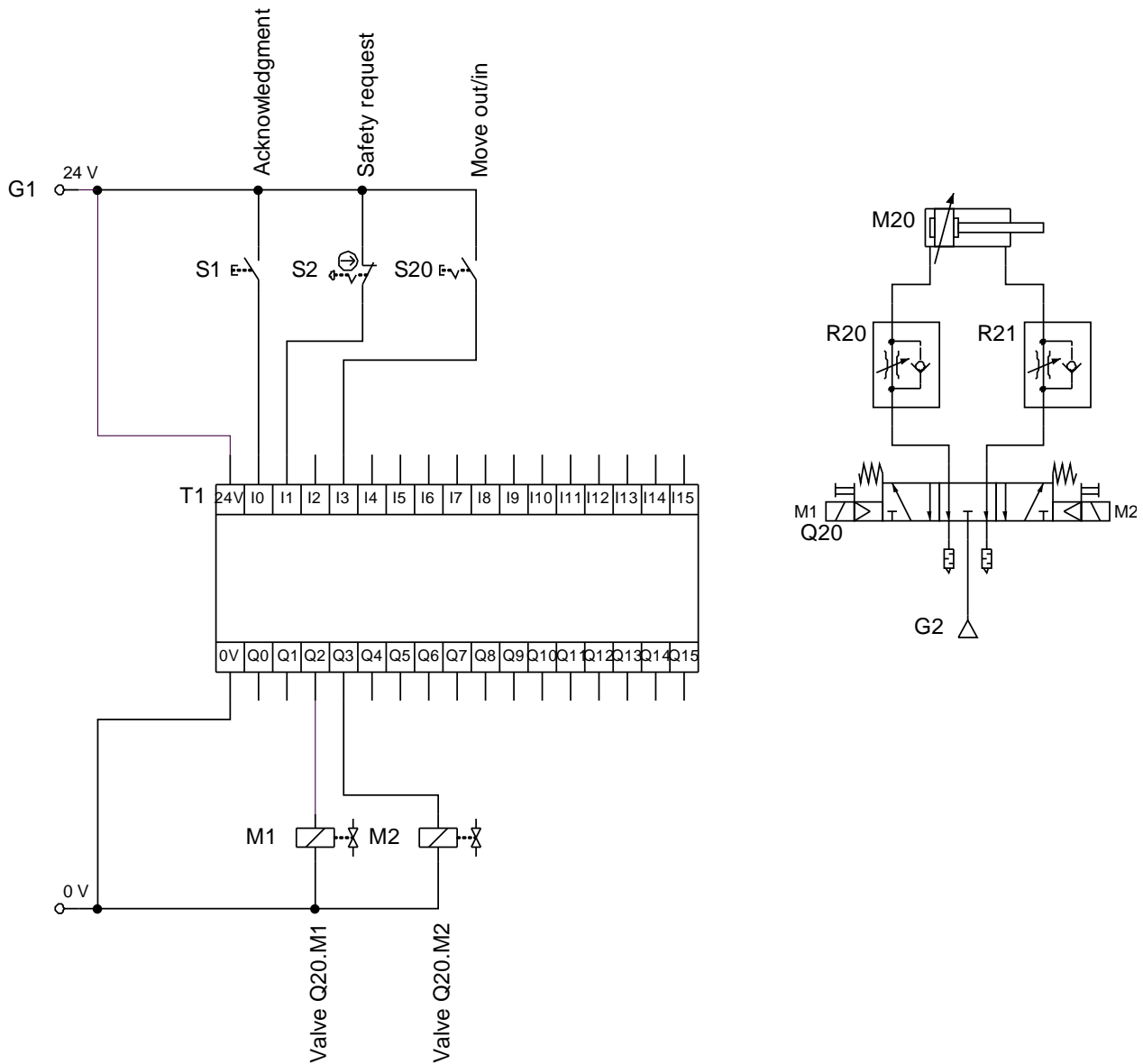
Important note

- In addition, further design features and requirements may exist, which must be determined depending on the application.

1.1 SLS permanent, Category 1, up to PL c

STO, PUS and SLS according VDMA 24584 [1] and category 1, up to PL c according EN ISO 13849-1 [2].

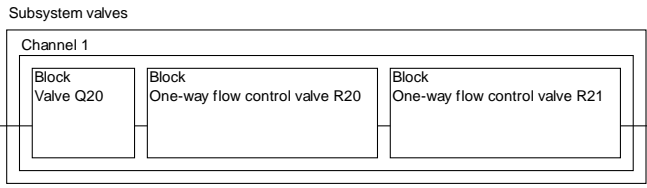
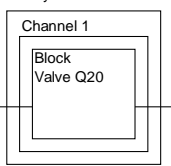
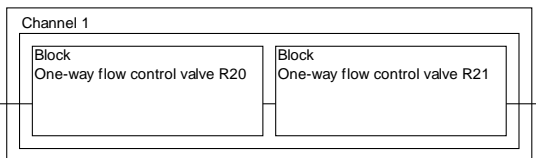
1.1.1 Circuit Diagram



1.1.2 Components

Component	Type	Description / Part Number / Remarks	Qty.	Mssr.
M20		Pneumatic drive	1	Festo
Q20		5/3 directional control valve, monostable	1	Festo
		Silencer, if necessary	2	Festo
R20, R21	GRLA-...; GRLZ-...; VFOF-LE-BAH-...	One-way flow control valve	2	Festo
S1		Acknowledge push button	1	
S2		Safety commanding device, e.g. emergency stop switch	1	
S20		Switch functional control	1	
T1		Safety switching device	1	

1.1.3 Description

Application	Double acting pneumatic drive, horizontal
Triggering event	Safety request, e.g. by emergency stop switch, safety gate
Reaction (Safety Sub-function)	<p>Safe torque off (STO), category 1, PL c</p>  <p>Prevention of unexpected start-up (PUS), category 1, PL c</p>  <p>Safely-limited speed (SLS), category 1, PL c</p> 
Safe state	<p>After a safety request, the pneumatic drive is exhausted and energy-free after an application-specific time. It is presumed that the exhausted state of the pneumatic drive is the safe state.</p> <p>In normal operation, the pneumatic drive cannot exceed a specified speed by limiting the exhaust air volume flow. It is assumed that this limitation is the safe state of the pneumatic drive.</p> <p>Notes:</p> <ul style="list-style-type: none"> • The precondition for the safety sub-function SLS is that the operating pressure remains constant and that no external forces are acting on the pneumatic drive (M20) that have not been taken into account. • The speed of the drive can be changed with the throttle adjustment screw. To prevent manipulation, sufficient measures must be taken to prevent manipulation, e.g. hidden installation. • The exhaust air throttles extend the time until the pneumatic drive is exhausted. • Different speeds can be set for extension and retraction using the throttle check valves.
Function	<p>The safety requirement (S2):</p> <ol style="list-style-type: none"> 1. Interrupts the input circuit of the safety switching device (T1). 2. Switch off the safe outputs of the safety switching device (T1). 3. The solenoids of the valve (Q20) are no longer controlled. 4. Valve (Q20) moves to its normal position, separates the compressed air supply and exhaust both chambers of the pneumatic drive (M20). This exhausts the pneumatic drive (M20). 5. The one-way flow control valves (R20, R21) consist of a throttle and a non-return valve. <ul style="list-style-type: none"> ○ When pressure is applied to a chamber of the pneumatic drive (M20), the non-return valve opens and allows fast movement of the pneumatic drive (M20). ○ If a chamber of the pneumatic drive (M20) is exhausted, the non-return valve closes and the possible flow is limited by the throttle. This limits the maximum possible speed of the pneumatic drive (M20). This limitation is always active when exhausting.

Manual reset function	<ol style="list-style-type: none"> 1. After resetting the safety request (S2), e.g. by mechanically unlocking the emergency stop switch or closing the safety guard, the start or restart can be made possible by pressing the acknowledge push button (S1). 2. The safety switching device (T1) can then allow the solenoids of the valve (Q20) to be controlled so that normal operation is possible.
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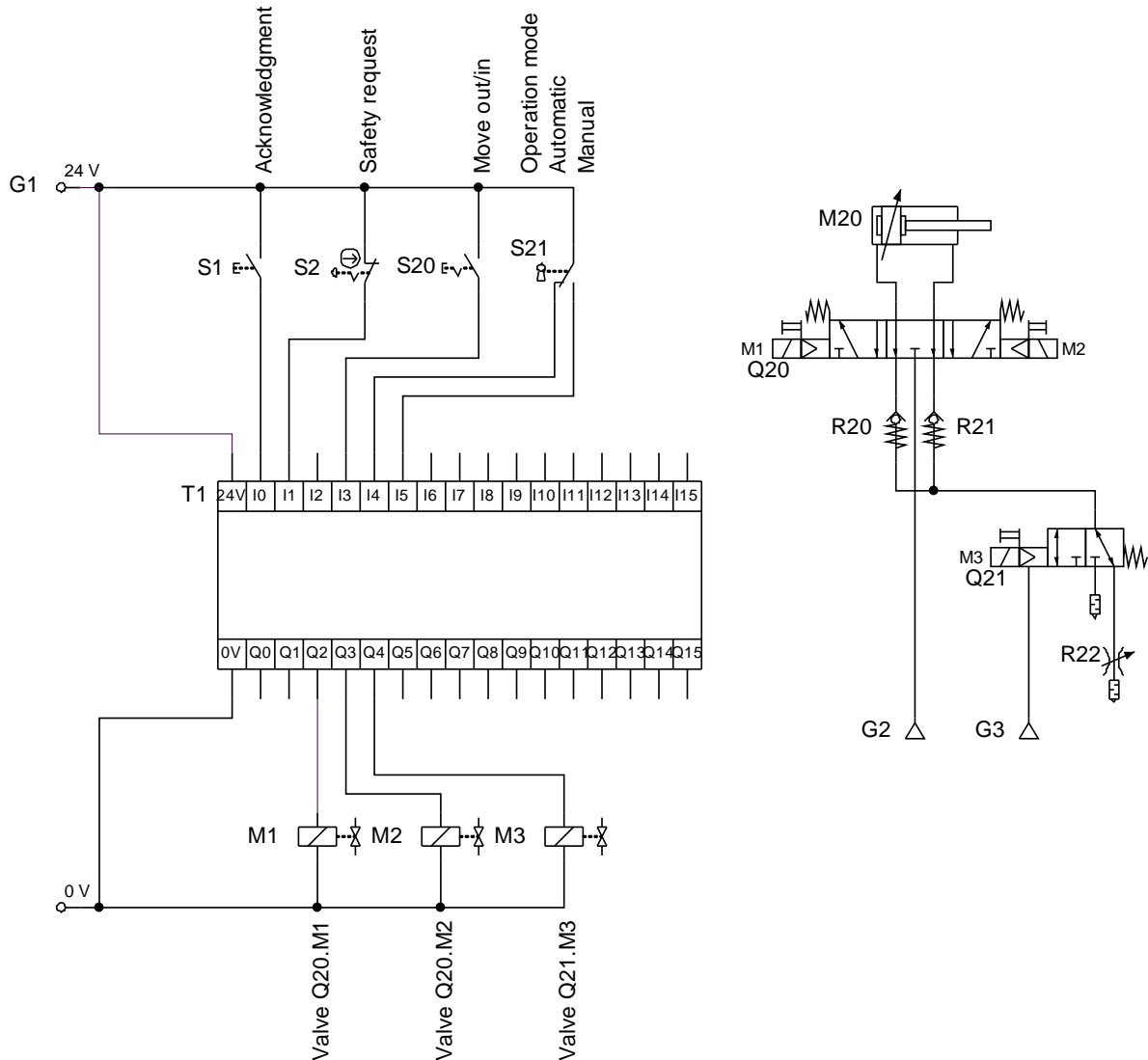
1.1.4 Safety Considerations

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).
Output	The valve (Q20) and the one-way flow control valves (R20, R21) are well-tried components according to EN ISO 13849-1 and the relevant basic and well-tried safety principles have been observed. B10 value required for the calculation of the $MTTF_D$ must be available.

1.2 SLS switchable, Category 1, up to PL c

STO, PUS and SLS according VDMA 24584 [1] and category 1, up to PL c according EN ISO 13849-1 [2].

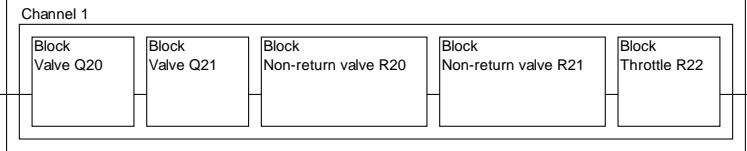
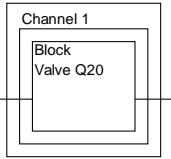
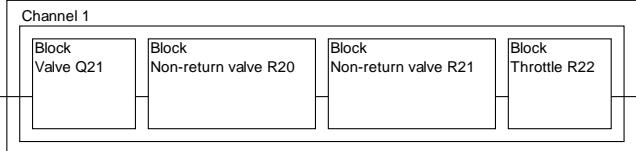
1.2.1 Circuit Diagram



1.2.2 Components

Component	Type	Description / Part Number / Remarks	Qty.	Mssr.
M20		Pneumatic drive	1	Festo
Q20		5/3 directional control valve, monostable	1	Festo
Q21		3/2 directional control valve, monostable	1	Festo
		Silencer, if necessary	2	Festo
R20, R21	H-1/2...; H-1/4...; H-3/4...; H-3/8...; H-M5	Non-return valve, if necessary	2	Festo
R22	GRO-...	Throttle	1	Festo
S1		Acknowledge push button	1	
S2		Safety commanding device, e.g. emergency stop switch	1	
S20		Switch functional control	1	
S21		Operation mode switch	1	
T1		Safety switching device	1	

1.2.3 Description

Application	Double acting pneumatic drive, horizontal
Triggering event	Safety request, e.g. by emergency stop switch, safety gate
Reaction (Safety Sub-function)	<p>Safe torque off (STO), category 1, PL c</p> <p>Subsystem valves</p>  <p>Prevention of unexpected start-up (PUS), category 1, PL c</p> <p>Subsystem valves</p>  <p>Safely-limited speed (SLS), category 1, PL c</p> <p>Subsystem valves</p> 
Safe state	<p>After a safety requirement (S2):</p> <ul style="list-style-type: none"> The pneumatic drive is exhausted after an application-specific time and is energy-free. It is presumed that the exhausted state of the pneumatic drive is the safe state. <p>In “manual” operating mode additionally:</p> <ul style="list-style-type: none"> The pneumatic drive cannot exceed a set speed by limiting the exhaust air volume flow. It is presumed that this limitation is the safe state of the pneumatic drive. <p>Notes:</p> <ul style="list-style-type: none"> The precondition for the SLS safety sub-function is that the operating pressure remains constant and that no external forces are acting on the pneumatic actuator (M20) that have not been taken into account. The speed of the drive can be changed with the throttle adjustment screw. To prevent manipulation, sufficient measures must be taken to prevent manipulation, e.g. hidden installation. The exhaust air throttle extends the time until the pneumatic drive is exhausted. Due to the check valves (R20, R21), a residual pressure remain in the pneumatic drive (M20). This should not lead to any additional hazard. The non-return valves (R20, R21) were used to prevent the pneumatic drive (M20) from moving in the other direction due to the back pressure when it was exhausted. Depending on the specific application and the pneumatic components used, the use of these non-return valves may not be necessary.
Function of the circuit	<p>By the safety request (S2):</p> <ol style="list-style-type: none"> The input circuit of the safety switching device (T1) is interrupted. The safe outputs of the safety switching device (T1) for the valve (Q20) are then switched off. The solenoids of the valve (Q20) are no longer actuated. The valve (Q20) switches to the normal position, separates the supply of the operating pressure and exhausts both chambers of the pneumatic drive (M20) via the valve (Q21). This exhausts the air from the pneumatic drive (M20). <p>When switching from “automatic” mode to “manual” mode (S21)</p> <ol style="list-style-type: none"> The safety switching device (T1) detects the change from automatic mode to manual mode.

	<ol style="list-style-type: none"> 2. The safe outputs of the safety switching device (T1) for the valves (Q20, Q21) are then switched off. 3. The solenoids of the valves (Q20, Q21) are no longer actuated. 4. The valve (Q21) switches to the normal position and switches to the volume flow path with the throttle (R22) to limit the exhaust air volume flow. 5. The valve (Q20) switches to the normal position, separates the supply of the working pressure and exhausts both chambers of the pneumatic drive (M20) via the valve (Q21) and the throttle (R22). This exhausts the air from the pneumatic drive (M20).
Manual reset function	<p>For the safety request (S2):</p> <ol style="list-style-type: none"> 1. After resetting the safety request (S2), e.g. by mechanically unlocking the emergency stop switch or closing the safety guard, the start or restart can be made possible by pressing the acknowledge push button (S1). 2. The safety switching device (T1) can then allow the solenoids of the valve (Q20) to be controlled so that normal operation is possible. <p>Additionally in “automatic” operating mode:</p> <ol style="list-style-type: none"> 1. The operating mode switch (S21) is in the switching position for the operating mode “automatic”. 2. The safe output of the safety switching device (T1) for the valve (Q21) is then switched on. 3. The solenoid of the valve (Q21) is actuated. 4. The valve (Q21) switches to the switching position and switches from the flow path with throttle (R22) to the flow path without throttle. This means that the flow path is not limited and a higher speed is possible. <p>Also in the “manual” operating mode:</p> <ol style="list-style-type: none"> 1. The operating mode switch (S21) is in the switching position for the “manual” operating mode. 2. The safe output of the safety switching device (T1) for the valve (Q21) remains switched off. 3. The solenoid of the valve (Q21) is not actuated. 4. The valve (Q21) remains in its normal position and the flow path with throttle (R22) remains the same. This limits the flow rate and allows only a low speed.

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).
Output	The valves (Q20, Q21, R20, R21) and the throttle (R22) are well-tried components according to EN ISO 13849-1 and the relevant basic and well-tried safety principles have been observed. B10 value required for the calculation of the $MTTF_0$ must be available.

2 Literature

- [1] VDMA 24584:2016-08 - Safety functions of regulated and unregulated (fluid) mechanical systems (German edition)
- [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