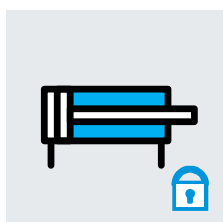


Safety Sub-functions PUS Category 1, up to PL c



Application Note
PUS, 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:
 - PUS: Prevention of unexpected start-up
- 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: 5/2 bistable
 - Type of actuation: electrical
 - 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 MTTFD 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 Selection Guide for the Circuits

The circuits specified in this application note differ in the characteristics of the bistable 5/2 directional control valves used and the resulting control:

- 5/2 directional control valve with fault exclusion “spontaneous change of the initial switching position (without an input signal) for the main stage”
- 5/2 directional control valve with detent on the main stage
- 5/2 directional control valve without fault exclusion and without detent

Section	Characteristic bistable 5/2 directional control valve	Control
1.2	With fault exclusion “spontaneous change of the initial switching position (without an input signal) for the main stage”	with pulse signals permissible
1.3	With detent on the main stage	with pulse signals permissible
1.4	Without fault exclusion and without detent	only with permanently applied control signal

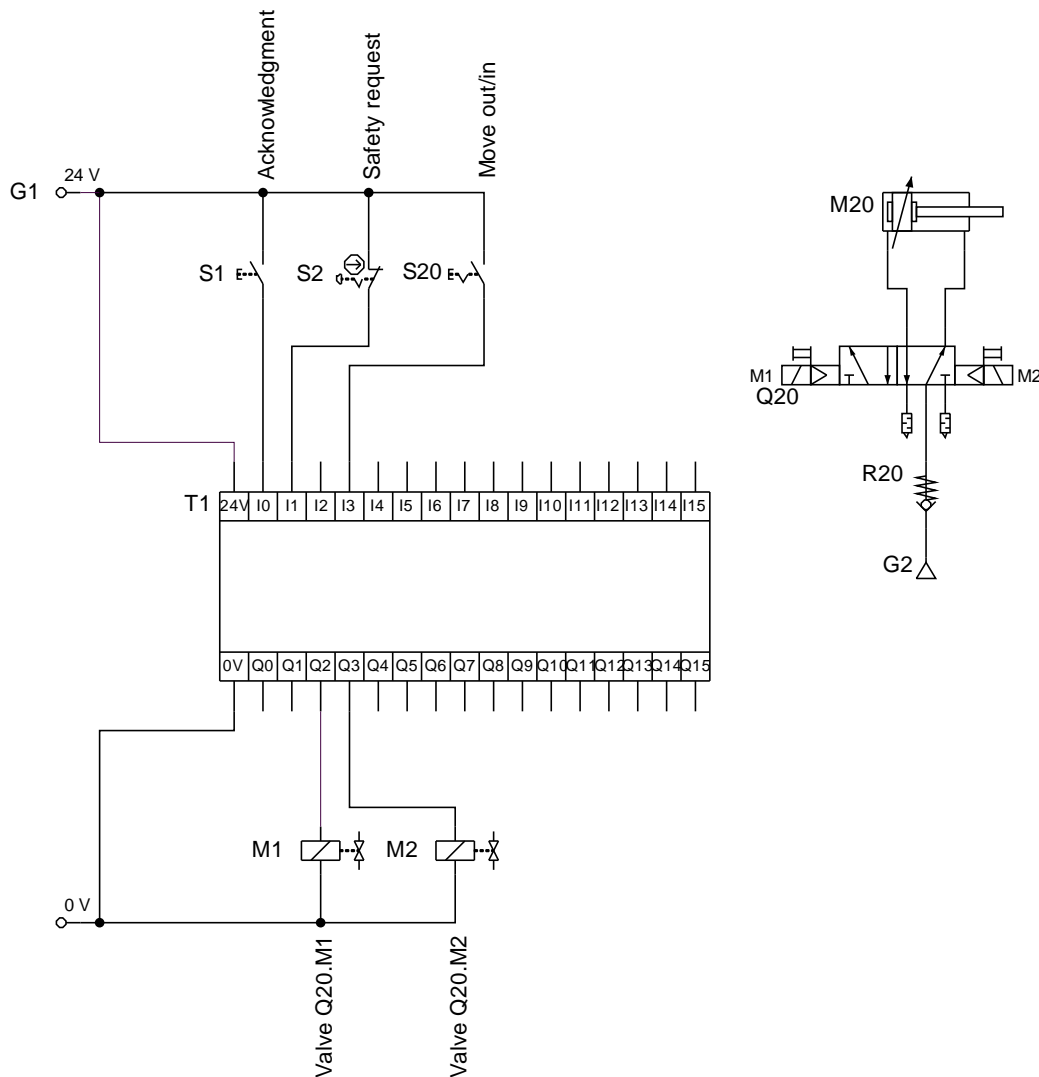
1.2 PUS with 5/2 Directional Control Valve with Fault Exclusion, Category 1, up to PL c

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

1.2.1 Circuit Diagram



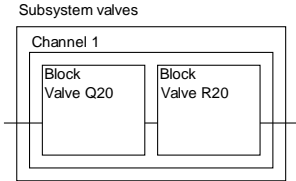
According to EN ISO 14118 enclosed pressurized air shall be marked and shall be provided with a possibility for manual pressure release.



1.2.2 Components

Component	Type	Description / Part Number / Remarks	Qty.	Mssr.
M20		Pneumatic drive	1	Festo
Q20		5/2 directional control valve, bistable	1	Festo
		Silencer, if necessary	2	Festo
R20	H-...-B; H-QS-...; HA-...-QS-...; HB-...-QS-...	Check valve	1	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	

1.2.3 Description

Application	Double acting pneumatic drive
Triggering event	Safety request, e.g. by emergency stop switch, safety gate
Reaction (Safety Sub-function)	<p>Prevention of unexpected start-up, category 1, PL c</p>  <p>The diagram shows a rectangular frame labeled 'Subsystem valves'. Inside this frame is a smaller rectangle labeled 'Channel 1'. Within 'Channel 1', there are two boxes: 'Block Valve Q20' on the left and 'Block Valve R20' on the right. Lines connect the valves to the channel boundaries.</p>
Safe state	<p>One chamber of the pneumatic drive is supplied with compressed air and the other chamber is exhausted. The pneumatic drive is then kept in an end position. It is presumed that this may be a safe state.</p> <p>If the operating pressure supply (G2) is exhausted, actuating the valve (Q20) can cause the pneumatic drive (M20) to be exhausted.</p> <p>Notes:</p> <ul style="list-style-type: none"> • The safety sub-function PUS is not a function for stopping the pneumatic drive, it only prevents unexpected start-up. • If the safety sub-function PUS is used with a pneumatic drive in conjunction with a safety request, the positioning time of the pneumatic drive (M20) must always be so short that the hazard area cannot be reached before the pneumatic drive (M20) has come to a standstill in its end position. • The fault exclusion “spontaneous change of the initial switching position (without an input signal) for the main stage” is required for the valve (Q20). • The non-return valve (R20) is used to maintain the operating pressure when the compressed air supply is switched off or fails. After switching off or after failure of the operating pressure, a movement may occur due to the leakage which cannot be stopped. • The non-return valve (R20) is not necessary if there is no hazard after switching off or failure of the compressed air supply. • The use of a soft-start valve is recommended in order to be able to approach an end position in a controlled manner when the compressed air supply is switched on.
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. The valve (Q20) remains in its current switching position, one chamber of the pneumatic actuator (M20) is supplied with compressed air and the other chamber is exhausted. This keeps the pneumatic drive (M20) in one end position. <p>Note:</p> <ul style="list-style-type: none"> • The valve (Q20) is controlled with pulses. It is recommended that the control signal be applied for at least twice as long as the valve (Q20) requires to switch from one switching position to the other.
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.

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	<p>The valve (Q20, R20) 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.</p> <p>Notes:</p> <ul style="list-style-type: none">• The fault exclusion “spontaneous change of the initial switching position (without an input signal) for the main stage” is required for the valve (Q20).• For the safety sub-function PUS with category 1, safe switch off of either the electrical control signal or the pilot air supply for the valve (Q20) is sufficient.

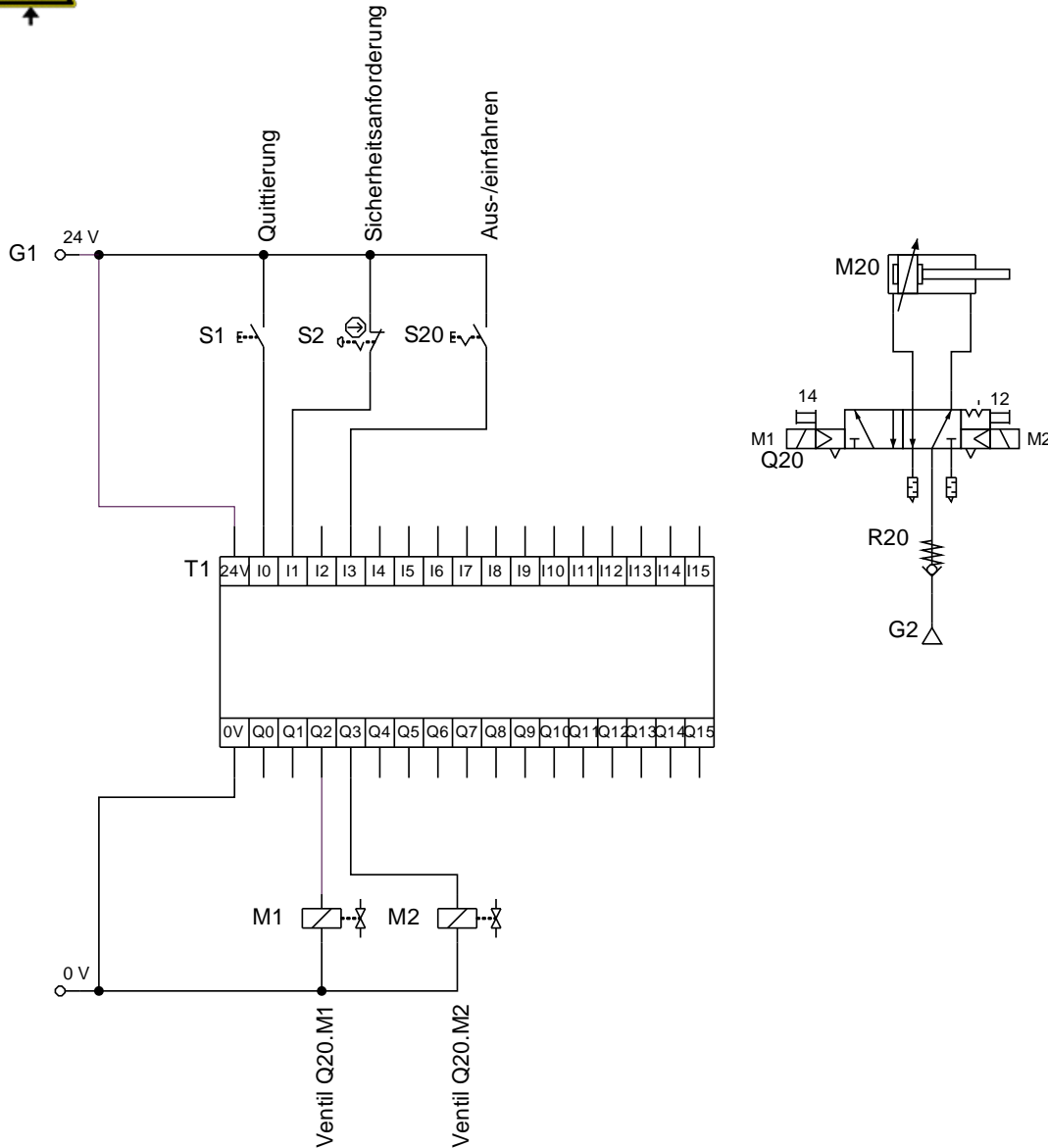
1.3 PUS with 5/2 Directional Control Valve with Detent, Category 1, up to PL c

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

1.3.1 Circuit Diagram



Nach DIN EN ISO 14118 muss eingeschlossene Druckluft gekennzeichnet werden und mit einer Möglichkeit zur manuellen Druckentlastung versehen sein.

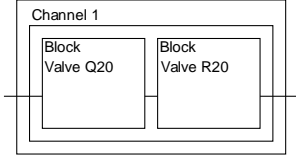


1.3.2 Components

Component	Type	Description / Part Number / Remarks	Qty.	Mssr.
M20		Pneumatic drive	1	Festo
Q20	JMFH-5-... (however not series B)	5/2 directional control valve, bistable, with detent	1	Festo
		Silencer, if necessary	2	Festo
R20	H-...-B; H-QS-...; HA-...-QS-...; HB-...-QS-...	Check valve	1	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
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1.3.3 Description

Application	Double acting pneumatic drive
Triggering event	Safety request, e.g. by emergency stop switch, safety gate
Reaction (Safety Sub-function)	<p>Prevention of unexpected start-up, category 1, PL c</p> <p>Subsystem valves</p>  <p>The diagram shows a rectangular frame labeled 'Channel 1'. Inside this frame, there are two smaller rectangular blocks. The left block is labeled 'Block Valve Q20' and the right block is labeled 'Block Valve R20'. Lines connect the top and bottom of these blocks to the inner boundary of the 'Channel 1' frame.</p>
Safe state	<p>One chamber of the pneumatic drive is supplied with compressed air and the other chamber is exhausted. The pneumatic drive is then kept in an end position. It is presumed that this may be a safe state.</p> <p>If the operating pressure supply (G2) is exhausted, actuating the valve (Q20) can bring the pneumatic drive (M20) to the exhausted state.</p> <p>Notes:</p> <ul style="list-style-type: none"> • The safety sub-function PUS is not a function for stopping the pneumatic drive, it only prevents unexpected start-up. • If the safety sub-function PUS is used with a pneumatic drive in conjunction with a safety request, the positioning time of the pneumatic drive (M20) must always be so short that the hazard area cannot be reached before the pneumatic drive (M20) has come to a standstill in its end position. • The detent on the main stage of the valve (Q20) ensures the well-tried safety principle “safe position” in a switching position. • The non-return valve (R20) is used to maintain the operating pressure when the compressed air supply is switched off or fails. After switching off or after failure of the operating pressure, a movement may occur due to the leakage which cannot be stopped. • The non-return valve (R20) is not necessary if there is no hazard after switching off or failure of the compressed air supply. • The use of a soft-start valve is recommended in order to be able to approach an end position in a controlled manner when the compressed air supply is switched on.
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) keeps its normal position, connects one chamber of the pneumatic drive (M20) to the operation pressure and exhausts the other chamber. This keeps the pneumatic drive (M20) in its end position. <p>Note:</p> <ul style="list-style-type: none"> • The valve (Q20) can be controlled with pulses. It is recommended that the control signal be applied for at least twice as long as the valve (Q20) requires to switch from one switching position to the other.
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.

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).
Output	<p>The valve (Q20, R20) 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.</p> <p>Notes:</p> <ul style="list-style-type: none">• The valve (Q20) must have a detent on the main stage.• For the safety sub-function PUS with category 1, safe switch off of either the electrical control signal or the pilot air supply for the valve (Q20) is sufficient.

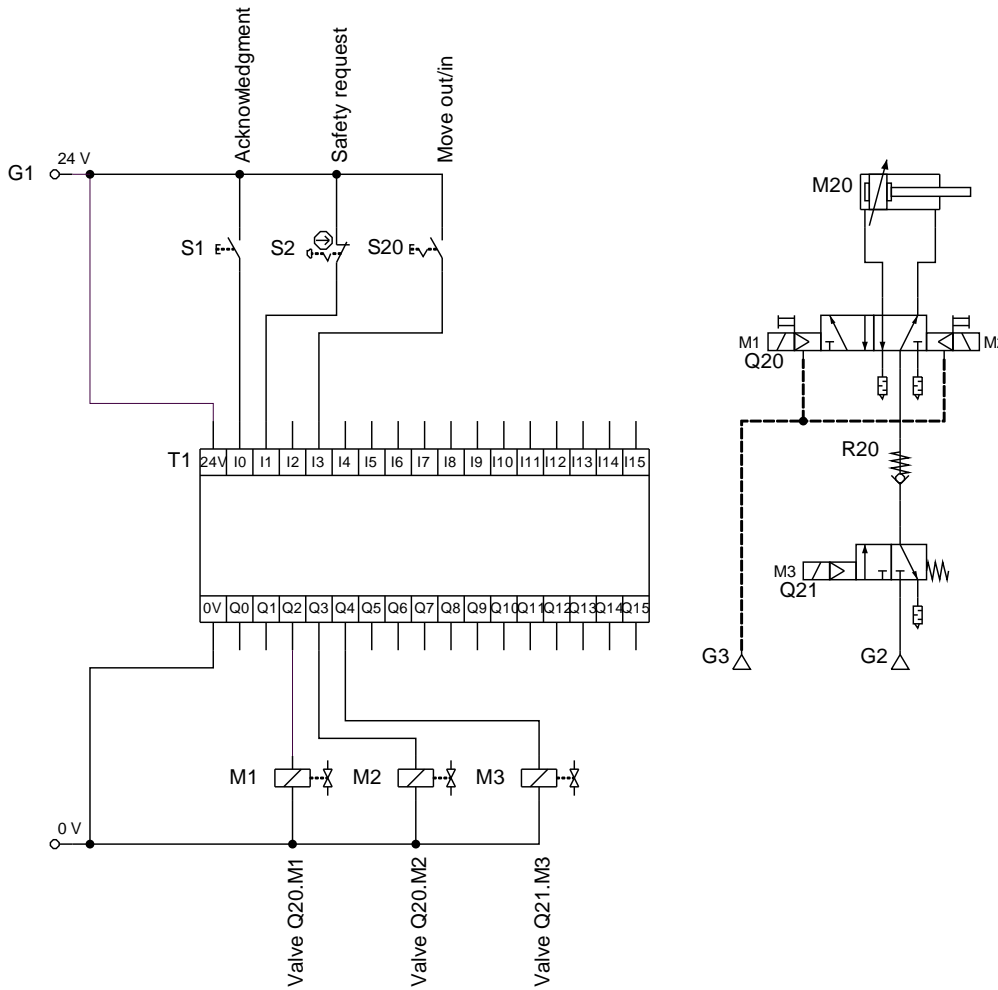
1.4 PUS with 5/2 Directional Control Valve, Permanently Controlled, Category 1, up to PL c

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

1.4.1 Circuit Diagram



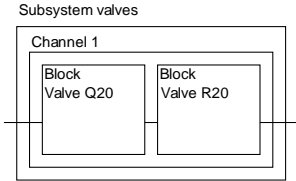
According to EN ISO 14118 enclosed pressurized air shall be marked and shall be provided with a possibility for manual pressure release. Leakage can cause movements that cannot be stopped.



1.4.2 Components

Component	Type	Description / Part Number / Remarks	Qty.	Mssr.
M20		Pneumatic drive	1	Festo
Q20		5/2 directional control valve, bistable	1	Festo
Q21		3/2 directional control valve, monostable	1	Festo
		Silencer, if necessary	2	Festo
R20	H-...-B; H-QS-...; HA-...-QS-...; HB-...-QS-...	Check valve	1	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	

1.4.3 Description

Application	Double acting pneumatic drive
Triggering event	Safety request, e.g. by emergency stop switch, safety gate
Reaction (Safety Sub-function)	<p>Prevention of unexpected start-up, category 1, PL c</p> 
Safe state	<p>One chamber of the pneumatic drive is supplied with compressed air and the other chamber is exhausted. The pneumatic drive is then kept in an end position. Slow movements are possible by leakage that cannot be stopped. It is presumed that this may be a safe state.</p> <p>The exhausted state of the pneumatic drive (M20) can be achieved by actuating the valve (Q20).</p> <p>Notes:</p> <ul style="list-style-type: none"> • The safety sub-function PUS is not a function for stopping the pneumatic drive, it only prevents unexpected start-up. • If the safety sub-function PUS is used with a pneumatic drive in conjunction with a safety request, the positioning time of the pneumatic drive (M20) must always be so short that the hazard area cannot be reached before the pneumatic drive (M20) has come to a standstill in its end position. • The valve (Q20) must be controlled permanently. Assuming that the electrical control signal and pilot air supply are available, the requirements of the safety principle “safe position” are met. However, this measure does not correspond to the positive mode principle. • If the electrical control signal or the pilot air supply fails, changing the switching position should not lead to any hazard or additional measures are necessary. • The non-return valve (R20) is used to maintain the operating pressure when the compressed air supply is switched off or fails. After switching off or after failure of the operating pressure, a movement may occur due to the leakage which cannot be stopped. • The non-return valve (R20) is not necessary if there is no hazard after switching off or failure of the compressed air supply. • The valve (Q21) only serves to illustrate the interrelationships between the control of the valve (Q20). The safety function implemented by this valve is not described in this document. • The use of a soft-start valve is recommended in order to be able to approach an end position in a controlled manner when switching on the compressed air supply.
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. The state of the safe outputs (Q2, Q3) of the safety switching device (T1) for controlling the valve (Q20) is not changed. With the electrical control signal and the pilot air, the control of the last switching position of the main stage of the valve (Q20) is not changed. This keeps the pneumatic drive (M20) in an end position. 3. The safe output (Q4) of the safety switching device (T1) for the valve (Q21) is switched off. 4. The solenoid of the valve (Q21) is no longer actuated. 5. The valve (Q21) goes into its normal position, separates and exhausts the operating pressure. 6. If the switching position of the switch (S20) is changed, the safety switching device (T1) prevents the switching position of the valve (Q21) from changing.
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. When starting or restarting, the safe output of the safety switch device (T1) for the valve (Q21) is switched on so that it moves to its switching position and thus releases the operating pressure.

	3. 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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1.4.4 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).
Output	The valve (Q20, Q21, R20) 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 MTTFD 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