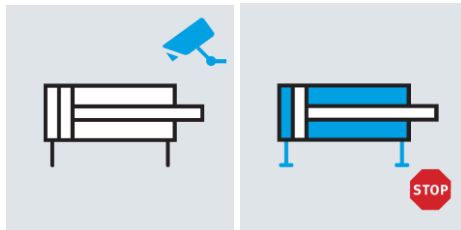


Circuit

Safety Subfunctions Pneumatics

Test cycle for SSC with Proximity Switches on Drive



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Title Safety Subfunctions Pneumatics - Circuit
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- Specialist for the programming of control systems and safety switching devices

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Table of Contents

1	General	4
1.1	Objectives of This Document	4
1.2	General Notes	4
1.3	Notes on Safety-Related Features of the Subcircuits	4
1.4	Definitions	5
1.5	Selection of the Test Cycle	6
2	Test Cycles ‘Stopping Movement’	7
2.1	Basic Circuit and Principal Sequence of the Test Cycle	7
2.2	Flowchart	8
2.3	Description	8
2.4	Failures	9
2.5	Test cycle 1 “Stop movement” with 5/3-way valve	11
2.5.1	Circuit	11
2.5.2	Signal Sequence and Position of the Drive	12
2.5.3	Test Procedure for 5/3-Way Valves	12
2.5.4	Programming Simulation with Logic Elements	14
3	Test Cycle ‘Holding in end position for drives with piston rod’	17
3.1	Principle Circuit and Basic Sequence of the Test Cycle	17
3.2	Flowchart	17
3.3	Description	18
3.4	Failures	19
3.5	’Test cycle 2 “Hold End Position for Drives with piston rod” with 2 x piloted check valves	21
3.5.1	Circuit	21
3.5.2	Signal Sequence and Position of the Drive	22
3.5.3	Test Procedure for 2 x Piloted Check Valves	22
3.5.4	Programming Simulation with Logic Elements	25
4	Used Literature	28
4.1	Cited Documents from Festo	28
4.2	Standards	28
4.3	Legal Regulations	28
5	Information about the Document	29
5.1	General Information	29
5.2	Revision History	29
5.3	Approval/Release of the Document	29
5.4	Period of Validity	29

1 General

1.1 Objectives of This Document

- This document presents possible example circuits and test cycles for the safety subfunction SSC (safe stop and closing) for the following valves:
 - 5/3-way valve, closed
 - 2 x pilot-operated check valve
- The specified test cycles demonstrate that during the execution of the test, a “stop of movement” or “holding in the end position” with the safety subfunction SSC was possible.

1.2 General Notes

- The circuits shown are schematic diagrams that, due to clarity and scope, cannot be complete. They are recommendations that do not exclude other possibilities.
- The abbreviations used for the safety subfunction are based on the definitions in VDMA 24584 for pneumatics. The definitions used by Festo and important notes are provided in the document “[100406 Safety Subfunctions Pneumatics – SSC, PUS.](#)”
- To detect as many faults as possible in the components used, the following tests are required in addition to the “Test Cycle for the Safety Subfunction SSC”:
 - Continuous “switching time and plausibility monitoring”

This test should be performed with every switching operation of the working valve (5/3-way valve, closed). In the test cycle described here for the 5/3-way valve, switching time monitoring is therefore indicated as optional.

In the test cycles for pilot-operated check valves, this switching time monitoring is also marked as optional. However, it is recommended to use switching time monitoring because faults in the working valve can be masked during simultaneous demand of the safety subfunction. Since these valves are typically actuated less frequently over their service life, switching times can increase more significantly than with the working valve.
 - Leakage test

Leakage limits the time during which the safety subfunction SSC can be executed. The leakage test can detect an increase in leakage and prompt a repair. It is recommended to perform the leakage test once a year (Category 3).

Important Notes

- In all circuit examples, throttle check valves are shown to limit speed. These must be set according to the dimensioning of the application or the maximum permissible speed before the required switching and positioning times can be determined and taken into account in the programming.

1.3 Notes on Safety-Related Features of the Subcircuits

- The components relevant to the implementation of the safety subfunction are listed in the Application Notes for implementing the safety subfunction SSC.
- The test cycles specified here are diagnostic measures for which no assessment of the category and Performance Level (PL) is required. Programming can also be done in a standard PLC, as long as the safety PLC can release or block further use of the application based on the result. However, the program in the standard PLC must be adequately protected against manipulation. We recommend implementation in the safety PLC.

- How often must the test cycle for SSC be executed?

This depends on the category to be implemented, the application, and the components used. This must always be assessed in the risk assessment.

At a minimum, consider:

- For Category 2: The test cycle should be executed before or at least when the safety subfunction is requested and before a hazard can occur. ISO 13849-1, 6.1.3.2.4 recommends the following times:
 - Before the start of a new machine cycle,
 - Before the start of movements,
 - Regularly during operation if the risk assessment considers it necessary.

It should be noted that for Category 2, the test cycle must be called 100 times more frequently than a request for the safety subfunction. The time from detecting the fault until reaching the safe state by shutting down the test channel must be shorter than the time it takes to reach the hazard zone.

- For Category 3: The test cycle should be executed before or at the time of the safety subfunction request. A single fault must be detected at or before the next request for the safety subfunction (ISO 13849-1, 6.1.3.2.5).
- For the application, the following must be assessed:
 - How often the safety subfunction is called.
The test cycle should be performed before or at the request of the safety subfunction. Accordingly, the test cycle should be included in the machine cycle.
 - How long the pneumatic drive must be held in the safe state of SSC (holding a position with trapped compressed air).
The determining factor for the safe state of SSC is the pressure and leakage of the pneumatic subcircuit including the actuator. Leakage reduces the pressure of the trapped compressed air until the actuator slowly moves from its position to be held, which can create a hazard. This must be checked regularly with a leakage test.
 - Which faults in the application can lead to a failure of the safety subfunction SSC.
- The usual behaviour of the components used should be taken into account. Festo recommends performing a complete switching cycle once a week (forced dynamic operation) for all directional and seat valves.

1.4 Definitions

In this document, the following terms are used in the flowcharts, descriptions, and programming for simulation. These definitions differ from the product-specific characteristics but indicate what is tested with these times in the test cycles.

- Switching Time

The time from the rising edge (0→1) of the valve control signal until the end position is left, i.e., the signal of the corresponding limit switch has a falling edge (1→0). There are two ways to determine this switching time:

- This switching time can be determined or estimated based on a measurement in the application. It is recommended to multiply this value by a safety factor of 2 to avoid limiting availability due to false trips and still allow fault detection.
- Use the switching time specified in the valve datasheet, multiplied by a safety factor of 3 to 5.

The definition of switching time for valves is described in Application Note [100396](#), Section 4.

- Positioning Time

The time from the rising edge (0→1) of the valve control signal until the other end position is reached, i.e., the signal of the corresponding limit switch has a rising edge (0→1).

This value should be multiplied by a safety factor that does not limit availability due to false trips and still allows fault detection. Depending on changing friction and forces over the service life, a safety factor of 1.2 to 2 may be sufficient.

- Depending on the forces, friction, acceleration, and speed in the application, additional adjustments to the safety factors may be necessary. Evaluating these adjustments is not possible within the scope of an Application Note.

1.5 Selection of the Test Cycle

First, it must be decided which function is to be tested. The test cycles included here can be used to test the following functions:

- Safe stop locked-in compressed air and holding in an undefined intermediate position
- Safe stop with locked-in compressed air and holding in the end position.

The following aspects must be considered for the decision:

- Minimum stroke: For a stroke length of approximately 2 to 3 times the piston diameter, the pneumatic actuator can often be stopped in an undefined intermediate position; in this case, “2 Test Cycles for ‘Stopping Movement’” can be used.
- For a stroke length of less than 2 to 3 times the piston diameter, it is generally aimed to hold in an end position.

Table 1 Selection of test cycle based on function and type of drive

Function: Safe Stopping and ...	Conditions	Section
Holding in a not defined intermediate position	Consider minimum stroke	➔ 2
Holding in end position	Drive with piston rod	➔ 3

2 Test Cycles ‘Stopping Movement’

2.1 Basic Circuit and Principal Sequence of the Test Cycle

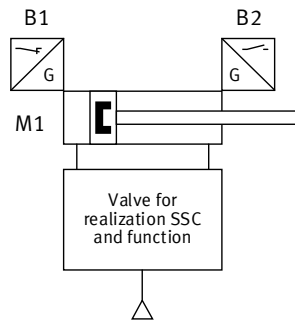


Figure 1 Basic circuit for test cycle ‘stop movement’

The basic procedure for this test cycle is that the pneumatic drive M1 is controlled to both end positions B1 and B2 using the working valve. After leaving the end position, the movement is stopped by the safety subfunction SSC with enclosed compressed air, and the drive is held in an undefined position. If the control signals and the signals from limit switches B1 and B2 show a non-plausible timing and signal sequence – for example, if the opposite end position is reached during stopping – the test cycle is aborted with a failure.

Note

- This test cycle can be used for drives with or without a piston rod.

2.2 Flowchart

The typical sequence for the test cycle “Stopping Movement” is shown in the flowchart.

Note

- If plausibility and positioning time monitoring of the valves is implemented for every switching operation, the parts marked as “Optional” (highlighted in blue) can be omitted. The tests marked as “Optional” in the steps are time monitoring during the test cycle, which can also be performed through plausibility and positioning time monitoring.

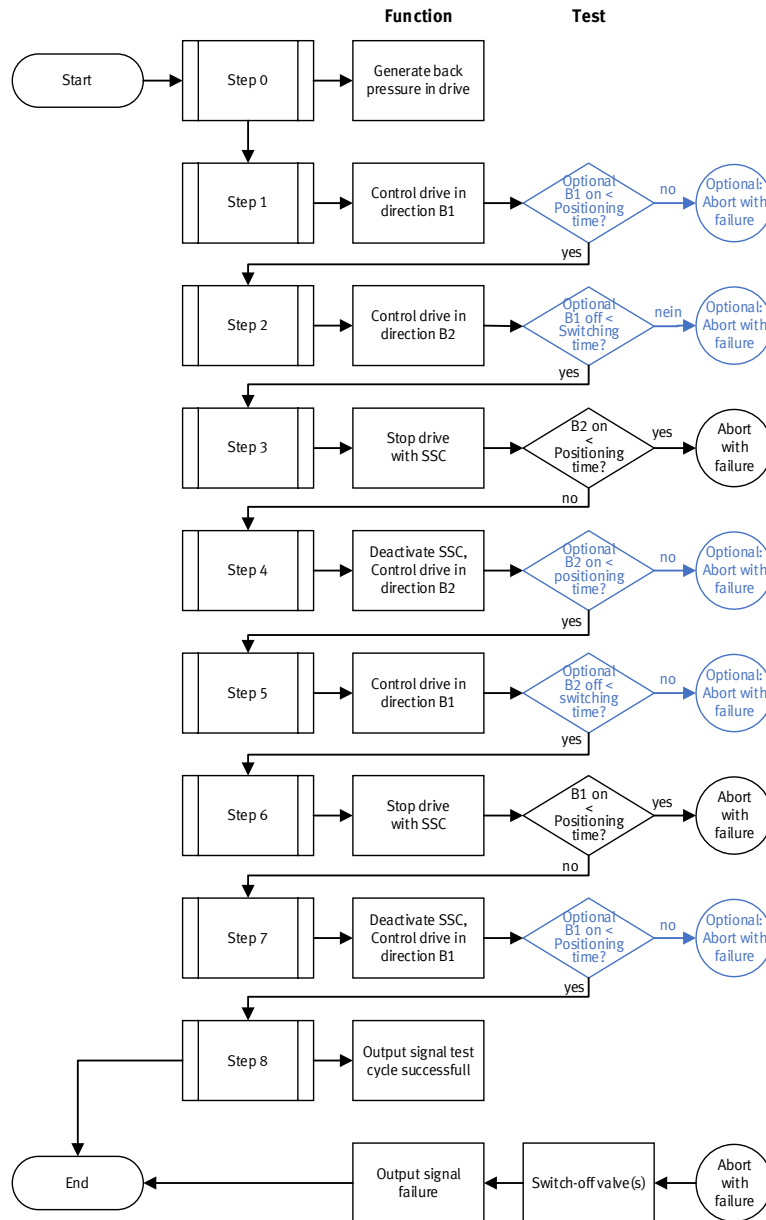


Figure 2 Flowchart Test Cycle Safety Subfunction SSC (Stopping Movement)

2.3 Description

- Step 0:** Generate back pressure in the drive
This step serves solely to build up back pressure in the drive for the movements starting from Step 1. This step is optional if there is already pressure in the drive at the start of the test cycle, e.g., if the drive is in a pressurized end position.
- Step 1:** Move drive in direction B1
The drive is moved to the end position with proximity switch B1.

Optional: It is checked whether a specified positioning time from the activation of the working valve until the activation of proximity switch B1 is not exceeded.

- **Step 2:** Move drive in direction B2

The drive is moved to the end position with proximity switch B2.

Optional: It is checked whether a specified switching time from the activation of the working valve until the deactivation of proximity switch B1 is not exceeded.

- **Step 3:** Stop drive with SSC

The drive is stopped using the safety subfunction SSC.

It is checked whether proximity switch B2 is actuated. If the proximity switch is reached within the specified positioning time, the safety subfunction SSC was not executed, and a failure is present.

- **Step 4:** Deactivate SSC, move drive in direction B2

The drive is moved to the end position with proximity switch B2.

Optional: It is checked whether a specified positioning time from the activation of the working valve until the activation of proximity switch B2 is not exceeded.

- **Step 5:** Move drive in direction B1

The drive is moved to the end position with proximity switch B1.

Optional: It is checked whether a specified switching time from the activation of the working valve until the deactivation of proximity switch B2 is not exceeded.

- **Step 6:** Stop drive with SSC

The drive is stopped using the safety subfunction SSC.

It is checked whether proximity switch B1 is actuated. If the proximity switch is reached within the specified positioning time, the safety subfunction SSC was not executed, and a failure is present.

- **Step 7:** Move drive in direction B1

The drive is moved to the end position with proximity switch B1.

Optional: It is checked whether a specified positioning time from the activation of the working valve until the activation of proximity switch B1 is not exceeded.

- **Step 8:** Output signal "Test cycle successful"

The valves are switched off, and the signal "Test successful" is output.

- **Abort with failure**

The valves are switched off, and the signal "Failure" is output.

2.4 Failures

The following failures according to ISO 13849-2, Tables B.4 and D.4, can be detected with this test cycle:

- Changes in switching times (only if the program parts marked as "optional" are used) or if plausibility and positioning time monitoring is performed for every valve switching operation.
- Sticking in the middle position or an end position.
- Sticking in an intermediate position.
- Permanent short circuit to 24 V or 0 V in the line to the solenoid coil, causing the valve to take a switching or normal position.
- Permanent interruption of 24 V or 0 V in the line to the solenoid coil.

The following failures cannot be (reliably) detected:

- Spontaneous change of the output switching position (without an input signal)
Detecting this failure requires continuously active plausibility and positioning time monitoring of control and sensor signals.
- Leakage
Detecting leakage requires an additional leakage test.

- Short circuits and cross-circuits

Short-term short circuits to 24 V or 0 V in the line to the solenoid coil, which can cause brief valve switching.

Detecting short circuits and cross-circuits requires at least one of the following measures:

- Short-circuit and cross-circuit monitoring of the safety outputs,
- A fuse in the active conductor for electromechanical contacts, or
- Continuously active plausibility and time monitoring of control and diagnostic signals.

2.5 Test cycle 1 “Stop movement” with 5/3-way valve

Function: Safe Stopping and ...	Ventil(e)	Drive	Mouning position	Test
Holding in intermediate position	5/3-way valve, closed	Any, consider minimum stroke, see section 1.5	Any	Closed volume flow paths

This section describes a possible test cycle for 5/3-way valves with the diagnostic measure of proximity switches on the drive for the safety subfunction “safe stopping and closing (SSC).”

Notes

- The required characteristics of the components and recommendations for possible Festo products are included in the Application Notes for the circuits of the safety subfunction SSC.
- When calculating reliability, the test cycle for valve Q1 must include three complete switching cycles.

2.5.1 Circuit

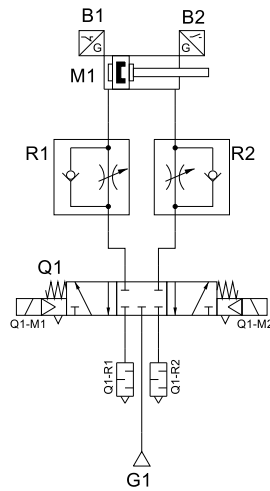


Figure 3 Used circuit for test cycle with 5/3-way valve, closed

2.5.2 Signal Sequence and Position of the Drive

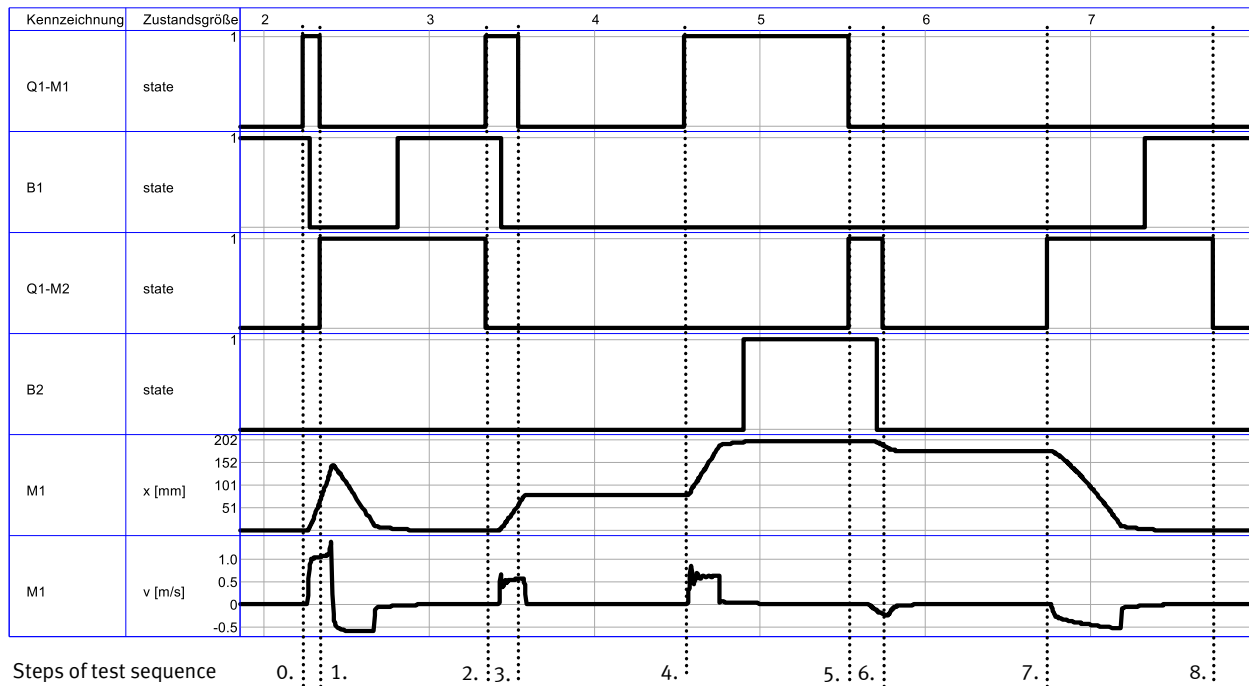


Figure 4 Signal sequences and position of the drive during the test sequence

2.5.3 Test Procedure for 5/3-Way Valves

This test procedure is for 5/3-way valves based on the flowchart in Section → 2.2 and the description in Section → 2.3. The circuit used is shown in “Figure 3,” and the resulting signal sequence is given in “Figure 4.” For each step, the executed function, the signals, and the required tests and reactions according to the test results are described.

Notes

- The specified switching and positioning times between signal changes are the times used in the simulation:
 - Switching time: Control Q1-M1 to deactivation of B1: 200 ms (leaving the end position)
 - Positioning time: Control Q1-M1 to activation of B2: 1000 ms (reaching the end position)
 - Switching time: Control Q1-M2 to deactivation of B2: 200 ms (leaving the end position)
 - Positioning time: Control Q1-M2 to activation of B1: 1000 ms (reaching the end position)

In other test cycles, a switching time of 300 ms may be specified. This is because two valves are actuated sequentially there, resulting in a longer switching time.

- If plausibility and positioning time monitoring of the valves is implemented for every switching operation, the parts marked as “Optional” (highlighted in blue) can be omitted. The tests marked as “Optional” in the steps are time monitoring during the test cycle, which can also be performed through plausibility and positioning time monitoring.

Step 0: Move drive in direction B2 (Generate back pressure)

- Function:** First, drive M1 is briefly moved toward the end position with B2 without reaching the end position, so that pressure builds up in the drive.
- Control signals:** Q1-M1 = ON; after 100 ms Q1-M1 = OFF
- Test:** None
- Transition condition:** After 100 ms Q1-M1 = OFF

Step 1: Move drive in direction B1

- **Function:** Drive M1 is moved to the end position with B1 until it reaches the end position.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = ON
- **Test (optional):** The drive must reach the end position with B1 within the specified positioning time of 1000 ms.
- **Abort with failure (optional):** Time from Q1-M2 ON to B1 signal ≥ 1000 ms.
- **Transition condition:** Time from Q1-M2 ON to B1 signal < 1000 ms

Step 2: Move drive in direction B2

- **Function:** The drive is moved to the end position with B2.
- **Control signals:** Q1-M1 = ON; Q1-M2 = OFF
- **Test (optional):** The drive must leave the end position with B1 within the specified switching time of 200 ms.
- **Abort with failure (optional):** Time from Q1-M1 activation to B1 signal OFF ≥ 200 ms.
- **Transition condition:** Time from Q1-M1 activation to B1 signal OFF < 200 ms.

Step 3: Stop drive with SSC

- **Function:** The drive is stopped using the safety subfunction SSC.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = OFF
- **Test:** It is checked whether proximity switch B2 is actuated. If the proximity switch is reached within the positioning time of 1000 ms, the safety subfunction SSC was not executed.
- **Abort with failure:** Time from Q1-M1 and Q1-M2 OFF to B2 actuation ≥ 1000 ms.
- **Transition condition:** Time from Q1-M1 and Q1-M2 OFF to B2 actuation < 1000 ms.

Step 4: Move drive in direction B2

- **Function:** The drive is moved to the end position with B2.
- **Control signals:** Q1-M1 = ON; Q1-M2 = OFF
- **Test (optional):** It is checked whether the positioning time of 1000 ms from activation of the working valve to activation of B2 is not exceeded.
- **Abort with failure (optional):** Time from Q1-M1 ON to B2 signal ON ≥ 1000 ms.
- **Transition condition:** Time from Q1-M1 ON to B2 signal ON < 1000 ms.

Step 5: Move drive in direction B1

- **Function:** The drive is moved to the end position with B1.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = ON
- **Test (optional):** It is checked whether the switching time of 300 ms from activation of the working valve to deactivation of B2 is not exceeded.
- **Abort with failure (optional):** Time from Q1-M2 activation to B2 signal OFF ≥ 200 ms.
- **Transition condition:** Time from Q1-M2 activation to B2 signal OFF < 200 ms.

Step 6: Stop drive with SSC

- **Function:** The drive is stopped using the safety subfunction SSC.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = OFF
- **Test:** It is checked whether proximity switch B1 is actuated. If B1 is reached within the positioning time of 1000 ms, the safety subfunction SSC was not executed.
- **Abort with failure:** Time from Q1-M1 and Q1-M2 OFF to B1 actuation ≥ 1000 ms.

- **Transition condition:** Time from Q1-M1 and Q1-M2 OFF to B1 actuation < 1000 ms.

Step 7: Move drive in direction B1

- **Function:** The drive is moved to the end position with proximity switch B1.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = ON
- **Test (optional):** It is checked whether the positioning time of 1000 ms from activation of the working valve to activation of B1 is not exceeded.
- **Abort with failure (optional):** Time from Q1-M2 activation to B1 signal $\geq$ 1000 ms.
- **Transition condition:** Time from Q1-M2 activation to B1 signal < 1000 ms.

Step 8: Output signal “Test cycle successful”

- **Function:** The valves are switched off, and the signal “Test successful” is output.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = OFF; P2 = ON
- **Test:** None
- **Transition condition:** None

Abort with failure

- **Function:** The valves are switched off, and the signal “Failure” is output.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = OFF; P1 = ON
- **Test:** None
- **Transition condition:** None

2.5.4 Programming Simulation with Logic Elements

Important Notes

- This programming example uses simulation software for implementing the test cycle “Stopping Movement.” From this, a program for safety controllers can be derived, taking into account legal and normative requirements.
- This is the programming for the digital module K20, which is used in the accompanying FluidSim project file or the video “100506-1 - 5-3-Way Valve - Stopping.”

Test cycle

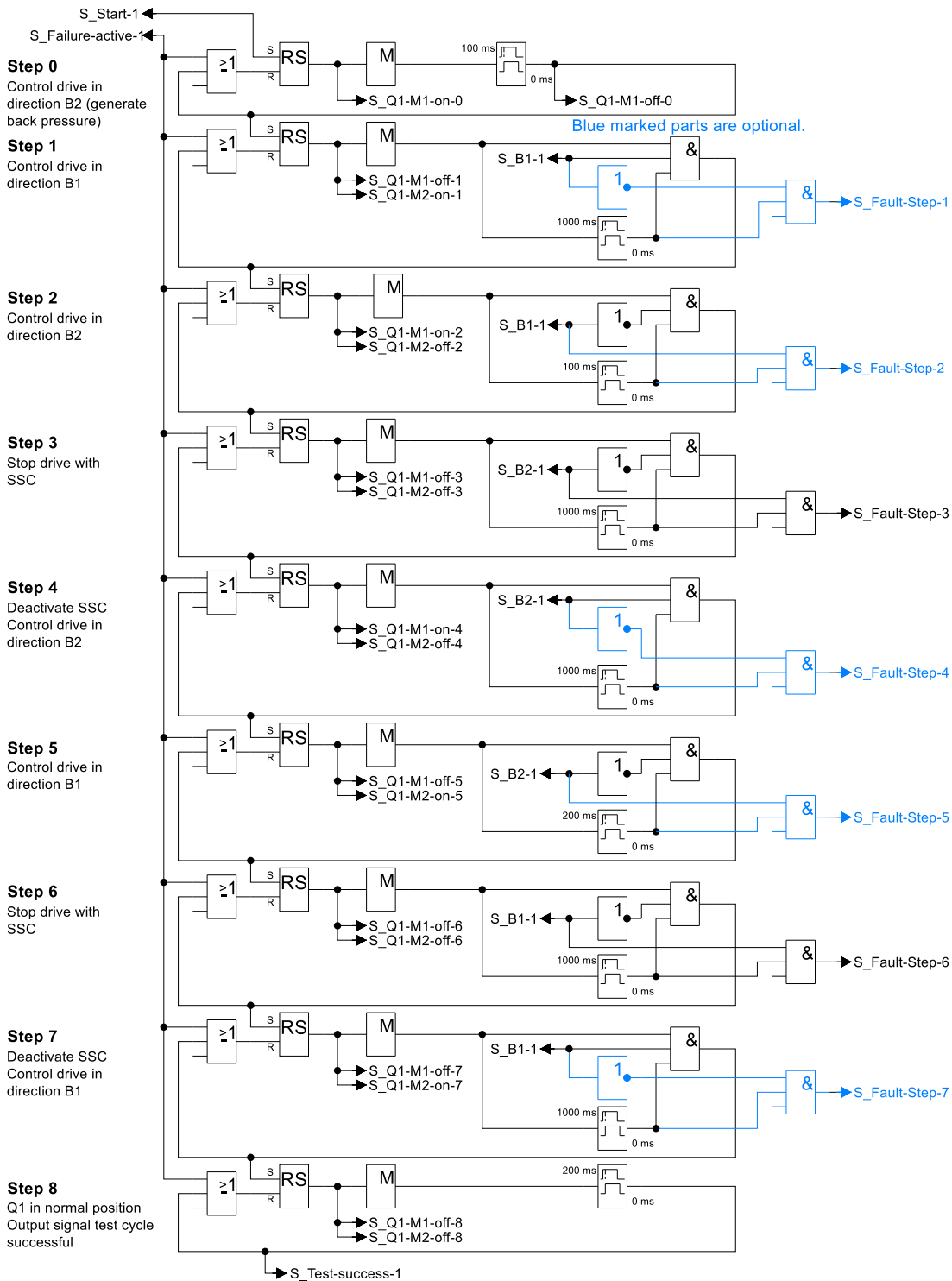
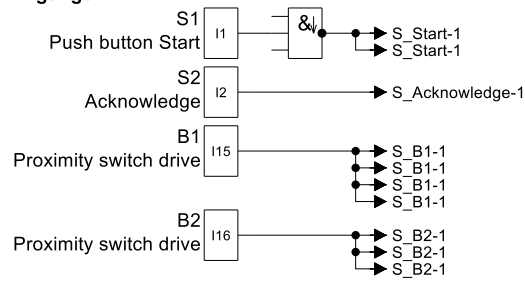
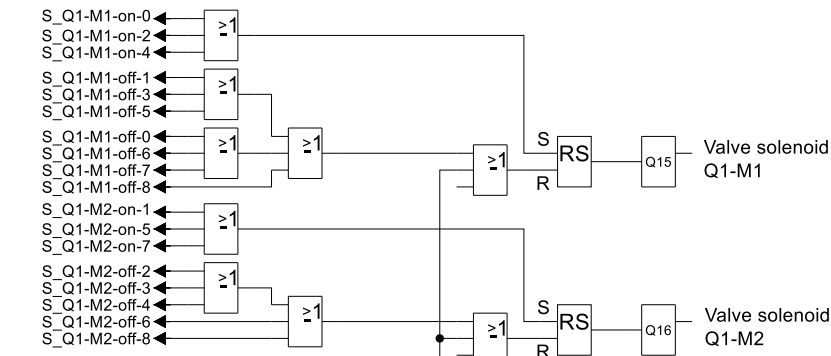


Figure 5 Program simulation: Test cycle

Eingänge



Outputs control valve solenoids



Outputs signal lamps

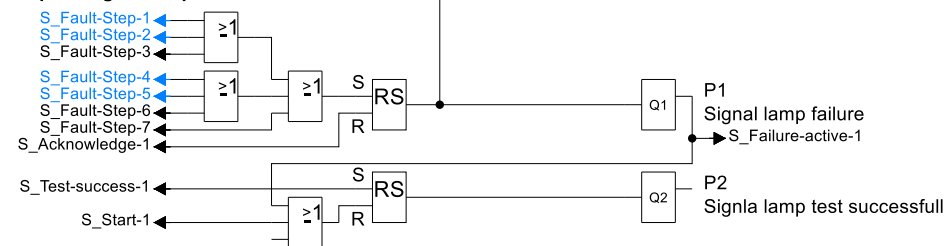


Figure 6 Program simulation: Inputs and outputs

3 Test Cycle ‘Holding in End Position for Drives with Piston Rod

3.1 Principle Circuit and Basic Sequence of the Test Cycle

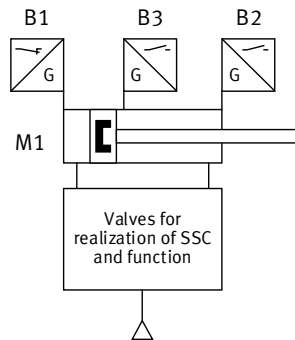


Figure 7 Principle circuit for the test cycle “Holding in end position for drives with piston rod

The basic procedure of the test sequence is that the pneumatic actuator M1 is moved to the respective end position of B1 and B2 using the operating valve. The end position is then held using the SSC safety sub-function. To test the SSC safety sub-function, the operating valve is used to move the drive out of the respective end position. Since, in a pneumatic drive with a piston rod, the actuator will move out of the end position monitored by B1, limit switch B3 is used to monitor the point that normally can no longer be reached. The movement occurs because the piston areas are different, resulting in different forces. Consequently, the drive moves out of the end position monitored by B1 and stops once the forces on the piston have reached equilibrium.

If the control signals and the signals from limit switches B1, B2, and B3 result in an implausible signal sequence or timing, the test cycle is aborted with a failure.

3.2 Flowchart

The standard sequence for the test cycle “Holding the End Position for drives with piston rod” is shown in the flowchart below.

Note

- If plausibility monitoring and positioning-time monitoring of the valves are implemented for every switching operation, the parts marked “Optional” (highlighted in blue) can be omitted. The tests marked “Optional” in the steps are time monitoring functions performed during the test cycle, which are also covered by plausibility and positioning-time monitoring.

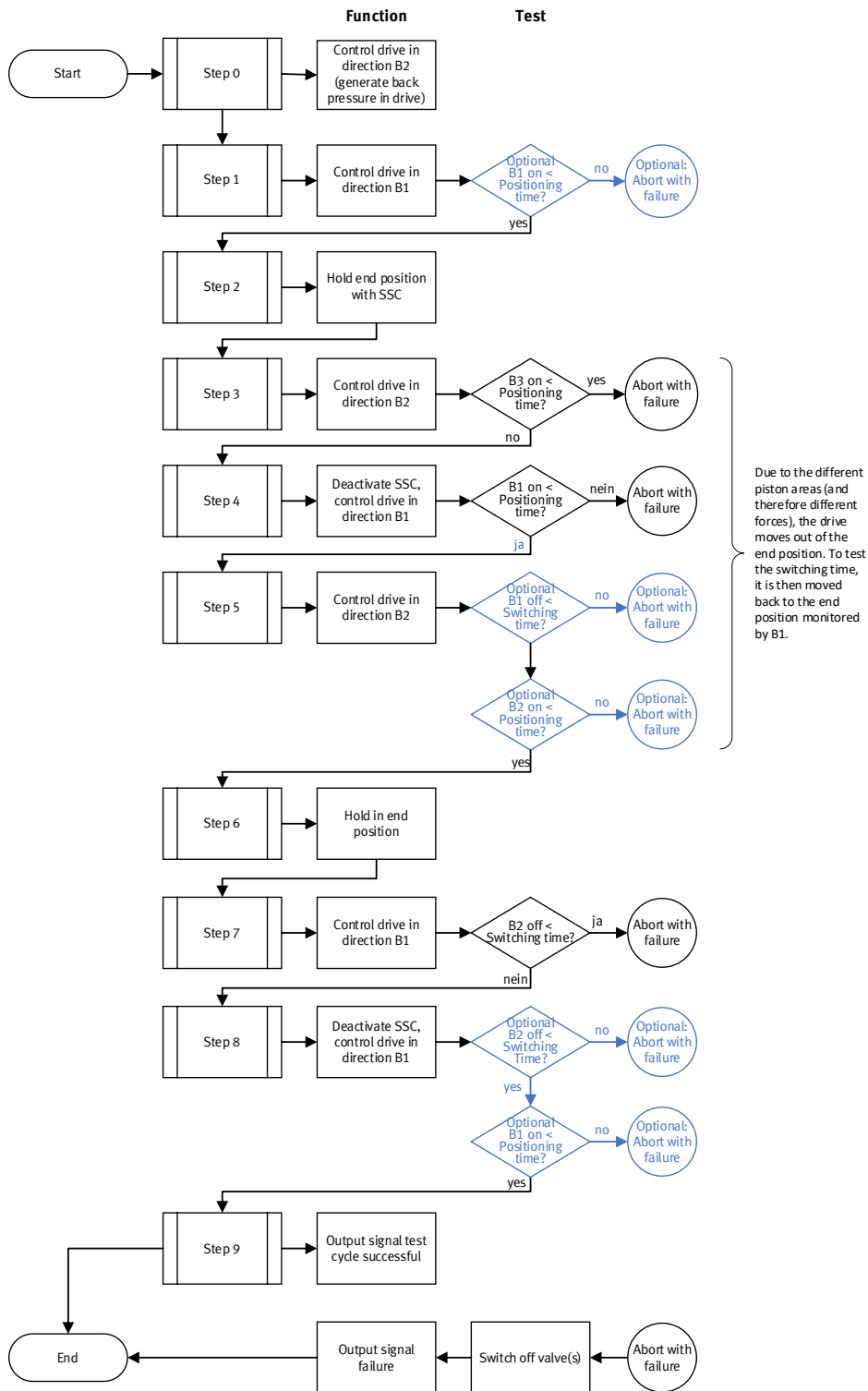


Figure 8 Flowchart of the SSC safety sub-function test cycle (holding the end position for drives with piston)

3.3 Description

- Step 0:** Build up counterpressure in the drive
 This step is used solely to build up counterpressure in the drive for the movement during Step 1. This step is optional if pressure is present in the drive when the test cycle starts, for example, if the drive is in a pressurized end position.
- Step 1:** Move the drive toward B1
 The drive is moved to the end position monitored by limit switch B1.

Optional: It is checked that a specified positioning time is not exceeded from actuation of the operating valve until limit switch B1 is switched on.

- **Step 2:** Hold the drive in the end position using SSC

The drive is held in the end position using the SSC safety sub-function.

- **Step 3:** Move the drive toward B2

The drive is moved to the end position monitored by limit switch B2.

It is checked whether limit switch B3 is reached within the specified positioning time. If limit switch B3 is reached, the SSC safety sub-function has not been executed and a fault has occurred.

- **Step 4:** Move the drive toward B1

It is checked that a specified positioning time is not exceeded from actuation of the valve until limit switch B1 is switched on.

- **Step 5:** Move the drive toward B2

The drive is moved to the end position monitored by limit switch B2.

Optional: It is checked that a specified switching time from actuation of the operating valve until limit switch B1 is switched off, or a specified positioning time until limit switch B2 is switched on, is not exceeded.

- **Step 6:** Hold the drive in the end position using SSC

The drive is held in the end position using the SSC safety sub-function.

- **Step 7:** Move the drive toward B1

The drive is moved to the end position monitored by limit switch B1.

It is checked whether the drive leaves the end position monitored by B2. If the end position is left, the SSC safety sub-function has not been executed and a fault has occurred.

- **Step 8:** Move the drive toward B1

The drive is moved to the end position monitored by limit switch B1.

Optional: It is checked that a specified switching time from drive of the operating valve until limit switch B2 is switched off, or a specified positioning time until limit switch B1 is switched on, is not exceeded.

- **Step 9:** Output the “Test successful” signal

The valves are switched off and the “Test successful” signal is output.

- **Abort due to a fault**

The valves are switched off and the “Fault” signal is output.

Notes

- Depending on the particular test cycle, individual steps may be omitted or additional steps may need to be added. This generally depends on the drive selected and is explained in the detailed descriptions.

3.4 Failures

The following failures specified in Tables B.4 and D.4 of ISO 13849-2 can be detected with this test cycle:

- Changes in switching times (only if the program sections marked “Optional” are used)
- Sticking in the center position or in an end position
- Sticking in an intermediate position
- Permanent short circuit of the solenoid-coil line to 24 V or 0 V, resulting in the valve moving to a switching or rest position- Permanent interruption of 24 V or 0 V in the solenoid-coil line

The following faults cannot be detected reliably:

- Automatic change of the output switching position (without an input signal)
Detecting this fault requires continuously active plausibility monitoring of the control and diagnostic signals.
- Leakage

An additional leakage test is required to detect leakage.

- Short circuits and cross-circuits
- Temporary short circuits of the solenoid-coil line to 24 V or 0 V, which may cause the valve to switch briefly.

Detecting short circuits and cross-circuits requires at least one of the following measures:

- Short-circuit and cross-circuit monitoring of the safety outputs
- For electromechanical contacts, a fuse in the active line
- Continuously active plausibility monitoring of the control and diagnostic signals

3.5 'Test cycle 2 "Hold End Position for Drives with piston rod" with 2 x piloted check valves

Function: Safe Stopping and ...	Ventil(e)	Drive	Mouning position	Test
Holding in end position	2 x piloted check valves	Drive with piston rod	Any	Closed volume flow paths

This section describes a possible test cycle for two piloted check valves with the diagnostic measure of proximity switches on the drive for the safety subfunction "safe stopping and closing (SSC)."

Notes

- The required characteristics of the components and recommendations for possible Festo products are included in the Application Notes for the circuits of the safety subfunction SSC.
- When calculating reliability, the test cycle for valve Q1 must include three complete switching cycles, and for valves K1, Q2, and Q3, four complete switching cycles must be considered.

3.5.1 Circuit

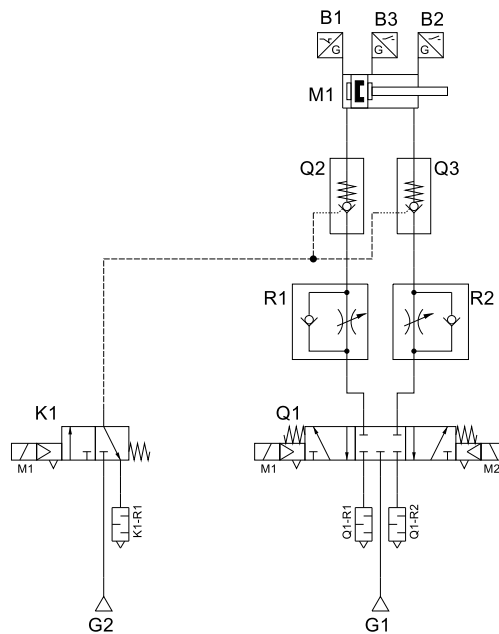


Figure 9 Used circuit for test cycle with 2 x piloted check valves

3.5.2 Signal Sequence and Position of the Drive

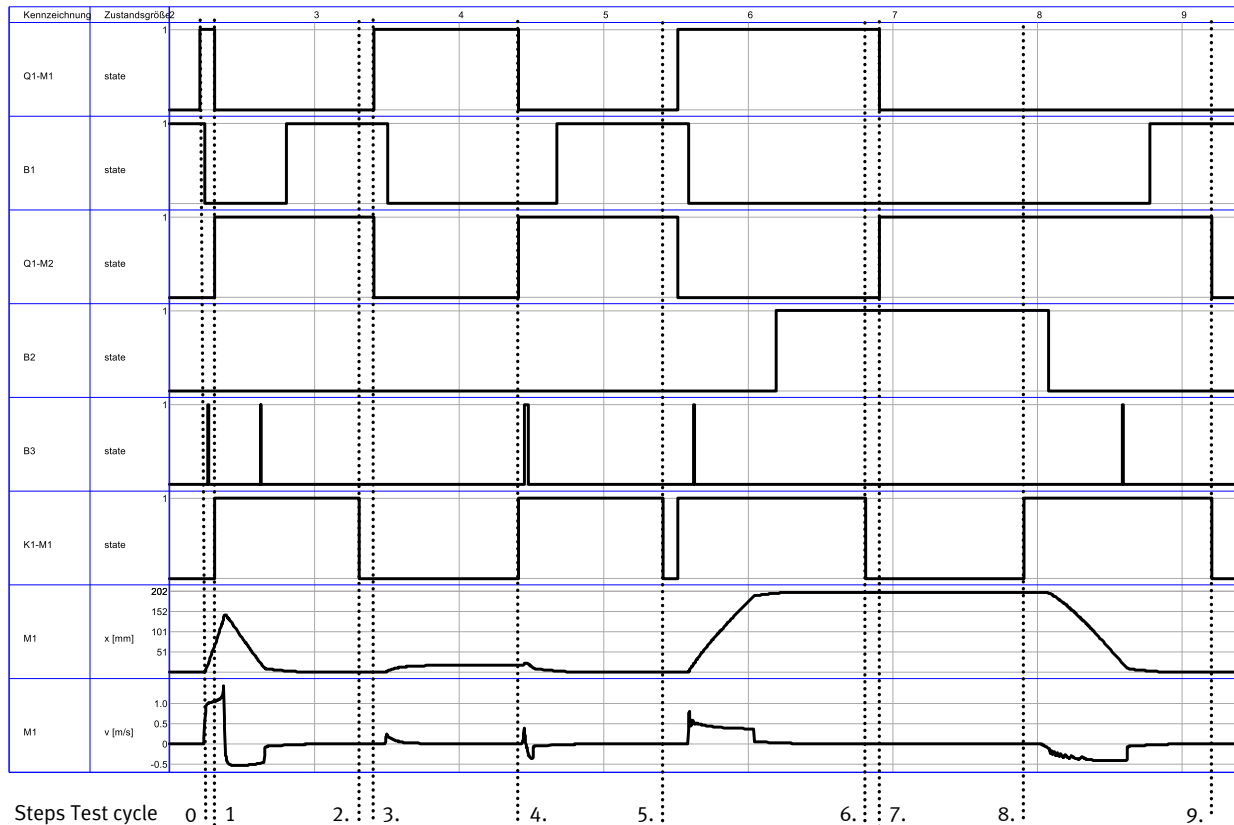


Figure 10 Signal sequences and position of the drive during the test sequence

3.5.3 Test Procedure for 2 x Piloted Check Valves

This test procedure is for 2 x piloted check valves based on the flowchart in Section → 3.2 and the description in Section → 3.3. The circuit used is shown in “Figure 9,” and the resulting signal sequence is given in “Figure 10.” For each step, the executed function, the signals, and the required tests and reactions according to the test results are described.

Notes

- The specified switching and positioning times between signal changes are the times used in the simulation:
 - Switching time: Control Q1-M1 to deactivation of B1: 300 ms (leaving the end position)
 - Positioning time: Actuation Q1-M1 with K1-M1 switched off until B3 is reached: 1,000 ms (fault in the controlled check valve Q3)
 - Positioning time: Control Q1-M1 to activation of B2: 1000 ms (reaching the end position)
 - Switching time: Control Q1-M2 and switched off K1-M1 to deactivation of B2: 300 ms (leaving the end position)
 - Positioning time: Control Q1-M2 to activation of B1: 1000 ms (reaching the end position)
 - Switching time: Control K1-M1 and piloted check valves Q2 and Q3: 100 ms

In other test cycles, a switching time of 200 ms may be specified. This is because two valves are actuated sequentially there, resulting in a longer switching time.

- The circuit also includes a closed-center 5/3-way valve. The test cycle described here tests only the two pilot-operated check valves Q2 and Q3. The test cycle for a closed-center 5/3-way valve is provided in Section → 2.5.
- If plausibility and positioning time monitoring of the valves is implemented for every switching operation, the parts marked as “Optional” (highlighted in blue) can be omitted. The tests marked as

“Optional” in the steps are time monitoring during the test cycle, which can also be performed through plausibility and positioning time monitoring.

Step 0: Move drive in direction B2 (Generate back pressure)

- **Function:** First, drive M1 is briefly moved toward the end position with B2 without reaching the end position, so that pressure builds up in the drive.
- **Control signals:** Q1-M1 = ON; after 100 ms Q1-M1 = OFF
- **Test:** None
- **Transition condition:** After 100 ms Q1-M1 = OFF

Note: Control valve K1 does not need to be actuated because the pilot-operated check valve Q2 opens due to the pressure difference while Q3 remains closed. This builds up pressure in the drive.

Step 1: Move drive in direction B1

- **Function:** Drive M1 is moved to the end position with B1 until it reaches the end position.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = ON; K1-M1 = ON
- **Test (optional):** The drive must reach the end position with B1 within the specified positioning time of 1000 ms.
- **Abort with failure (optional):** Time from Q1-M2 and K1-M1 ON to B1 signal $\geq$ 1000 ms.
- **Transition condition:** Time from Q1-M2 and K1-M1 ON to B1 signal $<$ 1000 ms

Step 2: Hold end position with SSC

- **Function:** The control of the piloted check valves is switched off.
- **Control signals:** K1-M1 = OFF and waiting of switching time 100 ms
- **Test:** None.

Step 3: Move drive in direction B2

- **Function:** The drive is moved to the end position monitored by B2; however, it must not reach B3.
- **Control signals:** Q1-M1 = ON; Q1-M2 = OFF
- **Test:** The drive must not reach B3 within the specified positioning time of 1000 ms.
- **Abort with failure (optional):** Time from Q1-M1 ON to B3 signal ON $<$ 1000 ms.
- **Transition condition:** Time from Q1-M1 ON to B3 signal ON $\leq$ 1000 ms.
- **Note:** The signal from B3 is stored in an RS flip-flop so that it remains available for testing after the delay times have elapsed.

Step 4: Move drive in direction B1

- **Function:** The drive is moved to the end position with B1.
- **Control signals:** K1-M1 = ON; Q1-M1 = OFF; Q1-M2 = ON
- **Test (optional):** It is checked whether the positioning time of 1,000 ms is exceeded between actuation of the control valve for the pilot-operated check valves and the operating valve and the activation of B1.
- **Abort with failure (optional):** Time from K1-M1 and Q1-M2 activation to B1 signal $\geq$ 1000 ms.
- **Transition condition:** Time from K1-M1 and Q1-M2 activation to B1 signal $<$ 1000 ms.
- **Note:** Control valve K1 and the pilot-operated check valves Q2 and Q3 are switched off so that the duration of the switching operation can be monitored during the next activation.

Step 5: Move drive in direction B2

- **Function:** The drive is moved to the end position monitored by B2

- **Control signals:** Q1-M1 = ON; Q1-M2 = OFF; K1-M1 = ON
- **Test (optional):** It is checked that the switching time of 300 ms is not exceeded from actuation of the operating valve and the control valve for the pilot-operated check valves until B1 switches off. Subsequently, it is checked that the positioning time of 1,000 ms is not exceeded from actuation of the operating valve and the control valve for the pilot-operated check valves until B2 switches on.
- **Abort with failure (optional):** Time from actuation of Q1-M1 and K1-M1 until the B1 signal switches off ≥ 300 ms.
Time from actuation of Q1-M1 and K1-M1 until the B1 signal switches on ≥ 1000 ms.
- **Transition condition:** Time from actuation of Q1-M1 and K1-M1 until the B2 signal switches off < 300 ms, and time from actuation of Q1-M1 and K1-M1 until the B2 signal switches off < 1000 ms

Step 6: Hold end position with SSC

- **Function:** The control of the piloted check valves is switched off.
- **Control signals:** K1-M1 = OFF and waiting of switching time 100 ms
- **Test:** None.

Step 7: Move drive in direction B1

- **Function:** The drive is moved to the end position with proximity switch B1.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = ON
- **Test:** The drive must not leave the end position monitored by limit switch B2 within the switching time.
- **Abort with failure:** Time from Q1-M2 activation to B2 signal < 300 ms.
- **Transition condition:** Time from Q1-M2 activation to B2 signal ≥ 300 ms.

Step 8: Move drive in direction B1

- **Function:** The drive is moved to the end position monitored by B1
- **Control signals:** Q1-M2 = ON; Q1-M1 = OFF; K1-M1 = ON
- **Test (optional):** It is checked that the switching time of 300 ms is not exceeded from actuation of the operating valve and the control valve for the pilot-operated check valves until B2 switches off. Subsequently, it is checked that the positioning time of 1,000 ms is not exceeded from actuation of the operating valve and the control valve for the pilot-operated check valves until B1 switches on.
- **Abort with failure (optional):** Time from actuation of Q1-M1 and K1-M1 until the B2 signal switches off ≥ 300 ms.
Time from actuation of Q1-M1 and K1-M1 until the B2 signal switches on ≥ 1000 ms.
- **Transition condition:** Time from actuation of Q1-M1 and K1-M1 until the B1 signal switches off < 300 ms, and time from actuation of Q1-M1 and K1-M1 until the B1 signal switches off < 1000 ms

Step 9: Output signal "Test cycle successful"

- **Function:** The valves are switched off, and the signal "Test successful" is output.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = OFF; K1-M1 = OFF; P2 = ON
- **Test:** None
- **Transition condition:** None

Abort with failure

- **Function:** The valves are switched off, and the signal "Failure" is output.
- **Control signals:** Q1-M1 = OFF; Q1-M2 = OFF; K1-M1 = OFF; P1 = ON
- **Test:** None

- **Transition condition:** None

3.5.4 Programming Simulation with Logic Elements

Important Notes

- This programming example uses simulation software for implementing the test cycle “Holding End Position for Drives with Piston Rod.” From this, a program for safety controllers can be derived, taking into account legal and normative requirements.
- This is the programming for the digital module K20, which is used in the accompanying FluidSim project file or the video “100506-6 – Piston Rod Drive – Piloted Check Valves – End Position.”

Test cycle

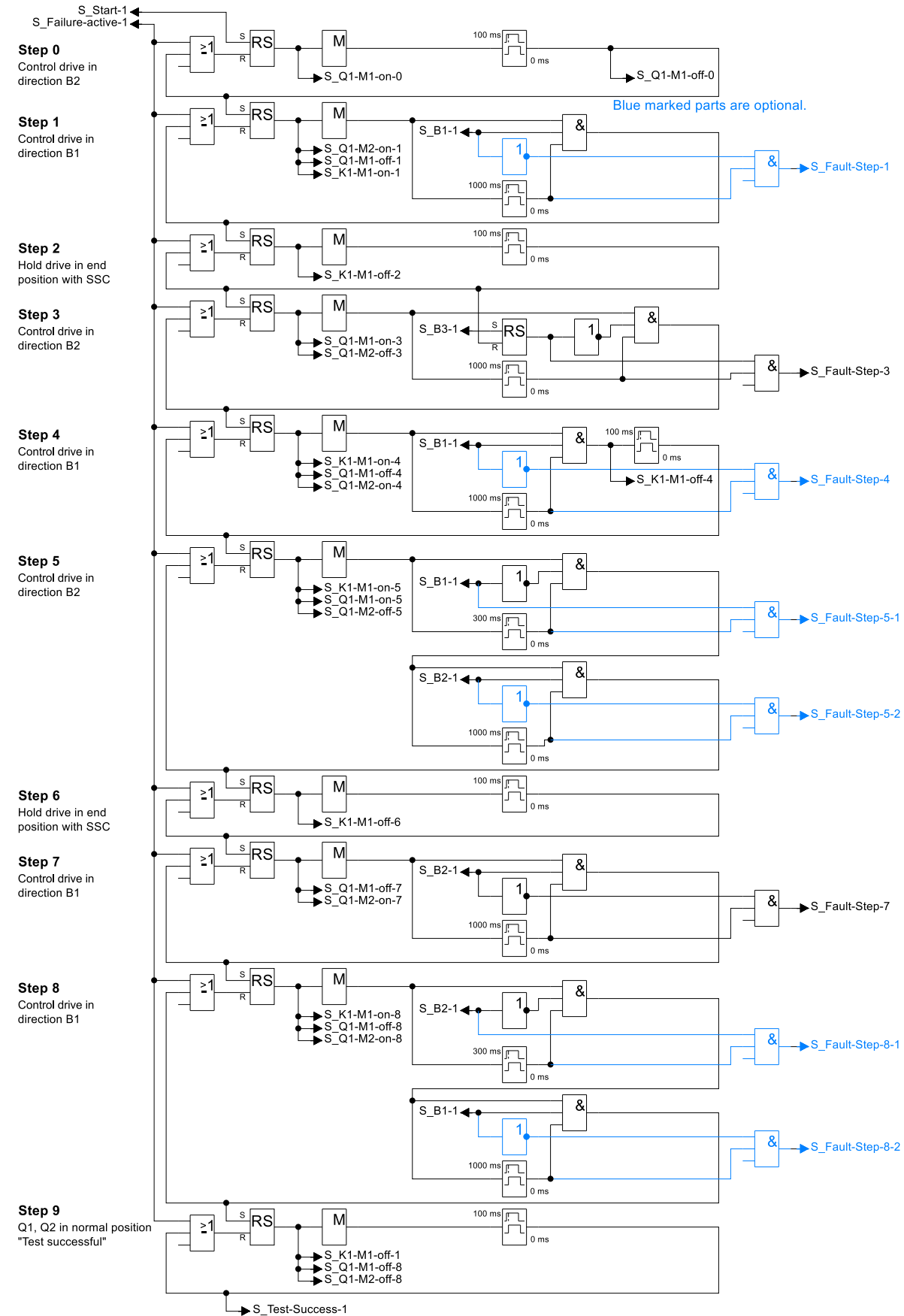
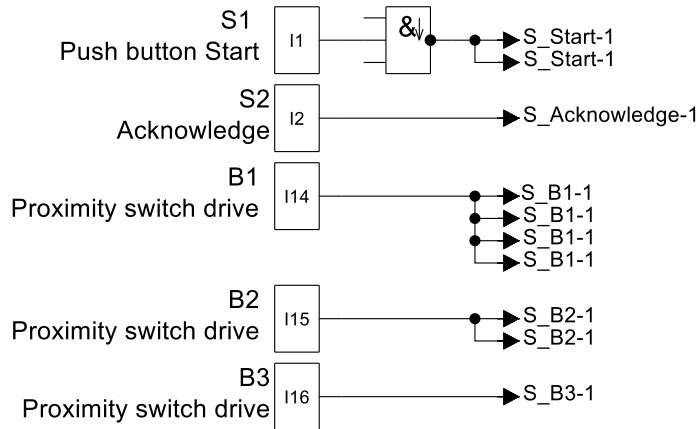
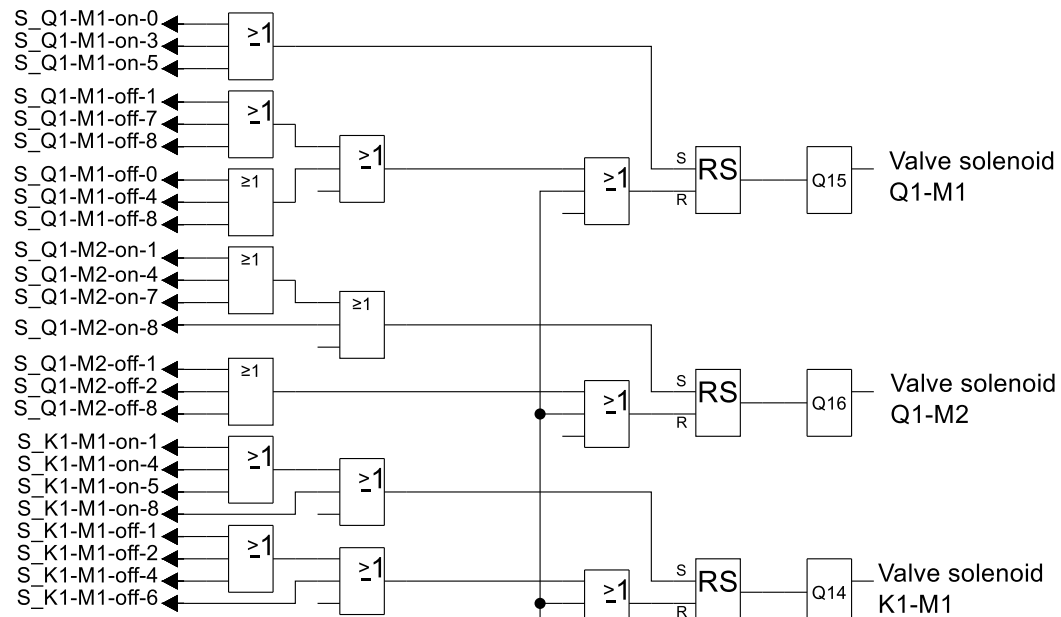


Figure 11 Program simulation: Test cycle

Inputs



Outputs control valve solenoids



Outputs signal lamps

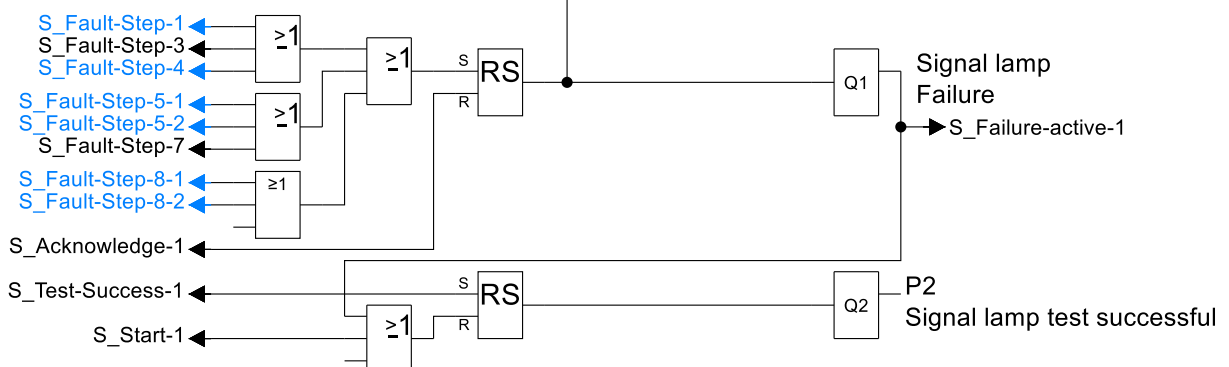


Figure 12 Program simulation: Inputs and outputs

4 Used Literature

4.1 Cited Documents from Festo

- [1] [100396 Notes on features of directional control valves](#)
- [2] [100406 Safety Subfunctions Pneumatics – SSC, PUS](#)

4.2 Standards

- [3] DIN EN ISO 4414:2011-04 – Pneumatic fluid power - General rules and safety requirements for systems and their components (ISO 4414:2010); German version EN ISO 4414:2010
- [4] ISO 5598:2020-01 – Fluid power systems and components - Vocabulary
- [5] DIN EN ISO 12100:2011-03 - Safety of machinery - General principles for design - Risk assessment and risk reduction (ISO 12100:2010); German version EN ISO 12100:2010
- [6] DIN EN ISO 13849-1:2023-12 – Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design (ISO 13849-1:2023); German version EN ISO 13849-1:2023
- [7] 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
- [8] VDMA 24584:2022-06 – Safety functions of regulated and unregulated (fluid) mechanical systems; German Version
- [9] DIN EN 61508:2011-02 - Functional safety of electrical/electronic/programmable electronic safety-related systems (IEC 61508:2010); German version EN 61508:2010
- [10] DIN EN 61508-4:2011-02 - Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 4: Definitions and abbreviations (IEC 61508-4:2010); German version EN 61508-4:2010
- [11] DIN EN 61511:2019-02 - Functional safety - Safety instrumented systems for the process industry sector - (IEC 61511:2016); German version EN 61511:2017
- [12] DIN EN IEC 62061:2023-02 - Safety of machinery - Functional safety of safety-related control systems (IEC 62061:2021); German version EN IEC 62061:2021

4.3 Legal Regulations

- [13] Machinery Directive: Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast)
- [14] Machinery Regulation: Regulation (EU) 2023/1230 of the European Parliament and of the Council of 14 June 2023 on machinery and repealing Directive 2006/42/EC of the European Parliament and of the Council and Council Directive 73/361/EEC

5 Information about the Document

5.1 General Information

Document Number	100506	
Diagnostic Measure	Test Cycle SSC	

5.2 Revision History

Ver.	Date	Ed.	Chapter	Description of Change/Impact
1.10	2026-08-17	JKHL	All	Creation of document

5.3 Approval/Release of the Document

Role	Signature
Release	

5.4 Period of Validity

Document is valid until 2031-08-18 or until one of the documents used or the required relevant base are changed.



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