

Competence in Functional Safety

Solenoid valves for safety-instrumented systems –
functional principle and typical applications



Binary converters

Diaphragms

Applications

SAMSON

AIR TORQUE · CERA SYSTEM · KT-ELEKTRONIK · LEUSCH
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Founded in 1907, SAMSON has since become a world-wide leader in the manufacture of expertly engineered control valves.

SAMSON has over 50 subsidiaries, amongst them noted manufacturers of special valves.

With these subsidiaries, SAMSON is represented in over 80 countries to assist its customers on all continents.



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1 Scope

In safety-instrumented systems, pneumatic valves are used to shut off or open pipelines. Solenoid valves are the interface between the electric control level and the pneumatic actuator. SAMSOMATIC has been active in developing and manufacturing solenoid valves with a high reliability at a low power consumption for many years. The solenoid valves meet the highest quality requirements and are suitable for use in safety-instrumented systems up to SIL 3 according to IEC 61511, up to SIL 4 according to IEC 61508 as well as PL e according to ISO 13849.

2 What makes SAMSOMATIC solenoid valves superior?

1. Solenoid valves with diaphragms are preferably used in safety-instrumented systems. The decisive advantage provided by diaphragms is that the solenoid valves operate reliably on demand and move the valve to the fail-safe position even after the solenoid valves have remained static for long periods of time or when the booster valves are slightly clogged with dirt.
2. An electropneumatic binary converter, which has proven reliable in service a million times over, working together with a flapper/nozzle system, guarantees reliable switching even after it has remained static for long periods of time.
3. By constantly purging the electronics compartment with instrument air, the solenoid valves are protected against corrosion even when installed in damp or aggressive environments.
4. All solenoid valves are subjected to function and leak tests, minimizing the probability of failure on demand due to defective components or leaks.



3 Functional principle of the electropneumatic binary converter

The electropneumatic binary converter is supplied with a constant supply pressure of 1.4 bar.

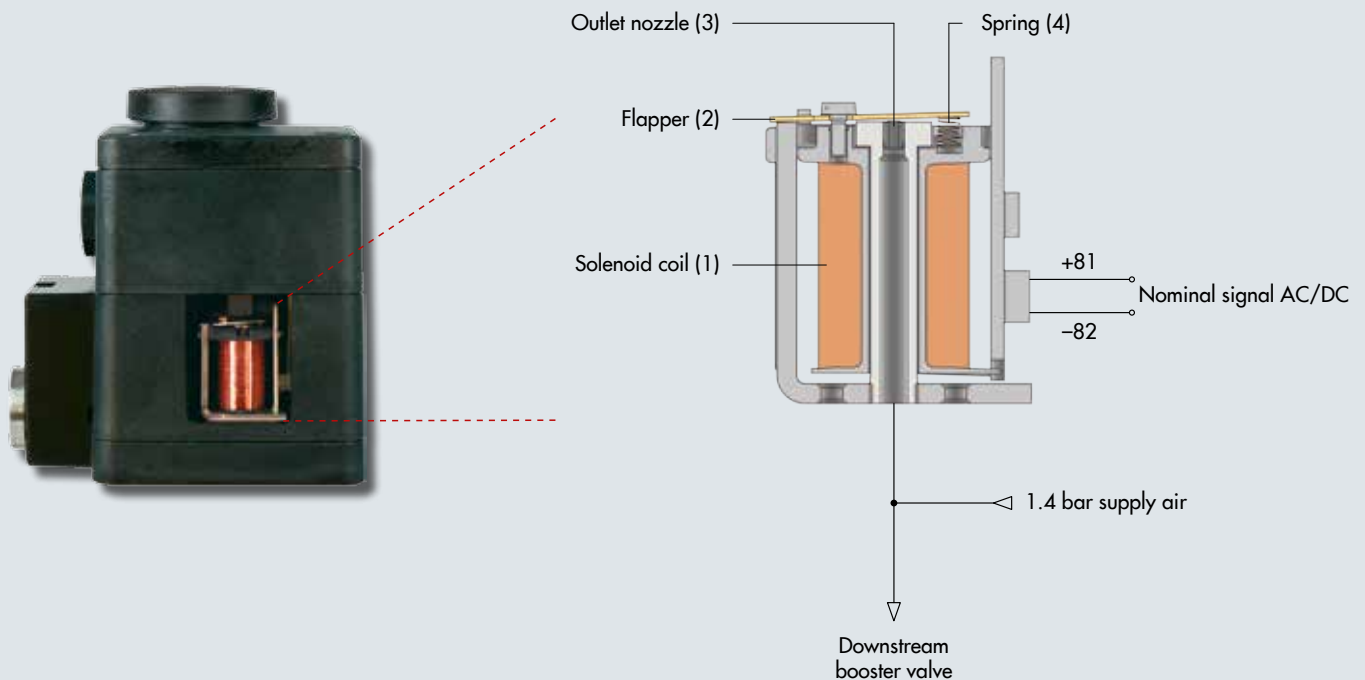
In the idle position, the flapper (2) is lifted off the outlet nozzle (3) by the spring (4), allowing a small rate of air to flow through the outlet nozzle into the electronics compartment. This causes the pressure in the system to drop to a level at which the downstream booster valve is not activated (refer to section 4).

When the solenoid coil (1) is energized by an electric binary signal, the magnetic field causes the flapper (2) to be pushed downwards against the force of the spring (4) and the outlet nozzle (3) to be closed. As a result, the pressure in the system rises and the booster valve is switched to the operating position.

When the electric binary signal is deactivated, the booster valve is switched to the idle position again by the spring (4).

Advantages of the flapper/nozzle system

- Reliable switching even after remaining static for long periods of time
- No memory effect, as occurs in piezo elements for example
- Switching behavior independent of the mounting position
- Long service life (over 20 million switching cycles)
- Low power consumption thanks to frictionless bearing of the flapper



4 Functional principle of solenoid valves with diaphragms

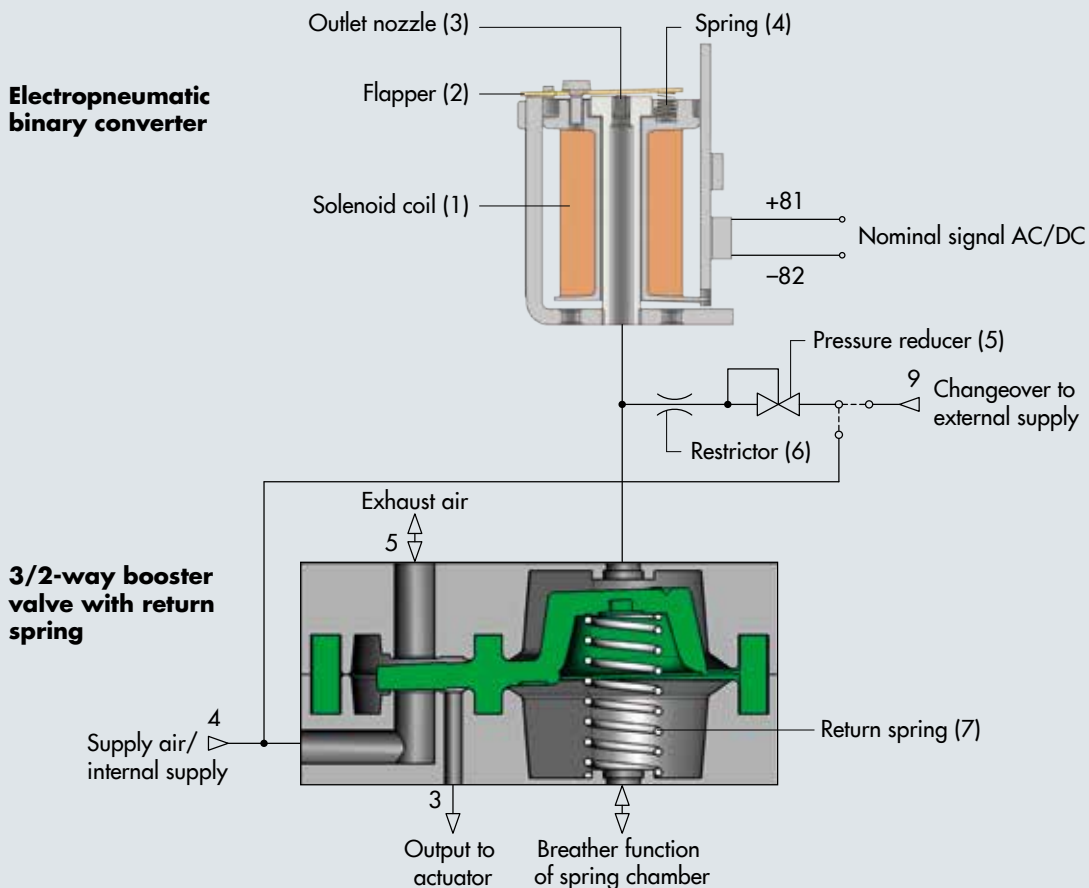
The solenoid valves consist of an electropneumatic binary converter (refer to section 3) and a booster valve with return spring. The supply pressure is applied to connection 4. Connection 3 is routed to the actuator. The actuator is vented over connection 5.

The air supply for the electropneumatic binary converter is routed internally through connection 4 at the booster valve. Connection 9 is sealed by a blanking plug. The pressure reducer (5) reduces the supply air pressure to 1.4 bar.

In the idle position, the flapper (2) is lifted off the outlet nozzle (3) by the spring (4). This causes a pressure lower than the switch-on pressure of the booster valve to build up in the pressure divider, which consists of the restrictor (6) and outlet nozzle (3).

When the solenoid coil (1) is energized by an electric binary signal, the outlet nozzle (3) is closed by the flapper (2) against the force of the spring (4). This causes the pressure in the pressure divider to rise above the switch-on pressure of the booster valve, switching it to the operating position.

After the solenoid coil is de-energized, the booster valve is switched to the idle position again by the return spring (7). The solenoid valve can be converted to accept an external air supply at connection 9 by turning a flat gasket on the enclosure. This is necessary when the solenoid valve is mounted onto an actuator for modulating service and a constant control pressure of at least 1.4 bar must be guaranteed at the electropneumatic binary converter.



5 Applications

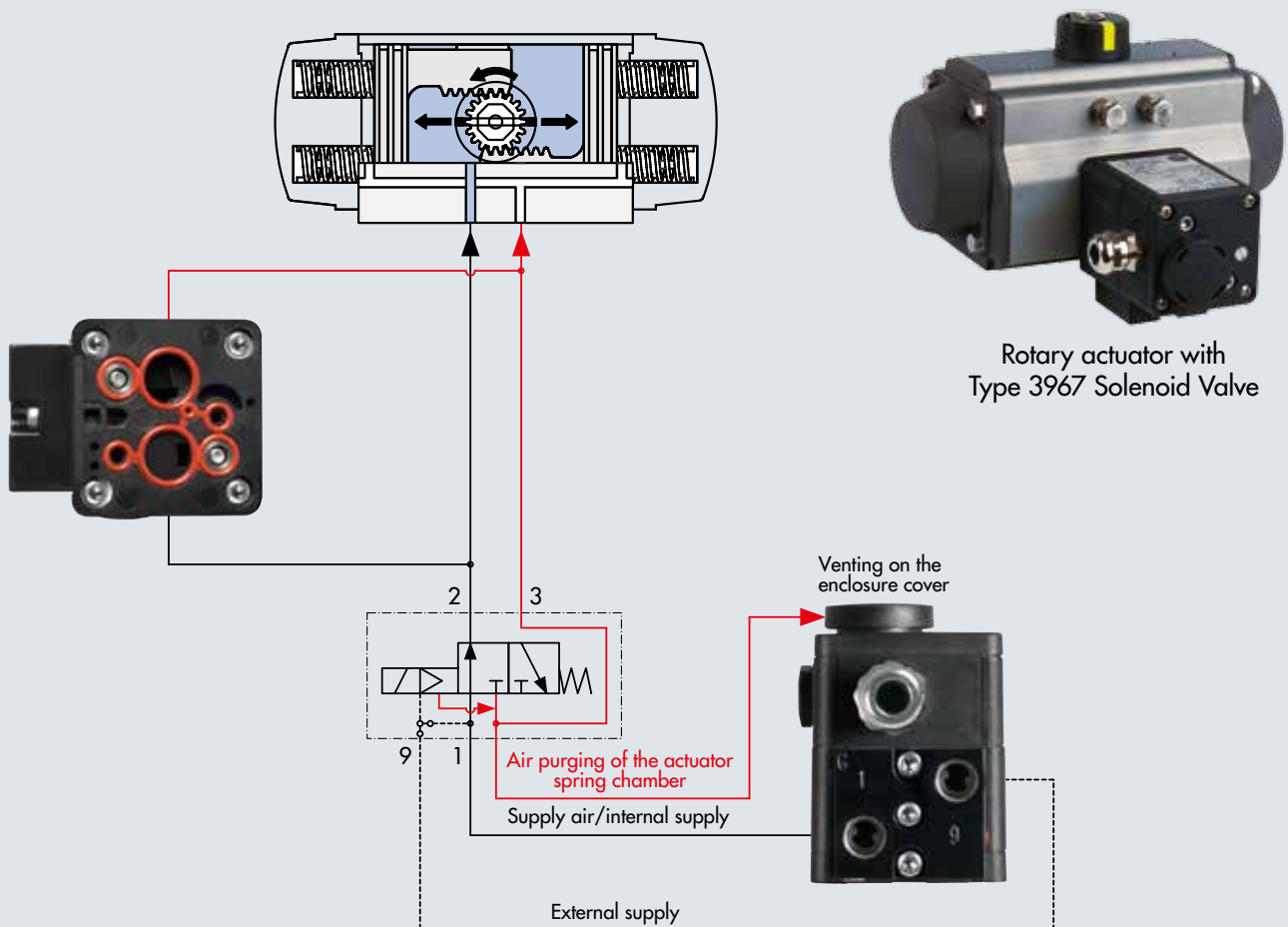
5.1 Air purging of the actuator spring chamber to protect the actuator springs against corrosion

Task

In safety-instrumented systems, valves often remain static in one position for long periods of time. During this time, the actuator springs are at risk of corroding if moisture enters the actuator.

Solution using a Type 3967 Solenoid Valve

The electronics compartment of the solenoid valve is constantly purged with instrument air through the flapper/nozzle system (refer to section 3). This air purging is also guaranteed when the solenoid valve is energized. The electronics compartment is directly connected to the actuator's spring chamber over the NAMUR interface. The solenoid valve is vented at the enclosure cover by a filter check valve (with IP 65 degree of protection), which opens at a defined excess pressure. As a result, a minimal level of positive pressure constantly exists in the electronics compartment and the actuator spring chamber, preventing moisture from entering the spring chamber and inhibiting corrosion.



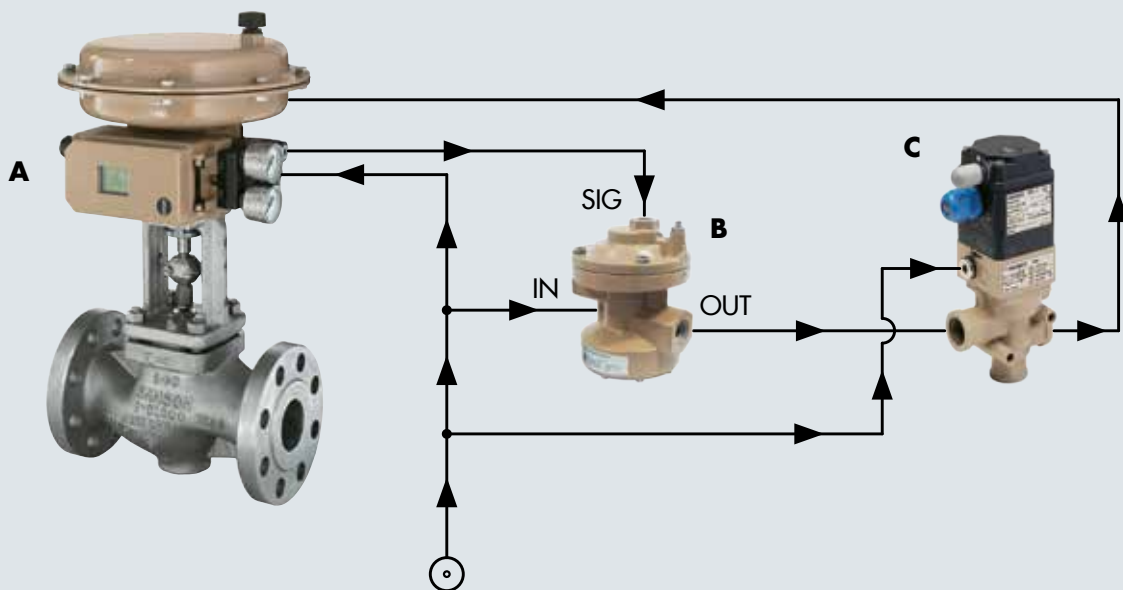
5.2 Emergency venting of an actuator

Task

In the event of failure, an actuator is to be vented independent of the control signal.

Solution

The actuator is often controlled by a positioner (A) and a solenoid valve (C) in a process control system. When the solenoid valve (C) is energized, the output of the pneumatic booster (B) is connected to the actuator. The pneumatic booster (B) supplies the actuator with an air flow output whose pressure corresponds exactly to the signal pressure, except that it has a much higher volume. This increases the positioning speed even of large pneumatic actuators. In the event of failure, the electric power supply is cut off by the process control system and the solenoid valve (C) is switched to the fail-safe position. The actuator is vented independent of the output of the positioner (A) and pneumatic booster (B). This solution can also be implemented for small actuators without a pneumatic booster (B).



A – SAMSON Type 3730-3 Positioner

B – SAMSON Type 3755 Pneumatic Booster

C – SAMSOMATIC solenoid valve (e.g. Type 3963-1310014211101000)

5.3 Venting an actuator when the supply pressure falls below a minimum pressure

Task

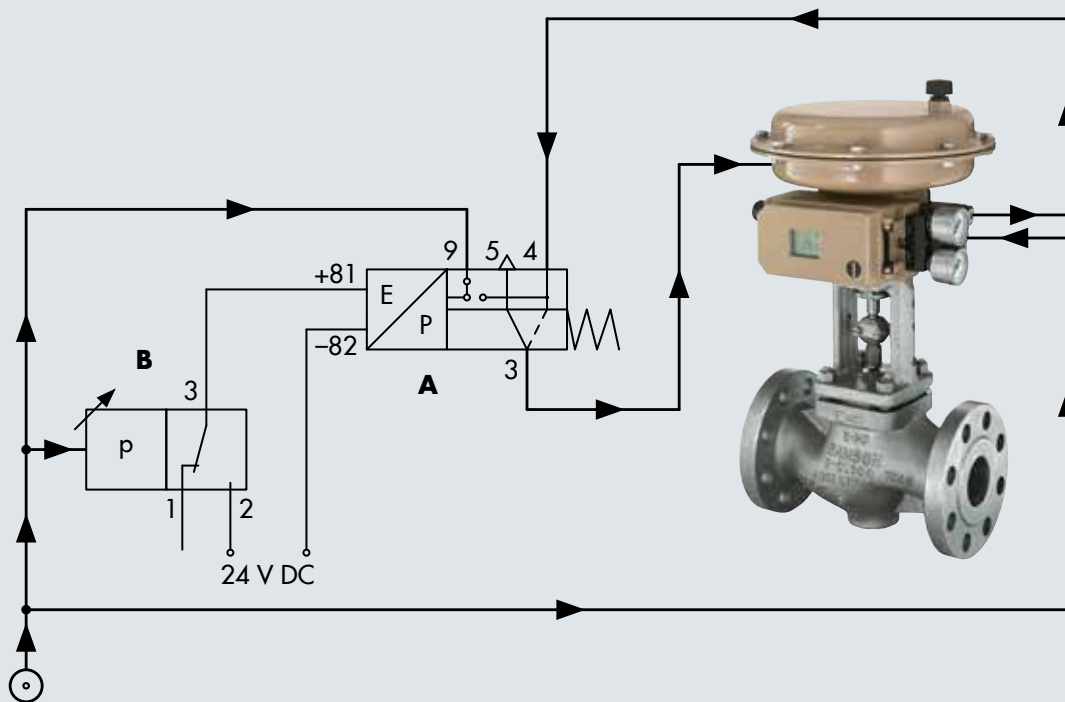
If the supply pressure level falls below a certain pressure, the actuator is to be vented and the valve moved to its fail-safe position.

Solution using a solenoid valve and an electric pressure monitor or pressure limiter

In normal operation, the actuator is controlled by a positioner together with a solenoid valve (A). The supply pressure is constantly monitored by an electric pressure monitor (B). When the supply pressure falls below a certain minimum pressure, the electric power supply is automatically cut off and the solenoid valve (A) is switched to fail-safe position. The actuator is vented as a result. The electric signal is not reactivated immediately after the supply pressure increases again due to the hysteresis of the pressure monitor (B).

An electric pressure limiter with internal interlock can also be used instead of the electric pressure monitor. In this case, the electric signal must be reactivated manually.

This solution can also be implemented for rotary actuators and on/off valves.



- A – SAMSOMATIC solenoid valve (e.g. Type 3963-13100220111100000)
- B – SAMSOMATIC Type 3994-0370-DWR-6 Electric Pressure Monitor, or alternatively Type 3994-0370-DWR-6.206 Electric Pressure Limiter with internal interlock (adjustment range between 0.5 and 6 bar)

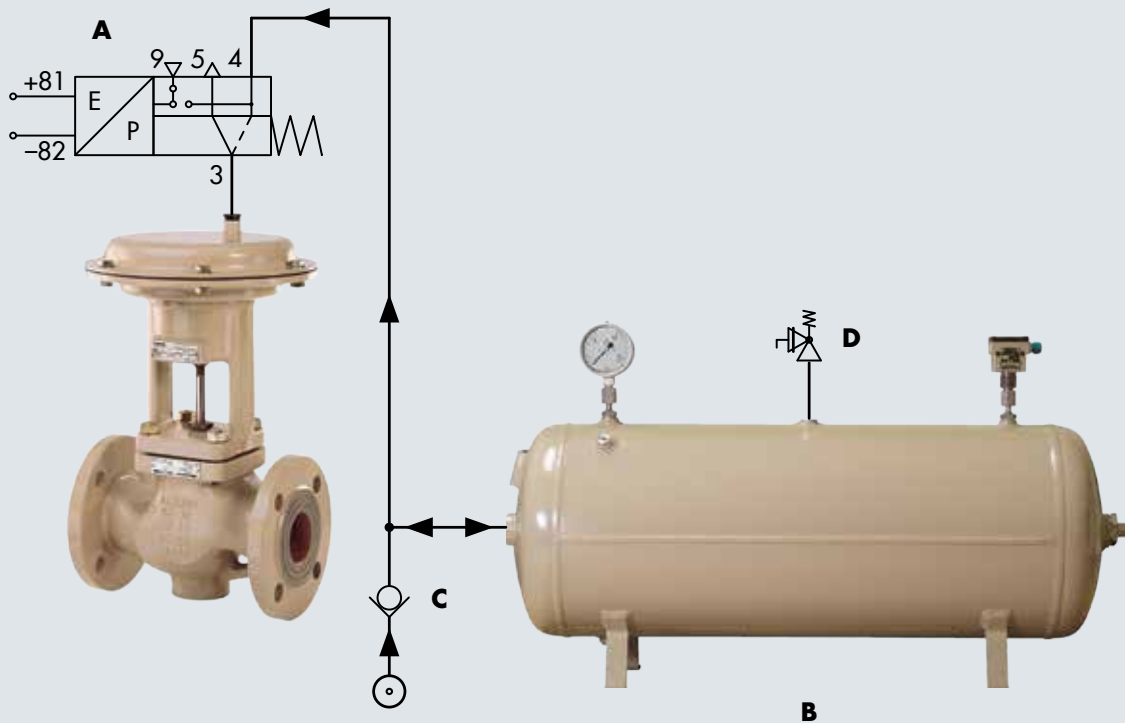
5.4 Switching to a backup buffer tank when the air supply fails

Task

After a supply air failure, the position of an on/off valve is to be maintained for a certain period of time.

Solution using a buffer tank for instrument air

In normal operation, the actuator is filled with air or vented by a solenoid valve (A) according to the process requirements. The required instrument air is supplied by a main supply air station. In the event that this air station fails, the air supply is maintained by a backup buffer tank (B), which provides the solenoid valve (A) with instrument air. The continued operation of an on/off valve over a certain period can be guaranteed in this way. This allows repairs to be performed on the supply air station while the process is running or the plant to be shut down safely. The supply pressure can be monitored by an electric pressure monitor (e.g. Type 3994-0370-DWR-6, not shown in the diagram) to signal when the pressure falls below a certain limit.



- A – SAMSOMATIC solenoid valve (e.g. Type 3963-13100120011100000)
- B – Buffer tank (sized according to customer requirements)
- C – Check valve
- D – Safety valve

5.5 Reliable fail-safe action of actuators

Task

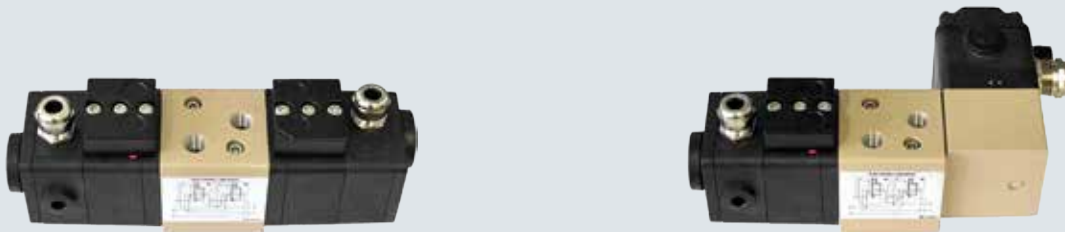
To achieve better reliability and possibly also a higher level of safety (SIL or PL) in safety-instrumented systems, the solenoid valves must be designed in a redundant configuration. In this way, if one solenoid valve fails, the fail-safe action of the actuator is still guaranteed by a second solenoid valve. A hook-up of the solenoid valves in series or in parallel is used depending on the safety requirements. This usually involves complex hook-ups.

Solution using a redundancy plate

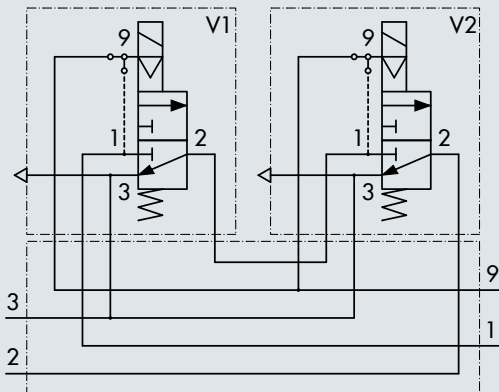
A redundancy plate allows two solenoid valves to be connected in series or in parallel without any additional hook-up. The solenoid valves are mounted either on the left or right side to the NAMUR interfaces of the redundancy plate. The redundancy plate can be directly attached to rotary actuators over a third NAMUR interface. An additional adapter plate also allows a hook-up using threaded connections or the attachment of the solenoid valves to linear actuators with a NAMUR rib.

Advantages of the redundancy plate

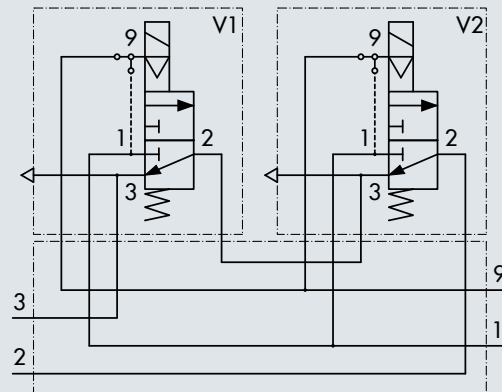
- Easy and quick mounting
- Compact design
- Captive fastening screws
- Body made of powder-coated aluminum or stainless steel
- G or NPT threaded connections
- Attachment to rotary actuators with NAMUR interface according to VDI/VDE 3845
- Attachment to linear actuators with NAMUR rib according to IEC 60534-6-1



Reliable fail-safe action to vent the actuator



Reliable fail-safe action to fill the actuator with air



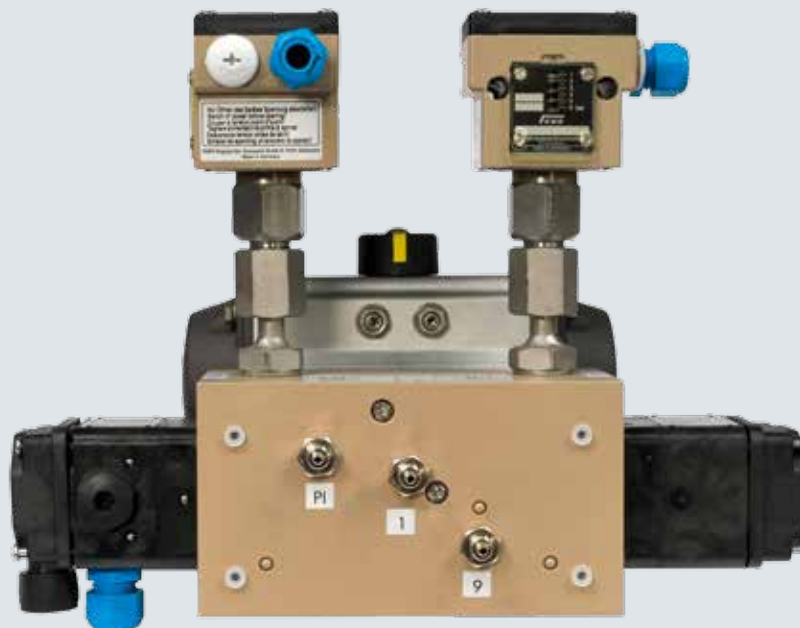
5.6 Reliable fail-safe action of actuators with pressure monitoring

Task

To achieve better reliability and possibly also a higher level of safety (SIL or PL) in safety-instrumented systems, the solenoid valves must be designed in a redundant configuration. In this way, if one solenoid valve fails, the fail-safe action of the actuator is still guaranteed by a second solenoid valve. However, it is not possible to identify which solenoid valve has failed without pressure monitoring.

Solution using integrated pressure switches

The output pressure of the solenoid valves is constantly monitored by two integrated pressure switches. If an energized solenoid valve does not produce the minimum output pressure, an electric contact indicates this failure, for example to the process control system. This not only allows the detection of a faulty solenoid valve, but enables the switching functions to be tested while the process is running, without changing the position of the process valve.



6 Appendix: Certificates

Certificate no. V 60.09/14 Rev. 01

Types 3701, 3963 and 3967 Solenoid Valves with safety function
Suitable for use in safety-instrumented systems

Certificate



No.: V 60.09/14 rev.01

Product tested	Solenoid valves with safety function	Certificate holder	Samsomatic GmbH Weismüllerstr. 20-22 60314 Frankfurt / Main Germany
Type designation	3963, 3701, 3968, 3776, 3756, 3730, 3731, 3967		
Codes and standards	IEC 61508 Parts 1-2 and 4-7:2010	IEC 61511 Parts 1-3:2004	
Intended application	The valves are suitable for use in a safety instrumented system up to SIL 2. For higher SIL the architecture and the interval of periodic tests must be adjusted accordingly. For each application the required hardware fault tolerance (HFT) of the complete system must be considered.		
Specific requirements	The instructions of the associated Installation and Operating Manual shall be considered.		
Summary of test results	see back side of this certificate.		
Valid until	2019-11-27		

The issue of this certificate is based upon an examination, whose results are documented in Report No. V 60.09/14 rev.01 dated 2015-02-10.
This certificate is valid only for products which are identical with the product tested. It becomes invalid at any change of the codes and standards forming the basis of testing for the intended application.

TÜV Rheinland Industrie Service GmbH
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Am Grauen Stein, 51105 Köln
Certification Body for FS-Products

Köln, 2015-02-10

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TÜVRheinland®
Precisely Right.

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Weismüllerstraße 20-22
60314 Frankfurt / Main

Product tested **Electromagnetic control valves with safety function**

Device-Specific Values	3963, 3701, 3968, 3776, 3756, 3730, 3731		3967	
	Probability of Dangerous Failure on Demand	PFD_{spec}	1,56 E-05	PFD_{spec}
Test Interval	Ti	1 a	Ti	1 a
Confidence Level	1- α	95 %	1- α	95 %
Safe Failure Fraction <small>(see note)</small>	SFF	90 %	SFF	92 %
Hardware Fault Tolerance	HFT	0	HFT	0
Diagnostic Coverage	DC	0 %	DC	0 %
Type of Sub System		Typ A		Typ A
Mode of Operation		Low Demand		Low Demand
Proof Test Coverage	PTC	92 %	PTC	92 %
Partial Stroke Test Coverage	PSTC	70 %	PSTC	70 %

Note

The Safe Failure Fraction (SFF) was estimated by an alternative method with a FMEDA according to EN161:2011/A3:2013.

Derived Values for 1oo1-Architecture	3963, 3701, 3968, 3776, 3756, 3730, 3731		3967		
	Assumed Demands per Year	t_{sp}	1 / a		1 / a
Total Failure Rate	$\lambda_S + \lambda_D$	1,78 E-08 / h	18 FIT	2,22 E-08 / h	22 FIT
Lambda Dangerous Detected	λ_{DD}	0,00 E+00 / h	0 FIT	0,00 E+00 / h	0 FIT
Lambda Dangerous Undetected	λ_{DU}	1,78 E-09 / h	2 FIT	1,78 E-09 / h	2 FIT
Lambda Safe Detected	λ_{SD}	0,00 E+00 / h	0 FIT	0,00 E+00 / h	0 FIT
Lambda Safe Undetected	λ_{SU}	1,60 E-08 / h	16 FIT	2,05 E-08 / h	20 FIT
Mean Time Between Failures	MTBF	5,62 E+07 h	6.416 a	4,50 E+07 h	5.132 a
Mean Time Between Dangerous Failures	MTBF _D	5,62 E+08 h	64.156 a	5,62 E+08 h	64.156 a
Average Probability of Failure on Demand	PFD_{avg}	7,79 E-06		7,79 E-06	

Time of Usage

A useful lifetime of 11 years (+ 1.5 years of aging) can only be advocated in the responsibility of the operator, taking into account the specific conditions of use (ensure the required quality of operating fluids, the max. operating temperature and exposure time) and in consideration of appropriate test cycles.

Quality Management

These statements are bound to a proven and verified deployment of safety-related quality management of the manufacturer.

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SAMSON SAMSOMATIC

MANUAL

Competence in Functional Safety



● Production sites ● Subsidiaries

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