Safety Application Note ISO 13849

FESTO

Transient Suppresion

Basic Safety Principles

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100568

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- Specialist in pneumatics
- Specialist in electrical engineering
- Specialist for the programming of control systems and safety switching devices

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Table of Contents

1 General

1.1 Objectives of this Document

- This document describes the basic safety principle of “transient suppression” for valves and solenoid valves from Festo. This document can also be partially used, together with an application-specific assessment, for other components with integrated inductances.
- The objectives and various implementation options for this safety principle are described.
- Templates with justifications are provided indicating when this safety principle applies or does not apply.
- The appendix contains tables listing protective circuits for solenoid coils, valves, valve manifolds, and connection cables from Festo.

1.2 General Notes

- This document contains possible interpretations of the ISO 13849-2 standard. Whether these interpretations apply to a specific application must always be assessed on a case-by-case basis.
- The interpretations relate to the use of electrical components for installation in machines. How these are to be implemented within the limits of a component, e.g., an electrically operated valve, is not specified.
- The circuits shown are schematic representations that, due to clarity and scope, cannot be complete. They are recommendations and do not exclude other possibilities.

2 Basic Safety Principle “Transient Suppression”

Basic Safety Principle	Remarks	Relevant for	Source
Transient Suppression	Use of a suppression device (RC, diode, varistor) parallel to the load, but not parallel to the contacts. NOTE A diode increases the switch-off time.	Components Subsystems	ISO 13849-2, Table D.1

2.1 Definitions

- **Voltage peak** (transient overvoltage, according IEV dictionary 614-03-14)
  Oscillating or non-oscillating, generally heavily damped overvoltages with a duration of a few milliseconds or less.

2.2 Basics

When the coil of a relay, contactor, valve, etc., is switched off, the magnetic field collapses and a self-induction voltage is generated. This self-induction voltage can reach up to twenty times the applied operating voltage. These high voltages can destroy electronic outputs, cause arcing and contact erosion in switching contacts, or lead to electromagnetic interference (EMI).

2.3 Objectives

The safety principle of “transient suppression” is intended to prevent disturbances to the function of electronic outputs, reduction of the service life of switching contacts, or the generation of electromagnetic interference (EMI) when switching off inductive loads.

3 Implementation Through Protective Circuits

To avoid the negative effects of self-induction voltage, protective circuits are used. The components of these protective circuits usually do not significantly affect the normal function of the coils but can divert their voltage spikes. The following protective circuits are common:

- Protective circuit with diode
- Protective circuit with diode and Zener diode
- Protective circuit with varistor
- Protective circuit with RC network

3.1 Protective Circuit with Diode

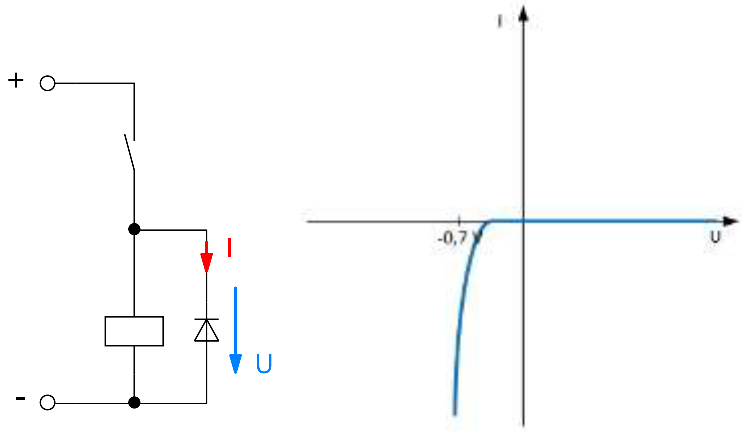


Figure 1 Protective Circuit with Diode, U/I Diagram of Switch-Off Process

In this protective circuit, a diode is connected in reverse polarity parallel to the coil. Since the polarity of the self-induction voltage is opposite to the applied voltage, the self-induction voltage is diverted through the diode, and the current flows through the coil.

Disadvantages

- Suitable only for DC voltage
- Causes a delay in the coil current decay
- Incorrect polarity connection can destroy the diode

Advantages

- Reliable protective function, as even low self-induction voltages are diverted
- The voltage spike is limited to the threshold voltage of the diode used
- Dimensioning is not critical

Notes on Dimensioning

The diode should be selected according to the nominal current of the coil and the maximum permissible operating voltage of the circuit.

3.2 Protective Circuit with Diode and Zener Diode

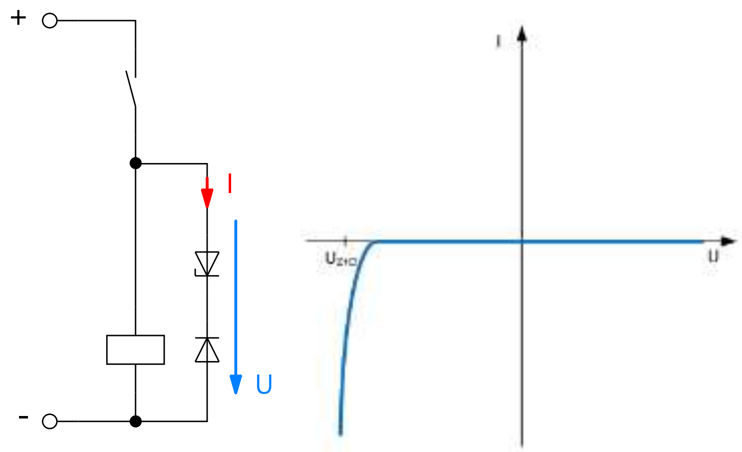


Figure 2 Protective Circuit with Zener Diode and Diode, U/I Diagram of Switch-Off Process

In this circuit, a Zener diode is connected in series with a diode. When the self-induction voltage exceeds the Zener voltage plus the diode's forward voltage, the self-induction voltage is diverted through these diodes and the current flows through the coil.

Disadvantages

- Suitable only for DC voltage
- Incorrect polarity can destroy the diode(s)
- Below the Zener voltage plus the diode's forward voltage, no damping of the self-induction voltage occurs

Advantages

- Results in a shorter coil current decay delay
- Dimensioning is not critical

Notes on Dimensioning

- The diodes should be selected according to the nominal current of the coil and the maximum permissible operating voltage of the circuit.

3.3 Protective Circuit with Varistor

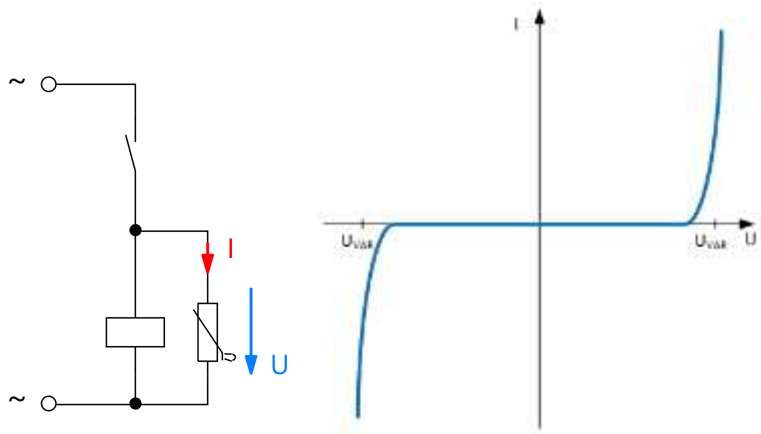


Figure 3 Protective Circuit with Varistor, U/I Diagram of Switch-Off Process

A varistor becomes low-resistance above a certain threshold voltage. When the self-induction voltage exceeds the varistor's threshold voltage, the self-induction voltage is short-circuited through the varistor and the coil.

Disadvantages

- No damping of the self-induction voltage occurs below the varistor's threshold voltage

Advantages

- Low coil current decay delay
- Suitable for both DC and AC voltage

Dimensioning

- The varistor's threshold voltage should be significantly higher than the operating voltage used
- No continuous current should flow through the varistor

3.4 Protective Circuit with RC Network

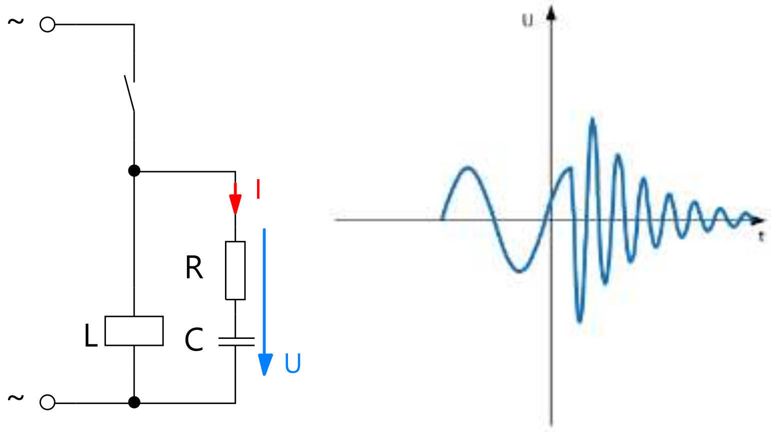


Figure 4 Protective Circuit with RC Network, U/t Diagram of Switch-Off Process

The series connection of a resistor and capacitor causes the current to decay in a damped oscillation during the switch-off process. During switch-on, the resistor prevents the capacitor from charging directly.

Disadvantages

- The circuit must be precisely dimensioned.

Advantages

- Low coil current decay delay
- Immediate limitation of the self-induction voltage
- Suitable for AC voltage

Dimensioning

$$R \approx R_L$$

$$C = \frac{4 \cdot L}{R_{ges}}$$

Whereat

C	Capacitance of the RC network
L	Inductance of the coil
R	Ohmic resistance of the RC network
R_L	Ohmic resistance of the coil
R_{ges}	Total resistance R + R_L

- The voltage peak depends on the chosen RC combination.
- If the capacitor's capacitance is properly dimensioned, only a small voltage occurs. With correct dimensioning, the voltage is determined by the resistance of the RC network.
- The dimensioning should be verified using an oscilloscope.

3.5 Implementation: Safe Output with Switching Capacity for Inductive Loads

There are safe outputs with switching capacity for inductive loads. The user information for these safe outputs includes specifications such as “limitation of inductive switch-off voltage to typically 2 × 47 V.” In such cases, a protective circuit is usually integrated within the safe output.
However, the implementation of the safety principle “transient suppression” requires the protective circuit to be placed in parallel with the load.
Whether these safe outputs are suitable for implementing the safety principle “transient suppression” must be evaluated on a case-by-case basis. These safe outputs are not a suitable measure to avoid or reduce electromagnetic interference (EMI).

4 Evaluation: Safety Principle Not Applicable

This safety principle can only be applied when inductive loads (e.g., relays, contactors, valves) are being switched. Conversely, if no inductive load is switched, this safety principle is not applicable.
When valves in valve manifolds are controlled via a fieldbus or digital inputs, the valves are actuated through the internal electronics of the valve terminal, and the suppression of voltage spikes is handled within the valve terminal. This means that the safety principle applies within the valve terminal but not within the subsystem of a safety circuit.

Table 1 Templates for Evaluations: Safety Principle Not Applicable

Evaluation or Implemented Solution	**Compliant Evidence**
No inductive loads are switched, so this safety principle is not applicable.	× Safety principle not applicable
Valves are controlled via fieldbus or digital inputs of a valve terminal. Thus, the valve coils are actuated through the internal electronics of the valve terminal, and the suppression of voltage spikes is handled within the boundaries of the valve terminal. The safety principle is not applicable in the subsystem.	× Safety principle not applicable

5 Evaluation: Safety Principle Applicable

This safety principle can only be applied when inductive loads (e.g., relays, contactors, valves) are being switched.

Table 2 Templates for Evaluations: Safety Principle Applicable

Evaluation or Implemented Solution	**Compliant** **Evidence**
Coil, valve, or connection cable is equipped with an internal protective circuit. Valves on valve terminals with individual connections have an internal protective circuit.	☑ Coil, valve, valve terminal or connection cable is listed in the tables in the appendix. Verification via parts list.
Coil, valve, valve terminal, or connection cable is **not** equipped with an internal protective circuit.	☐ Implementation and verification must be performed by the user.
Component with integrated inductance is equipped with an integrated protective circuit according to manufacturer specifications.	☑ Verification via parts list.
Component with integrated inductance is not equipped with an integrated protective circuit.	☐ Implementation and verification must be performed by the user.

6 Appendix: Product List with Integrated Protective Circuit

Notes

- This appendix lists only products for 24 VDC.
- No solenoids, valves, or lines are specified for ATEX. For applications that must meet ATEX requirements, additional measures are necessary (for example, energy limitation or encapsulation). In those cases, only the applicable laws and standards, along with the product operating instructions and certificates, should be taken into account.
- It cannot be verified whether the possible combinations of solenoid coils, valves, valve manifolds, and connection cables listed in this appendix are suitable for a specific application, e.g. with IP65 requirements.
- The lists contained here do not claim to be complete.
- If a solenoid coil or valve with an integrated solenoid coil is not listed in these lists, it is likely that protective circuit is not present in the solenoid coil or in a cable from Festo.

6.1 Solenoid Coils with Protective Circuit

The protective circuit for solenoid coils is either integrated in the connection cable or in the solenoid valve. If the protective circuit is in the connection cable, reference is made to the corresponding table with the cables. If the protective circuit is in the solenoid valve, the source confirming this information from Festo is indicated.

Table 3 Solenoid Coils for 24 VDC with Protective Circuit

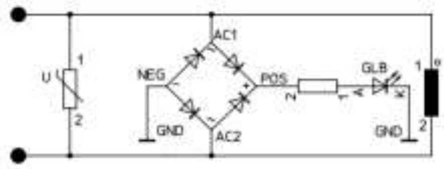
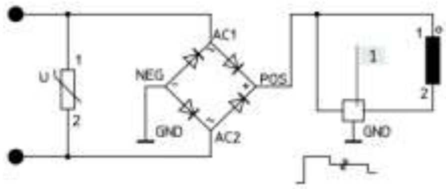
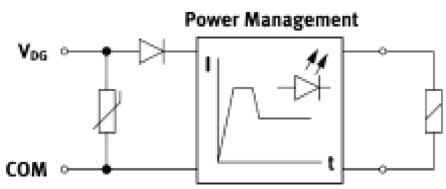
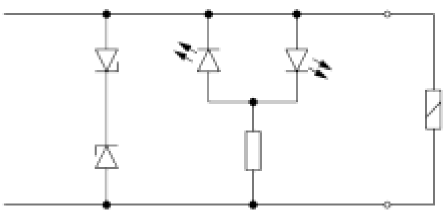
Type	Part No.	Protective Circuit	Connector, Connection Cable, Protective Circuit
Solenoid coil MD-2-24VDC-PA	549903	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil MH-2-24VDC-PA	549906	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil MSFG-24/42-50/60	34410	In connecting cable	Connector according to Industrial Standard, Form B ➔ Table 7
Solenoid coil MSFG-24/42-50/60-DS	13264	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil MSFG-24/42-50/60-DS-OD	34412	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil MSFG-24/42-50/60-OD	34411	In connecting cable	Connector according to Industrial Standard, Form B ➔ Table 7
Solenoid coil MSFW-24-50/60-OD	34415	In connecting cable	Connector according to Industrial Standard, Form B ➔ Table 7
Solenoid coil MSG-24DC	3599	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil MSG-24-OD	34401	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil MSN1G-24DC-OD	123060	In connecting cable	Connector according EN 175301, Form A ➔ Table 6

Type	Part No.	Protective Circuit	Connector, Connection Cable, Protective Circuit
Solenoid coil VACC-S13-18-A1-1	562889	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
VACC-S13-18-A1-1U	562890	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
VACC-S13-18-A1-2U	562891	In connecting cable	Connector according EN 175301, Form A
VACC-S13-18-A1-3U	562892	In connecting cable	➔ Table 6
Solenoid coil VACC-S18-120-A1-1	8040580	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil VACC-S18-35-A1-1	562906	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil VACF-A-A1-1	8030822	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil VACF-B-B2-1	8030802	In connecting cable	Connector according to Industrial Standard , Form B ➔ Table 7
Solenoid coil VACF-B-C1-1	8030811	In connecting cable	Connector according EN 175301, Form C ➔ Table 8
Solenoid coil VACF-B-E1-1	8153947	In connecting cable	Connector according EN 175301, Form C ➔ Table 8
Solenoid coil VACF-B-R1-1RAL	8150879	Integrated	See catalogue "Solenoid coils", 2024/07, page 10, Type codes VACF
Solenoid coil VACF-B-R3-1RAL	8150873	Integrated	See catalogue "Solenoid coils", 2024/07, page 10, Type codes VACF, page 23, Ordering data – Solenoid coils width 22 mm for armature tube 8mm
Solenoid coil VACF-B-R4-1RAL	8150880	Integrated	See catalogue "Solenoid coils", 2024/07, page 10, Type codes VACF, page 23, Ordering data – Solenoid coils width 22 mm for armature tube 8mm
Solenoid coil VACF-B-R8-1RAL	8150878	Integrated	See catalogue "Solenoid coils", 2024/07, page 10, Type codes VACF, page 23, Ordering data – Solenoid coils width 22 mm for armature tube 8mm
Solenoid coil VACN-H1-A1-1	8022877	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil VACN-N-A1-1	8029144	In connecting cable	Connector according EN 175301, Form A ➔ Table 6
Solenoid coil VACS-C-C1-1	8025330	In connecting cable	Connector according EN 175301, Form A ➔ Table 6

6.2 Valves with Protective Circuit

The protective circuit for valves is either integrated in the connection cable, the solenoid coil, or the valve itself. If the protective circuit is in the connection cable or solenoid coil, reference is made to the corresponding table. If the protective circuit is integrated in the valve, the source confirming this information from Festo is indicated.

Table 4 Valves for 24 VDC with Protective Circuit

Type	Part No.	Protective Circuit	Connector Connection Cable Protective Circuit
Valve MDH with individual connection		In connection cable	Plug according EN 175301, Form A ➔ Table 6
Valve VMPA		Integrated	See „Solenoid Valves VMPA“, 2025/07, page 13, Electrical power as a result of current reduction
Valve VSVA, size 42 mm, with central plug M12, 3-pole		Integrated	With varistor  Source: „Standards-based valves to ISO 5599-1“, 2025/11, page 80
Valve VSVA, size 52 mm, with central plug M12, 3-polig		Integrated	With varistor  Source: „Standards-based valves to ISO 5599-1“, 2025/11, page 85
Valves VUVG with individual connector, with holding current reduction		In E-box integrated	With varistor  Source: „Solenoid Valves VUVG/Valve Manifold Assembly VTUG-S“, 2025/08, Seite 111, E-boxes
Valves VUVG with individual connector, without holding current reduction		In E-box integrated	With Zener diodes 

Type	Part No.	Protective Circuit	Connector Connection Cable Protective Circuit
			Source: „Solenoid Valves VUVG/Valve Manifold Assembly VTUG-S“, 2025/08, Seite 111, E-boxes
Valve VUVS			See solenoid coils VACF ➔ Table 3
Valve terminal VTUX		Integrated	Manifold sub-bases for serial communication See "Valve Terminal VTUX", 2025/10, page 51, inductive protective circuit Manifold sub-base for vacuum See "Valve Terminal VTUX", 2025/10, page 57, inductive protective circuit

6.3 Valve Terminals with Protective Circuit

The protective circuit for valve terminals is either integrated in the valve terminal or in the valve itself. If the protective circuit is in the valve, reference is made to the corresponding table. If the protective circuitry is in the valve terminal, the source of the assessment is specified.

Table 5 Valve Terminals with Protective Circuit

Type	Part No.	Protective Circuit	Connector Connection Cable Protective Circuit
Valve terminal MPA-C	575465	Integrated	See „Valve Terminal MPA-C“, 2025/11, page 19, Electrical power as a result of current reduction
Valve terminal MPA-L with individual connection or multi-pin	569926	Integrated	See „Valve Terminal MPA-L“, 2025/11, page 33, Electrical power as a result of current reduction
Valve terminal MPA-S with individual connection or multi-pin	530411	Integrated	See „Valve Terminal MPA-S“, 2025/06, page 58, Electrical power as a result of current reduction
Valve terminal VTSA-...	8073100	Integrated	See valves VSVA ➔ Table 4
Valve terminal VTUX	8000805	Integrated	Manifold sub-bases for serial communication See "Valve Terminal VTUX", 2025/10, page 51 Manifold sub-base for vacuum See "Valve Terminal VTUX", 2025/10, page 57

6.4 Connecting Cables with Protective Circuit

For the connecting cables, there are different wiring diagrams for the connectors. Where possible, the internal protective circuitry is indicated along with the corresponding source.

Table 6 Connection Cable, Connector according EN 175301, Form A

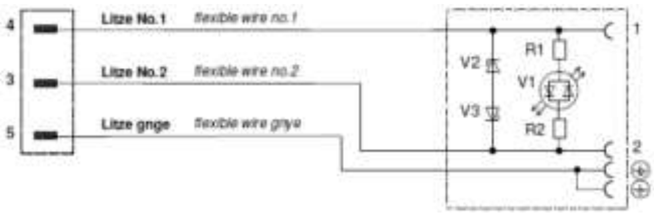
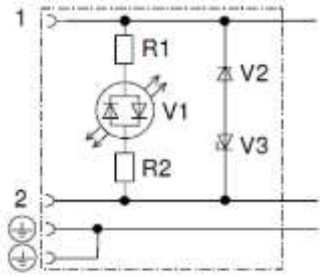
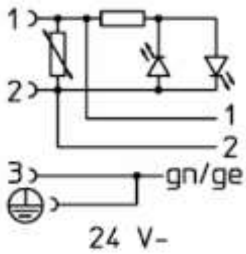
Type	Part-No.	Protective Circuit
NEBV-A1W3F-P-K-0.3-N-M12W3	3679771	With Zener diodes  Source: Internal datasheet document-no. 4391831, 2023-10-16
NEBV-A1W3F-P-K-0.6-N-M12W3	3679772	
NEBV-A1W3F-P-K-0.6-N-LE3	3679776	With Zener diodes  Source: Internal datasheet document-no. 4391831, 2023-10-16
KMC-1-24DC-2,5-LED	30931	With varistor  Source: Internal datasheet document-no. 959505, 2024-04-17
KMC-1-24DC-5-LED	30933	
KMC-1-24-10-LED	193459	

Table 7 Connection Cable, Connector according EN 175301, Form B

Type	Part-No.	Protective Circuit
NEBV-B2W3F-P-K-0.3-N-M12W3	3679773	With Zener diodes 
NEBV-B2W3F-P-K-0.6-N-M12W3	3679774	
NEBV-B2W3F-P-K-0.6-N-LE3	3679778	

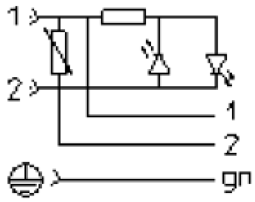
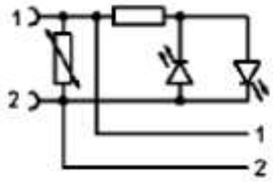
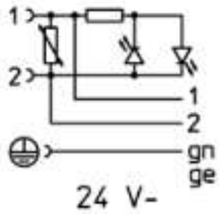
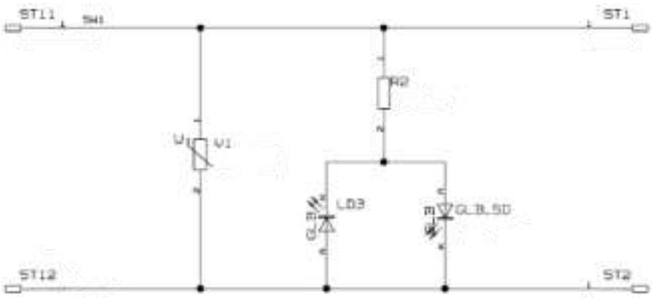
Type	Part-No.	Protective Circuit
		Source: Internal datasheet document-no. 4391831, 2023-10-16
KMF-1-24DC-2,5-LED	30935	With varistor  Source: Internal datasheet document-no. 959502, 2022-06-07
KMF-1-24DC-5-LED	30937	
KMF-1-24DC-10-LED	193458	

Table 8 Connection Cable, Connector according EN 175301, Form C

Type	Part-No.	Protective Circuit
KME-1-24-2,5-LED	30943	With varistor  Source: Internal datasheet document-no. 958414, 2022-05-25
KME-1-24-5-LED	30945	
KME-1-24-10-LED	193455	
KMEB-1-24-2.5-LED	151688	With varistor  Source: Internal datasheet document-no. 958407, 2020-10-05
KMEB-1-24-5-LED	151689	
KMEB-1-24-10-LED	193457	
NEBV-C1SW2L-P-K-2.5-N-LE2-S9	8032623	With varistor  Source: Internal datasheet document-no. 3217472, 2025-02-12
NEBV-C1SW2L-P-K-5-N-LE2-S9	8032626	
NEBV-C1SW2L-P-K-10-N-LE2-S9	8032627	

7 Used Literature

7.1 Cited Documents from Festo

[1] Catalogue “Solenoid coils”, 2024/07,

[2] Catalogue “Solenoid Valves VMPA”, 2025/07

[3] Catalogue “Standards-based valves to ISO 5599-1”, 2025/11,

[4] Catalogue “Solenoid Valves VUVG/Valve Manifold Assembly VTUG-S”, 2025/08

[5] Catalogue “Valve Terminal VTUX”, 2025/10,

[6] Internal datasheet document-No. 4391831, 2023-10-16

[7] Internal datasheet document-No. 959505, 2024-04-17

[8] Internal datasheet document-No. 4391831, 2023-10-16

[9] Internal datasheet document-No. 959502, 2022-06-07

[10] Internal datasheet document-No. 958414, 2022-05-25

[11] Internal datasheet document-No. 958407, 2020-10-05

[12] Internal datasheet document-No. 3217472, 2025-02-12

7.2 Standards

[13] 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

[14] ISO 5598:2020-01 – Fluid power systems and components - Vocabulary

[15] 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

[16] 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

[17] 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

[18] ISO 19973-1:2015-08 - Pneumatic fluid power - Assessment of component reliability by testing - Part 1: General procedures

[19] VDMA 24584:2022-06 – Safety functions of regulated and unregulated (fluid) mechanical systems; German Version

[20] DIN EN 61508:2011-02 - Functional safety of electrical/electronic/programmable electronic safety-related systems (IEC 61508:2010); German version EN 61508:2010

[21] 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

[22] DIN EN 61511:2019-02 - Functional safety - Safety instrumented systems for the process industry sector - (IEC 61511:2016); German version EN 61511:2017

[23] 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

7.3 Legal Regulations

[24] 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)

8 Information about the Document

8.1 General Information

Document Number	**100568**
Basic Safety Principle	Transient Suppression

8.2 Revision History

Ver.	**Date**	**Ed.**	**Chapter**	**Description of Change/Impact**
1.10	2026-01-09	JKHL	All	Creation of the document

8.3 Approval/Release of the Document

Role	**Signature**
Release	Jürgen Kühnle Digital signiert von Jürgen Kühnle DN: cn=Jürgen Kühnle gn=Jürgen Kühnle c=DE Germany l=DE Germany o=Festo SE & Co. KG ou=SC-OTP e=juergen.kuehnle@festo.com Grund: Freigabe dieses Dokuments Ort: Esslingen Datum: 2026-01-09 06:09+01:00

8.4 Period of Validity

Document is valid until 2031-01-09 or until one of the documents used or the required relevant base are changed.

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