Safety proportional valves with on-off signals
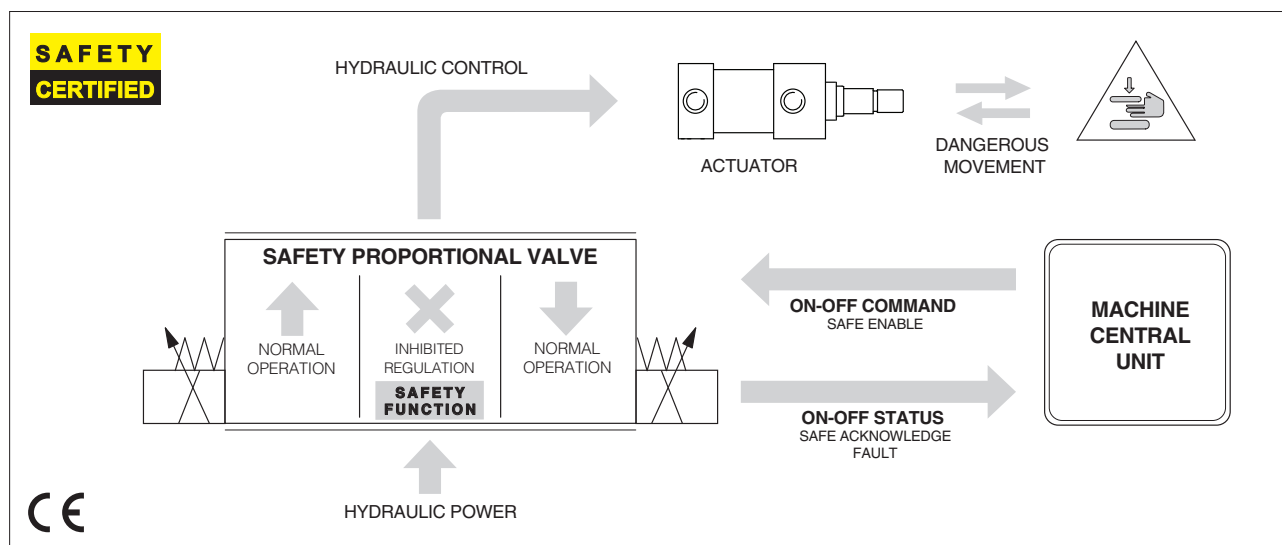
directional valves with on-board driver and LVDT transducer

IEC 61508 Safety Integrity Level and **ISO 13849** Performance Level - certified by

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1 | **GENERAL DESCRIPTION**

Safety proportional valves with on-off signals are identified by option /K and are intended for use in hydraulic circuits of machines which must comply with safety requirements of Machine Directive 2006/42/EC.

They are designed to perform **Safety Functions**, in addition to the standard control of direction, speed, pressure/force or position of hydraulic actuators, depending to the valve features.

The Safety Function is operated to reduce the potential dangerous risks which may happen in a specific phase of the machine cycle.
It is activated by the machine central unit (PLC) which inhibits the regulation of proportional valve /K via on-off enable signals in case of emergency or for specific requirements along the working cycle.

Upon valve's disable command input, the valve driver generates on-off output signals as soon the spool has reached the safety position, confirming that hydraulic regulation has been inhibited. The machine central unit (PLC) manages this information as "safe condition".

Safety proportional valves with option /K are certified by TÜV in compliance with IEC 61508 and ISO 13849

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2 | **CERTIFICATION**

IEC 61508, IEC 61511, IEC 62061	max **SIL 2** for **non-redundant** safety architecture max **SIL 3** for **redundant** safety architecture	See techinical table Y010 for details about SIL, PL and safety architetures
ISO 13849	**category 1, PL c** for **non-redundant** safety architecture **category 4, PL e** for **redundant** safety architecture	

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3 | **VALVES RANGE**

Option /K is available for high performance proportional directional valves and servoproportional valves with TES/LES on-board digital driver or TEZ/LEZ axis controller.

It adds the safety functions to standard control of direction, speed, pressure/force (for SP, SF, SL version) and position (for TEZ, LEZ versions).

Valve's performance characteristics and overall dimensions remains unchanged as per standard valve models, refer to specific FS** technical tables.

High perfomance proportionals:
DHZO-TES, DKZOR-TES - direct, positive spool overlap - technical table **FS165**
DPZO-TES - piloted, positive spool overlap - technical table **FS172**
DPZO-LES - piloted, positive spool overlap - technical table **FS175**

Servoproportionals:
DHZO-TES, DKZOR-TES - direct, zero spool overlap - technical tables **FS168**
DPZO-LES - piloted, zero spool overlap - technical table **FS178**
DLHZO-TES, DLKZOR-TES - direct, zero spool overlap - technical tables **FS180**

Servoproportionals with TEZ/LEZ axis controller:
DHZO-TEZ, DKZOR-TEZ - direct, zero spool overlap - technical tables **FS620**
DPZO-LEZ - piloted, zero spool overlap - technical tables **FS630**
DLHZO-TEZ, DLKZOR-TEZ - direct, zero spool overlap - technical tables **FS610**

4 FUNCTIONAL DESCRIPTION

Valves with option /K are designed to receive on-off enable signals from the machine central unit in order to inhibit the valve's regulation.

When this enable signal is switched OFF, the current to the valve's solenoid is safely cut-off, while the valve's diagnostics and communication remain active to continuously exchange its status with the machine central unit.

In consequence of the solenoid current cut-off, the valve's spool is moved by the spring towards the safe rest position and then the valve regulation is consequently inhibited.

When the spool has reached the safe position, the valve's driver generates an on-off output signal confirming to the machine central unit that the valve is in SAFE condition.

The time required by the valve's spool to reach the safe position is detailed in section 5

Safe enable input signal - SAFE_ENABLE

The SAFE_ENABLE is the command signal to cut-off the current to the solenoids in order to inhibit the valve's regulation:
- inhibited regulation: SAFE_ENABLE = **0 VDC**
- permitted regulation: SAFE_ENABLE = **24 VDC**

Double solenoids valves are equipped with two independent enable circuits SAFE_ENABLE 1 and SAFE_ENABLE 2 permitting to:
   a) cut-off the current to both solenoids when the valve regulation must be inhibited in both directions
   b) cut-off the current to one solenoid when only one side of the valve regulation must be inhibited. This condition permits to intercept the actuator movement in one direction, permitting the actuator movement in the opposite direction (typical in motion/non-motion controls)

Safe enable acknowledge output signal - SAFE_ENABLE_ACK

The SAFE_ENABLE_ACK is the output signal generated by the driver to confirm that the valve has effectively reached the safe position in consequence of SAFE_ENABLE command switch-off.

SAFE_ENABLE_ACK is switched ON (24 VDC) when the internal diagnostics verifies that solenoid current has been cut-off and the spool, monitored by the LVDT transducer, has reached the safe position.

Fault output signal – FAULT

Fault signal is a diagnostic output which states faults or warning according to the valve's status

This signal must be monitored by the machine central unit in addition to the SAFE_ENABLE_ACK signal, to intercept failures which may compromise the valve safety function.

The FAULT signal is switched OFF (0 VDC) when the internal diagnostics detects valve failures or incorrect behavior (e.g. : spool sticking, solenoid short circuits, missing coils connection, reference signal cable broken for 4 ÷ 20 mA input, etc)

For piloted valves the FAULT signal = 0 VDC indicates also the absence of pilot pressure.

5 SWITCH-OFF TIME

The valve switch-off time is the time between the SAFE_ENABLE signal = 0 VDC and the SAFE_ENABLE ACK signal = 24 VDC.

It is influenced by the working conditions like flow, pressure and fluid viscosity.

The switch-off times shown in the table are considered in the following conditions:
- max flow and max pressure values as per specific technical table of each valve model
- fluid viscosity 46 mm^2/s
- fluid contamination level: ISO4406 CLASS 18/16/13

The following switch-off times can be considered as the longest ones.

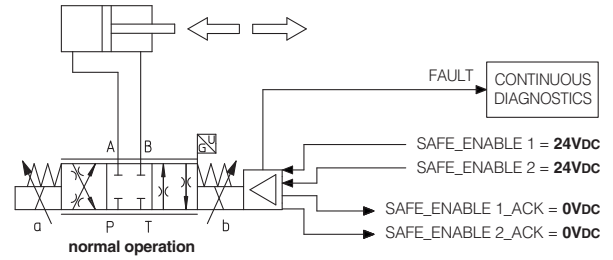For different working conditions, consult Atos technical office.

Valve model	DHZO	DKZOR	DLHZO	DLKZOR	DPZO-1	DPZO-2	DPZO-4 DPZO-4M	DPZO-6	DPZO-8
Switch-off time [ms]	50	80	40	60	180	250	300	350	400

6 FUNCTIONAL EXAMPLES

The following examples show the condition of a double solenoid valve and of the controlled actuator depending to the SAFE_ENABLE status.
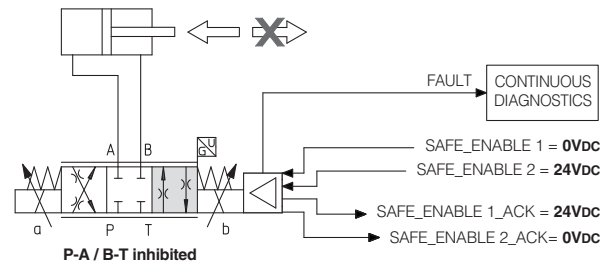
Valve normal operation

Input signals [VDC]		Output signals [VDC]	
SAFE_ENABLE 1	SAFE_ENABLE 2	SAFE_ENABLE 1_ACK	SAFE_ENABLE 2_ACK
24	24	0	0

normal operation

FAULT — CONTINUOUS DIAGNOSTICS

SAFE_ENABLE 1 = **24VDC**
SAFE_ENABLE 2 = **24VDC**
SAFE_ENABLE 1_ACK = **0VDC**
SAFE_ENABLE 2_ACK = **0VDC**

Valve safe operation with P-A/B-T regulation inhibited to prevent the actuator forward movement

Input signals [VDC]		Output signals [VDC]	
SAFE_ENABLE 1	SAFE_ENABLE 2	SAFE_ENABLE 1_ACK	SAFE_ENABLE 2_ACK
0	24	24	0

P-A / B-T inhibited

FAULT — CONTINUOUS DIAGNOSTICS

SAFE_ENABLE 1 = **0VDC**
SAFE_ENABLE 2 = **24VDC**
SAFE_ENABLE 1_ACK = **24VDC**
SAFE_ENABLE 2_ACK= **0VDC**

Valve safe operation with P-B/A-T regulation inhibited to prevent the actuator backward movement

Input signals [VDC]		Output signals [VDC]	
SAFE_ENABLE 1	SAFE_ENABLE 2	SAFE_ENABLE 1_ACK	SAFE_ENABLE 2_ACK
24	0	0	24

P-B / A-T inhibited

FAULT — CONTINUOUS DIAGNOSTICS

SAFE_ENABLE 1 = **24VDC**
SAFE_ENABLE 2 = **0VDC**
SAFE_ENABLE 1_ACK = **0VDC**
SAFE_ENABLE 2_ACK = **24VDC**
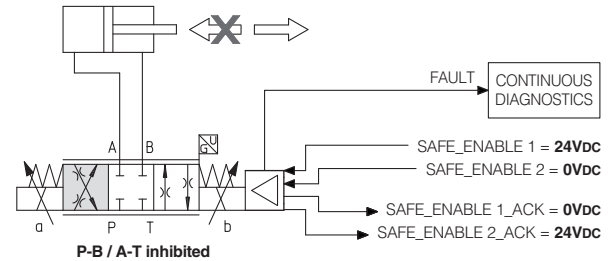
Valve safe operation with regulation completely inhibited

Input signals [VDC]		Output signals [VDC]	
SAFE_ENABLE 1	SAFE_ENABLE 2	SAFE_ENABLE 1_ACK	SAFE_ENABLE 2_ACK
0	0	24	24

regulation completely inhibited

FAULT — CONTINUOUS DIAGNOSTICS

SAFE_ENABLE 1 = **0VDC**
SAFE_ENABLE 2 = **0VDC**
SAFE_ENABLE 1_ACK = **24VDC**
SAFE_ENABLE 2_ACK = **24VDC**
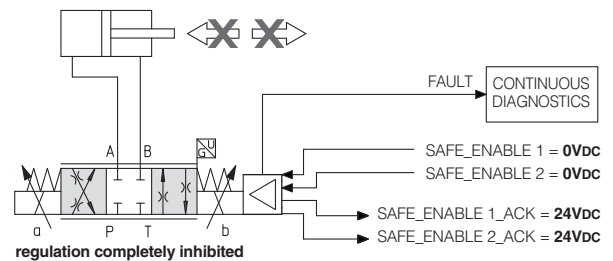
INHIBITED SPOOL POSITION SAFE_ENABLE = **0VDC**

PERMITTED SPOOL POSITION SAFE_ENABLE = **24VDC**

INHIBITED DIRECTION

PERMITTED DIRECTION

7 | INHIBITED / PERMITTED SPOOL POSITION

The below tables show the inhibited / permitted spool position depending to the SAFE_ENABLE status for all models of safety proportional valves.

Note: the inhibition of the actuator direction may be affected by other valves present in the circuit, then the whole hydraulic system where the valve /K is applied must be considered.

7.1 High performance proportionals

☐ (shaded) INHIBITED SPOOL POSITION

☐ PERMITTED SPOOL POSITION

DHZO-TES, DKZOR-TES - direct operated, positive spool overlap - technical table **FS165**

Input signals [VDC]		Output signals [VDC]		Configuration 51, 53		Configuration 71, 72, 73	
SAFE ENABLE 1	SAFE ENABLE 2	SAFE ENABLE 1_ACK	SAFE ENABLE 2_ACK	standard	option /B	standard	option /B
24		0					
0		24					
24	24	0	0	①	①		
0	24	24	0				
24	0	0	24				
0	0	24	24			①	①

DPZO-TES - pilot operated, positive spool overlap - technical table **FS172**

Input signals [VDC]		Output signals [VDC]		Configuration 51, 53		Configuration 71, 72, 73	
SAFE ENABLE 1	SAFE ENABLE 2	SAFE ENABLE 1_ACK	SAFE ENABLE 2_ACK	standard	option /B	standard	option /B
24		0					
0		24					
24	24	0	0	①	①		
0	24	24	0				
24	0	0	24				
0	0	24	24			①	①

DPZO-LES - pilot operated, positive spool overlap - technical table **FS175**

Input signals [VDC]	Output signals [VDC]	Configuration 71, 72, 73	
SAFE ENABLE 1	SAFE ENABLE 1_ACK	standard	option /B
24	0		
0	24	①	①

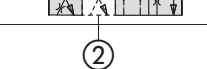① = Spool safety rest position

7.2 Servoproportionals
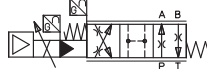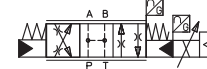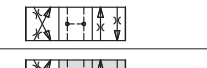
 INHIBITED SPOOL POSITION

 PERMITTED SPOOL POSITION

DHZO-TES/TEZ, DKZOR-TES/TEZ - direct operated, zero spool overlap - technical tables **FS168**, **FS620**

Input signals [VDC]		Output signals [VDC]		Configuration 70	
				standard	option /B
SAFE ENABLE 1	SAFE ENABLE 2	SAFE ENABLE 1_ACK	SAFE ENABLE 2_ACK		
24	24	0	0		
0	24	24	0		
24	0	0	24		
0	0	24	24	②	②
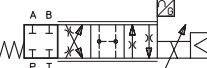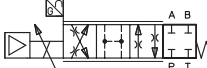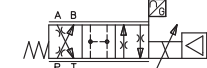
DPZO-LES, DPZO-LEZ - pilot operated, zero spool overlap - technical table **FS178**, **FS630**

Input signals [VDC]	Output signals [VDC]	Configuration 60		Configuration 70	
		standard	option /B	standard	option /B
SAFE ENABLE 1	SAFE ENABLE 1_ACK				
24	0				
0	24	①	①	②	②

DLHZO-TES/TEZ, DLKZOR-TES/TEZ - direct operated, zero spool overlap - technical tables **FS180**, **FS610**

Input signals [VDC]	Output signals [VDC]	Configuration 40 with fail safe 1 or 3		Configuration 60 without fail safe	
		standard	option /B	standard	option /B
SAFE ENABLE 1	SAFE ENABLE 1_ACK				
24	0				
0	24	①	①	①	①

① = Spool safety rest position

② = Spool safety rest position for valves with zero spool overlap, configuration 70 - see 7.3

7.3 Safety rest position - for valves with zero spool overlap, configuration 70

In absence of solenoid power supply (SAFE_ENABLE1 = 0 and SAFE_ENABLE2 = 0), the valve spool is moved by the springs force to the **safety rest position** characterized by a small offset of about 1% to 6% of the total stroke in P-B / A-T configuration.

This is specifically designed to avoid that in case of interruption of solenoid power supply, the actuator moves towards an undefined direction (due to the tolerances of the zero spool overlap), with potential risk of damages or personnel injury.
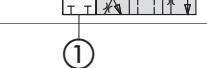
Thanks to the **safety rest position** the actuator movement is suddenly stopped and it is recovered at very low speed towards the direction corresponding to the P-B/ A-T connection.

Spool position with solenoid power supply ON and reference signal = 0 (zero overlap position)

Spool offset position 1% to 6% of total stroke with solenoid power supply OFF (central safety rest position)
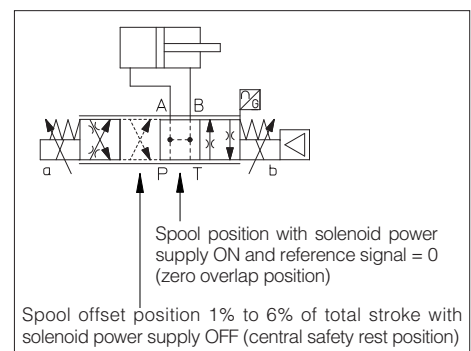
8 ELECTRONIC CONNECTIONS

8.1 Main connector signals - 12 pin - options /K

| PIN	TES LES	TEZ LEZ	TECHNICAL SPECIFICATIONS	NOTES
1	V+		Power supply 24 V_{DC}	Input - power supply
2	V0		Power supply 0 V_{DC}	Gnd - power supply
3	SAFE_ENABLE1		Enable (24 V_{DC}) or disable (0 V_{DC}) the solenoid at side of the driver and position transducer, referred to V0	Input - on/off signal
4	Q_INPUT+		Flow (spool position) reference input signal: ±10 V_{DC} / ±20 mA maximum range Defaults are ±10 V_{DC} for standard and 4 ÷ 20 mA for /I option	Input - analog signal **Software selectable**
4		P_INPUT+	Position reference input signal: ±10 V_{DC} / ±20 mA maximum range	Input - analog signal **Software selectable**
5	INPUT-		Negative reference input signal for Q_INPUT+, F_INPUT+ and P_INPUT+	Input - analog signal
6	Q_MONITOR		Flow (spool position) monitor output signal: ±10 V_{DC} / ±20 mA maximum range, referred to V0. Defaults are ±10 V_{DC} for standard and 4 ÷ 20 mA for /I option	Output - analog signal **Software selectable**
6		P_MONITOR	Position monitor output signal: ±10 V_{DC} / ±20 mA maximum range, referred to V0	Output - analog signal **Software selectable**
7	F_INPUT+ (1)		Pressure/force reference input signal: ±10 V_{DC} / ±20 mA maximum range Defaults are ±10 V_{DC} for standard and 4 ÷ 20 mA for /I option	Input - analog signal **Software selectable**
8	SAFE_ENABLE1_ACK		Safe condition acknowledged (24 V_{DC}) or unacknowledged (0 V_{DC}) for solenoid at side of the driver and position transducer, referred to V0	Output - on/off signal
9	SAFE_ENABLE2_ACK (2)		Safe condition acknowledged (24 V_{DC}) or unacknowledged (0 V_{DC}) for solenoid at the opposite side of the driver and position transducer, referred to V0	Output - on/off signal
10	SAFE_ENABLE2 (2)		Enable (24 V_{DC}) or disable (0 V_{DC}) the solenoid at the opposite side of the driver and position transducer, referred to V0	Input - on/off signal
11	FAULT		Fault (0 V_{DC}) or normal working (24 V_{DC}), referred to V0	Output - on/off signal
PE	EARTH		Internally connected to driver housing	

(1) Connection NOT available for **TES/LES** in **SN** execution
(2) Connections available only for double solenoid valves

9 ELECTRICAL CHARACTERISTICS

SIGNALS	SPECIFICATIONS	NOTES
SAFE_ENABLE1 SAFE_ENABLE2	Input range: -3 ÷ 5 V_{DC} (OFF state), 15 ÷ 30 V_{DC} (ON state), 5 ÷ 15 V_{DC} (not accepted) Input impedance: Ri > 10 kΩ	Input - on/off signal
SAFE_ENABLE1_ACK SAFE_ENABLE2_ACK FAULT	ON state depends on input power supply V+: ON state > V+ - 2V @ max 50 mA e.g. in case of V+ = 24V, the ON state > 22V OFF state < 1 V; External negative voltage not allowed (e.g. due to inductive loads)	Output - on/off signal

Note: for the electrical characteristic of all other signals, refer to the technical table of each valve model - see section 3
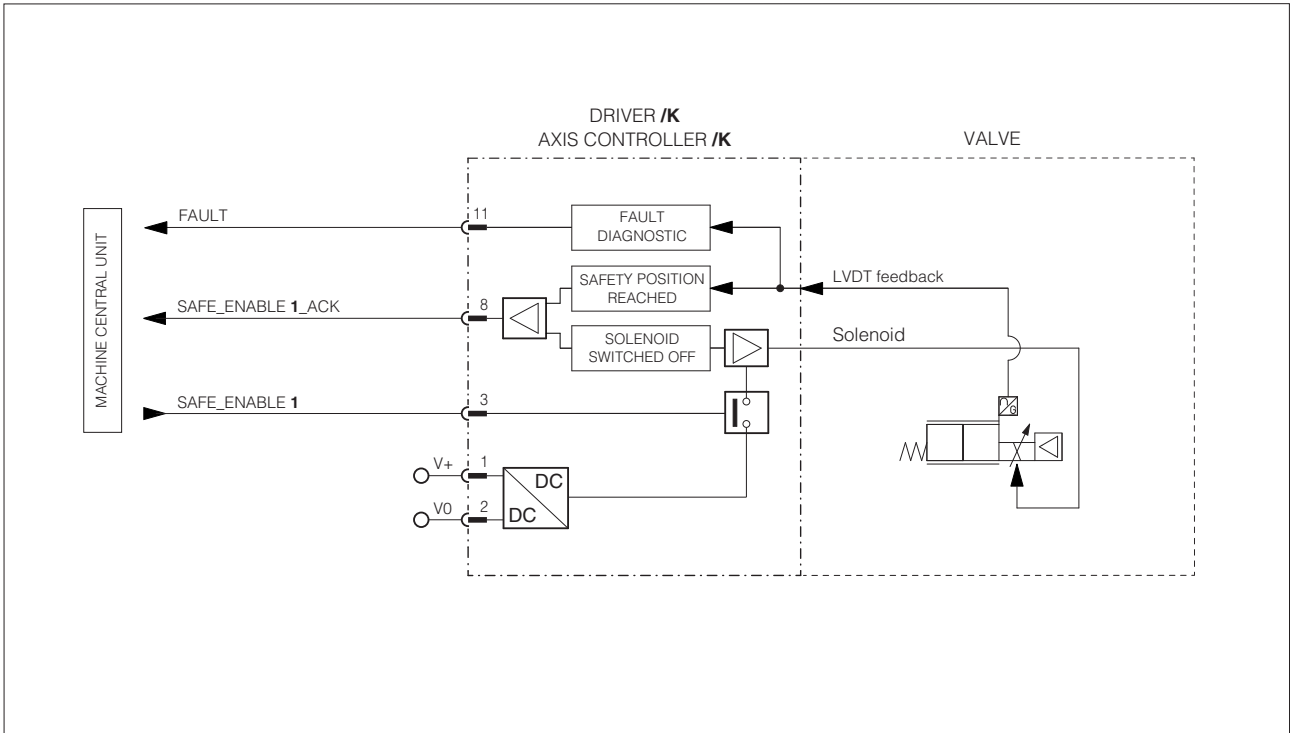
9.1 Connections layout
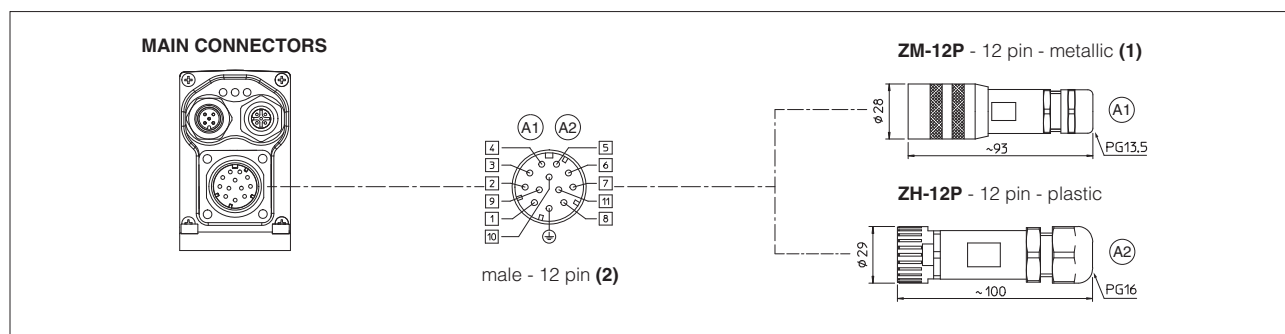
(1) Use of metallic connectors is strongly recommended in order to fulfill EMC requirements
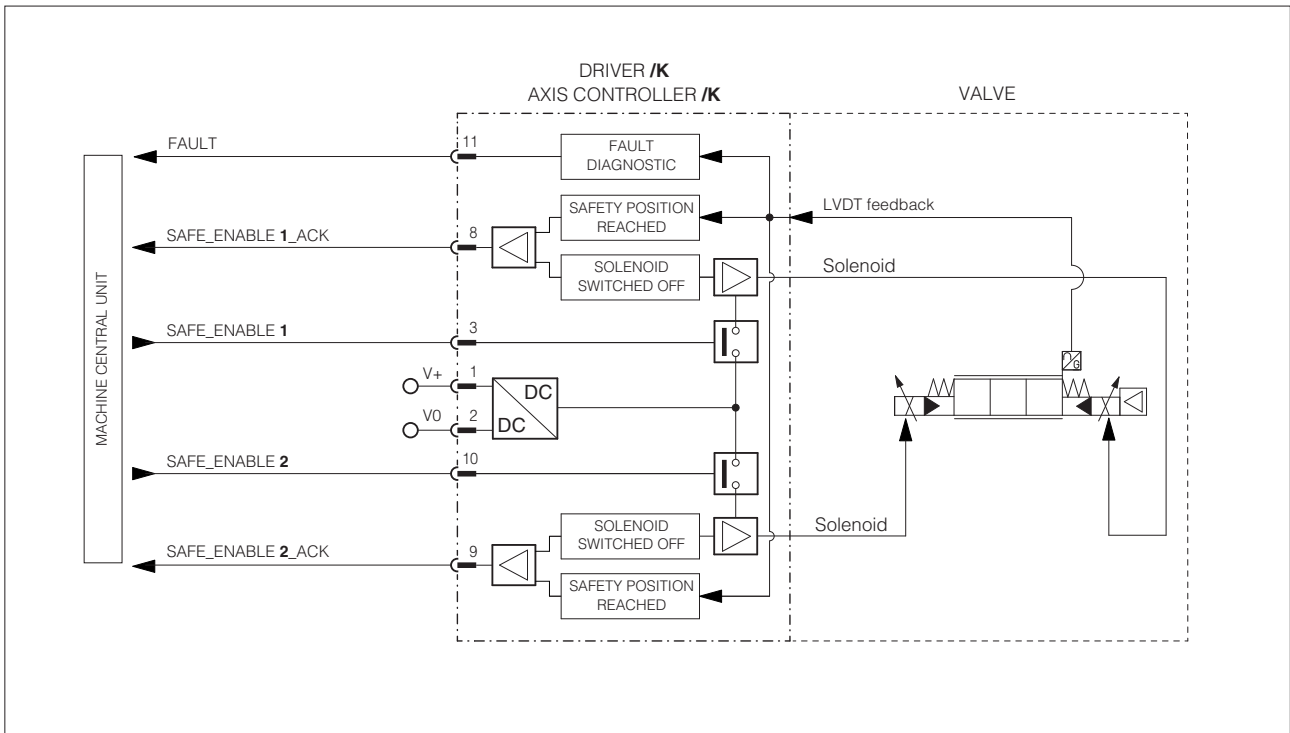(2) Pin layout always referred to driver's view
For fieldbus and/or transducers connections, refer to specific technical tables of each valve model - see section 3

10.1 Single solenoid valves

10.2 Double solenoid valves

General tables:

Y010	Basics for safety components
FS001	Basics for digital electrohydraulics
FS500	Digital proportional valves with P/Q control
FS900	Operating and maintenance information for proportional valves
GS500	Programming tools
GS510	Fieldbus
K800	Electric and electronic connectors
P005	Mounting surfaces for electrohydraulic valves

Valves technical tables:

FS165	DHZO-TES, DKZOR-TES, direct operated
FS172	DPZO-TES, pilot operated
FS175	DPZO-LES, pilot operated
FS168	DHZO-TES, DKZOR-TES, direct operated, zero spool overlap
FS180	DLHZO-TES, DLKZOR-TES, direct operated, sleeve execution
FS178	DPZO-LES, pilot operated, zero spool overlap
FS610	DLHZO-TEZ, DLKZOR-TEZ digital proportional valves with on-board axis card
FS620	DHZO-TEZ, DKZOR-TEZ digital proportional valves with on-board axis card
FS630	DPZO-LEZ digital proportional valves with on-board axis card

Commissioning and troubleshooting tables:

QF300	Quickstart for TES direct operated proportional valves (supplied with the valve)
QF320	Quickstart for TES/LES pilot operated proportional valves (supplied with the valve)

Operating and fieldbus manuals for TES and LES:

E-MAN-RI-LES -	TES and LES drivers user manual
E-MAN-RI-LES-S -	TES and LES drivers with P/Q control user manual
E-MAN-S-BC -	CANopen protocol programming manual
E-MAN-S-BP -	PROFIBUS DP protocol programming manual
E-MAN-S-EH -	EtherCAT protocol programming manual
E-MAN-S-EW -	POWERLINK protocol programming manual
E-MAN-S-EI -	EtherNet/IP protocol programming manual
E-MAN-S-EP -	PROFINET IRT protocol programming manual

Operating and fieldbus manuals for TEZ and LEZ:

Z-MAN-RI-LEZ -	TEZ and LEZ controllers user manual
Z-MAN-RI-LEZ-S -	TEZ and LEZ controllers with P/Q control user manual
Z-MAN-S-BC -	CANopen protocol programming manual
Z-MAN-S-BP -	PROFIBUS DP protocol programming manual
Z-MAN-S-EH -	EtherCAT protocol programming manual
Z-MAN-S-EW -	POWERLINK protocol programming manual
Z-MAN-S-EI -	EtherNet/IP protocol programming manual
Z-MAN-S-EP -	PROFINET IRT protocol programming manual

SIL safety manuals for operating, installation and maintenance (on request):

TT366	DHZO-TES/TEZ, DKZOR-TES/TEZ
TT367	DLHZO-TES/TEZ, DLKZOR-TES/TEZ
TT368	DPZO-TES/LES/LEZ

TÜV certificates (on request):

TUV IT 22 SIL 0092	Safety proportional valves, direct operated
TUV IT 22 SIL 0091	Safety proportional valves, piloted operated