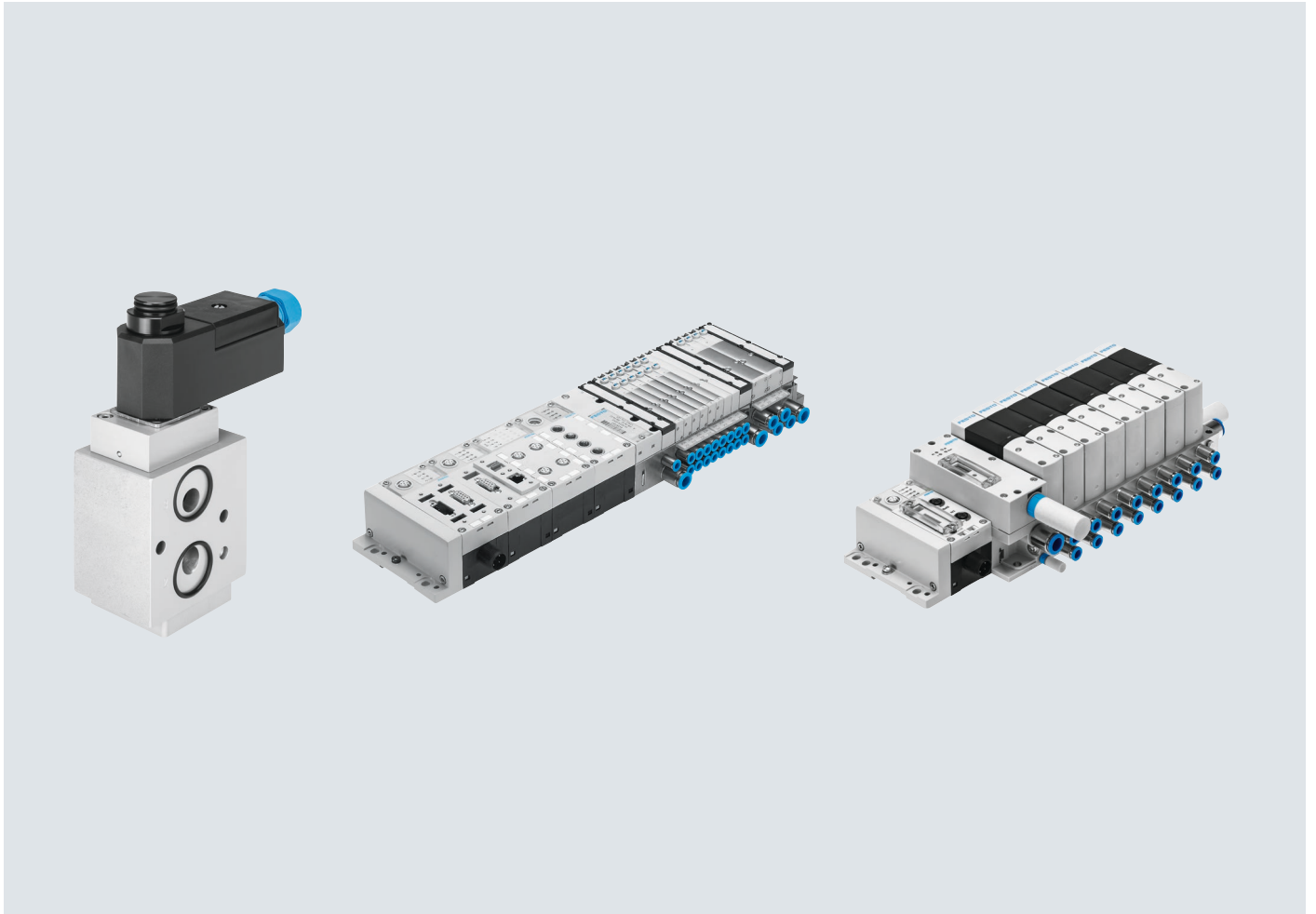


White paper: Automating on/off process valves.

A comparison of actuation methods for pneumatic actuators.



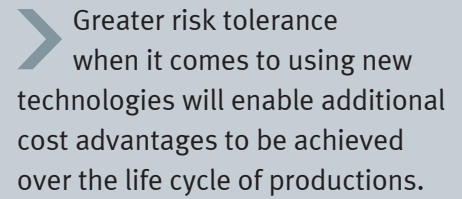
On/off process valves can be automated in different ways using pneumatics.

This white paper looks at automation using an individual valve, a valve terminal and a digital valve terminal, and compares the three actuation methods in terms of:

- Required hardware/components and the installation effort involved
- Investment costs
- Potential for compressed air savings and increased energy efficiency
- Diagnostic and maintenance options
- Potential for function integration
- Possible applications in safety-related circuits
- Possible applications in potentially explosive areas

Executive summary

Process valves such as butterfly valves or ball valves can be automated in different ways using pneumatics. The automation concept is usually determined by the specifications, which in turn are influenced by the conditions of a process plant, e.g. the physical size of the plant. However, there are also systems in which the requirements can be met using several concepts. The decision is often based on good experiences in the past with a particular concept. But a general reluctance and a low risk tolerance for using new technologies prevent additional cost advantages being achieved over the life cycle of productions. This applies even more to those new technologies that are used to consistently utilise the opportunities offered by digitalisation and that give rise to completely new automation functions, including autonomous process control adjustments in the event of process changes. On the following pages, various options for automating pneumatic actuators are compared using the example of simple on/off valves.



Greater risk tolerance when it comes to using new technologies will enable additional cost advantages to be achieved over the life cycle of productions.

Automation with individual valves directly on the actuator

When using individual valves for actuation, these are mounted directly on the actuator via Namur interface. Actuation is carried out via an electrical signal from the higher-level controller using binary outputs. This means that each valve is separately connected to the controller via I/O modules (input/output modules). The compressed air is connected directly to the individual valve via a ring line so that the control pressure is applied to the actuator immediately after the switching process. The feedback signals of the process valve positions are normally transferred to the higher-level controller via individually wired sensor boxes. This variant, when compared to the ones described hereafter, only has very limited diagnostic functions with regard to possible changing process conditions or the field components themselves.

➤ Individual valves are mounted directly on the actuator, which means that the control pressure is applied immediately after the switching process.

Typical applications for individual valves are central automation architectures in systems covering a large area, for example for continuous processes in the chemical industry, where fast switching times are required despite the large physical area. In addition, high-end individual valves are very durable and thus well suited to being used in harsh outdoor conditions such as at low temperatures as well as demanding requirements for safety and explosion prevention and protection.

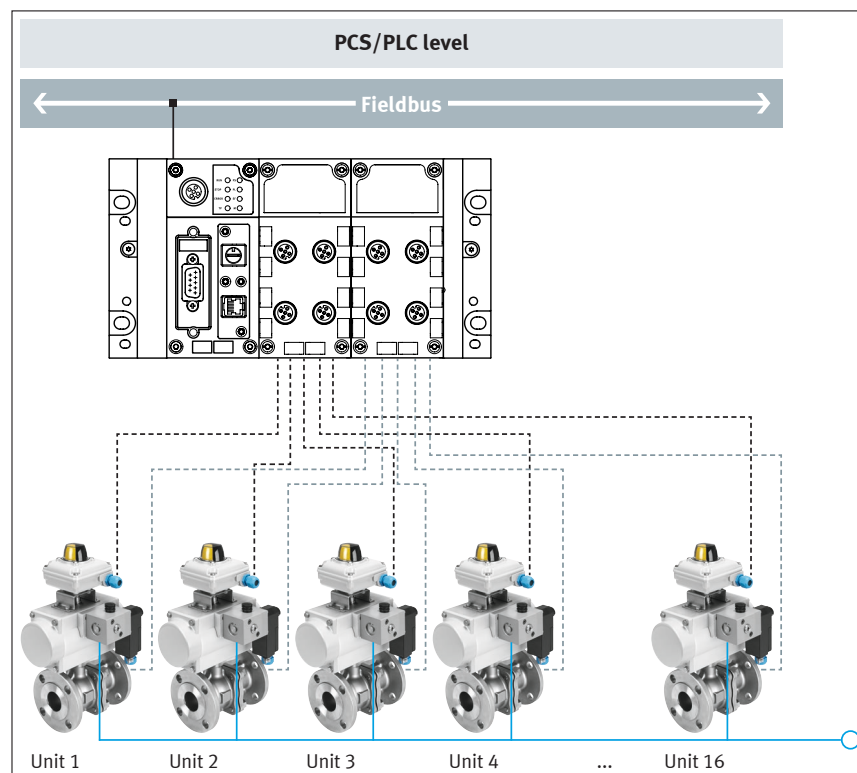


Figure 1: Actuation using individual valves

Automation using valve terminals

When using valve terminals for automation, the function of the individual valve is integrated into the valve terminal, i.e. the actuators are actuated via the valve slices on the valve terminal. With this solution there's no need for binary outputs in the higher-level controller, which are required for actuation when using individual valves (see the section "Automation with individual valves directly on the actuator"). This in turn saves investment costs for I/Os and cabling. With this variant, the compressed air supply is connected to the valve terminal and then routed from the individual valve slices directly to the actuators. The feedback signals of the process valve positions are normally transferred to the higher-level controller via individually wired sensor boxes.

➤ Valve terminals offer integrated diagnostic options, comprehensive function integration options and high flexibility.

Automation using valve terminals, as opposed to individual valves, has its limits in systems covering long distances if specific opening and closing times for the process valve are required. However, this actuation method offers numerous advantages in smaller systems with decentralised/modular automation and with shorter tubing distances, for example in indoor systems for batch processes. The benefits of valve terminals are their integrated diagnostic options, the possibility of integrating a wide range of functions directly on the valve terminal platform and greater flexibility, for example through the ease with which valve slices can be replaced/added.

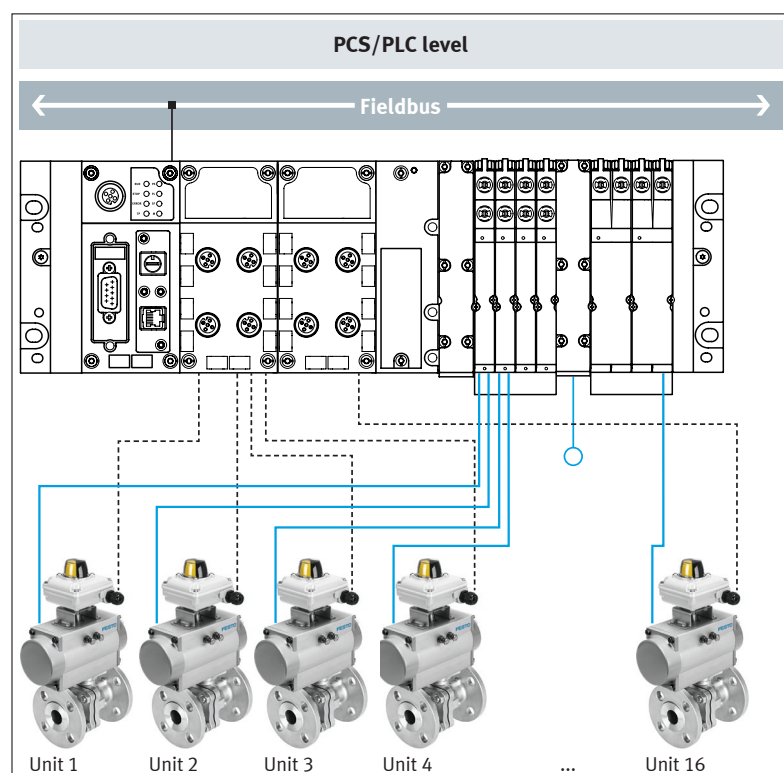


Figure 2: Actuation using valve terminals

Automation using digitised valve terminals

One example of digital field components is the new digital valve terminal from Festo, the Motion Terminal VTEM. By adding extra sensors and consistently integrating mechanics, electronics and software, completely new cost benefits can be achieved in all phases of the system life cycle. Up to 50 different pneumatic applications can be realised on a standardised hardware platform by installing software apps. With these software apps, the advantages of hardware standardisation can be combined with the flexibility of the automation function.

New apps are constantly being added, such as for end-position detection for on/off process valves, thus eliminating the need for traditional limit switches or sensor boxes and wiring of these components. This possibility has been included in the comparison. As with valve terminals, there is no need for binary outputs since the actuators are actuated directly via the integrated valve slices. The compressed air is supplied in the same way as for the variant “Actuation using valve terminals”.

Digitised valve terminals can be used wherever even more intelligence is required directly in the field. They offer enormous flexibility in terms of warehousing (just one piece of hardware is required) as well as in terms of functionality, which can be easily changed and adapted using apps. Digitised valve terminals also demonstrate their advantage in that they can self-optimize and self-adapt in processes that need to provide consistent results despite changing conditions. In terms of the physical areas of application, the options are the same as for regular valve terminals.

➤ Digital valve terminals are controlled using software apps and offer a large number of pneumatic applications on a single hardware platform. Comprehensive sensor technology also enables self-optimisation and self-adaptation.

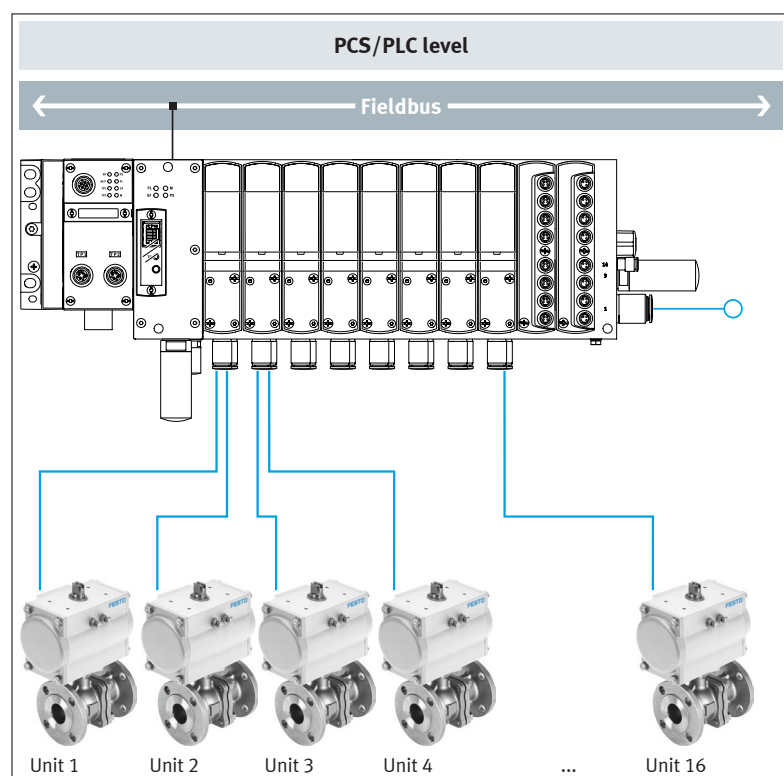


Figure 3: Actuation using the digital Motion Terminal

Comparison of investment costs

Test setup

The investment costs for two different environmental conditions and system characteristics were compared:

- Indoor system without explosion protection requirements
- Outdoor system with ATEX zone 2 requirements

The evaluation includes the costs for:

- Automation components including control cabinets
- Assembly services and materials

A total of 16 actuators are connected via electric cables and pneumatic tubing with an average length of 25 metres each. The pneumatic ring line required for the variant with individual valves was assumed to be cost-neutral as compared to the tubing requirements of the actuators in the other variants.

Indoor system without explosion protection requirements

The comparison for the system without explosion protection requirements shows that when using valve terminals, the investment costs are approx. 20% lower than when using individual valves. The savings are mainly the result of assembly and the lower cost of automation components. The costs for the Motion Terminal are comparable to those for valve terminals. However, a look at the individual aspects reveals significant differences. Since the position feedback signals are omitted, only the pneumatic tubing is required for the connection. This significantly reduces the assembly costs, although the investment costs for the automation components are higher compared to the other variants.

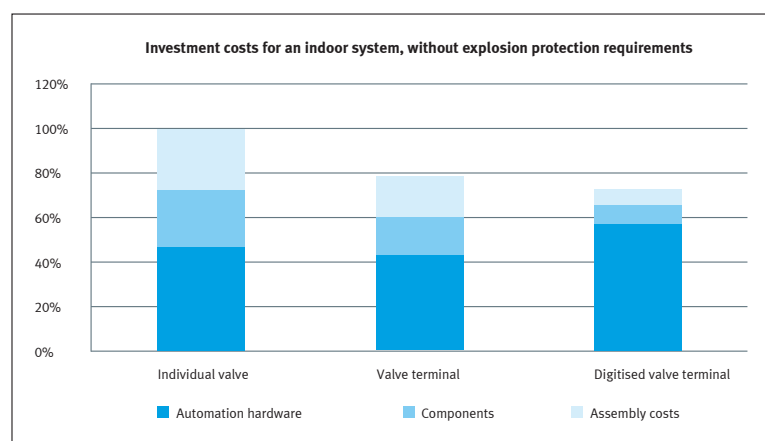


Figure 4: Comparison of investment costs for an indoor system without explosion protection requirements

Outdoor system with ATEX zone 2 requirements

For the outdoor system with explosion protection requirements, the ratios are comparable with the individual valve and valve terminal variants. However, the overall costs for the valve terminal variant are significantly lower, i.e. approximately half those of the individual valve variant. This is because the requirements for the individual valves used in hazardous and outdoor areas are much more demanding. These differences also apply to the indoor variant if the high-end individual valves used have a solenoid system with terminal box typical for the chemical industry. By contrast, the simplest individual valve variant has been included in the example “indoor system without explosion protection requirements”. The significant cost increase for the Motion Terminal variant compared to the valve terminal is due to the need for pressurised cabinets, as the terminal is currently not available with ATEX certificates. But the costs of this variant are still significantly lower than those for the individual valve variant.

➤ Individual valves can be used directly in an ATEX zone. However, this involves meeting much higher requirements and this, in turn, has a noticeable effect on overall costs.

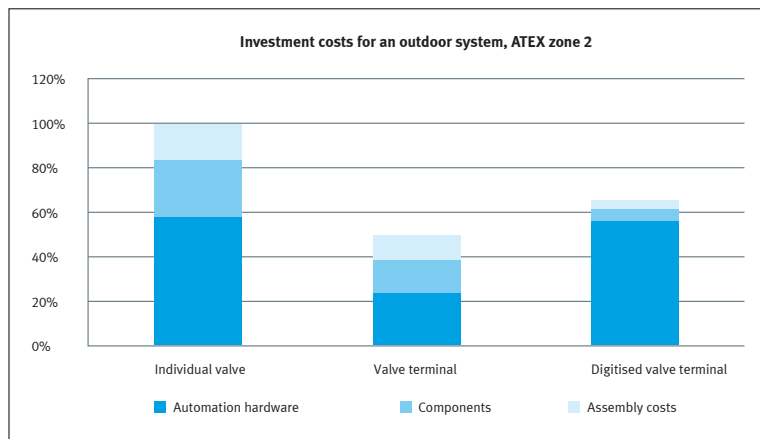


Figure 5: Comparison of investment costs for an outdoor system with ATEX zone 2 requirements

Further potential for cost reductions

In addition to just the investment costs, there are further significant differences between the variants that account for the associated cost reductions over the entire life cycle of the system and thus also an important increase in competitiveness. We will explain the relevant functions and differences further on in this white paper.

Potential for compressed air savings and increased energy efficiency ...

... with individual valves

By mounting directly on the actuator without additional tubing, the potential for leaks at this interface is generally low. The only other way to leverage further potential for compressed air savings when using individual valves is by using additional sensors in the air piping system.

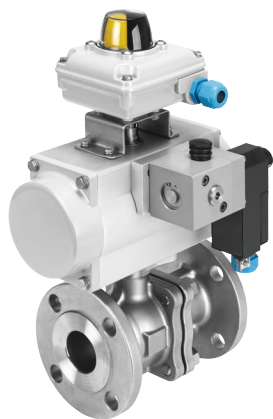


Figure 6: Process valve unit with individual valve mounted directly on the actuator

... with valve terminals

Function integration enables the valve terminal to be configured precisely in line with the application, thus supporting energy-efficient operation. For example, integrated proportional pressure regulators (Figure 7) can adapt the pressure as needed or permanently configured pressure zones only permit a predefined pressure build-up. Both functions can be easily implemented on the valve terminal platform and prevent unnecessarily high pressures and thus compressed air consumption.

A further benefit of valve terminals is the straightforward diagnostic options offered by integrated pressure switches and flow sensors. This enables faults and leaks to be easily detected and eliminated.

➤ Valve terminals offer diagnostic and control options for controlling pressure and compressed air consumption as needed.



Figure 7: Valve terminal with four directly integrated proportional pressure regulators

... with digitised valve terminals

Taking the Festo Motion Terminal as an example of a digitised valve terminal, the integrated approach followed with this valve terminal was to ensure energy-efficient operation. In addition to apps for saving energy, low-energy piezo valves have been developed for controlling the main valve stages. These reduce the power consumption for pilot control by up to 90%.

Of the ten apps currently available, the following two have been specifically designed for saving compressed air.



Reduced compressed air consumption with "ECO drive"

During the project engineering stage, every pneumatic actuator is designed with more torque or more force than would be necessary for the actual working stroke. Depending on the planner/operator, this safety factor can vary by up to half the required torque or force. This is particularly noticeable later in the compressed air consumption of systems in continuous operation. The "ECO drive" Motion App is able to pare down the increased compressed air consumption caused by the safety factor and the actuator size, and reduce the pressure in the actuator to the minimum required for the application. This means that less compressed air is needed. Experience has shown that energy savings of up to 50% are possible. This is particularly interesting in applications with continuous compressed air consumption, for example in cement bagging machines. The fact that the app and its processing method are decentralised is another benefit, as there is no need for intervention in higher-level controllers or thus no additional communication on the bus is generated.

➤ Digital valve terminals offer numerous opportunities for increasing the energy efficiency of the automated process. In addition, low-energy piezo valves are used in the valves themselves, which reduces the power consumption for pilot control by up to 90%.

➤ ECO drive reduces the pressure in the actuator to the minimum required, thus reducing compressed air consumption by up to 50%.

Save time and money with "Leakage diagnostics" for actuator-specific



leakage diagnostics

Identifying leaks in day-to-day operations usually requires a fairly significant amount of time. The "Leakage diagnostics" app offers major benefits when production has to run continuously without any downtime. It enables faults to be detected rapidly as the leaks can be accurately pinpointed to a specific actuator. Trouble-shooting, which can be time-consuming especially in large networks, is not necessary and work on eliminating the leaks can start immediately. In normal system operation, a certain number of switching cycles can be defined individually. When the specified number is reached, testing for possible leaks is carried out.

➤ With leakage diagnostics, leaks are found directly at the actuator. Time-consuming manual locating of leaks is thus eliminated.

... by optimising the complete compressed air system

In addition to selecting efficient components, optimising the entire compressed air system also contributes to significant savings in many cases. An integrated and long-term analysis helps to identify potential compressed air savings and exploit them to the full. The Energy Saving Services to DIN EN ISO 11011 offered by Festo serve precisely this purpose. It is a tailored, modular service programme where the customer decides the extent to which they want to make use of the service.

➤ A correctly sized complete compressed air system offers major potential for savings.

Diagnostic/maintenance options ...

... with individual valves

Simple, state-of-the-art individual valves do not offer any integrated diagnostic options at present. If this or similar functionalities are required, the individual valve or the valve peripherals must be equipped with additional sensors and wired up. There are a few newly developed solutions with integrated sensors on the market; however, an in-depth assessment with regard to their cost/benefit ratio and installation space is required before they are used.

There are concepts with which condition monitoring of valves is carried out by simply measuring/analysing the solenoid coil's current flow instead of using additional sensors; however, they are not yet well established on the market.

On-site troubleshooting of production plants is often a time-intensive process with individual valves due to the large physical area covered.

... with valve terminals

Compared to individual valves, valve terminals offer a large number of integrated diagnostic options for the components themselves as well as additional monitoring functions (e.g. for the number of switching cycles of the actuator), thus providing the basis for preventive maintenance.

In terms of self-diagnostics, valve terminals offer the following (using the example of the MPA from Festo):

- Determining and locating undervoltage
- Detecting wire breakage and short circuits (down to the individual valve slice)
- Condition monitoring (setpoint specification of the switching cycles per valve, monitoring downstream mechanical system/process, preventive diagnostics/maintenance).

Modular valve terminal solutions enable pneumatics, electrics and even control modules to be integrated on one and the same platform. This opens up further possibilities, especially for on-the-fly diagnostics. Even predictive maintenance functionalities, for example, can be implemented using individual programming options and additional sensors. In addition to simpler troubleshooting with valve terminals as compared to individual valves (all valves in a system section are in the same place, LED-assisted diagnostics, etc.), they also have numerous connection options that enable remote condition monitoring and remote troubleshooting. Output can take place via fieldbus/Ethernet on the control system or be sent via OPC UA from the valve terminal directly to cloud-connected dashboards (Figure 8). These dashboards can be called up worldwide via the Internet, which means that the live condition can be viewed from anywhere and at any time using a digital image of the valve terminal.

➤ Modular valve terminal solutions such as the CPX-MPA from Festo offer a large number of integrated diagnostic options. Evaluation can take place on site or in the higher-level control system, or be called up via cloud services worldwide over the Internet.

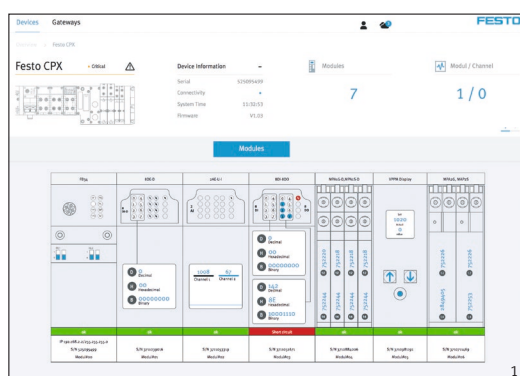


Figure 8: The dashboard shows an exact image of the individual configuration including actual characteristics and data

... with digitised valve terminals

Digitised valve terminals offer the same maintenance and diagnostics options as conventional valve terminals, but go even further.

Each valve slice has integrated analogue pressure, stroke and temperature sensors (Figure 9) that continuously exchange their data with the controller. This enables the system to run its own evaluations and make its own decisions. The digitised valve terminal therefore self-adapts to a certain extent in order to maintain the (app-)defined process values. The system outputs warning messages if any deviations are identified that cannot be regulated using self-adaptation.

➤ Digitised valve terminals can self-diagnose and self-adapt to a certain extent. Manual intervention is thus reduced to a minimum.

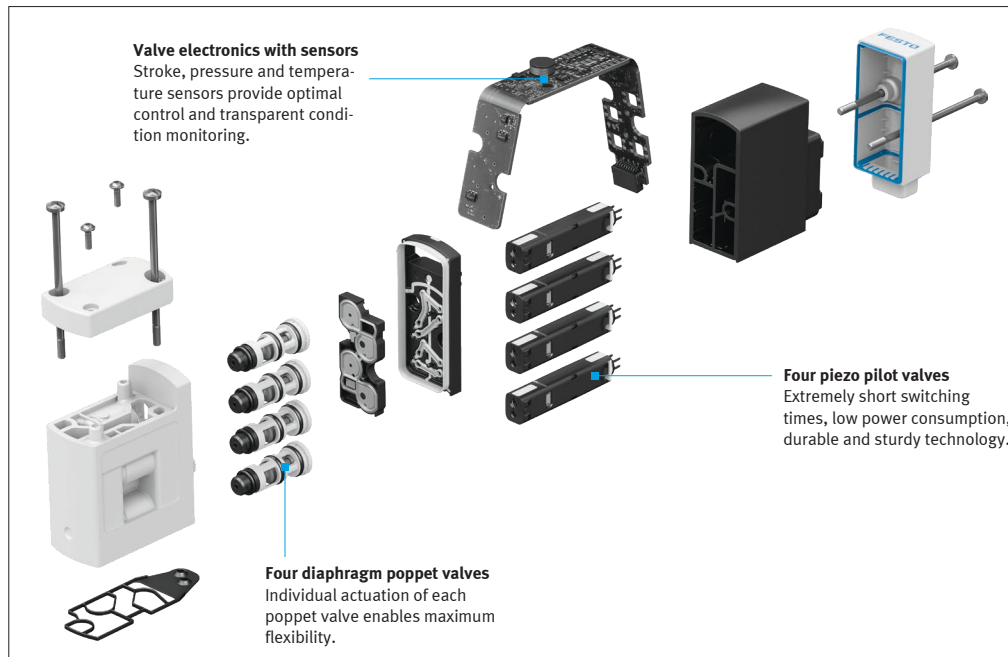


Figure 9: Structure of a Motion Terminal valve slice. Stroke, pressure and temperature sensors are directly integrated

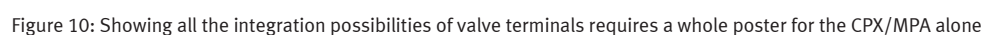
Individual valves don't usually offer the option of direct function integration as standard. Of course it is possible to develop customer-specific solutions (following a prior assessment of the cost/benefit ratio); however, this involves a high level of engineering effort and is therefore only to be recommended in very few cases.

... with valve terminals

➤ Modular valve terminal solutions combine pneumatics, electrics and control on one hardware platform. This technology enables maximum connectivity and flexibility.

- Various possibilities for the power supply connection
- More than 15 different bus nodes
- Numerous variants of digital and analogue I/O modules
- Technology modules for measurement and proportional technology
- Safety engineering and diagnostic systems

In addition to the integration of hardware modules, the integratable controller provides further scope for individual functionalities.



... with digitised valve terminals

Function integration through hardware configuration is almost completely eliminated with digitised valve terminals. As explained at the beginning of this white paper, up to 50 different pneumatic functions can be realised on a standardised hardware platform by installing software apps.

The following functions are currently available via apps:



Directional control valve functions

The standard directional control valve functions such as 4/2-way, 4/3-way, 3/2-way, etc. can be modified at any time and as often as necessary, even during operation.



Proportional directional control valve

Two proportional flow control systems in one valve.



Soft Stop

Highly dynamic yet gentle positioning motion without wear-prone shock absorbers.



Proportional pressure regulation

Two individual and independent proportional pressure regulators in just one valve, including with vacuum.



Model-based proportional pressure regulation

By storing fewer boundary parameters for the system, such as tube length, tube diameter and cylinder size, the anticipatory control system ensures maximum accuracy, as the app can compensate for a drop in pressure and volume using the control technology.



ECO drive

The actuator is operated with the minimum necessary pressure based on the load. This eliminates the rise in pressure in the actuator chamber at the end of the movement.



Selectable pressure level

Easy to set multiple pressure levels. Enables the pressure for selected movements to be reset to a reduced level. Also enables the speed to be controlled by adjusting the flow control valve setting.



Leakage diagnostics

Thanks to separate diagnostic cycles and predefined threshold values, leaks can be individually detected and pinpointed to a specific actuator.



Supply and exhaust air flow control

Eliminates the need for separate flow control valves on the actuator. Allows tamper-proof travel speeds to be set quickly and conveniently at the touch of a button. There is also an option to implement new motion sequences such as dynamic flow control adjustment.



Presetting of travel time

The exhaust air flow control function adapts itself to the travel time for retracting and advancing and then maintains it. The system automatically adjusts the values in the case of influences such as increased friction due to wear.

➤ Something that was previously available on smartphones has now also found its way into valve terminals: one and the same piece of hardware performs a wide range of functions depending on the app used.

Possible applications in safety-related circuits

... for individual valves

Individual valve technology has been on the market for several decades. The benefit of these many years of experience in using this technology is that the reliability of individual valves has been/will be continuously optimised. A number of individual valve types (e.g. VOFC/VOFD from Festo) are considered tried and tested since they are still switching perfectly, even after many years of use. The requirements in safety-related circuits within the process industry, where the valves often have very low switching cycles and long idle periods, are particularly demanding. This is because the valve has to switch reliably in an emergency, without sticking, even after a prolonged idle period. Long-term and high-quality empirical values about the use of individual valves in safety-related circuits up to SIL3 are now available on the market.

SIL certified
according IEC 61508

Figure 11: Tried-and-tested, certified individual valves meet the highest safety requirements

Another advantage of individual valves in safety-related applications is their fast reaction times. In case of emergency (e.g. compressed air failure, power failure or irregularities in the process), the valves must move into the safe position in the shortest time possible. Individual valves can do this even when the compressed air lines are long.

... for valve terminals

Valve terminal technology is well established on the market. As it is more firmly rooted in factory automation, it is used less frequently in safety-related circuits in the process industry; but there are possible applications:

Valve terminal with integrated safety shutdown

In operating mode, the valve terminal is actuated via a fieldbus and switches actuators in the process. The valve terminal also has a separate supply from a safety PLC, which actuates the valves on the valve terminal for the safety shutdown. That means that in an emergency it is possible to either switch the actuators required for the safety shutdown (connected in series with the actuators for operating mode) (Figure 12) or to actuate the actuators for operating and safety mode simultaneously (Figure 13) and thus safely shut down the process. Both solutions are suitable for SIL2 circuits. To increase the safety level, it is also possible to connect the process valves in a redundant circuit (1oo2).

➤ Valves in the process industry often have few switching cycles and long idle times. However, they still have to switch reliably in an emergency, without sticking. Individual valves have been proving themselves on the market for several decades, including under demanding conditions.

➤ Valve terminals are mostly used for operating mode, but they can also include valves for safety shutdown that are actuated by a separate safety PLC.

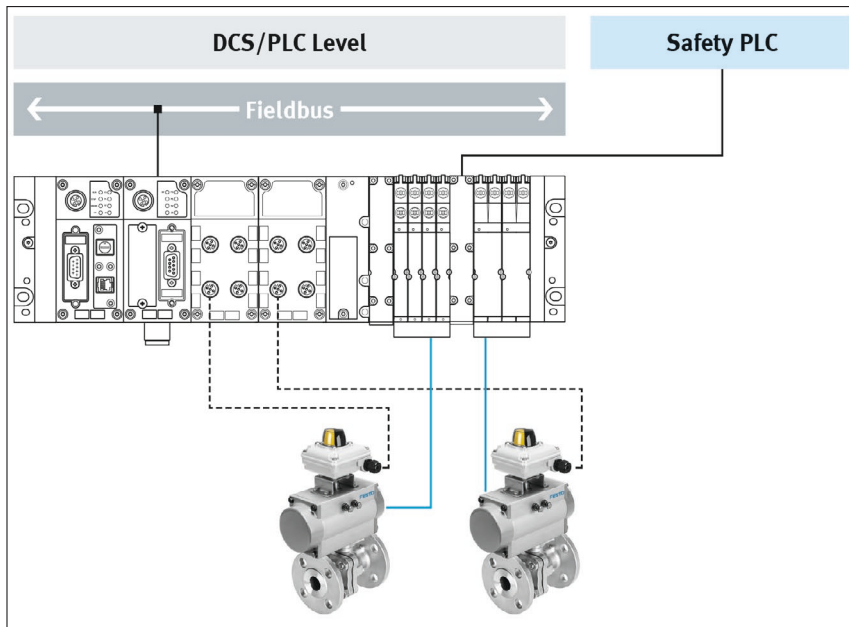


Figure 12: Valve terminal with integrated safety shutdown for actuating separate actuators

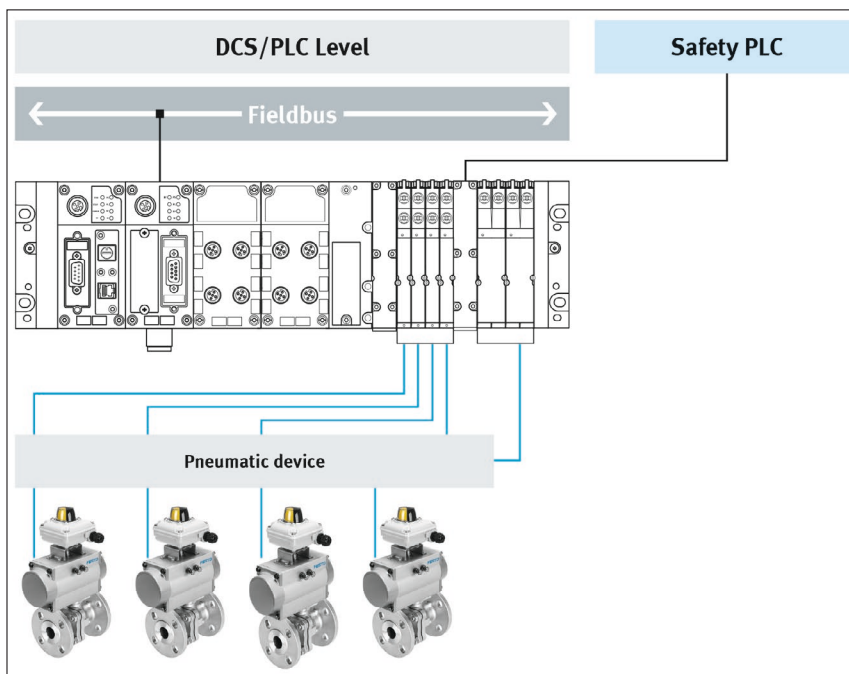


Figure 13: Valve terminal with integrated safety shutdown for simultaneously actuating actuators for operating and safety mode

Valve terminal for operating mode plus individual valve for safety shutdown

In this setup the valve terminal, when in operating mode, is also actuated via a fieldbus and switches actuators in the process. In addition, a certified individual valve is mounted on each safety-related actuator, which is actuated directly via the safety PLC (Figure 14) and safely shuts down as needed. These individual valves can be used in safety-related circuits up to SIL3.

The diagnostic options offered by valve terminals for detecting critical faults (under-voltage, wire breakage, short circuits) also help to increase safety.

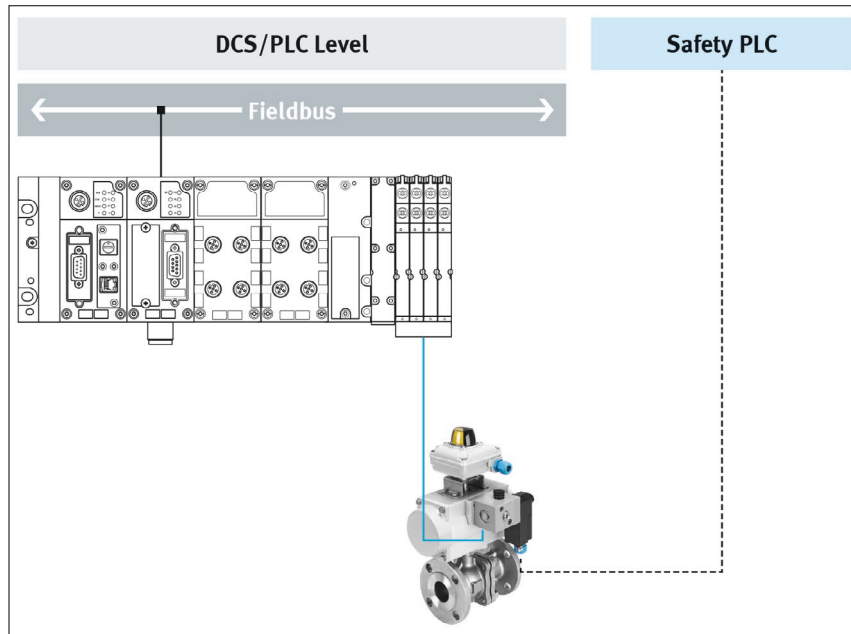


Figure 14: Valve terminal for operating mode plus individual valve for safety shutdown

... for digitised valve terminals

This new technology is not intended for safety-related functions at the moment.

Possible applications in potentially explosive areas

... for individual valves

There is a wide range of individual valve versions that are available for use directly in potentially explosive areas (mostly zones 1 and 2) and that have various types of ignition protection. The option to combine a basic valve with various solenoid coils provides additional flexibility for use in ATEX zones. Almost all individual valves commonly found in the market offer this option, and can thus be optimally adapted to the ambient conditions.

➤ Many individual valves can be used directly in potentially explosive areas.

... for valve terminals

When used directly in potentially explosive areas, standard valve terminals must be installed in a control cabinet with an appropriate type of ignition protection (increased safety Ex e, flameproof enclosure Ex d, pressurised encapsulation Ex p) (Figure 15).

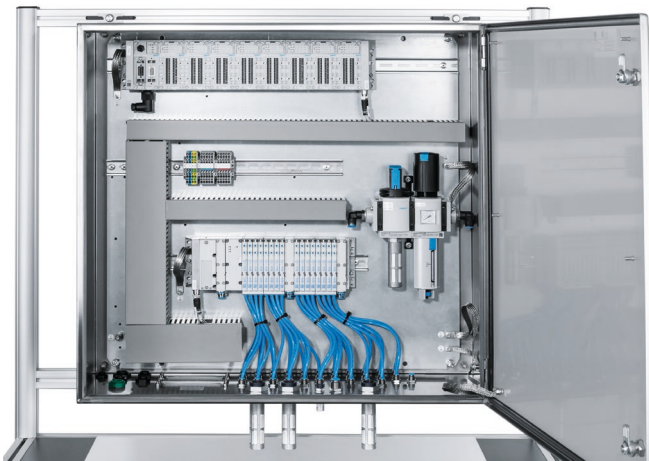


Figure 15: Control cabinet for use in zone 2/22 with valve terminal

Special valve terminal variants (e.g. CPX-P from Festo, Figure 16) are available with digital input modules that are designed in accordance with ignition protection type Ex i (intrinsic safety). With these input modules it is possible to receive feedback signals from potentially explosive zones 0, 1 and 2 without using an additional barrier.

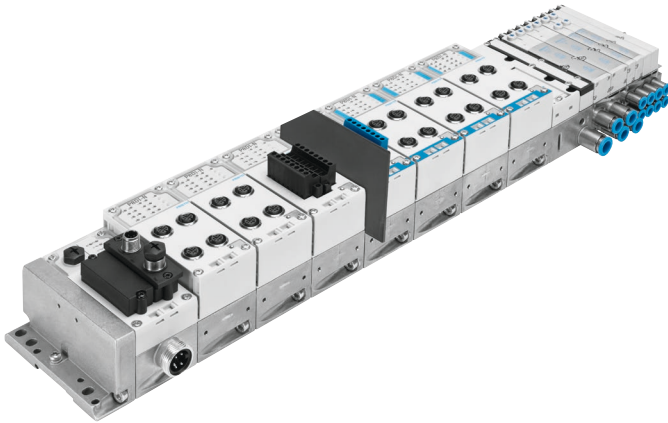


Figure 16: Valve terminal (CPX-P) with intrinsically safe input modules (shown in blue)

... for digitised valve terminals

As with standard valve terminals, digitised valve terminals must also be housed in an explosion-proof control cabinet (Ex d or Ex p) when used directly in potentially explosive areas.

Conclusion/outlook

Digitalisation will significantly change both the automation technology of production plants and the associated processes over the life cycle of those plants. There are technologies that have been around for some time, but that, for various reasons, are not utilised to the full. The comparison of investment costs shows that automation structures based on valve terminal technologies have a distinct advantage. In addition to just the investment costs, these variants offer additional benefits for maintenance and operation and make it possible to start digitising production.

Individual valves, on the other hand, still show their strong points first and foremost in safety-related applications with defined opening and closing times, when used in potentially explosive areas and when the requirements for sturdiness and reliability in operation are particularly stringent.

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