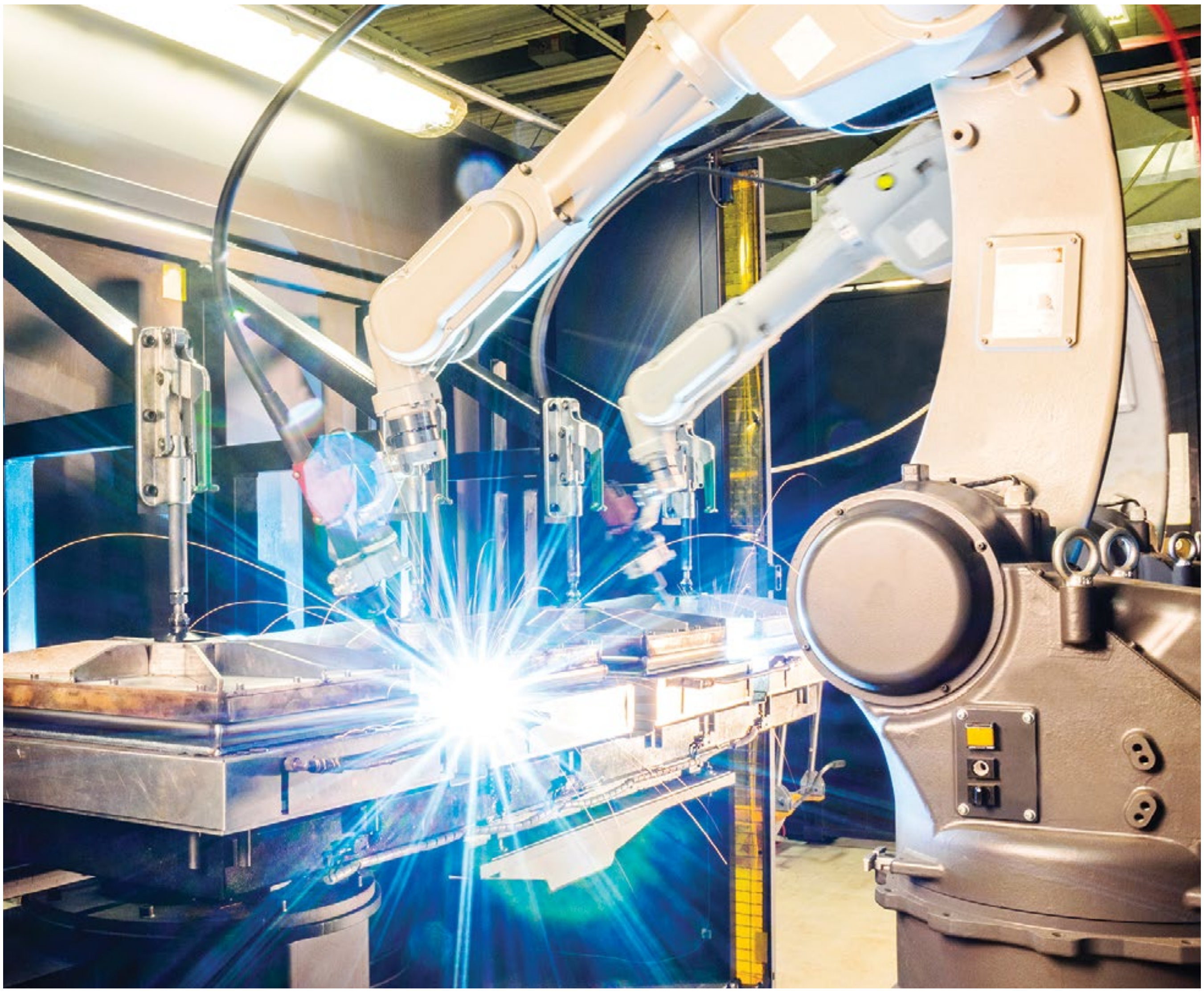
White Paper
February 2020

Key Elements in Proportional Pressure Control Valve Technology



EMERSON

Your customers need to maintain profit margins by optimizing their manufacturing operations in a competitive manner. That means that your machines must provide higher efficiencies, operate with reduced energy consumption, use intelligent components, and often provide a smaller footprint. These advancements are done one component at a time and often include proportional pressure valves.

Proportional control technology is ideal where precise performance is required in variable pressure or flow applications (see sidebar on page 9). Proportional valves are designed to change output values in proportion to their input values, while providing dependable, cost-effective, compact solutions for fast response and consistent control. Often perceived as more complicated than other solenoid valves, the technology used can offer many benefits once a few things are understood.

EMERSON

Control Methods

Depending on the needs of your application, whether having a stable setpoint or variable operation, you'll want to consider using feedback or not **(see Figure 1).** Open loop operation relies on the stepped operation of the valve while, closed-loop operation requires feedback so that you can compare where the valve was told to go versus where it actually went and make adjustments appropriately.

On/off operations are ideal for open-loop control. As long as the result of the open valve or closed valve operation doesn't rely on a secondary measurement, the valve can be set for a particular time between operations. Therefore, the open and/or close action would be consistent, providing less wear on internal components. The valve simply opens or closes based on the controller.

In a closed-loop operation, there is a need to monitor the outcome of the valve operation in order for the application to work properly. Either the valve itself needs to be monitored to provide accuracy and repeatability of the valve action or something in the process needs to be monitored to let the valve controller know when it has completed its operation. An example of controlling the valve might be in a flow situation where a particular liquid must flow at a certain rate to perform properly. In a paint sprayer, the flow of paint must be controlled accurately via closed loop monitoring that adjusts the valve. On the other hand, during a filling operation, a user might want to open a valve completely during the early stages of filling a tank, then slowing in degrees as the tank fills, eventually controlling valve output precisely to *top-off* the tank without causing turbulence that could spill over.

AVENTICS™ Sentronic series of valves is able to be configured for double-loop (cascaded) control, which means that multiple feedback components can be incorporated. Each feedback loop would be involved in monitoring a different variable, such as pressure, flow, force, speed, or temperature. The only additional component needed would be the sensor that will provide the feedback.

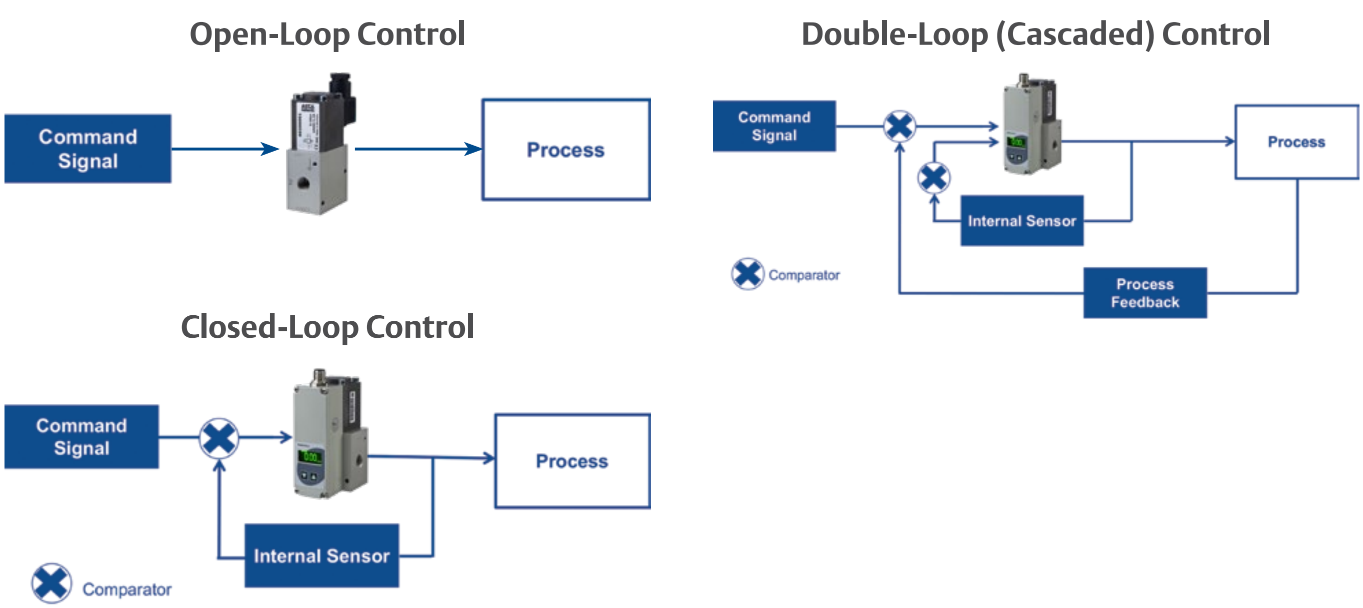


Figure 1: Know what type of feedback you need prior to making your valve selection.

Application Requirements

When selecting a proportional valve, original equipment manufacturers (OEMs) need to consider a few critical questions early in the application development process. First off, what variable needs to be controlled? A pneumatic proportional pressure control valve can do more than just control pressure. Proportional pneumatic pressure can control other process variables such as flow, force, rotational speed, position, temperature or level. Acceptable control is often possible without actually measuring the controlled variable. An example might be the relationship between pressure and flow, which is stable through a fixed orifice. However, the controlled variable will need to be measured for applications with tight tolerance specifications, where the correlation between pressure and the controlled variable changes over time, or based upon application setup.

When a variable other than pressure near the outlet of the proportional valve is measured and controlled, OEMs typically must run a control loop on that variable and modify pressure output accordingly. Some proportional pressure valves, such as the AVENTICS Sentronic valves can be setup for a cascade control loop to handle that external control loop processing. OEMs must decide whether to run their own control loop or hand that processing off to the proportional valve. Some applications may lack the controller to perform this function, but even when present the processing load on that controller must be considered. Overloaded controllers can result in variable performance based on processing priorities and speeds. In contrast, the proportional valve has dedicated processing, which eliminates this concern.

After considering what needs to be controlled and the best architecture to do it, other standard application criteria must be evaluated, including:

- Media type, which may influence required valve construction or materials
- Inlet pressure and maximum controlled output pressure
- Required flow range
- Media and ambient temperature
- Other environmental factors such as hazardous location, vibration, weight or space restrictions
- Power consumption, especially for mobile applications
- Required action on loss of power
- Static vs. dynamic application requirements
  - Mostly static pressure?
  - Frequently changing pressure requirements?
  - High cycle rates?
  - Shifting loads causing backpressure?

This last point regarding static versus dynamic applications is particularly important to consider and lends itself to a discussion of the most common types of electronic proportional pressure valves.

Valve Design Considerations

There are five basic operating methods used in proportional valve technology.

- **Direct-acting proportional solenoids** act directly on pistons or spools to adjust valve open or close positions based on a varying voltage across the coil.
- **Pulsed air-piloted solenoids** load and unload air pressure in a pilot control chamber which moves a diaphragm and, in turn, acts on a piston to open or close the valve.
- **Piezoelectric valves** operate in a way that, when voltage is applied, they actually deform to either open or close the valve. Piezoelectric operators are incorporated where extremely low power consumption is necessary.
- **Pneumatic positioners** act as pilots to enable air to enter or vent from a diaphragm or cylinder to open or close a much larger valve.
- **Electrical motor actuated valves** operate using a simple linear actuator to open and close the valve. Designs are based on specific needs of the application and can vary in both dimension and size.

Of these five methods, direct-acting and air-piloted are the most commonly used—and fall in the middle of the range of capabilities. Therefore, this paper will focus on a comparison between these two approaches.

For cost reasons and lower power consumption OEMs purchase **pulsed air-piloted proportional valves.** These are great reasons when the application requires a static setpoint for the proportional valve. Basically, air-piloted solenoid valves move air into and out of a pilot control chamber, which can be a slow process that is reliant on pilot valve cycle rates. Through the use of stepped pressure adjustments based on pilot valve cycle times the result in pressure swings can become too large for some applications where accuracy is critical. These valves also provide minimal adjustment capabilities to optimize their performance.

Air-piloted valves are designed and manufactured incorporating wearable components such as rolling diaphragms and pulsed solenoid pilot valves that *move* the piston to regulate pressure. These components add complexity and increase performance variability from valve to valve and can also wear, resulting in degraded performance levels and excess air consumption. Overall, this means that air-piloted valves are less suited for use with applications that have demanding requirements and/or constantly changing set points—producing heavy solenoid cycling rates that quickly wear out components and they are generally less sensitive to any air quality concerns.

More dynamic applications are better suited for using **direct-acting proportional coil solenoid valves,** which offer advantages that air-piloted valves don't. For example, direct-acting proportional solenoid valves fit a considerably wider range of applications and provide simpler construction with fewer mechanical parts, simpler principles of operation, and more dependable performance capabilities. Direct-acting valves last longer in dynamic operations where valves are cycled more often. Their robust construction reduces the concern about wearable component failures and they are generally less sensitive to any air quality concerns.

Other technical advantages include the ability to reduce overshoot, which is the tendency for a valve to accelerate toward a set point and then go past it only to have to reverse back toward the set point—and possibly overshooting again. This is a common occurrence in systems tuned for short response times. The oscillations typically take less time to settle in direct-acting proportional coil designs because the valve directly moves the piston by varying current to the coil.

Direct-acting proportional coil designs typically provide a finer resolution of pressure control, which can be critical in applications such as polishing, which demands small pressure changes to avoid damaging parts. Direct-acting valves precisely vary coil current to make very controlled pressure adjustments. Overall, the direct-acting design possesses greater speed, responsiveness, and resolution that make it superior to air-piloted designs for a number of applications **(see Table 1).**

Valve Type	Response Resolution	Response Time	Flow vs. Size Ratio	Power Consumption	Application
Air-Piloted			Larger		Static*
Direct Acting	Finer	Faster		Higher	Dynamic*

* Static: For applications with few setpoint changes.
* Dynamic: For applications with constantly changing setpoints or fluctuating pressure feedback.

Table 1: Quick comparison between air-piloted and direct acting valves

Digital Parameter Tuning

Proportional pressure valves typically offer only a handful of settings for a variety of applications. These settings can be adjusted but often require a time-consuming series of physical adjustments at the factory. Rather than spending lengthy back-and-forth consultations between the customer and the manufacturer to match the valve with the application or try to adjust a manual potentiometer in the field—which lacks precision—consider selecting direct-acting solenoid valves that feature newer valve technology that offers digital tuning software.

Parameter adjustment software, incorporating a digital oscilloscope, supplies quick and easy adjustments with advantages such as providing high-precision pressure control, streamlining development times, allowing the valve to be adjusted for the application in situ, and enabling parameters to be saved and emailed to tech support. For OEMs, this permits pre-setting of valve parameters at the factory, which supplies the best product performance for suitable applications. While dynamic applications are the best candidates for tuning software, applications with ultra-stable pressure control, such as leak testing systems, can also benefit greatly.

Figure 2: An online software program is available to easily check and adjust the parameters of your proportional valves.

Parameter adjustment software **(see Figure 2)** places control in the users' hands and provides them the ability to change almost any setting, including dead band, analog signal type, and shutoff level. This means that early on during the prototype phase of OEM assembly, design engineers can immediately see the effects of any changes they make. For example, they can quickly and easily fine tune the pressure received by a cylinder to obtain a specific force. If necessary, they can make these real-time changes while on the phone receiving expert advice from the manufacturer's tech support specialists. These features increase speed to market by allowing an OEM to modify the proportional valve as needed during design revisions.

Advanced Capabilities

To get optimized performance and long life from a proportional pressure valve that fits into today's Industrial Internet of Things (IIoT) is an important step in product design. AVENTICS' Sentronic valves can be applied to a broad range of specialist machinery applications, while the company's engineering services can help you customize the products or manifolds to provide everything from making it fit properly to cost effectiveness to ensuring particular features relevant to your application.

Figure 3: Shown is the Sentronic^{Plus} (Series 614) and proportional pressure control valve, which is available with the integrated IO-Link® communications.

The Sentronic Series of valves are available in various designs so that the most appropriate can be selected for an application. Both the Sentronic^{PLUS} **(see Figure 3)** direct-acting and Sentronic^{LP} solenoid air-piloted models are available with IO-Link communication. Using IO-Link communications to gain insight into these devices on the factory floor supports future implementation of Industry 4.0 and IIoT applications that will contribute toward greater plant reliability, availability and profitability. IO-Link is increasingly being applied to a range of automation applications, providing a cost-effective digital communication interface for sensors, actuators, and controllers via unshielded, industry-standard M12 I/O cables. To reduce maintenance time and complexity, the IO-Link module allows the Sentronic valves to identify and configure themselves automatically during component replacement, thereby eliminating the need for configuration via a laptop. Supporting greater ease-of-use, the addition of IO-Link technology to the Sentronic valves uniquely enables device parameters to be changed directly with the PLC during a process without the need of data acquisition software.

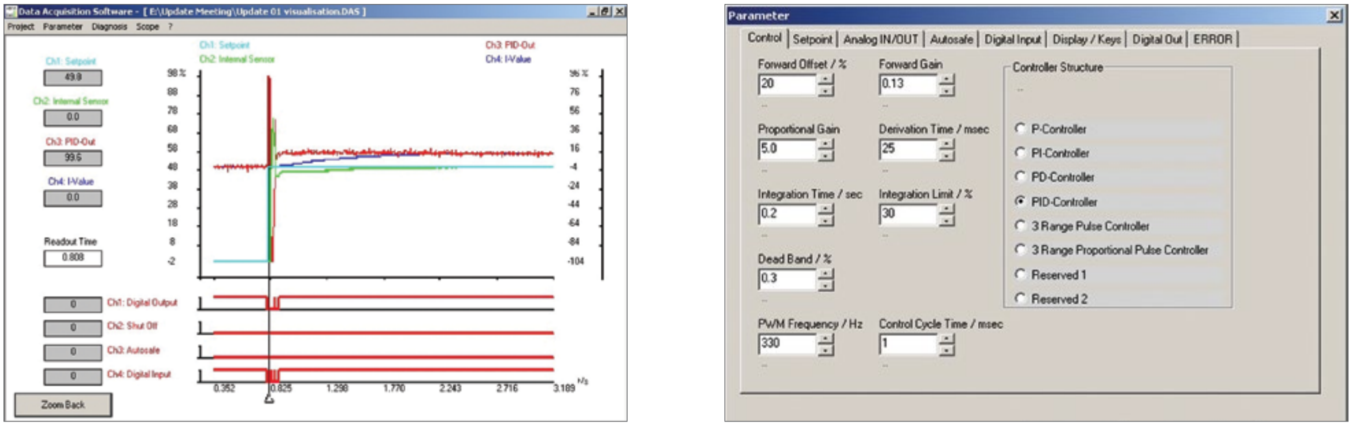


Figure 4: The Data Acquisition Software (DaS) is designed to simplify configuration and setup for proportional valves and can be used to adapt the proportional valve's settings to your application.

The entire Sentronic portfolio can be customized for a wide variety of applications using an included data acquisition software **(see Figure 4)** that grants access to the PID control loop of the valves. This software includes an oscilloscope feature that charts valve performance, **(see Figure 5)** PID output, and PID variables right in the application—a valuable tool during prototype design. Design engineers can get a visual confirmation of pressure control as machine designs are modified. Control can be modified and checked in an iterative process to ensure the application is performing optimally. In addition to PID parameters, other variables and features such as deadband, custom ramps, and digital outputs can all be adjusted as per application needs. All of these custom settings can be loaded at production and designated with a part number suffix for re-ordering needs. These valves can also be configured for dual loop (cascade) control. In this configuration, the valves directly receive an external process variable and adjust their output pressure as needed to control it. The external measurement could be downstream pressure, flow, force, temperature, RPM, or position. The valves provide fast, dedicated processing of this control loop as an alternative to placing these demands on the PLC or controller.

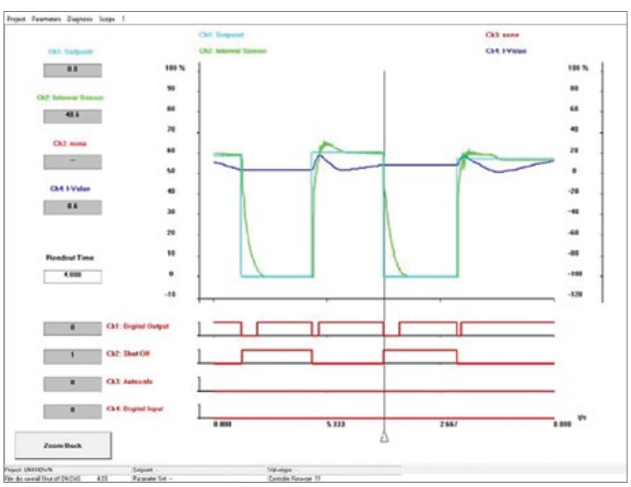


Figure 5: The digital oscilloscope, one of the features available in the Data Acquisition Software, helps visualize the performance of the valve and understand potential impacts in the application.

Proportional Valve Applications

Specifiers and users must closely consider relevant characteristics of their application to determine future valve performance. The most important question to ask is whether the application is static or dynamic.

Static applications often require that the set point of a desired pressure, controlled via valve opening and closing, remains fixed for the majority of time. This is the case in leak testing systems where the valve applies a fixed pressure to a component in order to test for soundness. This set point pressure only changes when a different component is to be tested.

Dynamic applications require the set point to change frequently, causing the valve to open and close continually. An example of this situation is in material testing, where the pressure output of the valve is steadily increased until the tested material failures. Other characteristics might be frequently commanded pressure changes with heavy-duty cycling or shifting loads with backpressure that needs continual firing/adjustment. Dynamic applications usually demand a more robust type of proportional valve, and also share these other characteristics:

Some typical proportional valve applications

- Web/roll tensioning (converting, textiles, paper)
- Laser cutting
- Leak testing
- Fluid spraying or coating (paint, glue, other)
- Medical (air bag, vacuum, other)
- Spot welding
- PET blowing
- Tire balancing & tensioning
- Analytical instrumentation

Choosing the Right Supplier

It is impossible to cover every aspect necessary to select the perfect proportional pressure control valve for your specific needs, which is why specifiers and users should consult their valve manufacturer regarding any additional valve selection factors. They have the expert knowledge of their own devices that will greatly help in making a choice that fits your application. It's best to research the manufacturer that offers long-standing expertise in valve design and innovation—rather than on price alone. A supplier should have a broad range of technologies, sizes, and operator types or your choices may be limited to only what they provide and not what's best for your needs. If possible, ask your supplier for evidence of their specialist knowledge such as long-term customer relationships. Finally, a well-known brand is important as long as your potential partner also has in-house capabilities to help you specify and service your final device.

As you can see, there are many options to consider and this paper has gone through some of the more important ones. Analyzing your application needs, your control concerns, and your level of digitization are all key in getting to the right decision. Once you're close to making a decision you will want to talk with your supplier to assure that they, too, are the right fit for your needs. From there, you have the background to make a decision that you can trust.