Electronic Pressure Control: Making Smart Choices

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Electronic pressure control (EPC) methods are more commonly being used where manual regulation does not address the growing needs of instrument manufacturers who need to provide their endusers with automated control, error correction, and increased functionality. This overview of EPC technology covers requirements with operating ranges of 0–150 psig with control ranges as low as 0.005 psi and resolutions down to 0.001 psi, typical uses, advantages, and suggested guidelines for development and implementation of high-performance EPC.

The "Make Versus Buy" Decision

At technically savvy organizations, most engineering departments have the resources to develop their own electronic pressure controllers. The choice becomes either to do it themselves or purchase available EPC technologies depending upon available resources and timelines. Making the right choice can reduce development costs and time to market greatly.

Your organization can be successful only by meeting its customers' needs and constantly adapting to changing market factors. Engineers are uniquely challenged with meeting customers needs and often are the backbone of successful organizations, responsible for meeting performance criteria as well as time-to-market requirements.

To generalize, all of us are often tasked with, "Do it well and fast but with limited resources." There is a way to do it and do it well. You can meet your desired organizational outcomes by providing feature-rich products, quickly to market, while controlling your costs through staying focused on your core technologies.

Again, organizations are most successful when they stay focused on their own strengths. This allows them to provide the most value to their customers. Smart instrumentation designers with fluidic requirements look for organizational partners that can provide them with a complete fluidic package that allows them to focus on their own strengths.

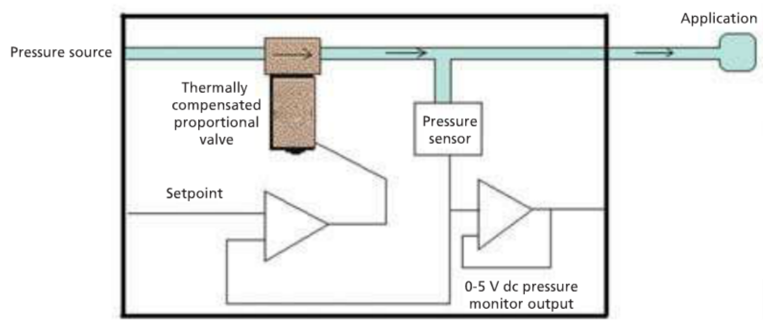

Figure 1: Electronic pressure control system (Pneutronics VSO-EP) that includes a thermally compensated proportional valve, a pressure sensor, and PID control circuitry.

They are not looking for a "component" provider. Spending their time, money, and resources in sourcing, qualifying, and validating components does not allow them to be responsive to their own customers' needs. Sourcing application-specific assemblies that can be integrated easily into their instruments allows them to better meet their customers' needs and meet their organizational objectives.

Electronic Pressure Controllers

A typical instrumentation grade electronic pressure controller is made up of the following components with the associated characteristics.

The valve should come in many orifice sizes to suit a variety of applications. Selecting a metering valve that has an orifice that is too large for the application can cause undesired oscillations or leakage. The benefits of thermal compensation address extremely low flow or high accuracy requirements as valves without thermal compensation often drift due to temperature-related movement or gas permeation into the elastomer.

Digital or analog pressure sensor selection must meet the accuracy and repeatability requirements of the application. If the pressure sensor is digital, then it must have appropriate bit resolution. All sensors should have temperature compensation to prevent temperature-related drift as instrumentation heats up.

Closed loop "PID" circuits are developed to meet gain, accuracy, temperature-drift, and response-time requirements of applications. Circuit boards commonly are viewed as inexpensive. However, circuit design, artwork, component selection, validation, testing, and associated software and training quickly can become very expensive and time consuming.

Selection of under- or over-specified components often results in unnecessary bill-of-material costs.

Electronic pressure controllers typically are used in three ways: True pressure control as shown in Figure 1, flow control, and piloting, such as for use in liquid-flow control.


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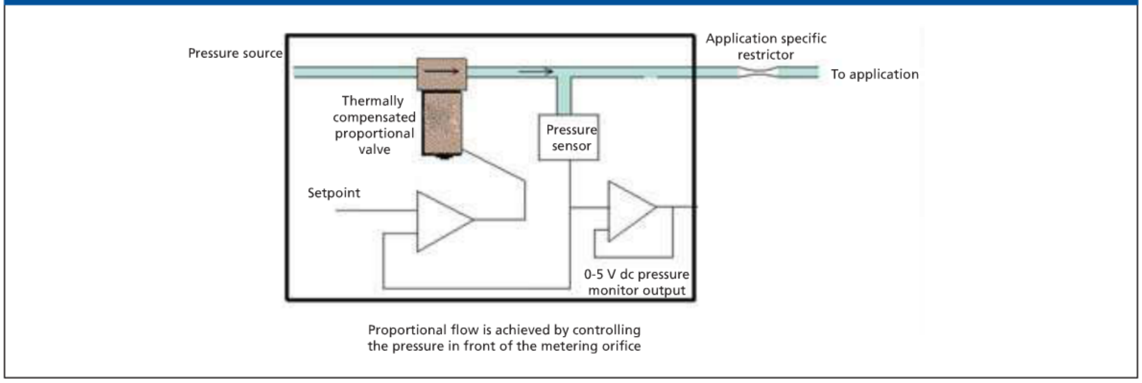

Figure 2: EPC system (VSO-EP) set up for flow control.

Typical applications include vessel pressurization, microfluidics, dispensing, precision cylinder positioning, and lower tech applications such as web tensioning, clamping, and other industrial automation applications.

Manual regulation again is obviously the least expensive and fits many requirements, however, the benefits of electronic pressure control include: closed loop control, automation of multiple setpoints, eliminating or minimizing operator intervention, and feedback to a host controller for process control and error detection.

EPC Versus Mass-Flow Control

When electronic pressure controllers are configured as a flow controller (Figure 2), there are multiple benefits over using mass-flow controller-type technology. Typical applications include gas chromatography (GC), both as a head pressure and split flow controller, fuel cells, microfluidic "lab on a chip" channels and carrier gas flow control for applications such as environmental, chemical, and biological warfare detection, that have become more prevalent since September 11, 2001.

An application-specific restrictor, such as shown in Figure 2, can be a GC column, metering orifice, porous substance such as a membrane or fuel cell stack, nozzles, or various detectors such as flame ionization detectors.

When used in carrier gas applications, electronic pressure controllers must be "analytically clean" to prevent contaminants from interfering with the detectors' ability to detect trace target compounds. Additionally, elastomer-type seals must not outgas.

Why not just use mass-flow controllers for flow control?

The bypass-sensing tubes in mass-flow controllers are costly as they were designed primarily for compatibility of corrosive gases using exotic materials and processes and to create good laminar flow across the sensing regions. The sensing technology is relatively slow and inaccurate, giving readings in a few seconds rather than in milliseconds.

Direct-sensing mass-flow controllers are an improvement in speed, however, they still are not as fast as EPC methods, which

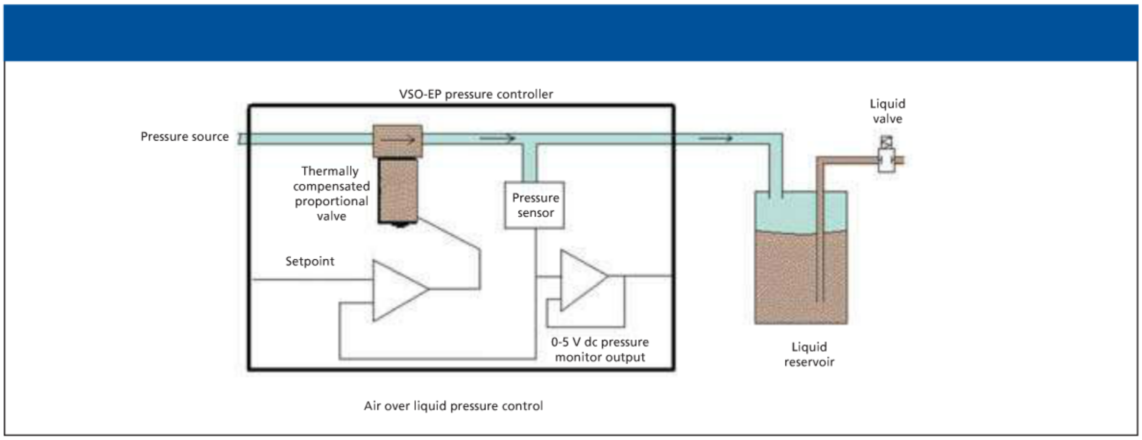

Figure 3: EPC system (VSO-EP) set up for liquid pressure control.

often are below 1 ms. They are typically gas-specific and are not easily interchangeable between applications of different gases. Also, extreme caution should be taken when used with combustible gases, as they incorporate heating elements.

The weight of semiconductor-grade mass-flow controllersis not well suited for portable applications such as chemical and biological warfare detectors, where size, weight, speed, and ease of use are paramount. Linear flow versus the control voltage of a mass-flow controller is a nice feature, but the increased speed, lower weight, smaller size, multigas capability, and repeatability of an electronic pressure controller enables their use at significantly lower cost.

One of the more, well publicized benefits of mass-flow controllers has been insensitivity to changing back pressures. When controlling flow with EPC, using pressure in front of an application-specific orifice, changing back pressures can cause flow differences. This can be be monitored easily and corrected by the use of an additional low-cost pressure sensor, and that information can be fed back to the host controller to compensate. This is especially cost effective, as it provides the ability for use with any type of gas, eliminating the need for gas-specific flow sensors or lengthy compensation algorithms.

EPC Piloting Liquids

EPC can be very effective at controlling liquid flow, as shown in Figure 3. There are varied applications, such as hydrodynamic focusing of both sheath and sample solutions in flow cytometry, microfluidic flow in lab-on-a-chip applications, liquid dispensing such as in inkjet printing and sample management, and high-speed liquid handling for analytical and drug discovery instrumentation, often combined with motion-control platforms.

Key features here are again high accuracy and pressure control in ranges and accuracies as low as 0.001 psi. Proportional valve and sensor compatibility does not become a concern when they are piloting liquids in an “air over liquid” method, as they are not directly in contact

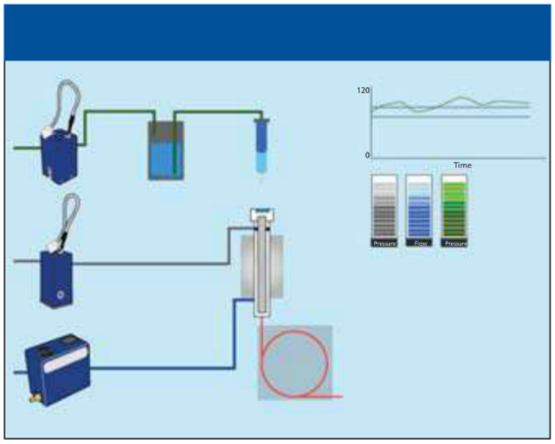

Figure 4: EPC systems for splitless-flow, split-flow, and liquid pressure control.

with the liquid or vapors. Proportional valves are not subject to leakage or failure issues due to contamination or crystallization of solutions.

In syringe-driven, liquid-dispensing applications, finite stepper motor resolution and lead-screw machining marks can create undesired pulsatile flow, which the dampening effects of a compressible gas over liquid EPC methodology is not prone to.

This method is substantially less expensive than multigas and liquid-capable massflow controllers.

Cost savings by using EPC can be utilized toward selection of high-speed dispensing technologies in which the applications true requirements often exist.

Application Example — GC

In Figure 4, three application-specific electronic pressure controllers, all with unique features and requirements, are shown performing the typical functions required for a

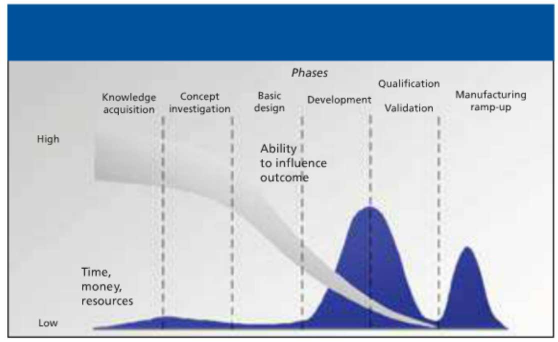

Figure 5: The development cycle.

GC application with sample injection.

On the top left in Figure 4 is a Pneutronics high-accuracy VSO-HP pressure controller used to control critical sample injection pressures for nanoliter volume injection. This sample is injected into the heated injector of a GC system shown in gray in the center of the diagram, for separation into its different compounds in the column loop and on to further detection of the elements that make up the sample.

An OEM-EP (Pneutronics) pressure controller is shown in the center left of Figure 4, and is designed for portable pressure-control applications used to provide a steady supply of analytically clean carrier gas that will carry the gaseous sample through the heated column loop. As the sample is vaporized in the heated injector, and its volume increases significantly and rapidly, the pressure controller must regulate the resultant pressure increase quickly and accurately in the injector to provide the precise flow of gas coming out of the column loop that the detectors require.

The VSO-EP pressure controller shown in the bottom left of Figure 4 is used to control back pressure or precise flow of excess unneeded vaporized sample for split flow control to prevent too much sample from clogging the column loop.

Development Challenges

As a design engineer, there are two key phases shown in Figure 5 within your instrument development cycle that you should be most aware of. The first phase, “knowledge acquisition,” is at the beginning of a project, where you have the greatest ability to influence the “desired organizational outcomes,” which is “meeting your customers needs” in a timely fashion.

Making an initial conscious choice at the beginning of the design cycle to decide whether to “make or buy” solutions to your critical pressure-control requirements will greatly affect your project timeline, control project costs, reduce time to market, and will allow you to focus on your organization’s expertise and keep up with your competition.

Although a bill-of-material comparison of a make-versus-buy scenario initially might cause you to lean toward a “make” decision, the true costs can be revealed by looking at the amplitude of the costs and resources in the design, development, and validation stages.

Often, our organizations are made up of individuals who are expertly versed in their own organization’s core technologies, yet are lacking in other required areas. This might indicate a need to review available resources or outsource to a suitable vendor who has expertise in that area in order for you to meet your design, budget, and timeline requirements, allowing you to stay focused on your core technologies and abilities.

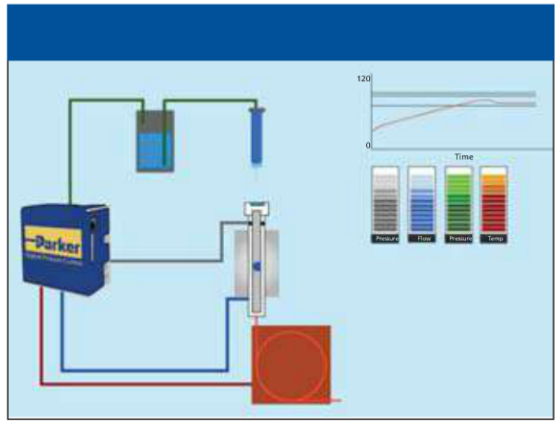

Figure 6: Microfluidic process controller that provides splitless-flow, split-flow, liquid pressure, and temperature control.

What is not realized initially in Figure 5 is the ability to shorten the time associated with these stages, allowing you to maximize your market opportunities by increasing your speed to market when you stay focused on your core technology.

Is your company’s core technology something other than fluidics? You need to decide whether to invest the time and money educating yourselves on an area that is not within your core competency. Testing and validation is often a costly and time-consuming stage of instrument development. Often, visibility of test and validation requirements and appropriate budgeting is not determined adequately at the beginning of the development cycle. This is the area where timelines and budgets slip the most, and organization pressure increases, unfortunately causing the adherence to timelines to become more important than the focus on quality of the product being developed.

If you do decide to make your own controller, the three major components need to be specified, qualified, and validated as well as the finalized controller.

The proportional valves orifice mus be sized appropriately for gain and flow to prevent oscillations, ensure adequate response time, accuracy, etc., and required flow and pressure measurement test equipment must be accurate within the requirements of the application and should be traceable. The electrical control signal required by the valve must be compatible with the drive circuitry you are going to design, whether it is PWM, voltage, or current control. Power-versus-flow requirements of the valve technology you choose also must be realistic.

The pressure sensor accuracy and repeatability should be verified over temperature and pressure range. This obviously requires measurement equipment orders of a magnitude better for verification. Published sensor specifications often do not reflect the actual application requirements and engineers often minimize their risk by choosing the sensor with the best published specification although this can contribute to unnecessary bill-of-material expenses. A frequently overlooked test requirement is that bench meters for verification can have worse accuracy or resolution than the devices being tested.

The control circuitry needs thorough design, validation, qualification, and testing, and requires similar development, test equipment, and expertise as the previous components.

Summary

The majority of well known EPCs were developed for industrial applications and do not fit the needs of instrumentation manufacturers with critical pressure control requirements.

These vendors are not versed in instrumentation requirements and add little value and application-specific support. Additionally, component vendors or distributors rarely get a thorough understanding of the true application requirements and fall back on competitive published specifications and pricing strategies rather than providing the best product for their instrument. The partner who has an intimate knowledge of the application and specific requirements can expedite your development cycle substantially as they become an extension of your development team.

Being able to communicate the true "endgame" requirements of the fluidic components you are selecting is an important initial step that will help your product through production keep you on budget.

Whether you decide to develop your own EPC or purchase an available EPC, you should be looking for vendors that can provide:

- thermally compensated valves;
- application-specific designs;
- electronic feedback;
- process control;
- multigas compatibility;
- analytical cleanliness;
- good price-to-performance value;
- good vendor "partnership";
- applications knowledge and expertise;
- future development direction. ■