Automating Flow Control in the Laboratory: Options from Analogue to Industrial

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When setting up the automated components for controlling flow and pressure in your lab, you will have many things to take into account. Your considerations will be shaped by your end goal, and by the speed, methods, costs and complexity of the processes used to reach the goal. With unlimited funds, one could create a spectacular - albeit Rube Goldberg-esque - lab with every type of instrument, and it might tell you the deepest, darkest secrets of the universe. This is unrealistic, of course: labs are expected to adopt processes that produce the desired result, efficiently and cost-effectively. Automated processes assist in accomplishing such goals. In most cases, the range of choices short-listed for consideration will depend on what is already used in the current lab, and what may make the test or process faster, more controllable and efficient - and produce the most usable outcome, whether that be a physical change or data-based insight into a result.

Choosing a Road to Travel

Having decided on remote communications, the next consideration is, what form should that take? While it is certainly true that most organisations with previously installed communications protocols will want to continue in the same vein, networking and communications have undergone decades of revolution - a greater variety of installable instruments, cheaper networking hardware, or larger, faster networks may now be essential considerations. Who today would opt for dial-up speed internet, if high speed is cheaply available?

Figure 1: Device level ring connections for Ethernet/IP devices. Image source: Alicat Scientific, Inc.

Going Analogue in a Digital World

Digital is not the only option. Although the technology environment is binary, in small scale systems with complexity equivalent to a benchtop seed-culture bioreactor, or automating the calibration of several gas chromatographs, analogue I/O is easier to configure. Its simplicity makes it an attractive option to many experimenters. If speed is paramount, the continuous data stream of an analogue connection remains the fastest method of communications available. In processes that are extremely timing-sensitive, that speed may be decisive. That said, this advantage is diminishing with the increase in digital protocol speeds.

On the downside, a potential risk in analogue communications is that of signal degradation. Signal degradation can lead to inaccurate readings, and can be caused by excessive cable length or external noise sources.

For some analogue installations, wiring complexity is very high, causing troubleshooting and maintenance issues, and raising costs. This comes of being able to read only one sensor, or signal, per wire. In a fluid (plasma, gas or liquid) control process, the gauge pressure, input and output pressure, flow rate, species of gas, process temperature and even humidity each have interdependent effects. Tracking all the variables means that wiring complexity gets high.

The reality is that much of the instrumentation today uses digital signal processing internally, so converting those signals to analogue, and then possibly back to digital for analysis at a later point in the process, itself adds noise to the originally lossless digital signal. This may not be decisive, but it does eat into one's measurement uncertainty budget.

Analogue communications may offer only limited control. In many cases, analogue communications permit only the most rudimentary commands, such as changing the setpoint of pressure or flow control. Given that many fluid control instruments incorporate extensive programmability (such as being able to change engineering units or fluid mix settings), this reduces the device's native flexibility and power in a process control application.

> *Analogue Connections*
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> Reading an output from an analogue signal can be as simple as using a multi-meter to measure the voltage or current output, and interpreting the scale to acquire your reading. Your readings will be proportionally slaved to the range of the device.
>
> Consider a flow meter with a range from zero to one hundred litres per minute, configured with an analogue signal of 0 to 5 volts. A reading of zero volts is zero flow. At 2.5 volts the reading is 50% of the flow scale, and a reading of 5 volts is full scale flow (100 litres per minute). If your instrument has an integrated display screen, you can verify your readings during process setup with a visual check.
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> By connecting the device to a programmable logic controller (a PLC which can accept a 4-20 mA input signal), the PLC can be configured with a multiplier to interpret the analogue signal and provide the reading. By measuring current instead of voltage, you avoid the risk of voltage drop over long lines, which would entail re-ranging your interpretation of the scale.

Quick Serial Options

Where the precision and versatility of digital communication is desirable, but the purchase of industrial PLCs for handling automation is beyond the wallet, instrument manufacturers offer drivers and even starter software kits. This may serve as a toehold entry to digital communications.

Through serial communications, a common computer can be substituted for a proprietary PLC. It would provide data processing, monitoring of closed loop conditions, a human-machine interface, and data logging. Indeed, smaller process control systems can be managed using nothing more than ASCII commands over RS-485 and a common data management program like LabVIEW. Basic RS-485 networks, and even some RS-232 variants, can communicate with 26 or more instruments by assigning a unique letter-based unit ID to each instrument. For new users, it's best to look for a vendor with driver and communications utilities prepared for download, written instructions and readily available tech support.

Figure 2: Multi-drop kits can be used to attach batches of fluid control instruments through serial connections to a computer. Source: Alicat Scientific.

In comparison to an industrial protocol system, there are some shortcomings. A computer-serial-device connection probably means adding upfront coding. It's likely that the entire system would take longer to respond to operational changes because of the added overhead of the computer operating system, and relatively slow COM port transfer rates. The lack of standardisation also means it can be burdensome to change system administrators, or transfer the custom application to any other process.

Complex Control Loops and Processes

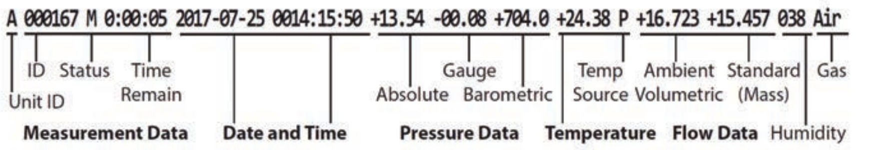
Academic, aerospace, biotech and chemical research labs require great versatility, precision and repeatability to be valuable and effective in their findings. Whether replicating human breathing through life-saving apparatuses, analysing chemical catalysts, or transfer-filtering a culture's by-products for a pharmaceutical test, the stability of fluid control is critical. Each of these examples requires precise control to ensure that the lab results are repeatable.

The control mechanisms that need to be in place to achieve this are myriad. Let's consider the simple example of what happens when a storm front comes through your region. The barometric pressure drops, and this changes the baseline of every device in your lab that references gauge pressure. The systems that incorporate these gauge pressure devices must compensate for the change in pressure, and these resulting system changes may in turn reduce the stability of your flow control processes. Even this simple scenario reveals the need for closed-loop process control instrumentation that can continuously monitor changes in pressure and temperature in order to keep flow control processes stable.

Multivariate Digital Data Streams

A significant advantage of using multivariate process control instruments that communicate digitally is that a single digital data frame can carry data from multiple process variables. The example below is a data frame from a flow monitoring instrument that features data for eight different process variables, in addition to date and time stamps and other data that supplement the measurement. Such a multivariate data frame can be obtained via simple ASCII commands at a frequency of about 20 Hz. Considering just the eight process variables, the effective transmission frequency of the data from this single device becomes 160 Hz.

Figure 3: Data frame with multivariate readings from an Alicat Scientific flow calibration device. Source: Alicat Scientific, Inc.



Complex data streams like the example above make individual instruments more efficient, reducing the overhead of purchasing and maintaining multiple flow, humidity, pressure and temperature instruments for individual variables. This reduction of equipment naturally makes lab setups physically smaller and more easily managed.

Figure 4: The front display of an Alicat Scientific multivariate flow controller, demonstrates multivariate process data for mass flow, volumetric flow, absolute pressure and temperature. Source: Alicat Scientific, Inc.

Getting Faster Performance out of Networked Digital Protocols

The advantages of industrial protocols, compared to serial and analogue, are standardisation of requirements, ubiquity of appliances, and expandability. For larger networks, numerous industrial digital protocols are available, some of which have been around for several decades. Long-established industrial automation protocols include CANopen, DeviceNet, FOUNDATION Fieldbus, HART, Modbus, PROFIBUS and many others. These older protocols provide communication with 64 to 250 individual devices per network.

More recently, a number of Industrial Ethernet (IE) protocols have been developed, including EtherCAT, Ethernet/IP, DeviceNet, Modbus TCP/IP and PROFINET. They are designed for fast communications, typically requiring as little as 30-100 microseconds (about 10-30 kHz) per data update cycle. They can operate over Gigabit Ethernet optical fibre for lossless transmissions. Additionally, these protocols enable communications with a nearly unlimited number of devices on a single network, (except for EtherCAT, which has a cap of 65,536 devices). One thing to remember is that Industrial Ethernet data frames are larger, at a minimum 64 kb, compared to non-Ethernet industrial protocol data frames that can be as small as 1 kb. Although this greater size is included in the transmission figures above, the automation management system must be capable of managing these larger data packets from potentially thousands of devices.

In practice, however, Industrial Ethernet data transmission bandwidth is actually much slower for many industrial automation devices, because so many do not directly communicate over an IE protocol. In order to connect these devices to your IE network, you must use an intermediate adapter module that can translate the device's proprietary communications language to an IE protocol. Even when used with a single process measurement device, the IE conversion slows data transfer to and from the device. When up to eight devices must share one translator, this can create a bottleneck in communications. To preserve the fast native speeds of IE protocols, it is best to choose fluid control instruments that communicate over IE directly, without the need for intermediate translators. Eliminating translators also makes it much easier to update older IE networks, or to create new ones.

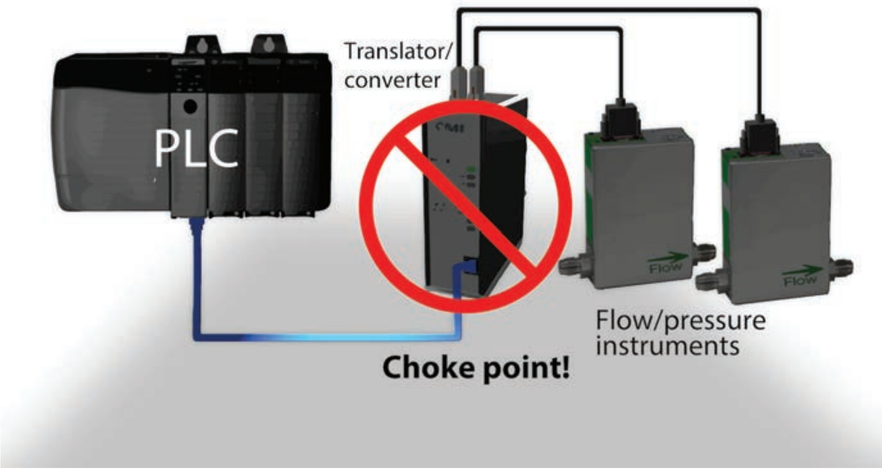


Figure 5: Optimising speed in a digital network is often a concern.

Taking the leap to Industrial Ethernet Communications for Fast Multivariate Process Control

Ethernet/IP is one of the most rapidly growing Industrial Ethernet protocols, and its communications speeds are more than fast enough for most applications, provided your instruments do not require the addition of translators. If you are establishing a new IE network, Ethernet/IP is often a safe choice, as there is a large and growing catalogue of devices that are available with this protocol, with what is reputed to be the largest number of installed instruments in the world. Their peripherals are usually less expensive than those required for proprietary PLCs.

For typical users, the difference between analogue and IE speeds will be insignificant to the operation of a lab. However, the increases in accuracy and efficiency that result from the elimination of noisy analogue signals can make a very positive impact indeed. The greater data throughput of an IE protocol can significantly increase efficiency for closed-loop control systems. This throughput is especially critical for fluidic process control instruments that rely upon rapid feedback in order to adjust to changing process conditions.

While Rube Goldberg contraptions are entertaining for the way they cobble together different mechanisms, they are memorable because they *work*. Because there is no single version of a laboratory, there is no one-size-fits-all solution for lab automation of flow and pressure control. For those accustomed to analogue signals, going digital may seem like distancing oneself from the process, but the increased variety of data, precision and efficiency are compelling benefits. Which isn't to say that a direct analogue signal has no place in automation, it's just reaching a point of diminishing returns. Explore the range, and go with the best for your situation - from analogue to the most modern industrial protocols, there are a lot of choices that can work.

About the Author:

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