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- Speed vs. precision considerations
- Impact of multivariate process controls
- Getting faster responses from Industrial Ethernet

Taking the Leap from Analog to Digital for Multivariate Process Control in Manufacturing

Think back for a moment to the late 1980's. Analog cassettes tapes were destroying vinyl record sales because of their greater ease of use, despite lower audio quality. Digital music had been in existence for some time among professionals, but the challenge was how to shrink the high-quality audio into a format that could compete with the ubiquitous Sony Walkman in the mass market. The digital audio compact disc (CD) was the answer, but it came at a cost: all of the audio data below 20 Hz and above 22,000 Hz, the thresholds of human hearing, were thrown away to reduce file size. Even though most people could not discern a difference resulting from the lost data, many resisted the new format on principle. In time, the greater ease of use that resulted from instant track selection and, much later, the ability to transfer individual digital audio files without any signal loss doomed the older analog formats.

ANALOG VS. DIGITAL, SPEED VS. PRECISION

Manufacturing processes now are in the midst of a similar transformation as catch phrases like the Industrial Internet of Things (IIoT) are becoming embedded into our lingo. The benefits of going digital are undeniable--efficiency in transferring data, portability of data without loss, greater precision--and yet analog signals persist in industrial communications for a number of reasons. They are typically easier to set up and less expensive, though there are hidden costs of complex analog networks, as we will see. Perhaps more importantly, the continuous data stream of an analog remains the fastest method of communications available.

On the other hand, analog signals degrade as cable length increases, and they are susceptible to interference from outside sources. These factors generate noise in the signal, which reduces the effective dynamic range and in turn the accuracy of the data. Much of the instrumentation in use today uses digital signals natively, so converting these signals to analog and then possibly back to digital for analysis at a later point in the process adds even more noise to the originally lossless digital signal.

Despite the advantages of going digital, the higher costs and slower data speeds of digital industrial protocols (IPs) have deterred many manufacturing plants from converting their analog automation systems into digital ones. This is now changing, as the increasing use of process control within manufacturing is causing many to take another look at making the leap to digital.

Multivariate process control of fluids in manufacturing

Today's manufacturing processes are very different from those that existed even just a few decades ago. Increasing precision and speed in manufacturing robotics has enabled a far greater variety of products to be manufactured using repetitive, open-loop control. At the same time, manufacturing complexity has increased due to the incorporation of fluidic elements within the manufacturing process. Automotive painting robots and flame sprayers require consistent flows of atomized fluids to achieve a homogenous finish. Fiber optics manufacturers need highly repeatable gas flows to ensure that the composition of their glass is the same meter after meter. Meat packers inject their packages with precisely mixed gases to extend the shelf lives of their products. Chemical reactions in vacuum coating processes can occur in just a few microseconds, and this leaves the whole process open to target poisoning if the reactants are not precisely balanced.

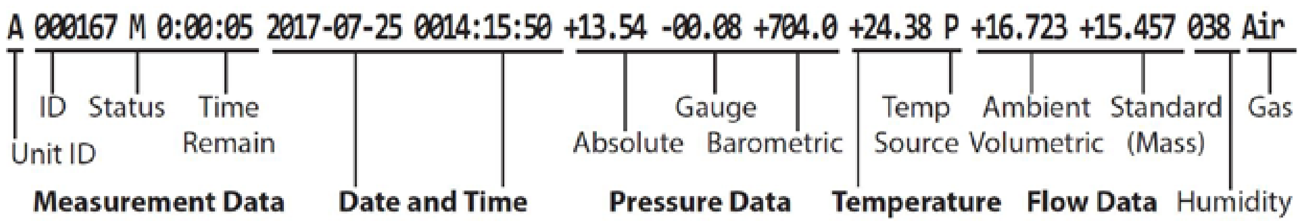
Each of the above examples requires precise control of a fluid (plasma, gas or liquid) to ensure that the quality of the final manufactured product is consistent. The control mechanisms that need to be in place in order to achieve this are myriad. Let's consider the simple example of what happens when a storm front comes through your city. The barometric pressure drops, and this changes the baseline of every device in your plant 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 process control and data management

The introduction of process control instrumentation yields better control of manufacturing processes that incorporate fluids. This is because the closed-loop control of flow, for example, keeps flow rates consistent as pressure and temperature vary. This undoubtedly increases the quality of the final manufactured product, but introduction of closed-loop process control also creates a new problem. Closed loop control increases the number of variables you are monitoring, and this in turn generates much more data, often more than enough to overwhelm analog data networks.

Take, for instance, the need to counteract the effects of

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



Data frame with multivariate readings from an Alicat Scientific flow calibration device.

environmental variations, as mentioned above in the context of the storm front. Analog signals can transmit data for only one variable, so monitoring barometric pressure, process line gauge pressure, ambient temperature, line temperature and flow rates requires five distinct analog signals running across five dedicated wires. The cost of deploying analog process control quickly escalates, even just considering the lengths of extra cabling that analog installations require. Some of this cost can be defrayed by using multivariate instruments that measure multiple process variables. However, such an instrument must be capable of outputting multiple analog signals simultaneously, and these multiple signals of course require more complex (and expensive) cabling that can handle the numerous wires.

If you carefully scrutinize what factories end up doing with their analog data, you will find that most of it eventually becomes digital at some point. Analog data signals are collected by a programmable logic controller (PLC), for example, which then converts these analog signals to digital data packets and sends them to a digital computer for recording and analysis. Even when an analog signal never makes it to a computer, we humans convert it to a discrete digital measurement ourselves by limiting the number of decimal places when we write it down.

The objective, then, is determining the point in your process at which you should make the transition from analog to digital. In considering this, plant managers need to balance the need for high-integrity data (stemming from the portability and precision that digital communications provide) with the continuous drive towards increasing efficiency in the manufacturing process (stemming from the high speed of analog communications). New advances in digital industrial protocols are moving the transition point closer to the individual instruments that are being used to regulate manufacturing processes.

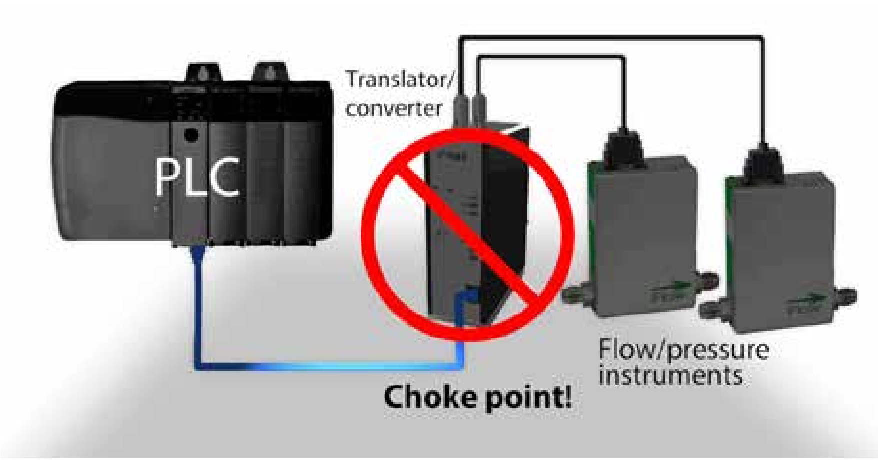
Multivariate digital data streams

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.

Complex data streams like the example above make individual instruments more efficient, and this reduces the overhead of purchasing and maintaining multiple flow, humidity, pressure and temperature instruments that can measure only one variable. This reduction of equipment naturally makes your network physically smaller and more easily manageable. 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.

Getting faster performance out of networked digital protocols

For larger networks, numerous industrial digital protocols are



Optimizing speed in a digital network is often a concern.

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 typically communicate with between 64 and 250 individual devices per network.

More recently, a number of Industrial Ethernet (IE) protocols have been developed, including EtherCAT, Ethernet/IP, Modbus TCP/IP and PROFINET. These protocols enable communications with an almost limitless (except for EtherCAT, which has a cap of 65,536 devices) number of devices on a single network. They are also designed for very fast communications, typically requiring 30-100 µs (about 10-30 kHz) per data update cycle, and can operate over Gigabit Ethernet optical fiber for lossless transmissions. One caveat 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, Industrial Ethernet data transmission bandwidth is actually much slower for many industrial automation devices, because so many do not yet directly communicate over an IE protocol. In order to connect these devices to your IE network, you must use an intermediary translation module that can convert the device's proprietary communications to an IE protocol. Even when used with a single process measurement device, the IE translation process slows down the transfer of data to and from the device. When up to eight devices must share a single translator with two-way communications, this can generate a significant bottleneck in communications bandwidth. In order to preserve the fast native speeds of IE protocols, it is best to choose process automation instruments that communicate over IE directly, without the need for any additional translators that could slow down your network communications. Eliminating translators also makes it much easier to update older IE networks, or to create new ones.

Taking the leap to Industrial Ethernet communications for fast multivariate process control

Ethernet/IP is one of the fastest growing IE protocols, and its communications speeds are more than fast enough for most applications, provided that your process 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 base of devices that are available with this protocol. Such devices may have a higher initial cost than those built for older industrial networks, but their peripherals are usually much less expensive than those required for proprietary PLCs.

In most cases, the difference between analog and IE speeds will be insignificant to the operation of your manufacturing process. However, the increases in accuracy and efficiency that result from the elimination of noisy analog signals can make a very significant impact indeed. The increased data throughput of an IE protocol can significantly increases efficiency for closed-loop control systems. This faster speed is especially critical for fluidic process control instruments that rely upon rapid feedback in order to adjust to changing process conditions.

Going digital may fill you with trepidation if you have been accustomed to using analog signals, but the benefits of increased accuracy, precision and efficiency are worth it. Go ahead; take the leap.

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Mike Hodges-Owen is a Key Account Manager at Alicat Scientific, Inc. Working from their headquarters in Tucson, Arizona, he has four years of experience as an Applications Engineer in the measurement and control of flow and pressure, and has worked as a trainer of applications engineers in that industry. You can contact him at: mike.owen@alicat.com

Why Alicat?

- Display, Serial and Analog are standard on instruments without industrial protocols
- Industrial protocols: Profibus, Modbus RTU, Ethernet/IP, DeviceNet, Modbus TCP/IP, EtherCAT
- Free LabVIEW drivers for serial communications
- Unique multidrop serial connections BB9/BB3 accessories
- 200 to 1 turndown reduces ranges required
- Gas Select reduces spare inventory
- One family of instruments from lab, to pilot to production

Useful Links from Alicat:

Industrial protocol options

Mass Flow Controllers

Mass Flow Meters

Liquid Flow Controller

Pressure Controllers (electronic pneumatic regulators)

Youtube video on getting faster results from industrial protocols

Multidrop serial communications accessories

Selected specifications:[1]

Mass flow controller MC:

Accuracy at calibration conditions after tare: up to ±(0.4% of reading + 0.2% of full scale) NIST-traceable
Repeatability: ±0.2% of Full Scale
Operating range: 0.5% to 100% Full Scale / 200:1 Turndown
Typical control response times: 50-100 ms (Adjustable)
User selectable 98 gases at specified accuracy (130 gases on models with aggressive gas resistance)
The only lifetime warranty in the industry

Pressure controller:

Repeatability: ±0.08% Full Scale
Operating range: 0.5% to 100% Full Scale / 200:1 Turndown
Typical response time: 100ms (Adjustable)

Left: MC Mass flow controller with display, serial and analog I/O included. Center: MC mass flow controllers with Industrial Ethernet protocols, with and without display. Right: Low pressure drop mass flow meter with DeviceNet.

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