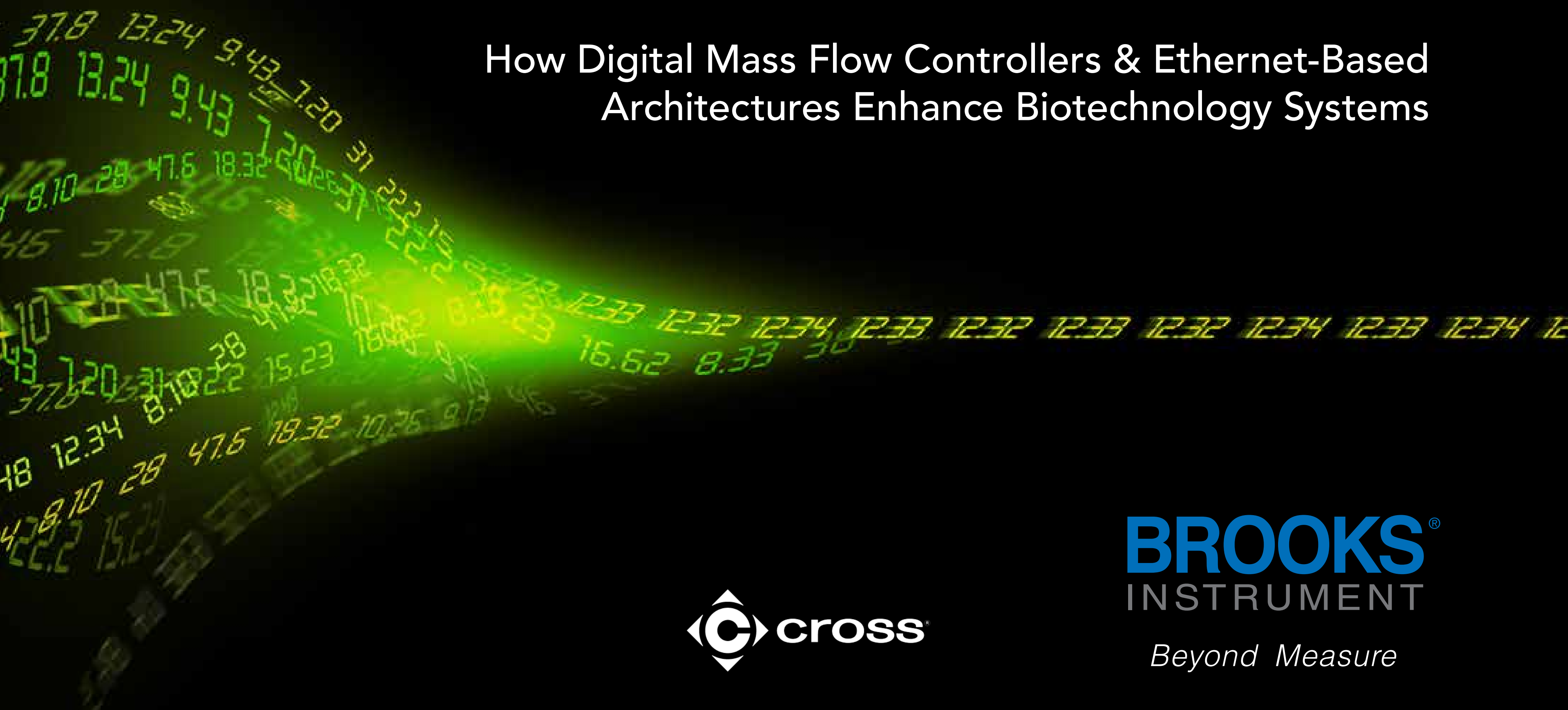
Solve Compliance, Integration & Process Challenges Using Rich Data From Your Instrumentation

How Digital Mass Flow Controllers & Ethernet-Based Architectures Enhance Biotechnology Systems



Beyond Measure

Solve compliance, integration & process challenges using rich data from your instrumentation

Everything from your PC and smartphone to your clock, refrigerator and automobile have sensors, memory and communication capabilities, increasingly known as the internet of things (IoT). Incredible intelligence is being built into just about every device we touch, and, if it's not built in, the information is available via communication with "the cloud."

This same evolution of intelligence and communication capability is occurring in industrial process control instrumentation and systems. By using the information available in smart/digital devices and the communication capabilities of Ethernet-based digital communication protocols, the integration, startup, maintenance and productivity of industrial process systems such as biotechnology production equipment and bioreactors can be dramatically improved.

In this paper, we will review the information available from digital instrumentation, various digital communication protocols and how Ethernet-connected digital MFCs can be used to enhance your biotechnology systems and processes.

We will examine:

- Evolution of process control instrumentation and communications from analog to digital
- Range of traditional digital and Ethernet-based communication protocols and their key capabilities
- Ways to enhance your biotechnology process systems and bioreactors by using the full breadth and depth of information available from digital MFCs

Digital communications evolution

In the beginning… If we travel all the way back to the dawn of electronic communication, to the telegraph, we discover the earliest limits on how much information could be sent, and how fast. In 1841, when U.S. President William Henry Harrison died of pneumonia a month after taking office, it took 110 days for the news to reach Los Angeles via mail.

If you do the math on the number of letters carried, number of words per letter and the time to get there, it adds up to a data transmission rate of about 6 bits per second. Today, we have data rates of 100 megabits per second (Mbps) and higher. And the density and complexity of information sent at those speeds is truly transformative.

Advanced communications protocols enable ultra-fast information exchange between devices. This is one of the fundamental changes driving the evolution of automation systems from analog to digital: giving automation systems greater ability to leverage the amount of information that can be communicated through I/O or machine busses.

These protocols also enable sophisticated, real-time interaction and control between the PLC or DCS and digital instrumentation. This is crucial to taking full advantage of advanced control, diagnostic and alarming capabilities available on digital instrumentation.

Ethernet-based communications enable sophisticated, real-time interaction and control between automation PLCs and digital instrumentation.

Range of digital communications protocols

While some of the older technologies like 4-20 mA analog I/O are used, mainly for I/O purposes, most new systems use some form of digital communications for factory-wide monitoring and control. Furthermore, there is a trend toward Ethernet-based protocols like EtherNet/IP and EtherCAT®.

There are multiple digital communications protocols in use across the automation market in general, and specifically in biotechnology process systems, including the following:

RS-232

RS-485

Brooks digital MFCs and other digital instruments support a wide range of protocols. One of the fundamental design decisions OEMs and systems integrators make, early in the design process, is the communications protocol.

Advantages of "going digital"

No matter what digital communication protocol you have selected, there are fundamental advantages provided by "going digital":

Provides a powerful source of **rich data** from MFC to PLC/DCS to enhance process control.

- Multivariable (Flow, Temperature, etc.), alarms, totalizer values, valve drive/position and other data

Real-time diagnostics information is readily available.

- **Facilitates installation**, start up and troubleshooting
- Supports predictive and/or preventive maintenance

Increased **device flexibility**—such as devices with multiple calibrations—reduces spares inventory and maximizes uptime.

Achieve simplification and **cost savings** with standardized cables.

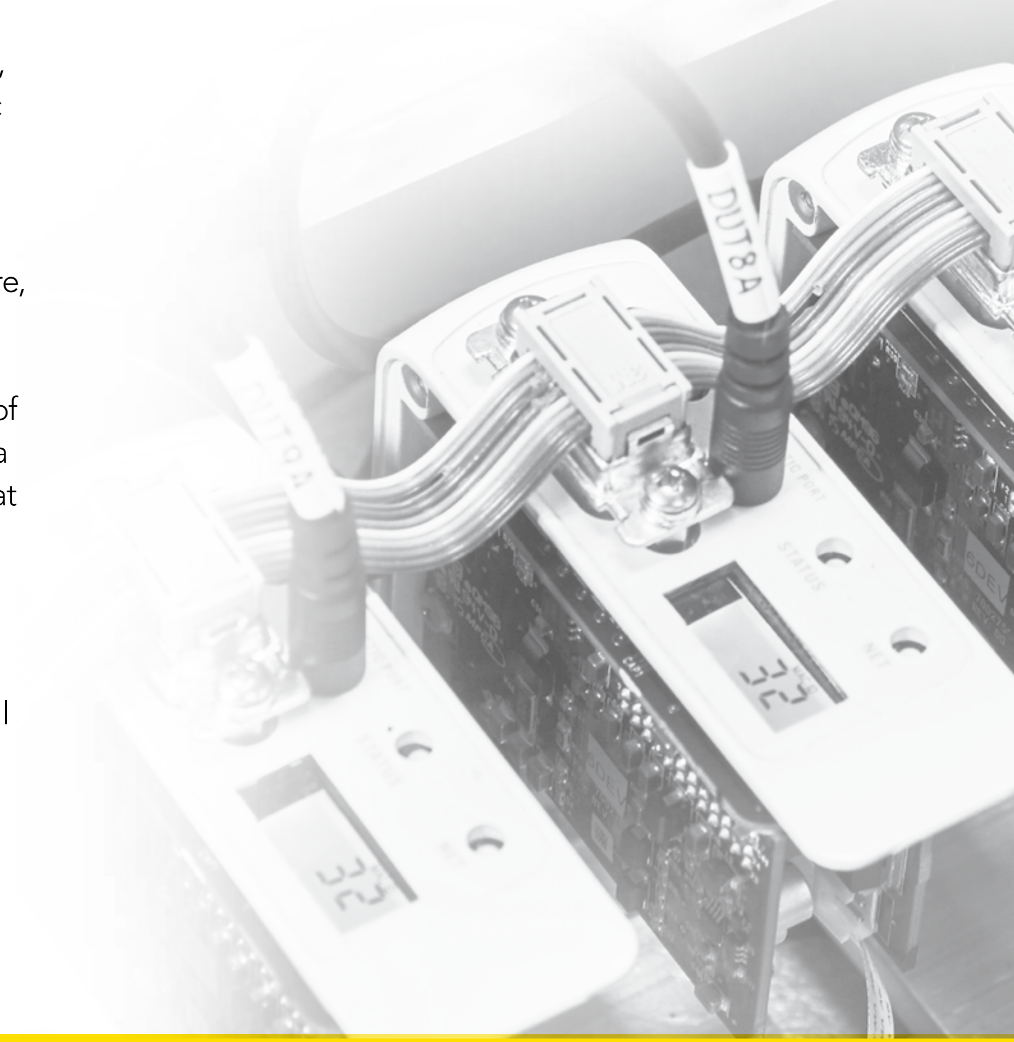
- Off-the-shelf multi-drop cables are more cost-effective vs. custom discrete wiring
- Multi-drop system configurations simplify wiring requirements vs. analog point-to-point installations
- Simplified wiring reduces documentation level of effort and errors
- Flexible topologies offered by digital systems simplify future expansions

How digital protocols enhance device performance

Automation devices with digital I/O, regardless of the protocol used, can provide a myriad of information that is not available from a basic analog I/O device. A typical analog I/O device can provide a single process variable or, in some cases, two.

With a digital MFC, you can read the flow, totalized flow, temperature, valve drive and other variables simultaneously—and you can communicate that information to the PLC/DCS or other devices on the network for further action, in real time. You can take advantage of multi-gas capabilities and dynamic gas range switching by sending a digital command. For example, you can set up your system such that an MFC can be changed from a 25 standard liters per minute (slpm) oxygen device to a 20 slpm CO_2 device.

This capability can enable significant process equipment cost savings. For example, by taking full advantage of a Brooks digital MFC's multi-gas/multi-range capabilities, it is possible to reduce the number of SKUs required by 90 percent, reducing inventory and simplifying purchasing.



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How digital protocols enhance device performance

Preventive maintenance and process quality are also enhanced by having a broad array of thresholds and alarms that can be set and monitored by Brooks digital MFCs. These include:

- High-flow alarm
- Low-flow alarm
- No-flow indication
- Setpoint deviation alarm
- Valve drive alarm
- Temperature out of limits
- Totalizer overflow
- Internal power supply failure
- Valve drive out of limits
- Device calibration due
- Device overhaul due
- Internal diagnostic alarms

Alarms like these can help keep critical process systems on track. For example, it's common in biotechnology operations to schedule regular device calibration at six-month or annual intervals, often to comply with regulatory requirements. So "device calibration due" and "device overhaul due" can alert operations personnel to these intervals, making sure they schedule process equipment downtime to comply.

How digital protocols enhance device performance

Alerts such as "valve drive out of limits" can help operators pinpoint the source of problems. If O_2 pressure feeding a bioreactor chamber goes too low, it could be because a filter is clogged or a regulator is not working properly. A Brooks digital MFC will open the device's valve to try and compensate for that.

Eventually, the valve will reach the limit of its ability to open and won't be able to achieve full scale flow. The bioreactor's PLC gets an indication of valve drive out of limits and takes advantage of that alarm before the bioreactor reaches that point; further investigation of the system can be undertaken to reach the root cause of the issue.

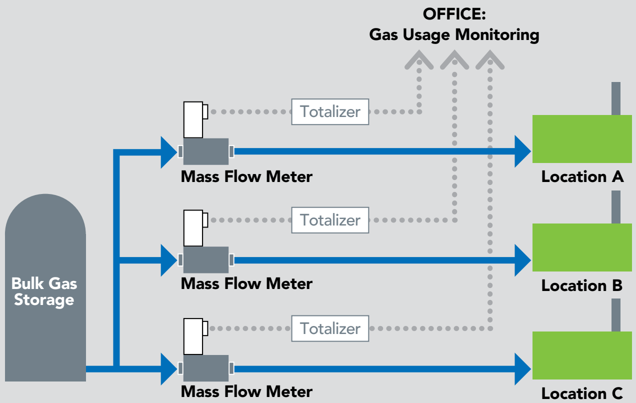
Digital application: Flow totalization in gas usage monitoring

A common application where accurate flow totalization is required is gas usage monitoring. In this example, several different systems or locations within a bioprocessing facility share a single gas source, which is a common system design. To account for usage, or allocate costs properly, the facility needs to monitor the amount of gas consumed by each user.

Typical installation: A typical installation for this application includes several flow meters plus secondary electronics with totalizer function cabling from each device connected to a central monitoring system. The totalizer gets a flow signal from the flow meter, calculates the totalized flow and sends that value to the central monitoring system.

With this approach, the accuracy of the totalized flow may not be optimized. There may be some additional error due to resolution of the analog-to-digital converters (ADC) and signal noise. The user also needs to be sure the analog signals were calibrated properly and that they match the span and time units of the flow meters.

Signal filtering, signal cutoffs, sample rates and sample period can also have an impact. All these factors could lead to improper billing or cost allocation. There are also additional hardware and cabling costs with this approach that could be avoided.

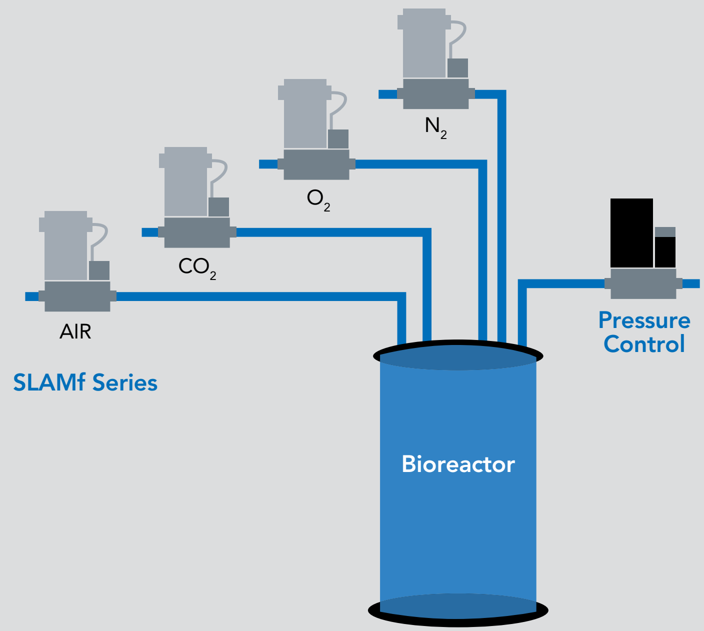


Typical gas usage monitoring installation

Digital application: Bioreactor total flow measurement

Using digital mass flow meters: An alternate approach uses digital mass flow meters, like the Brooks SLAMf Series, which calculate the totalized flow value internally. With this approach, no additional inaccuracy is introduced with a secondary calculation, and the need for digital-to-analog conversion is eliminated.

Understanding the total flow into the bioreactor, in real time and without the need for digital-to-analog conversion, is a key factor that process managers can use to optimize bioreactor yields. The digital totalizer command provides real-time feedback to process and equipment engineers.



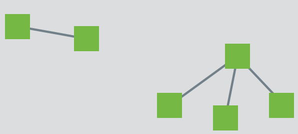
Gas usage monitoring installation using Brooks SLAMf Series Mass Flow Meters

Considerations when choosing digital communications protocols

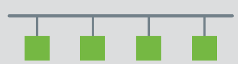
Supported network topologies

It's important to realize that when selecting the digital protocol, you will be designing a *network* in the machine: sensors, drives, devices like MFCs, HMIs and the machine PLC or DCS are all going to be networked together. There are several network topologies that can be implemented:

Point-to-point or star networks offer easy set-up, fast and reliable pathways (one can fail and the others keep working) and the ability to add nodes; however, this topology is not good for large networks. Also, this is the only topology for analog and RS-232 devices.



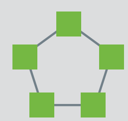
Multi-drop networks can use either a bus or daisy chain arrangement. They offer easy setup but are vulnerable to disruption if there is a break in the chain. This is typical for RS-485, DeviceNet™ and PROFIBUS® networks.



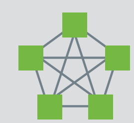
Bus

Daisy Chain

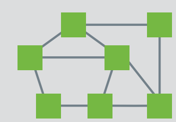
A ring topology can handle a lot of traffic and is easy to install, manage and troubleshoot. EtherCAT®, EtherNet/IP and other Ethernet-based protocols support this topology.



The mesh topology, while the most complex (it's the topology the internet uses), is extremely reliable because of its built-in redundancy: Adding devices actually improves data rates and reliability. It works well for wireless networks; however, in a wired environment, it can be expensive.



Full



Partial

Along with a system's network topology, digital protocol selection should also be based on the essential performance characteristics of each protocol. While there are many factors to assess for each protocol, the number of nodes supported, the throughput (or baud) rates and the message size are essential.

Considerations when choosing digital communications protocols

This information can help OEM design engineers and end-user engineering staffs consider the real-time communications requirements for their systems, as well as how much/how dense the information each digital device needs to share in real time with the system controller.

Protocol/ Characteristics	Nodes	Baud Rates	Message Size
DeviceNet	64	125K, 250K, 500K	8 Bytes
PROFIBUS	127	1200–12M	244 Bytes
EtherCAT®	65535	100M	1500 Bytes
EtherNet/IP	No Limit	10 Mbps, 100 Mbps or 1 Gbps	511 Bytes
Foundation Fieldbus	240	31.25K	240 Octets (Bytes)
HART	15	1200	31 Bytes (plus data)
PROFINET	No Limit	100 Mbps or 1 Gbps	1440 Bytes
RS-485	16	1200–115K	24 Bytes

Expanding portfolio of digital instruments

Brooks Instrument continues to invest in its portfolio of digital MFCs and other automation instruments and is committed to supporting multiple digital and Ethernet-based communications interfaces on its devices. This will help ensure that OEMs and end users in the biotechnology sector have automation systems equipped with state-of-the-art fluid measurement and control systems that offer the enhanced flexibility and efficiency the industry requires.

How can we help?

No matter what your digital MFC needs, Brooks has a solution for you. We can help identify the optimum digital communications protocol and configure our devices with the multivariable data capabilities, alarms and diagnostics to fully satisfy your bioprocessing system requirements.

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