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THE CURRENT QUANDARY: Reducing Signal Noise In Practice

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Reader's Brief

This issue covers process control solutions, with editorial including *The Current Quandary: Reducing Signal Noise in Practice* and *Alarming Solutions: ISA Alarm Sequencing in a Nutshell*. The *Letter from Sales* discusses the struggle industrial operators face during product installation and how we are working to make our products even more user-friendly and easier to install.

We have moved to our new headquarters in Hopkinton, MA. Please make note of our new address below.

- Precision Digital

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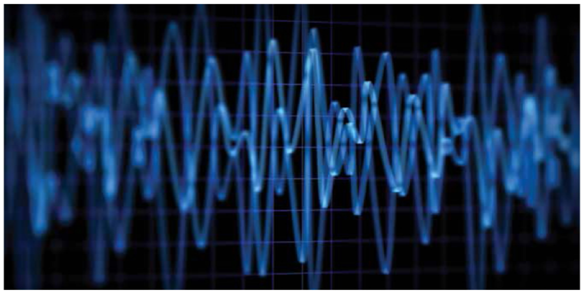

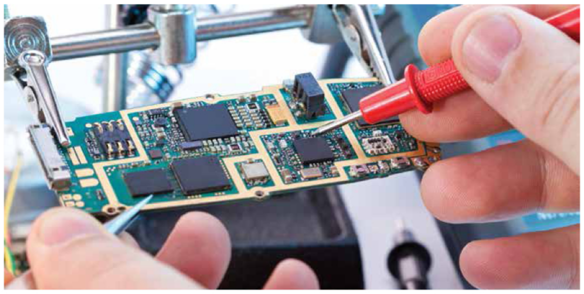

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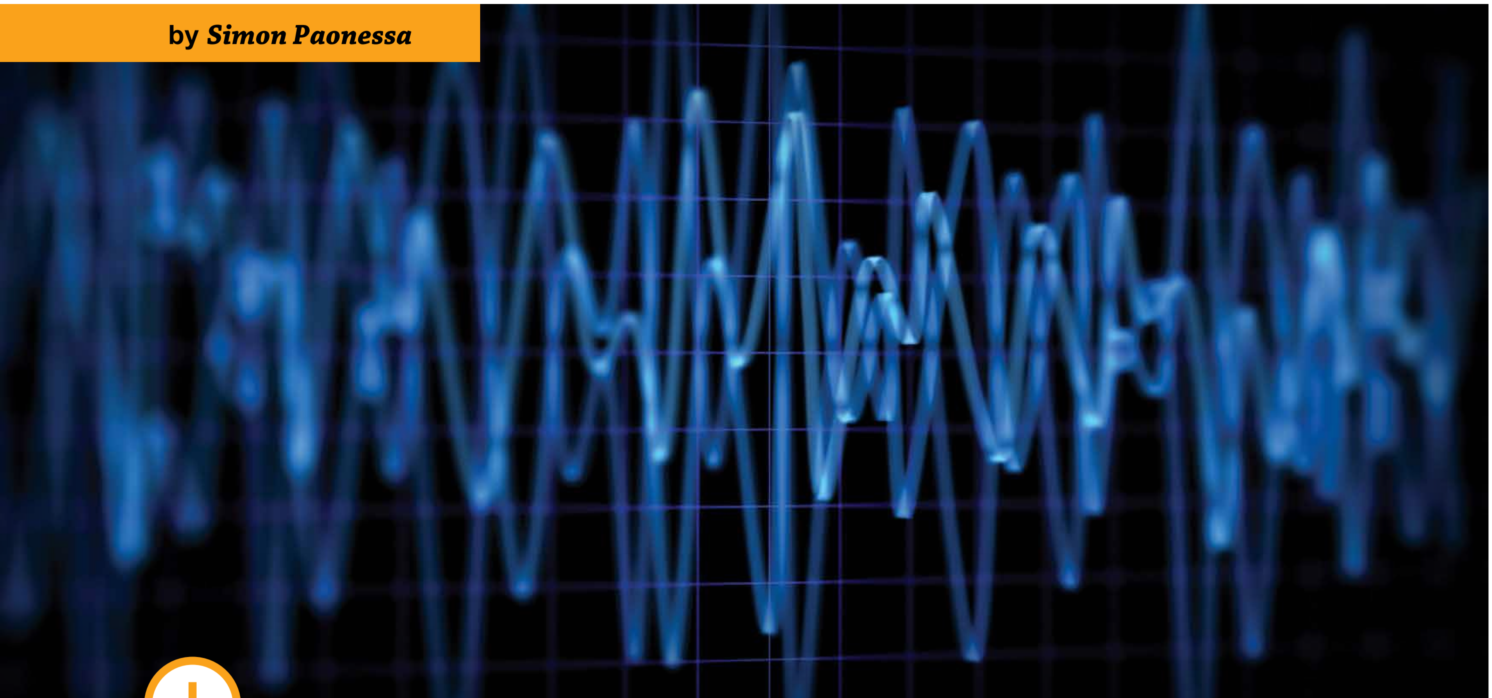
Reducing Signal Noise in Practice

by *Simon Paonessa*



Signal noise in an industrial environment has the ability to cause havoc with process control systems. This electrical noise can inject itself onto analog or digital signals and fool control equipment into thinking the process variable is different from what it actually is. This miscommunication between process control equipment, as with all kinds of miscommunication, can lead to any number of unforeseen, unintended consequences. As any electrical engineer will tell you, no system can continue to function properly without proper communication.

> ***"Signal noise, in its most basic sense, is any unwanted interference that degrades a communication signal."***

No industrial facility is going to ever be 100% free of electrical noise. The low levels of noise present in most plants is typically not enough to cause a problem. It is when the signal-to-noise ratio gets to unmanageable levels that it becomes a problem. Hardware and software solutions are available to help combat signal noise in particularly noisy environments, including noise filter settings that may be available in existing equipment already installed but inadequately utilized. Buying expensive new equipment in order to filter noise or isolate signals should, in most cases, be unnecessary if proper planning and installation practices are adhered to in the first place. Knowing what signal noise is, what causes it, and how to prevent it from interfering with signal networks should provide the right arsenal of tools needed to keep communication flowing.

DEFINING SIGNAL NOISE

Signal noise, in its most basic sense, is any unwanted interference that degrades a communication signal. Signal noise can interfere with both analog and digital signals; however, the amount of noise necessary to affect a digital signal is much higher. This is because digital signals communicate using a set of discrete electrical pulses to convey digital "bits." As can be seen in Figure 1, those electrical pulses would require a lot of noise in order to be confused with one another.

Conversely, analog signals represent an infinite range of possible values using an established range, such as 4-20 mA or 0-10 V. In this case, any unwanted voltage or current spikes will cause a fluctuation in the message being communicated. Minuscule variations along analog signals, on the order of millivolts or microamps, typically do not result in a significant (or even perceptible) discrepancy. High levels of electrical noise, however, can produce large variations and therefore lead to substantial discrepancies making communication between process control devices utterly impossible.

As seen in Figure 2, signal noise injected onto electrical communication will add or detract from the expected signal value. In an industrial situation where vital processes are automatically controlled based on the measurement of that signal, any variation can lead to unpredictable and potentially damaging results.

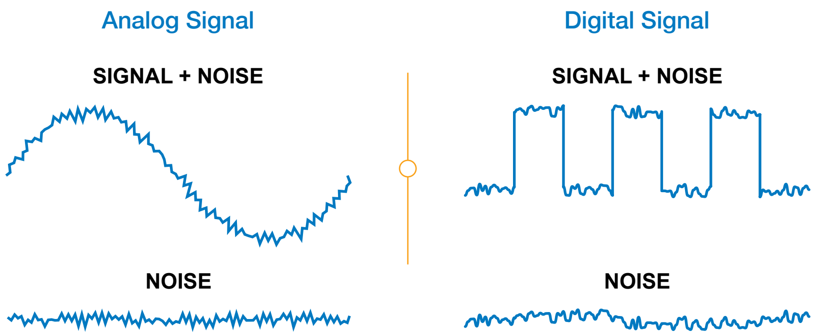


FIGURE 1. Noise in Analog and Digital Signals

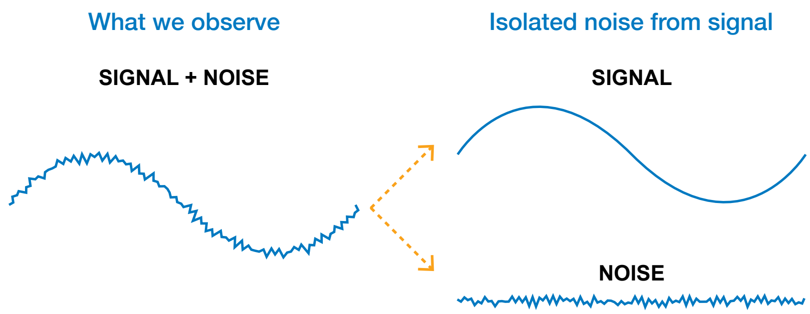


FIGURE 2. Isolated Noise from Signal

COMMON CAUSES OF SIGNAL NOISE

Noise injection can occur anywhere in the system and at any physical location in which the network is exposed. It can be the result of various factors at any location on the network. It may seem a daunting task to troubleshoot signal noise; nonetheless, there are some causes that are more common than others. These common causes account for the vast majority of signal noise interfering with process control networks.

1. GROUND LOOPS AND IMPROPER GROUNDING

As discussed in the previous issue of *The Current Quandary*, ground loops inject additional current onto the signal loop via a voltage differential between two grounding locations in a multi-ground system. This and other grounding issues can lead to an influx of signal noise on an otherwise functional network.

2. POOR WIRING PRACTICES

Poorly wired networks, such as those not utilizing shielded twisted-pair and conduit, are more susceptible to ambient electrical noise.

3. POORLY DESIGNED PRODUCT CIRCUITRY

Poorly designed electronic circuitry within devices, which does not provide adequate shielding against internal and external sources of noise, will also be more likely to have signal issues.

4. CLOSE PROXIMITY TO OTHER ELECTRICAL EQUIPMENT

Devices or wires placed in close proximity to electrical equipment that generates strong magnetic fields, such as generators, motors, or power lines, can pick up some of that interference, which can contribute to fluctuations in communications signals.

5. LONG WIRE LEADS PICKING UP RADIO FREQUENCY

Long segments of wire (especially unshielded wire) essentially act as antennae; they pick up radio waves and convert them to electrical signals, contributing to additional noise in the system.

PROBLEMS ASSOCIATED WITH SIGNAL NOISE

PROCESS SIGNAL DISTORTION

The most common and obvious problem caused by signal noise is the distortion of the process signal, causing incorrect interpretation or display of a process condition by the equipment. The addition to and/or subtraction from the process signal translates into an incorrect process variable. To put this into context, see the example in Figure 3 below.

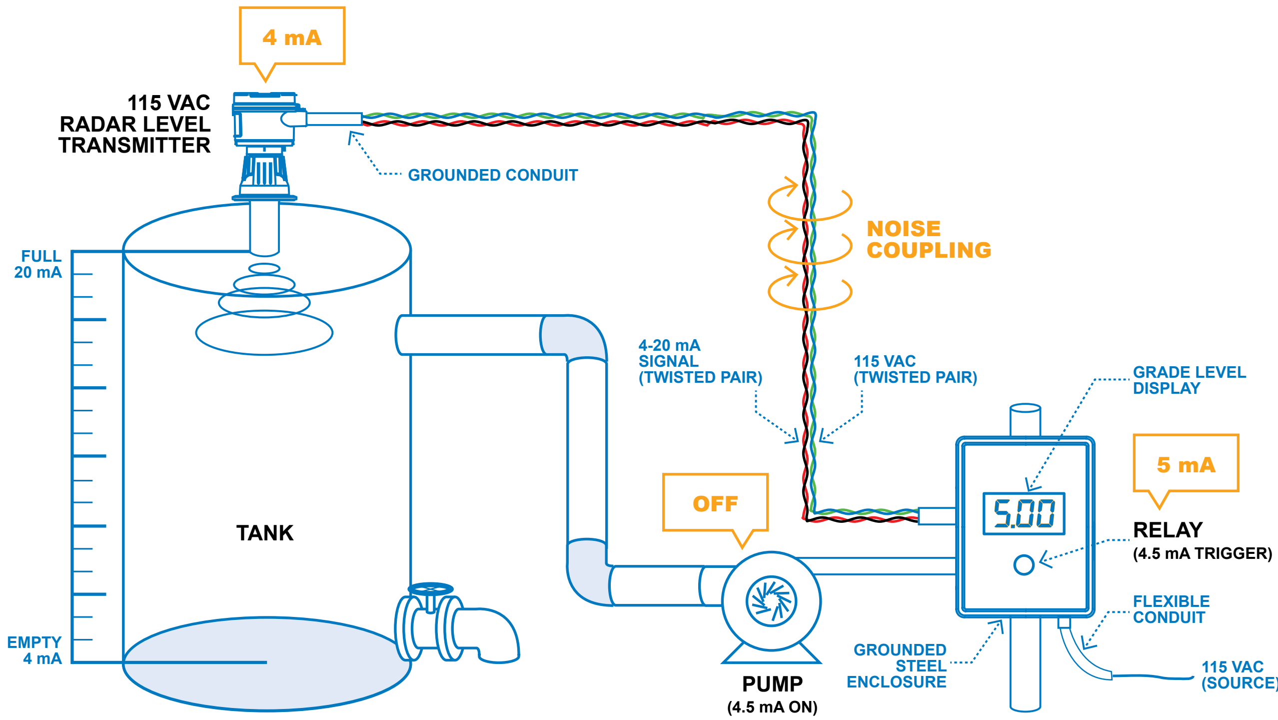
IMPROPER CONTROL OF PROCESS

In the example discussed in Figure 3, each device on the network is functioning exactly as intended; however, the signal noise caused a miscommunication between devices. Consequently the tank remained empty. A system experiencing signal noise fluctuations could inadvertently turn relays and alarms on / off at irregular intervals because the noisy signals are being misunderstood. A situation like this results in the improper control of an industrial process.

APPARENT SIGNAL LOSS

Though uncommon, extreme signal noise can lead to an apparent loss of signal. Most modern electronic equipment have built in noise filtering. However, in extremely noisy environments, this filter will not be enough, which can lead to the equipment not receiving a signal and no communication taking place at all.

FIGURE 3. Signal Noise Causing Miscommunication Between Devices



THE APPLICATION

A radar level transmitter is measuring tank liquid level. It outputs a 4-20 mA signal (4 mA when empty and 20 mA when full) to a mechanical relay that when triggered at 4.5 mA, activates a pump to begin filling the tank.

THE PROBLEM

The tank empties and the transmitter outputs a 4 mA signal but, because of extreme signal noise, the relay receives a 5 mA signal and never triggers or activates the pump. The tank remains empty and the process grinds to a halt.

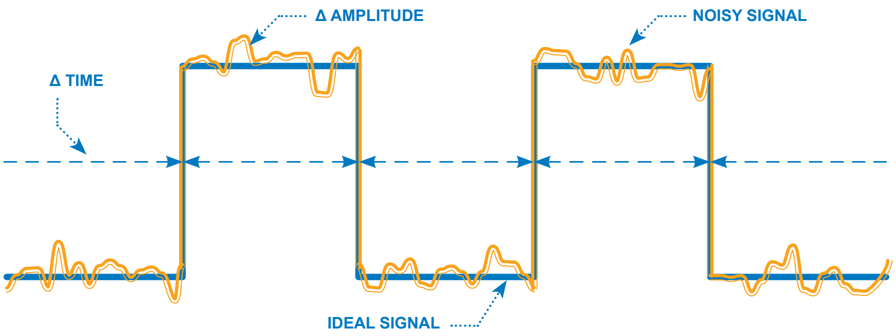


FIGURE 4. Digital Signals Are More Immune to Signal Noise

BEST PRACTICES

As with all industrial process control connection problems, it is far easier to follow some simple best practices while planning, designing, and installing process control devices than it is trying to troubleshoot problems with a system after it has become operational. Successful planning can save hundreds of man-hours and untold frustration when it comes to preventing signal noise from interfering with the system.

PLANNING AND DESIGN

When it comes to preventing signal noise, the smaller a signal is the more susceptible to noise it is. Low-level signals such as the pulse signal from a magnetic pickup flowmeter or the millivolt output of a thermocouple are highly susceptible to ambient noise. Any amount of noise injected onto these types of systems is bound to have some effect on the signal being transmitted.

Though it may be tempting to simply extend the wires from these devices to connect them to display or control devices, it is highly recommended that a transmitter or conditioner be used to amplify the signal before sending it over any length of wire. This amplified signal will be able to sustain greater quantities of noise before its intended value begins to be muddled. A more effective way to avoid noise, however, is to covert the analog signal to a digital signal instead of amplifying it. As shown in Figure 4, digital signals, with their set of discrete bits, are far more immune to noise than analog.

If a system needs to be installed in an area prone to electrical noise, the installer must plan on using software or hardware noise filters, which are often included in modern process control devices. Look in the device's instruction manual to ensure noise filters are available. An in depth understanding of the installation's environment and devices can save time and frustration.

> *"A more effective way to avoid noise... is to covert the analog signal to a digital signal..."*

INSTALLATION

As the saying goes, no plan ever survives first contact with the enemy. However, installers must make sure not to let unforeseen environmental or device limitations hinder the installation process or allow for future troubleshooting nightmares. Taking shortcuts to overcome installation challenges might be tempting for the short-term, but in the future that decision will come at a cost.

Installers should always use shielded twisted-pair wire to connect the components of the system. Common mode noise, or noise that is shared between the two wires of the twisted-pair, is more easily filtered out than noise that is only present on one wire. Also, though it may seem convenient to run the signal lines through the same conduit as power lines, this should always be avoided. The noise from those 120 or 240 V lines can easily make its way onto the signal lines.

Wires should also be kept away from any equipment that produces magnetic fields, such as motors, transformers, or large relays with inductive loads. Wires connecting different circuits should be installed perpendicular to one another as parallel lines are more likely to exchange noise. Wires should also be kept as short as possible to avoid acting as antennae.

Wiring must always be installed with the intention of avoiding ground loops. This is done by only using a single point of ground for all of the devices present on the network. If multiple devices on the network require grounding, make certain to run the same ground source throughout the entire system on shielded cable.

Keeping these simple best practices in mind throughout the installation process will help to ensure that your implementation takes signal noise into consideration as much as the original planning stages. If the installer of the setup shown in Figure 3 on the previous page had been following best practices during planning and installation, they would have known that AC power lines should always be isolated from 4-20 mA signal lines by running it along shielded cables inside independent conduit.

SUMMARY

Signal noise is an issue that all industrial facilities experience by virtue of having electrical equipment running. Signal noise becomes a problem for these facilities when it interferes with process signals being conveyed between devices. This can lead to inaccurate communication of critical process variables that can hinder or even halt process control systems. Following some simple best practices while planning and installing your process control solution can help to keep the communication flowing and eliminate the current quandary.

by Simon Paonessa - Technical Writer
Precision Digital Corporation

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Letter from Sales

BRIDGING THE GAP -
Considering Ease-of-Use for Industrial Products

by ***Simon Paonessa***
Technical Writer
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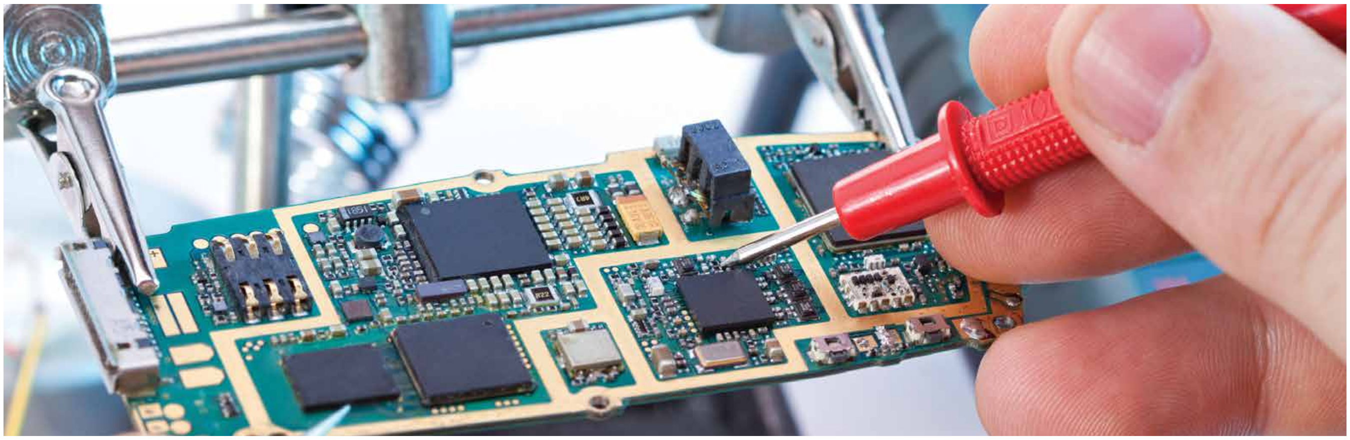

Products created and marketed for use in manufacturing and industry often do not receive the same attention to ease-of-use as consumer products. Imagine if a consumer was to buy a new smartphone and, upon opening the box, realize that not only do they have to assemble the phone from its base components, but the instruction manual was written by an electrical engineer and is as thick as the dictionary. What would a typical consumer do in this situation? Reading the manual and meticulously following each step would eventually get them to the desired end result (with about thirty "extra screws" and that one component that probably isn't important). However, the smartphone will probably not get very much use even after it is assembled because the software menus are nearly as convoluted as the instruction manual!

Looking at this scenario, it is clear that such a smartphone would quickly be considered an abject failure. Who would put up with all of that hassle and headache when they could buy a user friendly, easy-to-use Android™ or Apple® smartphone? Nearly any consumer electronics device manufactured by a reputable company is going to include easy-to-read quick start guides, instruction manuals, and often offer compelling online resources in order to get the end user up and running and enjoying their device as quickly as possible.

The logical question to ask is why electronic products produced for the process control industry are not held to the same standard. The first question asked by an equipment installer should never be "where is the tech support phone number?" Unfortunately, this has become the trend for installers in the process control industry due in part to manufacturers' lack of attention to ease-of-use and user friendly instruction. Here at Precision Digital Corporation, we have been working tirelessly over the past year and a half to bridge this gap between consumer and industrial products.

After conducting market research, it became clear to us that our instruction manual bore the brunt of complaints among users of our products. In response to this revelation, we have been working to improve how we present product information to our users with the creation of quick start guides for many of our most popular products, new mobile learning tools such as the Trident Virtual Meter and instructional programming videos, a recently launched completely renovated website, and an overall continuing focus on ease-of-use with all of our product documentation.

In a world where technological advancements are outstripping many people's ability to understand the intricacies of all of the products we are using, getting "up and running" has become the primary focus. Just as a consumer does not understand how his smartphone works, an equipment operator should not have to understand how every part of a process control system works. This is why being able to provide easy-to-understand product documentation that will allow any installer to get their systems working quickly is critical. At Precision Digital, we are working toward that goal.

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ALARMING POSSIBILITIES

ISA Alarm Sequencing In A Nutshell

by ***Simon Paonessa***

Alarms are a necessary part of the process control industry. Unintended faults in automation equipment are inevitable and must be communicated to operators clearly in order to avoid dangerous conditions.

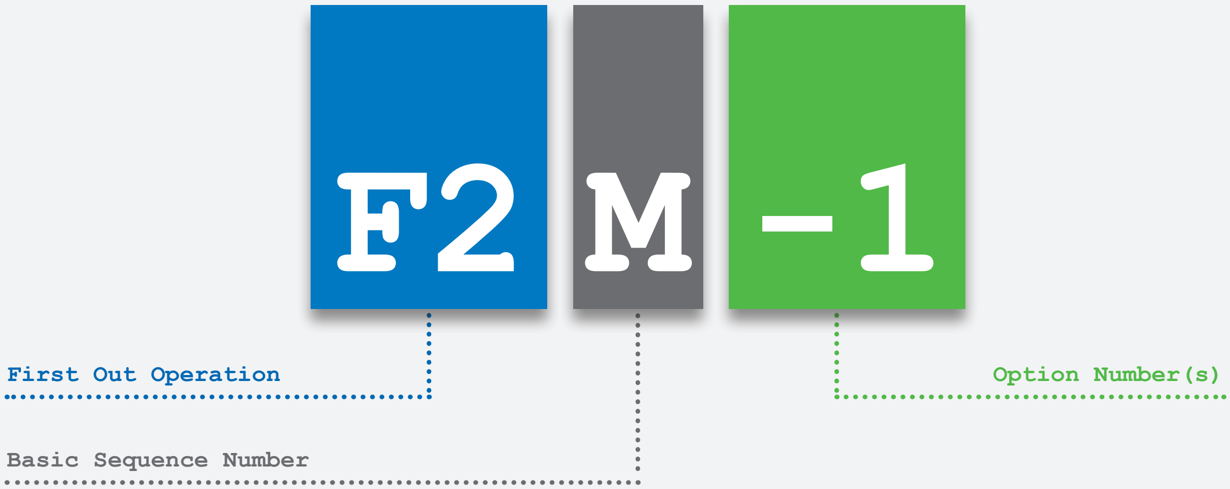

Figure 1. ISA Sequence Example

The ideal industrial facility is one in which all process variables remain consistently within normal operating parameters. Such facilities are few and far between, however, so it is necessary that personnel are quickly and effectively notified of abnormal process conditions so that they may be dealt with accordingly. In industrial facilities where there are a multitude of process variables at play, such as automated manufacturing plants, waste water treatment facilities, and the oil and natural gas industries, implementing a successful alarm indication protocol can quickly become frustratingly complex.

Because of the amount of alarms required to monitor all relevant process variables in modern industrial facilities, "an important … component of safety system design is alarm rationalization and alarm management."[1] It may be the case that in order for an operator to return one process variable to normal, another related variable might need to temporarily go into an abnormal state, triggering the alarm and flashing hazard lights for the system again. Variables that routinely go abnormal only briefly can trigger alarms excessively and do more to annoy operators than to alert them of potentially troublesome process conditions. An excess of alarms and incorrect alarm sequencing can lead to general confusion about alarms' meaning and a "boy who cried wolf" mentality about alarms in the facility.

> ***"The ISA 18.1 standard, the standard that defines alarm sequencing, exists… so that alarm systems are designed to meet the specific requirements of any number of industrial applications."***

TYPES OF ALARM SYSTEMS

Alarms can be communicated to operators via a variety of means. Some process control devices include built in alarm lights or audible sounds. These can allow limited alarming for small numbers of alarm points, but can quickly become overwhelming (or underwhelming) when a large number of variables are introduced. Software solutions can display alarm conditions on an operator's computer screen and allow for remote acknowledgment of the alarm state. These, however, have led to a decline in the "recognition of and response to alarm conditions" because, "on computer screens, [alarms] are not very visible and can go unnoticed."[2]

Annunciators are discrete devices that are specifically designed to make operators aware of abnormal operating conditions in an industrial facility through the use of lights and sounds. The lights can be anything from internal LEDs to large external flashing hazard lights and the sound can be generated from a horn, buzzer, or bell. These separate hardware alarming units are typically used "in installations where simplicity is desired or where separation from the basic process control system is required for safety reasons."[3] The use of an independent alarm system can put more emphasis on the alarm condition and potentially lead to a more active alarm response. Annunciators can be programmed to manage large groups of process variable alarm points and administer alarm notification in a manner that suits the needs of the operator.

ISA SEQUENCES

The ISA 18.1 standard, the standard that defines alarm sequencing, exists in order to "establish uniform annunciator terminology, sequence designations, and sequence presentation… to improve communications among those that specify, distribute, manufacture, or use annunciators."[4] It's needed so that alarm systems are designed to meet the specific requirements of any number of industrial applications. It is therefore necessary to first understand the designations defined by the ISA standard before being able to determine what alarming sequence is best for a specific process control system. Each alarm sequence in the ISA 18.1 standard is given a unique identifier which can be broken down into three parts:

1. First Out Operation
2. Basic Sequence Number
3. Option Numbers (if any)

Figure 1 shows an example of one such sequence.

First Out Operation

The first part of the sequence is the first out operation. According to the ISA 18.1 standard, it "indicate[s] which one of a group of alarm points operated first."[5] Essentially, this designates what will happen if another alarm in the alarm group triggers when the first alarm to sound is still in its alarm state. There are four first out operations.

—

Having no first out operation defined means that each subsequent alarm will behave identically to the initial alarm. If the annunciator is programmed to sound a horn and flash lights at any given alarm point until the process variable returns to a normal state, then that is exactly what the annunciator will do regardless of if there is already an active alarm state.

F1

The F1 first out operation is the opposite, acknowledging new alarms and bypassing the audible and visual alarm notifications for these subsequent alarm conditions. The first out operation is reset when the acknowledge button is pressed.

F2

F2 is similar, except that it bypasses the audible and visual notifications without acknowledging the new alarms.

F3

F3 first out operation flashes alarm indication lights in a different pattern in order to differentiate new alarms from the first out alarm. This type of first out operation requires an additional first out reset button on the annunciator. Pushing this button will reset the first out indication whether or not the alarms have been acknowledged.

Basic Sequence Letter

The second part of the sequence is the basic sequence letter which determines the rudimentary alarm functionality. There are three of these: A (automatic reset), M (manual reset), and R (ringback).[6]

A

Automatic reset returns the sequence to the normal state automatically after the acknowledge button is pushed and the process condition has returned to a normal state.

M

Manual reset will only return the sequence to the normal state after pressing the acknowledge button, returning the process condition to normal, and pressing the reset button.

R

Ringback behaves similarly to manual reset except that it also provides distinctive visual and audible indications when the process condition returns to a normal state. This mode requires an annunciator that is equipped to provide these unique indication modes in order to work.

The ISA-18.1 standard may be found at the ISA website (www.isa.org).

Option Numbers

In order to provide as much flexibility as possible, the ISA 18.1 standard defines option numbers that can be affixed to the sequence designation. There are fourteen such option numbers defined as part of the standard that define everything from the use of alarm silence buttons, whether or not to sound an audible alarm, and even alarm lamp test functionality.[7]

Some examples of options available are:

-1

-1 (Silence Pushbutton): A separate pushbutton is added to allow silencing the alarm audible device without affecting the visual display.

-3

-3 (First Out Reset Interlock): An interlock is added to require operation of the acknowledge pushbutton before first out alarms can be reset by the first out reset pushbutton.

-5

-5 (No Flashing): The visual display flashing feature is deleted. New alarms have the same visual display indication as acknowledged alarms.

-6

-6 (No Audible): The audible device is disabled.

-7

-7 (Automatic Alarm Silence): A time delay device is added to silence the alarm audible device after a set time without affecting the visual displays.

Figure 2. Understanding an ISA Sequence

F2 M -1

The F2 designates that any subsequent alarms in the alarm group will be automatically silenced but not acknowledged.

F2 M -1

The M defines this sequence as being a manual reset and will require pressing the reset button after pressing the acknowledge button and returning the process condition to a normal state.

F2 M -1

The -1 indicates that there is a separate audible alarm silence button which can be used to turn off the horn, buzzer, or bell that is associated with the active alarm.

EXAMPLE SEQUENCE USAGE

The ISA 18.1 standard enables manufacturers, installers, and operators to communicate alarm planning in a uniform manner. Understanding the meaning behind the numbers and letters that make up a sequence can allow one to think logically about what sequence would be best utilized in a given situation. The following scenarios illustrate when different sequences might be utilized to meet the needs of the application.

TANK LEVEL MONITORING (sequence A)

It is often necessary to measure the level of some liquid in a tank. In situations such as this, a buoyancy level switch can be wired to an annunciator. In a tank that is five and a half feet tall, this switch, which is open when the tank has less than five feet of liquid and closed when the liquid exceeds this amount, can use an annunciator with sequence A-1 to indicate a high level alarm. When the level exceeds five feet and the level switch closes, the annunciator will sound its horn and flash its light. The operator can press a button to silence the audible alarm so that the issue can be addressed without added distraction. Once the alarm is acknowledged and the liquid in the tank returns to below five feet, opening the level switch, the alarm sequence returns to its normal state and the annunciator light turns off.

STEAM BOILER TEMPERATURE AND PRESSURE (sequence F2A)

Monitoring the temperature and pressure in a steam boiler being fired by natural gas is essential to ensuring the safety of nearby personnel and property. A pressure buildup could easily lead to an explosion. Separate sensors are used to measure the temperature and the pressure, so they would be represented by different channels on an annunciator alarm group. These variables are, however, interconnected, as the increase in temperature will lead to an increase in pressure and vice versa. In many cases, for troubleshooting purposes the most important thing an operator wants to know is whether the high temperature or high pressure occurred first so sequence F2A would be the best choice.

SEQUENCE A

Acknowledge Pushbutton and Automatic Reset

Momentary Alarm

Condition	LED	Horn
Normal	Off	Off
Alert	Flash	On
Normal	Flash	On
ACK Pushbutton		
Acknowledge	Off	Off

Maintained Alarm

Condition	LED	Horn
Normal	Off	Off
Alert	Flash	On
ACK Pushbutton		
Acknowledge	Steady	Off
Normal	Off	Off

SEQUENCE F2A

First-Out Indication w/Ack Pushbutton & Automatic Reset

Momentary Alarm

Condition	LED		Horn
	1st Pt	Next Pt	
Normal	Off	Off	Off
Alert	Flash	Steady	On
Normal	Flash	Steady	On
ACK Pushbutton			
Ack	Off	Off	Off

Maintained Alarm

Condition	LED		Horn
	1st Pt	Next Pt	
Normal	Off	Off	Off
Alert	Flash	Steady	On
ACK Pushbutton			
Ack	Steady	Steady	Off
Normal	Off	Off	Off

Figure 3. Common ISA Sequences A and F2A

PRESSURIZED CLEAN ROOM MONITORING (sequence F1R)

Clean rooms, such as computer rooms and hospital isolation rooms, as well as asbestos abatement projects (just to name a few instances) require differential pressure in order to keep zones of air separated from one another. The pressure levels of these zones should be constantly monitored as pressure equilibrium would lead to cross-contamination of other zones. In the case of asbestos abatement, this could lead to heavy fines levied by the EPA. Annunciators monitoring differential pressure in cases such as this might use the sequence F1R-3. This sequence would only show first out indication, limiting the alarming to the origin of pressure destabilization rather than sounding for surrounding areas into which air could be escaping, so that operators know in which area to concentrate their containment efforts. It also incorporates a ringback, announcing when the differential pressure has returned to acceptable levels. Lastly, the -3 shows that this sequence incorporates a first out reset interlock, ensuring that the alarm remains active for the original room only until the acknowledge button is pressed.

SUMMARY

Alarms are a necessary part of the process control industry. Unintended faults in automation equipment are inevitable and must be communicated to operators clearly in order to avoid the potentially troublesome or hazardous results of neglected abnormal process conditions. Alarms can be managed using basic alarming functions included in some process control devices, software based alarming applications, or dedicated hardware annunciators. The ISA 18.1 standard is a means with which to uniformly define alarm sequencing logic for manufacturers, installers, and operators of process control equipment. This standard allows for the simple communication, and therefore the logical research, planning, and installation of alarm sequencing. Understanding what the numbers and letters of an ISA sequence mean, and the available alarm management options defined under the ISA standard, can help to alleviate the confusion and frustration of process control alarm indication in industrial environments.

by Simon Paonessa - Technical Writer
Precision Digital Corporation

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