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THE PRECISION DIGITAL MAGAZINE

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{PART 3}
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Reader's Brief

This issue focuses on 4-20 mA signals, with editorial including *The Current Quandary* and the conclusion to the *Back to Basics* series. The remainder consists of a case study and the *Letter from Sales* discussing success stories and best practices.

If you are attending the WEFTEC 2015 show this September, make sure to visit the Precision Digital booth (#1081).

We are pleased to inform you that our company is growing and moving soon to our new headquarters in Hopkinton, MA. Please make note of our new address below.

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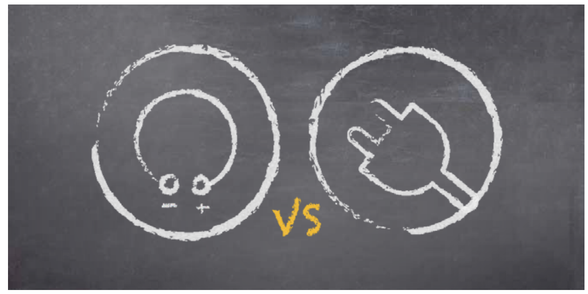

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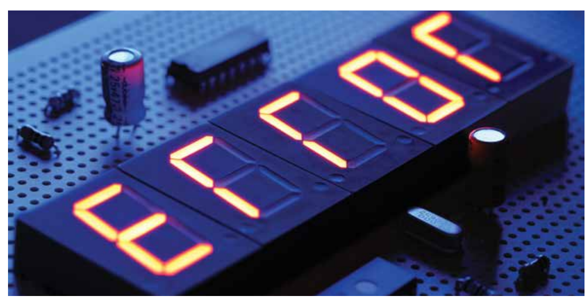

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Letter from Sales

TAKING ANOTHER LOOK - *The Value in Reassessing Old Solutions*

by ***Joe Ryan***
Sales & Marketing Manager
Precision Digital Corporation

During a period of economic slowdown, many process plants prepared for unfavorable financial conditions will use the opportunity to conduct much needed maintenance, repair, operations upgrades, and new installations. Upgraded process instruments (sensors, controllers, etc.) may only get considered at that time, due to holds on major new products. However, regularly evaluating your daily processes during normal maintenance and repairs can lead to immediate opportunities for improvement that will have a huge impact on the capabilities, efficiency, and effectiveness of a plant's procedures. Don't wait for something to break down before replacing outdated equipment when you can proactively modernize your process instrumentation.

> ***"Modernization of existing equipment can be a cost-effective way to see dramatic improvements..."***

Modern equipment features such as through-window buttons allow operators to configure instruments without removing the cover in hazardous areas.

Installing new, advanced products for your application could add previously unknown functionality that helps improve your process solution. For example, my flip phone did everything I wanted it to do seven years ago. It could easily place calls, was small, and could send text messages. I was not in the market for a new phone. It wasn't until I was on a trip and kept using someone else's modern smartphone that I realized what a difference the features available in the smartphone made, and how they could be of use to me. This same concept applies to the components of your process instrumentation. Software monitoring and setup, more informative displays, more accurate readings, wireless capabilities, through-glass buttons, and so much more are available in modern systems. Evaluating the new features available with modern equipment for existing processes may yield a solution you never considered possible with your original system.

Upgrading to newer systems simplifies operations, maintenance, and repair while enhancing accuracy and usability. Efforts to streamline maintenance can have a big return on investment. Using Modbus devices to replace dozens of 4-20 mA loops, or replacing long and complicated wiring in conduits with a simple wireless device can make future upkeep, as well as process automation, much easier. Updating your facility with modern instruments that can be programmed or monitored with software or serial communications will greatly reduce the time to set up replacement equipment, speed up data collection, and reduce troubleshooting time. These kinds of one-time upgrades pay off quickly, given the cost of troubleshooting and repairing a process that has been shut down.

The user experience may also be improved significantly by updating the system components that the operators interact with daily. Though often overlooked, the display and user interface of a process can be the most critical. A simple, intuitive front end makes a process safer, less prone to error, and easier to comprehend. A good example of this is tank level monitoring. Top of tank level transmitters may have a display, but adding a remote indicator at grade level will reduce operator time spent monitoring level and improve safety by reducing the need to climb the tank. An update to just the user-facing equipment can have a major impact on the ability of operators to use the equipment for a fraction of the cost of an entire system upgrade.

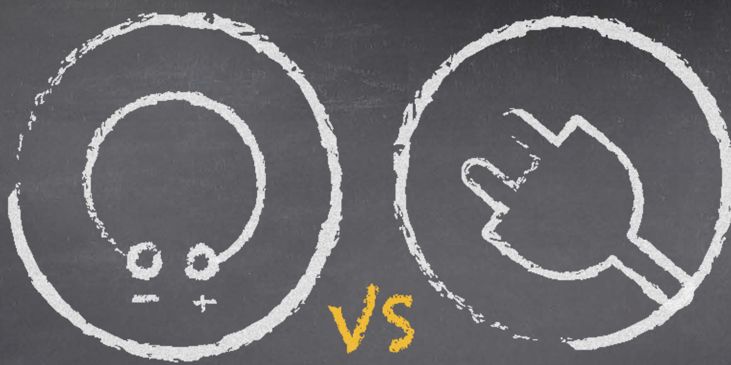
A remote display eliminates the need for operators to climb tanks for level readings.

There is inherent value in reevaluating existing process solutions. This reevaluation must occur proactively and continuously in order to have the most efficient solution for your needs. Modernization of existing equipment can be a cost-effective way to see dramatic improvements to the reliability and efficiency of your processes.

{PART 3}

BACK TO BASICS:

Loop vs Line Power



The previous article in this series discussed loop-powered, or two-wire, devices. These instruments utilize the power supplied to the current loop to power themselves. A two-wire connection may not always be the most optimal power solution because of its inability to power devices that require a large voltage drop. Three and four-wire devices incorporate an external power supply in order to effectively eliminate the voltage drop placed on the process signal current loop. It is important to understand the differences between these three setups as they are fundamentally different and each has its own advantages as well as limitations.

Defining 2, 3, and 4 Wire Connections

All devices in a 4-20 mA current loop need to be supplied power from somewhere in order to function. Two-wire devices receive their power from the process signal loop itself. The power for the loop usually comes from the transmitter power supply or some other kind of external power supply, and all of the power for the system travels through the wires that also carry the signal. Since this setup only requires two wires, loop-powered instruments are also referred to as two-wire devices. Three and four-wire devices, by contrast, receive the power they require to function from a power supply that is separate (but not necessarily isolated) from the current loop. These devices cannot be loop-powered.

A four-wire connection uses the current loop as a means to transmit the 4-20 mA process signal only. This type of connection will not draw the power it needs from the current loop. It will create a voltage drop on the loop, but this is minimal when compared to that of a loop-powered device. The power four-wire devices need is instead provided by an external power supply. This can be either an alternating or direct current power supply because the device is powered independently from the direct current loop. 24 VAC or VDC supplies are common, as are 120 or 240 VAC. It all depends on the specifications of the device.

Isolated four-wire connected devices “float” within the current loop. This means that the common, or the return process signal wire from the device does not connect to the power supply ground. As may be apparent from the name “four-wire,” two wires connect the power supply to the device and two wires connect the process signal to the device. Isolation, therefore, is built into the system. There is no electrical connection between the power supply and the process signal.

A three-wire connection is essentially the same as a four-wire connection except that the isolation just discussed is not present; a three-wire device does not float in comparison to the current loop. In a three-wire connection, the process signal return from the device and the common of the power supply are a shared connection.

Understanding the Pros and Cons

2-Wire Pros and Cons

Recalling the advantages of two-wire connections from the previous article, you will remember that they are simple to setup, lower cost, commonly feature hazardous area approvals, and do not require local power. On the other hand, they have very limited features due to the limited amount of power they can draw from the current loop. Three and four-wire devices have their own set of pros and cons which must always be taken into account when attempting to determine the best solution for a process control environment.

4-Wire Pros and Cons

Because four-wire devices are externally powered, they can accommodate a lot more energy intensive features such as mechanical relays, bright LED displays, advanced serial communications such as

Modbus®, and powered outputs, among other things. Four-wire connections can be easier to understand because there is no need to worry about voltage drop across the current loop. A four-wire device can be powered by simply plugging it into a wall outlet or some sort of DC power supply such as a battery.

> *“Because four-wire devices are externally powered, they can accommodate a lot more energy intensive features…”*

As mentioned, four-wire devices often have excellent built in signal isolation. In a device with power-to-signal isolation, the current signal and the power supply utilize completely separate wires. This can make setup and maintenance a whole lot easier when dealing with complex 4-20 mA signal networks (featuring multiple 4-20 mA process variables over multiple loops) or if there is a lot of electronic noise from the power supply.

Four-wire connections, as opposed to two-wire connections, require a separate power supply for the device, which can be disadvantageous depending on the availability of power. Generally they are more expensive as they require an internal power supply circuit to handle the external power they are receiving and generally feature more expensive components.

The amount of wire needed to connect four-wire devices can become a problem for installers, especially in hazardous areas where all of that wire would need to run through conduit. This can also make maintenance and troubleshooting more difficult down the road, requiring evaluation and repair of nearly double the circuitry compared to a similar two-wire system.

Four-wire connections also have fewer options when it comes to hazardous areas. The high power requirements alone make Intrinsic Safety (I.S.) and Non-incendive (N.I.) approvals exceedingly rare. In order for a four-wire device to be suitable for use in a hazardous area, it often needs to be enclosed in an explosion-proof enclosure which, though effective, might not always be the best possible option.

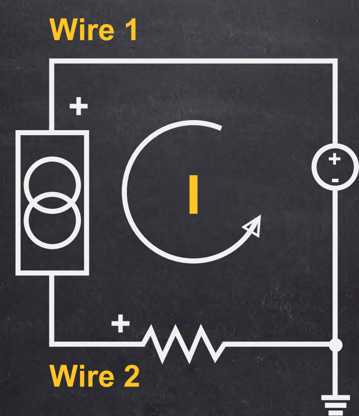
3-Wire Pros and Cons

Three-wire devices are commonly found to be lower cost than four-wire primarily because they do not feature isolation. They can also be slightly easier to install because they require less wire and, in the case where wire needs to be run through conduit, this wire can often be run along the same channels because they are already electrically connected. Moreover, many of the same benefits of four-wire devices mentioned above also apply to three-wire, such as the availability of mechanical relays, advanced serial communication, powered outputs, etc.

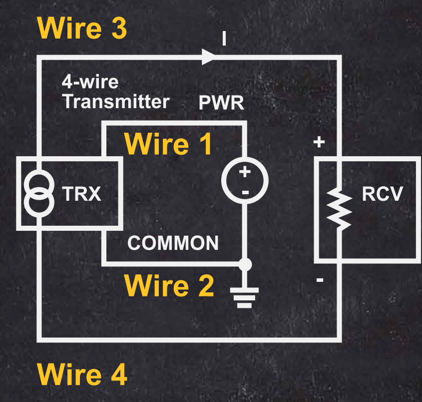
In contrast to four-wire, three-wire devices do not feature isolation because of the fact that the power supply common and the process signal return share the same wire. When dealing with complex 4-20 mA signal networks, an installer must be very careful while wiring the devices to avoid crossing current paths. Any grounds, commons or returns that cross paths with the process signal loop will cause current to travel into different circuits and the process signal will no longer provide predictable, usable current values.

Three wire devices cannot be powered by an alternating current (AC) power supply. Four-wire devices can be powered via AC current, such as that available from a wall outlet, because the connection powering the device is completely separate from the connection to the process signal. Three-wire devices do not feature this isolation, so all of the power in the system must be direct current (DC), just like the process signal loop.

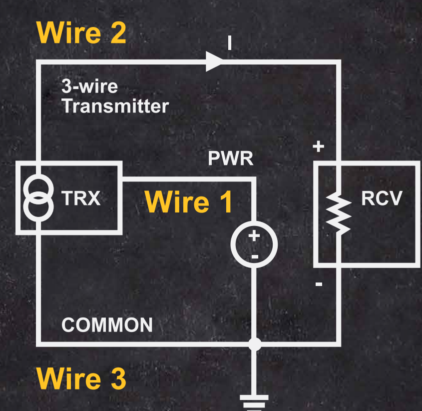
Wiring Examples



2-Wire Connections



4-Wire Connections



3-Wire Connections

Things to Remember

- 4-wire or 3-wire require a separate power supply
- 3-wire works - be aware of isolation requirements first
- 2-wire - be aware of voltage drops
- Costs increase as more wires are used
- Some devices are not available as 2-wire

Choosing the Right Wiring for your Application

At the core of this topic are a few essential factors which need to be taken into consideration when deciding on the right choice for a process control environment. Remember that three and four-wire devices will always require a power supply that is separate from the process signal loop, though this does not inherently imply isolation. Two-wire devices are powered by the current loop itself and do not require an external power supply.

Although there were many cons mentioned in regard to three-wire connections, remember that they do work and they are a valid option when power supply isolation is not a concern. They are often cheaper than four-wire devices, which is a definite plus; however, the installer needs to understand what they are doing and know the implications of crossing current loops.

Four and two-wire devices can be easier to connect than three-wire, though both for different reasons. Two-wire devices are easier because there are less connections to make, but voltage drop must be taken into account. Four-wire devices are easier to connect because of the built in isolation, but external power requirements must be taken into account.

As a general rule of thumb when it comes to cost of process control devices, think of two-wire devices being the least expensive, three-wire being in the middle, and four-wire devices as the most expensive. Some devices and device features are just not available as two-wire, however, because of inherent power consumption requirements.

Back to Basics: Series Summary

As discussed in the first part of this series, The Fundamentals of 4-20 mA Current Loops, the 4-20 mA current loop is the dominant process control signal standard in many industries which require process control. The fact that the current will not change from the time it leaves the transmitter to when it reaches the receiver makes it an ideal means for transferring process information. It is also much simpler and cost effective than other process control protocols. However, voltage drops and number of process variables that need to be monitored can have an impact on the cost and complexity of implementing this standard.

Devices which transmit and/or receive information over a current loop are connected with either two, three or four wires. Part two, The Fundamentals of Loop-Powered Devices, explored how two-wire, or loop-powered, devices receive their power from the 4-20 mA process signal loop connected to the device. This is possible because current is the same throughout the loop, so voltage drops caused by loop-powered devices do not affect the current signal. Loop-powered devices are simple, easy to wire and use very little power. However, it is important to be aware of the limitations of loop-powered devices such as the unavailability of relays, LED displays, or advanced serial communications.

Three and four-wire devices, unlike two-wire, utilize an external power supply which allows them to feature much more advanced components such as brighter LED displays and advanced output options. Four-wire devices also frequently feature built in power supply isolation. Three and four-wire devices might not always be the appropriate option, however, if running additional power is infeasible or they need to operate in a hazardous area with Intrinsic Safety or Non-incendive approvals.

A device installer must be able to pay attention to the specifications relevant to their particular process control environment in order to avoid problems with their specific control system. Maintenance personnel should know how the environment is setup, and what that means in terms of electrical connectivity, in order to properly maintain and troubleshoot existing process control networks. Knowing the fundamentals of the 4-20 mA current loop standard and means by which devices connect to current loop networks can go a long way towards being able to make more informed decisions about process control in your facility.

by Simon Paonessa - Technical Writer
Precision Digital Corporation

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Boosting Efficiency in a Natural Gas Flow Application

Application

The end user is a natural gas transportation and storage service provider in the USA with a natural gas storage well flow application. The customer's primary concern when considering a system upgrade was to track flow rate and display the rate locally.

The plant contains 180 Class I, Div 2 hazardous area stations in total. The locations are spread out over a five-mile radius and are controlled and monitored from a single control room. The system turnaround was completed over three years.

Challenge

Prior to the system turnaround, technicians doing daily routine maintenance would have to check the flow rates at each station before performing their work. This process could be very time-intensive due to the lack of a local display. The operator would have to call the control room from a declassified area to find out the flow rate at the station location, then return to the classified area to make the necessary valve adjustments to obtain the desired flow rate.

Installation

In the installation photo to the right, there are two sets of transmitters per station location. Two are differential pressure transmitters and two are line pressure transmitters. The V-cone flowmeters use differential pressure to measure flow rates.

Mass flow is measured with temperature, pressure, and differential pressure being the primary variables. On the low end, the pressure measured represents a quarter-inch water column, while on the high end there is a 500-inch water column representation. This wide range necessitates the additional transmitters.

The transmitters collect the information on pressure, differential pressure, and temperature and send it to a PLC within the locked metal enclosure pictured in the photo. Once the PLC gathers the information, the signal is then split into two separate signals, one branch of which goes to the control room. The other, a 4-20 mA signal branch, routes out to the Precision Digital PD6820 Flow Rate/Totalizer, located in close proximity to the PLC.

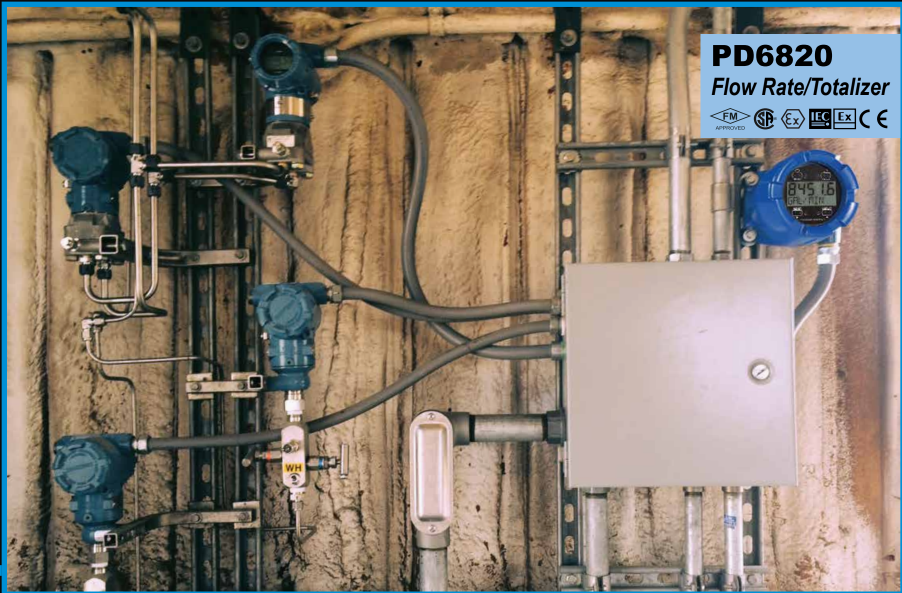
Increasing Safety While Saving Man-Hours

Now, since the PD6820 displays the flow rate locally, there are no more extended calls to the control room to seek or verify flow rate. Plant operators like the PD6820's easy-to-read display, its custom units & tags, and that it works with all differential pressure transmitters. Plus, with this system upgrade, making adjustments to the flow rate is as simple as pushing a button.

The customer could not quantify the monetary savings of this installation. However, he relayed that the local display saved significant man-hours by making critical information instantly accessible.

Explosion-proof PD6820 meters are agency-approved for use in a natural gas environment or other hazardous area. Features such as SafeTouch® thru-window buttons promote safety by eliminating the need to remove the cover for programming. This system upgrade not only increased the company's overall efficiency, but instituted an additional level of safety that both plant operators and management value.

- by Bob Fedor
Marketing Communications Specialist
Precision Digital Corporation



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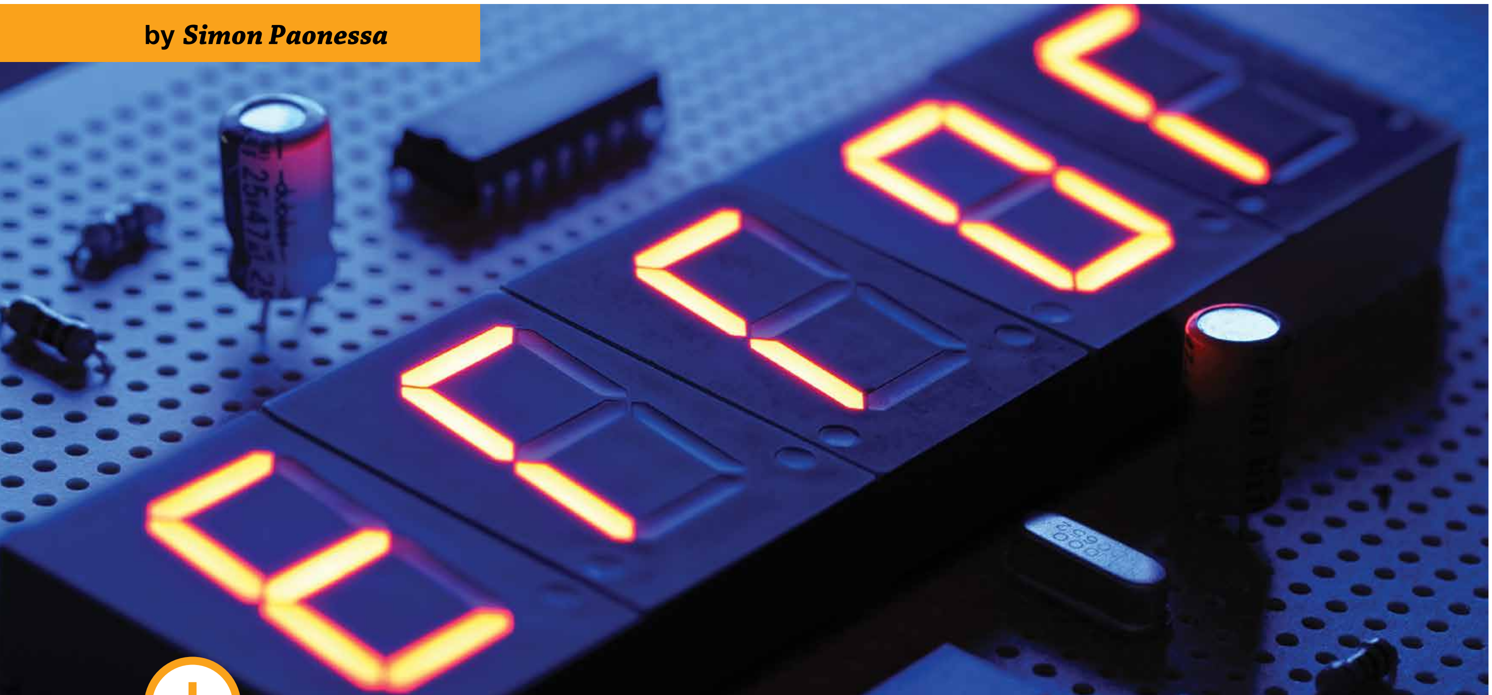
THE CURRENT QUANDARY

Ground Loops & Non-Isolated Commons

by ***Simon Paonessa***



Any installer of industrial process control equipment will tell you that ground loops are one of the most frustrating signal connection errors to diagnose and repair. The steps required in order to troubleshoot them are often equated to something as mysterious as magical incantations. Issues caused by shared, non-isolated commons are viewed with a similar outlook. Difficulties with shared signal returns are often even confused with ground loops. Ground loops and shared commons can both cause unpredictable signals and render your current loop unusable.

The best and most practical way to repair these signal issues is to prevent them from occurring in the first place by planning proper device wiring and following specific best practices. However, if you suspect that you are having signal issues related to ground loops or shared commons in an existing network, no need to pull out the spell book and magic wand, there are some predictable symptoms which you can look for in order to diagnose the problem.

First of all, you need to know the definition of ground loops and shared commons. A ground loop is the flow of current from one signal ground to another because of a voltage differential between the two grounds. This can happen if two devices in the network are grounded at separate locations and one of the locations causes the signal ground there to experience a higher voltage potential. As any electrical engineer will tell you, any voltage differential will result in a current flow. It is this current flow that causes the symptoms of a ground loop.

"The best and most practical way to repair these signal issues is to prevent them from occurring in the first place…"

A shared, non-isolated common can become problematic when it is improperly wired. Multi-input and multi-output devices, especially those with more than one loop going through them, are notorious for difficulties related to shared commons. These are commonly referred to as "ground loops" because of the similarity of their symptoms, but are not true ground loops because they are not caused by grounding issues. These kinds of problems arise when nodes are created, intentionally or not, prior to reaching all of the applicable devices on the circuit requiring a clean, predictable signal. This will result in mixed current flow and signal averaging, which will produce an unusable process signal.

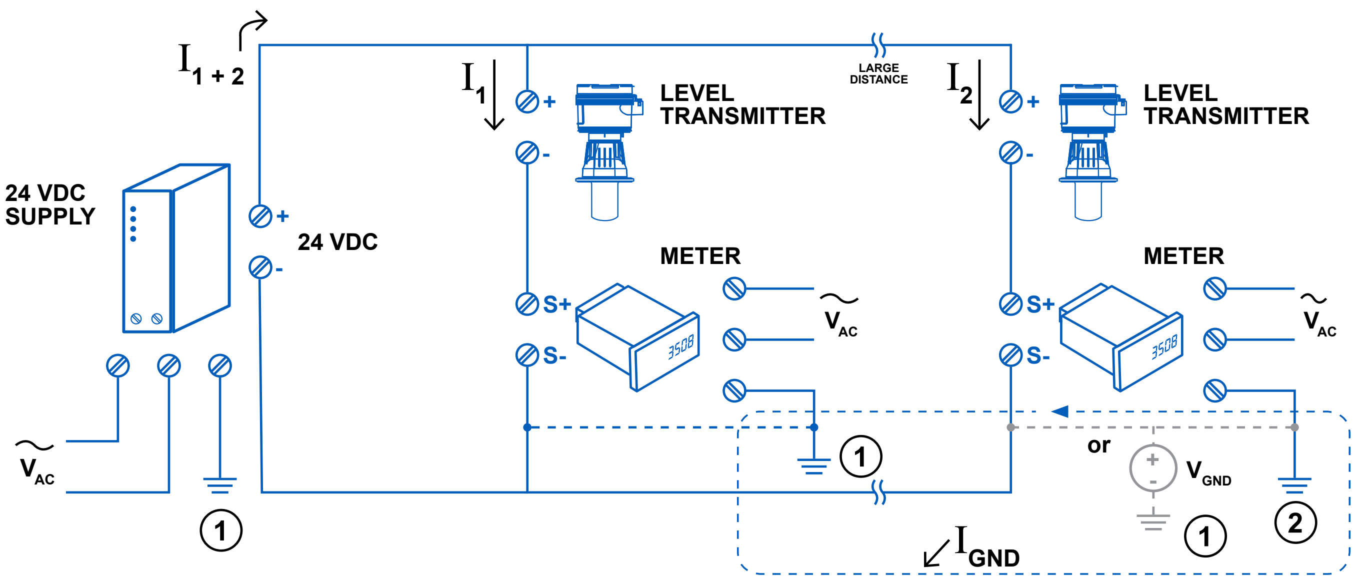


FIGURE 1. Multiple Grounds in System

GROUND LOOPS

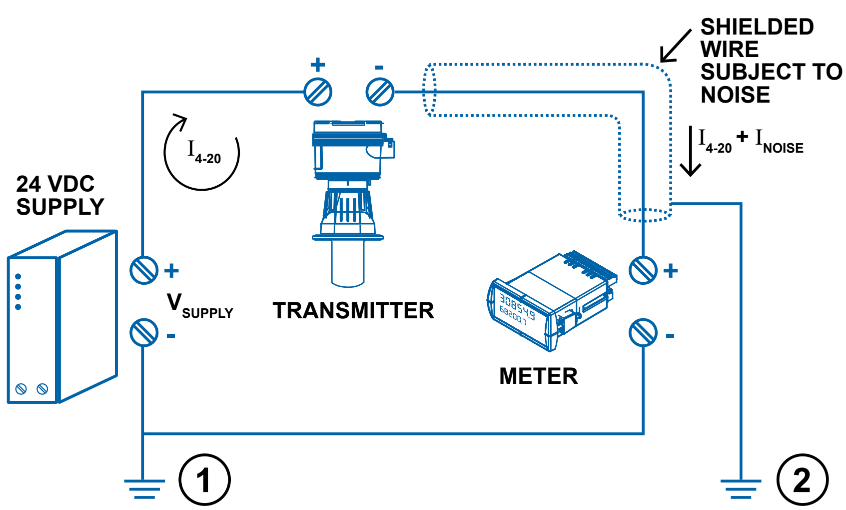
Figure 1 above shows a 24 VDC power supply providing voltage to the current loop. This loop is connected in parallel to two level transmitter/local display pairs, presumably on different tanks at completely separate locations in an industrial facility. The two transmitters are using the voltage provided to them to generate a 4-20 mA process signal which is then run along the wire connecting them to the local display showing the process variable. The circuit is completed by running a return back to the power supply.

This all sounds like a typical, functional current loop until you notice that both of the local displays' power inputs are grounded at their individual locations. Ground 2, because the environment in which it is located experiences more noise and has inferior connections for its grounding rails than the other location, has a higher voltage potential than ground 1. This results in the current flow labeled I_{GND} above. This current flow runs along the same wires that are supposed to only carry the 4-20 mA process signal to the displays, resulting in the two currents mixing and the process signal becoming unpredictable and therefore unusable.

In the example illustrated in Figure 1, it was a device on the 4-20 mA loop which was injecting ground current onto the loop. It is possible, however, that a device not located on the loop can be the culprit. Consider if some device on the loop is connected via non-isolated RS-485 or input/output power to a device that has a higher voltage potential ground. Multi-point grounding of devices in a current loop is generally best avoided. Ground potentials are often unequal because of different electrical noise, ground path resistances, and poor initial power rail installation.

A ground loop can occur in a single-point grounded system as well. Consider a system in which insulated twisted pair wires are not used, such as the one illustrated in Figure 2. Any electrical noise picked up by the ground wire, such as stray magnetic fields or 50/60 Hz AC power supply noise, may be injected onto the current loop and result in an unpredictable signal. This type of ground loop is most often caused by improper pathing and the lack of shielded twisted pair wire.

FIGURE 2. Ground-to-Signal Wire Current



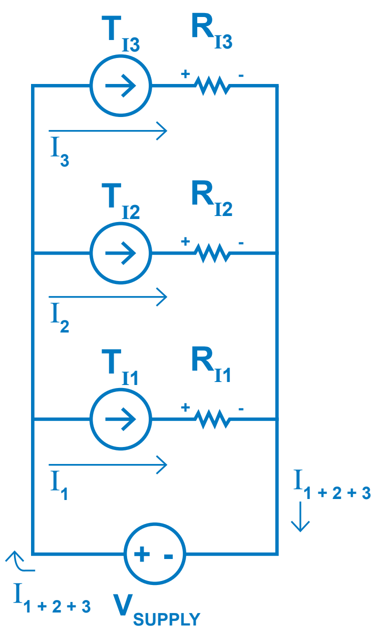


FIGURE 3. Correct Wiring

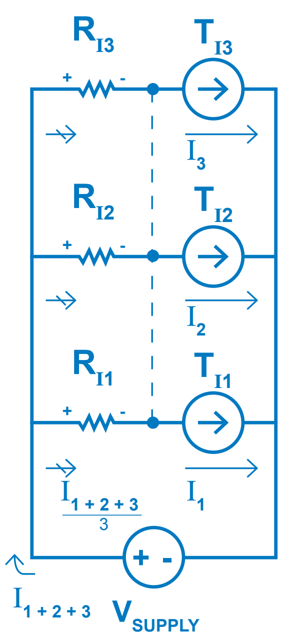


FIGURE 4. Improper Wiring

NON-ISOLATED COMMONS

Figure 3 shows a properly wired current loop and Figure 4 an improperly wired current loop. In Figure 3, the voltage potential supplied by the power supply causes a current flow to each of the three parallel transmitters. This current is used to produce a 4-20 mA current signal which is sent along to local displays which show the process variable.

In Figure 4, the devices have been wired haphazardly because, in a series electrical circuit, the order of devices does not normally matter. However, a node has been created on a shared common of a multi-input device, connecting the current signals. This results in the process signal currents mixing and being averaged out, causing all of the displays to show the same value. These images make this type of issue seem trivial to repair: simply remove the additional junction from the circuit. However, when complex networks of equipment experience this very same issue, the solution is not always quite as intuitive.

Problems like this are most commonly caused by the inclusion of non-isolated multi-input devices such as low cost PLCs. Because the device has multiple physical current inputs, an installer might make the assumption that each input is isolated. However, if these inputs are internally connected, the current signals will merge causing the current to average out before continuing through the circuit. This problem can also be caused by improper wiring of three wire devices or complex multi-loop networks.

SYMPTOMS

Because of the nature of signal connection problems and the unique variables present in industrial facilities, the symptoms caused by these problems are going to also be unique. Nonetheless, there are some general cues that can be looked for if you suspect that you are experiencing one of these issues with your existing network.

1. UNPREDICTABLE 4-20 MA SIGNAL FLUCTUATIONS

Unpredictable signal fluctuations are a sure sign that something is interfering with your current loop. This is likely the result of electrical noise or a ground loop.

2. ADDS TO, DETRACTS FROM, OR PUTS THE DISPLAY SIGNAL OUT OF RANGE

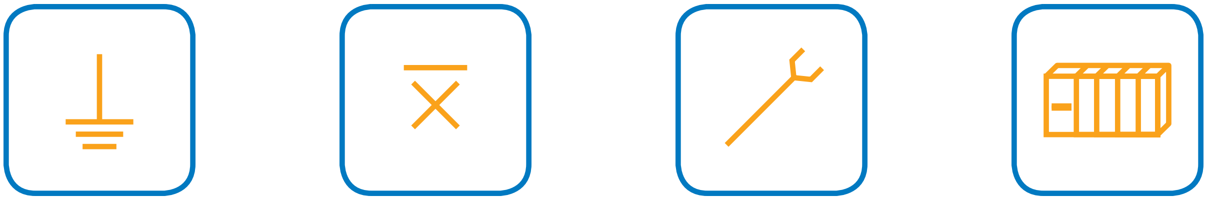
The signal may also experience an addition or subtraction by some value from one point in the loop to another. This addition or subtraction could even put the signal out of range of the devices designated to measure the signal.

3. SHARED COMMONS CAUSING SIGNAL AVERAGING

Problems with shared, non-isolated commons will commonly average the process signal causing the same value variable to be registered on devices which should be receiving different process variables.

4. PHYSICAL DAMAGE TO THE COMPONENTS

The most drastic (and thankfully rare) symptom of these problems is physical damage to the devices on the network. If the voltage differential between two grounds, for instance, happens to be substantial, it could overwhelm the sensitive signal electronics of the devices such as the signal inputs and outputs. Damage to higher-level electronics such as power supplies and relays is exceedingly rare, due to their ability to withstand very high voltage potentials.



A ground loop is the result of current flowing from one signal ground in a circuit to another signal ground at a different voltage potential.

Shared, non-isolated commons will cause signal averaging, which makes devices display the same value rather than different and unique values.

It is much easier to avoid ground loops during installation and project planning than to diagnose and resolve them in the field after installation.

“Ground loops” are often blamed on issues related to shared signal return (-) pins on multiple input/output devices (PLCs, multi-channel controllers, etc).

FIGURE 5. Basics to Remember

INSTALLATION BEST PRACTICES

As mentioned previously, the best way to repair ground loops is to avoid them in the first place. Multi-point grounding problems can be alleviated by only using a single-point ground. Any two grounding locations will have different voltage potentials, though the severity of this differential is a matter of the environment in which they are located. Whenever possible, use floating (non-grounded) devices. If there is a situation in which multiple devices in a network must be grounded (for safety reasons, etc.) make sure to carry the ground throughout the entire system, on shielded cable through conduit when possible.

All wire in the system should be shielded twisted pair in which both wires are used. All signals should be isolated whenever possible and within budget using devices with isolated inputs and outputs. Lastly, always be aware of non-isolated multi-loop devices and take extra care while planning your wiring. By following these few installation best practices whenever you install process control equipment, you can save yourself a lot of headache trying to diagnose and repair these issues in the future.

SUMMARY

Ground loops and non-isolated commons can be a nuisance for both industrial process control equipment installers and maintenance personnel, but they can be easily avoided by good planning and installing practices. Ground loops cause problems for systems when multiple devices are grounded at different locations that have different voltage potentials or when improperly wired, grounded devices experience noise injection from their ground connection. Non-isolated shared commons can become an issue when current paths cross and become unpredictable. These two signal connection problems can lead to unpredictable, incorrect, out of range, or averaged process signals and, in rare cases, damage to devices. This can all be avoided, not with the use of magical incantations, but by following standard installation best practices that can reduce or potentially eliminate the current quandary.

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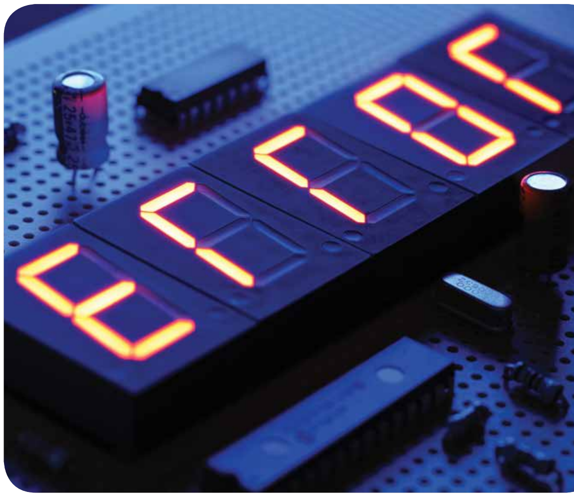

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