BASIC ELECTRONICS FOR FIELD MEASUREMENT

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Introduction

Measurement technicians deal with electronic flow computing and field devices daily. Most of the field instrumentation are tightly integrated in a complete system with interdependencies on several different electronic products. The larger the metering station, the more complex the system.

Basic field duties related to electronic instrumentation would include:

- installation
- calibration
- data collection
- configuration
- orifice plate changes
- communication checks
- maintenance

Some of the basic types of connections and measurements include power as well as analog signals and digital signals going into and out of the device. Each of these play unique circuitry roles and require different knowledge of their intended operation.

Fluid Flow Analogy and Ohm's Law

Electricity has three components: voltage measured in volts (equivalent to pressure in a fluid piping system), resistance to the flow, measured in Ohms (equivalent to pipe roughness) and current, measured in amps (equivalent to the fluid (gallons of water)). Ohm's law is the mathematical relationship between voltage, current, and resistance. Given any two of these values you can calculate the third. The units of measure include V for voltage (Volts), I for current (Amps), R for resistance (Ohms Ω).

$$V = I \times R \quad \textit{Equation 1}$$

$$I = \frac{V}{R} \quad \textit{Equation 2}$$

$$R = \frac{V}{I} \quad \textit{Equation 3}$$

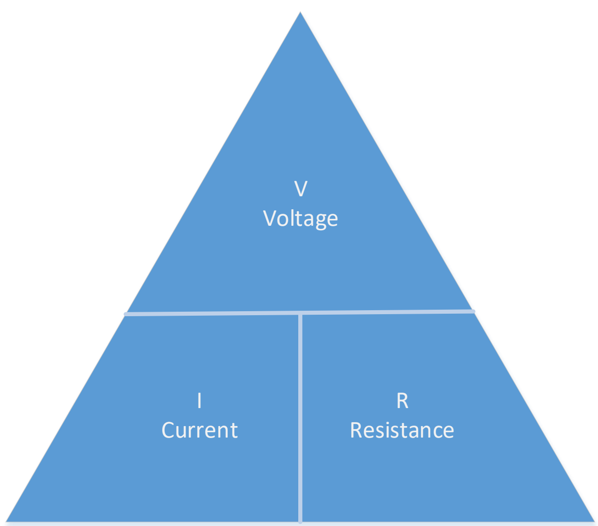

Figure 1 – Ohm's Law Graphic

The example below shows a circuit diagram. Included in this is a DC power source, a resistor, and a switch. When the switch is open, the current cannot flow as there is no path for it to flow along. When the switch closes, the circuit is complete which allows the current to flow. Using Ohm's law you can calculate the current.

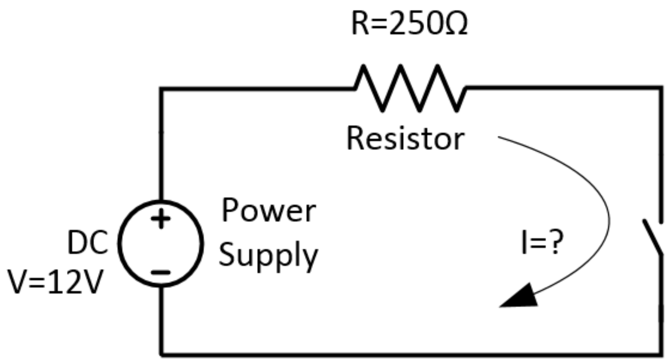

Figure 2 – Circuit Diagram

$I = \frac{V}{R}$ *Equation 2*

$I = \frac{12V}{250\Omega}$ *Equation 2*

$I = 0.048A$ *Equation 2*

Analog I/O

Analog I/O can take the form of current or voltage. Typically, 4 to 20 mA or 1 to 5 volts are generated, so their level is in proportion to or analogous to the level of signal being sensed. As a result, they are called analog signals. Depending on your application and equipment, one type could be better suited to your needs.

Most instrumentation (RTUs, PLCs and flow computers) and sensors (temperature transmitter, pressure transmitter and low meters) create outputs in the form of a transmitted signal that generates a current proportional to some level of measurement. The signal usually ranges from 4 mA to 20 mA. The 4 to 20 mA signal is typically scaled to represent some value to measure, where 4 mA represents the minimum (sometimes zero) and 20 mA the maximum (full scale). The graph below shows an example of this scaling in action for temperature. A transmitter calibrated in this manner would send 4 mA when the temperature is 0°C and 20 mA when the temperature is 100°C. Thus a 12 mA signal would represent the half way point and would indicate 50°C. A 8 mA signal would mean 25°C and 16 mA signal would mean 75°C.

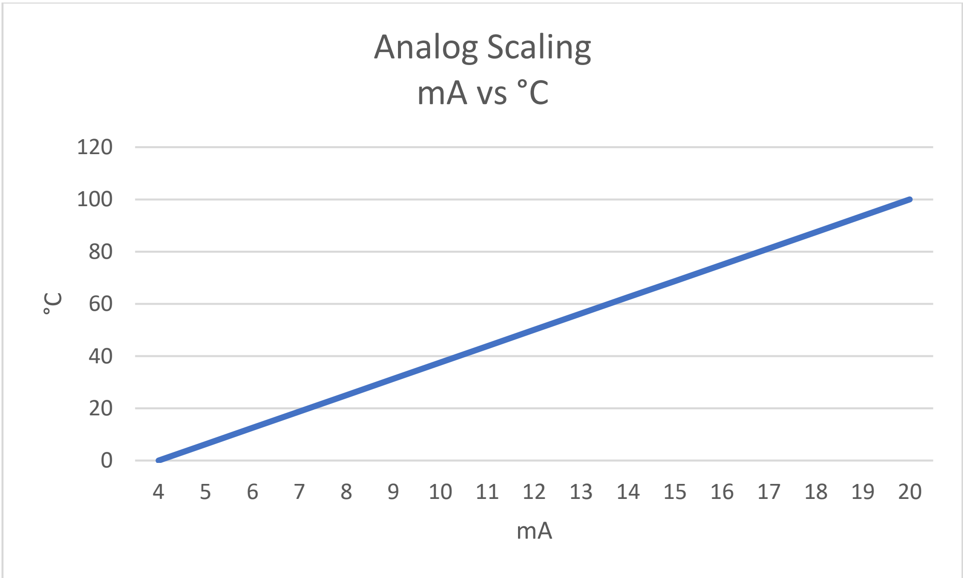

Figure 3 - mA vs °C

In some scenarios the analog signals could be required in voltage mode. If the field device does not support voltages for analog outputs, common practice is to convert this using a resistor. By installing a 250 Ohm resistor to a current based analog output the 4-20mA signal can be converted into a voltage that will range from 1 to 5 volts. This can be shown using Ohm's law.

$$R = 250\,\Omega$$
$$I_{min} = 4mA = 0.004\,A$$
$$I_{max} = 20mA = 0.02\,A$$
$$V = I \times R \text{ Equation 1}$$
$$V_{min} = I_{min} \times R$$

$$V_{min} = 0.004\,A \times 250\,\Omega$$
$$V_{min} = 1\,V$$
$$V_{max} = I_{\max} \times R$$
$$V_{max} = 0.02\,A \times 250\,\Omega$$
$$V_{max} = 5\,V$$

Digital I/O

Digital signals are signals that are either on or off, indicated by a voltage transition from a low to high or high to low state. Digital inputs are normally used as status type indicators that sense a voltage level transition, such as from a valve limit switch. Digital outputs are normally used to trigger an event like controlling odorant injection or when to take a sample with a gas sampler.

Frequency or Pulse Signals

Some signals are in the form of a series of pulses where the number of pulses in one second represent the value of the signal. For instance, ten pulses in one second could indicate ten volts or ten barrels of oil.

Turbine meters, PD, Coriolis meters, and Ultrasonic meters have a pulse or frequency type outputs. The pulse represents the flow rate of fluid and is used by the flow computer to calculate the flow at base conditions. Un-amplified pulse signals are usually small amplitude sine waves. Amplified device outputs are more than likely a square wave.

Resistance Temperature Devices – RTD

RTDs are commonly used in the industry to measure temperature. These devices use well researched material properties of metal to allow temperature to be measured. Platinum RTDs are typically used in the oil and gas industry. The resistance of the RTD changes in relation to temperature, which is interpreted into a temperature through an equation known as Callendar-Van Dusen. An example of this would be if PT100 RTD was at 100 Ohms it would mean the temperature is 0°C. Two, three, and four wire RTDs are available, with 4-wire being the most accurate and 2-wire being the least accurate.

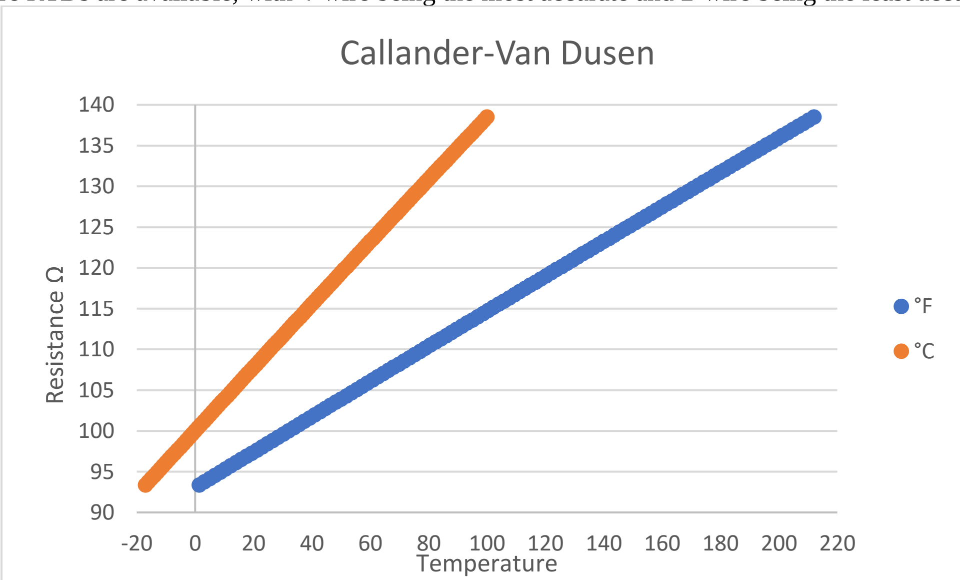

Figure 4 – Temperature vs Resistance

Batteries and Solar Panels
Typical field electronics use 12V or 24VDC. It's often preferable to use products which can accept a range of input voltage such as 10.5-30VDC, which allow more flexibility in your power source.

Batteries are used in many field devices to provide power in remote locations or where it is cost prohibitive to install site power. Typically, field sites use 12V lead acid batteries. These types of batteries have been field tested for decades and have well known properties.

Along with a battery, your field device will likely need solar panels as well. Solar panels convert the sun's energy into electricity which is then used to charge the battery. Careful consideration needs to be applied in sizing your solar panel and battery system. Factors to consider are the power draw of your field device, the size of the battery, and solar panel rating. Solar insolation is the typical amount of sun power available based on your distance from the equator and other geographical and environmental factors. In North America, you will always face the solar panel true south, not magnetic south, to capture the most energy from the sun. Also, you will need to find the ideal angle based upon your latitude, which can be looked up in widely available tables. Another item to consider is that you will need a solar charge controller, which takes the output from the solar panel and uses it to charge the battery in a proper manner which ensures safety and long battery life. Some new to the market devices even include lithium type batteries which enable autonomous power. These do not need to be charged which allow for easier installation, less maintenance, and reduced theft or vandalism risk.

Latitude	Installation Angle
0 to 4°	10° from horizontal
5 to 20°	Add 5° from the local latitude
21 to 45°	Add 10° from the local latitude
46 to 65°	Add 15° from the local latitude
66 to 75°	80° from horizontal

Figure 5 – Solar Panel Tilt Angle

Relays
Relays are a type of magnetically operated switch. A wetting voltage usually DC is applied to the coil windings which produce a magnetic field used to open or close the relay switch. Solid state relays also exist which do not rely on mechanical devices to switch but instead use electronics to operate. Relay terminals are referred to as "Normally Open", or "Normally Closed". Relays can be used to turn on or off different field devices such as: solenoid valves, gas samplers, and radios.

Communication Port
Communications are digital in nature because they carry the binary information needed for data transfer. While there are many different hardware formats for carrying data serial communications, RS232 and RS485, are still the most common device interface today in the oil and gas industry.

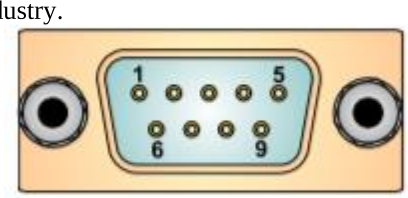

Figure 6 – Typical DB9 Serial Connector

Ethernet connectivity is also used for operations involving flow computers, most RTUs, gas chromatographs (GCs), and gas ultrasonic meters.

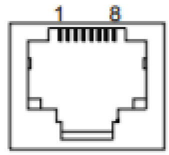

Figure 7 – Ethernet RJ-45 Connector

Wireless communications are a recent development that allows field devices to communicate with each other. One advantage of wireless communication is that some operations can be performed on the field devices without requiring entrance to potentially hazardous areas or opening of field enclosures. Another advantage is that they can simplify and reduce the cost of installation since trenching or cables are not required.

Communication Protocols

A protocol is a method of sending digital voltage transitions that are designed to transmit information. Morse code used in telegraph messages is an example of an early protocol. The de facto standard for flow computer protocol is MODBUS, (developed by Modicon) or ASCII (developed by EIA). All major vendors offer some variation of MODBUS. Various other protocols exist; however, many protocols are proprietary to the products' vendor.

Area Classifications

If the equipment is installed in a hazardous area where gas or liquid hydrocarbons may be present, it must meet certain safety requirements. In the Americas, UL, FM, or CSA hazardous area type ratings are required, which are specific by Class, Division, and Group. These are to ensure that the electronic devices do not excessively contribute to creating a more dangerous situation when installed in a hazardous area.

Conclusion

As measurement devices and techniques change, so must the skill level of the technician or engineer. Training is a necessity and not a luxury in order to keep up with new products and best practices in the industry.   Technicians must maintain a sound knowledge of the device's operations, along with a thorough understanding of basic electronics, as related to liquid hydrocarbon and gas control operations.