BASIC ELECTRONICS FOR FIELD MEASUREMENT

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INTRODUCTION

Electronics have worked their way into every aspect of our lives today. This fact is especially true in the oil and gas industry. With modern electronics it has become easier to attain accurate measurement and automated controls using electronic systems. These devices have become increasingly capable and affordable cementing their use in nearly every company regardless of size. The field measurement personnel must have a basic understanding of electrical principles to be effective in their positions.

This paper will focus on the use of electric circuits that apply to the devices used in the oil and gas industry.

BASICS

Electricity is made-up, in part by electrons and protons. Electrons have a negative charge and protons have a positive charge. Electrons repel each other, protons repel each other, but electrons and protons are attracted to each other. The heart of all this is the electron movement. This electron movement is enabled by electric circuits.

There exists what are called Alternating Current (AC) circuits, and Direct Current (DC) circuits. An in depth discussion of these topics and the differences between them are out of the scope of this document. Only DC circuits will be discussed.

There are three elements always present in an operating electric circuit are:

Current. A progressive movement of free electrons along a wire or other conductor. Current is expressed in Amperes or Amps.

Electromotive Force. This is also known as voltage. This is the force that pushes or pulls electrons (current) through the circuit. Voltage is expressed in Volts

Resistance. Any opposing effect that hinders free-electron progress (current flow) through wires when an electromotive force (voltage source) is attempting to produce a current in the circuit. Resistance is expressed in Ohms or (Ω)

The simplest of circuits consists of the following:

1. A voltage Source, such as a battery.
2. A load, such as a light bulb.
3. Connecting wires.
4. Control device (switch).

Figure 1 shows a diagram of a simple circuit.

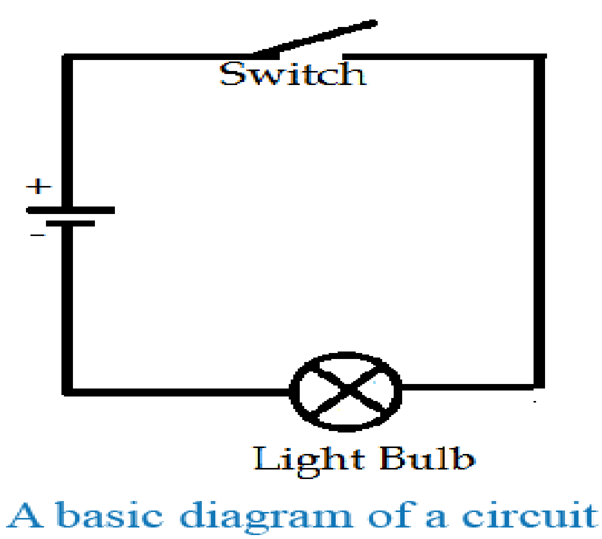

Figure 1. Simple Circuit

OHM'S LAW

One of Ohm's major contributions was the establishment of a definite relationship between voltage, current, and resistance in a closed (complete) circuit. Ohm stated this relationship as: Current is directly proportional to voltage in inversely proportional to resistance.

Ohm's law can be expressed mathematically as

$$I = E/R \qquad \text{(Equation 1)}$$

Where I = current (amps)
E = voltage (volts)
R = resistance (ohms, Ω)

Solving for voltage can be accomplished by multiplying both sides of the equation by R. This will create the equation

$$E = IR \qquad \text{(Equation 2)}$$

With this equation, if you divide by "I" the Ohm's law formula becomes

$$R=E/I \qquad \text{(Equation 3)}$$

These variations of the formula make it possible to determine current if voltage and resistance are known (equation 1), voltage if current and resistance are known (equation 2), and resistance if voltage and current are known. Figure 2 shows a method of helping to remember when to use each equation.

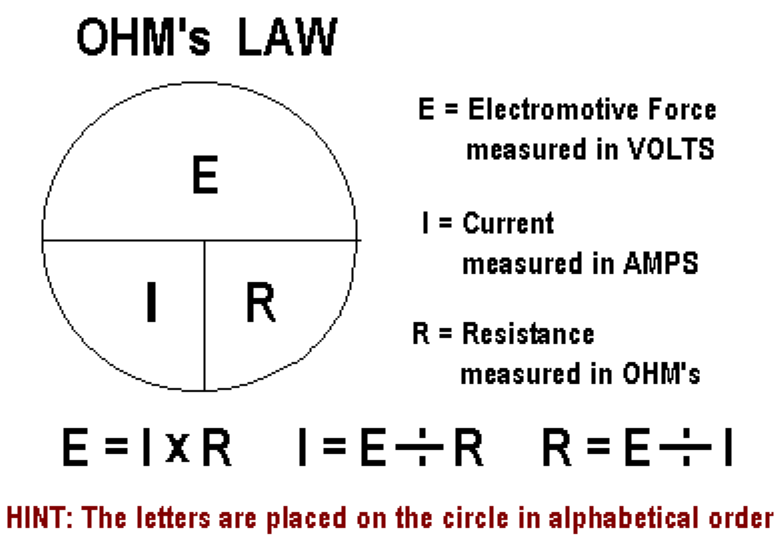

Figure 2. OHM's Law

CIRCUIT COMPONENTS AND BASIC CIRCUIT

Conductors are basically the wire or etching path on a circuit board that make the path for the circuit. Although there are no conductors with zero resistance, for practical purposes they are considered to be zero ohms. Silver, copper, and gold are considered some of the best conductors. Figure 3 shows the symbol for a conductor.

Insulators are the opposite of conductors. They have a very high resistance and are used to insulate. An example would be insulating between two conductors with a rubber coating or sleeve.

There may be a need to reduce the magnitude of current flow in a circuit to protect a device. This is accomplished by manufactured resistors. Figure 4 shows the symbol for a resistor.

A battery is a common source for creating a DC voltage. Power supplies also create voltages for DC circuits. Figure 5 shows a common symbol which is often used to symbolize a DC voltage source whether from a power supply or battery.

Figure 3. Conductor Symbol

Figure 4. Resistor Symbol

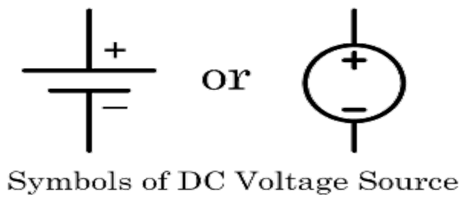

Figure 5. DC Voltage Source Symbols

Figure 6 shows a schematic diagram of a very basic circuit.

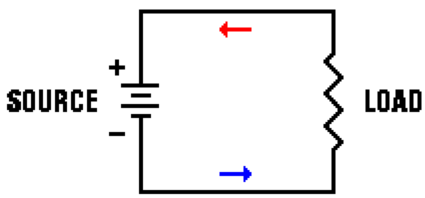

Figure 6. Schematic of a basic circuit

POWER
Voltage is the pressure which causes current through resistance. Power is a measure of the energy used per unit time. The unit of measure for power is the watt. When one amp of current passes through a one-ohm resistor, energy is dissipated at the rate of one watt. Figure 7 shows the power equations.

Power equations

$$P = IE \qquad P = \frac{E^2}{R} \qquad P = I^2R$$

Figure 7. P is power, E is voltage, I is current.

SERIES CIRCUITS
The circuit below in Figure 8 is known as a series circuit. In this circuit, the current is constant and the voltage drop across each resistor will equal the supply voltage.

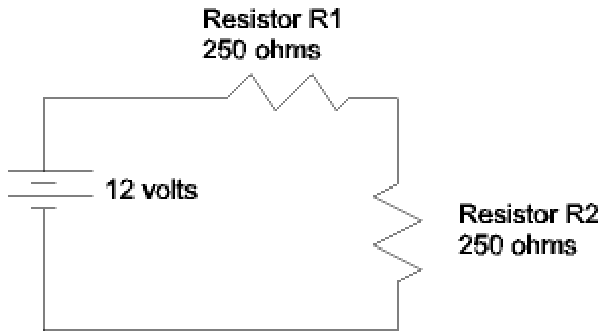

Figure 8. Series Circuit

Taking Ohm’s law, let’s determine the current.

I = E/R = 12v/500 ohms = .024 amps or 24 milliamps

In this case R will be the total resistance of R1 + R2. Since the current is constant is a series circuit, the resistance can be computed by using the equation:

E1 = I*R1 = .024 amps * 250 ohms = 6 volts.

Since R2 is the same resistance value it is equal to 6 volts. This confirms that the voltage drop of each resistor equals the supply voltage.

V supply = E1 + E2 = 6 volts + 6 volts = 12 volts.

PARALLEL CIRCUITS

The circuit in Figure 9 is known as a parallel circuit. In this circuit, the voltage is constant and the total current is equal the sum of currents in each branch. The total resistance is not additive, but a reciprocal of the reciprocals. Figure 10 shows the formula.

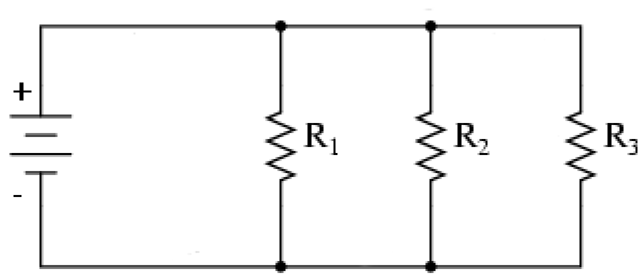

Figure 9. Parallel Circuit

$$R_{total} = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \ldots + \frac{1}{R_n}}$$

Figure 10. Parallel Resistance Formula

If the supply voltage is 12 volts then there will be 12 volts across R1, R2 and R3. The current will be calculated per branch and will vary depending on the value of the resistors. Assuming R1 is 100 ohms, R2 is 10000 (10K) ohms and R3 is 25K ohms, the current for each leg will utilize Equation 1.

To compute the current for the each branch:

$I1 = 12/100 = .12$ amps or 120 milliamps
$I2 = 12/10000 = 1.2$ milliamps
$I3 = 12/25000 = .48$ milliamps

So the total current is:

$I1 + I2 + I3 = .12 + .0012 + .00048 = 121.68$ milliamps.

Using the resistance formula in Figure 10, the total resistance is 98.62 ohms. As a rule, the total resistance in a parallel circuit will be less the smallest value resistor.

PRACTICAL APPLICATIONS

BATTERIES

One of the most common batteries is the wet cell, consisting of a mixture of water and acid. Automobiles use this type of battery. Generally, a lead acid gel cell is what is used for electronic devices in the oil and gas industry. This type of cell uses an acid paste or gel. Individual lead acid cells make up a battery. The cells have a nominal 2.1 volt output. A 12 volt battery would have six cells, providing a nominal output of 12.6 volts.

The capacity of a battery is rated in discharge current for a specific time period, 8 amp hours for example. This means the battery should be able to deliver one amp for 8 hours. The amp hour capacity is increased by adding more cells in parallel. When battery cells are wired in series the voltage increases. When wired in parallel, the current, or capacity increases. If 6 2.1 volt cells in series provide 12.6 volts at 8 amp hours, then adding 6 more cells in parallel would double it to 16 amp hours but the output voltage would remain the same. To summarize, cells wired in series, increases voltage, cells wired in parallel increase capacity.

BATTERY CHARGING

The most commonly used charging method is called Float Charging. This means the charger, battery, and1loads are tied together and the voltage floats. The charging source should put out about 15 volts for a 12 volt battery.

When using solar as a charging source field personnel often under estimate how much charging capacity will be needed on installation, and will find later in the life of the measurement station that the charging capability is not enough to keep the battery charged and the end devices powered. This is caused by battery degradation, temperature changes, and a lack of sun exposure. These interruptions can often times be avoided by properly calculating the amount of solar and battery needed.

ANALOG SIGNALS

Many field devices such as pressure or temperature transmitters just to name a couple use analog signals. Transmitters that use an analog signal take the measurement and convert it to a current representing the value the transmitter was reading. The most commonly used signal is a 4-20ma signal. There are many different signal types but all use the same principle of operation. For example, a pressure transmitter with a 100 PSIG (Pounds per Square Inch Gauge) device will output 4 milliamps at 0 PSIG and 20 milliamps at 100 PSIG.

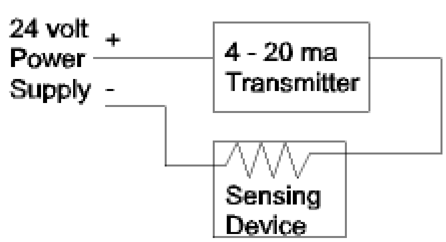

Figure 11. 4-20ma transmitter

Most RTU's analog inputs are for a two wire input and are labeled with a + and – symbol. This can often be misleading causing an improper installation and unnecessary frustration. Generally the 4-20ma transmitter will be powered by an external power source that will be connected to the positive side of the transmitter and the negative (signal return) side will land on the RTU's analog input positive terminal. The negative side of the RTU"s analog input should be returned to ground if not done so internally. See figure 11 for an illustration.

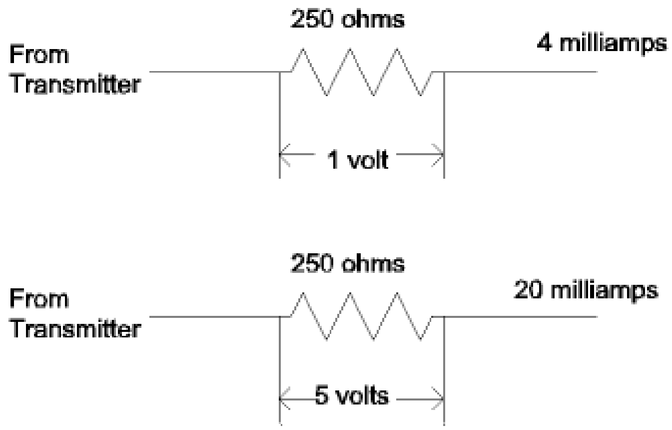

Figure 12. 4-20 read as 1-5 volt

Figure 12 shows how a 4-20ma signal can be translated by the RTU to a 1-5 VDC signal utilizing a series circuit. The 250 ohm resistor converts the 4 – 20 ma signal to a 1-5 VDC signal since most analog inputs actually read a 1-5 VDC input. Ohms law helps us see this. See figure 12.

$E = IR = .004 * 250 = 1$ volt. $.020 * 250 = 5$ volts

Analog signals are often times used as an output from a RTU to control something like a current to pressure transducer (I/P) for valve control. Most units like this will take a 4-20ma signal and turn it into pneumatic pressure that in turn controls valve positioning. Aside from being used for valve control analog output signals have many uses and can be used any time you need to communicate a variable from within your RTU.

Highway Addressable Remote Transducer (HART) protocol is another form of analog signals. HART protocol provides more than just an analog signal it can also provide multiple variables and diagnostics information from a transmitter. The HART protocol does this in two different ways. The first being a point to point mode when only a single transmitter is used this allows the HART transmitter to utilize the 4-20ma signal for the primary variable and overlay the 4-20ma with digital signals that communicate the other variables and diagnostics to the RTU. The second possible way is to use HART in a multidrop mode which allows the user to use multiple transmitters on a single wire pair and input on an RTU. When in multidrop mode the 4-20ma signal is set to a fixed value of 4ma and all variables and diagnostics are transmitted digitally. One convenience factor of HART is the ability to add more transmitters when IO capability is limited.

Analog signals whether it is an input or an output should be calibrated to ensure accuracy. Technicians should have a certified device that can output the signal type. There are many devices on the market today that combine a loop calibrator within a multi meter. These devices will reduce cost and the number of devices a technician must carry in order to do the job.

DIGITAL SIGNALS

Digital signals are often times thought of as a simple on or off switch; while this may be true digital signals have a large variety of uses and come in different signal types. The most commonly used are the standard digital input or output and pulse input or output.

Digital inputs and outputs have two states off and on much like a switch. Digital inputs achieve the desired high or low state by sensing voltage. This requires some sort of switch that when closed sends voltage to the RTU to sense a high signal and when open connects the input to ground to read a low signal state. In measurement and control applications the digital input can be used for various functions for indicating a status or command to the RTU for example an Emergency Shutdown button may be a digital input that when pressed; the RTU will read a high voltage and then trigger a programed response of shutting a station down. Digital outputs are much the same as inputs they act as the switch to turn something on or off such as a strobe light or valve. Outputs may need to utilize a relay coil to control more complex items.

Digital pulse inputs are generally used to transmit a flow rate to a flow computer from a turbine, ultrasonic, or Coriolis meter. These meters will sometimes employ the use of a preamp to change the signal from a small amplitude sine wave to a square wave that can be read by the flow computer. Newer technology has brought forth flow computers that can use dual pulse fidelity. This takes two pulse inputs from a meter and checks them against each other to provide greater measurement accuracy. Pulse outputs from a RTU or flow computer are basically the same as what may come from a flow meter and can be used for various functions such as stroking a sampler or for the accretion of a barrel totalizer.

Digital inputs and outputs often use what is referred to as an “open collector” these signals often require a pull up resistor to pull the voltage up towards the power supply voltage the resistor is connected too. Many RTU’s may come with a software selectable pullup resistor or require a jumper to be moved to activate the pull up resistor while others may require you to install an external resistor.

CONCLUSION

The oil and gas industry has made significant technological advances over the years and more so today than ever understanding basic electrical principles is crucial to every measurement technician. The industry will see a large majority of the most experienced personnel retire in the next few years leaving a gap of knowledge with the next generation of field technicians. While this short paper cannot fill that knowledge gap I hope it has given you a small insight into the vast world of electronics our industry has delved into, and will inspire you to dig deeper and learn more about this very important topic that is now at the core of our industry.