INTRODUCTION

The Natural Gas Industry is utilizing electronic devices in many different and diverse areas. One of the areas that has seen a rapidly growing usage of Electronics is Gas Measurement. Thus many Gas Measurement Technicians have been forced to take on the responsibility of installing and operating Electronic Flow Measurement (EFM) devices with little or no background in Electronics. It is hoped, therefore, that this paper will supply a broad brushed overview of electronics basics and how they are utilized in today’s increasingly technical world. There are references to established formulas and relationships as well as a discussion on some state-of-the-art technology. The latter is often short-changed in these types of presentations and it seemed a good idea to hit some of these basics, too. Perhaps the discussion herein will prove at least informative to those who have limited exposure to computer technology. This understanding is more and more vital to the successful implementation of computerized measurement and automation systems in our Natural Gas Industry.

A FEW OF THE BASICS

All electric circuits will have at least four things; a source (...of power), a load (light bulb, motor, etc.), a controlling device (a switch, a relay, etc.), and connecting wires (aka: conductors).

The source varies from circuit to circuit in that the power may be provided by a battery, an AC wall outlet or a relay that may have closed completing a circuit that uses an alternate power source like a solar panel or another battery.

About the simplest circuits in common use today are a flashlight and a household table lamp. These circuits can be illustrated by using appropriate symbols and drawing a 'schematic'. A schematic is, basically, a road map for voltage (signal) path through a given circuit. For your convenience, three simple schematics are included in Figure 1, below.

The difference in these three circuits is the supply and the load. Figure 1-A is a simple flashlight circuit that utilizes DC ‘source’ voltage from a battery. Figure 1-B is a household table lamp that gets its ‘source’ voltage from an AC wall outlet. The actual lamp; often referred to as light bulb, is considered the ‘load’. The switch controls the presence or absence of supply voltage. The ‘components’ of this circuit are connected by wire. In Figure 1-C the load is different. Instead of a lamp symbol, another common symbol is used to represent the ‘load’. This symbol represents a resistor. This symbol is quite often used when referring to a ‘load’. A load could be referred to as a device that resists the free flow of electrical current through a circuit.

Current is the name associated with the rate of flow of electrons through a conductor. In Figure 1 all components of each circuit is considered a conductor, even the resistor. Electrons do flow through a resistor (or load) just not as freely, perhaps as through a straight piece of wire.

To recap a bit, power is provided by the ‘source’. This power is supplied in two forms — voltage and current. In fact, the standard formula for calculating power in a DC circuit is $P = I \times E$ where $P$ is Power expressed in watts, $I$ is current expressed in amps and $E$ is voltage expressed in volts.
To appreciate the difference between voltage and current only requires some thought about what happens when a flashlight dims over time. The battery can be taken out and the voltage measured. The voltage may still read 6 volts (in a 6 volt lantern) but it simply cannot provide enough current when in the circuit to light the lamp as brightly. The same symptom often can be seen in a car battery when hard starting problems occur. The battery’s capacity to provide adequate ‘current’ is reduced, but the measured voltage may well remain normal — at least until the load is applied (or the circuit is completed).

**OHM’S LAW**

Sometime before 1854, Mr. George S. Ohm discovered a relationship between the movement of electrons through an electrical circuit, the voltage drop across a load, and the amount of resistance of the load(s) in a circuit. To verbalize this relationship would result in the following:

\[
E = I \times R \\
I = E / R \\
R = E / I
\]

\(E\) = Voltage (volts)  
\(I\) = Current (amperes)  
\(R\) = Resistance (ohms)

The value of current that will flow in a circuit will be directly affected by the value of the voltage but will be inversely affected by the value of the resistance.

Determining what this means is easier if we look at the mathematics that this statement is trying to describe.

Simply put, if any two of the three values are known, a calculation can be done to determine the value of the third.

**KIRCHHOFF’S VOLTAGE LAW**

Another law that is important when analyzing circuits was founded by Gustav Kirchhoff. This law could be stated as:

The sum of the voltage drops around a circuit will equal the source voltage.

To appreciate and understand this law it is important to view examples of some circuits that illustrate how Kirchhoff’s Law can be used to analyze a problem (see Figure 2).

Both circuits in Figure 2 use a DC source voltage. Figure 2-A is a schematic illustrating a series circuit. This means that current is forced through both loads to complete the current flow through the circuit. Assume that \(R_1\) and \(R_2\) are both the same, and the switch is closed. By using Kirchhoff’s Law we know the voltage measured across each resistor will be one half of the total supply voltage. If the supply voltage were 12 volts then the voltage measured across each resistor will equal 6 volts. If \(R_1\) is double the size of \(R_2\), then the voltage measure across \(R_1\) will be twice the voltage measured across \(R_2\). For the mathematicians this can be determined as follows:

\[\text{Voltage } R_1 + \text{Voltage } R_2 = 12 \text{ Volts or,} \]
\[(2 \times \text{Voltage } R_2) + \text{Voltage } R_2 = 12 \text{ Volts or,} \]
\[3 \times \text{Voltage } R_2 = 12 \text{ Volts or,} \]
\[\text{Voltage } R_2 = 12/3 \text{ volts or,} \]
\[\text{Voltage } R_2 = 4 \text{ Volts so if} \]
\[\text{Voltage } R_1 + \text{Voltage } R_2 = 12 \text{ Volts then} \]
\[12 \text{ Volts - Voltage } R_2 = \text{Voltage } R_1 \text{ or,} \]
\[12 \text{ Volts - 4 Volts = 8 Volts = Voltage } R_1 \]
This does not mean that all of the current will go through the lowest resistance, just most of it. Another way of stating this relationship follows:

In parallel circuits, currents will be inversely proportional to the resistance values.

Calculating the total resistance of the parallel resistor circuit in Figure 2-B is accomplished by inputting various values for $R_1$ and $R_2$ in the following formula:

$$\frac{R_1 + R_2}{R_1 \cdot R_2} = \text{Effective Resistance (in ohms)}$$

By applying Ohm’s Law other values can be determined as in the series circuit.

Along these lines, it is important to note that when a single power source is utilized for multiple functions, there is a point at which the current requirements can exceed the current available. The result may be a total or partial failure of some or all of the equipment using this single power source. A decision must then be made as to the addition of another power source, a reduction of the equipment using the power source, or a redesign of the original power source.

Both Ohm’s Law and Kirchhoff’s Law are applicable to AC and DC circuits. There are some unique characteristics of AC circuits that are beyond the scope of this paper but would be good for the technician to be familiar with. Excellent references for researching AC circuits are detailed in the bibliography at the end of this document.

**APPLICATION BASICS**

In a high percentage of new measurement/automation installations, if not most, the electronics that are used require a DC supply voltage. Often this voltage is converted to DC from an AC supply. Sometimes there is simply no connection to any external power and a unit is self-contained with its own internal batteries and integral power source for recharging them.

Digital circuits include all the new microprocessor and computer type hardware. These devices typically require DC voltages for a source. Often these same devices use so little power especially when CMOS is used — that the power supplies are relatively low power, too.

This power consideration is a real concern especially when commercial power is unavailable. This means that a remotely located product must be self sufficient with power reliably provided for. If a product requires a lot of power, multiple batteries may be necessary. Sometimes this may mean quantities of solar panels are necessary, too. Aside from running up the price per installation, more maintenance may be required compared with the site that does not need so much power. This is especially true when audit data is at risk. If a device requires more power, the ability of this device to sustain normal operation in the event of a power source failure is harder to provide for than the lower power alternative.

At the risk of oversimplifying, digital circuits utilize dual, in-line, pin-out (DIP) configurations often referred to as IC’s (for Integrated Circuit). They almost always have a DC power supply input, a ground pin, and several input and output pins. Digital circuits involve the changing of states on input lines and a corresponding changing of states on output lines. Changing states refers to the voltage level that would be measured on the pin in question. Basically, a pin that is low (0 volts) changes states when it goes high (5 volts). If this happens slowly enough, this change of state can be monitored with a voltmeter. In some hardware configurations, this state change happens so fast that a voltmeter is useless except to check the power supply voltage. Often a logic probe or an oscilloscope or a data analyzer is used to examine output voltage (logic) levels.

Please note that the power supply referred to as 5 volts could as easily have been 12 volts or even 24 volts. Circuits are designed to detect the presence or absence of this voltage on an input and respond in a predetermined (logical) fashion and vary some output. In the case of a flow computer for example, the presence of a DP high limit alarm may activate logic that says to highlight a particular display. This logic is determined when a programmer writes a computer program.

**SOFTWARE — MAN OR MACHINE?**

The output generated from a corresponding input is generally controlled by a program. Microprocessors have basic memory locations built into them that point to specific memory locations for the microprocessor to find its next instruction. After the microprocessor executes this instruction, it may well continue to execute other instructions that combine to make a whole program. At this level this programming is called machine-level. At this level, instructions are very machine specific and depend on the make, model, and internal makeup of the microprocessor. It takes significant time when working directly with a microprocessor to learn its complete instruction set and how to efficiently program it. As well, it takes a long time to program in machine level.

One level above machine level programming is called assembly language. Often, thoughts and concepts as to programming technique can be discussed with other programmers using the different assembly language commands without referring to the actual bits and bytes commonly used in machine level. Still, this is more complex than programming techniques that are common today, more complex in the sense that a lot of instructions are required to effect a simple multiplication function, perhaps.

Higher level languages are increasingly the accepted method for implementing various programs to accomplish
various tasks. While a basis can be found in machine level code for most products, the high level language offers a much faster and easily transported (only when compared with lower level programming techniques) program. Also, once trained in a higher level programming language, a programmer should be able to understand other programmers’ code if it is written in the same language. Popular higher level programming languages includes the various types of BASIC, C, FORTRAN, PASCAL, etc.

The field technician who uses state-of-the-art products such as a flow computer or a PLC frequently interfaces with the product using a terminal. As frequently, a programmer has developed a menu with a list of options for the technician to choose from when working with the terminal. This menu selection technique is the same that many of us encounter when taking money from our bank accounts from a money machine (ATM). This is not programming. This is answering questions that the programmer had about what the user wants to do with the product. In the case of a flow computer:

Select from the following list of options:

1) Collect Data
2) Calibrate Flow Computer
3) Enter Monitor Mode

Depending on the user response to a given menu, a new menu may come up or specific instructions detailing the next user action may be displayed. These menus can be abbreviated and hard for a user to understand. An easy to understand menu can mean the difference between a user’s success or failure with a system. A good menu system can go a long way toward reducing user training time by spelling out the available options and instructions.

TROUBLESHOOTING TODAY

Troubleshooting a given product in the field necessarily involves a level of product knowledge, certainly. Surprisingly however, a significant amount of problems is found without ever lifting a screwdriver or a test meter.

1) Visual Inspection — This technique is often not concentrated on or sometimes not used at all. Many problems can be found by simply looking at an installation and determining if all is proper or if something is out of place.

A visual inspection of a measurement site, for example, would include:

- Looking for proper plumbing connections (i.e. high side of orifice to high side of transducer/transmitter). Inspection for proper wiring — no loose or dangling wires that could interfere with normal operation. Are wires terminated according to manufacturer’s recommendations?

2) Check Power Sources/Supplies — Perhaps the most common problem with all things electrical or electronic is related to the power supply. This has been the way of things since electricity has been used. For this reason, a field technician should always check for proper power supply voltages. The best procedure is one that checks each instrument requiring power and ensures that the power is at the proper level. When a site incorporates several different products connected together, it is especially important to determine that each product has the required power available. The alternative may have the effect of taking the whole system down and lead even a good technician on a wild goose chase including blaming the wrong product or component for the failure. It’s often a matter of time and money — if a technician enjoys implementing the same repair over and over again, the symptom will get good service and the problem will persist.

3) Signals — Next to the power supply, perhaps the most common problem can be traced to a signal problem. This is to say that the proper transmitter signal, for example, is not getting to its proper destination. This could be due to a broken wire or a connection that could not be made due to broken wire insulation or a stray strand of wire. More simply, there could be an open connection or a shorted connection.

Another area where signals could be a problem has to do with the signal being available at a certain point when it is expected. This is often referred to as timing. Since modern electronic technology often uses fractions of a second to accomplish routine functions, the timing is increasingly critical. Timing can be affected if changes are made to the system installation, for example. Changes
can be made in the routine configuration of a device that affect the timing. Of course, the technician following these procedures would have found this at the data review section, above.

In the measurement business it is important to note that this signal can certainly be a voltage and could be verified with a voltmeter, but a signal can also be pneumatic. A flow computer could be regularly sampling a transducer and if the pneumatic signal (pressure) is not properly applied to that transducer, results will vary and probably be incorrect.

4) Assuming that our technician has isolated a problem the most common procedure for servicing electronic devices now comes into play. This procedure is often referred to as R & R, removal of the failing component or board or module and replacement with another ‘non-failing’ component or board or module. NOTICE: If this replacement is not done according to the manufacturer recommended procedures other problems may be induced.

IN CONCLUSION

Because of a constantly changing technology, field technicians are asked to perform assignments ranging from simple to extremely delicate. This reliance on technicians keeps some companies very competitive and can be a significant burden on others. If a technician is required to work on sophisticated electronic equipment the facts and tips contained herein can be helpful, certainly. To maximize a technician’s productivity, it is important for his/her company to realize that training is a requirement — not a luxury.

To elaborate a bit, there are at least a dozen different flow computers available from various manufacturers. Each flow computer has characteristics that are unique to its design. The nuances and configuration options and recommended procedures may differ significantly. To assume that a technician who is proficient with one flow computer can easily and quickly become as proficient with another is a common mistake. For this reason, companies must spend additional funds on training for new devices. This training can be conducted in-house but must be done in accordance with manufacturer specific recommendations. In closing (and borrowing from another unknown author), if training seems expensive, consider the cost of ignorance.

BIBLIOGRAPHY


