What is ELECTRICITY?

Richard L. Howard, CPL, DHC, DHT, explains how electricity works so you can better understand electronic access control.

It was the ancient Greeks who first observed electricity. As noted in the book *Basic Electricity* by Van Valkenburgh, Nooger and Neville, Inc.: "...when amber (a fossilized resin) was rubbed with a cloth, it would attract bits of material such as dried leaves." Interestingly, it was an American founding father — Benjamin Franklin, whom we all know for his truly brilliant and study-worthy kite experiment — who coined the terms "positive" (the red wire in low-voltage DC work) and "negative" (the black wire in low-voltage DC work). He also used the term "battery" when experimenting with Leyden jars (see *Figure 1*). These glass jars produced electrical circuits by using an external high-voltage electric charge between electrical conductors on the inside and outside of the jars.

The experiments with Leyden jars were the basis for his conclusions about lightning, noting how they were inherently the same as his Leyden jar observations. Franklin also observed the phenomenon of how opposite charges attract and like charges repel each other, that the conservation of charge is a law of nature. All this occurred more than two decades before the American Revolution and 150 years before the discovery of the electron.

Regarding the electron, it is the construct used that allows us to understand electricity and predict electricity's behavior. The study of low-voltage (below 50V, according to the National Electrical Code) hardware and its successful implementation in your application is based on a basic understanding of electron theory. This article will provide an introductory understanding of electrons and help you understand why electricity behaves as it does.

Purpose of Electrified Hardware

Electrified hardware allows the user to enjoy functionality that may not be otherwise provided. Perhaps you need to allow hundreds of people to access a door, but handing out mechanical keys is impractical. Maybe you need an audit trail of who entered the door and when. Perhaps you need the ability to remotely control rights and privileges over an opening. There are countless ways electrified hardware serves the needs of the user and does so in ways mechanical hardware simply cannot. In fact, the more you study the owner's requirements for functionality of an opening, you'll usually find multiple ways that electrified hardware can accommodate these needs.

What Is Electricity?

In this section, I'll attempt to explain how electricity behaves. I'll frame this article using Ohm's law, which is expressed as E=IxR. Ohm's law is used constantly in low-voltage access control work to determine many things in a circuit, such as suitability of the chosen power supply or for understanding the relationship between voltage and current flow. Ohm's law just happens to be a handy way to construct the "flow" of writing this article. Following E=IxR seems an elegant way to speak about how electricity flows through a circuit. In the spirit of Ohm's law, let's start with the "E" in E=IxR and a little bit of background information.

Electricity is the movement of electrons through a conductor. Electrons flow because of attraction. Like poles — or charges — repel, and opposite poles — or charges — attract. This means electrons (which are negatively charged and therefore repelled by other electrons) flow through a conductor toward positive charges. In other words, electrons will always flow toward a place deficient in electrons (as that area carries a net positive charge). Now that we know what is happening inside the conductor, what impels these electrons to flow? To explain this, we need a power source.

Power Sources and Energy

A battery — a power source — made of special metals and chemicals can cause electrons to flow. The act of touching a wire to its two terminals will impel electrons to flow. These electrons will flow as the negatively charged electrons will now move toward the terminal that has a net positive charge. It's the interaction of these special metals and chemicals inside the battery that has the byproduct of exciting electrons to move. The flow of this movement, as defined earlier, is away from negative charges toward positive charges (aka, an area deficient in negative charge). But how does this work? As we said just now, it's the special metals and chemicals at work. But the underlying cause is the amount or value of "potential" between the negative and positive terminals (just envision a battery with the (-) and (+) symbols, as these are the terminals). The new term is "potential." If you lift a case of locksets from the floor up 1½' and you hold them there, there is now "potential" energy.

I like to think of the potential between different voltages by thinking of the following analogy: For an AAA 1.5V battery — such as one used in a computer mouse — I hold that case of locksets 1½' above the ground. To compare that potential to a greater potential like that of a 12V battery — such as one used in a car — I imagine holding that case of locksets 12' above the ground. In this mental example, I don't drop the locksets,

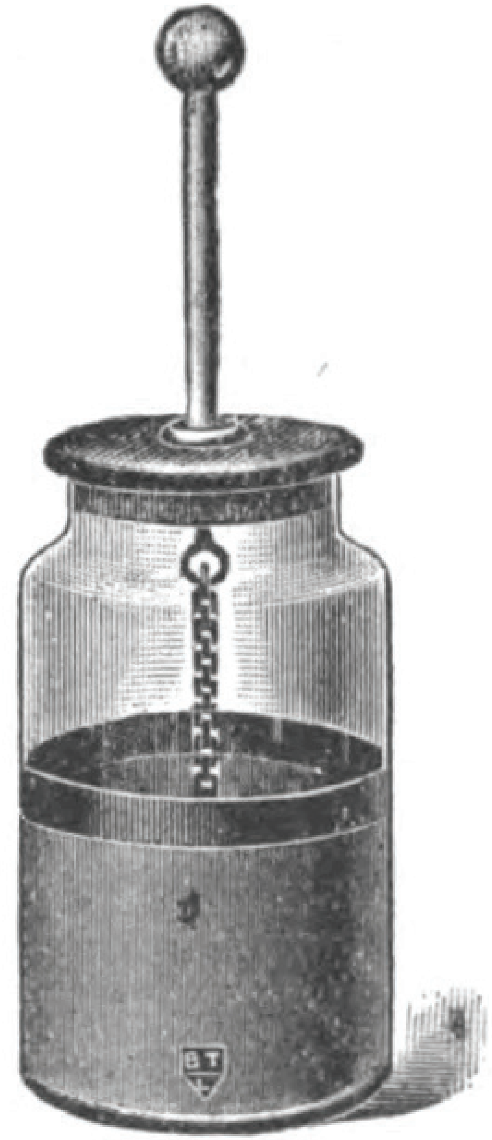

Figure 1. This is an example of a Leyden jar.

but use this mental picture to visualize and explain this term potential and the huge potential difference between 1.5V and 12V. The student will always imagine the crash of locksets to the floor released from 1½' and how much greater that crash is when the locksets are held and released from 12' in the air. No science backs this analogy, and it's simply a way to better grapple with understanding "potential."

In the battery, there's also "potential" energy. Potential is the difference between the value of the (-) and (+) charges at the terminals and "how much" difference there is. It's the conversion of this potential energy to another form of energy that impels

"The dangerous part of the circuit is the amperage, and with a high enough voltage, you will have a circuit that can be dangerous or even deadly."

electrons to flow. Consider the example of a wire connected from a terminal on the (-) battery to a lightbulb and back to the other terminal (+), which will cause the lightbulb to illuminate. To speak technically, we are transforming "potential" energy into an electron moving force, or "electromotive force," known as "EMF."

And herein lies our first breakthrough: The "potential" energy, or EMF, is measured in voltage. Named after Alessandro Volta (1745-1827), voltage is our first of three key components in understanding what electricity is, and this is the "E" in Ohm's law. "E" can also be expressed as "V," but "E" represents electromotive force, whereas "V" represents a scientist's last name. Therefore, we'll refer to voltage as "E." (Another example would be $E=mc^2$, where "E" stands for "energy" and does *not* stand for $Einstein=mc^2$).

We can prove this by applying the probes of our volt meter on each of the terminals of a battery. The readout/display of the voltmeter will tell us how many volts the battery is producing, and therefore we'll know how much "potential" energy the battery contains. Sticking your tongue on the terminals of a 9V battery will also give you an idea of the "potential" contained in the battery — or, at a minimum, whether or not the battery is "dead."

Flow of Electrons

There are many ways to impel electrons to flow. In our work, we impel electrons to flow in our low-voltage circuit by connecting our loads and switches, via the conductors to our power supply. This is done via power supplies (DC), transformers (AC) or batteries (DC). There are several additional ways to create power, such as friction, light, pressure, heat, chemicals and magnetism (magnetism, how transformers work, plays a large role in access control). But this knowledge is not required for our purposes.

Whenever a force of any kind causes motion, work is done, as stated in *Basic Electricity.* As an aside, the potential energy (measured in voltage) between the battery terminals is "work" when converted to EMF. Work is measured in watts, which is the rate work is done in an electrical circuit. To define watt further, 1 watt = 1 amp of current flowing as a result of applying 1 volt of potential energy.

So long as there is continuous potential energy being converted to EMF, current will continuously flow. The quantity of voltage (potential difference) supplied defines the resulting electrical profile of the circuit. This can be understood by re-introducing the formula E=IxR. Voltage is the "E" component. Recalling basic algebra, when the value of "E" changes, so will the values of "I" and "R." Basic algebra tells us that when voltage is increased, the greater the amount of current may flow — because "I" and 'R," yet to be defined, must also increase in some type of relationship between each other.

It's timely to mention here the requirement that all components (the power supply, loads and switches) be rated at the same voltage. The conductor must also be rated to handle the current flow). If you have components in your circuit rated at something other than the supplied voltage, the mismatched component will contend with too much or too little voltage or amperage, and the circuit won't work as anticipated. Said another way, supplying 24V to a 12V load will cause damage or at least a severe shortening of the life expectancy of the component. Supplying 12V to a 24V load will not permit the load to work correctly, if at all. As stated in *Basic Electricity*, "The value of the voltage determines how much current will flow."

Many pieces of equipment we use in access control are measured in milliamps, also known as 1/1000 of an amp. A Von Duprin 6210 requires 333 milliamps, or .333 of an amp to work at 24VDC. (The 12VDC version requires 600 milliamps or .600 of an amp. Studying E=IxR helps understand why lower voltages result in higher amperages.

The "I"

I have often heard the saying "It's not the volts that will kill you." This saying allows us to bring into our conversation the "I" in the E=IxR formula. As we know, "E" is voltage and voltage can be thought of as the amount of "push" that exists in a circuit. Having "push" is a required component in an electrical circuit, but without something to push, there is not much that the "push" can accomplish. What the voltage — or push — needs is something to push, and that is the "I" in the formula (also known as amperage, or current). If you have lots of push (voltage) and little current (amperage) to push, you will not have an effective circuit. If a fictional circuit had a million

volts but practically zero amps, there would be practically zero current. The dangerous part of the circuit is the amperage, and with a high enough voltage, you will have a circuit that can be dangerous or even deadly.

To prove this point, I have read that static electricity (think dragging your feet across the carpet and then touching a metal object in the middle of winter) can generate thousands of volts. But because there is practically zero amperage —therefore practically zero current, the effect is practically zero. Conversely, a car battery at a mere 12VDC has a small amount of "push." But when rated at 500 amps, under particular circumstances, it can certainly make you aware of the current, or worse. (Google "Vaporizing a Nail with a Car Battery.") Think about how E=IxR works, and you can understand how a large "E" with a small amount of "I" is very different than a small amount of "E" and a large amount of "I."

Resistance

As we have discussed, voltage is the potential difference of energy, and without a force, electrons will not flow. If we focus on this concept — that "electrons will not flow" without a force — it's a logical leap to conclude there must be something that stops that flow from happening. What is it? Current will only flow when there is a force that impels it to do so. When that force is removed, the current flow stops. What is the nature of this phenomenon that holds onto the electrons? This is the final component to explain in electricity, and that is the new term, "resistance." This leads us to the "R" in the formula E=IxR. "R" can be thought of as resistance and is measured in ohms. Ohm's law, named after German physicist Georg Ohm (1789-1854), is the name of our indispensable formula, E=IxR.

Resistance varies for different materials. Said another way, an item's ability to "conduct" is equal to how readily electrons can flow through it. Also related is the size (diameter) of the conductor, as a thicker conductor will provide more free electrons. In fact, resistance is proportional to diameter. A conductor's diameter will have a specific resistance at a specific length. If you double the diameter and keep the length constant, you will halve the resistance. Resistance is also proportional to a conductor's length. The resistance value of a 50' length of conductor is exactly half the resistance of a 100' length of the same diameter conductor. In our work, we deal with copper wire, as copper is a very good conductor. Resistance can be thought of as a conductor's reluctance to permit free-flowing electrons.

We can put together a working mental model of all three components in Ohm's law by agreeing that voltage (E) and its ability to push current (I) is based on the conductor's resistance (R) to allow the current to flow. As resistance goes up, amperage goes down. Conversely when amperage increases, resistance must decrease. This fact rests on the principle that "I" and "R" are proportional to each other, assuming voltage remains the same. Again, from Basic Electricity: "Current flow is caused by the voltage between two points and is limited by the resistance between two points."

Summary

In summary:

The basic unit of voltage is the "volt."

- measured in "volts," or "V"
- is the "E" in our formula
- is the electromotive force that is equal to the charge difference between (-) and (+)
- is equal to 1 joule per 1 coulomb

The basic unit of current is the "amp"

- measured in "amps" or "A"
- is the "I" in our formula
- is the amount of current (free electrons) that flows through a conductor from (-) towards (+)
- is equal to 1 coulomb flowing in 1 second

The basic unit of resistance is the "ohm"

- is measured in "ohms" or 'Ω'
- is the "R" in our formula
- is a conductor's nature to inhibit current or free electron flow
- is equal to 1 amp flowing from 1 volt

The direct relationship between voltage, current and resistance is absolute and immutable, and E=IxR, or just E=IR, can be equal to 1=1x1 because when 1 V causes 1 A of current flow, the resistance is 1Ω but can also be expressed as R=E/I or I=E/R.

May your work in electrified hardware be rewarding and profitable. Know that learning to master low-voltage work will set you apart from those you compete against who are not able to offer the same service. Finally, for further study, I suggest the book Basic Electricity by Van Valkenburgh and subscribing to Jim Pytel's YouTube channel "bigbadtech."

Richard Howard, AAADM, CFDAI, CPL, DHC, DHT, ICPL, IQP, has 30-plus years industry experience working in distribution specializing in hollow metal, wood doors and commercial hardware. An active member of both ALOA and DHI, he enjoys the ever-changing and challenging field of locksmithing.