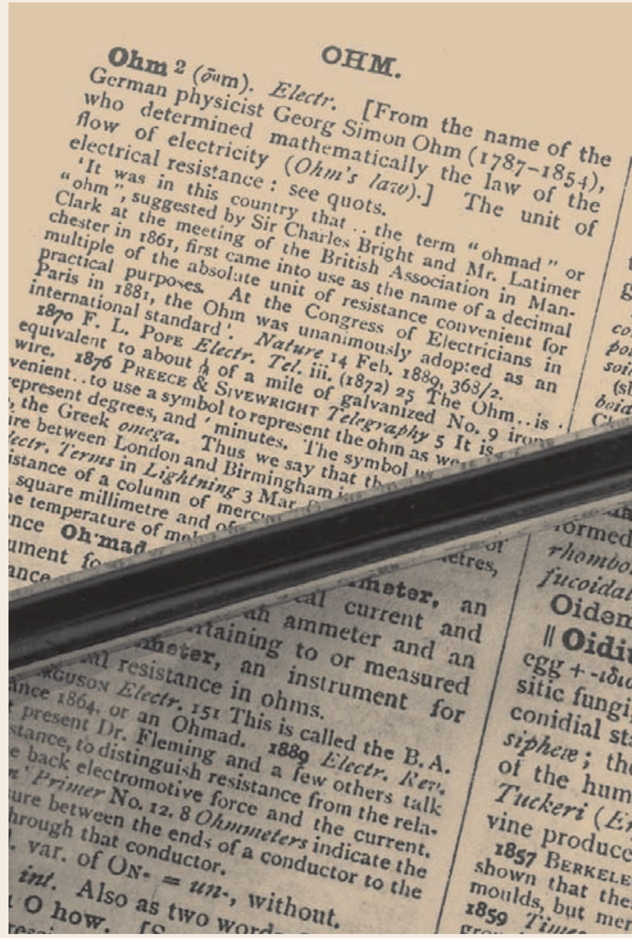
"Simon Says..."

Part Two

As we learned in Part One of this article (*Import Service*, June 2000), we owe Georg Simon Ohm a debt of gratitude for the electrical principles he published in 1827, which later came to be known as Ohm's Law. These principles explained in mathematical form the relationship of voltage (E), current (I) and resistance (R) in a simple circuit. Every scientist, engineer and technician since then has used Ohm's Law to understand, explain and design electrical circuits. Even kids in grade-school science classes are introduced to the concepts of how electricity works based on what 'Simon said.'

But as scientists got more interested in electricity and began to put it to work, they realized there were a few things left to understand about applying Ohm's Law in the real world. The scientists had no trouble conceiving of the idea of an electric lamp, at least on paper. All it took was a voltage source (a battery), a couple of wires and a lamp bulb. Connect the bulb to the terminals of the battery with the wires and current from the battery flowed through the lamp creating light, just like Simon said it would.

Then an enterprising German physicist named Gustav Robert Kirchhoff (1824-1887) appeared on the scientific scene. He agreed with what Simon said would happen when one lamp circuit was involved, no doubt about it. But Gus began to wonder about current and voltage in the more complex circuits that would be developed over time. Gus thought things could get a little complicated if two bulbs (lamp-loads) were connected to the same voltage source at the same time in a certain configuration. In other words, what would happen in a parallel circuit like the one shown in **Figure 1**, where there are two lamps instead of one?



In **Figure 1** *(page 31)*, there are two lamps connected in what is known as a parallel circuit because they are connected to the same two voltage-source and voltage-ground points. Both lamps are connected to the positive (voltage) side at TP1 (Test Point #1). Lamp 1 is connected to TP1 through switch S1. Lamp 1 is connected to the negative (ground) side at G102. Lamp 2 is connected to the negative (ground) side to G103 through switch S2. G102 and G103 are drawn separately in the schematic diagram but are actually connected to the same piece of metal.

Would what Simon said about the relationship of voltage, current and resistance in a simple circuit hold up in a parallel circuit arrangement? The problem is, Simon died when Gus was 30 years old, just about the time Gus was getting known in scientific circles for his work in physics. If Simon had lived longer, he might have said something about what happens to voltage, current and resistance in a parallel circuit. Gus decided to take up the slack and carry Simon's work a step further. After all, somebody had to explain how voltage, current and resistance work in a parallel circuit. Gus couldn't say 'let Simon do it,' because Simon was dead.

So Gus looked at **Figure 1** and thought and thought. 'Hmmm, two bulbs at the same time would work.' He could see that both would light up because current could flow through each lamp independently. Gus might have thought, 'I don't have the parts to make this circuit because they haven't been invented yet, but I can see it on paper, just like Simon did. A parallel circuit could work, but how do I prove it to other scientists? I already know they can be an ornery lot.'

Gus' Two Discoveries

Gus began by tracing the current through the circuit, because he knew from Ampere's publications that electricity (current) flows through a circuit. At that, time scientists did not know electricity was the movement of electrons through a circuit or even that there *were* electrons, much less which direction they moved. So Gus developed the idea of how electricity flowed through a conductor. This discovery put his name on the electrical map, and he still gets the credit to this day. He avoided the issue of the direction of current in a circuit, but stated that "the current flowing into a point in a circuit must be equal to the current leaving that point." Maybe you're thinking 'everybody knows that, what's the big deal?'

To simplify what Gus was telling us, let's look at the circuit in **Figure 2** *(page 33)*. Gus had a 50-50 guess on his hands. Does current flow from positive to negative, or does it flow from negative to positive? Gus didn't know, didn't know how to find out and wasn't very concerned about it then. In those days they didn't know about diodes or transistors, so it didn't matter much which way current flowed in a circuit.

Ampere also had no clue which way current flowed. He was just happy to discover the stuff. If it's any comfort to the descendants of Gus and of Monsieur Ampere, even today some unenlightened folks still bicker about which direction current flows through a circuit. For simplicity, let's suppose Gus guessed correctly and said that current flowed from negative to positive. Now, with the circuit in **Figure 2**, we can illustrate what Gus was saying, that current flowing into a point must equal current leaving that point.

Gus understood that current was flowing into the accessory ground from the negative terminal of the voltage source. **Figure 2** shows six electrons of current passing through the accessory ground. We know in reality it would be several billion electrons, but Gus couldn't have known that since the electron was yet to be discovered. The six electrons divide to flow through the two lamps.

Simon said the current through a circuit composed of each lamp and switch is determined by the amount of voltage applied to the circuit and the resistance in the circuit. Both lamps are connected in parallel, so they both have the same voltage applied. Since both circuits have identical lamps and each has the same resistance, the current divides equally between the two lamp circuits.

If one lamp circuit had a different resistance from the other lamp, according to what Simon said, the current would be greater in the circuit with lower resistance and lower in the circuit with the greater resistance. It's comforting to imagine that Simon and Gus could have worked so well together if they'd had the chance.

But let's return to our explanation of what Gus said. The two lamp currents exit the two lamp circuits and flow into the circuit point designated as TP1. If six electrons enter the circuit at TP1, three from Lamp 1 and three from Lamp 2, then according to Gus, six electrons must leave TP1 and flow to the positive terminal of the voltage source.

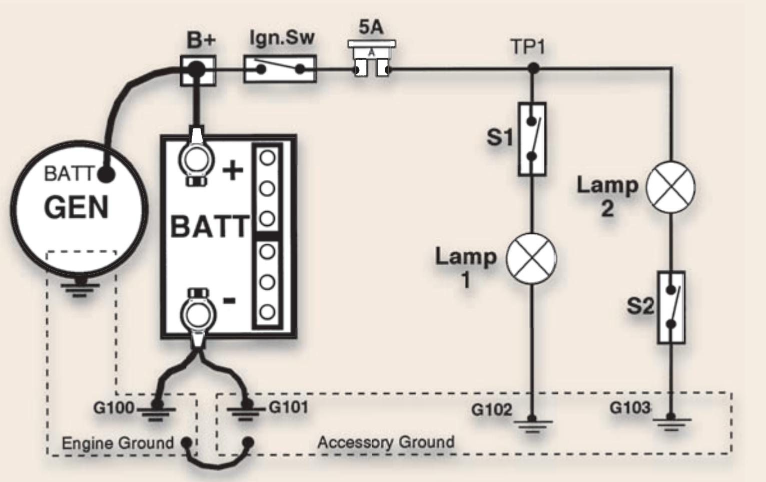
While Simon said the same thing when one circuit path was involved, which we now call a *series circuit*, Gus came along after Simon and explained how current behaved in a circuit with more than one current path, which we now call a *parallel circuit*. His explanation is still called *Kirchhoff's First Law of Electric Networks*. It got him a lot of attention in the scientific community of his day because it began to develop a scientific understanding of how electrical networks (called *electrical circuits* today) behave. They still behave the same way.

But ol' Gus didn't stop there. He could see another question about parallel circuits. He needed to know more about how voltage – not just current – behaved in a circuit with more than one path for current. To illustrate, we have to use the circuit in **Figure 3** *(page 33)*. There are two resistors added to the circuit, one in series with each lamp. Simon said adding a resistor to a circuit increases resistance and decreases current. Gus agreed, but G. Simon Ohm was talking about the current. Gus wanted to know how the voltage behaved. Again it was up to Gus to figure it out.

Gus could see that the current divided into two separate currents, one in each branch, and then the current recombined at TP1. He also knew from Simon when current passed through a resistance, a voltage drop appeared across that resistance. Gus agreed with that but took it a step further. He reasoned that 'the algebraic sum of the voltage drops around a closed circuit is equal to zero.' Of course, he had to do all of this mathematically because nobody had live circuits for experiments in those days.

What Gus was really saying to those of us who are not 19th-century physicists is that the sum of the voltage drops all around a closed circuit is exactly equal to the source voltage.

Figure 1: *Parallel Circuit*



A closed circuit is determined by tracing a circuit starting at the negative terminal of the voltage source, tracing up through R1, Lamp 1, S1, TP1, then back to the positive terminal of the voltage source. A second closed circuit is found by tracing a circuit starting at the negative terminal of the voltage source, tracing up through R2, Lamp 2, S2, TP1, then back to the positive terminal of the voltage source.

The circuit in **Figure 3** has two closed circuits. According to Gus, the sum of the voltage drops in each closed circuit must equal the source voltage.

Simon said a voltage drop appears across a resistance as current passes through it. Other researchers have established that the polarity of the voltage drop is negative on the side where electrons are entering the resistance and positive on the side where electrons are leaving the same resistance. In **Figure 3**, notice the voltage drops across each resistance. Simon also says the size of the voltage drop is directly proportional to the current and to the resistance. If either current or resistance increases, the voltage drop increases. If either current or resistance decreases, the voltage drop decreases.

Let's keep it simple for purposes of this explanation and say that source voltage (or B+) is 12.00 volts. Normally, if we had that kind of B+ voltage on a vehicle, it would be troubleshooting time.

Let's also keep our voltage drops very simple. Let's agree the voltage drops from the positive terminal of the voltage source to TP1 and through the ignition switch and fuse are very small, small enough so we can completely ignore any voltage drop produced on the voltage side of the circuit. This keeps our calculations simple to illustrate what Gus was telling us about voltage in a closed circuit. Let's also agree the voltage drop on the ground side of the circuit, from the negative terminal of the voltage source to G102 and G103, is so small we can ignore it, too.

According to Gus, when added together, the voltage drop of R1, Lamp 1 and the small voltage drop across the closed contacts of S1 must equal 12.00 volts. They do. Suppose Lamp 1 drops voltage by 6.00 volts. That leaves 6.00 volts for R1 and S1. If S1 drops 0.30 volt (a good voltage-drop for good switch contacts), then the voltage drop at R1 must be 5.70 volts. The same is true for the closed circuit consisting of S2, Lamp 2 and R2. The sum of those three voltage drops must equal B+.

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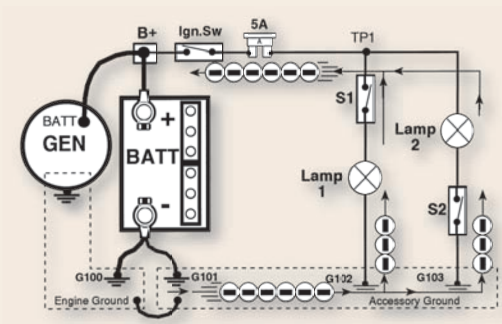

Figure 2: *Current in a Parallel Circuit*

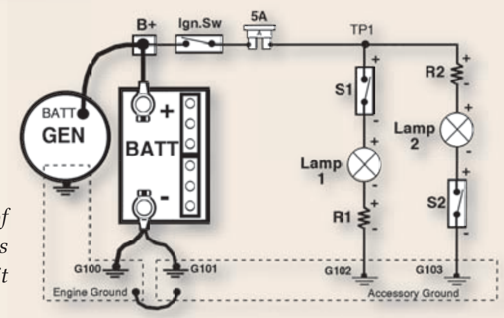

Figure 3: *Polarity of Voltage Drops in a Parallel Circuit*

Simon said that if the resistance values change in either of the circuits, the individual voltage drops would change, but their sum would still equal B+. Simon was right, and Gus proved it while taking the concept one step further.

Future Speculations

We should thank Signore Volta, Monsieur Ampere, G. Simon Ohm and Gus for the electrical principles they discovered, because they made troubleshooting electrical and electronic systems not merely easier but even possible for us. These men were the first to recognize these electrical principles as laws of the universe. After all, that is what they are — Laws of the Universe. That’s why these principles are so dependable, and why they behave in the same way, regardless of when they were discovered or where they are used to understand, operate or repair an electrical circuit.

Let’s speculate a little in closing. Suppose for a moment that there are alien spacecraft. Hold on — I’m not saying aliens actually exist. I’m just supposing there might be intelligent life in other parts of the universe to make an interesting point. Suppose one day an alien spacecraft lands, and the aliens emerge to make first contact with the Earthlings (that’s us, by the way). The aliens probably wouldn’t look like us, and they wouldn’t speak like us, either. We’d have to figure their technology to be more advanced than our own, because by our supposition they got to our planet before we could find our way to theirs.

Even though we can assume their electronics would be more advanced than our own, their circuits would still be composed of series and parallel circuits, and they would have to work like ours work. It’s all based on the same laws of the universe, regardless of what century, planet or galaxy you come from.

If that doesn’t warp your mind, let’s wind one bizarre twist further. What if one day we discovered that Volta, Ampere, G. Simon Ohm or Gus actually *were* aliens planted here to get us started in our understanding of electrical principles? That might help to explain why they were so far ahead of the other scientists in their time. Hmmm.

—By Vince Fischelli