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INTRODUCTION

One of the most frustrating aspects of a Triumph restoration, as least for the majority of owners, is the electrical system. Folks who have no fear at all of tearing the engine completely apart and rebuilding it cringe at the thoughts of dealing with the "Lucas" demons. This is certainly understandable, given the nature of the electrical systems when compared to the mechanical systems. Take the head off of the engine, and you can see the valves opening and closing and the pistons going up and down, and you can fairly easily understand the operation of these components. Look at a bundle of wire, on the other hand, and there are no visual clues as to what's going on.

In reality, though, electrical repairs and/or maintenance are not any more difficult than any other aspect of restoration if you have a basic understanding of the principles involved. Unfortunately, just as it takes a time to become familiar with engine, transmission, or suspension principles, it also takes time to become familiar with electrical systems. Also unfortunately, most of us don't have the time to spend to delve deeply into theory, and that's where this manual comes in. If I have done my job well, electrical repairs should be well within the capability of the typical Triumph owner, using simple test equipment.

Although no theory is required, a little bit of theory will be of benefit never the less, so I have included a little bit of theory in this chapter. In keeping with the direction of this handbook, the theory is as simple as I can make it, including only what I think is required to understand electrical theory as it applies to our cars.

To start, study **figure 1** at the top of the page for a moment, and then take a little quiz. This figure is a modified version of one of the figures in the chapter on starters, but I have cut the heavy gauge cable from the battery to the starter solenoid and spliced in a small light bulb, such as the ones found inside the instruments for night time illumination. The wires to the light bulb are very small gauge. Suppose I then hit the starter switch as if to start the engine. What will happen?

A. The starter will turn as usual, and the bulb will light as an indication that the starter is working.

B. Neither the starter not the bulb will operate.

C. The bulb will be smoked!

D. The bulb will light at full brilliance, but the starter will not turn over

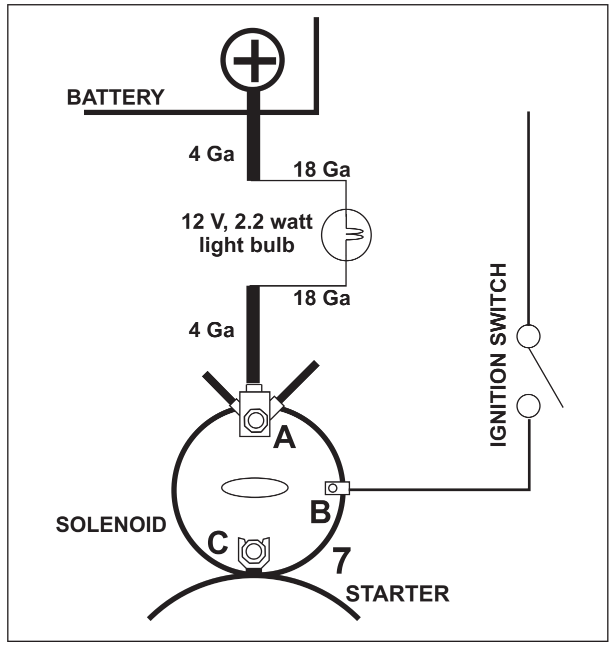

FIGURE 1

The correct answer is D. To the light bulb, the starter solenoid looks like a solid ground connection, while the resistance of the bulb will prevent the solenoid from engaging. Details on this later.

CONVENTIONS

In this handbook, I will use the following conventions:

V = Voltage,

A = Amperes (current),

Ω = Resistance (Ohms)

W = Power (Watts)

In other sources, you may see E instead of V, I instead of A, R instead of Ω, and P instead of W.

When describing the operation of various circuits in this handbook, I will use the "current flow" theory, rather than the "electron flow" theory. The current flow theory states that electricity consists of positive charges moving from the positive pole of the battery, through the circuit, and back to the negative pole of the battery. Electron flow states that electricity consists of a flow of electrons moving from the negative pole of the battery, through the circuit, and back to the positive pole.

Which one is correct? Actually, they are both correct. For more details on this topic, refer to appendix A.

Why am I using the current flow theory? Quite simply, because it is easier, both to describe and to understand circuit operation. Somehow, it just seems to make more sense to think of current flowing from the battery to the loads, and then dispersing through the loads to chassis ground on its way back to the battery. Thinking of electricity flowing through the chassis, up through the loads, and then returning to the positive post of the battery just doesn't seem right (right though it may be).

Additionally, the symbols for various electrical devices are aligned to the current flow theory. Way back when, as electricity was just beginning to be understood, and devices were being designed to use electricity, the current flow theory was the only one in use, so all the symbols for electrical devices were created with this in mind. A good example of this is the symbol for a diode (or rectifier prior to the invention of the diode). The arrow in this symbol points in the direction of current flow. If you use electron flow, you have to think of the electrons flowing against the arrow. It can be done, but it can very easily be confusing to do so, and, as the answers are the same using either theory, there is just no reason to. If you dig deep enough into electrical theory that it really makes a difference, you will by then have a deep enough understanding of the differences that you will not be confused.

FORMULAS

There are only two formulas to remember, which can be re-arranged as needed. They are:

Volts = Current X Ohms, V = A X Ω

Power = Current X Volts, W = A X V

These two formulas can be rearranged as:

A = V/Ω, Ω = V/A, A = W/V, and V = W/A. To make these easier to remember, use the diagrams in **figure 2**.

To use these figures, place your thumb over the parameter you're trying to find, and see the equation which gives you that parameter. For example, in **figure 2c**, with your thumb over A, the wheel shows A = V/Ω. Similarly, with your thumb over V in **figure 2d**, the wheel shows V = W/A. In **figure 2e**, V = A X Ω, and in **figure 2f**, A = W/V.

OK, so what is voltage, current, resistance, and power? A simple analogy to a household water system may be helpful. Voltage would correspond to the water pressure (PSI), and current would be the equivalent of flow (GPM). Resistance would have the same effect on current flow that pipe restrictions would have on the flow of water. There is no ready equivalent for power in a water system, but power is simply a measure of the work performed by the flow of current. In most cases, this work takes the form of heat and light, as in a light bulb, or in motion, as in a heater fan motor. This analogy breaks down as you delve deeper into electrical theory, but it is adequate as an aid to understanding electricity.

Battery (or alternator) voltage is the "pressure" that pushes electricity (current) through the wires (pipes) against restrictions (resistance). Power is the work done by the current as it overcomes the resistance of the circuit (typically, the resistance is in the form of lights or motors).

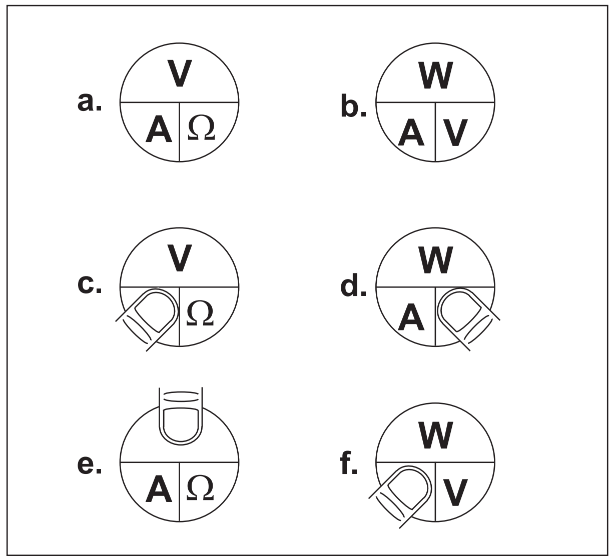

FIGURE 2

NOMINAL VALUES

When you go to the lumber company and ask for a 2 by 4, you get a board that is 3 ½ inches wide by 1 ½ inch thick. Similarly, when you buy a 12 volt battery, you get a battery that produces about 12.6 volts with a full charge. When the engine is running fast enough to spin the alternator to its full output RPM, the voltage in your car's electrical system is around 14.6 volts. Never the less, for the same reason that we call a 3 ½ by 1 ½ board a 2 by 4, we refer to our car's electrical system as a 12 volt system.

When you are using the above formulas to determine the current draw of a light bulb, for example, what value should you use? 12 volts? 12.6 volts? Or 14.6 volts? To be exact, you should use the voltage value the manufacturer used in determining the wattage of the bulb. Unfortunately, unless you have the manufacturer's data sheet handy, there is no way to tell what value he used. They use all three of the aforementioned values, plus a few others, when evaluating wattage ratings. In fact, in some dual element bulbs, they use one voltage for one element, and another for the other element. Luckily, there is no need for precision. There is enough conservatism in the various ratings for such things as wire and fuse sizes that using 12 volts for all calculations will be fully adequate.

To see how these formulas work, examine **figure 3** below. In this figure, we have a simple circuit, with one light bulb. This bulb is listed as a 21 watt bulb, typical of the bulbs used for back up lights in our Triumphs. Placing our thumb over the A symbol in wheel "b" of the diagram on the preceding page, we find that this bulb will have a current of 1.75 amps with 12 volts applied (all calculations are rounded off to 2 decimal points). Placing our thumb over the Ω symbol in wheel "a", we see that the resistance of this bulb is 6.86 ohms. You will rarely have a need to know the resistance of a device, but an understanding of resistance values will be of help when you get to the chapter on bad grounds and connections.

The diagram on the left of **figure 3** is a complete circuit diagram, showing all of the components in the circuit. In most diagrams, the circuit would be shown as on the right, the battery and the ground connection being understood. Almost always, the ground, or return connection, in an automotive circuit is either the chassis or the body sheet metal, or a combination of both.

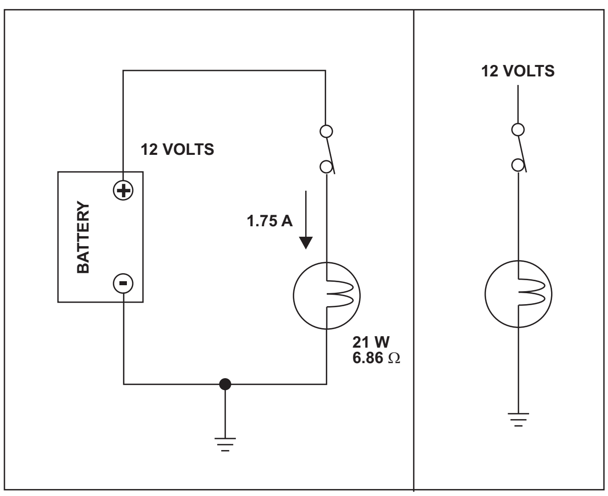

FIGURE 3

PARALLEL CIRCUITS

Most of the circuits you will find in an automobile will be of the parallel type. In this type of circuit, the high end of each device (or the plus side) will be connected to a 12 volt source, and the low, or ground side, will be connected to the chassis. **Figure 4** illustrates a parallel circuit, typical of the circuit you might find at the rear of the car, with one tail light, one marker light, and one license plate light per side.

In a parallel circuit, the voltage at each device is the same, but the current may vary, depending on the resistance of the device. The current through the main power feed is the sum of the individual currents through each of the bulbs, and the current flow through the rest of the wire is reduced as each lamp draws off its own current demand.

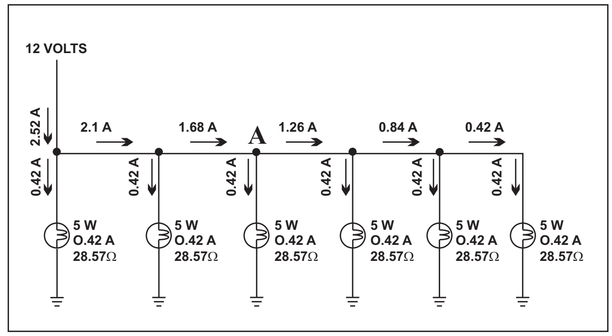

FIGURE 4

This is a fundamental law of electricity: ***the sum of all current flowing into a junction is equal to the sum of all current flowing out of the junction.*** For example, the current flowing into the junction marked "A" is 1.68 A, and the current through the lamp connected at "A" is 0.42 A (A = W/V), leaving 1.26 A to flow to the rest of the circuit.

Even though the current is different for each device in a parallel circuit, it should be noted that the voltage applied to each device is the same. All of the lamps in the above figure receive 12 volts.

Christmas tree lights that continue to work when one bulb is out is an example of a parallel circuit. Removing one lamp from the circuit above has no impact on the other lamps; the voltage to each lamp stays the same, but the total current supplied by the power lead will be reduced, as will the current in each leg of the circuit.

This diagram above is a stylized representation of the circuit, or a schematic diagram. The diagram below, **figure 5**, is the same circuit, but is laid out to more or less represent the actual wiring of the circuit. It is still a schematic, but is can also be considered a connection diagram, as it shows the actual connectors used in the car. The small rectangles shown on the wiring represent the bullet and sleeve connectors used for most connections in a Triumph.

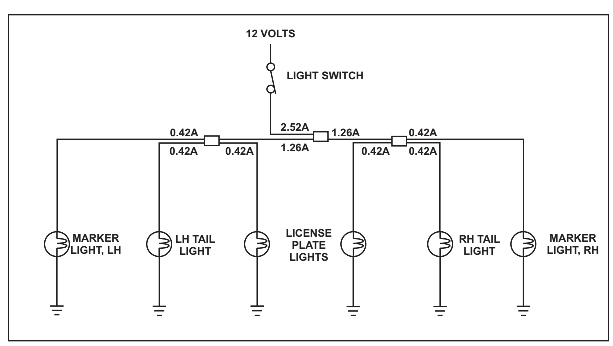

FIGURE 5

This is the type of diagram normally used in the Triumph manuals, and can be beneficial, as it helps to locate the circuit connectors, and to a lessor extent, the routing of the wires. In this diagram, the bullet connectors are the junctions, and the current flowing into each connector must be equal to the current flowing out.

Now, let's redraw the circuit shown in **figure 4** just a little bit, by drawing a box around the lamps, as shown below in **figure 6**.

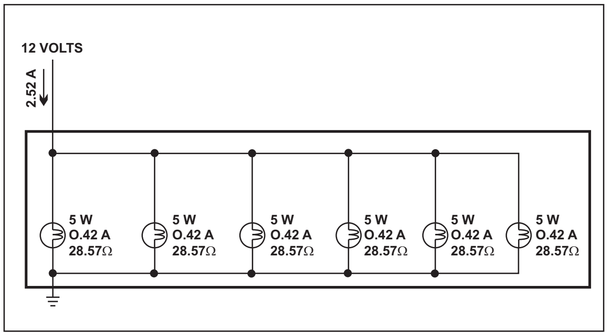

FIGURE 6

Let's go one more step in **figure 7**, and put the cover on our "black box" so we can't see what's inside.

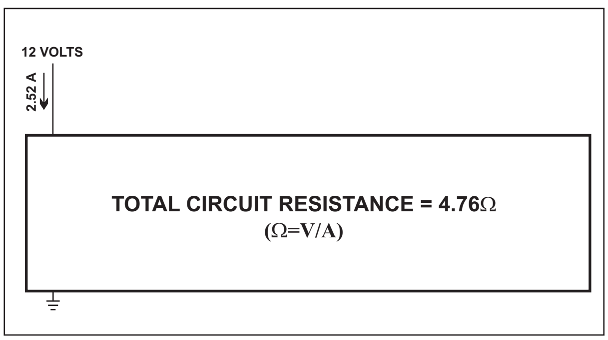

FIGURE 7

Using our formulas from the beginning of the chapter, we can see that the total resistance of the components inside the box is only 4.76Ω, much less than the 28.57Ω of each individual lamp, 1/6 as much, in fact.

This represents another fundamental law of electricity: ***The resistance of a parallel circuit is less than the resistance of the smallest resistance in the circuit.*** This is really just another way of saying the more devices you add to a parallel circuit, the more current it will draw.

SERIES CIRCUITS

Only rarely used in automobiles, series circuits are worthy of study never the less, as an understanding of them can be very helpful in understanding the trouble shooting techniques described in later chapters of this manual. The figures below show four examples of series circuits. Christmas tree lights that all go out if one bulb fails is an example of a series circuit.

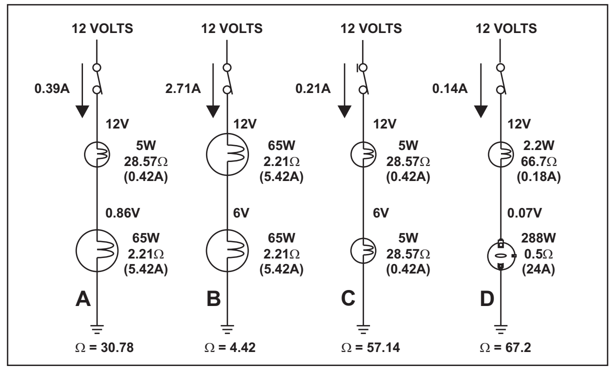

FIGURE 8

In circuit A of **figure 8**, above, I have placed a small 5W bulb, typical of the type used for the trunk lamp, in series with a 65W headlamp. Using the formulas given earlier, we find that a 5W bulb has a resistance of 28.57Ω, while a 65 W bulb has a resistance of 2.21Ω. In a series circuit, resistance adds, so the total circuit resistance is 30.78Ω. Using the formulas again, we find that a circuit resistance of 30.78Ω allows a current of 0.39A. Back in **figure 4**, we saw that a 5W bulb in a parallel circuit draws 0.42A (the current values shown in parenthesis in the above figure are the currents that would be drawn by the device if it were in a parallel circuit). With 0.39A, a 5W bulb will be drawing 93 % of its rated current, so it will be almost as bright as if it were in the circuit by itself. A 65W bulb, on the other hand, normally draws 5.42A. A current of 0.39A is only 7 % of its rated current, so it will not be drawing enough current to light it at all.

This is another fundamental law of electricity: ***The current through all devices in a series circuit is the same.*** No matter how many devices I wire in series, the current through each and every one will be the same. The amount of current will be determined by the ***total*** resistance of all devices in the circuit. This law will be invaluable later when you get into the trouble shooting sections of this manual, particularly when reading the chapter on bad grounds and connections.

It should also be noted that in a series circuit, all devices ***do not*** receive the same voltage. More on this later.

Circuits B, and C are two more examples of series circuits, which should be reviewed for understanding before proceeding. Use the formulas from the beginning of the chapter to see how the values were derived.

Circuit D is a representation of the light bulb/starter circuit shown in figure one, and discussed in the quiz. A starter solenoid has a resistance of about 0.5Ω, and a 2.2 W bulb has a resistance of about 66.7Ω. Total resistance for the circuit, then, is 67.2Ω, or almost the same as the 2.2W bulb by itself. The solenoid resistance represents less than 1 % of the bulb resistance, so current through the circuit is, for all practical purposes, determined solely by the resistance of the bulb. The 0.5Ω resistance of the solenoid looks to the bulb almost like a short circuit to ground. Thus the answer to the quiz is D. The bulb doesn't know the solenoid is there, and the solenoid doesn't know any current is flowing in the circuit.

Notice the voltages applied to the last device in each circuit. In circuit A, the voltage on the 65 watt bulb is 0.86V (0.39A X 2.21Ω), which means that the remainder of the battery voltage must be dropped across the smaller bulb (12V - 0.86V = 11.24V). Applying 0.86 V to the headlight is virtually the same as applying zero volts, while the 11.24V applied to the smaller bulb is almost full voltage. In other words, the headlight doesn't receive enough voltage to illuminate it, while the smaller bulb does. This jibes very nicely with the results obtained by comparing the current flow to the required current flow for each device.

SUMMARY

As stated earlier, it is not necessary to know all of this to fix your TR. The information presented in the remaining chapters (with the exception of chapter 3 - Bad Grounds and connections), should be sufficient to enable you to find and fix most any electrical fault you may encounter without this knowledge, but it will make your job so much easier, and more fun, if you understand the proceeding material.

The most important things to remember are:

1. Resistance limits current. The higher the resistance, the less the current (this is true whether we are talking about the resistance of a light bulb, the resistance of a bad connection, or the resistance of switch contacts).

2. The higher the wattage of a device, the less resistance it has. A 65W headlight bulb has much less resistance than a 5 W marker lamp, and will draw much more current.

3. A high resistance device in series with a low resistance device may limit the current such that the high resistance device will work but the low resistance device won't.

4. Current through resistance produces wattage, usually in the form of heat.

5. In a series circuit, the current through each device is the same, but each device may see a different voltage.

6. In a parallel circuit, each device will see the same voltage, but the current through each device may have a different current through it.