Very Basic Motorcycle Electrical Skills

By Quigg

Introduction

Scope and Purpose

Reading this will not qualify you as a journeyman electrician nor will it answer all your questions about your bikes electrical systems. It is meant to give you some basic knowledge of how things work and enough confidence to tackle minor maintenance and troubleshooting.

If you ride these two wheeled contraptions long enough you will eventually find yourself stranded in the middle of nowhere with only your tool kit and what's in your brain to get you home. Even a small understanding of what makes things go can sometimes be enough to save you a long walk. What you will learn here will allow you to add accessories with confidence, help in maintaining your machine, and perform emergency repairs, however, you should keep in mind there *is* a time to call an expert.

There exist expensive components in your electrical system that can be permanently damaged if handled improperly. Know your depth. If you aren't sure, ask an expert.

Very Basic Electrical Theory

Electrical Current

Current is defined as the flow of electrons and is measured in Amperes (Amps). It is this current flowing around in all those wires you see crammed into that mysterious harness running everywhere on your bike that does the work. Like the water current in the river turning the water wheel, electrical current delivers the power to run the starter, lights, and all those other electrical gadgets we are so fond of. Where gravity supplies the push to move the water along in the riverbed, it is electrical pressure supplied by a battery and generator that pushes the electrons along the wire creating electrical flow. This pressure is measured in units of electrical potential or Volts. Increasing the drop of the river increases the force of the water flow. Increasing the electrical pressure (voltage) causes more Amps to flow in the electrical circuit. The wider and deeper the river the more water can flow and likewise, the larger the wire diameter the more electrical current can safely flow.

Resistance is anything that interferes with or slows down the free flow of current. Resistance is measured in Ohms. One Volt of electrical pressure will push one Amp of current through one Ohm of resistance. That's Ohms Law. Ohms Law is a lot more than that but generally the formula E=IR, where E is in Volts, I is in Amps, and R is in Ohms, is Ohms Law.

Electrical power is measured in Watts. Amps times Volts equal Watts or, P=IE, where P is power and I and E are current and electrical potential respectively. With these two formulas it is possible to calculate the size of the fuse you will need to protect a lighting circuit where all you know is the Wattage of the light bulb and the battery voltage. Fuses are rated in Amps and Amps equal Watts divided by Volts. So if you have a 20Watt lamp and a 12 Volt battery you know that you will need a circuit capable of handling at least 1.7 Amps to keep the light burning. Actually you will use a heavier circuit than that, probably a 5Amp circuit with a fuse rated to protect it at that level but an understanding of these relationships will help you to decide what is a necessary minimum.

In order for any work to be done, electrical energy must be dissipated in some sort of resistance or load. Energy is dissipated in only three ways, either through heat or light or sound and in most cases it is a combination of the three. The type of resistance will determine how the electrical energy is spent or used. In your headlight the electrical energy supplied by the battery is converted to light and heat. When you turn the headlamp on the filament is heated by the current to a temperature so high that it begins to glow. During this heating time most of the power is given up in the form of heat. When the filament begins glowing the electrical energy is converted to both heat and light. The resistance of the filament is low when it's cold and high when it's hot and glowing. So the current is high at first and then drops off as the lamp becomes bright and hot. This is one reason why you need a heavier circuit than what is predicted by the power formula using the rated Wattage of the lamp. That rated wattage is figured by the current draw of the lamp when it is "lit" and it's resistance is high and the resulting current is at it's lowest. (This is also one of the reasons the fuse in the turn signal circuit is 15 A while the one in the headlight circuit is only 10A even though the rated wattage of the turn signal lamp is lower. The turn signal is constantly turning on and off, heating and cooling, and draws much more current than it would if it is lighted continuously. That and the fact that there are two of them in a parallel circuit doubling the wattage.)

Anytime current is forced through a resistance heat will be produced. In the case of the headlight the resistance producing heat is not really a bad thing since that is it's purpose but there are places where a resistance producing heat is very bad. Connections that are corroded, loose, or poorly made offer resistance to current flow and will produce heat and will eventually burn themselves out causing complete failure or at least be the cause poor performance of the system. A wire conductor too small for the load it must handle will heat up and just as in the light filament it's resistance will increase with temperature making the situation worse by heating up even more and it will eventually fail. Fuses depend on this heating effect to protect the wiring and components of your electrical systems. The heat produced by too much current in a circuit melts the material in the fuse and so breaking the connection halting current flow and any further damage.

Circuits

You flick a switch and a light comes on. You've completed a circular path for current to flow from a power supply through a load and back to the power supply. When you throw the switch back you've interrupted the flow of current and the light goes out. That's as hard as it gets. Really! Every electrical circuit consists entirely of a power supply, a load, conductors to connect the load to the power supply, and some sort of device to control the current flow in the circuit. That's it! No matter how complicated a circuit looks on paper it can be broken down to this simple "series" circuit. What makes it look so complicated on the schematic in your manual is that all the many series circuits used to drive all the various load devices on your bike, all from a common power supply your battery, are all printed on one page! To make it seem even more confusing they throw in a lot of components with cryptic names and symbols and wires with color codes and little black boxes with numbered terminals, and hickies, and widgets, and other weird stuff. I'll try here to give you a short list of some of the more important electrical components and a short explanation of what they do for you. With an idea of what things are and what they should be doing it will be easier to simplify and understand the circuits you are interested in.

Electrical Components

Conductors

A wire is a conductor. Anything that will carry electric current, and everything does by the way, is by definition a conductor. Even an insulator is a conductor though a very poor one. But for our purposes here a conductor is a wire. It's the pipe that carries the current from the battery to the horn, the starter, and the turn signals so it can do its work. Wires come in many sizes and many colors. The larger the diameter of the wire the more current it is capable of carrying without heating up. Wire size is measured as "gage" the higher the gage number, the smaller the diameter of the wire. Hook-up wire of the same gage can be either single strand or multiple strand meaning one solid conductor or many smaller ones that when wrapped together like a rope have the same diameter as the single strand. Single strand wire is stiff and holds it's position once bent and it is easier to *push* through tight places. Multiple strand wire is flexible, a little more expensive, and easier to *pull*. The insulation covering the wire is rated by how much voltage it can handle without breaking down. The insulation on the hook-up wire used in the wiring harness of your bike need only stand up to tens of Volts but the High tension leads to the spark plugs has to contain as much as 50,000Volts. Some insulation are meant for high temperature applications and/or harsh environmental conditions. This is a consideration when you wish to run a lead near an engine where heat and solvents like gasoline and oil are present.

On the schematic a wire is represented as a line. Somewhere along the line you will find color markers like Bl, Blk, Brn, or R and sometimes you'll see Bl/Blk or R/Grn. This is an abbreviation for the actual color of the insulation on the physical wire on the bike. Bl means a blue wire, Bl/Blk means a blue wire with a black tracer or a blue wire with a skinny black line painted on it. Sometimes a wire is identified only by a number placed at both ends of the line representing the wire. Lines on a schematic are allowed to cross over one another without being connected. If two wire lines touch on a schematic and they are connected there will be a small dot at their intersection.

Switches

Switches turn the flow of current in a circuit on or off. They provide or deny a path for current flow. Diodes, vacuum tubes, relays, SCR's, and a hundred other electrical devices are also switches but for simplicity's sake here I'll consider a switch to be only those current interrupters operated directly by a human hand or foot with specific intent to turn something on or off.

Hand operated switches on a motorcycle are of necessity, physically small, and are therefore incapable of handling large currents. There are rotary switches like the ignition switch, momentary contact switches like the horn and starter button, single pole switches (on/off) that do only one thing like your kill switch, and double pole switches that handle two operations at once like dimmer switches that turn one light on and at the same time turn another off.

Schematic symbols for switches vary with application and type of switch. They are generally clearly labeled and identified and are pretty much self-explanatory. You will run into labels like “K Sw” for “kill switch” or “PB” for “pushbutton”, “Ig Sw” for “ignition switch” and so on.

Relays

Relays are remote controlled magnetically operated switches. They are be used primarily to remotely control large current (power) switching applications from low current (control) circuits. The starter relay is a good example. Starter motors do a lot of work cranking the engine and therefore require large currents to develop the needed torque. Large conductors are needed to carry these high currents to the motor and the contacts in the control switch must be of large physical dimension for the same reason. To mount a switch and conductors of this size on the handlebars to operate by hand would be difficult at best and ugly even if possible. The answer then is to use a small switch and small conductors to operate a relay.

The relay consists of an electromagnet that can develop a strong magnetic field with very little current. The electromagnet (the coil) is connected to the power supply through the small, low current, starter button on the handle bar. When the starter button is pushed it completes a path for current to flow through the coil of the relay. The coil is then energized and the magnetic field developed pulls an iron armature attached to the contacts of a high current switch and closes the starter motor circuit allowing the starter motor to run. The starter button, battery, and relay coil, along with all the associated logic circuitry (kill switch, clutch switch, neutral switch, etc.) is called the control circuit. The starter motor, battery, and starter relay contacts make up the power circuit. Relays may also be used in horn circuits and lighting circuits where heavy current loads are present and small operating switches are desired.

Relays are often used in logic circuits. An example is the kickstand relay on your Volusia. The switch attached to the side stand energizes the side stand relay. The contacts of the side stand relay are placed in the control circuit for the starter as a permissive device. In this case the relay can be small because the currents being controlled are small.

Relays are usually represented schematically as a black box and will sometimes show internal wiring but not always. They are usually labeled as “Relay” but sometimes you’ll see, “Sol”, meaning “solenoid”, as in “starter solenoid, but whatever the label, the job it does is the same.

Connectors and plugs

Connectors are a convenient way to tie wires together in a wiring harness so they may be taken apart and put back together at will. They lower the cost of assembly and repair, they are most often indexed or polarized so you can’t hook them up backwards, and they often have some sort of weather guard to protect them from moisture. They are also a source of heartache.

I like to think of a connector as a device connecting lots of wires together like the one under the speedometer cluster. A connector that connects only one or two wires like the one used to hook up the turn signals or gas gage is a plug. Connectors offer a small resistance to current flow even when they are in new condition. Dirty or loose connectors offer a lot of resistance to current flow and as you already know, resistance causes heat. Heat causes an oxide film to build on the surface of the male and female parts and also takes the temper out of the connector metal, which gives it grip. All this makes the situation worsen and failure is inevitable. Weather is a connector’s worst enemy. Corrosion not only increases resistance in the connector by building a film of corrosion products, it reduces the cross sectional area of the conductor by eating away at it reducing it’s current carrying capability.

Connectors are necessary evils we must learn to live with but it is best not to learn from a bad experience. Be very careful connecting and disconnecting these things. Never force them together or apart, you don’t want to distort the pins or damage the case. Do not pull on the wires! If it takes three hands get help. After reconnecting always double check the keeper or lock that holds the connector together and the weather seal to make sure it is tight. Applying a little Vasoline or water proof grease to help guard against moisture isn’t a bad idea either. Be sure to replace any ties or clamps.

Schematic representation of connectors is usually easy to understand and recognize and usually they are clearly labeled. Plugs are sometimes shown as a break in a line representing a conductor with a couple greater than symbols (> >) to represent the male and female parts of the plug.

A second type of connector is used to *permanently* attach one wire to another or to a lug or post. These connectors come in a wide verity of size, shape, and purpose. Terminal connectors such as eye and fork connectors are meant to land a wire to a screw type terminal or lug. Splices join two or more wire ends together. The most commonly used permanent connectors are crimped onto the wire end and have their own insulation. My opinion of these crimp on connectors is they are a last resort and only for emergency use. They simply suck! They may be fine everywhere else but a motorcycle is not the place for these things. They are neither permanent nor are they dependable. Learn to solder and use heat shrink to insulate all your permanent connections. You'll thank me for it. I may throw in a short soldering tutorial at the end of this piece.

Miscellaneous Devices

A *resistor* is a device of known resistance value and is used to limit current flow in a circuit. There are fixed resistors and variable resistors. The volume control on your radio is an example of a variable resistor.

A *capacitor* is a device that resists any change in applied voltage. Sometimes called a condenser they may be used as an arc suppressor to protect the contacts of a switch or relay or they can be used to store a charge to recover or smooth out a dip in applied voltage.

A *coil* is simply a conductor wound in the shape of a coil. Also called a choke it resists any change in current flow. When you hear someone use the term "coil" as in "ignition coil" it is really a transformer they are talking about.

A *transformer* is a device that transforms a low voltage/high current input signal into a high voltage low current output signal. It is actually two coils coupled together by a common iron core. The voltage at the spark plug is anywhere from 20,000 volts to 50,000 volts and is developed from your 12 volt battery by the step-up action of the ignition transformer or ignition coil.

Pickup coils are small coils of wire that develop a current when they are passed through a magnetic field just like a generator or alternator. Ignition timing is a perfect application for a pickup coil. A magnet is placed on the crankshaft and each time it comes around it induces a pulse of current into the pickup coil which in turn tells timing module where the piston is in its cycle.

A *sensor* is something that feels for a condition and then reports its findings to some caring entity. There are temperature sensors, oil pressure sensors, fuel gages, and environmental sensors of various types. They report their information to idiot lights, meters, gages, and microprocessors. They also may be connected so to shut down your engine if the condition they sense reaches some preset level where permanent damage will occur. Rev limiters do that.

A *diode* is a device that allows current to flow in only one direction. You can think of them as an electrical check valve.

LEDs, or Light Emitting Diodes, are solid-state devices that emit light when energized. They are a saving grace for those of you who wish to have lots of lights mounted for increased visibility or just to show off your machine. They draw very little current and replacing the high current, heated filament type lighting with LEDs where possible will allow you to pile on the lumens without overloading your alternator.

Batteries

In the old days you didn't need a battery. We had kick-starters and there were magnetos to do those few things electrical on a motorcycle. Today without a fully charged battery in good condition you're dead in the water mister! Your battery is *the* *prime component* of your bike. It is for this reason I am giving it its own section. The charging system and battery are often forgotten during regular maintenance because they are today so dependable and trouble free that we take them for granted.

I won't get into how a battery works other than to say it is an electrochemical device capable of generating and storing electrical energy and it is rechargeable. Most modern batteries are sealed. They call them "maintenance free" because you never need to add electrolyte but no battery is "*maintenance free*". It is important to keep the surface of the battery clean and free of dirt and moisture. Any moisture or other contaminants present on the surface between the terminals of the battery will act as a conductor effectively shorting it out and will discharge the battery. The presents of electrical current accelerates the corrosion process and a rapid attack on the terminal posts and associated wiring will follow!

The terminals must be clean and the connections to them tight with as much surface area as possible. Let us return to Ohms Law for a moment. E=IR. Let us say your battery is in a low state of charge because you had to crank the engine several times before it started. The charging current and voltage from your alternator and voltage regulator can be as much as 5 Amps at 13.6 Volts at the battery terminals. This will quickly bring your battery back up to snuff assuming there is no resistance in the circuit except for the internal resistance of the battery. But if there exists some resistance due to oxidation between the battery post and the cable attached to it, say as little as .5 ohms, it will "drop" or use up some of that applied 13.6 volts. With 5 Amps flowing, ½ ohm will develop 2.5 Volts! That means your battery is only receiving 11.1 Volts of the 13.6 Volts supplied by the charging system. A fully charged battery is 12.6 volts! It ain't gonna happen! You're going to have a perfectly good but dead battery! Remember this is a series circuit and resistance anywhere along the current path will have the same affect so battery maintenance includes checking all the connections in the charging system for integrity.

As an aside, your starter motor must draw a lot of current from the battery to crank the engine, as much as 30Amps. That small .5ohm contact resistance at the battery terminals will rob the starter of enough voltage to render it ineffective. 30 Amps through ½ ohm is 15 Volts! 15Volts from a 12Volt battery?

There is another interesting relationship of current and resistance. P=I^2 * R or Watts = the current squared times the resistance. From the above example, 30A x 30A x ½Ohm = 450 Watts! Your alternator on your Volusia is only a 375Watt generator! A little resistance goes a long way when the current is high. If you are not impressed by that number, think of the heat a 450 watt light bulb puts off and remember some of that 450Watts used in the light bulb is in the form of light! That battery post is going to get hot! These numbers are only to demonstrate the principle involved and the importance of zero resistance connections in high current applications and are not actual measurements.

Well enough about batteries for now. I'll get into the care and feeding of storage batteries later on in the trouble shooting, repair and maintenance section.

Fuses

Fuses deserve their own section too. A fuse is a device designed to interrupt the flow of excessive current. It is a common misconception that a fuse is there to protect another device such as radio or a cigarette lighter. It is not! The fuse is there to protect the wiring harness and power supply. A circuit is designed to operate a certain device or load. The size of the wire to be used in the circuit is determined by the normal current required of that load plus a little margin. Lets say you want to operate a 60Watt headlamp on a 12Volt system. That figures to a normal load of 5Amps. Lets double that figure to 10Amps to give us a safety margin of two. We select a wire size that will comfortably handle 10Amps, a switch and connectors with the same capability and now we select a fuse to protect the whole circuit. It will also be rated at 10Amps. This is a 10 Amp circuit to operate a 5Amp load yet fused at 10Amps. If for some reason the current should exceed that 10Amps the wire, switches, and connectors will suffer. They will over heat and fail if the fuse is not there to protect them. There is no reason that a properly operating 60Watt headlamp should ever exceed its rated 5Amps and if it does it is not in need of protection because it has already failed. The fuse is there to protect the circuit in case of a short or other type overload like the installation of more lights or accessories on a circuit not designed for it.

The main fuse has the additional job of protecting the generator against overload along with protecting the wiring harness. Again using the power formula, P=IE, a 30 Amp main fuse in a 12.6Volt system will open up at 378Watts. The alternator in your Volusia is rated at 375Watts. Ain't science wonderful?

One of the great things about fuses is that once they do their job they must be replaced. Unlike circuit breakers that can be reset a fuse gives you time to consider what happened and a chance to repair the fault. There is always the possibility that the fuse was weak and there *is* no problem but it is always best to check things out before replacing it with another fuse. Never under any circumstances replace it with a larger fuse. Fix the fault and use the proper fuse. Of course if you are in the middle of nowhere in the dark, a chewing gum wrapper folded around the spent fuse will handle about 40Amps.

Other Circuit Protection

Just a note about preserving the integrity of your bikes electrical system before I get into troubleshooting and repair. Circuit protection doesn't stop with the over-current protection provided by fuses. The wiring harness, switches, connectors, and other components must be protected from the environment, the heat of the engine and exhaust, vibration, and solvents. The fuse is the last line of defense. A short anywhere in the system can take out the main fuse and then nothing will work. If the main fuse blows on a dark night at 60 miles per hour your wiring harness will be saved but you will be in big trouble.

You can be part of the circuit protection built into your bike by simply taking care of your wiring. Be neat. Take the time to route new runs along the frame as far from heat and other potential dangers as possible. Tie it down. Don't let the wires flop and move. Use wire ties, lots of wire ties. Put it in place and keep it there. Make good, well insulated, physical connections and use electrical tape only when there is no other option. Make sure all screws and lugs are tight with lock washers in place. Use silicone sealant wherever possible to keep the weather away from electrical parts. Keep it clean and keep it dry.

I hope I have impressed you with the importance of good electrical maintenance. If not, try this short story on for size.

Last year at the National Rally I fell off my bike and broke my little finger. I had to ride 1000 miles with my pinkie sticking up in the air like Duchess drinking tea. The reason I fell off my bike was a bad electrical connection.

I was just moving out onto a main highway from a side road. I was in first gear and barely moving. I had the front end bent nearly to the lock and had her healed over ready to accelerate into traffic. When I twisted the handle the engine stalled and locked up the rear wheel. The next thing I know I'm rolling around in the dinky weeds with a busted pinky!

I found the problem at the throttle position sensor, an intermittent open. A bad connection was driving the Ignitor nuts and it just decided to quit.

You wouldn't ride on bald tires or with worn out break lining. You wouldn't think of running the same oil for 20,000 miles and you certainly would not leave the garage on a dirty bike. Why not include the electrical system in your safety check?

The following section is all about electrical testing, trouble shooting, repair, and maintenance, and tips on adding accessories. There will be something on emergency roadside repair and tool kits as pertain to the electrical side of things and maybe that soldering tutorial I promised.

Very Basic Electrical Trouble Shooting and Repair

Tools

Common Hand Tools

In order to get to the electrics on your bike you will have to disassemble portions of the machine. The wiring harness is tucked away out of sight for esthetic purposes. Everything else is hidden behind covers and stuffed into small, sometimes inaccessible, otherwise unused spaces all over the place. So a complete set of wrenches, screwdrivers, Allens wrenches, pliers, and sockets will be of necessity. It's nice to have a few small stiff brushes and lots of rags handy too. A good flashlight is a must.

I know these following considerations are not tools but over the years I found the most important part of a repair shop is space. Nice, clean, warm in winter, cool in summer, well lighted, space. A clean workbench where parts may be laid out in order of disassembly so reassembly is made easier will make any job more enjoyable. Of course you can never have enough tools. There is always a job where a certain special tool would make life better but you have to make do with what you have. Make a note of it and put it on your Christmas list.

Specialized tools

There are hand tools designed specifically for electrical repair. Some are basic tools and others are very specialized. General tools include linesmans pliers for cutting and twisting wire and diagonal wire cutters (dikes) for snipping wires to length. Long nose pliers are handy for holding connectors to a terminal while the screw is set. Crimpers to attach those dreaded crimp-on connectors and wire strippers to remove insulation come as a 2 in 1 combination tool.

I recommend using wire strippers because they don't knick the wire when the insulation is cut. Using a pocket knife or box-cutter knife to strip a wire is alright so long as you do it as if you were sharpening a pencil instead of first "ringing" the insulation and then dragging it off with the blade. The danger is cutting into the copper especially on single strand wire. This reduces the cross sectional area of the wire and this "stress riser" makes the wire physically weak at that point too. With only a few bends it will break. Cutting into multiple strand wire with a sharp knife will sever some of the small wires reducing its current carrying ability and physical strength.

Radio Shack has small inexpensive tool kits that contain everything you need. Batteries not included.

A good soldering iron and a supply of rosin core solder is a must for any shop to my mind. The pencil type irons are fine for hook-up work and repairs on your motorcycle. The battery powered one they're advertising on TV really interests me. If it works as well as they say it would be a fine addition to your tool kit on your bike.

Testers

Meters

When diagnosing electrical problems there is no substitute for a good multi-meter. A multi-meter is a combination Voltmeter – Ohmmeter – Ammeter. Prices for these meters range from a few dollars to hundreds of dollars. Again Radio Shack has many good quality inexpensive meters in their showcase. $20 will buy you all the meter you'll need for general purpose repair and maintenance.

Meters are of two general types, digital and analog. The more expensive digital meters are loaded with features like auto ranging and peak voltage recording. Auto ranging is convenient because it reads voltage in any range without having to manually set the meter to a specific level. There will be times when you just don't know beforehand how much or how little voltage is there. When you are checking things like a pick-up coil where the output of the device is a pulse it is necessary to capture the peak voltage of the pulse to determine if it is operating properly. These pulses are very rapid and analog meters are not fast enough to display them and will show only an average voltage. The peak voltage feature of the digital meter measures the highest (peak) voltage it sees and displays it.

Without getting too involved I want to introduce you to *impedance*. Impedance in a voltmeter is important because meters can fool themselves and you too.

First, I told you a lie when I said "Voltmeter". There is no such thing as a Voltmeter. All meters are current meters. To get the power to move the little needle, a meter must sap current from, or "load", the circuit it is measuring. Analog meters operate much like a motor. An electrical current of some magnitude is passed through a coil creating a magnetic field. The strength of this field is proportional to the amount of current flowing. The indicator (pointer) of the meter is attached to a permanent magnet that can move inside the field and a calibrate spring is used to oppose the pull of the magnet when attracted by the field of the coil. The result is an indication of how much current is flowing through the coil. Because the meter coil has a fixed resistance and the meter is telling you how much current is flowing, it is possible, with Ohms Law and a little algebra, to calculate the voltage at the meter terminals. So a current meter becomes a voltmeter by simply changing the scale on the face of the meter.

The resistance of the meter coil will determine how much current the meter will rob from the circuit under test. One with a very high resistance or impedance will have little effect on the circuit because it requires very little energy to operate. Those with very low input impedance drain large amounts of current and can affect the actual operation of the circuit being tested causing the readings to be inaccurate. For this reason, a high input impedance voltmeter is desirable. Most digital meters are high impedance meters. But be careful because they can fool you.

Example:
In normal operation your headlight draws about 5 A.

P = IE
Or I = P/E
Current = 60 Watt lamp divided by 12 volts operating voltage.
I = 5 A
(That's just to keep you in shape.)

One day you switch it on and nothing happens. Your first thought is that it has burned out so you replace it with a new one but the new one doesn't work either. What? Maybe it's the switch, maybe there is a wire broken off somewhere. You remove the lamp and place your high impedance digital voltmeter on the headlamp connector and throw the switch. It reads 12.5 volts, full battery voltage! If there is power at the plug and the light bulb is good it has to work! Right? But it doesn't.

Remember that high impedance means very low current draw. Now picture the circuit in your mind. The battery is connected through a switch and probably a few connectors to the plug for the headlight. Because the headlight has been removed the circuit is open and no current is flowing even though the switch is turned on. When you place your meter across the plug you complete the circuit and current flows through the meter. This current will be very small because of the very high impedance of the meter. These meters can have input impedances of tens of megohms (millions of ohms). With only 12 volts applied the resulting current will be in the order of micro amps. (Millionths of an amp)

Back at the light switch weather has corroded the contacts resulting in a poor connection. The contact resistance may be on the order of 4 or 5 ohms. 1 micro amp passing through a 5 ohm resistance will drop only 5 micro volts and the rest of the applied voltage is seen at the meter as full battery voltage.

Your headlight offers only a little over 2 ohms of resistance. In a clean circuit with 12 volts applied it will draw about 5 amps but in this circuit where there is an additional 5 ohms of contact resistance at the switch the total resistance of the circuit is now 7 ohms and with the same 12 volts applied the resulting current will only be 1.7 amps and far from the 5 amps needed to operate the headlight.

Test Lights

Sometimes a low tech tester is of more value to the trouble shooter than a high tech $200 digital wonderbox. A simple test light can be made from a 12 volt brake light bulb by soldering a couple wires to it. When placed into the headlight circuit in the example above it will draw lots of current, enough to expose the problem by burning very dim.

Test lights are simple, rugged, and easy to pack into your tool kit. There are many on the market. They're sold in every auto parts store and they are cheap.

Materials

It's nice to have stuff handy when you need it. It is impossible to keep an inventory of everything you will ever need in a shop but there are a few things that should be on stock.

An assortment of hook-up wire in several colors and sizes. You'll use mostly #12, #14, and #16.

And yes, you should have some of those damnedable crimp-on connectors around.

Electrical insulating tape in ¾" wide. I like the 3M stuff.

Heat shrink insulation is made of a plastic that shrinks when it is heated. It comes in a verity of lengths and diameters. Slipped over the wire before a permanent connection is made it is then pushed over the bare wire and heated. It shrinks down to form a tight, weather resistant, insulating cover for the connection. It makes a nice looking job too.

Cleaning solvents can be anything from soap and water to contact cleaner in aerosol cans. Just be careful when using volatile solvents around stuff that can make sparks.

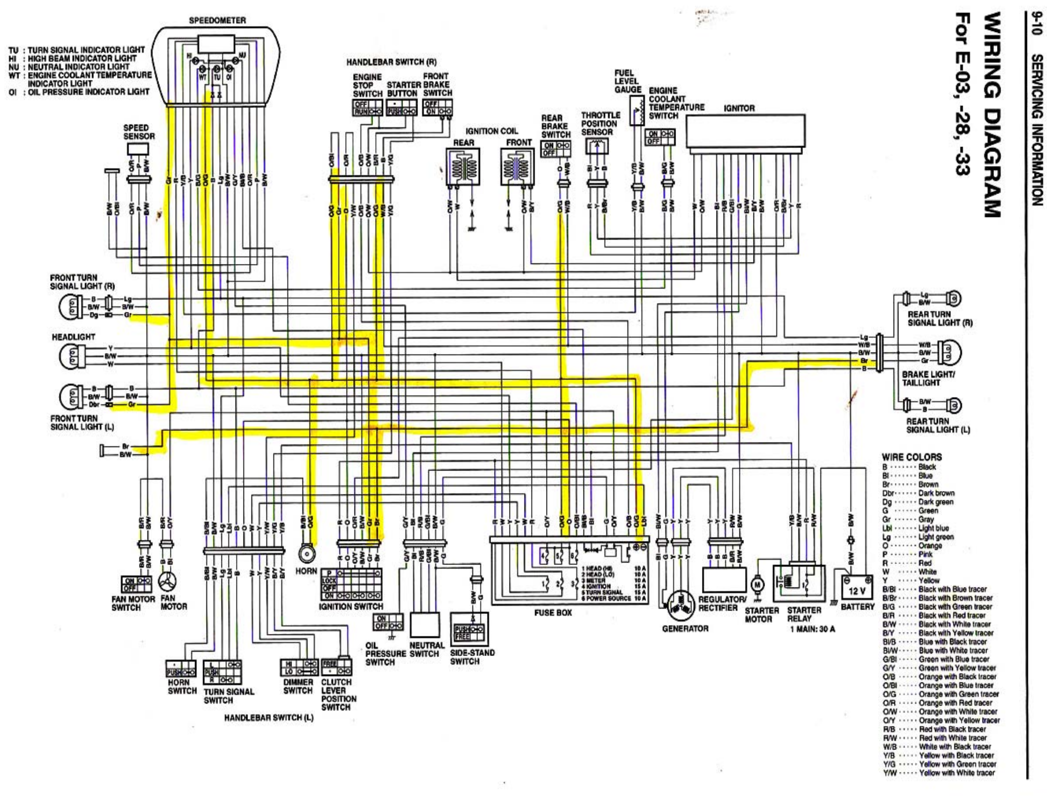
Wire ties, clamps, and grommets make the job complete. You can never have enough of those lying around.

Records and References

A shop manual isn't really necessary for diagnosis of most of the electrical problems that will crop up but when the trouble is not obvious the manual is a must. They are expensive so before you plop down the cash decide how involved you want to get in this electrical repair thing.

If I make changes to existing wiring or add on an accessory I will sometimes draw up a print of the wiring I've installed with wire numbers, tie points, and wire colors noted and keep it in a notebook along with all the other maintenance records for the bike. It has saved me time and aggravation when my memory decided to take a short vacation.

Reading Electrical Prints



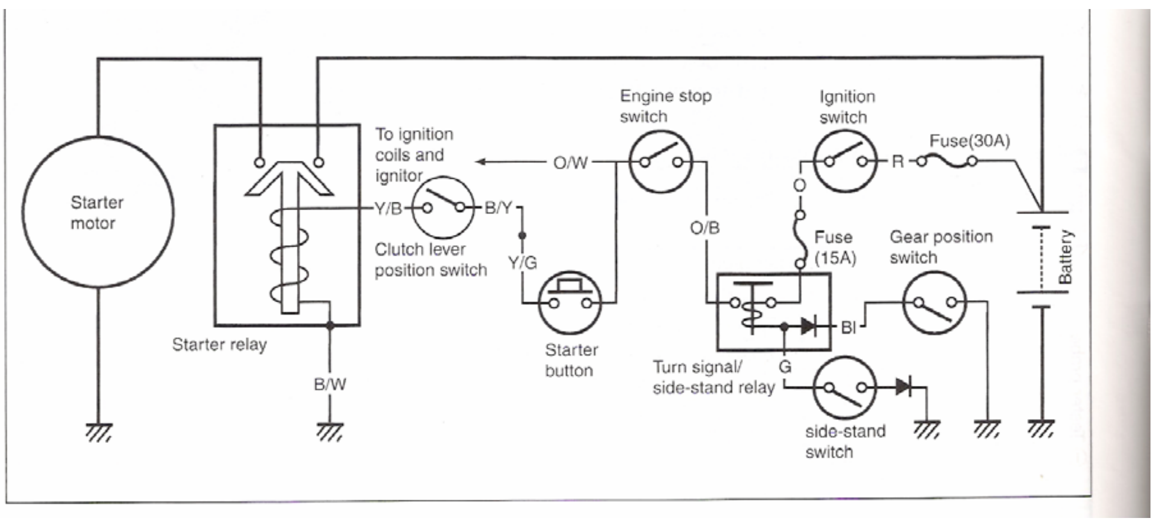
There are three kinds of electrical drawings. A block diagram shows the major components of the electrical system and their relationship to one another. Something like a flow chart. A schematic drawing gives you the scheme of things in detail and a parts layout diagram shows you the actual physical placement of components and it shows the actual physical wiring exactly as it is on the equipment. Electrically the three drawings are identical. The difference is in the way parts and wiring are shown. On a schematic drawing a wire may be shown to connect to a point on another wire half way along its run between two devices when in fact it is connected at either one end of the wire or the other on the bike. This is done to simplify the drawing and to keep lines from crossing over making them harder to follow on the print. Every point along a conductor is the same point electrically so the drawing is accurate, electrically. The parts placement drawing shows the conductor connected to the end of the other wire just as it is in reality. Every attempt is made to picture the different parts placed in relationship to one another as they are on the bike and the actual hook up.

Schematic symbols identify electrical parts and components on the drawing, labels tell you the size or value of a component and can help identify the circuit each is associated with. For example, the label "R112" beside the schematic symbol for a fixed resistor identifies it as the number 12 resistor, in the 100 circuit. All components associated with that circuit will use the 100 designator; C105, Tx190, F104, etc. Usually there is a value near the component name. For a resistor the number 10 below R112 means it is a 10ohm resistor.

On some schematics you will find "TP" with a number following written at some point in a circuit. This is a test point meant to aid in testing a system and there will sometimes be information given as to what voltage or resistance should be seen there under normal operating conditions.

Simplifying the schematic:

You may with a little effort draw a simplified diagram of the circuit you are interested in from the information on the schematic.   A simplified drawing doesn't have to use the complicated symbols used on the main print. So long as you understand the symbols you do use you can use whatever you like. Empty boxes are fine to show relays or switches or groups of devices but it is important that all the wire numbers and colors are accurate. This is a block diagram where no internal wiring is shown and is more a sequence chart than schematic. Below is a simplified schematic drawing of the starting circuit used on the Volusia. Compare this to the schematic for the whole motorcycle above. This is so much easier to follow and understand making the time spent scratching it out worthwhile.



This drawing may be simplified even further by breaking the total starter circuit down into the two major circuits that make it up, the control circuit and the power circuit but really it is pretty straightforward and needs no further reduction.

To read the print start at the power supply, in this case the battery. You'll notice the battery symbol is a long line next to a short line. This symbol represents a cell. A lead/acid cell produces about 2 Volts. There are six of these cells in your bike battery totaling 12 Volts. To show the battery accurately all six cells would be drawn but to save ink this drawing shows only two cells connected by a dotted line. The short line of the symbol represents the – terminal of the cell and the long line the + terminal. The negative terminal of the battery is connected by a line to a symbol representing the frame of the motorcycle. Across the bottom of the print you'll find other frame symbols connected to other points in the circuit. The motorcycle frame is used as a common conductor or "return" so you can mentally connect these points. Using the frame saves wire.

From the positive side of the battery a heavy dark line runs directly to one contact of the starter relay. Notice there is no fuse in this line. From the other relay contact a line goes to the starter motor and the other side of the motor is connected to the frame or return. This is the power circuit. In order for the starter to run we must close the starter relay contacts and complete the circuit.

The control circuit begins at the battery but this time we will start at the other end at the starter relay. What has to happen to close the relay contacts? The coil must be energized to pull the relay armature. One side of the coil is attached to the frame the other to the clutch lever switch. If we close the clutch lever switch, push the start button and the kill switch is in the run position we have a complete path for current up to the kickstand relay. If the kickstand relay contacts were closed and the ignition switch is on the starter relay will energize and the starter motor will run.

So how do we close the kickstand relay? The bottom or negative lead to the relay coil is connected to two wires, each with a switch and a diode in series circuit which is then tied to the frame. The positive lead from the relay coil is attached to the ignition switch through a fuse. Because the two switches in the return side of the relay coil circuit are in parallel closing either one will energize the relay.

This is a relay logic circuit, an "and" and an "or" logic circuit. In order to start the bike you must have the ignition switch on "and" you must have the kickstand up "or" the transmission in neutral "and" you must have the kill switch closed "and" you must have the clutch pulled in "and" you have to push the start button. Simple. Don't let all the lines and squiggles scare you.

Reading an electrical print will help you understand how something works or is supposed to work but as long as it is working who cares and why would we spend the time to study a schematic when we could be riding? It is when it doesn't work that we get out the manual. Then the electrical print becomes a troubleshooting aid.

Trouble Shooting Philosophy and Techniques

Troubleshooting is an art as much as it is a science. It takes a certain mental attitude and a lot of practice and sometimes a little luck to run down a fault efficiently. I've seen very able and successful troubleshooters become so frustrated they begin stabbing their gas tank with a screwdriver and calling their best buddy dirty names all because they went into a problem with the sure knowledge that they already had it fixed! Every new trouble is a new trouble and you must approach the repair with an open mind and method. Because the symptoms are the same as the last time it broke, it doesn't necessarily follow that it's the same problem this time. Method is the secret to successful troubleshooting.

The Smoke Test

The whole idea is to find what is broke. There are symptoms with every electrical illness and part of the process of diagnosis is recognizing symptoms. What does it do? What doesn't it do? To find out you gotta fire her up. This is a form of smoke test. It's a destructive sort of testing and not always reliable. When you blow a fuse there is a tendency to replace it with a heavier one and see what smokes. If the problem is a short circuit what smokes is usually not the problem and a general meltdown is always a possibility.

Eyeballing

The sure way is to gather all the information you can before you "do" anything. Were there any indications of trouble before it broke. Is there more than one system involved? Did you just wash the bike? Have you fixed anything recently or added any new accessories? Is the fuse blown or maybe even shaken out of its socket? Is there gas in the tank?

Look the thing over. Eyeballing will solve about 50% of troubles you'll run into in the electrical system. Check for loose connections, frayed or chaffed wires, corrosion, dirt, light bulbs that have shaken loose from their sockets, and smoke stains too. Feel for hot spots around the affected area. Use your nose to sniff out cooked insulation.

Testing for continuity

When eyeballing fails to uncover the trouble it's time to begin troubleshooting. If something doesn't work the first thing to check is its power supply. Is the battery fully charged and is it connected to the system. Test for power at the fuse. Somewhere there is a switch or other control device to turn the system on and off, see if there is power there. These tests can all be made with a test light or voltmeter.

Test the conductors to and from the failed device for continuity. For this test you will need an ohmmeter and you must remove the battery from the circuit. Do not depend on having the fuse removed to isolate the circuit under test. Remember there is a problem and the problem may be a direct short to another circuit which is still powered up. Placing an ohmmeter in an energized circuit will damage the meter.

Continuity testing is easy. From the schematic you can find test points where you can check individual wires to see if they are intact, open, or shorted to ground. It is always best to completely isolate the wire if possible. You can do this by disconnecting it at both ends or by removing the load device and pulling the fuse or opening a switch or removing a light bulb.

Place one test lead on one end of the wire in question and the other meter lead on the frame. Zero ohms means it is connected to ground, an infinite reading means it is clear. A reading of zero ohms to ground may be normal if the wire in question is a return lead. With one test lead still attached to the wire touch the other lead to the other end of the wire. A zero reading means the wire is intact; any other indication means something is wrong.

Switches are tested in the same way. Place the meter leads across the switch and turn it on and off. The meter should show zero ohms when the switch is closed and infinite when open, anything else is a fault.

Coils can be tested with an ohmmeter too but here you will need to know what the normal resistance of the coil should be so you can compare your findings to that.

Testing under load can reveal problems that passive tests miss. Intermittent troubles associated with overheating will not be seen unless the system is under load. Testing that ignition pick-up coil for peak voltage can only be done while the crankshaft is turning. Tracing a circuit means following along its path with a voltmeter while power is applied and checking it at selected points for power. When you get to a point where power is lost you have isolated the trouble.

When you are satisfied that no problem exists in the circuitry itself then it’s time to test the load device. The easiest way is to replace it with a known good one but for the most part electrical parts are not returnable and can be expensive. It is best to make sure the thing is bad before you get a new one. For these tests check the manual for instructions and specifications.