Relays & Wiring 101

Basically, a relay is an electrically operated, remotely controlled switch.

A simple electromagnetic relay is an adaptation of an electromagnet. It consists of a coil of wire surrounding a soft iron core, an iron yoke, which provides a low reluctance path for magnetic flux, a movable iron armature, and a set, or sets, of contacts. The armature is hinged to the yoke and mechanically linked to a moving contact or contacts. It is held in place by a spring so that when the relay is de-energized there is an air gap in the magnetic circuit.

When an electric current is passed through the coil, the resulting magnetic field attracts the armature, and the consequent movement of the movable contact or contacts either makes or breaks a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movement opens the contacts and breaks the connection, and vice versa if the contacts were open. When the current to the coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to its relaxed position.

When energizing the coil of a relay, polarity of the coil does not matter unless there is a diode across the coil. If a diode is not present, you may attach positive voltage to either terminal of the coil and negative voltage to the other, otherwise you must connect positive to the side of the coil that the cathode side (side with stripe) of the diode is connected and negative to side of the coil that the anode side of the diode is connected. Diodes are not common in motorcycle applications.

Some basic relay definitions:

Coil
That part of a relay which is energized to create a magnetic field that attracts a hinge that in turn carries out the switching function. The coil voltage (nominal coil voltage) is set by the manufacturer. The presence or absence of a voltage supply to the coil switches the relay. The coil will activate its hinge at a certain voltage (the pick up voltage) and release it at the drop out voltage.

Contacts
The moveable contact, which is the one affected by the armature is sometimes referred to as the hinge contact.

Normally Open (NO). A pair of contacts including the hinge that are separated at rest with no electrical connection, sometimes called the front contact.

Normally Closed (NC). A pair of contacts including the hinge that are connected at rest. Sometimes called the back contact.

A relay will always have at least two contacts, one being the hinge.

Any circuit utilizing a set of relay contacts will always utilizes a hinge contact. Depending on circuit design, that hinge contact will act in conjunction with either a NO or NC contact, or both. The hinge contact will only connect to either the NO or the NC contact, but not both at the same time. What this means is that as the hinge contact transverses the space between the NO and NC contact, for an instant, it is not touching either one. There are special contacts that are called 'Make before Break', these are used when the design of the circuit requires a bridging continuity between the NO and NC contact. This type of contact is seldom found in automotive or motorcycle applications.

The following designations are commonly encountered:

SPST – Single Pole Single Throw. A hinge contact connects to another fixed contact. Including two for the coil, such a relay has four active terminals.

SPDT – Single Pole Double Throw. A common hinge contact connects to either of two fixed contacts. Including two for the coil, such a relay has five active terminals.

DPDT – Double Pole Double Throw. Similar to the SPDT, this type has two sets of contacts, The hinge contact for each set of contacts acts in unison with the other hinge contact. Including two for the coil, such a relay has eight active terminals.

The current flow ratings for automotive style accessory relay contacts are typically in the 30 to 40 amp range.

Coil resistance values are in 50 to 100 ohm range. This produces a current flow of 200 -250 ma (1/4 amp) when energized.

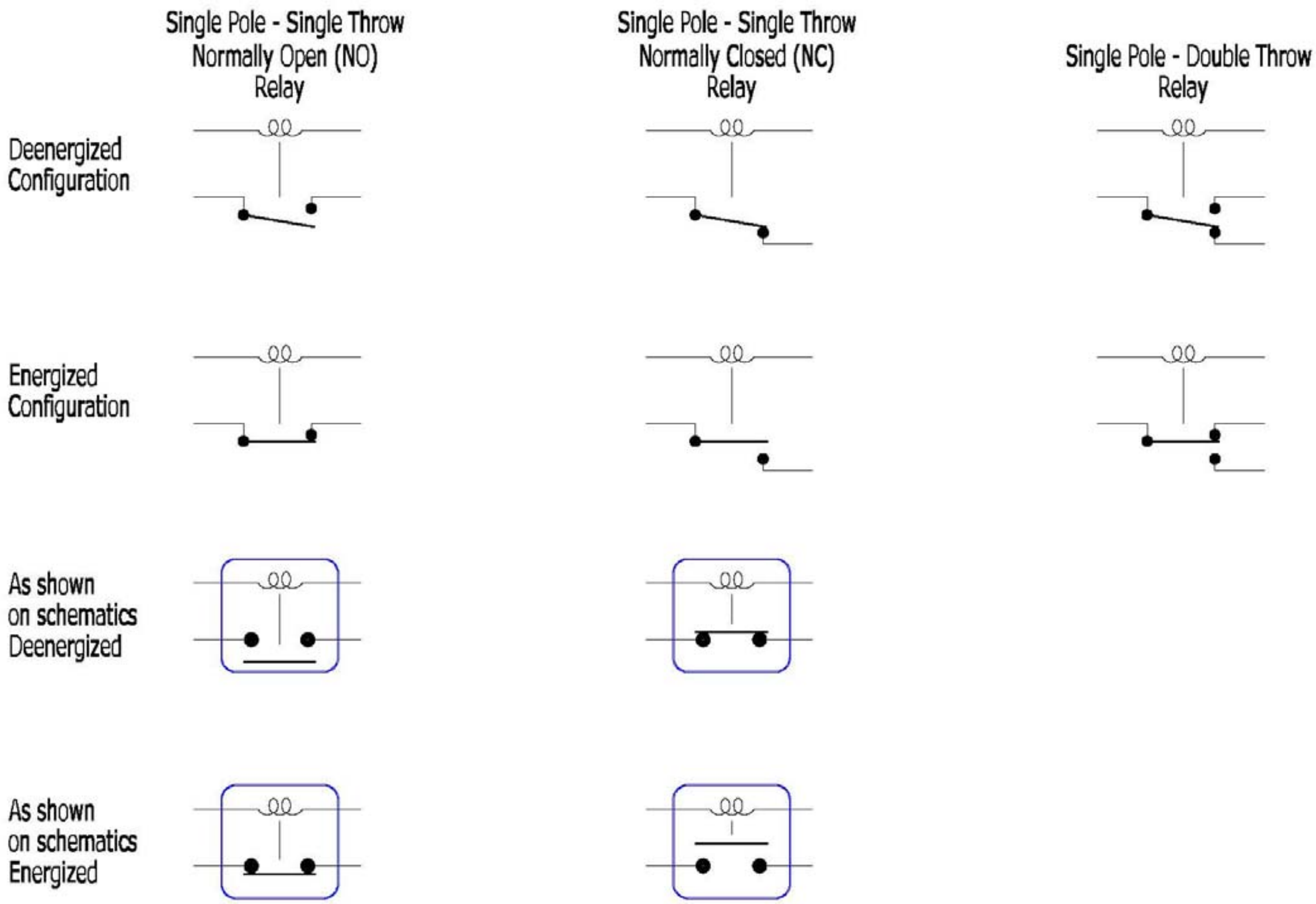

Figure 1 Relay schematic representations

Shown above are some of the ways of schematically depicting relay contact and coils.

The bottom two rows are the format that I used when I redrew the schematics for the Ventures. This method of representation does not indicate which contact is the hinge contact though. With a SPST configuration, which is the only style used on the Ventures, I felt this was an easier format to draw.

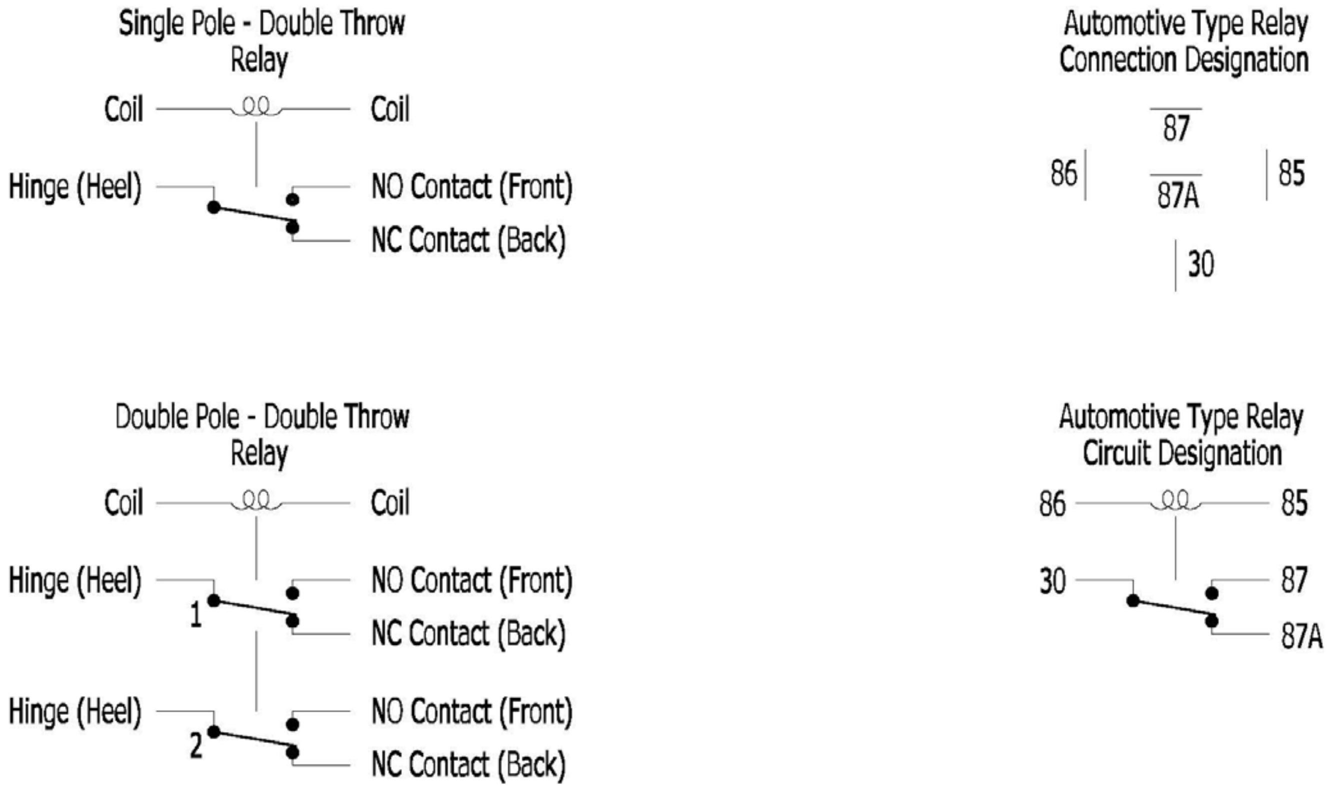

Figure 2 Relay contact designation

Shown above left, is the configuration for SPDT relay configurations. Below right is the configuration for a DPDT relay. On the top right is the contact arrangement for a typical accessory automotive style relay. If the relay is a SPST (Normally Open) configuration, the 87A connector on the base may be omitted. I have such a relay that has this connector on the base, but it is labeled 87. It is electrically tied to the 87 contact internally. What this means is that it can not always be determined if a relay is a SPST or a SPDT by counting the connectors on the base of the relay.

Determining a Relay configuration using an Ohm meter:

To determine the internal configuration of an automotive style relay with an Ohm meter, first check for a resistance reading in the range of 50 to 100 ohms between terminals 85 & 86. If this is the reading obtained then the coil is connected to these two contacts.

Next check for a reading between terminals 30 and 87A, if the reading is zero, then this relay has a NC contact. If this reading is open then there is no NC contact in the relay. There should be a reading showing open between terminals 30 and 87 when the coil is de-energized.

Next energize the relay by placing a 12 volt power supply across terminals 85 and 86. This will cause the relay to produce a clicking sound as the coil energizes.

Now check the ohm reading from terminals 30 to 87A again, it should now read open. The reading from terminals 30 to 87 will now read zero.

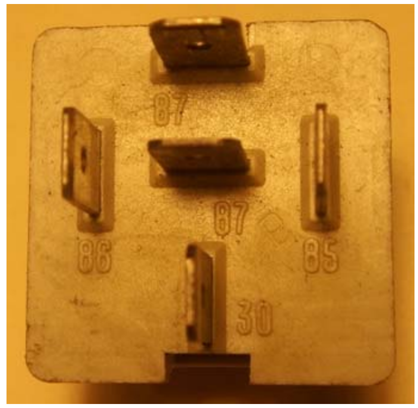

Figure 3 Bottom view of automotive style relay

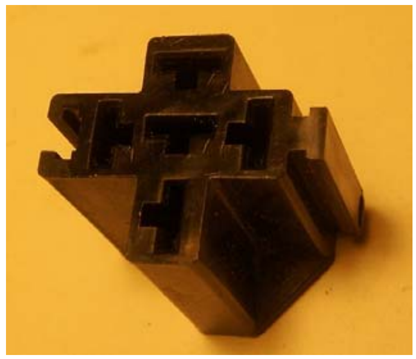

Figure 4 Plug connector for automotive style relays

In **Error! Reference source not found.**, the center terminal is shown as #87, in actuality this is terminal should be 87A, it is connected to the NC contact. This is the base of the relay shown in Figure 8 and Figure 9. This discrepancy is the reason that the procedure for using an ohm meter to verify the contacts is described above. Figure 4 shows a plug in base that is available for the automotive style relays. The base is designed to be used with spade lug connectors that are captured in base.

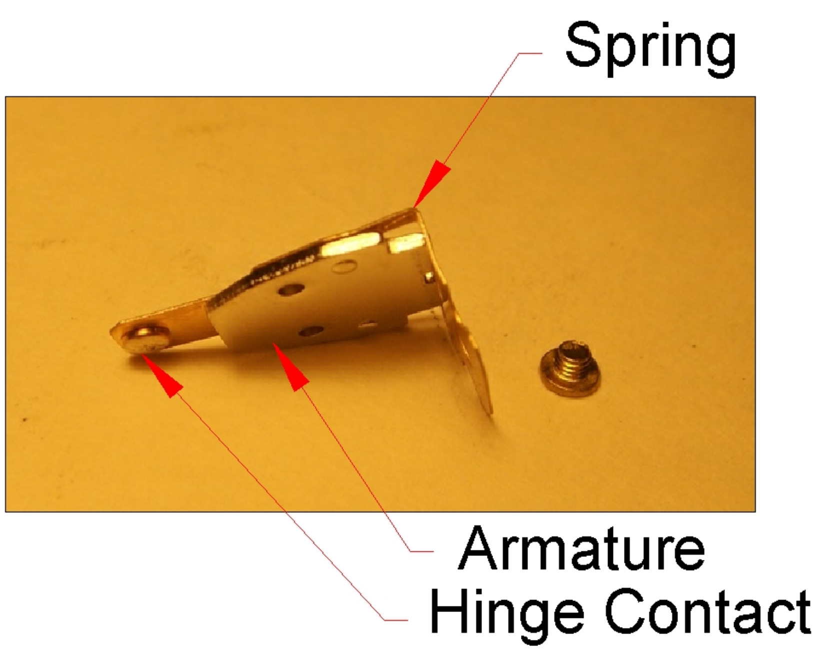

Figure 5 Hinge contact from a typical SPST NO 1st Generation Yamaha Venture relay.

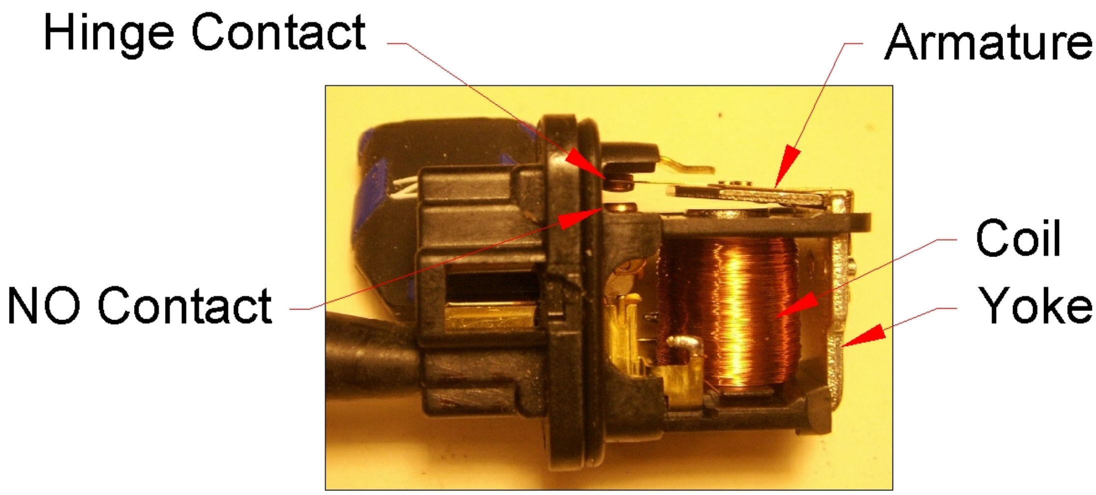

Figure 6 De-energized, Normally Open, Single Pole Single Throw

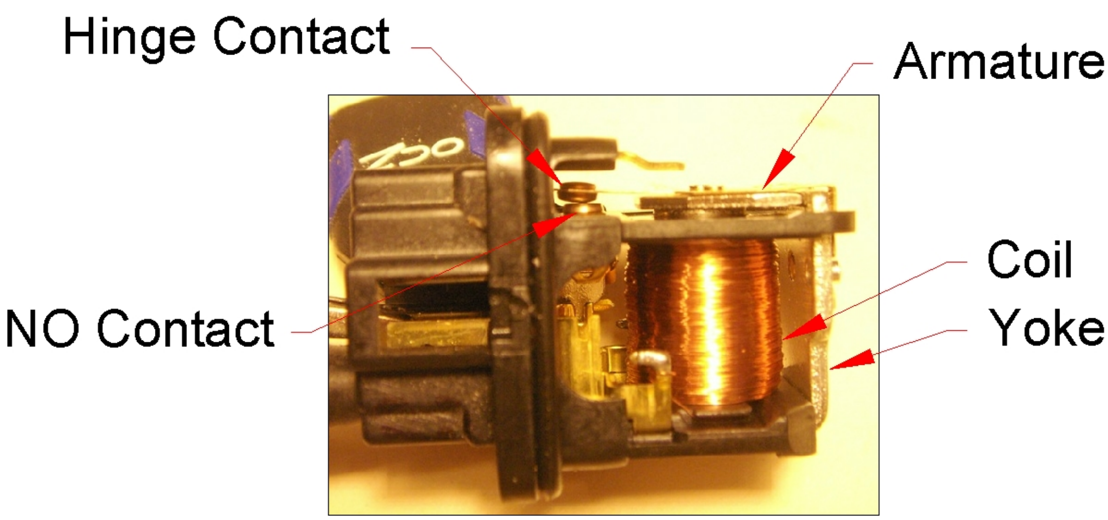

Figure 7 Energized, Normally Open, Single Pole Single Throw

Figure 6 and Figure 7 show a typical Yamaha Venture relay internally. All of the relays in the stock Venture are Single Pole Single Throw. All relays, with the exception of the side stand relay (1983-1993 models) are NO type contacts. The side stand relay (1983-1993 models) is a NC type contact.

Note that in Figure 6 the armature is not pulled down against the yoke. This allows the spring in the armature to move the hinge contact away from the NO contact which opens the circuit going through the contacts. In Figure 7, the coil is now energized, pulling the armature down in contact with the yoke. This movement then closes the connection between the hinge contact and the NO contact.

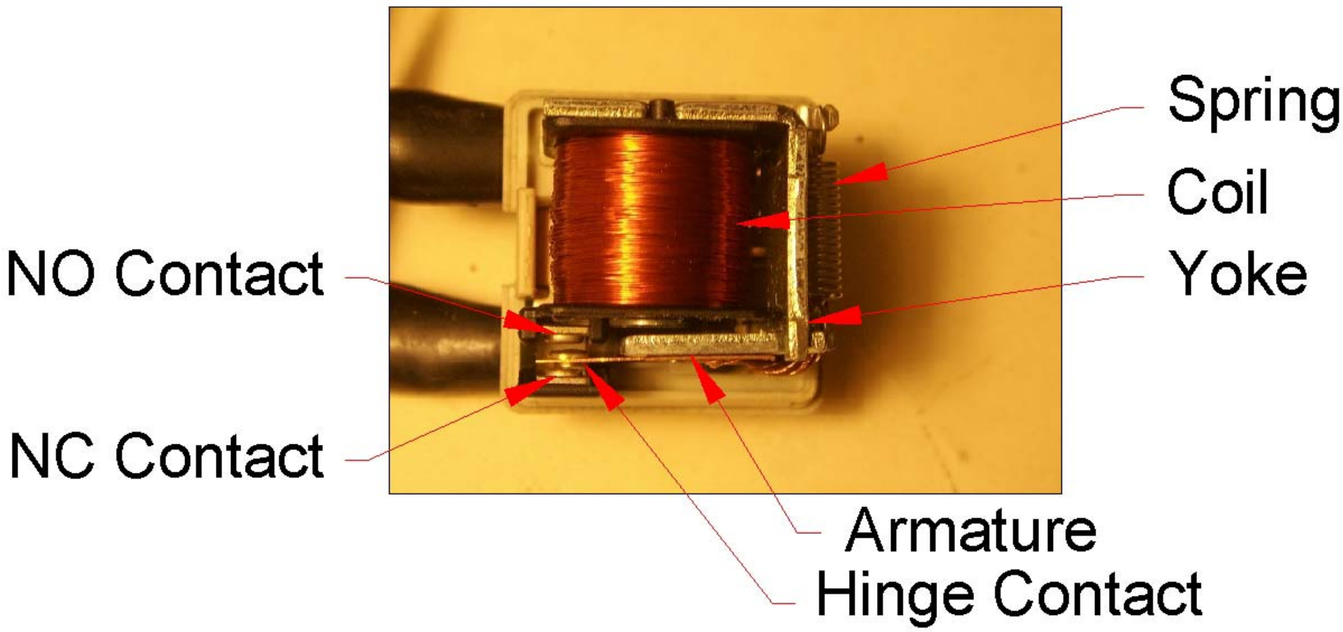

Figure 8 De-energized, Single pole Double Throw

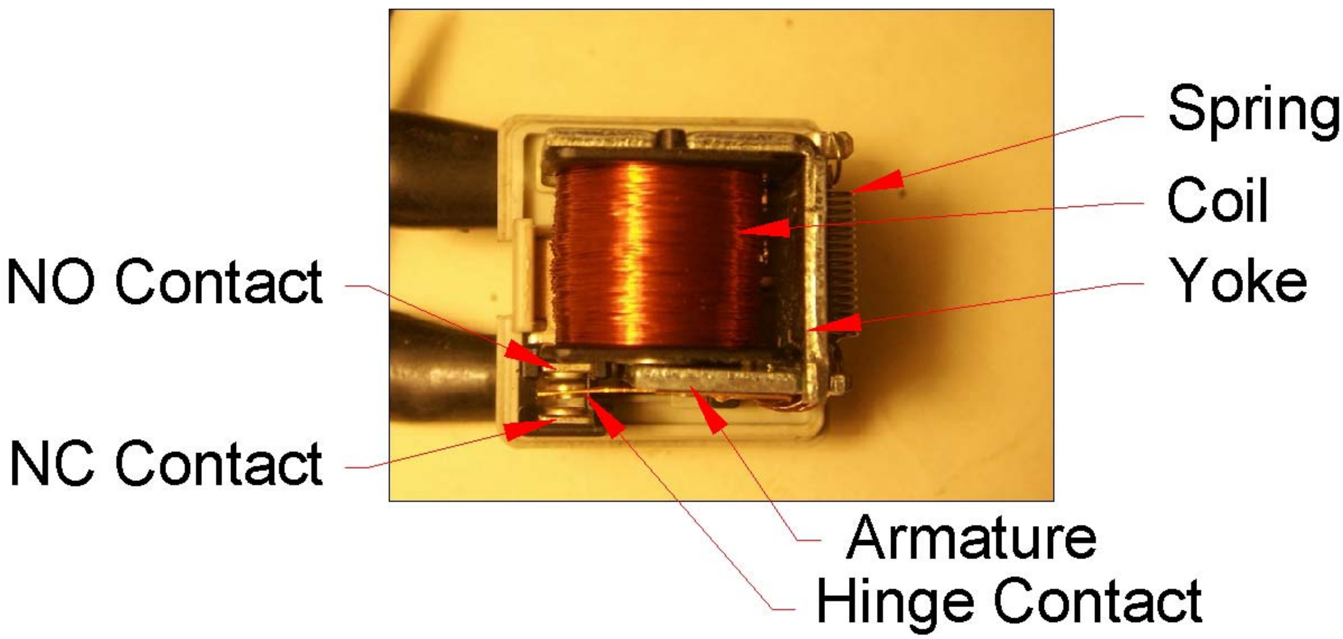

Figure 9 Energized, Single Pole Double Throw

Figure 8 and Figure 9 show a typical automotive type accessory relay that is available from auto parts stores.

Note that in Figure 8 the armature is not pulled up against the yoke. This allows the spring in the armature to hold the hinge contact away from the NO contact which opens the circuit going through this contact. The circuit going through the NC contact is closed. In Figure 9, the coil is now energized, pulling the armature up in contact with the yoke. This movement closes the connection between the hinge contact and the NO contact, and at the same time opening the connection between the hinge contact and the NC contact.

There are four basic units of measurement for electricity.

- **Current**, measured in Amps, commonly referred to as "I"
  Definition: Electrical current is a measure of the amount of electrical charge transferred per unit time. It represents the flow of electrons through a conductive material.
- **Voltage**, measured in Volts, commonly referred to as "V"
  Definition: Voltage is a representation of the electric potential energy per unit charge. If a unit of electrical charge were placed in a location, the voltage indicates the potential energy of it at that point. In other words, it is a measurement of the energy contained within an electric field, or an electric circuit, at a given point.
- **Resistance**, measured in Ohms, commonly referred to as "R"
  Definition: Opposition that a material or electrical circuit offers to the flow of electric current. It is the property of a circuit that transforms electrical energy into heat energy as it opposes the flow of current. The ohm is the common unit of electrical resistance; one ohm is equal to one volt per ampere.
- **Power**, measured in Watts, commonly referred to as "P"
  Definition: The standard unit of measurement of electrical power. The watt is used to specify the rate at which electrical energy is dissipated. One watt is one ampere of current flowing at one volt.

If you know any two of these values, you can solve for the other two values using Ohm's law. It is necessary to be able to calculate these values in order to properly select wire and fuse sizes.

Normally, on a motorcycle, the voltage is a known. Even though the battery is referred to as a 12 volt, the value that should be used for calculations is 14.5 volts. This is the system voltage when the charging of the generator is taken into consideration. One other value is needed. Depending on the purpose of the circuit being installed, generally the wattage or amp draw is available.

In the case of lights, the total wattage of lights being added can be determined. Since you know the voltage and watt load on the circuit, the value that needs to be calculated is the current load of the circuit. The resistance of the circuit could also be calculated, but that value is of little use knowing the voltage and watts. Using the Ohm's law chart shown in Figure 10, in the amps quadrant, the formula used when voltage (V) and watts (P) are known is P / V.

Assuming that a pair of 50 watt lights are being installed, this would then be 100 / 14.5 = 6.89 amps.

Now with the amperage of the circuit known, it is possible to make proper decisions as to wire and fuse sizes. For the purpose of wiring and fusing selection, multiply the calculated circuit amps by a 1.50 value. In this case, 6.89 amps x 1.50 factor = 10.33 amps.

Next, determine the total length of wire in the power circuit. This length does not include any wiring used to control the relay coils. Only estimate the wire needed from the power source to the relay contacts, then to the accessory being added, then the return back to ground.

Using the Wire Size Requirement Chart shown below, across the top locate the length of wire required and down the left side locate the amperage of the circuit that was calculated. Where these two intersect is the size of wire that should be used for the circuit. In the example of a pair of 50 watt lights, and assuming a wire run of 10', the needed wire size would be 14 gauge.

Next, using the Stranded Wire Size Chart, locate the row for the required wire size. The right hand column will list the maximum fuse size that should be used with the listed wire sizes.

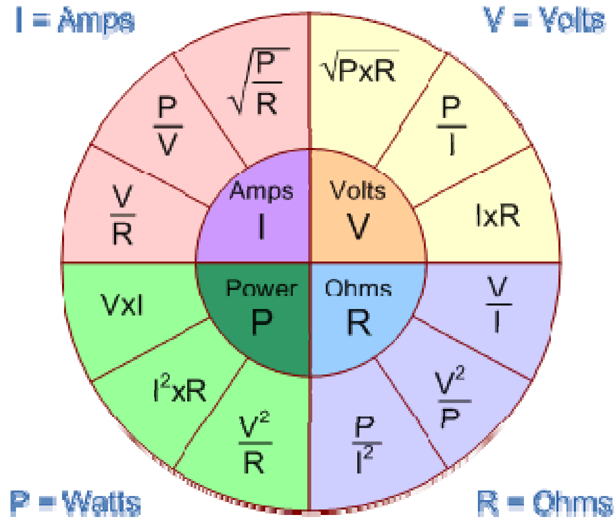

Figure 10 Chart detailing Ohm's law formulas

Fuse
An over current protective device with a fusible link that operates and opens the circuit in an over current condition.

The purpose of a fuse in an electrical circuit is to protect the components in the circuit in case of a malfunction in the circuit. This protection prevents overheating in the wiring when the current flow exceeds the expected values. When current through the fuse exceeds the rating of the fuse, it opens by the melting of a current sensitive element.

Fuses are specified to interrupt within a maximum of 5 seconds when driven at 200% of their rated current for nominal ratings up to and including 10 amperes. A fuse with a nominal rating higher than 10 amperes is specified to interrupt within a maximum of 10 seconds when driven at 200% of its rated current. The longer a fuse is driven above the rated current the lower the current value required to interrupt.

Fuse size selection needs to be done taking into consideration the lightest gauge wiring in the protected circuit. If you are going to tap into a circuit for power that is protected by a 20 amp fuse, you need to use a wire size that will not overheat if there is a failure in that leg of the circuit. If 18 gauge wire were to be tied into a circuit protected by a 20 amp fuse, there is the possibility that due to a failure in the 18 gauge portion of the circuit, the wire could over heat enough to cause a fire without reaching the 20 amp rating of the fuse. An acceptable exception to the preceding statement would be tapping into a circuit then immediately branching off to an appropriately sized fuse for the circuit being installed.

You can put a smaller size fuse in a circuit that has wiring rated for more amperage, but you should not put a larger fuse in a circuit than the wiring is rated for. An example of using a smaller fuse would be the audio backup circuit in the 1st Generation ventures (83-85 models). This circuit used a 1 amp fuse in a circuit with 20 gauge wiring. This fuse size was determined by the component specifications that that the circuit powered.

When installing a fuse, choose a location as near the power source as possible. This will reduce the amount of wire that is unprotected in the circuit.

Stranded wire sizes chart (AWG)

Fuse size shown below are conservative suggestions for added circuits.

Gauge	Dia.	Maximum fuse @ 14 volts
20	.032"	5 amp
18	.040"	10 amp
16	.051"	15 amp
14	.064"	20 amp
12	.081"	30 amp
10	.102"	40 amp
8	.128"	50 amp

Wire size requirement chart

Amps @ 14 Volts DC	Total Length of Wire in Circuit American Wire Gauge (AWG)						
	3'	5'	7'	10'	15'	20'	25'
0 to 1	20	20	20	20	18	18	18
2	20	20	20	18	18	18	16
3	20	20	18	18	18	16	16
5	20	18	18	18	16	16	16
7	18	18	18	16	16	16	14
8	18	18	16	16	16	14	14
10	18	16	16	16	14	14	12
11	16	16	16	14	14	12	12
12	16	16	14	14	12	12	12
15	16	14	14	12	12	12	10
18	14	14	12	12	12	10	10
20	14	12	12	12	10	10	10
25	12	12	12	10	10	10	8
30	12	10	10	10	10	8	8
35	10	10	10	10	8	8	8
40	10	10	8	8	8	8	8
50	8	8	8	8	8	8	8

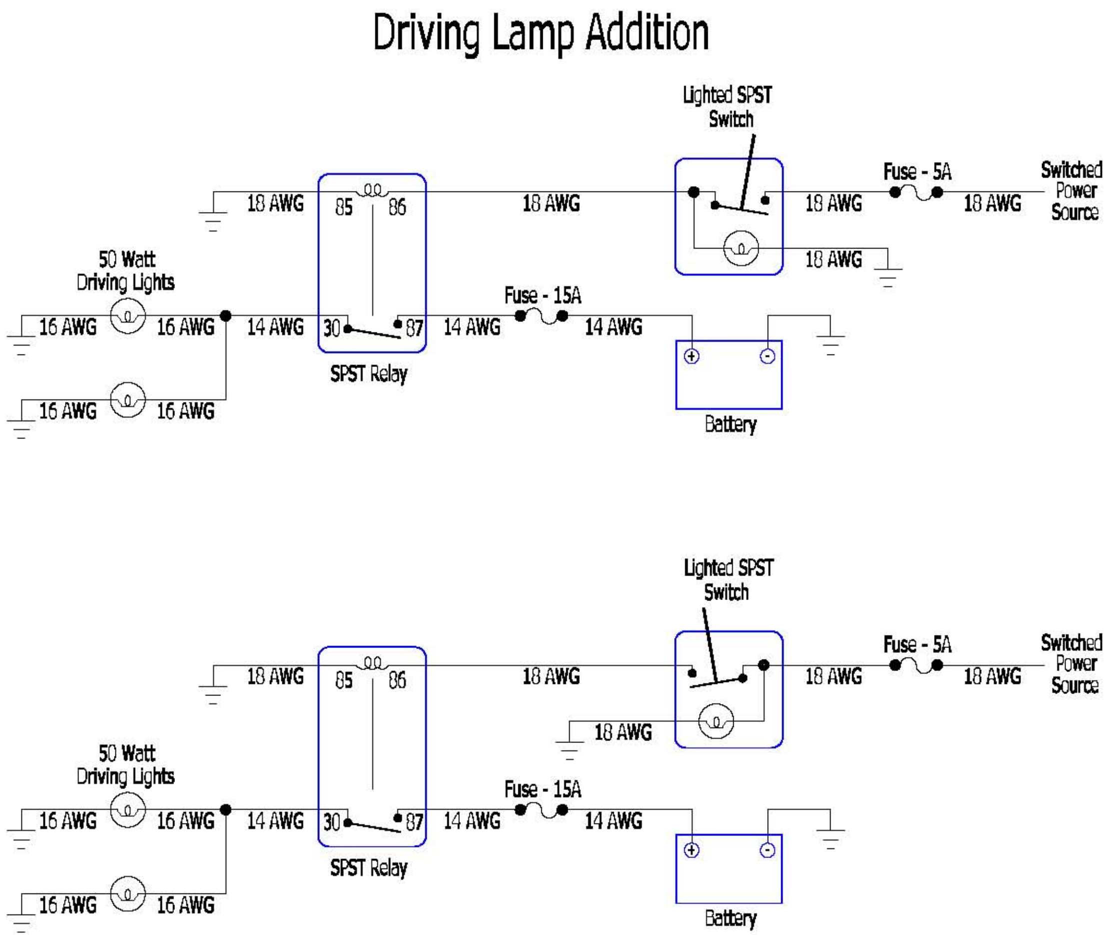

Figure 11 Driving Lamp addition

Figure 11 shows an addition of a pair of driving lamps. The circuit is shown twice with a wiring variation described next.

There are some things in this circuit that could be modified depending on your preference. The lighted switch, as shown in the top version is illuminated when the switch is on. If desired, the switch could be continually illuminated as shown in the bottom version whenever the key switch is on, regardless of the position of the switch. This may be desired to illuminate the switch at night for easier locating.

Another item that could be changed is the 16 AWG wire that is noted after the circuit splits to each light on left side of the relay. The 16 AWG wire is sufficient due to the load of only one light is running through these wires. In practicality, you are probably not going to buy different sizes of wire to do this and run in 14 AWG wire.

Note that I have shown the power source from the battery on terminal 87 of the relay. The reason I prefer to put power on this terminal as opposed to putting it on terminal 30 is that if a SPDT relay is used there would be a terminal 87A present. When the relay is in the de-energized position, there would then be power present on terminal 87A. It is better from a design perspective to put the load on the hinge side of the contact pair.

As a point of interest, I checked the wiring used in the headlight circuit of a 1983 and a 1988 Venture. The 1983 used 20 gage wiring and the 1988 used 18 gauge wiring.

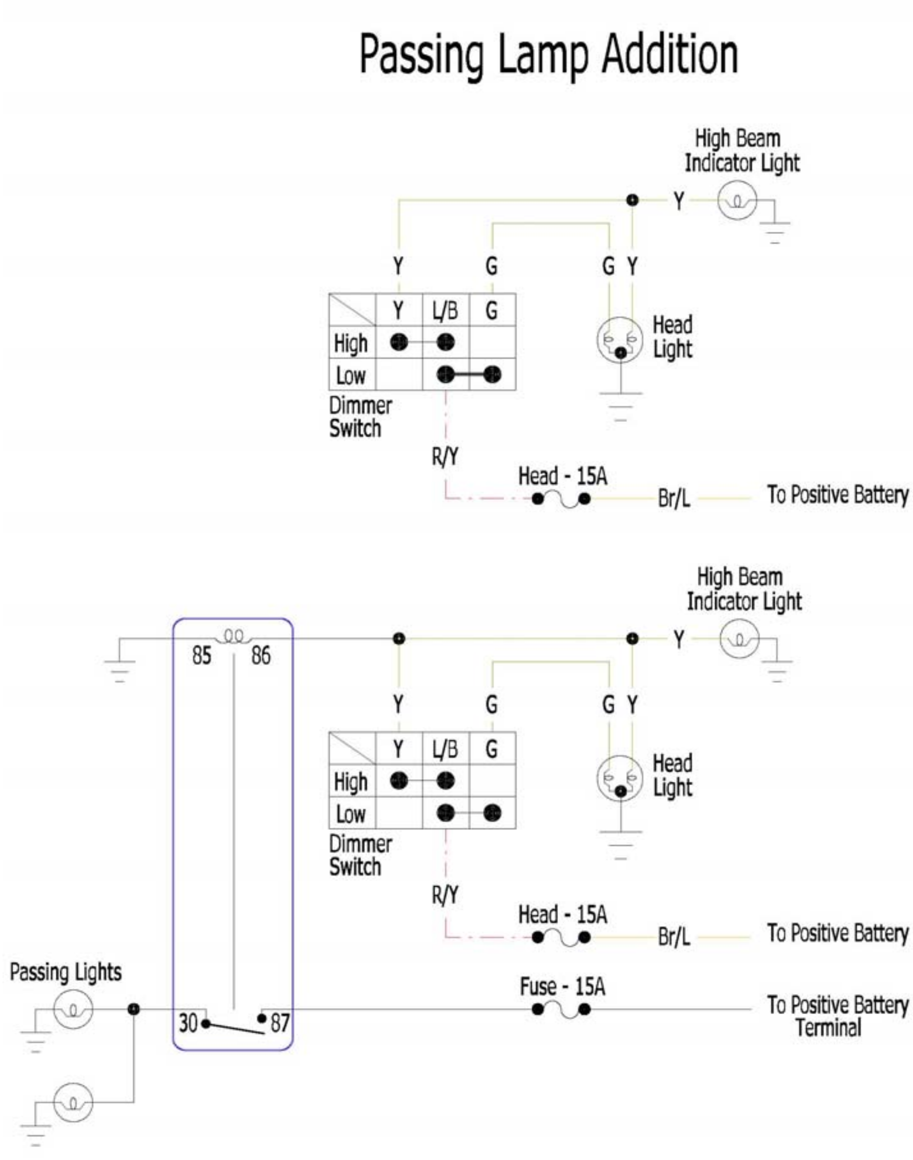

Figure 12 Passing Lamp addition for RSV's

Figure 12 shows an addition of a pair of passing lamps. This circuit is similar to the driving light example shown in figure 8, thus I have not went to the detail of showing the individual wire sizes. In this example, the lights will turn on when the high beam is activated. If you flash the high beams, these lamps will flash as well.

The circuit is shown twice, at the top it is shown as it is in a stock bike. At the bottom is shown the modifications.

As shown in the bottom circuit the relay coil is wired in parallel with high beam element of the bike. It is then protected by the existing 15 amp fuse in the headlight circuit.

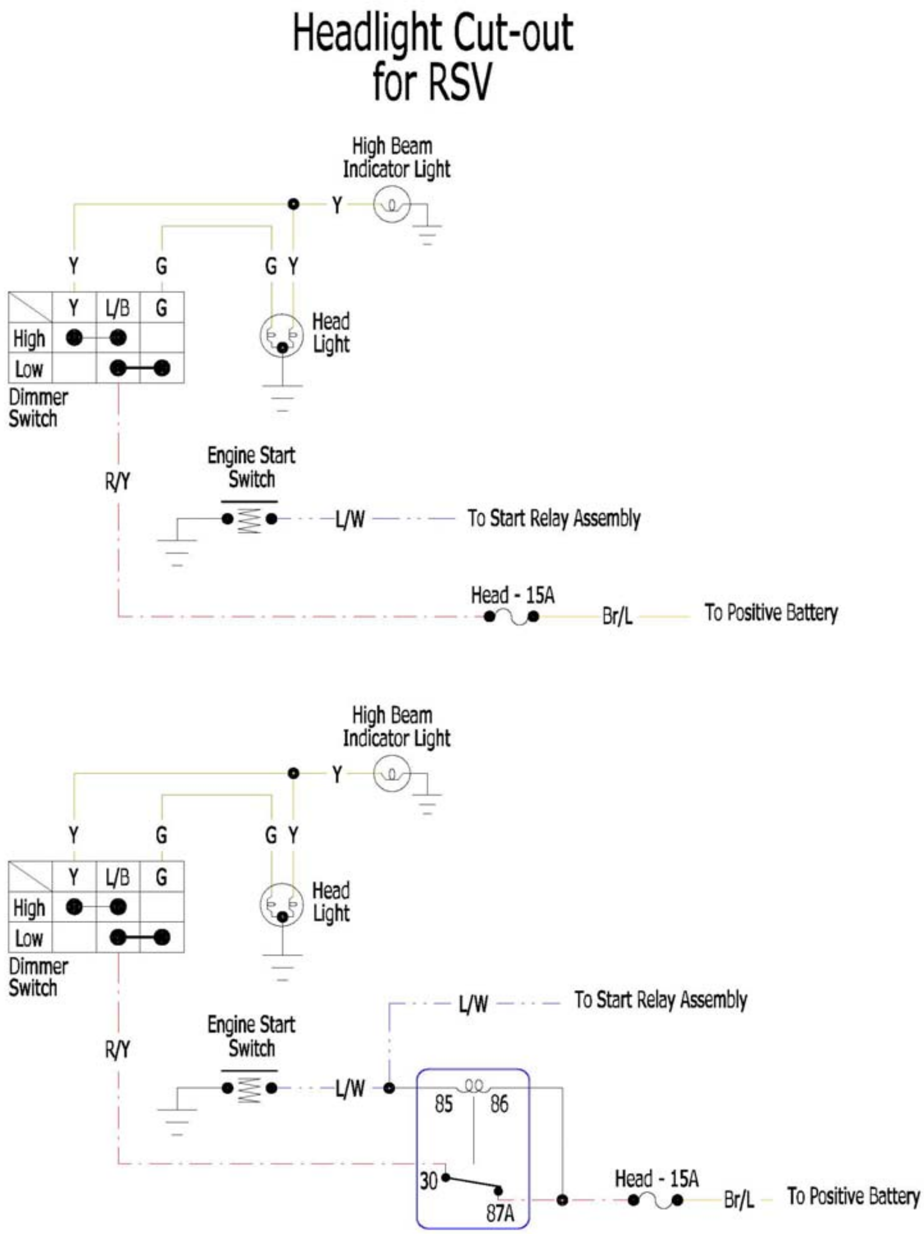

Figure 13 Headlight Cut-out for RSV's

Figure 13 shows an addition of a circuit that will turn of the headlight when the engine is being started. This circuit requires the use of a SPDT relay.

The circuit is shown twice, at the top it is shown as it is in a stock bike. In the top view, the start button circuit is only partially shown. This circuit continues on to the Starting Circuit Cut-off Assembly

At the bottom is shown the modifications. As the circuit is shown at in the bottom view, when the relay is de-energized the headlight circuit operates normally. When the start button is pressed, a path to ground is completed through the start switch which energizes the relay coil. This causes the relay hinge contact to break its connection with the 87A contact, thus opening the circuit to the headlight. As soon as the start button is released, the relay returns to its de-energized position and the headlight circuit is restored.

In this example, no additional fusing is required. The relay coil and contacts are protected by the existing 15 amp headlight fuse.

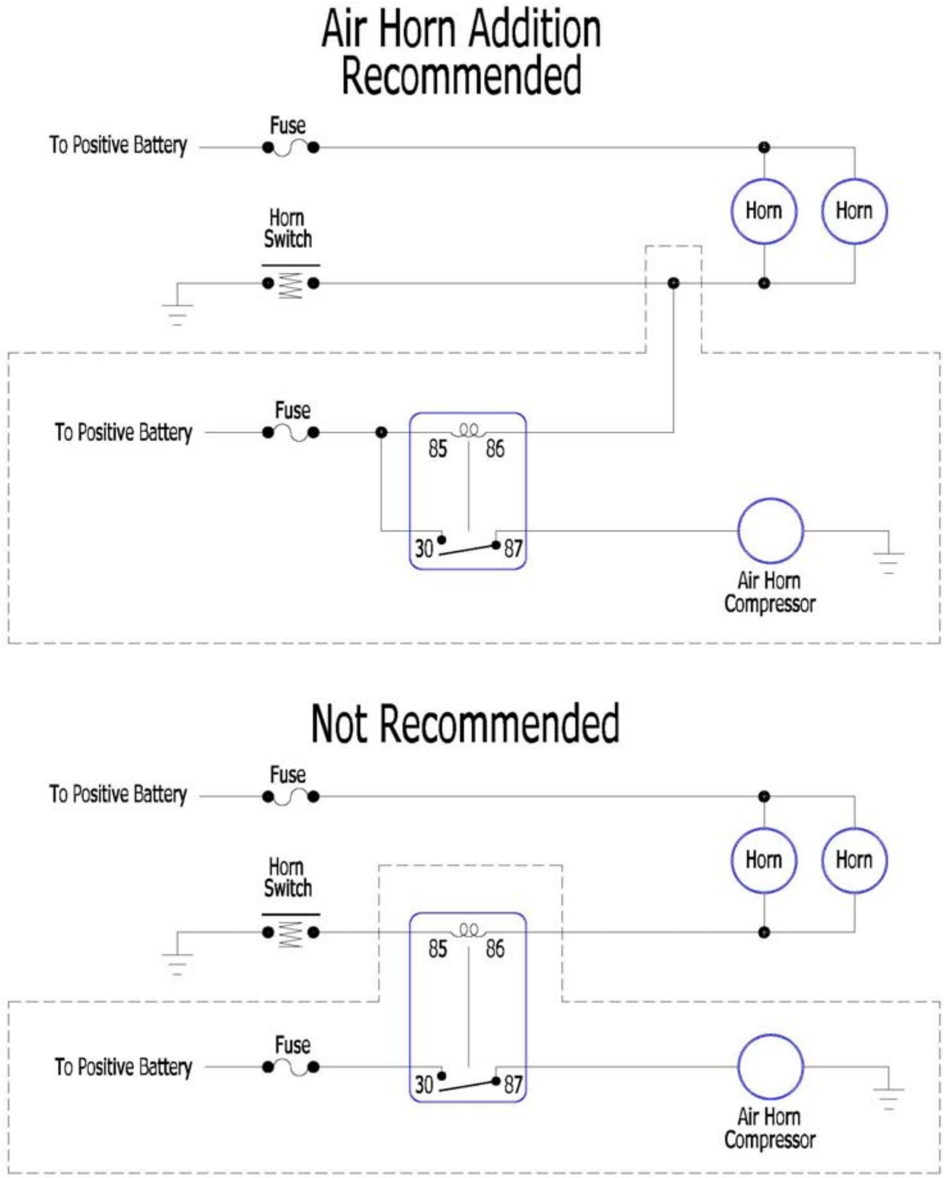

Figure 14 Air Horn addition

Figure 14 shows an addition of a circuit that will turn on the compressor of an air operated horn utilizing the existing horn button. The new circuit is addition is shown inside the dashed box. The top version shows the relay coil being installed in parallel with the existing horns. The bottom version shows the relay coil being installed in series with the existing horns.

The relay coil appears as though it would function in either example. When the horn button is pressed there is a current path in both examples. The problem with the bottom example is that the energy load of the existing horns is now routed through the coil of the new relay. This will, in effect, place a resistor in the circuit for the existing horns. The existing horns performance will be diminished.

The top circuit shows the coil of the relay being placed in a new circuit, separately fused. The only change to the existing circuit is the additional power required to operate the coil of the relay, which is approximately 200-250ma or ¼ of an amp. There is no resistive load placed on the existing circuit.

RSV Ignition switch bypass

Disconnect the negative battery cable. Some of the wires being modified have energy on them even when the key is in the Off position.

Refer to Figure 16 and Figure 17 for schematics of this modification, before and after. I have only showed the pertinent wiring in these two schematics. The full RSV schematics are located at the link below.

http://www.venturerider.org/forum/forumdisplay.php?f=91

Locate the relay under the fuel tank of the RSV on the left side of the frame with the wiring harness just above the cruise throttle cable joint, where the relay can lay next to the frame and be out of the way for the fuel tank to go back on.

Next locate the wires coming out of the ignition switch. The picture in Figure 15 is used to help locate the two connectors. Do not cut or modify the wires between the ignition switch and the connectors attached to the ignition switch. Make the modifications on the main wiring harness. The reason this is recommended is that if the ignition switch ever does fail, you will be able to unplug the two connectors and remove the switch.

Soldering wires as large as 10 AWG is very difficult with a soldering iron. Unless you have a high wattage gun in the 150 – 200 watt range, I would not recommend soldering larger gauge wires. Use an alternate style connector such as a Posi-Lock tap. These must be high quality connections.

As shown Figure 15, there are two red connectors on the key switch. One has three wires in it, and the other has two 10 gauge wires in it. The one with the larger wires (one Red and one Brown with blue tracer) are the only wires being modified.

Splice a new piece of 10 AWG to the existing large Red wire in the ignition switch circuit. Route this wire to the relay and connect to the terminal labeled "87" on the on the relay. This is the Normally Open contact.

Cut the Brown with Blue tracer wire. Connect the end of this wire that goes back into the wiring harness to terminal labeled "30" on the relay. This is the hinge contact of the relay. If extra wire length is needed to reach the relay, use 10 AWG wire.

Connect the other cut end of the Brown with Blue tracer wire that goes to the ignition key switch to an ATC style fuse holder. Connect the other side of the fuse holder to the terminal labeled "86" on the on the relay. This is one side of the coil. If extra wire length is needed to reach the relay, use 16 AWG wire.

Connect a 16 AWG wire to terminal "85" on the on the relay to Ground. There is a ground lug on the right side of the frame neck (it has a wide flat taped up wire under an unpainted bolt with a 10 mm head). This will complete the circuit for the relay coil.

The following thread on the VentureRider.org can be referenced for further discussion on this modification.

http://www.venturerider.org/forum/showthread.php?threadid=31394

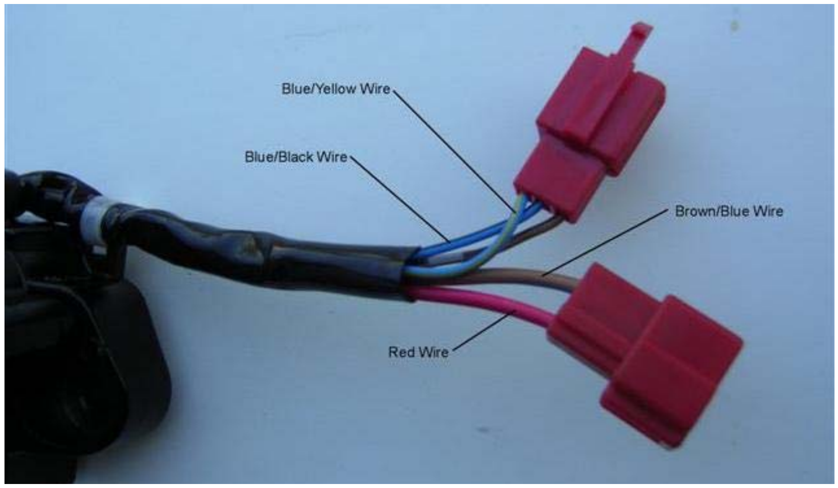

Figure 15 RSV ignition switch wires & connectors

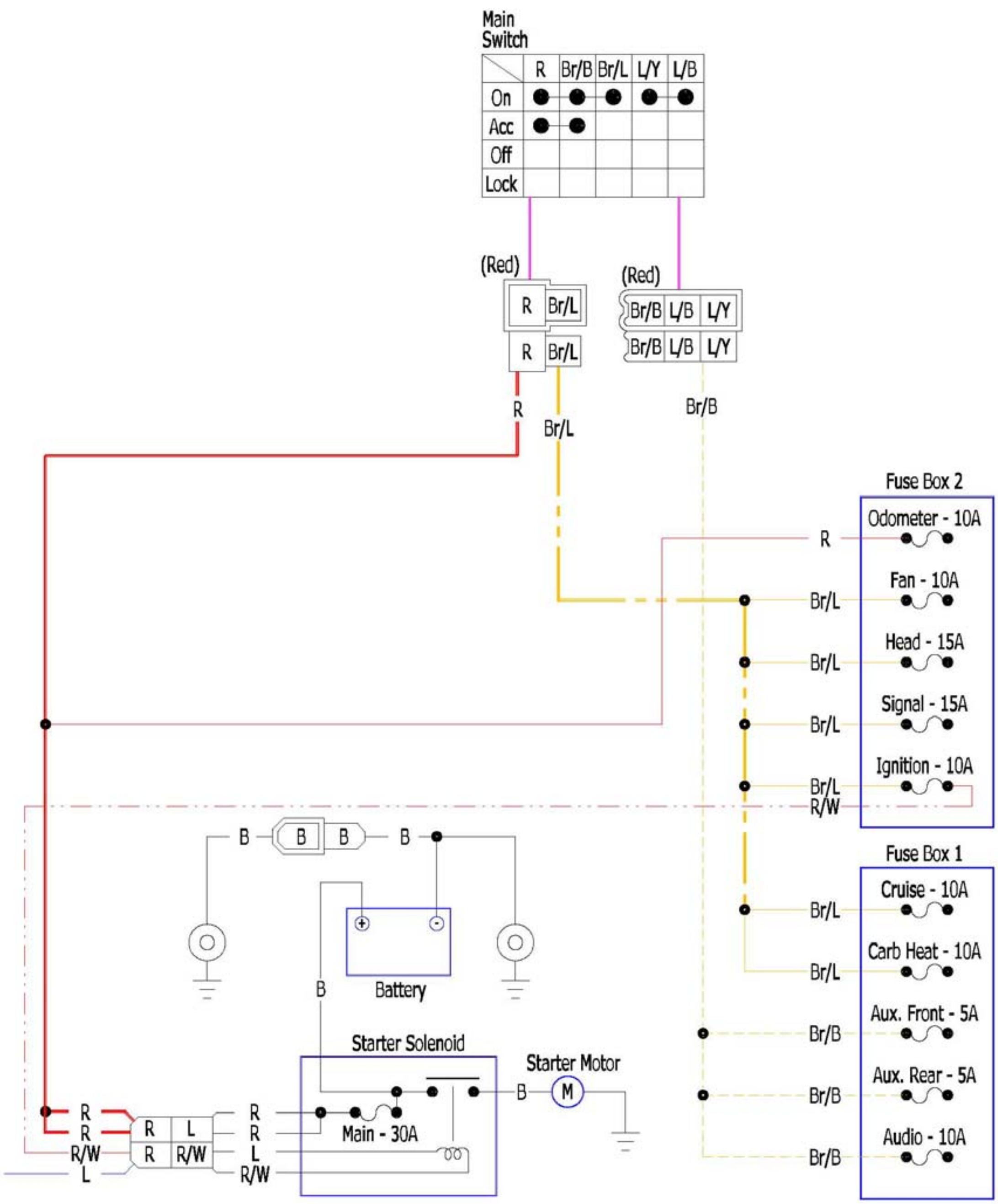

Figure 16 RSV Ignition bypass modification Before

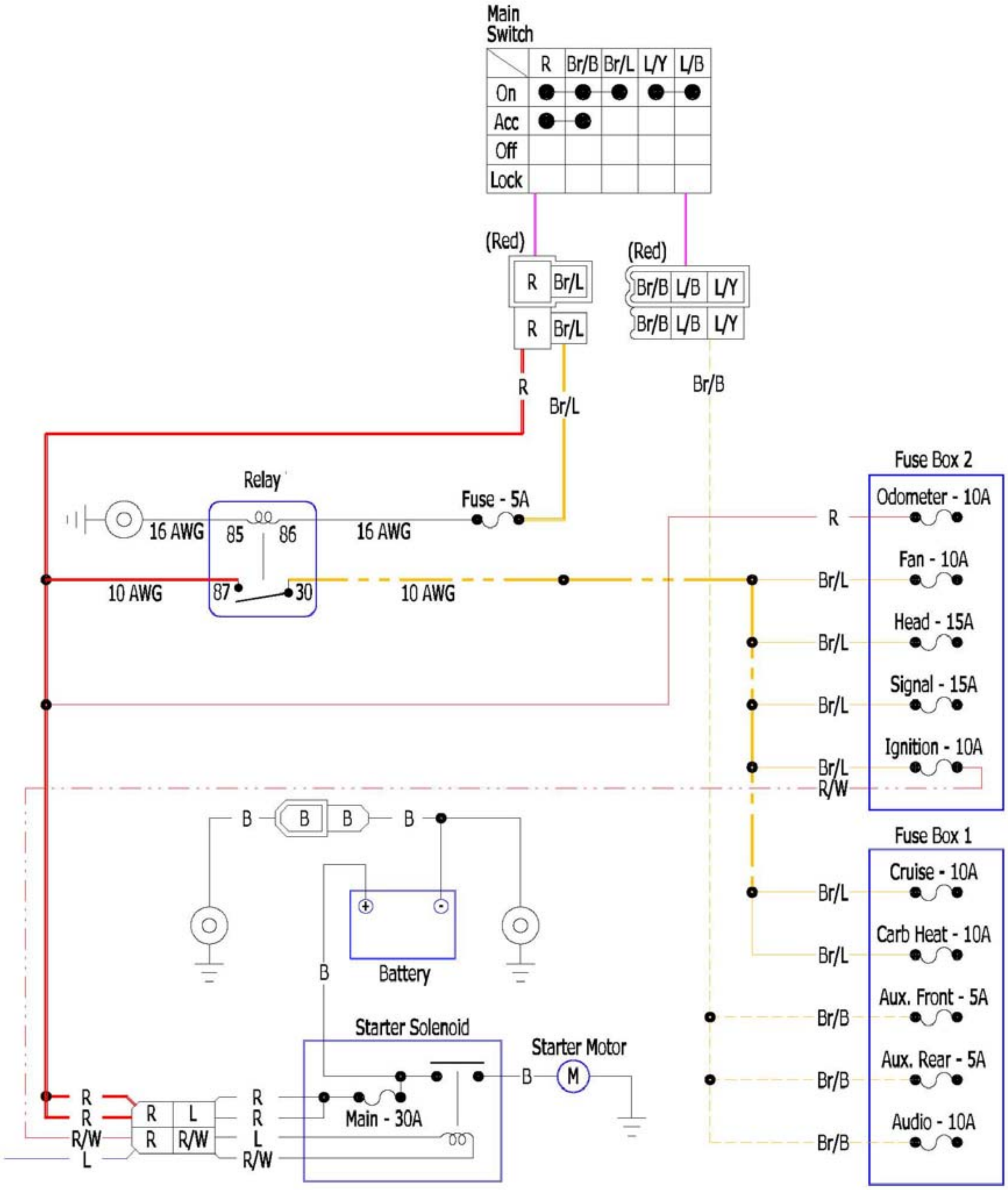

Figure 17 RSV Ignition bypass modification After