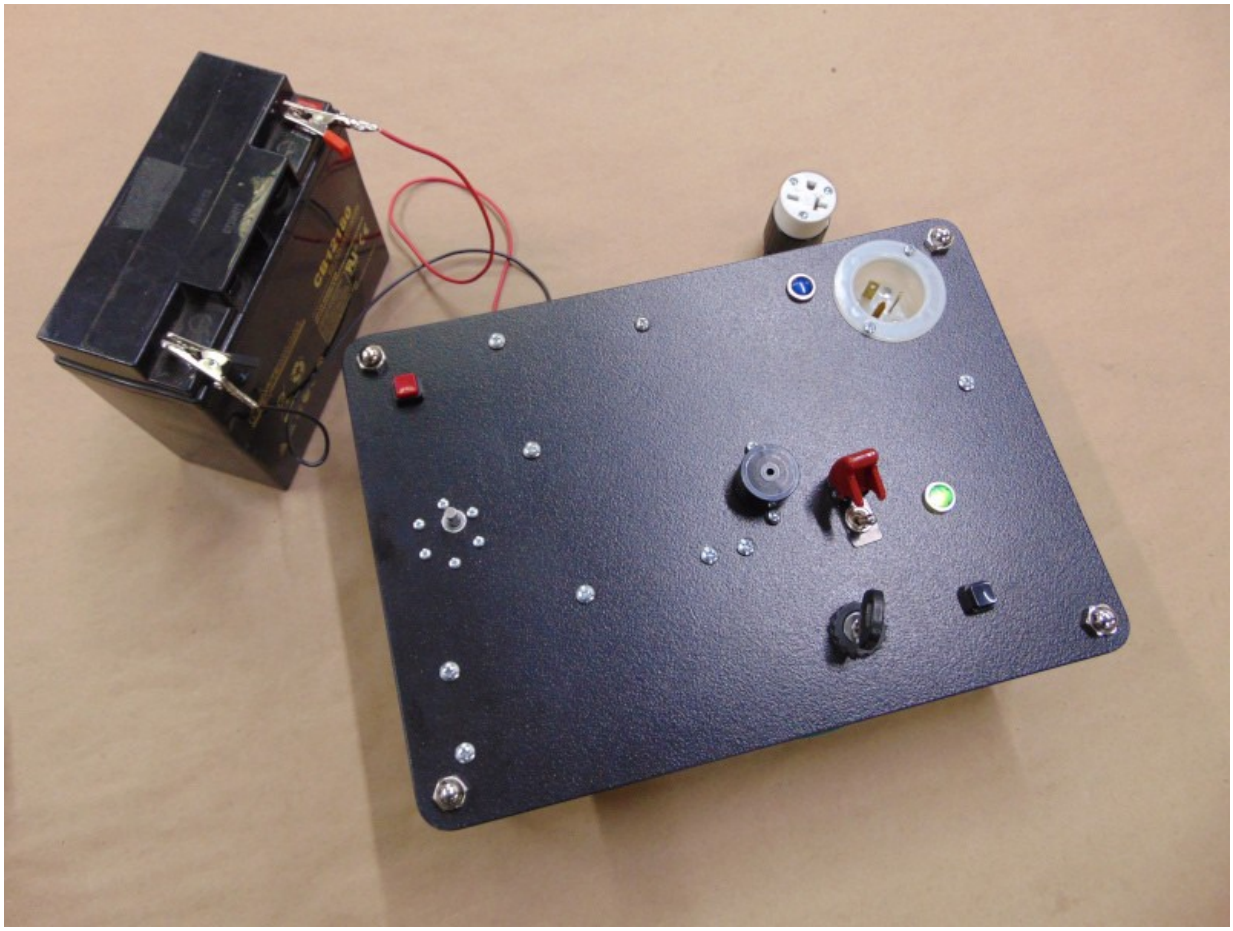
PROJECT LAB

Relay Lab Kit



Overview

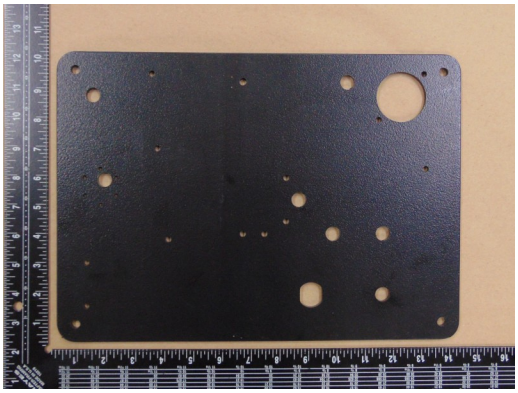
The Relay Lab Kit is a hands on project designed to teach the basics of relay circuits in an applied manner. The panel is a condensed version of the dash of a Switch vehicle and most of the components can be exchanged directly with parts on the vehicle. The focus of the panel is to model two of the most important circuits in the vehicle: the Key On circuit, and the Charging Active circuit. To accomplish this, the kit includes 4 different switches, relays, fuse blocks, a motor, lights, hardware to mount them all to the panel, and enough terminations to create all necessary wire connections.

The order of assembly and wiring in this manual is just one way of completing the project, and while it does work, many other variations will also work. As long as the component connections match the schematic, the panel will work, giving a large freedom for component placement and wire routing choices.

Tools Needed

- #2 Phillips Head Screwdriver
- 5/16” Wrench
- 3/8” Wrench
- 1/2” Wrench
- 9/16” Wrench

Components

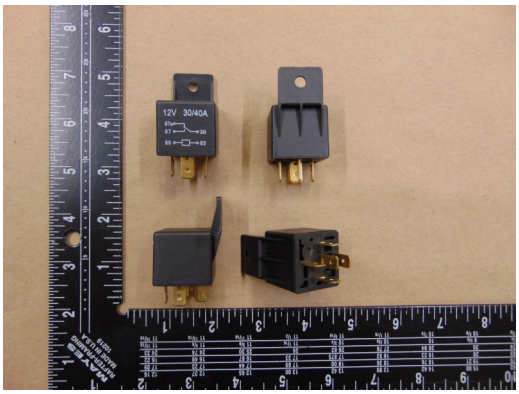


Mounting Panel
Dimensions: l4” x 10” x 3/16”
Top View: Large hole is in Upper Right

Relay Lab Hardware Kit
SVI-ID: HK-RLK

Wire Termination Kit
1/4” Female Spade Terminations
1/4” Male Spade Terminations
1/4” Ring Terminations
Alligator Clips
Termination Cripers
Wire Strippers
Fuse Pack:
4x 3Amp, 4x 5Amp, 4x 10Amp, 2x 30Amp

COMPONENTS



4x Relays

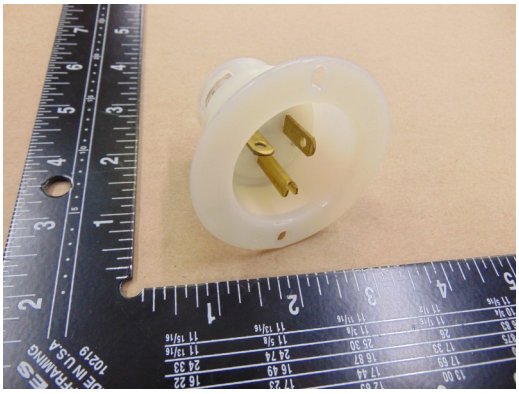
Single Pole Double Throw

Equivalent vehicle relays:

- Key
- Charge
- Forward
- Reverse

DC Motor

Output shaft with built in gear reduction



Socket

Represents AC power inlet for vehicle charging

*Only use with the corresponding plug from the kit.

*Do not plug extension or other cords into the socket.

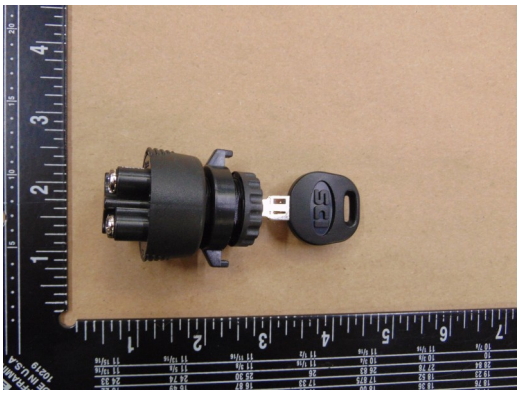
Plug

Represents AC line power

*Only use with the corresponding socket from the kit.

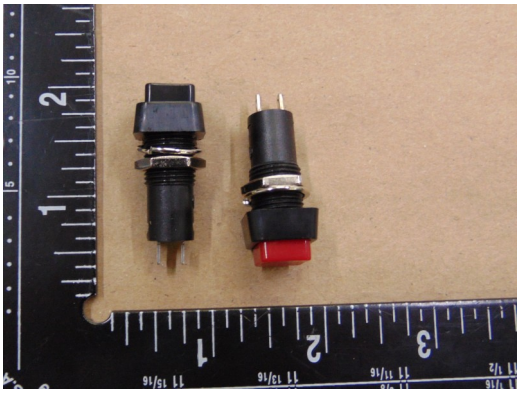
*Do not plug extension or other cords into the plug.

COMPONENTS



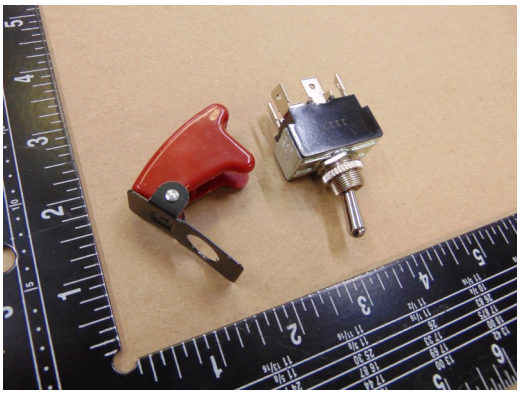
Off-On-(On) Key Switch

Pin 1: Common
Pin 2: Active if Momentary is ON
Pin 3: Active if Switched On
Pin 4: Active if Switched On or Momentary is On



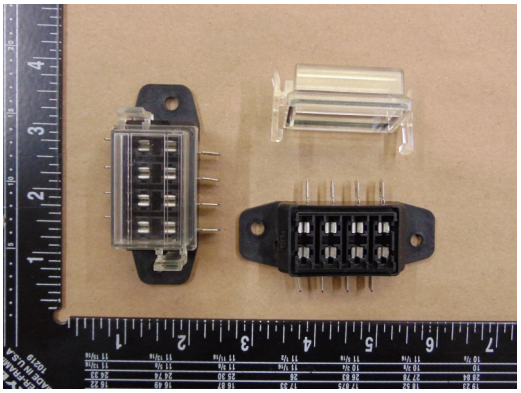
On-Off Toggle Switches

Red toggle switch represents the Big Red Button
Black toggle switch represents the Inertia Switch



On-Off-On Toggle Switch

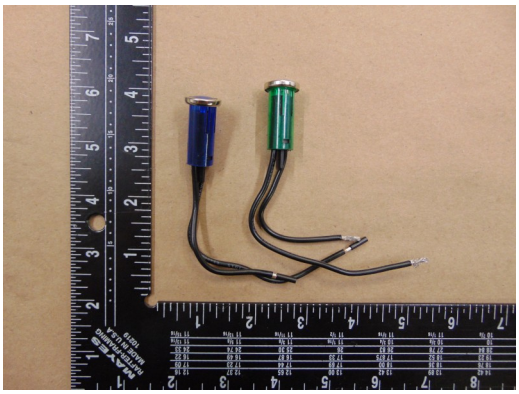
Double pole double through switch
Protective switch cover
Represents the Forward-Neutral-Reverse switch.



2x Fuse Blocks

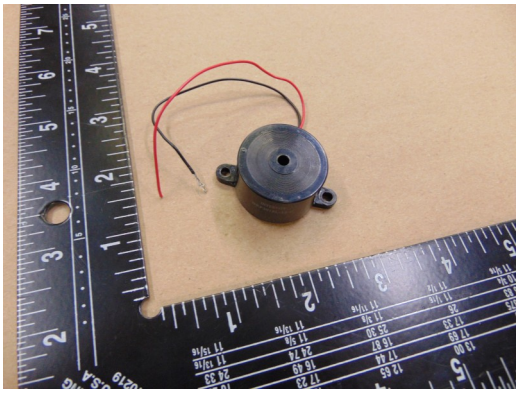
Clear protective cover

COMPONENTS



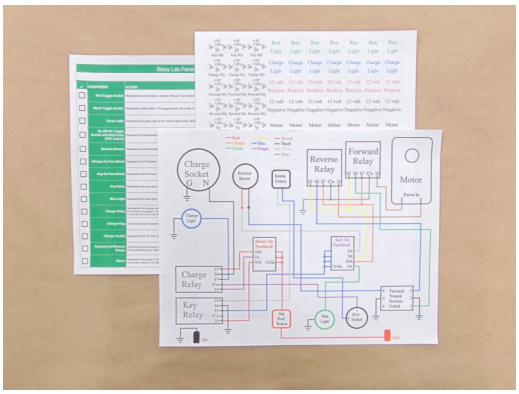
2x Lights

Blue Light: Represents vehicle state “Charging”
Green Light: Represents vehicle state “Drive Ready”



Buzzer

Represents reverse buzzer in vehicle



Documentation

Wiring Diagram
Component Labels
Component Action Sheet

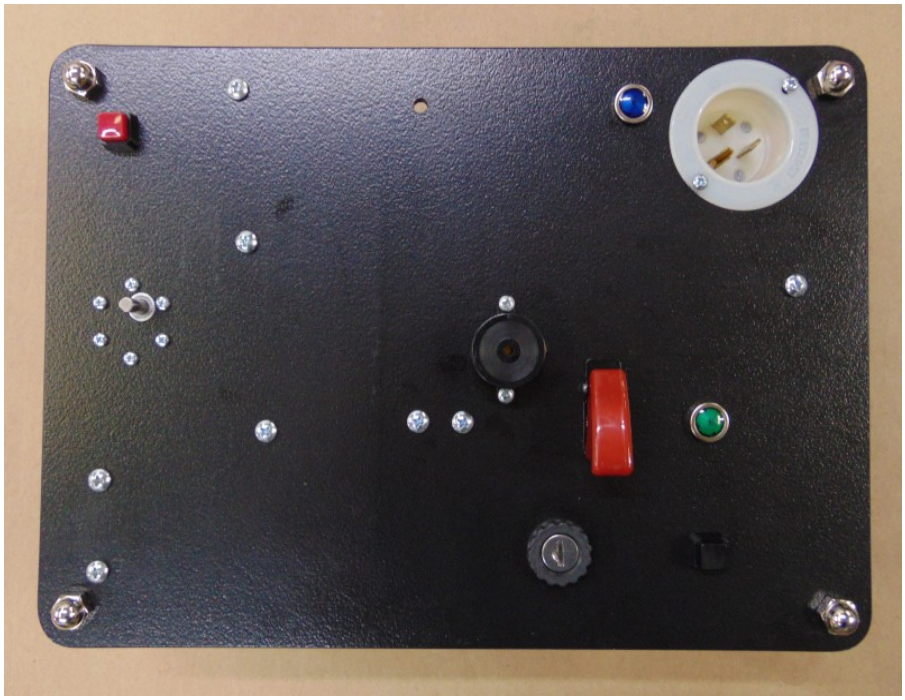
Wire Spools

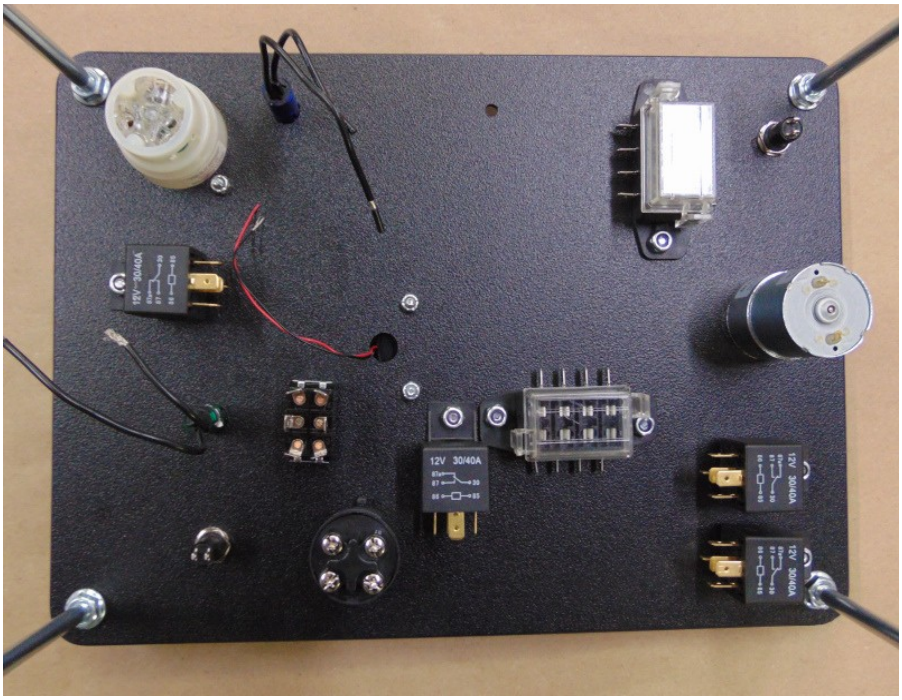
One 100 foot spool of each color:
Red, Orange, Yellow, Green, Blue, Purple,
Brown, Black, Gray, White

*Spools are included in the Relay Lab Kit Pro version.

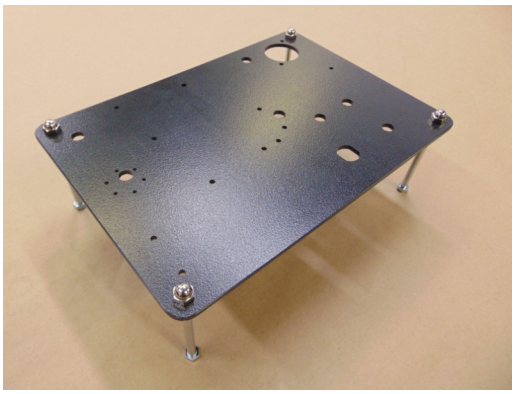
Assembly of the Panel

The project begins with the installation of all components onto the panel. The switches and toggles, lights, buzzer and socket are all accessible from the top of the panel. The relays, fuse blocks, and wiring is all done underneath the panel. Below is the top and bottom view of the panel after all parts have been mounted. This is only one of many ways to build it. Most parts can be placed on either side of the panel, and in multiple locations. The order of installation is also a suggestion, and the parts may be installed in any order.

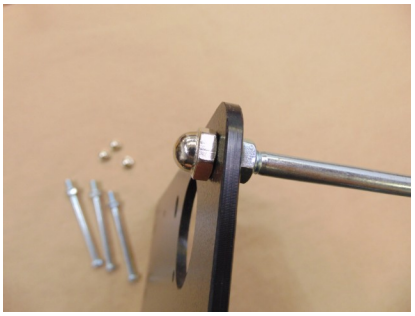


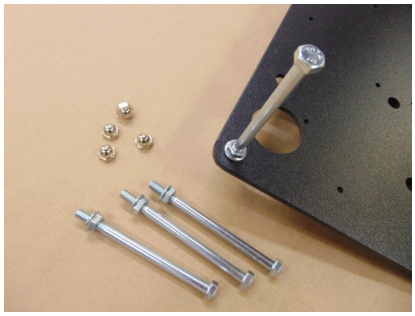


Panel Supports

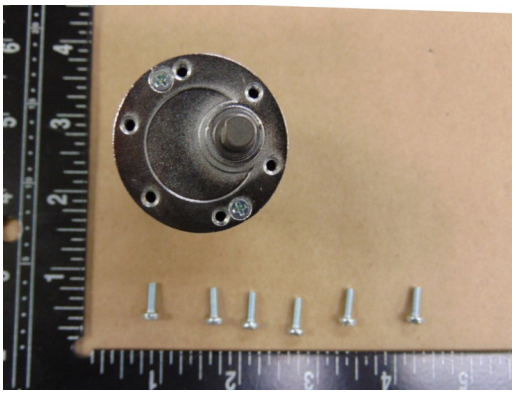


Begin by bolting the support legs onto the panel, this will make it easier to work on through out the project. Each leg uses a **5/16”-18 x 4-1/2” bolt,** with a flange nut underneath the panel, and a cap nut above the panel. Thread the flange nut to the bottom of the threads first, placing the bolt in the hole next, with the cap last. Screw the cap nut all way down, then adjust the flange nut location to tighten the bolt to the board.

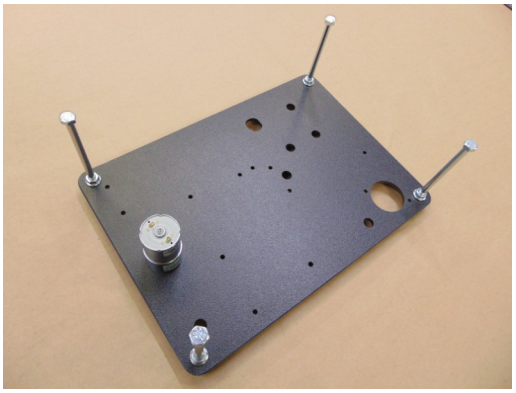


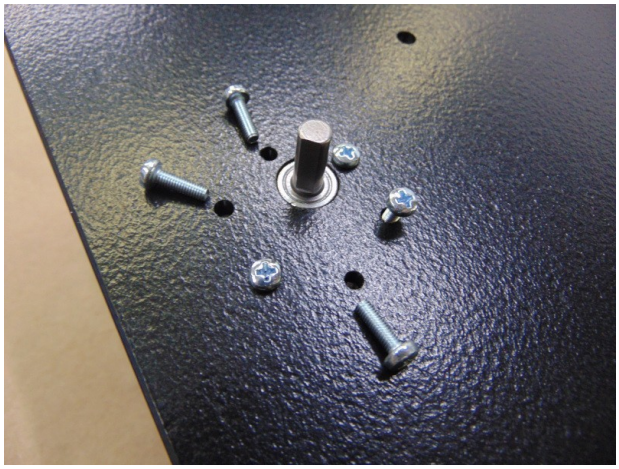


The Motor

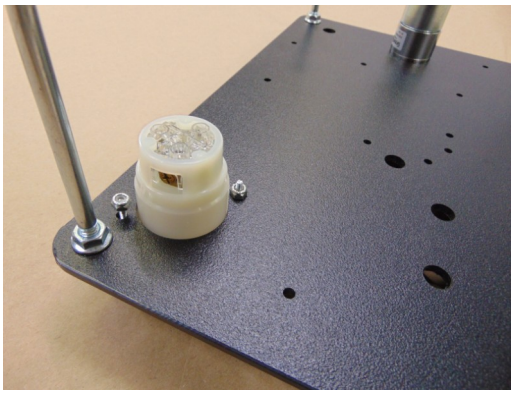


The motor is mounted underneath the board with the output shaft pointing upwards. It uses six **M3 x 10mm** screws to hold it in place.

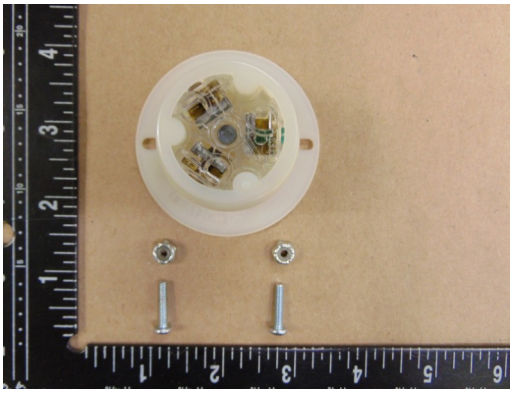




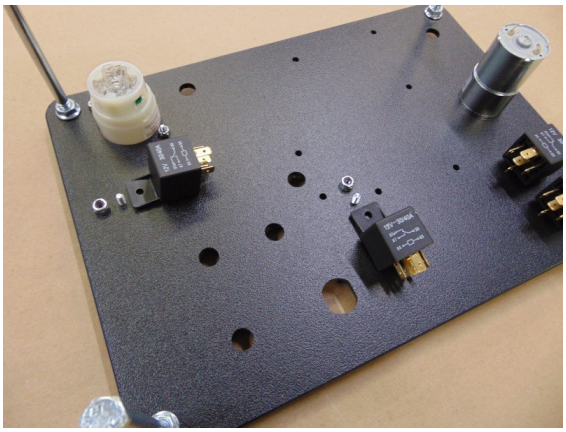
Charge Socket



The charge socket is mounted in the upper right corner of the panel when looking directly at the panel. It is installed using two **#6 x 3/4" machine screws** with nylon insert lock nuts. The socket represents the power receptacle use to charge the vehicle with an extension cord.



Relays

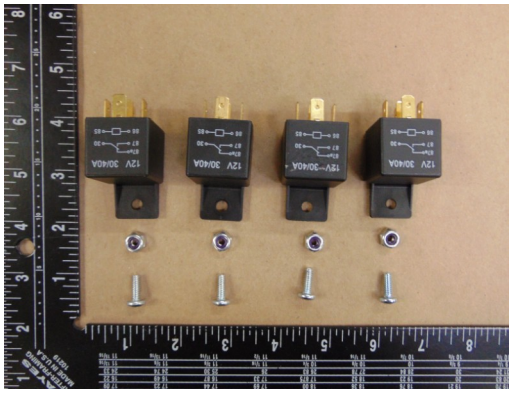


There are four *single pole double throw* relays. They consist of a coil (Pins 85 and 86), a normally closed contact(Pin 87a), a normally open contact(Pin 87), and a common contact(Pin 30). Each relay uses a **#10-24 x 1/2" machine screw** with nylon insert locknut to secure it to the panel.

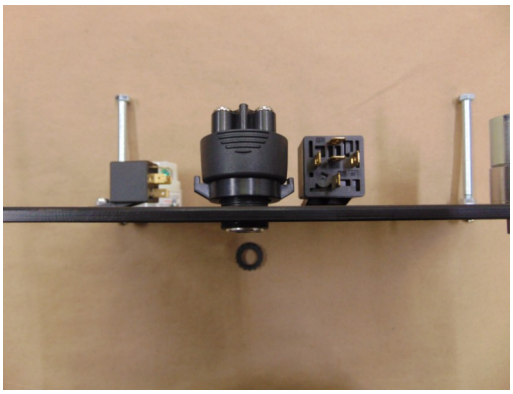
Two relays are mounted near the motor. These will be the forward and reverse relays, representing the Forward-Reverse Contactor in the vehicle.

One relay is mounted near the charge socket, representing the charge relay.

The final relay is mounted near the center of the panel, and represents the key relay.



Key Switch



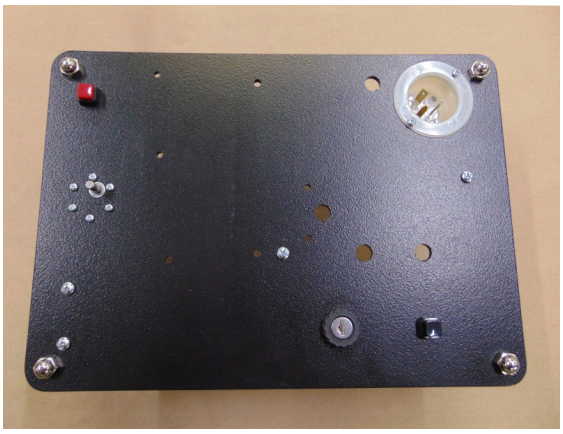
The key switch includes a key, the switch body, a locking nut for underneath the panel, and a top nut for above the panel. The locking nut has two flats to match the flats on the key switch body, this is to allow the nut to slide freely along the body until it is in contact with the panel, then twisted off the flats and into the threads to tighten the switch into place.

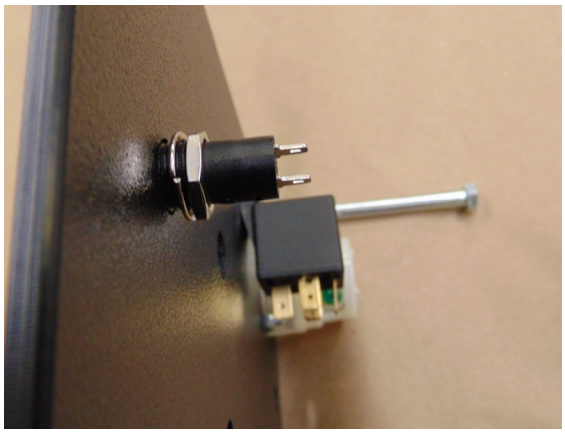
The key switch fits snuggly into the oblong hole near the middle relay. Back the locking nut all the way against the body, insert the switch through the hole and screw on the over nut until tight. Adjust the bottom nut to firmly secure the switch.

Push button Toggle Switches

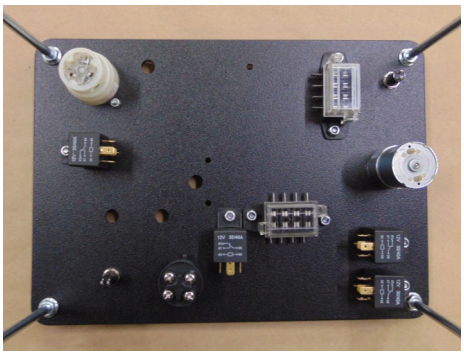
The red toggle switch represents the Big Red Button in the vehicle, and effectively disconnects all 12 volt power supplies to the *Always On Fuse Block*. It is mounted in the upper left corner of the panel above the motor using the 1/2" nut and lock washer included with the switch.

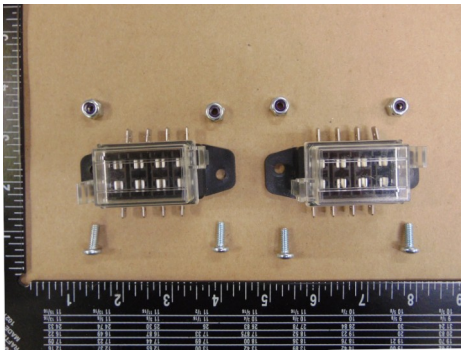
The black toggle switch represents the Inertia Switch in the vehicle. When triggered, the coil power for the key relay is disconnected, effectively turning off the vehicle. It is mounted to the right of the key switch with a 1/2" nut and lock washer.





Fuse Blocks



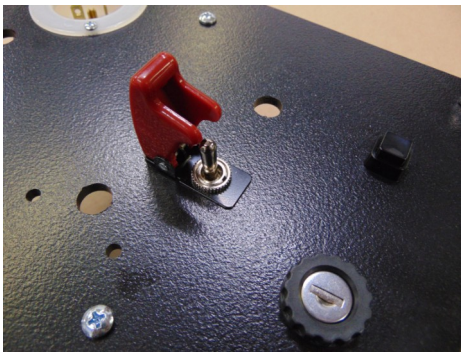


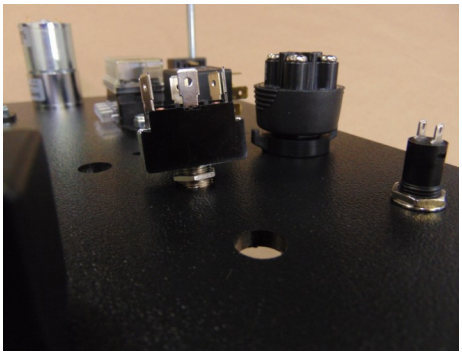
The two fuse blocks are mounted underneath the panel, each using two **#10-24 x 1/2" machine screws** with a nylon insert locknut.

One fuse block is mounted near the center relay and key switch, this is the *Key On Fuse Block.* When the key is switched on, the key relay activates and allows power to supply this fuse block from the Always On Fuse Block.

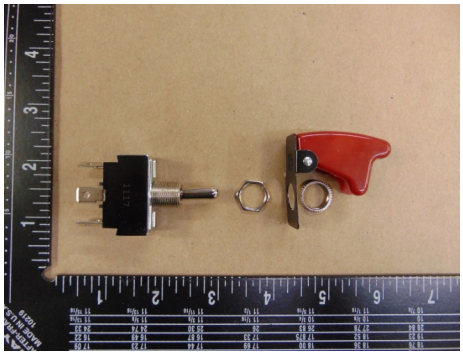
The second fuse block is the *Always On Fuse block*, and is mounted near the red toggle switch on the motor side of the panel. The 12 volt battery provides the supply to this fuse block, with only the Red Toggle Switch(Big Red Button) in line between the fuse block and the battery.

On – Off – On Toggle Switch with Cover

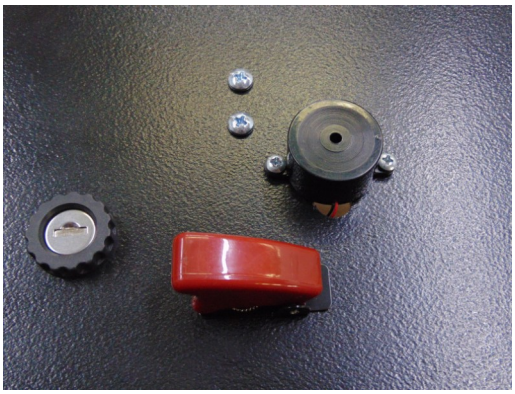




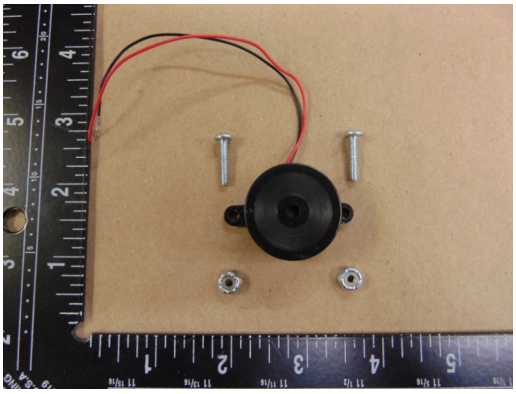
This On-Off-On switch is a *double pole double throw* switch, representing the Forward-Neutral-Reverse(FNR) switch in the vehicle. It has six contacts split into two separate circuits. The center contact on each side of the switch(Pin 2, Pin 5) is the common for that side, the contacts on the top(Pin 1, Pin 4) and bottom(Pin 3, Pin 6) are switched on then the switch is flipped down or up respectively. Pins 1, 2 and 3 are a separate circuit from pins 4, 5 and 6. The switch is mounted with a nut underneath the panel, as well as one above the cover. The cover has tab that aligns with a notch on the switch for correct orientation. The switch is mounted near the key switch.



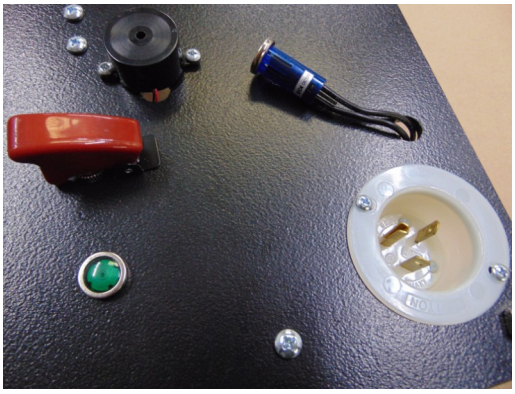
Buzzer



The buzzer is installed on the top of the panel, with the lead wires going through the 1/2” relief hole. It uses two **#6 x 3/4” machine screws** with nylon insert locknuts. The buzzer represents the reverse buzzer on the vehicle, and turns on when the vehicle is put into reverse via the Forward-Neutral-Reverse Switch.



Blue and Green Lights

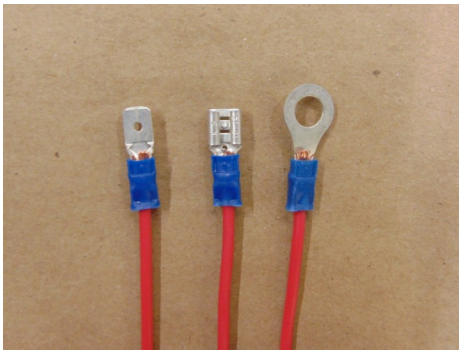


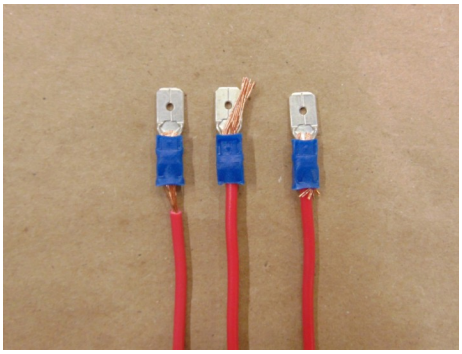
The blue light is pressed into the 1/2” hole next to the charge socket. It represents the charge light in the vehicle, activating when the charging circuit is active.

The green light is pressed into the 1/2” hole next to the Forward-Neutral-Reverse Switch. It represents the ready light in the vehicle, activating when the key is switched on and the vehicle is ready to drive.

Wiring Terminations

To create circuits that provide various functions, all the relative components need to be connected using electrically conductive wire. There is number of options when terminating wires, including soldering, shrink tube insulation, crimping, double crimping, and several others.





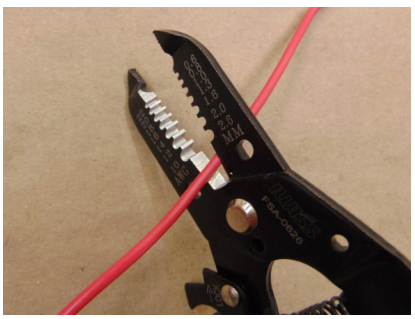
For this lab, the focus is on simple, effective crimping. The process involves cutting a wire to the proper length, stripping the insulation off the wire, and making a secure connection to a termination by crimping the termination around the wire.

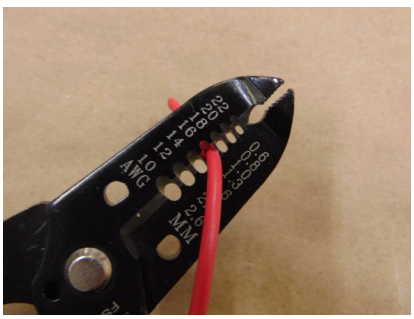
The picture to the above left shows examples of good crimps. The copper wire protrudes minimally from the nylon termination shroud, the wire insulation ends inside the shroud, and the termination itself is not deformed in any way.

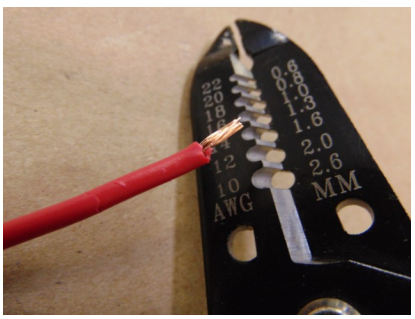
The picture to the below left shows examples of bad crimps. The insulation ends well before the shroud, leaving exposed wire. The copper wire exceeds the shroud to the extent it would interfere with the connection, also leaving exposed wire. The third example shows the copper wire being split when inserted into the termination, with some strands folding backwards and sticking out of the shroud on the insulation side. This exposes wire behind the termination as well as effectively reducing wire gauge as not all strands are able to carry current through the connection.

Cutting and Stripping

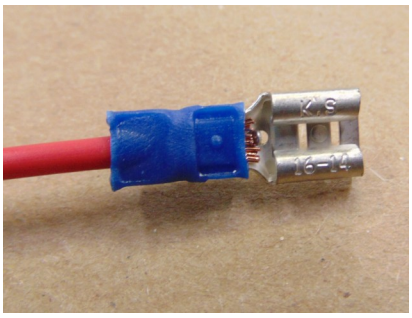
Most multi-purpose crimpers or pliers have a location for cutting. In the crimper set provided with the lab kit, the cutting blade is on the stripping tool. The stripping tool is a cross between scissors and pliers, with specific locations to precisely remove insulation without damaging the wire. Each hole has a corresponding wire gauge labeled next to it for easy reference. Wire included in the kit is 16 gauge. Place the wire in the strippers in the correct notch then close the strippers completely, this cuts the insulation down to the wire. Pull the wire away from the tool while holding the tool closed. The insulation will be pulled off, and the stripped wire is ready to use. The amount of insulation to remove depends on the termination.

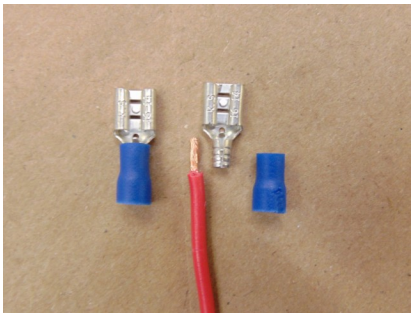


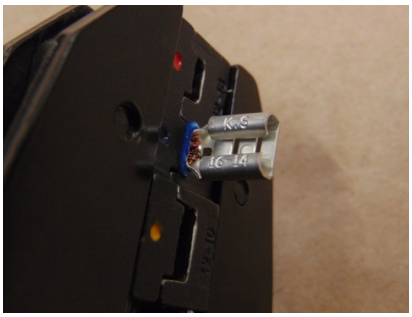


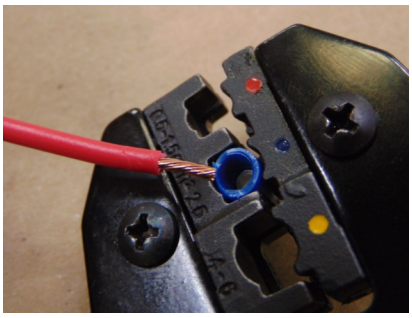


CRIMPING









Effective crimping is essential to secure connections. A poorly made crimp can lead to numerous headaches down the road if something is not working as it should, or more commonly, only working intermittently or randomly.

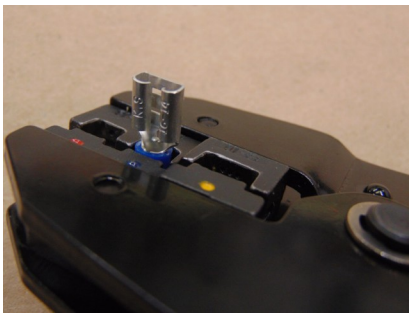
COMMON CRIMPING MISTAKES

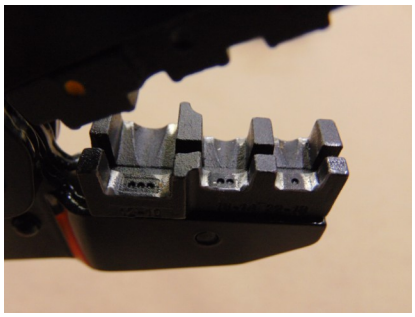
- Not crimped enough. Vibrations over time and accidental pulling of wires will physically remove the wire from the termination, breaking contact.
- Crimping some but not all of the strands. This will limit the current that can safely travel through the termination.
- Excessive stripping of wires. Exposed wire strands before or after the termination are vulnerable to short circuiting. Any conductive element can short the exposed wire.

Crimping starts with stripping the insulation from a wire to match the crimp space of a termination. 1/4” of insulation removed is a good start point for almost all of the terminations in the kit. If unsure of how much to strip, remove the shroud on a termination and match the strip length to the crimp length.

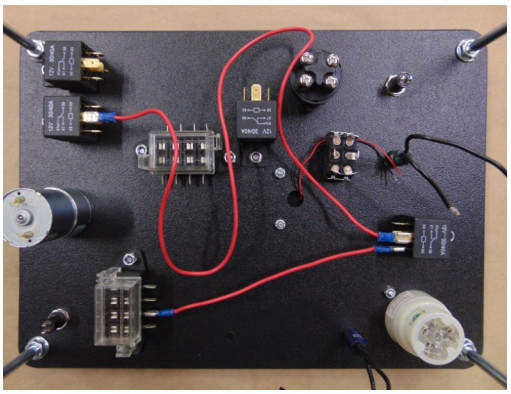
Terminations vary in size and shape, but follow a standard for wire size. Use the proper gauge termination to match the gauge of the wire. Crimp locations on tools are generally marked or labeled by gauge or color. Not all tools are the same, even if they are meant for the same gauge. If you use a crimp location, and the termination falls off after crimping, try the next size smaller. If the crimp cuts some of the wire strands, use the next size larger.

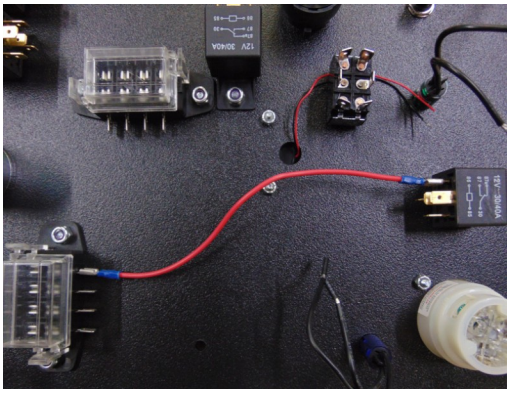
When starting out, the easiest way to achieve a solid crimp is to hold the termination in the tool, then feed the wire in and squeeze down. Some tools crimp both the shroud and the termination, while others the crimp is at a single point.

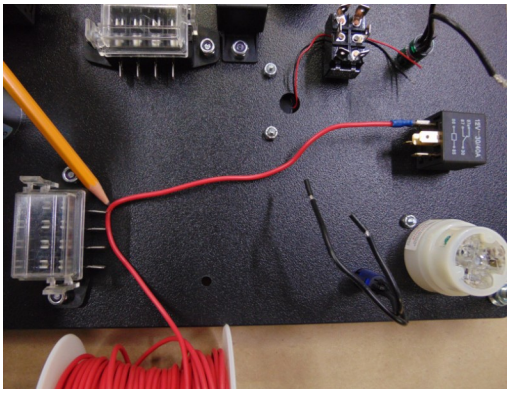




Cutting the Wire to Length



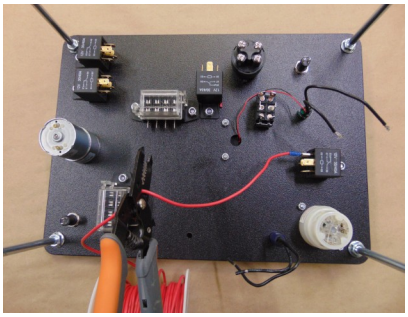


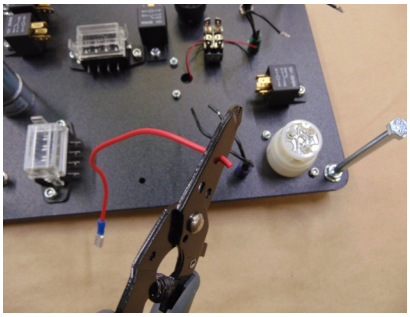


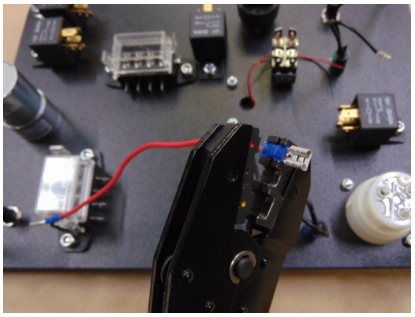
The length of wire to make connections can make a huge difference, not only in looks, but also in troubleshooting problems. The longer a wire is, the harder it will be to follow it. Long wires also contribute to excess resistance in the system, and are more prone to damage. Overly short wires are prone to becoming disconnected at the slightest tug, or break over time from vibrations. Both long and short wires will get in the way when trying to work. The best length is short as you can make it, but allowance for routing and vibration. Wires should not be pulling against the terminations then they are connected. Examples of overly long and short wires are in the photo to the above left. To the direct left, an example of a good wire length is show.

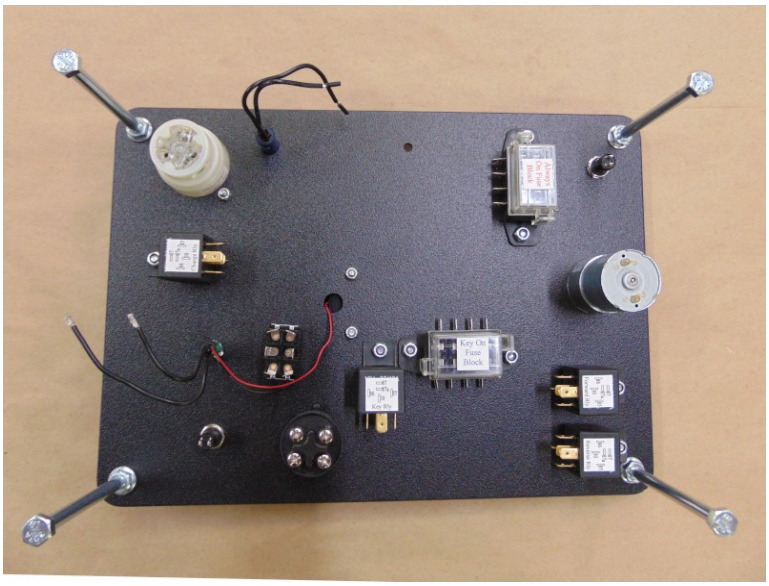
There are multiple ways to find an acceptable length to cut the wire to. An easy, reliable way is to connect one end to where it needs to be, route the wire to where you want it, along the path you want it, then cut the wire from the spool at that point. Spools are not always available, so starting with a longer wire, routing it, then trimming it to a refined length also works well.

Routing wires is a healthy mix of art and functionality. Sometime there is no choice but to bundle wires together and have them travel long distances, around corners and through connectors. Other times, wires will only travel the same direction for short lengths before diverging again. As long as all wire get to where they need to go, the project will work. Working isn't always the only goal, however, and care should be taken to keep the wires as organized as possible. Spider webs of crisscrossing wires are extremely difficult to troubleshoot.



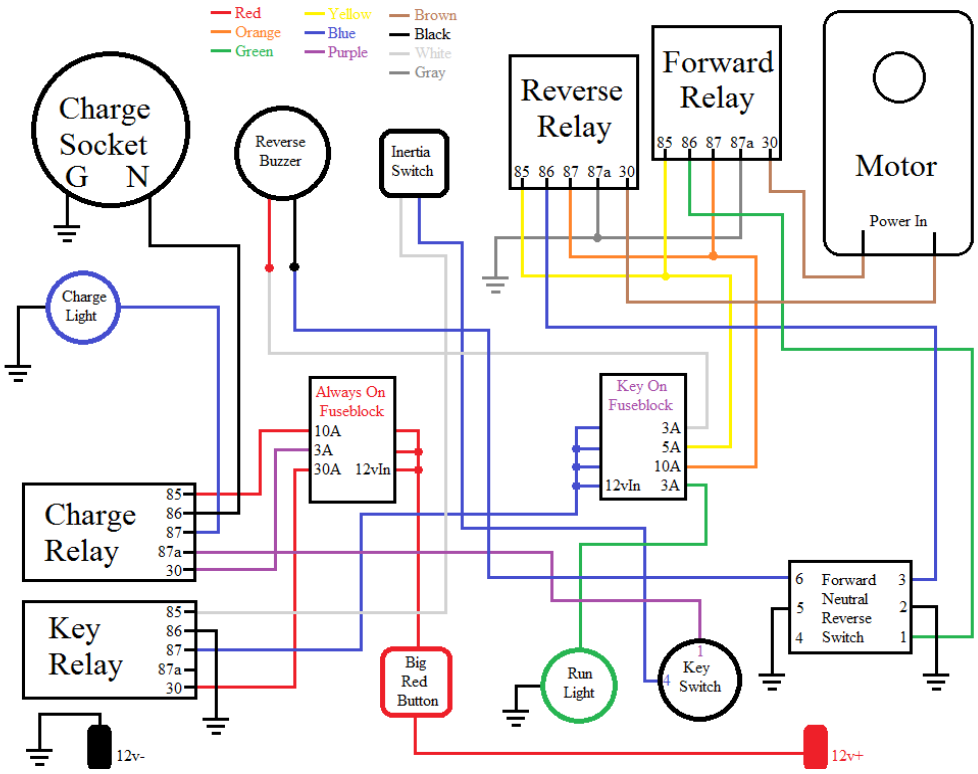


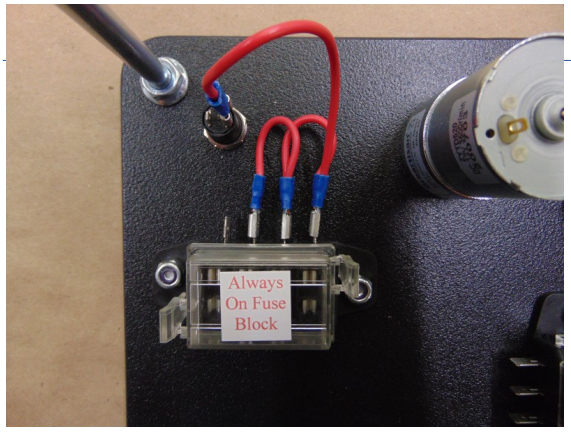




The easiest way to begin is by labeling the relays and fuse blocks. The relay on the far left of the picture is the Charge Relay. The relay in the lower center is the *Key Relay*. The upper relay on the right is the *Forward Relay*, and below it is the *Reverse Relay*. The vertical fuse block on the upper edge of the panel is the *Always On Fuse Block.* The horizontal fuse block near the key relay is the *Key On Fuse Block.* The remaining component labels can be added now or any time during the process.

The order in which the panel can be wired can be varied in as many ways as there are components. The order presented here is arranged in a way so that it flows from one component to the next, for ease of location reference of each component. Wires may be routed in any number of ways, and be any number of lengths. The wire routing and lengths depicted here are general starting points, applicable to this component configuration, and may be adjusted or routed differently. If components are installed in alternative locations, reference the wiring diagram for connection information.



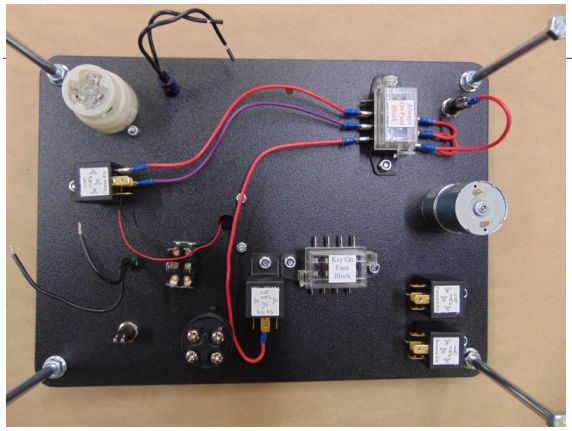


Red Push Button Toggle Switch

The Red Toggle Switch is powered directly from the battery and supplies power to the Always On Fuse Block. New wires:

5” Red, chained with two 3” pieces to the Always On Fuse Block

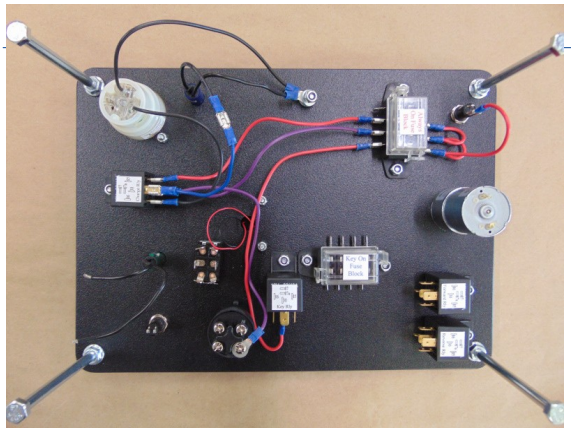
Note: To chain wires together, insert two wires into the termination before crimping.



Always On Fuse Block

The Always On Fuse Block is supplied power by the Red Toggle Switch, and supplies power to the Charge and Key relays. New wires:

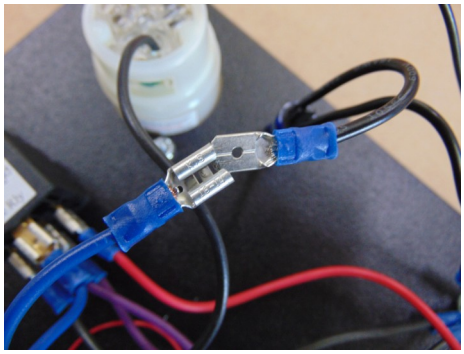
8” Purple to Charge Relay 30 from
8” Red to Charge Relay 85
14” Red to Key Relay 30

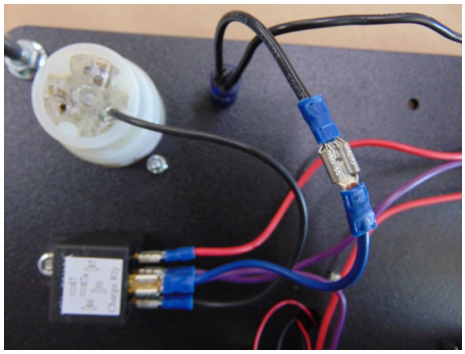


Charge Relay

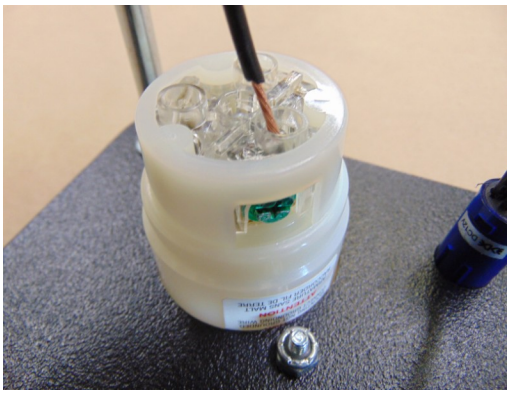
The Charge Relay is supplied by the Always On Fuse Block, and governs power to the Key Relay and Blue Light based on charging status. To connect the Blue light, a Male-Female connection is needed. To connect the socket, a stripped wire is inserted into the hole and screw is tightened. New wires:

8” Purple to Key Switch Post #1 from Pin 87a
7” Black to Charge Socket from Pin 86
4” Blue to Blue Light from Pin 87





Charge Socket and Plug

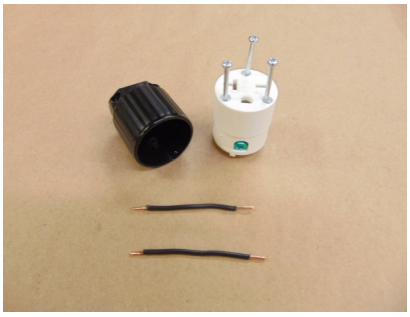


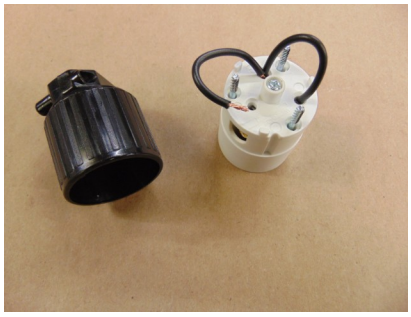
The Charge Socket has three wire locations. The green screw represents the ground termination and is connected to the ground pin on the front of the socket. The other two locations link to the other two pins. For the lab, we want to simulate plugging in a vehicle, without actually plugging anything into the wall. One socket wire will go to ground, and the other will go to the coil of the charge relay. Inside the Charge Plug, all three terminations are linked together. When the plug is inserted into the socket, it completes the coil circuit and the charge relay activates. The plug and socket are not intended for and should never be used with live AC line power.

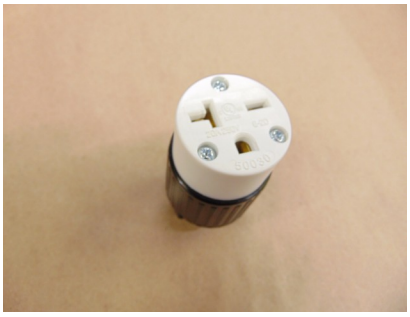
New wires:

9” Black to Ground Post from the Socket

Two 3” wires to link all plug pins

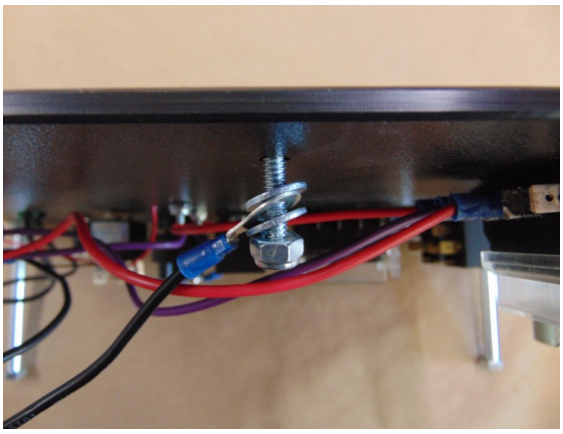






Common Ground

The common ground is located along the edge of the panel between the Blue Light and the Always On Fuse Block. It consists of a single **#10-24 x 1” machine screw** with two washers and a nylon insert locknut. The screw goes in from the top of the panel, has a washer underneath the panel, space for wire terminations, and a second washer with nut to make the connections secure. For ease of wire assembly, finger tighten the nut only, as several ground rings will end up on this post. Only after the final ground has been added should the nut be tightened fully.



There will be a total of seven grounds when the panel is complete. In order of the manual, they are:

9” Black from Charge Socket

4” Black from Blue Light

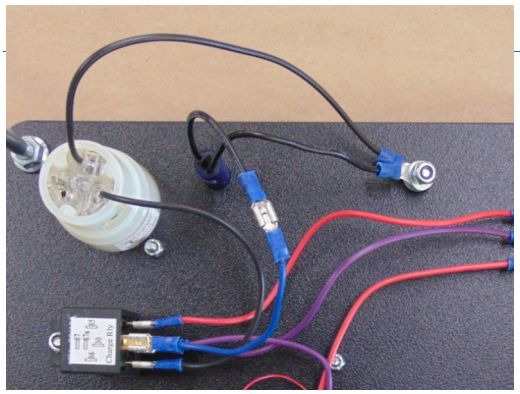
12” Black from Key Relay Pin 86

3” Black from Green Light

8” Gray from Forward and Reverse Relay Pins 87a

9” Black from On-Off-On Toggle Pins 2 & 5

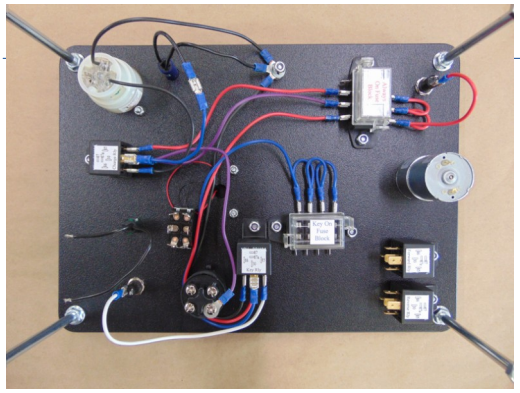
24” Black from Battery Alligator Clip



Blue Light

The Blue Light is powered by the Charge Relay, turning on when the relay is activated during charging. The light has two leads coming out of it, either one can be the ground or the positive voltage source. If a lead is long enough, it can terminate directly onto its destination, otherwise it will need to have a male-female junction to extend the lead length. New wire:

4” Black to Ground Post (Default Lead Length)



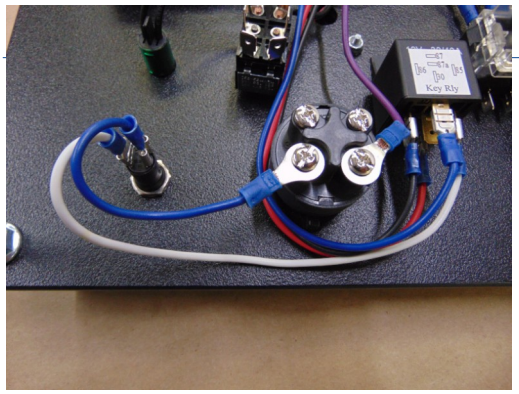
Key Relay

The Key Relay controls power to the Key On Fuse Block. It is triggered by the Key Switch and supplied by the Always On Fuse Block. New wires:

12” Black to Ground Post from Pin 86

8” White to Black Push Button Toggle Switch from Pin 85

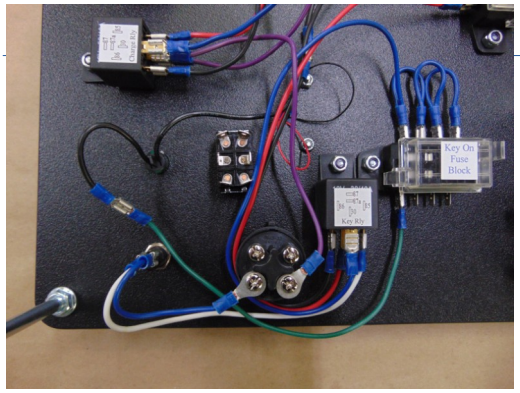
13” Blue from Pin 87, to Key On Fuse block. Chained with three 3” pieces.



Black Push Button Toggle Switch

The Black Toggle Switch supplies power to the coil of the Key Relay, getting its power from the Key Switch when switched on. New Wire:

4” Blue to Key Switch Post 4

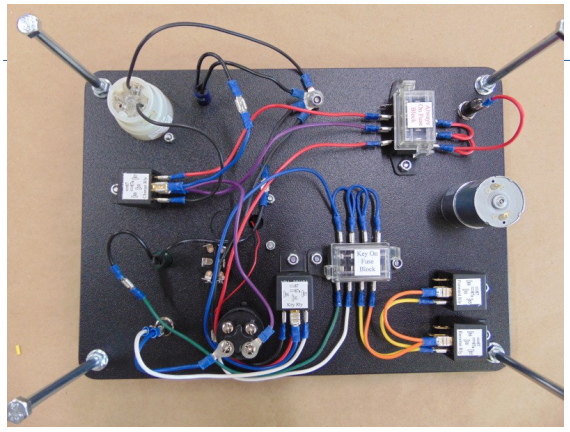


Green Light

The Green light turns on when the Key On Fuse Block is powered on. It is between the Black Toggle Switch, On-Off-On Toggle Switch, and the Charge Relay. New wires:

3” Black to Ground post from Light lead

9” Green to Key On Fuse Block from Light lead



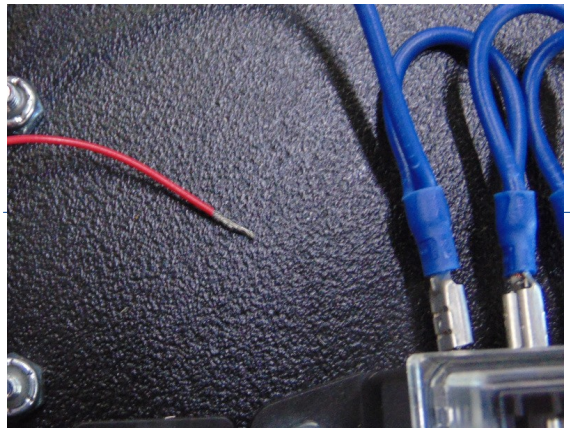
Key On Fuse Block

The Key On Fuse Block is the main switched power supply of the panel. It is supplied from the Always On Fuse Block through the Key Relay. The Key switch needs to be turned on and the Black Toggle Switch has to be set before the Key relay can activate and power the fuse block. The Key On Fuse Block powers the Green Light, Reverse Buzzer, Motor, and both directional relays. New wires, coming from the fuse block:

4" Yellow with chained 4" piece to Forward Relay Pin 85 and Reverse Relay Pin 85

4" Orange with chained 4" piece to Forward Relay Pin 87 and Reverse Relay Pin 87

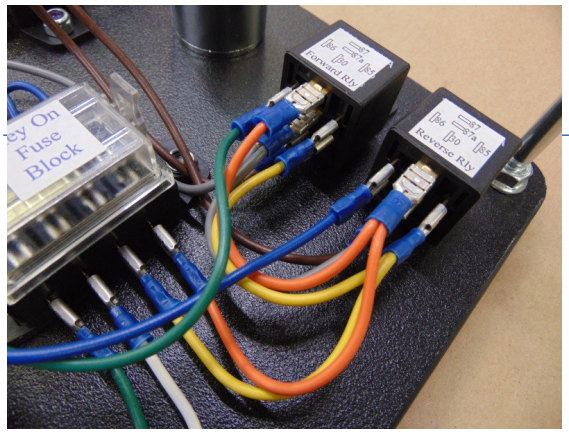
7" White to Red Buzzer lead



Buzzer

The Buzzer leads are very small gauge. Care must be taken to not pull them apart. To get an acceptable crimp on a small gauge wire with an over sized termination, strip two or three times as much insulation off as needed and fold the wire over on itself to artificially increase the gauge for crimping. New Wires:

4" Black Buzzer Lead to On-Off-On Toggle Pin 6



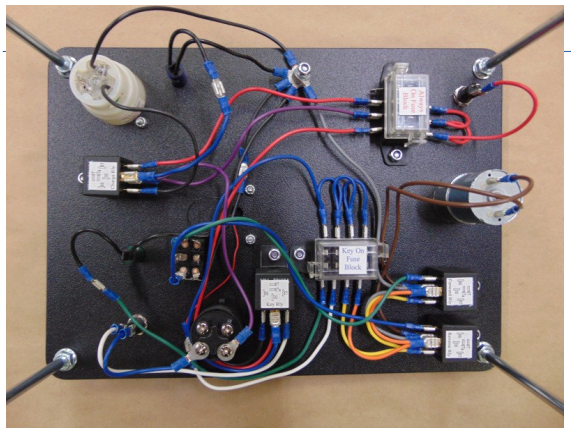
Forward and Reverse Relays

The Forward and Reverse Relays control the rotational direction of the motor by reversing the polarity across the motor terminals based on which relay is active. The coil input pins(85) for both relays are linked together, as well as the normally open pins(87), both being powered directly from the Key On Fuse Block. The normally closed pins(87a) are linked together and go to the Ground Post. The common pin on each relay goes to the terminals on the motor. When a direction relay is active, power flows into Pin 87 of that relay, out through Pin 30 to the motor, out of the motor and into Pin 30 of the other Relay. The other relay, being inactive, Pin 30 is connected to the normally closed Pin 87a. The power then leaves through Pin 87a and goes to the common ground post. New wires:

8" Gray chained with 4" piece to Ground post from Forward and Reverse Relay Pins 87a

10" Green to On-Off-On Toggle Pin 1 from Forward Relay Pin 86

10" Blue to On-Off-On Toggle Pin 3 from Reverse Relay Pin 86



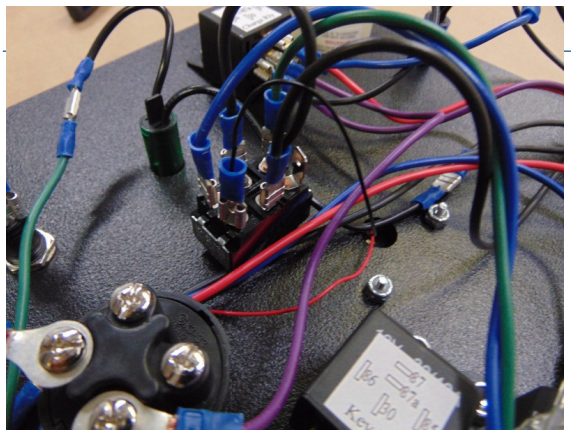
Relay Pin 87

Motor

The motor wires, while having designated locations, don't always work as intended. Variances in motor construction and terminal placement may cause your motor to turn forward when you want it to go in reverse and vice a versa. The simplest way to adjust this is swap the two wires on the motor.

10" Brown to Motor Positive from Forward Relay Pin 87

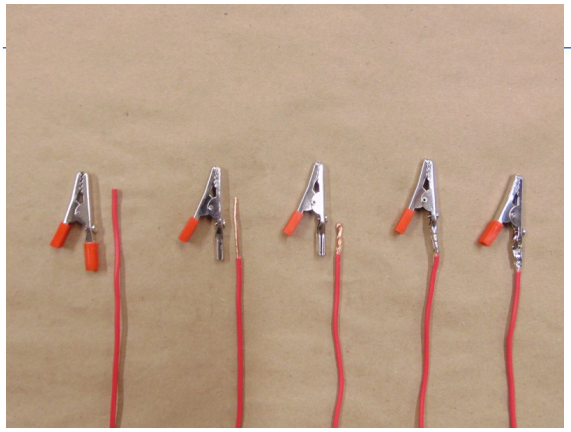
10" Brown to Motor Negative from Reverse



On-Off-On Toggle Switch

The On-Off-On Toggle Switch controls the direction of the motor via the directional relays. When switched on, it completes a ground to the relay coil, activating the direction relay of your choice. New wires:

9" Black chained with 4" piece from On-Off-On Pins 2 & 5 to Ground Post



Battery Leads

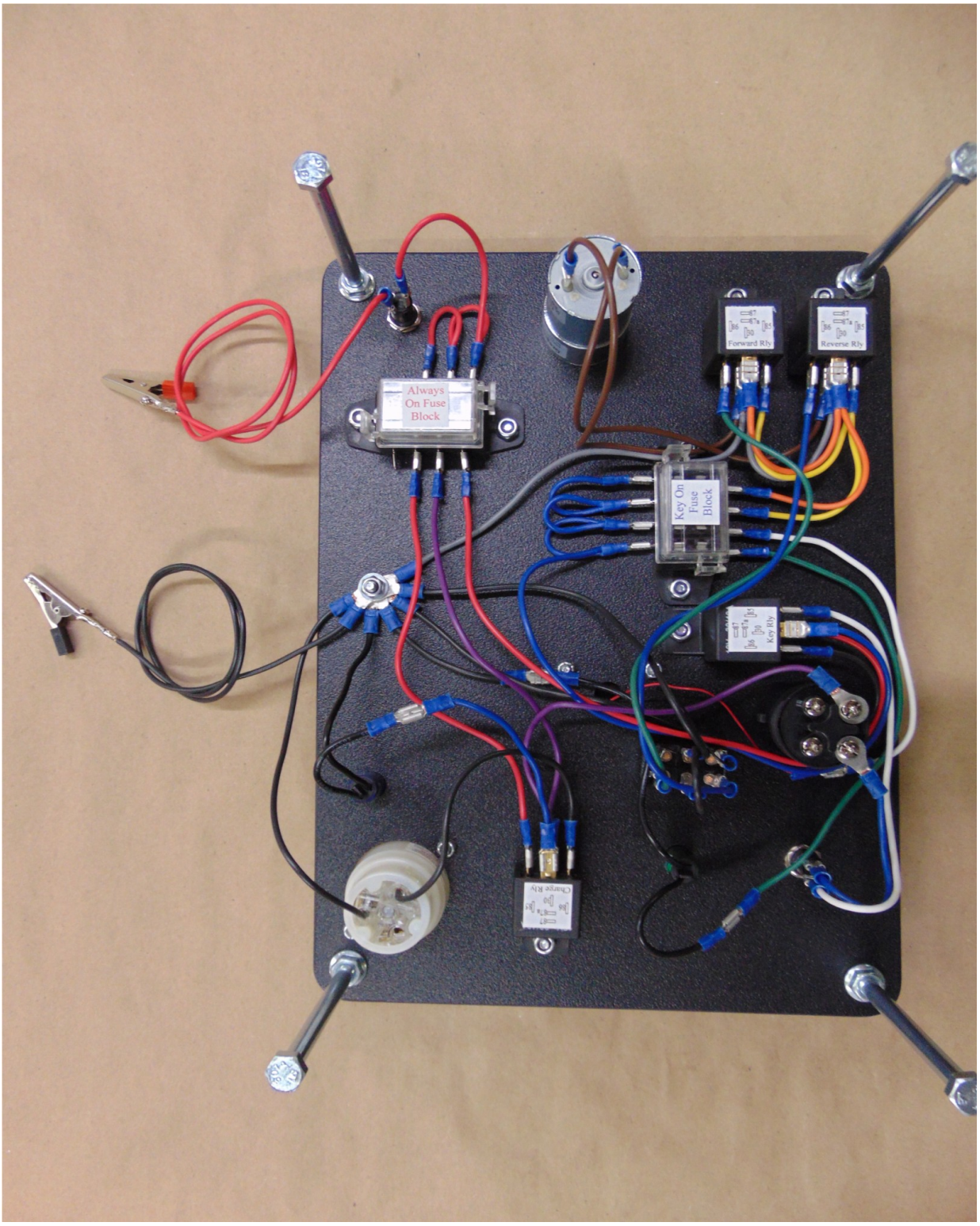
At this point, the wiring of the panel is complete aside from a power source. For power, the auxiliary battery of the vehicle is the most ready source, but any 12 volt battery will work. The battery positive will connect to the Red Toggle switch. The battery negative will connect to the Ground Post. To connect them, use the provided alligator clips to make leads long enough to reach the battery. The clips can be challenging to crimp, and may need to be double crimped, crimping one direction, rotating the termination 90 degrees and crimping a second time. Doubling the wire on itself will also facilitate a solid connection. After adding the Battery Lead to the Ground Post, tight the nut completely to ensure a solid connection between all the terminations.

New wires:

24" Red to Red Toggle Switch from Battery Positive

24" Black to Ground Post from Battery Negative

COMPLETED PANEL



How the Panel Works

The panel mimics the vehicles in many ways. The key, lights, and relays all match the respective components in the vehicle, and are wired in nearly the same configuration. Dividing the panel into circuits based on function is the most effective way to test the components. The first division of the panel is isolating the charge circuit from the key circuit. The charge circuit is active whenever the panel, or vehicle, is plugged in. The key on circuit is active when the key is turned on. The different circuits are important because they cannot be active at the same time, primarily for safety reasons such as driving away with the vehicle plugged in.

Charge Circuit

The charge circuit on the panel is comprised of the Charge Socket and Plug, Blue Light, Charge Relay, Always On Fuse Block and the Red Toggle Switch. The Red Toggle Switch simulates the Big Red Button on the vehicle to completely disconnect the 12 volt auxiliary battery. It serves the same function on the panel, being inline between the battery and the Always On Fuse Block, and will either stop all panel function or allow power to the fuse block. After going through a fuse on the fuse block, power heads over to the charge relay in two places: Charge Relay Pins 85 and 30. Relay pin 85 is the power supply for the activation coil and pin 30 is the common for the switched pins of the relay. Pin 87a is the normally closed pin, and when the relay is inactive(no current flow in coil), current passes through pin 30 and pin 87a. Pin 87a on the charge relay goes to the key switch, and not part of this circuit. Pin 87 is normally open, and only allows current to pass when the relay is active. Charge Relay pin 87 goes to the Blue Light to indicate the panel is in charge mode. On the vehicle, pin 87 would go to another relay, energizing a more complex charging circuit. Relays are used in this fashion to allow small amounts of power to drive larger switched power consumers.

Relay activation coils can be controlled by stopping or allowing current flow in or out of the relay. On the panel, power is connected directly to the coil, and the switch is on the ground side of the coil. A switch at the basic level is a device to allow or stop current flow. The relay needs to activate when plugged in, this makes the plug the switch. The Charge socket is wired to Charge Relay pin 86 on one terminal, and to the common ground on a different terminal. The Plug is shorted internally so that when plugged into the socket, all the socket pins are connected together, allowing current to flow from the charge relay to the ground post, activating the charge relay. When the relay activates, the normally closed pin(87a) is switched off, and the normally open pin(87) is switched on. This allows power to flow in from the common pin 30, out through pin 87 to the blue light, turning the blue light on signaling the panel is in charge mode. The vehicle works in the same way, however, there is a transformer between the charge relay and charge socket to convert the AC line voltage to the 12 volts needed to drive the charge relay coil.

When the Charge Relay activates, it switches off the normally closed pin 87a, disabling the circuit attached to that pin. The normally closed pin of the charge relay goes directly to the key switch, without power to the key switch, the panel or vehicle will not turn on. The charge relay is effectively an OR gate, allowing us to charge the vehicle OR allow us to drive the vehicle, but not both simultaneously.

KEY CIRCUIT

The key circuit on the panel include everything except the charge socket and blue light. Much like the charge circuit, power from the battery flows through the red toggle switch and always on fuse block before being distributed. From the Always On Fuse Block, a small amount of power flows through the common and normally closed pins charge relay before being directed to the Key Switch terminal 1. When the Key Switch it turned on, power flows out of the Key Switch terminal 4 over to the Black Toggle Switch. The black toggle switch represents the inertia switch in the vehicle. The inertia switch is a normally closed switch that is triggered open when hit by a high enough G-force, such as running into something. The inertia switch is inline with key switch, effectively turning the vehicle off automatically in case of an accident. The three primary drive safety features installed are: Emergency 12 volt disconnect via the red toggle switch or big red button, the charge relay prohibiting driving while plugged in, and the automatic shut off when high impact is detected via the inertia switch or black toggle switch.

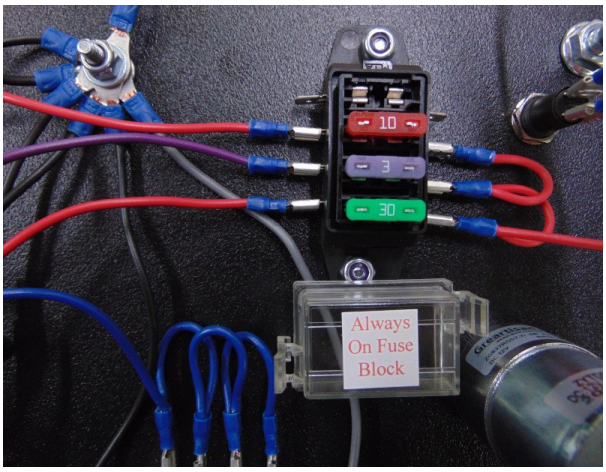
From the Black Toggle Switch, power travels to the coil of the Key Relay, pin 85. Pin 86 of the Key Relay, the other side of the coil, is connected directly to the ground post. This means that for the Key Relay to activate, both the red and black toggle switches must be set and the Key Switch must be turned on. The Key Relay is the switch that feeds power into the Key On Fuse Block. We use a relay here to keep current through the key switch as minimal as possible. Running all 12 volt power through the key switch is not only unsafe practice, it would require a heavy duty key switch to handle the current for all the relays, lights, contactors, fans and other 12 volt power draws. Using a fraction of an amp to trigger a switch that has enough rating to handle 50 amps of power is the exact purpose of a relay. The Key Relay pin 30 is supplied power directly from the Always On Fuse Block, and when activated, allows power to flow out through pin 87 to feed the Key On Fuse Block.

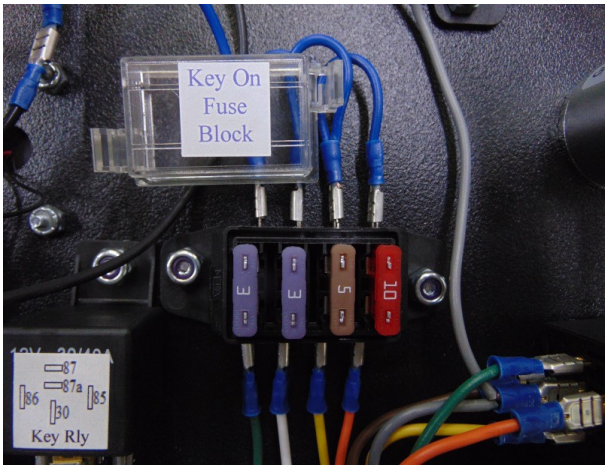
The Key On Fuse Block is only powered when the key is switched on, powering most accessories, lights, fans and other relays. The focus of the key circuit on the panel is the directional control of the motor using relays. The Key On Fuse Block powers four things: The green light, reverse buzzer, and directional relays. The green light is powered directly by the fuse block, if the key is on with no other problems, the green light is on signaling everything is ready to go. The buzzer is supplied power from the fuse block and is switched on and off on the ground side via the On-Off-On toggle switch, otherwise know as the Forward-Neutral-Reverse or FNR switch.

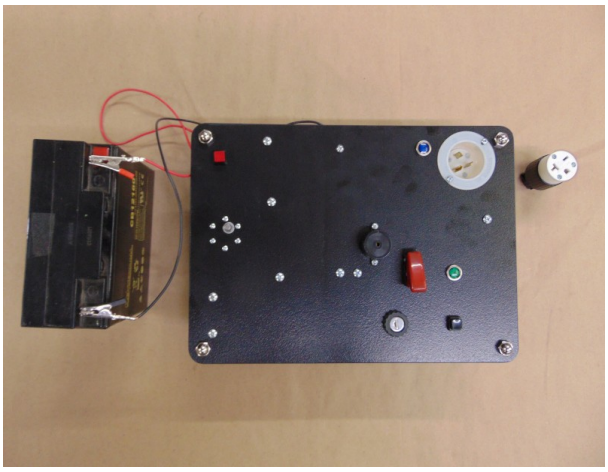
The relays are fed power in pairs of pins with linked wires. A small fuse supplies power to the both relay coils, making sure the relays can only activate if the key is on. The ground return side of each relay is connected to either side of the On-Off-On toggle switch, with the common in the middle of the switch linked directly to the ground post. This allows either of the direction relay coils to be active, but not both at the same time. The toggle switch works the same way in the vehicle, controlling the ground side of the coils of the Forward Reverse Contactor(FRC). The remaining fuse block output uses a higher amp fuse to feed the normally open pin of the relays, pin 87. The normally closed pin of each relay(87a) are linked together and connected to the ground post. The motor is connected to pin 30 on each relay. Pin 30 outputs power when the relay is active, coming in from the pin 87 connection to the fuse block. When one relay is supplying power, the other relay is acting as the ground return for the motor.

Testing the Panel

Before any testing happens, double check all wires. Look for loose connections. Reference the wire diagram and look for missing or misconnected wires. Ensure there are no terminations touching each other, causing potential shorts. After the wire check, the next step is to add fuses, connect the power, and test the all possible circuit configurations.







For protection of devices, fuses are placed in line with nearly all circuits. The placement of fuses is generally as close to the power source as possible, in the case of the lab panel and vehicle, the power source is the 12 volt auxiliary battery. The Always On Fuse Block is the first line of fuses. A 10 amp fuse drives the charge relay coil, while a 3 amp fuse leads to the charge relay common pin to drive the key relay coil when the charge relay is inactive, and light the blue light when the charge relay is active. A 30 amp fuse is the source for the wire leading to the common pin on the key relay, which will supply power to the Key On Fuse Block when the key relay is active.

The Key On Fuse Block is the second layer of fuses on the panel. Active only when the key is on, it provides protection for everything active under normal running conditions. On the panel, a 3 amp fuse provides protection for the buzzer. 5 amp fuse for the direction relay coils. 3 amp fuse for the green light. 10 amp fuse for driving the motor. This is similar to the vehicle, however, the motor in the vehicle runs off pack voltage and uses a high power fuse in the order of 250-400 amps.

Fuses not only protect devices, they provide an effective insight for troubleshooting. For example, if the key turns on some but not everything, the first thing to check is the fuse for the parts that are not working. If the fuse is blown, the problem lies after the fuse, if the fuse is intact, its a problem somewhere before the fuse.

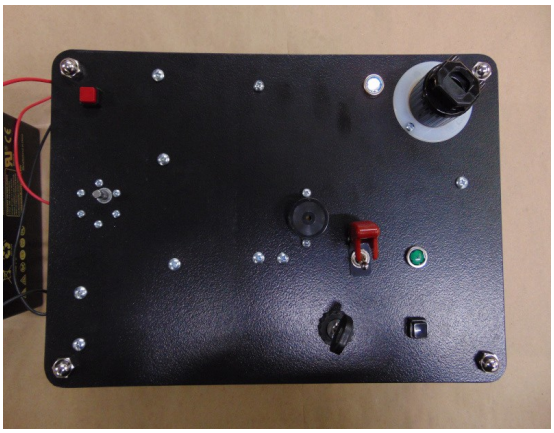
Once the fuses are in, connect the alligator clips to the auxiliary battery. The red wire from red toggle to the positive side, and the black from the ground post to the negative side of the battery.

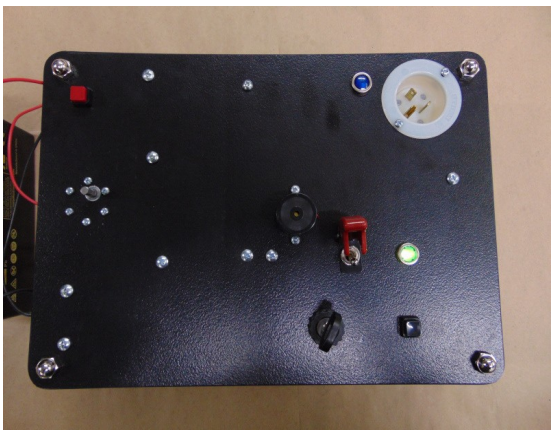
Testing the Charge Circuit

With the fuses in, key off, and battery connected, insert the charge plug into the charge socket. If wired correctly, the charge relay will activate with a click, and the blue light will turn on.

If the light does not turn on, first check the red toggle switch(Big red button equivalent) to ensure power is allowed to reach the Always On Fuse Block. If the light is still out, check the fuses. If the fuses are good, the problem will be in the wiring and will need to be thoroughly checked for loose, missing, or incorrect connections.

Testing the Key Circuit





Once the charge circuit is working, test the key circuit. With the charge plug still inserted and blue light on, turn on the key. Nothing should happen. This is the protection from driving away while plugged in.

Turn the key off and remove the plug from the socket. With the On-Off-On toggle switch in the center(neutral) position, turn the key on. The key relay will click on as well as the green light. If the key switch does nothing, ensure the black toggle switch(Inertia switch equivalent) is toggled on.

With the green light on, toggle the On-Off-On toggle down(Forward-Neutral-Reverse switch equivalent). If wired correctly, the motor will begin to rotate “forward.” Toggle the On-Off-On switch to the up position. The motor will reverse directions and the buzzer will turn on, signaling the motor is rotating in reverse. If the motor fails to turn on, check all safety switches, fuses, and wiring.

Further Testing

Experiment with different toggle switch settings to see how they effect motor operation. Try inserting the plug with the motor running, or pulling it out with key still in to see what happens. If a second lab kit is available, try connecting the alligator clips to a second motor instead of the battery and rotate the shaft to power the panel.