

Safe conversions: Electrical Thoughts

10/28/2009 Version 1 David Kerzel

I look at converted vehicles and see a wide range of safety consciousness and workmanship. These vehicles are being converted for a number of reasons and with wide expectations. Most conversions are done by an individual at home who is learning as they go. My concerns are is the resulting car safe when parked, when it is being shown to other enthusiasts, when it is being driven, and when its time has past.

There are a few basic guidelines that any electrical machine should follow.

Please always wear Safety Glasses. If something happens at these energy and current levels metal of tools, batteries, wires, and components melts and is often splattered from the explosive arc that may happen.

Most builders agree safe low voltage control signals need to be isolated from high voltage high power wires. The 12 volt system that ran the donor vehicle is the safe low voltage (<50V). The traction batteries are the high power, the two systems are not electrically connected, and the high voltage is isolated from the cars chassis.

Use standard wire colors. This helps everyone understand what is safe and what is not.

	Safe low voltage (12V)	Traction Voltage (High)
Positive	Red	Orange
Negative	Black	Orange/Black stripe
Signals	Any unused color	Orange

Orange wire is hard to find in larger sizes so mark it with orange tape or cover it with plastic tube used to bundle wires.

Keep different types of wire bundles separate. Always separate high power wires from safe low level control signals. Wires operating at different voltages, such as safe low voltage and traction voltage should not be mixed for safety reasons. The high current pulses of the traction electrical system can induce noise in to nearby wires and that noise may affect battery management of communications.

Make sure your wire is appropriate for the use. Standard automotive wire may not be suitable for use at higher traction voltages. Solid or 7 strand wire for house wiring will fail due to vibrations in the car. Wire needs to have at least 19 strands for flexibility. Wires need to be bundled or put in plastic tube for mechanical support.

Keep your positive and negative wires together. Often in cars, ground comes from one place and 12 volts comes from another. This is fine for low power low speed DC signals. AC power in your home always has the two wires side by side. It helps there magnetic fields cancel each other and prevents eddy currents from forming in metal nearby. The high current pulses the battery delivers to the motor control have AC characteristics. Keeping the wires together is logical and reduces radiated electrical noise.

Most conversions use 150 Volts for DC motors and about twice that for AC motors. These are dangerous voltages. DC is different from AC, many people seem to think DC from a battery pack as harmless, it is not, and burns or death can occur. Some simple steps could eliminate most of the traction voltage risks and actually improve the reliability of the converted vehicle.

Never work on a circuit that is powered. If you can switch it off, unplug it or pull a fuse always do so. If you are working on a battery pack where there are no other options extra caution is needed.

Do not work alone and make sure whoever is with you knows how to help and understands touching you may not be an option. They need to know who to call for emergency help fast.

Everyone has heard the advice to keep one hand in your pocket and only work with the other. Should something bad happen this greatly reduces the likely hood an electrical shock current will pass through your heart.

Everyone has heard the advice to remove all jewelry and metal on their hands and wrists. A lot of years ago, I was working on a mainframe computer and my wedding ring shorted a power supply and welded itself to the computer. I was stuck for hours, trapped with a burnt finger. Never again for me.

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Electricians rubber insulating gloves, Class 00 (about \$60) are rated safe to 500 volts would be ideal protection. Other plastic gloves or even dry cotton gloves may provide some protection but this is serious voltage. Do not forget about the rest of your body. Bare arms or legs can become part of the circuit here so opt for long sleeves.

A tool such as a wrench for tightening a battery post clamp should have its mid section and unused end covered with electrical tape, if it gets dropped, it is safe. The shaft of a screwdriver being used on a sensor wire can be taped up or special insulated screwdrivers are available.

The traction electrical system needs to be 100% touch safe from batteries to motor.

There are a number of protective caps for battery terminal connections. They normally just snap on, cover the terminal, and lug on the cable. Using them makes the top of the battery touch safe. Using black and red color coded ones will help some day when a battery needs replacing. It may look like a frill to do later but it is important from the day the battery pack is assembled. Some of us occasionally drop a tool and it always lands where it will do the most damage. If you are showing the car there are no worries about a viewer pointing and touching a battery post. Protected battery posts are essential.

Most conversions have the motor controller under the hood with the traction voltage wires and wires to the motor nicely dressed with professional looking crimped on lugs but no insulation. All these high power wires close to one another, many look as if a bolt came loose they could short out. These connections need some form of protective boot, heat shrink tubing or wrapped tape covering. Any metal object that gets in that area be it a tool or a metal chain on a friend's necklace can instantly become a big problem. You may claim the hood will be closed when it is energized but there are always those special occasions when the hood is up and traction voltage is available intentionally or not, please eliminate the worry.

The connections to the motor are just more of the same.

The connections main contractor and current shunt all need the same attention to becoming touch safe. One good idea is to locate these parts in a box or enclosure that has a cover that screws shut. Then things like the shunt and contactor which are difficult to protect are safe inside the box. As long as the cover is on it is touch safe. Opening the cover so people can see what inside defeats the boxes main purpose. What about putting a clear plastic window in the box, or some electrical boxes are actually clear?

Some builders often put the motor control in this same box. This is fine if it is a water-cooled controller such as a Zilla. Some controllers like the Zilla have a separate interface module for safe low voltage control signals. If you choose to mix safe low voltage and traction voltage in a box, please take extra care to insure they always stay separate even if a connection comes loose.

Putting the traction power components in a box makes them touch safe but if you use a gasketed sealed box you can protect these components from water as well. The wires that enter the box also need be sealed. If you look at the controls for production EV's the controls are always in a sealed metal box. Most motor controllers are not well designed for a potentially wet environment even though they likely will be used in one. Traction voltage connections near the throttle input or open ventilation gaps all can lead to water related problems. Most water has some contaminants and that cause the water to conduct electricity. If the terminals of a controller get wet unexpected currents can flow along wet plastic surfaces and create false control signals or false throttle settings. The water can actually damage the internal circuit if higher voltages find a path to sensitive computer parts. Keeping these components dry is important for longevity and preventing unexpected operation.

Other motor controllers that are air-cooled would over heat in a secondary box or enclosure so they must stay out in the open. As the layout is being planned, consider how water may come in through the grill or splash in. The electrical insulation will make it touch safe but water will find ways in. Keep the controller away from the front of the car, consider baffles to help keep the electrical connections dry.

None of these items are difficult or overly expensive. If done well will show an extra level of attention to detail and safety that the builder should be proud of.