Electric Vehicle Grand Prix

2020 Recommended Assembly Manual



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Introduction and List of Components

This document provides specific information regarding the components you are receiving for your vehicle and some assembly suggestions. We are including photos to clarify some of the suggestions but you should consider all other options when assembling your vehicle. The components in the kit include:

1. Steel Chassis
2. Roll Hoop and Supports
3. Hardware bag A for Roll Hoop Attachment:
4. Clear Acrylic Canopy (optional)
5. Velcro with Adhesive Backing (box with two white rolls)
6. Five Point Harness
7. Seat Strapping Net (packed inside Five Point Harness Box)
8. Seat Pad
9. Grommet Kit
10. Velcro Double Sided (self-stick)
11. Rear Tire
12. Hardware Bag B for Rear Wheel
13. Valve Stem for Rear Wheel - 0.453" diameter (inside Hardware Bag B)
14. Hardware bag C for Spindle Assembly
15. Spindles (one right and one left) (inside Hardware Bag C) (Qty-2)
16. Castellated Nut - 1/2" (Mounted on Spindle Axles) (inside Hardware Bag C) (Qty-2)
17. Axle Spacer (Mounted on Spindle Axles-2 per spindle) (inside Hardware Bag C) (Qty-4)
18. Hardware Bag C-1 (inside Hardware Bag C)
19. Hex Barrel Nuts 1/4-20 X 7/8 long, nut size 1/2" (inside Hardware Bag C-1) (Qty-2)
20. 3/64 X 1" Cotter Pins (inside Hardware Bag C-1) (Qty-2)
21. Brake Cable Cup Stop Bolt (inside Hardware Bag C-1) (Qty-2)
22. Polypropylene Bushing/Spacer ¼" length (inside Hardware Bag C-1) (Qty-2)
23. Front Wheels with Hub Brakes mounted (Qty-2)
24. Front Tires (mounted on Front Wheels) (Qty-2)
25. Front Inner Tubes (mounted on Front Wheels) (Qty-2)
26. Steering Wheel
27. Hardware Bag D for Steering Assembly
28. Tie Rod (black tube with right and left hand female threads) (inside Hardware Bag D) (Qty-2)
29. Steering Column (inside Hardware Bag D)
30. Hardware Bag D-1 for Steering Assembly (inside Hardware Bag D)
31. Steering Column Support Bracket (Large Metal Tube) (inside Hardware Bag D-1)
32. Flanged Sleeve Bushings for Steering Shaft/Tube Interface: 5/8"ID (inside Hardware Bag D-1) (Qty-2)
33. Rod End - Right Hand Thread (each zip-tied pair has one left and one right) (inside Hardware Bag D-1) (Qty-2)
34. Rod End - Left Hand Thread (each zip-tied pair has one left and one right) (inside Hardware Bag D-1) (Qty-2)
35. Pre-packed steering shaft hardware kit (inside Hardware Bag D-1)
36. Steering wheel mounting flange (inside pre-packed Steering Hardware Kit)
37. Small cotter pin (inside pre-packed Steering Hardware Kit) (Qty-3)
38. 1/4-20 castellated nuts (slotted) (inside pre-packed Steering Hardware Kit) (Qty-3)
39. Large cotter pin (inside pre-packed Steering Hardware Kit)
40. Large castellated nut (slotted) (inside pre-packed Steering Hardware Kit)
41. Steering shaft collars with set screw (inside pre-packed Steering Hardware Kit) (Qty-2)
42. Hardware Bag E for Brake Pedal Assembly
43. Brake Cable (Qty-2)

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44. Hardware Bag E-1 for Brake Pedal Assembly (inside Hardware Bag E)
45. Brake Pedal (inside Hardware Bag E-1)
46. Brake Cable Stop (L-shaped bracket) (inside Hardware Bag E-1)
47. Nylon saddle washers for 1" tube, 5/16" uses 5/16" bolt, standoff height 5/16" (inside Hardware Bag E-1) (Qty-6)
48. 6" long coil spring with loop ends (inside Hardware Bag E-1)
49. Cable Knarps (inside Hardware Bag E-1) (qty-2)
50. Plywood for Floorpan (not provided with base kit)
51. Floor Pan Supports (sheet metal Aluminum straps) (Qty-8)
52. Hardware Bag F for Floor Attachment
53. 6 AWG Red Battery Cable
54. 6 AWG Black Battery Cable
55. Battery Kill Switch
56. Low Voltage Red/Black Wire Pair
57. Box of Heat Shrink Tubing Assortment
58. Electrical Tape - 5 color
59. Hardware Bag G for High Voltage Wires:
60. 6 AWG 1/4" Terminal Lug (inside Hardware Bag G) (Qty-10)
61. 6 AWG 5/16" Terminal Lug (inside Hardware Bag G) (Qty-2)
62. 6 AWG 3/8" Terminal Lug (inside Hardware Bag G) (Qty-4)
63. Zip Ties – Black (Qty-25)
64. Zip Ties - Three Color Assortment in Bag
65. NuGen Mobility Wheel Motor
66. Controller Assembly (includes controller, contactor, 100A and 2A fuses, shunt, resistor, diode)
67. Bag I (Miscellaneous Electrical)
68. Spare 100 Amp Fuse (inside Hardware Bag I)
69. 2 Amp switch with on/off labels (inside Hardware Bag I) (Qty-3)
70. 2 Amp Fuse Holder (inside Hardware Bag I) (Qty-3)
71. 2 Amp fuse inside Fuse Holder (inside Hardware Bag I) (Qty-3)
72. Bag J (throttle devices – Note: base kit only includes item 73)
73. Thumb Throttle with 48V charge indicator (inside Hardware Bag J)
74. Foot throttle pedal (optional – not included with base kit)
75. USB-RS232 cable for controller programming
76. Cycle Analyst Data Logger
77. 12V deep cycle batteries with lug screws and nuts– Qty 4
78. 48V battery charger with connectors
79. FRP Body Shell

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Project Tips

Review the manual first. It will help you get a good idea of the assembly sequence and the scope of the project.

Identify all the parts of the kit and organize them neatly on shelves. Keep ALL components and hardware in their bags until you are ready to use them.

Have the parts and tools all ready for each step.

Test fit the parts together before you bolt, drill or cut them. "Measure twice, cut once."

Build it strong. You have to finish to win.

Give yourself plenty of time. "If you don't have time to do it right, when will you have time to do it over?"

Give yourself plenty of space to work in.

When cutting, grinding, or drilling ABS/plastic body or canopy components make sure to wear a nose/mouth filter or mask and proper eye protection. Only work in properly ventilated areas and have a second person use a shop vacuum to collect as much debris as possible as it leaves the work piece.

Use the right tools, the right way.

Sharp drill bits work much faster. Drilling in steel should be done with lots of pressure and a drill speed slow enough that the flutes (grooves) of the bit aren't a blur.

Enjoy the process. Be creative!

Know your car. Know your batteries. Know the competition regulations.

Develop a race strategy. Drive Efficiently.

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Assembly Steps

Each Assembly Step lists the required kit parts and their numbers as they appear on the parts list. It may also list suggested items not included with the kit that you may need to obtain before you start (e.g. side mirrors). Buying those items a few steps ahead will save you lots of time during assembly.

When you receive the kit make sure to identify all the parts against the parts list, and keep fasteners and electrical connectors with their respective components to avoid confusion during assembly. Devise a process to properly label and store the parts for retrieval when needed.

Read the competition rules and regulations carefully. The kit and the suggested assembly procedures take the regulations into account, but it is your responsibility to ensure that the completed car meets the rules and will pass the technical inspection. If you are not sure, ask. Don't wait until race day to find out.

Fasteners

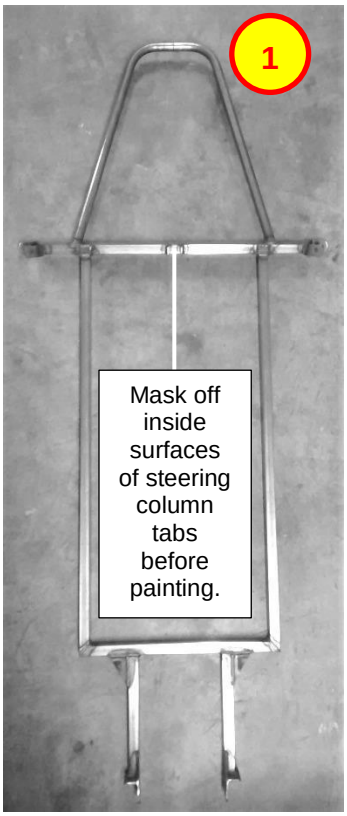
The kit includes most of the mechanical fasteners you will need such as bolts, washers, and nuts to assemble your car. Note that all fasteners are SAE (sized in inches) with the exception of the bolts/nuts for connecting the motor cables to the controller and shunt, which are metric. If replacing nuts, make sure to acquire the proper size and threading. Note that certain nuts on the steering links have reverse threading, so do not force them on if they don't seem to fit. This is explained in the appropriate section of the manual.

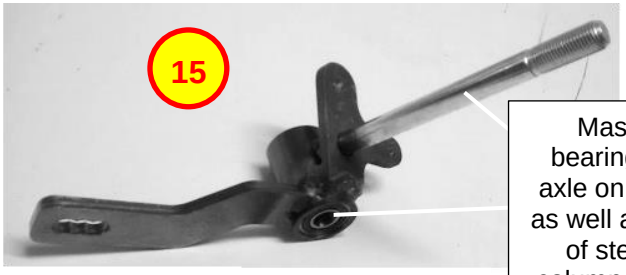
It is necessary that every fastener on the car is locked in place. Nylon backed nuts (nylock) should be used everywhere except on the front axles where castellated nuts should be used in conjunction with cotter pins as indicated in the rules. In places where the locknuts aren't tightened snugly, such as on the brake pedal mounting, a jam nut must be tightened against the locknut to prevent it from loosening. Nuts used to secure high voltage electrical cables must be tightened properly to avoid sparking and damage to the components. This is the leading cause of electrical failures in races.

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STEP 1: Paint metal parts

Kit Parts: Steel chassis (1), steel roll hoop with side supports (2), steering spindles (15), and steering column support (31)
Materials: Painter's tape and spray paint (any type that adheres well to steel)







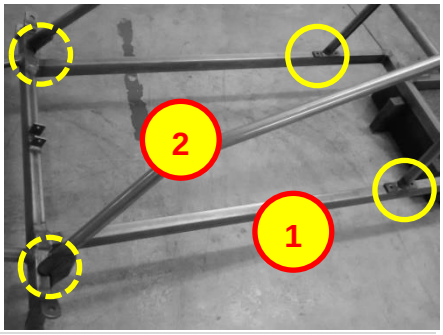


Metal parts have been coated with a light layer of oil to prevent rust. This must be cleaned off prior to painting, so research available solvents. If water and detergent are used, make sure to dry the metal parts thoroughly. Mask off the inside of the steering column support since a layer of paint will make installing bushings difficult later. Mask off the bearings and the axles (shiny rod threaded at end) on the spindles. Mask off the inside sides of the tabs on the frame that hold the steering column support tube.

Paint all the metal parts. This will prevent them from rusting and it is easier to mark and measure on a painted surface; lighter colors are easiest to mark on. Follow the paint manufacturer instructions and let the paint dry completely, which may take a few days.

STEP 2: Mount roll hoop to chassis

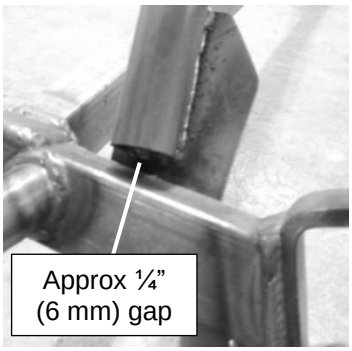
Kit Parts: Steel chassis (1), steel roll hoop (2) and supplied mounting hardware (Bag A)
Tools: Drill, ¼" drill bit, and wrenches



The holes for mounting the roll bar may be drilled prior to

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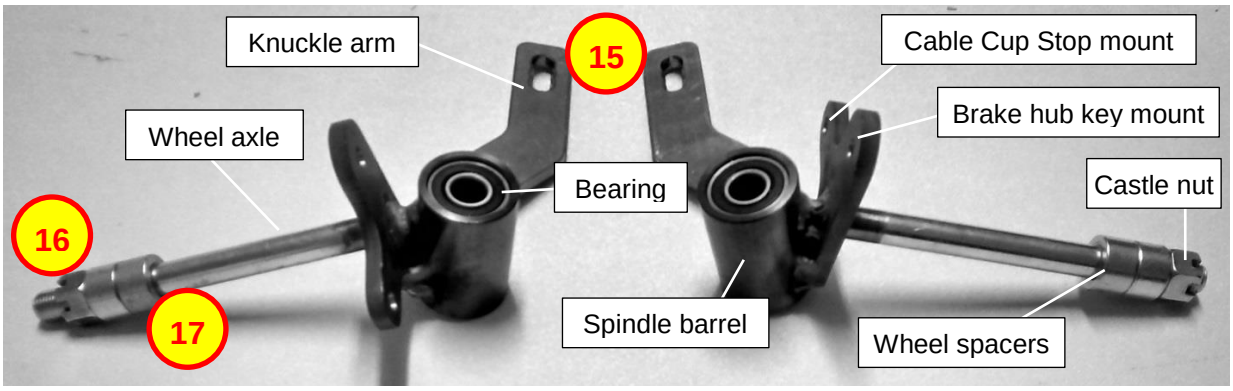
painting the chassis in STEP 1, but do not assemble the units together before painting. Place the roll hoop on the chassis as shown in the image and measure the locations of the four support points to center properly. The bottom of the tube at the front of the side support bars should be about ¼" (6 mm) above the frame. Use clamps to hold the roll bar to the frame. Mark the frame where the two ¼" holes meet it, and drill the frame on each front mounting tab (circled in dashed yellow line), then bolt these tabs to the frame. The forward tabs will use 1-3/4" long 1/4-20 bolts. Drill four ¼" holes for the rear mounting tabs (circled with solid yellow line.). The kit hardware includes one nylock nut, and two flat washers for each mounting hole. The rear mounting plates will use 2-1/4" long 1/4-20 bolts. It may be necessary to cut down some of the washers on the side mounting holes to make them fit as the roll bar hoop could interfere with the washers. The roll bar may get in the way of the drill or tools tightening bolts. So marking the hole, removing the hoop, drilling and replacing may be necessary. For the rear-most bolts, it is easier to insert the bolts from the bottom of the frame and place the nut on top. Be sure to use washers under the bolt heads and nuts.



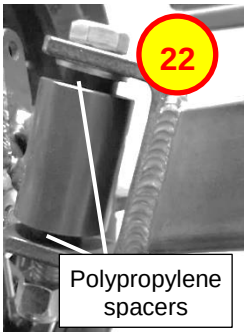
STEP 3: Attach steering spindles

Kit Parts: Steering spindles and hardware (15, 16 and 17), hardware (18), and polypropylene spacers (22)
Tools: Wrenches

The figure below defines the various components and the naming terminology. There are different steering spindles for the left and right sides. They are mirror images of one another. Note that the direction of the knuckle arms determines the side they go on. When attaching the spindles to the steel chassis, the knuckle arms must be pointing to the rear of the vehicle.



The kit hardware includes one 4" long 1/2"-13 bolt, one nylock 1/2" nut, and 1/2" flat washers for each of the two spindles. Also included are four ¼" black polypropylene spacers (22) that fit as shown in the photo on the right. These need to be cut squarely so the loads are evenly distributed along the inner race of the bearings in the spindles. When assembling, insert the 4" bolt from the top with the nut on the bottom such that if the nut comes off, the bolt, and hence spindle, remain in place. The black polypropylene spacer is the same diameter as the inner race of the bearing, and must therefore be inserted on both sides of the bearings as shown in the image.

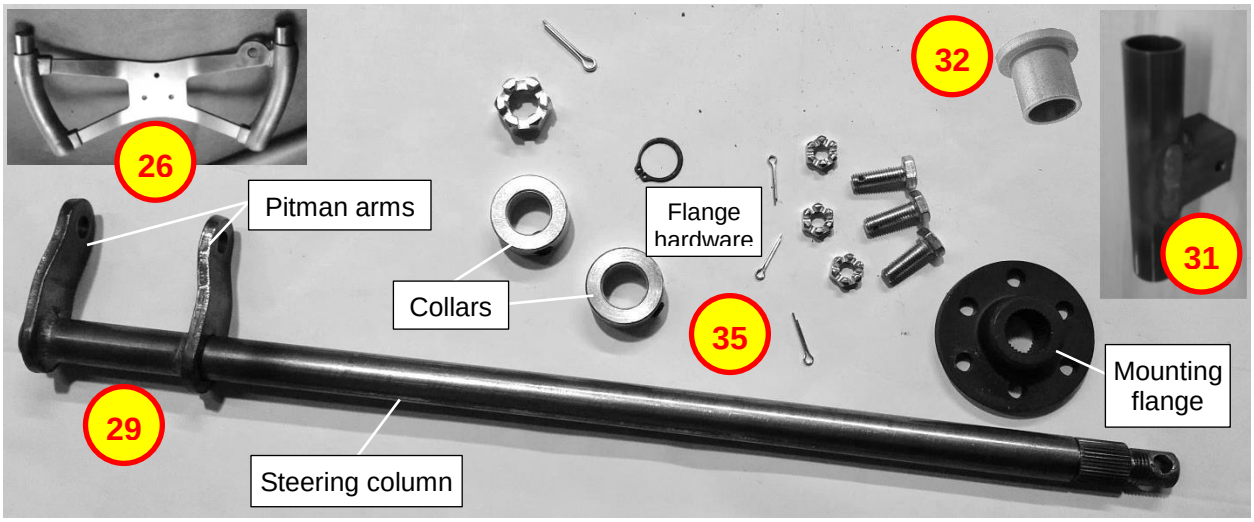


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Place one of the flat washers above the top polypropylene spacer as shown to keep the spindle from sliding up and down. You may place additional washers under the cap head and the nylock nut, but they are not necessary. Make sure spindles rotate freely.

STEP 4: Attach steering wheel and column

Kit Parts: Steering wheel (26), steering column (29), support bracket (31), flanged sleeve bushings (32), and steering hardware kit (35)
Tools: Wrenches and drill with different bit sizes



The figure above shows the steering components and their names. Begin by pressing the two 5/8" ID oil-impregnated bushings into the steering column support. This should be done with a press, not hammered. If bushings are hammered, they may deform, causing difficulty when installing the steering column. Once the bushings are installed, slip one of the collars over the steering column and push it all the way towards the Pitman arms. Make sure the set screw in the collar is loose enough so it fits easily over the steel rod. Insert the steering column through the two bushings in the support tube. If there is difficulty, the bushings can be lightly reamed with a 5/8" drill bit running *backwards*. Slip the second collar over the steering column. The lower collar should be snug against the Pitman arms and against the bottom bushing, while the upper collar should be snug against the top bushing. Tighten the set screws on both collars to keep the steering column from moving up and down, but it should rotate freely.

Prior to attaching the steering column support to the frame, any paint on the outside of the support and the inside of the attachment tabs on the frame where they come in contact should be sanded off. This area should be greased to prevent rust. Attach the steering column support to the frame such that the Pitman arms are on the bottom pointing towards the back of the car (see image below). Bolt in place with the 2½" long ¼-20 bolt, using a washer on each side and a nylock nut. Do not overtighten. This arrangement allows for the steering to tilt forward to aid driver ingress and egress. Teams may wish to place a piece of rubber of a certain thickness to the back of the frame where the tube contacts it to act as a stop and fine-tune the fore-aft placement of the steering wheel, while also protecting the frame.

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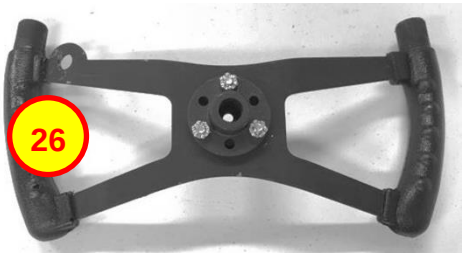
The mounting flange for the steering wheel sits on the column as shown in the right figure below. Before mounting the flange to the steering wheel, you will need to enlarge the whole in the center of the steering wheel so the shaft may go through. Note the shaft is 5/8" diameter.







Place the steering wheel over the mounting flange as shown in the left figure below. Rotate the steering wheel around to get three of the holes to align properly. Enlarge the holes slightly as needed if they don't align properly. Insert the three bolts, castle nuts, and cotter pins to secure the steering to the mounting flange. For proper alignment, the steering wheel must be perfectly horizontal when the Pitman arms are vertical. It may be necessary to take off the flange, rotate it by one spline and reinstall for alignment.





Attaching the Throttle/Regen Thumb Control

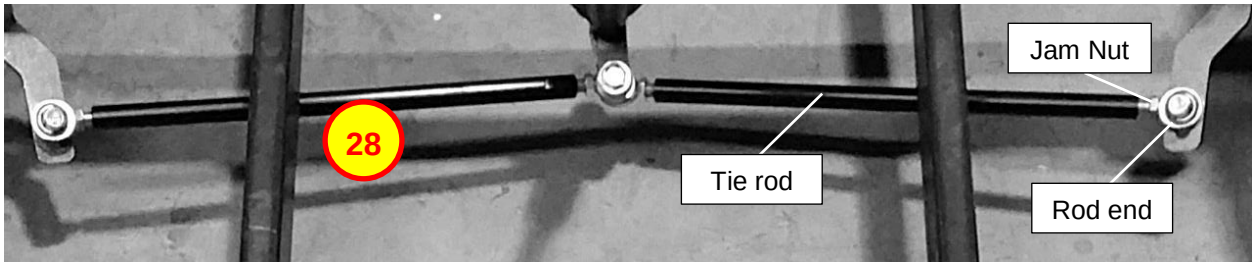
As described in the electrical section, the kit includes a thumb control unit which could be used as a throttle or regenerative braking input device. To attach the thumb control to the steering, install the thumb unit on the top portion of either side of the wheel and tighten the set screw.

STEP 5: Connect steering links

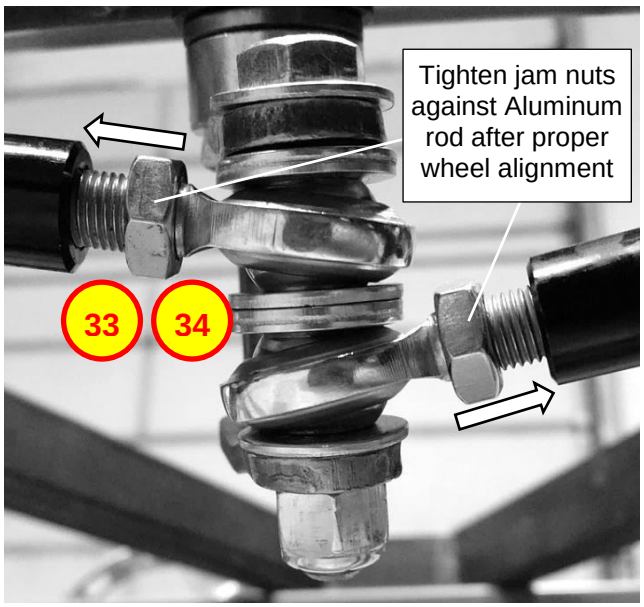
Kit Parts: Reverse thread Aluminum adjustable steering tie rods (28), rod ends (33 and 34), and hardware (30)
Tools: Wrenches

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Refer to the images below for this section. The kit includes two high-precision, light-weight aluminum steering tie rods (black). The ends of the tie rods are threaded with reverse threads. There are four rod ends in the kit and four corresponding nuts. Two of the rod ends and nuts are left turn while the other two are right turn. Begin by placing the correct nut on each rod end threaded shaft and turn all the way until reaching the tie rod head. Do not tighten as they will need to be turned back later. Insert the four rod ends into the corresponding side of the tie rods. Next connect the rod ends to the Pitman arms on the steering column and the knuckle arms on the spindles as shown below. Sufficient flat washers will need to be added as shown to ensure that the rod ends do not snag or bind when the steering turns to each extreme.







The final step is to align the front wheels so there is no “toe-in” or “toe-out”. Hold the steering wheel steady so the Pitman arms are perfectly vertical. Next, grab the black Aluminum rod in its middle and rotate in the proper direction to align the corresponding wheel so it is pointing forward with no toe. Finally, turn back the jam nuts on the rod ends until they are tight against the Aluminum rod. Use wrenches to secure the nuts. Once both sides are aligned, turn the steering wheel through the entire range of motion to make sure they move freely and that none of the rod ends snag. Make adjustments as necessary with the flat washers on the rod ends.

You will notice three hole locations on the knuckle arms. This provides some flexibility in setting up the steering geometry. Using the holes closer to the spindle barrel also increases the Ackerman geometry. By moving the tie rod closer to the spindle barrel you get a tighter turning radius, but the steering requires a higher force to turn. This can be adjusted through drive testing once the car is completely built. Begin with the hole closest to the spindle barrel.

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STEP 6: Mount tires on front wheels

Kit Parts: Aluminum alloy rim spoked front wheels (23), 12” tires (24), and 12” tubes (25)
Tools: Tire mounting tools and air pump

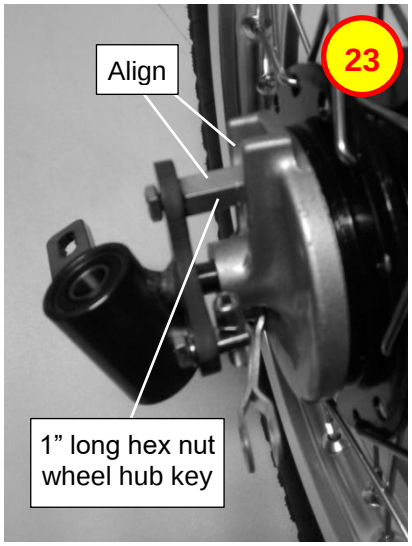
If you are not familiar with properly mounting bicycle tubes and tires please consult with a local bicycle shop to assist with this step. It is important that a member of your team is trained in this procedure to maintain the wheels and tires during the competition.

The two front wheels will be installed in opposite directions, so note the proper direction of rotation marked on the tires and ensure that one is mounted in the reverse direction of the other. When the wheels are attached in the next step, the tire rotation should be correct if the wheels are placed on the axle such that the brake hubs are on the inside. Pump the tires prior to the race to the pressure recommended by the manufacturer. To gain efficiency, make your wheels as perfectly circular as possible. Bleed air out of the tires until they barely contact the rim, then carefully manipulate the tire sidewalls where they meet the rim to get a constant tire height around the entire wheel then re-inflate the tire. Make sure the spokes are tightened properly.

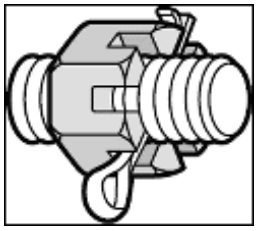
STEP 7: Attach front wheels

Kit Parts: Aluminum alloy rim spoked front wheels (23) and axle hardware (16, 17)
Tools: Wrenches and grinder or metal file

The two front wheels supplied with the kit have built-in hub drum brakes making wheel replacement during the race faster compared to disk brakes. Remove the castle nut and two axle spacers, then slip the wheel on the axle with the hub brake side first. Do not force the wheel on as it should slip in freely. After the wheel is on all the way, place both wheel spacers on the outside followed by the castle nut. Do not tighten yet as further adjustments will be required.



Align the wheel hub key mount and brake hub notch as shown in the figure on the right. A 1” long hex nut is used as the wheel hub key (see image). Attach Wheel Hub Key and spring washer, and secure firmly with the 1” 1/4-20 bolt. You will need to grind or file down the 1” hex nut to make it fit inside the brake hub notch. Do not hammer in, rather, file down until it fits when pressing by hand or gently tapping in. Once completed, tighten the castle nut on the axle. Drill a hole in the axle and insert the cotter pin in the hole and pull the pin legs apart to secure. The castle nut should only be tightened about ¼ to ½ turn past hand tight. Note that the castle nut and cotter pin are required by the regulations and must be secured correctly.

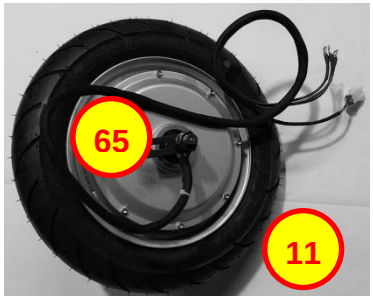


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STEP 8: Mount tire on rear wheel

Kit Parts: NuGen wheel motor (65), valve stem (13) and 10” tubeless tire (11)
Tools: Tire mounting tools and air pump

If you are not familiar with properly mounting bicycle tubes and tires please consult with a local bicycle shop to assist with this step. It is important that a member of your team is trained in this procedure to maintain the wheels and tires during the race. Be very careful when handling the wheel motor so as not to damage the cable and connectors. The motor contains strong rare-earth magnets (Neodymium-Boron-Iron) therefore keep metal parts and metal shavings away. Be careful not to drop the motor as the wheel rim will bend and cannot be replaced.

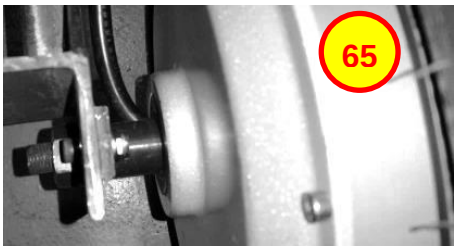


Carefully attach the valve stem to the wheel by inserting it from the inside of the rim. Note the proper spin direction of the tire (when the motor is mounted on the chassis, the cable will be on the left side of the car) then mount the tire and inflate it to the manufacturer recommended pressure. It may be necessary to apply soapy water to the inside of the rim in order to lubricate it so that the tire will be able to expand out to the lip of the rim. It may be necessary to use an air compressor to quickly inflate the tire so it will seat the sides of the tire enough to seal.

STEP 9: Attach rear wheel motor

Kit Parts: NuGen wheel motor (65) and hardware (12)
Tools: Wrenches

Revert to the figure on the right for proper mounting of the wheel motor. Note that the cable is on the left side of the car. The kit includes a 3/4” long 1/4”-20 bolt, a nylock 1/4" nut, and two flat washers per side. Use this hardware to secure the vertical tabs to the steel chassis dropouts. Tighten the 1/2" axle nuts securely.

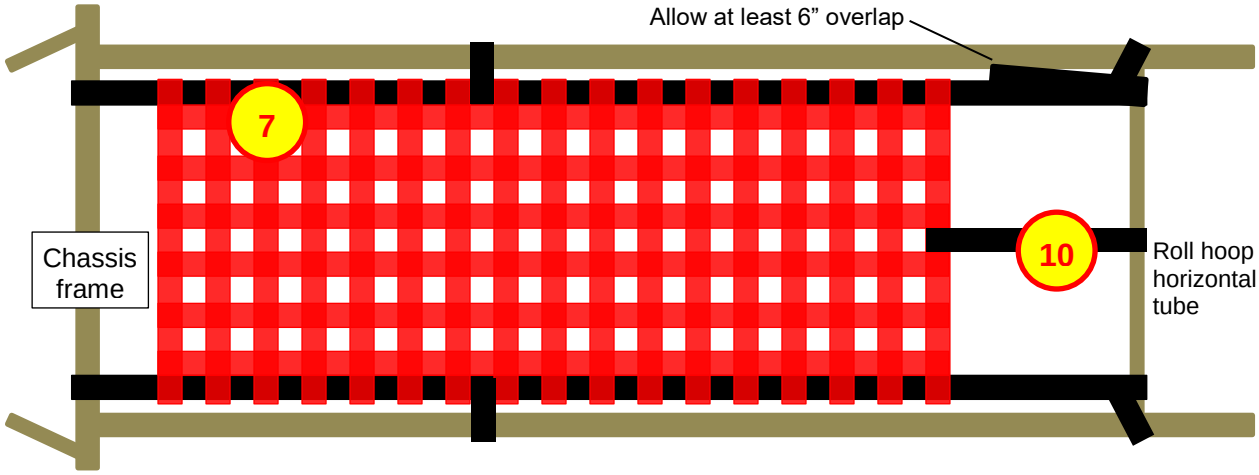


STEP 10: Install seat

Kit Parts: Seat net (7), light-weight seat pad (8), grommet kit (9), and double sided Velcro (10)
Materials: Scissors for Velcro roll

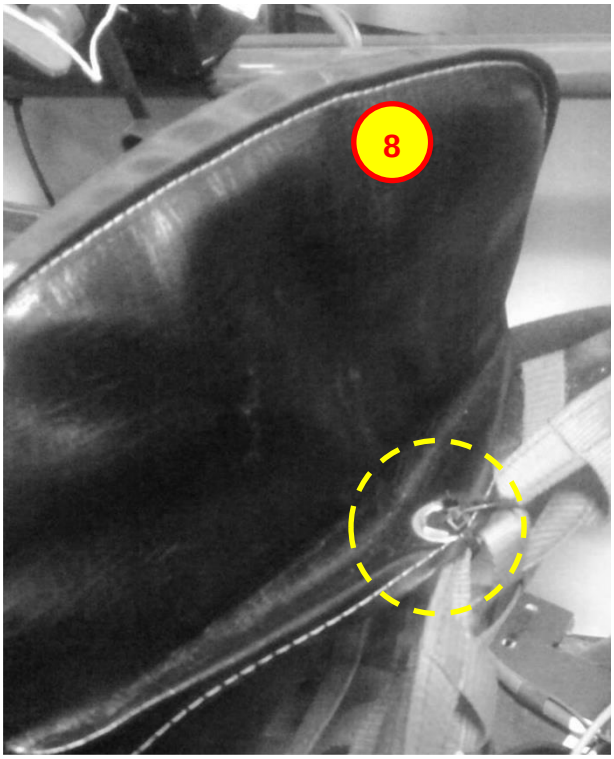
The seat should be installed such that it is completely suspended from the steel chassis and roll bar, and should not be resting on the floor of the car. Use the Velcro to attach the net to the chassis frame and roll hoop. Begin by feeding two long pieces of Velcro through the net as shown in the figure below. Permanently secure the net to the front cross member of the chassis and the roll hoop horizontal tube. Make sure to measure carefully before cutting the Velcro, and allow at least 6” of overlap past the frame to ensure that you get a strong connection.

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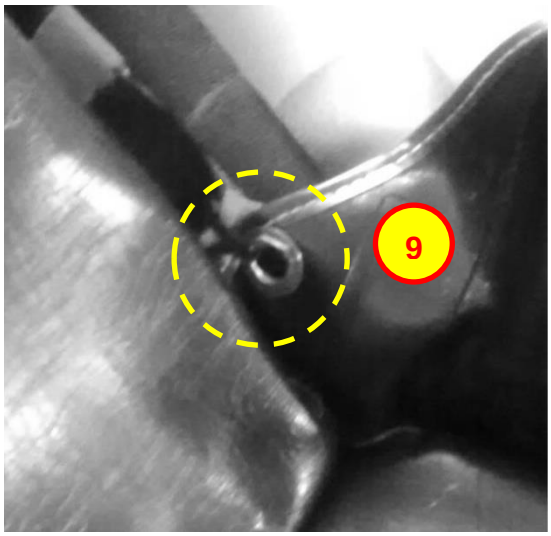


A driver should sit on the net to make adjustments of the Velcro lengths. Use two short pieces of Velcro strap to wrap around the sides of the frame to hold the center of the netting up. Short pieces can also be used to pull other parts of the net as needed. Adjustments will be necessary to attain a comfortable fit for the driver. The goal is to allow the driver to sit as low as possible without applying weight to the wood floor. The driver’s hips should fit between the chassis rails.

Finally, follow the instructions in the grommet kit and install three grommets on the seat pad in the locations shown in the figures. Place the seat pad on the netting and with the driver sitting on the pad in driving configuration, use zip-ties to attach the pad to the netting through the grommets. The purpose of the zip-ties is simply to keep the seat pad from moving, therefore keep them loose enough so as not to stretch and tear the seat vinyl



Place one grommet on the flap on the back of the seat pad, and two on the flaps on the sides, then use zip-ties to loosely secure them to the net



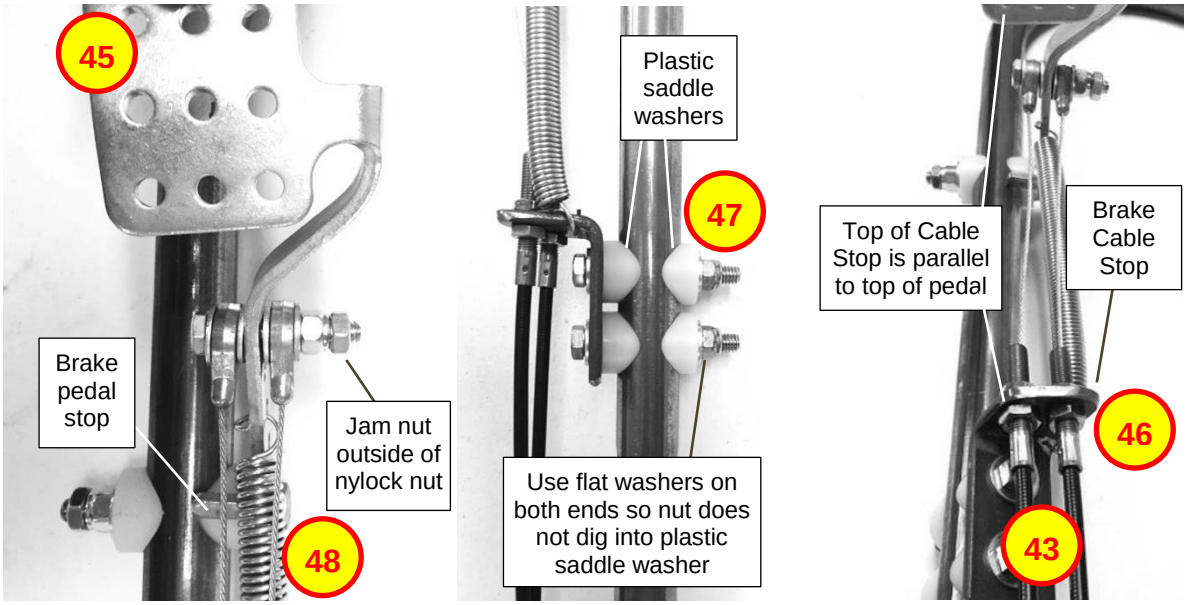
Note that drivers should step on the seat when getting in and out of the car to prevent applying

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force to the wood floor, which is not designed to hold weight, but rather to protect from abrasion.

STEP 11: Install brake pedal and connect cables

Kit Parts: Steel brake cables with sleeves (43), brake pedal (45), brake cable stop (46), white plastic saddle washers (47), coil spring (48), cable knarps (49) and hardware (44)
Tools: Wrenches, screwdrivers and drill with various bits



Refer to the figures above for details on installing the brake pedal, tension spring, and brake cable stop to the front bumper. Note that although the pedal is shown to be vertical in the photos, it can be at any orientation from vertical to horizontal by rotating the axis of the hole that mounts it to the frame. It is suggested that teams find an ideal pedal position for their drivers keeping in mind height and fore/aft placement. The pedal should be placed first, then the cable stop bracket should be aligned to the pedal with a 23° difference so that the top of the bracket is parallel to the top of the pedal. If your pedal has the bolt and pedal stop mounted on the opposite side of the bumper hoop than the one in the photo, the Brake Cable Stop will need to be turned around so that the bolts mounting it are between the pedal and Brake cable stop. This will ensure that the cables extend back straight from the pedal parallel to the frame tube.

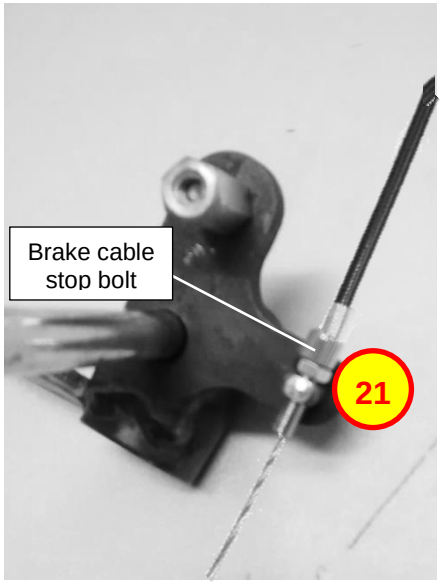
The pedal should be secured with a nylock lock nut that is tightened down lightly, then backed off until the pedal can move freely. It should be able to fall. Then use a jam nut as shown in the figure above to tighten against the nylock nut to ensure it will not rotate.

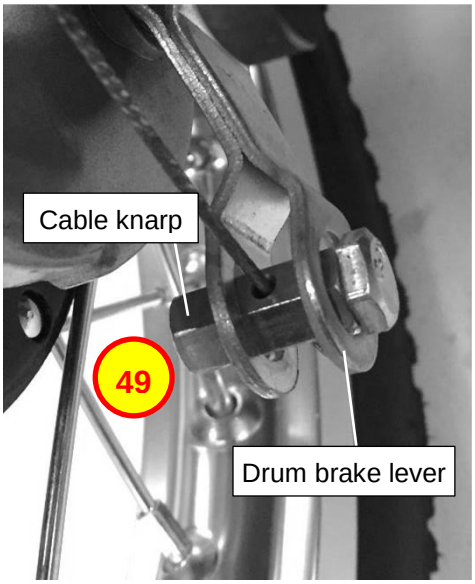
To mount the two brake cables to the brake cable stop, first pull the steel cables completely out of the black cable housing sleeves. One end of the sleeve has a threaded metal piece with two nuts. Remove one of the nuts, insert the threaded piece into the brake cable stop, then place the nut back on the threaded piece and tighten both nuts. You may need to enlarge the holes in the brake cable stop to fit the threaded piece. Insert the two brake cables back inside sleeves.

Next, attach the two brake cable loop ends to the pedal with a washer on each side of each loop. Use a nylock nut to hold the loops on, but just as with the pedal installation, leave the nut

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loose enough that the loops can rotate. Use a jam nut to secure this lock nut by tightening it against the lock nut. The cable housing sleeve should be shortened to reduce excess length. Take care to ensure that the cable still makes large radius turns. Do not kink the cable or housing. Insert the loose cable end through the brake cable stop bolts, which were mounted to the spindles earlier, then use the cable knarps to attach the cable to the drum brake lever. Some preload of the lever will be necessary. Use the adjustment nuts on each end of the cable to tighten the cable. Spin the wheels to check for brake rubbing and adjust accordingly.



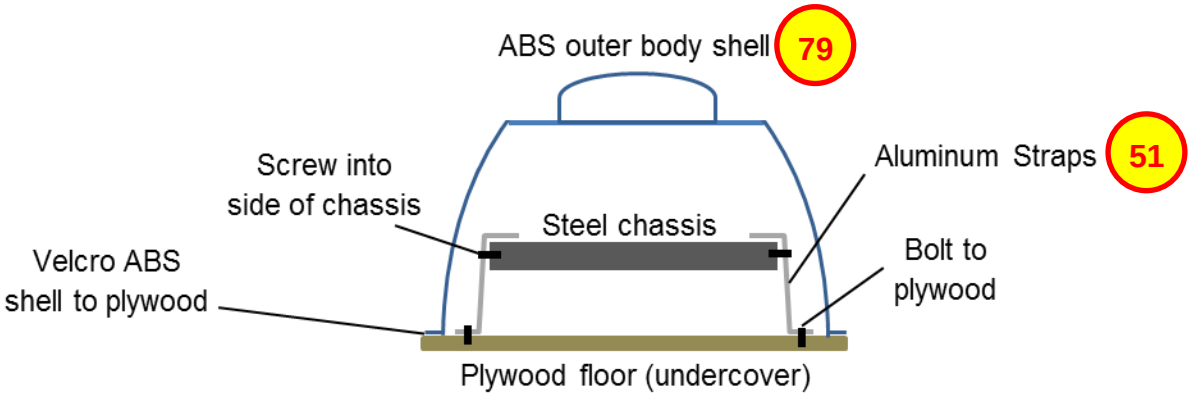


STEP 12: Install Aluminum straps, plywood floor, and body

Kit Parts: Aluminum Floor Pan Support Straps (51), plywood (50) ABS Body shell (78) and Velcro hook and loop (5)

Tools: Jigsaw power tool, drill with ¼" hex driver, tin snips, Dremel tool,

The following schematic demonstrates the connection between the steel chassis, the Aluminum straps, the plywood undercover, and the ABS outer body shell.

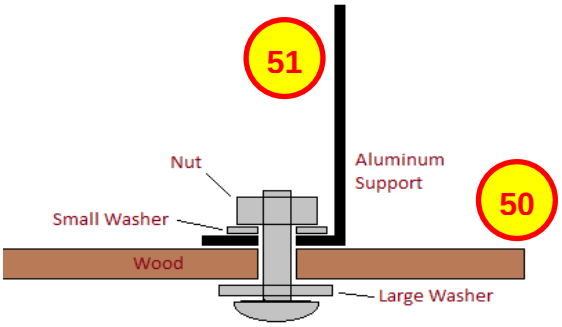


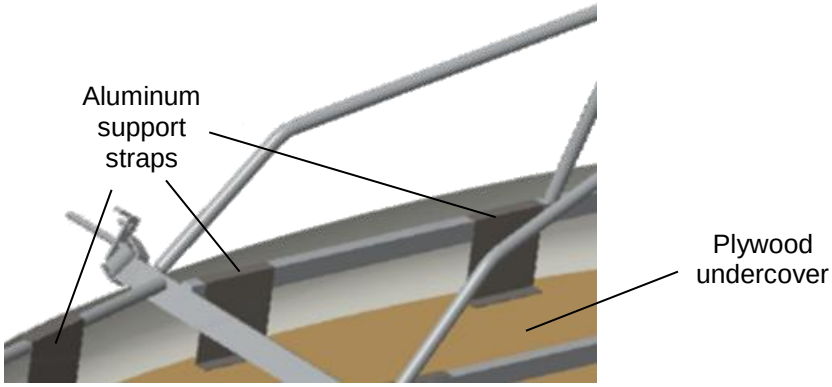
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The fore-aft placement of the plywood is important to get correct since it will dictate the placement of the body. There is a narrow window where the body will clear both the front bumper and the rear wheel. Be careful to measure and calculate where placement of the body will work and attach the plywood undercover accordingly. A good starting point is that the roll hoop legs will protrude through the body at the back of the flat area that is trimmed away on the top of the body.

Your kit includes eight custom made aluminum sheet metal straps. They have vertical bends down the center. This provides stiffness, and allows the use of the supports on a corner if desired by simply cutting the top and bottom pieces at the center and folding the strap. See the image below for details of connecting the aluminum straps, plywood, and ABS outer body shell to the steel chassis. All the hardware for making these connections is included in the kit.







The straps can be mounted where teams choose, with suggested locations as shown above. The locations on the front bumper will be dictated by pedal placement. Be careful not to place supports too far forward since the front of the body has a slope to it and the plywood may not extend far enough below the straps. Straps should be screwed into the side of the frame rail with self-drilling screws while the top tab aligns the strap with the top of the frame rail. Should you choose to place a strap at a corner as opposed to a straight section, cut the top and bottom of the strap in the center with tin snips then bend to a 90° angle to form around a corner.

The next step is to cut the 1/4" plywood to form the undercover of the car, which will support the body and protect the driver from the ground. The footprint of the plywood needs to match the outside of the bottom of the body. This can be achieved by placing the body on the plywood and tracing a line to cut on. Cut the plywood with a jigsaw.

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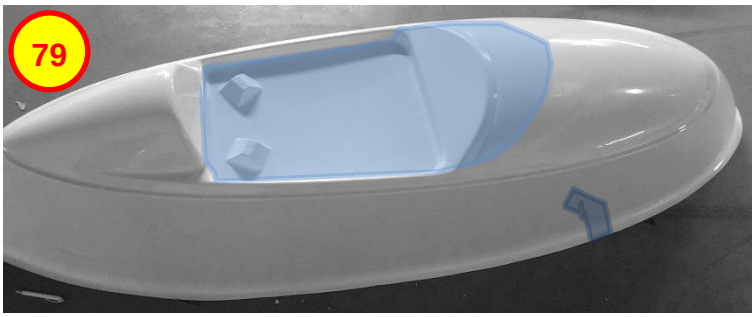
Before attaching the plywood, do as much work as possible trimming away parts of the body such as flat area on the top, the dash area, and about 15-20 cm of the hood extending forward from the dash. Then do some more measuring to determine a suitable fore and aft placement of the body, which will dictate the placement of the floor. Take time to get this right.

Secure the plywood piece to the aluminum straps with the remaining bolts in hardware bag F. Refer to the figure above for location of washers and bolt orientation. Note that the head is on the bottom for increased ground clearance as compared to a nut. To complete the installation you will need to cut out a section in the rear to fit the wheel motor/tire, and it may be necessary to cut a small hole for the bottom of the steering column.

Attaching the body shell

Before attaching the body shell you will need to cut out the cockpit, and front frame/steering link areas. This will require patience, measuring, marking, and skill. A few trial fittings of the body may be necessary. The image below shows the body shell with the areas that need to be removed. You can use the Dremel with an abrasive wheel, a jigsaw, or shears (tin snips). If using a Dremel, use a shop-vacuum to collect the debris while cutting, and make sure to wear proper eye and breathing protection. Only straight cuts should be made with an abrasive disc since trying to turn will likely break the disc, which sends dangerous pieces flying.

If done properly, the body should sit on the plywood floor. Make sure all the cutouts for the spindles, tie rods and front frame are complete then turn the steering wheel to both extremes to ensure that the lower body does not interfere with the steering link movement.





Keep in mind that the less you cut from the cockpit area the more rigid the shell will be. So you are trading front visibility, feet space, and driver ingress/egress ease with rigidity. A few trial fittings of the body may be necessary to ensure that the roll hoop fits properly and the driver space is adequate. Clean up the cut edges with sandpaper.

Lastly, once the undercover has been mounted and the body trimmed to fit, Sticky back Velcro (5) should be installed to hold the body in place. Even though you are provided with enough Velcro to go around the car, it is suggested to use a few shorter lengths of perhaps 30 to 50 cm each separated by empty regions so that body removal is not too difficult. To install it, leave the two mating pieces of Velcro attached, then peel the cover off of the adhesive on only one side of the Velcro, then attach it to the top of the undercover where the body will meet. Then remove the second adhesive covering and use several people to carefully lower the body onto the undercover ensuring proper alignment. Then go around the perimeter of the car squeezing the body and undercover together to strengthen the bond.

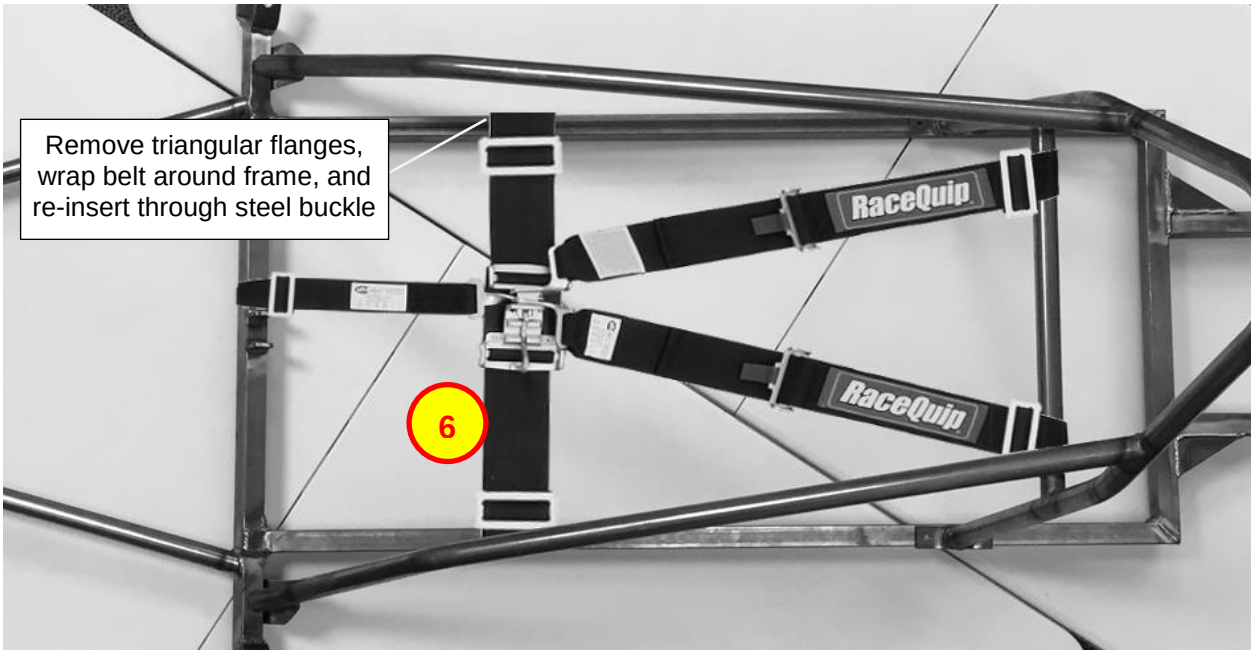
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Caution: The shell can break if the driver places weight on the shell along the cockpit opening when entering or exiting. The driver's weight should be supported with the roll hoop, chassis, or seat rather than the shell itself. If needed, you can reinforce the body under the rear corners and sides of the cockpit opening by attaching a length of small wooden dowel or metal tubing with a suitable adhesive. Add additional support for the body in other areas if necessary.

STEP 13: Attach 5-Point Harness

Kit Parts: Five-point harness (6)

The seat belt is installed by wrapping the straps around the chassis and roll bar cross member. This step must be performed properly to ensure that the belts are secure and tight. Begin by removing the triangular flanges which are typically used to bolt to a steel chassis. These belts have dual attachment functions and since they are being wrapped around the frame, the triangular flanges are not required and only add weight. See the image below for more details.



STEP 14: Electrical system installation and connections

Electrical System

Appendix A shows a circuit diagram of the entire electrical system and images of all the components. The instructions below will describe the various components provided in the kit as they correlate with the schematic. Keep in mind that your system is 48V DC and all the components are rated for this voltage. All wires shown in thick lines on the circuit diagram are high power lines, and will be physically made with the 6 gauge red and black wires and crimped terminal lugs on the ends. The thin wires will be made with low voltage wire (red/black pair) with

crimped or soldered connectors on the ends. To understand the schematic you should first be familiar with the operation of the vehicle. Here are some basic points:

1. The vehicle is driven by an electric DC brushless wheel motor (65). The speed and/or torque of the motor are controlled by the controller (66). The motor is connected to the controller with two sets of cables. The large wires are used to connect the three phases of the motor to the input tabs on the controller labeled A, B, and C. The bolts and nuts for the controller are metric and are provided in the kit. The low voltage wires and connector are for the hall sensor signals and the motor temperature sensor. Both sets of wires and connectors come pre-installed in the kit.



2. In this version of the kit, you have a couple of different choices for the throttle input and regenerative braking (regen). There is a throttle/regen foot pedal (74 - optional) and a throttle/regen thumb control unit (73). Both are comprised of hall sensors which send a signal to the controller proportional to the position of the input lever. Mating connectors for both units are provided in the kit. There are four options for connecting these input devices:

   a. Foot pedal for throttle. Thumb control for regen braking.
   b. Thumb control for throttle. Foot pedal for regen braking.
   c. Foot pedal for both throttle and regen braking. Thumb control not used.
   d. Thumb control for both throttle and regen braking. Foot pedal not used.

For options c and d, the controller sets the input device to provide regen braking at the low end of the travel (up to 20%) and throttle at the high end. In other words, if the vehicle is stationary, pressing the pedal (or thumb control) the first 20% of lever travel would not move the vehicle. Going past the 20% point would begin to accelerate the vehicle. The further the pedal is pressed, the more torque the motor produces. Reducing the pedal position produces the opposite effect, until the 20% position is reached. At this point the controller switches to regen braking mode, and releasing the pedal further would increase the amount of regen braking. This approach is less confusing to the driver and may produce more efficient results since there is only one input device plus the mechanical brake pedal. The driver would only engage the brake pedal if a sudden stop is required. Otherwise, acceleration and deceleration would be accomplished entirely through the throttle/regen device used.

3. The controller gets the power to control the motor from the four 12V lead acid batteries, which will be connected in series. You will need to make three harnesses using 6 gauge wire and the terminal lugs to connect the +ve terminal of one battery to the –ve terminal of the next battery, and so on, hence putting them in series. The remaining two terminals will be connected per the circuit diagram (+ve and –ve 48V). The controller is mounted on a metal back plate (controller frame), along with a 100 Amp fuse, a shunt (for measuring current draw), resistor for controller precharge, and a high power relay/contactor. There is a quick disconnect switch with red key to use as the Main Power Switch. All these components are labeled in the circuit diagram and are connected using 6 gauge wire and terminal lugs. Note that the quick disconnect switch is a race rule requirement and its physical location in the car is dictated by the rules. You may add a second one in series in which one is accessible from inside the car and the other from outside. When either of the two switches is turned off, the main power from the battery is disconnected. Finally, the shunt is used to measure the current in the system and the cycle analyst manual will describe how you connect the low voltage wires to get a reading.

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4. The kit includes three On/Off low-voltage switches with label plates, three 2A fuse holders, and three 2A fuses. The location of these switches/fuses is shown in the electrical schematic and the addendum for the battery installation, with the following functions:

a. Cycle Analyst power switch to view battery state and monitor charging

b. Controller power switch (note the 2A fuse is already installed on controller frame)

c. Forward (throttle) switch, which should be turned off during driver change. The red toggle switch on the thumb throttle can be wired in instead of this switch

Since one of the fuses is already installed in the controller assembly (4.b) and if you use the red toggle switch on the throttle unit (4.c) then you should have one extra fuse and extra switch.

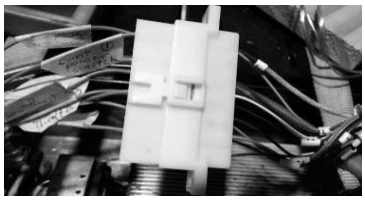
5. The controller allows for a reverse switch as well. This is not required and teams should consider whether they wish to have that option implemented. The schematic shows where the reverse switch connects into the controller.

6. In starting the vehicle, the order followed should be: turn on the Cycle Analyst switch (4.a) to see the battery readings, then turn on the Main Power Switch (or both if you have two). At this point the capacitors inside the controller will begin to charge through the precharge resistor. *As a learning experiment place a volt-meter across the B+ and B- terminals on the controller.* You will see the voltage slowly rise. Typically you should wait about 10 seconds before the next step to allow proper precharging of the controller. Now the controller switch (4.b) can be turned on. You will hear the contractor/relay click indicating that it is allowing the high voltage to pass to the controller. Also, the controller green light will come on. If you see a blinking red light on the controller, refer to the manual for the fault message. *These steps are very important. Failure to precharge the capacitors prior to turning on the main power switch may damage the controller.* The final step is to turn on the throttle switch (4.c) to drive.

Main Power (aka Master Disconnect) Switch

The rules and regulations require that the main power switch be accessible from both outside the car for course workers and inside the car for the driver. One switch is provided in the kit and it may be possible to meet this rule with a single properly positioned switch. For example, a strong string tied to the switch may be run through a small hole to the outside of the shell so it can be tripped by someone outside the vehicle in an emergency. Tie a 1” plastic washer onto the end of the string. Note that competition rules require a 3” triangle to locate this extension.

Main controller connector



The electrical schematic in Appendix A shows the low voltage signals from the throttle/regen devices, fuses, and switches. The wires terminate at a connector already installed on the controller cables. You will need to configure the mating connector ensuring that the proper wires and pins align with the controller connector. Label your wires carefully with the numbers as they appear on the schematic and the controller connector. When inserting the pins, make sure the locations are correct before pushing them in all the way as changes could be quite difficult after insertion.

Batteries

The battery pack included with the kit is comprised of four sealed lead-acid gel absorbed glass mat (SLA AGM) cells. The amount of energy available is inversely proportional to the current draw; i.e. the lower the current draw, the higher the available energy to propel the

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vehicle. This is very important for the drivers to understand to achieve better results. The regulations require the batteries to be strapped so they do not move or fall out in a crash. It is best to create a wood frame with foam isolation, and connect it with two-sided Velcro to the chassis frame behind the driver. A suggested mounting method is included at the end of Appendix A. This is not the only acceptable mounting method. These batteries can be stacked. However, allow sufficient room around them for passive cooling as their temperature will increase when driving, and be careful to protect them from vibration by using foam at all points that they contact solid surfaces. Make sure that the terminals from two adjacent batteries are not touching or near each other. It is best to orient them such that terminals are on opposite sides. It is often easiest to attach battery cables while assembling a pack since access is unobstructed. Plan accordingly.

Cycle Analyst Data Logger



The cycle analyst is an important device that provides valuable information about the state of charge of the batteries and feedback to the driver while racing. Make sure to review the manual and learn to utilize all the features it offers. You will need to enter the tire dimensions for calibrating the speedometer readings, as well as the shunt parameters. The cycle analyst reads the voltage across the shunt (essentially a large resistor), and using the relationship between voltage, resistance, and current, calculates the current drawn by the motor/controller. It also computes the amount of energy (in Amp-hours) taken out of the battery from the last full charge. Make sure to reset the unit after charging to insure that the state of charge is accurate.

USB to RS232 cable

The kit includes a USB to RS232 cable which is used to change the settings in the controller. Please contact Global EEE at kits@GlobalEEE.org to request a copy of the software.

Charger connection and operation

The charger included with the kit is specifically designed for deep discharge lead-acid batteries. It is configured for 110 VAC input and 48 VDC output. We highly recommend that you follow the suggested connection per Appendix A which places the 100 Amp fuse in line with the charger to protect it and the batteries. Also, the shunt is in line with the negative terminal so by turning on the cycle analyst during charging, you will be able to read the current in Amps. This will give you an idea of where the system is in the charge cycle and will confirm that the charger is working properly. *Note, you must first plug the AC cable side, wait a few seconds, then plug the charger connector and turn on the main switch. Failure to do so may damage the charger.*

STEP 15: Installing various items to the body

Kit Parts: Tinted Canopy (4)
Other: Mirrors (not included in the kit)

Rear view mirrors

Many options exist for mirrors. The rules require a total of 8 square inches of mirror that will enable the driver to see behind them on both sides. Bicycle handlebar type mirrors or small add-on parabolic mirrors that stick onto car RV mirrors can be adapted. Custom brackets may be necessary. Experiment with different locations while sitting in the vehicle. To reduce air drag, try to put them inside the canopy.

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Head rest
The driver's seated position is reclined, and will need a head/neck rest for support. Head rest design should be tested by drivers with their helmet on. A simple head rest can be strips of duct tape across the front two roll bar tubes to support the back of the helmet. Nicer headrests could be made of fabric, foam, vinyl, etc., and can be attached in other places. Make sure it is easily removable to allow battery access, and does not prevent cool air from reaching the batteries.

Fitting the canopy
The canopy improves the aerodynamics and appearance of the car. Begin by checking the canopy fit on the body shell. Because it is blow formed, variations may occur. The canopy may be mounted either with Velcro or wire ties in a few locations around the bottom, or by mechanical fasteners. It can be cut into 2 or 3 pieces to create different options. Care must be exercised when cutting or drilling any holes in the canopy as it cracks easily. When deciding if a team wants to permanently mount the canopy, driver egress must be considered.

Care must be exercised when cutting or drilling any holes in the canopy as it cracks easily. Cutting should not be done with a reciprocating tool like a jigsaw since the reciprocating motion can cause a lot of stress at the cut. An abrasive cutoff disc on either an angle grinder or dremel works very well. Care must be taken to cut slowly enough to not damage the canopy, but quickly enough to not melt it excessively. Drilling should be done gently. Running the drill backwards with light pressure decreases the likelihood of creating cracks.

Painting the canopy
You may want to paint the canopy to provide shade or as part of your design. If you prefer the one piece canopy look, and for shade, paint the inside of the canopy roof area now. Otherwise you can wait and paint the outside of the canopy later when you paint the body shell. The painting technique is the same either way. Visibility should be considered when painting.

Note:

- Be sure the masking tape is stuck down well by running your finger nail along the edge. Otherwise the paint may bleed under the tape.
- With a plastic scrubbing pad or fine sandpaper, sand the canopy where you will be painting until the plastic is evenly fogged.
- Mask off the rest of the canopy with newspaper, making sure there are no gaps where the paint could get through.
- Apply thin, even coats of paint until opaque. Remove the masking when the paint is completely dry.

STEP 16: Graphics / body shell painting

Materials: Paint, masking tape, old newspapers

Like most plastics, the body shell will last longer if you protect it from the effects of sun UV exposure. Wax and protective products like Armor All will help.

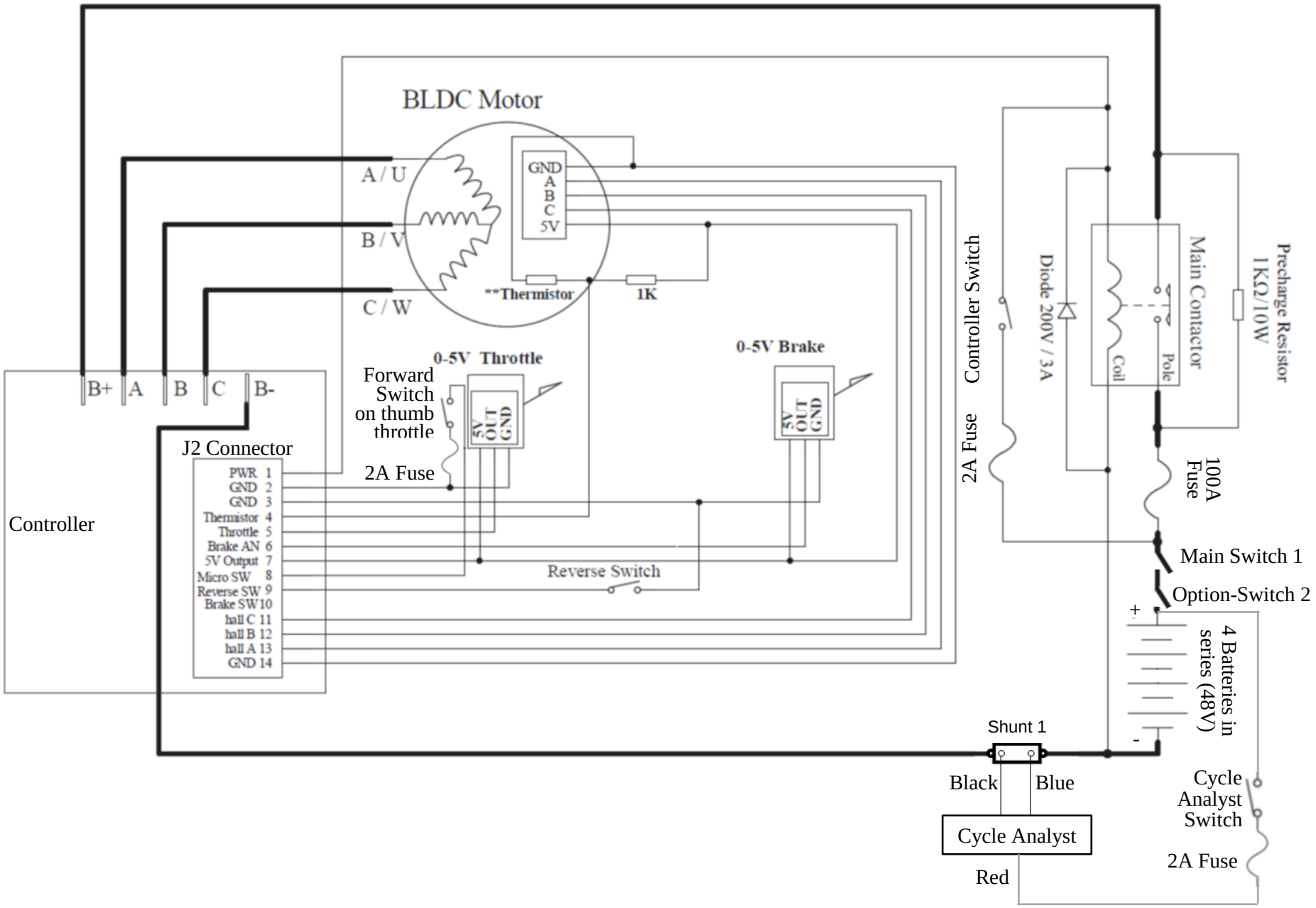
A paint job will protect the plastic and is a great opportunity to personalize your car. You may have some ideas, or you can look at other race cars for inspiration. You may want to use your

school colors, or maybe you have a sponsor. There is an award for best graphics design!

Note, the regulations stipulate the required space for the event sticker/car number:

All vehicles must display the assigned vehicle competition numbers. An unobstructed space measuring 16 in wide by 12 in high (40.6 x 30.5 cm) must be made available on both sides of the vehicle to affix the event sticker. The sticker includes the assigned vehicle number and event name/sponsor. Two stickers with the assigned vehicle number and event name/sponsor will be provided to each team at registration. The stickers but be properly affixed to both sides of the vehicle. The teams will be given the option to choose from a limited number of color choices for the stickers to ensure contrast with the background color and to match the car's color scheme.

Appendix A



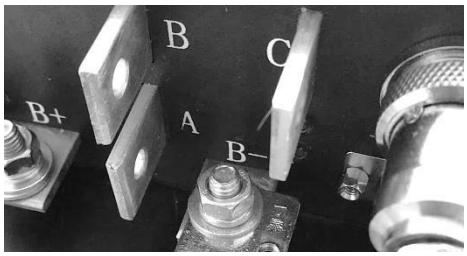
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Electrical Connections

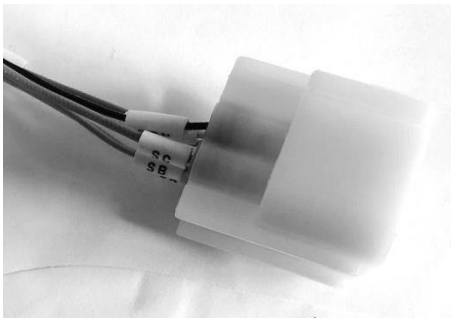
Motor to controller connections:

High power (thick) wires coming out of motor should be connected to the controller as follows:

Motor wires	Controller tabs
Yellow wire: U	A
Green wire: V	B
Blue wire: W	C



For the low power wires simply attach the two square connectors.



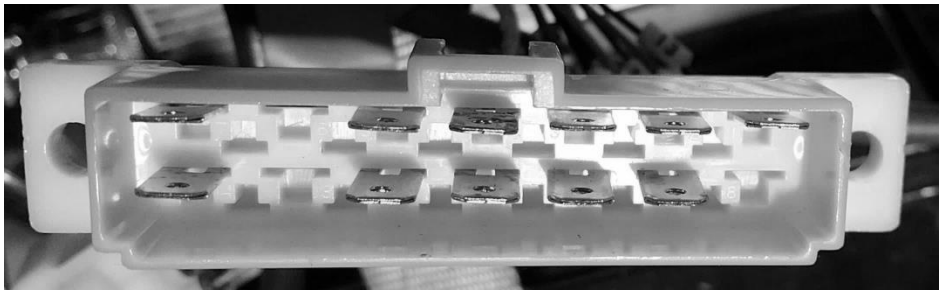
Note the six wires on the schematic:

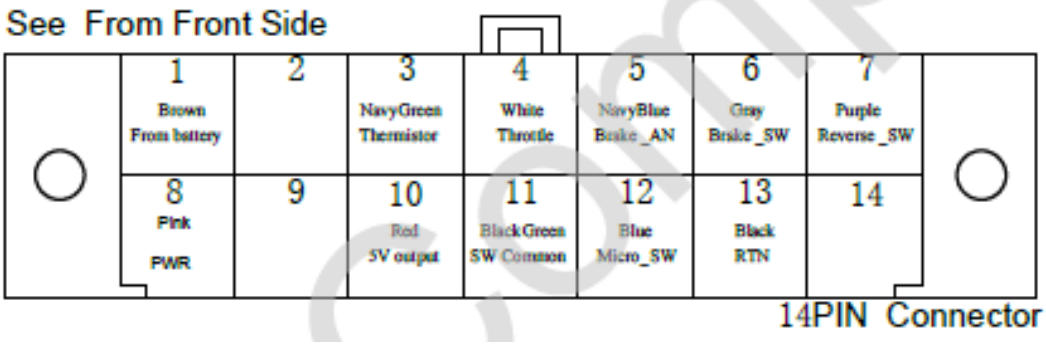
Motor wire color	Controller J2 connector
Black	RTN – 14
Yellow	Hall A – 13
Green	Hall B – 12
Blue	Hall C – 11
Red	5V Output - 7
White	Thermistor temp sensor - 4

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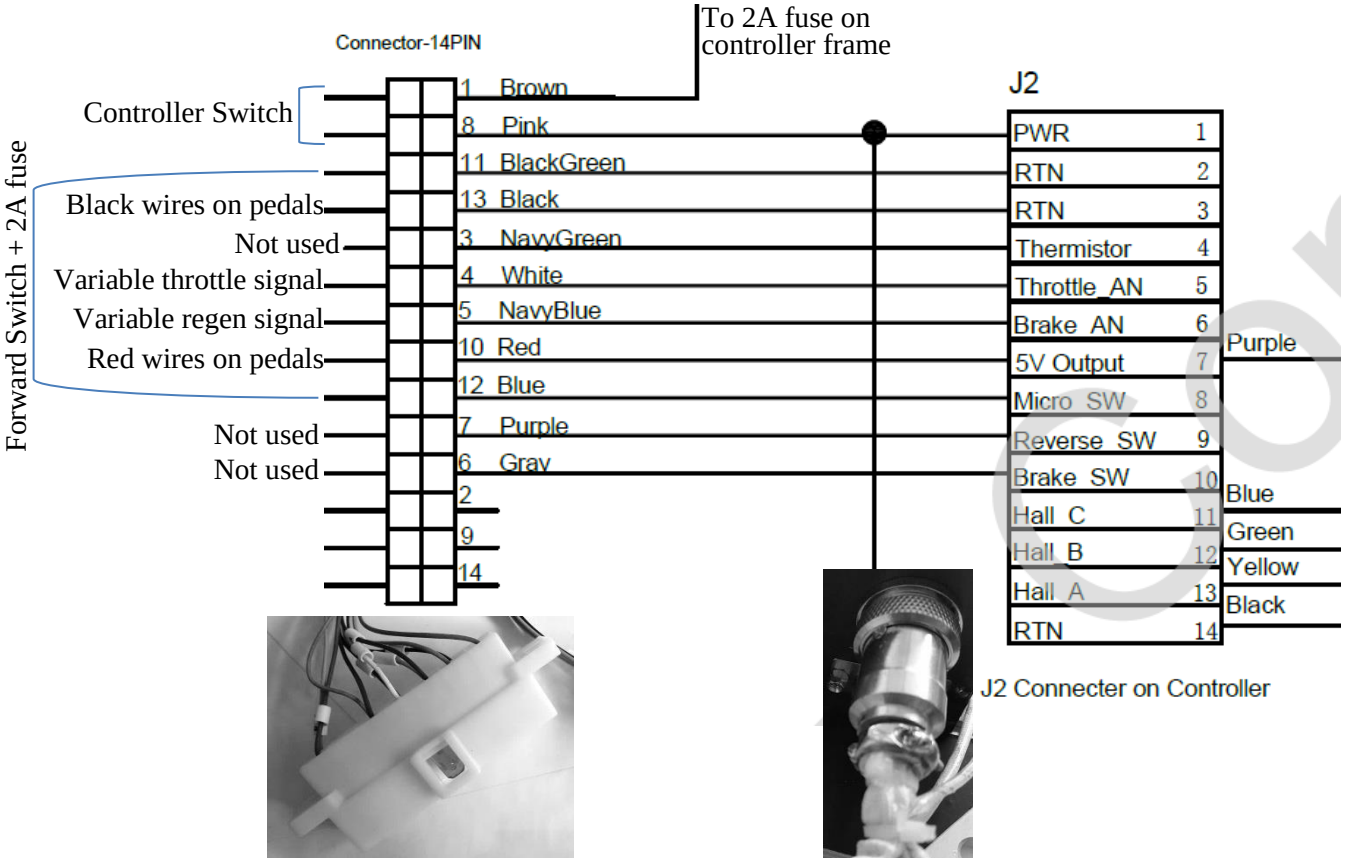
Controller Connections:

You need to make the 14 pin connector which mates to the following controller pins:





This is how the connector correlates with the circuit diagram:



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Thumb Throttle Wiring:

This is the wiring if you use the thumb unit as a throttle input device. You can program the controller to incorporate regen braking during the first 20% of travel, so when it is released, regen kicks in. Note that this is a Hall sensor device and not a variable resistor/potentiometer. Therefore, to test the signals, you must apply a voltage across the Red and Black wires. This can be done with a small battery.

Throttle Connector	Controller 14 pin connector
Red: +5V	Pin 10 - Red
Black: GND	Pin 13 - Black
White: Throttle Signal	Pin 4 - White
Yellow: Switch Common	Pin 11 – Black/Green
Brown: Micro Switch	Pin 12 - Blue
Green: Battery Voltage state of charge Indicator	Connect to +48V point (not in controller connector)



Foot Pedal Throttle (optional) Wiring:

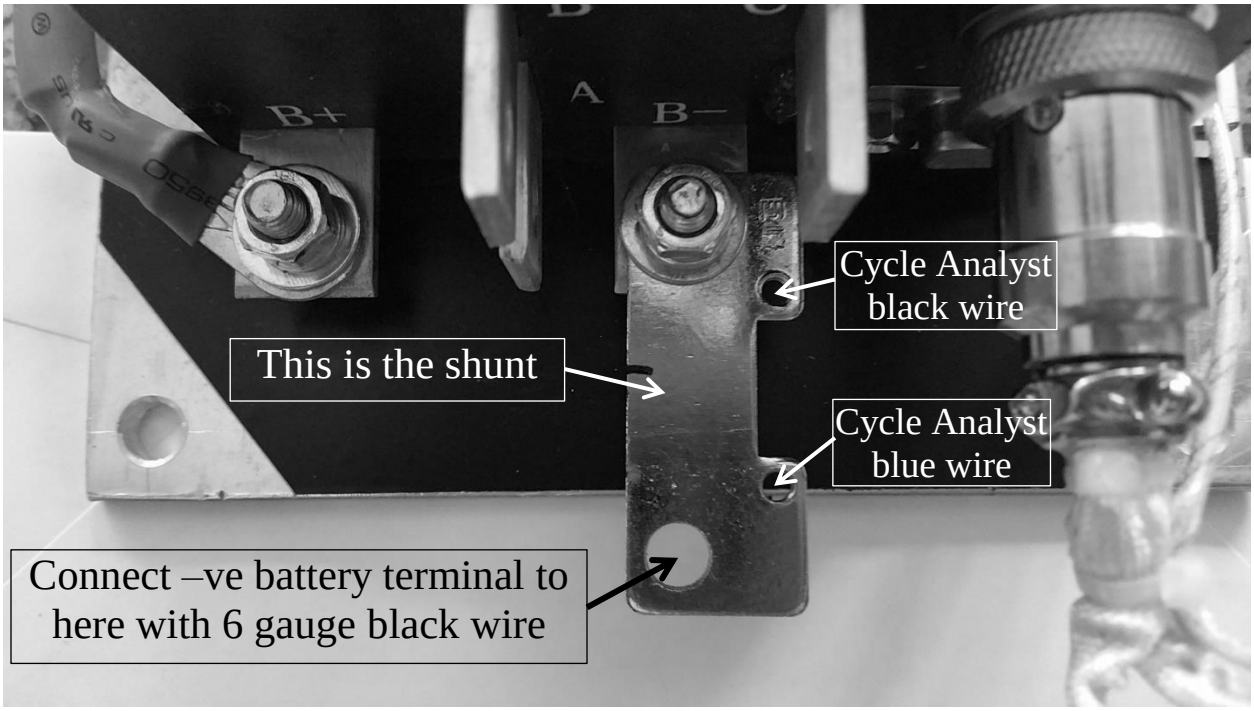
This is the wiring if you use the thumb unit as a throttle input device. You can program the controller to incorporate regen braking during the first 20% of travel, so when it is released, regen kicks in. Note that this is a Hall sensor device and not a variable resistor/potentiometer. Therefore, to test the signals, you must apply a voltage across the Red and Black wires. This can be done with a small battery. Also note that this device does NOT have a microswitch.

Throttle Connector	Controller 14 pin connector
Red: +5V	Pin 10 - Red
Black: GND	Pin 13 - Black
White: Throttle Signal	Pin 4 - White



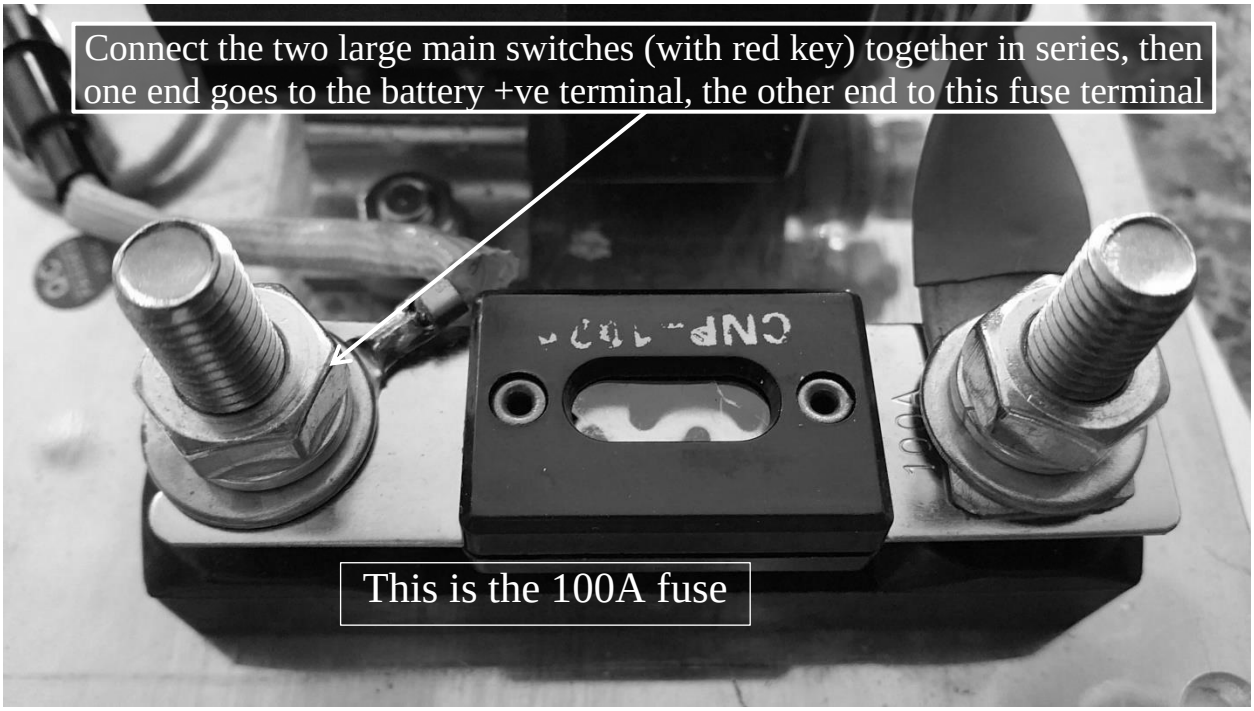
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Battery connection +ve terminal



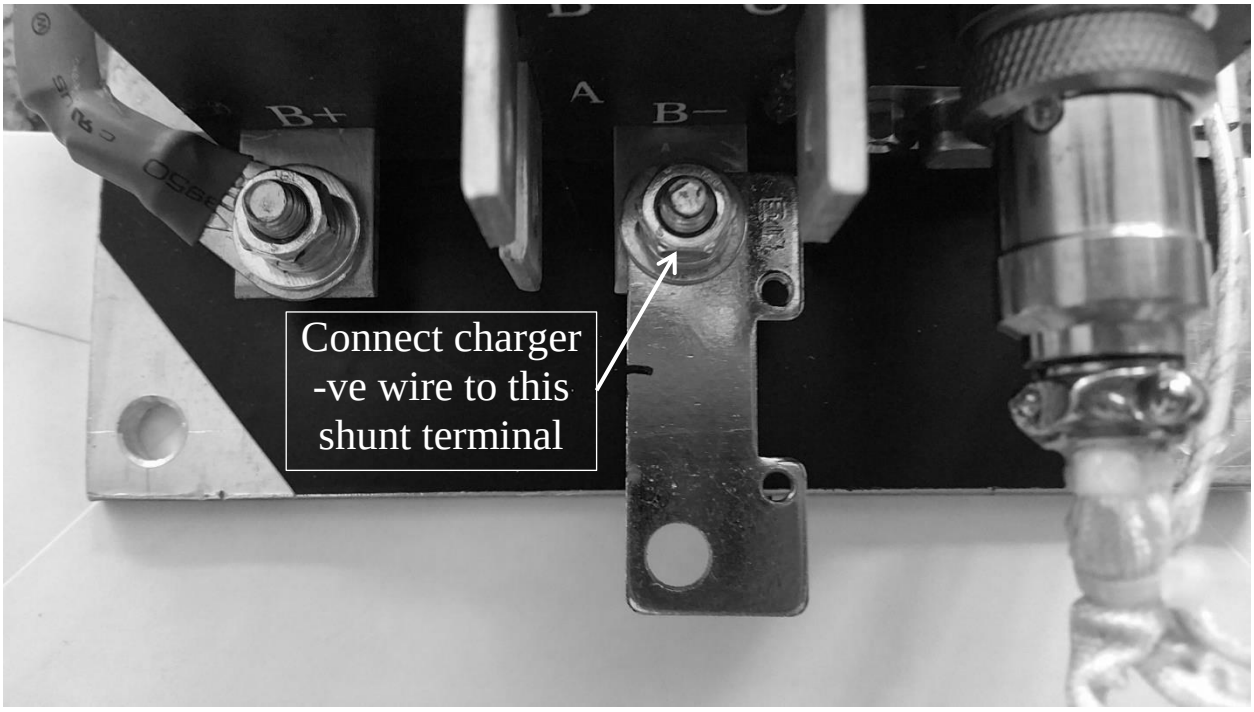
** Note: Red Cycle Analyst wire goes to 2 Amp fuse, then small switch, then +ve battery terminal*

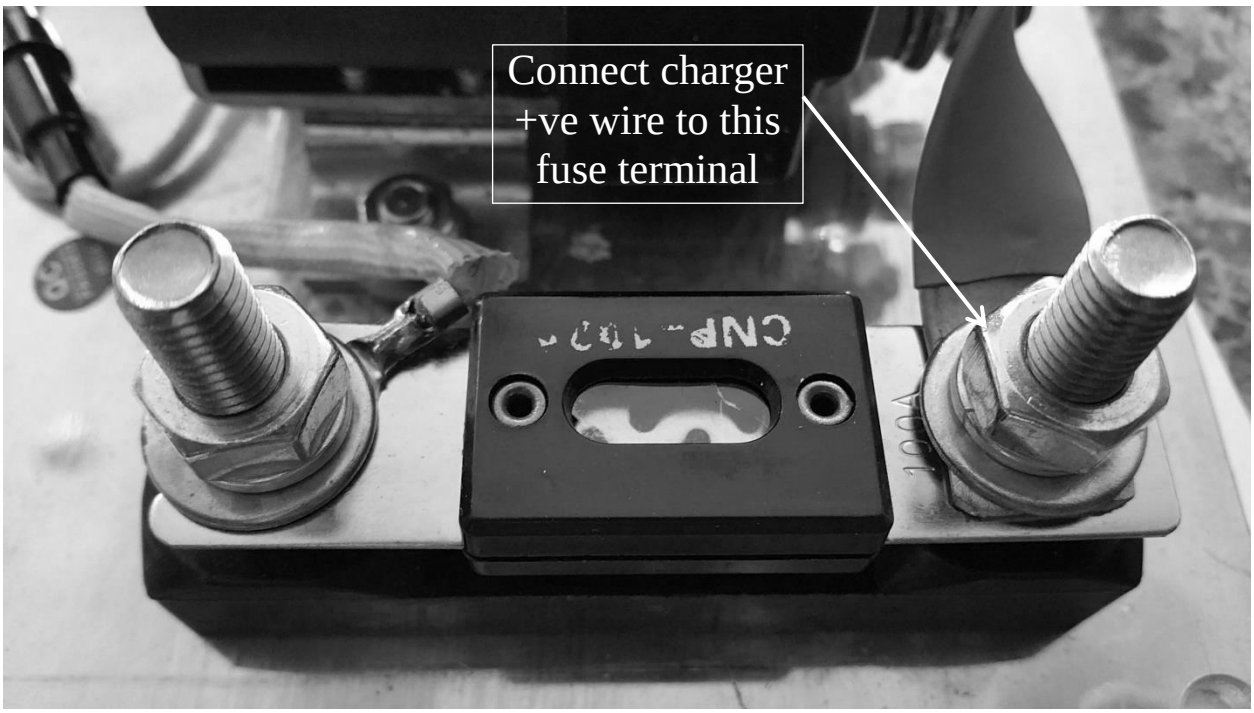
Battery connection -ve terminal



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Charger Connections





To operate the charger, plug the AC side into the wall outlet first and make sure AC power is on. Then plug the DC side connector, and turn on main power switch (with red key). If you are using two main switches in series, both must be on.

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Other Components on Controller Frame

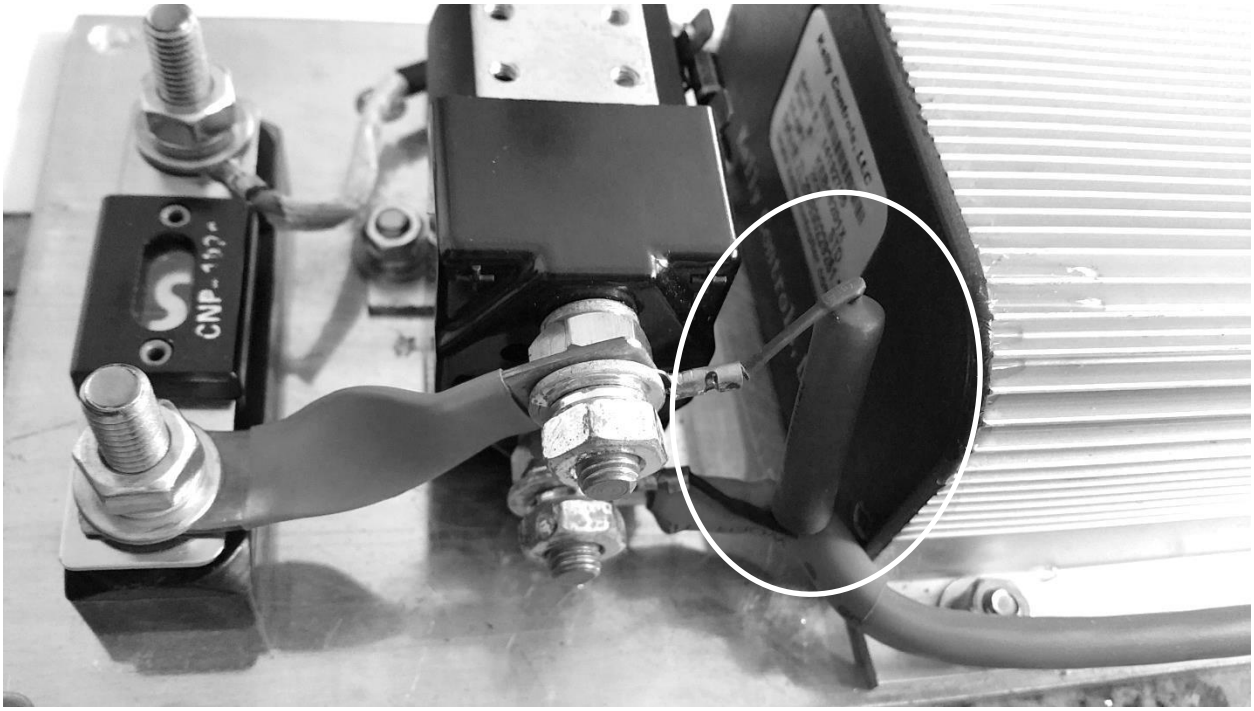
Controller 2A fuse (in series with controller switch per circuit diagram)



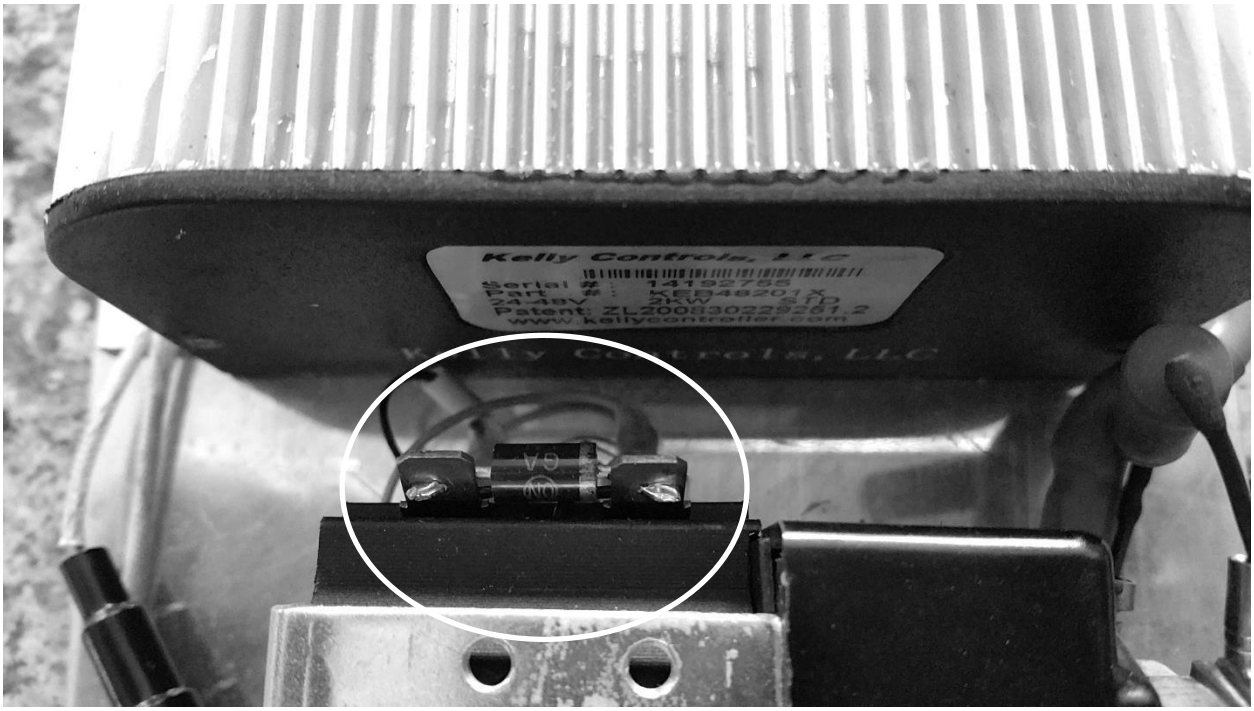
Contactor



Pre-charge resistor



Diode



Suggested Installation of Batteries in Chassis Using Double Sided Velcro, Wood and Foam



