EcoCAR EV Challenge

Front HV Box (-)

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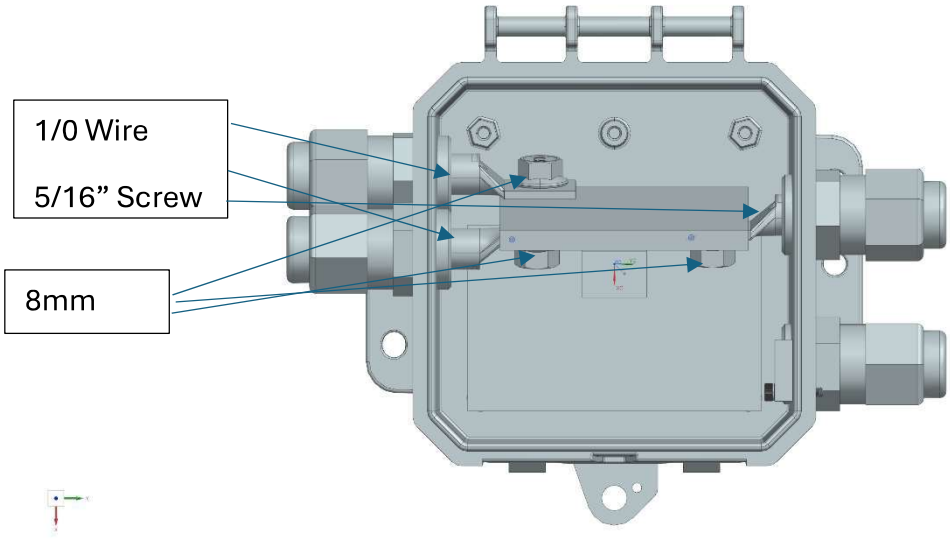
A. Problem Definition

A distribution box is required in the vehicle for the purposes of safely dividing power from the battery (-) to the front EDU and IPE. The box must contain an HVIL switch, to ensure the safety of anyone who services it. This HV distribution box will be housed in the front compartment of the vehicle, above the F-EDU.

Requirements

The main requirements for the HV distribution box are as follows:

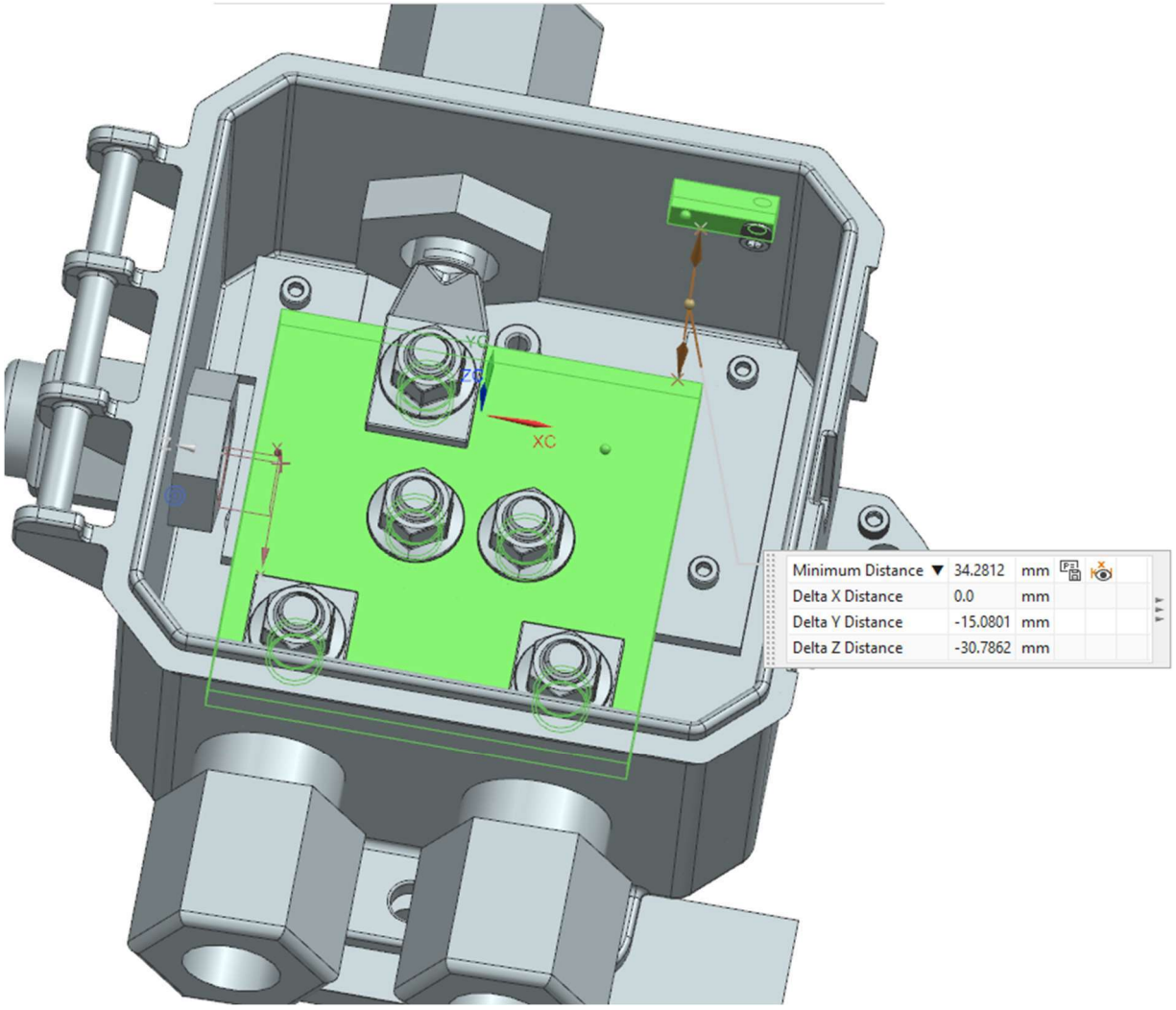
- All electrical connections must be made with appropriate terminals. Terminals must be either crimped or soldered, depending on the type of connection.
    - The compression lugs for the HV wires are the proper means of connection.
    - Attach LV wires to the HVIL switch.
- Lugs must be rated for the wire size that is being used in the connection. Holes in electrical lugs may not be enlarged and terminals must not have oversized holes for the bolts connecting them.
    - The compression lugs are rated for 1/0 wires as appropriate.
    - The holes in the compression lugs and the bolts securing those lugs fit each other without a need to alter each other.



- Bolted connections must use a locking mechanism if the wire is part of the HV system (lock washer...). Teams may not stack more than 3 lugs, terminals, or any combination of the two on a single side of the bus bar.
    - Lock washers are used for each connection which is a part of the HV system.
    - No more than two lugs are on a single side of the bus bar.
- Terminal blocks must use a positive connection to secure wires.

    - Bolts secure compression lugs for the ends of the HV wires.
- All electrical components must be covered or shielded to prevent any tool or small metal part from falling onto exposed energized surfaces and causing a short circuit.
    - The box is a sufficient measure for preventing short circuiting from falling parts when the lid is closed, and it does not need to prevent shorting when the lid is open because this system can be discharged.
- All portions of an electrical system that are inside the same compartment as components that use liquids or corrosives must be shielded from spills, leaks, or corrosive vapors.
    - This distribution box will be in the same compartment as coolant, brake fluid, as well as transmission fluid. This box is made of polycarbonate and will keep the internal electrical components safe from these liquids.
    - According to Polycarbonate Chemical Compatibility Chart (calpaclab.com):
        - Polycarbonate has a B-Good rating for ethylene glycol, methanol, and propylene (components of coolant).
        - Polycarbonate has a B-Good rating for diethylene glycol which is in brake fluid.
- Any system that may generate arcs must be fully shielded or enclosed in a sealed, flame-resistant enclosure to prevent the possibility of fused material contacting flammable substances.
    - This enclosure fully shields the components which may arc, is sealed, and flame-resistant.
- All LV circuits must be grounded to the vehicle chassis.
    - There must be a ground for the HVIL switch.
- All non-current carrying conductive elements of HV enclosures must be grounded to the vehicle chassis.
    - No externally exposed hardware is conductive.
- All connections must be made through proper automotive-grade connectors rated for the dimensional size, voltage, current, temperature, and environmental conditions that will be present.
    - The compression lugs used for the HV connections should be sufficient for this task.
- All HV connectors and enclosures must be finger-proof. HV enclosures should have access panels that can be removed only through the use of tools.
    - The box cannot be opened without the use of tools due to an M2 bolt fastened through the tip of the lid.
- Any enclosures or components containing HV must be properly labeled, “Warning High Voltage.” These labels must be sufficiently large with sufficient font size and contrast to be clearly visible to bystanders and placed in locations where they are clearly visible. All components containing HV that is not de-energized by the EDS must be labeled with “Warning High Voltage Always Energized.”
- All HV wiring (positive and negative) must be visibly orange. Large conductors and/or conduit containing HV conductors may have orange tape spiraled along their lengths, or small pieces of orange tape my be periodically wrapped around smaller leads to easily identify them as HV.
    - The HV wires must be orange
- Teams are required to have a HV test connection on an HV enclosure in an easily accessible location and orientation while the vehicle is resting on the ground.

    - N/A
- All HV circuits must be isolated from all LV systems and the vehicle chassis. The isolation level must be greater than or equal to 500 ohm/V at all times. This is the minimum safety requirement and should not match the expected value of the team vehicle. The student performing the test should know the expected value the test will measure, considering environmental factors and electrical components connected to the bus at the time of the test.
    - In theory, the HV circuit is isolated from the LV circuit.
    - Verify the isolation/resistance
- All vehicles must be equipped with an on-board isolation monitoring system that regularly measures the isolation resistance between all HV circuits and LV circuits any time HV is energized.
    - There is a ground fault detection system included in the Rear HV Box
- Bus bars may be used as conductors, provided they have a direct insulation barrier to prevent accidental contact.
    - All bus bars are contained in the sealed box and supported through a plastic support which will be mounted on a polycarbonate plate which is mounted to the box.
- Bus bars must use a positive connection, such as a rivet or bolt. All bus bar connections must have a locking mechanism such as a lock washer.
    - Both bus bars use bolts to attach the wires and have lock washers for each bolt.
- A copper bus bar must have a cross sectional area of at least 483.9mm^2 to have 800 A of current.
    - The cross-sectional area of the bus bar is about 6.35x76.2mm=483.87mm^2.
- All HV fuses external to purchased components must be protected in a junction box. Use of automotive fuse holders rated for HV is required. This includes the fused HV test connector.
    - N/A
- If both high and low voltages are present in an enclosure, they must be separated by an insulating barrier with adequate dielectric strength, or must maintain the following spacing through the air: 3cm if voltage is over 200 V.
    - The LV components are sufficiently far from the HV components.



- There must be an insulating material between any conductive HV component and the enclosure.
    - The bus bar is supported by a plastic support, which is attached to a polycarbonate plate, which is attached to the box.
- There must be at least 9.5mm through air between any two uninsulated live parts of opposite polarity if the voltage is over 300 V.
    - N/A
- All HV circuits must be in an enclosure rated for use with HV components.
    - The enclosure (Enclosure: 10 x 8 x 4in, wall mount, polycarbonate (PN# H10084SCF-P10) | AutomationDirect) is properly rated for the environment it is in (see NEMA 3S rating description here: Enclosures Climate Control (automationdirect.com))
    - The brochure states that HV components are used in these boxes, so it must be fine. (See Enclosures Climate Control (automationdirect.com))
        - Qualification: This (Materials for high voltage EV components in batteries, powertrain and EE. | Covestro AG) states that polycarbonates usually don't qualify for HV distribution boxes, but they make some that do. At the same

time, I assume the first website also makes the boxes of polycarbonates that do qualify.

- HVIL is required to be incorporated into all HV enclosures, including connectors that can be removed and lids/covers.
    - An HVIL system is incorporated into this box.
- Covers, boxes, and shielding must not be designed or intended to carry current.
    - They are not.
- Wiring contained in a high voltage enclosure should be mechanically secured via retaining clips to ensure they maintain the proper spacing.
- Electrical connections within an enclosure must be established using the proper fasteners (nuts, bolts, etc.). Bolts and nuts must include a lock washer and all bolts and nut torque must be documented. After final torques have been applied, fasteners must be marked with torque indication marks.
    - The proper fasteners are used with a lock washer.
    - Document and mark torques.
- The box should be dust and waterproof
    - The box is both dust and waterproof
    - The cable glands are also dust and waterproof
- Empty pins in electrical connections must be sealed using proper sealing technique.
- Teams must add contactors for within their junction boxes for both front and rear drive units.
    - N/A
- Teams have the option to include one contactor on the positive leg and one on the negative, or only one contactor on the positive leg.
    - One contactor is used on the positive leg
- Teams shall implement a normally-open contactor that actuates to the closed position while the vehicle is operating normally.
    - N/A

Objectives

- Ensure the EDU and IPE is safely powered.
- Everything is safely isolated and contained in the HV distribution box.
- Someone servicing will not be shocked by the HV circuit (the presence of the HVIL system should prevent this).

Relevant Rules

This content is missing due to confidentiality agreements.

B. Design Research

The first step in this design process consisted of Matthew and I going over the basic requirements and layout of the components which will need to fit in the box. He had already

spent time making everything fit (and Whittle had made a list of everything that would need to go in it before that), so it was efficient for him to give a rough sketch of his latest work on the whiteboard to outline what he was thinking.

My next step was to review the rules in the VDR and summarize the most important ones to ensure I don't miss anything that would require me to start over. From these requirements, I chose the components which would need to fit in the box and designed the box to fit these components. (Part of this was ensuring the parts that Whittle chose worked properly.) Finally, I added the bolts to secure the components in place and checked the requirements to ensure I didn't forget anything.

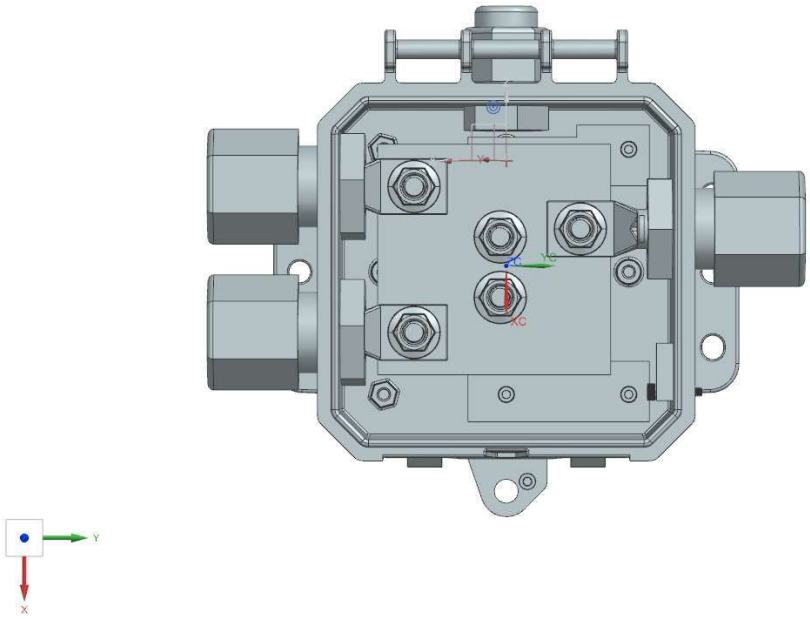
A few days after the design was completed and parts were ordered, a change in the rules stated that contactors must be added to the HV circuits. This design was then altered to fit this requirement.

I was then notified the box with the GFD and test connector would not fit in the front and would need to be moved to the back of the vehicle, resulting in significant changes. Two smaller boxes were then designed for the front so that they could both fit in the green zones of the crush zone. One holds only positive components and the other negative.

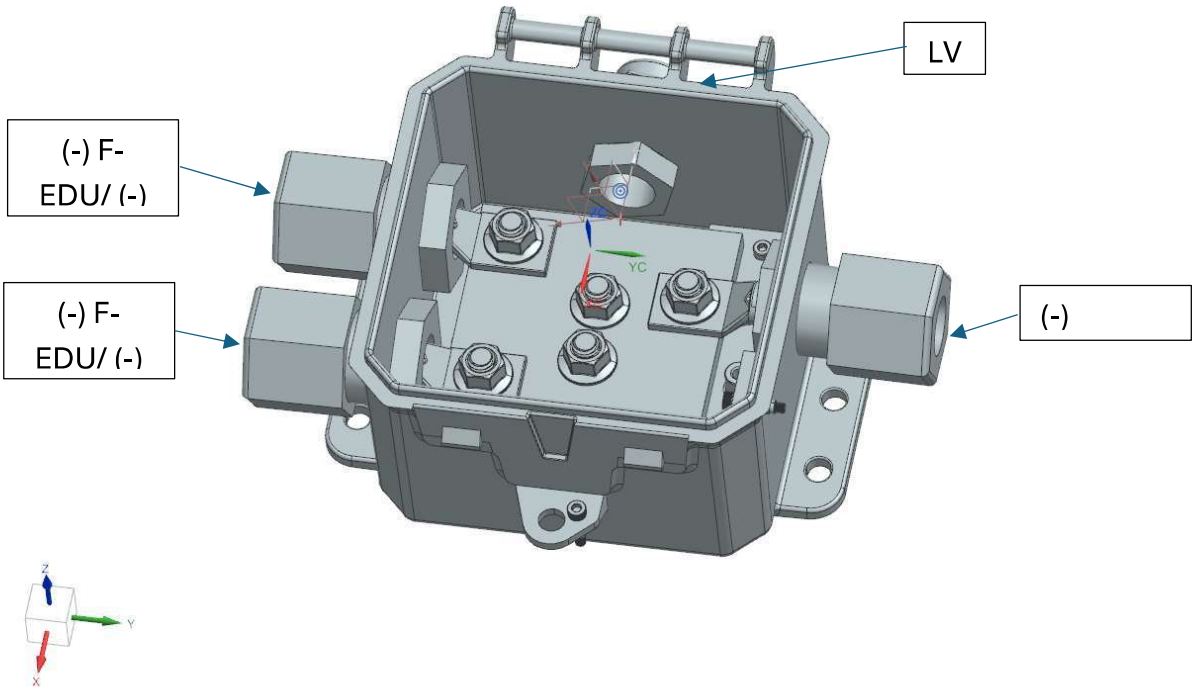
After assembling, it was realized that the lugs could not fit through the cable glands, which would be needed to easily service the HV system. New cable glands were ordered and integrated into the boxes. Only the Front HV Box (-) needed to be redesigned, but it had not yet been built at the time. The cable glands were sanded on one part on the inside (in each) to ensure the compression lug easily fits through.

More details on the design process can be found in these folders: Links removed for confidentiality purposes.

C. Final Design

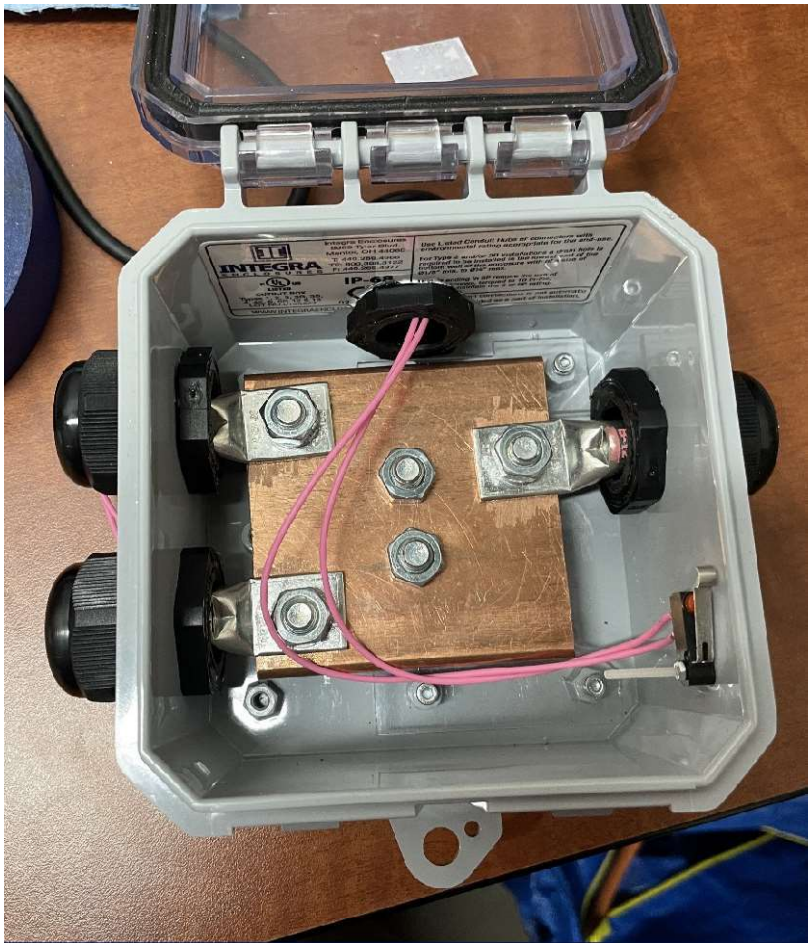


Top view of Front HV Box (-). (Lid hidden)



Angled view of Front HV Box (-). (Lid hidden)

General placement of Front HV Box (-) in the vehicle.



Assembled Front HV Box (-)

The CAD for the Front HV Box (-) can be found in the full CAD under the name: A03_V02_Front HV Box (-).

D. Integration

The following steps will need to be taken to successfully implement the distribution box into the vehicle:

~~40) Machine the copper bus bar to the proper size. Drill the holes.~~
~~41) Cut bus bar support out of polycarbonate 1/8” sheet.~~

~~42) Attach the two and test attaching the lugs with the bus bar and sheet in the box to see if it is possible.~~
~~43) If it is possible, drill the appropriate holes into the box.~~
~~44) Attach the HVIL switch to ensure it works properly when closing the lid. Then remove.~~
~~45) Cut off the bottom threads for all the cable glands.~~
~~46) Place the bus bar and bottom plate in the box.~~
47) If the compression lugs fit through the cable glands:
    a. Attach the compression lugs to the end of the respective HV wires.
    b. Fit the HV wires into the box through the glands.
    c. Attach the ends of the compression lugs through the bus bar.
        i. Start with the (if the hinge is in the back) top left.
        ii. Then do bottom left.
        iii. Finish with right.
    ~~d. Secure the cable glands to the box with JB Weld.~~
~~48) Properly attach the LV wires to the HVIL switch and attach the switch to the box with gorilla glue (or something else rated for 100C)~~
49) Group the exiting LV wires and wrap them in conduit, then wrap the conduit in waterproofing tape. Fit this conduit through the LV cable gland through the back of the box.
50) Close all of the cable glands to make them waterproof.
51) Retain the wiring as necessary.
52) Secure the lid on the box with the M2 nut and bolt.
53) Label the box with “Warning High Voltage” and ensure the HV wiring is orange.
54) Verify the isolation/resistance of the HV circuits from the LV systems and vehicle chassis.

E. Risk Management

One possible risk is that the contactors for the HVIL switch fuse together and don’t indicate when the box is opened. This can be mitigated by adding a separate component which will allow the HV circuit to be manually opened. The user should then wait a few minutes before working on the fuse enclosure. An alternate is to open the HVIL circuit through opening another switch.

Another risk is the enclosure deteriorating or allowing water to enter the enclosure. Specifically, this box has the risk of being damaged by brake fluid. Ideally, this would only result in the HV current ‘leaking’ which can then be detected by the GFD (ground fault detection) device. The LV wire conduit could be a source of water leakage and should be carefully wrapped in tape or other substance to prevent this from occurring.

The presence of this distribution box also hints towards the mitigation of another risk, namely the possibility of the EDU or IPE being damaged by too much current. The fuses this enclosure houses will break before the incoming current has the ability to damage the EDU or IPE.

F. B.O.M

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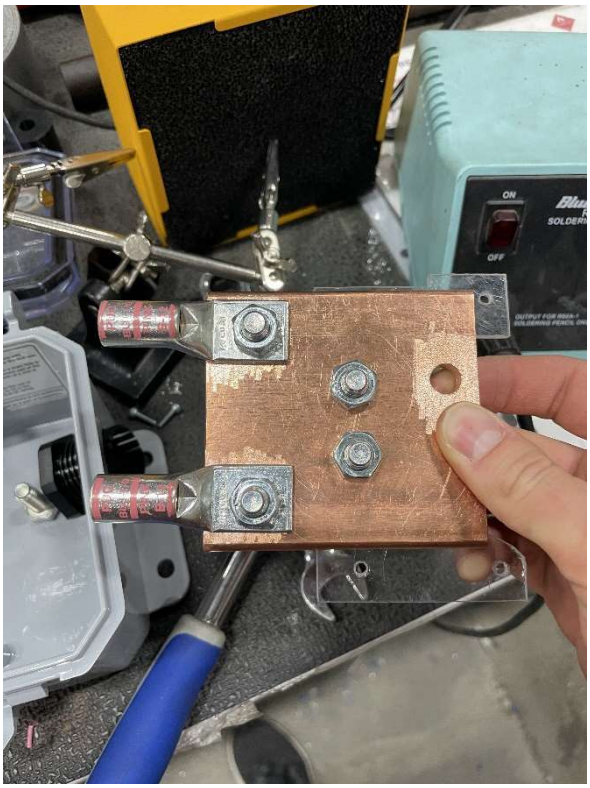
G. Servicing and Operation

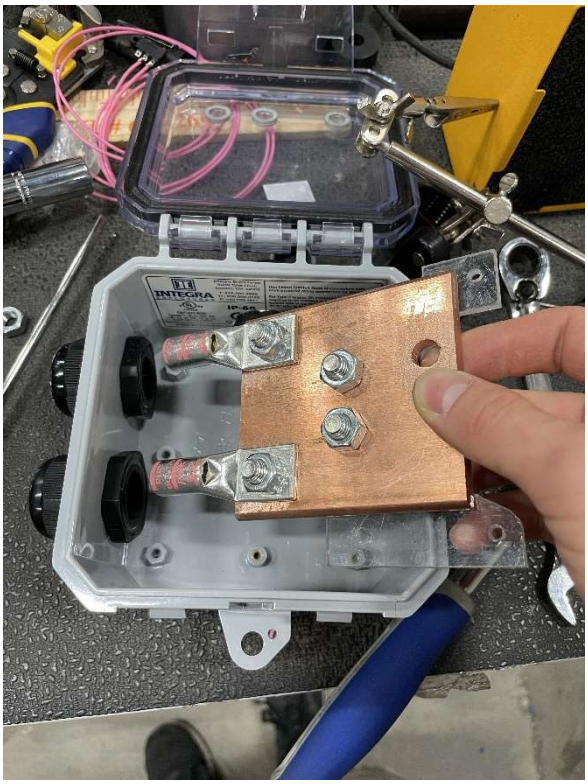
The box should be regularly inspected to ensure it has not been damaged by chemicals such as brake fluid and the environment. When servicing the brake fluid, this box should be carefully covered to avoid exposure.

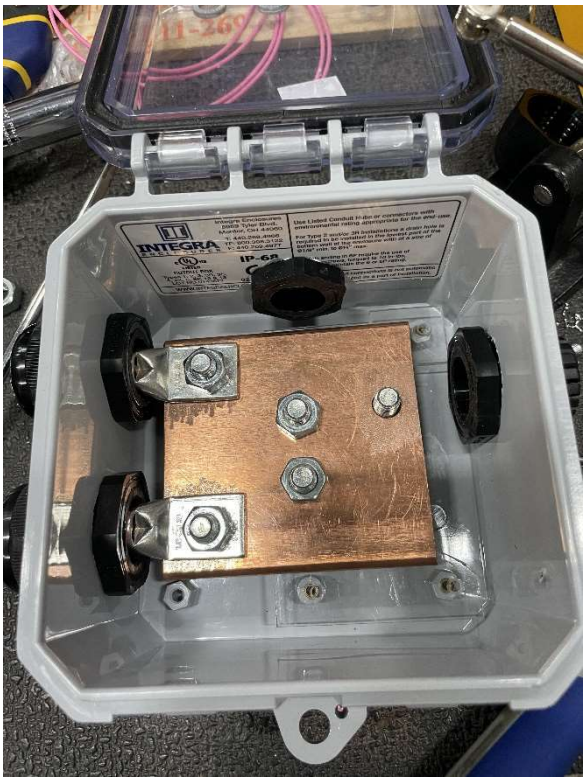
General Assembly (Disassembly is Reverse):

1) Fit HV wire for F-EDU (-) and IPE (-) through cable glands (if the lug doesn't fit, turn the cable gland) and attach compression lugs to bus bars, ensuring to torque to spec (22 N-m)

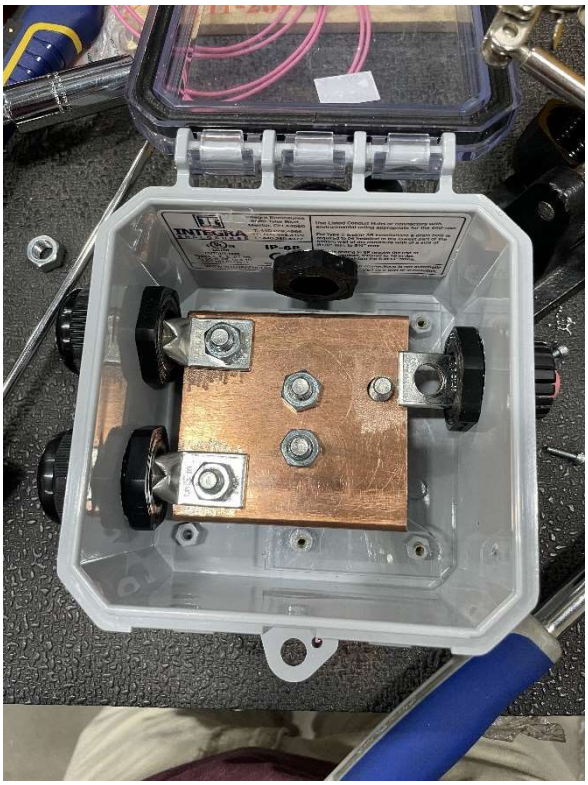


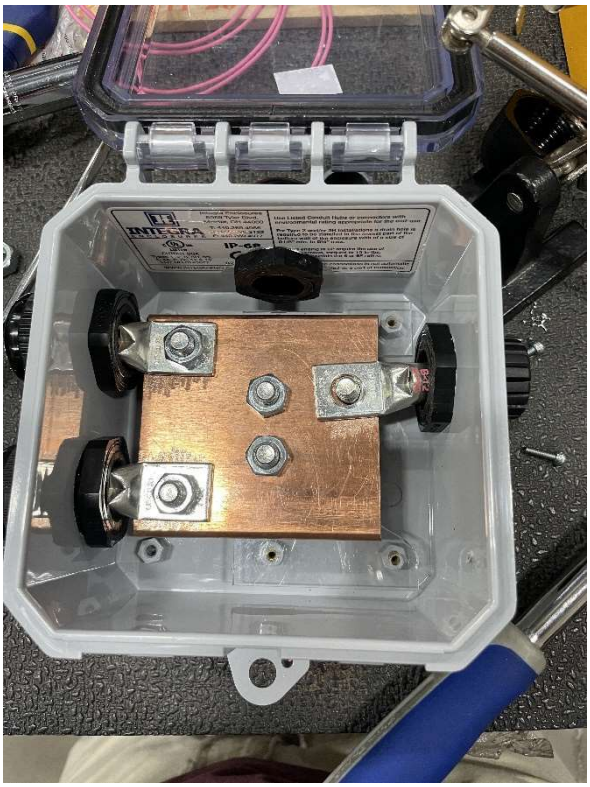
2) Place the M8 for the battery (-) in the box and put the bus bar into the box, careful to avoid bending the HV wire (especially not more than a radius of 45mm) and to line up bolt through the hole



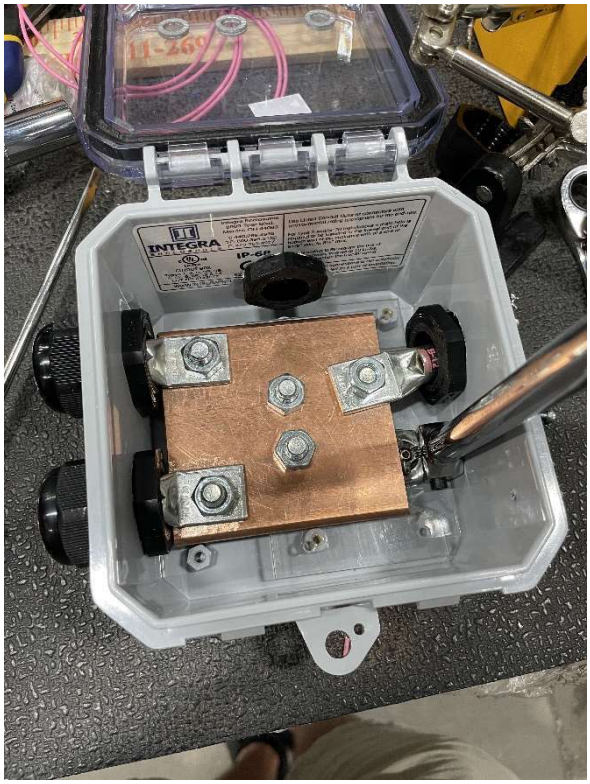


3) Push the battery (-) compression lug through the cable gland and onto the bolt





4) Fit the M13 wrench under the bus bar and under the M8 bolt



5) Torque the bolt to the correct torque (22 N-m)

6) Remove wrench

7) Done!

H. Future Work

HV wires need to be installed in the box, everything needs to be torqued, marked and documented.