



# PEER Reviewers Guide

2016





# Formula Hybrid IEEE Pre-Event Electrical Review

## INTRODUCTION

Thank you for volunteering to help out a team of student engineers by performing the Pre-Event Electrical Review (PEER) of their race vehicle prior to the Formula Hybrid competition.

The PEER program was initiated in 2015 in an effort to improve the percentage of student-built race vehicles that arrive at the competition ready to pass the safety inspections.

This Guide has been created to assist you as you prepare for and conduct the Electrical Review.

**Note:** We are not asking you to perform a safety inspection, nor are we asking you to “sign off” on anything. As an experienced electrical engineer, we are asking you to look over a student-built electric-powered vehicle. The purpose of this is to help the student team be better prepared to pass our safety inspections, which take place after the vehicles arrive at the competition.

What this also means is, that if you tell the team that something looks OK to you, the team cannot then protest the ruling of an inspector at the competition by saying that their reviewer said it was OK. (It may be helpful to remind the team of this periodically.)

One thing that you will discover during your interactions with the students, is that only a minority of them will be pursuing EE degrees. Most will be mechanical engineers. Therefore you may have to tailor your responses and advice accordingly.

We sincerely appreciate your volunteering your time and engineering skills to help out your team of student engineers, and we will provide as much support from our end as we can. Please feel free to contact us at any time and for any reason. Our contact information can be found at the end of this document.

Finally, in the likely event that you develop an attachment to your team and wish to accompany them to the competition, please let us know. We’ll provide you with credentials along with complimentary lunch and an invitation to Tuesday night’s VIP reception.

Either way, we would like to show our appreciation by sending you a Formula Hybrid/IEEE “Official” shirt. Let us know your size and we’ll get one off to you.

## **BEFORE YOU VISIT THE TEAM**

The Formula Hybrid rules can be downloaded from: <http://www.formula-hybrid.org> > *Students* > *Rules and Deadlines*. Please read section **A1** for an overview, and familiarize yourself with the contents of section **EV**.

We do not expect you to become rules experts, but you should know where to find things.

### **PRELIMINARY VEHICLE REVIEW**

All Formula Hybrid teams are required to submit three documents relating to their electrical systems during the development and construction of their vehicle.

#### **ESF-1** (*Due November 11, 2015*)

The first Electrical System Form (ESF) is a subset of ESF-2 which contains those elements of a design that any well-prepared team will have settled on early in the design process. Besides pressuring the team to finalize these decisions, this gives us the opportunity to catch potential problems early in the program.

#### **ESF-2** (*Due February 24, 2016*)

The ESF-2 is an extensive document with a great deal of information in it. The students fill in a template that we provide. Contact us if you have any questions or for assistance. If there are errors or inconsistencies, you should send it back to the team for corrections.

Note that the ESF-2 must be complete and accurate before the team will be allowed to present their vehicle for inspection at the competition.

#### **FMEA** (*Due February 24, 2016*)

The FMEA should be treated in the same manner as the ESF-2. Note that this may be the first time that many of the students will have seen an FMEA, so again, your feedback to the team will be very helpful to them.

Note that for 2016, the FMEA has been changed significantly. Previously we provided a large number of “canned” failure scenarios. This year we are requiring the teams to come up with their own.

### **Formula Hybrid Uploads Page**

All PEER reviewers will be given a “reviewer” account on the Formula Hybrid [uploads page](#) which is where the teams submit their documents.

Please familiarize yourself with the site. This is where comments and feedback to the teams should be conducted. The site also provides for internal communications among the reviewers.

You should also feel free to browse other team entries and the reviewer's responses if you are new to the process.

## **VISITING THE FORMULA HYBRID TEAM**

Your visit to the team should be thought of as both an electrical review of their vehicle and an educational session.

Remember that the goal is to help the teams arrive at the competition with a vehicle that is ready to pass our electrical safety inspections.

A secondary goal is to point out technical issues that in your opinion, might lessen a team's likelihood of completing all the dynamic (on-track) events.

What this means is, in addition to performing a formal electrical review, you should feel free to give the teams any advice you feel is appropriate in order to help them become better engineers and project managers. The only limitations that we impose on professional assistance can be found in the Formula Hybrid rules, sections **A7.1** through **A7.4**.

Seasoned Formula Hybrid electrical inspectors can provide real-time support (via Skype or equivalent) during all or part of your review. They will have rules at hand and can provide information as you need it.

It will be helpful to us if you could email photographs of areas of the vehicle that concern you. When the vehicles arrive at the competition, our inspectors will review these photos to see how well teams have addressed issues that you have pointed out to them.

## **THE REVIEW PROCESS**

The review should be a "non-energized" review, meaning that all high voltage (Tractive System Voltage or TSV) should remain off during the review.

Unless the accumulator devices can be proven to contain a sum total of no more than 30V the accumulator containers should remain closed. (You can ask the team to provide photographs or engineering drawings of the container contents, or similar uncharged containers may be reviewed.)

## **EQUIPMENT**

It is recommended that you bring the following to the review:

1. A copy of the current Formula Hybrid Rules (Rules supersede any wording in this document)
2. Flashlight or Headlamp
3. Safety Glasses (Team members are required to wear safety glasses when working on the vehicle and you should set an example for them. See section **D10.7**)
4. A small, non-conductive rod (~1/4" dia. x 8" -- To see around wires without touching them with your fingers.)

5. A Camera or smartphone to photograph areas of concern.

The team should be able to provide a Digital Multimeter (DMM) in order to do continuity and ground bonding measurements.

## **SAFETY FIRST**

Each team is required to have a “Rules and Safety Officer” (RSO) and your review should start by talking with the RSO.

Ensure that the team has the following safety equipment, and that it is in good condition: (See **Article T15**)

1. Insulated screw drivers
2. Multimeter with shrouded banana jacks and protected probe tips
3. Insulated tools, if screwed or bolted connections are used in the tractive system
4. Face shield which meets ANSI Z87.1-2003
5. HV insulating gloves (which are within 14 Months of the test date) and protective outer glove.
6. HV insulating blankets of sufficient quantity and size to cover the vehicles accumulator(s)
7. Safety glasses with side shields (ANSI Z87.1-2003 compliant) for all team members.

**Note:** All electrical safety items must be rated for at least the maximum tractive system voltage. Formula Hybrid imposes an absolute limit of 300V in any system.

You should also discuss lock-out/tag out procedures with the RSO. (See **A6.4, EV4.7.5** and **Appendix F**)

## **CHARGING (EV8.2):**

The charging equipment for the vehicle should be UL listed, or the RSO should present documented approval from the FH Rules committee for use of the team’s charger. If the charger is not UL listed, and the team has not obtained approval from the FH Rules committee, the team should submit a support ticket to the FH organizers ASAP.

1. Physically inspect the charger.
  - a. Are there any exposed conductors?
  - b. Do all connectors have proper strain relief?
2. Review the team’s charging procedures with the RSO.
  - a. Do they have a designated charging area?
  - b. Does a knowledgeable team member stay with the vehicle during charging?
  - c. Do they have warning signs to notify people High Voltage is in use? (Formula Hybrid uses free-standing flashing amber beacons.)

## DOCUMENTATION REVIEW:

You should have reviewed the team's ESF-2 and FMEA prior to arrival, and may have already gone through a few iterations with the team to correct errors or discrepancies.

This is now your opportunity to compare their documents to the actual vehicle.

### SCHEMATIC:

1. What circuitry is located in which container in the vehicle? Do any of the containers contain both grounded low voltage (GLV) and tractive system voltage (TSV)? (See **EV4.1**)
2. Fusing
  - a. Are fuses rated for DC?
  - b. Are the DC voltage ratings of the fuses greater than the maximum voltage of the system they are protecting?
  - c. Is there a fuse table for the GLV and TSV systems?
  - d. Are wires sizes adequate based on the fuses chosen to protect them? (**EV6**)

3. Locate the Accumulator Isolation Relays (AIRs). Are they directly controlled by the shutdown circuit (i.e. not using logic or microprocessors)?

When the AIRs are open, is there any way for TSV to be present outside the accumulator container? (See **EV3.4**)

4. Are there Traction System Measuring Points (TSMPs)? Are they current limited? (Fuses are not permitted - See **EV4.4**)
5. Locate the Tractive System Energized Light (TSEL) Will it illuminate when the AIRs are energized? (See **EV4.10**)
6. Locate the Tractive System Voltage Present (TSVP) lights. (See **EV4.12**) Are they directly controlled by voltage being present outside the accumulator container (i.e. not using logic or microprocessors)?

If an isolated dc/dc converter is used to power the TSVPs, is the output ground referenced?

### SHUTDOWN CIRCUIT AND SYSTEMS (SECTION EV5):

1. Does the team have a diagram showing their safety loop similar to **Figure 35** in the rules? Does it contain all the necessary components:
  - a. Three Big Red Buttons (BRBs)
  - b. Master Switches
  - c. Brake over-travel switch
  - d. Insulation Monitoring Device (IMD)
  - e. Accumulator Monitoring System (AMS)
  - f. Accumulator Isolation Relays (AIRs)
2. Can the team explain how it operates? Does it comply with the state diagram in **Figure 32** and **Table 16** of the rules?

**NOTE:** A large part of the electrical inspection at the competition focuses on the safety loop and schematic, and a team that can explain both clearly and concisely will expedite the inspection process at the event.

## FMEA

Quiz the team: Pick a few scenarios from the FMEA. Can they explain the failure mode and the expected vehicle response? Can you think of failure scenarios that they have overlooked?

## VEHICLE INSPECTION:

A majority of your review time will be spent looking at the actual vehicle. Depending on the preparedness of the team, the vehicle could be complete, or it could be in several pieces. In any event, this is your opportunity to work with the team to identify possible issues.

Before looking for specific rules infractions, take a few moments to get some general impressions:

1. Does the wiring/conduit look neat and purposefully routed? Conversely, do you see any “rat nests” of wiring?
2. Are electrical containers within the physical outline of the vehicle (including the underside)? Do they look solid and securely attached to the vehicle?

Ask the team to point out key elements to you, such as the accumulator, motors, motor controller, GLV battery, test points and safety circuit components.

At this point, you should be able to take a closer look at the vehicle. Ask the team to remove any body panels or compartment covers to make wiring and components accessible. Below are some of the key things to look for on the vehicle:

1. Is there any TSV in the cockpit (either in conduit or exposed)?
2. Exposed/uninsulated TSV anywhere?

Weak areas are often at the motor connections and transition between conduit and electrical components. Review **EV4.5 - TSV Insulation, wiring and conduit** for guidelines.

3. Are all the body parts/hardware/frame grounded (defined as <300 mOhms)? While the frame is usually well grounded (most are welded steel tubing) there are a lot of other ways where teams have problems meeting this rule (See **EV 4.3 - Grounding**)
  - a. Some teams make their instrument panel out of non-conductive material (Plexiglas, etc.). If they use a standard toggle switch, the metal nut holding the switch to the panel is considered ungrounded.
  - b. A metal panel connected to the frame using non-conductive hardware is considered ungrounded and must be connected to the frame with a ground strap.
  - c. Check the driver harness attachment points.
  - d. Carbon fiber is very problematic, especially if the team did not incorporate a conductive mesh during fabrication. Multiple points of the carbon fiber should be tested to see if it is less than 5 Ohms to ground.
  - e. Check that their grounding wires are at least 16 AWG, and that the connections are mechanically solid.

4. Is wiring inside the electrical enclosures neat and organized? Is it easy to inspect? Are appropriate electrical connections used?
5. If low voltage and tractive voltage are in the same container, are they properly segregated or mechanically separated? If an insulator is used to separate low voltage from tractive voltage, is it UL listed and rated for 150°C? If the team designed a circuit board with both low voltage and tractive voltage on it, are the traces properly separated (See **Table 15**)?
6. **Note:** Teams are sometimes confused about which wires fall in which category. It doesn't matter what the voltage is on a particular wire—it only matters whether it is galvanically connected in any way to one or the other system. A wire must be either a Grounded Low Voltage wire or a Tractive Voltage wire (never both), as the two systems must be galvanically isolated. Ideally it would be apparent just from looking which wires were in which system, but if it's not, point at a wire and ask they team which system it is part of. They should be able to tell you immediately. If they can't, provide guidance on how the team can improve on wire routing and separation.
7. Check that bolted electrical connections:
  - a. Do not have plastic in the stack-up. (So that pressure on the contacts is maintained even if they got hot enough that plastic would soften.)
  - b. Do not have steel washers between the Cu (or Al) conductors.
  - c. Fasteners are tight.

#### POUCH CELLS

**NOTE:** Examining the inside of the accumulator housing is optional, and should only be undertaken if you are certain that the voltages are below 30 VDC or you are comfortable working in the presence of potentially lethal voltages:

**Bolted stack-ups:** Are they tight? There should not be any plastic or any other deformable material in the stack-up as contact pressure could be lost if the plastic softens due to heat. Steel washers are acceptable in the stack up so long as they are not between (i.e. in the current flow path) of the conductors in the stack-up.

**NOTE:** If the team has assembled their own battery using Lithium-Ion pouch cells, they should be able to produce considerable evidence of communications with the Formula Hybrid rules committee.

Our requirements for the use of pouch cells are extensive and teams that have not communicated with us may find passing the electrical tech inspection difficult.

#### FINAL COMMENTS

The term “professional standards” is scattered throughout the rules. You are the professional, and the team members will learn a lot from you as you point out items that do not meet this definition.

If you are unsure of anything, there is a team of experienced inspectors to help. Document those items which may remain unresolved through the review, and the seasoned inspectors will review them to provide further guidance.

*Thank you!!*

*The Formula Hybrid Electrical Inspection Team*



## 2015 Electrical Tech Inspectors



Robert Barry Dartmouth College	Heath Hoffman Univ. of Michigan	Paul Messier BAE Systems	Jenna Pollock Tesla Motors	Adam Ing LG Chem, Inc	Brian Nadau Infineo	Bruce Allen SCCA	Dennis Brown General Motors	Terrence Lippert Intralinks	Mike Irvine Clearpath Robotics
Charles Sullivan Dartmouth College	Ted Arbo Test Equity	Rob Wills Net Solar, llc	Abess El-Mokadam LG Chem Power, Inc	Carrie Okma Fiat-Chrysler	Vernon Miller Dell, Inc	Ben Groen General Motors	John Gudice Intralinks	Tony Nuzzo Pika Energy	

Not in the photo: Ricky Willems, Innovative Dynamics

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## FORMULA HYBRID ELECTRICAL ACRONYMS

AIR	Accumulator Isolation Relay
AMS	Accumulator Management System
BRB	Big Red Buttons (Emergency shutdown switches)
ESF-2	Electrical System Form (Part 2 – the first part of the ESF is submitted and reviewed early in the program.)
EV	Electrical Vehicle
FMEA	Failure Modes and Effects Analysis
GLV	Grounded Low Voltage
GLVMS	Grounded Low Voltage Master Switch
HVD	High Voltage Disconnect
IMD	Insulation Monitoring Device
IMDT	Insulation Monitoring Device Test
IMT	Insulation Measurement Test
RSO	Rules Safety Officer
TSAL	Tractive System Active Light
TSMP	Tractive System Measuring Point
TSMS	Tractive System Master Switch
TSV	Tractive System Voltage (i.e. High Voltage)
TSVP	Tractive Voltage Present