IC3.4 Noise Level Re-testing

At the option of the officials, noise may be measured at any time during the competition. If a car fails the noise test, it will be withheld from the competition until it has been modified and re-passes the noise test.

ARTICLE 4: ELECTRICAL SYSTEM AND SHUTDOWN SYSTEM

IC4.1 Master Switches

IC4.1.1 The vehicle must be equipped with two (2) master switches which form part of the shutdown system. Actuating either switch must stop the engine.

IC4.1.2 The international electrical symbol consisting of a red spark on a white-edged blue triangle must be affixed in close proximity to each switch.

Any alternator field wire must also be disabled by each master switch to prevent any possible feedback through the field coil circuit.

IC4.2 Primary Master Switch

IC4.2.1 The primary master switch must:

a. Be located on the (driver's) right side of the vehicle, in proximity to the Main Hoop, at shoulder height and be easily actuated from outside the car.
b. Disable power to ALL electrical circuits, including the battery, alternator, lights, fuel pump(s), ignition and electrical controls.
c. All battery current must flow through this switch.
d. Be of a rotary type and must be direct acting, i.e. it must not act through a relay.

An example of a typical switch that meets these requirements is shown below.

IC4.2.2 The master switches must be mounted so that the rotary axis of the key is near horizontal and across the car. The "ON" position of the switch must be in the horizontal position and must be marked accordingly. The "OFF" position of the primary master switch must also be clearly marked.

IC4.3 Cockpit-mounted Master Switch

IC4.3.1 The cockpit-mounted master switch:

a. Must be located to provide easy actuation by the driver in an emergency or panic situation.
b. Must be located within easy reach of the belted-in driver, alongside the steering wheel, and unobstructed by the steering wheel or any other part of the car. It is suggested that it be placed on the same side of the steering wheel as the shifter mechanism.
c. Must be a push/pull Emergency switch with a minimum diameter of 24 mm. The switch must be installed such that:

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i. From the ON position, pushing on the switch will disable power to the ignition and all fuel pumps, and
ii. From the OFF position, pulling on the switch will enable power to the ignition and fuel pump(s). Switches that require a twist or twist and pull to enable power are acceptable.

d. May act through a relay.

Examples of typical switches that meet these requirements are shown below.

IC4.4 Batteries

IC4.4.1 All batteries, i.e. on-board power supplies, must be attached securely to the frame.

IC4.4.2 Any wet-cell battery located in the driver compartment must be enclosed in a nonconductive marine-type container or equivalent.

IC4.4.3 The hot (ungrounded) terminal must be insulated.

IC4.4.4 Battery packs based on Lithium Chemistry:

a. Must have overcurrent protection that trips at or below the maximum specified discharge current of the cells.
b. Must have a rigid, sturdy and fire retardant casing.
c. Must be separated from the driver by a firewall as specified in T4.5

IC4.4.5 All batteries using chemistries other than lead acid must be presented at technical inspection with markings identifying it for comparison to a datasheet or other documentation proving the pack and supporting electronics meet all rules requirements

IC4.5 Brake-Over-Travel-Switch

The Brake-Over-Travel-Switch forms part of the shutdown system and as defined in T7.3 must remove power from the engine and fuel pumps.

IC4.6 Voltage limit for IC vehicles

The maximum permitted voltage between any two electrical connections is 60V DC or 25V AC RMS. The following systems are excluded from this voltage limit:

a. High voltage systems for ignition
b. High voltage systems for injectors
c. Voltages internal to OEM charging systems designed for <60VDC output.

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2017-18 FORMULA SAE RULES
PART EV - TECHNICAL REGULATIONS – ELECTRIC VEHICLES

The principle of the Electric Vehicle part is to allow the development of fully electric vehicles within the FSAE framework. These rules are based on the electric vehicle regulations developed by Formula Student and Formula Student Germany, and also include elements of the Formula Hybrid Rules.

ARTICLE 1: ELECTRIC SYSTEM DEFINITIONS

EV1.1 High-Voltage (HV) and Low-Voltage (LV)

EV1.1.1 Whenever a circuit has a potential difference where the nominal operation voltage is greater than 60V DC or 25V AC RMS it is defined as part of the High Voltage or tractive system.

EV1.1.2 The maximum permitted voltage that may occur between any two electrical connections is different between the competitions allowing electric vehicles. The following table lists the respective values:

Competition	Voltage Level
Formula SAE Electric	300 VDC
Formula SAE Brazil	300 VDC
Formula SAE Australasia	600 VDC
Formula SAE Italy	600 VDC
Formula Student	600 VDC
Formula Student Germany	600 VDC
Student Formula Japan	600 VDC

EV1.1.3 Low voltage is defined as any voltage below and including 60V DC or 25V AC RMS.

EV1.1.4 The tractive system accumulator is defined as all the battery cells or super-capacitors that store the electrical energy to be used by the tractive system.

EV1.1.5 Accumulator segments are sub-divisions of the accumulator and must respect either a maximum voltage or energy limit. Splitting the accumulator into its segments is intended to reduce the risks associated with working on the accumulator.

EV1.2 Grounded Low Voltage and Tractive System

EV1.2.1 The tractive system of the car is defined as every part that is electrically connected to the motor(s) and tractive system accumulators.

EV1.2.2 The grounded low voltage (GLV) system of the car is defined as every electrical part that is not part of the tractive system.

EV1.2.3 The tractive system must be completely isolated from the chassis and any other conductive parts of the car.

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EV1.2.4 The tractive-system is a high-voltage system by definition, see EV1.1.1.

EV1.2.5 The GLV system must be a low-voltage-system, see EV1.1.3.

EV1.2.6 The GLV system must be grounded to the chassis.

EV1.2.7 The entire tractive and GLV system must be completely galvanically separated. The border between tractive and GLV system is the galvanic isolation between both systems. Therefore, some components, such as the motor controller, may be part of both systems.

EV1.2.8 All components in the tractive system must be rated for the maximum tractive system voltage.

EV1.2.9 The tractive system motor(s) must be connected to the accumulator through a motor controller. Bypassing the control system and connecting the tractive batteries directly to the motor(s) is prohibited.

EV1.2.10 The GLV system must be powered up using a specified procedure before it is possible to activate the tractive system, see EV4.10. Furthermore, a failure causing the GLV system to shut down must immediately deactivate the tractive system as well.

ARTICLE 2: ELECTRIC POWERTRAIN

EV2.1 Motors

EV2.1.1 Only electrical motors are allowed. Any type of electrical motor is allowed. The number of motors is not limited.

EV2.1.2 The rotating part of the motor must be contained within a structural casing where the thickness is at least 3.0 mm (0.120 inch) for Aluminum alloy 6061-T6 or 2.0 mm (0.080 inch) for steel. The motor casing may be the original motor casing, a team built motor casing or the original casing with additional material added to achieve the minimum required thickness. If lower grade Aluminum Alloy is used, then the material must be thicker to provide an equivalent strength.

NOTE: Use of a higher grade alloy does not enable a reduced thickness to be used.

EV2.1.3 If the motor casing rotates around the stator, or the motor case is perforated, then a scatter shield must be included around the motor. This scatter shield must be at least 1.0mm (0.04 inch) thick and made from aluminum alloy 6061-T6 or steel.

EV2.2 Power and Voltage Limitation

EV2.2.1 The maximum power drawn from the battery must not exceed 80kW. This will be checked by evaluating the Energy Meter data.

EV2.2.2 The maximum voltage in the tractive system must not exceed the voltage defined in EV1.1.2. This will be checked by evaluating the Energy Meter data.

EV2.2.3 Violating these values will lead to disqualification for the entire dynamic event in which the violation occurred e.g. if a violation occurs during one single acceleration run, the team will be disqualified for the complete acceleration event.

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EV2.2.4 A violation is defined as using more than 80kW or exceeding the specified voltage for more than 100ms continuously or using more than 80kW or exceeding the specified voltage, after a moving average over 500ms is applied.

EV2.2.5 The respective data of each run in which a team has drawn more than 80kW from the battery or where the maximum permitted voltage is exceeded and the resulting decision will be made public.

EV2.2.6 Non-availability of Energy Meter data due to the team's fault will be treated as a violation.

EV2.2.7 Regenerating energy is allowed and unrestricted but only when the vehicle speed is > 5kph. It is not allowed at vehicle speeds <= 5kph.

EV2.2.8 Supplying power to the motor such that the car is driven in reverse is prohibited.

EV2.3 Accelerator Pedal Position Sensor - APPS

EV2.3.1 Drive-by-wire control of wheel torque is permitted.

EV2.3.2 The APPS must be actuated by a foot pedal. Pedal travel is defined as percent of travel from a fully released position to a fully applied position where 0% is fully released and 100% is fully applied.

EV2.3.3 The foot pedal must return to its original position when not actuated. The foot pedal must have a positive stop preventing the mounted sensors from being damaged or overstressed. Two springs must be used to return the foot pedal to the off position and each spring must be capable of returning the pedal to the fully released position with the other disconnected.

The springs in the APPS are not acceptable pedal return springs.

EV2.3.4 At least two entirely separate sensors have to be used as APPSs. The sensors must have different transfer functions, each having a positive slope sense with either different gradients and/or offsets to the other(s).

NOTE: The intent of this rule is that in a short circuit the APPSs will only agree at 0% pedal position.

EV2.3.5 If an implausibility occurs between the values of the APPSs and persists for more than 100msec, the power to the motor(s) must be immediately shut down completely. It is not necessary to completely deactivate the tractive system, the motor controller(s) shutting down the power to the motor(s) is sufficient.

EV2.3.6 Implausibility is defined as a deviation of more than 10% pedal travel between the sensors or other failure as defined in EV2.3.9.

EV2.3.7 If three sensors are used, then in the case of an APPS failure, any two sensors that agree within 10% pedal travel may be used to define the torque target and the 3rd APPS may be ignored.

EV2.3.8 Each APPS must have a separate detachable connector that enables a check of these functions by unplugging it during Electrical Tech Inspection or else an inline switchable break-out box must be made available during Technical Inspection that allows disconnection of each APPS signal.

EV2.3.9 The APPS signals must be sent directly to a controller using an analogue signal or via a digital data transmission bus such as CAN or FlexRay. Any failure of the APPS or APPS wiring must be detectable by the controller and must be treated like an implausibility, see EV2.3.5.

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EV2.3.10 When an analogue signal is used, e.g. from a 5V sensor, the APPS will be considered to have failed when they achieve an open circuit or short circuit condition which generates a signal outside of the normal operating range, for example <0.5V or >4.5V. The circuitry used to evaluate the sensor will use pull down or pull up resistors to ensure that open circuit signals result in a failure being detected.

EV2.3.11 When any kind of digital data transmission is used to transmit the APPS signal, the FMEA study must contain a detailed description of all the potential failure modes that can occur, the strategy that is used to detect these failures and the tests that have been conducted to prove that the detection strategy works. The failures to be considered must include but are not limited to the failure of the APPS, APPS signals being out of range, corruption of the message and loss of messages and the associated time outs.

EV2.3.12 Any algorithm or electronic control unit that can manipulate the APPS signal, for example for vehicle dynamic functions such as traction control, may only lower the total driver requested torque and must never increase it. Thus the drive torque which is requested by the driver may never be exceeded.

EV2.3.13 The current rules are written to only apply to the APPS (pedal), but the integrity of the torque command signal is important in all stages.

EV2.4 Brake System Encoder - BSE

EV2.4.1 A brake system encoder or switch to measure brake pedal position or brake system pressure must be fitted to check for plausibility – see EV2.5

EV2.4.2 The brake system encoder may be used to control regenerative braking

EV2.4.3 The BSE must have a separate detachable connector that enables detection of error states and the response of the ECU to be checked by unplugging it during Electrical Tech Inspection, otherwise an inline switchable break-out box must be made available during technical inspection that allows disconnection of each BSE signal.

EV2.4.4 The BSE or switch signals must be sent directly to a controller using an analogue signal or via a digital data transmission bus such as CAN or FlexRay. Any failure of the BSE or BSE wiring that persists more than 100 msec must be detectable by the controller and treated like an implausibility such that power to the motor(s) is immediately and completely shut down. It is not necessary to completely deactivate the tractive system, the motor controller(s) shutting down the power to the motor(s) is sufficient.

EV2.4.5 When an analogue signal is used, e.g. from a 5V sensor, the BSE sensors will be considered to have failed when they achieve an open circuit or short circuit condition which generates a signal outside of the normal operating range, for example <0.5V or >4.5V. The circuitry used to evaluate the sensor will use pull down or pull up resistors to ensure that open circuit signals result in a failure being detected.

EV2.4.6 When any kind of digital data transmission is used to transmit the BSE signal, the FMEA study must contain a detailed description of all the potential failure modes that can occur, the strategy that is used to detect these failures and the tests that have been conducted to prove that the detection strategy works. The failures to be considered must include but are not limited to the failure of the sensor, sensor signals being out of range, corruption of the message and loss of messages and the associated time outs. In all cases a sensor failure must result in power to the motor(s) being immediately shutdown.

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EV2.5 APPS / Brake Pedal Plausibility Check

The power to the motors must be immediately shut down completely, if the mechanical brakes are actuated and the APPS signals more than 25% pedal travel at the same time. This must be demonstrated when the motor controllers are under load.

EV2.5.1 The motor power shut down must remain active until the APPS signals less than 5% pedal travel, no matter whether the brakes are still actuated or not.

ARTICLE 3: TRACTIVE SYSTEM - ENERGY STORAGE

EV3.1 Allowed Tractive System Accumulators

EV3.1.1 All types of accumulators except molten salt and thermal batteries are allowed. E.g.: Batteries, Super-capacitors, etc. Fuel cells are prohibited.

EV3.1.2 There are no concessions for using LiFePO4 chemistry cells.

EV3.2 Tractive System Accumulator Container – General Requirements

EV3.2.1 All cells or super-capacitors which store the tractive system energy will be built into accumulator segments and must be enclosed in (an) accumulator container(s).

EV3.2.2 If spare accumulators are to be used then they all have to be of the same size, weight and type as those that are replaced. Spare accumulator packs have to be presented at Electrical Tech Inspection.

EV3.2.3 If the accumulator container(s) is not easily accessible during Electrical Tech Inspection, detailed pictures of the internals taken during assembly have to be provided. However, at the end of the event the tech inspectors reserve the right to check any accumulators to ensure that the rules are adhered to.

EV3.2.4 Each accumulator container must be removable from the car while still remaining rules compliant.

EV3.3 Tractive System Accumulator Container - Electrical Configuration

EV3.3.1 If the container is made from an electrically conductive material, then the poles of the accumulator segment(s) and/or cells must be isolated from the inner wall of the accumulator container with an insulating material that is rated for the maximum tractive system voltage. All conductive surfaces on the outside of the container must have a low-resistance connection to the GLV system ground, see EV4.3. Special care must be taken to ensure that conductive penetrations, such as mounting hardware, are adequately protected against puncturing the insulating barrier.

EV3.3.2 Every accumulator container must contain at least one fuse and at least two accumulator isolation relays, see EV3.5 and EV6.1.

EV3.3.3 Maintenance plugs, additional contactors or similar measures have to be taken to allow electrical separation of the internal cell segments such that the separated cell segments contain a maximum static voltage of less than 120VDC and a maximum energy of 6MJ. The separation must affect both poles of the segment.

This separation method must be used whenever the accumulator containers are opened for maintenance and whenever accumulator segments are removed from the container.

It must not be physically possible to connect the Maintenance Plugs in any way other than the design intent configuration.

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Maintenance plugs requiring tools to separate the segments will not be accepted.

Maintenance plugs must include a positive locking feature which prevents the plug from unintentionally becoming loose.

Maintenance plugs must be non-conductive on surfaces that do not provide any electrical connection.

EV3.3.4 Each segment must be electrically insulated by the use of suitable material between the segments in the container and on top of the segment to prevent arc flashes caused by inter segment contact or by parts/tools accidentally falling into the container during maintenance for example. Air is not considered to be a suitable insulation material in this case.

EV3.3.5 The Accumulator Isolation Relays (AIRs) and the main fuse must be separated with an electrically insulated and fireproof material to UL94-V0 from the rest of the accumulator. Air is not considered to be a suitable insulation material in this case.

EV3.3.6 If the tractive system connectors to the accumulator containers can be removed without the use of tools, then a pilot contact/interlock line must be implemented which activates the shutdown circuit and opens the AIRs whenever the connector is removed.

EV3.3.7 Contacting / interconnecting the single cells by soldering in the high current path is prohibited. Soldering wires to cells for the voltage monitoring input of the AMS is allowed, since these wires are not part of the high current path.

EV3.3.8 Every wire used in an accumulator container, no matter whether it is part of the GLV or tractive system, must be rated to the maximum tractive system voltage.

EV3.3.9 Each accumulator container must have a prominent indicator, such as an LED that will illuminate whenever a voltage greater than 60V DC is present at the vehicle side of the AIRs.

EV3.3.10 The voltage being present at the connectors must directly control the indicator using hard wired electronics (no software control is permitted). Activating the indicator with the control signal which closes the AIRs is not sufficient.

EV3.3.11 The accumulator voltage indicator must always work, e.g. even if the container is disconnected from the GLVS or removed from the car and carried around.

EV3.4 Tractive System Accumulator Container - Mechanical Configuration

EV3.4.1 All accumulator containers must lie within the Primary Structure of the Frame (see T3.3).

EV3.4.2 The accumulator container must be built of mechanically robust material.

EV3.4.3 The container material must be fire resistant according to UL94-V0, FAR25 or equivalent.

EV3.4.4 All accumulator containers must be protected from side or rear impact collisions by structure equivalent to that defined in T3.4 and must be included in the SES. **NOTE**: The container must not form part of the equivalent structure.

EV3.4.5 All accumulator containers must be designed to withstand forces from deceleration. Teams have the option to use the design guidelines in rule EV3.4.6 or analyze the accumulator through the "Alternative Frame Rules" process. Design of the Accumulator container must be documented in the

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SES or SRCF. Documentation includes materials used, drawings/images, fastener locations, cell/segment weight and cell/segment position.

EV3.4.6 Accumulator containers must be constructed of sheet/plate steel or aluminum in the following configuration:

a. The floor or bottom of the accumulator container must be constructed of steel 1.25mm (0.049 inch) thick or aluminum 3.2mm (0.125 inch) thick.
b. The external vertical walls must be constructed of steel 0.9mm (0.035 inch) thick or aluminum 2.3mm (0.09 inch) thick.
c. Internal vertical walls separating cells and/or segments must be a minimum of 75 percent of the height of the external vertical walls and must be constructed of steel 0.9mm (0.035 inch) thick or aluminum 2.3mm (0.090 inch) thick.
d. Covers and lids must be constructed of steel 0.9mm (0.035 inch) thick or aluminum 2.3mm (0.09 inch) thick.
e. The floor and walls of the accumulator container must be joined by welds and/or fasteners. Any fasteners must be 6 mm Metric Grade 8.8 (1/4 inch SAE Grade 5) fasteners, or stronger.
f. Internal vertical walls divide the accumulator container into "sections". A maximum of 12kg (26.5 lbs.) is allowed in any section of the accumulator container.

    i. Fastened connections between the floor and any vertical wall of each section must have at least 2 fasteners.
    ii. Fastened connections between internal vertical walls and external vertical walls must be located in the top half of the internal vertical wall.
    iii. Sections containing 8 kg (18 lbs) or less must have a minimum of 2 fasteners connecting any two vertical walls.
    iv. Sections containing between 8 kg (18 lbs.) and 12 kg (26.5 lbs.) must have a minimum of 3 fasteners connecting any two vertical walls.

    Example: An accumulator container with 2 internal walls has 3 sections. Each section contains less than 8 kb (18 lbs). Therefore 18 floor to wall joints are required in total with at least 2 fasteners per joint.

g. Folding or bending plate material to create flanges or to eliminate joints between walls is acceptable.
h. Covers and Lids must be fastened with a minimum of one fastener for each external vertical wall per section.
i. Alternate materials are allowed with proof of equivalency per rule T3.31. Proof of equivalency must be documented in the SES and test samples must be available at technical inspection.
j. Substituting one 6 mm (1/4 inch) bolt with two 5 mm (#12) bolts or three 4 mm (#10) bolts is allowed.

NOTE 1: An Example of an Accumulator complying with the design guidelines is available in the FAQs at http://fsaeonline.com/.

NOTE 2: The accumulator design guidelines are intended to generate a structure that does not fail under the following accelerations:

a. 40g in the longitudinal direction (forward/aft)
b. 40g in the lateral direction (left/right)
c. 20g in the vertical direction (up/down)

EV3.4.7 The cells and/or segments must be appropriately secured against moving inside the container.

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This mounting system must be designed to withstand the following accelerations:

a. 40g in the longitudinal direction (forward/aft)
b. 40g in the lateral direction (left/right)
c. 20g in the vertical direction (up/down)

Calculations and/or tests proving these requirements are met must be included in the SES or SRCF. Any fasteners must be 6mm Metric Grade 8.8 (1/4 in SAE Grade 5) or stronger.

EV3.4.8 Accumulator containers must be attached to the major structure of the chassis

a. The number of attachment points that must be used depends on the total weight of the container:

Accumulator Weight	Minimum Attachment Points
< 20 kg	4
20 – 30 kg	6
30 – 40 kg	8
> 40 kg	10

b. Any brackets must be made of steel 1.6mm (0.063 inch) thick or aluminum 4mm (0.157 inch) thick and must have gussets to carry bending loads.

c. Each attachment point, including any brackets, backing plates and inserts, must:
   i. Be able to withstand 20kN in any direction
   ii. Use at least one 8 mm Metric Grade 8.8 (5/16-inch Grade 5) fastener, or stronger.

d. Composite monocoque chassis and/or accumulator containers must satisfy the following requirements:
   i. Data obtained from the laminate perimeter shear strength and 3-point bending tests (T3.30) must be used for any strength calculations.
   ii. Each attachment point requires steel backing plates with a minimum thickness of 2 mm. Alternate materials may be used for backing plates if equivalency is approved.
   iii. The calculations and physical test results must be included in the SES or SRCF.

EV3.4.9 The Accumulator containers and mounting systems are subject to approval of the Chief Technical Inspector or their representative.

EV3.4.10 The accumulator segments contained within the accumulator must be separated by an electrically insulating and be fire resistant barrier (according to UL94-V0, FAR25 or equivalent) and must subdivide the accumulator into 6MJ segments if this is not already met by the separation due to the 120VDC voltage limit.

The contained energy of a stack is calculated by multiplying the maximum stack voltage with the nominal capacity of the used cell(s). Documentation of segment separation must be provided in the ESF.

EV3.4.11 Holes, both internal and external, in the container are only allowed for the wiring-harness, ventilation, cooling or fasteners. External holes must be sealed according to EV4.5.

EV3.4.12 The container must be completely closed at all times, when mounted to the car and also when dismounted from the car without the need to install extra protective covers. Openings for ventilation should be of a reasonable size, e.g. completely open sidepods containing accumulators are not allowed.

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EV3.4.13 A sticker with an area of at least 750 mm² and a red or black lightning bolt on yellow background or red lightning bolt on white background must be applied on every accumulator container. The sticker must also contain the text "High Voltage" or something similar.

EV3.4.14 Any accumulators that may vent an explosive gas must have a ventilation system or pressure relief valve to prevent the vented gas from reaching an explosive concentration.

EV3.4.15 Every accumulator container which is completely sealed must also have a pressure relief valve to prevent high-pressure in the container.

EV3.5 Accumulator Isolation Relay(s) (AIR)

EV3.5.1 In every accumulator container at least two isolation relays must be installed.

EV3.5.2 The accumulator isolation relays must open both (!) poles of the accumulator.
If these relays are open, no HV may be present outside of the accumulator container.

EV3.5.3 The isolation relays must be of a "normally open" type.

EV3.5.4 The fuse protecting the accumulator tractive system circuit must have a rating lower than the maximum switch off current of the isolation relays.

EV3.5.5 The accumulator isolation relays must not contain mercury.

EV3.6 Accumulator Management System (AMS)

EV3.6.1 Each accumulator must be monitored by an accumulator management system whenever the tractive system is active or the accumulator is connected to a charger. For battery systems this is generally referred to as a battery management system (BMS) however alternative electrical energy storage systems are allowed and therefore AMS will be the terminology used in this document.

EV3.6.2 The AMS must continuously measure the cell voltage of every cell, in order to keep the cells inside the allowed minimum and maximum cell voltage levels stated in the cell data sheet. If single cells are directly connected in parallel, only one voltage measurement is needed.

EV3.6.3 The AMS must continuously measure the temperatures of critical points of the accumulator to keep the cells below the allowed maximum cell temperature limit stated in the cell data sheet or below 60°C, whichever is lower.

Cell temperature must be measured at the negative terminal of the respective cell and the sensor used must be in direct contact with either the negative terminal or its busbar. If the sensor is on the busbar, it must be less than 10mm away from the cell terminal.

NOTE: A competition may use a special device to check the conformance to the temperature limits. Please check the website of the respective competition for further information.

EV3.6.4 For centralized AMS systems (two or more cells per AMS board), all voltage sense wires to the AMS must be protected by 'fusible link wires' or fuses so that any the sense wiring cannot exceed its current carrying capacity in the event of a short circuit. The fusing must occur in the conductor, wire or pcb trace which is directly connected to the cell tab.

Any distributed AMS system (one cell measurement per board) where the sense wire connections at the board are <25mm does not need additional fusing if the board is protected from short circuit and

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the connection to the AMS is also protected. If these conditions are not met, then the positive cell terminal must be protected with a fusible link wire.

Where required, the fusible link wire may form the entire sense wire or a section of the sense wire. If the fusible link wire forms a section of the sense wire, then the gauge of the fusible link wire must be sized appropriately to protect the remaining part of the voltage sense wire from currents above its continuous current rating. If any of these fusible link wires are blown or if the connection to measure the cell voltage is interrupted in any other way, then this must be detected by the AMS and must be reported as a critical voltage problem.

NOTE 1: If a 'fusible link wire' is required and the resistance of the connection from the AMS board to the cell for the voltage measurement is too high, then this can affect the AMS voltage measurement especially during cell balancing and charging, therefore an appropriately large gauge wire must be used.

NOTE 2: A fusible link wire works such that when an over current event occurs, the conductor within the link is melted while the ensuing flame and spark is contained within the link's insulation. Specific products can be purchased which perform this function.

EV3.6.5 Any GLV connection to the AMS must be galvanically isolated from the tractive system.

EV3.6.6 For lithium based cells the temperature of at least 30% of the cells must be monitored by the AMS. The monitored cells have to be equally distributed within the accumulator container(s).

It is acceptable to monitor multiple cells with one sensor, if EV3.6.3 is met for all cells sensed by the sensor.

NOTE: It is strongly recommended to monitor every cell temperature.

EV3.6.7 The AMS must shutdown the tractive system by opening the AIRs, if critical voltage or temperature values according to the cell manufacturer's datasheet and taking into account the accuracy of the measurement system are detected. If the AMS does perform a shutdown, then a red LED marked AMS must light up in the cockpit to confirm this.

EV3.7 Grounded Low Voltage System (<=60V DC)

EV3.7.1 All GLV batteries, i.e. on-board power supplies, must be attached securely to the frame.

EV3.7.2 Any wet-cell battery located in the driver compartment must be enclosed in a nonconductive marine-type container or equivalent.

EV3.7.3 The hot (ungrounded) terminal must be insulated.

EV3.7.4 GLV battery packs must comply with IC4.4.4

ARTICLE 4: TRACTIVE SYSTEM – GENERAL REQUIREMENTS

EV4.1 Separation of Traction System and Grounded Low Voltage System

EV4.1.1 The layout of electrical devices designed by the team must be documented accurately in the ESF.

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EV4.1.2 There must be no connection between the frame of the vehicle (or any other conductive surface that might be inadvertently touched by a crew member or spectator), and any part of any tractive system circuits.

EV4.1.3 Tractive system and GLV circuits must be physically segregated such that they are not run through the same conduit or connector, except for interlock circuit connections.

EV4.1.4 GLV systems must not be included in the accumulator container except for required purposes. Exceptions include the AIRs, HV DC/CD converters, the AMS and the IMD. The galvanic isolation of any LV wiring within the accumulator container, and where appropriate elsewhere, must be described within the ESF.

EV4.1.5 Where both tractive system and GLV are present within an enclosure, they must be separated by insulating barriers made of moisture resistant, UL recognized or equivalent insulating materials rated for 150 C or higher (e.g. Nomex based electrical insulation), or maintain the following spacing through air, or over a surface (similar to those defined in UL1741):

- U < 100VDC 10 mm (0.4 inch)
- 100VDC < U < 200VDC 20 mm (0.75 inch)
- U > 200VDC 30 mm (1.2 inch)

EV4.1.6 Spacing must be clearly defined. Components and cables capable of movement must be positively restrained to maintain spacing.

EV4.1.7 If tractive system and GLV are on the same circuit board, they must be on separate, clearly defined areas of the board. Furthermore, the tractive system and GLV areas have to be clearly marked on the PCB.

NOTE: The following spacing is related to the spacing between traces / board areas. If integrated circuits are used such as opto-couplers which are rated for the respective maximum tractive system voltage, but do not fulfill the required spacing, then they may still be used and the given spacing do not apply.

Required spacing are as follows:

Voltage	**Over Surface**	**Thru Air (Cut in board)**	**Under Coating**
0-50VDC	1.6 mm (1/16”)	1.6 mm (1/16”)	1 mm
50-150VDC	6.4 mm (1/4”)	3.2 mm (1/8”)	2 mm
150-300VDC	9.5 mm (3/8”)	6.4 mm (1/4”)	3 mm
300-600VDC	12.7 mm (1/2”)	9.5 mm (3/8”)	4 mm

EV4.1.8 Teams must be prepared to demonstrate spacing on team-built equipment. Information on this must be included in the electrical system form (EV9.1). For inaccessible circuitry, spare boards or appropriate photographs must be available for inspection.

EV4.1.9 All connections to external devices such as laptops from a tractive system component must include galvanic isolation.

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EV4.2 Positioning of tractive system parts

EV4.2.1 Except as allowed by EV4.2.3, all parts belonging to the tractive system including cables and wiring must be contained within the envelope of any part of the frame which is made from any regulated tubing defined in T3.4 and/or an additional envelope of tubing which meets the minimum specification defined in T3.4 or equivalent, such that they are protected against being damaged in case of a crash or roll-over situation.

EV4.2.2 If tractive system parts are mounted in a position where damage could occur from a rear or side impact (below 350mm from the ground), for example motors at the rear of the car, they have to be protected by a fully triangulated structure with tubes of a minimum outer diameter of 25.4mm and a minimum wall thickness of 1.25mm or equivalent – see T3.4.

EV4.2.3 Outboard wheel motors are allowed where the motor, attendant cables and wiring are outside of the frame but only if an interlock is added such that the shutdown circuit, EV5.1, is activated and the AIRs are opened if the wheel assembly is damaged or knocked off the car.

EV4.2.4 In side or front view no part of the tractive-system must project below the lower surface of the frame or the monocoque, whichever is applicable.

EV4.2.5 Additional regulations apply for accumulators, see EV3.4.

EV4.3 Grounding

EV4.3.1 All electrically conductive parts of the vehicle (e.g. parts made of steel, (anodized) aluminum, any other metal parts, etc.) which are within 100mm of any tractive system or GLV component, and any driver harness mounting points, seat mounting points and driver controls must have a resistance below 300 mOhms (measured with a current of 1A) to GLV system ground.

EV4.3.2 All parts of the vehicle which may become electrically conductive (e.g. completely coated metal parts, carbon fiber parts, etc.) which are within 100mm of any tractive system or GLV component, must have a resistance below 5 Ohm to GLV system ground.

EV4.3.3 Electrical conductivity of any part may be tested by checking any point which is likely to be conductive, for example the driver's harness attachment bolt, but where no convenient conductive point is available then an area of coating may be removed.

NOTE: Carbon fiber parts may need special measures such as using copper mesh or similar to keep the ground resistance below 5 Ohms.

EV4.4 Tractive System Measuring points (TSMP)

EV4.4.1 Two tractive system voltage measuring points must be installed directly next to the master switches, see EV5.2.

EV4.4.2 The TSMPs must be protected by a non-conductive housing that can be opened without tools.

EV4.4.3 The TSMP must be protected from being touched with bare hands / fingers, once the housing is opened.

EV4.4.4 4mm shrouded banana jacks rated to an appropriate voltage level must be used for the TSMPs, see the picture below for an example.

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EV4.4.5 The TSMPs must be connected to the positive and negative motor controller/inverter supply lines and must be marked HV+ and HV-

EV4.4.6 Each TSMP must be secured with a current limiting resistor according to the following table. Fusing of the TS measuring points is prohibited. Teams must ensure it is possible to directly measure the value of the resistor during Electrical Tech Inspection.

Maximum TS Voltage	**Resistor Value**
Umax<=200VDC	5kR
200VDC<Umax<=400VDC	10kR
400VDC<Umax<=600VDC	15kR

EV4.4.7 The TSMPs will be used to check during Electrical Tech Inspection that the tractive system is shut down properly in the given time, see EV5.1.3. They are also needed to ensure the isolation of the tractive system of the vehicle for possible rescue operations after an accident or when work on the vehicle is to be done.

EV4.4.8 Next to the TSMP a GLV system ground measuring point must be installed. This measuring point must be connected to GLV system ground and must be marked GND.

EV4.4.9 A 4mm shrouded banana jack must be used for the GLV ground measuring point; see the picture below for an example.

EV4.5 Tractive System Insulation, wiring and conduit

EV4.5.1 All parts, especially live wires, contacts, etc. of the tractive system must be isolated by non-conductive material or covers to be protected from being touched. In order to achieve this, it must not be possible to touch any tractive system connections with a 100 mm long, 6 mm diameter (4 x ¼ inch) insulated test probe when the tractive system enclosures are in place.

EV4.5.2 Non-conductive covers must prevent inadvertent human contact with any tractive system voltage. This must include crew members working on or inside the vehicle. Covers must be secure and adequately rigid. Body panels that must be removed to access other components, etc. are not a substitute for enclosing tractive system connections.

EV4.5.3 Tractive system components and containers must be protected from moisture in the form of rain or puddles.

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NOTE: A rating of IP65 is recommended for the rain test.

EV4.5.4 Insulation material that is appropriate for the expected surrounding temperatures must be used and this must have a minimum temperature rating of 90°C. Using only insulating tape or rubber-like paint for insulation is prohibited.

EV4.5.5 All wires and terminals and other conductors used in the tractive system must be sized appropriately for the continuous tractive system current and the wires must be marked with wire gauge, temperature rating and insulation voltage rating. Alternatively, a serial number or a norm printed on the wire is sufficient if this serial number or norm is clearly bound to the wire characteristics for example by a data sheet. The minimum acceptable temperature rating for tractive system cables is 90°C.

NOTE: Sizing of the conductors for the 'continuous tractive system current' may take account of the RMS or average electrical current that will be used and the anticipated duration of time at maximum electrical current.

EV4.5.6 All tractive system wiring must be done to professional standards with appropriately sized conductors and terminals and with adequate strain relief and protection from loosening due to vibration etc.

EV4.5.7 All tractive system wiring that runs outside of electrical enclosures must either be enclosed in separate orange non-conductive conduit or use an orange shielded cable. Except in the case where the tractive system wiring runs in a fully enclosed container, the conduit or shielded cable must be securely anchored at least at each end so that it can withstand a force of 200N without straining the cable end crimp, and must be located out of the way of possible snagging or damage. Body work is not sufficient to meet this enclosure requirement. Any shielded cable must have the shield grounded.

EV4.5.8 All tractive system connections must be designed so that they use intentional current paths through conductors such as copper or aluminum and should not rely on steel bolts to be the primary conductor. The connections must not include compressible material such as plastic in the stack-up.

EV4.5.9 Tractive system wiring must be shielded against damage by rotating and / or moving parts.

EV4.5.10 If external, un-insulated heat sinks are used, they must be properly grounded to the GLV System ground, see EV4.3.

EV4.5.11 Wiring that is not part of the tractive system must not use orange wiring or conduit.

EV4.5.12 All electrical connections, including bolts, nuts, and other fasteners, in the high current path of the tractive system must be secured from unintentional loosening by the use of positive locking mechanisms that are suitable for high temperatures, for example torque prevailing nuts.
For some applications, for example AIRs, it is possible that locking helicoils or similar need to be used. In the case that a locking helicoil or an approved positive locking mechanism is required that cannot easily be inspected at electrical technical inspection, information about this item must be included in the ESF.

It is also allowed to construct custom locking features that prevent fasteners from coming loose as long as they can be seen to be in place and do not rely on the clamping force for the locking feature.

Lock washers and thread locking compounds, e.g. Loctite®, DO NOT meet the positive locking requirement and Nyloc nuts do not meet the temperature requirements.

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EV4.6 Tractive System Enclosures

EV4.6.1 Every housing or enclosure containing parts of the tractive system, except motor housings, must be labeled with (a) reasonably sized sticker(s) with a red or black lightning bolt on yellow background or red lightning bolt on white background. The sticker must also contain the text “High Voltage” or something similar if the voltage is more than 60V DC or 25VAC.

EV4.6.2 If the housing material is electrically conductive or possibly electrically conductive, it must have a low-resistance connection to GLV system ground, see EV4.3.

EV4.7 HV Disconnect (HVD)

EV4.7.1 It must be possible to disconnect at least one pole of the tractive system accumulator by quickly removing an unobstructed and directly accessible element, fuse or connector, in case of (a) stuck accumulator isolation relay(s) for example. It must be possible to disconnect the HVD without removing any bodywork. The HVD must be above 350mm from the ground and easily visible when standing behind the vehicle. Remote actuation of the HVD through a long handle, rope or wire is not acceptable.

EV4.7.2 An untrained person must be able to remove the HVD within 10 seconds in ready-to-race condition. This will be tested during Electrical Tech Inspection. Being able to quickly disconnect the accumulator(s) from the rest of the tractive system by its connector(s) will satisfy this rule.

EV4.7.3 EV4.5 remains valid, therefore a dummy connector or similar may be needed to restore the system's isolation.

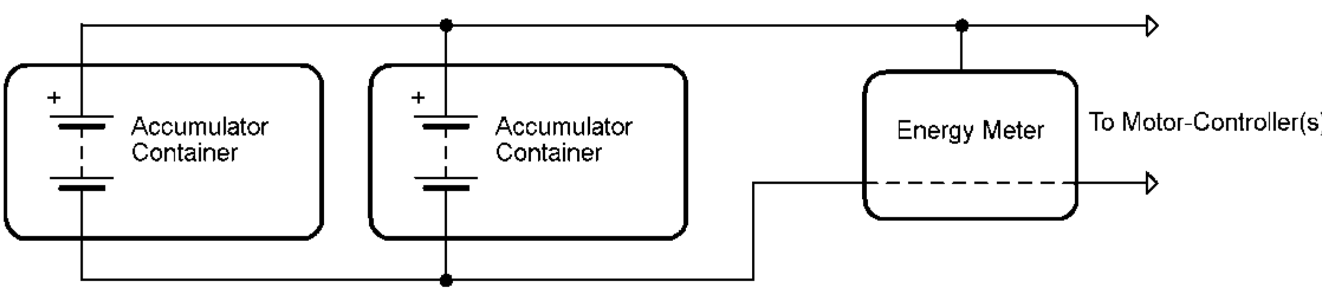
EV4.7.4 The HV Disconnect must be clearly marked with "HVD".

EV4.7.5 No tools must be needed to open the HVD. Therefore, an interlock must activate the shutdown circuit and open the AIRs when the HVD is removed.

EV4.8 Wiring of the tractive system supply

EV4.8.1 All accumulator containers must be wired to a single point. It does not matter if they are wired in series or parallel, but all the power supplying the tractive system must flow through this single point and must pass the energy meter position, see EV4.9.

EV4.8.2 No further energy storages except for reasonably sized intermediate circuit capacitors are allowed beyond this point.



EV4.9 Energy meter

EV4.9.1 In the tractive system supply wires, see EV4.8, a calibrated energy meter must be inserted at the competition. The energy meter is used to calculate the efficiency score by measuring the total energy being sourced by the accumulator(s).

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EV4.9.2 The energy meter is sealed by the officials before the dynamic events. Any manipulation or broken seals of the energy meter result in at least a DNF for the efficiency scoring.

EV4.9.3 The energy meter must be in an easily accessible location so that the recorded data can be quickly downloaded by the officials after the Endurance Event to calculate the efficiency score.

EV4.9.4 The energy is calculated as the time integrated value of the measured voltage multiplied by the measured current logged by the Energy Meter.

EV4.10 Activating the Tractive System

EV4.10.1 The driver must be able to (re-)activate or reset the tractive system from within the cockpit without the assistance of any other person except for situations in which the AMS, IMD or BSPD have shut down the tractive system, see EV5.1.4 and EV5.1.5.

EV4.10.2 Closing only the shutdown circuit must not set the car to ready-to-drive mode. The car is ready to drive as soon as the motor(s) will respond to the input of the APPS. Therefore, additional actions are required by the driver to set the car to ready-to-drive-mode e.g. pressing a dedicated start button, after the tractive system has been activated. One of these actions must include the brake pedal being pressed as ready-to-drive-mode is entered.

EV4.11 Pre-Charge and Discharge Circuits

EV4.11.1 A circuit that is able to pre-charge the intermediate circuit to at least 90% of the current accumulator voltage before closing the second AIR must be implemented. This circuit must be disabled by a de-activated shutdown circuit, see EV5.1. Therefore, the pre-charge circuit must not be able to pre-charge the system, if the shutdown circuit is open.

EV4.11.2 Any pre-charge circuitry must be supplied directly from the TSMS

EV4.11.3 It is allowed to pre-charge the intermediate circuit for a conservatively calculated time, before closing the second AIR. A feedback via measuring the current intermediate circuit voltage is not required.

EV4.11.4 If a discharge circuit is needed to meet EV5.1.3, it must be designed to handle the maximum discharge current for at least 15 seconds. The calculation proving this must be part of the ESF.

EV4.11.5 The discharge circuit must be wired in a way that it is always active whenever the shutdown circuit is open. Furthermore, the discharge circuit must be fail-safe such that it still discharges the intermediate circuit capacitors if the HVD has been opened.

EV4.11.6 Fusing of the precharge and discharge circuits is prohibited.

EV4.12 Tractive System Active Light (TSAL)

EV4.12.1 The vehicles must include a single Tractive Systems Active Light (TSAL) that must illuminate when the voltage outside the accumulator container(s) exceeds 60V DC or 25V AC RMS. The TSAL must not perform any other functions.

EV4.12.2 The TSAL itself must:

a. Be directly controlled by the voltage present within the tractive system using hard wired electronics. Software control is not permitted.
b. Be red in color.
c. Flash continuously with a frequency between 2Hz and 5Hz when illuminated.

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EV4.12.3 The TSAL mounting location must:

a. Be near the main roll hoop at the highest point of the vehicle.
b. Be mounted lower than the highest point of the main roll hoop.
c. Be no lower than 150 mm from the highest point of the roll hoop.
d. Not allow contact with the driver's helmet in any circumstances.
e. Not be in proximity to other lights.

EV4.12.4 The TSAL must be visible:

a. From every horizontal direction, except small angles which are blocked by the main roll hoop.
b. From a point 1.6m vertically from ground level, within a 3m horizontal radius from the TSAL.
c. In direct sunlight.

EV4.13 Ready-To-Drive-Sound

EV4.13.1 The car must make a characteristic sound, continuously for at least 1 second and a maximum of 3 seconds when it is ready to drive.

EV4.13.2 The car is ready to drive as soon as the motor(s) will respond to the input of the APPS.

EV4.13.3 The sound level must be a minimum of 80dBA, fast weighting. The sound level will be measured with a free-field microphone placed free from obstructions in a radius of 2m around the car.

EV4.13.4 The used sound must be easily recognizable. No animal voices, song parts or sounds that could be interpreted as offensive will be accepted.

EV4.13.5 The vehicle must not make sounds similar to the ready to drive sound.

ARTICLE 5: SHUTDOWN CIRCUIT AND SYSTEMS

EV5.1 Shutdown Circuit

EV5.1.1 The shutdown circuit directly carries the current driving the accumulator isolation relays (AIRs).

EV5.1.2 The shutdown circuit consists of at least 2 master switches, 3 shut-down buttons, the brake-over-travel-switch, the insulation monitoring device (IMD), the inertia switch, the brake system plausibility device, all required interlocks and the accumulator management system (AMS).

EV5.1.3 If the shutdown circuit is opened/interrupted the tractive system must be shutdown by opening all accumulator isolation relay(s) and the voltage in the tractive system must drop to under 60V DC or 25V AC RMS in less than five seconds after opening the shutdown circuit. All accumulator current flow must stop immediately.

An explanatory schematic of the required shutdown circuit, excluding possibly needed interlock circuitry, is shown below.

Cell balancing when the accumulator isolation relays are open is not permitted.

EV5.1.4 If the shutdown circuit is opened by the AMS, the IMD or the BSPD the tractive system must remain disabled until being manually reset by a person directly at the car which is not the driver. Remote reset, for example via WLAN or use of the three shutdown buttons or the TS master switch to reset the AMS, IMD or BSPD is not permitted.

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EV5.1.5 It must not be possible for the driver to re-activate the tractive system from within the car in case of an AMS, IMD or BSPD fault.

For example: Applying an IMD test resistor between HV+ and GLV system ground must deactivate the system. Disconnecting the test resistor must not re-activate the system. The tractive system must remain inactive until it is manually reset.

EV5.1.6 All circuits that are part of the shutdown circuit must be designed in a way, that in the de-energized/disconnected state they are open such that each circuit will remove the current controlling the AIRs.

EV5.1.7 If the tractive system is de-activated while driving, the motor(s) has/have to spin free e.g. no brake torque must be applied to the motor(s).

EV5.1.8 In order to offer additional protection to the AIRs, it is allowed to use a capacitor to hold the AIRs closed for up to 250ms after removing the current source that keeps them closed, such that the motor controller has some opportunity to reduce the tractive current before the AIRs isolate the accumulator from the rest of the tractive system.

EV5.1.9 It must be possible to demonstrate that all features of the Shutdown circuit function correctly. It should be noted that this includes all interlocks.

EV5.1.10 Every system required or able to open the shut-down circuit must have its own, non-programmable power stage to achieve this. The respective power stages must be designed such that a failure cannot result in electrical power being fed back into the electrical shutdown circuit.

EV5.1.11 The Shutdown buttons, the brake over travel switch, the TSMS and all interlocks must not act through any power stage, but must directly carry the AIR current.

EV5.2 Master Switches

EV5.2.1 Each vehicle must have two Master Switches, the Grounded Low Voltage Master Switch (GLVMS) and the Tractive System Master Switch (TSMS).

EV5.2.2 The GLVMS must completely disable power to the GLV System and must be direct acting, i.e. it must not act through a relay or logic.

EV5.2.3 The GLVMS must be located on the right side of the vehicle, in proximity to the Main Hoop, at the driver's shoulder height and be easily actuated from outside the car.

EV5.2.4 The TSMS must be located next to the GLVMS and must open the shutdown circuit. The TSMS must be direct acting, i.e. it cannot act through a relay or logic, and must be the last switch before the AIRs except for pre-charge circuitry and hardwired interlocks. Interlocks between the TSMS and AIR's must not be in the low (ground) connection to the AIR coils.

EV5.2.5 The TSMS must be fitted with a "lockout/tagout" capability to prevent accidental activation of the tractive system. The electrical system officer must ensure that the TSMS is locked in the off position whenever work is done on the vehicle.

EV5.2.6 Both master switches must be of the rotary type, with a red, removable key, similar to the one shown in the explanatory shutdown circuit.

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EV5.2.7 The master switches must not to be easily removable, e.g. they must not be mounted onto removable body work.

EV5.2.8 The function of both switches must be clearly marked with “LV” and “HV”. A sticker with a red or black lightning bolt on a yellow background or red lightning bolt on a white background must additionally mark the Tractive System Master Switch.

EV5.2.9 Both master switches must be mounted so that the rotary axis of the key is near horizontal and across the car. The “ON” position of both switches must be in the horizontal position and must be marked accordingly. The “OFF” position of both switches must also be clearly marked.

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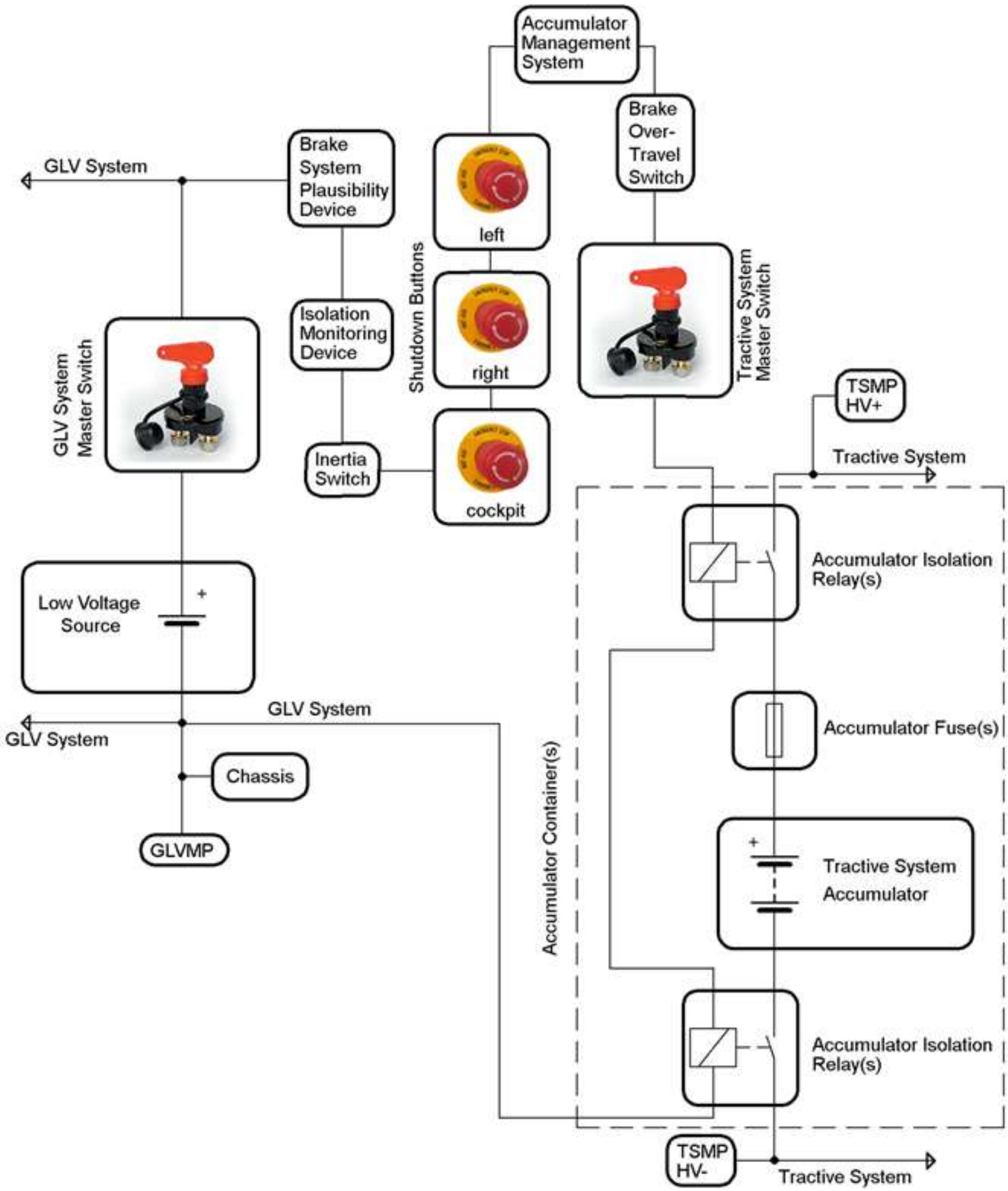

EV5.3 Shutdown Buttons

EV5.3.1 A system of three shut-down buttons must be installed on the vehicle.

EV5.3.2 Pressing any one of the shut-down buttons must separate the tractive system from the accumulator block by opening the shutdown circuit, see also EV5.1.

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EV5.3.3 Each shut-down button must be a push-pull or push-rotate emergency switch where pushing the button opens the shutdown circuit. The shut-down buttons must not act through programmable logic.

EV5.3.4 One button must be located on each side of the vehicle behind the driver's compartment at approximately the level of the driver's head. The minimum allowed diameter of the shutdown buttons on both sides of the car is 40 mm. The international electrical symbol consisting of a red spark on a white-edged blue triangle must be affixed in close proximity to this button.

EV5.3.5 One shutdown button serves as a cockpit-mounted Master Switch. The minimum allowed diameter of the shutdown button in the cockpit is 24 mm. The international electrical symbol consisting of a red spark on a white-edged blue triangle must be affixed in close proximity to this switch. It must be located to provide easy actuation by the driver in an emergency or panic situation. It must be located within easy reach of the belted-in driver, alongside the steering wheel, and unobstructed by the steering wheel or any other part of the car.

EV5.3.6 The shutdown buttons are not allowed to be easily removable, e.g. they must not be mounted onto removable body work.

EV5.4 Brake-Over-Travel-Switch

The Brake-Over-Travel-Switch as defined in T7.3 must shut down the tractive system by activating the shutdown circuit and opening the AIRs, see EV5.1.

EV5.5 Insulation Monitoring Device (IMD)

EV5.5.1 Every car must have an insulation monitoring device (IMD) installed in the tractive system.

EV5.5.2 The IMD must be a Bender A-ISOMETER ® iso-F1 IR155-3203 or -3204 or equivalent IMD approved for automotive use. Equivalency may be approved by the rules committee based on the following criteria: robustness to vibration, operating temperature range, IP rating, availability of a direct output, a self-test facility and must not be powered by the system which is monitored.

EV5.5.3 The response value of the IMD must be set to 500 Ohm / Volt, related to the maximum tractive system operation voltage.

EV5.5.4 In case of an insulation failure or an IMD failure, the IMD must open the shutdown circuit. This must be done without the influence of any programmable logic. See also EV5.1.4 and EV5.1.5 regarding the re-activation of the tractive-system after an insulation fault.

EV5.5.5 The status of the IMD must be shown to the driver by a red indicator light in the cockpit that is easily visible even in bright sunlight. This indicator must light up, if the IMD detects an insulation failure or if the IMD detects a failure in its own operation e.g. when it loses reference ground.
The IMD indicator light must be clearly marked with the lettering "IMD".

EV5.6 Brake System Plausibility Device (BSPD)

A standalone non-programmable circuit must be used on the car such that when braking hard (without locking the wheels) and when a positive current is delivered from the motor controller (a current to propel the vehicle forward), the AIRs will be opened. The current limit for triggering the circuit must be set at a level where 5kW of electrical power in the DC circuit is delivered to the motors at the nominal battery voltage. The action of opening the AIRs must occur if the implausibility is persistent for more than 0.5sec. This device must be provided in addition to the plausibility checks which are carried out by the controller which interprets the drivers torque request and delivers torque to the wheels. See also EV5.1.4 and EV5.1.5 regarding the re-activation of the tractive system after triggering of the BSPD.

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The team must devise a test to prove this required function during Electrical Tech Inspection. However, it is suggested that it should be possible to achieve this by sending an appropriate signal to the non-programmable circuit that represents the current to achieve 5kW whilst pressing the brake pedal to a position or with a force that represents hard braking.

EV5.7 Inertia Switch

EV5.7.1 All vehicles must be equipped with an inertia switch. This must be a Sensata Resettable Crash Sensor or equivalent.

EV5.7.2 The inertia switch must be part of the shutdown circuit and must be wired in series with the shutdown buttons such that an impact will result in the shutdown circuit being activated and the AIRs being opened. The inertia switch must latch until manually reset.

EV5.7.3 The device must trigger due to an impact load which decelerates the vehicle at between 6g and 11g depending on the duration of the deceleration (see spec sheet of the Sensata device).

EV5.7.4 The inertia switch may be reset by the driver from within the driver's cell.

EV5.7.5 The device must be mechanically attached to the vehicle; however, it must be possible to demount the device so that its functionality may be tested by shaking it.

EV5.8 Charging Shutdown Circuit

EV5.8.1 The charging shutdown circuit when charging consists of at least the charger shutdown button, the insulation monitoring device (IMD) and the accumulator management system (AMS).

EV5.8.2 If the shutdown circuit is opened by the AMS or the IMD the tractive system must remain disabled until it is manually reset.

EV5.8.3 The charging shutdown systems must comply with EV5.1.1, EV5.1.3, EV5.1.6, EV5.1.8, EV5.1.9 and EV5.1.10.

EV5.8.4 The charger must include a push type emergency stop button which has a minimum diameter of 25mm and must be clearly labeled.

ARTICLE 6: FUSING

EV6.1 Overcurrent Protection

EV6.1.1 All electrical systems (both low and high voltage) must have appropriate overcurrent protection.

The continuous current rating of the overcurrent protection must not be greater than the continuous current rating of any electrical component, for example wire, busbar, cell or other conductor that it protects.

Note: Fuses are the most common form of overcurrent protection.

EV6.1.2 All overcurrent protection devices must be rated for the highest voltage in the systems they protect. Overcurrent protection devices used for DC must be rated for DC, and must carry a DC rating equal to or greater than the system voltage.

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EV6.1.3 All overcurrent protection devices must have an interrupt current rating which is higher than the theoretical short circuit current of the system that it protects.

EV6.1.4 If multiple parallel batteries, capacitors, strings of batteries or strings of capacitors are used then each string must have individual overcurrent protection to protect all the components on that string. Any conductors, for example wires, busbars, cells etc. conducting the entire pack current must be appropriately sized for the total current that the individual overcurrent protection devices could transmit or additional overcurrent protection must be used to protect the conductors.

EV6.1.5 Battery packs with low or non-voltage rated fusible links for cell connections may be used provided that:

1. An overcurrent protection device rated at a current three times lower than the sum of the parallel fusible links and complying with Section EV6.1.1 is connected in series.
2. The accumulator monitoring system can detect an open fusible link, and will shut down the electrical system by opening the AIRs if a fault is detected.
3. Fusible link current rating is specified in manufacturer's data or suitable test data is provided.

EV6.1.6 Cells with internal over-current protection may be used without external overcurrent protection if suitably rated.

NOTE: Most cell internal over-current protection devices are low or non-voltage rated and conditions of EV6.1.5 will apply.

EV6.1.7 The ESF must include all details of internal and external over current protection including documentation from manufacturer for the particular series and parallel configuration, and string voltage.

ARTICLE 7: ELECTRICAL SYSTEM TESTS

EV7.1 Insulation Monitoring Device Test (IMDT)

EV7.1.1 The insulation monitoring device will be tested during Electrical Tech Inspection. This is done by connecting a resistor between the measuring points; see EV4.4, of the tractive system and several electrically conductive vehicle parts while the tractive system is active, as shown in the example below.

EV7.1.2 The test is passed if the IMD shuts down the tractive system within 30 seconds at a fault resistance of 50% below the response value corresponding to 250 Ohm / Volt.

EV7.1.3 The IMDT may be repeated at any time during the event. After the car passes the test for the first time, critical parts of the tractive system will be sealed. The vehicle is not allowed to take part in any dynamic event if any of the seals are broken until the IMDT is successfully passed again.

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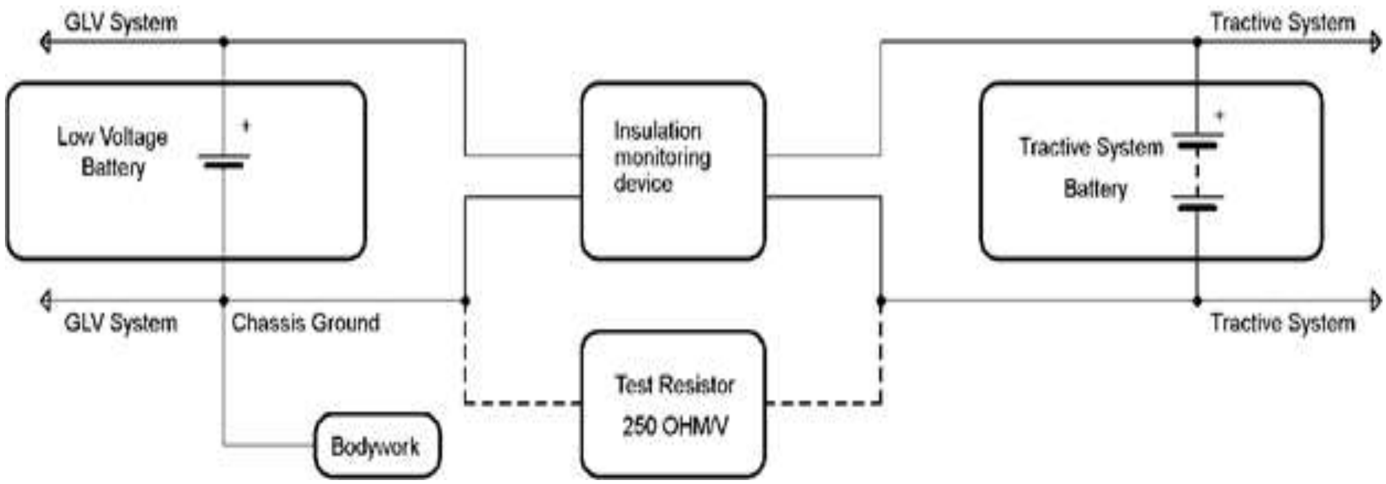

EV7.2 Insulation Measurement Test (IMT)

EV7.2.1 The insulation resistance between the tractive system and GLV system ground will be measured during Electrical Tech Inspection. The available measurement voltages are 250V and 500V. All cars with a maximum nominal operation voltage below 500V will be measured with the next available voltage level e.g. a 175V system will be measured with 250V, a 300V system will be measured with 500V etc. All teams with a system voltage of 500V or more will be measured with 500V.

EV7.2.2 To pass the IMT the measured insulation resistance must be at least 500 Ohm/Volt related to the maximum nominal tractive system operation voltage.

EV7.3 Rain test

EV7.3.1 Teams have to pass a rain test during Electrical Tech Inspection to be allowed to move the car under its own power on the event. The car must pass the IMDT; see EV7.1, before the rain test can be performed.

EV7.3.2 During the rain test the tractive system must be active and none of the driven wheels may touch the ground. The car must NOT be in ready-to-drive-mode. It is not allowed to have a driver seated in the car during the rain test.
Water will then be sprayed at the car from any possible direction for 120 seconds. The water spray will be rain like. Therefore, there will be no direct high-pressure water jet shot at the car.

EV7.3.3 The test is passed if the insulation monitoring device does not react while water is sprayed at the car and 120 seconds after the water spray has stopped. Therefore, the total time of the rain test is 240 seconds, 120 seconds with water-spray and 120 seconds without.

EV7.3.4 Teams have to make sure that water cannot aggregate anywhere in the chassis.

ARTICLE 8: HIGH VOLTAGE PROCEDURES & TOOLS

EV8.1 Working on Tractive System Accumulator Containers

EV8.1.1 Opening of or working on accumulator containers is only allowed in the charging area, see EV8.2, and during Electrical Tech Inspection.

EV8.1.2 Whenever the accumulator containers are opened the cell segments must be separated by using the maintenance plugs, see EV3.3.3.

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EV8.1.3 Whenever the Accumulator or tractive system is being worked on, only appropriate insulated tools may be used.

EV8.1.4 Safety glasses with side shields must be worn by all participating team members when (a) parts of the tractive system are exposed while it is active, or (b) work is being done on the accumulators.

EV8.2 Charging

EV8.2.1 There will be a separated charging area on the event site. Charging tractive system accumulators is only allowed inside this area.

EV8.2.2 Accumulators **must** be removed from the car for charging within a removable accumulator container and placed on the accumulator container hand cart for charging.

EV8.2.3 The accumulator containers must have a label with the following data during charging: Team name and Electrical System Officer phone number(s).

EV8.2.4 No grinding, drilling, etc. is allowed in the charging area.

EV8.2.5 At least one team member who has knowledge of the charging process must stay with the accumulator(s) / car during charging.

EV8.2.6 Moving accumulator cells and/or accumulator segment(s) around at the event site is only allowed inside a completely closed accumulator container.

EV8.3 Chargers

EV8.3.1 Only chargers presented and sealed at Electrical Tech Inspection are allowed. All connections of the charger(s) must be isolated and covered. No open connections are allowed.

EV8.3.2 All chargers must either be accredited to a recognized standard e.g. CE or where built by the team they must be built to high standards and conform with all electrical requirements for the vehicle tractive system, for example EV4.1, EV4.3 and EV4.6 as appropriate.

EV8.3.3 The charger connector must incorporate an interlock such that neither side of the connector become live unless it is correctly connected to the accumulator.

EV8.3.4 HV charging leads must be orange

EV8.3.5 When charging, the AMS must be live and must be able to turn off the charger in the event that a fault is detected.

EV8.3.6 When charging the accumulator, the IMD must be active and must be able to shut down the charger. Either the charger must incorporate an active IMD or an active IMD must be within the accumulator.

EV8.4 Accumulator Container Hand Cart

EV8.4.1 In order to accommodate charging, a hand cart to transport the accumulators must be presented at Electrical Tech Inspection.

EV8.4.2 The hand cart must have a brake such that it can only be released using a dead man's switch, i.e. the brake is always on except when someone releases it by pushing a handle for example.

EV8.4.3 The brake must be capable to stop the fully loaded accumulator container hand cart.

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EV8.4.4 The hand cart must be able to carry the load of the accumulator container(s).

EV8.4.5 The hand cart(s) must be used whenever the accumulator container(s) are transported on the event site.

EV8.5 Each team must present the following basic set of tools in good condition during technical inspection:

a. Insulated cable shears
b. Insulated screw drivers
c. Multimeter with protected probe tips
d. Insulated tools, if screwed connections are used in the tractive system
e. Face Shield
f. HV insulating gloves which are within test date
g. 2 HV insulating blankets of at least 1.0m² each
h. Safety glasses with side shields for all team members that might work on the tractive system or accumulator

All electrical safety items must be rated for at least the maximum tractive system voltage.

ARTICLE 9: ELECTRICAL SYSTEM FORM AND FMEA

EV9.1 Electrical System Form (ESF)

EV9.1.1 Prior to the event all teams must submit clearly structured documentation of their entire electrical system (including control and tractive system) similar to the SEF called electrical system form (ESF).

EV9.1.2 The ESF must visualize the interconnection of all electric components including the voltage level, the topology, the wiring in the car and the construction and build of the accumulator(s).

EV9.1.3 Teams must present data sheets with rated specifications for all tractive system parts used and show that none of these ratings are exceeded (including wiring components). This includes stress caused by the environment e.g. high temperatures, vibration, etc.

EV9.1.4 A template including the required structure for the ESF will be made available online – see website for your competition or www.fsaeonline.com.

EV9.1.5 The ESF must be submitted as Adobe PDF-File.

EV9.1.6 The minimum allowed font size is 11pts. The font used must be Arial. Small pictures and small schematics should be put inside the text for easy reference, not in the appendix.

EV9.1.7 Data sheets and large schematics should be put in the appendix.

NOTE: Passing the ESF does not mean that you automatically pass Electrical Technical Inspection with the described items / parts.

EV9.2 Failure Modes and Effects Analysis (FMEA)

EV9.2.1 Teams must submit a complete failure modes and effects analysis (FMEA) of the tractive system prior to the event.

EV9.2.2 A template including required failures to be described will be made available online – see your competition website for details.

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Do not change the format of the template. Pictures, schematics and data sheets to be referenced in the FMEA have to be included in the FMEA on additional table pages

EV9.3 Submission of the ESF or FMEA

Electrical Systems Form (ESF) or Failure Modes and Effects Analysis (FMEA) must be submitted in compliance with the procedure and by the deadline published on the website of the competition your team is attending.

EV9.4 Penalty for Late Submission or Non-submission

Penalties for Late Submission of the ESF or FMEA will be imposed per A8.4.1.

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