GLV Systems Test Plan

ECE 492 - Spring 2015

Abstract

This document details the acceptance test plan for the Grounded Low Voltage system being developed for the LFEV design project. This is only a test plan draft, and will be replaced by a more specific document in the future.

Revision 4.0.0

GLV Team

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Summary

The grounded low voltage system (GLV) being designed and developed in the LFEV project is intended to power all of the vehicle's elements, except for the tractive system. To verify the operation of the GLV system, the following subsystems must be designed and tested:

- GLV Power: This system is responsible for powering all aspects of the vehicle except for the tractive system. The power system must run on a rechargeable battery and last for at least three hours.
- Safety: This system runs the shutdown circuit and safety loop. If any device detects a failure, or if a user engages a shutdown button, the system will shut down according to the procedure outlined in the EV.
- Tractive System Interface (TSI): This system acts as an interface between the tractive system voltage and the grounded low voltage. Specifically, it is responsible for requirements associated with galvanic isolation, the insulation monitoring device (IMD), the tractive system active light (TSAL), and the TSV load controller.
- Vehicle Computer Interface (VCI): This system acts as an interface between the VSCADA software and the rest of the vehicle. Specifically, it must interface vehicle sensors and the system computer.

Requirements Matrix

Use the requirements matrix to follow as a reference to the individual Test Plan used to demonstrate each requirement.
Note: Any item that has been strikethrough (~~example~~) is to be considered Out Of Scope (OOS).

Req.	Description	Subsystem	Functional Requirement/Interface	Requirement Check Type
R000	**Formula Hybrid Competition Rules**	**TSI, Power, VCI, Safety**	**The final LFEV shall meet all requirements given in the Formula Hybrid rules for 2015.** **The initial goal for competition entry shall be the pure electric vehicle (EV) category.**	
EV1.2.2	GLV Max Voltage	Power	The GLV system may not have a voltage greater than 30 VDC or 25 VAC.	**TEST** T1.0
EV1.2.3	GLV Grounding	Power	The GLV system must be grounded to the chassis (RESCOPE: Use frame of car instead of chassis).	**OUT OF SCOPE**
EV1.2.4	GLV/ TSV Isolation	TSI	The tractive and GLV system must be galvanically isolated from one another.	**TEST** T3.3
EV1.2.7	GLV Powerup/ Shutdown	Safety	The GLV system must be powered up before it is possible to activate the tractive system. (See EV4.7). Furthermore, a failure causing the GLV system to shut down must immediately deactivate the tractive system as well (RESCOPE: Inherent in the safety loop tests).	**TEST** T2.0
EV1.3.1	Electrical Insulation	TSI, Power, VCI, Safety	All Electrical insulating materials used must: (a) be UL recognized (i.e, have an Underwriters Laboratories (www.UL.com) or equivalent rating and certification). (b) be rated for the maximum expected operating temperatures at the location of use or (c) have a minimum temperature rating of 90C. (Whichever is greater) Note: Electrical insulating barriers used to meet the requirements of EV4.1.5 for separation of tractive system and GLV wiring must be rated for 150 ºC.	**INSPECTION** I-1
EV1.3.2	Prohibited Insulators	TSI, Power, VCI, Safety	Vinyl electrical insulating tape and rubber-like paints and coatings are not acceptable electrical insulating materials.	**INSPECTION** I-1
EV2.2	Accelerator Signal Limits	**OUT OF SCOPE**	~~All analog acceleration control signals (between accelerator pedal and motor controller) must have error checking which can~~	**OUT OF SCOPE**

	Check		~~detect open circuit, short to ground and short to sensor power and will~~ ~~shut down the torque production in less than one (1) second if a fault is detected.~~ ~~The accelerator signal limit shutoff may be tested during electrical tech inspection by replicating any of the fault conditions listed in EV2.2.1~~	
EV3.3.1	TSV Container Electrical Requirement	TSI	All conductive surfaces on the outside of the container must have a low-resistance connection to the GLV system ground. All conductive penetrations (mounting hardware, etc.) must be located outside of the insulation and configured such that there is no possibility that they could penetrate the insulating barrier.	**INSPECTION** I-2
EV3.7	GLV System specific	Power	EV3.7.1 All GLV batteries 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 and include a layer of 1.5mm of aluminum or equivalent between the container and driver.~~ EV3.7.3 The hot (ungrounded) terminal must be insulated. ~~EV3.7.4 Battery packs based on Lithium Chemistry other than LiFePO4 must have over-voltage, undervoltage, short circuit and over-temperature cell protection.~~ ~~EV3.7.5 A team built Lithium LV battery pack may be used, but details on how the required protection is achieved must be included as part of the ESF submission.~~ EV3.7.6 One terminal of the GLV battery or other GLV power source must be connected to the chassis by a ground wire. The ground wire must be sized adequately for the GLV system fusing. The ground wire must be robustly secured and protected from mechanical damage. Note that minimizing the length of the ground wire is also recommended.	**INSPECTION** I-3 I-4
~~**EV3.8**~~	~~Pouch type Lithium Ion Cells~~	~~Power~~	~~EV3.8.1~~ ~~EV3.8.2~~ ~~EV3.8.3~~ ~~EV3.8.4~~ ~~EV3.8.5~~ ~~EV3.8.6~~	**N/A** Pouch cells not used.
EV4.1	Separation of Tractive System and Grounded Low Voltage System	TSI	EV4.1.1 The layout of electrical devices designed by the team must be documented accurately in the ESF.	**DOCUMENT** See ESF
			~~EV4.1.2 There must be no electrical connection between the frame of the vehicle (or any other conductive surface that might be inadvertently touched by a crew member or spectator), and~~	**N/A** Handled by TSV

			~~any part of any tractive system circuits.~~	
			EV4.1.3 Tractive system and GLV circuits must be physically segregated. I.e. they may not run through the same conduit or connector, except for interlock circuit connections.	**INSPECTION** I-5
			~~EV4.1.4 GLV circuits must not be present in the accumulator container except for required purposes, for example the AMS and AIR. This must be demonstrated in the ESF submission.~~	**N/A** Handled by TSV
			EV4.1.5 Where both tractive system circuits and GLV circuits are present within an enclosure, they must be (a) separated by electrical insulating barriers meeting the requirements of EV4.1.6 or (b) separated by the spacings shown in Table 15 through air, or over a surface (similar to those defined in UL1741): Insulating barriers used to meet the requirements of EV4.1.5 (c) Must be UL recognized as electrical insulating materials for a temperature of 150 ºC or higher. (d) Must be adequately robust for the application and in no case thinner than 0.25 mm (0.010”). (e) Must be in addition to wire insulation. (f) Must extend far enough at the edges to block any path between uninsulated GLV and tractive-system conductors shorter than the distances specified in Table 15.	**INSPECTION** I-6
			EV4.1.6 Spacing must be clearly defined. Components and cables capable of movement must be positively restrained to maintain spacing.	**INSPECTION** I-6
			EV4.1.7 If tractive system circuits and GLV circuits are on the same circuit board they must be on separate, clearly defined areas of the board. Furthermore, the tractive system and GLV areas must be clearly marked on the PCB. Required spacing between GLV and TS circuits is as shown in Table 16. If a cut or hole in the board is used to allow the “through air” spacing, the cut must not be plated with metal, and the distance around the cut must satisfy the “over surface” spacing requirement.	**INSPECTION** I-7
			EV4.1.8 Teams must be prepared to demonstrate spacings on team-built equipment. Information on this must be included in the ESF (EV9.1). Spare boards and photographs must be available for inspection. Teams should also be prepared to remove boards for direct inspection if asked to do so during the technical inspection.	**DOCUMENT** See ESF **INSPECTION** I-6, I-7, I-15 I-16
			EV4.1.9 Plated prototyping boards having plated holes and/or generic conductor patterns may not be used for applications where both GLV and TS circuits are present on the same board. Bare perforated board may be used, if the spacing and marking requirements (EV4.1.7 and EV4.1.8) are met, and if the board is easily removable for inspection.	**INSPECTION** I-7

EV4.3	Grounding	All GLV Systems	EV4.3.1 All accessible metal parts of the vehicle, except conductors and components of the GLV system, must have a resistance below 300 mΩ (measured with a current of 1A) to GLV system ground. NOTE: Accessible parts include that those that are exposed in the normal driving configuration or when the vehicle is partially disassembled for maintenance or charging.	**TEST** T5.0
			EV4.3.2 All accessible parts of the vehicle containing conductive material (e.g. coated metal parts, carbon fiber parts, etc.) which might contact a damaged wire or electrical part, no matter if tractive system or GLV, must have a resistance below 5 ohm to GLV system ground.	**TEST** T5.0
			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 bolts. 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 modifications to keep the ground resistance below 5 ohms. NOTE: Conductors used for grounding shall be stranded and 16 AWG minimum.	**TEST** T5.0
EV4.4	Tractive System Measuring Point	TSI	EV4.4.8 Next to the TSMP, a GLV system ground measuring point must be installed. This measuring point must be connected to the GLV system ground.	**INSPECTION** I-8
			EV4.4.9 A 4 mm safety banana jack that accepts shrouded (sheathed) banana plugs with non-retractable shrouds must be used for the GLV ground measuring point. See Figure 29 for examples of the correct jacks and of jacks that are not permitted because they do not accept the required plugs (also shown).	**INSPECTION** I-8
EV4.6	Tractive System Enclosures	TSI	EV4.6.1 Every housing or enclosure containing parts of the tractive system except motor housings must be labeled with sticker(s) (minimum 4 x 4 cm) 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 30 VDC or 25 VAC.	**INSPECTION** I-9
			EV4.6.2 If the housing material is electrically conductive, it must have a minimum-resistance connection to GLV system ground.	**TEST** T5.0
			EV4.6.3 If external, un-insulated heat sinks are used, they must be properly grounded to the GLV system ground.	**TEST** T5.0
EV4.8	Activating the Tractive System	TSI	EV4.8.1 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 or IMD have shut down the tractive system; see EV5.1.5.	**TEST** T2.6
			EV4.8.2 Resetting or re-activating the tractive system by	**TEST**

			operating controls which cannot be reached by the driver is considered to be working on the car.	T2.0
			EV4.8.3 At least one action in addition to enabling the shutdown circuits is required to 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 torque control sensor / acceleration pedal.) For example, the additional action could be pressing a dedicated "start" button. However this must be configured such that it cannot inadvertently be left in the "on" position after system shutdown. Note: This action may also be used to trigger the required "Ready to drive" sound. (See EV4.11)	**TEST** T2.6
EV4.9	Pre-Charge and Discharge Circuits	TSI	EV4.9.1: The AIR contacts must be protected by a circuit that is able to pre-charge the intermediate circuit to at least 90% of the rated accumulator voltage before closing the second AIR. 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.	**TEST** T3.1
			EV4.9.2: It is allowed to pre-charge the intermediate circuit for a conservatively calculated time before closing the second AIR. A feedback via monitoring the intermediate circuit voltage is not required.	**TEST** T3.1
EV4.10	Tractive-System-Active Light (TSAL)	VCI	~~EV4.10.1 The car must be equipped with a TSAL mounted under the highest point of the main roll hoop which must be lit and clearly visible any time the AIR coils are energized.~~ EV4.10.2 The TSAL must be red or amber. (RESCOPE: Use a test lamp for demonstration purposes.) EV4.10.3 The TSAL must flash continuously with a frequency between 2 Hz and 5 Hz. ~~EV4.10.4 It must not be possible for the driver's helmet to contact the TSAL~~ ~~EV4.10.5 The TSAL must be clearly visible from every horizontal direction, (except for the small angles which are covered by the main roll hoop) even in very bright sunlight.~~ ~~EV4.10.6 The TSAL must be visible from a person standing up to 3m away from the TSAL itself. The person's minimum eye height is 1.6m.~~ ~~NOTE: If any official e.g. track marshal, scrutineer, etc. considers the TSAL to not be easily visible during track operations the team may not be allowed to compete in any dynamic event before the problem is solved~~	**TEST** T4.3

			~~EV4.10.7 It is prohibited to mount other lights in proximity to the TSAL~~	
EV4.11	Ready- To- Drive- Sound	VCI	EV4.11.1 The car must make a characteristic sound, for a minimum of 1 second and a maximum of 3 seconds, when it is ready to drive. (See EV4.8.3-At least one action in addition to enabling the shutdown circuits is required to set the car to ready to-drive mode, such as a dedicated "start" button) (CHANGE OF SCOPE: Offical buzzer will not be purchased and will be substituted for a buzzer already owned)	**TEST** T4.0
			~~EV4.11.2 The emitting device must produce a tone of approximately 2500 to 3500 Hz with a minimum loudness of 68 dB(A) at 2 ft. One device that meets this requirement is the Mallory Sonalert SC648AJR11.~~ ~~The emitting device must be located and oriented so as to be easily audible from in front of the vehicle in noisy environments.~~ (RE-SCOPE: Provide power to the speaker and modify the amplifier so the speaker meets the above requirements.)	**TEST** T4.0
EV4.12	Tractive System Voltage Present (TSVP) Indicators	TSI	~~There must be two TSVP lamps. One mounted on each side of the roll bar in the vicinity of the side-mounted shutdown buttons (EV5.3.3) that can easily be seen from the sides of the vehicle.~~ ~~EV4.12.1 They must be red, complying with DOT FMVSS 108 for trailer clearance lamps. See Figure 30~~ EV4.12.2 They must be lit and clearly visible any time the voltage outside the accumulator containers exceeds 30 VDC or 25 VAC RMS. EV4.12.3 The TSVP system must be powered entirely by the tractive system and must be directly controlled by voltage being present at the output of the accumulator (no software control is permitted). TS wiring and/or voltages must not be present at the lamps themselves. Note: This requirement may be met by locating an isolated dc-dc converter inside a TS enclosure, and connecting the output of the dc-dc converter to the lamps. Although the wiring from the dc-dc converter to the TSVP lamps must not be connected to the main GLV system, it must be ground-referenced by connecting one side of it to the frame or GLV ground in order to comply with EV1.1.4 and EV1.2.3.	**TEST** T3.0
EV4.9.5	After Automatic Shutdown	Safety	Pre-charge circuit must operate regardless of the sequence of operations used to energize the vehicle, including after automatic safety shut down.	**TEST** T2.0
EV5.1	Shutdown Circuit	Safety	EV5.1.1 The shutdown circuit must directly carry the current driving the accumulator isolation relays (AIRs). EV5.1.2 The shutdown circuit consists of at least 2 master	**TEST** T2.1 **ANALYSIS**

			switches, 3 shut-down buttons, the brake-over-travel-switch (BOTs), the insulation monitoring device (IMD), all required interlocks and the accumulator management system (AMS). EV5.1.3 If the shutdown circuit is opened/interrupted the tractive system must be shut down by opening all accumulator isolation relay(s). The voltage in the tractive system must drop to under 30 VDC or 25 VAC RMS in less than five seconds after opening the shutdown circuit. EV5.1.4 An example schematic of the required shutdown circuit, excluding possibly needed interlock circuitry, is shown in Figure 33. 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 or IMD fault. Remote reset, for example via WLAN or use of the three shutdown buttons or TSMS to reset the AMS or IMD is not permitted Note: Applying an IMD test resistor between tractive system positive 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 If the tractive system is deactivated while driving, the motor(s) must spin free, e.g. no braking torque may be derived from the motor(s).~~ (TSV) EV5.1.7 The recommended sequence of operation of the shutdown circuit and related systems is shown in the form of a state diagram in Figure 31. Teams are required to either: (a) Demonstrate that their vehicle operates according to this state diagram (b) Obtain approval for an alternative state diagram by submitting an electrical rules query on or before the ESF submission deadline, and demonstrate that the vehicle operates according to the approved alternative state diagram. EV5.1.8 If the shutdown circuit operates differently from the standard or approved alternative state diagram during inspection, the car will be considered to have failed inspection, regardless of whether the way it operates meets other rules requirements.	A-1
EV5.2	Master Switches	Safety	EV5.2.1 Each vehicle must have two Master Switches: (a) Grounded Low Voltage Master Switch (GLVMS) (b) Tractive System Master Switch (TSMS). EV5.2.2 The GLVMS must: (a) Disable power to ALL electrical circuits, including the alternator, lights, fuel pump(s), ignition and electrical controls.	**TEST** T2.2 **ANALYSIS** A-2

			(b) All battery current must flow through this switch. (c) Be of a rotary type and must be direct acting, i.e. it cannot act through a relay. ~~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. EV5.2.5 Both master switches must be of the rotary type, with a red, removable key, similar to the one shown in the explanatory shutdown circuit and in Figure 32. ~~EV5.2.6 The master switches are not allowed to be easily removable, e.g. mounted onto removable body work.~~ EV5.2.7 The function of both switches must be clearly marked with "GLV" and "TSV". 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. EV5.2.8 The "ON" position of both switches must be parallel to the fore-aft axis of the vehicle.	
EV5.3	Shutdown Buttons	Safety	EV5.3.1 A system of three shut-down buttons ("Big Red Buttons" or BRBs) must be installed on the vehicle. EV5.3.2 Each shut-down button must be a push-pull or push-rotate switch where pushing the button opens the shutdown circuit. The shut-down buttons must not act through logic, e.g. a micro-controller. EV5.3.3 Pressing any of the shut-down buttons must separate the tractive system from the accumulator by opening the shutdown circuit, and must also kill the engine and fuel pumps; see EV5.1. ~~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.~~ EV5.3.5 In addition to the requirements in EV5.3.3, the side-mounted shutdown buttons must also shut down all electrical systems. (See Table 17) Note: Electronic systems may have local energy storage sufficient to allow an orderly shutdown of operations upon the loss of GLV, but must be prevented from feeding power back into the GLV.	**TEST** T2.3

			~~EV5.3.6 One shutdown button is mounted in the cockpit and must be easily accessible by the driver in any steering wheel position.~~ The minimum allowed diameter of the shutdown button in the cockpit is 24 mm. The cockpit mounted button must comply with EV5.3.3, but is not required to de-energize control, instrumentation or telemetry. (See Table 17) EV5.3.7 If the shutdown circuit is opened by the cockpit-mounted shutdown button, it must be driver resettable. For example: If the driver disables the system by pressing the cockpit-mounted shutdown button, the driver must then be able to restore system operation by pulling the button back out. Note: There must be one additional action by the driver after pulling the button back out to reactivate the motor controller and make the vehicle ready-to-drive, per EV4.8.3. ~~EV5.3.8 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	Safety	~~EV5.4.1 The brake over-travel switch, as defined in T7.3, must shut down:~~ ~~(a) The tractive system by opening the shutdown circuit (see EV5.1) and~~ ~~(b) the engine and fuel pumps, as illustrated in Table 17.~~ ~~EV5.4.2 The Brake over-travel switch may not be driver resettable. See T7.3.2.~~	**OUT OF SCOPE**
EV5.5	Insulation Monitoring Device (IMD)	TSI, Safety	EV5.5.11 Every car must have an insulation monitoring device (IMD) installed in the tractive system.	**TEST** T3.3
			EV5.5.2 The IMD must be a Bender A-ISOMETER ® iso-F1 IR155-3203 or IR155-3204 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, availability of a direct output, a self-test facility and must not be powered by the system which is monitored.	**INSPECTION** I-10
			EV5.5.3 The response value of the IMD needs to be set to 500 ohm / volt, related to the maximum tractive system operation voltage.	**TEST** T3.3
			EV5.5.4 In case of an insulation failure or an IMD failure, the IMD must shut down all the electrical systems, open the AIRs and shut down the I.C. drive system. (See Table 17) This must be done without the influence of any logic (e.g., a micro-controller).	**TEST** T3.3
			EV5.5.5 The tractive system must remain disabled until manually reset by a person other than the driver. It must not be possible	**TEST** T3.3

			for the driver to re-activate the tractive system from within the car in case of an IMD-related fault. (See Appendix H – Example Relay Latch Circuits.) Note: The electrical inspectors may test the IMD by applying a test resistor between tractive system positive (or negative) and GLV system ground. This must deactivate the system. Disconnecting the test resistor must not re-activate the system.	
			EV5.5.6 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.	**TEST** T3.3
			EV5.5.7 The IMD indicator light must be clearly marked with the lettering “IMD” or “GFD” (Ground Fault Detector).	**INSPECTION** I-11
			EV5.5.8 The IMD ground connection must be wired according to the manufacturer's instructions so that the reference ground detector is functional.	**ANALYSIS** A-2
EV6.1	Fusing	Safety, TSI, VCI, Power	EV6.1.1 All electrical systems (including tractive system, grounded low voltage system and charging system) must be appropriately fused. Note: For further guidance of fusing, see the Fusing Tutorial on the Formula Hybrid Web site.	**ANALYSIS** A-3
			EV6.1.2 The continuous current rating of a fuse must not be greater than the continuous current rating of any electrical component, for example, wire, busbar, battery cell or other conductor that it protects. See Appendix E for ampacity rating of copper wires.	**ANALYSIS** A-3
			EV6.1.3 All fuses and fuse holders must be rated for the highest voltage in the systems they protect. Fuses used for DC must be rated for DC, and must carry a DC rating equal to or greater than the system voltage of the system in which they are used.	**INSPECTION** I-12 **ANALYSIS** A-3
			EV6.1.4 All fuses must have an interrupt current rating which is higher than the theoretical short circuit current of the system that it protects.	**INSPECTION** I-12 **ANALYSIS** A-3
			EV6.1.5 The fuse protecting a circuit must be physically located at the end of the wiring closest to an uncontrolled energy source (e.g., a battery). Note: For this rule, a battery is considered an energy source even for wiring intended to charge the battery, because current could flow in the opposite direction in a fault scenario.	**INSPECTION** I-13
			EV6.1.6 Circuits with branches using smaller wire than the main	**Analysis**

			circuit require fuses located at the branching point, if the branch wire is too small to be protected by the main fuse for the circuit.	A-3
			~~EV6.1.8 If multiple parallel strings of batteries or capacitors are used then each string must be individually fused. If individual fuses are used this must provide a total fusing equal to the number of fuses multiplied by the fuses rating. Any conductors, for example wires, bus bars, cells etc. conducting the entire pack current must be appropriately sized to this total fusing or an additional fuse must be used to protect the conductors.~~	**N/A** Single string of GLV Batteries used
			EV6.1.11 The ESF must include all details of fuse and fusible link and internal over current protection including documentation from manufacturer for the particular series and parallel configuration, and string voltage.	**DOCUMENT** See ESF
EV7.1	Electrical Systems Tests	TSI	EV7.1.1 The insulation monitoring device will be tested during Electrical Tech Inspection. This is done by connecting a resistor between the TSMP (see EV4.4) and several electrically conductive vehicle parts while the tractive system is active, as shown in the example below.	**TEST** T3.3
			EV7.1.2 The test is passed if the IMD shuts down the tractive system within 30 seconds at a fault resistance of 250 ohm / volt (50% below the response value).	**TEST** T3.3
			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 participate in any dynamic event if any of the seals are broken until the IMDT is successfully passed again.	**TEST** T3.3
EV 7.2	Insulation Measurement Test (IMT)	TSI	EV7.2.1 The insulation resistance between the tractive system and control system ground will be measured during Electrical Tech Inspection. The available measurement voltages are 250 V and 500 V. All cars with a maximum nominal operating voltage below 300 V will be measured with the next available voltage level. For example, a 175 V system will be measured with 250 V; a 300 V system will be measured with 500 V etc.	**TEST** T5.2
			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.	**TEST** T5.0
EV8.2	Charging	Power	EV8.2.11 All chargers must be UL (Underwriters Laboratories) listed. Any waivers of this requirement require approval in advance, based on documentation of the safe design and construction of the system, including galvanic isolation between the input and output of the charger. Waivers for chargers must be submitted at least 30 days prior to the start of the	**INSPECTION** I-14 **ANALYSIS** A-3

			competition. EV8.2.12 The vehicle charging connection must be appropriately fused for the rating of its connector and cabling in accordance with EV6.1.1.	
EV8.3.6	Safety Ratings	Safety	All electrical safety items are rated for (at least) the maximum tractive system voltage.	**INSPECTION** **ANALYSIS** A-1
EV9.1	Electrical System Form (ESF)	Safety, TSI, VCI, Power	EV9.1.1 All teams must submit clearly structured documentation, prior to the posted deadline, of their entire electrical system (including control and tractive system) called the Electrical System Form (ESF). EV9.1.2 The ESF must illustrate 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 pages 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. EV9.1.5 The ESF must be submitted as an Adobe PDF file. Data pages and large schematics should be put in an appendix.	**DOCUMENT** See ESF Document
EV9.2	Failure Modes and Effects Analysis (FMEA)	Safety, TSI, VCI, Power	~~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.~~ ~~Note: Do not change the format of the template. Pictures, schematics and data sheets to be referenced in the FMEA must be included in the ESF.~~	**OUT OF SCOPE**
Req.	**Description**	**Subsystem**	**Functional Requirement/Interface**	**Requirement Check Type**
R002	**VSCADA Sensor Integration**	**VCI**	**The VSCADA must be connected to all sensors**	
R002-0	Required Sensors	VCI, TSI	~~R002-0.1 Power, Current, and Voltage to Load~~ (Handled by Dyno) ~~R002-0.2 Tractive System DC current and motor phase current~~ (Handled by TSV)	**TEST** T5.1

			~~R002-0.3 Rate of charge/discharge of accumulator and individual cells~~ (Handled by TSV) R002-0.4 System Temperatures- (Temperatures within each GLV box) ~~R002-0.5 Data from GPS / INS~~	
R002-1	Uncertainty of measurements	VCI	R002-1.1 Uncertainty of all measurands shall be analyzed and specified in D011 and a Calibration and Error Analysis document required.	**DOCUMENT** See Calibration and Accuracy
			~~R002-1.2 Each measurand shall have programmable sampling rates~~. (see VSCADA)	**OUT OF GLV SCOPE**
Req.	**Description**	**Subsystem**	**Functional Requirement/Interface**	**Requirement Check Type**
R006	**GLV Power**	**Power**	**Supply power for all non-tractive systems**	
R006-0	DC GLV Power	Power	The GLV system shall provide DC supply voltage with sufficient current to supply all the power needs of the GLV systems and other non-tractive systems.	**TEST** T1.1
R006-1	Rechargeable Battery	Power	The GLV system shall contain a rechargeable battery of sufficient capacity to run the car GLV systems for at least three hours.	**TEST** T1.1
R006-2	Charging Specifications	Power	i) The GLV system shall be rechargeable by means of a UL listed charging device that plugs into the 120 VAC mains. ii) The charging system shall be capable of powering the GLV system indefinitely as it simultaneously charges the GLV battery in a plug and forget functionality in a manner similar to typical laptop computers or cell phones. iii) It shall be possible to charge a fully discharged GLV battery without disassembly or special actions. iv) The GLV battery shall be protected from full discharge, overcharge, overcurrent, and overvoltage.	**TEST** i T1.0 ii T1.0 iii T1.2 iv T1.0 T1.2
R006-3	Power Management	Power	Power management software and hardware should allow the GLV system to safely sit idle without fear of over-discharge and damage.	**TEST** T1.2
R006-4	GLV Data Measurement	Power	GLV voltage, ~~current,~~ temperature, and ~~SOC~~ shall be measured by VSCADA (RESCOPE does not include current sensing).	**TEST** T5.1
Req.	**Description**	**Subsystem**	**Functional Requirement/Interface**	**Requirement**

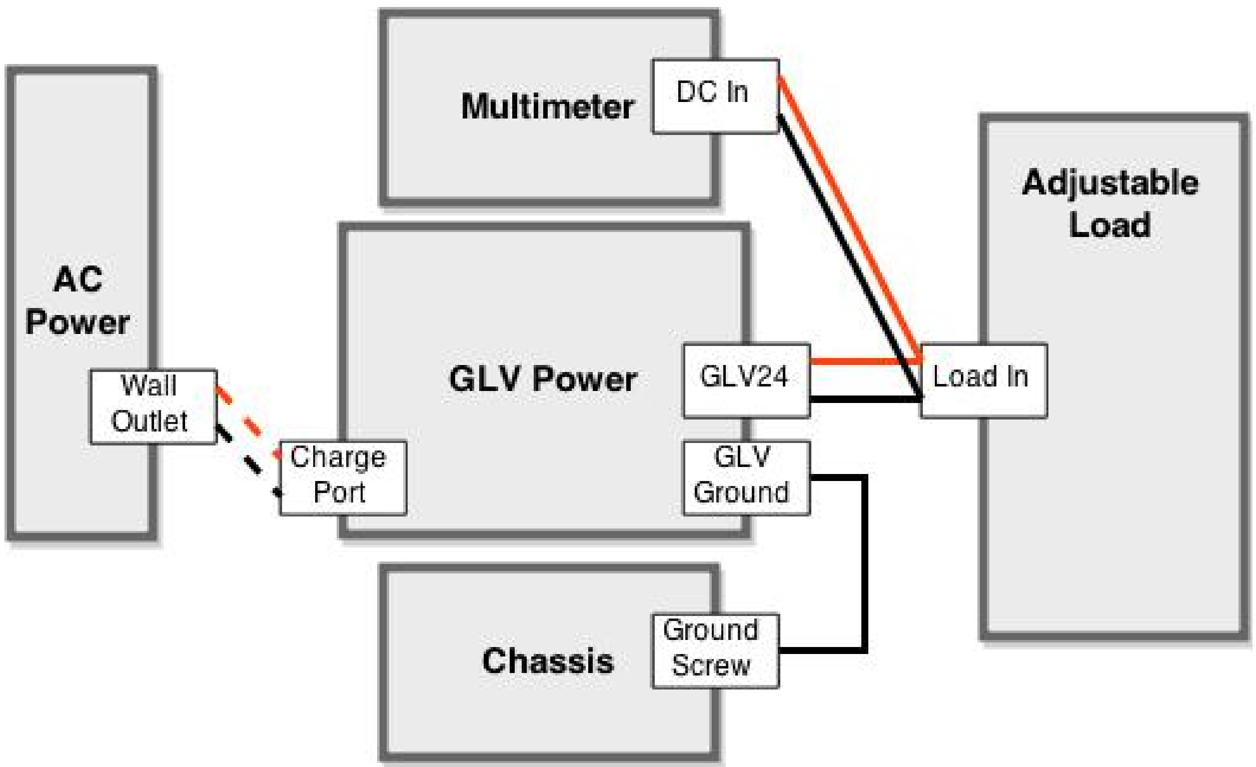
				Check Type
R007	**Safety Loop**	**Safety**	**Review the existing safety loop design and revised to improve electrical and mechanical performance, reliability, and maintainability.**	
R007-0	Easily Integratable	Safety	The safety loop system shall be packaged so it is straightforward to integrate with the car The safety loop system shall be packaged so as to be fully compliant with all Formula EV rules, including shock, vibration, temperature, and humidity (including rain).	**INSPECTION** I-15
R007-1	Cabling	Safety	The cabling requirements for car installation shall be analyzed and a set of safety cables suitable for use on the car shall be designed, fabricated, and tested. Cables required to support the MCS Test Stand shall be designed, fabricated, and tested.	**INSPECTION** I-15
R007-2	Safety Loop Analysis Document	Safety	The Safety Loop Analysis Document shall justify the design of the safety loop. Possible faults and risks shall be analyzed. Discussion and justification of the 4-wire loop versus 2-wire loop is required.	**DOCUMENT** Safety Loop Analysis Document
R007-3	Previous Years	Safety	Be familiar with, use, and improve upon the safety function and documentation from previous years.	**COMPLETE**
Req.	**Description**	**Subsystem**	**Functional Requirement/Interface**	**Requirement Check Type**
R008	**TSV Load Controller** [TSI]	**TSI**	**Review and revise existing design to improve electrical and mechanical performance, reliability, and maintainability**	
R008-0	Easily Integratable	TSI	The load controller [TSI] system shall be packaged so it is straightforward to integrate with the car. The load controller [TSI] shall be packaged so as to be fully compliant with all Formula EV rules, including shock, vibration, temperature, and humidity (including rain).	**INSPECTION** I-16
R008-1	Cabling	TSI	The cabling requirements for load controller shall be analyzed and a set of GLV and TSV suitable for use on the car shall be designed, fabricated, and tested. In addition, cables required to support the MCS Test Stand shall be designed, fabricated, and tested.	**INSPECTION** I-16
R002	TSV Measurment	TSI	The overall voltage delivered to the load must be monitored and stored my VSCADA	**TEST** T3.2

GLV Power

The GLV Power subsystem provides power to all of the non-tractive systems in the electric vehicle. This includes the rest of the GLV system, TSV AIRS, VSCADA computer, Motor, and Motor Controller. The Power subsystem consists of a Power Box, which houses the battery and a Power Monitor. This Power Box has a Charging Port, circuit breaker, and multiple LEDS. The following tests will be performed to demonstrate that GLV Power meets all requirements.

Testing Configurations

Configuration A:



T1.0: GLV Charging + Max Voltage Test Passed: Y__ N__

This test ensures that the GLV system is rechargeable by means of a UL listed charging device that plugs into the 120 VAC mains. The ability for the charging system to power the GLV system indefinitely as it simultaneously charges the GLV battery in a *plug and forget* functionality is also tested. The battery's protection from full discharge and overcharge is also tested. Finally, correct LED function is also tested.

Test Configuration: A

Preconditions

- The GLV Power Box is securely mounted to the rack.
- The GLV Ground terminal is connected to the designated screw terminal on the rack. This will represent chassis ground.
- The Power Supply being used for charging is UL listed and plugs into the 120 VAC mains.

Test Procedure

1. Attach the Power Box to the rear of the adjustable load. Use a cable with the correct TE 3 Pin Connector on one end and two crimped terminals on the other.
2. Turn on the AC Power button on the load. Press the CURR button underneath the adjustable load knob. Turn on DC Power.
3. Turn the adjustable load knob until the current value is 2A. Record the time.
4. Monitor the Power Box voltage. Probe the terminals on the rear of the adjustable load with a multimeter for increased accuracy.
5. When the GLV24V <26V attach the charger to the charge port and record the time. Ensure that the "Charging" LED turns on and the "Battery Power" LED remains on.
6. Monitor the voltage. Once the voltage reaches >28.5V the Power Box should throw an internal switch to deactivate charging. Ensure the "Charging" LED turns off and the "Battery Power" LED remains on. Record the time and the maximum voltage.
7. Monitor the voltage. Once the voltage reaches <22.5V the internal switch should close to reactivate charging. Ensure the "Charging" LED turns back on and the "Battery Power" LED remains on. Record the time.

Acceptance Threshold

1. GLV Power to the adjustable load is not interrupted when the charger is connected, disconnected, or any time while the charger is connected.
2. The GLV24 voltage never reaches >28.5V.
3. The GLV24 voltage never reaches <24.5V.

T1.1: GLV Power and Battery Duration Test Passed: Y__ N__

This test ensures that the GLV system provides a DC supply voltage with sufficient current to supply the power needs of the GLV systems and other non-tractive systems. This test also ensures that the GLV system contains a rechargeable battery of sufficient capacity to run the car GLV systems for at least three hours.

Test Configuration: A

Preconditions

- The GLV Power Box is securely mounted to the rack.
- The GLV Ground terminal is connected to the designated screw terminal on the rack. This will represent chassis ground.
- Turn the manual switch on the Power Box so that it is in the open position.

Test Procedure

1. Determine the power needs of all systems that rely on GLV Power. For instance, each AIR that the TSV uses requires 2.04W of power. Perform these calculations in the space provided below.
2. Calculate the current required to provide that Wattage at 24VDC. Multiply this current by 1.5; the GLV battery must have the capacity to provide 50% more Amperage than is necessary.
3. Ensure the GLV battery is fully charged by opening the manual switch on the front panel and charging the battery until the “Charging” LED is turned off automatically. At this point the charger should be removed.
4. Wait fifteen minutes to ensure the GLV battery settles at its charged voltage once the charger is removed.
5. Turn on the manual switch on the front panel.
6. Attach the Power Box to the rear of the adjustable load. Use a cable with the correct TE 3 Pin Connector on one end and two crimped terminals on the other.
7. Turn on the AC Power button on the load. Press the CURR button underneath the adjustable load knob. Turn on DC Power.
8. Turn the adjustable load knob until the current value matches the calculation from Step 2. Record the time.
9. Monitor the Power Box voltage. Probe the terminals on the rear of the adjustable load with a multimeter for increased accuracy. Record battery voltage every 15 minutes in the space provided.
10. If the voltage drops below 21V, turn off the adjustable load and record the time.

Acceptance Threshold

1. The test is run for over three hours before the voltage drops below 21V.

T1.2: Safely Idle and Charge-from-Zero Test Passed: Y__ N__

This test ensures that it is possible to charge a fully discharged GLV battery without disassembly or special actions. Also, this tests that the power management software and hardware allows the GLV system to safely sit idle without fear of over-discharge and damage.

Test Configuration: A

Preconditions

- This test will take many hours. Ensure the test equipment is available for an extended period of time.
- The GLV Power Box is securely mounted to the rack.
- The GLV Ground terminal is connected to the designated screw terminal on the rack. This will represent chassis ground.
- Turn the manual switch on the Power Box so that it is in the closed position.
- The GLV battery has some charge. This means that when the manual switch is closed the “Battery Power” LED is lit.

Test Procedure

1. Attach the Power Box to the rear of the adjustable load. Use a cable with the correct TE 3 Pin Connector on one end and two crimped terminals on the other.
2. Turn on the AC Power button on the load. Press the CURR button underneath the adjustable load knob. Turn on DC Power.
3. Turn the adjustable load knob so that minimal (~0A) current is being drawn from the battery.
4. Monitor the Power Box voltage. Probe the terminals on the rear of the adjustable load with a multimeter for increased accuracy. Record battery voltage and time at the beginning of the test.
5. Let the battery sit idle. Current will still be drawn to power the “Battery Power” LED. The DC-to-DC converter will also draw some current with no load.
6. Eventually, battery voltage will drop below the 15.7 VDC required to trigger the DC-to-DC undervoltage shutdown. Record the time at which the “Battery Power” LED turns off and the voltage of GLV24 at this time.
7. Plug in the charger. Ensure that both the “Charging” and “Battery Power” LEDs activate.
8. After charging the battery for one hour, remove the charger and ensure the “Battery Power” LED remains active.
9. Turn the adjustable load know so that the current drawn from the Power Box is 2A. Record whether the battery can sustain this level of power (it is not damaged).

Acceptance Threshold

1. The measured voltage does not drop below 15.2 VDC before the Power Box turns off GLV Power.
2. The battery charges and can provide current to the adjustable load after the charger is removed.

Safety Loop

The Safety Circuit and Safety Loop are designed to keep the high voltage system in a safe operational state via constant monitoring of each individual electrical subsystem. The Safety Loop flows throughout the system while the Safety Circuit exists in the Cockpit Box. The following tests will be performed to demonstrate that the Safety Loop meets all requirements:

T2.0: General Safety Loop Operation — Passed: Y__ N__

The pre-charge circuit must operate regardless of the sequence of operations used to energize the vehicle, including after automatic safety shut down.

Test Procedure:

1. Power on GLV Power, make sure that that the GLV Master Switch is on and the side BRBs are off.
2. Close all components of the safety loop.
   VERIFY: The safety loop is open
3. Open a single component of the safety loop (i.e. the Tractive System Master Switch)
4. Attempt to reset the safety loop using the Reset button on the side panel, then the CPR in the Cockpit panel.
   VERIFY: The safety loop is open
5. Close all components of the safety loop.
6. Attempt to reset the safety loop using the Reset button on the side panel, then the CPR in the Cockpit panel.
   VERIFY: The safety loop closes
7. Open any component of the safety loop
   VERIFY: The safety loop is open
8. Close all components of the safety loop.
   VERIFY: The safety loop is open
9. Attempt to reset the safety loop using the Reset button on the side panel, then the CPR in the Cockpit panel.
   VERIFY: The safety loop closes

Acceptance Threshold:

1. The safety loop is considered closed if the AIRs24 line is 24±2.4V
2. The safety loop is considered open if the AIRs24 line is ±2.4V

T2.1: Shutdown Circuit Test Passed: Y__ N__

All of the current flowing to the AIRs is supplied by the Shutdown Circuit and when the circuit is opened it should shut down the tractive system.

Test Procedure:

1. Integrate TSV system with GLV system
2. Repeat Test T2.0
3. Monitor physical AIRs instead of the AIRs24 line

Acceptance Threshold:

1. When the safety loop is closed, the AIRs must be closed
2. When the safety loop is open, the AIRs must be open

T2.2: Master Switches Test Passed: Y__ N__

The Master Switches are required to be placed on the right side of the vehicle and oriented parallel to the fore-aft axis. They should be able to disable the electrical circuits of the car (GLVMS) and the tractive system (TSMS) directly.

Test Procedure:

1. Design the circuits such that all power to electrical circuits flow directly through the GLV Master Switch and that the TS Master Switch opens the shutdown circuit.

   VERIFY: No current flows through the system (including TS) when GLVMS is off
2. Show securely mounted switches on the right side of the car, labeled, next to each other and orient them such that "ON" is parallel to the fore-aft axis of the car.

Acceptance Threshold:

1. The preliminary circuit design and designs from previous years account for the specific use of the switches. Make sure the Master Switches directly terminate electrical system function and tractive system function.

T2.3: Shutdown Buttons Test Passed: Y__ N__

Each of three push-rotate BRBs opens the shutdown circuit and kills the tractive system. The side mounted BRBs also kill all electronics.

Test Procedure:

1. Obtain three push-rotate buttons were pushing the button directly opens the shutdown circuit. One button on each side of the vehicle (40mm) at the level of the drivers head, and one button in the cockpit (24mm).
2. Push any of the buttons to separate the tractive system from the accumulators. The buttons on the side of the car will also shut down all electrical systems.

   VERIFY: The safety loop is open

3. Be able to press the cockpit button no matter where the drivers hands are and no matter the orientation of the wheel.
4. If the driver pushes this button (with nothing else wrong), have the driver rotate this button to close the shutdown circuit and perform an additional action (Cockpit Reset Button) to make the vehicle ready-to-drive again.

   VERIFY: Refer to T2.0
5. Try removing the shutdown buttons from the car.

Acceptance Threshold:

1. The shutdown button test will be passed if each of the buttons disabled the tractive system and the electrical systems as well.
2. The buttons are the appropriate sizes and are appropriately mounted and secured to the vehicle.

T2.4: Brake Over-Travel Switch Test Passed: Y__ N__

The BOTS shuts down the tractive system by opening the shutdown circuit.

Test Procedure:

1. Flip the BOTS and check the status of the tractive system. Do this manually; not by slamming on the brake pedal itself.

   VERIFY: The safety loop is open
2. Once mounted, have the driver attempt to reset the BOTS by him/herself while sitting in the vehicle as they normally would during a race.

   VERIFY: The driver cannot reset the BOTS themselves

Acceptance Threshold:

1. This test will be passed when the tractive system is successfully disabled by the BOTS and is out of reach and not driver resettable.

T2.5: Safety Ratings Test Passed: Y__ N__

All electrical safety items are rated for (at least) the maximum tractive system voltage.

Test Procedure:

1. Items purchased should be checked against the maximum tractive system voltage and purchased only if they are up to such specifications.
2. Check the most up-to-date BOM to see that listed parts are up to specifications.

Acceptance Threshold:

1. Only if safety items meet the requirement of their rating exceeding the maximum tractive system voltage will this test be passed.

T2.6: Cockpit Safety Loop Control Passed: Y__ N__

The driver must be able to re-activate or reset the tractive system from within the cockpit without the assistance of any other person by resetting the BRB and performing one additional action.

Test Procedure:

1. Power on GLV Power, make sure that that the GLV Master Switch is on and the side BRBs are off.
2. Close all components of the safety loop.
3. Attempt to reset the safety loop using the Reset button on the side panel, then the CPR in the Cockpit panel.
   VERIFY: The safety loop closes
4. Open the safety loop by pressing the cockpit BRB.
   VERIFY: The safety loop opens
5. Attempt to reset the safety loop using only the CPR in the Cockpit panel
   VERIFY: The safety loop closes

Acceptance Threshold:

1. The safety loop is considered closed if the AIRs24 line is 24±2.4V
2. The safety loop is considered open if the AIRs24 line is ±2.4V

Tractive System Interface

The Tractive System Interface includes all low voltage circuits that are connected to the TSV. Most of these circuits are contained within the TSI box and the following tests will be performed to demonstrate that the TSI meets all requirements:

T3.0: TSVP Test **Passed: Y__ N__**

The vehicle must have two TSVP lamps that can be seen from the sides of the vehicle. The lamps must be on whenever the voltage outside of the accumulator container exceeds 32V. The lamps must be powered entirely by the tractive system.

Test Procedure:

1. Connect the HV+ and HV- terminals to the high voltage power supply.
2. Connect the Load+ and Load- terminals to the high voltage load.
3. Connect the low voltage power terminal to a 24V power supply.
4. Increase the voltage from the high voltage power supply from 0V to 100V at 1V intervals.
5. Observe the lamp as voltage is increased.

Acceptance Threshold:

1. The TSVP light is on when the voltage from the power supply is greater than or equal to 32V.

T3.1: Pre-Charge Circuit Test **Passed: Y__ N__**

The pre-charge circuit is intended to protect the motor controller from inrush current. The motor controller must be connected to TSV through a precharge resistor until the motor controller reaches 90% of the accumulator voltage. It has been previously determines that it takes 4.6 second to reach 100% of the accumulator voltage. Our design charges the motor controller through a pre-charge resistor for 4.6 seconds then closes the main relay. Since the circuit does not operate with a voltage feedback, this test will verify that the relays switch at the correct times.

Test Procedure:

1. Connect the low voltage power terminal to a 24V power supply.
2. Set up a digital multimeter so that it is measuring the resistance between the HV+ and the Load+ terminals of the TSI system.
3. Connect a 5V power supply to the Start terminal which is located on the JGB header on the tractive system interface PCB.

4. Turn the 5V power supply on and start a stopwatch at the same time. Verify that the multimeter reads 200 ohms immediately after turning the supply on.
5. The multimeter will read about zero ohms when the main relay closes, record the time when this occurs.
6. Turn the 5v power supply off.

Acceptance Threshold:

1. Before step 4 the multimeter should be infinite resistance between the terminals.
2. Multimeter reads 200 ohms immediately after turning the power supply on.
3. Time recorded at step 5 is at 4.6 seconds or greater.
4. Multimeter reads infinite resistance immediately after the power supply is shut off.

T3.2: TSV Battery Pack Voltage Measurement Test Passed: Y__ N__

This test verifies that the voltage measuring circuit accurately measures the voltage present across all four TSV battery packs.

Test Procedure:

1. Connect the HV+ and HV- terminals to the high voltage power supply.
2. Connect the Load+ and Load- terminals to the high voltage load.
3. Connect the low voltage power terminal to a 24V power supply.
4. Connect a digital multimeter to the TSMP- and TSMP+ banana jacks.
5. Increase the voltage from the high voltage power supply from 0V to 100V.
6. Record the measured voltage in the table provided in the Acceptance Test Checklist section of this document.

Acceptance Threshold:

1. The voltages measured by the multimeter should agree with the table in the Acceptance Test Checklist.

T3.3: Insulation Monitoring Device Test Passed: Y__ N__

This is a specific test that is outlined in the EV rules and will be done during the Electrical Tech Inspection.

Test Procedure:

1. Connect the HV+ and HV- terminals to the high voltage power supply at 10V.
2. Connect the Load+ and Load- terminals to the high voltage load.
3. Connect the low voltage power terminal to a 24V power supply.

4. Using a digital multimeter measure the resistance between the SL_IN and the SL_OUT terminals.
5. Connect the GLVGND measuring point to the TSMP- measuring point through a 2500 ohm resistor.

Acceptance Threshold:

1. Before step 5, the digital multimeter indicates that there is 0 resistance between SL_IN and SL_OUT and the IMD fault indicating light in the cockpit is off.
2. Before step 6, the digital multimeter indicates that there is infinite resistance between SL_IN and SL_OUT and the IMD fault indicating light in the cockpit is on.

Vehicle Computer Interface

The Vehicle Computer Interface (VCI) will deliver data from sensors located throughout the car to the VSCADA system. Data from theses sensors will be converted from analog to digital data using microprocessors and then formated for the cockpit display by the VSCADA computer. The Ready-to-Drive sound speaker will also be designed and implemented as a safety feature for the electric car. The following tests will be performed to demonstrate that the VCI meets all requirements:

T4.0: Ready to Drive Sound Length Test Passed: Y__ N__

The car must make a characteristic sound, for a minimum of 1 second and a maximum of 3 seconds, when it is ready to drive.

Test Procedure:

1. Set the car into ready to drive mode.
2. Use a stopwatch to time the length of the sound that is emitted by the speaker.

Acceptance Threshold:

1. The sound must last between one second and three seconds.

T4.1: Relay/TSAL PCB Test Passed: Y__ N__

These tests are for testing the PCB outside of the system. The Relay/TSAL board is responsible for:

- Signalling when there is voltage supplying the AIRs via a TSAL output
- Signalling when there is voltage supplying the AIRs via a AIRs monitor output
- Signaling when the safety loop is closed
- Control a Electromechanical relay which is integrated into the safety loop

T4.1.0 TSAL and Safety Monitor Tests

Test Procedure:

1. Connect a DMM to measure the SL_M and AIRs_M outputs of the Relay/TSAL PCB.
2. Connect an Oscilloscope to measure the TSAL output of the Relay/TSAL PCB
3. Connect a 5V Voltage source to the 5V input of the Relay/TSAL Board and the voltage source return on the Gnd input of the Relay/TSAL Board.
   VERIFY: The TSAL to be off and both monitor to be logic low.
4. Connect a 24V Voltage source to the SL_IN input of the Relay/TSAL Board with the voltage source return connected to the AIRs Gnd input.
   VERIFY: The TSAL to be off and the SL Monitor to go to logic high.

5. Connect a 24V Voltage source to the AIRs24 input of the Relay/TSAL Board with the voltage source return connected to the AIRs Gnd input.
   VERIFY: Both monitors are logic high, the TSAL is sending out a square wave.
6. Remove the 24V voltage source to the AIRs24 input.
   VERIFY: We would expect the TSAL to stop and the AIRs Monitor to go to logic low.
7. Remove the 24V voltage source to the SL_IN input.
   VERIFY: We would expect the TSAL to be off and both monitor to go to logic low.

Acceptance Threshold:

1. SL_M and AIRs_M logic high of 5 ± 0.5V
2. SL_M and AIRs_M logic low of 0 ± 0.5V
3. TSAL square wave between 2 Hz and 5 Hz
4. TSAL square wave peak of 12 ± 1.2V

T4.1.1 Safety Loop Control Tests

Test Procedure:

1. Connect a DMM to measure the SL_OUT2 outputs of the Relay/TSAL PCB.
2. Connect a 5V Voltage source to the 5V input of the Relay/TSAL Board and the voltage source return on the Gnd input of the Relay/TSAL Board.
   VERIFY: SL_OUT2 logic low
3. Connect a 24V Voltage source to the SL_OUT1 input of the Relay/TSAL Board with the voltage source return connected to the AIRs Gnd input
   VERIFY: SL_OUT2 logic low
4. Connect a 5V Voltage source to the SL_Ctrl input of the Relay/TSAL Board with the voltage source return connected to the AIRs Gnd input
   VERIFY: SL_OUT2 logic high
5. Disconnect the 5V Voltage source to the SL_Ctrl input of the Relay/TSAL Board
   VERIFY: SL_OUT2 logic low
6. Connect a 5V Voltage source to the SL_Ctrl input of the Relay/TSAL Board with the voltage source return connected to the AIRs Gnd input. Disconnect the 24V voltage supply to the SL_OUT1 input.
   VERIFY: SL_OUT2 logic low

Acceptance Threshold:

1. SL_OUT2 logic high of 24 ± 2.4V
2. SL_OUT2 logic low of 0 ± 2.4V

T4.2: Relay/TSAL PCB Integration Test Passed: Y__ N__

These tests are for testing the PCB integrated with the VCI Box.

T4.2.0 TSAL and Safety Monitor Tests

Test Procedure:

1. Connect a DMM to measure the SL_M and AIRs_M outputs of the Relay/TSAL PCB.
2. Connect an Oscilloscope to measure the TSAL output of the Relay/TSAL PCB
3. Connect a 12V Voltage source to the GLVPD, GLV12 volt pin, and the voltage source GLVPD GLV_Gnd on the Gnd input of the VCI Box.
   VERIFY: The TSAL to be off and both monitor to be logic low.
4. Connect a 24V Voltage source to the SL1, SL_IN pin input of the VCI with the voltage source return connected to the SL1, AIRs_Gnd pin input
   VERIFY: The TSAL to be off and the SL Monitor to go to logic high.
5. Connect a 24V Voltage source to the SL1, AIRs24 pin input of the Relay/TSAL Board with the voltage source return connected to the SL1 AIRs_Gnd pin input
   VERIFY: Both monitors are logic high, the TSAL is sending out a square wave
6. Remove the 24V voltage source to the SL1, AIRs24 input.
   VERIFY: We would expect the TSAL to stop and the AIRs Monitor to go to logic low.
7. Remove the 24V voltage source to the SL1, SL_IN input.
   VERIFY: We would expect the TSAL to be off and both monitor to go to logic low.

Acceptance Threshold:

1. SL_M and AIRs_M logic high of 5 ± 0.5V. VSCADA sees logic high.
2. SL_M and AIRs_M logic low of 0 ± 0.5V. VSCADA sees logic low.
3. TSAL square wave between 2 Hz and 5 Hz.
4. TSAL square wave peak of 12 ± 1.2V

T4.2.1 Safety Loop Control Integration Tests

Test Procedure:

1. Connect a DMM to measure the SL2, SL_OUT pin output of the Relay/TSAL PCB.
2. Connect a 12V Voltage source to the GLVPD GLV12 volt pin, and the voltage source GLVPD GLV_Gnd on the Gnd input of the VCI Box.
   VERIFY: SL2, SL_OUT logic low
3. Connect a 24V Voltage source to the SL1, SL_OUT pin input of the VCI with the voltage source return connected to the SL1, AIRs Gnd input.
   VERIFY: SL2, SL_OUT logic low

4. Make VSCADA force the SL_Ctrl output high
   VERIFY: SL2, SL_OUT logic high
5. Make VSCADA force the SL_Ctrl output low
   VERIFY: SL2, SL_OUT logic low
6. Disconnect the 24V Voltage source to the SL1, SL_OUT pin input of the VCI. Make VSCADA force the SL_Ctrl logic high.
   VERIFY: SL2, SL_OUT logic low

Acceptance Threshold:

1. SL_OUT2 logic high of 24 ± 2.4V
2. SL_OUT2 logic low of 0 ± 2.4V

T4.3: TSAL Test   Passed: Y__ N__

The tractive system active light needs to turn on when there is a voltage of greater than 5V on the high voltage lines, or when the AIRs are closed.

Test Procedure:

1. Make sure Load Controller is properly connected to all other systems.
2. Attach the high voltage lines to the high voltage power supply.
3. Keep the AIRs open
4. Increase the power supply voltage from 0 to 10 in increments of 1 volt. Then increase the power from 10 to 100 in increments of 10 volts.
5. Close AIRs and repeat step 4.

Acceptance Threshold:

1. When the AIRs are open the TSAL should be on when the power supply voltage is over 5 volts.
2. When the AIRs are closed the TSAL should always be on.

GLV General Requirements Tests

The following tests demonstrate compliance for requirements that do not fit into one specific GLV subsystem:

T5.0: GLV Grounding Passed: Y__ N__

All accessible metal parts of the vehicle (test rack) must have a resistance below 300 mΩ to GLV ground. All other conductive parts of the vehicle (test rack) must have a resistance below 5 Ω to GLV ground.

Test Procedure:

1. Measure the resistance of all accessible metal points of the rack system to the GLV Ground Reference line from the GLV Power System using an DMM.
2. Measure the resistance of all conductive points of the rack system to the GLV Ground Reference line from the GLV Power System using an DMM

Acceptance Threshold:

1. All step one tests must be below 300 mΩ
2. All step 2 tests must be below 5 Ω

T5.1: GLV Data Collection Passed: Y__ N__

All sensor data must be collected by the VSCADA computer.

Test Procedure:

1. Power Up System
2. Ping each sensor in the sensor list and monitor response.
3. For all voltage/current/resistance sensors, use DMM to verify value.
4. For all temperature sensors, use handheld temp sensor

Acceptance Threshold:

1. Data found by VSCADA is within 90% of data found by the alternate sensor device used.

T5.2: GLV/TSV Isolation Passed: Y__ N__

According the the EV requirements, all parts of the Tractive High Voltage must be insulated from Grounded Low Voltage parts of at least 50 000 ohms (500 ohms/v * 100V). To be safe we will use 1 Million Ohms as a safe benchmark level.

Test Procedure:

1. Connect one end of a DMM to a point on the High Voltage power lines
2. Connect the other end to the GLV Power ground terminal.
3. Note the resistance between the two points
4. Repeat from step until most portions of the High Voltage power lines have been tested.

Acceptance Threshold:

1. If any point is found to be below 1 Million Ohms, the test fails.

GLV Unaddressed Requirements

The following requirements are listed in the Formula Hybrid EV specifications but are not proven by the tests in this document. The reason for omission is generally a lack of relevance to the current GLV design. For instance, there are many power requirements that are contingent upon the purchased battery being a certain chemistry. Without a battery of that chemistry, there is no need to prove compliance. Another reason for omission would be that the requirement is out of scope for this year. The GLV system will be designed with these requirements in mind, but compliance will not be able to be proven until the project advances in future years.

EV 1.2.3 - The GLV system must be grounded to the chassis.

The GLV system will not be mounted to a chassis this year. An appropriate ground will be chosen for the system using the temporary mounting stand.

EV 2.2 - Accelerator Signal Limits Check

There will not be a physical connection between Accelerator as we will not be developing a chassis this semester.

EV 3.7.2 - Any wet-cell battery located in the driver compartment must be enclosed in a nonconductive marine-type container or equivalent and include a layer of 1.5mm of aluminum or equivalent between the container and driver.

The GLV battery is dry-cell.

EV3.7.4 - Battery packs based on Lithium Chemistry other than LiFePO4 must have over-voltage, undervoltage, short circuit and over-temperature cell protection.

The GLV battery is not based on Lithium Chemistry.

EV3.7.5 - A team built Lithium LV battery pack may be used, but details on how the required protection is achieved must be included as part of the ESF submission.

The GLV battery is not team built or based on Lithium Chemistry.

EV3.8 - Pouch Type Lithium Ion Cells

The GLV battery will not use pouch type Lithium ion cells.

EV4.1.4 - GLV circuits must not be present in the accumulator container except for required purposes

The TSV Team is responsible for isolation of TSV and GLV within the TSV Battery Packs.

EV4.10.1 - TSAL located at the highest point of the vehicle

No chassis will be developed this semester.

EV4.10.4 - TSAL cannot be contacted by drivers helmet.

No chassis will be developed this semester.

EV4.10.5-7 - TSAL Visibility

No chassis will be developed this semester, no TSAL lamp will be purchased.

EV4.12.1 - TSVP Lighting Compliance

No chassis will be developed this semester, no TSVP lamp will be purchased.

EV5.1.6 - Motor Free Spin when deactivated

Requirement addressed by TSV and Dyno Teams

EV5.2.3 - GLV Master Switch Location

No chassis will be developed this semester.

EV5.2.6 - Master Switch Attachment

No chassis will be developed this semester.

EV5.3.4- Shutdown Button Location

No chassis will be developed this semester.

EV5.3.8- Shutdown Button Attachment

No chassis will be developed this semester.

EV5.4- Brake over Travel Switch

No chassis will be developed this semester, so no braking system will be developed. A Location for its attachment to the cockpit box will however be available.

EV6.1.8- Parallel Strings of Batteries Requirements

Single string of GLV batteries are used in our design.

EV9.2- FMEA Document

Should be completed in the future. The failure modes will be documented in the Maintenance Document.

R002-0.1, 0.2, 0.3- Sensor Requirements

Only sensors in GLV Systems are required to be developed and tested.

R002-0.5- GPS Data

This will not be added this semester. A USB input will be left for later addition.

R002-1.2- Sensor Sampling Rates

Analog Sensor data of GLV sensors are red by VSCADA Microcontrollers. VSCADA is then responsible for sampling GLV data.

Acceptance Test Report

This Acceptance Test Report (ATR) section will keep track of the progress of the GLV Acceptance Test Plan. It should be filled out as the tests and inspections are completed. There are the following sections of the ATR.

- **Inspection Checklist**
  This section outlines all inspections which must be completed to prove the system meets requirements. These inspections usually require pictures or diagrams showing that a certain component meets system requirements.

- **Analysis Checklist**
  This section outlines all analyses which must be completed to prove the system meets requirements. These analyses usually require schematics/drawings/BOMs showing that a certain component meets system requirements.

- **Acceptance Test Checklist**
  This section lists all tests written previously in the document, and includes additional information regarding acceptance thresholds and areas to fill in information about the tests.

- **Deliverables Checklist**
  This section lists all requirements laid out by the Statement of Work for the LFEV-Y3-2015

Inspection Checklist

Inspection Number	Description (Requirements Covered)	Passing Criteria	Result / Figure Number	Complete
I-1	**Electrical Insulation** (EV1.3.1, EV1.3.2)	All Wires: ● UL Recognized ● Have ratings exceeding max expected temp or 90C ● Don't use paints or tapes for insulation	**Figure 2**	
I-2	**TSI Container** (EV3.3.1)	All conductive surfaces on the outside of the container must have a low-resistance connection to the GLV system ground. All conductive penetrations (mounting hardware, etc.) must be located outside of the insulation and configured such that there is no possibility that they could penetrate the insulating barrier.		
I-3	**GLV Battery Mount** (EV3.7.1)	The GLV Batteries must be securely mounted	**Figure 1**	
I-4	**GLV Terminals** (EV3.7.3 , EV3.7.6)	● The hot (ungrounded) terminal must be insulated. ● One terminal of the GLV power must be connected to system ground.	**Figure 3 & 4**	
I-5	**TSV/GLV Separation, Wires** (EV4.1.3)	Tractive system and GLV circuits must be physically segregated. I.e. they may not run through the same conduit or connector, except for interlock circuit connections		
I-6	**TSV/GLV Separation, Enclosures** (EV4.1.5, EV4.1.6, EV4.1.8)	Where both tractive system circuits and GLV circuits are present within an enclosure, they must be (a) separated by electrical insulating barriers meeting the requirements of EV4.1.6 or (b) separated by the spacings shown in Table 15 through air, or over a surface (similar to those defined in UL1741): Insulating barriers used to meet the requirements of EV4.1.5 (c) Must be UL recognized as electrical insulating materials for a temperature of 150 ºC or higher. (d) Must be adequately robust for the application and in no case thinner than 0.25 mm (0.010"). (e) Must be in addition to wire insulation. (f) Must extend far enough at the edges to block any path between uninsulated GLV and tractive-system conductors shorter than the distances specified in Table 15. Spacing must be clearly defined. Components and cables capable of movement must be positively restrained to maintain spacing.		
I-7	**TSV/GLV Separation, Circuits**	If tractive system circuits and GLV circuits are on the same circuit board they must be on separate, clearly defined areas of the board.		

	(EV4.1.7, EV4.1.9, EV4.1.8)	Furthermore, the tractive system and GLV areas must be clearly marked on the PCB. Required spacing between GLV and TS circuits is as shown in the Table 16. If a cut or hole in the board is used to allow the “through air” spacing, the cut must not be plated with metal, and the distance around the cut must satisfy the “over surface” spacing requirement. Plated prototyping boards having plated holes and/or generic conductor patterns may not be used for applications where both GLV and TS circuits are present on the same board. Bare perforated board may be used, if the spacing and marking requirements (EV4.1.7 and EV4.1.8) are met, and if the board is easily removable for inspection.		
I-8	**TSV Measuring Points** (EV4.4.8 , EV4.4.9)	Next to the TSMP a GLV system ground measuring point must be installed. This measuring point must be connected to the GLV system ground. A 4 mm safety banana jack that accepts shrouded (sheathed) banana plugs with non-retractable shrouds must be used for the GLV ground measuring point.		
I-9	**High Voltage Labeling** (EV4.6.1)	Every housing or enclosure containing parts of the tractive system except motor housings must be labeled with sticker(s) (minimum 4 x 4 cm) 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 30 VDC or 25 VAC.		
I-10	**IMD Inspection** (EV5.5.2)	The IMD must be a Bender A-ISOMETER ® iso-F1 IR155-3203 or IR155-3204 or equivalent IMD approved for automotive use.	**Figure 5**	
I-11	**IMD Indicator Inspection** (EV5.5.7)	The IMD indicator light must be clearly marked with the lettering “IMD” or “GFD” (Ground Fault Detector).		
I-12	**Fuse Ratings** (EV6.1.3, EV6.1.4)	All fuses and fuse holders must be rated for the highest voltage in the systems they protect. Fuses used for DC must be rated for DC, and must carry a DC rating equal to or greater than the system voltage of the system in which they are used. All fuses must have an interrupt current rating which is higher than the theoretical short circuit current of the system that it protects.		
I-13	**Fuse Locations** (EV6.1.5)	The fuse protecting a circuit or must be physically located at the end of the wiring closest to an uncontrolled energy source (e.g., a battery).		
I-14	**Charger UL Listing** (EV8.2.11)	All chargers must be UL (Underwriters Laboratories) listed.		
I-15	**Safety Loop Packaging**	The safety loop system shall be packaged so it is straightforward to integrate with the car		

	(R007-0, R007-1, EV4.1.8)	The safety loop system shall be packaged so as to be fully compliant with all Formula EV rules, including shock, vibration, temperature, and humidity (including rain). The cabling requirements for car installation shall be analyzed and a set of safety cables suitable for use on the car shall be designed, fabricated, and tested. Cables required to support the MCS Test Stand shall be designed, fabricated, and tested.		
I-16	**TSI Packaging** (R008-0, R008-1, EV4.1.8)	The load controller [TSI] system shall be packaged so it is straightforward to integrate with the car. The load controller [TSI] shall be packaged so as to be fully compliant with all Formula EV rules, including shock, vibration, temperature, and humidity (including rain). The cabling requirements for load controller shall be analyzed and a set of GLV and TSV suitable for use on the car shall be designed, fabricated, and tested. In addition, cables required to support the MCS Test Stand shall be designed, fabricated, and tested.		

Inspection Tests

Examiner Signature

Date Complete

Analysis Checklist

Analysis Number	Description (Requirements Covered)	Passing Criteria	Result / Figure Number	Complete
A-1	**Safety Circuit** (EV5.1, EV5.2, EV8.3.6)	A schematic/diagram of the safety circuit is consistent with the requirements of EV5.1 The schematic/diagram must also show that the Master Switches carry all circuit for system power (EV5.2.2a,b) A BOM indicates that all safety items are rated for the maximum tractive system voltage.		
A-2	**IMD** (EV5.5.8)	A schematic/diagram of the TSI box shows that the IMD ground connection must be wired according to the manufacturer's instructions so that the reference ground detector is functional.		
A-3	**Fusing** (EV6.1.1, EV6.1.2, EV6.1.3, EV6.1.4, EV6.1.6, EV 8.2)	GLV Power, TSI, VCI, and Cockpit Box diagrams indicate proper fusing. BOM Wiring, Components, and Fusing indicate that fuses are rated lower than the rating if the wire and system the fuse is protecting.		
A-4				

Analysis Tests

______________________________________ ______________

Examiner Signature Date Complete

Acceptance Test Checklist

GLV Power

Test Num				
T1.0	**Description** (Requirements Covered)	**Passing Criteria**	**Result / Figure Number**	**Complete**
	UL listed charger	The charging device is UL listed.	**Figure 6**	
	Plug and forget charging	The charger is attached without interrupting the current supplied to load.	Time:	
	LED function	The “Charging” LED activates when the charger is attached.		
	Plug and forget charging	The Power Box switches to battery power without interrupting the current supplied to the load.	Time: Maximum:	
	Overcharge/overvoltage protection	Maximum voltage < 29 VDC.	Pass/fail:	
	Plug and forget charging	The Power Box switches to battery power without interrupting the current supplied to the load.	Time: Minimum:	
	Full discharge protection	Minimum voltage > 22 VDC.	Pass/fail:	
T1.0	**Device**	**Power Consumption (W)**	**/ 24V (A)**	**x 1.5 (A)**
	TSV Airs			
	TSV Misc.			
	GLV Relays			
	GLV Misc.			
	VSCADA Computer			

	VSCADA Screen			
	Total			

Time	Voltage	Time	Voltage	Time	Voltage

	Description (Requirements Covered)	**Passing Criteria**	**Result / Figure Number**	**Complete**
	Battery Power	GLV Power supplies a current equal to the value calculated above.	Current:	
	Battery Duration	GLV Power supplies the specified current for three hours.	Start Time: End Time: Test Duration:	
T1.2	**Full Discharge Protection Safely Idling**	The battery begins to sit idle.	Time: Starting Voltage:	
	Full Discharge Protection Safely Idling	The Power Box stops supplying power.	Time:	

	Full Discharge Protection Safely Idling	Minimum voltage > 15.2 VDC	Minimum Voltage:	
	Full Discharge Protection	The battery successfully supplies power to the load after being charged.	Time:	

GLV Power Tests

Examiner Signature Date Complete

Safety Loop

Test Num	Description (Requirements Covered)	Passing Criteria	Result / Figure Number	Complete
T2.0	**General Safety Loop Operation**	All VERIFY sections are met the following thresholds: -The safety loop is considered closed if the AIRs24 line is 24±2.4V -The safety loop is considered open if the AIRs24 line is ±2.4V		Yes
T2.1	**Shutdown Circuit Test**	All VERIFY sections from T2.0 are met. -When the safety loop is closed, the AIRs must be closed -When the safety loop is open, the AIRs must be open		Yes
T2.2	**Master Switches Test**	TSV Master Switch opens the safety loop GLV Master Switch turns off entire GLV system		Yes
T2.3	**Shutdown Buttons Test**	The shutdown button test will be passed if each of the buttons disabled the tractive system and, depending on which button, the electrical systems as well.		Yes
T2.4	**Brake Over-Travel Switch Test**	The Brake Over-Travel Switch is able to open the safety loop.		
T2.5	**Safety Ratings Test**	Safety items meet the requirement of their rating exceeding the maximum tractive system voltage.		
T2.6	**Cockpit Safety Loop Control**	All VERIFY sections are met the following thresholds: -The safety loop is considered closed if the AIRs24 line is 24±2.4V -The safety loop is considered open if the AIRs24 line is ±2.4V		Yes

Safety Loop Tests

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Examiner Signature Date Complete

Tractive System Interface

Test Num	Description (Requirements Covered)	Passing Criteria	Result / Figure Number	Complete
T3.0	**TSVP Test**	Lamps are on when the power supply voltage is 32V or greater	**Lights remain on when supply is 32V or greater**	**Yes**
T3.1	**Pre-Charge Circuit Test**	Pre-charge relay and main relay are open before start is asserted.		**No**
		Pre-charge relay closes immediately after start is asserted		**No**
		Main relay closes after 4.6 seconds		**No**
		Pre-charge relay and main relay open immediately after start signal goes low	Both Relays are open when starts signal goes low	**Yes**
T3.2	**TSV Battery Pack Voltage Measurement Test**	The voltages measured at the output of the voltage measurement circuit agree with the voltages in the table below.		

Supply Voltage(V)	Expected Measurement(V)	Actual Measurement	Pass
0	0	0	Y
5	0.208	0.208	Y
10	0.416	0.414	Y
15	0.625	0.621	Y
20	0.833	0.828	Y
25	1.04	1.035	Y
30	1.25		▯
35	1.46		▯
40	1.67		▯
45	1.88		▯
50	2.08		▯

55	2.29		☐
60	2.5		☐
65	2.71		☐
70	2.92		☐
75	3.13		☐
80	3.33		☐
85	3.54		☐
90	3.75		☐
95	3.96		☐
100	4.17		☐
105	4.38		☐
110	4.58		☐
115	4.79		☐
120	5.0		☐

T3.3	**Insulation Monitoring Device Test**	Before GLVGND and TSMP- are connected, the digital multimeter indicates that there is 0 resistance between SL_IN and SL_OUT and the IMD fault indicating light in the cockpit is off.	Relay remains closed and OK signal i sent to VSCADA	**Yes**
		After GLVGND and TSMP- are connected, the digital multimeter indicates that there is infinite resistance between SL_IN and SL_OUT and the IMD fault indicating light in the cockpit is on.	Saftey loop relay opens and OK signal goes low	**Yes**

Tractive System Interface Tests

Examiner Signature Date Complete

Vehicle Computer Interface

Test Num	Description (Requirements Covered)	Passing Criteria	Result / Figure Number	Complete
T4.0	**Ready to Drive Sound Length Test**	Sound lasts for 2±1 seconds		
T4.1.0	**PCB - TSAL and Safety Monitor Tests**	All **VERIFY** thresholds are within the following limits SL_M and AIRs_M logic high of 5 ± 0.5V SL_M and AIRs_M logic low of 0 ± 0.5V TSAL square wave between 2 Hz and 5 Hz TSAL square wave peak of 12 ± 1.2V		
T4.1.1	**PCB - Safety Loop Control Tests**	All **VERIFY** thresholds are within the following limits SL_OUT2 logic high of 24 ± 2.4V SL_OUT2 logic low of 0 ± 2.4V		
T4.2.0	**Integrated - TSAL and Safety Monitor Tests**	All **VERIFY** thresholds are within the following limits SL_M and AIRs_M logic high of 5 ± 0.5V. VSCADA sees logic high. SL_M and AIRs_M logic low of 0 ± 0.5V. VSCADA sees logic low. TSAL square wave between 2 Hz and 5 Hz. TSAL square wave peak of 12 ± 1.2V		
T4.2.1	**Integrated - Safety Loop Control Tests**	All **VERIFY** thresholds are within the following limits SL_OUT2 logic high of 24 ± 2.4V SL_OUT2 logic low of 0 ± 2.4V		
T4.3	**TSAL Test**	When the AIRs are closed the TSAL should always be on.		

Vehicle Computer Interface Tests

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Examiner Signature Date Complete

GLV General Requirements

Test Num	Description (Requirements Covered)	Passing Criteria	Result / Figure Number	Complete
T5.0	**GLV Grounding**			

Accessible Metal Point	Resistance (<300mΩ)	Pass?
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
Other Conductive Points	**Resistance (<5Ω)**	**Pass?**
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐

T5.1

GLV Data Collection

System Device	Data Collected	Alternate Sensor	Data Collected	Pass?
				☐
				☐
				☐
				☐
				☐
				☐
				☐

T5.2

GLV TSV Isolation

Point	Resistance (>1MΩ)	Pass?
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐
	Ω	☐

GLV General Requirements Tests

Examiner Signature Date Complete

Deliverables Checklist

Item	Description	Complete (Y/N)	Date	Signature
D000	PDR Presentation and Materials	Y		
D001	CDR Presentation and Materials	Y		
D002	User Manual	Y		
D003	Final Report and Maintenance Manual	N		
D004	Acceptance Test Plan	Y		
D005	Acceptance Test Report	Y		
D006	QA Audit Report	N		
D007	Project Web Site	Y		
D008	Integrated System Demo	N		
D009	Conference Paper, Presentation, and Video	Y		
D010	Project Poster	Y		
D011	Calibration and Accuracy Document	N		
D012	Maintainability Plan	N		
D015	Project Interface Control Document	Y		

Deliverables

Examiner Signature Date Complete

ATR Figure Listing

Figure 1.--Battery mounted

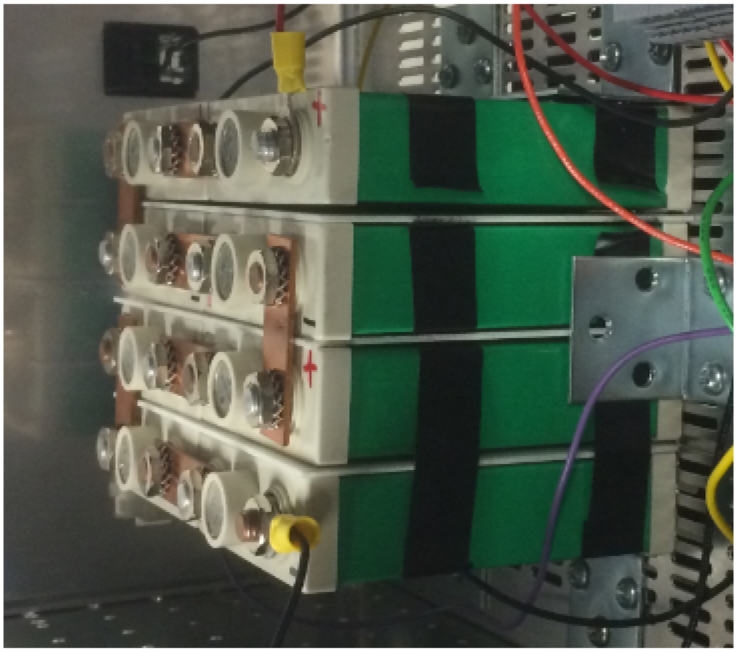

Figure 2--Proper wiring

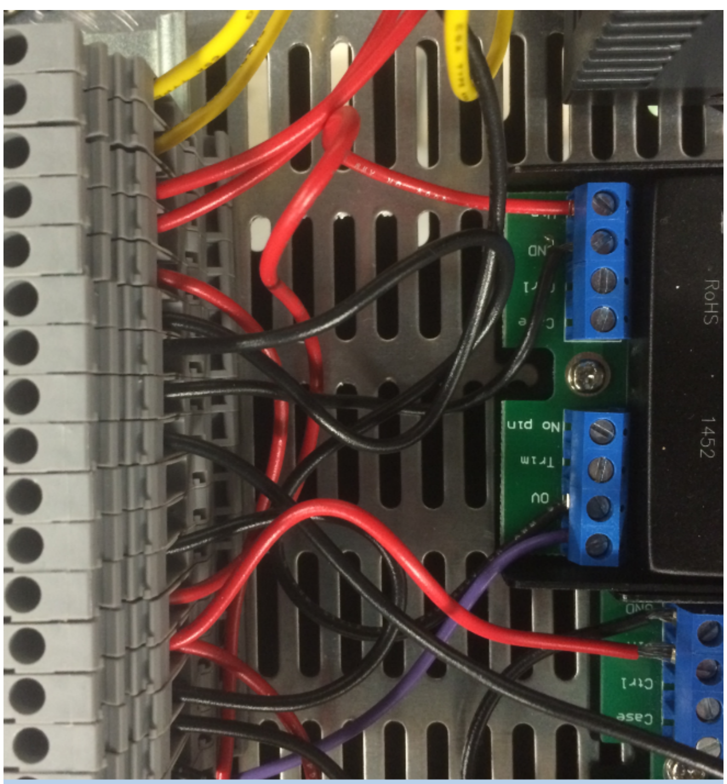

Figure 3. Power connected to ground part a

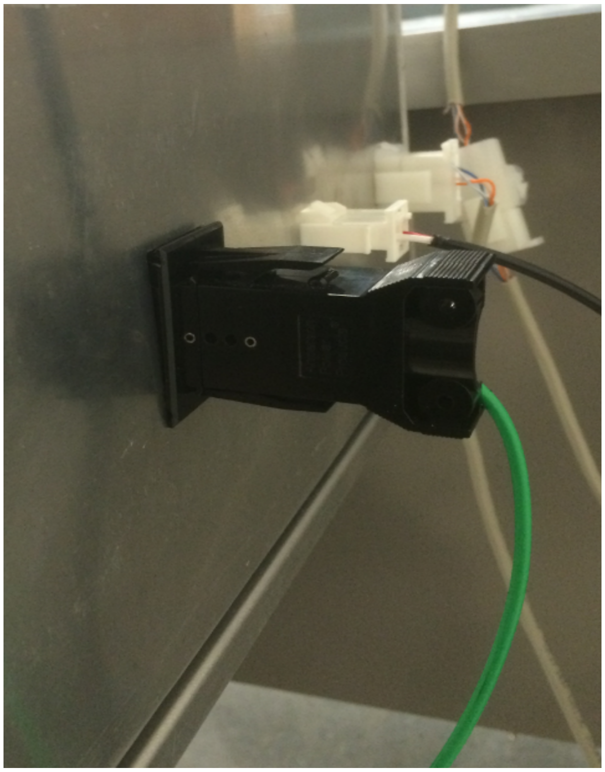

Figure 4. Power connected to ground part b

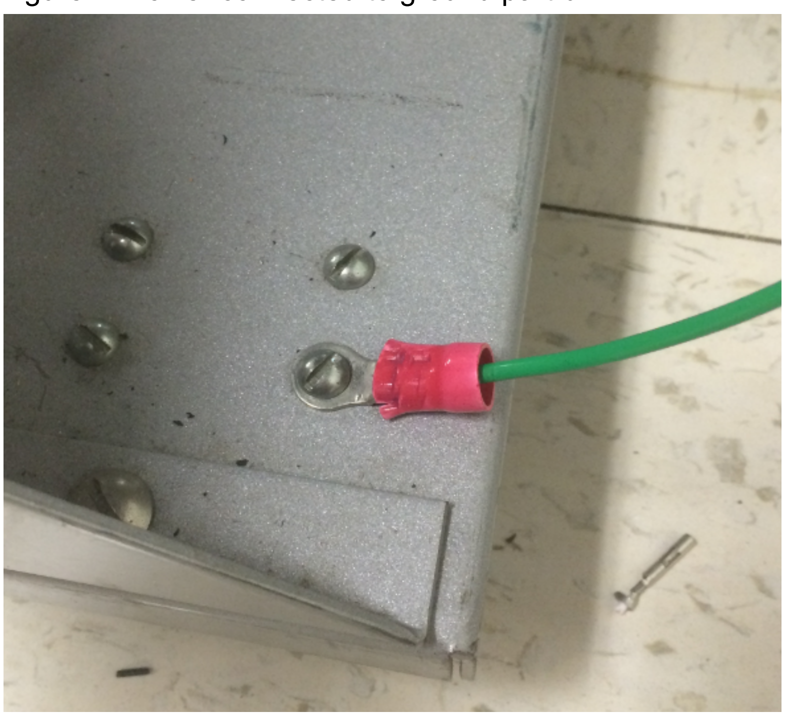

Figure 5.

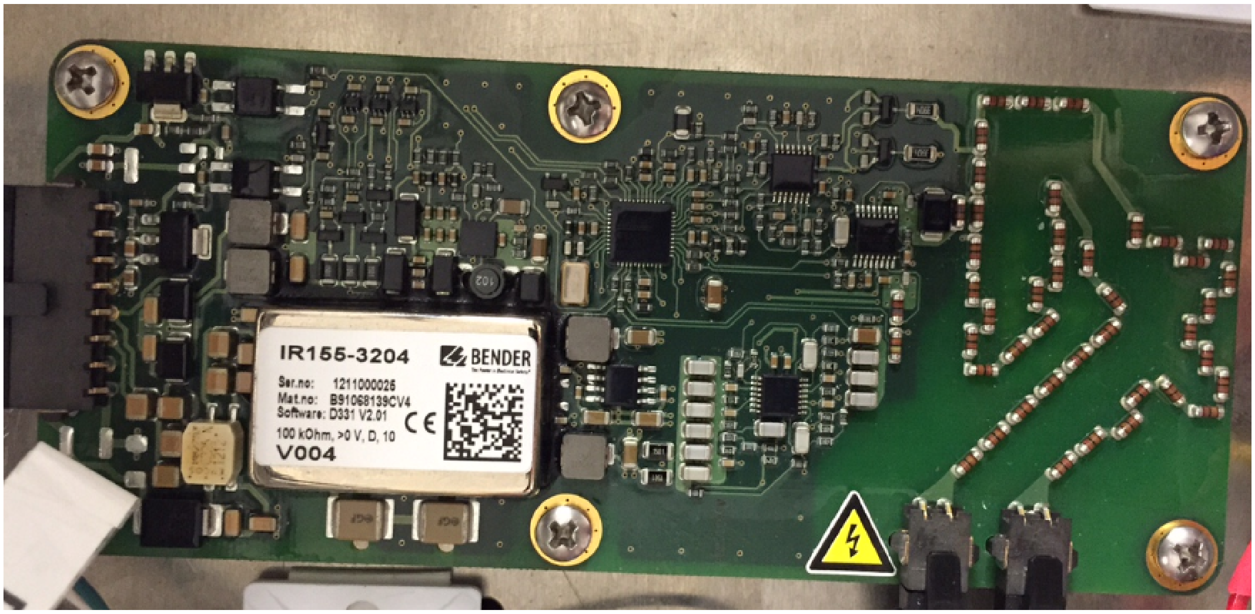

Figure 6.