|  |  |
| --- | --- |
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|  |
| --- |
| **NOTE: For Alternative Fuelled Vehicles and Hybrids please raise an FSQD question on the specific requirements for your ESF before beginning to complete the form**  **\*\*\*\* Requirements & Guidance on completion of ESF \*\*\*\***  **This section should be deleted before submission of your ESF** Note that deletion of this section indicates that you have read, understood and complied with it.  Read the document “How to complete ESF” which is available at: <https://www.fsaeonline.com/content/How-to-Complete-ESF.pptx>  Maximum number of pages for the ESF is 120 pages without the Appendix and Changelog.  Links to video or audio data are prohibited.  Every section of the ESF Template must be filled with content. If the respective part is not relevant for your concept, briefly describe why not. For EVs, if you do not fill out the tables or if you change the format of the ESF Template, you will fail by default.  The table of contents must be hyperlinked.  Use internal reference links. For example, when describing wiring and mentioning a figure in the text then link it to the figure.  Do not just copy all of your datasheets in the appendix, e.g. we do not need to know what you have to do to program your motor controller; we do not need the whole user manuals of microcontrollers to review your ESF, etc. However, do not just paste only a link to the entire data sheet. ***We should not need an internet connection to obtain the information necessary to review your ESF.***  Single pages/figures/tables extracted from the complete datasheet showing the important parameters, figures, etc. are usually sufficient, but the source/link to the complete datasheet must be provided. If the datasheet describes more than one type, clearly mark in the datasheet to which type you are referring / which type you plan to use (e.g. if you copy a datasheet describing a complete range of relays. If you selected the 24V SPDT monostable version, you must highlight the information referring to this specific version).  Datasheets should only be used as a reference. Please cover the important data in your text by using tables, figures, etc.  If you refer to parts of a data sheet, then you need to provide an internal document links from the text to the respective datasheet and another internal document link back from the datasheet to the text section.  For example a link in the motor controller section “The datasheet can be found here (clickable)” and a link above the motor controller datasheet in the appendix “The section covering the motor controller can be found here (clickable)”.  If you are unsure with respect to feedback of the reviewer, do not hesitate to write an e-mail and ask.  Parts of the ESF which are changed because of reviewer’s feedback must be noted in the Changelog  Following these guidelines will guarantee a swift review process |

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Must be hyperlinked!

# List of Abbreviations

Define any abbreviations/acronyms which are not listed in the rules.

|  |  |
| --- | --- |
| Abbreviation/ Acronym | Definition |
| ACC AIR  AMS BMS  BOTS BSPD  GLV GLVMP GLVMS HV HV+ HV- IC  IMD MaxTSVolt PCB SC TS TSAC TSAL TSMP TSMS | Accumulator (High voltage battery) Accumulator Insulation Relay Accumulator Management System Battery Monitoring System Brake-Over-Travel-Switch Brake System Plausibility Device Grounded Low Voltage Ground Low Voltage Measurement Point Ground Low Voltage Master Switch High Voltage  Positive terminal of the HV battery (at the vehicle side of the AIR) Negative terminal of the HV battery (at the vehicle side of the AIR) Integrated Circuit Insulation Monitoring Device Maximum Tractive System Voltage Printed Circuit Board Shutdown Circuit Tractive System Tractive System Accumulator Container Tractive System Active Light Tractive System Measurement Point Tractive System Master Switch |

# System Overview

|  |
| --- |
| This electric vehicle is designed for a race environment where it must have high acceleration, good stability, and the ability to run for 30 minutes continuously with safety as the highest priority. The vehicle is driven by a single electric motor driving our two rear wheel, the motor is control via our VCU. Our battery pack is in 140s5p configuration composed of ten 14s5p segments in series with total available energy of 7,56kWh and nominal voltage of 504 VDC.   * Rough Schematic (blocks) showing all parts affected with the electrical systems and function of the tractive system * No detailed wiring |

Complete the following table, replacing the values with your specifications:

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Maximum Tractive-system voltage: | Nominal Tractive-system voltage: | Control-system voltage: | Accumulator configuration: | Total Accumulator capacity: | Nominal TS Accumulator current: | Maximum TS Accumulator current: | TS accumulator cell type: | GLV Accumulator cell type: | Motor type: | Number of motors: | Maximum combined motor power in kW |
| 588VDC | 504VDC | 12VDC | 140s5p | 15Ah | 100A | 175A | Lithium nickel manganese cobalt oxides (NMC) | Lithium-Ion Polymer | synchronous permanent magnet electric motor | Total 1, one for the 2 rear wheel | 100kW |

Table 1.1 General parameters

# Electrical Systems

## Shutdown Circuit

### Description/concept

|  |
| --- |
| The shutdown circuit is a series of relays and switches cutting the power of the AIRs coils in case of a problem or when the vehicle is disabled on purpose via one of the Master Switches. When the Shutdown Circuit is open, the AIRs coils are not powered and the TS is desactivate. |

Complete the following table replacing the values with your specification and append additional switches from your setup:

| **Part** | **Function** |
| --- | --- |
| Main Switch (for control and tractive system; GLMS, TSMS) | Normally open |
| Brake over travel switch (BOTS) | Normally closed |
| Shutdown buttons (SCBs) | Normally closed |
| Insulation Monitoring Device (IMD) | Normally open |
| Accumulator Management System (AMS) | Normally open |
| Inertia Switch | Normally closed |
| HVD interlock | Closed when HVD is connected |
| Brake System Plausibility Device (BSPD) | Normally Opened |
| TS Activation relays | Normally Opened |
| VCU Fault relays and Inverter Fault relays | Normally Opened |
| Precharge circuit relays | Normally Opened |

Table 2.1 List of switches in the shutdown circuit

### Wiring / additional circuitry

|  |
| --- |
| To comply with the FSUK rules the SC is composed of 2 main switches : the GLVMS and the TSMS, 3 SCBs, an inertia switch, a BOTS, 3 relays controlled respectively by the BSPD, the AMS and the IMD, the HVD interlock. We also add 2 relays in parallel for the AIR+ and the precharge contactor, 2 relays controlled by the VCU and the Inverter and a relays ensuring activation of the TS in compliance with FSUK rules.  In this Shutdown circuit except for the SCBs, the inertia switches, the BOTS and HVD (when connected) all systems are in Normally Opened configuration.    Figure : Shutdown circuit schematic |

Fill out and add information to the following table:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Total Number of AIRs: | Current per AIR: | Additional parts consumption within the shutdown circuit: | Total current: | Cross sectional area of the wiring used: |
| 2 | 1,5A | 0,5A | 3,5A | 1.31 mm² |

Table 2.2 Wiring – Shutdown circuit

### Position in car

|  |
| --- |
| Provide CAD renderings showing the relevant parts. Mark the parts in the renderings, if necessary. |

### Failure control, detection and mitigation

|  |
| --- |
| Key failure of the SC usually comes from a sensor (current or pressure sensor for BSPD, temperature sensor for AMS, ground sensor for IMD) being short circuit or open circuit. SC circuit (AMS, IMD, BSPD) are designed to pulled down the signal at fault, immediately cutting the power to the respective relays coil resulting in an open SC. Each of these circuit are controlled during the scrutineering by disconnecting each sensor and verifying it open the SC. |

## IMD

### Description (type, operation parameters)

|  |
| --- |
| To comply with FSUK rules we used a Bender IR155-3203 IMD with a setpoint of 300kOhms because it ensure an isolation superior to 500Ohms/Volt for our MaxTSVolt which is 588V. In our vehicle, the IMD is connected to the HV+ and HV- at the vehicle side of the AIR and to the grounded roll hoop which is in direct connection with the GLV, thus the IMD can detect an isolation fault between the HV and the GLV. When a fault is detected, the Output signal is pulled low which open the Shutdown Circuit by an intermediate circuit which is place outside of the TSAC. The IMD indicator light is power on by the intermediate circuit when the IMD fault signal is pulled down.  The datasheet of the IMD can be found [here](#IMD_Rating). |

Complete the following table replacing the values with your specification:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Supply voltage range: | Supply voltage | Environmental temperature range: | Self-test interval: | High voltage range: | Set response value: | Max. operation current: | Approximate time to shut down at 50% of the response value: |
| 10..36VDC | 24VDC | -40..105°C | Always at startup, then every 20 minutes | DC 0..1000V | 300kΩ (500Ω/Volt) | 500mA | 27s |

Table 2.3 Parameters of the IMD

### Wiring/cables/connectors/

|  |
| --- |
| The IMD itself is place in an housing inside the TSAC, the HV+ and HV- are wired directly from the AIR to the IMD housing. The IMD signal output is wired from the IMD to an intermediate circuit which is place in an housing outside of the TSAC. The IMD intermediate circuit is shown below, the SC can be seen in green. To ensure proper connection trough IMD housing and TSAC we use 8STA SOURIAU connectors. Datasheet of the connectors can be found [here](#SOURIAU_8STA_Rating). To ensure proper wiring inside the TSAC we use AWG22 wire which can handle voltage up to 600Vdc, and temperature over 60°C which is the maximum temperature the TSAC can reach. Full datasheet of the wire can be found [here](#IMD_wire).    Figure : IMD intermediate circuit schematic |

### Position in car

|  |
| --- |
| Provide CAD renderings showing the relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |
| --- |
| A failure of the IMD usually comes from an opened circuit or a short circuit to ground of the output fault wire, it cause the intermediate circuit to opened the SC and powered on the IMD Indicator Light. Proper verification is perform during scrutineering by disconnecting the IMD fault wire. |

## Inertia Switch

### Description (type, operation parameters)

|  |
| --- |
| The inertia switch used is a Sensata Technologies’ 360° Resettable Crash Sensors, it meets the FSUK 2022 regulations. Ratings of the inertia switch can be found [here](#Inertia_switch_datasheet). |

Complete the following table replacing the values with your specification:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Inertia Switch type: | Supply voltage range: | Supply voltage: | Environmental temperature range: | Max. operation current: | Trigger characteristics: |
| Sensata Technologies’ 360° Resettable Crash Sensors | 10..36VDC | 12VDC | **e.g.** -40..105°C | 10A | 8g for 50ms / 13g for 20ms |

Table 2.4 Parameters of the Inertia Switch

### Wiring/cables/connectors/

|  |
| --- |
| The Inertia Switch wiring is shown in [Figure 1.](#SC_schematic) |

### Position in car

|  |
| --- |
| Provide CAD renderings showing the relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |
| --- |
| The Inertia Switch is tested during scrutineering by shaking it. |

## Reset / Latching for IMD and AMS

### Description/circuitry

|  |
| --- |
| The latching and the reset of the AMS and the IMD is performed by an intermediate circuit composed of an open drain transistor which close the SC relay if an optocoupler has already been closed by the reset/set signal. When the SC relay is closed the optocoupler doesn’t remain closed. In case of fault, the transistor is open which open the SC relays. When the IMD or AMS signal gets back to safe state, a short push on the reset push button will closed the optocoupler which will close the SC relays. |

### Wiring/cables/connectors

|  |  |
| --- | --- |
| The schematic of the latching and reset circuit is shown below.    Figure : IMD and AMS latching / reset circuit schematic | Describe wiring, show schematics, describe connectors and cables used and show useful data regarding the wiring. If not detailed in section 2.1, be sure to show how the device opens the shutdown circuit. |

### Position in car

|  |
| --- |
| Provide CAD renderings showing the relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |
| --- |
| A failure of the IMD or AMS latching / reset circuit usually comes from an opened circuit or a short circuit to ground of one of the wire that transmit the fault signal or the reset signal. If the failure comes from the fault signal wire it cause the intermediate circuit to opened the SC and powered on the IMD Indicator Light which is directly detected. If the failure comes from the reset signal wire we cannot reset the IMD or the AMS ones the SC is opened by one or the other system which is directly detected. Proper verification is perform during scrutineering by disconnecting the IMD and the AMS fault wire and resetting both. |

## Brake Over-Travel Switch (BOTS)

### Description/circuitry

|  |  |
| --- | --- |
| The BOTS is a normally close two-position switch which block in the open position if push. It is place behind the brake pedal but far enough to ensure that the actuation of the pedal push open the BOTS only if the pedal over travel due to a failure of the brake system. The BOTS is place in series in the SC, an open BOTS leads to an open SC. | Describe the concept and circuitry of the BOTS. Describe the method how your BOTS solution fulfils T6.2.1. |

### Wiring/cables/connectors

|  |  |
| --- | --- |
| The BOTS wiring schematic is shown in [Figure 1.](#SC_schematic) Full datasheet of the BOTS can be found [here](#BOTS_schematic). | Describe wiring, show schematics, describe connectors and cables used and show useful data regarding the wiring. If not detailed in section 2.1, be sure to show how the device opens the shutdown circuit. |

### Position in car

|  |
| --- |
| Provide CAD renderings showing the relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |  |
| --- | --- |
| Failure of the BOTS can be cause if the switch is broken. It can be mechanic or electric. In both of those case it can be detected during scrutineering if the BOTS doesn’t block in the open position when push or if it doesn’t open the SC when push. | Briefly describe the causes and consequences of key failures of your BOTS, its inputs or outputs and how they are detected, mitigated and controlled. |

## Brake System Plausibility Device (BSPD)

### Description/additional circuitry

|  |  |
| --- | --- |
| The BSPD receive both current sensor signal and brake pressure signal, we use a comparator to ensure both signals are below the threshold that correspond to 5kW of power coming from the battery and 30Bar brake pressure. If those two conditions are not respected for more than 500ms, the SC is open by the BSPD relay. The circuit have an automatic reset that last 10 second after any of the sensor signal is back to safe state. To check implausibility we compared both sensors signals to a low voltage value (around 0,05V). Sensors signals can only be below this threshold in case of short circuit to ground or open circuit (both signals being pull down). If an error is detected the signal is put at fault and the SC is open if both signals are at fault. | Describe how your electronic hardware brake plausibility system works (this is in addition to your ECU controlled brake plausibility software), provide tables with main operation parameters, and describe additional circuitry used to check or for an implausibility. Describe how the system reacts if an implausibility or error is detected. |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Brake sensor used: | Brake sensor physical response value: | Tractive system power sensor type | Tractive system sensor physical response value: | Tractive System power sensor current threshold (5kW/Nominal TS voltage): | Supply voltages: | Maximum supply currents: | Operating temperature: | Output used to control AIRs: |
| 130 bar Toyota pressure sensor ETM-603X | 0,76 V | Hall effect current sensor | 3,16 V | 9,92 A | 5V | 1A | -20..150 °C | Open a relay |

Table 2.5 BSPD data

### Schematic

|  |  |
| --- | --- |
| Figure : BSPD Schematic | Describe the wiring, show schematics including the circuit board, show data regarding the cables and connectors used. |

### Connection with the shutdown circuit

|  |
| --- |
| How the BSPD open the SC is shown in [Figure 1.](#SC_schematic) |

### Position in car/mechanical fastening/mechanical connection

|  |
| --- |
| Provide CAD renderings showing all relevant parts and discuss the mechanical connection of the sensors to the pedal assembly. Mark the parts in the rendering, if necessary. |

### Disconnection of BSPD sensors

|  |  |
| --- | --- |
| If one sensor is disconnected the BSPD will be at fault if the signal of the other sensor is over the threshold.  The pressure sensor connector is more or less the same than last year and can be disconnected easily as we can see in the picture below.  Figure : pressure sensor connector  The current sensor uses the same type of connector which can be disconnected easily. | Show how the current sensor and brake system pressure sensor can be disconnected from the BSPD. Describe the BSPD operation if any sensor is disconnected. Provide CAD renderings showing all relevant parts if necessary. |

### Failure detection, control and mitigation

|  |  |
| --- | --- |
| Key failure of the BSPD happened when a sensor is disconnected, short circuit to ground or in open circuit. We already describe how the BSPD handle such situation in part [2.6.5](#_Disconnection_of_BSPD) and [2.6.1](#_Description/additional_circuitry) | Briefly describe the causes and consequences of key failures of your BSPD, its inputs or outputs and how they are detected, mitigated and controlled. |

## Shutdown System Interlocks

### Description/circuitry

|  |
| --- |
| Describe the concept and circuitry of the Shutdown System Interlocks. *Note: Interlocks are circuits used to open the shutdown circuit if a connector is disconnected or enclosure is opened. This is not the entire shutdown circuit.* |

### Wiring/cables/connectors

|  |
| --- |
| Describe wiring, show schematics, describe connectors and cables used and show useful data regarding the wiring. |

### Position in car

|  |
| --- |
| Provide CAD renderings showing the relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the causes and consequences of key failures of your interlocks, their inputs or outputs and how they are detected, mitigated and controlled. |

## Measurement points

### Description

|  |  |
| --- | --- |
| Describe the housing used and how it can be accessed, etc. Describe how the measurement points are protected/covered when not in use and how the electrical connections on the back of the measurement points are protected when the measurement points are being used. | |
| Current limiting resistor Value: |  |

### Wiring, connectors, cables

|  |
| --- |
| Describe wiring, show schematics, and describe connectors and cables used and show useful data regarding the wiring. Include details on the protection resistor including resistance, voltage and power rating. |

### Position in car

|  |
| --- |
| Provide CAD renderings showing the relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the causes and consequences of key failures of your measurement points or their inputs and how they are detected, mitigated and controlled. |

## HV Disconnect (HVD)

### Description

|  |
| --- |
| Describe your concept of the HVD and how it can be operated. |

### Wiring, cables, current calculations, connectors

|  |
| --- |
| Describe wiring, show schematics, describe connectors and cables and show useful data regarding the wiring. Include information on the working voltage and current rating of the HVD. |

### Position in car

|  |
| --- |
| Provide CAD renderings showing all relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the impact of failures of your HVD and how they are detected, mitigated and controlled. |

## Pre-Charge circuitry

### Description

|  |  |
| --- | --- |
| The precharge circuit is composed of the precharge relay and the precharge resistor. The precharge relay is controlled by a circuit that measure the voltage at the accumulator side of the AIR and at the vehicle side of the AIR. When the TS is activated, the circuit close the precharge relay, when the voltage at the vehicle side reach 95% of the voltage at the accumulator side the AIR+ is closed and the precharge relays opened. | Describe your concept of the pre-charge circuitry. |

### Wiring, cables, current calculations, connectors

|  |
| --- |
| To measure the high voltage we use wire connected directly at the AIR pole. The wire datasheet can be found [here](#IMD_wire).    Figure : Precharge circuit simplify schematic    Figure : Precharge circuit plot  For the different plot the equation are :  For the precharge circuit itself we use wire with a cross section of 4mm2 that can withstand the maximum precharge current which is 6A .  Full datasheet of the precharge relay can be found [here](#Precharge_relays), and full datasheet of the resistor can be found [here](#Precharge_resistor). |

Additionally, fill out the tables:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Resistor Type: | Resistance: | Continuous power rating: | Overload power rating (1 sec): | Overload power rating (5 sec): | Overload power rating (15 sec): | Voltage rating: | Cross-sectional area of the wire used: |
| Aluminium housed power resistor | 100Ω | 50W | 1250W | 250W | 100 | 1900V | 4 mm² |

Table 2.6 General data of the pre-charge resistor

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Relay Type: | Contact arrangement: | Continuous DC current: | Voltage rating | Nominal Coil Voltage: | FET type: | Maximum Drain-Source Current: | Drain-Source Breakdown Voltage: | On Characteristics Gate Threshold Voltage: | Cross-sectional area of the wire used: |
| High current high voltage DC contactor relay | DPST | 50A | 750VDC | 12 Vdc |  | 300 | 4000 Vdc | 8 Vdc | 4mm² |

Table 2.7 General data of the pre-charge relay

### Position in car

|  |
| --- |
| Provide CAD renderings showing all relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |  |
| --- | --- |
| Key failure happened when the AIR+ is closing while the inverter DC link capacitor is not fully charge. The inrush current can cause soldering of the AIR main contact. We can detect such failure by hearing the electric arc. We can also detect it when the pilot want to desactivated the TS and the TSAL light off due to the implausibility between the wanted state and the real state of the AIR which main contact has been soldered. | Briefly describe the causes and consequences of key failures of your pre-charge system, its inputs or outputs and how they are detected, mitigated and controlled. |

## Discharge circuitry

### Description

|  |
| --- |
| Describe your concept of the discharge circuitry. |

### Wiring, cables, current calculations, connectors

|  |
| --- |
| Describe wiring, show schematics, describe connectors and cables used and show useful data regarding the wiring. |
| Plot “Voltage” vs. time and show the formula describing this behaviour |
| Plot “Discharge current” vs. time and show the formula describing your plot |

Additionally, fill out the table:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Resistor Type: | Resistance: | Continuous power rating: | Overload power rating (1 sec): | Overload power rating (5 sec): | Overload power rating (15 sec): | Voltage rating: | Maximum expected current: | Average current: | Cross-sectional area of the wire used: |
| **e.g.** ABC Resistor | **e.g.** 680Ω | **e.g.** 350W | **e.g.** 600W |  |  | **e.g.** 1500V | **e.g.** 0.7A | **e.g.** 0.3A | **e.g.** 0.205 mm² |

Table 2.8 General data of the discharge circuit

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Relay Type: | Contact arrangement: | Continuous DC current: | Voltage rating | Nominal Coil Voltage: | FET type: | Maximum Drain-Source Current: | Drain-Source Breakdown Voltage: | On Characteristics Gate Threshold Voltage: | Cross-sectional area of the wire used: |
| **e.g.** DEF Relay | **e.g.** SPDT, SPST, SPCO, SPTT, DPST, …. | **e.g.** 25A | **e.g.** 2000VDC |  |  |  |  |  | **e.g.** 0.205 mm² |

Table 2.9 General data of the dis-charge relay

### Position in car

|  |
| --- |
| Provide CAD renderings showing all relevant parts. Mark the parts in the rendering, if necessary |

### Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the causes and consequences of key failures of your discharge system, its inputs or outputs and how they are detected, mitigated and controlled. |

## Tractive System Active Light (TSAL)

### Description/circuitry

|  |  |
| --- | --- |
| The TSAL is constituted of the RED and GREEN light which are place under the main hoop of the car, of a circuitry that measure the ACC voltage, the AIR state and the pre-charge relays state which is placed inside the TSAC, of a circuit that measure the voltage across DC link capacitor of the inverter and is placed inside the discharge circuit housing and of a circuit that perform the logic of the TSAL and powered on the RED and GREEN light and is placed at the rear of the car.    Figure : TSAL state machine diagram  To measure the state of the AIR and the pre-charge relays we put a resistor in the connector between the auxiliary contact of the relays and the TSAL board. When the Auxiliary contact is closed the signal is 5 V, when it is open the signal is 2,5 V and when there is an open circuit in the connector or a short circuit to ground of the signal it is 0V.  To measure the voltage of the ACC we use a voltage divider bridge such that the voltage of the divider bridge is 5V for the MaxTSVolt, hence a signal greater 0,5 V when the ACC voltage is greater than 60 Vdc.    Figure : TSAL AIR & pre-charge relays state detection and ACC voltage measurement inside the TSAC | Describe the tractive system active light and additional circuitry. Show a state-machine diagram describing the operation modes of the TSAL. Provide schematic how the TS voltages are measured (DC-link capacitors and AIR vehicle side) and how the mechanical relay states (2 AIRs + pre-charge relay) are detected. |

Additionally, fill out the table:

| Indication | Supply voltage | Max. operational current | Lamp type | Power consumption: | Brightness | Frequency: | Size (length x height x width): |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **RED** | 12VDC | 90mA | LED | 1W | 120 Lumen | 2Hz | 96mm x 20mm x 20mm |
| **GREEN** | 12VDC | 90mA | LED | 1W | 120 Lumen |  | 96mm x 20mm x 20mm |

Table 2.10 Parameters of the TSAL

### Wiring/cables/connectors

|  |  |
| --- | --- |
| For the wiring of the TSAL inside the TSAC we use AWG 22 wire that can handle 600V, and a temperature up to 105°C, the wire datasheet can be found [here](#IMD_wire). | Describe wiring, show schematics, describe connectors and cables used and show useful data regarding the wiring. Include gauge, voltage and temperature rating of wiring used and any fuses or other overcurrent protection used. |

### TSAL Power

The TSAL is powered by a small battery of 3000mAh, we can deactivate the TSAL by switching off the power of the TSAL coming from this battery.

|  |
| --- |
| Describe how your TSAL is powered to ensure it can remain active for at least 15 minutes after the LVs is switched off. Describe the method used (if any) to deactivate the TSAL when the LVS is switched off and the TS is confirmed to be deactivated. |

### Position in car

|  |
| --- |
| Provide CAD renderings showing the relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |  |
| --- | --- |
| Failure of the TSAL usually comes from an implausibility of a relays state signal or a voltage measurement signal. It is easily detected because the TSAL will continue flashing red while we try to deactivate the TS. | Briefly describe the causes and consequences of key failures of your TSAL system, its inputs or outputs and how they are detected, mitigated and controlled. |

## Activating the tractive system

### Description

|  |
| --- |
| Describe the process for activating the tractive system and explain how the TS cannot be activated closing the shutdown circuit (EV4.11.3). Having all components on the high side of the AIRs doesn’t activate the TS because we have a Normally open relays in the low side of the AIRs allowing us to activate the TS when we want to. The circuitry controlling the relays is supply by the SC on the high side of the AIRs that’s why the TS cannot be activated if one of the components on the high side of the AIRs is opened. In order to activate the TS, the pilot must push a button on the dashboard to close the relays, which then close the SC and activate the TS. The activation circuit is design in such a way that the pilot will need to push the activation button to activate the TS ones again if the SC is open and closed by any part. |

### Wiring, cables, current calculations, connectors

|  |
| --- |
| Figure : TS activation circuit |

### Position in car

|  |
| --- |
| Provide CAD renderings showing all relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |
| --- |
| Key failure of the system is cause by an open circuit or a short circuit to ground of the activation signal. In this case the pilot cannot activate the TS which allow us to detect the failure. |

## Ready-To-Drive Mode

### Description

|  |
| --- |
| To activate Ready-To-Drive mode, the pilot must press to brake pedal and a dedicated button on the dashboard for 1 second. The Ready-To-Drive mode can’t be activated unless the shutdown circuit is closed. The VCU is constantly looking for the input on the dashboard and the pressing on the brake pedal. The Ready-To-Drive mode is deactivated when any of this is detected: the shutdown circuit is opened, a fault from the APPS is detected, the pilot presses both the accelerator and the brake pedals, an error is detected by the inverter. When the Ready-To-Drive mode is activated, a sound of approximately 90 dB is produced for 2 seconds by a buzzer located on the top of the main hoop. This buzzer is directly powered by a logic output of the VCU (12 VDC). |

### Ready to Drive Sound (RTDS)

|  |
| --- |
| A continuous sound is produced by a buzzer located on the top of the main hoop. This buzzer is powered by the VCU. This sound is produced during 2 second when the Ready-To-Drive mode is activated. |

### Wiring, cables, current calculations, connectors

|  |
| --- |
| The buzzer is directly connected to a digital output of the VCU. |

### Position in car

|  |
| --- |
|  |

### Failure detection, control and mitigation

|  |
| --- |
| If a fault is detected by the VCU, the Ready-To-Drive mode stops. |

# Accumulators

## TS Accumulator pack(s)

### Overview/description/parameters

|  |  |
| --- | --- |
| 1 | Describe the concept of the TS accumulator pack, provide table with main parameters like number of cells, cell stacks separated by maintenance plugs, cell configuration, resulting voltages (minimum, maximum, nominal), currents, capacity etc.    The accumulator is built with TYVA’s A5 modules (configuration : 14s5p) they are connected in series with before each modules a 150 A fuse. |
| 2 | Where more than one TS accumulator is used, add additional rows describing any differences, etc. (if identical parts are used, just refer to the corresponding sections, do not copy and paste) |

Fill out the following table (add additional rows for additional accumulators if required):

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Accumulator | Maximum Voltage: | Nominal Voltage: | Minimum Voltage: | Maximum output current: | Maximum nominal current: | Maximum charging current: | Total numbers of cells: | Cell configuration: | Total Capacity: | Number of cell stacks < 120VDC |
| **1** | 600VDC | 504VDC | 30VDC | 405A for 10s | 250A for 20s | 175A | 700 | 140s5p | 27.62 MJ | 10 |
|  |  |  |  |  |  |  |  |  |  |  |

Table 3.1 TS accumulator parameters

### Cell description

|  |
| --- |
| The cells used are the Sony MP 18650 SG3 it is a Lithium ion chemistry. The mechanical characteristics of these cells are : |

Fill out the following table:

| Cell Manufacturer and Type | Cell nominal capacity: | Maximum Voltage: | Nominal Voltage: | Minimum Voltage: | Maximum output current: | Maximum nominal output current: | Maximum charging current: | Maximum Cell Temperature | | Cell chemistry: |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Discharging | Charging |
| Sony  MP 18650 SG3 | 3120mAh | 4.25 V | 3.6V | 2.0V | 10C for 10s**?** | 5C**?** | 2C **?** | 60°C | 60°C | Lithium ion |

Table 3.2 Main cell specification

### Cell configuration

|  |  |
| --- | --- |
| 1 | Describe cell configuration, cell interconnect, show schematics of electrical configuration and CAD rendering of connection techniques, cover additional parts like internal cell fuses etc. |
| 2 | Our battery pack is made of 10 modules in series with a 14s5p configuration developed by TYVA Energie. Each module contains 70 cells with 5 segments in parallels containing each 14 cells in series. Thus, our battery pack is in a 140s5p configuration. Describe cell configuration, cell interconnect, show schematics of electrical configuration and CAD rendering of connection techniques, cover additional parts like internal cell fuses etc. |

### Cell temperature monitoring

|  |  |
| --- | --- |
| 1 | Describe how the temperature of the cells is monitored, where the temperature sensors are placed, how many cells are monitored, etc. Show schematics, cover additional parts, etc.  One module contains normally in the commercial solution 3 temperature sensors. 4 others were added to be able to monitor 40% of a module cells temperature. In fact there is 7 sensors which are monitoring 4 cells each. It means that 24 cells are monitored. [Datasheet](https://www.vishay.com/docs/29152/ntcle101e3c9017x.pdf) |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Temperature sensor accuracy: | Total number of cells: | Total number of sensors: | Max. distance from monitored negative cell terminal: | AMS opens AIRs during dis-charging if cell temperature is above: | AMS opens AIRs during charging if cell temperature is above: |
| 1 °C in operating temperature range between -55°C-125°C | 70 | 7 | 179.8mm | 60°C | 60°C |

Table 3.3 Cell temperature monitoring

### Accumulator Materials

Complete the table below, identifying the materials used within the accumulator(s)

| Material | Usage | Fire Retardancy | Data Sheet Reference |
| --- | --- | --- | --- |
| 2.5mm x 100mm Cable Ties | Sense wire looms | UL94 V-0 | (link to appendix) |
| Bus bar |  |  |  |
| 70 Lithium ion cells | Energy source |  |  |
| 7 temperature sensor | Measuring 4 sell’s temperature |  | [Datasheet](https://www.vishay.com/docs/29152/ntcle101e3c9017x.pdf) |

Table 3.4 Accumulator Materials

### Accumulator Management System

|  |  |  |
| --- | --- | --- |
| Minimum cell voltage (shutdown limit): | Maximum cell voltage (shutdown limit): | Measurement precision (mV): |
| 2.0V | 4.2V | 1mV |

Table 3.5 Cell voltage limits

|  |
| --- |
| Describe the AMS used including at least the following:   * Sense wiring protection (fusing / fusible link wire used) * The upper voltage is 5V and 0V is the lower one : the Accumulator Management System considers that a 5V signal is activate and a 0V is a no signal. The communication is made with CAN 2.0B. * The AMS reacts when the temperature measured is out of the following range [-120°C; 60°C] * Show tables of operation parameters            * Each AMS board senses 15 cellsDescribe how many cells are sensed by each AMS board, the configuration of the cells, the configuration of the boards and how any comms wiring between boards is protected * If any error is detected the relay AIR stay in the same state as usual that mean open, if no problems are detected, the signal is a 1 so the relays is closed * Describe how the AMS is able to open the AIRs if any error is detected * Describe where galvanic isolation occurs between TS and GLV system connections.      * Galvanic isolation between TS and GLV occurs in the inverter BAMOCAR D3. |

#### Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the causes and consequences of key failures of your AMS, its inputs or outputs and how they are detected, mitigated and controlled.   * One cell’s temperature is upper than 60°C or under -20°C * If the BMS is not controlling 30% of the cell’s temperature * Cell overvoltage (above 4.2V) or undervoltage (below (2.0V) * If the current delivered by the HV battery is above the limit calculated by the BMS based on the current cell conditions * If the BMS assess that there is an open circuit on precharge or an isolation failure in the accumulator * If the charger send an error |

### Accumulator indicator

|  |  |
| --- | --- |
| 1 | The indicator voltage is directly supply from the ACC, it uses a DC-DC converter to reduce the voltage of the ACC and supply the board and the indicator in 12V and 5V. This indicator uses a voltage divider bridge and a comparator to detect when the ACC voltage is higher than 60 Vdc, when it is the case it lights out the indicator.    Figure : Indicator voltage circuit schematic |

#### Failure detection, control and mitigation

|  |
| --- |
| Key failure happened when one of the ACC wire is disconnected, in this case the circuit is not supply and the indicator stay off. We detect this failure when the indicator doesn’t light out while the TSAL is flashing red.   * One cell’s temperature is upper than 60°C or under -20°C * If the BMS is not controlling 30% of the cell’s temperature * Cell overvoltage (above 4.2V) or undervoltage (below (2.0V) * If the current delivered by the HV battery is above the limit calculated by the BMS based on the current cell conditions * If the BMS assess that there is an open circuit on precharge or an isolation failure in the accumulator * If the charger send an error |

### Wiring, cables, current calculations, connectors

|  |
| --- |
| Describe the internal wiring, show schematics, provide calculations for currents and voltages and show data regarding the cables and connectors used.   * Discuss maximum expected current, DC and AC how long will this be provided? * Compare the maximum values to nominal currents * Describe your maintenance plugs, provide pictures |

Complete the table below for each type of wire in your tractive system

| Wire type | Continuous current rating: | Cross-sectional area | Maximum operating voltage: | Temperature rating: | Wire connects the following components: |
| --- | --- | --- | --- | --- | --- |
| **e.g.** Company A, 0.205 mm² | **e.g.** 150A | **e.g.** 0.205mm² | **e.g.** 800VDC | **e.g.** 150°C | **e.g.** Cell and AMS |
|  |  |  |  |  |  |

Table 3.6 Wire data

### Maintenance Plugs

|  |
| --- |
| Describe your maintenance plugs, provide images and explain how the design ensures that it is physically impossible to electrically connect them in an incorrect configuration. |

### Accumulator isolation relays

|  |
| --- |
| Describe the AIRs used and their main operation parameters, how their state is monitored, etc.  The AIR used are normally open relays on the borne + and – on the battery, they are closed only when the shut down circuit transmit the signal of activation that assess that there is no failure.  From the data sheet |

Additionally, fill out the following table:

| Relay Type: | Contact arrangement: | Continuous DC current rating: | Overload DC current rating: | Maximum operation voltage: | Nominal coil voltage: | Normal Load switching: | Maximum Load switching |
| --- | --- | --- | --- | --- | --- | --- | --- |
| DCNLEV50 Relay | 1 Form X (SPST-NO, DM) | 50A | 100A for 3 minutes | 900VDC | 12VDC | Make and break up to 500A | 25ms to close and 10ms to release |

Table 3.7 Basic AIR data

#### Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the causes and consequences of key failures of your AIRs, their inputs or outputs and how they are detected, mitigated and controlled.   * The AIR‘s temperature range is from -40 to +85 ̊C which includes in the temperature range of the battery and cables so the AIR would be open before reaching that temperature. * Electrical life failure that can be handled by checking that the AIR can respond to a signal that close it within 1 second. * Loosening of the contact : check the connection and ensure that : Contact torque: 30 - 40 lb.in (3.4 - 4.5 N.m) Max. Active length of thread is 7.0 mm or Mounting torque: 20 lb.in (2.3 N.m) |

### Fusing

|  |
| --- |
| Describe the fuses used and their main operation parameters, use tables, etc. |

Additionally, fill out the following table for each fuse type used:

| Fuse manufacturer and type | Continuous current rating | Maximum operating voltage | Type of fuse | I2t rating | Interrupt Current (maximum current at which the fuse can interrupt the current) |
| --- | --- | --- | --- | --- | --- |
| **e.g.** ABC Fuse company, MNO Fuse  Fuse 150 A Grainger | 150A | 600VDC | High speed | 1690A2s at 300VDC | 20000A |
| Fuse 110A | 110A | 600VDC | High speed | 1500A²s[Data](https://rexel-cdn.com/Products/Littelfuse/JLS110.pdf?i=906851D4-9F4B-4535-B53A-4809A6FF2B71) | 20000A |

Table 3.8 Basic fuse data

Create a table with components and wires protected by the fuse(s) and the according continuous current rating. There is an example table below with some potential entries. Complete this table with information for your design and add / remove additional locations as applicable. Ensure that the rating of all the components is greater than the rating of the fuse such that none of the other components become the fuse.

| Location | Wire Size | Wire Ampacity | Fuse type | Fuse rating |
| --- | --- | --- | --- | --- |
| e.g. Cells to AIRs | e.g. 2 AWG |  | e.g. MNO Fuse |  |
|  |  |  |  |  |

Table 3.9 Fuse Protection Table

#### Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the causes and consequences of key failures of your fuses and how they are detected, mitigated and controlled.  When the fuse is burnt, the voltage difference between input and output is 5V that means that the AMS understand that there is a problem with cables. For the fuses in the battery, it directly disconnects the battery from the TS, the amperemeter sensors find out that the current is null. It implies that the AIRs would open. |

## GLV Accumulator

### Description

|  |
| --- |
| Describe your concept of the GLV Accumulator. |

| Cell/ Accumulator: | Accumulator configuration – parallel: | Accumulator configuration – series: | Maximum Voltage: | Nominal Voltage: | Minimum Voltage: | Max. Continuous Discharge Current: | Peak Discharge Current: | Peak Discharge Current Time: | Max. Continuous Charge Current | Total capacity [MJ]: |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |

Table 3.10 GLV accumulator data

### Wiring, cables, current calculations, connectors

|  |
| --- |
| Describe wiring, show schematics, describe connectors and cables and show useful data regarding the wiring. Include information on the working voltage and current rating of the accumulator. Show how the GLV battery fulfils T11.7.6 regulation on overcurrent protection. |

### Position in car

|  |
| --- |
| Provide CAD renderings showing all relevant parts. Mark the parts in the rendering, if necessary. |

## DC/DC Converters (if used)

|  |
| --- |
| If you use a DC/DC converter, describe it here. Provide details about its overcurrent, overtemperature protection and main operating parameters. Introduce how it is turned on and off and how it is ensured that it is turned off by deactivating the GLVS system as described in T11.3.1. Use tables or figures, etc. |

# Charging

|  |
| --- |
| Describe how the accumulator will be charged. How will the charger be connected? How will the accumulator be supervised during charging? Show schematics, CAD renderings, etc., if needed.    The accumulator will be charged out of the car on the handcart with charger cables that match with the battery entry connectors. |

Additionally, fill out the table:

| Charger Type: | Maximum charging power: | Maximum charging voltage: | Maximum charging current: | Interface with accumulator | Input voltage: | Input current: |
| --- | --- | --- | --- | --- | --- | --- |
| TC Charger | 3.3kW | 440V | 40A | CAN-Bus | 200VAC | 16A |

Table 4.1 General charger data

### Mechanical Configuration/materials

|  |
| --- |
| Describe the concept of the container, show how the cells are mounted, use CAD renderings, show data regarding materials used, etc.  The container is made in iron contains in the lower part all cell’s modules. On the upper part there is the AMS, the precharge circuit, the sensor card, the AIR and finally the TSAL card. |

### Position in car

|  |
| --- |
| Provide CAD renderings showing the relevant parts. Mark the parts in the rendering, if necessary. Ensure that the required mechanical structure to protect the accumulator and other electrical components are clearly identified.    Also the container is dimensioned in iron S235 to withstand 40g in front and Ansys simulation have proven it could bear it. |

### Charging Shutdown Circuit

|  |
| --- |
| Describe your charging shutdown circuit  The shutdown circuit is charged by the same mean than in the car, the charger cable connects with the battery for the low voltage and high voltage. |

### Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the causes and consequences of key failures of your charger, its inputs and outputs and how they are detected, mitigated and controlled.   * Insulation Resistance : Input, output, signal terminal to casing≥10MΩ Testing Voltage 1000VDC * Lose response time : From 100% to10%≤50mS， |

# Data Logger

## Description

|  |
| --- |
| Describe where the data logger, current sensor and voltage sensor are mounted, etc. |

## Wiring, cables, current calculations, connectors

|  |
| --- |
| Describe the wiring, show schematics, provide calculations for currents and voltages, and show data regarding the cables and connectors used. |

## Position in car

|  |
| --- |
| Provide CAD renderings showing positions of Data logger, current sensor and voltage sensor. Mark the parts in the rendering, if necessary. |

# Motors and controllers

## Motor controller(s)

### Description, type, operation parameters

|  |  |
| --- | --- |
| 1 | The motor controller receives the torque setpoint sent by the VCU by CAN. The VCU also command the activation of the motor. The controller then sends many information back to the VCU (speed, current, temperature, status…). |

Fill out the following table (add additional rows where more than one motor controller is used):

| Motor controller | Motor controller type | Maximum continuous power | Maximum peak power | Maximum Input voltage | Output voltage | Maximum continuous output current | Maximum peak current | Control method | Cooling method | Auxiliary supply voltage |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | Unitek Bamocar 700-400 | - | 135 kVA | 700 VDC | max 3x450Vrms | 285 Arms | 200 Arms | PWM | Water | 12 VDC |

Table 6.1 General motor controller data

### Wiring, cables, current calculations, connectors

|  |
| --- |
| Describe the wiring, show schematics, provide calculations for currents and voltages and show data regarding the cables and connectors used.  The inverter receives the power coming from the HV battery with 2 wires of section 25mm2. It then powers the motor with 3 wires of section 16 mm2. These 5 wires are shielded to avoid electromagnetic interferences. |

Additionally, fill out table:

| Wire type | Continuous current rating: | Cross-sectional area | Maximum operating voltage: | Temperature rating: | Wire connects the following components: |
| --- | --- | --- | --- | --- | --- |
| Evshop, 25 mm² | 130A | 25 mm² | 720 Vac | -40..150°C | Motor controller and HV battery |
| eveurope | 100A | 25 mm² | 720 Vac | -40..150°C | Motor controller and motor |

Table 6.2 Wire data

### Position in car

|  |
| --- |
|  |

### Failure detection, control and mitigation

|  |
| --- |
| The motor controller stops powering the motor and open the shutdown circuit if one of the following errors is detected: defective parameter, hardware fault, faulty safety circuit, CAN timeout time exceeded, bad or faulty encoder signal, no power supply voltage, motor temperature too high, device temperature too high, overvoltage reached, over-current or strongly oscillating current detected, current measuring fault. |

## Motors

### Description, type, operating parameters

|  |  |
| --- | --- |
| 1 |  |

Additionally, fill out table:

| Motor | Motor Manufacturer and Type: | Motor principle | Maximum continuous power: | Peak power: | Input voltage: | Nominal current: | Peak current: | Maximum torque: | Nominal torque: | Cooling method: |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | Emrax 228 MV | Synchronous | 53 kW | 109 kW | max 500 V | 160 Arms | 340 Arms | 230 Nm | 102 Nm | Water |

Table 6.3 General motor data

| Motor | Give a plot of Power vs. RPM including a line for nominal and maximum power | Give a plot of Torque vs. RPM including a line for nominal and maximum torque |
| --- | --- | --- |
| 1 |  |  |

### Wiring, cables, current calculations, connectors

|  |
| --- |
| Describe the wiring, show schematics, provide calculations for currents and voltages and show data regarding the cables and connectors used. |

### Position in car

|  |
| --- |
|  |

### Failure detection, control and mitigation

|  |
| --- |
| The motor controller checks the temperature of the motor thanks to a temperature sensor located on the stator. If the temperature is too high, it stops powering the motor and open the shutdown circuit. A resolver transmits the position and rotating speed of the motor to the motor controller. If a defect is detected on this feedback, again the controller opens the shutdown circuit. |

## Regenerative Braking Systems

### Description

|  |
| --- |
| Describe any regenerative braking systems fitted to the vehicle and how they are activated. |

### Brake Light Activation

|  |
| --- |
| If the regenerative braking system can initiate a deceleration of 1 ms-² ± 0.3 ms-² without operation of the brake pedal describe the system for illuminating the brake light. |

### Wiring, cables, current calculations, connectors

|  |
| --- |
| Describe wiring, show schematics, describe connectors and cables and show useful data regarding the wiring. |

### Position in car

|  |
| --- |
| Provide CAD renderings showing all relevant parts. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the causes and consequences of key failures of your regenerative braking system, its inputs or outputs and how they are detected, mitigated and controlled. |

# Overall Grounding Concept

## Description of the Grounding Concept

|  |
| --- |
| Describe how you intend to achieve the resistances between components at the required levels as defined in rules. |

## Grounding Measurements

|  |
| --- |
| Describe which measurements you will take to ensure that low resistance described in rules is achieved. |

## Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the impact of grounding failures and how they are detected, mitigated and controlled. |

# Firewall(s)

## Description/materials

|  |  |
| --- | --- |
| 1 | The firewall is composed three parts (top, middle and lower part) each composed of two layers:   * the one facing the tractive system side is made of aluminum 1mm thick * the one facing the driver is made of nomex 1mm thick (electrically insulating and fire retardant material)   The grounding is achieved thanks to steel brackets holding the firewall from the tractive system side |
| 2 | Where more than one firewall is used, add additional rows describing the differences (where structure, materials, etc. are the same, refer to the corresponding sections, do not copy and paste) |

## Position in car

|  |
| --- |
|  |

# Torque and Brake Encoders

## Torque Encoders

### Description/additional circuitry

|  |
| --- |
| The position of the accelerator pedal is obtained thanks to 2 linear potentiometers. The first one is powered by 5 VDC while the second one received 12 VDC. This is how we manage to have two different transfer functions. Both 5V and 12V are provided by the VCU. The VCU measures the two voltage and verify if the two position sensors give the same angular value for the accelerator pedal angle. If the error between the two sensors is higher than 10 %, the VCU stop the Ready-To-Drive mode. If one of the voltages is out of range (out of 1-4.4V or out of 2.4-10.5V), the same happens. So, in case of short circuit or open circuit, the VCU is able to stop the car.    Transfer functions: |

| Torque encoder manufacturer: | Torque encoder type: | Torque encoder principle: | Total number of Torque Encoder Sensors: | Supply voltage: | Maximum supply current: | Operating temperature: | Used output: |
| --- | --- | --- | --- | --- | --- | --- | --- |
| AK Industries | Linear Potentiometers MS 94 | potentiometer | 1 | 5V | - | -40..150 °C | 1-4.4V |
| AK Industries | Linear Potentiometers MS 94 | potentiometer | 1 | 12V | - | -40..150 °C | 2.4-10.5V |

Table 9.1 Torque encoder data (add additional rows for each type of torque encoder used)

### Torque Encoder Plausibility Check

|  |
| --- |
| In case of a short circuit or an open circuit, the voltage will be either 0V or 5V/12V and the VCU will detect the fault. |

### Wiring

|  |
| --- |
| The wires are attached to the VCU using this connector that regroups all inputs, outputs and alimentation cables on the VCU. |

### Position in car/mechanical fastening/mechanical connection

|  |
| --- |
|  |

### Failure detection, control and mitigation

|  |
| --- |
| If a failure like a short circuit or an open circuit happens, the VCU will stop the Ready-To-Drive mode. |

## Brake encoder

### Description/additional circuitry

|  |
| --- |
| Describe the type of the Brake system encoder(s) used for regenerative braking (if any). |

| Brake encoder manufacturer: | Brake encoder type: | Brake encoder principle: | Total number of Brake Encoder Sensors: | Supply voltage: | Maximum supply current: | Operating temperature: | Used output: |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **e.g.** ABC Encoder |  | **e.g.** potentiometer |  | **e.g.** 5V | **e.g.** 20mA | **e.g.** -20..180 °C | **e.g.** 0-5V |

Table 9.2 Brake encoder data

### Brake Encoder Plausibility Check

|  |
| --- |
| Describe additional circuitry used to check or manipulate the signal going to the motor controller. Describe how failures (e.g. Implausibility, short circuit or open circuit or equivalent) are detected and how the system reacts if an implausibility or errors is detected. |

### Wiring

|  |
| --- |
| Describe the wiring, show schematics, show data regarding the cables and connectors used. |

### Position in car/mechanical fastening/mechanical connection

|  |
| --- |
| Provide CAD renderings showing all relevant parts and discuss the mechanical connection of the sensors to the pedal assembly. Mark the parts in the rendering, if necessary. |

### Failure detection, control and mitigation

|  |
| --- |
| Briefly describe the causes and consequences of key failures of your torque encoder(s), their inputs and outputs and how they are detected, mitigated and controlled. |

# Additional LV-parts interfering with the tractive system

Describe those parts here which interfere or influence the tractive system, for example a controlling unit that measures wheel speeds and steering angle and calculates a target torque for each motor or a DC/DC Converter providing power for the LV-system from the HV-system, etc.

## LV part 1

### Description

Describe the parts used and their circuitry, and provide main operation parameters, use tables or figures, etc.

### Wiring, cables,

Describe the wiring, show schematics, etc.

### Position in car

Provide CAD renderings showing the relevant parts. Mark the parts in the rendering, if necessary.

## LV part 2

### Description

Describe the parts used and their circuitry, and provide main operation parameters, use tables or figures, etc.

### Wiring, cables,

Describe the wiring, show schematics, etc.

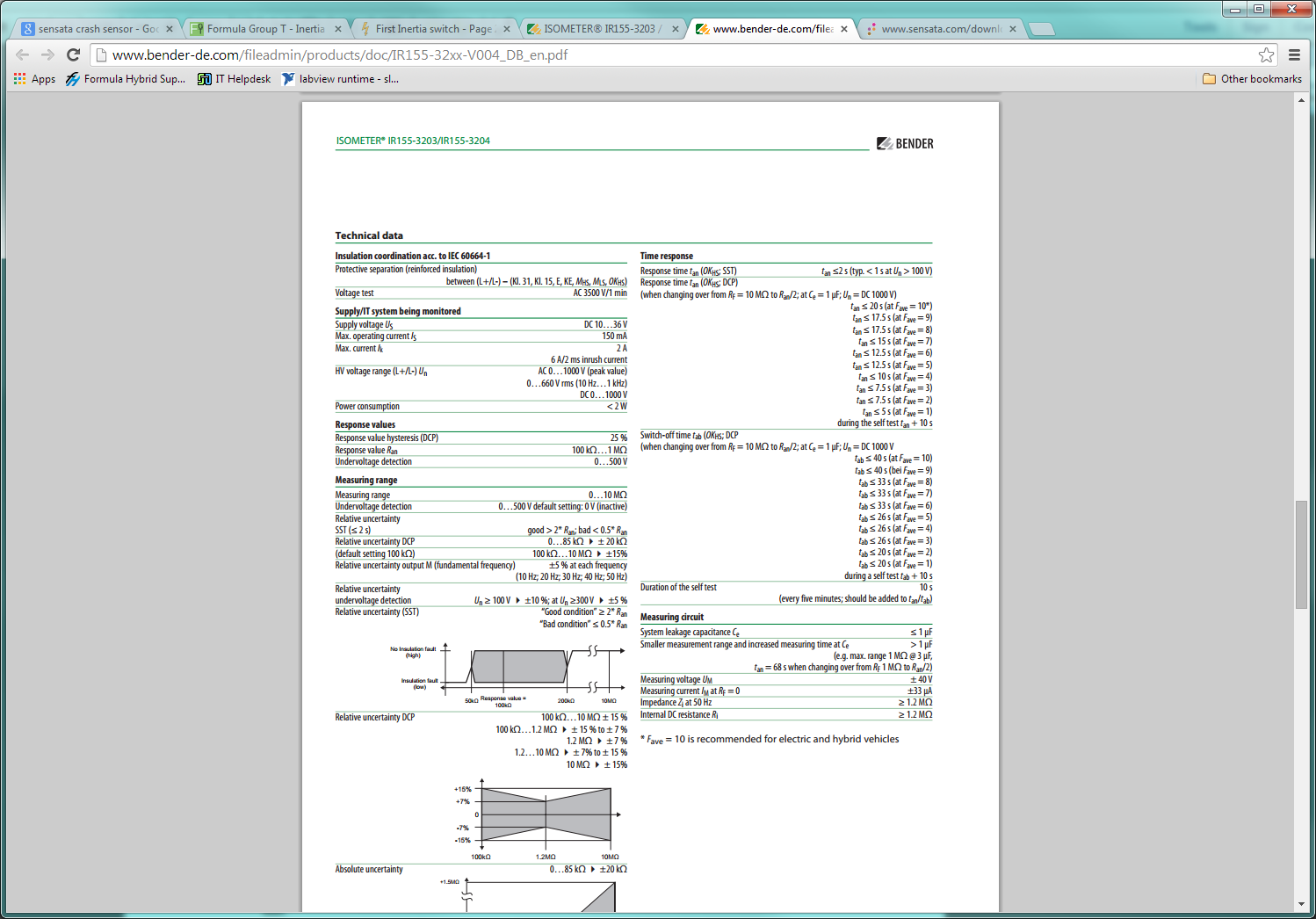
### Position in car

Provide CAD renderings showing the relevant parts. Mark the parts in the rendering, if necessary.

# 

# Appendix

11.1 – Bender IR155-3203 IMD ratings



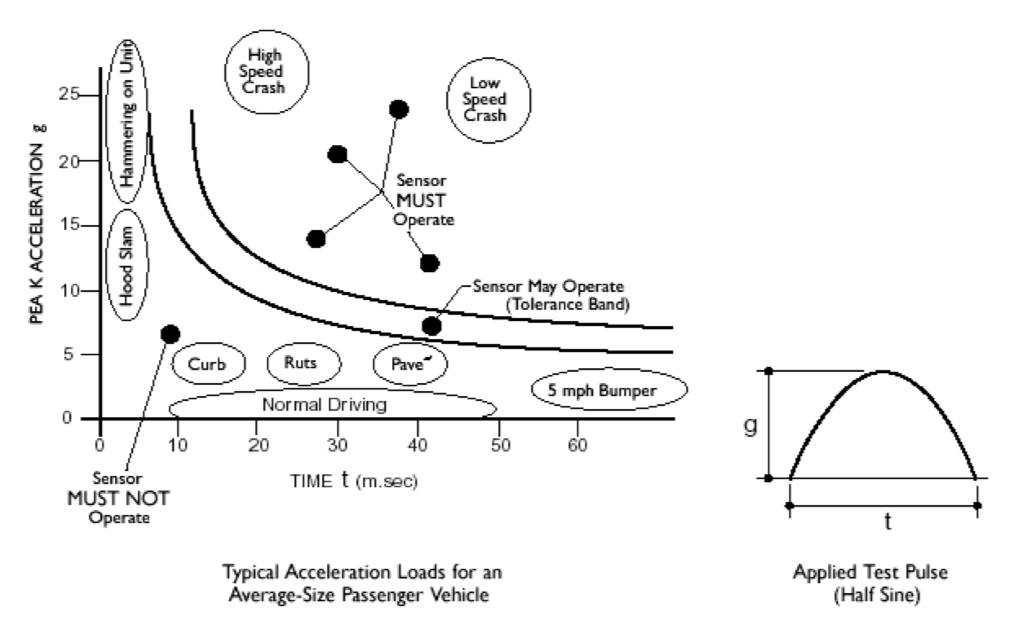
Complete data sheet located at:   
<https://www.bender.de/fileadmin/content/Products/d/e/IR155-32xx-V004_D00115_D_XXEN.pdf>

11.2 – 8STA SOURIAU connectors ratings

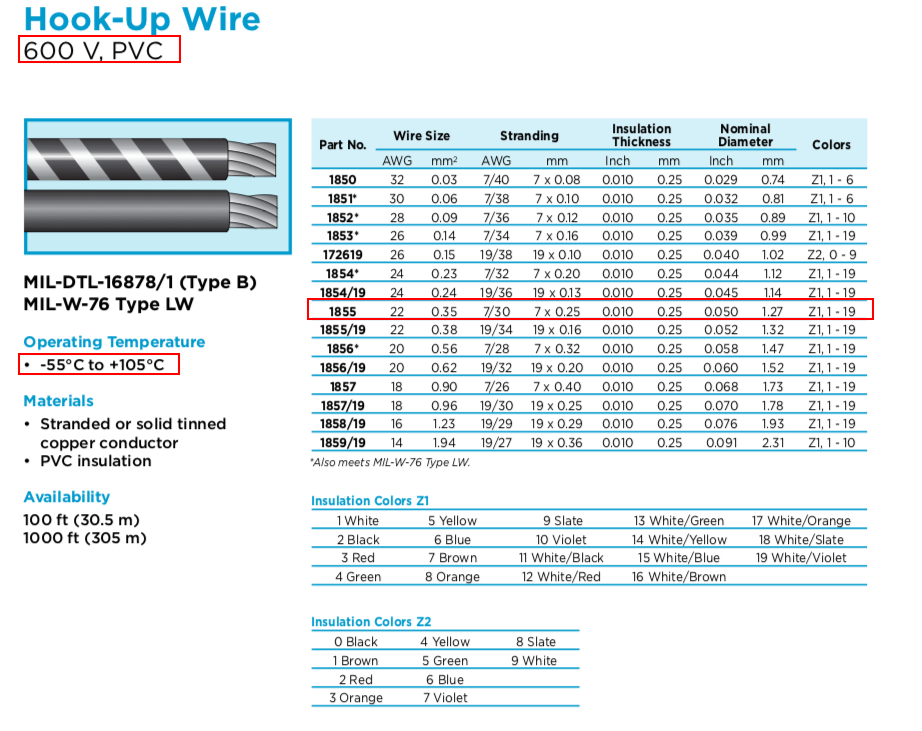


Complete data sheet located at: <https://ipaper.ipapercms.dk/SOURIAU/catalog-motorsport/?>

11.3 Inertia switch ratings

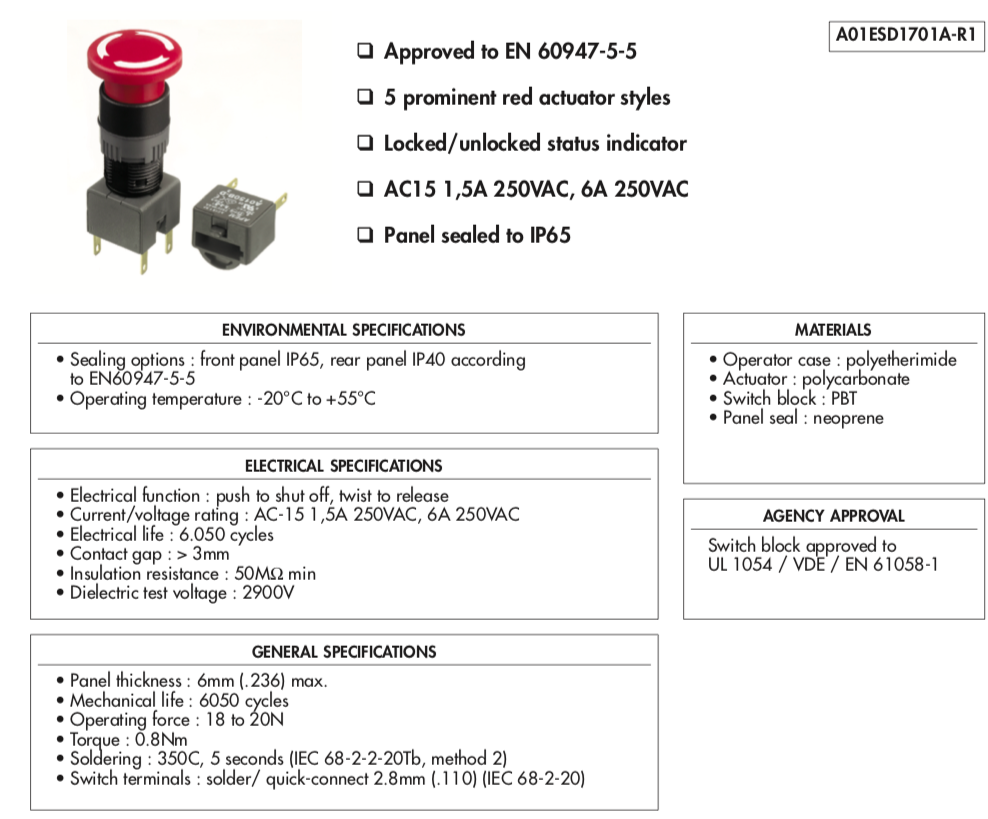


Complete data sheet located at: <https://www.jsae.or.jp/formula/jp/SFJ/docu/STJ_resettable-crash-sensor.pdf>

11.4 IMD wire  


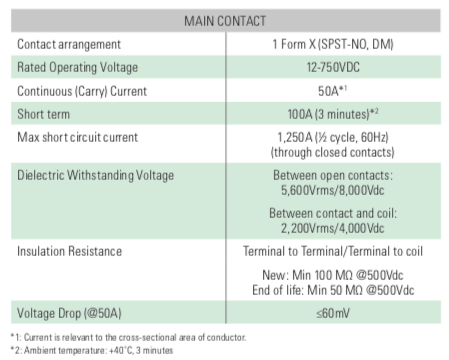
Complete data sheet located at: <https://docs.rs-online.com/6310/0900766b8137d176.pdf>

11.5 BOTS datasheet



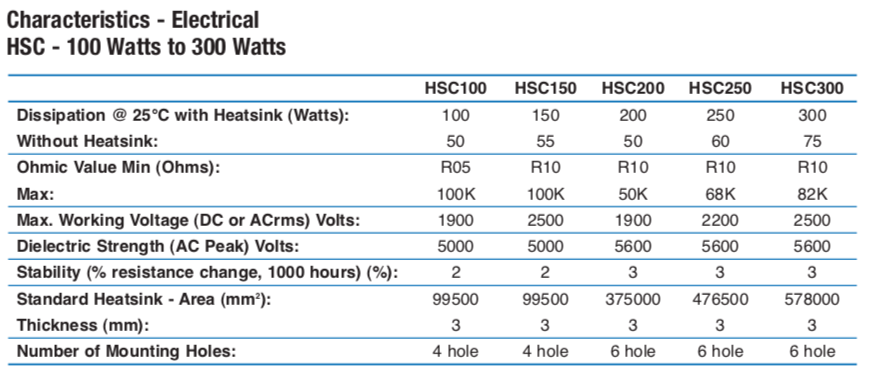
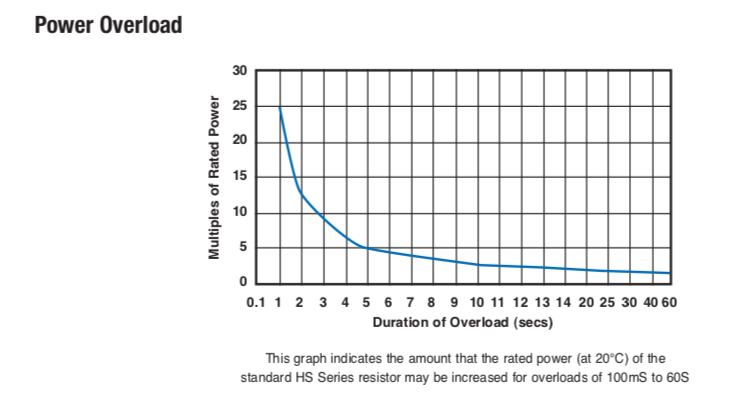
Complete data sheet located at: <https://www.mouser.fr/datasheet/2/26/apem_appm-s-a0002947927-1-1748468.pdf>

11.6 Precharge relays datasheet



Complete data sheet located at: <https://www.mouser.fr/datasheet/2/240/Littelfuse_DCNLEV_50_Datasheet-2891678.pdf>

11.7 Precharge resistor



Complete data sheet located at: <https://www.te.com/commerce/DocumentDelivery/DDEController?Action=showdoc&DocId=Data+Sheet%7F1773035%7FC%7Fpdf%7FEnglish%7FENG_DS_1773035_C.pdf%7F1625999-1>