**2016 Formula Hybrid Electrical System Form (ESF)**

INTRODUCTION

The goal of the ESF is to ensure that vehicles are as safe as possible, and that they comply with the Formula-Hybrid completion rules. The ESF is divided seven main sections:

1 – Overview

2 – Cables, Fusing & Grounding

3 – Isolation & Insulation

4 – Electric Tractive System

5 – Accumulator System

6 – Safety Controls and Indicators

7 – GLV System

The *Cables and Fusing,* and *Insulation and Isolation* sections are at the beginning of the ESF as these are the areas where teams most often have trouble in complying with FH rules.

A clear, concise ESF will help you to build a better car. It will also help you to pass tech testing as most common tech problems can be addressed before the car reaches the track.

IMPORTANT INSTRUCTIONS AND REQUIREMENTS

1. Every part of this ESF must be filled with content. If a section is not relevant to your vehicle, mark it as “N/A” and describe briefly why not.
2. Leave the written instructions in place and add your responses below them.
3. All figures and tables must be included. An ESF with incomplete tables or figures will be rejected.
4. The maximum length of a complete ESF is 100 pages.
5. Note that many fields ask for information that was submitted in your ESF-1. This information must be reentered – in some cases will be different than what was entered in ESF-1, which is OK.
6. When completed, this document must be converted to a pdf and submitted to: <http://formula-hybrid.com/uploads/>

Please submit any questions, corrections and suggestions for improvement to: <http://www.formula-hybrid.org/level2/support>

REVIEW PROCESS

Once submitted, your ESF will be reviewed by at least two FH reviewers. One will be the designated *primary reviewer* for your team.

Feedback on your ESF occurs through the Formula Hybrid upload system. You will receive emails via this system from your reviewers offering guidance and feedback. You will also submit revised versions of your ESF in this system. When you submit a revised ESF, please indicate the REVISION DATE AND LETTER (starting with Letter A) and which sections have been updated in the following table:

|  |  |
| --- | --- |
| REVISION DATE: |  |
| REVISION: (A, B, C, etc…) |  |
|  |  |
| Section | Revised (Yes / No) |
| 1 – Overview |  |
| 2 – Cables and Fusing |  |
| 3 – Insulation and Isolation |  |
| 4 – Electric Tractive System |  |
| 5 – Accumulator System |  |
| 6 – GLV System |  |
| 7 – Safety Controls and Indicators |  |
| 8 – Appendices / Datasheets |  |

TITLE PAGE

*Please include team logo, car picture, etc..*

|  |  |
| --- | --- |
| University Name: |  |
| Team Name: |  |
| Car Number: |  |

**Main Team Contact for ESF related questions:**

|  |  |
| --- | --- |
| Name: |  |
| e-mail: |  |

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*Must be hyperlinked!*

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*Must be hyperlinked*!

# List of Abbreviations

AIR Accumulator Isolation Relay

AMS Accumulator Management System

FH Rules Formula Hybrid Rule

GLV Grounded Low-Voltage

IMD Insulation Monitoring Device

SMD Segment Maintenance Disconnect

TS Tractive System

TSEL Tractive System Energized Light

TSMP Tractive System Measurement Point

TSV Tractive System Voltage

TSVP Tractive System Voltage Present

*(Add more as needed)*

# Vehicle Overview

Person primarily responsible for this section:

|  |  |
| --- | --- |
| Name: |  |
| e-mail: |  |

Check the appropriate boxes:

**Vehicle is**

New (built on an entirely new frame)

New, but built on a pre-existing frame (FSAE, FS, FH-HIP, FH electric-only, etc.)

Updated from a previous year vehicle

**Architecture**

Hybrid

Series

Parallel

Hybrid in Progress (HIP)

Electric-only

**Drive**

Front wheel

Rear wheel

All-wheel

**Regenerative braking**

Front wheels

Rear wheels

All wheels

None

NARRATIVE OVERVIEW

*Provide a brief, concise description of the vehicles main electrical systems including tractive system, accumulator, hybrid type (series or parallel) and method of mechanical coupling to wheels. Describe any innovative or unusual aspects of the design.*

Include the following figures:

* **Figure 1** – an electrical system block diagram showing all major parts associated with the tractive-system. (Not detailed wiring).
* **Figure 2** – Drawings or photographs showing the vehicle from the front, top, and side
* **Figure 3** – A wiring diagram superimposed on a top view of the vehicle showing the locations of all major TS components and the routing of TS wiring.
* **Figure 4** -- Include a complete TSV wiring schematic per FH Rule **S4.4.1** showing connections between all TS components. This should include accumulator cells, AIRs, SMDs, motor controller, motor, pre-charge and discharge circuits, AMD, IMD, charging port and any other TS connections. **NOTE:** Figure 4 is the most important diagram in the ESF



Figure 1 - Electrical System Block Diagram



Figure 2 - Drawings showing the vehicle from the front, top, and side

Replace with your own diagram or figure


Figure 3 - Locations of all major TS components



Figure 4 - TSV Wiring Schematic

Fill in the following table:

|  |  |
| --- | --- |
| Item | Data |
| Nominal Tractive System Voltage (TSV) | VDC |
| Max. TSV (typically this is during charging) | VDC |
| Control System voltage (GLV) | VDC |
| Total Accumulator capacity (Wh)[[1]](#footnote-1) | Wh |
| Accumulator type (Lead-acid, Li-Ion, NiMH, Ultracap..) |  |
| Number of electric motors, total |  |
| Are wheel motors used? | Yes /  No |

Table 1- General Electrical System Parameters

# Cables, Fusing & Grounding

Person primarily responsible for this section:

|  |  |
| --- | --- |
| Name: |  |
| e-mail: |  |

## Fusing & Overcurrent Protection

*List TS and GLV fuse (or circuit breaker) data, and where used*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Mfg. | Fuse Part Number | Cont. Rating (A) | DC Voltage Rating | DC Interrupt Rating (A) | Where Used |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table 2 - Fuse Table

## Component Fusing

*List major components (e.g., motor controller, dc-dc converter) and data sheet max fuse rating. Ensure that the rating of the fuse used is less than the maximum value for the component*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Component | Fuse Part Number | Max Fuse Rating A | Installed Fuse Rating A | Notes |
|  |  |  |  |  |
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Table 3 - Component Fuse Ratings

## System Wire Tables

*List wires and cables used in the Tractive System and the GLV system - wires protected by a fuse of 1 A or less may be omitted.*

*Cable capacity is the value from FH Rules* ***Appendix E*** *(Wire Current Capacity). A revised version of* ***Appendix E*** *that includes metric wire sizes is available at the FH web site. Show available fault current and how calculated. Available fault current can be calculated from*

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mfg. | Part Number | Size AWG / mm2 | Insul-ation Type | Voltage Rating | Temp. Rating C | Cable Capacity A | Fuse Part # | Fuse Cont. A | Fuse Interr-upting Rating Adc | Avail. Fault Current A | Where Used & How fault current is calculated |
|  |  |  |  |  |  |  |  |  |  |  |  |
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Table 4 - System Wire Table

## Grounding System

*Describe how you keep the resistances between accessible components below the required levels as defined in FH Rules* ***EV4.3****. If wire is used for ground bonding, state the AWG or mm2 of the wire*

## Conductive Panel Grounding

*If carbon fiber or coated conductive panels are used in your design, describe the fabrication methods used to ensure point to point resistances that comply with* ***EV4.3.2****. Describe results of measurements made per* ***EV4.3.3****.*

# Isolation & Insulation

Person primarily responsible for this section:

|  |  |
| --- | --- |
| Name: |  |
| e-mail: |  |

## Separation of Tractive System and Grounded Low Voltage System

*Describe how the TS and GLV systems are physically separated (****EV4.1****). Add CAD drawings or photographs of how TS and GLV are segregated in key areas of the electrical system.*



Figure 5 - TS and GLV separation

*List all electrical circuit boards designed by team that contain TS and GLV voltage in the following table.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Device / PCB | TS Voltage Present (V) | Minimum Spacing mm | Thru Air of Over Surface | Notes |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
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Table 5 - PCB Spacings

*Add a figure (board layout drawing) for each team-designed PCB showing that spacings comply with* ***EV4.1.8***



Figure 6 - Team Designed PCB Layout

*List all purchased components with both TS and GLV connections (at min motor controller and AMS)*

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Isolation Method | Link to Document Describing Isolation | Notes |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

## Isolation & Insulation

*Provide a list of containers that have TS and GLV wiring in them. If a barrier is used rather than spacing, identify barrier material used (reference* Table 7*).*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Container Name | Segregation by Spacing (Y or N) | How is Spacing maintained | Actual Measured Spacing mm | Alt – Barrier Material P/N | Notes |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
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Table 6 – List of Containers with TS and GLV wiring

*List all insulating barrier materials used to meet the requirements of* ***EV1.3*** *or* ***EV4.1.5***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Insulating Material / Part Number | UL Recog-nized ? | Rated Temper-ature ºC | Thickness mm | Notes |
|  |  |  |  |  |
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|  |  |  |  |  |

Table 7- Insulating Materials

## Conduit

*List different types of conduit used in the design. Specify location and if manufacturer’s standard fittings are used. Note Virtual Accumulator Housing FH Rules* ***EV3.3.1*** *requires METALLIC type LFMC.*

*Describe how the conduit is anchored if standard fittings are not used.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Conduit Type | MFR | Part Number | Diameter  Inch or mm | Standard Fittings  (Y or N) | Location / Use |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table 8 - Conduit Data

*Is all conduit contained within the vehicle Surface Envelope per* ***EV4.2.1****? (****Y or N****).*

*Does all conduit comply with* ***EV4.5.10****? (****Y or N****).*

## Shielded dual-insulated cable

*If Shielded, dual-insulated cable per EV4.5.8 used in the vehicle, provide specifications and where used:*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| MFR | Part Number | Cross Section mm2 | Shield grounded at both ends (Y or N) | Location / Use |
|  |  |  |  |  |
|  |  |  |  |  |

Table 9 - Shielded Dual Insulated Cable Data

## Firewall(s)

#### Description/materials

*Describe the concept, layer structure and the materials used for the firewalls. Describe how all firewall requirements in FH Rules* ***T4.5.1*** *are satisfied. Show how the low resistance connection to chassis ground is achieved.*

#### Position in car

*Provide CAD-rendering or photographs showing the location of the firewall(s).*

# Electric Tractive System

Person primarily responsible for this section:

|  |  |
| --- | --- |
| Name: |  |
| e-mail: |  |

## Motor(s)

*Describe the motor(s) used and reason for this particular choice. Add additional tables if multiple motor types are used*

|  |  |
| --- | --- |
| Manufacturer and Model: |  |
| Motor type (PM, Induction, DC Brush..) |  |
| Number of motors of this type used |  |
| Nominal motor voltage (Vrms l-l or Vdc) |  |
| Nominal / Peak motor current (A or A/phase) | Nom: / Peak: |
| Nominal / Peak motor power | Nom: / Peak: |
| Motor wiring – conductor size and type |  |

Table 10 - Motor Data

*Provide calculations for currents and voltages. State how this relates to the choice of cables and connectors used.*

## Motor Controller

*Describe the motor controller(s) used and reason for this particular choice. Add additional tables if multiple motor controller types are used.*

|  |  |
| --- | --- |
| Manufacturer and Model: |  |
| Number of controllers of this type used |  |
| Maximum Input voltage: |  |
| Nominal Input Current (A) |  |
| Max Input Fuse (A) per Mfr. |  |
| Output voltage (Vac l-l or Vdc) |  |
| Isolation voltage rating between GLV (power supply or control inputs) and TS connections |  |
| Is the accelerator galvanically isolated from the Tractive System per **EV2.3**? | Yes /  No |

Table 11 - Motor Controller Data

*If the answer to the last question is NO, how to you intend to comply with rule* ***EV2.3*** *(an external isolator is acceptable)..*

*Provide calculations for currents and voltages. State how this relates to the choice of cables and connectors used.*

## Tractive System Measurement Points (TSMP)

*The TSMP must comply with FH Rule* ***EV4.4****. Describe the TSMP housing and location. Describe TSMP electrical connection point.*

|  |  |
| --- | --- |
| TSMP Output Protection Resistor Value | kΩ |
| Resistor Voltage Rating | V |
| Resistor Power Rating | W |

Table 12 – TSMP Resistor Data

## Pre-Charge circuitry

*Describe your design for the pre-charge circuitry. Describe wiring, connectors and cables used.*

* *Include a schematic of the pre-charge circuit*
* *Include a plot of calculated TS Voltage vs. time*
* *Include a plot of calculated Current vs. time*
* *Include a plot of resistor power vs time.*

*Provide the following information:*

|  |  |
| --- | --- |
| Resistor Type: |  |
| Resistance: | Ω |
| Continuous power rating: | W |
| Overload power rating: | W for sec |
| Voltage rating: | V |

Table 13 - Data for the pre-charge resistor

|  |  |
| --- | --- |
| Relay MFR & Type: |  |
| Contact arrangement (e.g. SPDT) |  |
| Continuous DC contact current (A): | A |
| Contact voltage rating (Vdc). | V |

Table 14 - Data of the pre-charge relay

## Discharge circuitry

*Describe your concept for the discharge circuitry. Describe wiring, connectors and cables used.*

* *Include a schematic of the pre-charge circuit*
* *Include a plot of calculated TS Voltage vs. time*
* *Include a plot of calculated “Discharge current” vs. time*
* *Include a plot of resistor power vs time.*

*Provide the following information:*

|  |  |
| --- | --- |
| Resistor Type: |  |
| Resistance: | Ω |
| Continuous power rating: | W |
| Overload power rating: | W for \_\_\_\_\_ sec |
| Voltage rating: | V |
| Maximum expected current: | A |
| Average current: | A |

Table 15 - Data of the discharge circuit.

## HV Disconnect (HVD)

*Describe your design for the HVD and how it is operated, wiring, and location. Describe how your design meets all requirements for* ***EV4.7***

## Accelerator Actuator / Throttle Position Sensor

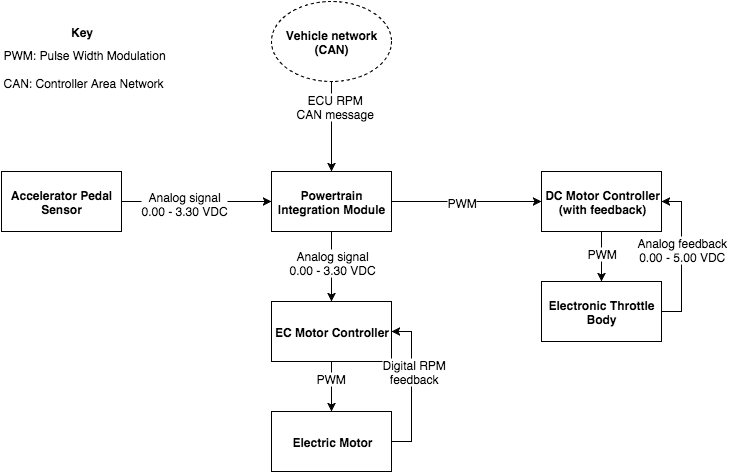
*Describe the accelerator actuator and throttle position sensor(s) used, describe additional circuitry used to check or condition the signal going to the motor controller. Describe wiring, cables and connectors used. Provide schematics and a description of the method of operation of any team-built signal conditioning electronics. Explain how your design meets all of the requirements of FH Rules* ***IC1.6*** *and* ***EV2***

Our vehicle utilizes a Penny & Giles TPS280DP Contactless Hall-Effect sensor for our throttle position sensor. The sensor will output on two channels, providing 0.00 to 3.30 VDC based on a rotational position of the throttle peddle. This analog output is routed to our micro-controller, labeled the Powertrain Integration Module (PIM). The PIM accepts the throttle position analog signal, and outputs control signals to both our throttle body's motor controller and our electric motor's motor controller.

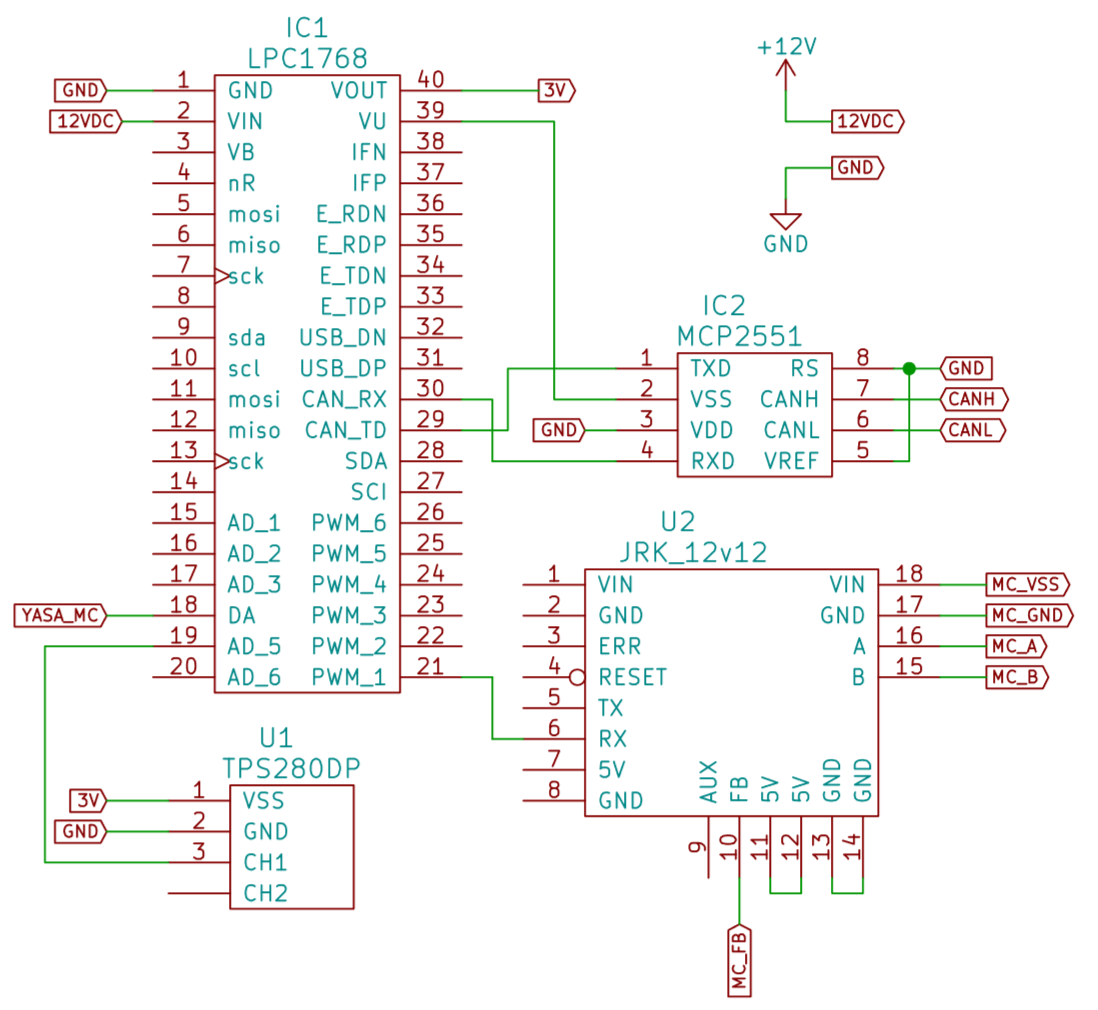
The control signal to the throttle body's motor controller, a Pololu Jrk 12v12 USB Motor Controller with Feedback, is a pulse-width modulated signal representing the desired position for the butterfly-value for the throttle body. The motor controller will automatically utilize analog feedback from the throttle body to attempt to achive the desired position.

The electric motor’s motor controller, a Sevcon Gen 4 size 8, utilizes an analog 0.00 VDC to 3.30 VDC analog control signal. This will dictate the torque output desired from the Yasa electric motor.

Lastly, a safety feature has been included. Due to the possible torque output difference between the Yasa electric motor and our KTM 250cc combustion engine, our PIM will monitor the ICE’s internal RPM to ensure that it does not begin to redline. This is achived by reading the Engine’s RPM via outputted CAN messages from our ECU. If the engine’s RPM is above a threshold of 13,000 RPM all torque production from the Yasa is creased.



High-level schematic of Throttle control



Low-level schematic of Throttle control

|  |  |
| --- | --- |
| Actuator / Encoder manufacturer and model: | Penny & Giles TPS280DP |
| Encoder principle (e.g.Potentiometer): | Contactless Hall-effect Sensor |
| Output: | Duel and Linear. 0.00-3.30 VDC, 3.30-0.00 VDC |
| Is motor controller accelerator signal isolated from TSV? | Yes /  No |
| If no, how will you satisfy rule **EV2.3**? |  |

Table 16 - Throttle Position encoder data

## Accelerator / throttle position encoder error check

*Describe how the system reacts if an error (e.g. short circuit or open circuit or equivalent) is detected. Describe circuitry used to check or condition the signal going to the motor controller. Describe how failures (e.g. Implausibility, short circuit, open circuit etc.) are detected and how the system reacts if an error is detected. State how you comply with* ***EV2.2***

To meet the requirements of EV2.2.1, our PIM will be used detect an open circuit, short to ground and short to sensor power between our throttle position sensor and our two motor controllers. To an open circuit or short to ground, the PIM will observe any rapid changes in the voltages outputted from the throttle position sensor. Upon drastic voltage drops of 30% or more, within 1.00ms or less, an open circuit or short to ground is presumed and torque production is ceased until normal conditions resume. Furthermore, upon a drastic voltage increase of 30% or more, and within 1.00ms or less, a short to sensor power is presumed, and toque production is ceased until normal conditions resume. To halt the production of torque, an analog voltage of 0.00 VDC is outputted to the Sevcon motor controller to cease toque output from the electric motor. A digitized signal of zero (0) is transmitted via PWM to the throttle body’s motor control to close the throttle body’s butterfly-valve.

# Accumulator System

Person primarily responsible for this section:

|  |  |
| --- | --- |
| Name: |  |
| e-mail: |  |

## Accumulator Pack

*Provide a narrative design of the accumulator system and complete the following table.*

|  |  |
| --- | --- |
| Maximum Voltage (during charging): | VDC |
| Nominal Voltage: | VDC |
| Total number of cells: |  |
| Cell arrangement (x in series / y in parallel): |  |
| Are packs commercial or team constructed? | Commercial /  Team |
| Total Capacity (per FH Rules **Appendix A**): | kWh |
| Maximum Segment Capacity | MJ |
| Number of Accumulator Segments | (#) |

Table 17 - Main accumulator parameters

*Describe how pack capacity is calculated. Provide calculation at 2C (0.5 hour) rate? How is capacity derived from manufacturer’s data? If so, include discharge data or graph here. Include Peukert calculation if used (See FH Rules* ***Appendix A****)*

*Show your segment energy calculations. The segment energy is calculated as*

(The 80% factor is not applied for this calculation.)

## Cell description

*Describe the cell type used and the chemistry and complete the following table.*

|  |  |
| --- | --- |
| Cell Manufacturer and Model |  |
| Cell type (prismatic, cylindrical, pouch, etc.) | Yes /  No |
| Are these pouch cells | Yes /  No |
| Cell nominal capacity at 2C (0.5 hour) rate: | Ah |
| Data sheet nominal capacity | Ah at \_\_\_C rate |
| Maximum Voltage (during charging): | V |
| Nominal Voltage (data sheet value): | V |
| Minimum Voltage (AMS setting): | V |
| Maximum Cell Temperature (charging - AMS setting) | °C |
| Maximum Cell Temperature (discharging - AMS setting) | °C |
| Cell chemistry: |  |

Table 18 - Main cell specification

*Show your calculations for 2C nominal AH capacity if the data sheet uses a different discharge rate. Refer to FH rules* ***Appendix A***

## Cell configuration

*Describe cell configuration, show schematics, cover additional parts like internal cell fuses etc.*

*Describe configuration: e.g., N cells in parallel then M packs in series, or N cells in series then M strings in series.*

*Does the accumulator combine individual cells in parallel without cell fuses?* Yes /  No

*If Yes, explain how* ***EV6.1.7*** *is satisfied.*

## Segment Maintenance Disconnect

*Describe segment maintenance disconnect (SMD) device, locations, ratings etc.*

|  |  |
| --- | --- |
| Is HVD used as an SMD? | Yes /  No |
| Number of SMD Devices |  |
| SMD MFR and Model |  |
| SMD Rated Voltage (if applicable) | V |
| SMD Rated Current (if applicable) | A |
| Segment Energy (6 MJ max) | MJ |
| Segment Energy Discharge Rate (Ref FH Rules **Appendix A**) | C |

Table 19 - SMD Data

## Lithium-Ion Pouch Cells

*The vehicle accumulator uses individual pouch cells.* Yes  No

Note that designing an accumulator system utilizing pouch cells is a substantial engineering undertaking which may be avoided by using prismatic or cylindrical cells.

*If your team has designed your accumulator system using individual Lithium-Ion pouch cells, include drawings, photographs and calculations demonstrating compliance with all sections of rule* ***EV3.9.*** *If your system has been issued a variance to* ***EV3.9*** *by the Formula Hybrid rules committee, include the required documentation from the cell manufacturer.*

## Cell temperature monitoring

*Describe how the temperature of the cells is monitored, where the temperature sensors are placed, how many cells are monitored, etc. Show a map of the physical layout. Provide schematics for team-built electronics.*

|  |  |
| --- | --- |
| Number of Cells with Temperature Monitoring (#1) |  |
| Total Number of Cells (#2) |  |
| Percentage Monitored (#1 / #2) |  |
| Percentage Required by FH Rules **Table 12** |  |
| If each sensor monitors multiple cells, state how many: |  |

Table 20 - Cell Temperature Monitoring

## Accumulator Isolation Relays (AIR)

*Describe the number of AIRs used and their locations. Also complete the following table.*

|  |  |
| --- | --- |
| MFR & Model |  |
| Contact arraignment: |  |
| Continuous DC current rating: | A |
| Overload DC current rating: | A for \_\_\_\_\_ sec |
| Maximum operation voltage: | VDC |
| Nominal coil voltage: | VDC |
| Normal Load switching: | Make and break up to \_\_\_\_\_ A |

Table 21 AIR data

## Accumulator Management System (AMS)

*Describe the AMS and how it was chosen. Describe generally how it meets the requirements of* ***EV3.7***

|  |  |
| --- | --- |
| AMS MFR and Model |  |
| Number of AMSs |  |
| Upper cell voltage trip | V |
| Lower cell voltage trip | V |
| Temperature trip | °C |

Table 22 - AMS Data

* *Describe other relevant AMS operation parameters.*
* *Describe how many cells are monitored by each AMS board, the configuration of the cells, the configuration of the boards and how AMS communications wiring is protected and isolated.*
* *Describe how the AMS opens the AIRs if an error is detected*
* *Indicate in the AMS system the location of the isolation between TS and GLV*

## Accumulator wiring, cables, current calculations

*Describe internal wiring with schematics if appropriate. Provide calculations for currents and voltages and show data regarding the cables and connectors used.*

*Discuss maximum expected current, DC and AC, and duration*

*Compare the maximum values to nominal currents*

## Accumulator indicator

*If accumulator container is removable, describe the indicator, including indicating voltage range*

## Charging

*Describe how the accumulator will be charged. How will the charger be connected? How is the accumulator to be supervised during charging?*

*Complete the table*

|  |  |
| --- | --- |
| Charger Manufacturer and model: |  |
| Maximum charging power: | kW |
| Isolation | Yes /  No |
| UL Certification (If “no”, fill in the line below) | Yes /  No |
| Do you have a waiver from the FH rules committee? | Yes /  No |
| Maximum charging voltage: | V |
| Maximum charging current: | A |
| Interface with accumulator (e.g. CAN, relay etc) |  |
| Input voltage: | VAC single phase |
| Input current: | A |

Table 23 - Charger data

## Accumulator Container/Housing

*Describe the design of the accumulator container. Include the housing material specifications and construction methods. Include data sheets for insulating materials. Include information documenting compliance with UL94-V0, FAR25 or equivalent.*

*If the housing is made of conductive material, include information on how the poles of the accumulators are insulated and/or separated from the housing, and describe where and how the container is grounded to the chassis.*

*Include additional photographs if required to comply with rule* ***EV3.2.***

*Show how the cells are mounted, use CAD-Renderings, and include calculations showing compliance with FH Rules* ***EV3.4.***

# Safety Controls and Indicators

## Shutdown Circuit

*Include a schematic of the shutdown circuit for your vehicle including all major components in the loop*



Figure 7 – Safety Shutdown Circuit Schematic

*Describe the method of operation of your shutdown circuit, including the master switches, shut down buttons, brake over-travel switch, etc. Also complete the following table*

|  |  |
| --- | --- |
| **Part** | **Function  (Momentary, Normally Open or Normally Closed)** |
| Main Switch (for control and tractive-system; CSMS, TSMS) |  |
| Brake over-travel switch (BOTS) |  |
| Shutdown buttons (BRB) |  |
| Insulation Monitoring Device (IMD) |  |
| Battery Management System (AMS) |  |
| Interlocks (if used) |  |

Table 24 - Switches& devices in the shutdown circuit

*Describe wiring and additional circuitry controlling AIRs. Write a functional description of operation*

|  |  |
| --- | --- |
| Total Number of AIRs: |  |
| Coil holding current per AIR: | A |
| Current drawn by other components wired in parallel with the AIRs. | A |
| Total current: | A |

Table 25 - Shutdown circuit Current Draw

*Provide CAD-renderings showing the shutdown circuit parts. Mark the parts in the renderings*



Figure 8 – Location of Shutdown Circuit Components

## IMD

*Describe the IMD used and use a table for the common operation parameters, like supply voltage, temperature, etc. Describe how the IMD indicator light is wired. Complete the following table.*

|  |  |
| --- | --- |
| MFR / Model |  |
| Set response value: | \_\_\_ kΩ (\_\_\_ Ω/Volt) |

Table 26 Parameters of the IMD

*Describe IMD wiring with schematics.*

## Reset / Latching for IMD and AMS

*Describe the functioning and circuitry of the latching/reset system for a tripped IMD or AMS. Describe wiring, provide schematics.*

## Shutdown System Interlocks

*(If used) describe the functioning and circuitry of the Shutdown System Interlocks. Describe wiring, provide schematics.*

## Tractive System Energized Light (TSEL)

*Describe the tractive system energized light components and method of operation. Describe location and wiring, provide schematics. See* ***EV4.10***

## Tractive System Voltage Present light (TSVP)

*Describe the tractive system voltage present light components and method of operation. Describe location and wiring, provide schematics. See* ***EV4.12***

## Ready-To-Drive-Sound (RTDS)

*Describe your design for the RTDS system. See* ***EV4.11***

# GLV System

Person primarily responsible for this section:

|  |  |
| --- | --- |
| Name: |  |
| e-mail: |  |

## GLV System Data

*Provide a brief description of the GLV system and complete the following table*

|  |  |
| --- | --- |
| GLV System Voltage | V |
| GLV Main Fuse Rating | A |
| Is a Li-Ion GLV battery used? | Yes /  No |
| If Yes, is a firewall provided per **T4.5.1**? | Yes /  No |
| Is a dc-dc converter used from TSV? | Yes /  No |
| Is the GLV system grounded to chassis? | Yes /  No |
| Does the design comply with **EV1.2.7**? | Yes /  No |

Table 27- GLV System Data

# Appendices

Include only highly-relevant data. A link to a web document in the ESF text is often more convenient for the reviewer.

The specification section of the accumulator data sheet, and sections used for determining accumulator capacity (FH Rules **Appendix A**) should be included here.

1. Calculate accumulator capacity per 2016 FH Rules Appendix A. Be sure to use the 2C (0.5 hour) discharge rate for the Ah value. [↑](#footnote-ref-1)