**FSR 2025 HSF** **Template v250312**

## Coversheet

**The Coversheet must contain the following:**

- **Heading “Hybrid System Form FSR 2025”**
- **University and Team Name**
- **Car number**

Feel free to add team logo, car picture, and so one.

**Requirements (delete this section after you have read and understood it):**

1. Complete all sections and tables of the HSF. Do not hesitate to add additional tables and pictures if needed.
2. If a section is not applicable to your design state that in the document, **do not delete any sections**.
3. Remove instructions (gray text) from document as you complete the sections. If necessary, you can easily change text style by clicking right mouse button on selected text, clicking “Styles” button, and choosing “Default” style.
4. Provide **hyperlinks** to all datasheets. All datasheets must be accessible via Internet.
5. Ensure that all Figures and Tables are included in Table of Figures and Table of tables.
6. If you are unsure with respect to feedback of the reviewer, do not hesitate to ask the judges via sport@fstudent.ru
7. Parts of the ESF which are changed because of reviewer’s feedback must be marked in **red**.
8. Export the final document to **PDF** and send it to sport@fstudent.ru.
9. Following these guidelines will guarantee a swift review process.

HSC attachments have to be documented here in the HSF instead of the SES as it is currently written in the Rules → see Rules FAQ ticket
https://www.formulastudent.de/nc/fsg/rules/faq/issue/view/12185/?

# Table of Contents

# 1 System Overview

Include a brief description of the vehicle (1 paragraph).

Complete the information in the table below.

| | |
|---|---|
| Maximum Hybrid System Voltage: | 40VDC |
| Nominal Hybrid System Voltage: | 30VDC |
| Nominal Hybrid System Current: | 500A |
| Peak Hybrid System Current: | 1000A |
| Battery configuration | 5s3p |
| Cell chemistry / Capacity | NMC / 20Ah |
| Number of Hybrid Storage Containers: | 2 |
| Total Hybrid Storage Energy: | 500Wh |
| Motor Type: | AC Induction |
| Number of Motors: | Total 1 |
| Maximum Combined Motor Power: | 5kW |
| Grounded Low Voltage System Voltage: | 24VDC |

*Table 1-1 – High Level Specifications*

Insert a system overview block diagram showing major electrical components and system interactions.

# 2 Hybrid System Schematics

## 2.1 Hybrid System Schematic

Insert a large (full page) schematic of the Hybrid system. This schematic should focus on the components that are not within the HSC. Provide boxes and 1st level interfaces when details will be provided later in this document. Some details of components within the HSC may be included for better understanding (ie AIR).
The figure must include the following:

- Wire Size (AWG or $mm^2$)
- Relative location of overcurrent protection (end of wire vs middle)
  Note: Fuses are typically used as overcurrent protection
- Overcurrent protection rating (Amperage and Voltage)
- Motor controller (1st level interfaces...inputs & outputs)
- Motor
- Connection to GLVS (if any)
- Connectors and interfaces for charging
- Show enclosures as dashed lines


*Figure 2-1 – Hybrid System Schematic*

### 2.1.1 Fuse Specifications

Complete the information in the table below.

| Model/Name | Fuse Location | Voltage Rating | Current Rating nominal/max | Datasheet |
|---|---|---|---|---|
| Fusefuse 123a | LV battery connection | 24V | 2A/5A@10s | Datasheet |
| | | | | |
| | | | | |

*Table 2-1 – Fuse Specifications*

### 2.1.2 Conductor Specifications

Complete the information in the table below.

| Model/Name | Conductor Location | Size | Voltage Rating | Current Rating nominal/max | Datasheet |
|---|---|---|---|---|---|
| Wirewire AB2C | LV connections | 24AWG | 600V | 2A/5A@10s | Datasheet |
| Wirewire AC3B | Motor connection | 15 mm2 | 600V | 150A/250A@1min | Datasheet |
| | | | | | |

*Table 2-2 – Conductor Specifications*

### 2.1.3 Connector Specifications

Complete the information in the table below.

| Model/Name | Connector Location | Voltage Rating | Current Rating nominal/max | Includes Interlock | Datasheet |
|---|---|---|---|---|---|
| Connector UniPlug 2 | TSAC to Motor controller | 600V | 200A/350A@1min | Yes | Datasheet |
| Connector UniPlug 1 | LV battery connector | 600V | 5A/10A@1min | Yes | Datasheet |

# 3 Table 2-3 – Connector SpecificationsShutdown Circuit

## 3.1 Shutdown Circuit Schematic

Insert a large (full page) schematic of the shutdown circuit.
The schematic must include the following:

- All shutdown circuit switches/devices (indicate Normally Open or Closed)
- Hybrid control system connection to shutdown circuit
- BSPD connection to shutdown circuit
- BOTS
- Inertia switch
- AIR coils
- Pre-charge relay coil (if used)
- GLV battery
- Overcurrent protection(s)
- Wire size (AWG or $mm^2$)

Explain how you meet the following requirement: The hybrid system may only be activated when the combustion engine is running or during engine start.


*Figure 3-1 – Shutdown Circuit Schematic*

# 4 Hybrid Storage Container

## 4.1 Hybrid Storage Container

Insert a large image (top or nearly top view) of the complete Hybrid Storage Container assembly without cover.
Figure must include the following:

- Attachment points to the chassis
- Electronics for the cell monitoring (at least one PCB mock-up)
- AIR
- Overcurrent protection device (typically: fuses)
- All electrical connections for the high current path
- Main power connector

(additional images may be needed to provide clear views of all elements).


*Figure 4-1 – Accumulator Schematic*

## 4.2 Hybrid Storage Container Attachments

Insert calculations showing that the following criteria are being met: The HSC itself, the mounting of the HSC to the chassis, and the mounting of each cell to the HSC must be designed to withstand the following accelerations:

- 40 g in the longitudinal direction (forward/aft)
- 40 g in the lateral direction (left/right)
- 20 g in the vertical direction (up/down)

The HSC and its attachments DO NOT HAVE TO FOLLOW EV 5.5.4, EV 5.5.5 or EV 5.5.13!

## 4.3 Segments

### 4.3.1 Segment Overview

Insert a large image of the complete segment assembly. Describe segment materials and how the design provides a safe environment from dropped tools.

### 4.3.2 Segment Specifications

Complete the information in the table below.

| | |
|---|---|
| # of Segments: | 5 |
| Cells per segment: | 15 |
| Cell configuration in segment: | 5S3P |
| Energy in segment: | 2.8MJ / 0.78 kWhr |

*Table 4-1 – Segment Specifications*

### 4.3.3 Cell Connections

Describe how the electrical connections are made to the cells (welded/bolted/clamped)? Define what kind of weld (resistance/laser), what kind of bolt (copper w/deforming nut),

and the material of the clamp. If bus bars are used what is the cross-sectional area and ampacity?

### 4.3.4 Temperature sensors

Provide images showing where the temperature sensors are placed and how they are in direct contact with the busbar. How many sensors are used, and which percentage of cells is monitored?

## 4.4 Cells

### 4.4.1 Cell Specifications

Complete the information in the table below.

| | |
|---|---|
| Cell Make / Model / Style: | Kokam XYZ- pouch, cylindrical, or metal can |
| Cell nominal capacity: | 5.4 Ah |
| Maximum Voltage: | 4.2 V |
| Nominal Voltage: | 3.7V |
| Minimum Voltage: | 2.8V |
| Maximum output current: | 12A for 10s |
| Maximum continuous output current: | 5A |
| Maximum charging current: | 1A |
| Maximum Cell Temperature (discharging) | 65°C |
| Maximum Cell Temperature (charging) | 55°C |
| Cell chemistry: | LiFePO4 |
| Cell weight: | 65g (+/-5%) |
| Total number of cells in HSC(s) | 42 |
| Total weight of active material | 2730 g (+/-5%) |
| Datasheet | Datasheet |

*Table 4-2 – Cell Specifications*

Explain how the power sinking elements of the precharge circuit (if present) are cooled.

## 4.5 HSC Monitoring System

### 4.5.1 Monitoring System Specifications

Describe the system that has been selected for voltage and temperature monitoring of the HSC(s). Provide a datasheet and show the position of the measurement system in your HSC. What is the sampling rate of your measurements?

### 4.5.2 Voltage Monitoring

Provide details of the voltage measurement system (accuracy, acquisition frequency, …).
Describe how and where the voltage sense leads are overcurrent protected (fused). What size are the sense leads? What is their ampacity? If your sense leads are not fused, please reason why and how your system detects a malfunction of one of the measurements. Also, include an error calculation of how precise your system is.

### 4.5.3 Temperature Monitoring

Provide details of the temperature measurement system (accuracy, acquisition frequency…). Give details of the temperature sensors used. Also, include an error calculation of how precise your system is.
Provide images showing the position of the temperature sensors and describe how you meet the following requirements:
The HSC must include overtemperature protection of at least 30 % of the cells that trips when any cell leaves the allowed temperature range according to the manufacturer's datasheet, but not more than 60 ◦C, for more than 1 s and disconnects the battery.
Cell temperature must be measured at the negative terminal of the respective cell. The sensor used must be in direct contact with the electrically exposed negative terminal or less than 10 mm along the high current path away from the terminal in direct contact with the respective busbar. It is acceptable to monitor multiple cells with one sensor if this requirement is met for all cells sensed by the sensor.

### 4.5.4 HSC Monitoring System Limits

Complete the table below.

| | |
|---|---|
| Max Cell Voltage: | 6.8V |
| Min Cell Voltage: | 4.2V |
| Max Temperature: | 60°C |
| Min Temperature: | -5°C |

*Table 4-3 – HMS Setpoints*

## 4.6 Charging

### 4.6.1 Charger Specifications

Complete the information in the table below.

| | |
|---|---|
| Make / Model: | ElectronPusher Inc 100V200 |
| Power: | 0.082kW |
| Output Voltage: | 30V |
| Output Current: | 0.273A |
| Input Voltage: | 120V |
| Input Current: | 1A |
| Datasheet: | Datasheet |

*Table 4-4 – Charger Specifications*

Provide images of the charger assembly and charging setup as it'll be used during the events.

### 4.6.2 Charger Control

Describe how the charging process is controlled (voltage, current and temperature monitoring)
If there is a connection between the HSC monitoring system and the charger, please explain.

### 4.6.3 Charger Demonstration

Describe numbered steps you would use to demonstrate the safe operation of charging, including how to connect, and how to disconnect. Include any safe use practices, as well as what to look for proper operation vs. a faulted condition.

# 5 Motor controller

## 5.1 Motor controller 1

### 5.1.1 Description, type, operation parameters

Describe important functions, provide a table with main parameters like resulting voltages (minimum, maximum and nominal), currents, etc.
Fill out the following table:

| | |
|---|---|
| Motor controller type: | ABC Controller |
| Maximum continuous power: | 60kW |
| Maximum peak power: | 75kW for 10s |
| Maximum Input voltage: | 600VDC |
| Output voltage: | 250VAC |
| Maximum continuous output current: | 100A |
| Maximum peak current: | 200A for 5s |
| Control method: | PWM, analog signal... |
| Cooling method: | Air, water, oil... |
| Auxiliary supply voltage: | 24VDC |
| Datasheet (if not self-developed): | Datasheet |

*Table 5-1 – General motor controller data*

### 5.1.2 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.
Additionally, fill out the table:

| | |
|---|---|
| Wire type: | Company A, 0.205 mm² |

| | |
|---|---|
| Current rating: | 150A |
| Maximum operating voltage: | 800V |
| Temperature rating: | 150 °C |
| Datasheet | Datasheet |

*Table 5-2 – General motor controller data*

### 5.1.3 Position in car

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


*Figure 5-1 – Motor Controller Position*

## 5.2 Motor Controller 2

If identical parts are used, just refer to the corresponding sections, don't copy and paste.

# 6 Electrical Motors

## 6.1 Electrical Motor 1

### 6.1.1 Description, type, operating parameters

Describe the motor used, provide a table with main parameters like resulting voltages->minimum, maximum, nominal, currents, resulting motor power, use figures to show important characteristics. Describe the casing and if the casing rotates the finger guards used. Please also include a picture of the Electrical Motor.
Additionally, fill out the table:

| | |
|---|---|
| Motor Manufacturer and Type: | ABC Motor |
| Motor principle | Asynchronous, permanently excitated |
| Maximum continuous power: | 25kW |
| Peak power: | 70kW for 5s |
| Input voltage: | 250VAC |
| Nominal current: | 50A |
| Peak current: | 70A |
| Maximum torque: | 60Nm |
| Nominal torque: | 20Nm |
| Cooling method: | Water, oil, air... |
| Datasheet (if not self-developed): | Datasheet |

*Table 6-1 – General motor data*

Give a plot of power vs RPM including a line for nominal and maximum power.


*Figure 6-1 – Power vs. RPM*

Give a plot of torque vs RPM including a line for nominal and maximum torque.


*Figure 6-2 – Torque vs. RPM*

### 6.1.2 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.

### 6.1.3 Position in car

Provide CAD renderings showing all relevant parts. Mark the parts in the rendering, if necessary, and identify the structure used to protect all relevant parts. How do you integrate the electrical Motor into your System?


*Figure 6-3 – Motor Position*

## 6.2 Electrical Motor 2

If identical parts are used, just refer to the corresponding sections, don't copy and paste

# 7 Other Items

## 7.1 Firewall

### 7.1.1 Firewall Layer Specifications

Complete the information in the table below.

| | |
|---|---|
| Aluminum layer thickness: | 0.2mm |
| Insulating layer thickness: | 2mm |
| Insulating Material Make / Model: | Conductive Co. FLDPRDCT |
| Insulating Material Datasheet: | Datasheet |
| Insulating layer side: | Driver |

*Table 7-1 – Firewall Specifications*

### 7.1.2 Firewall Location

Provide CAD rendering(s) or photographs showing the firewall components. Mark the parts that the firewall is protecting from (HSC, fuel, oil, and cooling system components) in the pictures, if necessary.


*Figure 7-1 – Firewall Location*

## 7.2 Other components

Add additional sections here to discuss other unique aspects of your design that you feel are appropriate for the HSF. For example, DC/DC converters, details of team designed motor controller, control units, etc.