

# FORMULA STUDENT

## NETHERLANDS

TECHNICAL INSPECTION SHEET  
ELECTRICAL INSPECTION

V1.0 / 2021



**Formula Student Netherlands**

2020 Inspection Sheet

Electrical Inspection

Car Number

University

**REQUIRED RESOURCES**

No.

Checkpoint

- LV battery or cell datasheet
- Samples of all wire types used for the tractive system
- Laptop and cables to display data of the AMS
- Print-outs of Rule Requests, if applicable
- Photographs of all inaccessible TS connections
- Fully assembled spare boards of all inaccessible TS boards
- Power Supply for TSAL test
- Datasheets for used wiring, insulation materials, and TS components
- For self developed LV battery packs: an opened battery pack

**LV Battery**

No.

Checkpoint

- 1 Voltage  $\leq 60\text{VDC}$
- 2 Rigid and sturdy casing
- 3 Only for wet-cell batteries: IPX7 rated and acid resistant casing if inside cockpit
- 4 Short circuit protection (e.g. fused)
- 5 Behind Firewall
- 6 Grounded to the chassis
- 8 Proper insulation of internal electrical connections
- 9 Proper mounting of cells
- 10 Complete battery pack inside rollover protection envelope
  - All following checks only needed for Li-Ion batteries (other than LiFePO4):
- 11 UL94-V0 , FAR25 or equivalent casing
- 12 Overcurrent protection that trips below max. discharge current
- 13 Overtemperature protection of at least 30% of the cells (max. 60 C or datasheet, whichever is lower)
- 14 Voltage protection of all cells
- 15 Signal failures electrically disconnect the LV battery (SCS)
  - ▶ Ask the team to connect their laptop to the AMS.
- 16 Cell voltages can be displayed.
- 17 Cell temperatures can be displayed.

**SELF DEVELOPED PCBs**

No.

Checkpoint

- ▶ Ask for spare PCB of self developed PCBs.
- 18 Sufficient spacing regarding system voltage and implementation.
- 19 Sufficient insulation and temperature rating of coating if used, datasheet available
- 20 Coating process according to datasheet
- 21 BSPD PCB is standalone with only minimum interface

**Master Switches**

No.

Checkpoint

- 22 TSMS & LVMS installed on the right side of the vehicle and located next to each other.
- 23 All master switches are located above 80% of shoulder height of Percy.
- 24 Not mounted on removable bodywork.
- 25 LVMS located above 80% of shoulder height of Percy.
- 26 Rotary type with removable handle (50mm).
- 27 ON position in horizontal.
- 28 ON and "OFF" positions marked.
- 29 TSMS with locking mechanism for "OFF" position.
- 30 LVMS marked with "LV" and symbol showing a red spark in a white edged blue triangle.
- 31 LVMS mounted on an red circular area.
- 32 Circular area diameter  $\geq 50\text{ mm}$
- 33 TSMS marked with "TS" and triangle with black lightning bolt on yellow background.
- 34 TSMS mounted on an orange circular area.
- 35 Circular area diameter  $\geq 50\text{ mm}$

<b>Measuring Points</b>	
No.	Checkpoint
36	Two non-black TS voltage measuring points on orange background
37	A black LV ground measuring point installed.
38	Next to the master switches
39	4mm shrouded banana jacks.
40	Non conductive cover.
41	Cover removable without tools.
42	Correctly marked (TS+, TS-, GND).
<b>TS Shutdown Devices</b>	
No.	Checkpoint
43	Two shutdown buttons installed next to the main hoop.
44	Right and left on the vehicle at approx. height of drivers head.
45	Push-Pull or Push-Rotate-Pull functionality.
46	Diameter $\geq 39$ mm
47	Marked with red sparked sticker.
48	One cockpit shutdown button installed.
49	Push-Pull or Push-Rotate-Pull functionality.
50	Marked with red sparked sticker.
51	Easy actuation by the driver
52	Diameter $\geq 24$ mm
53	Inertia switch rigidly mounted to the chassis and can be demounted for functionality test. ▶ Check interlocks on ..
54	TS accumulator container(s).
55	Inverters.
56	HVD
57	Power distribution boxes.
58	EM box.
59	Outboard wheel motors.(Interlocks must act before a TS wiring failure.)
<b>TS voltage</b>	
No.	Checkpoint
	▶ Measure voltage at TS measuring points.
60	Equal or less than 60 VDC.
<b>Discharge Circuit and Body Protection Resistors</b>	
No.	Checkpoint
	▶ Switch off LV. Measure resistance between TS+ and TS- Measuring Points.
61	Resistance is 30 k $\Omega$ + discharge resistor
62	Body protection resistor power and voltage rating is sufficient
63	Dis-charge power rating is sufficient for continuous dis-charge
<b>TS Wiring</b>	
No.	Checkpoint
64	All TS wiring and components (including the HVD) has to be in the envelope and behind the impact structures.
65	TS wires of outboard wheel motors must not be able to reach the cockpit opening in case of a wire break
66	All TS wires and connectors have proper overcurrent protection.
67	TS wiring channels are orange.
68	No other wires than TS wires are orange.
69	TS wiring outside electrical enclosures in separate nonconductive enclosure or orange shielded cable.
70	Securely anchored to withstand at least 200 N.
71	Located out of the way of possible snagging or damage.
72	Shielded against rotating/moving parts.
73	No wire lower than the chassis
74	TS and LV wires separated (n/a for interlock).
75	Marked with gauge, temperature rating $\geq 85^{\circ}\text{C}$ and voltage rating(max. TS voltage)
76	Suitable temperature rating for used position
77	Positive locking mechanism on every screwed connection.(Photographs for all inaccessible TS connections)
78	Insulation is not insulating tape or rubber-like paint.

<b>TS warning stickers</b>	
No.	Checkpoint
	▶ Check for warning stickers on TS containing enclosures. (triangle with black lightning bolt on yellow background)
	79 Inverter(s).
	80 Motor(s).
	81 Power Distribution box(es).
	82 Energy meter box.
	83 Other TS containing enclosures.
<b>Tractive System Protection</b>	
No.	Checkpoint
	▶ Check opening in TS enclosures, try to reach TS potentials with insulated test probe (100mm length, 6mm diameter).
	84 Not possible to reach any TS potentials.
	85 TS components and containers protected from moisture.
<b>High Voltage Disconnect</b>	
No.	Checkpoint
	86 Clearly marked with "HVD".
	87 Distance to ground greater than 350 mm.
	88 Inside roll-over protected envelope
	89 Easily visible while standing behind the vehicle.
	90 No remote actuation (e.g. through wires).
	91 Integrated interlock.
	▶ Stand next to the vehicle, remove HVD.
	92 Removed within 10 s without tools.
	93 TS protection still given (insulated test probe).
<b>Tractive System Active Light and Indicator</b>	
No.	Checkpoint
	94 Mounted below highest point of the main roll hoop and within the roll-over protected envelope
	95 Visible by a person standing 3 m away from TSAL (1.6m eye height).
	96 A device logically replacing an accumulator container is available.
	▶ Deactivated TS, deactivated LV, removed HVD, connect power supply >60VDC to the TS of the accumulator and inverter side
	▶ Activate LV
	97 TSAL flashes red and TS indicator is off
	▶ Disconnect the power supply from one side of the TS
	98 TSAL is off and TS indicator is off
	▶ Reconnect the power supply again and disconnect the other side
	99 TSAL is off and TS indicator is off
	▶ Disconnect the power supply from the complete TS
	100 TSAL is green and TS indicator is off
	• TS Indicator . . .
	101 . . . is inside the cockpit and marked with TS off
	102 . . . is green and visible in bright sunlight.
	103 . . . is visible for the driver
<b>Data Logger</b>	
No.	Checkpoint
	104 Data Logger is enclosed in a housing.
	105 All energy from accumulator flows through the energy meter.
<b>Firewall</b>	
No.	Checkpoint
	Separates any point of the driver (less than 100mm above the bottom of the helmet of the tallest driver) from any TS component (including TS wiring)
	106 . . . behind the driver's back.
	107 . . . at the sides of the driver.
	108 . . . at the front of the vehicle.
	109 First layer, facing TS must be made of Aluminum with a thickness of at least 0.5mm
	110 Second layer, facing driver must be made of electrically insulated material (no CFRP).
	111 Material meets UL94-V0, FAR25 or equivalent.
<b>Acceleration Pedal Position Sensor (APPS)</b>	

No.	Checkpoint
112	Returns to original position if not actuated
113	At least two sensors with different transfer functions, each having a positive slope sense with either different gradients and/or offsets to the other(s) are installed. (For digital sensors, a checksum is necessary)
114	Sensors do not share supply or signal lines.
115	Sensors are protected from being mechanically overstressed (positive stop of pedal).
116	Minimum two springs installed to return pedal.
117	Each spring still returns pedal with the second one disconnected (springs in the torque encoders not counted).
<b>Brakelight</b>	
No.	Checkpoint
118	Only one brakelight in red color.
119	Clearly visible from behind the vehicle.
120	Located on vehicle centerline.
121	Height between wheel centerline and drivers shoulder.
122	Round, triangle, or rectangular on black background
123	15 cm <sup>2</sup> minimum illuminated area OR LED strips with a total length greater than 150mm with elements closer than 20 mm apart.
<b>Accumulator Management System</b>	
No.	Checkpoint
	<ul style="list-style-type: none"> <li>AMS indicator light . . .</li> </ul>
124	. . . is inside the cockpit and marked with AMS or BMS.
125	. . . is red and visible in bright sunlight.
126	. . . is visible for the driver.
	▶ Ask the team to connect their laptop to the AMS
127	Cell voltages can be displayed.
128	Cell temperatures can be displayed
129	Accumulator current can be displayed.
<b>Insulation Measurement Test</b>	
No.	Checkpoint
	▶ Choose test voltage to 500V
	▶ Connect insulation tester to TS+ and LV ground
	▶ Measure resistance: Riso+ = MΩ
130	Resistance is much higher than (min. 500Ω/V*Umax)
	▶ Connect insulation tester to TS- and LVMP
	▶ Measure resistance: Riso- = MΩ
131	Resistance is much higher than (min. 500Ω/V*Umax)
132	Resistances are nearly equal.
133	IMD chassis ground measurement line connected to the accumulator container
<b>Grounding Checks</b>	
No.	Checkpoint
	Electrically conductive parts of the vehicle (e.g. parts made of steel, (anodized) aluminum, any other metal parts, etc.) <ul style="list-style-type: none"> <li>within 100mm of any TS component</li> <li>the driver harness mounting points</li> <li>the seat mounting points</li> </ul> must have a resistance below 300mΩ (measured with a current of 1 A) to LVS ground. Parts of the vehicle which may become electrically conductive (e.g. completely coated metal parts, carbon fiber parts, etc.) within 100mm of any TS component must have a resistance below 5Ω to LVS ground.
	Part: [Measured resistance in mΩ)
	Frame/Monocoque:
	Firewall:
	Accumulator Container:
	Seat mounting points:
	Driver harness mounting points:
	Conductive housings with TS parts inside:

Main Roll Hoop:  
 Suspension Front left(AWD only!):  
 Suspension Front right(AWD only!):  
 Suspension Rear left:  
 Suspension Rear right:  
 Radiator:  
 AMS Data Connector:  
 Additional Parts:

## TEST AT HIGH VOLTAGE

### Tractive System Power Up

No.	Checkpoint
	▶ All driven wheels are off the ground, driven wheels removed
	▶ Connect multimeter between TS+ and TS-.
	▶ Switch on TSMS with LVMS deactivated
134	Voltage at TS measurement points less or equal 60VDC
	▶ Switch on LVMS with TSMS deactivated
135	IMD and AMS indicator light illuminate for 1 to 3 s for visible check
136	Voltage at TS measurement points less or equal 60VDC
	▶ Switch on TSMS and all shutdown buttons.
	▶ Reset any IMD or AMS errors
137	TS still deactivated
	▶ Activate TS, measure TS voltage during TS power-up
138	System is precharged before second AIR closes
	▶ Switch off TSMS
139	TS voltage decreases below 60VDC within 5 s
	▶ Try to power-up TS with switched off TSMS
140	TS still deactivated
	▶ Switch on TSMS
141	TS still deactivated

### Tractive System Shutdown

No.	Checkpoint
	▶ Connect multimeter between TS+ and TS-
	▶ For every of the following switches, deactivation leads to TS shutdown, voltage decreases below 60VDC within 5 s.
142	LVMS
143	Shutdown button left
144	Shutdown button right
145	Cockpit shutdown button
146	Inertia switch (may be demounted for test)
147	Brake-over-travel switch
	▶ Show schematic of TS with all interlocks (ESF)
148	Interlocks

### Tractive System Indicators

No.	Checkpoint
	▶ Activate LV system
149	TSAL and Cockpit Indicator(CI) is green only
	▶ Activate TS
150	TSAL flashes red with freq 2 Hz - 5 Hz and CI is off
151	TSAL is clearly visible (horizontal position)
	▶ Disconnect AIR state detection circuitry (disconnect data connection to accumulator container), activate LV
152	TSAL not illuminated and CI is off(TSAL flashes red if EV4.10.12 is met)
	▶ Remove HVD, override HVD interlock (!! cover HV potentials !!), activate TS
153	TSAL not illuminated or green and CI is off

### Insulation Monitoring Device

No.	Checkpoint
	▶ Determine $R_{test} = (\max \text{ TS voltage} * 250 \Omega/V) - BPR$
	• IMD indicator light . . .
154	. . . is inside the cockpit and marked with IMD.

155	... is red and visible in bright sunlight.
156	... is visible for the driver. ▶ Activate TS, connect RTest between TS+ and LV GND
157	Shutdown circuits opens within 30 s.
158	IMD indicator light illuminates.
159	TS voltage decreases below 60VDC within 5 s after shutdown circuit opens ▶ Try to activate the TS by the required additional action (EV4.11.1)
160	Reactivation of TS is not possible ▶ Push the reset button which is not accessible to the driver, if any
161	Reactivation of TS is not possible ▶ Remove RTest. Wait 40 s until IMD resets status output
162	Reactivation of TS is not possible ▶ Push all reset buttons in the cockpit, if any
163	Reactivation of TS is not possible ▶ Push the IMD reset button which is not accessible to the driver, if any
164	Reactivation of TS is possible ▶ Push and hold the reset button which is not accessible to the driver, if any. Connect RTest between TS+ and LV GND
165	Shutdown circuits opens within 30 s
166	IMD indicator light illuminates ▶ Activate TS, connect RTest between TS- and LV GND
167	Shutdown circuits opens within 30 s
<b>Ready to Drive activation Sequence</b>	
No.	Checkpoint
	▶ Activate TS, press torque pedal
168	No turning of motors ▶ Let the team set the vehicle to ready to drive mode.
169	Pressing brake pedal WHILE activating is necessary. ▶ Repeat the activation sequence, but push the brake pedal only once before finally pushing the activation button.
170	No ready to drive mode possible. ▶ Disconnect the brake sensor.
171	No ready to drive mode possible
172	Ready to drive sound duration is 1 s to 3 s.
173	Ready to drive sound is min 80 dBA (2m around the vehicle).
174	Ready to drive sound is easy recognizable and no animal sound or song part
175	Sufficient brightness of the brake light even in bright sunlight
<b>Implausibility Checks</b>	
No.	Checkpoint
	▶ Set vehicle to ready to drive state. Press accelerator pedal >25 %. Push brake pedal.
176	Motors stop turning. ▶ Release brake, while accelerator pedal still activated.
177	Motors do not turn. ▶ Release accelerator pedal slowly.
178	Motors turn again when APPS position is <5 %. ▶ Get motors turning, disconnect ≥50% of APPS while motors turn.
179	Motors stop turning. ▶ Disconnect all APPS.
180	Motors do not turn. ▶ Reconnect all APPS, disconnect any communication connection between APPS and inverter while motors turn.
181	Motors stop turning ▶ Disconnect Brake Pedal sensor
182	Motors stop turning ▶ Team simulates 5kW power, press brake representing hard braking (>0.5 s).
183	TS shuts down. ▶ Reactivate TS, Disconnect current sensor, press brake representing hard braking(>0.5s)
184	TS shuts down • Automatic BSPD reset installed?
185	Reactivation of TS is only possible after 10 s without implausibility

<b>Regenerative Braking</b>	
No.	Checkpoint
	▶ Ask the team to mount wheels
	▶ Set vehicle to ready to drive state, press brake slightly without activating hydraulic brake system housing
186	Turning a driven wheel by hand is possible
<b>Sealing of Components</b>	
No.	Checkpoint
	▶ After all tests have been passed successfully seal the inspected TS housings:
187	Motor Controller housing
188	Energy Meter housing
189	IMD housing
190	TSAL circuitry housing
191	BSPD casing /BSPD calibration
192	Additional Part:
193	Additional Part:
<b>Regenerative Braking</b>	
No.	Checkpoint
194	Check data logger functionality and connectivity
<b>OTHER COMMENTS</b>	
<b>APPROVAL STATUS</b>	
	Approval (Control box) (DON'T CHANGE MANUALLY)