



# INTERNATIONAL EFFICIENCY CHALLENGE ELECTRIC VEHICLE DOMESTIC PRODUCT RULES

2024

## VERSIONS

Version	Date	Description	Changes
Y20.V1.0	December 16, 2023		20. EC Electric Vehicle Races; First Release
Y20.V2.0	January 3, 2024		2.12. Brake System 7. Contact are updated
Y20.V3.0	January 23, 2024		2.4. Battery Appendix 1: Penalty List are updated
Y20.V4.0	February 20, 2024		2.3. Motor Driver 2.7. Vehicle Control Unit (VCU) 2.7.1. Telemetry 2.8. Insulation Monitoring Device 2.11. Hydrogen System (Fuel Cell, Fuel Cell Control System, Hydrogen Line and Metal Hydride Cylinders) Appendix 1: Penalty List are updated
Y20.V5.0	March 5, 2024		2.4.3. Embedded Recharging Unit Appendix 1: Penalty List are updated

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## 1. DEFINITIONS

**Advisor:** Academic person who advises the team within the scope of the competition or person who has knowledge and experience about electric vehicles.

**Jury:** The Advisory and Assessment Committee was established by TÜBİTAK to benefit from the opinions of its members and to execute the International Efficiency Challenge Electric Vehicle.

**Announcement:** Announcement text that defines the activity topic, scope, application conditions, support amounts, competition calendar, and special issues determined by TÜBİTAK.

**Ethical Violation:** Unethical situations such as plagiarism etc., (for example, quoting from another team's report/video or the same/very similar reports/videos of 2 or more teams).

**Directorate:** The Activities Directorate where the International Efficiency Challenge Electric Vehicle is conducted.

**Team Captain:** The person who is determined by the team and who is responsible for communication with TÜBİTAK, who will take responsibility for the administrative and financial issues of the team, and who is obliged to be in the competition area during the registration and technical inspections during the competition week.

**Team Member:** Each person who takes an active role in the team and registered in the KYS.

**Team:** The group consisting of the team captain, assistant captain, and other team members.

**TEKNOFEST:** Türkiye's first and only Aerospace and Technology Festival organized with the participation of many institutions playing a critical role in developing national technology in Türkiye.

**TÜBİTAK:** The Scientific and Technological Research Council of Türkiye.

## **2. TECHNICAL RULES**

### **2.1 Being Domestic**

In this section, the parts that are expected to be present in the vehicle specifically for this race and designed and produced by the teams themselves will be discussed. One of these parts is the motor driver.

The importance of the motor driver in electric vehicles is increasing rapidly in today's world. The motor driver is one of the most critical components of electric vehicles and greatly affects the vehicle's performance. The motor driver ensures that the motor operates as required by taking electric energy from the battery. As a result, the vehicle moves with high efficiency and consumes less energy.

The motor driver plays a significant role in the safety and driving experience of electric vehicles. It controls the basic functions of the vehicle, such as acceleration, braking, and steering. A properly adjusted and optimized motor driver improves the vehicle's responsiveness, enables faster acceleration, and allows for more efficient braking. As a result, the driver experiences a safer and more enjoyable driving experience.

In this year's competitions, the motor driver in the International (Electromobile and Hydromobile) category has been determined as a mandatory domestic component: In order for a team to participate in the final races in any category, they must design and produce their own motor driver in accordance with the domesticity requirements specified in the race booklets and must have completed the technical inspections and obtained the "eligible for participation" label. Otherwise, they will not be able to participate in the final races.

In this year's competitions, in the Inter-High School (Electromobile) category, teams were offered three different options as mandatory domestic parts: Motor driver, battery packaging, or steering system. A team must have designed and produced any of these mandatory domestic parts in accordance with the domestic content requirements specified in the race booklets and completed the technical inspections in order to receive the "eligible to participate" label and participate in the race. Otherwise, their participation in the final races is not possible.

In the International (Electromobile and Hydromobile) category, the sub-parts classification for this year's races will be as follows:

#### **Mandatory domestic sub-parts:**

- 1.** Motor driver (Electromobile and Hydromobile)

#### **Non-mandatory (optional) domestic sub-parts:**

- 1.** Motor (Electromobile and Hydromobile)
- 2.** Battery management system (BMS) (Electromobile and Hydromobile)
- 3.** Embedded recharging unit (Electromobile and Hydromobile)
- 4.** Battery packaging (Electromobile and Hydromobile)
- 5.** Electronic differential application (Electromobile and Hydromobile)
- 6.** Vehicle control unit (VCU) (Electromobile and Hydromobile)

7. Insulation monitoring device (Electromobile and Hydromobile)
8. Steering system (Electromobile and Hydromobile)
9. Door mechanism (Electromobile and Hydromobile)
10. Braking system (Electromobile and Hydromobile)
11. Passenger seat (Electromobile and Hydromobile)
12. Fuel cell (Hydromobile)
13. Fuel cell control system (circuit) (Hydromobile)
14. Energy management system (EMS) (Hydromobile)

In the Inter-High School (Electromobile) category, the sub-parts classification for this year's races will be as follows:

**Mandatory domestic sub-parts:**

1. Motor driver (Electromobile)
2. Battery packaging (Electromobile)
3. Steering system (Electromobile)

**Non-mandatory (optional) domestic sub-parts:**

1. Motor (Electromobile)
2. Battery management system (BMS) (Electromobile)
3. Embedded recharging unit (Electromobile)
4. Electronic differential application (Electromobile)
5. Vehicle control unit (VCU) (Electromobile)
6. Insulation monitoring device (Electromobile)
7. Door mechanism (Electromobile)
8. Braking system (Electromobile)
9. Passenger seat (Electromobile)

**Rules of Domestic Product Award:**

- In order for a team to be evaluated under the domestic product award, the team must first successfully pass technical inspections and obtain the "eligible to participate in the race" label.
- Afterwards, teams that make at least one mandatory domestic component and four non-mandatory (optional) domestic components native according to the conditions specified in the Domestic Rules Booklet are eligible to be evaluated under this award.
  1. In technical inspections by DDK, it will be checked whether the part declared as domestic in the technical design report meets the domesticity requirement, and the score of the technical design report of the relevant part, taking into account the evaluation score, will determine the score of the candidate team for this award.
  2. After evaluating the domestic components declared by the team within the scope

of this award, the points awarded for each component will be summed up as done in the previous item.

**3.** The collected points will form the team's award score: Since the maximum points that can be obtained from the technical design reports of teams in different categories (Electromobile and Hydromobile) may vary in the international category, and there is no distinction made for Electromobile and Hydromobile categories within this award, this award score will be converted to a unit value by dividing it by the maximum points that can be obtained from the technical design report in the category where the team is located.

**4.** Teams will be ranked in descending order based on the unit values they will achieve, and the award winners will be determined.

**5.** If the evaluation results of the candidates are the same for both teams, the team with a higher number of domestic components will be ranked higher than the other.

- In technical inspections, it will be checked whether the parts declared as domestic in the technical design report meet the being domestic requirement. Reporting and production of domestic parts are expected to be team specific.
- In the reports of the Electromobile and Hydromobile teams affiliated with the same student club, both teams get 0 (zero) points for each part/title that is the same for the mandatory domestic parts with the same design, those parts are not counted as domestic.
- In the reports of Electromobile and Hydromobile teams affiliated to the same student club, both teams get 0 (zero) points for each part/title that is the same for optional domestic parts with the same design and those parts are not counted as domestic.
- The design of the domestic parts must have been originally made by the team. Even if the production works of the designs belonging to ready-made products are made by the team, they will not be considered domestic.
- In order for a team to use the domestic part made in the previous year, the comparison table requested in the technical design report must be presented in detail.
- A vehicle part that was accepted as domestic in the past races will not be considered as domestic unless it meets the necessary conditions specified in this document. Designs of domestic parts need to be defended by team members during technical checks.
- Even if the designs made by third parties, such as consultant, design office etc. are produced domestically, they are not considered as domestic. The students taking part in the team are responsible for the domestic design, production, reporting and making the necessary explanations in the technical inspections.

## 2.2 Motor

- The teams that design and manufacture the electric motor domestically are responsible for the following items during the technical inspections:
  - i. Awareness of general electrical machine theory and construction.
  - ii. Awareness of electrical and mechanical properties.
  - iii. Giving information about magnetic and thermal analysis.
  - iv. Giving information on production stages with visuals such as photos and videos.
  - v. Giving information about the test method and results.
- It will be checked in the technical design report and technical inspections that the required analyses are done by the team. The thermal, magnetic and electrical analyses provided by the manufacturer for ready-made products (core, winding, etc.) prevent the motor from being accepted as a domestic product.
- All design and optimization stages of the motor should be done by the team, and the simulation results should be presented in stages in the technical design report and technical inspections.
- In order for the electric motor to be accepted as domestic, the motor's operational functionality needs to be demonstrated with applications in which it performs its function.
- In order for the electric motor to be accepted as a domestic part, the raw files of the program showing the design and simulation results of the motor must be sent together with the technical design report. In technical inspections, TÜBİTAK may request these files be run and shown.

## 2.3 Motor Driver

- Teams that perform the design and production of motor drivers domestically are responsible for providing information on the following subjects during technical inspections:
  - i. Electrical circuit design and protection circuits
  - ii. Efficiency analysis of electrical circuit design
  - iii. Simulation study and control algorithm
  - iv. Printed circuit board design
  - v. Production stages with visuals such as photos and videos
  - vi. Test method and results
- All design and optimization stages of the motor driver and simulation results should be presented step by step in the technical design report and technical checks.
- The motor driver circuit must be placed in a box and fixed inside the vehicle. The box should be designed to protect the motor driver circuit from external factors such as water, oil, dust etc. Boxing of the motor driver is mandatory and teams not complying with this rule will not be allowed to participate in the race.

- During the technical checks, TÜBİTAK may request that the motor driver be removed from its fixed location and shown for detailed examination.
- Plug-in connectors should be used for electrical connections between motor driver and other units such as motor, battery etc. Teams that don't use plug-in connectors can participate in the race with penalty (see Appendix 1: Penalty List).
- When the vehicle breaks down or needs to be towed during a race, the towing process is performed by lifting the front of the vehicle with the help of a tow truck. In this case, it is the responsibility of the team to disconnect the connection between the engine and the motor driver. Additionally, if any problems arise during the towing of the vehicle, the team will be held responsible.
- For the motor driver to be accepted as a domestic part, the raw program files showing the design and simulation results must be sent together with the technical design report. During technical checks, TÜBİTAK may request these files to be run and shown.
- In order for the electric motor driver to be accepted as domestic, the motor's operational functionality needs to be demonstrated with applications in which it performs its function.

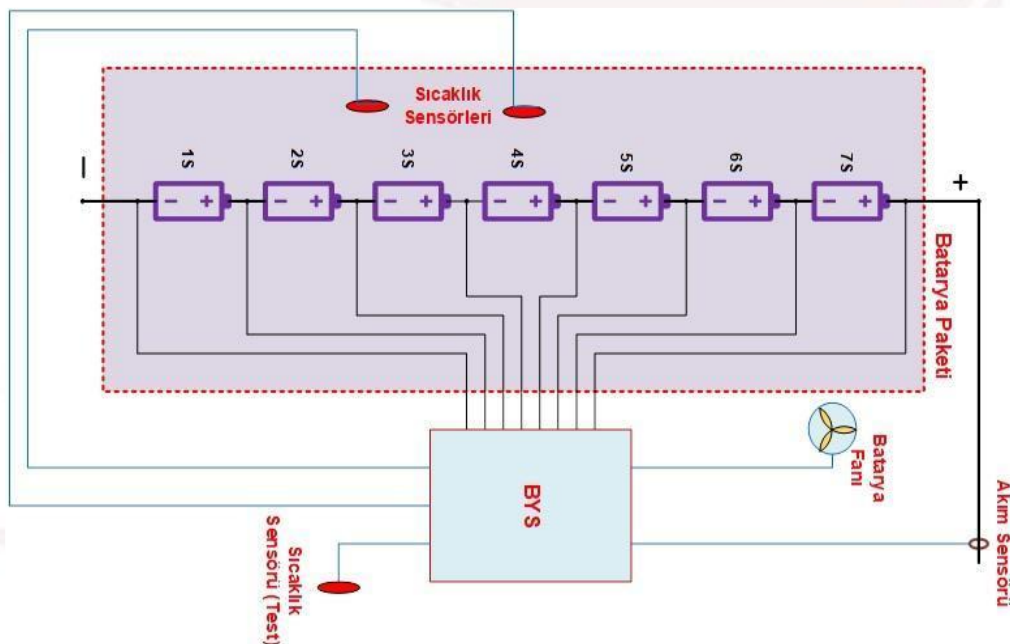
## 2.4 Battery

- **Battery:** is the system which generally consists of a battery protection container and one or more battery packs formed by battery cells.
- **Battery Cell:** is a single cell with lithium-ion based plus and minus terminals.
- **Battery Pack:** is the group that includes multiple battery cells combined in series, parallel, series-parallel or parallel-series and includes temperature sensors.
- Since lithium-ion based battery technologies are used in electric vehicles today, only lithium-ion based batteries will be allowed to be used in the race.
- The expression "lithium-ion based" refers to a technology used in rechargeable batteries that utilizes the reversible reactions of lithium in both electrodes. There are various types of cells in the lithium-ion chemistry, and they are usually named based on the composition of the cathode commonly used. As an example, within this scope:
  - LiNiMnCo (Lithium Nickel Manganese Cobalt)
  - LiFePO<sub>4</sub> (Lithium Iron Phosphate)
  - Li<sub>4</sub>Ti<sub>5</sub>O<sub>12</sub> (Lithium Titanate Oxide)

In chemical structures like these, it is suitable to use cells in vehicles.

- Lithium Polymer (LiPo) cells can be more prone to safety issues such as leakage, swelling, and thermal leakage/leakage due to their use of polymer or gel electrolytes. Therefore, it is recommended not to use LiPo batteries in vehicle battery packs, as other lithium battery technologies are safer in terms of preventing such risks. It is necessary to refrain from using LiPo batteries in vehicle battery packs. LiPo battery usage is prohibited in battery packs.

- The battery should be placed inside the vehicle and protected from short circuits and leakage by a protection container.
- The battery pack should be insulated from the driver's compartment without leaving a gap to prevent flame and gas transfer. This insulation must be provided by a solid wall. In addition, the battery package should be placed in an easily accessible location that allows measurement and inspection during technical inspections.
- The battery package should be protected by a barrier to prevent direct damage in the event of an accident.
- The battery must be easily accessible from the outside without removing any component of the vehicle (hood, motor, seat, BMS, etc.).
- The protection container should be securely fastened to the floor of the vehicle using grade 8.8 bolts and nuts with a minimum diameter of 8 mm. The fixing process must be done such that the fixing apparatus and fixing points cannot move out of position even in the event of an accident.
- The battery should have a fuse for high current and short circuit protection, and a manual breaker to ensure safety in cases where interference to the battery is required (e.g. service disconnect).
- There should be at least two temperature sensors in the battery package to measure the temperature of the package, and one temperature sensor outside the battery package to use in technical inspections, as shown in Figure 1.



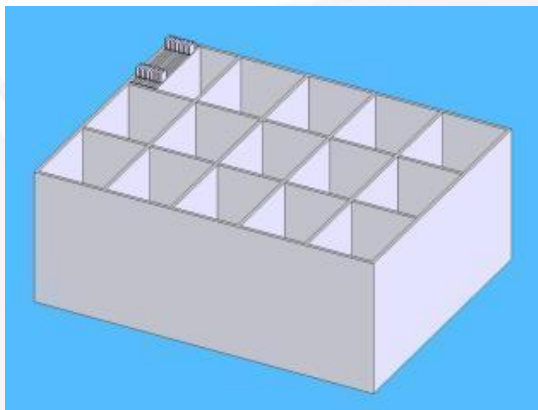
**Figure 1.** BMS connection of battery packaging.

- The placement of the cells used in the package should be visible after opening the case. The placement of the temperature sensors should be determined by the results of the thermal analysis.

### 2.4.1 Battery Management System (BMS)

- BMS is an electronic system that enables the rechargeable battery cells and packages to operate within safe operating limits, and its use is mandatory.
- For this purpose, the BMS should monitor the voltage, current, temperature (of the hottest cell in the package), state of charge (SOC) of each battery cell and package and take the necessary safety measures when the safe operating limits are exceeded.
- The voltage of the battery, the one with the highest temperature among the battery packs, and the state of charge (SOC) should be displayed clearly, accurately, and consistently on the instrument panel in the vehicle cockpit.
- How the SOC and the maximum temperature value is determined should be described in detail in the technical report. A passive or active balancing system should be used to eliminate voltage imbalances that may occur in the battery cells:
  - i. The use of voltage divider circuit to measure individual cell voltages is not permitted. BMS ICs or differential amplifiers should be used to measure cell voltages. It is recommended to use BMS ICs in BMS design.
  - ii. There should be at least two temperature sensors in the battery package to measure the temperature of the package, and one temperature sensor outside the battery package to use in technical inspections. The total number of temperature sensors should be at least  $2 \times \text{Battery Modules} + 1$ . For example, if the battery pack consists of two modules, then the pack should have at least 5 ( $2 \times 2 + 1 = 5$ ) temperature sensors.
  - iii. It should be the highest temperature value of the battery pack if only one temperature value is to be monitored. The determination process of the highest temperature value should be described in the technical design report.
  - iv. The temperature indicator should be electrically connected to a warning flasher. The flasher should give an audible warning when the battery temperature reaches the critical temperature level. The audible warning should be heard at 80 dB from a distance of 2 m.
  - v. At the same time, the electrical connection of the battery pack to the system should be interrupted by an automatic protection system. In ideal condition, a range must be provided between the activation temperature ( $55^{\circ}\text{C}$ ) of the audible warning system and the system shutdown temperature ( $70^{\circ}\text{C}$ ) to allow testing.
  - vi. However, due to the position of the temperature sensor in the battery pack or the battery packaging technique, these values may vary within a temperature range of  $15^{\circ}\text{C}$ .
  - vii. It is required that the cells be integrated (series, parallel, series-parallel or parallel-series) in groups (4 or 5, etc.) and each group should be separated from the others by an inflammable material (see Figure 2). The number of cells, the cell connection diagram, and a diagram showing the placement of temperature sensors should be detailed in the technical design report.

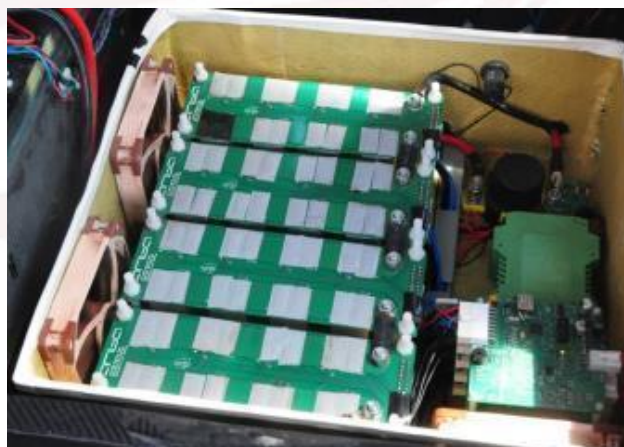
- Teams that develop the BMS domestically shall be responsible for the following items during technical inspections:
  - i. Physical demonstration of the BMS (the BMS should be easily accessible from outside the vehicle).
  - ii. Providing required information and block diagrams on the BMS design and operation principles (Circuit diagram, PCB drawings, simulation, etc.).
  - iii. Providing information on the balancing method used in the system and its implementation.
  - iv. Providing algorithms used to perform measurements and estimations, such as individual battery cell voltage, temperature of each pack, detection of the package with the highest temperature and state of charge (SOC).
  - v. The voltage of each battery cell must be measured by the BMS and displayed on the driver dashboard (all cell voltages or at least peak/low cell voltage).
- In technical inspections, the passive or active balancing system, safety measures described above, and whether the flasher is functional or not will be checked.



**Figure 2.a.** Sample drawing for battery box.



**Figure 2.b.** Sample BMS for lithium-ion based batteries.



**Figure 2.c.** Box and sample BMS for lithium-ion based batteries.

**Figure 2.** Battery box and ve BMS examples.

## 2.4.2 Battery Packaging

- The battery's protective housing has to completely encircle the batteries (to prevent short circuits of conducting parts as well as battery terminals) and must be made of a material that is resistant to mechanical impacts and fire (protective vessels manufactured from wood, plexiglass, polystyrene, and inflammable plastic are not acceptable) and prevents leakage of battery liquid (see Figure 2).
- The team that owns the vehicle is obliged to prove that the battery fixing mechanism and battery compartments are strong enough to resist the stresses defined for the roll bars by a test result or analysis data.
  - i. In order to cool the batteries, an air or water cooled system should be designed, and if an air-cooled system is to be used, the outlet of the ventilation duct should be outside of the vehicle.
  - ii. The cooling air or water system valves, fans or pumps should be activated with the increase of battery temperature and keep it at the temperature limits that the battery can perform efficiently.
  - iii. "High Voltage" warning signs/labels should be visible on each battery pack.
  - iv. The location of the battery pack should be indicated on the exterior of the vehicle with a visible "High Voltage" sign.
  - v. The control measures given below should be implemented in case of a fire hazard in the vehicles.
    - Short circuit protection must exist for the pack and cells. Cells with these protections (CID, PTC) should be preferred if possible.
    - High (overcharged) and low (over-discharge) voltage protections must be provided.
    - There must be temperature protection. The cooling system should be designed to shut down the entire system when the critical temperature is exceeded.
    - During the module design, heat distribution balancing between the cells should be considered.
    - The cells, modules and packages should be free of mechanical deformation.
    - A physical separation must be placed between the battery pack and the BMS.
- The cells inside the battery pack should not be simply connected to each other by a cable. For the connecting of the cells, bus bars or special connecting apparatuses should be used.
- Thus, welding (laser, ultrasound, direct, etc.), soldering, or screwed systems can be used for connecting the cells to each other. The cells should be fixed to the battery housing. Flammable materials such as silicone or polyurethane foam should not be used for fixing.
- The wiring of the BMS should be done in a certain manner and in a such way that does not cause isolation problems.

- The battery housing, battery, and BMS should be accessible with ease from the outside of the vehicle. Connection and fixing equipment must definitely be in accordance with the previous definitions and suitable for an external measurement.
- During the technical inspections, the data sheets of the batteries, the protective housing, and safety measures will be checked. It will not be allowed to participate to the race with inappropriate battery and battery components, including batteries which have location problems that can not be accessed from the outside.
- In order for the battery pack to be accepted as a domestic product, the following points need to be detailed in the technical design report as well as explained during the technical inspections:
  - i.**Cell type (pouch, cylindrical, prismatic, etc.), electrochemical data sheets (charge-discharge characteristics of the cells, nominal voltage of the cells, energy density of the cells, etc.).
  - ii.**Battery housing material and mechanical (tensile strength, impact resistance), thermal (melting point), and electrical (dielectric constant) properties of the material.
  - iii.**Placement of the battery cells and temperature sensors in the battery pack.
  - iv.**The method of fixing the cells in the battery housing.
  - v.**Thermal and mechanical properties of each component (including the battery housing),
  - vi.**Thermal analysis of the battery pack.
  - vii.**Battery cooling system (air, water, etc.) details.
  - viii.**The placement and fixing details of the battery pack.
  - ix.**If the battery housing is designed with an electrically conductive material (carbon fiber, stainless steel, etc.), the inner surface of the battery housing must be isolated with an insulating and inflammable material (inflammable PVC-inflammable paper, etc.).
- Moreover, details of the design should be supported by photographs in the technical design report.
- In summary, the considered parameters in the scoring of the battery packaging are as follows:
  - Characteristics of the cell:
    - i.**Electrical characteristics of the cell
    - ii.**Thermal characteristics of the cell
    - iii.**Mechanical characteristics of the cell
  - Thermal analysis of the battery pack
  - Battery housing:
    - i.**Design details
    - ii.**Explanations with the design
  - Cooling system details of the battery pack
  - If exist, pre-charge circuit design and explanations

### 2.4.3 Embedded Recharging Unit

- This is a switched power supply that is fixed on the vehicle and can charge the battery group by being fed from the grid. Since this power supply will manage the recharging process of the battery group together with the control unit, it could be considered a part of the BMS. The specifications of this unit are listed below.
  - i. It should have a minimum power level of 500 W in order to recharge the battery group in an acceptable time.
  - ii. The battery group should be able to be recharged over a single-phase grid (220 Vrms / 50 Hz). Three phase sources could be used; nonetheless, a single separate phase input should be provided.
  - iii. Active or passive power factor correction feature is not obligatory but is recommended.
  - iv. Besides a full-bridge or half-bridge converter, other switching converter topologies can also be used. It is necessary to provide electrical insulation of the power supply between the grid and the battery group.
  - v. A transformer operated at grid frequency (50/60 Hz) cannot be used as the main power transformer inside a switching power supply. These kinds of power supplies will not be accepted as switching converters. Similarly, if a grid frequency operating transformer is used as electrical insulation between the grid and the vehicle, that power supply will not be regarded as a switched power supply.
  - vi. Chopping grid voltage by thyristor or triac will also not be considered as a switched power supply.
  - vii. These kinds of on-board power supplies that contain a grid frequency-operating transformer can be used to charge batteries and partial report points will be given, but they will not be regarded as domestic components.
  - viii. For electrical safety, a converter that rectifies the grid and decreases the voltage by a buck converter and charges the battery will not be permitted since galvanic electrical insulation between the grid and the vehicle is not provided.
  - ix. An embedded recharging unit must be on the vehicle during the races.
  - x. An embedded recharging unit must be on the vehicle during technical checks.
  - xi. The operational control of the embedded recharging unit will be carried out by charging the battery on the vehicle itself.

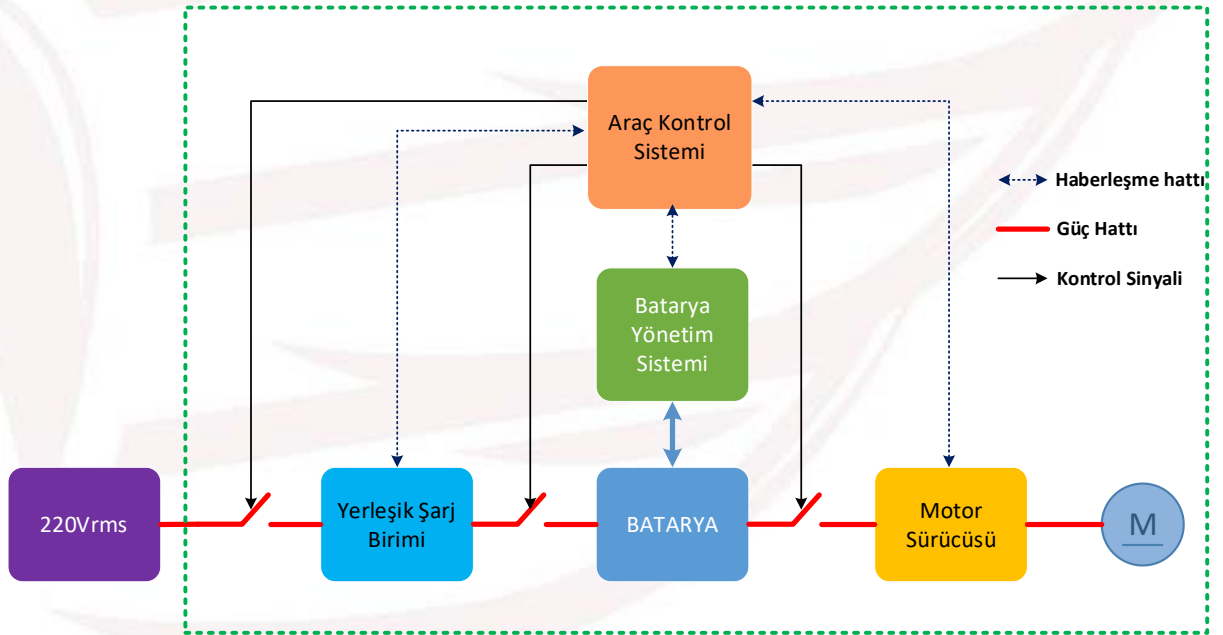
### 2.4.4 Procedure to be Followed in Technical Inspections

- During the technical inspection, BMS, Battery pack and on-board charger will be inspected.
  - i. During the inspection, the wheels will be lifted. The current and voltage measurements will be measured from the on-board charger. The schematic of this inspection was shown in Figure 3 below.
  - ii. Battery needs to be at 30-60 % SOC before the inspection.

- iii. Once the battery is connected to the charger, the VCU or BMS system should be able to close and open the S1 and S2 gates, respectively like shown in Figure 4.
- iv. As soon as the vehicle switches to the driver mode the VCU or BMS system should open and close S1 and S2 gates, respectively.
- v. During the vehicle operation, battery voltage, current, temperature and SOC information should be displayed on the driver screen.
- vi. Temperature and balancing will be inspected during these tests.
- vii. In case of emergency, S1 and S2 gates will be opened by VCU or BMS system.

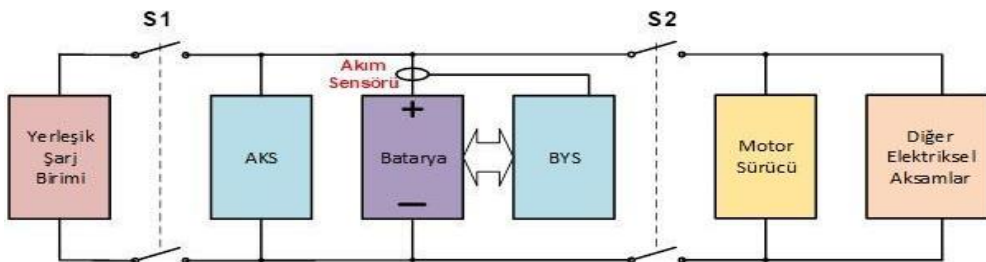


**Figure 3.a.** Battery pack, BMS and embedded recharging unit controls.



**Figure 3.b.** Embedded recharging unit controls.

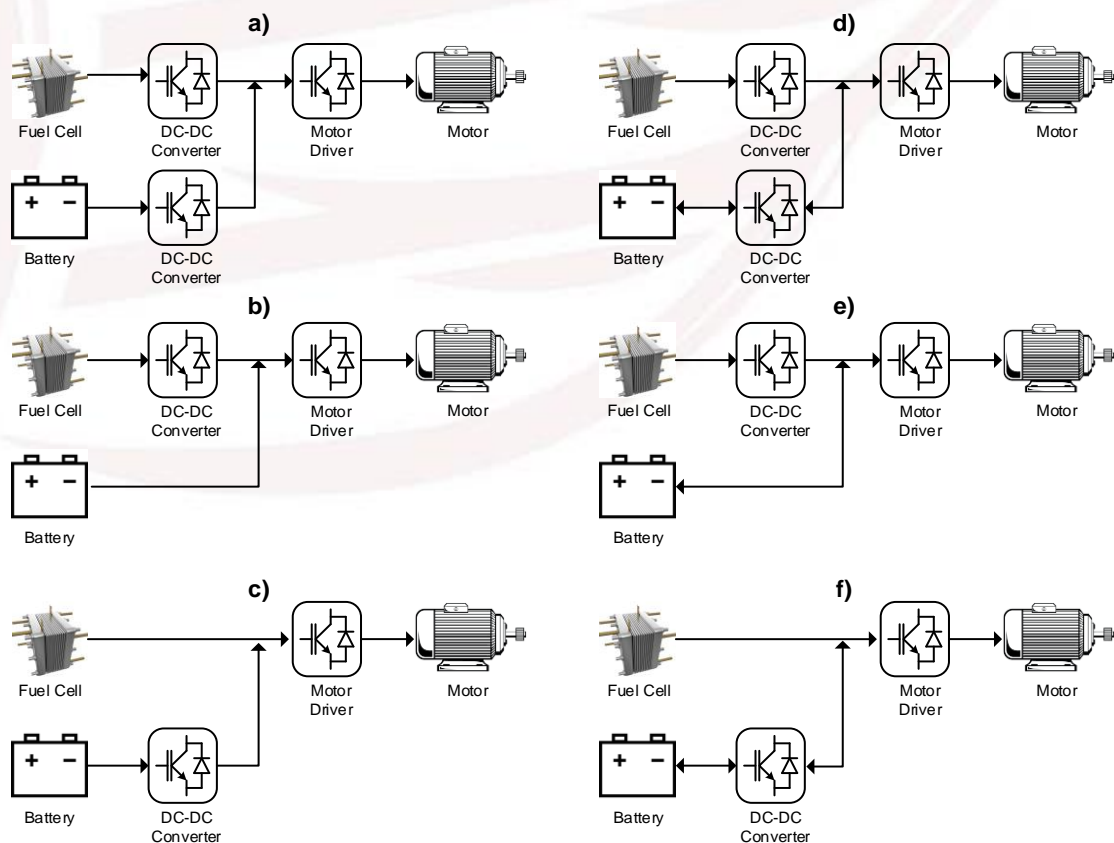
**Figure 3.** Battery pack, BMS and embedded recharging unit control mechanism and scheme.



**Figure 4.** S1 and S2 gates and how it should look once the battery is connected to charger.

## 2.5 Energy Management System (EMS)

- For Hydromobile vehicles, software and hardware that optimizes power flow between the energy sources and the load can be regarded as an EMS. In order for the EMS to be accepted as domestic, the DC-DC converter must be designed and produced by the team. Figure 5 should be checked for details.
- This DA-DA converter should be able to transfer all the power generated by the battery or fuel cell and should be positioned in the circuit in this way.
- Teams that develop a domestic EMS will be responsible for the following items during technical inspections:
  - i. Demonstrating the EMS product physically.
  - ii. Providing general information about the EMS design and operating principles.
  - iii. Displaying the current and voltage values by measuring while the DA-DA converters are operating.
  - iv. Systems where the ratio between the battery output current and the fuel cell output current can be changed at the desired level will be considered as domestic. In this sense, clamp ammeters are attached to the fuel cell and battery outputs of the vehicles during technical inspections and the ratio will be requested to be changed by the driver or telemetry. Systems that cannot be changed by the rate vehicle telemetry or driver are not considered domestic.



**Figure 5.** Possible power sources connections.

## **2.6 Electronic Differential Application**

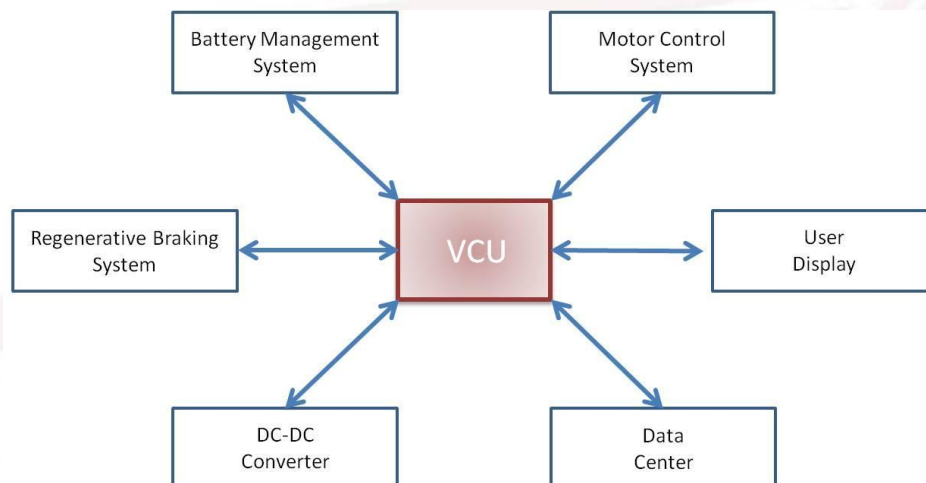
- Detailed information about the application of the differential used in electric vehicles is published additionally on [www.teknofest.org](http://www.teknofest.org) website.
- It is expected that teams that design their own electronic differential application conform to the principles detailed in the above-mentioned Appendix. To this end, teams must provide sufficient information about the design steps and give correct and clear answers to questions about the application.
- Furthermore, for the electronic differential application to be approved as a domestic component, demonstration of the motor reference signals through a suitable digital platform integrated into the vehicle is mandatory.
- If necessary, the vehicle will be moved and tested on a track. The design will be verified by reading values through the digital interface of the electronic differential and measurements to be taken.

## **2.7 Vehicle Control Unit (VCU)**

- The vehicle control unit (VCU) is a central control system that acquires, analyses, and interprets various signals coming from different components and sensors of the vehicle to command and regulate the same sub-systems that those items belong to or other substantially distinct units.
- The VCU is an embedded electronic component enabling the control of several sub-systems implemented on the vehicle, such as the battery management system, the DC-DC converter, and the motor control unit, utilizing information obtained from the same sub-systems. The VCU consists of software and hardware.
- A microprocessor, EPROM or flash memory, and some other electronic components make up the hardware. The software should be a low-level code written into the microprocessor.
- Generally, the VCU is characterized as follows:
  - i.** Numerous analogues and digital I/O data (low and high power):
    - 1.** Power supply (required power for sensor)
    - 2.** Communication (CAN or similar)
    - 3.** Digital input/output
    - 4.** Analogue input (feedback signal from sensor)
    - 5.** PWM output
    - 6.** Frequency output
  - ii.** Different communication profiles (CAN, Flexray, KWP2000, or similar)
  - iii.** Power device control/interface
  - iv.** Intelligent communication interface adaptor

- The VCU is generally expected to perform the following main functions:
  - i.Motor Torque Control:** It will receive the acceleration reference information from the vehicle driver and provide the reference motor torque signal in a way that will improve both driving quality and energy efficiency. Thanks to the motor torque control algorithm, the necessary safety functions, such as providing predefined acceleration and deceleration measures, current limiting during sudden load changes, and limiting of overspeed will also be provided.
  - ii.Regenerative Braking Optimization:** It will take the deceleration reference from the vehicle driver and convert it to the motor torque reference, which is required for additional electrical braking to increase energy efficiency without interrupting mechanical braking. Regenerative braking optimization will prevent overcharging, considering the state of charge of the battery.
  - iii.Vehicle's Energy Management System:** It should limit the excessive use of energy resources in the vehicle and optimize the use of energy.
  - iv.Management of Vehicle's Communication System:** This means converting different communication protocols in vehicle modules into a common protocol (e.g., Canbus), being manageable, and generating control signals.
  - v.Diagnostics:** Evaluation of signals coming from various sub-systems to detect and diagnose possible faults occurring during operation and informing the driver of suggested corrective actions in terms of the VCU screen.
  - vi.Monitor Vehicle's Condition and Warning the Driver:** Demonstration of critical data reflecting the current situation of the vehicle, such as vehicle speed, battery temperatures and voltages, remaining energy amount, charging power and estimated full charge time on the VCU screen.
  - vii.Transferring Vehicle Data to the Monitoring Center:** Vehicle speed, temperature of the battery pack (the temperature of the highest one), total battery voltage and remaining energy amount data are collected and transferred to the monitoring center via the RF or GSM module.  
In the vehicle, personal computers, laptops, mobile phones, tablets, switches, modems, and similar mobile devices cannot be used.
- The developed VCU will not be approved as domestic unless it performs at least three of the above listed functions on a single mainboard. If the use of a single microcontroller on the mainboard is insufficient, teams can use more than one microcontroller.
- For the control card designed by the teams to be accepted as domestic, the circuit design of the relevant card must be a unique design for them, and ready development cards must not be used on the designed card. During technical inspections, the teams claiming to have domestic VCU should provide the following items:
  - i.**The final VCU hardware with a detailed verbal description.
  - ii.**Comprehensive information about the main functions and the mandatory signal acquisition and data transfer function.

- iii. A clear description of the communication protocols used between the VCU and the other sub-systems.
  - iv. Real-time display of data transferred to the user or monitoring center.
- The sub-systems used in the vehicles recognize the operating conditions according to the data received from the sensors and perform the necessary action through the actuators it has.
  - For example, the existing Electromobile vehicles' battery management system activates the flasher of the vehicle when the temperature of the battery exceeds the specified limit. However, it cannot take any preventive action to inhibit very high battery temperature. If there is a VCU, the desired electric motor power can be limited according to the temperature of the batteries. Even if the temperature continues to increase, all current flow can be set to zero, and if the temperature continues to increase it can open the emergency contactors.
  - As described in the example, the VCU collects all information, evaluates the collected data according to written algorithms, and sends commands to the actuator to apply the decision.
  - All data transferred from the systems inside the vehicle needs to be detected, processed, and transmitted within a common communication protocol in order to be perceived, decisioned, and conveyed within the same control system. Different communication protocols can be used for the data transferred to the monitoring center and user screen (see Figure 6).



**Figure 6.** Vehicle control unit.

### 2.7.1 Telemetry

- Telemetry is a system where all the data of the vehicle specified below are collected by an electronic card with a micro-controller and transmitted to the monitoring center via a radio frequency module. Telemetry is mandatory in all vehicles. Telemetry unit have to transfer the following data combined with a time stamp:
  - i. Vehicle speed (km/h) (See Speedometer)

- ii. Temperatures of the battery cells (°C)
- iii. Metal hydride tank temperature for vehicles in the Hydromobile category (°C)
- iv. Total voltage of the battery cells (V)
- v. Amount of energy remaining (Wh)

Optionally, it should be verified by checking in the application layer that the integrity of the transferred data packet is ensured using one of the relevant algorithms.

- Data packets that cannot be transmitted in cases such as signal loss or corruption, at least 60 seconds of data that could not be sent last should be sent back to the monitoring center when the connection is re-established.
- In addition, the records of the transferred data at the monitoring center should be kept in a text file (see. csv) with a sample per line. The first line of the file must have a header line to indicate the value labels with their units. Each line should contain the timestamp, vehicle speed, battery temperature, battery voltage, remaining energy information in order and separated by commas.
- The timestamp should be kept in milliseconds, with reference to the moment the vehicle started up. There should be a maximum of 5 seconds between recordings. The log file must be recreated with a unique name each time the vehicle is started, in order to avoid data loss due to reasons such as overwriting the log file.

Example:

```
time_ms;vel_kmh;temp_bat_C;volt_bat_C;energy_remaining_Wh
10000;30;24400;100;10000
11000;35;24400;100;10000
12000;32;24400;100;10000
```

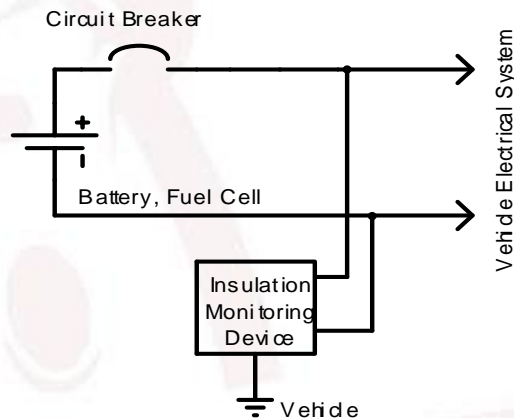
- During the racing stage, teams that cannot keep their records in the monitoring center could also keep them in the vehicle with a separate recording mechanism (using an SD card). Teams that cannot show their records cannot participate in the race or the final evaluation.
- Ready-made or team-prepared micro-controller cards can be used for this system, but personal computers, laptops, cell phones, tablets, switches or routers and other mobile devices will not be allowed in the vehicle. Additionally, the use of mobile phones for displaying speed information or any other purpose is prohibited.
- The data transfer range of the cards to be used must be at least 1000 meters. The transfer of the information in the five items listed above to the monitoring center (telemetry computer) via telemetry will be controlled during technical inspections. Teams that cannot show the transfer of the required functionality or information during the technical inspections can participate in the race without the award points for each unsatisfied item.
- The telemetry system does not need to be utilized as an external unit if the vehicle control unit (VCU) performs the function given in the title of the Vehicle Control Unit (VCU) in the Rule Booklet.

## 2.8 Insulation Monitoring Device

- Insulation monitoring device is an electronic system that measures the insulation resistance level between the electrical systems that are electrically isolated from the ground voltage level and the ground and generates a safety warning in case of insulation loss or turns off the system.
- Especially in electricity generation, storage systems, electric vehicle subsystems, loss of isolation between chassis or ground and subsystems can cause major malfunctions and accidents that may cost the life of the users.
- The Insulation monitoring devices in electric vehicles are connected between the subsystems containing high voltage and the chassis and measure by reference to a resistance value that may pose a risk of life-threatening current flow.
- The insulation monitoring device is a mandatory safety device in vehicles. Whether it is designed and manufactured to meet the domestic requirements specified in the racing rules booklet for electric vehicles or not, the presence of this device is mandatory.
- The insulation monitoring device ensures safety measures and provides information to the user by monitoring the insulation status of the vehicle. It continuously monitors the isolation level inside the vehicle and issues a warning when any isolation issue is detected. This allows users to always check the isolation status of their vehicles and ensure their safety. This device is an effective tool for preventing potential hazards by monitoring the isolation status of vehicles.
- If the measured resistance value falls below the reference limit value, it is expected to give a warning and shut down the system. The reference lower limit value can be taken as  $(\text{Battery Peak Voltage}) \times 100\Omega/\text{V}$ . For example, in a vehicle with a maximum battery voltage of 100V, the lowest lower limit value for the insulation resistance is 10k $\Omega$ . It is recommended to increase this limit value to higher values (eg 100k $\Omega$ ) as it will increase the safety level against electric shocks.
- The insulation monitor must be connected between the positive and negative terminals of the battery and the vehicle chassis as shown in Figure 7. When the equivalent resistance between these terminals and the ground falls below the reference lower limit value, it should give an audible warning at the level of 80dB at a distance of 2 m.
- If there is an insulation resistance value, it should be displayed on the insulation monitor screen or on the AKS screen. There is no need to cut off the energy of the vehicle in order to prevent the vehicle from being out of the race during the loss of insulation. In the electrical system of a safe vehicle with no insulation loss, the insulation resistance between chassis and electrical system is in the range of several M $\Omega$ .
- It is expected that the insulation monitoring device will not reduce the vehicle insulation resistance below 1M $\Omega$  after it is connected to the system. In other words,

the insulation monitor must not connect the battery positive or negative terminals to the vehicle chassis with an impedance of less than  $1\text{M}\Omega$ .

- During the technical inspections, test resistors of different values ( $1\text{M}\Omega$ ,  $100\text{k}\Omega$  etc.) will be connected to the vehicle chassis from the + and – poles of the vehicle battery, and the systems of the teams that cannot show these values with 20% error are not considered domestic.



**Figure 7.** Insulation monitoring device.

## 2.9 Steering System

- Easy-to-remove steering wheel systems can be used if there is a seamless connection between the steering column and the steering wheel. Otherwise, it will be disqualified for safety reasons.
- If the steering wheel is printed with a 3D printer and/or made of hard material such as carbon fiber, castermid, etc., the steering wheel should be prevented from flexing, bending, torsion, etc. The steering wheel must be rigid and inelastic, regardless of the material of manufacture.
- The steering angle should have a maximum steering angle of 30 degrees at the wheel. The steering system must have restrictions that prevent excessive steering in both directions.
- There should not be more than 10 degrees of gap in the steering system.
- The steering system must have a rack and pinion structure and must be mechanically (screw-nut) connected to the vehicle chassis and must be stationary. Safety wire or fiber nut should be used in the nut-bolt connections used in the steering system.
- The use of chain-gear mechanism in the steering system is prohibited.
- The steering angle should be designed in such a way that it does not hinder or strengthen the driver's movements according to the seat position.
- In order for the steering system to be considered as domestic production, teams must do the following:
  - i. The technical drawing of all the elements used in establishing the relationship between the rotation of the steering wheel of the vehicle and the rotation of the

wheel and the three-dimensional assembly CAD model of the whole system must be prepared. Each part must appear as a separate element in the CAD model. CAD file should be submitted with .stp extension.

- ii. According to the steering wheel turning angle, the inner and outer wheel turning angles should be displayed graphically. Also, according to the steering wheel's maximum turning angle, the maximum turning angles of the wheels should be indicated on the graph. The chart should include the angle of turns of the wheels in both right and left turns.
- iii. The steering wheel has to turn left and right at least 180 degrees and at most 360 degrees, and this turn causes the wheel to rotate. During the rotation of the wheels, there should be at least 1 cm space between the wheels and any part on the shell or vehicle.
- iv. The characteristic speed of the vehicle should be indicated. According to the Ackerman principle, the angle values of the outer wheel should be plotted according to the angle of the inner wheel and the results obtained by showing the actual values measured on the vehicle on the same graph should be compared and interpreted.
- v. Teams need to demonstrate the kinematic structure of the wheel suspension geometry using computer-aided simulations.
- vi. The control of the calculated and given design files will be done on the vehicle. The design and the car must be the same.

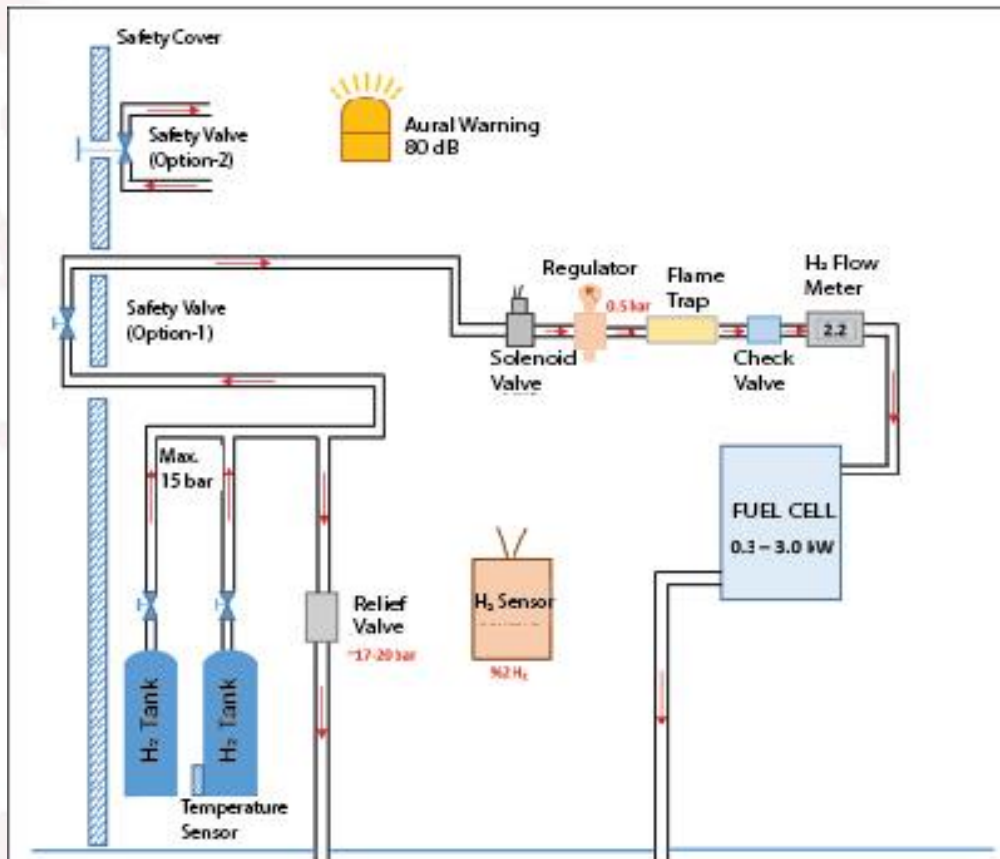
## **2.10 Door Mechanism**

- The designed door system will be considered as domestic if the following listed features are found in the design of the doors used for access to the vehicle:
  - i. The vehicle should have 2 doors opening from both sides, the dimensions of the doors should be the same, the surface area of the doors should be at least 0.4 m<sup>2</sup>.
  - ii. 3-D CAD drawing of each of the parts in the door system and a 3-D dimensional montaged CAD drawing of the whole system must be prepared. The file should be submitted as .stp extension.
  - iii. The door should be hinged to the vehicle body at at least two points. Teams need to show which calculations or analyses are based on the selection of hinge locations and dimensions based on door geometry and physical properties.
  - iv. The entire outer frame of the door must be in contact with a surface of at least 2 cm wide on the vehicle body.
  - v. When the vehicle rolls over or turns over, at least one of the doors must be able to be opened and the pilot must be able to exit the vehicle using this door. Vehicles with door designs that do not meet this rule will be disqualified from the race.
  - vi. It is necessary to use a seal between the door and the vehicle body.
  - vii. The door must be lockable with a key. The door must not be opened by the door handle movement without opening with the key.

- viii. The door should be closed with only the pushing force, without interfering with its handle.
- ix. An object of 2 mm thickness should not enter anywhere between the door and the body when the door is closed.

## **2.11 Hydrogen System (Fuel Cell, Fuel Cell Control System, Hydrogen Line and Metal Hydride Cylinders)**

- Technical rules of hydrogen lines and systems used in the Hydromobile category can be found below.
- Low-temperature metal hydride hydrogen cylinders (maximum of 15 bar) may be used in vehicles. These cylinders must not be replaced during the race and no fuel (hydrogen) additions may be made to the existing tank.
- In order to be protected from external mechanical impacts; Hydrogen cylinders should be together and among the mechanically resistant protection shield, connected and bundled with strong belts or clamps. Hydrogen cylinders together with the protection shield can be located behind the driver's seat or in the front of the vehicle, provided that they are located further than the cockpit windscreen.
- The protection shield must provide natural ventilation of the cylinders. The compartment where the rollers are located should be designed in such a way that they are not exposed to static electricity. Cylinders must be positioned to provide maximum safety.
- There should be a pressure relief valve at the closest point to the outlet of the metal hydride hydrogen cylinders, before the other elements on the line. The pressure relief valve should evacuate the gas depending on the pressure increase in the hydrogen cylinders in an emergency and protect the other elements and connection points on the line against excessive pressure. The pressure relief valve should be activated in the range of 17-20 bar. The line outlet of the pressure relief valve should be vertical to the outside of the vehicle, preferably vertical to the ground, not to be damaged in cases of possible friction, impact, etc.
- After the pressure relief valve, there must also be a safety valve (ball valve) on the line. The safety valve should be well located in the vehicle for the driver at a point where he/she can reach while the seatbelt fastens and during driving periods. In conditions where the safety valve is inside the cockpit, care should be taken that the hydrogen line/pipes are not inside the cockpit. The safety valve can be installed in the vehicle in two different ways, as seen in Figure 8.



**Figure 8.** An example of a flow diagram in Hydromobile.

- After the in-vehicle safety valve, there must first be a solenoid valve and then a regulator on the line. In case of temperature rise detected by the thermocouple (thermalcouple) and hydrogen gas leakage detected by the gas sensor, the solenoid valve should cut off the gas flow.
- The hydrogen, whose pressure is reduced to the fuel cell inlet pressure in the regulator, must reach the fuel cell by passing through the flame trap and check valve. The regulator must reduce the hydrogen pressure to the required pressure before it enters the fuel cell. The flame trap or check valve must be a suitable type for hydrogen gas and must be suitable for the pressure level of the fuel line at the point where the operating range is.
- There must be a suitable place on the hydrogen line before the fuel cell for the connection of the hydrogen flowmeter (Hydrogen Consumption Measurement Device) which will be given by TÜBİTAK before the race. The hydrogen flowmeter will be installed in an easily visible spot before the race. Teams must prepare the appropriate location for the hydrogen flowmeter (See Rules Booklet: Hydrogen Consumption Meter for details).
- A sample flow chart for the hydrogen line and its elements is given in Figure 8. The parts to be used in the hydrogen line from metal-hydride cylinder tanks to the fuel cell are as in Figure 8, respectively, pressure relief valve, safety valve (ball valve), solenoid valve, regulator, flame trap, check valve, hydrogen flow. meter and fuel cell input.

- In addition, teams can create a different flow diagram within the framework of the above-mentioned issues, considering the safety of the driver. This flowchart should be shown in detail in the technical design report. The flow chart will be checked during technical checks.
- During technical inspections, technical specification documents and certificates will be checked for all materials used on the hydrogen line (pipe, valves, and connection elements). Teams should keep these documents as a file during the controls.
- The vehicle should have the following fire safety measures:
  - i. A thermocouple must be provided on the surface of the metal hydride cylinders to measure the temperature. The thermocouple must transmit the temperature measurement values to the temperature indicator in the vehicle's cockpit.
  - ii. In case of using more than one metal-hydride cylinder, preferably, a separate sensor should be used for each cylinder, or it should be placed between the two cylinders to measure their temperatures. There should be no metal-hydride cylinders without temperature control.
  - iii. The temperature indicator should be electrically connected to a warning flasher. The flasher must be positioned in a place where the referees and the driver can see the image warning during the race. The diameter of the flasher cannot be less than 4 cm and its height cannot be less than 5 cm. The flasher should be red colored, rotating type with reflector.
  - iv. An audial and visual alert should be emitted by the flasher and the solenoid valve should close when the surface temperature of the metal hydride cylinder goes 10°C above the maximum operating temperature of the metal hydride as declared by the manufacturer (e.g.,  $T > 55^{\circ}\text{C}$ ).
- There must be a hydrogen sensor in the area in which the fuel cell is located. In case of the presence of 2% hydrogen in volume in the environment, the hydrogen sensors must emit an audible alarm of 80 dB to be heard at 2 m and shut down the solenoid valve.
- The hydrogen line should not pass through the cockpit. All valves and fittings used on the hydrogen line should be of 316 quality and stainless steel or brass, and pipes should be of 316 quality and stainless steel or PTFE (Teflon) material.
- Changes may be demanded by the technical team if any violations are observed related to safety during technical inspections. While designing the parts of the vehicle related to hydrogen gas and mounting these parts, the requirements of the following standards must be considered:
  - i. ISO/TR 15916:2004: Basic considerations for the safety of hydrogen systems.
  - ii. ISO 16111:2008: Transportable gas storage devices - Hydrogen absorbed in reversible metal hydride.
  - iii. BSI BS EN ISO 1114-1:1998: Transportable gas cylinders-compatibility of cylinder and valve materials with gas content - Part 1: Metallic materials.

**iv.**ISO 11114-2:2000: Transportable gas cylinders-compatibility of cylinder and valve materials with gas content - Part 2: Non-metallic materials.

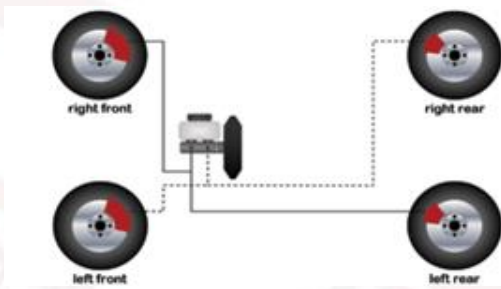
- If the above-mentioned elements are included in the ready-made fuel cell, it is not obligatory to use the same element repeatedly on the hydrogen line. However, it is obligatory to use elements that are not included in the ready-made fuel cell.
- In the kits that will use ready-made fuel cells, if there are elements integrated into the fuel cell, they should be given clearly and in detail in the technical design report. Teams using ready-made fuel cells are required to show the fuel cell diagram during technical inspections.
- The nominal fuel cell (may be more than one) to be used, the sum of the output power label values shall be at most 3 kW and at least 300 W. If the fuel cell is supplied with oxygen, the oxygen and hydrogen lines should be placed at a distance of at least 10 cm between them.
- The anode and cathode outputs of the fuel cell will be independent of each other and will be released to the atmosphere from the back of the vehicle with two separate discharge lines. The fuel cell water vapor outlet should not be upwards to prevent the accumulative water from blocking the gas outlet and creating pressure. Regarding the fuel cell to be used, "The rules given in the Rules Booklet heading "Drive System and Electrical Equipment" must be followed.



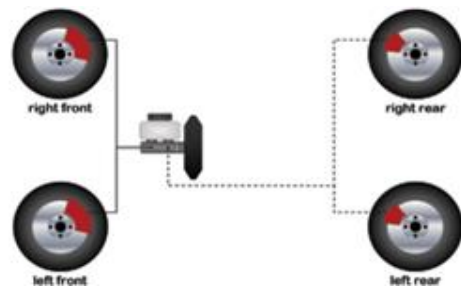
**Figure 9.** Examples of materials that can be used in Hydromobile vehicles.

## 2.12 Brake System

- It is mandatory to use at least two cylinders and/or two-circuit cylinders with a single pedal. The same pedal should engage all the brakes. With the coupling not engaged, the perimeter wheels can effectively act.
- Disk brakes or drums can be used on 4 wheels.
- The brake system should be a double circuit. (Feeding on the front-rear cross and/or front-rear separate circuits, (see Figure 10)



**Figure 10.a.** Dual-diagonal braking system.



**Figure 10.b.** Front rear split system.

**Figure 10.** Dual-diagonal braking system examples.

- The brake master center must have a single brake cylinder with two different outputs and/or two hydraulic circuits in which two separate cylinders are controlled by a single pedal (see Figure 11).



**Figure 11.a.** Single reservoir dual outlet port.



**Figure 11.b.** Dual reservoir dual outlet port.

**Figure 11.** Dual outlet port construction.

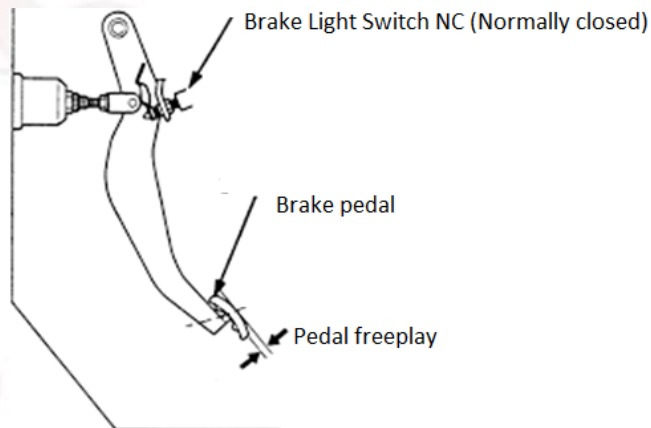
- The brake pedal and brake master cylinder(s) must be mechanically connected. The pedal's center pressing point must be rigidly connected with the master cylinder extension (see Figure 12).



**Figure 12.** Rigid connection between braking pedal and master cylinder.

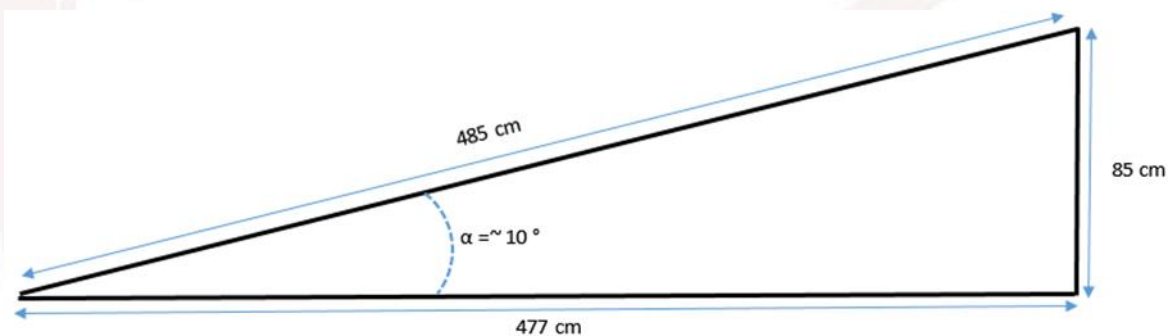
- The brake light switch/button must not be mounted on the pedal. In the brake system, mechanical normally closed contact mechanical contact switch should be used, (The circuit that lights the brake light must be an electrical circuit in NC / NC normally closed form).
- Hall effect sensor, magnetic sensor, reed relay, etc. products should not be used to activate the brake light (see Figure 13) Brake pedal and connection point must be made of metal (steel sheet). Motorcycle and bicycle type magnets cannot be used as brake centers.
- Brake calipers and brake discs must be rigidly connected to the connection points with bolts of conforming diameter.

- The return spring must be used when the pedal is not depressed at the brake pedal connection point.



**Figure 13.** Brake light switch normally closed (NC) circuit.

- If the brake center hydraulic reservoirs are not located on the brake center and are connected to the center with the help of a pipe, the split reservoirs must be securely fixed perpendicular to the ground in a suitable position.
- In the connection of brake calipers and brake master cylinder, a pipe should be compatible with hydraulic fluid, resistant to brake pressure, and not swell under pressure. Wire brake will not be accepted in the brake system.
- Brake performance of the vehicle will be performed on a braking platform. Figure 14 shows the dimensions of the platform for the brake test. Length, height, and width of the platform are 485 cm, 85 cm, and 200 cm, respectively. Slope angle of the platform is approximately 10 degrees.



**Figure 14.** Dimensions of the braking platform.

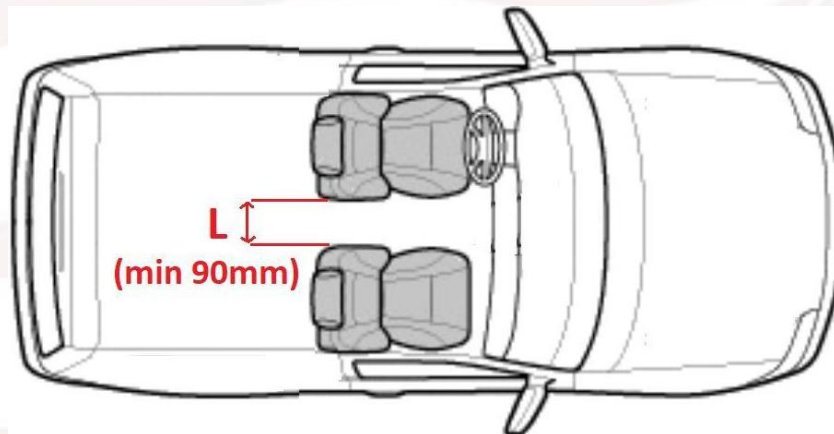
- It is expected that the designed vehicles are able to stay still without sliding on the braking platform during the braking tests carried out before and after the competition.
- Dynamic performance of the brake system is evaluated with an extra test conducted on the braking platform which consists of two steps. In the first step, while staying still on the platform without moving, the driver will be asked to release the brake pedal completely so that wheels start turning. Then in the second step, the driver

will apply full brake to prove that vehicle can stay still on the platform again without moving and not having any sliding wheel.

- The vehicle should be precisely aligned with the platform either by driving or by pushing. Positioning on the test ramp is the team's responsibility to lift the vehicle and put it on the ramp. The team is responsible for the fault situation. Teams should consider the dimensions of the platform during the design phase of the vehicle.
- The braking tests on the braking platform will be performed while the vehicle is placed on the platform with its front side pointing the downward direction.
- The brake test will be repeated after the competition.
- In case of an unavailable braking platform during the competition, an alternative brake test which is carried out by pushing the vehicle by two persons corresponding to the application of 650 N pushing force will be applied. The wheels of the vehicle shall not move during the pushing test.
- For the brake system to be considered as a novel, the teams must do the following:
  - a. Acceleration of deceleration calculations and speed graph during full braking.
  - b. Depending on the acceleration of friction, the graph of linear load transfer.
  - c. Fixed braking force distribution curve.

## 2.13 Seat

- The seats must be placed side by side. The distance between two seats must be at least 90 mm. This measurement will be checked from the two closest points of the seats.



**Figure 15.** Minimum distance between adjacent seats.

- The seat must be securely fixed to the chassis. The back support should not have an angle of more than 30 degrees from the vertical. In the selection of the driver's seat, it is obligatory to choose products with FIA certification, which surrounds the driver, prevent skidding in both directions.
- Products that expired FIA certificates can be used if they are not damaged. In the case of using a seat that is not by FIA standards but meets the safety requirements,

penalty points are applied due to the ineffective use of the race allowance given to the teams.

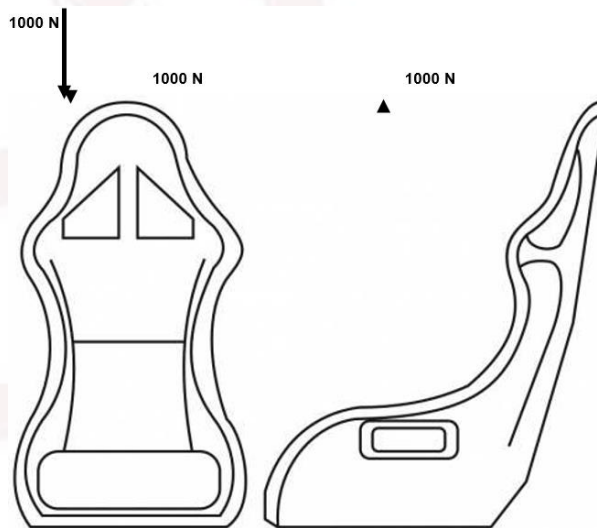


**Figure 16.** Sample race driver seats.

- The same or different seats can be used for the driver and passenger. Teams do not have to use an FIA-certified seat as a passenger seat. They can use a seat in the form of a racing seat that surrounds the passenger, prevents them from being thrown in two directions, has a head restraint, is suitable for at least a five-point seat belt. In case of not using a seat in the form of a racing seat with headrest and side supports, penalty points are applied due to the ineffective use of the race allowance given to the teams.
- Teams can design and manufacture the passenger seat themselves and use it as a domestic product.
- Seat assemblies formed by shaping the lower body of the vehicle in the form of a seat are not accepted. An external seat is required.
- The passenger seat and the driver's seat must be on the same plane.
- In technical inspection, the certificate on the driver's seat will be checked. Certified seats are monoblock. Seats with folding features are not suitable for both drivers and passengers.
- At the controls, both the driver and one person (passenger) from the team will be asked to sit in their seats and fasten their seat belts. Designs where the passenger does not fit the passenger seat will not be accepted.
- The top level of the helmet-mounted driver and passenger sitting on the seats should be lower than the highest point of the seats. Otherwise, a headrest should be made between the seat and the highest point of the rear roll bar.
- For the passenger seat to be considered as a domestic product, the teams must do the following:
  - a. Three-dimensional CAD assembly and separate technical drawings of the seat, the chassis parts where the seat is mounted, and all the mechanical elements used in the seat assembly must be prepared. Each part must appear as a separate element in the CAD assembly. The CAD file must be submitted with the .stp extension.
  - b. The seat should be in the form of a racing seat, where a passenger 1.70 m tall and weighing 70 kg can sit comfortably. Seat dimensions should be in

accordance with the drawing.

- c. All materials in the seat structure should be given in detail.
- d. Teams are obliged to prove that the seat is resistant to accidents from different regions. For this, separate structural analyzes should be performed under the loads (up, down, forward, and sideways) indicated in Figure 17. The analyzes should be made using modules suitable for the materials used in the seat. For example, if a design is made using composite material, the analyzes should be made in accordance with the composite material analysis.
- e. Teams must indicate the displacements that occur in the seat under the loads given in their reports. The appropriateness of the maximum displacement amount should be discussed.
- f. There should be spaces on the seat for the passage of the seat belt.
- g. The seat should be ergonomic, there should be no sharp and pointed areas anywhere.



**Figure 17.** The forces that must be applied in analyses.

### 3. REPORT TITLE SCORES

- The evaluation of the technical design report will be done considering the score distribution shown in the table below.

**Table 1.** Technical design report evaluation criteria.

	Title Description		Score		
			International		Inter-High School
			Electro	Hidro	Electro
1	Vehicle Features Table		100	100	100
2	Vehicle Electrical Diagram		50	50	50
3	Motor	*	300	300	300
4	Motor Driver	*	400	400	400
5	Battery Management System (BMS)	*	200	200	200
6	Embedded Recharging Unit	*	200	200	200
7	Battery Packaging	*	150	150	150
8	Electronic Differential Application	*	150	150	150
9	Vehicle Control Unit (VCU)	*	300	300	300
10	Insulation Monitoring Device	*	150	150	150
11	Steering System	*	300	300	300
12	Door Mechanism	*	150	150	150
13	Braking System	*	150	150	150
14	Mechanical Details		150	150	150
15	Passenger seat	*	150	150	150
16	Fuel Cell	*	-----	500	-----
17	Fuel Cell Control System (Circuit)	*	-----	300	-----
18	Hydrogen Line and Metal Hydride Cylinders		-----	100	-----
19	Energy Management System (EMS)	*	-----	300	-----
<b>Total</b>			<b>2900</b>	<b>4100</b>	<b>2900</b>

\*If the design is made by the team, it is mandatory to provide details; if it is a ready-made product, please explain briefly.

## 4. GENERAL RULES

To access the General Rules booklet applicable to the competition, [click here](#).

## 5. ETHICS

To access the Ethics booklet applicable to the competition, [click here](#).

### Declaration of Responsibility

T3 Foundation and TEKNOFEST are not responsible in any way for any product delivered by the competitors, or any injury or damage caused by the competitor.

T3 Foundation and organization officials are not responsible for the damage caused to third parties by competitors. T3 Foundation and TEKNOFEST are not responsible for ensuring that teams prepare and implement their own systems within the framework of the laws of the Republic of Türkiye.

**Hereby, the Turkish Technology Team Foundation reserves the right to make any changes to this specification.**

## 6. CONTACT

- For application and report upload: <https://www.t3kys.com>
- For information and announcements: [www.teknofest.org](http://www.teknofest.org) and [iletisim@teknofest.org](mailto:iletisim@teknofest.org)
- For your questions (**International**): <https://groups.google.com/u/1/g/uluslarasrasi-effcency-challenge-elektrkl-ara-yarilari?hl=tr>
- For your questions (**High school**): <https://groups.google.com/g/lsele-arasi-effcency-challenge-elektrkl-ara-yarilari>

## 7. APPENDIX

### Appendix 1: Penalty List

	TITLE	BREACHES	ELECTROMOBILE	HYDROMOBILE
DESIGN PROCESSES	Progress Report	Not sending the Progress Report	Disqualification	Disqualification
	Technical Design Report	Not sending the Technical Design Report	Disqualification	Disqualification
	Dynamic Driving Test Video	Failure of the video to upload or failure to meet any or all of the expected features expressed in the rulebook.	Disqualification	Disqualification
	Braking Test Video	Failure of the video to upload or failure to meet any or all of the expected features expressed in the rulebook.	Disqualification	Disqualification
RACE WEEK PROCESS	Dynamic driving test	Failure to complete the dynamic driving test on the first day	5 Wh	5 Wh
	Dashboard camera	No video recording during the race/ Not uploaded to the system	2.5 Wh	2.5 Wh
VEHICLE OUTSIDE CONTROLS	Vehicle dimensions	Not suitable for the dimensions specified in the rules	2.5 Wh for each violated cm	2.5 Wh for each violated cm
		The ground clearance of the vehicle is not at least 10 cm	Disqualification due to the security reasons	Disqualification due to the security reasons
		Vehicle height is more than 1.25 times vehicle width	Disqualification due to the security reasons	Disqualification due to the security reasons
		Wheel span is less than half of the vehicle width inside	Disqualification due to the security reasons	Disqualification due to the security reasons
	Vehicle body	Open place with a bird's eye view, wheels are outside the vehicle	Disqualification due to the security reasons	Disqualification due to the security reasons
		Fragile windows/sharp corners/dangerous protrusions and similar problems	Disqualification due to the security reasons	Disqualification due to the security reasons
		No cover on the front/back of the shell to access the battery	Disqualification due to the security reasons	Disqualification due to the security reasons
		No cover on the front / back of the shell for access to other parts	5 Wh	5 Wh
	Vehicle doors and mechanisms	50x80 cm frame cannot pass	Disqualification due to the security reasons	Disqualification due to the security reasons
		Preventing the driver from exiting the vehicle in case the vehicle turns upside down or leans on its side.	Disqualification due to the security reasons	Disqualification due to the security reasons
		Does not comply with the dimensions specified in the rules	Disqualification due to the security reasons	Disqualification due to the security reasons
		The door cannot be closed without using the handle, but it is safe	5 Wh	5 Wh
		The door cannot be opened from the outside, there is a risk of opening during the race.	Disqualification due to the security reasons	Disqualification due to the security reasons
		After the race, it is determined that the door is glued with duct tape / fastened with plastic clamps from the inside	Disqualification due to the security reasons	Disqualification due to the security reasons
	Vehicle rear view mirrors	Non / Only one	Disqualification due to the security reasons	Disqualification due to the security reasons
		Areas less than 50 cm <sup>2</sup>	Disqualification due to the security reasons	Disqualification due to the security reasons
		The driver cannot see the text shown	Disqualification due to the security reasons	Disqualification due to the security reasons

	TITLE	BREACHES	ELECTROMOBILE	HYDROMOBILE
	Vehicle towing eye	No towing eye	Disqualification due to the security reasons	Disqualification due to the security reasons
		Inner diameter less than 20 mm/Non steel	Disqualification due to the security reasons	Disqualification due to the security reasons
	Vehicle taillight	None/Cannot be seen from 25 m	Disqualification due to the security reasons	Disqualification due to the security reasons
	Vehicle headlights	Non	5 Wh	5 Wh
		Cannot be seen from 25 m	2.5 Wh	2.5 Wh
	Vehicle windshield	The material does not comply with the rules, it is not transparent	Disqualification due to the security reasons	Disqualification due to the security reasons
	Windscreen wiper	Non	5 Wh	5 Wh
		Available but not working properly	2.5 Wh	2.5 Wh
VEHICLE INSIDE CONTROLS	Vehicle tire	Using tires other than those supplied by TÜBİTAK	Disqualification due to rule violation	Disqualification due to rule violation
	The tire pressure of the vehicle	Being over the specified limit value	Disqualification due to the security reasons	Disqualification due to the security reasons
	Cockpit	Not enough space/unsafe for the driver	Disqualification due to the security reasons	Disqualification due to the security reasons
	Seat belt	Not secured by at least 5 points or not compliant with FIA rules	Disqualification due to the security reasons	Disqualification due to the security reasons
		No passenger seat belt or not in compliance with FIA regulations	Disqualification due to the security reasons	Disqualification due to the security reasons
	Roll bars	Missing roll bar	Disqualification due to the security reasons	Disqualification due to the security reasons
	Roll cage	Tensile strength less than 200 MPa	Disqualification due to the security reasons	Disqualification due to the security reasons
		Roll bar not perpendicular to vehicle floor	Disqualification due to the security reasons	Disqualification due to the security reasons
		Front roll bar does not start at least 3 cm above the steering wheel	Disqualification due to the security reasons	Disqualification due to the security reasons
		Rear roll bar does not start at least 5 cm above helmet level	Disqualification due to the security reasons	Disqualification due to the security reasons
		Profile does not follow the rules	Disqualification due to the security reasons	Disqualification due to the security reasons
		The roll cage is not independent of the body and is not safe	Disqualification due to the security reasons	Disqualification due to the security reasons
		The roll cage is not independent of the body, but it is safe	5 Wh	5 Wh
		Welding or bolt not properly fixed	Disqualification due to the security reasons	Disqualification due to the security reasons
	Fire extinguisher	Less than 2 kg	Disqualification due to the security reasons	Disqualification due to the security reasons
	Seat	Vertical angle more than 30°	Disqualification due to the security reasons	Disqualification due to the security reasons
		There is a seat, no passenger seat	Disqualification Due to Rule	Disqualification Due to Rule
		Not have FIA standards, not safe	Disqualification due to the security reasons	Disqualification due to the security reasons
		Not have FIA standards, but safe	2.5 Wh / seat	2.5 Wh / seat
		Distance between adjacent seats is less than 90 mm	Disqualification due to the security reasons	Disqualification due to the security reasons

	TITLE	BREACHES	ELECTROMOBILE	HYDROMOBILE
	Steering wheel	Open form	Disqualification due to the security reasons	Disqualification due to the security reasons
	Horn	Not play for 3 seconds without interrupt	Disqualification due to the security reasons	Disqualification due to the security reasons
	Speedometer	Non / not working	Disqualification due to the security reasons	Disqualification due to the security reasons
		Cannot be displayed on telemetry computer but external speedometer is used	1 Wh	1 Wh
	Foot Accelerator Pedal	Non / not working	Disqualification due to the security reasons	Disqualification due to the security reasons
SECURITY CONTROLS	Driver suit and equipment	Unsuitable due the rules	Disqualification due to the security reasons	Disqualification due to the security reasons
		Not FIA standards, but safe	2.5 Wh	2.5 Wh
	Brake test	Not enough	Disqualification due to the security reasons	Disqualification due to the security reasons
	Brake system	Not multi-circuit or hydraulic	Disqualification due to the security reasons	Disqualification due to the security reasons
	Electrical cable connections	Open connection / No isolation	Disqualification due to the security reasons	Disqualification due to the security reasons
	Emergency stop button	Non / not working	Disqualification due to the security reasons	Disqualification due to the security reasons
	Overcurrent circuit breaker	Non / Improper Design	Disqualification due to the security reasons	Disqualification due to the security reasons
	Battery	Non	Disqualification due to rule violation	Disqualification due to the security reasons
	Battery management system	Non / not working	Disqualification due to the security reasons	Disqualification due to the security reasons
	Battery management system	Temperature sensors not properly placed in battery	Disqualification due to the security reasons	Disqualification due to the security reasons
	Battery management system	Temperature sensors not working	Disqualification due to the security reasons	Disqualification due to the security reasons
	Battery management system	Balancing system not working	0.5 Wh	0.5 Wh
	Battery management system	State of charge (SOC) calculation is incorrect	0.5 Wh	0.5 Wh
	Battery temperature measurement	No flasher and temperature indicator	Disqualification due to the security reasons	Disqualification due to the security reasons
	Battery box	Non / unsuitable design & materials	Disqualification due to the security reasons	Disqualification due to the security reasons
	Battery box fixing	Unfixed	Disqualification due to the security reasons	Disqualification due to the security reasons
		Screw thinner than 8 mm is used		
	Safety curtain	No safety curtain between driver's seat and battery pack	Disqualification due to the security reasons	Disqualification due to the security reasons
	Energy meter connection	Has an external battery supply	(Battery capacity) Wh	(Battery capacity) Wh
	Energy meter	Battery voltage levels are outside the capacity of the energy meter	Disqualification due to rule violation	Disqualification due to rule violation
	Onboard charge unit	No electrical isolation between grid and battery pack	Disqualification due to the security reasons	Disqualification due to the security reasons

	TITLE	BREACHES	ELECTROMOBILE	HYDROMOBILE
	Telemetry	Non / unsuitable	Disqualification due to rule violation	Disqualification due to rule violation
	Fuel cell	Non/not working/greater than 3 kW		Disqualification due to the security reasons
	Super capacitor	Greater than 110 kJ		Disqualification due to the security reasons
	Pressure relief valve	Non / unsuitable		Disqualification due to the security reasons
	Gas outlet safety valve	Non / unsuitable		Disqualification due to the security reasons
	Thermocouple	Non / unsuitable		Disqualification due to the security reasons
	Flasher	Non / unsuitable		Disqualification due to the security reasons
	Temperature indicator	Not connected with flasher		Disqualification due to the security reasons
		Not working/low sound level		Disqualification due to the security reasons
	Metal hydride cylinders	Inside the cockpit / unsuitable		Disqualification due to the security reasons
		No protection shield		Disqualification due to the security reasons
		Unsafe connecton		Disqualification due to the security reasons
	Hydrogen line	Inside the cockpit / unsuitable		Disqualification due to the security reasons
		Unsuitable design		Disqualification due to the security reasons
	Ball valve	Non / unsuitable		Disqualification due to the security reasons
		Unsuitable materials		Disqualification due to the security reasons
	Hydrogen sensor	Non / unsuitable		Disqualification due to the security reasons
	Emergency evacuation (driver and co-driver)	More than 10 sec / Help needed	Disqualification due to the security reasons	Disqualification due to the security reasons
	Motor Driver	Unboxed	Disqualification due to the security reasons	Disqualification due to the security reasons
		Plug connectors not used	1 Wh	1 Wh
	Insulation Monitoring Device	Non / not working / low sound level	Disqualification due to the security reasons	Disqualification due to the security reasons

