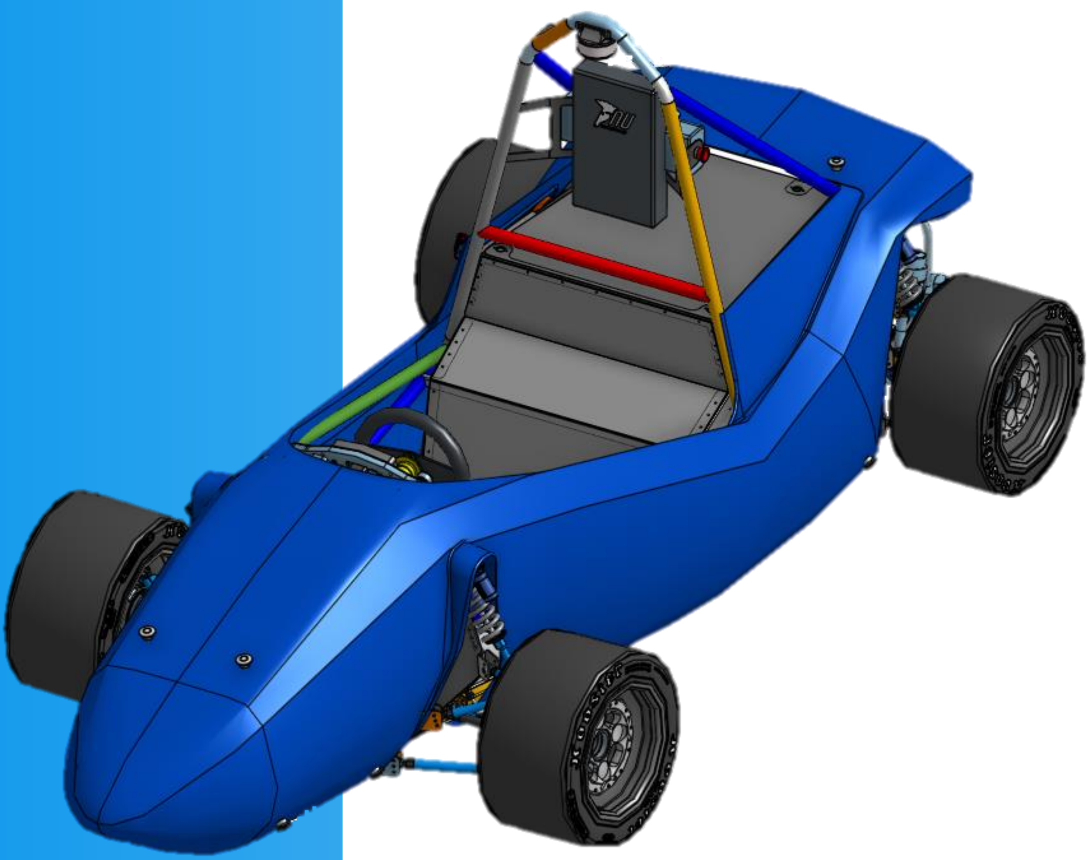
Chief Mechatronic Engineer

Directed Reading

NU24



Alec Chapman

2024

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Abstract

2024 was an extremely challenging year for NU Racing, and that was very much felt as the Chief Mechatronic Engineer (Author). The author was forced to have a larger than normal amount of involvement with all mechatronic aspects in the year due to the team's low member count when compared to recent years to ensure quality engineering outcomes and to enhance team performance.

The MCHA team successfully tested the new MCHA system on the 2023 competition car NU23 before NU24 was a rolling chassis which directly contributed to achieving the earliest testing a competition car in NU Racing history in July.

The failure of the Cascadia CM200DZ Motor Controller halted the car from driving for two and a half months before a new Cascadia CM200DX was purchased by the team after a rigorous troubleshooting and commissioning period. At the time of writing, the damaged inverter has not officially been diagnosed but Cascadia has likely put the failure down to the variable PWM frequency setting on the inverter, damaging the current regulator.

During the two and a half months, the MCHA Team efficiently used the downtime of NU24 to upgrade and fix found issues with the MCHA systems, as well as complete essential competition documents like the ESF and Cost Report. The team used the remaining one and a half months before competition to test and develop NU24's functionality, reliability and driveability, while also ensuring compliance in the Technical Inspections.

The team made it to the 2024 Formula SAE Australasia Competition in Calder Park Victoria with an acceptable amount of static event preparation and with a car ready to perform dynamically. The team worked the best it ever had in the 2 months between testing and competition, and such completed every event in the competition and finishing 4th overall, NU Racing's joint best ever finish and with the highest point score in NU Racing history at 733.86 points.

2024 was an incredible year to be the Chief Mechatronic Engineer of NU Racing, providing a valuable experience from both a technical and managerial perspective. While the year was heavily compromised, 2024 and the author's role in the team was wildly successful.

Figure 1 NU24 - NU Racing's 2024 Competition Platform

Introduction

This report details the observations and events of 2024 as NU Racing's Chief Mechatronic Engineer, as well as recommendations and key points for future Mechatronic Department Leads. It is assumed that the reader has a good understanding of NU Racing's electric cars, including the major components and the PCBs on the car.

NU Racing is a small Formula Student team, one which centres itself around hard work, determination and the special chemistry created by the team, supported by the University's valued staff members.

In recent years, NU Racing has overachieved considering both the team size and the budget size, and historically has run high risk teams, trying to do too much each year. This has almost ended in heartbreak but hasn't thus far, even considering an accumulator fault during 2023 Endurance, the team still scored three second place trophies and finished 7th overall.

2024 was the year of change, with a smaller team of final year students, more reliance on directed and extracurricular members, and the academic advisor, Dr Alexander Gregg departing the university. It was the first year to be handed a car capable of a podium at the Australasian Formula SAE event.

The Role of Chief Mechatronic Engineer

The author was lucky enough to be one of the critical members of the team as Mechatronic Department leader. This included being responsible for:

- The mechatronic team and their growth in the team
- Working with the constrains set by the Team Leader and Chief Engineer
- Working with the Mechanical Department Lead
- Participating and/or leading Industry Partner Visits
- The delegation and management of mechatronic scopes and projects
- The Mechatronic Budget
- All the mechatronic components used in the team
- Competition documents (ESF, ESO/ESA)
- The mechatronic aspects of the Cost Report, Design Event and Technical Inspection
- Regular Track Day Attendance
- Mechatronic Testing
- Mechatronic Performance and Safety at Competition

This role has evolved and adapted over the years and now as the team grows it is becoming more and more developed. It has shifted away from heavy technical work with a small amount of management to a role that focuses more on management than in-depth technical work and that is what the author experienced.

It is vital for the role that a broader systems perspective is taken with every decision, as choices will affect other mechatronic systems, as well as mechanical systems. When in-depth attention is needed for an extended period of time on a system, it is vitally important to delegate.

The Leadership Aspect of the Role

The role is both a technical and leadership role, both being equally important.

It is recommended to scope out the projects for the mechatronic team based on the member's interest, as they are more likely to be self-motivated, reliable and positive, this should be done through an interviewing process. Self-awareness is very important in the role as it is very demanding and burn out is likely if safeguards and limits are not set in place. The limit of knowledge must also be accepted as making a rash decision is much worse than asking for help, this also goes the other way. Newer members will be inexperienced, and it is important for members to upskill, this only happens when members do the work. Help should be given when asked but ideally in a way which is informative rather than just supplying the answer.

It is important to be a warm and welcoming member of the team, as the team will work better if members are social and fond of each other, rather than just present in the team for experience or course credit. This is the chemistry which separates NU Racing from other teams. Checking in on members should also be done, not just on technical work but also administrative to ensure they are staying up to date with what is needed from the Team Leader.

Once the team is established and its members are getting comfortable with their position in the team, trust must be given, as more will be required out of the department leads as competition approaches, and time will be needed to oversee and check the work as a whole system. This will allow for issues to be found faster and ideally fixed before becoming destructive and time consuming.

The year can fly by quickly, so the author also recommends using a journal explicitly for NU Racing, this was something that helped the author switch off at the end of the day as well as remember all the necessary details for record and future action. The end of the year and the build up to competition is very high pressure and it is important for a level head to be kept, ideally, the leaders are the calm in the chaos of competition.

At the end of the day, the team is made of undergraduate engineers who are in the team to learn, and it is important to be considerate of everyone. Asking too much of people will only make them harder to manage.

Overall, the role is very exciting and offers a very valuable experience hard to find as an undergraduate engineer. As challenging as it is, it is extremely rewarding, especially if a career in leadership is to be considered.

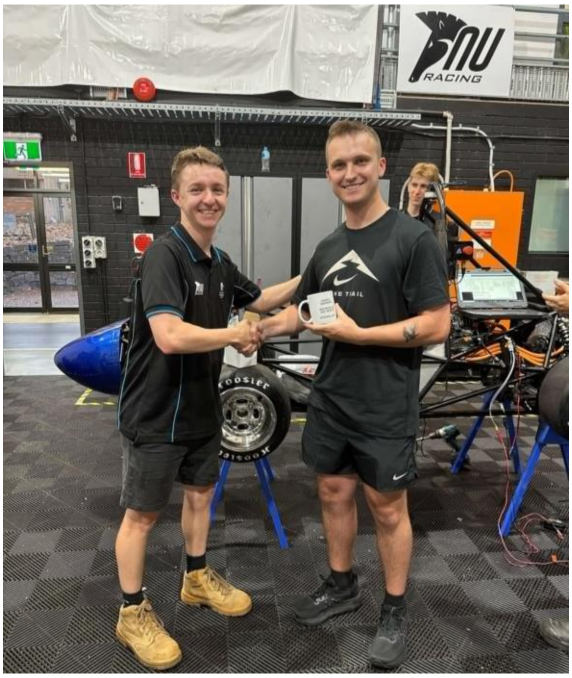

Figure 2 Presenting the Engineering of the Month Award for October to Josh Hayward (RIGHT)

The State of the Art

NU23 was built in 2023 by NU Racing. It completed almost 450 km of testing and was a very competitive platform to begin with.

This car featured, Teensy 4.0 Microcontrollers, a 7.2 kWh 453.6 V Accumulator, capable of discharging 180 A, a 60 kW Emrax 188 AC Motor and a Cascadia CM200DZ inverter, propelling the car to 2nd place in both Skidpad and AutoX during the 2023 competition.

The accumulator is comprised of 108 Enepac Li1x6pVTC6 modules connected in series, monitored by an Orion BMS2 and our own temperature monitoring device, the CANaMON, a PCB which converts Analogue temperatures onto the CAN BUS. It also features the Low Voltage Distribution board (LVD), Precharge Board and Insulation Monitoring Device, the BENDER ISOMETER IR155-3203.

The low voltage system on the car has a nominal voltage of 12 V and is comprised of multiple individual nodes situated in the car, these include:

- The Pedal Electronic Node (PEN): Reads the Brake Pressure Sensors, Accelerator Pedal Position Sensors (APPS), and Brake Over Travel Switch (BOTS)
- The Dash Electronic Node (DEN): Reads the Dash E-Stop and Ready-To-Drive (RTD) button, and relays PEN signals.
- The Central Electronic Node (CEN): Reads the Tractive System Master Switch (TSMS), Hard Fault Latch (HFL), Top E-Stops, HV and HV Disconnect (HVD) Interlocks, Brake System Plausibility Device (BSPD), Tractive System Active Light (TSAL), OK High Signals (OKHS) and Discharge Relay. Communicates to the DCDC, Motor Controller, REN, and Accumulator. (This board also is HV)
- Rear Electronic Node (REN): Read the Temperature Sensors of the Radiator, and relays Power to the Brake Light, RTD Sounder and Cooling Pumps and Fan.
- Low Voltage Distribution (LVD): Relays Power to the Accumulator Fans and Communicates Accumulator Temperatures from the Battery Monitor System (BMS) to the CEN as well as BMS OKHS. (This board also is HV)

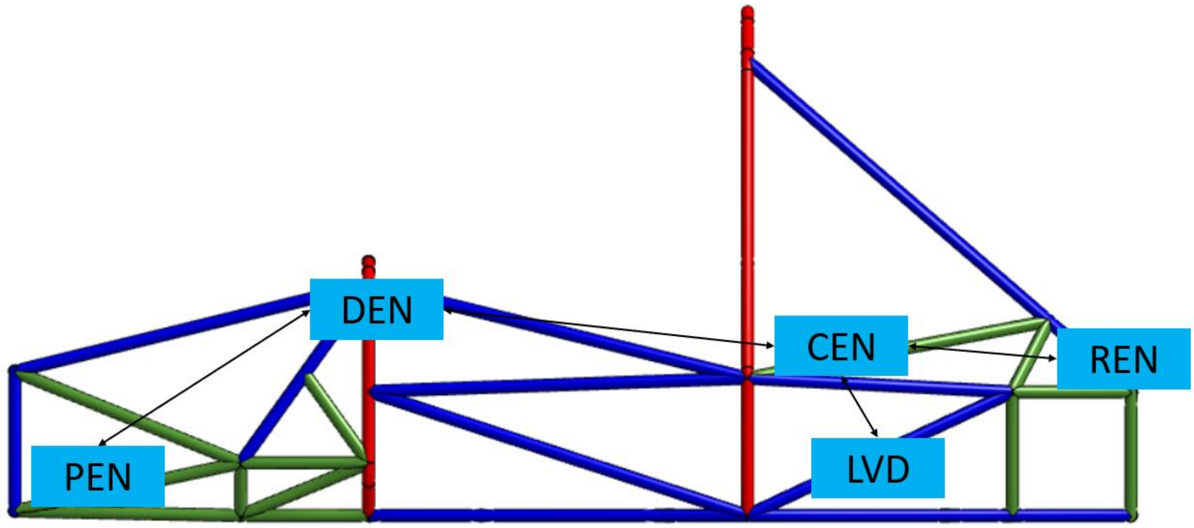

Figure 3 NU23 LV Topology and the position of the Nodes

This system was reliable, apart from the issue which stopped the car during the 2023 Endurance. The fault originated 2 weeks before competition, with no time to properly investigate and fix due to a fault with the old Bamocar inverters (details in Jye Hollier's and Jacob Bush's FYP reports), the car also successfully completed a full test day between the fault and the competition, making it unpredictable. Before the 2024 final year project (FYP) members started, Jacob Bush who was 2023's Chief Mechatronic Engineer was about to identify and recreate the issue on the LVD, which was shorting 5 V to ground whenever the accumulator management system (AMS) Active High Signal (OKHS) went bad. A fix was designed for the next iteration of the LVD.

The only ongoing unresolved issue was a BMS fault, which at the time had only occurred twice and at random instances, making it hard to replicate and investigate.

The shutdown circuit is the car's safety signal, everything along the circuit must be good for the car to enter and stay in HV, if something goes wrong, the car drops out of HV to ensure the safety of the team and the cars components.

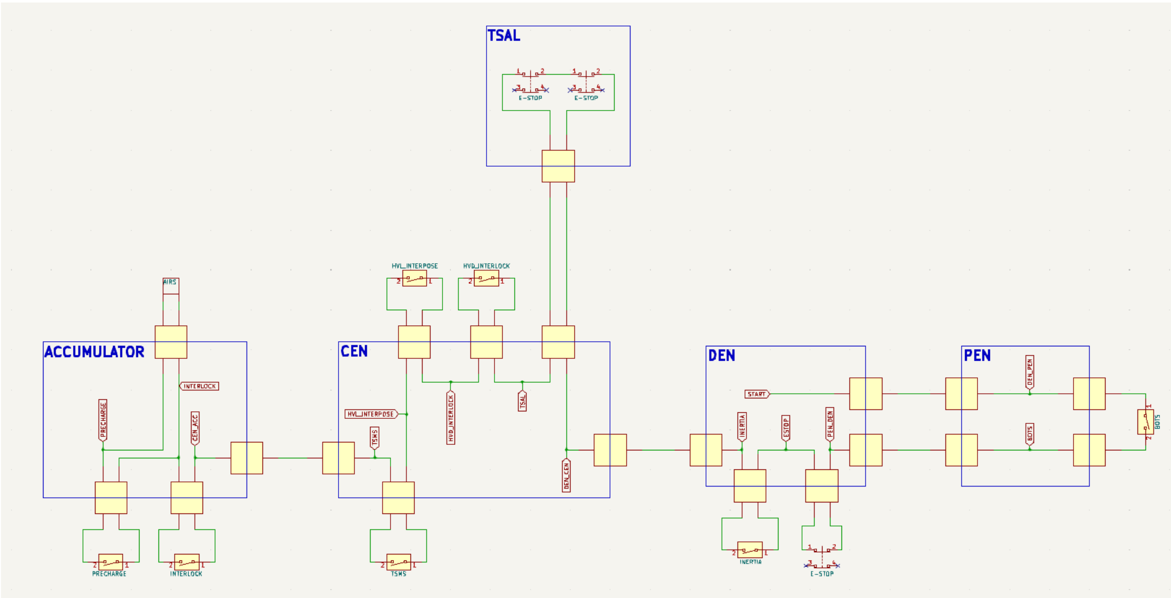

Figure 4 NU23 Shutdown Circuit

This shutdown circuit remained mostly unchanged from the 2022 car EV3. More detail of the car's shutdown circuit can be found in NU23 LV Systems in the Appendix, as well as information on the car's Hard Faults.

NU23 was not traction limited so did not feature any form of torque limits, and did not feature regenerative braking either.

At the end of 2023, two new EMRAX 228 MV AC motors were ordered for the 2024 team, in hope of having excess torque and power as the EMRAX 188 HV was the bottleneck in NU23's drivetrain.

Mechatronic Team Management and Design

The 2024 Mechatronic (MCHA) Team

The 2024 Team as a whole was smaller than 2023, with the mechatronic team being the worst off. The 2024 MCHA team consisted of three FYPs, two directed readings and one extracurricular, only one FYP and directed readings were MCHA by degree, with the other-directed reading and extracurricular as ELEC. This meant that an AERO and a MECH were needed to make up the numbers. These were selected based on their prior course knowledge and involvement within the team.

As the FYP's are required to be around the most, the most critical roles were selected for them, followed by the directed readings and the extracurricular.

- Powertrain Engineer – Josh Hayward (MCHA) (FYP)
  - Major components: Motor controller, Motor and BMS
  - Scope: Ensure Cascadia MC is currently configured, implement new EMRAX 228 AC motor, implement torque and power limiting and REGEN.
- Accumulator Electronics – Daniel Iveson (MECH) (FYP)
  - Major components: LVD, Precharge, CANaMONS, Cells
  - Scope: Implement updates to LVD, commission 2024 accumulator, fault find BMS comp issue, improve accumulator serviceability, Accumulator indicator light (AIL) and investigate a new Precharge board.
- LV Engineer – Jackson Boustany (AERO) (FYP)
  - Major components: Sensors, DEN, Looms
  - Scope: Implement steering angle sensors and shock pots using a CANBUS expansion board, redesign DEN to custom fit of NU24 Chassis, make/alter looms to fit NU24 including grounding and other compliance requirements
- CEN Engineer – Jacob Lukes (ELEC) (Directed SEM1)
  - Major components: CEN Motherboard and breakout boards (taking over from Jacob Bush)
  - Scope: Design new Motherboard and commission with new breakout boards and HIP
- HIP Engineer – Marisa McLean (MCHA) (Directed SEM1)
  - Major Components: HIP
  - Scope: Design new HIP PCB with intent to fit enclosure (Kieran Burgess designed the enclosure)
- PEN Engineer – Eliza O'Donnell (ELEC) (Extra)
  - Major Components: PEN PCB
  - Scope: Design new PEN PCB to fit the NU24 Pedal box (designed by the author)

The main goal of the 2024 MCHA team was to have the NU24 LV system running on NU23 before NU24 is a rolling chassis. This would speed track integration of NU24, only having the worry about the Powertrain with the new motor.

It was thought that the team would be able to complete their respective aspects of the Cost Report, Design Event and Technical Inspection as they complete their work, but due to the decreased team size, the individual workload increased, making it harder to finish everything with time to spare. This meant that these were completed close to the due date of these events and normally in a rush.

Due to the team size, it was critical that only necessary and easy projects were undertaken, as to not overextend the team this year. This also allows time and funding to be allocated for unknown problems that occur throughout the year.

The Budget

The budget for 2024 was larger than 2023 due to its success and NU Teams allowing more funding. It is the responsibility of the department leaders to create their proposed budgets and thus it is better to start with more than what is needed and to slowly reduce.

Float is critical and should be calculated into each project with projects classified into necessary, high value, medium value and low value to ensure that nothing vital is underfunded.

Once the desired changes for the year are selected, the cost of each should be estimated to the best possible accuracy before the float is added. To do this the author recommends going through last year's purchase orders, seeing the total spent as well as the spending across each category. For things which have not been done before research is necessary.

It is much harder to add to the budget after the fact than to overestimate and have money left over. This needs to be worked out as soon as possible with the other leaders under the guidance of the Team Leader, as they will be the one asking for the money.

MCHA				
Category	**Cost**	**Notes**	**Month to be purchased**	**Importance**
PCB's	$ 3,700.00	CEN - $1200, PEN - $500,DEN - $600, LVD - $600 and Dyno - $800	March	req
Spare parts	$ 4,200.00	Teensy's - $1000, DT's - $1000, Raychem - $1000, Boots - $800, Cabling - $500	April	req
HV	$ 400.00	Surelocks - $400,	April	req
Steering Wheel	$ 300.00	Buttons, plugs etc - $300	May	perf
Sensors	$ 900.00	Steering angle - $100, Shock potentiometers - $500, Brake temp - $300	April	perf/re
Accumulator Cells	$ 5,000.00	Possibly need new cells - $5000	July	real
E-stops	$ 300.00	Waterproof E-stops - $300	April	no
Total	$ **14,800.00**			

Figure 5 2024 NU Racing MCHA Start of Year Budget (does not include Driverless)

It is recommended that the budget is checked through the year, with higher frequency nearing the end, ensuring all costs are added, with remaining costs still to come.

Start of Year Assessment

As something that was not performed at the start of 2024, that potentially cost the team greater success at the 2024 competition, was a 'stock count'. It is important that during the hand over from leadership from one year to the next, all assets are known as well as where they are stored.

Ideally the new team should go through all NU Racing property and reorganise it. It's very normal that things are misplaced in the heat of competition, so it is likely that things go missing.

It is highly recommended that spare parts of critical components are kept in a realistic amount within NU Racing. All PCBs should have spares, especially PCBs which won't or might not change throughout the year. Ideally vital components like motors, motor controllers, cells, the BMS, the MoTeC display and DCDC have spares, as these components normally have long lead times and in both 2023 and 2024, having a spare of these components ready would have increased testing time as well as competition performance.

NU24 Changes

The biggest change to NU24 from NU23, MCHA wise, is the upgrade of the motor. The new EMRAX 228 MV produces more than double the power and torque of the old EMRAX 188 HV. This new motor is significantly larger but due to that fact, it less strained for our usage, compared to the 188.

Table 1 Comparison Between EMRAX 188 HV [1] and 228 MV [2]

MOTOR	EMRAX 188 HV	EMRAX 228 MV
POWER OUTPUT (KW)	60	124
TORQUE OUTPUT (NM)	100	230
WEIGHT (KG)	7.9	13.5
MAXIMUM CURRENT (A)	190	360

Although, it is the author's opinion that an Emrax 208 should have been selected, the 228 provides a massive upgrade for NU Racing. For the first time, NU Racing has a motor capable of producing more power than the FSAE EV competition rules (80 kW), and will have the potential to be traction limited, rather than torque limited. This is the only Tractive System (HV) upgrade for NU24.

This upgrade was selected by the 2023 team and the 2024 leadership agreed. The remainder of the MCHA changes were selected by the author as the most experienced active MCHA team member.

It is vital that any changes are carefully thought out and selected with various reason to why the change is necessary and/or worth it. It is recommended that a Decision Matrix is made in 2025 that should be used for all large and medium changes on the car, both MECH and MCHA. It is also important to consult with any previous NU Racing experts on the changes, as well as the academic advisor and Malcolm Sidney, more perspectives are always useful and will ensure the correct decision is made.

When making a change, all the below needs to be considered to ensure compliance and performance in static and dynamic events, as well as safety:

1. The current FSAE-A Rules and Addendum
2. Technical Inspection (use the most recent version, normally released early November so the previous years is what should be used)
3. Design Event – Every design must include process, analysis, validation, understanding and resources for the event.

All of the above points need to be cross referenced with each other when selecting a change.

Due to the LV system being robust and reliable, the idea for NU24 was to only make incremental improvements for these boards, only change shape to fit the new chassis and to add simple, easy to test functionality. The exception to this was the CEN and REN.

Due to the complexity and size of the CEN, it was extremely difficult to alter and work on during testing. This resulted in the decision to separate the complex circuitry onto separate breakout boards (developed by Jacob Bush), a central mother board (developed by Jacob Lukes) and an interface/High Voltage board, the HIP (developed by Marisa Mclean).

The functionality of the BSPD and HFL was moved onto the individual breakout boards which connect to the motherboard and the HV functionality, TSAL and Discharge was combined into a single breakout board and connected to the HIP. As these separated circuits were analogue, only one teensy was required.

Another change from 2023 would be combining the functionality of the REN into the CEN motherboard as the REN with its board mounted brake light was deemed over complicated. This moved the sounder, cooling control and brake light switching onto the motherboard. The radiator coolant temperature sensors were also removed

NU24's LV topology now includes:

- The Pedal Electronic Node (PEN): Reads the Brake Pressure Sensors, Accelerator Pedal Position Sensors (APPS), and Brake Over Travel Switch (BOTS)
- The Dash Electronic Node (DEN): Reads the Dash E-Stop and Ready-To-Drive (RTD) button, MoTeC connection, MoTeC button and relays PEN signals.
- The Central Electronic Node (CEN): Hard Fault Latch (HFL) breakout board, Top E-Stops, Brake System Plausibility Device (BSPD) breakout board, OK High Signals (OKHS), Cooling and brake light switching, sounder and LV Power distribution.
- The Human Interface Panel (HIP): Switches on LV Power, Tractive System Master Switch (TSMS), HV Disconnect (HVD) Interlocks, Test Points and Tractive System Active Light (TSAL) and Discharge Relay Breakout board. (This board also is HV)
- Low Voltage Distribution (LVD): Relays Power to the Accumulator Fans and Communicates Accumulator Temperatures from the Battery Monitor System (BMS) to the CEN as well as BMS OKHS. (This board also is HV)

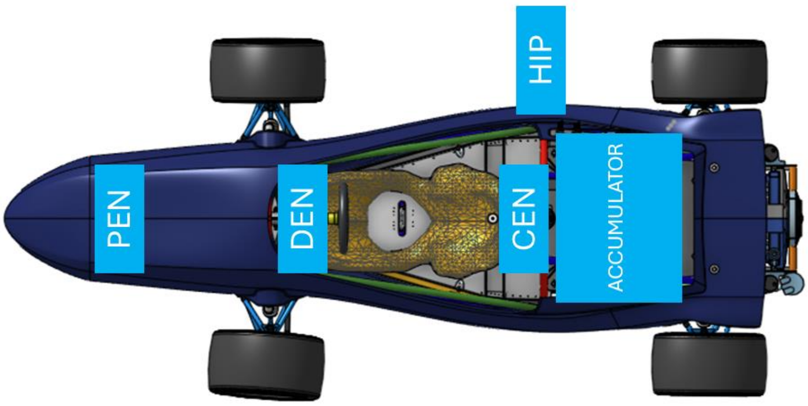

Figure 6 NU24 LV Topology

At the 2023 accumulator technical inspection, the team had trouble proving compliance with the 2 pin HV Autosport connector used on the main tractive path. To ensure this would not occur again, the team decided to change connectors. With this the team interpreted rules change incorrectly, choosing new HV connectors without an inbuilt interlock, thus removing the HV connector interlock from the shutdown circuit.

It was also believed that the interpose relay in the HFL was also not compliant and redundant, thus it was also removed from the initial design of NU24. The Shutdown start was also moved to the PEN, as in NU23, it was travelling directly from the DEN to the PEN already. This resulted in a simplified and rearranged shutdown circuit.

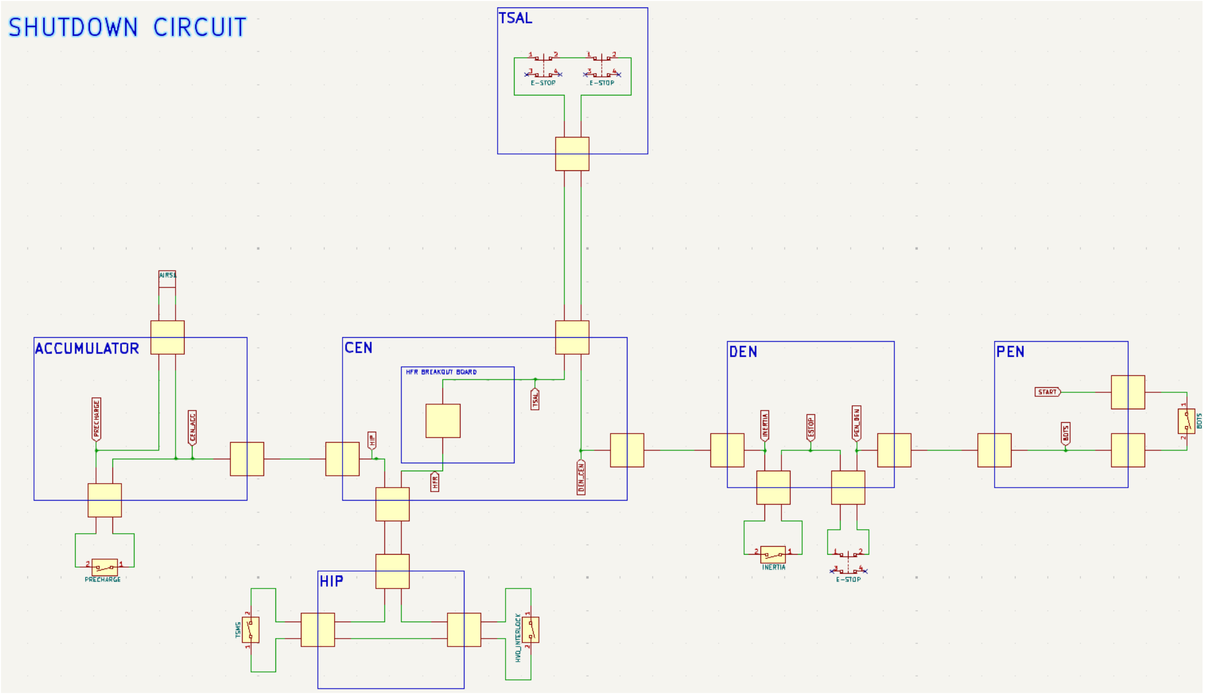

Figure 7 NU24 Shutdown Circuit (found on GitHub)

NU24 Design, and Testing:

To ensure that the team met the required criteria for each of their systems, their projects were scoped out, documenting the required steps, checkpoints and deliverables. Due to the size of the team and the ever-changing requirements from NU Teams, the goals and deadlines of the projects were regularly changed to setbacks and were recorded by the author in a shared document with the other leaders.

Each team member was encouraged to ask for as much help as possible including from their teammates, as were regularly checked up on by the author, ensuring that everyone was on track and had everything they needed.

As majority of the design work consisted of PCBs which have lead times and are manufactured in China, a system of ensuring design quality was created. Thus, the Detailed Design Review (DDR) was created by Robert Stanley in 2023. This was extremely detailed and long and due to that, was only used by a few team members.

Before the new 2024 team start the author and Marisa McLean, who had used the DDR in 2023, updated the DDR. This version was streamlined and much simpler, allowing for team members to run through the document themselves before getting it checked with a senior MCHA. This system still ensured that nothing was missed and caught problems before commissioning.

The DDR has multiple sections, as well as places for notes about issues with prior versions and improvements for new boards, as well as commissioning steps, unit testing. The major parts during design are the schematic and layout, which correlate to the KiCAD design stages, which help reduce time fixing errors as the team member needs to pass everything on the schematic before doing the layout. The updated DDR is found in Detailed Design Review (DDR) in the Appendix.

Once the new PCBs were ordered, team members would then think about commissioning the new boards, and as the car uses NUCAN, team members would need to learn how to use it. Thus, the author created a NUCAN Zero-To-Hero. While not on the Wiki or not made to the same standards of existing Zero-To-Heros (ZTH), it was decided by the author that the short form explanation would be sufficient as there is not too much information to convey.

This document outlines what all the functions within NUCAN do as well as using the GitHub Repository, automated DBC editor software. It also builds from the CANBUS ZTH which is a pre-requisite. The NUCAN Zero-To-Hero can be found in the Appendix.

This helped both NU Racing and NU Marine member who also use CAN BUS and NUCAN.

The in-depth design and testing of the individual board can be found in the reports of the responsible team member.

NU24 LV System Integration and Test on NU23

Due to the hard work of the MCHA team, the NU24 LV System was ready to test on NU23 before the end of May.

Figure 8 The MCHA team working on Looms in the new MCHA Lab

The team experienced the first late night of the year while integrating the system on NU23, running into a problem with the shutdown circuit. Due to the removal of the interpose relay on the HFL, the voltage drop across the car was too great, and the shutdown circuit could not close the AIRs, allowing the car to go into HV. Once diagnosed, the problem was patch fixed by using an automotive relay, spliced into the shutdown circuit to boost the voltage, allowing the AIRs to close and the car to go into HV, the car operated correctly and spun the wheels on the stands, ready to drive the next morning at a car park test day.

Figure 9 The Team Diagnosing the Voltage Drop

Once out, the team ran into issues with the BSPD's current sensor. The new design of the HIP meant that there was noise subjected to the sensor signal, triggering the BSPD and shutting down the car. Details of the issue can be found in Jacob Lukes ENGG3200 Report. There were also issues with the HFL board and APPS PLAUS, the HFL required more testing and simulation, resulting in another version that worked, and APPS PLAUS was triggering due to Zener Diodes. These Zener Diodes were used as overvoltage protection for the Teensy, but due to their design, create non-linearity within the signals, removing them from the PEN fixed the issue.

Overall, the test was very successful, achieving the goal of a test with NU23, allowing issues to be found as soon as possible.

While not yet on NU24, being able to test the system as early as possible put the team in the best position, especially going into the last half of the year which is much busier for the MCHA team. The team really pulled together during this period and the team morale really picked up, as the MECH team was receiving their first parts, and the chassis was almost finished welding.

It is recommended to repeat this in future years, allowing for more driving of the new competition car and less problems in the busier half of the year.

Figure 10 Tim Kerr getting ready to drive NU23 with the new LV System

Although the BSPD issue could not be fixed in the short term, the team prepared for the last Sydney Motorsport Park (SMSP) Test Day for NU23. The APPS PLAUS was fixed, and the issue had not been identified with the HFL.

The test day found an issue with the HIP and the Master Switches, halting a lot of driving. The master switches must be very carefully tightened to the pads of the HIP and tested with a Multimeter using continuity, too tight and the switch would fail. This was replaced by the team, and we continued testing.

This track day was very successful, highlighting the work the team needed to do during the downtime between the decommissioning of NU23 and the first drive of NU24.

Figure 11 SMSP Test Day, NU23 Final Drive

Cascadia CM200DZ Propulsion Inverter Failure

Background and Inverter Failure

At the end of 2023, the team purchased a Cascadia CM200DZ inverter to replace the failed Bamocar units that were used that year. The new unit was only received a week before competition and integrated into NU23 in less than a day.

The preparation for this unit was short and the goal was to get it working rather than a deep understanding, thus Josh Hayward spent the first 2 months of 2024 reading and documenting all the information regarding this new inverter, as well as planning to set it up again slowly, following the instructions he had now researched. When paired with the EMRAX 188 and Cascadia's designated settings for the unit, the inverter functioned correctly and without fault. For the documentation and anything related to the inverter, find Josh Hayward's FYP Report.

Figure 12 Cascadia CM200 Inverter

When adapting the inverter for NU24 and the EMRAX 228, the same process was completed using Cascadia's setting for the motor. This was successful and NU24 was driving for the first time without issues from the motor controller, running at a reduced torque setting due to doubt of the integrity of the power box, information on the power box can be found in Lachlan Fisher's and Rishi Mathuria's FYP Reports.

Before NU24's second drive, NU24 was spun on the stands to ensure everything was working. During this an overcurrent fault on Phase A occurred. This issue was similar to the issues experienced with the old Bamocar, although, the condition of the fault's occurrence is not similar. After some initial troubleshooting and restarting the commissioning process for the inverter and motor, it was quickly realised that the inverter was broken beyond NU Racing's understanding to fix.

Fault Finding and the Purchase of a New Inverter

Josh Hayward began receiving support online through Stealth EV, the supplier of the inverter, and attempted to receive support from Cascadia themselves. Both of these methods were unsuccessful as Stealth EV had been purchased by Hypercraft USA and had a very poor support team taking weeks to reply with very little useful information, and Cascadia would not offer support for a unit purchased through another supplier.

While this was being investigated, the author contacted Cascadia directly for a brand-new inverter directly from the manufacturer. Purchasing through another third party was considered, but after the lack of support received from Stealth EV, it was clear that the new unit had to be purchased from Cascadia to unlock their support to ensure a replacement inverter does not have the same fate. Luckily NU Racing had a large amount of float remaining in the budget as well as saving money from completed projects or additional items which would only be purchased at the end of the year and so could afford to purchase the new inverter from Cascadia with the help of Dr Dylan Cuskelly, Mr Malcolm Sidney and Mr Tom Rabbit. The purchase also included new Phase Cables which were too short on NU24. The total cost of the new unit and cables was $13391.53.

During the conversations with Cascadia, they also recommended the DX unit rather than another DZ unit as its operation voltage range matches NU24's better and will create a smoother drive. The units have the same weight, geometry and connectors and so would require no modification to NU24.

Table 2 CM200 Unit Comparison [3]

INVERTER	CM200DX	CM200DZ
OPERATING VOLTAGE (V)	50-480	20-840
MOTOR CURRENT PEAK (A)	740	400
POWER OUTPUT PEAK (KW)	225	225
MOTOR CONTINUOUS CURRENT (A)	300	200

Once the purchase was made from Cascadia, they offered support on the set up of the new inverter, as well as some support on why the old inverter failed. After analysis of our log files, Cascadia found an issue with the motor stalling at low RPM due to the variable PWM frequency setting on the inverter, resulting in the loss of current regulation. It turns out Cascadia did not tune inverter settings for the EMRAX 228 MV very well, as such the variable PWM frequency setting was switched off.

Whilst the purchase of the new inverter was still being organised, Josh Hayward continued to get support from Hypercraft, eventually getting to a stage where they required diagnostic of the inverter. At this stage the author took over communication with Hypercraft so Josh Hayward's focus could turn to the new inverter. The old, damaged inverter was sent to Hypercraft's office in USA for diagnosis in November and has been followed up with several times, but no information has been relayed back to the team. The team should continue contacting Hypercraft for the diagnosis and repair of the unit, or if possible, a full refund.

Figure 13 Josh Hayward receiving the new CM200DX

CM200DX Integration and Noise Troubleshooting

Once the new inverter arrived at the university, it was slowly and carefully commissioned.

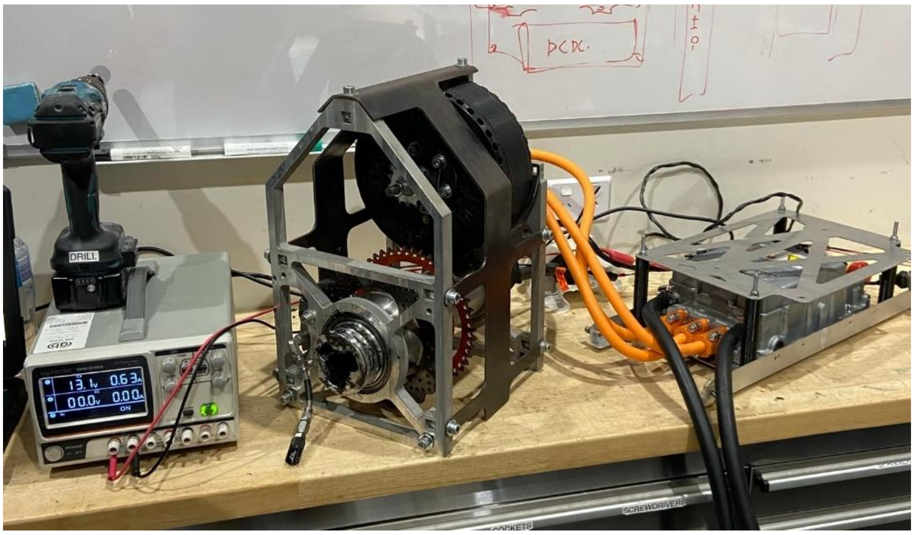

Figure 14 Resolver Tuning with CM200DX

It was set up and the resolver for the motor was tuned on the bench with the bare minimum connected to the components for simplicity. Once this was completed it was them installed back into the car.

All other components were connected and tested to ensure an optimum test. Once the car was fully operational excluding the inverter, the inverter was enabled. When the inverter was enabled, a large amount of noise was induced onto the cars CAN BUS network. Once all other systems were investigated, it was found that the inverter was indeed the source of the noise.

To properly identify what needed shielding, the MCHA system of the car was taken off the car and set up on the bench next to the car. Cascadia support was also contacted with no information as to why we were experiencing the new noise.

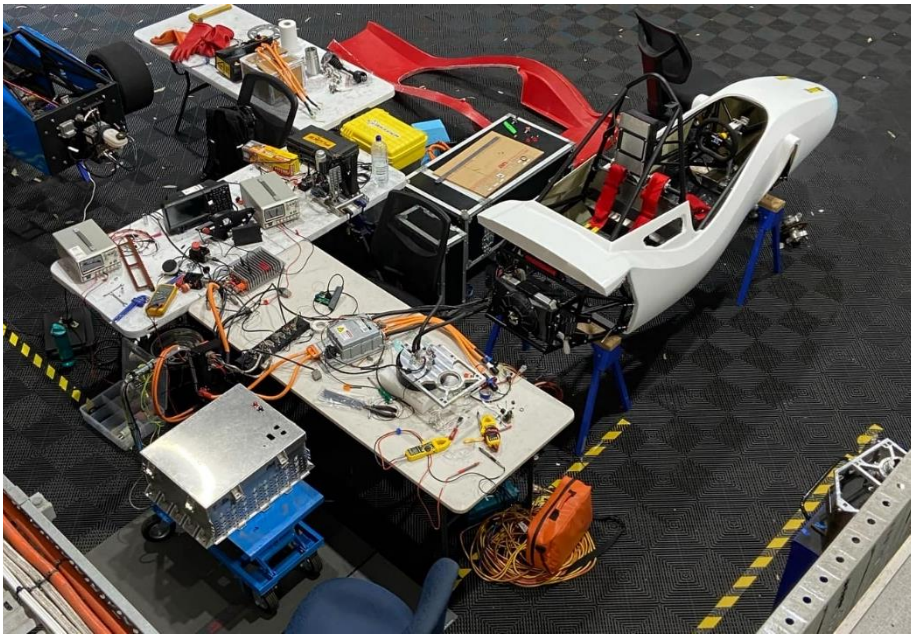

Figure 15 NU24 Bench Testing

Some other MCHA issues arose during the setup which had to be resolved before noise testing commenced. Each component was slowly added into the system to ensure the noise could be identified, resulting in the noise being generated in the MC-CEN loom.

The inverter had a dedicated isolated CAN GND pin which was used as the shielding ground for the CAN wires and the original wires were swapped to twisted shielded pair wire. Once installed the noise was greatly reduced, allowing for the car to stay in an enabled state, this was when another problem occurred with the inverter. During the troubleshooting of the inverter, firmware was reinstalled onto the inverter, but the wrong package was chosen, a package with did not support our motor. The team was not able to identify this issue without the help of a Cascadia support engineer on a zoom call early in the morning, who quickly realised we were in the wrong group of firmware. Once this was rectified and the motor resolver was retuned, the motor was able to spin on the bench without fault and with no noise on the CAN.

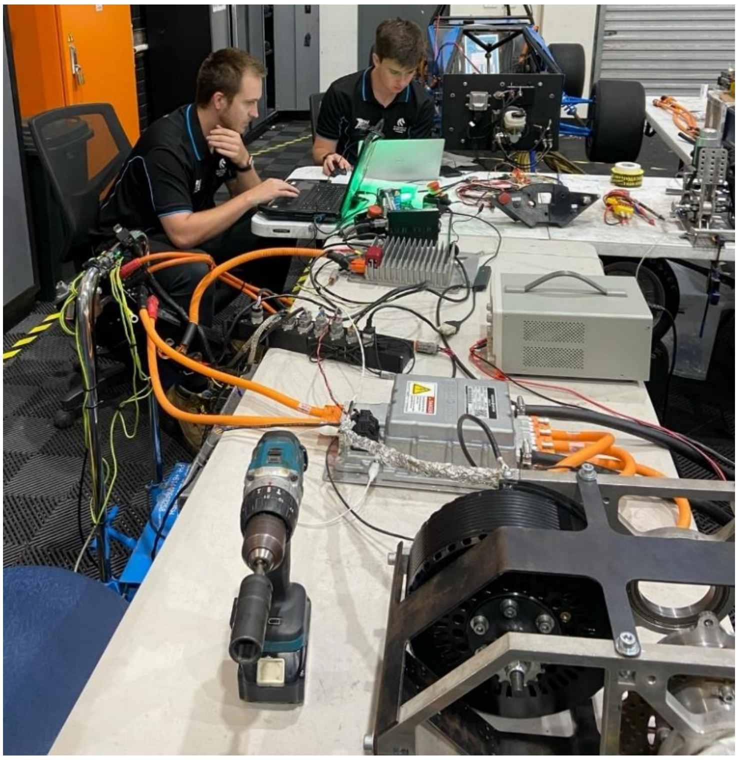

Figure 16 Early Morning Zoom call with Cascadia, Josh Hayward and Jacob Lukes

It is still unknown why the new inverter produced a large amount of noise, but it is recommended to shield all the CAN looms on the back half of the car in future years to prevent this issue from occurring.

The failure of the CM200DZ almost cost NU Racing the 2024 competition, taking two and a half months to fix and costing the team all its spare funds. This limited NU24 to only 5 weeks of testing before competition, halting the finding of issues until it was almost too late to fix them. It is highly recommended to either fix the damage inverter or to source a spare inverter for years to come, as they have a very long lead time and are still new manufactured components with limited testing even at the commercial level as we were not the only FSAEA team who suffered from inverter issues in 2024. It should also be noted that Cascadia is very helpful with their support but are situated in USA and thus are operational in Australia in the early morning, communication can be slow. For more information about the technical aspects of this fault and recommendations, read Josh Hayward's FYP report. Josh Hayward was the lead for this problem and stepped up to the challenge, doing an excellent job.

Electrical System Form (ESF)

The ESF is a document needed for submission to FSAE using the Team Leaders submission page that is usually due in late August. It is a systems information form for SAE that outlines all the critical electrical systems on the car, this includes the tractive system, throttle, BSPD, shutdown circuit, the accumulator, Precharge and discharge.

This form needs to be filled out accurately, with no information missing, that is why it is the responsibility of the Mechatronic Department lead. Lucky SAE rarely change this document, so the previous year's document is normally very helpful and will have majority of the information needed, with the rest requiring updates due to new designs.

Whilst completing this document, it is important to triple check everything submitted, as in 2024 the author found an issue with the compliance of the accumulator lining, this allowed time for the mechanical team to source a compliant material and change over the linings. Whilst reading the 2023 ESF the author also found an issue with the main fuse of the accumulator, something that the team needed to fix during the technical inspections at the 2023 competition.

From year to year all information should be checked and updated if now redundant or incorrect, this includes datasheets, values, item numbers, schematics and images. It is also likely that the current competition year's form will not be released until close to the due date, so it is recommended to start in July once the car is running. There is no harm in starting early if time presents.

Although it is a critical document to submit, NU Racing has had little issues with the form.

It is recommended to submit this form at least a week early and with the Electrical System Advisor / Electrical System Officer Form (ESA/ESO Form) which is a single page form that only requires the information of some of the team members. Some of the team will require low voltage rescue training for this. A copy of the 2024 ESF is attached in the Appendix and can be found on Teams. The blank forms to fill out can be found on SAE's website.

Cost

Cost is worth 100 points in the FSAE-A competition and is comprised of a cost report of the entire car (prior to competition), a cost scenario which normally focuses on an aspect of the report (at competition), and a cost event where a component on the car gets costed on the spot (at competition).

The cost report is the largest submission NU Racing makes in a competition year, detailing how every component on the car is made and assembled together, using cost values, components and multipliers defined by SAE. This an excel document that has specific rules and processes defined by SAE as well as the Cost leader within the team. This document is very MECH heavy, going into explicit details of mechanical systems but mechatronic systems are present including wiring diagrams.

It is recommended that a MECH on the team take the lead of this report, getting accustomed to the procedures and is able to teach others in the team. A MCHA lead should also be chosen as how things are done is complicated and someone is needed to check over everything before submission. It is recommended that the department leaders are not the Cost leaders, although involvement in the report is required.

This section will detail the MCHA systems in the cost report, general information about the cost report and the MECH system can be found in Lachlan Fisher's report. Involvement in the cost scenario and event will also be documented.

The Cost Report

The cost report should be started as early as possible, ideally the excel document should be set up so that then when a team member finishes a project, it can be completed before moving onto the next project. This method will reduce the main load of the cost report during submission time which traditional for NU Racing, has been a massive crunch period. The report submission date is normally early October for the report and must be submitted by the Team Leader on the submission portal.

In 2024, the detail of the electronic components in the cost report increased, adding accuracy to PCB assembly and increasing the MCHA load in the report with its complexity.

The MCHA load in the cost report includes:

- The Electrical System category (PCBs, looms, enclosures, brake light, DCDC and all other components which are LV)
- The MCHA components in the Accumulator in the Tractive Path and Drivetrain section (PCBs, looms, BMS, cells, etc.)
- Motor and Motor Controller in Tractive Path and Drivetrain.
- Autonomous System (for when the NU Racing competition vehicle is AV)

Before starting work on the cost report, the MCHA cost lead must complete the Bill of Materials (BOM) with the MECH lead, this will list every component which needs to be costed, allowing for others to start helping out if they are familiar with costing components. It is ideal if senior members like the MCHA department lead checks over this BOM.

Ideally by now, the procedures of creating part and assembly sheets are created allowing for the team to get familiar with the process. All team members should be assigned to their respective system in the report and can start working. The most complex part of the report is the large number of materials, processing, tooling and fasteners to select from. It is highly likely that majority of the sheets will have to be redone or adjusted due to incorrect materials or processes being selected or steps being missed.

In 2023 the electrical systems were not required to be very accurate and so could not be used as a guide for 2024, hopefully there will be no major changes in 2025 so the 2024 can be used as a useful guide. The 2024 document is found on teams and the sheets completed and checked by the author are found in the Cost Report in the Appendix.

PCB

The process in the cost report is similar to real life, and such existing experience of PCB manufacture is recommended for members doing these components. The materials should include all components on the PCBs, including simple components like resistors, capacitors and fuses, ICs, connectors, microcontrollers, the PCB itself and conformal coating.

It is recommended to look at all the PCBs in the 2024 document when starting 2025 to understand what components fit in what material category and how to fill out the unit information for the material. The materials each have a description of what fits in where and these should be read to ensure that everything is done correctly and accurately. An accurate description of each item should be included for each material, so it is as clear as possible for SAE.

The processes need to be taken extremely literally, this includes flipping the board over to access the other side, solder paste for SMD parts and individually soldering through hole parts. As NU Racing uses DT connectors which are fastened onto the board too, a washer has to be manually placed on a screw before being hand started and then screwed by screwdriver into place. Even programming the Teensy 4.0 and applying the conformal coating needs to be individual lines in the process section.

Fasteners are the same throughout the report so consult a MECH for assistance, but tooling for PCBs is specific. A PCB stencil and PCB component position jig must be added with a Present Value Factor (PVF) of 3000 or whatever is deemed the PVF size for the competition year.

Looms

Looms are fairly repetitive and simple in the cost report but how repetitions and quantities are done can be confusing. It is important that consistency is present in the report and all looms should be completed the same.

Wires are split up into what they are used for, so HV wire is different to LV wire, and the amount of wire should go the length of the loom, this is what goes in the unit section, and then how many of each type of wire is in the loom as the quantity.

Each boot, heat shrink, and conduit also need to be added in the materials list and be entered the same as wires. The connectors also need to be chosen correctly, with different connectors fitting in different categories, again study the 2024 report as well as the materials list. Eye crimps and the like count as connectors, and individual pins for like DT connectors are included within the connector rather than a separate material

The processes include, cutting and stripping the wire, sliding on heat shrink or conduit, assembling boots, crimping the pins of the connector before inserting into the connector and shrinking the heat shrink. Again, this process matches real life and such someone familiar with the looms should complete these parts.

There is no tooling required for looms.

Assemblies

Assemblies are similar to the MECH systems and are extremely repetitive. Assemblies are just processes and fasteners and every step is extremely literal. Each washer much be assembled onto each bolt, each nut needs to be hand started and reaction tools are needed. The quantity and multipliers need to be carefully thought about, and it is recommended to use the quantity as the amount needed for the individual part, and the multiplier for the amount of that individual part. A description of each step is needed too.

This is normally simple but for components like the HIP, the assembly is extremely complex, as such it is useful for the designer to produce these in the report. If not, it should be pulled apart by a knowledgeable team member and put back together while filling out the sheet.

All Other Components

Most of the other components like main fuses, switches, sensors, and off the shelf components all have a specific material and as such do not need to be custom made. If a component does not fit any material on the list, SAE can be contacted, and it can be requested to added to the material list, otherwise it will have to be custom made.

Enclosures are made using the weight of filament used and then the Rapid Prototype- Plastic process to be made. Threaded inserts are also just fasteners which are interference fit.

Common sense and an understanding of the current rules surrounding the cost report are needed to ensure the best result.

The Cost Scenario:

The Scenario is supplied by SAE a month before competition but traditionally has been completed by NU Racing whilst at accommodation in Melbourne which is not the best practise but has been successful. Usually, multiple scenarios are given by SAE to choose, and the team must present their solution to their choice scenario at competition during Cost.

The chosen scenario in 2024 was to take the team's cost report and reduce the cost of the vehicle by 5% without reducing performance by more than 1%. Lachlan Fisher and the Author were the team members involved, with Lachlan taking the lead. The amount the team needed to save was $2214.81.

First the serviceability items were removed by Lachlan, these were the dry disconnects in the brake lines and the quick release latches on the body kit and replaced these with hardlines and bolts. Attention then turned to the Motor controller and motor, as they are costed by continuous power, and both are capable of producing more power than the competition allows. It was found by the author that the EMRAX 208 motor was capable of producing the same amount of power and torque with modified gearing as the EMRAX 228 and the current gearing. Both members then costed the smaller 208 and appropriate gearing saving $1899.60. Combined with the $273 saving from the dry disconnects and the $584.72 from the quick latches, the team managed to save $2757.32, $542.52 more than what was required, with no performance loss.

The performance was verified by Josh Hayward's acceleration simulation which models the motor's output with a simplified model of NU24. It was actually found that the 208 was fractionally faster due to the weight savings, increasing performance by 1% rather than decreasing it.

The team was very happy with the performance of the Cost Scenario, leaving the judges with no questions. The slides of The Cost Scenario Presentation are attached in Appendix.

The Cost Event

This event requires the team to quickly cost a component on the team in front of the judges. It is highly likely that the component will be a mechanical component, (it has been the steering system for the last two years) but there is a chance a mechatronic component is chosen, thus both the MECH and MCHA cost report leads should be at this event.

Figure 17 Lachlan Fisher and the Author during Cost at FSAE-A 2024

NU24 Testing

The 2024 NU Racing team had the first drive of NU24 on the 13th of July, which was the earliest that a competition car has been ready for testing, which is a massive credit to the prior teams and the current teams hard work and dedication. This set the second half of the year up the best it possibly could, and the team needed as much time as possible with the motor controller issue descripted in the Cascadia CM200DZ Propulsion Inverter Failure section, stopping all driving after the first shakedown of NU24.

Once this issue was resolved and some very long nights, the car made it to the track for the first time in two and a half months on the 28th of October at SMSP.

Figure 18 NU24 at First SMSP Track Day

This first track day highlighted a lot of issues with the car, both MECH and MCHA.

- The motor could not be run near its maximum torque limit due to the motor plate bending and the motor hitting the chain guard. The torque limit was run between 140 Nm and 160 Nm rather than having the full range of 230 Nm. A new Powerbox had to be designed.
- The 2023 endurance AMS fault finally was repeated, having a poor cell performance on Cell 7 and 8. These cells were replaced with new cells which the team had spare.
- The LVD’s fan power Mosfet desoldered itself from the board. This is due to the heat generated at the high current and such needed to be replaced by a higher capacity automotive relay. This issue was an easy issue to diagnose and fix, and its failure highlighted the improved cooling of the aluminium accumulator container compared to the painted steel container. More details can be found in Daniel Iverson’s FYP report.
- The HFL board had a few problems with signal Mosfets and the soft starter. To fix this issue a new version of the board was made, and the circuitry was simplified, as well as a resistor on the soft starter was changed. This board had several issues during the cars down time too.
- The DEN and MC looms were incorrectly plugged in, damaging the BSPD functionality on the BSPD board and PEN. This was quickly diagnosed and fixed back at TA, the track day continued by bypassing the BPSD. To avoid this happening in the future, keyed connectors should be used.

- The TSAL enclosure failed at the very end, and such was fixed with super glue back in TA.
- More problems with the master switches arose, this time the GLVMS failed momentarily but did not need to be replaced as it started functioning again. It is recommended to investigate different master switches in the future.
- The MC required a power cycle after every drive due to an issue with the enable, this was fixed by Josh Hayward, and information can be found in his report.
- Due to the capacity of the motor, at the maximum torque limits, the motor could draw more current than what was chemically allowed by the cells. To fix this charge and discharge current limits (CCL and DCL) needed to be configured in the BMS and read by the MC. This is also completed by Josh Hayward and can be found in his report.

While all these issues were found. The track day was a big relief for the team. To see NU24 running again faster than it ever had was a massive reward for the team after all the late nights and hard work.

Figure 19 SMSP Track Day Crew

The team had a week to work on these issues before NU Racing's first day and night track day at SMSP. The accumulator lining was also swapped to FR4 during the week.

During the day the team was on the skid circuit and encountered another AMS fault in the morning. This was a different issue than what occurred on the first track day, with cells 48 displaying a high resistance. After inspecting the BMS logs, it was found that cells 48, 97, and 107 were all damaged and had high resistance, likely due to running without current limits on the first track day. Due to the large day planned, members of the team headed to SMSP later for the night shift, these members were able to bring spare cells so the team could open the accumulator and replace the damaged cells in the truck. Once this was done, the team charged the accumulator and moved to the skid pad.

Figure 20 Testing on SMSP Skid Circuit

Whilst on the Skidpad it was found that the BSPD wasn't functioning correctly from the damage it received last track day, but this did not require major attention at the track. The car did not have any more AMS faults during the day or night, and we managed to do two full charges before heading home. The only new issue was the LV power on the HIP PCB.

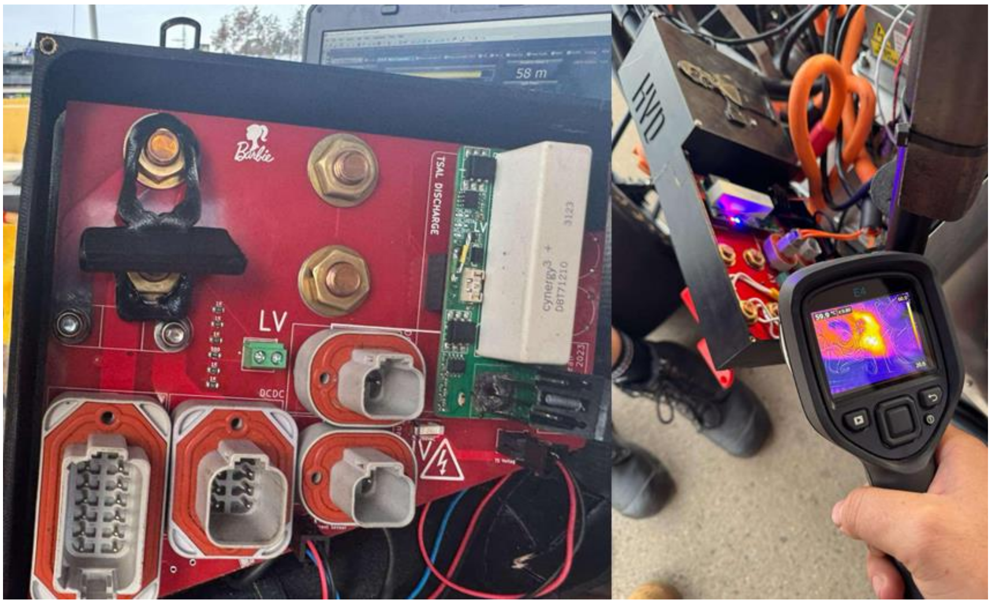

Figure 21 High Current Trace Damage on HIP PCB

One of the bolts used to mount the main fuse was galvanized, and created resistance in the circuit, heating up and damaging the power traces. The traces were undersized as well, creating a large amount of heat, melting the positive locking mechanism used to retain the master switch nuts. To patch-fix this issue and keep driving wires were added to support the trace in each section and the bolts were replaced with zinc coated bolts. A new HIP PCB was needed to permanently fix this issue, with enlarged copper traces and pad size for the main fuse and switches, the new PCB was also ordered with 2oz copper, rather than the default 1oz.

Figure 22 NU24 Driving Under the Lights

Once this HIP was patch fixed, the team got back out and continued testing, finishing the night with no future issues. This track day was the longest track day that the team has ever done but was still very successful, collecting a large amount of data. It was also found that the right side of the car near the HIP was very noisy, it is recommended that this is investigated and fixed in the future.

From this point, NU Racing had two track days a week in Sydney as competition was less than a month away. The new HIP PCB was ordered, the BSPD/PEN was still having some issues, and we couldn't run the car at its torque limit due to the weak Powerbox, all issues which had clear fixes.

Figure 23 Heading out to Test Spring Rates

The next track day was even more successful, regenerative braking was enabled and used during an endurance run, data and more testing on regen can be found in Josh Hayward's report. The only issue encountered was the BSPD which related to issues APPS TRAIL as well, making the car challenging to drive to unexperienced FSAE drivers. This was happening due to noise on the pressure sensors, making the BSPD flicker, stopping current draw when accelerating, due to the PEN becoming damaged when the CEN was plugged in incorrectly. To fix this issue, Jacob Lukes soldered a capacitor onto the input circuit of each pressure signal, smoothing the noise and fixing all the issues surrounding the BSPD. The brake sensor looms were also remade as they were quite damaged.

Figure 24 Skidpad Training at SMSP

Due to the short amount of time left until competition, the team did not want to change anything that did not need to be changed, only damaged or faulty components were to be altered. Thus, majority of the time, the car was run with minimal changes to systems and the focus was so train drivers for their events.

On an SMSP track day on the 14th of November, the AMS fault on cells 7 and 8 returned, which was alarming as these cells had already been replaced, the accumulator was opened, and the voltage taps on those cells were inspected, as well as the CANaMON. There was nothing visually wrong other than the trace on the PCB for those cells were black but had low resistance and work 99% of the time. The accumulator was put back together, and the fault was cleared from the BMS. The car worked for the rest of the day with no issues.

The next track day on the 18th of November was the first track day with no MCHA issues, in fact functionality was added to the PEN code, implementing a power limit now that the motor has the capacity to go over 80 kW. The AMS issue did not occur.

A wheel bearing failure meant that the car did not drive for a week but it was aptly timed as our chassis was deemed non-compliant in the SES. The fix was welding in 4 new members so the downtime of the car was used for that. The car was stripped so it could be welded so the opportuinity was taken to correctly size, heat shrink and boot every loom on the car.

Once reassembled and with a compliant chassis and new power box, the car was ran again in SMSP on the 21st. The AMS fault occurred again, and such new CANaMON PCBs had to be ordered with the hope that they would arrive before competition. The fault was cleared and the car continued driving. This day went well but it was highlighted that the Teensy on the PEN needed to be hot glued down and during the reassembly of the car it got knocked and came loose while driving, luckily the cars BSPD kicked in and turned HV off. This showed the rest why we have safe practises while testing, as well as trained drivers and safety systems on the car. This was the first drive with the strengthen power box too and such the torque limits were tested but the motor plate was still bending. The maximum torque request without motor bending was 180 Nm, and such seemed to be close to the traction limit on this surface.

Figure 25 NU24 Presented at the NU Teams Expo

NU24 was then presented at the NU Teams Expo as our competition platform, even with the inconsistent AMS issue, the team was content where the car was performance wise, 2 weeks out from competition.

Our last SMSP track day was on the 25th of November. The new HIP had arrived and was ready to be put on the car while charging although this swap was not easy. During the assembly of the new enclosure the HVD interlock connector and discharge resistor was damaged, the resistor being the most complex of the two. The interlock was an easy fix and was replaced with the one used in AVONE as there were not any spare, but the resistor required some questionable methods to reattach the resistor legs. After testing, the quick fix was sufficient for the day, allowing us to test the new HIP and continue driving, whilst there still was some heat generated, it was much better than the original HIP and low enough to be used without issues. The day seemed to be on track to end well until the DCDC failed.

Figure 26 NU24 Last SMSP Track Day before Competition

The DCDC had no signs of failure, still enabled correctly with both CAN and the 12V enable pin, displayed over CAN that it was enabled and that it had no faults, but it simply would not output current. The DCDC is a component which the team did not keep a spare of being an off the shelf part that is robust and simple to interface with.

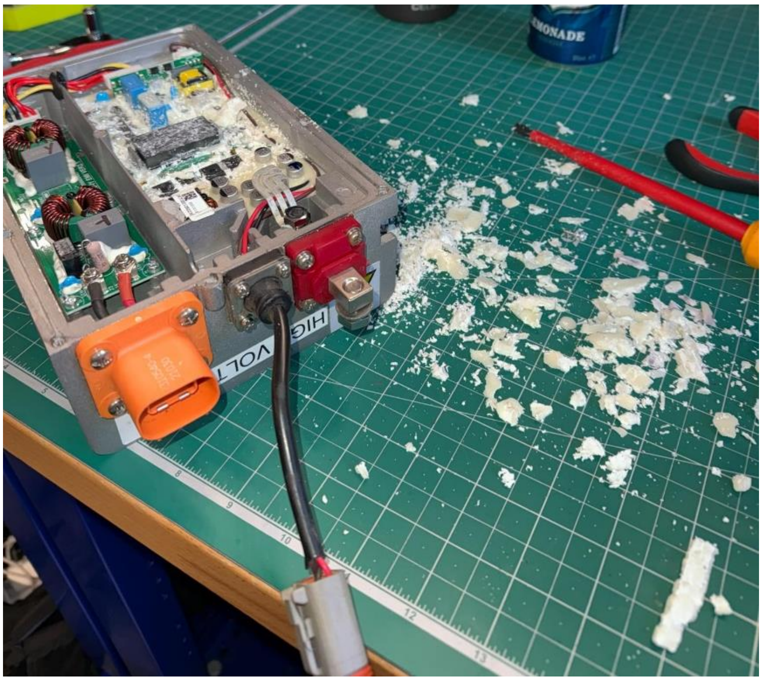

Figure 27 Fault Finding the broken DCDC without Success

With only 1 week to competition, a new DCDC had to be sourced and delivered. A replacement was coursed from EV Shop EU and expressed delivered to TA on Friday before being commissioned, the unit was slightly different but had the same mounting holes and an increased current capacity. Nothing had to be changed for the unit apart from the 12V connections, shortening the positive to a reasonable length before bolting the eyelet terminals together and the GND was now any point on the enclosure. The new unit worked immediately and without issue. Sadly, we had to cancel the Thursday track day planned due to the DCDC not arriving in time.

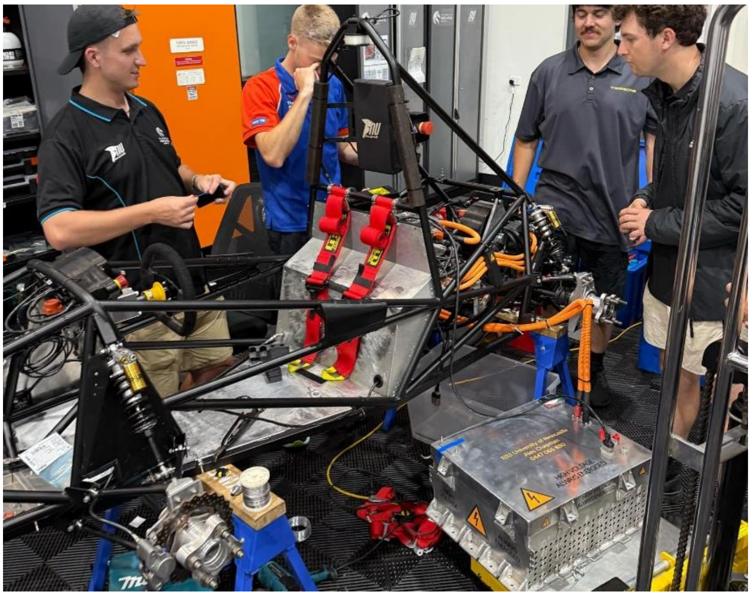

Figure 28 New DCDC Commission

As a precaution the author calculated the size LV battery needed to run the car for an endurance and NU Marine luckily had a spare we could use if worst came to worst. A second DCDC was also ordered as a spare from EV West in America, arriving on Wednesday for Mr Malcolm Sidney to bring down to competition in a packed suitcase.

On the Saturday before leaving for competition the car was ran momentarily, the motor was spinning in the opposite direction and the chain was skipping. These issues had quick fixes but that meant the car only ran a couple hundred metres. NU24 was taken back to TA and the PCB enclosures were disassembled to hot glue gun the PEN Teensy and potentiometers to ensure they did not move, as well as conformal coat the PCBs and seal the enclosures with silicone for the rain test.

After a resolver recalibration, reassembly of the enclosures, changing the chain and drive sprockets and the repair of a GND pin on the Precharge board in the accumulator, the car was ready to be checked at a final drive in the ICT carpark at the university.

Figure 29 NU24 Final Carpark Drive

Half a charge was completed due to weather and time restrictions, but all systems were operational, and the car was finally ready for competition.

Progress in 2024 was extremely compromised by the inverter fault, condensing the time to find and fix all the other issues on the car. The team worked so incredibly hard to get to competition and should be incredible proud regardless of the result. Whilst its reliability was still questionable, its performance was impressive, and team was ready to take on the other teams. With all drivers practised and ready.

Even with the delays, NU24 still did 350 km of testing, which is only 70 km less than NU23 did with many more track days. Overall, the track days were run very efficiently, and the team got the most out of everyone, even with the faults. The testing period of the car, while short, was very successful, although there is a lot to improve on in the future to avoid the issues and delays the 2024 team faced.

Some of these things are:

- Ensuring the team has spares of every major component on the car. This alone would have allowed the team to test for another 2 months as well as reduced the stress in the final week before competition. This not only increases the team's testing ability but will also reduce stress in every team member. Ensure a proper diagnosis of issues in undertaken before swapping over damaged components.

- More testing or at least driving should be done with the previous competition car, NU23 was only driven three times in the first half of 2024 before it's decommission. It is a perfect test bed for any changes that can be made early in the year or at the very least, is the best way for a new team to select potential drivers for the year. In 2024 only two members had previously driven, and such were the test drivers, but this left little room for when these members could not make testing events. More track days early on will let the team become comfortable with the operation of the day and will make the important track days in the back half of the year more efficient.
- A strict record of each change to the car should be kept. This change log should have a descriptive short comment attached to an in-depth long comment of the change and its success or failure. This document should be accessed by everyone, so every team member is up to date with the car as well as having a shared document for reference during report time.
- A condition log should also be made and documented such that every team member can understand the state at which the car is in during assembly and reassembly. It is not uncommon for components to be taken off the car between track days for repair, upgrades, setting changes or inspection and having a document which states the condition of the car will remove the risk of damaging a component or wasting a team members time thinking a system can be tested when it is currently affected by another. This document could also state whether or not a set list of functions is operational e.g. LV is operational, but HV is not operational.

These changes will ensure a much smoother year in 2025 and beyond.

Figure 30 The Author Pictured with NU24 at the NU Teams Expo

Technical Inspection

Overview

Technical Inspection (TI) is the gateway to the Dynamic Events at competition, putting the team through rigorous tests to ensure the car is ready to race. These inspections ensure the vehicle has quality made structures and has all the necessary safety systems and design requirements dictated by SAE in the rules, although not every rule is tested. There can be some disparity between the rules and the technical inspection requirements, so it is critical that all requirements are met in both documents to ensure an easy technical inspection at competition.

Helena De Gruchy did a deep dive on all the inspections in 2023, covering all inspections from the 2023 competition, as well as all important information regarding the inspections, this can be found in her ENGG4200 Report. Only the mechatronic aspects of the inspections will be covered by this section as in 2024, the inspections were separated into the separate departments. Both the MECH and MCHA department leads took the lead on their technical inspection sections. Information regarding the mechanical technical inspections can be found in Lachlan Fisher's FYP Report. In future, it is recommended that the department leads are not the leads in TI but should be highly involved.

The most effective way for TIs to run is the leads assess what is still needed to pass inspections and then inform the department leads who will double check and then delegate work to the team. Once the work is completed it is given to the TI leads to format and reassess until all TIs are passed.

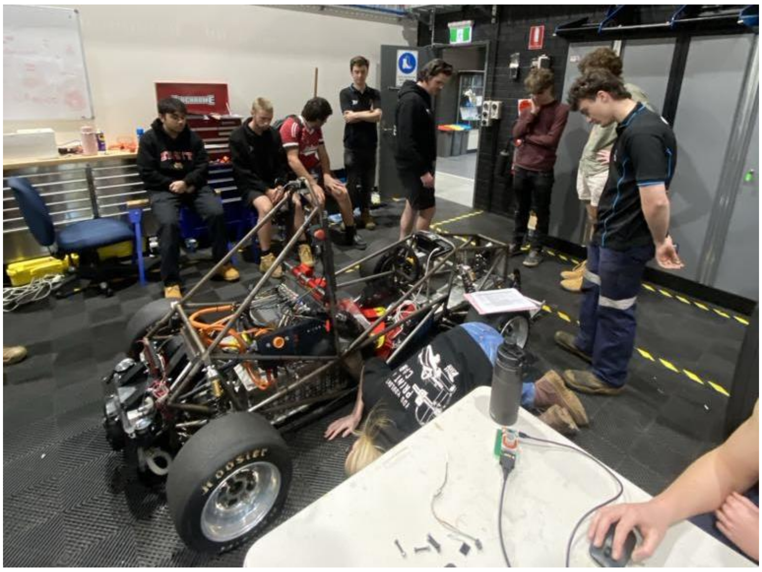

Figure 31 Team Conducting First Technical Inspection in August

The most important aspect of technical inspections is rehearsal. It is vital that all the members in TIs are practised and ready to tackle the hardest of questions from scrutineers, and part of this preparation includes proving all the components meet the requirements through datasheets, samples, images and videos. The majority of the work the TI leads will complete is the collection of all the evidence and formatting it in such a way that allows the inspection to flow from one point to the next. NU Racing has used a folder with all these documents sorted in order for the past years with great success. To pair with the documents, the TI's document from FSAE was also adapted with comments to reference what is needed at each inspection, what to do in each step and what reference documents to use, this is called The MCHA Technical Inspection Bible: and is attached in the Appendix.

Everything important to TI should be stored in the TI box and all documents can be found on Teams.

In the build up to competition, the tech teams should do mock TIs with increasing regularity, the earlier this starts, the better. Ideally the car is in the best state it could be at the time when completed and should be taken seriously, with the first run throughs being more relaxed but still fully aware of what passes and what doesn't. These also help identify non-compliant systems on the car, allowing for rectification by the team, but the TIs should already be familiar as they should be checked during system design. In 2024, TIs did not happen early enough due to the inverter issue, and such the car was not compliant until packing day for competition.

Each technical inspection is to be completed in one hour at competition and should be choreographed that it is possible. At every inspection, the inspection sheet supplied by SAE must be brought and the Team Leader and Academic Advisor should be present outside the bay if needed but are not needed for practise runs. It is likely that the TI document released by SAE will come out close to competition, and such the most recent TI document should be used. It is unlikely that there will be many changes, unless FSAE state otherwise earlier in the year during a webinar so it can be assumed to be the same.

Sometimes the inspectors and conditions of the inspections can be different to what is expected so all members should go in with an open mind and prepared for anything. If the team is prepared, the TI will be a calm and easy as possible.

Accumulator Tech

Accumulator tech is the first inspection at competition and is the most rigorous as it assesses the HV battery pack and other related equipment, and such requires the most supporting documentation and samples. The items needed for this TI is included in the tech bible. The accumulator, accumulator charging trolley, accumulator charger, and any tool and equipment used to service the accumulator is inspected.

This inspection is the most likely to run over time if the team is unlucky with an inspector and as such it is most important that this TI is practised. Only four members should be needed in this inspection, and they are:

- Accumulator Mechanical Engineer
- Accumulator Mechatronic Engineer
- Mechatronic TI leader
- Mechatronic Department Leader/document and sample handler

The core four members should always be involved, and each member should know and practise their role. The two accumulator engineers will be required to use tools, undo bolts and show case everything in the accumulator with safety glasses, HV gloves and leather outers on, and as such will answer all questions regarding the accumulator, only referencing to the TI lead when documentation and samples are needed. The TI lead will be on standby, ensuring they are up to date with the inspectors and ready for what is next, going to the document hander for anything that is needed and showing the inspectors. The TI lead will also be the first person to interact with the inspectors, contacting them and starting by introducing themselves and the other team members. The document and sample handler will also be following along, ready to hand documents and samples to the TI lead when needed.

TI leader might decide that a fifth member of the team is needed to do the charger section of the TI and will only be present for this section. This team member would be the engineer that worked closely with the charger and understands it well and would have to wear the same PPE as the accumulator members. If only four members are used, one of the accumulator engineers will have to demonstrate the charger.

Figure 32 FSAE-A 2024 Accumulator Technical Inspection

Through the use of documents and samples, the accumulator will not have to be disassembled, only opened and with the service handle out, although the team should be prepared to take it off if necessary. 2023 was the first-year accumulator tech was run, and such every team was caught out by it. NU Racing was caught out by a main fuse rated too high, some sharp edges, some nuts had to be changed to nylon and an issue with a datasheet for the main HV connector, which was all replaced, and such all was considered in the 2024 design.

Every year the HV mat and gloves will need to be tested and tagged, as well as the 3-phase cable going into the charger. The ESO information on the accumulator and trolley will need to be updated with the current ESO too. All other changes should only come from new designs which should have been designed with the rules and TI in mind.

Changes that should be made in 2024 are new HV connectors that have a built-in interlock loop (HVIL) for AI.5.16 and a new voltmeter should be selected for AI.5.17. Not having the interlock meant a 3D-printed lock out had to be designed which covered the connectors which was a major oversight during the selection of the new connectors. The voltmeter is very old and barely works so it is worth getting a new one, or creating a functioning AIL early on in the year.

EV Static (EV1)

EV Static is the first EV TI with the whole car and is a mix of demonstration and evidence providing. This TI can be taken with or without the accumulator if time is an issue but if time allows, the accumulator should be in. Everything that is needed for this TI is stated in the Bible before the first points, these include red stands to raise the car off the ground and high stands for the body kit.

The people required at this inspection are:

- Mechatronic TI Leader
- Mechatronic Department Lead
- LV Engineer (or experienced MCHA)
- Document and sample handler (experienced MCHA)
- Body kit team (4 designated team members) (standing outside the bay ready to help)

The team selection is less critical than accumulator tech but is still important that TI is rehearsed. During this TI the car must be lifted onto the red stand and such 4 people are needed to lift the car while two members position the stands, these should be the body kit team, and the two members should be the department lead and LV Engineer. Shortly after demonstrating the removal of the HVD (soon to be MSD), the body kit must also be removed, such the body kit team need to re-enter the back and assist. The top firewall should also be removed with a flat head screwdriver for better access to the electronics. There is a small change that the Structural equivalency schematic (SES) will be required too so a team member familiar with the document should have it opened on a computer.

The TI lead should be the first to introduce the team to the inspectors again but are not required to be the lead question responder. In 2024 the TI lead chose an experienced MCHA to be the main question responder in this TI, and instead followed along, ensuring all the documents and samples were ready when necessary. There is flexibility with how this TI is run and such should be chosen by the TI every year based off the current team. It is recommended to have a main question responder, a document and sample responder, the document hander and spare.

At the end of this inspection, it requires the grounding of all components near the tractive system and traditionally the inspector will not be happy and ask that a component which is not included on the list or logically makes sense is grounded. In 2023 it was the HVD bolts which mount to the enclosure, and such had to be fixed before passing. Luckily this issue is easily solved and only takes a short amount of time to make grounding looms. It is recommended to ground absolutely everything in 100 mm of the track system in the future and to practise measuring everything with a Multimeter.

Every year majority of this TI will need to be reorganised as even small changes will require compliance inspection due to the stickers and markings required for this TI to be passed. The HV/LV separation document will need to be updated too, as this document features PCBs which are regularly updated, added or removed. A copy of the separation booklet can be found in Josh Hayward's report. The energy metre supplied by SAE at competition will also need to be fitted before this inspection with instructions available on the SAE website.

It is recommended to have all the stickers and markings for the inspection ready as early as possible and with spares as in 2024 it was not passed until very late. The push bar should also be checked early on in case it needs modification.

EV Functional (EV2)

EV functional can only be completed after Accumulator Tech, EV Static and Mechanical Tech and is the first time the car is switched on at competition. This is the simplest TI when rehearsed as it requires demonstration of the safety systems on the car and a small amount of supporting documentation. The safety systems are critical to the design of the car and can only be changed during it, as such all systems should have been operational for all of testing and such the pressure is low during this TI. The required members are the same as EV Static and the same tools are required, plus a laptop to show the BMS voltages and temperatures. The main difference is that the wheels will spin, and such the wheels must be taken off.

The people required at this inspection are:

- Mechatronic TI Leader
- Mechatronic Department Lead
- LV Engineer (or experienced MCHA)
- Document and sample handler (experienced MCHA)
- Body kit team (4 designated team members) (standing outside the bay ready to help)

The body kit team are to assist again with lifting the car onto stands and removing the body kit. The top firewall can remain on as there should be enough access to the BMS port and ideally the spare member in the bay can take the wheels off using the impact gun.

Figure 33 EV Functional at 2024 FSAE-A Competition

The roles are the exact same as Static, with a lot of option of who can do what and it is up to the TI leader to decide. During this TI, the team is given a fluke Multimeter to use and will be used to demonstrate the precharge and discharge times of the car and will also have to spin the wheels to demonstrate APPS TRAIL and PLAUS. To do this a low torque mode was used, setting the torque limit to 40 Nm so the speed of the wheels can be easily controlled so these can be easily demonstrated under pressure. The BSPD is also demonstrated using a power supply to induce current into a wire that is wrapped around the current sensor in the HIP, and such only requires LV to be on.

Once everything is passed the energy meter is tested and such cannot be practised but as long as it is connected correctly, there is nothing to worry about on the team's end. In the past, NU Racing has completed EV functional on its first try due to preparation, and such, if everything is practised, TI should not be a worry at competition.

Rain Test

The Rain Test requires the car to be lifted onto the red stands and powered into HV whilst water pours from a sprinkler system onto it for 2 minutes, the water is then turned off and the car must also remain in HV for another 2 minutes to pass. Due to the nature of this TI, it is not practised by NU Racing and the only preparation made for the event is ensuring that all the enclosures are water resistant by sealing them shut with silicone before leaving for competition.

People needed at this TI:

- Mechatronic TI Leader
- Mechatronic Department Lead
- Body kit team (4 designated team members) (standing outside the bay ready to help)

The body kit team will lift the car for the stands, while the ESO which should be the Mechatronic Department Lead turns the car on. The TI Leader stands with the inspector as a spare. NU Racing has never had an issue with this event and is only conducted after passing functional.

Figure 34 FSAE-A 2024 Rain Test

2024 TIs at Competition

The team prepared as much as possible given the issues during testing, completing five rehearsals.

Accumulator Tech

Accumulator Tech was very chaotic this year, multiple teams were inspected at once and such was not a calm environment. The PPE and equipment were checked in one bay before setting up for the accumulator in another. Whilst this was happening the charger was inspected and such the TI leader was going back and forth between this bay. Due to the cramped nature of the room too, we could not bring in our TI box, instead the TI had to keep going outside to get anything extra. As crazy as the circumstances were, the team did very well but did not pass first try. The small HV fuse holders were not correctly rated for the voltage, a last-minute fix before competition in 2023 that was missed during that TI and during the 2024 preparation.

Members of the team travelled into Melbourne to get replacement parts, and the modifications were made the next morning. The new components had clear datasheets and once installed, the accumulator was rechecked and passed without further issues. This was an improvement on last year, having multiple changes necessary for passing and such the team should be proud. It is recommended that these fuses are changed again in 2025 to one of a better form factor.

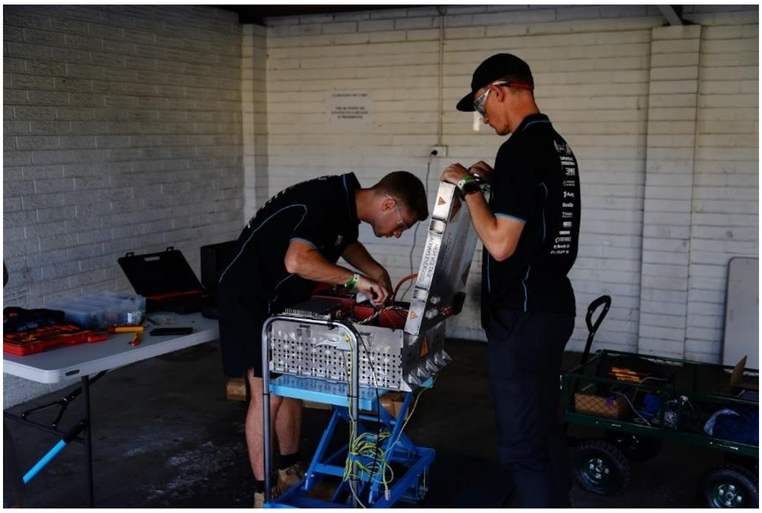

Figure 35 Installing Replacement Fuses for Accumulator Tech

EV Static

EV Static was in the same place as 2023, and such was open and calm. The team progressed well, with a small issue surrounding the water rating of the test point covers, luckily a datasheet was found during the inspection, and it satisfied the inspectors. The team's practise allowed for the car to be lifted, and the body kit taken off effortlessly. But just like 2023, the team was caught with an unknown requirement for grounding, the inspectors required the team to ground the hose clamps and the master switch mounting bolts. The components were on non-conductive material and are extremely low risk in becoming live with HV, and such this was explained to the inspectors. After discussion the team was only required to ground the hose clamps on the motor controller and motor. This rule was not enforced on other teams and such it seemed like the team had gotten unlucky, acting as a reminder that anything can happen during TI.

The team quickly returned to the pit and made grounding straps for the hose clamps and the car was re-inspected and passed within the same afternoon. Again, the team was well practised, and such was successful. It is recommended that everything metallic within 100 mm of the tractive system components are grounded.

EV Functional:

EV Functional has the easiest inspection, with the team having no doubt of passing first time. The team's rehearsal paid off and the team swiftly moved through the points, with the low torque settings working as planned.

After some trouble connecting to the energy metre on SAE's end, the team passed. It is recommended that the same torque settings are used in future.

MCHA Techs

The team also passed Mechanical Tech, Tilt, Weight and Egress tests first time but the team had an issue with the brake test, it seemed that with new tyres and a nicer surface than what the team tests on, the team could not lock all four tyres. The team had to return to the pits and bleed the brakes and raise the tyre pressures before going out again, eventually this was past. It is recommended that the braking system is upgraded for 2025.

Once this was completed the team had successfully past TI. The team should be very proud for producing a compliant car and overcoming all the obstacles thrown at the team. Whilst we did not continue NU Racing's streak of being the first team through TI for the last two years, NU Racing was the third team through, and such the team was ready to race.

Figure 36 2024 FSAE-A Technical Inspection Completed

2024 FSAE-A Competition

Travelling to Competition

The team finished packing the night before leaving TA to Victoria, leaving at 3am in the morning. The team was split into multiple University cars and travelled down individually, occasionally stopping together for a break and for food.

A few cars had to make stops for spare parts on the way and for food, but everyone managed to get to the accommodation in Ballan by 5pm.

Preparation and Bump In

After resting overnight, the team began preparing for the competition. Screens, 3D-printers and the simulator were setup, some members got the car out and checked all the systems to ensure nothing was damaged during the journey down, and the cost and business teams worked on their events.

Bump in was at 3pm, so the team leader and other core members arrived at Calder Park Raceway early for team registration and to unload the car and all equipment. While the garage was being set up, the Cost Team was finishing the Cost Report Amendment before heading into Calder Park. The team was given the energy meter at registration and members installed it into the car before leaving at the end of the day.

The Cost Team came back to the accommodation to work on the cost scenario into the night.

Day 1: Technical Inspections and Cost

This was the first day of competition, starting with Cost at 9am. The team pushed the car over to the cost bay and the team presented the scenario, negotiated about the accuracy of the report and participated in the event. The stands were brought to take the body kit off, but the judges did not require this. The Cost Team were happy with their performance, feeling confident on the points obtained.

Figure 37 Preparation of NU24 for Technical Inspections

The car was taken back to the pits and the accumulator was removed in preparation for Accumulator Tech at 11am. There was a moment of panic as one of the pieces of equipment was not brought to the track during bump in, luckily team members already had gone back for something else and would return before 11am. The team finished accumulator tech but needed to fix the fuses and as such members were sent into Melbourne to get the replacement fuses.

The accumulator was brought back to the garage and installed in the car for EV Static at 2pm. The team had lunch and then went to Static, only having to be reinspected later for the small grounding issue. Mechanical, Egress, Tilt and Weight were then completed immediately after Static, and one after another were passed first time.

Figure 38 NU24 During the Tilt Test

The team returned back to the garage to install the new ground straps and reorganised a re-inspection, passing EV Static before the end of the day. The members were back from Melbourne with the components, and the accumulator engineers went to the clean room to remove the current fuses to use as a guide to make the new fuse looms. These looms and the necessary equipment were taken back to accommodation as the track was closed at 6pm, so the most amount of work possible could done before Day 2. The Business Presentation team and Design team continued preparing for the events.

Day 2: Technical Inspections, Design and Presentation

The team arrived back at the track at 7am to continue working on the accumulator in the clean room. The work was completed, the accumulator was reinspected and had passed accumulator tech by 10am. The team quickly connected the accumulator to the charger to ensure the accumulator functioned correctly before returning to the pits and reinstalling the accumulator into the car.

The team then headed to EV Functional at 10:30am after asking the inspectors if they had a free spot we could fill. The team passed functional first try and went onto the rain test, which was viewed by a group of high school students. The author demonstrated the safety systems of the car for them before the team returned to the pits to prepare for the brake test. The torque limit was changed to 180 Nm.

While this was happening the Business Presentation team attended their event, and returned feeling good about how it went. The team ran into some issues during the brake test and had to return to the pits. The LV master switch would not work momentarily but began working again without reason once the brakes were bled. The team went out again and after several tries, the car locked all four tyres, and the brake test was passed. That meant that the team had finished all technical inspections by 2pm. The accumulator was charged once back in the pits for tomorrow events.

Figure 39 NU24 During the Brake Test

The team then relaxed and prepared for the Design event at 5pm. The team pushed the car over to the Design area and removed the body kit, before the team was introduced and then split into the different categories of design. Due to the small area, only 2 members for each design category were allowed in the bay, but members would switch with members outside the bay. The design judges were taken through the booklets and the car, grilling all team members about the design, and although the year had not set the team up well to do in this event, the team walked out happy.

The team returned to the accommodation to celebrate the completion of the static events and prepared for the dynamic events this weekend.

Day 3: Skidpad, Acceleration and Track Walk

Upon returning to the track at 7:30am, it was found that the car would not enter LV. The GLVMS had failed and needed replacement. Members of the team were already collecting a new master switch from Jaycar and would return to the track at 8:30 am and the HIP was opened, and the broken master switch was removed in preparation of the replacement. The new master switch was installed, and the HIP was reassembled and resealed before getting reinspected by SAE for the changes made.

Figure 40 2024 Skidpad First Driver

At this point the Skidpad event had already started, and being wet/damp, wet tyres were put on NU24 for the first driver. The team made it to the starting line 20 minutes late and with the track slowly drying, the first driver completed the two attempts without error. The wet tyres were several years old and supplied very little grip meaning a slow time was on the board. The second driver had 40 minutes to prepare, and such the dry tyres were fitted to match the drying track. By the time the second driver lined up, the track only had one wet patch and was able to deliver a competitive time for the conditions, banking valuable points for the team. Due to the drying conditions, the last teams to run had a much better track and were able to perform better and such the team's finishing position did not represent our true performance.

The team then had 2 hours to prepare for acceleration, sitting the dry tyres in the sun, topping up the accumulator with charge and preparing a viewing point on the trackside. The car was then pushed around to the starting line with the first driver with dry conditions. This event was action packed with multiple teams spinning out, having issues and even crashing, luckily NU Racing had a trouble-free event and performed very well. Both drivers handled the car well and produced NU Racing first ever sub 4 second times. The team was ecstatic with the result, finishing 4th overall, only narrowly missing out on third and with the fastest 2WD car in the competition.

Figure 41 NU24 Acceleration First Driver

After the Acceleration event, it was found that the front wheel bearings had failed, luckily the team was prepared and brought spares. Without any time pressure, the team was able to replace the bearings and get the car reinspected by SAE before the track walk at the end of the day. The team also charged the accumulator to full again.

The track walk is a critical part of the preparation for AutoX and Endurance, as this is the first time track access is granted. During this time the drivers will walk the track together, talking about how it will be driven, while this is happening a supporting team is recording the track to be reproduced by a team member back at the accommodation on the simulator. This means that when the team members return to accommodation, drivers will be able to practise driving the track in the simulator, giving drivers a better chance.

Day 4: AutoX, Endurance and Parc Freme

The team came into the pits with another issue on the final day, two tyres had deflated overnight. Luckily it was a minor issue on both the tyres, one had a bad valve core and was good once replaced and the other only had a small leak between the rim faces on one of the new rims. Once replaced the car was ready for AutoX.

Both drivers had been on the simulator last night and in the morning as it was brough to the pits by the team and were prepared. The first driver went out on a very slippery track and set a respected time but on the second lap, the AMS fault which could not be fixed during testing occurred. This stranded our car on the far side of the track, and it could not be rescued until the end of AutoX, meaning that the second driver did not get to drive and on a better performing track.

This really stung the team, under performing in the strongest events last year and losing vital points. While the car was stranded, the team had quickly concluded what must be done to ensure endurance and efficiency were completed.

Once the car had returned to the pits, charging was not needed as the accumulator was still full and the changes to finish endurance were completed. With the drivers prepared and the team watching the live telemetry, NU24 lined up for endurance.

After 18 laps and a driver swap, NU24 crossed the finish line with a very rapid time. The team was overjoyed with how the drivers and the car performed, completing a very clean endurance, bagging the largest number of points from a signal event and scoring well in efficiency.

Figure 42 NU24 Crossing the Line, Finishing Endurance

The car was brought around to Parc Freme while everyone continued celebrating, where the thermal strip in the accumulator was checked, and the energy meter was returned. A small hiccup slowed this process as the IMD required to be tested by an inspector and the resistor had a poor connection. Once fixed we had passed and were finished with the competition. The team packed up the garage and took some photos with the other teams before packing up the car and attending the award presentation.

Points and Competition Analysis

2024 was the highest point score in NU Racing's history, achieving 733.86 points, an improvement by 180.72 points achieved in 2023. The team also achieved its joint highest overall position in 4^{th} place, matching the teams finish in 2022 with EV3.

Considering all the events of 2024, it was impressive for the team to attend competition, let alone do so well. Although the team narrowly missed out on an overall podium and podiums in Acceleration and efficiency, the team could not be happier with the result. If one event when even marginally worse, we could have lost 4th place or worse.

Table 3 Competition Points Analysis: 2023 vs 2024 [4]

Event	*2023*	*Position*	*2024*	*Position*	*Delta*	*Out of*
Presentation	72.55	2nd	54.05	14th	-18.50	75
Cost	51.06	8th	75.55	8th	+24.49	100
Design	130.33	4th	120	12th	-10.33	150
Skid pad	65.77	2nd	42.64	9th	-23.13	75
Acceleration	50.92	7th	71.79	4th	+20.87	100
AutoX	120.99	2nd	78.13	8th	-42.86	125
Endurance	9	17th	250.87	5th	+241.87	275
Efficiency	52.52	DNF	40.82	4th	-11.70	100
Total	*553.14*	*7th*	*733.86*	*4th*	*+180.72*	*1000*

The 2024 competition was extremely competitive, and such the rankings do not represent the team's effort, instead they represent the level of the competition and its ability to create highly skilled engineers. The number of points scored by every team showed every team improvement.

Compared to 2023, the team did not perform as well in the static events due to the 2023 team being larger, having more testing time and had less change throughout the year. If not for the bad luck in Skidpad and AutoX, the team would have outperformed 2023 in every aspect. But many things can be improved in future.

- The BMS fault which occurred in 2023 Endurance, 2024 testing and 2024 AutoX should be the main concern in the start of 2025. Replacement CANaMONS have arrived and segment one should be replaced with a new one. The team should then complete a minimum of three chargers early on in the year to ensure this is the fix. If the fault returns then or later during testing, it is them highly likely that the BMS is damaged and will need repair or replacement. As a precaution it is recommended that a spare BMS is purchased at the start of the year.
- Wet tyres need to be purchased, as wet tyres in good condition could have changed the performance in Skidpad and running on the current set of tyres would have harmed the other events if the weather was too wet for the dry tyres.
- Design event preparation should happen throughout the entire year, data should be collected, and all changes should be properly validated. The feedback from the design event needs to be actioned.
- It would be ideal if the team could have business students do the business event, as there are also elements in the team they can assist on like industry partners.

The 2024 team overcame every obstacle and learned many valuable experiences, starting the change from a team which only thinks about the present year, to one that thinks about the future.

Figure 43 NU Racing 2024

Conclusions and Recommendations

2024 was a year of hardship, testing its core members and doubling down on the pressure from the work of the successful years previous. It has been an honour to work with the team in such a position and it has developed the author's skills as an engineering unlike anything else available at the university. Management skills were tested and learnt, as well as technical knowledge, creating a strong bond with the other team members and becoming friends with the whole team.

If the team had even one less core member, the team would not have done as well as it did, a larger team is recommended in future years to create redundance. A team of 20-25 core members with approximately 8 mechatronic engineers at various level would be ideal, with core jobs being presented to FYPs and high level directed students. This would balance out the work load much better than it was in 2024.

Both the department leaders did too much work this year, whether from issues faced with the car or due to the size of the core team, and as such both burnt out through the year. This also meant department leaders were incredibly important at every stage and were involved with almost every event at competition at a high level. This can not continue as it is not sustainable for the engineers or the team, operating with no redundancy.

The recommendations listed in each section of this report should be considered and implemented by future teams to improve the team and reduce the risk of wearing down the team and its vehicles but the high-level recommendations that should be used in 2025 are:

- Stock count of spare components
- Character interviews before role selection
- Read all that is available from past years and SAE
- Every change should be documented and logged for everyone to see
- Yearly goals sized correctly for team size
- Department leaders should not be the leads for cost or technical inspection
- Focus on validating designs for the design event
- Decision Matrix should be used for all big changes

Some of the technical changes that should be made:

- The BMS fault from AutoX needs to be fixed ASAP
- Change master switches
- Change HV connectors to ones with in inbuilt HVIL
- Shield all CAN wires
- All Power wires should be 16 AWG
- LVD Micro fit connector should be changed to a different connector that is more serviceable (new style or multiple small Micro fits)
- Change Mosfet to relay on LVD
- New TSMS lockout

NU Racing still remains the best experience that the University of Newcastle offers for engineers, with FSAE being a fun and interesting challenge for all members. The Chief Mechatronics Engineer is a highly rewarding but demanding role, requiring technical knowledge, leaderships skills, people skills and determination. The author was very grateful to be selected as in 2024 and will continue with the team in 2025, completed the author's final year project as the Chief Engineer for NU Racing.

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Appendix

NU23 LV Systems

Topology:

NU Racing does not use a typical single electronic node like an ECU. This means that the car does not have one large single loom. Instead, we use several electronic nodes across the car, with individual looms running between the nodes. This allows for an easily serviceable system, splitting up vital aspects of the car onto individual PCB's.

With this topology, the LV system is simple and intuitive and allows for the workload to be easily shared among different team members, each being able to focus on their individual board.

On NU23, the LV system includes:

- The Pedal Electronic Node (PEN): Reads the Brake Pressure Sensors, Accelerator Pedal Position Sensors (APPS), and Brake Over Travel Switch (BOTS)
- The Dash Electronic Node (DEN): Reads the Dash E-Stop and Ready-To-Drive (RTD) button, and relays PEN signals.
- The Central Electronic Node (CEN): Reads the Tractive System Master Switch (TSMS), Hard Fault Latch (HFL), Top E-Stops, HV and HV Disconnect (HVD) Interlocks, Brake System Plausibility Device (BSPD), Tractive System Active Light (TSAL), OK High Signals (OKHS) and Discharge Relay. Communicates to the DCDC, Motor Controller, REN, and Accumulator. (This board also is HV)
- Rear Electronic Node (REN): Read the Temperature Sensors of the Radiator, and relays Power to the Brake Light, RTD Sounder and Cooling Pumps and Fan.
- Low Voltage Distribution (LVD): Relays Power to the Accumulator Fans and Communicates Accumulator Temperatures from the Battery Monitor System (BMS) to the CEN as well as BMS OKHS. (This board also is HV)

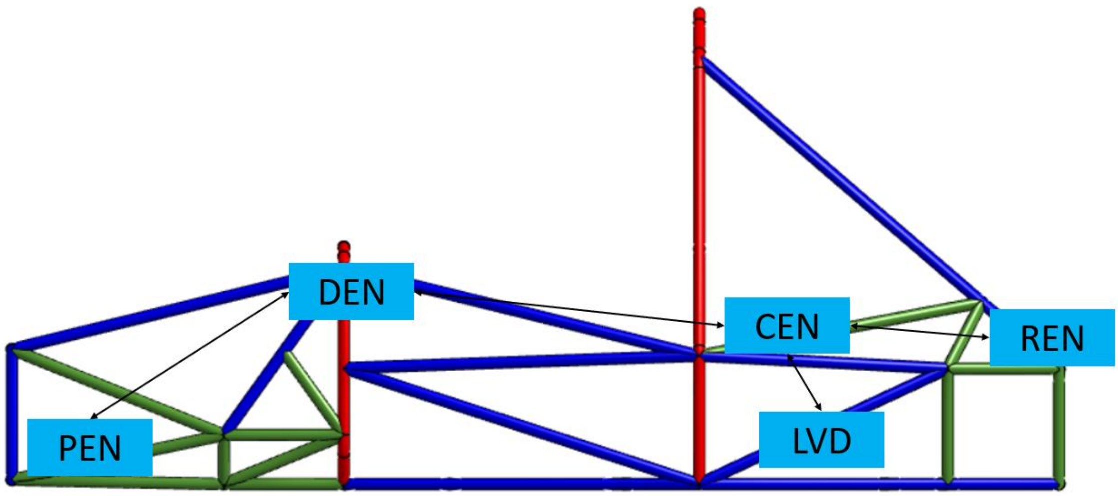


Figure 44 NU23 LV Topology

The Topology of NU24 will be very similar to NU23, as it was very successful as a whole. Due to the new Cascadia Motor Controller’s inbuilt coolant temperature sensors, the REN has become obsolete and such the power switching functionality has been moved to the CEN. The CEN has also been split up into two separate LV and HV boards, with the LV board remaining as the CEN and the HV board now becoming the Human Interface Panel (HIP), featuring the Master Switches, HVD and Test Points.

Shutdown Circuit:

The shutdown circuit is the most important LV circuit on the car, ensuring that the tractive system is discharged if any safety parameter within the rules is compromised.

A highly detailed explanation of the shutdown circuit and everything related can be found in the rules although it is not vehicle specific.

NU23’s shutdown circuit consists of:

- Brake Over Travel Switch (BOTS): Placed behind the brake pedal in such a way that if the hydraulic brake system of the car fails, the driver will be able to flip this switch, turning off the tractive system.
- Inertia Switch: This has to be placed in a vertical position on the car (on the steering gearbox on NU23) and will turn the shutdown circuit open in the event of a crash (8 – 11g).
- Dash E-Stop: This is an emergency stop button on the DEN, easily accessible by the driver, and is the easiest way to turn off the tractive system from within the car.
- TSAL E-Stops: Two emergency stop buttons on either side of the main roll hoop on the car. This is the main mode of turning the car off from the outside.
- HVD interlock: The HVD is an easily accessible High Voltage disconnect on the car (on the CEN on NU23) and as this is directly connected to HV, an interlock is used to monitor if it is disconnected.
- Hard Fault Latch Interpose: This is a latch on the CEN board which goes bad if any of the OKHS go bad. These signals are BMS, PRECHARGE, IMD, BSPD, and DISCHARGE. This latch activates an interpose relay which is directly connected to the shutdown circuit (the latch isn’t).
- TSMS: This is on the CEN enclosure and is the tractive system master switch.
- HV Interlocks: These are the same as the HVD interlocks but are for the HV connectors between the CEN and Accumulator.

Once all of these are good, the Precharge relay and Accumulator Isolation Relays (AIRS) will open to turn on the tractive system.

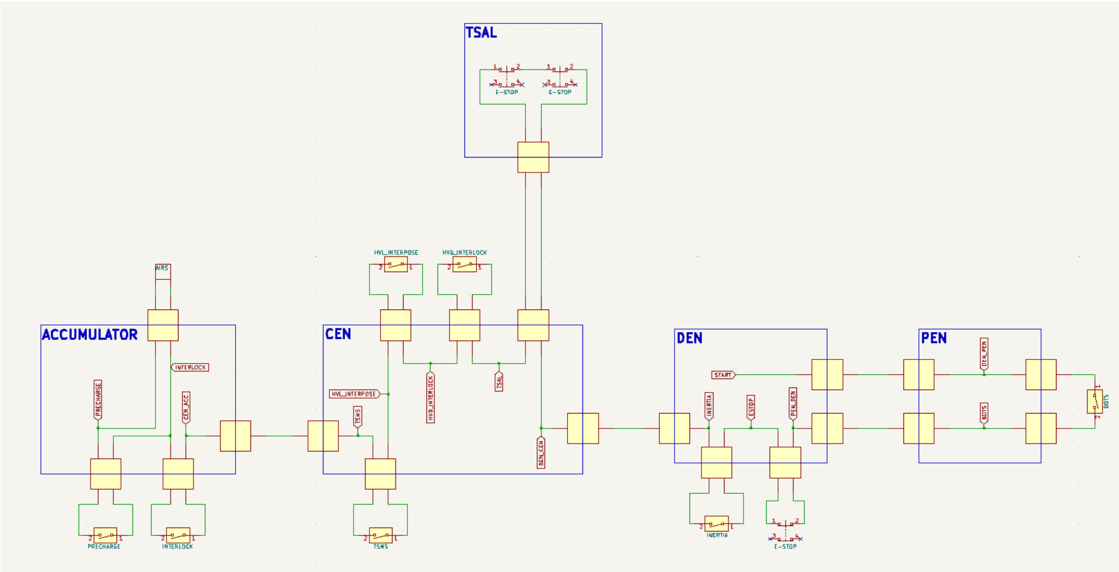


Figure 45 NU23 Shutdown Circuit Schematic (found in NU23 GITHUB)

The shutdown circuit of NU24 has changed, starting in the PEN now, and removing the HFL Interpose for the HFL itself. The HV interlocks are also no longer needed.

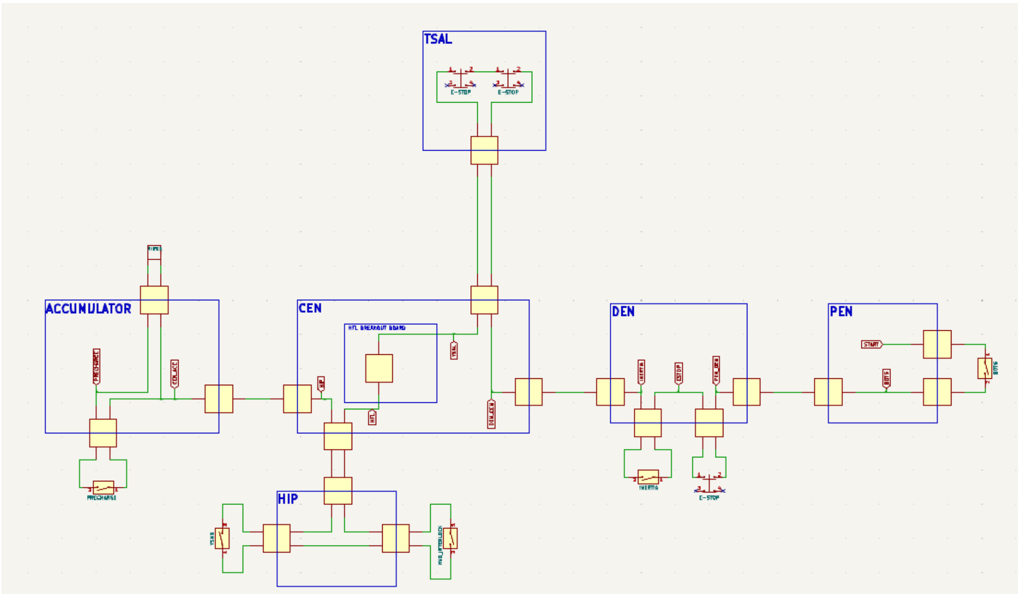


Figure 46 NU24 Shutdown Circuit Schematic (found in NU24 GITHUB)

Hard Faults:

Displayed on the driver's display via the shift lights.

- Precharge Discharge Open Circuit (PDOC):

  This hard fault is triggered when communication is lost with the Precharge circuit and/or the discharge circuit. The discharge circuit must be wired in a way that it is always active when the shutdown circuit is open and must be able to handle the maximum tractive system voltage for a least 15 seconds. The Precharge circuit is supplied by the Shutdown circuit and must be able to charge the immediate circuit to 90% of the accumulator voltage before closing the second AIR. If any these events do not occur or the circuits are disconnected in anyway, the hard fault is triggered, turning the Precharge or Discharge OKHS bad. The precharge board is located on the top plate and is communicated by the LVD. The discharge circuit in apart of the CEN on NU23 and will be on the HIP on NU24.

- Insulation Monitoring Device (IMD):
  This device monitors for an insulation failure within the tractive system, and it checks to see that the device itself is working properly. If either of these events occur, the IMD_OKHS goes bad. This device is located on the top plate of the accumulator and is communicated by the LVD.
- Accumulator Monitoring System (AMS):
  The AMS must measure the temperatures of critical points within the accumulator, ensuring that the maximum cell temperature does not exceed 60° C. It also must ensure that at least 20% of the cells have temperature monitoring. If the temperature readings drop below 20% or reads temperatures higher than 60° C, the AMS_OKHS goes bad. This comes from the Orion BMS on the top plate and is communicated by the LVD.
- Brake System Plausibility Device (BPSD):
  The BSPD monitors the average brake pressure between the two pressure sensors read by the PEN and the current of the electric motor to ensure that the shutdown circuit opens when the accelerator and brake pedal are pressed at the same time. Both the brake pressure and current draw have selected values, which if both are exceeded at the same time, make the BPSD_OKHS go bad. The BPSD circuit is located on the CEN.

Detailed Design Review (DDR)

PCB DDR

The DDR Process is aimed towards reducing errors in PCB design and manufacture, and ensuring that the design intent of the PCB is in line with the requirements of the car and is compatable with existing systems. ***This should be completed before any PCB is approved for manufacture.***

Your Name:	MASTER COPY DO NOT EDIT
PCB Name:	
Version:	
Date Of Review	
Reviewer 1	
Reviewer 2	
Reviewer 3	

*A Minimum of 2 people external from the designer should be involved in a Pre Production DDR, One of which should be of sufficient electrical experience (Multiple successful PCBS, over 1 years experience etc) such as Alex, Malcolm, Chief Mechatronic Engineer, LV System Engineer, etc.

PCB Design Intent	
Completed?	NO
Reviewed?	NO
Schematic Review	
Completed?	NO
Reviewed?	NO
Layout Review	
Completed?	NO
Reviewed?	NO
Unit Test Checklist	
Completed?	NO
Reviewed?	NO
CAD and Physical Design Review	
Completed?	NO
Reviewed?	NO

REVIEW NOT COMPLETE

PCB File Structure

After being sent off for manufacture, please ensure the PCB follows the following File Structure.

\Github
- \Racing-PCBs (Current PCB's should also be in Racing-NUXX)
  - **PCB_NAME** (e.g CEN)
    - **Version_NO** (e.g CEN_V2.1)
      - **Kicad_Project_Folder** (e.g CEN_V2.1)
      - **DDR_EXCEL FILE** (e.g CEN_V2.1_DDR.xlsx)
      - **Schematic PDF** (e.g CEN_V2.1_Schematic.PDF)
      - **Datasheets** (Folder)
        - **Datasheet_1** (e.g Component_1.PDF)
        - **Datasheet_2** (e.g Component_2.PDF)

PCB OVERVIEW

This is a top level overview of your PCB design, treat this like a blurb about your PCB aimed towards someone who has no knowledge of your PCB and a rudimentary understanding of the cars electrical systems. For example a new mechatronics team member who is continuing your work after you graduate.

PCB Design Intent	
Completed:	NO
Reviewed:	NO

Your Name:	
PCB Name:	
Version:	
Date of DDR:	

PCB Requirements:

This should be to a level to explain the reasoning for having this PCB to someone who is not already familiar with our electric topology.
E.g. This board is required to receive power from the CEN and distributed it to the cooling system

Changes from Previous Version:

Top Level Specs	
Input / System Voltage:	
.ogic / Control System Voltage:	
Max Current Draw:	

SCHEMATIC REVIEW

This part of the DDR reviews your electronic design intent, when designing a new PCB you should consider all of the below points in mind as good design practice.

PCB Design Intent			
Completed:	NO		
Reviewed:	NO		

	Designer	Reviewer	NOTES
Electrical Rules Checker			
Has the ERC been run with no errors?			
Title Block Checklist			
Has the title block been completed to the same standard as the example below?			
Neatness / Quality Of Life			
Distinct circuits are in blocks:			
All Blocks are labelled:			
Nonstandard Blocks have functionality / explanation labelled:			
Standard blocks used where possible:			
All unused pins on components have 'no connection flags' (x)			
All names are logical			
All test points and LEDS labelled as reference signal (NOT Dx or TPx)			
Integrated Circuits (ICs)			
Have all non-regular components been researched and have datasheets?			
Fusing / Protection			
Does the board have the necessary fusing/protection?			
Components			
1206 footprint used for standard components			
Standard ICs all using stocked footprint:			
Utilised standard MCHA lab components			
Voltage Regulators using 7805 SMD:			
Test Points using 1mm through hole loop style:			
Values present and correctly specified for all components (e.g. R,C)			
Design Features			
GREEN LED for any OKHS passing through the board			
Log all Shutdown circuit states on microcontroller and RED LEDs			
Screw Terminal (12V_RAW, GND) for commissioning (WJ126 Style 5mm Pitch)			
Rules Compliance			
Shutdown Circuit Is Compliant			
HV / LV Isolation Clearly Marked on Schematic			
Connectors dealing with high voltage need sufficient breakdown voltage/separation			

LAYOUT REVIEW

This part of the DDR reviews your electronic layout, when designing a new PCB you should consider all of the below points in mind as good design practice.

PCB Design Intent			
Completed:	NO		
Reviewed:	NO		

	Designer	Reviewer	NOTES
DRC			
Design Rules Check (DRC) has been run and passed - NO errors or warnings			
Component Placement			
All Connectors Placed such that mating connector fits			
Recepticles (e.g serial, usb port) are accessible when in service			
Small ICs (CAN Tranceiver etc) located accessibly (not under teensy)			
All locking tabs facing out of the board			
All Testpoints are accessible when fully populated			
Traces			
Trace placement and size has been consider for all traces			
Is all shutdown circuit using 2 mm traces?			
Are there no VIAs on solder pads?			
Are there no traces running under the DT connector screw holes?			
Silkscreen			
Is everything labelled correctly and to the standard of the DEN (see photo below)?			
Has the Screw Terminal Commissioning Port been labeled for 12V and GND?			
ave you considered added the values for Resistors and Capacitors to the silkscreen?			
Rules Compliance			
Labelled with HV / LV Separation if applicable			
HV international electical symbol present if applicable			
Silkscreen HV-LV dividing line clearly visible and THICC			
HV/LV Separation cut-outs present if applicable			
Edge Cuts / Mounting			
All Corners Rounded			
M3 Mounting Holes with GND pad Present or the USE of DT plugs			
Edge Cuts consider space requirements			
Standard dimensions (nearest 5mm) for both board and mounting holes			

PRE MANUFACTURE UNIT TEST CHECKLIST

This unit test checklist will serve as a valuble tool when comissioning your PCB, fill this in thoroughly and realising the correct function of your PCB will be simple and design errors will become clear.

PCB Design Intent		
Completed:	NO	
Reviewed:	NO	

Stage	Function	Description	Verification Method	Steps	Result	Notes
Before Assembly	QUALITY CONTROL	PCB Quality Control	Inspection	Check the PCB is has been manufactured to our expected quality as well as all hardware		
During Assemby - Unpowered	POWER DISTRUBUTION	Power and Ground are Isolated	Test	Use a multimeter to read that the resistance between power and ground is an open loop		
During Assemby - Powered	POWER INSPECTION	Regulator Quality Control	Test	Using a power supply with the screw teminales, Ensuring correct connections, with the regulator, fuse and reverse polarity protection soldered, Measure the voltage ensuring 12V is only where expected, and 5V is where expected. Ensure LED's are lighting up		
During Assemby - Unpowered	VISUAL INSPECTION	CAN Quality Control	Inspection	Using a multimeter measure the resistance across CAN high and low, Ensure temination switchs work. Test other pins on CAN transiever and ensure correct connection.		
During Assemby - Powered	TEENSY TEST	Test Teensy	Test	Ensuring Teensy is powered correctly, connect teensy and ensure powered, this is final step before serial and DT are soldered on		
Post Assembly	CORRECTLY ASSEMBLED	All Hardware Accountable	Inspection	Check the PCB and KiCAD schemetic to ensure all components are accounted for.		
Post Assembly	CONNECTOR TEST	Test Connectors	Inspection	Using a multimeter , measure the conductivitiy for the connectors and ensure continuity where required		
Post Assembly	CAN TEST	Check CAN	Test	Connect a known CAN signal on each line and read it using the Teensy, send messages where required and ensure messages can be sent and received		
Integration Test	POWER UP	LV system integration	Test	Ensure the system can be turned on with the whole LV system		
In Service Test	WORKING	Does it all work?	Demonstration	Test if the PCB has its full intended functionality		
				Add more steps if needed		

CAD AND PHYSICAL DESIGN REVIEW

This part of the DDR reviews your physical design intent, when designing a new PCB you should consider all of the below points in mind as good design practice.

PCB Design Intent		
Completed:	NO	
Reviewed:	NO	

	Designer	Reviewer	NOTES
PCB STEP FILE			
PCB step file has been generated and reflects all components			
Components do not touch and have space for mating receptacles			
Board can be mounted using included mounting holes			
All components accessible by hand soldering			
Enclosure CAD			
PCB STEP file has been added to ONSHAPE Assembly			
Enclosure has been considered as well as where it will be mounted to the car			
PCB Manufacture			
Has the PCB files been exported using the JLC or PCBGOGO KiCAD plug-in?			
Uploaded the files into JLC or PCBGOGO cart and purchase order submitted?			
Export the symbols to a PCB specific library and saved within the PCB folder?			
Used the HTML BOM plug-in to Generate the PCB's Bill of Materials?			

Comissioning Notes

Please fill in comissioning notes as you are completing comissioning of your new board. Things you should note include:
- Temporary fixes implemented onto your PCB such as jumper wires
- Areas you wish you had designed differently
- Recommended fixes for any errors on a future revision

These will be used when respinning your PCBs in the future, or ensuring spare / duplicate PCBs have the same temporary fixes applied even if you are not the one to do it

PCB Design Intent		
Completed:	NO	
Reviewed:	NO	

Date Of Note	Note	Temporary Fixes	Recomenations
1/01/2000	EXAMPLE: Molex Pin 1 Not Connected to DT Pin 3 As Intended	A Jumper wire has been run between the two affected pins	EXAMPLE: Rectify running of trace before revision 1.1

NUCAN Zero-To-Hero

NUCAN ZERO-TO-HERO

NUCAN is the NU Teams standard use medium for CAN BUS, featuring a DBC file and C++ scripts which generate a library of short cuts to allow for easy and efficient use of CAN BUS within code.

Instead of writing the information of each CAN BUS signal, NUCAN allows for a message to be sent with a single line of code. Setting up the CAN BUS code is also easier and NUCAN comes with some added functionality like heartbeat, internal CPU temperature sensing on Teensys and WATCHDOGS.

The WATCHDOG is built into NUCAN and does not need to be turned on, it will monitor the Teensy's heartbeat signal and reboot it if there is any problem. This means a heartbeat signal is needed for NUCAN to work.

The NUCAN GitHub:

The NUCAN GitHub repository is where all of NUCAN is stored for all teams.

There is a folder of all the DBC files as well as individual libraries for each DBC file within the folder.

The build_cpp_from_dbc.py file is a script which turns the DBC file, which humans can easily interact with, into C++ code that Arduino IDE uses. Whenever a new DBC file is added or removed this file needs to be updated. **Line 4 is the only line that needs to updated to represent the DBC files within the DBC Files folder.**

```
1  import cantools
2  import csv
3
4  cars = ['EV3', 'AV1', 'WAM23', 'WAM24', 'NU24', 'SLV24']
5
6  # Define car for DBC file name and subsequent cpp name
7  for car in cars:
8      # Load in DBC
9      db = cantools.database.load_file('./DBC Files/'+car+'.dbc')
```

Figure 47 build_cpp_from_dbc.py Script

Whenever this repository is 'pulled', the libraries which aren't being used by the Arduino code need to be deleted to avoid error when verifying or uploading the code to a teensy. An example of this is when using the NU24_CAN.h file, all other DBC created .h and .cpp files, e.g. WAM23.cpp, WAM23.h must be removed from the user's local device EXCEPT InternalTemperature, Watchdog_t4 and NUCAN.

HOWEVER, DO NOT push these deleted files as changes back to GitHub if changes to a DBC file are made. This will remove all the other files from the GitHub.

Whenever a change is made to a DBC file, NUCAN needs to be pushed to update the C++ files, then pulled. It may take a second for script to run fully and update the C++ files.

Creating and editing a DBC file:

To create a new DBC file or edit an existing one, either copy the format of an older DBC file (recommended) or create a new one from scratch using Kvaser Database Editor 3, which is a CAN message editor (DOWNLOAD: https://kvaser.com/single-download/?download_id=47183).

It is recommended to edit and create new DBC by copying what was already done before. There are many examples in GitHub within the DBC folder and it is important to get familiar with these before trying to edit and create new DBC files. Refer back to CAN BUS ZERO TO HERO to ensure that the DBC file format is understood.

Using the Kvaser Editor for DBC files:

The Kvaser Editor will format everything, and it is recommended to look and understand an existing DBC file (revise back to CANBUS ZERO TO HERO) before making changes or creating a new file to minimise mistakes.

Once the format and interface is understood, create new CAN messages using the plus icon in the 'Messages & Signals' tab in the top box. To add signals within a single CAN message, use the bottom box (this is what is specific to each signal, so consideration needs to be made).

Ensure there is a heartbeat message for each node as the Teensy's WATCHDOG needs a heartbeat signal to function.

Once the DBC file has been created or edited, it can then be saved/exported and save to the NUCAN DBC file folder and then added to the build_cpp_from_dbc.py file, before being pushed to GitHub and pulled shortly after.

Before using the DBC file and the generated libraries, double check everything was correctly created or use first in a very safe matter.

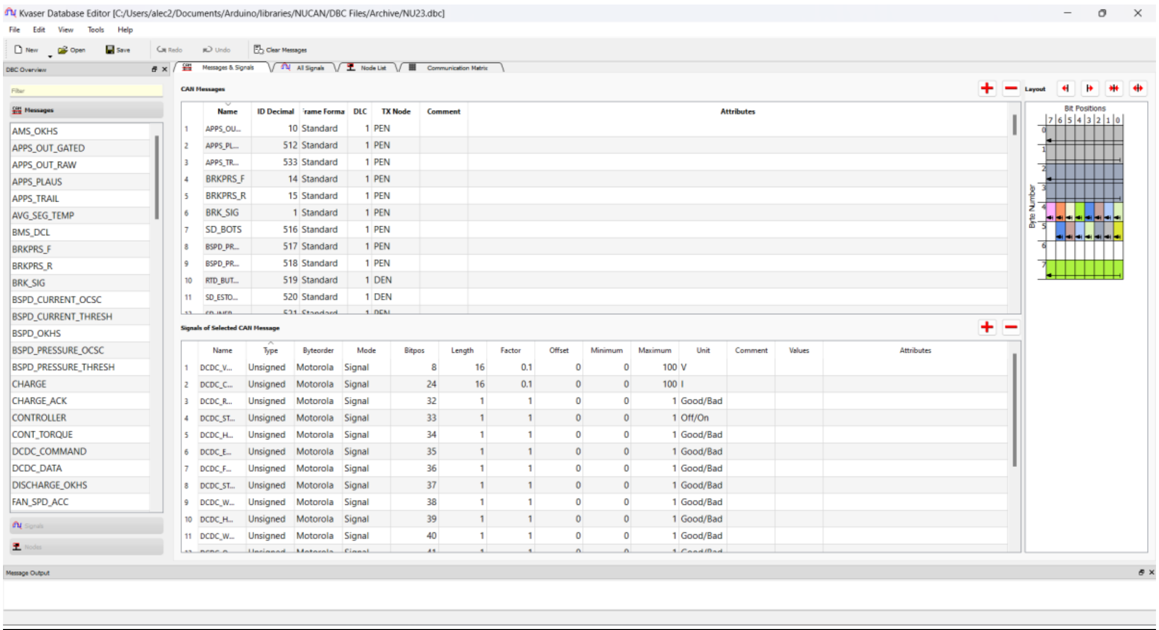


Figure 48 NU23 DBC file in Kvaser Database Editor

Using NUCAN on Arduino IDE

Set up:

Arduino requires the NUCAN library files to be in its libraries folder. The easiest way to ensure it can always find NUCAN is to put the whole NUCAN folder in the Arduino libraries folder (typically found in *User>Documents>Arduino*).

You also need to delete the other unused library files, e.g. SLV24.cpp and SLV24.h as described above now (if you are unsure, ask for help). You can see what files you need to delete by verifying your code, the trouble files will be displayed as an error.

Defining a Library:

Before reading or writing CAN messages with NUCAN, the respective header file for whichever variant of NUCAN you want to use must be included at the top of the Arduino script using '#include <(*file_name.*h)>'.

CEN_V9_NU23_INTEGRATION_TEST.ino

```
// CEN ECU V1.2
// Gabby Horsnell
// This is maybe not nice code
// This has MC included

// Josh Dawson
// Addition of Motor controller derating fault code variables

// CEN ECU V9
// Jacob Lukes
// Addition of REN switching functionality and altering of shutdown circuit variables

// Include necessary libraries and define pins
#include <EV3_CAN.h>
// Old REN functionality
#define SOUNDER_PIN 5   // Sounder signal enable pin
#define BRAKE_PIN 6     // Brake signal enable pin
#define FAN_SIG_PIN 7   // fan enable signal
#define PUMP_SIG_PIN 8  // pump enable signal
```

Figure 49 EV3_CAN.h Defined in CEN CODE

The example above uses the EV3 library.

Note: NUCAN does not need to be defined as it is included within each library.

CAN Variable:

Next the variables which NUCAN uses needs to be created. NUCAN requires the number of messages its receiving, sending, and the name and variable to store the value of the received messages.

```
// CAN 1 variables
// inputmsgs defines message, outputVar defines location for incoming data
// NUCAN fuctionality, refer to NUCAN README file for clarification
float *outputVar[] = {&RTD_state, &TS_state, &DCDC_status, &brake_light_CMD};
canmsg *inputmsgs[] = {&RTD_STATE, &TS_STATE , &DCDC_STATUS, &BRK_SIG};
int numreceive = 4;    // Number of messages that will be received
int numsend = 20;      // Total number of messages that can be sent
```

Figure 50 NUCAN Variables in CEN CODE

This is a good example of how to do this, as 4 messages are received, and their values are sorted into variables which were defined earlier in the code.

outputVar[] is an array of variables, these are where the received messages will be sorted for use within the code.

inputmsgs[] is an array of CAN BUS message names, these are the message to be read from the bus.

numreceive is the number of messages that NUCAN expects to read from the CAN BUS.

numsend is the number of messages that NUCAN expect to write onto the CAN BUS.

<u>NUCAN Initialisation:</u>

Now NUCAN variables have been created, NUCAN can be initialised in the 'void setup()' section of the code using 'NUCAN_init(numsend, numreceive)'.

```
// CAN bus initialisation. Bus speed initialisation not needed, handled by NUCAN
NUCAN_init(numsend, numreceive);
```

Figure 51 NUCAN initialised in CEN CODE

Above is an example of doing this. NOTE in this example the bus speed is set by NUCAN based on the CANBUS_speed.csv file in the DBC folder.

To set the bus speed manually, simply define the bus speed as a variable prior and include it as the third variable within the NUCAN_init function e.g. NUCAN_init(numsend, numreceive, bus_speed).

<u>Reading messages using NUCAN:</u>

As the number and names of the variables of the received messages have already been defined, NUCAN only needs to be told to read the BUS and update these variables using NUCAN_read(outputVar, inputmsgs, numreceive). This should be within 'void loop()'.

```
void loop()
{
  NUCAN_read(outputVar, inputmsgs, numreceive);
```

Figure 52 Using NUCAN_read in CEN CODE

Writing messages using NUCAN:

Once a variable is made and has a value, it is now ready to be sent using NUCAN_write(). To use this function, put the name of the signal you want this variable to update and then the variable. This name should be identical to the name used in the respective DBC file.

```
CEN_IN_okhs = digitalRead(SHUTDOWN_CEN_IN_PIN);    // read the input from the CEN_IN
NUCAN_write(&SD_CEN_IN, CEN_IN_okhs);              // Transmit shutdown circuit state of CEN_IN over CAN
```

Figure 53 Using NUCAN_write in CEN CODE

In the code above, a variable is defined from a digital read of a pin and then written to the bus using a NUCAN_write().

Using the NUCAN Heartbeat:

To call the NUCAN Heartbeat function, simply include NUCAN_heartbeat() within the void loop() section of the script.

```
// Final command in update function, update the heartbeat of the CEN. Used for checking if the CEN is
// alive over MoTeC
NUCAN_heartbeat(&HB_CEN);
```

Figure 54 Using NUCAN_heartbeat in CEN CODE

In this example, a heartbeat signal is sent to the CAN BUS using a message name specific to that node (i.e. ‘&HB_CEN’).

IMPORTANT: A heartbeat signal is necessary for NUCAN to work as the WATCHDOG will reset the Teensy if it does not see a heartbeat.

Using the NUCAN internal temperature:

This function writes the current CPU temperature of the Teensy. To use it, call NUCAN_Core_Temp() with the specific CAN BUS message name from a respective DBC, just like NUCAN_heartbeat.

e.g. NUCAN_Core_Temp(&LVD_CORE_TEMP).

Include this line within the void loop() section of the code.

By Alec Chapman 3/7/24

2024 ESF

The submitted document can be found in Teams

Instructions
-All cells for input have an orange background. -Cells, sections and worksheets have an overall status. The status cells have a blue background. -For sections which require an image or schematic, the image should be pasted and located over the specified area. Images should be pasted at a high resolution and then resized. This allows the reader to zoom into the image if more resolution is required. -Where datasheets are requested, a hyperlink to the datasheet from the manufacturer must be provided. -Additional Comments sections are provided throughout for documentation of things which the team feels are not adequately documented in the provided fields. These are optional and do not need to be completed.

Status	
Datasheets	OK
TS Schematics	OK
Accumulator	OK
Precharge/Discharge	OK
Charging	OK
Shutdown Circuit	OK
Torque Security	OK
Other	OK

Team Name	NU Racing
University	University of Newcastle
Competition Year	2024

Max TS Voltage	453.6	V
Accumulator Fuse	100	A

Additional Comments

Status	OK	
Battery Cell		OK
Make	Sony Murata	
Model	VTC6	
Nominal Capacity	3.1	Ahr
Maximum Voltage	4.2	V
Nominal Voltage	3.6	V
Minimum Voltage	2.5	V
Max output current	45	A
Max continuous current	30	A
Max Cell temp	60	C
Cell Chemistry	LiPO4	
Datasheet	https://enepaq.com	
SDS	https://enepaq.com	
Additional Comments	Cells assembled in Energus li1x6pvtc6t packs	

Conductors OK

Manufacturer	Part Number	Size [mm²]	Voltage [V]	Ampacity [A]	Temp [C]	Datasheet	Location Used		Additional Comments	Rules References
LAPP	3806143	25	600	136	110	https://lappaustralia	Accumula	OK	Goes from accumulator to HIP, Also used for small	EV.5.2.1
ELETECK	E254881	0.33	600	5	105	https://docs.rs-onlir	Accumula	OK	Used as auxilary wire when nessecery for HV, Such	EV.5.2.5
EXRAD	EXRAD-XH	50	1000	218	150	https://www.cascac	HIP to Mo	OK	Supplied by Cascadia as per of the Motor Controller	EV.6.3
										EV.6.3.2
										EV.6.6.4

Fuses								OK		
Manufacturer	Part Number	Voltage [V]	AC/DC	Current [A]	Interrupt [A]	Datasheet	Location Used		Additional Comments	Rules References
Littlefuse	L50QS10(	500	DC	100	50,000	https://au.mouser.c	Top Plate	OK		EV.5.2.1
Bel Fuse	C1Q 1	63	DC	1	50	https://www.belfuse	BMS	OK		EV.6.6
Energus	Internal	50	DC	270	500	https://enepaq.com	Accumula	OK	Parallel fuses incorporated into each Energus block	
Bel Fuse	0ACG-40(	500	DC	4	100	https://au.mouser.c	HIP	OK	DCDC HV Fuse	

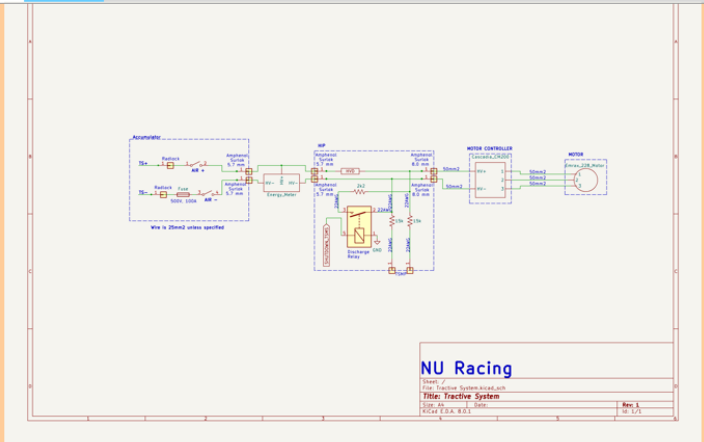
Resistors									OK		
Manufacturer	Part Number	Voltage [V]	Resistance [Ω]	Power [W]	Power for 15 sec [W]	Heatsink [°C/W] (Enter "None" if no heatsink)	Datasheet	Location Used		Additional Comments	Rules References
Arcol	HS25 1K5	550	1000	25	75	None	https://docs.rs-onlir	Accumula	OK		EV.5.2.1
Riedon	PF2472-3	700	3300	100	500	19	https://riedon.com/	HIP - Disc	OK		EV.5.6
Te Connectivi	SMF515K	500	15000	5	5	None	https://www.te.con	HIP	OK	Body Protection Resistors	EV.5.8.4

Contactors/Relays								OK		
Manufacturer	Part Number	Voltage [V]	Continuous Current [A]	Max Interrupt Current [A]	Normal State	Datasheet	Location Used		Additional Comments	Rules References
GigaVac	EPICGX	1000	350	500	NO	https://www.gigava	Accumula	OK		EV.5.2.1
Omron	G7L-2A-X	1000	20	20	NO	https://xonstorage.	Accumula	OK		EV.5.4
Cynergy	DBT7121(	7000	2	3	NC	https://www.cynerg	HIP - Disc	OK		EV.5.6

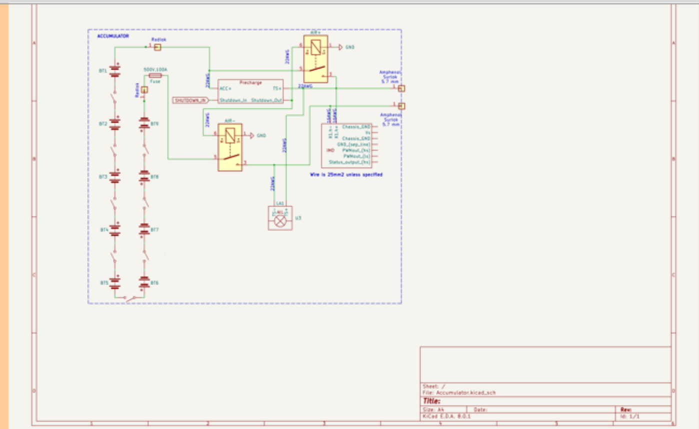
Connectors							OK		
Manufacturer	Part Number	Voltage [V]	Ampacity [A]	Wire Size [mm^2]	Datasheet	Location Used		Additional Comments	Rules References
Amphenol	SLPIPA25	1000	120	25	https://amphenol-in	Accumula	OK		EV.5.2.1
Amphenol	SLPIPA25	1000	120	25	https://amphenol-in	Accumula	OK		EV.5.10
Amphenol	SLPIRABP	1000	120	25	https://amphenol-in	Accumula	OK		EV.6.3.3
Ampehnol	SLPIRABP	1000	120	25	https://amphenol-in	Accumula	OK		
Methode	EBC 5.7m	600	320	60	https://www.metho	Accumula	OK		
Amphenol Te	RL00571-	1000	120	25	https://au.mouser.c	Accumula	OK		
Amphenol	SLPPB50E	1000	200	50	https://amphenol-in	HIP - Mot	OK		
Amphenol	SLPPB50E	1000	200	50	https://amphenol-in	HIP - Mot	OK		
Amphenol	SLPIRBBP	1000	200	50	https://amphenol-in	HIP Enclos	OK		
Amphenol	SLPIRBBP	1000	200	50	https://amphenol-in	HIP Enclos	OK		
Te Connectivi	DT04-2P-	900	13	16	https://www.te.con	HIP Enclos	OK		
Te Connectivi	DT04-2S-	900	13	16	https://www.te.con	HIP - DCD	OK		

Insulating Materials									OK		
Manufacturer	Part Number	Thickness [mm]	Dielectric strength [V/mm]	Voltage Rating [V]	Max Temp [C]	Flammability Rating	Datasheet	Location Used		Additional Comments	Rules References
Ultratrac	H950	9.5	20670	196365	160	UL94 V-0	https://www.profes	Accumula	OK		EV.5.2.1
RS PRO	20305179	3.2	31500	100800	130	UL94 V-0	https://docs.rs-onlir	Accumula	OK		EV.5.2.2.a
RS PRO	20305179	1	31500	31500	130	UL94 V-0	https://docs.rs-onlir	Accumula	OK		EV.5.2.3
RS PRO	20305179	0.8	31500	25200	130	UL94 V-0	https://docs.rs-onlir	Accumula	OK		EV.5.4.4
PCB	KB6165F	1.6	25000	40000	170	UL94 V-1	https://odakpcb.cor	Accumual	OK		EV.6.2
											EV.6.5.5.a

Status OK



Rules References	Vehicle Tractive System Schematic Shows		OK
	Shows details of all TS circuits outside of accumulator	TRUE	OK
	Accumulator is shown as a single element (without internal details)	TRUE	OK
	All wire gauges labeled	TRUE	OK
	All fuses labeled with ampacity	TRUE	OK
EV.6.6.6	All wires > 150mm have a fuse within the first 150mm from the source	TRUE	OK
	Fuse locations represent physical location	TRUE	OK
	Enclosures shown	TRUE	OK
	Connectors labeled with Make/Model	TRUE	OK
	Standard schematic symbols used	TRUE	OK
	All text is readable (zooming is allowed)	TRUE	OK
EV.5.8	TSMPs	TRUE	OK
	Motor Controller	TRUE	OK
	Motor	TRUE	OK
EV.5.8.5	TSMPs not fused	TRUE	OK



Rules References	Accumulator TS Schematic Shows		OK
	Details of all TS circuits within accumulator	TRUE	OK
	All wire gauges labeled	TRUE	OK
	All fuses labeled with ampacity	TRUE	OK
EV.6.6.6	All wires > 150mm have a fuse within the first 150mm from the source	TRUE	OK
	Fuse locations represent physical location	TRUE	OK
	Connectors labeled with Make/Model	TRUE	OK
	Standard schematic symbols used	TRUE	OK
	All text is readable (zooming is allowed)	TRUE	OK
EV.5.4	AIRs	TRUE	OK
EV.5.3	Maintenance plugs	TRUE	OK
	Cells (details of all intercell connections may be abstracted)	TRUE	OK
EV.5.7	Accumulator Indicator	TRUE	OK

Rules References	Must be shown on at least one schematic		OK
EV.7.6	IMD	TRUE	OK
EV.5.5	HVD	TRUE	OK
EV.5.6	Precharge	TRUE	OK
EV.5.6	Discharge	TRUE	OK
EV.3.2; EV.5.1.3	Energy Meter	TRUE	OK
EV.5.6.1.c	Precharge is not fused	TRUE	OK
EV.5.6.1.c	Discharge is not fused	TRUE	OK

Additional Comments

Each of the 9 accumulator segments are comprised of 12 li1x6pvtc6t packs arranged in series. These li1x6pvtc6t packs consist of 6 inidivdual Sony Murata 18650 cells arranged in parallel.

Status	OK	

Segment-to-Segment Connection	Series		OK
Maximum TS Voltage	453.6	V	OK
Nominal TS Voltage	388.8	V	
Total Cells	648		

Segment Data OK

Cell Connection Order	Parallel then Series						OK
Segment	Parallel cells	Series cells	Temp Sensors	Accumulator Number	Max Voltage [V]	Segment Energy [MJ]	
1	6	12	20	1	50.4	3.374784	OK
2	6	12	20	1	50.4	3.374784	OK
3	6	12	20	1	50.4	3.374784	OK
4	6	12	20	1	50.4	3.374784	OK
5	6	12	20	1	50.4	3.374784	OK
6	6	12	20	1	50.4	3.374784	OK
7	6	12	20	1	50.4	3.374784	OK
8	6	12	20	1	50.4	3.374784	OK
9	6	12	20	1	50.4	3.374784	OK
10					0	0	
11					0	0	
12					0	0	
13					0	0	
14					0	0	
15					0	0	
16					0	0	
17					0	0	
18					0	0	

BMS OK

BMS Type	Centralized		OK
BMS Source	Purchased		OK
Make: Ewert Energy / Model	Orion 2		OK
Galvanic Isolation TS to GLV	1500	V	OK
Galvanic Isolation between segments	2500	V	OK
Voltage Sense Leads			
Max Sense Lead Length	50	cm	OK
Sense Lead Overcurrent Protection Device	Bel Fuse C1Q 1		OK
Overcurrent Location	BMS PCB		OK
Overcurrent Voltage Rating	63		OK
Temperature Sensors			
Temp Sensor Location	On cell terminal		OK
Cells sensed per sensor	2	cells	OK
Thermal Contact material used			
Thermal contact material datasheet			
Thermal contact material conductivity		W/(m·K)	
Thermal contact material thickness		mm	
Percent of cells sensed	55.556	%	OK

Maintenance Plugs OK

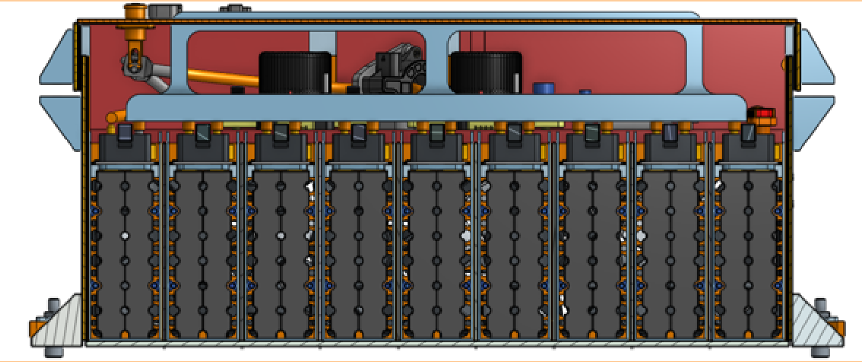
Connector	Methode EBC 5.7mm		OK
Ampacity	320	A	OK
AIR			
Make/Model	GigaVac EPICGX		OK
Contact Voltage Rating	1000	V	OK
Max switching current	500	A	
Max continuous current	350	A	OK
Main Fuse			
Main Fuse	Littelfuse L50QS100.1		OK
Main fuse ampacity	100	A	
Main fuse voltage	500	V	OK

Insulating Materials OK

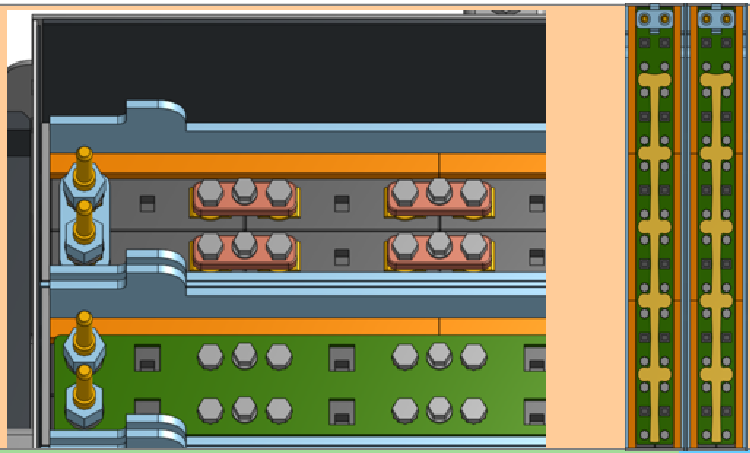
Between cells and accum. container	RS PRO 20305179		OK
Voltage Rating	100800	V	OK
Temperature Rating	130	C	OK
Flammability Rating	UL94 V-0		
On top of cells	Ultratrac H950		OK
Voltage Rating	196365	V	OK
Temperature Rating	160	C	OK
Flammability Rating	UL94 V-0		
Separating AIR and Fuse from cells	Ultratrac H950		OK
Voltage Rating	196365	V	OK
Temperature Rating	160	C	OK
Flammability Rating	UL94 V-0		

Additional Comments

Due to design of temp monitoring pcb the centre 2 battery packs in each segment will not have temperature monitored.



Maintenance Plug(s) Picture Shows		OK
Unique Configuration of plugs	TRUE	OK
Non-conductive on un-necessary surface	TRUE	OK
Accessible without any additional accumulator disassembly	TRUE	OK
Positive Locking	TRUE	OK
Additional Comments		Rules References
Busbar positively locked by accumulator lid.		EV.5.3

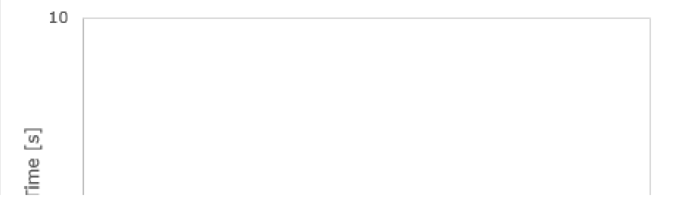


Cell Connections Picture Shows		OK
Bolted connection have positive locking	TRUE	OK
location of parallel cell overcurrent for parallel cells	TRUE	OK
Additional Comments		Rules References
		EV.6.4.1 EV.6.4.3

Parallel Cell Fusing			OK	Rules Referenes
Source	Purchased		OK	EV.6.6.3
Make/Model	Energus Internal		OK	EV.6.6.5
Continuous Current	270	A	OK	

Test Data Summary	
Tests at current 1	0
Tests at current 2	0
Tests at current 3	0
Tests at current 4	0

See Fusible Link Testing Guideline on FSAEOnline.com



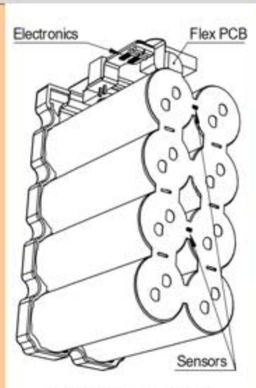
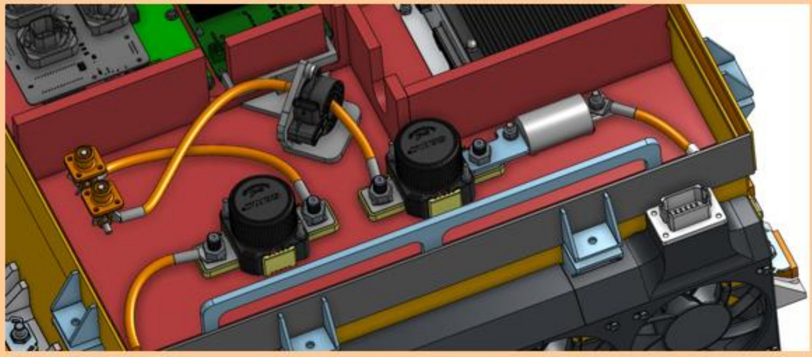


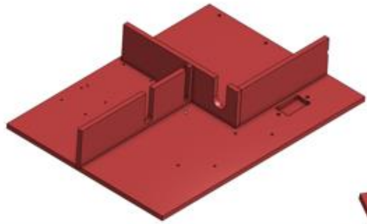
Figure 3: Sensor layout.

Temperature Sensor Picture Shows		OK
Temp sensor in direct contact with terminal or busbar	TRUE	OK
Distance from sensor to cell negative terminal	TRUE	OK
Additional Comments		Rules References
Please note that the li1x6pvtc6t packs used in our accumulator are configured in a 1x6 pack, not a 4x2 as pictured above. This image was taken from the pack's data sheet which covers a range of battery		EV.7.5



Fuse and AIR Separation Picture Shows		OK
Fuse and AIR are separated from cells	TRUE	OK
Additional Comments		Rules References
		EV.5.4.4

Segment Insulation Picture Shows		OK
Insulation between cells and accumulator container	TRUE	OK
Additional Comments		Rules References
		EV.5.2.2.a EV.5.2.3



Segment Insulation Picture Shows		OK
Insulation on top of cells (air not acceptable)	TRUE	OK
Additional Comments		Rules References
		EV.5.2.2.a EV.5.2.3

Status	OK

Precharge			OK
Resistor	Arcol HS25 1K5 J		OK
# parallel	1		OK
# series	1		OK
Resistance	1000	Ohms	
Cont power	25	W	
power @15 sec	75	W	
Voltage	550	V	OK
Bus Capacitance	0.22	mF	OK
End of precharge	Ratio		OK
ending ratio	90	%	OK
Peak power	205.75	W	
Peak current	0.45	A	
time to 90%	0.51	sec	
Precharge Res Energy to 90%	22.41	J	
Average Power	44.2	W	
Relay	Omron G7L-2A-X-L		OK
Relay voltage rating	1000	V	OK
Relay current rating	20	A	OK

Discharge			OK
Resistor	Riedon PF2472-3K3		OK
# parallel	1		OK
# series	1		OK
Resistance	3300	Ohms	
Cont power	100	W	
power @15 sec	500	W	OK
Voltage	700	V	OK
Peak power	62.349	W	
Peak current	0.14	A	
Discharge time (to 60V)	1.4686	s	OK
Relay	Cynergy DBT71210		OK
Relay voltage rating	7000	V	OK
Relay current rating	2	A	OK
Normal State	NC		OK

Rules References
EV.5.6; EV.7.2.2c

TSMP			OK
Resistor	Te Connectivity SMF		OK
# parallel	1		OK
# series	1		OK
Resistance	15000	Ohms	OK
Cont power	5	W	OK
Voltage	500	V	OK

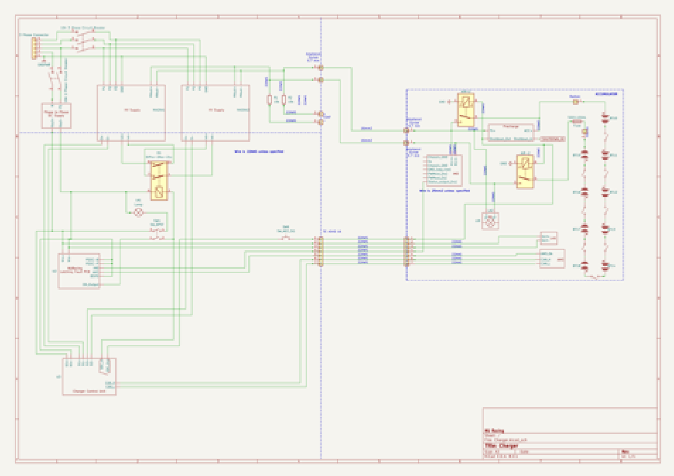
Rules References
EV.5.8.4

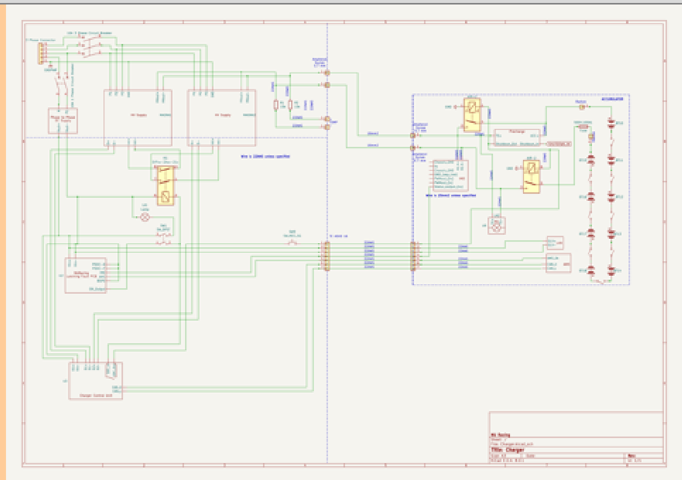
Additional Comments

Status	OK

Charger			OK
Make	Magna Power		OK
Model	SL series		OK
Datasheet	https://magna-pow		OK
Input Voltage	380/400	V	OK
Input Current	11	A	OK
Output Voltage	500	V	OK
Output Current	10	A	OK
Power	4	kW	OK
Input to Output isolation	2.5		OK

Additional Comments





Charging Tractive System Schematic Shows			OK
Rules References			
	Fuse	TRUE	OK
	Connectors	TRUE	OK
	Wire Gauge	TRUE	OK
EV.8.4	IMD	TRUE	OK
EV.8.4.2	AIRs	TRUE	OK
EV.8.2.6	TSMPs	TRUE	OK

Additional Comments

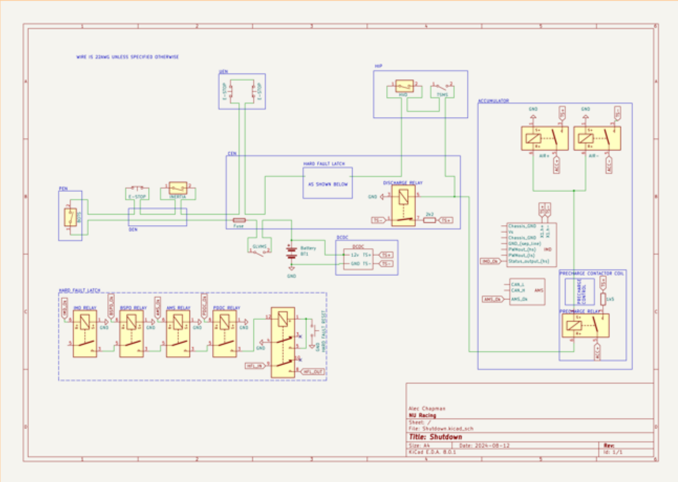
Charging Shtdown Circuit Shows			OK
Rules References			
EV.8.3	IMD Control and Powerstage	TRUE	OK
EV.8.3	AMS	TRUE	OK
EV.8.2.7	Charger Shutdown Button	TRUE	OK
EV.8.4	AIRs	TRUE	OK
	Charge Connector Interlock	TRUE	OK
	Charge Control (CAN, Enable, etc.)	TRUE	OK

Additional Comments

Status	OK

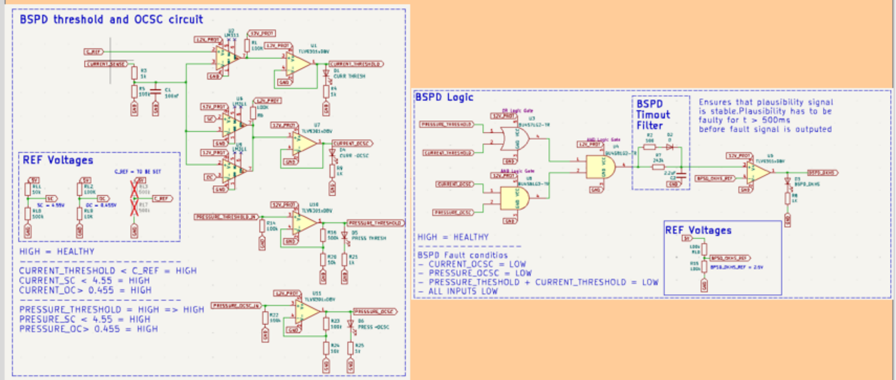
IMD			OK
Rules Reference	EV.7.6		OK
Make/Model	Bender IR155-3204		OK
Setpoint	250	kΩ	OK

BSPD			OK
Rules Reference	EV.7.7		OK
Current Sensor Make/Model	Tamura L31S100S0		OK
Current Sensor Datasheet	https://au.mouser.c		OK
Trip Current	11	A	OK
Sensor Output @ Trip Current	2.57	V	OK
Accuracy @ Trip Current	0.1	A	OK



Shutdown Circuit Schematic Shows | OK

Rules References



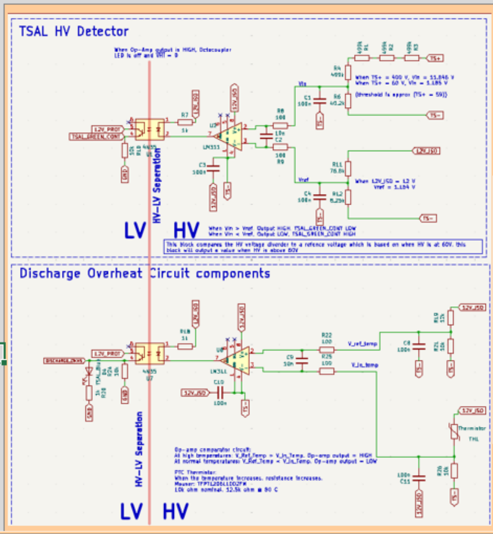
BSPD System Schematic Shows | OK

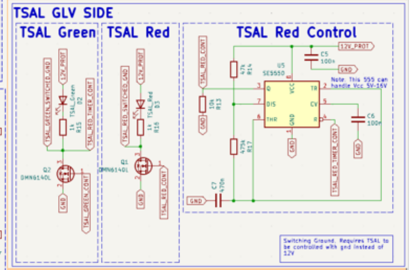
Rules References			OK
EV.7.9	GLVMS	TRUE	OK
EV.7.9	TSMS	TRUE	OK
EV.7.10	2 Side Shutdown Buttons	TRUE	OK
EV.7.10	1 Cockpit Shutdown Button	TRUE	OK
T.3.3	Brake Over Travel Switch (BOTS)	TRUE	OK
T.9.4	Inertia Switch	TRUE	OK
EV.7.3	AMS	TRUE	OK
EV.7.6	IMD	TRUE	OK
EV.7.7	BSPD	TRUE	OK
EV.5.5.2	HVD Interlock	TRUE	OK
EV.7.1.4	IMD, AMS, BSPD have independent power stages	TRUE	OK
EV.4.1.3	Outboard Wheel Motor Interlocks	TRUE	OK
	GLV Battery	TRUE	OK
	HV DC/DC converter GLV connection (if applicable)	TRUE	OK
T.9.2.2	GLV Fuse	TRUE	OK
	Wire Gauge	TRUE	OK
EV.7.1.2	Precharge Contactor coil	TRUE	OK
EV.7.1.2	Positive AIR coil	TRUE	OK
EV.7.1.2	Negative AIR coil	TRUE	OK
EV.5.6.3a	Discharge Contactor coil	TRUE	OK
EV.7.9.1; EV.7.9.3	TSMS is last switch	TRUE	OK
EV.7.9.1; EV.7.9.2	GLVMS is first switch	TRUE	OK
	Uses proper electrical schematic symbols	TRUE	OK
	Labels/text are readable (zooming in is acceptable)	TRUE	OK
EV.5.10	Interlocks on TS connectors outside of an enclosure	TRUE	OK

Additional Comments	Rules References
We do not have Outboard Wheel Motors	EV.7.1 EV.7.2

		OK
BSPD Current Sensor input open/short circuit protection	TRUE	OK
BSPD Brake Position input open/short circuit protection	TRUE	OK
Shutdown circuit powerstage	TRUE	OK

Additional Comments	Rules References
	EV.7.7

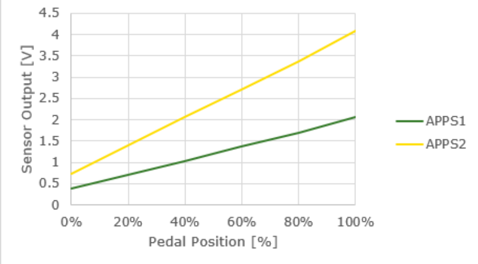




TSAL Schematic Shows		OK
TSAL controlled by >60V present in TS	TRUE	OK
TSAL powered by GLV	TRUE	OK
TSAL flashes red when HV present and solid green when not	TRUE	OK

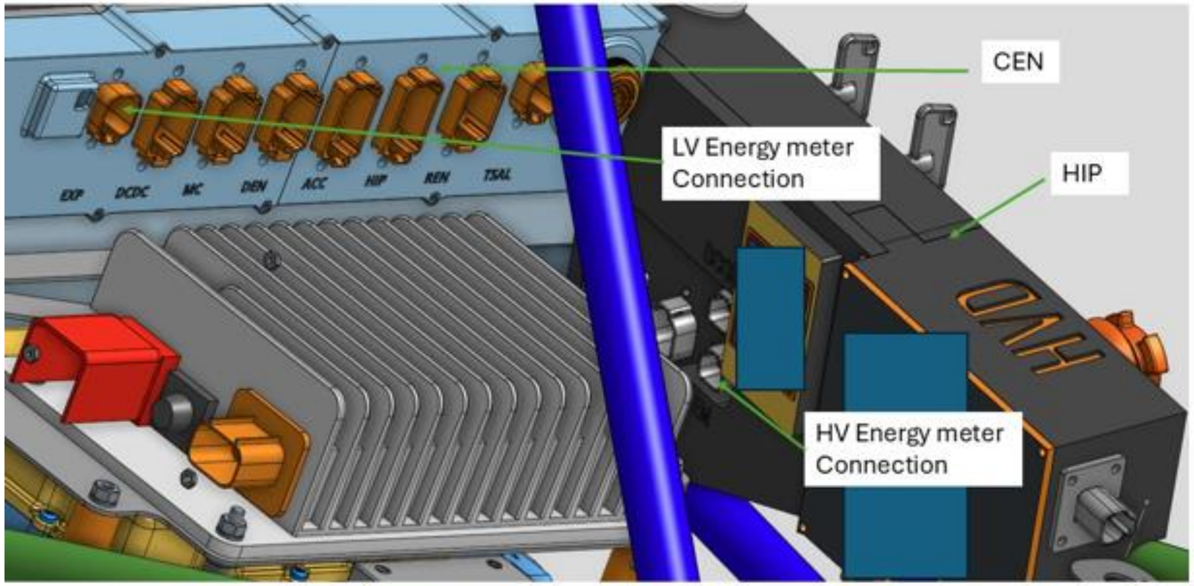
Additional Comments	Rules References
	EV.5.9

Status	OK		
APPS Sensor Transfer function			OK
Rules Reference	T.4.2.3		
Position	APPS1 Output [V]	APPS2 Output [V]	
0%	0.372	0.74	OK
20%	0.711	1.4	OK
40%	1.03	2.06	OK
60%	1.36	2.71	OK
80%	1.69	3.36	OK
100%	2.05	4.09	OK



Torque Control Path Security Checks									OK	
Source Device	Destination Device	Communication	Redundant	Out Of Range	Correlation	Checksum	Timeout	Other		Additional Comments
APPS	Pedal Box ECU	Analog	2 Sensors	Yes	no	no	no		OK	
Pedal Box ECU	DEN	Digital	no	no	no	CAN	Yes		OK	
DEN	CEN	Digital	no	no	no	CAN	Yes		OK	
CEN	Motor Controller	Digital	no	no	no	CAN	Yes		OK	
Motor Controller										

Status	OK					
Motor Controller		OK	**Motor**		OK
Make	Cascadia	OK	Make	Emrax	OK
Model	CM200DX	OK	Model	228 MV	OK
Datasheet	https://www.cascad	OK	Datasheet	https://emrax.com/	OK
Galvanic Isolation between TS and control	1500 V	OK			



Energy Meter Download Picture Shows		OK
Energy Meter Download Connector	TRUE	OK
Additional Comments		

Cost Report

University	University of Newcastle	A/N	E03-20-EL-011000-01	Part Cost	N/A
Competition Code	FSAE-A	System	Electrical System	QTY	N/A
Year	2024	Assembly	CEN	Extended Cost	$ 401.16
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-EL-012001-01	CEN Enclosure	$ 29.20	1	$ 29.20
	E03-20-EL-012002-01	CEN PCB	$ 286.17	1	$ 286.17
	E03-20-EL-012003-01	HFL PCB	$ 29.15	1	$ 29.15
	E03-20-EL-012004-01	BSPD PCB	$ 38.71	1	$ 38.71
Total					$ 383.23

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Assemble, 1 kg, Line-on-Line	Install HFL PCB to CEN PCB	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Line-on-Line	Install BSPD PCB to CEN PCB	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Line-on-Line	Install CEN enclosure lid to CEN PCB	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Hand - Start Only	Hand start screws to secure CEN PCB to enclosure lid	unit	1	Repeat 16	16	None	1	$ 0.12	$ 1.92
	Screwdriver > 1 Turn	Tighten screws to secure CEN PCB to enclosure lid	unit	1	Repeat 16	16	None	1	$ 0.50	$ 8.00
	Assemble, 3 kg, Loose	Install CEN enclosure lid to back of CEN enclosure	unit	1	None	1	None	1	$ 0.19	$ 0.19
	Hand - Start Only	Hand start bolts to secure enclosure lid to enclosure back	unit	1	Repeat 10	10	None	1	$ 0.12	$ 1.20
	Screwdriver > 1 Turn	Tighten bolts to secure enclosure lid to enclosure back	unit	1	Repeat 10	10	None	1	$ 0.50	$ 5.00
	Assemble, 3 kg, Loose	Install CEN assembly to chassis mounts	unit	1	None	1	None	1	$ 0.19	$ 0.19
	Install Tie Wrap (Zip Tie, Cable Clamp)	Install zip ties to fasten CEN to Chassis	unit	1	Repeat 4	4	None	1	$ 0.09	$ 0.36
Total										$ 17.25

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 6.8 (SAE 3) and All Grades less than Metric 8.8	M4 screws to secure Deutsch connectors to enclosure	4	mm	10	mm	16	0.02	0.32
	Bolt, Grade 6.8 (SAE 3) and All Grades less than Metric 8.8	M3 bolts to secure CEN PCB to enclosure	3	mm	38	mm	10	0.02	0.2
	Tie Wrap, Plastic	Zip ties for mounting CEN enclosure to chassis		Unit		0	4	$ 0.04	$ 0.16
Total									$ 0.68

University	University of Newcastle	P/N	E03-20-EL-012001-01	Part Cost	$ 21.13
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	CEN	Extended Cost	$ 21.13
Car #	E03	Part	CEN Enclosure		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG filament for 3D printing	0.52	kg							1	$ 1.72	$ 1.72
Total													$ 1.72

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	Print CEN Enclosure	kg	0.52	None	1	None	1	$ 32.00	$ 16.64
	Assemble, 1 kg, Interference	Pushing in Threaded Inserts	unit	10	None	1	None	1	$ 0.19	$ 1.90
Total										$ 18.54

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Thread Insert, Female Threads, Knurled Type	M5 threaded inserts	5	mm	12	mm	10	0.08784	$ 0.88
Total									$ 0.88

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-012002-01	Part Cost	$ 286.17
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	CEN	Extended Cost	$ 286.17
Car #	E03	Part	CEN PCB		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Connector, OEM Quality, High Power (>2A/25W)	6 Pin Deutsch connectors	6	pin		0					2	$ 6.00	$ 12.00
	Connector, OEM Quality, High Power (>2A/25W)	8 Pin Deutsch connectors	8	pin		0					4	$ 12.00	$ 48.00
	Connector, OEM Quality, High Power (>2A/25W)	12 Pin Deutsch connectors	12	pin		0					2	$ 12.00	$ 24.00
	Connector, General Purpose, Unsealed, Low Power (≤2A/25W)	Serial connector	9	pin		0					1	$ 8.00	$ 8.00
	Printed Circuit Board	CEN PCB	26516.291	mm^2	2	0					1	$ 106.07	$ 106.07
	Simple PCB component	3xCapacitors, 28xResistors, 12xFuse holders, 12xFuse Holders	1	unit		0					55	$ 0.02	$ 1.10
	Fuse, Power	4x10 A Fuse	1	unit		0					4	$ 1.00	$ 4.00
	Fuse, Signal and Control	2x0.5 A Fuse, 3x2 A Fuse, 3x3 A Fuse	1	unit		0					8	$ 0.50	$ 4.00
	Simple Integrated Circuit	LM7805_DPAK, TJA1051T-3	1	Unit		0					2	$ 2.00	$ 4.00
	Development Board, Hobby	Teensy 4.0	1	unit		0					1	$ 20.00	$ 20.00
	Semi-complex PCB component	2x2N7002, 4xIRLB8721PBF, 11xLEDs, 11xDiodes, 11xLEDs	1	unit		0					39	$ 0.05	$ 1.95
	Switch, Toggle	Termination switch	1	unit		0					1	$ 1.00	$ 1.00
	Conformal Coating	Conformal Coating	26516.291	mm^2	2	unit					1	$ 0.07	$ 0.07
Total													$ 234.19

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Solder Paste Apply	Front and Back	unit	1	Repeat 2	2	None	1	$ 1.00	$ 2.00
	Machining Setup, Install and remove	Pick and place set up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Pick and Place	Placement of all components Front	unit	70	None	1	None	1	$ 0.01	$ 0.70
	Machining Setup, Change	Pick and place change for 2nd side	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Circuit Card Assembly Labor - Pick and Place	Placement of all components Back	unit	3	None	1	None	1	$ 0.01	$ 0.03
	Machining Setup, Install and remove	Pick and place machine removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining Setup, Install and remove	Reflow oven set up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Reflow Oven	Reflow oven front side	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Change	Reflow oven change for 2nd side	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Circuit Card Assembly Labor - Reflow Oven	Reflow oven back side	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Install and remove	Reflow oven removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Hand Soldering	Hand solder all through-hole components	unit	8	None	1	None	1	$ 0.05	$ 0.40
	Assemble, 1 kg, Line-on-Line	Install M3 nylon washers to M3 screws	unit	4	Repeat 8	8	None	1	$ 0.13	$ 4.16
	Hand - Start Only	Hand start screws to secure Deutsch connectors to PCB	unit	4	Repeat 8	8	None	1	$ 0.12	$ 3.84
	Screwdriver > 1 Turn	Tighten screws to secure Deutsch connectors to PCB	unit	4	Repeat 8	8	None	1	$ 0.50	$ 16.00
	Circuit Card Assembly Labor - Hand Soldering	Solder Deutsch connectors to board	unit	8	None	1	None	1	$ 0.05	$ 0.40
	Programming, Dataset Upload, End of Line	Programming Teensy 4.0	Unit	1	None	1	None	1	$ 5.00	$ 5.00
	Conformal Coat Apply	Conformal Coat both sides	unit	1	Repeat 2	2	None	1	$ 5.00	$ 10.00
Total										$ 51.03

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Washer, Plastic, PolyAmide	M3 washers for M3 Deutsch connector screws	3	mm		0	32	0.002	0.064
	Bolt, Grade 6.8 (SAE 3) and All Grades less than Metric 8.8	M3 screws to secure Deutsch connectors to PCB	3	mm	18	mm	32	$ 0.02	$ 0.64
Total									$ 0.70

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	PCB Stensil	Stencil for both sides of PCB	0	1	3000	1	$ 700.00	$ 0.23
	PCB component positioning jig	Used for hand positioning and machine placement	0	1	3000	1	$ 50.00	$ 0.02
Total								$ 0.25

University	University of Newcastle	P/N	E03-20-EL-012003-01	Part Cost	$ 29.15
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	CEN	Extended Cost	$ 29.15
Car #	E03	Part	HFL PCB		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Printed Circuit Board	HFL PCB	1342.6943	mm^2	2	0					1	$ 5.37	$ 5.37
	Simple PCB component	28xResistors, 9xCapacitors, 30xIndividual Header Pins and 1xFuse Holder	1	unit		0					68	$ 0.02	$ 1.36
	Fuse, Signal and Control	1x1 A Fuse	1	unit		0					1	$ 0.50	$ 0.50
	Semi-complex PCB component	12xDiodes, 6xLEDs, 6x2N7002	1	unit		0					24	$ 0.05	$ 1.20
	Relay, Signal and Control	1xG5V-2 Relay	1	unit		0					1	$ 2.00	$ 2.00
	Switch, Pushbutton	1xButton	1	unit		0					1	$ 1.00	$ 1.00
	Simple Integrated Circuit	1x555 Timer	1	Unit		0					1	$ 2.00	$ 2.00
	Conformal Coating	Conformal Coating	1342.6943	mm^2	2	unit					1	$ 0.00	$ 0.00
Total													$ 13.43

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Solder Paste Apply		unit	1	Repeat 2	2	None	1	$ 1.00	$ 2.00
	Machining Setup, Install and remove	Pick and place set up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Pick and Place	Placement of all components Front	unit	62	None	1	None	1	$ 0.01	$ 0.62
	Machining Setup, Install and remove	Pick and place machine removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining Setup, Install and remove	Reflow oven set up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Reflow Oven	Reflow oven front side	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Install and remove	Reflow oven removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Hand Soldering	Hand solder all through-hole components and pins	unit	33	None	1	None	1	$ 0.05	$ 1.65
	Conformal Coat Apply	Conformal Coat both sides	unit	1	None	1	None	1	$ 5.00	$ 5.00
Total										$ 15.47

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	PCB Stensil		0	1	3000	1	$ 700.00	$ 0.23
	PCB component positioning jig		0	1	3000	1	$ 50.00	$ 0.02
Total								$ 0.25

University	University of Newcastle	P/N	E03-20-EL-012004-01	Part Cost	$	38.71
Competition Code	FSAE-A	System	Electrical System	QTY		1
Year	2024	Assembly	CEN	Extended Cost	$	38.71
Car #	E03	Part	BSPD PCB			

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Printed Circuit Board	BSPD PCB	857.4	mm^2	2						1	$ 3.43	$ 3.43
	Simple PCB component	31xResistors, 4xCapacitors, 20xIndividual Header Pins,	1	unit							55	$ 0.02	$ 1.10
	Fuse, Signal and Control	1x1 A Fuse	1	unit							1	$ 0.50	$ 0.50
	Semi-complex PCB component	5xDiodes, 5xLEDs, 3xLogic Gates	1	unit							13	$ 0.05	$ 0.65
	Simple Integrated Circuit	5xTLV9301xDBV, 1xMAX6035xxUR50, 3xLM311	1	Unit							9	$ 2.00	$ 18.00
	Conformal Coating	Conformal Coating	857.4	mm^2	2	unit					1	$ -	$ -
Total													$ 23.68

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Solder Paste Apply		unit	1	Repeat 2	2	None	1	$ 1.00	$ 2.00
	Machining Setup, Install and remove	Pick and place set up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Pick and Place	Placement of all components Front	unit	58	None	1	None	1	$ 0.01	$ 0.58
	Machining Setup, Install and remove	Pick and place machine removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining Setup, Install and remove	Reflow oven set up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Reflow Oven	Reflow oven front side	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Install and remove	Reflow oven removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Hand Soldering	Hand solder all through-hole components and pins	unit	20	None	1	None	1	$ 0.05	$ 1.00
	Conformal Coat Apply	Conformal Coat both sides	unit	1	None	1	None	1	$ 5.00	$ 5.00
Total										$ 14.78

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	PCB Stensil		0	1	3000	1	$ 700.00	$ 0.23
	PCB component positioning jig		0	1	3000	1	$ 50.00	$ 0.02
Total								$ 0.25

University	University of Newcastle	A/N	E03-20-EL-021000-01	Part Cost	N/A
Competition Code	FSAE-A	System	Electrical System	QTY	N/A
Year	2024	Assembly	HIP	Extended Cost	$ 425.17
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-EL-022001-01	HIP Enclosure	$ 30.70	1	$ 30.70
	E03-20-EL-022002-01	HIP PCB	$ 140.49	1	$ 140.49
	E03-20-EL-022003-01	TSAL DISCHARGE PCB	$ 90.06	1	$ 90.06
	E03-20-EL-022004-01	HIP Looms	$ 55.56	1	$ 55.56
	E03-20-EL-022005-01	Current Sensor	$ 4.00	1	$ 4.00
	E03-20-EL-022006-01	HV Bus Bars	$ 3.54	1	$ 3.54
	E03-20-EL-022007-01	HVD	$ 15.00	1	$ 15.00
	E03-20-EL-022008-01	2 PIN DT Coil Connector	$ 1.00	1	$ 1.00
	E03-20-EL-022009-01	Master Switch	$ 15.00	2	$ 30.00
	E03-20-EL-022010-01	Hv Surlok Connectors	$ 4.00	1	$ 4.00
Total					$ 374.35

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Assemble, 1 kg, Line-on-Line	Assemble Master Switch to	unit	1	Repeat 2	2	None	1	$ 0.13	$ 0.26
	Assemble, 1 kg, Loose	Assemble Washer onto bac	unit	2	Repeat 2	2	None	1	$ 0.06	$ 0.24
	Hand - Start Only	Assemble nut onto back of	unit	2	Repeat 2	2	None	1	$ 0.12	$ 0.48
	Ratchet <= 25.4 mm	Tighten Nut on back of mas	unit	2	Repeat 2	2	None	1	$ 0.75	$ 3.00
	Assemble, 1 kg, Line-on-Line	Assemble TSAL DISCHARGE	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 3 kg, Line-on-Line	Assemble PCB Assembly to	unit	1	None	1	None	1	$ 0.38	$ 0.38
	Assemble, 1 kg, Loose	M6 Washer onto M6 bolt	unit	2	Repeat 2	2	None	1	$ 0.06	$ 0.24
	Hand - Start Only	Ratchet M6 bolt to fasten H	unit	2	Repeat 2	2	None	1	$ 0.12	$ 0.48
	Ratchet <= 25.4 mm	Hand Start M6 bolt to faste	unit	2	Repeat 2	2	None	1	$ 0.75	$ 3.00
	Assemble, 1 kg, Line-on-Line	Assemble HVD to HIP Enclo	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Loose	Assemble M6 Washer to M	unit	2	None	1	None	1	$ 0.06	$ 0.12
	Hand - Start Only	Hand Start M6 bolt to faste	unit	2	None	1	None	1	$ 0.12	$ 0.24
	Ratchet <= 25.4 mm	Ratchet M6 bolt to fasten H	unit	2	None	1	None	1	$ 0.75	$ 1.50
	Lay Wire	Wrap the Coil loom around	m	0.45	None	1	None	1	$ 0.02	$ 0.01
	Assemble, 1 kg, Line-on-Line	Assemble the Coil Loom to	unit	2	None	1	None	1	$ 0.13	$ 0.26
	Assemble, 1 kg, Line-on-Line	Assemble the 2 PIN DT Coil	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Loose	Assemble M5 Washer to M	unit	4	None	1	None	1	$ 0.06	$ 0.24
	Hand - Start Only	Hand Start M6 bolt to faste	unit	4	None	1	None	1	$ 0.12	$ 0.48
	Ratchet <= 25.4 mm	Ratchet M6 bolt to fasten C	unit	4	None	1	None	1	$ 0.75	$ 3.00
	Lay Wire	Lay the rest of the HIP Loor	m	1	Repeat 3	3	None	1	$ 0.02	$ 0.06
	Assemble, 1 kg, Line-on-Line	Connect Molex Connectors	unit	1	Repeat 3	3	None	1	$ 0.13	$ 0.39
	Assemble, 1 kg, Line-on-Line	Connect Current Sensor Lo	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Line-on-Line	Connect HVD Interlook Loo	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Loose	Bus Bars to HIP Enclosure (t	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Assemble, 1 kg, Loose	Current Sensor to HIP Enclo	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Assemble, 1 kg, Loose	M4 Washer onto M4 Bolt	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Hand - Start Only	Hand Start M4 Bolt to HIP E	unit	1	None	1	None	1	$ 0.12	$ 0.12
	Ratchet <= 6.35 mm	Ratchet M4 Bolt to HIP Encl	unit	1	None	1	None	1	$ 0.50	$ 0.50
	Assemble, 1 kg, Line-on-Line	Assemble Surlok HV Conne	unit	1	Repeat 4	4	None	1	$ 0.13	$ 0.52
	Assemble, 1 kg, Loose	M4 Washer onto M4 Bolt	unit	4	Repeat 4	4	None	1	$ 0.06	$ 0.96
	Hand - Start Only	Hand Start M4 Bolts to Fast	unit	4	Repeat 4	4	None	1	$ 0.12	$ 1.92
	Ratchet <= 6.35 mm	Ratchet M4 Bolt to fasten S	unit	4	Repeat 4	4	None	1	$ 0.50	$ 8.00
	Assemble, 1 kg, Loose	M5 washer to M5 bolt	unit	4	None	1	None	1	$ 0.06	$ 0.24
	Assemble, 1 kg, Loose	Ring Terminals from HV Loc	unit	2	None	1	None	1	$ 0.06	$ 0.12
	Hand - Start Only	Hand Start M5 Bolt to Faste	unit	1	Repeat 4	4	None	1	$ 0.12	$ 0.48
	Ratchet <= 25.4 mm	Ratchet M5 Bolts to Fasten	unit	1	Repeat 4	4	None	1	$ 0.75	$ 3.00
	Assemble, 1 kg, Loose	M12 Washer to M12 Bolt	unit	1	Repeat 2	2	None	1	$ 0.06	$ 0.12
	Hand - Start Only	Hand Start M12 Bolt to Fast	unit	1	Repeat 2	2	None	1	$ 0.12	$ 0.24
	Ratchet <= 25.4 mm	Ratchet M12 Bolt to fasten	unit	1	Repeat 2	2	None	1	$ 0.75	$ 1.50
	Assemble, 1 kg, Loose	Assemble HIP Enclosure Lic	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Assemble, 1 kg, Loose	M4 Washer onto M4 Bolt	unit	1	Repeat 9	9	None	1	$ 0.06	$ 0.54
	Hand - Start Only	Hand Start M4 Bolt Fastenir	unit	1	Repeat 9	9	None	1	$ 0.12	$ 1.08
	Ratchet <= 6.35 mm	Ratchet M4 Bolt to Fasten L	unit	1	Repeat 9	9	None	1	$ 0.50	$ 4.50
	Hand - Start Only	Hand Start Screws to faster	unit	2	Repeat 4	4	None	1	$ 0.12	$ 0.96
	Screwdriver > 1 Turn	Screw screws to fasten DT's	unit	2	Repeat 4	4	None	1	$ 0.50	$ 4.00
	Assemble, 5 kg, Loose	Assemble Assembled HIP t	unit	1	None	1	None	1	$ 0.31	$ 0.31
	Install Tie Wrap (Zip Tie, Cabl	Install Zip ties to HIP to atta	unit	4	None	1	None	1	$ 0.09	$ 0.36
Total										$ 44.74

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Washer, Brass	Washers for Master Switch	8	mm		0	4	$ 0.01	$ 0.09
	Nut, Brass	Nuts for Master Switches	8	mm		0	4	$ 0.03	$ 0.28
	Washer, Grade 12.9	Washers for Master Switch	6	mm		0	4	$ 0.01	$ 0.07
	Bolt, Grade 12.9	Bolt for Master Switches	6	mm	20	mm	4	$ 0.07	$ 0.43
	Washer, Grade 12.9	Washers for Coil DT Connec	5	mm		0	8	$ 0.01	$ 0.05
	Bolt, Grade 12.9	Bolt for Coil DT Connector a	5	mm	15	mm	8	$ 0.04	$ 0.21
	Washer, Grade 12.9	Washer for Current Sensor	4	mm		0	17	$ 0.01	$ 0.03
	Bolt, Grade 12.9	Bolt for Current Sensor and	4	mm	15	mm	17	$ 0.03	$ 0.12
	Washer, Grade 12.9	Washer for HVD Bus Bar	12	mm		0	2	$ 0.03	$ 0.42
	Bolt, Grade 12.9	Bolt for HVD Bus Bar	12	mm	15	mm	2	$ 0.33	$ 3.95
	Washer, Grade 12.9	Washer for HIP Enclosure Li	4	mm		0	9	$ 0.01	$ 0.03
	Bolt, Grade 12.9	Bolt for HIP Enclosure Lid	4	mm	20	mm	9	$ 0.03	$ 0.14
	Bolt, Grade 6.8 (SAE 3) and Al	Phillips Head Screw	4	mm	18	mm	8	$ 0.02	$ 0.10
	Tie Wrap, Plastic	Zip tie for HIP	4	Unit		0		$ 0.04	$ 0.16
Total									$ 6.08

University	University of Newcastle	P/N	E03-20-EL-022001-01	Part Cost	$ 30.70
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	HIP	Extended Cost	$ 30.70
Car #	E03	Part	HIP Enclosure		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, UL94 Compliant, Any Compositi	FR-ABS Filament for 3D prir	0.65	kg							1	$ 10.00	$ 6.50
Total													$ 6.50

Processes / Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	Print HIP Enclosure	kg	0.65	None	1	None	1	$ 32.00	$ 20.80
	Assemble, 1 kg, Interference	Pushing in Threaded Insert	unit	10	None	1	None	1	$ 0.19	$ 1.90
	Assemble, 1 kg, Interference	Pushing in Threaded Insert	unit	4	None	1	None	1	$ 0.19	$ 0.76
Total										$ 23.46

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Thread Insert, Female Threads, Knurled	Inserts for Lip Fastening	3	mm	3	mm	10	$ 0.04	$ 0.39
	Thread Insert, Female Threads, Knurled	Inserts for Part Fastening	5	mm	12	mm	4	$ 0.09	$ 0.35
Total									$ 0.74

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-022002-01	Part Cost	$ 141.49
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	HIP	Extended Cost	$ 141.49
Car #	E03	Part	HIP PCB		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Printed Circuit Board	HIP PCB	21978.1233	mm^2	2	0					1	$ 87.91	$ 87.91
	Connector, OEM Quality, High Power (>	DCDC HV and Energy Meter Connectors	2	pin		0					2	$ 0.50	$ 1.00
	Connector, OEM Quality, High Power (>	DCDC LV Connector	6	pin		0					1	$ 0.50	$ 0.50
	Connector, OEM Quality, High Power (>	Motherboard connector	12	pin		0					1	$ 0.50	$ 0.50
	Simple PCB component	Resistors and Capacitors,. Header pin	30	unit		0					12	$ 0.02	$ 0.24
	Semi-complex PCB component	Diodes	7	unit		0					7	$ 0.05	$ 0.35
	Simple Integrated Circuit	Voltage Regulator	1	Unit		0					1	$ 2.00	$ 2.00
	Fuse, Power	60A LV	1	unit		0					1	$ 1.00	$ 1.00
	Fuse, Power		1	unit		0					1	$ 1.00	$ 1.00
	Fuse, Power	4A HV	1	unit		0					1	$ 1.00	$ 1.00
	Connector, General Purpose, Unsealed,	2x2 Molex MircoFit	4	pin		0					2	$ 2.00	$ 4.00
	Connector, General Purpose, Unsealed,	2x1 Molex MicroFit	2	pin		0					1	$ 2.00	$ 2.00
	Connector, General Purpose, Unsealed,	Banana Jack Test Point	4	pin		0					5	$ 1.00	$ 5.00
	Conformal Coating		21978.1233	mm^2	2	unit					1	$ 0.06	$ 0.06
Total													$ 106.56

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Solder Paste Apply	Front and Back	unit	1	Repeat 2	2	None	1	$ 1.00	$ 2.00
	Machining Setup, Install and remove	Pick and Place Setup	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Pick and P	Placement of all components Front	unit	13	None	1	None	1	$ 0.01	$ 0.13
	Machining Setup, Change	Pick and place change for 2nd side	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Circuit Card Assembly Labor - Pick and P	Placement of all components Back	unit	7	None	1	None	1	$ 0.01	$ 0.07
	Machining Setup, Install and remove	Pick and place machine removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining Setup, Install and remove	Reflow oven set up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Reflow O	Reflow oven front side	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Change	Reflow oven change for 2nd side	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Circuit Card Assembly Labor - Reflow O	Reflow oven back side	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Install and remove	Removal From Reflow Oven	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Hand Solc	Hand solder remaining components	unit	26	None	1	None	1	$ 0.05	$ 1.30
	Assemble, 1 kg, Loose	M3 Washer to M3 Screw for Deutsch Connectors	unit	4	Repeat 4	4	None	1	$ 0.06	$ 0.96
	Hand - Start Only	Hand start screws to secure Deutsch connectors to PCB	unit	4	Repeat 4	4	None	1	$ 0.12	$ 1.92
	Hand - Start Only	Hand start screws to secure 60A Fuse to PCB	unit	2	None	1	None	1	$ 0.12	$ 0.24
	Screwdriver > 1 Turn	Tighten screws to secure Deutsch connectors to PCB	unit	4	Repeat 4	4	None	1	$ 0.50	$ 8.00
	Screwdriver > 1 Turn	Tighten screws to secure 60A Fuse to PCB	unit	2	None	1	None	1	$ 0.50	$ 1.00
	Circuit Card Assembly Labor - Hand Solc	Solder Deutsch connectors to board	unit	4	None	1	None	1	$ 0.05	$ 0.20
	Conformal Coat Apply	Conformal Coat both sides	unit	1	Repeat 2	2	None	1	$ 5.00	$ 10.00
Total										$ 34.32

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Washer, Plastic, PolyAmide	M3 Screws to Secure Deutsch Connectors to PCB	3	mm		0	16	$ 0.02	$ 0.32
	Bolt, Grade 6.8 (SAE 3) and All Grades le	M3 Washer for Screws	3	mm	18	mm	16	$ 0.00	$ 0.04
Total									$ 0.36

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	PCB Stensil		0	1	3000	1	$ 700.00	$ 0.23
	PCB component positioning jig		0	1	3000	1	$ 50.00	$ 0.02
Total								$ 0.25

University	University of Newcastle	P/N	E03-20-EL-022003-01	Part Cost	$ 90.06
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	HIP	Extended Cost	$ 90.06
Car #	E03	Part	TSAL DISCHARGE PCB		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Printed Circuit Board	TSAL DISCHARGE PCB	3198.0624	mm^2	2	0					1	$ 12.79	$ 12.79
	Simple PCB component	Resistors and Capacitors, Header Pins, Fuse Holder	1	unit		0					40	$ 0.02	$ 0.80
	Semi-complex PCB component	Diodes, MOSFET	1	unit		0					3	$ 0.05	$ 0.15
	Simple Integrated Circuit	SE555D, LM311, 4N35, SPAN02A-12	1	Unit		0					6	$ 2.00	$ 12.00
	Relay, Power	DBT71210	1	unit		0					1	$ 4.00	$ 4.00
	Resistor, High Power, Precharge/Discha	Power Resistor	1	unit		0					1	$ 40.00	$ 40.00
	Heat Exchanger, Air-to-Air	Heat Sink	3.375	cm^3		0					1	$ 0.00	$ 0.00
	Fuse, Power		1	unit		0					1	$ 1.00	$ 1.00
Total													$ 70.74

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Solder Paste Apply	Front	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Install and remove	Pick and Place Setup	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Pick and F	Placement of all components Front	unit	33	None	1	None	1	$ 0.01	$ 0.33
	Machining Setup, Install and remove	Pick and Place Removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining Setup, Install and remove	Reflow Oven Set Up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Reflow O	Reflow Oven Front	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Install and remove	Removal from Reflow Oven	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Hand Solc	Hand Solder remaining components	unit	18	None	1	None	1	$ 0.05	$ 0.90
	Hand - Start Only	Hand Start Screw to secure Heat Sink to Power Resis	unit	1	None	1	None	1	$ 0.12	$ 0.12
	Screwdriver > 1 Turn	Tighten Screw	unit	1	None	1	None	1	$ 0.50	$ 0.50
	Conformal Coat Apply	Conformal Coat both side	unit	1	Repeat 2	2	None	1	$ 5.00	$ 10.00
Total										$ 19.05

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 12.9	M3 Screw to secure Heat Sink to Power Resistor	3	mm	10	mm	1	$ 0.02	$ 0.02
Total									$ 0.02

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	PCB Stensil			0	1	3000	1 $ 700.00	$ 0.23
	PCB component positioning jig			0	1	3000	1 $ 50.00	$ 0.02
Total								$ 0.25

University	University of Newcastle	P/N	E03-20-EL-022004-01	Part Cost	$ 55.56
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	HIP	Extended Cost	$ 55.56
Car #	E03	Part	HIP Looms		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Heat Shrink Tubing	Heat Shrink for Each Loom	0.45	m		0					3	$ 0.50	$ 1.50
	Wire, Signal and Control	HVD Interlock (2 wires), Coil wire (1 wire) and Current sensor (3 wires)	0.5	m		0					6	$ 1.00	$ 6.00
	Wire, HV Signal	TS Voltage for HIP	0.5	m		0					2	$ 5.00	$ 10.00
	Connector, General Purpose, Unsealed,	2x2 Molex MircoFit	4	pin		0					2	$ 2.00	$ 4.00
	Connector, General Purpose, Unsealed,	2x1 Molex MircoFit	2	pin		0					1	$ 2.00	$ 2.00
	Connector, General Purpose, Unsealed,	4x1 Molex MircoFit	4	pin		0					1	$ 2.00	$ 2.00
	Connector, General Purpose, Unsealed,	HVD Interlock	2	pin		0					1	$ 2.00	$ 2.00
	Connector, Single Wire	Ring Terminals	2	Unit		0					2	$ 0.05	$ 0.10
Total													$ 27.60

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cutting wires to length	unit	1	Repeat 8	8	None	1	$ 0.08	$ 0.64
	Strip Wire	Strip Both ends of all the wires	unit	2	Repeat 8	8	None	1	$ 0.08	$ 1.28
	Insert Bundle Into Tube or Sleeve	Insert looms into heat shrink	m	0.45	Repeat 3	3	None	1	$ 0.02	$ 0.03
	Connector Assembly, Crimp	Crimp DT pins onto Coil wire	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Connector Assembly, Crimp	Molex Pin Crimps Current Sensor Loom, Both Ends	contact	2	Repeat 3	3	None	1	$ 0.36	$ 2.16
	Connector Assembly, Crimp	Molex Pin Crimp HV Loom 1 side	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Connector Assembly, Crimp	Molex Pin Crimp HVD Interlock Loom 1 side	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Connector Assembly, Crimp	HVD Interlock Connector crimped onto other side of HVD loom	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Connector Assembly, Crimp	Ring Terminals Crimped to the ends of the HV loom	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Shrink Tube	Heat Shrink HVD, HV and Current Sensor loom	cm	45	Repeat 3	3	None	1	$ 0.15	$ 20.25
Total										$ 27.96

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
						#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
								$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-022004-01	Part Cost	$ 4.00
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	HIP	Extended Cost	$ 4.00
Car #	E03	Part	Current Sensor		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Sensor, Hall Effect	L31S100S05FS	1	unit		0					1	$ 4.00	$ 4.00
Total													$ 4.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
										$ -
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-022006-01	Part Cost	$ 3.54
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	HIP	Extended Cost	$ 3.54
Car #	E03	Part	HV Bus Bars		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Copper (by Dimensions)	4 mm plate (for Positive and Negative Bus Bar, and Positive Current Side Bus Bar)		kg		0	130 x 46 mm plate	5980	4	8940	1	$ 2.20	$ 0.47
Total													**$ 0.47**

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Machining Setup, Install and remove	Set up waterjet cutter	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Waterjet Cut	Waterjet cut the Positive and Negative Bus Bar, and Positive Current Side Bus E	cm	77.26313	None	1	None	1	$ 0.01	$ 0.77
	Sheet metal bends	Bend the Positive Bus Bar	bend	2	None	1	None	1	$ 0.25	$ 0.50
	Sheet metal bends	Bend the Postive Current Bar	bend	2	None	1	None	1	$ 0.25	$ 0.50
Total										**$ 3.07**

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-022007-01	Part Cost	$ 15.00
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	HIP	Extended Cost	$ 15.00
Car #	E03	Part	HVD		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Switch, Master Disconnect	High Voltage Disconnect		1 unit			0				1	$ 15.00	$ 15.00
Total													$ 15.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-022008-01	Part Cost	$ 1.00
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	HIP	Extended Cost	$ 1.00
Car #	E03	Part	2 PIN DT Coil Connector		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Connector, OEM Quality, Low Power (≤	Panel Mount Deutsch Sock	2	pin		0					1	$ 1.00	$ 1.00
Total													$ 1.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-022009-01	Part Cost	$ 30.00
Competition Code	FSAE-A	System	Electrical System	QTY	2
Year	2024	Assembly	HIP	Extended Cost	$ 60.00
Car #	E03	Part	Master Switch		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Switch, Master Disconnect	Master Switches for LV and	1	unit							2	$ 15.00	$ 30.00
Total													$ 30.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-022009-01	Part Cost	$ 4.00
Competition Code	FSAE-A	System	Electrical Systems	QTY	1
Year	2024	Assembly	HIP	Extended Cost	$ 4.00
Car #	E03	Part	HV Surlok Connectors		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Connector, OEM Quality, Low Power (≤	Surlok 5.7 mm Panel Moun	1	pin							1	$ 1.00	$ 1.00
	Connector, OEM Quality, Low Power (≤	Surlok 5.7 mm Panel Moun	1	pin							1	$ 1.00	$ 1.00
	Connector, OEM Quality, Low Power (≤	Surlok 8.0 mm Panel Moun	1	pin							1	$ 1.00	$ 1.00
	Connector, OEM Quality, Low Power (≤	Surlok 8.0 mm Panel Moun	1	pin							1	$ 1.00	$ 1.00
Total													$ 4.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	A/N	E03-20-EL-031000-01	Part Cost	N/A
Competition Code	FSAE-A	System	Electrical System	QTY	N/A
Year	2024	Assembly	DEN	Extended Cost	$ 1,812.62
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-EL-032001-01	DEN Enclosure	$ 11.15	1	$ 11.15
	E03-20-EL-032002-01	DEN Enclosure Standoff	$ 12.67	1	$ 12.67
	E03-20-EL-032003-01	DEN PCB	$ 211.81	1	$ 211.81
	E03-20-EL-032004-01	MoTeC C125 Display	$ 1,555.00	1	$ 1,555.00
	E03-20-EL-032005-01	Inertia Switch	$ 3.00	1	$ 3.00
	E03-20-EL-032006-01	Ethernet Cover	$ 1.30	1	$ 1.30
	E03-20-EL-032007-01	Rotary Knobs	$ 0.64	1	$ 0.64
	E03-20-EL-032008-01	E-stop	$ 3.00	1	$ 3.00
Total					$ 1,798.57

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Assemble, 1 kg, Loose	Assemble DEN PCB to backplate of DEN enclosure	unit	1	None	1		1	$ 0.06	$ 0.06
	Hand - Start Only	Hand Start screw to fasten Deutsch Connectors and DEN enclosure back plate	unit	2	Repeat 5	5		1	$ 0.12	$ 1.20
	Screwdriver > 1 Turn	Tighten Deutsch connectors to DEN enclosure	unit	2	Repeat 5	5		1	$ 0.50	$ 5.00
	Assemble, 1 kg, Line-on-Line	Place DEN enclosure backplate onto DEN enclosure frontplate	unit	1	None	1		1	$ 0.13	$ 0.13
	Assemble, 1 kg, Line-on-Line	Attach E-stop DEN enclosure frontplate	unit	1	None	1		1	$ 0.13	$ 0.13
	Connector Assembly, Solder	Solder E-stop on to DEN PCB	contact	6	None	1		1	$ 0.24	$ 1.44
	Hand - Start Only	Hand Start Stand off for MoTeC Dash Bolts	unit	1	Repeat 3	3		1	$ 0.12	$ 0.36
	Hand, Loose <= 6.35 mm	Hand Loose the stand off for the MoTeC Dash Bolts	unit	1	Repeat 3	3		1	$ 0.25	$ 0.75
	Assemble, 1 kg, Line-on-Line	Mount MoTec C125 Display to frontplate DEN enclosure	unit	1	None	1		1	$ 0.13	$ 0.13
	Hand - Start Only	Hand Start M6 bolts to fasten MoTeC Dash to DEN Enclosure	unit	1	Repeat 3	3		1	$ 0.12	$ 0.36
	Ratchet <= 6.35 mm	Ratchet M6 bolts to fasten MoTeC Dash to DEN Enclosure	unit	1	Repeat 3	3		1	$ 0.50	$ 1.50
	Assemble, 1 kg, Line-on-Line	Assemble DEN Enclosure Standoff to DEN Enclosure	unit	1	None	1		1	$ 0.13	$ 0.13
	Assemble, 1 kg, Line-on-Line	M6 Washer to M6 Bolt	unit	1	Repeat 2	2		1	$ 0.13	$ 0.26
	Hand - Start Only	Hand Start the bolt to fasten the DEN Enclosure to the DEN Enclosure Standof	unit	1	Repeat 2	2		1	$ 0.12	$ 0.24
	Ratchet <= 6.35 mm	Ratchet M6 bolts to fasten DEN Enclosure to the DEN Enclosure Standoff	unit	1	Repeat 2	2		1	$ 0.50	$ 1.00
	Assemble, 1 kg, Line-on-Line	Assemble Rotary Knobs and Ethernet Cover to DEN Enclosure	unit	1	None	1		1	$ 0.13	$ 0.13
	Assemble, 1 kg, Loose	Assemble DEN Enclosure Standoff to Chassis	unit	1	None	1		1	$ 0.06	$ 0.06
	Install Tie Wrap (Zip Tie, Cable Clamp)	Install Zip Tie to the DEN Enclosure Standoff to attach it to the Chassis	unit	4	None	1		1	$ 0.09	$ 0.36
	Install Tie Wrap (Zip Tie, Cable Clamp)	Install Zip tie to Inertia Switch to attach it to the back of the Steering Gearbox	unit	1	None	1		1	$ 0.09	$ 0.09
Total										$ 13.33

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 6.8 (SAE 3) and All Grades les	Screws to secure Deutsch Connectors	3	mm	10	mm	10	$ 0.00	$ 0.02
	Washer, Grade 12.9	M6 washer	6	mm		0	2	$ 0.01	$ 0.02
	Bolt, Grade 12.9	Bolts to secure MoTeC to DEN enclosure	6	mm	18	mm	3	$ 0.07	$ 0.20
	Bolt, Grade 12.9	M6 Bolts	6	mm	30	mm	2	$ 0.10	$ 0.21
	Standoff, Electrical and Circuit Board, Ste	Threaded for bolts for the MoTeC dash	6	mm		0	3	$ 0.09	$ 0.26
Total									$ 0.72

University	University of Newcastle	P/N	E03-20-EL-032001-01	Part Cost	$ 11.15
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	DEN	Extended Cost	$ 11.15
Car #	E03	Part	DEN enclosure		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG Filament for 3D Printing	0.316	kg		0					1	$ 3.30	$ 1.04
Total													$ 1.04

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	Print DEN Enclosure	kg	0.316	None	1	None	1	$ 32.00	$ 10.11
Total										$ 10.11

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-032002-01	Part Cost	$ 12.67
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	DEN	Extended Cost	$ 12.67
Car #	E03	Part	DEN Enclosure Standoff		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG Filament for 3D Printing	0.344	kg							1	$ 3.30	$ 1.14
Total													$ 1.14

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	Print DEN Enclosure Standoff	kg	0.344	None	1	None	1	$ 32.00	$ 11.01
	Assemble, 1 kg, Interference	Pushing in Threaded Inserts	unit	2	None	1	None	1	$ 0.19	$ 0.38
Total										$ 11.39

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Thread Insert, Female Threads, Knurled	M5 Inserts for Standoff fastening	5	mm	12	mm	2	$ 0.07	$ 0.14
Total									$ 0.14

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-032003-01	Part Cost	$ 211.81
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	DEN	Extended Cost	$ 211.81
Car #	E03	Part	DEN PCB		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Printed Circuit Board	DEN Printed Circuit Board	19003.4833	mm^2	2	0					1	$106.07	$ 106.07
	Simple PCB component	Resistors and Capacitors, Header Pins, Fuse Holder	1	unit		0					30	$ 0.02	$ 0.60
	Semi-complex PCB component	Diodes and MOSFET	1	unit		0					18	$ 0.95	$ 17.10
	Simple Integrated Circuit	LM7805, TJA1051T	1	Unit		0					2	$ 2.00	$ 4.00
	Relay, Power	DTI5-4P	1	unit		0					1	$ 1.00	$ 1.00
	Development Board, Hobby	Teensy 4.0	1	unit		0					1	$ 20.00	$ 20.00
	Connector, OEM Quality, High Power (>2A/25W	MOTEC - DT15-12PA	12	pin		0					1	$ 2.00	$ 2.00
	Connector, OEM Quality, High Power (>2A/25W	SENSORS - DT15-4P	4	pin		0					1	$ 2.00	$ 2.00
	Connector, OEM Quality, High Power (>2A/25W	GPS + TELEM - DT15-6P	6	pin		0					1	$ 2.00	$ 2.00
	Connector, OEM Quality, High Power (>2A/25W	PEN, CEN - DT15-08PA	8	pin		0					2	$ 2.00	$ 4.00
	Connector, OEM Quality, Low Power (≤2A/25W	ETHERNET - RJSSEPFFPLC7002	10	pin		0					1	$ 1.00	$ 1.00
	Switch, Pushbutton	MOTEC, RTD	1	unit		0					2	$ 1.00	$ 2.00
	Switch, Rotary Multi-position Selector	Rotary Switch	1	unit		0					2	$ 3.00	$ 6.00
	Switch, Toggle	DIP Switch for CAN Termination	1	unit		0					1	$ 1.00	$ 1.00
	Conformal Coating		19003.4833	mm^2	2	unit					1	$ 0.05	$ 0.05
Total													$ 168.82

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Solder Paste Apply	Front and back	unit	1	Repeat 2	2	None	1	$ 1.00	$ 2.00
	Machining Setup, Install and remove	Pick and Place Setup	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Pick and Place	Placement of all components Front	unit	1	Repeat 25	25	None	1	$ 0.01	$ 0.25
	Machining Setup, Change	Pick and Place change for 2nd side	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Circuit Card Assembly Labor - Pick and Place	Placement of all components Back	unit	1	Repeat 24	24	None	1	$ 0.01	$ 0.24
	Machining Setup, Install and remove	Pick and Place Removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining Setup, Install and remove	Reflow Oven Set Up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Reflow Oven	Reflow Oven Front Side	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Change	Reflow Oven change for 2nd side	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Circuit Card Assembly Labor - Reflow Oven	Reflow Oven Back Side	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Install and remove	Removal from Reflow Oven	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Hand Soldering	Hand Solder Remaining components	unit	1	Repeat 25	25	None	1	$ 0.05	$ 1.25
	Assemble, 1 kg, Line-on-Line	Assemble M3 Nylon Washer onto M3 Screw	unit	4	Repeat 5	5	None	1	$ 0.13	$ 2.60
	Hand - Start Only	Hand Start Screws to secure Deutsch connectors to PCB	unit	4	Repeat 5	5	None	1	$ 0.12	$ 2.40
	Screwdriver > 1 Turn	Tighten Screws to secure Deutsch connectors to PCB	unit	4	Repeat 5	5	None	1	$ 0.50	$ 10.00
	Circuit Card Assembly Labor - Hand Soldering	Solder Deutsch connectors to board	unit	1	Repeat 5	5	None	1	$ 0.05	$ 0.25
	Programming, Dataset Upload, End of Line	Program Teensy 4.0	Unit	1	None	1	None	1	$ 5.00	$ 5.00
	Conformal Coat Apply	Conformal Coat both side	unit	1	Repeat 2	2	None	1	$ 5.00	$ 10.00
Total										$ 42.49

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 6.8 (SAE 3) and All Grades less than	M3 Screws to Secure Deutsch Connectors to PCB	3	mm	18	mm	20	$ 0.01	$ 0.20
	Washer, Plastic, PolyAmide	M3 Nylon Washer	3	mm		0	20	$ 0.00	$ 0.05
Total									$ 0.26

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	PCB Stensil		0	1	3000	1	$700	$ 0.23
	PCB component positioning jig		0	1	3000	1	$50	$0
Total								$ 0.25

University	University of Newcastle	P/N	E03-20-EL-032004-01	Part Cost	$ 1,555.00
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	DEN	Extended Cost	$ 1,555.00
Car #	E03	Part	MoTeC C125 Display		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Datalogger, Motec, C125	Dash display with data logger		unit		0					1	$ 1,555.00	$ 1,555.00
Total													$ 1,555.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
										$ -
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-032005-01	Part Cost	$ 3.00
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	DEN	Extended Cost	$ 3.00
Car #	E03	Part	Inertia Switch		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Switch, Kill	Inertia Switch	1	unit		0					1	$ 3.00	$ 3.00
Total													$ 3.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
										$ -
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle		P/N	E03-20-EL-032006-01		Part Cost	$ 1.30
Competition Code	FSAE-A		System	Electrical System		QTY	1
Year	2024		Assembly	DEN		Extended Cost	$ 1.30
Car #	E03		Part	Ethernet Cover			

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG Filament for 3D Printing	0.0368	kg		0					1	$ 3.30	$ 0.12
Total													$ 0.12

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	Printing Ethernet Cover	kg	0.0368	None	1	None	1	$ 32.00	$ 1.18
Total										$ 1.18

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-032007-01	Part Cost	$ 0.64
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	DEN	Extended Cost	$ 0.64
Car #	E03	Part	Rotary Knobs		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG Filament for 3D Printi	0.009	kg		0					2	$ 3.30	$ 0.06
Total													$ 0.06

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	Printing Rotary Knobs	kg	0.009	Repeat 2	2	None	1	$ 32.00	$ 0.58
Total										$ 0.58

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-032008-01	Part Cost	$ 3.00
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	DEN	Extended Cost	$ 3.00
Car #	E03	Part	E-Stop		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Switch, Kill	E-Stop for Dash		unit		0					1	$ 3.00	$ 3.00
Total													$ 3.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
										$ -
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	A/N	E03-20-EL-041000-01	Part Cost	N/A		
Competition Code	FSAE-A	System	Electrical System	QTY	N/A		
Year	2024	Assembly	PEN	Extended Cost	$	154.31	
Car #	E03	Part	N/A				

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-EL-042001-01	PEN Enclosure	$ 3.79	1	$ 3.79
	E03-20-EL-042002-01	PEN PCB	$ 142.87	1	$ 142.87
Total					$ 146.66

Processes / Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Assemble, 1 kg, Line-on-Line	Install PEN PCB to PEN enclosure lid	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Hand - Start Only	Hand start screws to secure PEN PCB to enclosure lid	unit	1	Repeat 12	12	None	1	$ 0.12	$ 1.44
	Screwdriver > 1 Turn	Tighten screws to secure PEN PCB to enclosure lid	unit	1	Repeat 12	12	None	1	$ 0.50	$ 6.00
	Assemble, 1 kg, Loose	Install PEN enclosure lid to back of PEN enclosure	unit	1	None	1	None	1	$ 0.06	$ 0.06
		Rest of PEN assembly completed within PEDAL BOX assembly - E03-20-FR-021000-01								
Total										$ 7.63

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 6.8 (SAE 3) and All Grades less than Metric 8.8	M4 bolts to secure enclosure lid to PEN PCB	4	mm	18	mm	1	$ 0.02	$ 0.02
Total									$ 0.02

University	University of Newcastle	P/N	E03-20-EL-042001-01	Part Cost	$ 3.79
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	PEN	Extended Cost	$ 3.79
Car #	E03	Part	PEN Enclosure		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG Filament for 3D printing	0.117	kg							1	0.3861	0.0451737
Total													$ 0.05

Processes / Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	Print PEN Enclosure	kg	0.117	None	1	None	1	$ 32.00	$ 3.74
Total										$ 3.74

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None								
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-042002-01	Part Cost	$ 142.87
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	PEN	Extended Cost	$ 142.87
Car #	E03	Part	PEN PCB		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Simple PCB component	28xResistors, 7xCapacitors, 2xFuse holders	1	unit		0					37	$ 0.02	$ 0.81
	Semi-complex PCB component	10xDiodes, 5xLEDs	1	unit		0					15	$ 0.05	$ 0.75
	Connector, OEM Quality, High Power (>2A/25W)	2 Pin Deutsch connector	2	pin		0					1	$ 2.00	$ 2.00
	Connector, OEM Quality, High Power (>2A/25W)	8 Pin Deutsch connector	8	pin		0					1	$ 8.00	$ 8.00
	Connector, OEM Quality, High Power (>2A/25W)	12 Pin Deutsch connector	12	pin		0					1	$ 12.00	$ 12.00
	Fuse, Signal and Control	2x2 A Fuses	1	unit		0					2	$ 0.50	$ 1.00
	Simple Integrated Circuit	1xTJA1051T-3, 1xLM7805_DPAK, 1xMCP6002-xSN, 3xLM39	1	Unit		0					6	$ 2.00	$ 12.00
	Development Board, Hobby	Teensy 4.0	1	unit		0					1	$ 20.00	$ 20.00
	Connector, General Purpose, Unsealed, Low Power (≤2A/25W)	Serial connector	9	pin		0					1	$ 18.00	$ 18.00
	Switch, Toggle	Termination switch	1	unit		0					1	$ 1.00	$ 1.00
	Printed Circuit Board	PEN PCB	7823.05249	mm^2	2	0					1	$ 31.29	$ 31.29
	Conformal Coating		7823.05249	mm^2	2	unit					1	$ 0.02	$ 0.02
Total													$ 106.87

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Solder Paste Apply	Front and Back	unit	1	Repeat 2	2	None	1	$ 1.00	$ 2.00
	Machining Setup, Install and remove	Pick and place set up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Pick and Place	Placement of all components Front	unit	3	None	1	None	1	$ 0.01	$ 0.03
	Machining Setup, Change	Pick and place change for 2nd side	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Circuit Card Assembly Labor - Pick and Place	Placement of all components Back	unit	55	None	1	None	1	$ 0.01	$ 0.55
	Machining Setup, Install and remove	Pick and place machine removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Machining Setup, Install and remove	Reflow oven set up	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Reflow Oven	Reflow oven front side	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Change	Reflow oven change for 2nd side	unit	1	None	1	None	1	$ 0.65	$ 0.65
	Circuit Card Assembly Labor - Reflow Oven	Reflow oven back side	unit	1	None	1	None	1	$ 1.00	$ 1.00
	Machining Setup, Install and remove	Reflow oven removal	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Circuit Card Assembly Labor - Hand Soldering	Hand solder all through-hole components	unit	5	None	1	None	1	$ 0.05	$ 0.25
	Assemble, 1 kg, Line-on-Line	Install M3 nylon washers to M3 screws	unit	4	Repeat 3	3	None	1	$ 0.13	$ 1.56
	Hand - Start Only	Hand start screws to secure Deutsch connectors to PCB	unit	4	Repeat 3	3	None	1	$ 0.12	$ 1.44
	Screwdriver > 1 Turn	Tighten screws to secure Deutsch connectors to PCB	unit	4	Repeat 3	3	None	1	$ 0.50	$ 6.00
	Circuit Card Assembly Labor - Hand Soldering	Solder Deutsch connectors to board	unit	3	None	1	None	1	$ 0.05	$ 0.15
	Programming, Dataset Upload, End of Line	Program Teensy 4.0	Unit	1	None	1	None	1	$ 5.00	$ 5.00
	Conformal Coat Apply	Conformal Coat both sides	unit	1	Repeat 2	2	None	1	$ 5.00	$ 10.00
Total										$ 35.48

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Washer, Plastic, PolyAmide	M3 washers for M3 Deutsch connector screws	3	mm		0	12	0.002	0.024
	Bolt, Grade 6.8 (SAE 3) and All Grades less than Metric 8.8	M3 screws to secure Deutsch connectors to PCB	3	mm	18	mm	12	$ 0.02	0.24
Total									$ 0.26

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	PCB Stensil	Stencil for both sides of PCB	0	1	3000	1	$ 700.00	$ 0.23
	PCB component positioning jig	Used for hand positioning and machine placement	0	1	3000	1	$ 50.00	$ 0.02
Total								$ 0.25

University	University of Newcastle	A/N	E03-20-EL-051000-01	Part Cost	N/A
Competition Code	FSAE-A	System	Electrical System	QTY	N/A
Year	2024	Assembly	UEN	Extended Cost	$ 49.48
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-EL-052001-01	TSAL	$ 17.21	1	$ 17.21
	E03-20-EL-052002-01	UEN E-Stop	$ 3.00	2	$ 6.01
	E03-20-EL-052003-01	E-Stop Enclosure Right	$ 2.95	1	$ 2.95
	E03-20-EL-052004-01	E-Stop Enclosure Left	$ 5.06	1	$ 5.06
	E03-20-EL-052005-01	E-Stop Enclosure Connector	$ 2.00	2	$ 4.00
Total					$ 35.23

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Install Tie Wrap (Zip Tie, Cable Clamp)	Zip tie TSAL to chassis	unit	2	None	1	None	1	$ 0.09	$ 0.18
	Assemble, 1 kg, Loose	Assemble the back part of one UEN E-Stop into the E-Stop Enclosure	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Assemble, 1 kg, Line-on-Line	Assemble the wires of the Estop and the Sense wire into an Estop E	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Loose	Assemble the Connector to the Left Enclosure	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Assemble, 1 kg, Loose	M4 Washer onto M4 Bolts	unit	4	Repeat 4	4	None	1	$ 0.06	$ 0.96
	Hand - Start Only	Hand Start M4 Bolts to fasten Connector onto Left enclosure	unit	4	None	1	None	1	$ 0.12	$ 0.48
	Ratchet <= 6.35 mm	Ratchet M4 Bolts tight to fasten Connector onto Left Enclosure	unit	4	None	1	None	1	$ 0.50	$ 2.00
	Assemble, 1 kg, Line-on-Line	1 Estop front to Left Estop Chassis mount	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Line-on-Line	Left Estop enclosure to Estop front	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Hand - Start Only	Hand Start Estop Front to left Estop Enclosure	unit	1	None	1	None	1	$ 0.12	$ 0.12
	Hand, Loose <= 25.4 mm	Estop front to left Estop Enclosure (and lock)	unit	1	None	1	None	1	$ 0.50	$ 0.50
	Assemble, 1 kg, Loose	Estop Enclosure back to E Stop Enclosure	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Hand - Start Only	Hand Start M4 bolts to fasten Lid to enclosure	unit	4	None	1	None	1	$ 0.12	$ 0.48
	Ratchet <= 6.35 mm	Ratchet M4 bolts to fasten lid to enclosure	unit	4	None	1	None	1	$ 0.50	$ 2.00
	Assemble, 1 kg, Loose	M4 Washer onto M4 bolt	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Hand - Start Only	Hand Start M4 bolt to fasten Sense wire eyelet to headrest mount h	unit	1	None	1	None	1	$ 0.12	$ 0.12
	Screwdriver > 1 Turn	Screw to Fasten sense wire eyelet to headrest mount hole	unit	1	None	1	None	1	$ 0.50	$ 0.50
	Assemble, 1 kg, Loose	Assemble the back part of one UEN E-Stop into the E-Stop Enclosure	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Assemble, 1 kg, Line-on-Line	Assemble the wires of the Estop to the other Estop Enclosure Conne	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Loose	Assemble the Connector to the Right Enclosure	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Hand - Start Only	Hand Start M4 Bolts to fasten Connector onto Right enclosure	unit	4	None	1	None	1	$ 0.12	$ 0.48
	Ratchet <= 6.35 mm	Ratchet M4 Bolts tight to fasten Connector onto Right Enclosure	unit	4	None	1	None	1	$ 0.50	$ 2.00
	Assemble, 1 kg, Line-on-Line	1 Estop front to Right Estop Chassis mount	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Line-on-Line	Right Estop enclosure to Estop front	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Hand - Start Only	Hand Start Estop Front to Right Estop Enclosure	unit	1	None	1	None	1	$ 0.12	$ 0.12
	Hand, Loose <= 25.4 mm	Estop front to Right Estop Enclosure (and lock)	unit	1	None	1	None	1	$ 0.50	$ 0.50
	Assemble, 1 kg, Loose	Estop Enclosure back to E Stop Enclosure	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Hand - Start Only	Hand Start M4 bolts to fasten Lid to enclosure	unit	4	None	1	None	1	$ 0.12	$ 0.48
	Ratchet <= 6.35 mm	Ratchet M4 bolts to fasten lid to enclosure	unit	4	None	1	None	1	$ 0.50	$ 2.00
Total										$ 14.12

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 12.9	M4 Bolt	4	mm	12	mm	8	$ 0.03	$ 0.10
	Washer, Grade 12.9	M4 Washer	4	mm		0		$ 0.01	$ 0.03
Total									$ 0.14

University	University of Newcastle	P/N	E03-20-EL-052001-01	Part Cost	$ 17.21
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	UEN	Extended Cost	$ 17.21
Car #	E03	Part	TSAL		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG Filament in 3D printir	0.086	kg		0					1	$ 0.28	$ 0.02
	Connector, OEM Quality, Low Power (≤2A/25W)	Deutsch Panel Mount	4	pin		0					1	$ 2.00	$ 8.00
	Lamp, LED	Red and Green LED Strip	2	unit		0					1	$ 0.50	$ 1.00
	Wire, Power		0.3	m		0					1	$ 0.90	$ 0.27
Total													$ 9.29

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	TSAL Top	kg	0.047	None	1	None	1	$ 32.00	$ 1.50
	Rapid Prototype - Plastic	TSAL Clear	kg	0.008	None	1	None	1	$ 32.00	$ 0.26
	Rapid Prototype - Plastic	TSAL Bottom	kg	0.031	None	1	None	1	$ 32.00	$ 0.99
	Cut wire	Cut power wire to length	unit	3	None	1	None	1	$ 0.08	$ 0.24
	Strip Wire	Strip each end of wire	unit	3	None	1	Repeat 2	2	$ 0.08	$ 0.48
	Crimp Wire	Crimp one end of each wire	unit	3	None	1	None	1	$ 0.17	$ 0.51
	Lay Wire	Lay LED Strip	m	0.19	None	1	None	1	$ 0.02	$ 0.00
	Attach Wire, Solder	Solder wires on LED Strip	wire	3	None	1	None	1	$ 0.43	$ 1.29
	Connector Assembly, Crimp	Attach Wire to connector	contact	3	None	1	None	1	$ 0.36	$ 1.08
	Assemble, 1 kg, Line-on-Line	Assemble all wires into 4 P	unit	3	None	1	None	1	$ 0.13	$ 0.39
	Assemble, 1 kg, Loose	Put bolts through enclosure	unit	2	None	1	None	1	$ 0.06	$ 0.12
	Hand - Start Only	Hand start nuts to secure co	unit	1	None	1	Repeat 2	2	$ 0.12	$ 0.24
	Reaction Tool <= 6.35 mm	Tighten nuts to secure conn	unit	1	None	1	Repeat 2	2	$ 0.25	$ 0.50
	Liquid Apply - Spot	Attach bottom middle and	unit	1	None	1	None	1	$ 0.10	$ 0.10
	Assemble, 1 kg, Loose	Assemble Bottom Middle a	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Assemble, 1 kg, Loose	Assemble TSAL to Chassis	unit	1	None	1	None	1	$ 0.06	$ 0.06
Total										$ 7.83

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 12.9		3	mm	13	mm	2	$ 0.02	$ 0.04
	Nut, Grade 12.9		3	mm		0	2	$ 0.03	$ 0.05
Total									$ 0.09

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

Change to be the colour of the system and 5 wide

University	University of Newcastle	P/N	E03-20-EL-052002-01	Part Cost	$ 3.00
Competition Code	FSAE-A	System	Electrical System	QTY	2
Year	2024	Assembly	UEN	Extended Cost	$ 6.01
Car #	E03	Part	UEN E-Stop		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Switch, Kill	E-STOP Kill switch	1	unit		0					1	$ 0.28	$ 0.28
	Wire, Signal and Control		0.1	m		0					1	$ 0.90	$ 0.90
Total													$ 1.18

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wires to length	unit	1	None	1	Repeat 2	2	$ 0.08	$ 0.16
	Strip Wire	Strip each end of wires	unit	2	None	1	Repeat 2	2	$ 0.08	$ 0.32
	Crimp Wire	Crimp DT pin on to one end of each wire	unit	1	None	1	Repeat 2	2	$ 0.17	$ 0.34
	Attach Wire, to Fastener or Terminal Block	Attach wire to screw terminal on back of EStop or	wire	1	None	1	Repeat 2	2	$ 0.50	$ 1.00
Total										$ 1.82

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-052003-01	Part Cost	$ 2.95
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	UEN	Extended Cost	$ 2.95
Car #	E03	Part	E-Stop Enclosure Right		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG Filament for 3D Printing	0.053	kg		0					1	$ 0.17	$ 0.17
Total													$ 0.17

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	3D print housing	kg	0.053	None	1	None	1	$ 32.00	$ 1.70
	Assemble, 1 kg, Interference	Push in Nutserts	unit	1	None	1	Repeat 4	4	$ 0.19	$ 0.76
Total										$ 2.46

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 12.9		4	mm	12	mm	4	$ 0.03	$ 0.10
	Thread Insert, Female Threads, Knurled Type		4	mm	10	mm	4	$ 0.06	$ 0.22
Total									$ 0.32

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-052004-01	Part Cost	$ 5.06
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	UEN	Extended Cost	$ 5.06
Car #	E03	Part	E-Stop Enclosure Left		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG Filament for 3D printing	0.053	kg		0					1	$ 0.17	$ 0.17
	Connector, OEM Quality, Low Power (≤2A/25W)	Gland	1	pin		0					1	$ 1.00	$ 1.00
	Connector, Single Wire	eyelet crimp	1	Unit		0					1	$ 0.10	$ 0.10
	Wire, Signal and Control	IMD Sense wire, Black	0.3	m		0					1	$ 0.10	$ 0.10
Total													$ 1.37

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	3D print housing	kg	0.053	None	1	None	1	$ 32.00	$ 1.70
	Assemble, 1 kg, Interference	Push in Nutserts	unit	1	None	1	Repeat 4	4	$ 0.19	$ 0.76
	Assemble, 1 kg, Line-on-Line	Assemble Gland onto Enclosure	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Cut wire	Cut Sense Wire to Length	unit	1	None	1	None	1	$ 0.08	$ 0.08
	Strip Wire	Strip both end of Sense wire	unit	2	None	1	None	1	$ 0.08	$ 0.16
	Crimp Wire	DT pin on one end of the Sense Wire	unit	1	None	1	None	1	$ 0.17	$ 0.17
	Connector Assembly, Crimp	Crimp Eyelet Crimp	contact	1	None	1	None	1	$ 0.36	$ 0.36
	Lay Wire	Lay Sense wire through Gland	m	0.3	None	1	None	1	$ 0.02	$ 0.01
Total										$ 3.36

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 12.9		4	mm	12	mm	4	$ 0.03	$ 0.10
	Thread Insert, Female Threads, Knurled Type		4	mm	10	mm	4	$ 0.06	$ 0.22
Total									$ 0.32

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-052005-01	Part Cost	$ 2.00
Competition Code	FSAE-A	System	Electrical System	QTY	2
Year	2024	Assembly	UEN	Extended Cost	$ 4.00
Car #	E03	Part	E-STOP Enclosure Connector		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Connector, OEM Quality, High Power (>2A/25W)	Panel Mount Deutsch Connector	4	pin		0					1	$ 2.00	$ 2.00
Total													$ 2.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	**A/N**	E03-20-EL-061000-01	**Part Cost**	N/A
Competition Code	FSAE-A	**System**	Electrical System	**QTY**	1
Year	2024	**Assembly**	LV Power Stack	**Extended Cost**	$ 254.16
Car #	E03	**Part**	N/A		

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-EL-062001-01	DCDC	$ 187.50	1	$ 187.50
	E03-20-EL-062002-01	LV Battery	$ 50.42	1	$ 50.42
	E03-20-EL-062003-01	LV Battery Enclosure	$ 7.64	1	$ 7.64
Total					**$ 245.56**

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Assemble, 1 kg, Loose	Position DCDC over bolt holes on DCDC Mounting Plate	unit	1	None	1	None	1	0.06	0.06
	Assemble, 1 kg, Loose	M6 Washer on M6 bolts	unit	4	None	1	None	1	$ 0.06	$ 0.24
	Assemble, 1 kg, Loose	Bolts through bolt holes of DCDC	unit	4	None	1	None	1	$ 0.06	$ 0.24
	Assemble, 1 kg, Loose	Washer on rear side of bolt	unit	4	None	1	None	1	$ 0.06	$ 0.24
	Hand - Start Only	Hand start M6 nuts	unit	1	Repeat 4	4	None	1	$ 0.12	$ 0.48
	Reaction Tool <= 6.35 mm	Tighten nuts	unit	1	Repeat 4	4	None	1	$ 0.25	$ 1.00
	Assemble, 1 kg, Loose	LV battery into LV battery enclosure	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Connector Install	Connect wires from DT inside LV battery enclosure lid to LV battery	unit	1	None	1	None	1	$ 0.11	$ 0.11
	Install Tie Wrap (Zip Tie, Cable Clamp)	Zip Tie Enclosure shut	unit	2	None	1	None	1	$ 0.09	$ 0.18
	Assemble, 1 kg, Loose	Assemble Battery Enclosure to TS Stack Rail Supports	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Assemble, 1 kg, Loose	M5 Washer on M5 bolts	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Assemble, 1 kg, Loose	Bolts through bolt holes to mount onto TS Rails	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Assemble, 1 kg, Loose	Washer on rear side of bolt	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Hand - Start Only	Hand start M5 nuts	unit	1	Repeat 4	4	None	1	$ 0.12	$ 0.48
	Reaction Tool <= 6.35 mm	Tighten nuts	unit	1	Repeat 4	4	None	1	$ 0.25	$ 1.00
	Assemble, 1 kg, Loose	M4 Bolts through bolt holes on Deutsch connector mounts	unit	4	None	1	None	1	$ 0.06	$ 0.24
	Hand - Start Only	Hand start bolts	unit	1	Repeat 4	4	None	1	$ 0.12	$ 0.48
	Screwdriver > 1 Turn	Tighten bolts through Deutsch connector mounts	unit	1	Repeat 4	4	None	1	$ 0.50	$ 2.00
Total										**$ 7.59**

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 12.9	Bolts to secure DCDC to DCDC Mounting Plate	6	mm	25	mm	4	$ 0.09	$ 0.35
	Washer, Grade 12.9	Washer to secure DCDC to DCDC Top Mounting Plate	6	mm		0	8	$ 0.01	$ 0.09
	Nut, Grade 12.9	Nut to secure DCDC	6	mm		0	4	$ 0.05	$ 0.20
	Bolt, Grade 12.9	Bolts to secure LV Battery Enclosure	5	mm	25	mm	2	$ 0.06	$ 0.12
	Washer, Grade 12.9	Washer to secure LV Battery Enclosure	5	mm		0	4	$ 0.01	$ 0.04
	Nut, Grade 12.9	Nut to secure LV Battery	5	mm		0	2	$ 0.04	$ 0.08
	Bolt, Grade 12.9	Bolts to secure Deutsch Connector to LV Battery Enclosure	4	mm	18	mm	4	$ 0.03	$ 0.13
Total									**$ 1.01**

University	University of Newcastle	P/N	E03-20-EL-062001-01	Part Cost	$	187.50
Competition Code	FSAE-A	System	Electrical System	QTY		1
Year	2024	Assembly	LV Power Stack	Extended Cost	$	187.50
Car #	E03	Part	DCDC			

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Power Converter, DC-DC, HV to LV, per kW	DCDC (140V input to 14V input)	1.5	kW		0					1	$ 187.50	$ 187.50
Total													$ 187.50

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-062002-01	Part Cost	$ 50.42		
Competition Code	FSAE-A	System	Electrical System	QTY	1		
Year	2024	Assembly	LV Power Stack	Extended Cost	$ 50.42		
Car #	E03	Part	LV Battery				

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Battery, Advanced Chemistry (NiMH, Li-Ion, etc.	LV Battery	0.7	kg		0					1	$ 45.50	$ 31.85
	Connector, OEM Quality, High Power (>2A/25W)	Panel Mount Deutsch Connector	4	pin		0					1	$ 2.00	$ 8.00
	Wire, Power	12V and GND wires	0.25	m		0					4	$ 3.00	$ 3.00
	Connector, Single Wire	Female Blade Connector	2	Unit		0					1	$ 2.00	$ 4.00
Total													$ 46.85

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut power wires to length	unit	1	Repeat 4	4	None	1	$ 0.08	$ 0.32
	Strip Wire	Strip both ends	unit	2	Repeat 4	4	None	1	$ 0.08	$ 0.32
	Crimp Wire	Crimp Deutsch Pins to 1 end	unit	1	Repeat 4	4	None	1	$ 0.17	$ 0.68
	Connector Assembly, Crimp	Crimp 2 wires into the same cont	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Assemble, 1 kg, Line-on-Line	Assemble Crimp connector to ter	unit	1	Repeat 2	2	None	1	$ 0.13	$ 0.26
	Hand - Start Only	Hand Start M4 screw to terminal (	unit	1	Repeat 2	2	None	1	$ 0.12	$ 0.24
	Screwdriver > 1 Turn	Screw M4 Screw terminal of LV B	unit	1	Repeat 2	2	None	1	$ 0.50	$ 1.00
Total										$ 3.54

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 6.8 (SAE 3) and All Grades less than I	M4 Screw	4	mm	18	mm	2	$ 0.02	$ 0.03
Total									$ 0.03

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-062003-01	Part Cost	$ 7.64
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	LV Power Stack	Extended Cost	$ 7.64
Car #	E03	Part	LV Battery Enclosure		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG 3D print of LV Battery Enclosure	0.233	kg		0					1	$ 0.77	$ 0.18
Total													$ 0.18

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	3D print of LV Battery Enclosure	kg	0.233	None	1	None	1	$ 32.00	$ 7.46
Total										$ 7.46

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	A/N	E03-20-EL-071000-01	Part Cost	N/A
Competition Code	FSAE-A	System	Electrical System	QTY	N/A
Year	2024	Assembly	BOTS	Extended Cost	$ 3.68
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-EL-072001-01	Switch	$ 1.00	1	$ 1.00
	E03-20-EL-072002-01	Switch Mount	$ 0.32	1	$ 0.32
Total					$ 1.32

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Assemble, 1 kg, Line-on-Line	Install switch to switch mount	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Hand - Start Only	Lock nut of Switch to fasten switch to switch mount	unit	1	None	1	None	1	$ 0.12	$ 0.12
	Hand, Tight <= 6.35 mm	Lock nut of Switch to fasten switch to switch mount	unit	1	None	1	None	1	$ 0.50	$ 0.50
	Assemble, 1 kg, Loose	Position switch and mount over holes on pedal box	unit	1	None	1	None	1	0.06	0.06
	Assemble, 1 kg, Loose	Washer on top side of bolt	unit	1	None	1	None	1	0.06	$ 0.06
	Assemble, 1 kg, Loose	Bolt through hole	unit	1	Repeat 2	2	None	1	0.06	0.12
	Assemble, 1 kg, Loose	Washer on rear side of bolt	unit	1	None	1	None	1	0.06	0.06
	Hand - Start Only	Hand start nut	unit	1	Repeat 2	2	None	1	0.12	0.24
	Ratchet <= 6.35 mm	Tighten nut	unit	1	Repeat 2	2	None	1	0.5	1
Total										$ 2.29

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Washer, Grade 12.9	M3 washers	3	mm		0	4	0.006864027	0.02745611
	Bolt, Grade 12.9	M3 bolts	3	mm	18	mm	2	$ 0.02	$ 0.04
Total									$ 0.07

University	University of Newcastle	P/N	E03-20-EL-072001-01	Part Cost	$ 1.00
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	BOTS	Extended Cost	$ 1.00
Car #	E03	Part	Switch		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Switch, Toggle	Shutdown circuit start switch. Positioned behind brake pedal		unit		0					1	$ 1.00	$ 1.00
Total													$ 1.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
										0
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			0
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-072002-01	Part Cost	$ 0.32
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	BOTS	Extended Cost	$ 0.32
Car #	E03	Part	Switch Mount		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	Switch mount enclosure	0.00906759	kg		0					1	$ 0.03	$ 0.03
Total													$ 0.03

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	Print switch mount enclosure	kg	0.009068	None	1	None	1	$ 32.00	$ 0.29
Total										$ 0.29

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None								$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	A/N	E03-20-EL-081000-01	Part Cost	N/A
Competition Code	FSAE-A	System	Electrical System	QTY	N/A
Year	2024	Assembly	Accelerator Pedal	Extended Cost	$ 50.91
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-EL-082001-01	Accelerator Pedal	$ 47.52	1	$ 47.52
Total					**$ 47.52**

Processes / Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Assemble, 1 kg, Loose	Place Accelerator Pedal onto Accelerator Pedal Mount	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Assemble, 1 kg, Loose	Washer onto bolts	unit	1	Repeat 3	3	None	1	$ 0.06	$ 0.18
	Assemble, 1 kg, Loose	Bolts through Accelerator Pedal and Pedal Mount	unit	1	Repeat 3	3	None	1	$ 0.06	$ 0.18
	Hand - Start Only	Start nuts (no washers)	unit	1	Repeat 3	3	None	1	$ 0.12	$ 0.36
	Ratchet <= 6.35 mm	Tighten bolts	unit	1	Repeat 3	3	None	1	$ 0.50	$ 1.50
	Reaction Tool <= 25.4 mm	Tighten bolts	unit	1	Repeat 3	3	None	1	$ 0.25	$ 0.75
Total										**$ 3.03**

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 12.9	Accelerator Pedal Bolt	6	mm	15	mm	3	$ 0.06	$ 0.18
	Washer, Grade 12.9	Accelerator Pedal Washer	6	mm		0	3	$ 0.01	$ 0.04
	Nut, Grade 12.9	Accelerator Pedal Nut	6	mm		0	3	$ 0.05	$ 0.15
Total									**$ 0.36**

University	University of Newcastle	P/N	E03-20-EL-082001-01	Part Cost	$ 47.52
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Accelerator Pedal	Extended Cost	$ 47.52
Car #	E03	Part	Accelerator Pedal		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Polypropylene, High Modulus	Pedal Base Plastic	0.32862556	kg		0				900	0.328626	$ 35.00	$ 11.50
	Polypropylene, High Modulus	Pedal Plastic	0.05288624	kg		0				900	0.052886	$ 35.00	$ 1.85
	Wire, Power		0.12	m		0					4	$ 0.30	$ 1.20
	Wire, Signal and Control		0.12	m		0					2	$ 1.40	$ 2.80
	Spring, Compression (General)		2	unit		0					2	$ 1.00	$ 2.00
	Sensor, Angular Position	Pedal position sensors	1	unit		0					2	$ 4.00	$ 8.00
	Connector, OEM Quality, High Power (>2A/25W)	Dt Connecter (Recepticle)	3	pin		0					2	$ 1.00	$ 2.00
	Connector, OEM Quality, Low Power (≤2A/25W)	PPS Connector	6	pin		0					1	$ 1.00	$ 1.00
Total													$ 30.35

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Machining Setup, Install and remove	Set up injection mould die	unit	1	None	1	None	1	1.3	1.3
	Plastic injection molding	Mould Pedal Base	kg	0.328626	None	1	None	1	2.75	0.90372029
	Machining Setup, Install and remove	Set up injection mould die	unit	1	None	1	None	1	$ 1.30	$ 1.30
	Plastic injection molding	Mould Pedal	kg	0.052886	None	1	None	1	$ 2.75	$ 0.15
	Assemble, 1 kg, Line-on-Line	Place Spring in Pedal Base	unit	1	Repeat 2	2	None	1	$ 0.13	$ 0.26
	Assemble, 1 kg, Line-on-Line	Place Pedal Base on Pedal Base	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Line-on-Line	Push retaining tab (part of the pedal) over pedal base - to lock it in place	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Cut wire	Cut wires	unit	1	Repeat 6	6	None	1	$ 0.08	$ 0.48
	Strip Wire	Strip both ends of the wires	unit	2	Repeat 2	2	None	1	$ 0.08	$ 0.32
	Connector Assembly, Crimp	Crimp and Install one end of the wires into PPS Co	contact	6	None	1	None	1	$ 0.36	$ 2.16
	Connector Assembly, Crimp	Crimp and Install other end of the wires into DT Connectors	contact	3	Repeat 2	2	None	1	$ 0.36	$ 2.16
	Connector Install	Connect PPS Connector to PPS	unit	1	None	1	None	1	$ 0.11	$ 0.11
Total										$ 9.40

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	Plastic injection molding - Die	Pedal Base (sliders = 2, surface area = 0.083 m^2)	Number of Slide	1	3000	1	$ 11,831.46	$ 3.94
	Plastic injection molding - Die	Pedal (sliders = 2, surface area = 0.047m^2)	m^2	1	3000	1	$ 11,473.30	$ 3.82
Total								$ 7.77

University	University of Newcastle	A/N	E03-20-EL-091000-01	Part Cost	N/A
Competition Code	FSAE-A	System	Electrical System	QTY	N/A
Year	2024	Assembly	GPS and Telemetry	Extended Cost	$ 0.26
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Cost	QTY	Sub Total
	E03-20-EL-092001-01	GPS Module		1	$ -
	E03-20-EL-092002-01	Paraini SD1000 Bluetooth Serial Antenna		1	$ -
Total					$ -

Processes / Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Install Tie Wrap (Zip Tie, Cable Clamp)	Zip tie GPS Module to chassis member	unit	1	None	1	None	1	0.09	0.09
	Install Tie Wrap (Zip Tie, Cable Clamp)	Zip tie Paraini SD1000 Bluetooth Serial Antenna to chassis membe	unit	1	None	1	None	1	0.09	0.09
Total										$ 0.18

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Tie Wrap, Plastic			Unit		0	2	$ 0.04	$ 0.08
Total									$ 0.08

University	University of Newcastle	P/N	E03-20-EL-092001-01	Part Cost	$ 20.00
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	GPS and Telemetry	Extended Cost	$ 20.00
Car #	E03	Part	GPS Module		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Sensor, GPS	MoTeC GPS Node	1	unit		0					1	$ 20.00	$ 20.00
Total													$ 20.00

Processes / Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-092002-01	Part Cost	$ 5.00
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	GPS and Telemetry	Extended Cost	$ 5.00
Car #	E03	Part	Paraini SD1000 Bluetooth Serial Antenna		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Antenna	Parani SD1000 Bluetooth Serial Antenna		unit		0					1	$ 5.00	$ 5.00
Total													$ 5.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
Total										$ -

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	None			0		0			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	A/N	E03-20-EL-101000-01	Part Cost	N/A
Competition Code	FSAE-A	System	Electrical System	QTY	N/A
Year	2024	Assembly	Looms	Extended Cost	$ 1,264.91
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Co	QTY	Sub Total
	E03-20-EL-102001-01	BOTS - PEN (LV)	$ 11.60	1	$ 11.60
	E03-20-EL-102002-01	Pedals - PEN (LV)	$ 58.11	1	$ 58.11
	E03-20-EL-102003-01	PEN - DEN (LV)	$ 44.83	1	$ 44.83
	E03-20-EL-102004-01	Inertia Switch - DEN (LV)	$ 14.02	1	$ 14.02
	E03-20-EL-102005-01	DEN - MoTeC (LV)	$ 64.99	1	$ 64.99
	E03-20-EL-102006-01	GPS and Telemetry - DEN (LV)	$ 24.45	1	$ 24.45
	E03-20-EL-102007-01	DEN - CEN (LV)	$ 95.85	1	$ 95.85
	E03-20-EL-102008-01	CEN - UEN (LV)	$ 80.86	1	$ 80.86
	E03-20-EL-102009-01	CEN - DCDC (LV)	$ 43.87	1	$ 43.87
	E03-20-EL-102010-01	CEN - Motor Controller (LV)	$ 85.70	1	$ 85.70
	E03-20-EL-102011-01	CEN - Accumulator (LV)	$ 64.21	1	$ 64.21
	E03-20-EL-102012-01	CEN - HIP (LV)	$ 59.20	1	$ 59.20
	E03-20-EL-102013-01	CEN - Cooling and Brake Light (LV)	$ 108.94	1	$ 108.94
	E03-20-EL-102014-01	HIP - DCDC (LV)	$ 46.36	1	$ 46.36
	E03-20-EL-102015-01	HIP - DCDC (HV)	$ 77.22	1	$ 77.22
	E03-20-EL-102016-01	LV Battery - DCDC (LV)	$ 20.65	1	$ 20.65
	E03-20-EL-102017-01	Accumulator - HIP (HV)	$ 129.83	1	$ 129.83
	E03-20-EL-102018-01	HIP - Motor Controller (HV)	$ 121.30	1	$ 121.30
	E03-20-EL-102019-01	Motor Controller - Motor (HV)	$ 95.06	1	$ 95.06
Total					$ 1,247.05

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Lay Wire	Lay BOTS - PEN (LV) on Pedal Box	m	0.195	None	1	None	1	$ 0.02	$ 0.00
	Connector Install	Connect to BOTS Switch E03-20-EL-071000-01 and PEN E03-20-EL-041000-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay Pedals - PEN (LV) on Pedal Box	m	0.4	None	1	None	1	$ 0.02	$ 0.01
	Connector Install	Connect to Accelator Pedal E03-20-EL-081000-01, Brake Pressure Sensors E03-20-BR-012003-01 and PEN E03-20-EL-041000-01	unit	1	Repeat 3	3	None	1	$ 0.11	$ 0.33
	Lay Wire	Lay PEN - DEN (LV) on Chassis	m	0.8	None	1	Assemble - Length > 0.5m	1.25	$ 0.02	$ 0.02
	Install Tie Wrap (Zip Tie, Cabl	Zip tie to Chassis	unit	1	Repeat 3	3	None	1	$ 0.09	$ 0.27
	Connector Install	Connect to DEN E03-20-EL-031000-01 and PEN E03-20-EL-041000-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay Inertia Switch - DEN (LV) on Chassis	m	0.196	None	1	None	1	$ 0.02	$ 0.00
	Connector Install	Connect to DEN E03-20-EL-031000-01 and Inertia Switch E03-20-EL-031005-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay DEN - MoTeC (LV) on Chassis	m	0.2	None	1	None	1	$ 0.02	$ 0.00
	Connector Install	Connect to DEN E03-20-EL-031000-01 and MoTeC E03-20-EL-031004-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay GPS and Telemetry - DEN (LV) on Chassis	m	0.15	None	1	None	1	$ 0.02	$ 0.00
	Connector Install	Connect to DEN E03-20-EL-031000-01 and GPS and Telemetry E03-20-EL-091000-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay DEN - CEN (LV) on Chassis	m	1.5	None	1	Assemble - Length > 0.5m	1.25	$ 0.02	$ 0.04
	Install Tie Wrap (Zip Tie, Cabl	Zip tie to Chassis	unit	1	Repeat 3	3	None	1	$ 0.09	$ 0.27
	Connector Install	Connect to DEN E03-20-EL-031000-01 and CEN E03-20-EL-011000-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay CEN - UEN (LV) on Chassis	m	2	None	1	Assemble - Length > 0.5m	1.25	$ 0.02	$ 0.05
	Install Tie Wrap (Zip Tie, Cabl	Zip tie to Chassis	unit	1	Repeat 6	6	None	1	$ 0.09	$ 0.54
	Connector Install	Connect to CEN E03-20-EL-011000-01 and UEN E03-20-EL-051000-01	unit	1	Repeat 4	4	None	1	$ 0.11	$ 0.44
	Lay Wire	Lay CEN - DCDC (LV) on Chassis	m	0.7	None	1	Assemble - Length > 0.5m	1.25	$ 0.02	$ 0.02
	Connector Install	Connect to CEN E03-20-EL-011000-01 and DCDC E03-20-EL-062001-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay CEN - Motor Controller (LV) on Chassis	m	0.3	None	1	None	1	$ 0.02	$ 0.01
	Connector Install	Connect to CEN E03-20-EL-011000-01 and Cascadia Motion CM200DX E03-20-DR-042001-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay CEN - Accumulator (LV) on Chassis	m	0.8	None	1	Assemble - Length > 0.5m	1.25	$ 0.02	$ 0.02
	Connector Install	Connect to CEN E03-20-EL-011000-01 and Accumulator E03-20-DR-051000-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay CEN - HIP (LV) on Chassis	m	0.4	None	1	None	1	$ 0.02	$ 0.01
	Connector Install	Connect to CEN E03-20-EL-011000-01 and HIP E03-20-EL-021000-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay CEN - Cooling and Brake Light (LV) on Chassis	m	1.6	None	1	Assemble - Length > 0.5m	1.25	$ 0.02	$ 0.04
	Install Tie Wrap (Zip Tie, Cabl	Zip tie to Chassis	unit	1	Repeat 3	3	None	1	$ 0.09	$ 0.27
	Connector Install	Connect to CEN E03-20-EL-011000-01, Brake light E03-20-EL-111000-01 and Cooling E03-20-DR-031000-01	unit	1	Repeat 5	5	None	1	$ 0.11	$ 0.55
	Lay Wire	Lay HIP - DCDC (LV) on Chassis	m	1	None	1	Assemble - Length > 0.5m	1.25	$ 0.02	$ 0.03
	Connector Install	Connect to HIP E03-20-EL-021000-01	unit	1	None	1	None	1	$ 0.11	$ 0.11
	Lay Wire	Lay HIP - DCDC (HV) on Chassis	m	1	None	1	Assemble - Length > 0.5m	1.25	$ 0.02	$ 0.03
	Connector Install	Connect to HIP E03-20-EL-021000-01 and DCDC E03-20-EL-062001-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay LV Battery - DCDC (LV) on Chassis	m	0.3	None	1	None	1	$ 0.02	$ 0.01
	Connector Install	Connect to LV Battery E03-20-EL-062003-01	unit	1	None	1	None	1	$ 0.11	$ 0.11
	Assemble, 1 kg, Loose	Assemble Ring Terminals of LV Battery - DCDC, HIP - DCDC and CEN - DCDC onto the included fastener on the DCDC	unit	1	Repeat 2	2	None	1	$ 0.06	$ 0.12
	Hand - Start Only	Hand Start Fasteners on DCDC to fasten ring terminals to terminals	unit	1	Repeat 2	2	None	1	$ 0.12	$ 0.24
	Ratchet <= 25.4 mm	Ratchet Fasteners on DCDC to fasten ring terminals to terminals	unit	1	Repeat 2	2	None	1	$ 0.75	$ 1.50
	Install Tie Wrap (Zip Tie, Cabl	Zip tie all looms to the DCDC to Bundle them	unit	1	Repeat 2	2	None	1	$ 0.09	$ 0.18
	Lay Wire	Lay Accumlator - HIP (HV) to Chassis	m	0.75	None	1	Assemble - Length > 0.5m	1.25	$ 0.02	$ 0.02
	Connector Install	Connect to HIP E03-20-EL-021000-01 and Accumlator E03-20-DR-051000-01	unit	1	Repeat 4	4	None	1	$ 0.11	$ 0.44
	Lay Wire	Lay HIP - Motor Controller (HV) on Chassis	m	0.5	None	1	None	1	$ 0.02	$ 0.01
	Connector Install	Connect to HIP E03-20-EL-021000-01 and Cascadia Motion CM200DX E03-20-DR-042001-01	unit	1	Repeat 2	2	None	1	$ 0.11	$ 0.22
	Lay Wire	Lay Motor Controller - Motor (HV) onto Chassis	m	0.6	None	1	Assemble - Length > 0.5m	1.25	$ 0.02	$ 0.02
	Install Tie Wrap (Zip Tie, Cabl	Zip tie to Chassis	unit	1	Repeat 2	2	None	1	$ 0.09	$ 0.18
	Connector Install	Connect to Cascadia Motion CM200DX E03-20-DR-042001-01	unit	1	Repeat 3	3	None	1	$ 0.11	$ 0.33
	Assemble, 1 kg, Loose	Assemble M6 Washer on M6 Bolt	unit	1	Repeat 3	3	None	1	$ 0.06	$ 0.18
	Assemble, 1 kg, Line-on-Line	Assemble M6 Bolt through Motor E03-20-DR-013007-01 Lug and Motor Controller - Motor (HV) Lug	unit	1	Repeat 3	3	None	1	$ 0.13	$ 0.39
	Assemble, 1 kg, Line-on-Line	Assemble Washer on M6 bolt	unit	1	Repeat 3	3	None	1	$ 0.13	$ 0.39
	Hand - Start Only	Hand Start M6 Glenlock Nut onto M6 bolt	unit	1	Repeat 3	3	None	1	$ 0.12	$ 0.36
	Ratchet <= 25.4 mm	Ratchet M6 bolts to fasten Motor lugs to Motor Controller - Motor (HV) lugs together	unit	1	Repeat 3	3	None	1	$ 0.75	$ 2.25
	Reaction Tool <= 25.4 mm	Reaction tool for M6 bolt and Nut	unit	1	Repeat 3	3	None	1	$ 0.25	$ 0.75
	Assemble, 1 kg, Line-on-Line	Slide Heat Strink over Lugs and bolt	unit	1	Repeat 3	3	None	1	$ 0.13	$ 0.39
	Shrink Tube	Shrink Heat Strink	cm	7	Repeat 3	3	None	1	$ 0.15	$ 3.15
Total										$ 16.70

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 12.9	M6 Bolt	6	mm	15	mm	3	$ 0.06	$ 0.18
	Washer, Grade 12.9	M6 Washer	6	mm		0	6	$ 0.01	$ 0.07
	Nut, Grade 12.9	Glenlock M6 Nuts	6	mm		0	3	$ 0.05	$ 0.15
	Tie Wrap, Plastic	Zip Tie	1	Unit		0	19	$ 0.04	$ 0.76
Total									$ 1.16

University	University of Newcastle	P/N	E03-20-EL-102001-01	Part Cost	$	11.60
Competition Code	FSAE-A	System	Electrical System	QTY		1
Year	2024	Assembly	Looms	Extended Cost	$	11.60
Car #	E03	Part	BOTS - PEN (LV)			

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wire for PEN - BOTS	0.195	m		0					1	$ 0.59	$ 0.59
	Wire, Signal and Control	Signal wire for PEN - BOTS	0.195	m		0					1	$ 0.20	$ 0.20
	Heat Shrink Tubing	Heat shrink for looms	0.19	m		0					1	$ 0.10	$ 0.10
	Heat Shrink Tubing	Heat shrink for boots	0.05	m		0					1	$ 0.03	$ 0.03
	Connector, OEM Quality, High Power (>2A/25W)	DT connector for PEN	2	pin		0					1	$ 2.00	$ 2.00
	Connector, Single Wire	Power and Signal Spade Connection for BOTS	1	Unit		0					2	$ 0.10	$ 0.20
Total													$ 3.10

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut power and signal wires	unit	1	Repeat 2	2	None	1	$ 0.08	$ 0.16
	Strip Wire	Strip both ends of power and signal wires	unit	2	Repeat 2	2	None	1	$ 0.08	$ 0.32
	Connector Assembly, Crimp	Crimp one end of the wires with Spade Connecto	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Insert Bundle Into Tube or Sleeve	Insert loom into heat shrink	m	0.19	None	1	None	1	$ 0.02	$ 0.00
	Connector Assembly, Crimp	Crimp the other ends of the wire for the DT Conn	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Shrink Tube	Heat shrink for looms	cm	19	Repeat 2	2	None	1	$ 0.15	$ 5.70
	Assemble, 1 kg, Line-on-Line	Install Boot onto loom and slide up to connector	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Shrink Tube	Heat shrink for boot	cm	5	None	1	None	1	$ 0.15	$ 0.75
Total										$ 8.50

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102002-01	Part Cost	$	58.11
Competition Code	FSAE-A	System	Electrical System	QTY		1
Year	2024	Assembly	Looms	Extended Cost	$	58.11
Car #	E03	Part	Pedals - PEN (LV)			

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wires for Pedals	0.4	m		0					8	$ 1.20	$ 9.60
	Wire, Signal and Control	Signal wires for Pedals	0.4	m		0					4	$ 0.40	$ 1.60
	Heat Shrink Tubing	Heat Shrink for Looms	0.34	m		0					2	$ 0.17	$ 0.34
	Heat Shrink Tubing	Heat shrink for Boots	0.05	m		0					1	$ 0.03	$ 0.03
	Connector, OEM Quality, High Power (>2A/25W	DT Connector for Accelerator Pedal	3	pin		0					2	$ 3.00	$ 6.00
	Connector, OEM Quality, High Power (>2A/25W	DT Connector for PEN	12	pin		0					1	$ 12.00	$ 12.00
	Connector, OEM Quality, Low Power (≤2A/25W)	Brake Sensor Connector	3	pin		0					2	$ 3.00	$ 6.00
Total													$ 35.57

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut power and signal wires	unit	1	Repeat 12	12	None	1	$ 0.08	$ 0.96
	Strip Wire	Strip each end of wire	unit	2	Repeat 12	12	None	1	$ 0.08	$ 1.92
	Connector Assembly, Crimp	Crimp and install the PEN side into the 12 pin C	contact	1	Repeat 12	12	None	1	$ 0.36	$ 4.32
	Insert Bundle Into Tube or Sleeve	Insert loom into heat shrinks, separating for PP	m	0.34	Repeat 2	2	None	1	$ 0.02	$ 0.01
	Assemble, 1 kg, Loose	Slide Boot onto loom up to 12 Pin DT Connecto	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Connector Assembly, Crimp	Crimp and Install the PPS DT Connectors	contact	2	Repeat 3	3	None	1	$ 0.36	$ 2.16
	Connector Assembly, Crimp	Crimp and Install the BSC Connector	contact	2	Repeat 3	3	None	1	$ 0.36	$ 2.16
	Shrink Tube	Heat shrink for loom	cm	34	Repeat 2	2	None	1	$ 0.15	$ 10.20
	Shrink Tube	Heat shrink for boots	cm	5	None	1	None	1	$ 0.15	$ 0.75
Total										$ 22.54

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle		P/N	E03-20-EL-102003-01		Part Cost	$ 44.83	
Competition Code	FSAE-A		System	Electrical System		QTY	1	
Year	2024		Assembly	Looms		Extended Cost	$ 44.83	
Car #	E03		Part	PEN - DEN (LV)				

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wires for PEN - DEN	0.8	m		0					2	$ 2.40	$ 4.80
	Wire, Signal and Control	Signal wires for PEN - DEN	0.8	m		0					5	$ 0.80	$ 4.00
	Connector, OEM Quality, High Power (>2A/25W	DT connector for PEN and DEN side	8	pin		0					2	$ 8.00	$ 16.00
	Heat Shrink Tubing	Heat shrink for looms	0.75	m		0					1	$ 0.38	$ 0.38
	Heat Shrink Tubing	Heat shrink for boots	0.05	m		0					2	$ 0.03	$ 0.05
Total													$ 25.23

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wires to length	unit	1	Repeat 7	7	None	1	$ 0.08	$ 0.56
	Strip Wire	Strip BOTH ends of the wires	unit	2	Repeat 7	7	None	1	$ 0.08	$ 1.12
	Insert Bundle Into Tube or Sleeve	Insert loom into heat shrink	m	0.75	None	1	None	1	$ 0.02	$ 0.02
	Assemble, 1 kg, Loose	Slide boots onto wire	unit	1	Repeat 2	2	None	1	$ 0.06	$ 0.12
	Connector Assembly, Crimp	Crimp and install both ends of the wires int	contact	2	Repeat 7	7	None	1	$ 0.36	$ 5.04
	Shrink Tube	Heat shrink for looms	cm	75	None	1	None	1	$ 0.15	$ 11.25
	Shrink Tube	Heat shrink for boots	cm	5	Repeat 2	2	None	1	$ 0.15	$ 1.50
Total										$ 19.61

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102004-01	Part Cost	$ 14.02
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 14.02
Car #	E03	Part	Inertia Switch - DEN (LV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wires for Inertia Switch - DEN	0.196	m		0					2	$ 0.59	$ 1.18
	Wire, Signal and Control	Signal wires for Inertia Switch - DEN	0.196	m		0					1	$ 0.20	$ 0.20
	Heat Shrink Tubing	Heat shrink for looms	0.19	m		0					1	$ 0.10	$ 0.10
	Heat Shrink Tubing	Heat shrink for boot	0.05	m		0					1	$ 0.03	$ 0.03
	Connector, OEM Quality, High Power (>2A/25W)	DT connector for DEN	4	pin		0					1	$ 4.00	$ 4.00
	Connector, OEM Quality, Low Power (≤2A/25W)	Connector for Inertia Switch	2	pin		0					1	$ 2.00	$ 2.00
	Connector, Single Wire	Ring terminal Connector	1	Unit		0					1	$ 0.10	$ 0.10
Total													$ 7.59

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wires	unit	1	Repeat 3	3	None	1	$ 0.08	$ 0.24
	Strip Wire	Strip both ends of the wires	unit	2	Repeat 3	3	None	1	$ 0.08	$ 0.48
	Crimp Wire	Crimp Ring terminal Connector on one end o	unit	1	None	1	None	1	$ 0.17	$ 0.17
	Insert Bundle Into Tube or Sleeve	Insert looms into heat shrink tubing	m	0.19	None	1	None	1	$ 0.02	$ 0.00
	Assemble, 1 kg, Line-on-Line	Slide Boot onto wire for DEN DT	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Connector Assembly, Crimp	Crimp and Install DEN side into DT Connector	contact	1	Repeat 3	3	None	1	$ 0.36	$ 1.08
	Connector Assembly, Crimp	Crimp and Install remaning wires into Inertia	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Shrink Tube	Heat shrink looms	cm	19	None	1	None	1	$ 0.15	$ 2.85
	Shrink Tube	Heat shrink boots	cm	5	None	1	None	1	$ 0.15	$ 0.75
Total										$ 6.42

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102005-01	Part Cost	$ 64.99
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 64.99
Car #	E03	Part	DEN - MoTeC (LV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wire for DEN - MoTeC	0.2	m		0					3	$ 0.60	$ 1.80
	Wire, Signal and Control	Signal wires for DEN - MoTeC	0.2	m		0					8	$ 0.20	$ 1.60
	Heat Shrink Tubing	Heat Shrink for looms	0.15	m		0					1	$ 0.08	$ 0.08
	Heat Shrink Tubing	Heat Shrink for boots	0.05	m		0					1	$ 0.03	$ 0.03
	Connector, OEM Quality, High Power (>2A/25W)	DT Connector for DEN	12	pin		0					1	$ 12.00	$ 12.00
	Connector, OEM Quality, High Power (>2A/25W)	Connector for MoTeC	34	pin		0					1	$ 34.00	$ 34.00
Total													$ 49.50

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wires to length	unit	1	Repeat 11	11	None	1	$ 0.08	$ 0.88
	Strip Wire	Strip BOTH ends of the wires	unit	2	Repeat 11	11	None	1	$ 0.08	$ 1.76
	Crimp Wire	Crimp both ends of power and signal wires	unit	1	Repeat 11	11	None	1	$ 0.17	$ 1.87
	Insert Bundle Into Tube or Sleeve	Insert loom into heat shrink	m	0.15	None	1	None	1	$ 0.02	$ 0.00
	Assemble, 1 kg, Loose	Slide boot for DEN Connector onto loom	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Connector Assembly, Crimp	Crimp and Install DEN side DT Connector	contact	1	Repeat 11	11	None	1	$ 0.36	$ 3.96
	Connector Assembly, Crimp	Crimp and Install MoTeC side DT Connecto	contact	1	Repeat 11	11	None	1	$ 0.36	$ 3.96
	Shrink Tube	Heat shrink looms	cm	15	None	1	None	1	$ 0.15	$ 2.25
	Shrink Tube	Heat shrink boots	cm	5	None	1	None	1	$ 0.15	$ 0.75
Total										$ 15.49

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102006-01	Part Cost	$ 24.45
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 24.45
Car #	E03	Part	GPS and Telemetry - DEN (LV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wires for Telemetry - DEN (LV) (2 alrea	0.15	m		0					4	$ 0.45	$ 1.80
	Wire, Signal and Control	Signal wires for Telemetry - DEN (LV) (1 alrea	0.15	m		0					2	$ 0.15	$ 0.30
	Heat Shrink Tubing	Heat Shrink for looms	0.1	m		0					2	$ 0.05	$ 0.10
	Heat Shrink Tubing	Heat Shrink for boots	0.05	m		0					2	$ 0.03	$ 0.05
	Connector, OEM Quality, High Power (>2A/25W)	DT connector for DEN	6	pin		0					1	$ 6.00	$ 6.00
	Connector, OEM Quality, Low Power (≤2A/25W)	Connector for Antenna (serial)	9	pin		0					1	$ 9.00	$ 9.00
Total													$ 17.25

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut power and signal wires	unit	1	Repeat 6	6	None	1	$ 0.08	$ 0.48
	Strip Wire	Strip both ends of the wire	unit	2	Repeat 3	3	None	1	$ 0.08	$ 0.48
	Strip Wire	Strip the DEN Side of the remaining wires	unit	1	Repeat 3	3	None	1	$ 0.08	$ 0.24
	Insert Bundle Into Tube or Sleeve	Insert loom into heat shrink	m	0.1	Repeat 2	2	None	1	$ 0.02	$ 0.00
	Assemble, 1 kg, Loose	Slide boots onto loom	unit	1	Repeat 2	2	None	1	$ 0.06	$ 0.12
	Connector Assembly, Crimp	Crimp and Install Wires into DEN DT Connecto	contact	1	Repeat 6	6	None	1	$ 0.36	$ 2.16
	Connector Assembly, Solder	Solder Telemetry wires onto Serial Connecto	contact	1	Repeat 3	3	None	1	$ 0.24	$ 0.72
	Shrink Tube	Heat shrink looms	cm	10	None	1	None	1	$ 0.15	$ 1.50
	Shrink Tube	Heat shrink boots	cm	5	Repeat 2	2	None	1	$ 0.15	$ 1.50
Total										$ 7.20

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102007-01	Part Cost	$	95.85
Competition Code	FSAE-A	System	Electrical System	QTY		1
Year	2024	Assembly	Looms	Extended Cost	$	95.85
Car #	E03	Part	DEN - CEN (LV)			

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wires for CEN-DEN	1.5	m		0					8	$ 4.50	$ 36.00
	Wire, Signal and Control	Signal wires for CEN-DEN	1.5	m		0					8	$ 1.50	$ 12.00
	Connector, OEM Quality, High Power (>2A/25W)	DT connectors (DEN and CEN)	8	pin		0					2	$ 8.00	$ 16.00
	Heat Shrink Tubing	Heat shrink for loom	1.45	m		0					1	$ 0.73	$ 0.73
	Heat Shrink Tubing	Heat shrink boots	0.05	m		0					2	$ 0.03	$ 0.05
Total													$ 64.78

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut power and signal wires	unit	1	Repeat 8	8	None	1	$ 0.08	$ 0.64
	Strip Wire	Strip each end of wire	unit	2	Repeat 8	8	None	1	$ 0.08	$ 1.28
	Insert Bundle Into Tube or Sleeve	Insert loom into heat shrink	m	1.45	None	1	None	1	$ 0.02	$ 0.03
	Assemble, 1 kg, Loose	Slide on Boot	unit	1	Repeat 2	2	None	1	$ 0.06	$ 0.12
	Connector Assembly, Crimp	Crimp and Install both ends into DT Connecto	contact	2	Repeat 8	8	None	1	$ 0.36	$ 5.76
	Shrink Tube	Shrink heat shrink	cm	145	None	1	None	1	$ 0.15	$ 21.75
	Shrink Tube	Shrink Boot	cm	5	Repeat 2	2	None	1	$ 0.15	$ 1.50
Total										$ 31.08

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102008-01	Part Cost	$ 80.86
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 80.86
Car #	E03	Part	CEN - UEN (LV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wires TSAL to CEN	1	m		0					3	$ 3.00	$ 9.00
	Wire, Signal and Control	CEN to ESTOP, ESTOP to ESTOP and GND SENSE	1	m		0					3	$ 1.00	$ 3.00
	Wire, Signal and Control	ESTOP to CEN	2	m		0					1	$ 2.00	$ 2.00
	Connector, OEM Quality, High Power (>2A/25W)	DT Connector	4	pin		0					3	$ 4.00	$ 12.00
	Connector, OEM Quality, High Power (>2A/25W)	DT connector- CEN	6	pin		0					1	$ 6.00	$ 6.00
	Heat Shrink Tubing	Heat shrink for loom	2	m		0					1	$ 1.00	$ 1.00
	Heat Shrink Tubing	Heat shrink for loom	0.1	m		0					3	$ 0.05	$ 0.15
	Heat Shrink Tubing	Heat shrink boots	0.1	m		0					4	$ 0.05	$ 0.20
Total													$ 33.35

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut power and signal wires	unit	1	Repeat 7	7	None	1	$ 0.08	$ 0.56
	Strip Wire	Strip each end of wire	unit	2	Repeat 7	7	None	1	$ 0.08	$ 1.12
	Insert Bundle Into Tube or Sleeve	Insert loom into heat shrink	m	2.3	None	1	None	1	$ 0.02	$ 0.05
	Assemble, 1 kg, Loose	Slide on Boots for Connectors	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Connector Assembly, Crimp	Crimp and install into DT Connectors	contact	14	None	1	None	1	$ 0.36	$ 5.04
	Shrink Tube	Shrink heat shrink for loom	cm	230	None	1	None	1	$ 0.15	$ 34.50
	Shrink Tube	Shrink Boots	cm	10	Repeat 4	4	None	1	$ 0.15	$ 6.00
Total										$ 47.51

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102009-01	Part Cost	$ 43.87
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 43.87
Car #	E03	Part	CEN - DCDC (LV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	GND wires	0.7	m		0					6	$ 2.10	$ 12.60
	Wire, Signal and Control	CAN wires	0.7	m		0					2	$ 0.70	$ 1.40
	Heat Shrink Tubing	Heat shrink for Loom	0.7	m		0					1	$ 0.35	$ 0.35
	Heat Shrink Tubing	Boot for end of Loom	0.1	m		0					2	$ 0.05	$ 0.10
	Connector, OEM Quality, High Power (>2A/25W)	DT Connector for DCDC Control	2	pin		0					1	$ 2.00	$ 2.00
	Connector, OEM Quality, High Power (>2A/25W)	DT Connector for CEN	8	pin		0					1	$ 8.00	$ 8.00
	Connector, Single Wire	Ring crimps for DCDC GND	1	Unit		0					1	$ 0.10	$ 0.10
Total													$ 24.55

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wires to length	unit	1	Repeat 8	8	None	1	$ 0.08	$ 0.64
	Strip Wire	Strip wire ends	unit	2	Repeat 8	8	None	1	$ 0.08	$ 1.28
	Insert Bundle Into Tube or Sleeve	Slide Heat Shrink onto loom	m	0.7	None	1	None	1	$ 0.02	$ 0.01
	Assemble, 1 kg, Loose	Slide Boots onto loom	unit	1	Repeat 2	2	None	1	$ 0.06	$ 0.12
	Connector Assembly, Crimp	Crimp and Install wires into 8 Pin DT	contact	1	Repeat 8	8	None	1	$ 0.36	$ 2.88
	Connector Assembly, Crimp	Crimp and Install Signal wires for DCDC	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Crimp Wire	Crimp Ring terminal Connector with the 6 Pow	unit	1	None	1	None	1	$ 0.17	$ 0.17
	Shrink Tube	Shrink Heat Strink	cm	70	None	1	None	1	$ 0.15	$ 10.50
	Shrink Tube	Shrink Boots	cm	10	Repeat 2	2	None	1	$ 0.15	$ 3.00
Total										$ 19.32

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102010-01	Part Cost	$ 85.70
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 85.70
Car #	E03	Part	CEN - Motor Controller (LV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wires for CEN - Motor Controller (LV)	0.3	m		0					6	$ 0.90	$ 5.40
	Wire, Signal and Control	Signal wires for CEN - Motor Controller (LV)	0.3	m		0					2	$ 0.30	$ 0.60
	Heat Shrink Tubing	Heat shrink for looms	0.25	m		0					1	$ 0.13	$ 0.13
	Heat Shrink Tubing	Heat Shrink for Looms	0.5	m		0					1	$ 0.25	$ 0.25
	Heat Shrink Tubing	Heat shrink for boots	0.05	m		0					2	$ 0.03	$ 0.05
	Connector, OEM Quality, High Power (>2A/25W)	Deutsch Connector	8	pin		0					1	$ 8.00	$ 8.00
	Connector, OEM Quality, High Power (>2A/25W)	Cascadia Molex Connector	48	pin		0					1	$ 48.00	$ 48.00
Total													$ 62.43

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut power and signal wires for CEN - Motor Controller	unit	1	Repeat 8	8	None	1	$ 0.08	$ 0.64
	Strip Wire	Crimp BOTH ends signal and power wires	unit	2	Repeat 8	8	None	1	$ 0.08	$ 1.28
	Insert Bundle Into Tube or Sleeve	Insert loom into heat shrink	m	0.3	None	1	None	1	$ 0.02	$ 0.01
	Assemble, 1 kg, Loose	Slide boot onto loom	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Connector Assembly, Crimp	Crimp and install one side into DT CEN Connector	contact	1	Repeat 8	8	None	1	$ 0.36	$ 2.88
	Strip Wire	Strip wires coming from motor - E03-20-DR-013007-01	unit	1	Repeat 8	8	None	1	$ 0.08	$ 0.64
	Insert Bundle Into Tube or Sleeve	Heat Shrink wires coming from Motor	m	0.5	None	1	None	1	$ 0.02	$ 0.01
	Connector Assembly, Crimp	Crimp remaining wires and install into Cascadia Molex Conr	contact	1	Repeat 16	16	None	1	$ 0.36	$ 5.76
	Shrink Tube	Heat shrink looms	cm	75	None	1	None	1	$ 0.15	$ 11.25
	Shrink Tube	Heat shrink boots	cm	5	None	1	None	1	$ 0.15	$ 0.75
Total										$ 23.28

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102011-01	Part Cost	$ 64.21
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 64.21
Car #	E03	Part	CEN - Accumulator (LV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wires, CEN-ACC	0.8	m		0					4	$ 2.40	$ 9.60
	Wire, Signal and Control	Signal wires, CEN-ACC	0.8	m		0					8	$ 0.80	$ 6.40
	Heat Shrink Tubing	Heat shrink for loom	0.75	m		0					1	$ 0.38	$ 0.38
	Heat Shrink Tubing	Boot ends for DT connectors	0.05	m		0					2	$ 0.03	$ 0.05
	Connector, OEM Quality, High Power (>2A/25W)	12 Pin DT Connector	12	pin		0					2	$ 12.00	$ 24.00
Total													$ 40.43

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut power and signal wires	unit	1	Repeat 12	12	None	1	$ 0.08	$ 0.96
	Strip Wire	Strip each end of wire	unit	2	Repeat 12	12	None	1	$ 0.08	$ 1.92
	Insert Bundle Into Tube or Sleeve	Insert loom into heat shrink	m	0.75	None	1	None	1	$ 0.02	$ 0.02
	Assemble, 1 kg, Loose	Slide on Boot	unit	2	Repeat 2	2	None	1	$ 0.06	$ 0.24
	Connector Assembly, Crimp	Crimp ends and Install into 12 Pin DTs	contact	2	Repeat 12	12	None	1	$ 0.36	$ 8.64
	Shrink Tube	Shrink Heat Shrink	cm	75	None	1	None	1	$ 0.15	$ 11.25
	Shrink Tube	Shrink Boot	cm	5	None	1	None	1	$ 0.15	$ 0.75
Total										$ 23.78

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102012-01	Part Cost	$ 59.20
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 59.20
Car #	E03	Part	CEN - HIP (LV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power wires, CEN-ACC	0.4	m		0					8	$ 1.20	$ 9.60
	Wire, Signal and Control	Signal wires, CEN-ACC	0.4	m		0					4	$ 0.40	$ 1.60
	Heat Shrink Tubing	Heat shrink for loom	0.35	m		0					1	$ 0.18	$ 0.18
	Heat Shrink Tubing	Boot ends for DT connectors	0.05	m		0					2	$ 0.03	$ 0.05
	Connector, OEM Quality, High Power (>2A/25W)	12 Pin DT Connector	12	pin		0					2	$ 12.00	$ 24.00
Total													$ 35.43

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val. 2	Unit Cost	Sub total
	Cut wire	Cut power and signal wires	unit	1	Repeat 12	12	None	1	$ 0.08	$ 0.96
	Strip Wire	Strip each end of wire	unit	2	Repeat 12	12	None	1	$ 0.08	$ 1.92
	Insert Bundle Into Tube or Sleeve	Insert loom into heat shrink	m	0.75	None	1	None	1	$ 0.02	$ 0.02
	Assemble, 1 kg, Loose	Slide on Boot	unit	2	Repeat 2	2	None	1	$ 0.06	$ 0.24
	Connector Assembly, Crimp	Crimp ends and Install into 12 Pin DTs	contact	2	Repeat 12	12	None	1	$ 0.36	$ 8.64
	Shrink Tube	Shrink Heat Shrink	cm	75	None	1	None	1	$ 0.15	$ 11.25
	Shrink Tube	Shrink Boot	cm	5	None	1	None	1	$ 0.15	$ 0.75
Total										$ 23.78

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102013-01	Part Cost	$	108.94
Competition Code	FSAE-A	System	Electrical System	QTY		1
Year	2024	Assembly	Looms	Extended Cost	$	108.94
Car #	E03	Part	CEN - Cooling and Brake Light (LV)			

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	12V and GND wires	1.6	m		0					8	$ 4.80	$ 38.40
	Heat Shrink Tubing	Heat shrink for Loom	1.55	m		0					1	$ 0.78	$ 0.78
	Heat Shrink Tubing	Heat Shirnk for Loom	0.4	m		0					3	$ 0.20	$ 0.60
	Heat Shrink Tubing	Boot for end of Loom	0.05	m		0					5	$ 0.03	$ 0.13
	Connector, OEM Quality, High Power (>	DT Connector for Cooling a	2	pin		0					4	$ 2.00	$ 8.00
	Connector, OEM Quality, High Power (>	DT Connector for CEN	8	pin		0					1	$ 8.00	$ 8.00
Total													$ 55.90

Processes / Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wires to length	unit	1	Repeat 8	8	None	1	$ 0.08	$ 0.64
	Strip Wire	Strip wire ends	unit	2	Repeat 8	8	None	1	$ 0.08	$ 1.28
	Insert Bundle Into Tube or Sleeve	Slide Heat Shrink onto loor	m	2.75	None	1	None	1	$ 0.02	$ 0.06
	Assemble, 1 kg, Loose	Slide Boots onto loom	unit	1	Repeat 5	5	None	1	$ 0.06	$ 0.30
	Connector Assembly, Crimp	Crimp and Install wires intc	contact	1	Repeat 8	8	None	1	$ 0.36	$ 2.88
	Connector Assembly, Crimp	Crimp and Install on 2 pin D	contact	4	Repeat 2	2	None	1	$ 0.36	$ 2.88
	Shrink Tube	Shrink Heat Strink	cm	275	None	1	None	1	$ 0.15	$ 41.25
	Shrink Tube	Shrink Boots	cm	5	Repeat 5	5	None	1	$ 0.15	$ 3.75
Total										$ 53.04

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102014-01	Part Cost	$ 46.36
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 46.36
Car #	E03	Part	HIP - DCDC (LV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power Wires	1	m		0					6	$ 3.00	$ 18.00
	Heat Shrink Tubing	Heat shrink for Loom	0.95	m		0					1	$ 0.48	$ 0.48
	Heat Shrink Tubing	Boot for end of Loom	0.05	m		0					1	$ 0.03	$ 0.03
	Connector, OEM Quality, High Power (>	DT Connector for CEN	6	pin		0					1	$ 6.00	$ 6.00
	Connector, Single Wire	Ring crimps for DCDC GND	1	Unit		0					1	$ 0.10	$ 0.10
Total													$ 24.60

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wires to length	unit	1	Repeat 6	6	None	1	$ 0.08	$ 0.48
	Strip Wire	Strip wire ends	unit	2	Repeat 6	6	None	1	$ 0.08	$ 0.96
	Insert Bundle Into Tube or Sleeve	Slide Heat Shrink onto loor	m	0.95	None	1	None	1	$ 0.02	$ 0.02
	Assemble, 1 kg, Loose	Slide Boots onto loom	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Connector Assembly, Crimp	Crimp and Install wires intc	contact	2	Repeat 6	6	None	1	$ 0.36	$ 4.32
	Crimp Wire	Crimp Ring terminal Conne	unit	1	None	1	None	1	$ 0.17	$ 0.17
	Shrink Tube	Shrink Heat Strink	cm	95	None	1	None	1	$ 0.15	$ 14.25
	Shrink Tube	Shrink Boots	cm	5	Repeat 2	2	None	1	$ 0.15	$ 1.50
Total										$ 21.76

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102015-01	Part Cost	$ 77.22
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 77.22
Car #	E03	Part	HIP - DCDC (HV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, HV Signal	HV Supply to the DCDC (10	1	m		0					2	$ 5.00	$ 10.00
	Connector, OEM Quality, High Power (>	Deutsch Connector	2	pin		0					1	$ 2.00	$ 2.00
	Connector, HC-HV incl. Interlock	DCDC HV Connector	2	pin		0					1	$ 60.00	$ 60.00
	Heat Shrink Tubing	Boot	0.1	m		0					2	$ 0.05	$ 0.10
	Conduit incl. Nuts, Elbows etc.	HV Conduit	0.9	m		0					1	$ 0.90	$ 0.90
Total													$ 73.00

Processes / Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wires to length	unit	1	Repeat 2	2	None	1	$ 0.08	$ 0.16
	Strip Wire	Strip wire ends	unit	2	Repeat 2	2	None	1	$ 0.08	$ 0.32
	Insert Bundle Into Tube or Sleeve	Slide conduit onto loom	m	0.9	None	1	None	1	$ 0.02	$ 0.02
	Assemble, 1 kg, Loose	Slide Boots onto loom	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Connector Assembly, Crimp	Crimp and Install wires into	contact	2	Repeat 2	2	None	1	$ 0.36	$ 1.44
	Connector Assembly, Crimp	Crimp and Install wires into	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Shrink Tube	Shrink Boots	cm	5	Repeat 2	2	None	1	$ 0.15	$ 1.50
Total										$ 4.22

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102016-01	Part Cost	$ 20.65
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 20.65
Car #	E03	Part	LV Battery - DCDC (LV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Wire, Power	Power and GND Wires	0.3	m		0					4	$ 1.20	$ 4.80
	Heat Shrink Tubing	Heat shrink for Loom	0.25	m		0					1	$ 0.13	$ 0.13
	Heat Shrink Tubing	Boot for end of Loom	0.05	m		0					1	$ 0.03	$ 0.03
	Connector, OEM Quality, High Power (>	DT Connector for LV Batter	4	pin		0					1	$ 6.00	$ 6.00
	Connector, Single Wire	Ring crimps for DCDC 12V a	1	Unit		0					2	$ 0.10	$ 0.20
Total													$ 11.15

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wires to length	unit	1	Repeat 4	4	None	1	$ 0.08	$ 0.32
	Strip Wire	Strip wire ends	unit	2	Repeat 4	4	None	1	$ 0.08	$ 0.64
	Insert Bundle Into Tube or Sleeve	Slide Heat Shrink onto loom	m	0.25	None	1	None	1	$ 0.02	$ 0.01
	Assemble, 1 kg, Loose	Slide Boots onto loom	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Connector Assembly, Crimp	Crimp and Install wires into	contact	2	Repeat 4	4	None	1	$ 0.36	$ 2.88
	Crimp Wire	Crimp Ring terminal Conne	unit	2	None	1	None	1	$ 0.17	$ 0.34
	Shrink Tube	Shrink Heat Strink	cm	25	None	1	None	1	$ 0.15	$ 3.75
	Shrink Tube	Shrink Boots	cm	5	Repeat 2	2	None	1	$ 0.15	$ 1.50
Total										$ 9.50

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle		P/N	E03-20-EL-102017-01		Part Cost	$ 129.83	
Competition Code	FSAE-A		System	Electrical System		QTY	1	
Year	2024		Assembly	Looms		Extended Cost	$ 129.83	
Car #	E03		Part	Accumulator - HIP (HV)				

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Connector, HC-HV incl. Interlock	HV Surlocks	1	pin		0					4	$ 30.00	$ 120.00
	Conduit incl. Nuts, Elbows etc.	Conduit for HV Cables	0.65	m		0					1	$ 0.40	$ 0.40
	Wire, HV Power	25mm^2 HV wire	0.75	m		0					2	$ 3.75	$ 7.50
Total													$ 127.90

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wire length	unit	1	Repeat 2	2	None	1	$ 0.08	$ 0.16
	Strip Wire	Strip wire ends	unit	2	Repeat 2	2	None	1	$ 0.08	$ 0.32
	Insert Bundle Into Tube or Sleeve	Conduit install	m	0.65	None	1	None	1	$ 0.02	$ 0.01
	Connector Assembly, Crimp	Crimp and install cover of Surlok	contact	1	Repeat 4	4	None	1	$ 0.36	$ 1.44
Total										$ 1.93

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
									$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102018-01	Part Cost	$ 121.30
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 121.30
Car #	E03	Part	HIP - Motor Controller (HV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Connector, HC-HV incl. Interlock	HV Surlocks	1	pin		0					2	$ 30.00	$ 60.00
	Connector, HC-HV incl. Interlock	Cascadia HPK Connector WITH 2 50 mm^2 Shielded Cable attache	2	pin		0					1	$ 60.00	$ 60.00
Total													$ 120.00

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wire length	unit	1	Repeat 2	2	None	1	$ 0.08	$ 0.16
	Strip Wire	Strip wire ends	unit	1	Repeat 2	2	None	1	$ 0.08	$ 0.16
	Connector Assembly, Crimp	Crimp and install cover of Surlok	contact	1	Repeat 2	2	None	1	$ 0.36	$ 0.72
	Install Tie Wrap (Zip Tie, Cable Clamp)	Zip tie Cables together	unit	1	Repeat 2	2	None	1	$ 0.09	$ 0.18
Total										$ 1.22

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Tie Wrap, Plastic	Keep HV Cables together	1	Unit		0	2	$ 0.04	$ 0.08
Total									$ 0.08

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-102019-01	Part Cost	$ 95.06
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Looms	Extended Cost	$ 95.06
Car #	E03	Part	Motor Controller - Motor (HV)		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Connector, HC-HV incl. Interlock	Cascadia HPK Connector WITH 3 50 mm^2 Shielded Cables attached	1	pin		0					3	$ 30.00	$ 90.00
	Connector, HC-HV Lug Type	Lugs to attach wire to Motor Controller	1	pin		0					3	$ 1.00	$ 3.00
	Heat Shrink Tubing	Heat Shrink to Cover the Lugs when attached to the motor	0.07	m		0					3	$ 0.04	$ 0.11
Total													$ 93.11

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wire length	unit	1	Repeat 3	3	None	1	$ 0.08	$ 0.24
	Strip Wire	Strip wire ends	unit	1	Repeat 3	3	None	1	$ 0.08	$ 0.24
	Connector Assembly, Crimp	Crimp Lugs	contact	1	Repeat 3	3	None	1	$ 0.36	$ 1.08
	Assemble, 1 kg, Line-on-Line	Slide Heat Shrink onto Cable (heat shrink when assembled to motor	unit	1	Repeat 3	3	None	1	$ 0.13	$ 0.39
Total										$ 1.95

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	A/N	E03-20-EL-111000-01	Part Cost	N/A
Competition Code	FSAE-A	System	Electrical Systems	QTY	N/A
Year	2024	Assembly	Brake Light	Extended Cost	$ 17.82
Car #	E03	Part	N/A		

Parts

ID	P/N	Description	Part Co	QTY	Sub Total
	E03-20-EL-112001-01	Brake Light	$ 7.14	1	$ 7.14
	E03-20-EL-112002-01	Brake Light Enclosure	$ 5.16	1	$ 5.16
Total					**$ 12.30**

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Assemble, 1 kg, Loose	Assemble Brake Light to Brake Light Enclosui	unit	1	None	1	None	1	$ 0.06	$ 0.06
	Assemble, 1 kg, Loose	Assemble M6 Washer onto M6 Bolt	unit	1	Repeat 4	4	None	1	$ 0.06	$ 0.24
	Hand - Start Only	Hand Start M6 Bolt to fasten the Brake like tc	unit	1	Repeat 2	2	None	1	$ 0.12	$ 0.24
	Ratchet <= 25.4 mm	Ratchet M6 Bolt to fasten the Brake light to t	unit	1	Repeat 2	2	None	1	$ 0.75	$ 1.50
	Assemble, 1 kg, Line-on-Line	Assemble Brake light to chassis mount	unit	1	None	1	None	1	$ 0.13	$ 0.13
	Assemble, 1 kg, Line-on-Line	M6 bolts to Brake light and Chassis Mount	unit	1	Repeat 2	2	None	1	$ 0.13	$ 0.26
	Assemble, 1 kg, Line-on-Line	M6 Washer to M6 bolt	unit	1	Repeat 2	2	None	1	$ 0.13	$ 0.26
	Hand - Start Only	Hand Start M6 Nut to M6 Bolt	unit	1	Repeat 2	2	None	1	$ 0.12	$ 0.24
	Ratchet <= 25.4 mm	Ratchet M6 nut to fasten the Brake light to C	unit	1	Repeat 2	2	None	1	$ 0.75	$ 1.50
	Reaction Tool <= 6.35 mm	Reactive to hold M6 bolt	unit	1	Repeat 2	2	None	1	$ 0.25	$ 0.50
Total										**$ 4.93**

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
	Bolt, Grade 12.9	M6 Bolt	6	mm	30	mm	4	$ 0.10	$ 0.42
	Washer, Grade 12.9	M6 Washer	6	mm		0	6	$ 0.01	$ 0.07
	Nut, Grade 12.9	M6 Nylock Nut	6	mm		0	2	$ 0.05	$ 0.10
Total									**$ 0.59**

University	University of Newcastle	P/N	E03-20-EL-112001-01	Part Cost	$ 7.14
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Brake Light	Extended Cost	$ 7.14
Car #	E03	Part	Brake Light		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Lamp, Brake with Housing	Brake Light with Power Wir	1	unit		0					1	$ 4.00	$ 4.00
	Connector, OEM Quality, High Power (>	Deutsch Connectot Recepti	2	pin		0					1	$ 2.00	$ 2.00
	Heat Shrink Tubing	Heat Shrink	0.03	m		0					1	$ 0.01	$ 0.01
Total													$ 6.01

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Cut wire	Cut wires to length	unit	1	Repeat 2	2	None	1	$ 0.08	$ 0.16
	Strip Wire	Strip Wire ends	unit	1	Repeat 2	2	None	1	$ 0.08	$ 0.16
	Insert Bundle Into Tube or Sleeve	Slide on Heat Strink	m	0.03	None	1	None	1	$ 0.02	$ 0.00
	Connector Assembly, Crimp	Crimp and Insert into Deut:	contact	1	None	1	None	1	$ 0.36	$ 0.36
	Shrink Tube	Shrink Heat Shrink	cm	3	None	1	None	1	$ 0.15	$ 0.45
Total										$ 1.13

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

University	University of Newcastle	P/N	E03-20-EL-112002-01	Part Cost	$ 5.16
Competition Code	FSAE-A	System	Electrical System	QTY	1
Year	2024	Assembly	Brake Light	Extended Cost	$ 5.16
Car #	E03	Part	Brake Light Enclosure		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Plastic, Polyethelene (per kg)	PETG Filament for 3D Priniting	0.14605674	kg		0					1	$ 0.48	$ 0.48
Total													$ 0.48

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Rapid Prototype - Plastic	3D Printing Enclosure	kg	0.146057	None	1	None	1	$ 32.00	$ 4.67
Total										$ 4.67

Fasteners

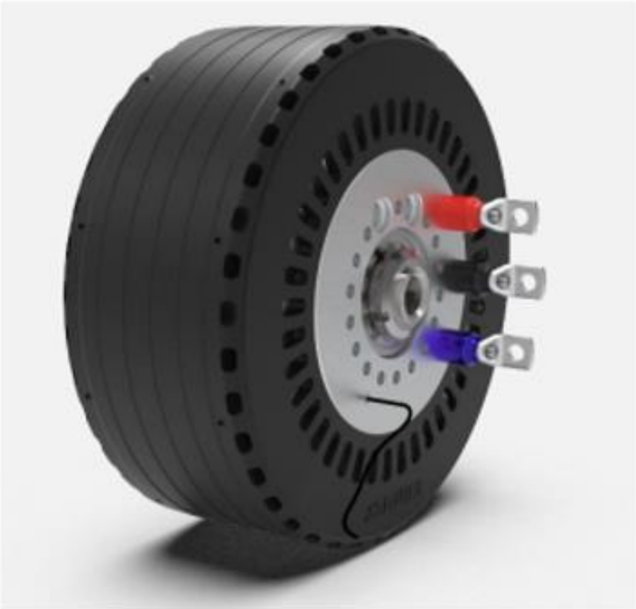
ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

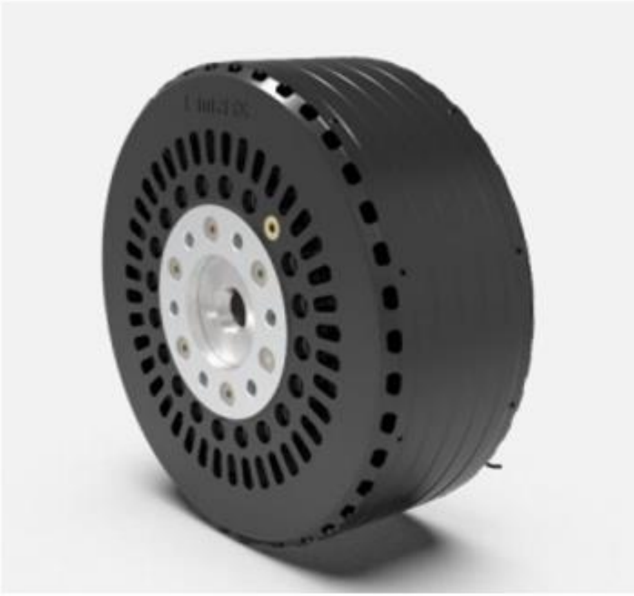
Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

The Cost Scenario Presentation

EMRAX 228 VS EMRAX 208 AC ELECTRIC MOTORS

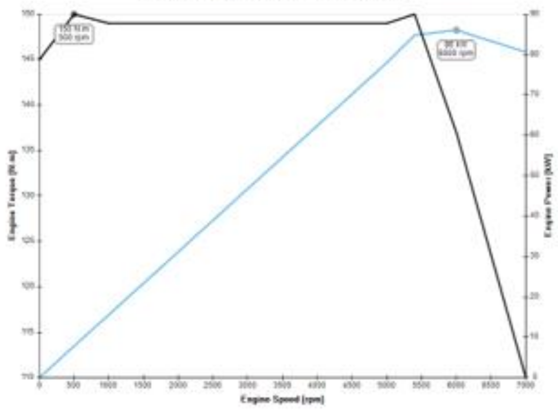




Motor Specs and Power Curves

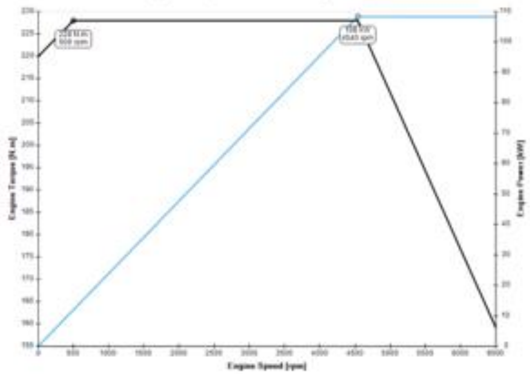
EMRAX 208	
DIAMETER | LENGTH	208 mm | 85 mm
WEIGHT	9,4-10,3 kg
COOLING	air / water / combined
PEAK | CONTINUOUS POWER	86 kW | 56 kW*
PEAK | CONTINUOUS TORQUE	150 Nm | 90 Nm*
MAXIMUM SPEED	7000 RPM
OPERATING VOLTAGE	50 - 580 V
EFFICIENY	up to 96%*
POSITION SENSOR	resolver / encoder

Engine Torque and Power vs Engine Speed

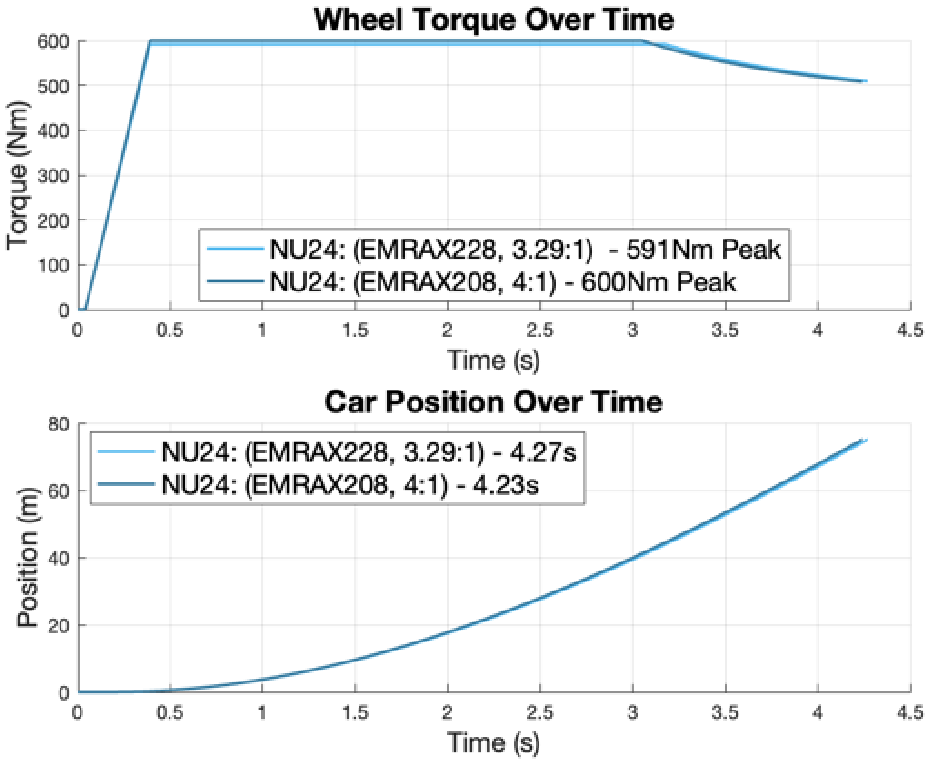


EMRAX 228	
DIAMETER | LENGTH	228 mm | 86 mm
WEIGHT	12,9-13,5 kg
COOLING	air / water / combined
PEAK | CONTINUOUS POWER	124 kW | 75 kW*
PEAK | CONTINUOUS TORQUE	230 Nm | 130 Nm*
MAXIMUM SPEED	6500 RPM
OPERATING VOLTAGE	50 - 710 V
EFFICIENY	up to 96%*
POSITION SENSOR	resolver / encoder

Engine Torque and Power vs Engine Speed



Speed vs Distance



Cost Savings

University	University of Newcastle		P/N	E03-20-DR-013007-01		Part Cost	$ 7,503.84
Competition Code	FSAE-A		System	Engine/Tractive Path and Drivetrain		QTY	1
Year	2024		Assembly	Motor		Extended Cost	$ 7,503.84
Car #	E03		Part	Emrax 228 Motor			

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Motor, Tractive AC	Emrax 228 Motor	75	kW		0					1	$ 7,500.00	$ 7,500.00
	Connector, Single Wire	Soldered connection in Motor	1	Unit		0					8	$ 0.05	$ 0.40
Total													$ 7,500.40

Processes

Process Multipliers

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val.	Unit Cost	Sub total
	Attach Wire, Solder	Solder motor connections	wire	1	Repeat 8	8	None	1	$ 0.43	$ 3.44
Total										$ 3.44

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

75 kW (continuous) * $100 / kW = $7500 for 228 EMRAX

Cost Savings

University	University of Newcastle	P/N	E03-20-DR-013007-01	Part Cost	$ 5,603.84
Competition Code	FSAE-A	System	Engine/Tractive Path and Drivetrain	QTY	1
Year	2024	Assembly	Motor	Extended Cost	$ 5,603.84
Car #	E03	Part	Emrax 228 Motor		

Materials

ID	Material	Description	Size 1	Unit 1	Size 2	Unit 2	Area Name	Area (mm^2)	Length (mm)	Density (kg/m^3)	QTY	Unit Cost	Sub Total
	Motor, Tractive AC	Emrax 228 Motor	56	kW		0					1	$ 5,600.00	$ 5,600.00
	Connector, Single Wire	Soldered connection in Motor	1	Unit		0					8	$ 0.05	$ 0.40
Total													$ 5,600.40

Processes / **Process Multipliers**

ID	Process	Use	Unit	QTY	Multiplier	Mult. Val.	Multiplier 2	Mult. Val. 2	Unit Cost	Sub total
	Attach Wire, Solder	Solder motor connections	wire	1	Repeat 8	8	None	1	$ 0.43	$ 3.44
Total										$ 3.44

Fasteners

ID	Fasteners	Use	Size 1	Unit 1	Size 2	Unit 2	QTY	Unit Cost	Sub Total
				#N/A		#N/A			$ -
Total									$ -

Tooling

ID	Tooling	Use	Unit	QTY	PVF	Frac. Incl	Unit Cost	Sub Total
	None		unit					$ -
Total								$ -

Page 1

56 kW (continuous) * $100 / kW = $5600 for 208 EMRAX

Cost Savings and Performance

Motors	Cost ($)	Performance (Seconds)
EMRAX 228	$7500	4.27
EMRAX 208	$5600	4.23
DELTA	$1900	-0.04 (1% INCREASE)

The MCHA Technical Inspection Bible:

2024 Formula SAE-A Technical Inspection Sheet

ACCUMULATOR INSPECTION

Initial Presentation Scrutineer Name:		**Initial Presentation Lane Number:**	
1st Reinspection Scrutineer Name:		**1st Reinspection Lane Number:**	
2nd Reinspection Scrutineer Name:		**2nd Reinspection Lane Number:**	
3rd Reinspection Scrutineer Name:		**3rd Reinspection Lane Number:**	

PERSONNEL Teams are required to have an Electrical Safety Officer.			**Inspection #** **Initial ins.**	**1st reins.**	**2nd reins.**	**3rd reins.**
AI.1.1	Identify the Electrical Safety Officer (ESO)	Ask for the ESO				
AI.1.2	Only team members involved in technical inspection can be in the technical inspection bay	Ask for non-essential people to leave the area				
	DO NOT PROCEED WITH TECHNICAL INSPECTION IF THE ESO IS NOT PRESENT					

INSTRUCTIONS FOR SCRUTINEERS

This section applies to Electric Vehicles (EV) and Autonomous Vehicles (AV) and Dual Purpose Vehicles.
If an item is acceptable, initial the "Passed" column.
If an item is unacceptable, initial the "Reinspect" column and inform the team members they have not meet the requirements for that item.
Teams are allowed to take their vehicle away from technical inspection and address any issues before representing for reinspection.
Scrutineers may continue with the inspection when unacceptable items are found, provided it is safe to do so.
Teams are required to pass all items before the vehicle can proceed to the Brake Test or compete in Dynamic Events.

Scrutineers reserve the right to refuse to proceed with Technical Inspection if a sufficiently serious issue which might jeopardize the safety of the technical inspection team, event personal or any other persons is found at any time.

- ESO (Alec), Daniel, Kris, Jackson and Malcolm (charger), Lukes (document hander), Fisher (SES)
- Charger, Accumulator (race ready) bolted to the accumulator trolley,
- Accumulator spares box
- Red toolbox, callipers and large cable crimps (blue handle)
- Tech Box which samples, documents and tech bibles
- 2 x HV Mats
- 4 x Safety Glasses, 3 x LV Gloves and 3 x Leather outers
- HV Insulated tools – Socket sets, Spanners, Screwdrivers, cutter, shears, Allen keys
- Fluke Multimeter with probes and banana jack proves

2024 Formula SAE-A Technical Inspection Sheet - R01.xlsx   ACCUMULATOR INSPECTION Page 1 of 9

EV CLASS - ACCUMULATOR INSPECTION

				Reinspect	Passed
SAFETY EQUIPMENT AND TOOLS Teams are expected to have appropriate safety equipment and tools to allow them to work on their vehicle. All safety equipment and tools must be in good usable condition and comply to Australian industry best practice standards. There must be a sufficient quantity of appropriate safety equipment (PPE) for everyone who needs to work on electrical systems. Insulated tools must be rated and appropriately marked as complaint to DIN/IEC 60900 (VDE 1000V), or an equivalent recognized standard. Improvised or repaired tools using heat shrink, tape or similar are not acceptable. Modified tools are not acceptable.					
AI.2.1	Safety Glasses	At least one pair per team member working on electrical systems. Safety Glasses should be non-conductive (non-metallic). Display safety glasses which should be laid out, know where safety rating is	Inspect		
AI.2.2	HV Insulating Gloves	HV Isolating gloves with leather outers. Gloves must comply with AS2225 or ASTM D120 or AS IEC 60903 The inner gloves must have been tested in the last 12 months and be free from damage or punctures. Outer gloves must be in serviceable condition. Gloves must be labelled with a working voltage, higher than the vehicle's maximum battery voltage. At least one pair per team member working on electrical systems. Size of the gloves should be appropriate for those conducting the work. Note: Class 00 gloves are rated for up to 500V, Class 0 gloves are rated for up to 1000V. Lay gloves out separated from the outers	Inspect 	p.g.1	
AI.2.3	HV Isolating Blanket	Two HV Isolating Blanket (at least 0.83 square meter) Measure or look at data sheet Blanket must be in good condition and free from punctures or tears. Blanket must be labelled with a working voltage, higher than the vehicle's maximum battery voltage.	Inspect	p.g.1-2	
AI.2.4	HV Insulated Tools	Check the team has an appropriate set of tools to maintain the vehicles electrical systems. These must include as a minimum all of the following: - Insulated cable shear Display - Insulated screwdrivers Display - Insulated pliers Display - Multimeter with protected probe tips (CATIII 600V or better) Display - A pair of quality insulated 5mm banana test leads (600V rated or higher) Display	Inspect	p.g.3	
AI.2.5	Additional Insulated Tools	If the accumulator uses bolted connections the team must also present tools appropriate for manipulating the selected fasteners such as: - Insulated spanners Display - Insulated socket set Display - Insulated Allen keys (hex wrenches) Display - Any other special tools required to maintain the accumulator and other electrical systems safely	Inspect	p.g.3	

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ACCUMULATOR INSPECTION Page 2 of 9

EV CLASS - ACCUMULATOR INSPECTION

CHARGING TROLLEY				Reinspect	Passed
AI.3.1	TSACHC Wheels	The hand cart must have at least two wheels. Appropriately rate to take the load of the accumulator and cart. Display datasheet, the accumulator is 70kg, trolley weight is much less than 70 kg	Inspect	p.g.4	
AI.3.2	TSACHC Brake	The hand cart must have a brake which acts on at least 2 of the wheels that is always on and only released if someone pushes the handle, or similar. The brake must be capable of safely stopping the fully loaded hand cart. Display by moving the trolley and operating the brake lever	Inspect		
AI.3.3	TSACHC Accumulator Mounting	Accumulator must be securely attached to the hand cart to enable safe transportation. Display trolley with accumulator bolted to the base.	Inspect		
AI.3.4	TSACHC Labels	The label on the TSACHC must include The vehicle number, the university name, and the ESO phone number(s) must be displayed and written in Roman characters of at least 10mm high on the lid or top of each TSACHC. The characters must be clearly visible and placed on a high-contrast background. Display labels on Trolley, Use a ruler to show height of letters	Inspect		

BATTERY CHARGER INSPECTION Only chargers presented and sealed at technical inspection are allowed.				Reinspect	Passed
AI.4.1	Battery Charger	Charger needs to be professionally built. All connections of the charger(s) must be insulated and covered. No open connections are allowed. Surloks must be covered, Malcolm to be present and to explain that he built it and is a qualified electrician	Inspect		
AI.4.2	Battery Charger Wiring	Battery Charger Power lead must be free of any damage, nicks, cuts, grease or grime. The plug shall be suitably rated for the current load and conforming to EN 60309-2, AS/NZS 3123. Charger shall have a valid test and tag sticker, or tag attached. Display Datasheet, display testing tag and conforming sticker	Inspect	p.g.5	
AI.4.3		HV wires must be marked with gauge, temperature rating and voltage rating, serial number or norm is also sufficient, if the team shows the datasheet in printed form. Display samples and datasheets	Inspect	p.g.6-10	
AI.4.4		Wire temperature and voltage rating must be suitable for use in the charger Display Datasheet	Inspect	p.g.7-10	
AI.4.5		Using only insulating tape or rubber-like paint for insulation is prohibited. We do not use	Inspect		
AI.4.6		The AC power supply to the battery charger and other associated devices must include a residual current device (RCD) with over current protection (fuses or an appropriate circuit breaker) or residual current circuit breaker (RCBO). The RCD or RCBO device must act to disconnect both the active and neutral supplies. The trip sensitivity of the RCD must not exceed 30mA. Where possible 10mA is preferred. Display Datasheet and show on charger. Display schematic	Inspect	p.g.11-13	
AI.4.7		Traction System charging leads must be orange. Display HV Charging Cable	Inspect	p.g.8	

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ACCUMULATOR INSPECTION Page 3 of 9

EV CLASS - ACCUMULATOR INSPECTION

BATTERY CHARGER INSPECTION CONTINUED... Only chargers presented and sealed at technical inspection are allowed.				Reinspect	Passed
AI.4.8	Charging system measuring points	Two charging system voltage measuring points must be provided on the charger output lines. Display Schematic and Test Points	Inspect	p.g.13	
AI.4.9		The measuring points must be protected from being touched with the bare hand/fingers once the housing is opened. Display Test points with covers	Inspect		
AI.4.10		4mm shrouded banana jacks rated to a voltage higher than the maximum tractive system voltage must be used Display datasheet	Ask the team to provide a datasheet	p.g.14	
AI.4.11		The Charger System Measurement Points must be protected by body protection resistors per EV6.8.4 Display schematic, datasheet and be prepared to demonstrate using FLUKE by doing the HV+ test point and outlet and the HV- test point and outlet. They should both be 15kΩ	Inspect	p.g.15	
AI.4.12		The Charger System Measuring Points must be marked with HV+ and HV- Display test points	Inspect		
AI.4.13	Battery Charger Emergency Stop	The charger must include a push-type emergency stop button which has a minimum diameter of 25mm and must be clearly labelled. The Pushbutton must be easy to reach with the accumulator in place. Display Estop and the length of the accumulator charging cables. Use callipers to measure button size	Inspect		
AI.4.14		When the E-stop is pressed, the output from the charger must be electrically disconnected from the battery, and the output from the charger must fall to less than 60 V in 5 seconds. Display video	Inspect		
AI.4.15		The international electrical symbol consisting of a red spark on a white-edged blue triangle must be affixed in close proximity to this switch Display sticker	Inspect		
AI.4.16	Battery Charger Earthing	The battery charger, accumulator and accumulator charging trolley, and any associated metallic components must be equipotential bonded and connected to the AC power supply earth such that the RCD function is not impeded. Cables used for earthing must be yellow/green stripped and at least 2.5mm^2 cross section. Display photos and earth cable connecting everything, display datasheet	Inspect	p.g.16-17	
AI.4.17	Battery Charger Galvanic Isolation	The Charger DC output must be galvanically isolated from the AC input display datasheets	Inspect	p.g.18	

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EV CLASS - ACCUMULATOR INSPECTION

				Reinspect	Passed
ACCUMULATOR INSPECTION Accumulator technical inspection will inspect the accumulator outside of the vehicle in the designated battery room. Teams are expected to bring the necessary tools for the safe opening of the accumulator for inspection. All accumulators will be physically inspected.					
AI.5.1	Accumulator Construction	HV Accumulator(s) must be enclosed in container(s). Display	Inspect		
AI.5.2		The bottom of the accumulator must be steel of minimum thickness 1.25mm or Aluminium of minimum thickness 3.2mm. Walls (internal and external) and cover/top, must be Steel of minimum thickness 0.9mm or aluminium of minimum thickness of 2.3mm. If alternative material used, they should present proof of equivalency (per SES or other) with a sample. Display photos and/or measure the physical container	Inspect	p.g.19	
AI.5.3		All components and parts of the accumulator container need to be properly fixed. Internal cables and components must not be able to move around causing chafing, stress to connections, or other damage. Display, wiggle and touch cables	Inspect		
AI.5.4		Fasteners in the tractive system high current path must have a positive locking mechanisim. The locking mechanism must be suitable for use at a minimum operating temperature of 90 degrees C. Bolts with nylon patches are acceptable only for blind holes and where used per OEM design. Any bolt which may pose a risk of fire or short circuit if loosened must utilise a positive locking mechanism. Display that only genlocks are used in the accumulator which are rated to 300 degrees C	Inspect		
AI.5.5		The accumulator cells must be secured from moving in the event of an impact. This includes if the accumulator in inverted. Generally, friction fitting is not sufficient, and some positive retention is required. If the accumulator lid is used as a method to retain the cells, it must be reinforced and robustly attached. Display calc of lid strength and that the top plate is reinforced. Display image of cells under top plate	Inspect	p.g.20 - 22	
AI.5.6		Internal vertical walls must be robustly fastened to the container Display welds on the outside of the container and the bottom, show photos	Inspect	p.g.19	
AI.5.7		If the accumulator container is made from an electrically conductive material, the poles of the accumulator stack(s) and/or cells must be insulated against the inner wall of the accumulator container, if the container is made of electrically conductive material. There must be an insulating barrier between the accumulator walls and any electrically live component within. This usually means that all of the internal walls of the accumulator need to be lined with an appropriate insulating material. Display photos and lining itself and the datasheet for the FR4, the CANaMONS are made from FR4 and protect it from above, as well as the GPO-3 on the Top Plate	Inspect	p.g.23	
AI.5.8		Holes in the accumulator external structure should be of the minimum practical size for cable passages, plugs etc. Holes for ventilation should be circular, no greater than 10mm in diameter, and not obviously weaken the accumulator container external structure. When installed in the vehicle, the holes must not face towards the driver with the firewall removed. Display photos and measure using Vernier Callipers	Inspect	p.g.19	

2024 Formula SAE-A Technical Inspection Sheet - R01.xlsx ACCUMULATOR INSPECTION Page 5 of 9

EV CLASS - ACCUMULATOR INSPECTION

ACCUMULATOR INSPECTION CONTINUED...				Reinspect	Passed
AI.5.9	Labelling	Accumulator must be marked with the ISO7010-W012 symbol triangle with black lightning bolt on yellow background) with triangle side length of 100 mm minimum, with text "ALWAYS ENERGIZED" If accumulator voltage is greater than 60VDC must also be Labelled as "HIGH VOLTAGE" Labelling should be on all practical external sides including top, bottom, front, rear, sides. Smaller labels accepted only if surface too small for defined size. Display Labelling on accumulator, measure using ruler	Inspect		
AI.5.10	Internals - cell connection	Contacting / interconnecting the single cells by soldering in the high current path is prohibited. Soldering wires to cells for the voltage monitoring input of the BMS is allowed Display photo, we do not use solder	Inspect	p.g.20	
AI.5.11		Connections to cell tabs must be adequately supported to prevent damage to the cells. Cables, busbars etc. must not be supported entirely by the cell tabs. Display photo, bolted to push bar	Inspect	p.g.24	
AI.5.12	Internals – AIR/fuse	Every accumulator container must contain at least one main fuse and at least two accumulator insulation relays. There must be no electrically live connection to the accumulator cells outside of the accumulator enclosure when the AIRs are open. This includes AMS wires. AIRs must be rated for the maximum expected current draw. The AIRs and main fuses must be separated from the cell segments by an electrically insulated and non-flammable material. Display the datasheets for the fuse and AIRs and point out the High current Path. Display that they are separated by the top plate and the GPO-3 datasheet	Inspect	p.g.25-27	
AI.5.13	Internals – fuses	The fuse(s) must be appropriately rated to protect the cable(s) and other electronic components. Fuses should be HRC type and marked with a DC voltage rating above the maximum expected operating voltage. Except where specifically stated in the rules, all small wiring connecting directly to the cells or tractive system should have appropriate fuses as close as possible to the source. Fusible links are acceptable but require evidence of appropriate voltage and current rating. Teams may justify undersized (current only) fuses based on average current draw and the manufacturer's thermal time curves. Display datasheet for fuses, and CANaMONS schematic to show fuses are used for the voltage taps, all fuses use 22 AWG or larger which is rated for 7 A, our fuses are 0.5 A. Datasheet for CANaMONS fuses is under the schematic.	Inspect	p.g.28-29	
AI.5.14	Internals - maintenance plugs	Maintenance plugs or similar measures have to be taken to allow separating the internal cell stacks in a way, that the separated cell stacks carry a voltage of less than 120VDC and a maximum energy of 12MJ. The separation has to affect both poles of the stack. It must not be possible to incorrectly install the maintenance plugs causing a short circuit. Display the service handle and how it is bidirectional and separates the pack into 9 segments. 1 Segment = 2.80MJ and 50.4 V maximum. Also display the tap covers we use. Display Methode Bud Connector Datasheet	Inspect	p.g.30	
AI.5.15	Internals – cell stack barriers	Each stack has to be electrically insulated by the use of suitable material towards other stacks in the container and on top of the stack. Air is not considered to be a suitable insulator for this purpose. The team should provide evidence that the material(s) used are appropriate (i.e. material datasheets, manufacturer's specifications, lab test reports etc.). Team manufactured composite materials are not acceptable (carbon fibre, Kevlar, fiberglass etc.). Display datasheets for FR4 and GPO3	Inspect	p.g.23-27	

2024 Formula SAE-A Technical Inspection Sheet - R01.xlsx ACCUMULATOR INSPECTION Page 6 of 9

EV CLASS - ACCUMULATOR INSPECTION

ACCUMULATOR INSPECTION CONTINUED...				Reinspect	Passed
AI.5.16	Accumulator container connectors	If HV-connectors of the accumulator containers can be removed without the use of tools, a pilot contact/interlock line has to be implemented which breaks the current through the AIRs whenever the connector is removed Display connector cover and how to requires a tool to remove	Inspect		
AI.5.17	Indicator light/voltmeter	Each container must have an indicator light or an analogue voltmeter showing that voltages greater than 60V DC are present outside of the container. This includes when the accumulator is being charged. Display on lid and how it is connected to AIRS	Inspect		
AI.5.18	Equalizing valve	If the container is completely sealed, it must have an equalizing valve to prevent integral build-up of pressure in the event of fire. N/A	Inspect		
AI.5.19	Electrical Connections	Electrical connections must be secure and of high quality. Connections must be made using appropriate hardware, correct sized lugs for selected cable, appropriate crimping methods etc. Electrical connections must not be able to loosen if they become hot. Electrical connections which rely on plastic or similar material being squeezed, which might soften and become loose if overheated are not acceptable. Information about the electrical connections supporting the high current path must be available at Elect Tech Inspection. Display Datasheets for Methode Buds, Radloks, and Surloks. Display Blue handle crimps and an example of a crimped lug	Inspect	p.g.30-32	
AI.5.20	Precharge and Discharge Resistors	Precharge and discharge resistors must be installed such that if they overheat, it is unlikely they will cause any of the accumulator cells to overheat. If the team has elected to utilize Precharge or discharge or discharge resistors with a continuous operation (not monitored by the PDOC per local addendum), the resistors must install according to the manufacturer's recommendations for heatsinking airflow, and such that heat soak cannot cause the accumulator cells to overheat. We do not have continuously operating Precharge or discharge resistors. Show datasheets for the Precharge and discharge resistor, only the Precharge resistor is in the accumulator. Discharge is in the HIP. The Precharge is only on when the accumulator is recharging, which is no more than a couple second and it will not overheat (controlled by teensy activating a Precharge relay)	Inspect	p.g.33-34	
AI.5.21	Accumulator Internal Wiring	All wires inside the accumulator must be marked with gauge, temperature rating and voltage rating, serial number or norm is also sufficient, if the team shows the datasheet in printed form. Display datasheets and samples	Inspect	p.g.35-36, pg.8	
AI.5.22		Wire temperature and voltage rating must be suitable for use in the accumulator. All Wires (including GLV and AMS/BMS) wires within the accumulator container must be rated for the full tractive system voltage. Display datasheets and samples	Inspect	p.g.35-36	
AI.5.23		Using only insulating tape or rubber-like paint for insulation is prohibited. N/A	Inspect		

EV CLASS - ACCUMULATOR INSPECTION

ACCUMULATOR INSPECTION CONTINUED...				Reinspect	Passed
AI.6.1	Plastic and 3D printed Components	Any plastic components which are critical to the integrity of the accumulator (structural elements, bolt locking devices, insulation, barriers etc.) must be manufactured from materials which have a glass transition temperature higher than the expected operation temperature. The operating temperature is considered to be the calculated maximum cable or busbar temperature, maximum battery temperature or pre-charge or discharge resistor operating temperature, or 90 degrees C whichever is higher. 90 degrees C is the highest temperature as our cables and bus bars are over specced, maximum battery temperature is 60 degrees C and the Precharge resistor is only in operation during Precharge. Display FireWire datasheet and operating temperatures for bus bars and cable	Inspect	p.g.37-38	
AI.6.2	Spare accumulator(s)	Spare Accumulators must be of the same type (construction, voltage, capacity, weight, fixing etc.) Only applicable if spare accumulators are used. N/A	Inspect		
AI.6.3	Temperature monitoring equipment	Teams will be provided with a thermally sensitive sticker to install into their accumulator. The thermally sensitive sticker must be mounted such that it is direct thermal contact with the negative most cell of an accumulator segment such that it the thermal sticker will reasonably represent the temperature of the cells. The sticker should be visible from outside the accumulator without needing disassembly of the accumulator. (2024 only - refer inaccessible stickers to Technical Inspection Captain for review) During the fitment of the thermal strip, take photos to show and ensure that it is visible through the hatch in the accumulator	Inspect		

EV CLASS - ACCUMULATOR INSPECTION

NOTES

INSTRUCTIONS FOR SCRUTINEERS - END OF EV ACCUMULATOR INSPECTION

If the team have passed all items in this section, go to the second page of this document and initial the relevant box, noting the date and time the team passed this section.

If the team have items requiring reinspection (did not pass all items), go to the second page of this document and initial the relevant box noting the time and date the team was released from the inspection. The team will need to rectify the reinspection items and may return for reinspection when they are ready. Reinspection is completed on a first come, first served basis, and is dependent on Technical Inspection lane availability. Teams with Scheduled Inspections times will be given priority over teams presenting for reinspection.

Once the team have been released from the inspection, make note of the team's progress on the central inspection record board.

2024 Formula SAE-A Technical Inspection Sheet
EV STATIC INSPECTION

Initial Presentation Scrutineer Name:		Initial Presentation Lane Number:	
1st Reinspection Scrutineer Name:		1st Reinspection Lane Number:	
2nd Reinspection Scrutineer Name:		2nd Reinspection Lane Number:	
3rd Reinspection Scrutineer Name:		3rd Reinspection Lane Number:	

PERSONNEL Teams are required to have an Electrical Safety Officer.			Initial ins.	Inspection # 1st reins.	2nd reins.	3rd reins.
SI.1.1	Identify the Electrical Safety Officer (ESO)	Ask for the ESO				
SI.1.2	Only team members involved in technical inspection can be in the technical inspection bay	Ask for non-essential people to leave the area				
DO NOT PROCEED WITH TECHNICAL INSPECTION IF THE ESO IS NOT PRESENT						

INERT VEHICLE The Vehicle must be in a condition which prevents unexpected energization of the HV electrical systems or movement of the tractive system			Initial ins.	Inspection # 1st reins.	2nd reins.	3rd reins.
SI.1.3	Disable the HV Systems - High Voltage Disconnect (HVD)	Check the HVD is removed				
SI.1.4	Disable the HV Systems - Tractive System Master Switch (TSMS) Lock	Check the TSMS Lock is fitted and effective				
SI.1.5	(AV and Dual Purpose only) Disable the ASMS - Autonomous System Master Switch (ASMS) Lock	Check the ASMS Lock is fitted and effective				
DO NOT PROCEED WITH TECHNICAL INSPECTION IF HVD IS INSTALLED OR THE TSMS LOCK IS MISSING						

INSTRUCTIONS FOR SCRUTINEERS
This section applies to Electric Vehicles (EV) and Autonomous Vehicles (AV) and Dual Purpose Vehicles.
If an item is acceptable, initial the "Passed" column.
If an item is unacceptable, initial the "Reinspect" column and inform the team members they have not meet the requirements for that item.
Teams are allowed to take their vehicle away from technical inspection and address any issues before representing for reinspection.
Scrutineers may continue with the inspection when unacceptable items are found, provided it is safe to do so.
Teams are required to pass all items before the vehicle can proceed to the Brake Test or compete in Dynamic Events.

Scrutineers reserve the right to refuse to proceed with Technical Inspection if a sufficiently serious issue which might jeopardize the safety of the technical inspection team, event personal or any other persons is found at any time.

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EV CLASS - EV STATIC INSPECTION

- ESO (Alec), Lukes, Hayward, Jackson (document hander) and Fisher (SES)
- HVD Disconnected (In ESO's possession)
- TSMS Lock Installed (Keys in ESO's possession)
- Car in Race Ready Condition (accumulator installed, everything connected, firewall and body kit on
- Push Bar
- High Stands x 2
- Red SCA Jack Stands x 4
- Red toolbox, callipers, spare zipties, DT crimps and large cable crimps (blue handle)
- Tech Box which samples, documents and tech bibles
- Fluke Multimeter with probes and banana jack proves
- Multiple hands to lift the car and remove the body kit
- Fisher ready with SES open on LAPTOP

Roll car into bay and immediately ask if the car can be put on the stands, leave body kit on

After HVD display take body kit off and place onto stands

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EV CLASS - EV STATIC INSPECTION

VEHICLE VISUAL INSPECTION

The primary purpose of the Vehicle Visual Inspection is to find and highlight any items which might cause a safety hazard for the drivers, team members, track marshals and anyone else who might interact with the vehicle.
The hazards most associated with EV tractive systems include fire, arc flash, electric shock or loss of control. The Visual Inspection is intended to check that the vehicle has been designed and constructed to an acceptable standard such that the likelihood of one of these hazards causing injury is minimized. Scrutineers are not generally concerned with the reliability of the vehicle unless the failure of a component or system might pose a safety hazard. Scrutineers may also look for rules compliance issues. Rules non-compliances should be referred to the EV Technical Inspection Captain. Because of the bespoke nature of the vehicles, Scrutineers reserve the right to reject vehicles for any reasonable safety concern based on their judgement, even if not specifically covered in this document.

				Reinspect	Passed
SI.2.1	Race Ready Condition	The vehicle should be fully assembled with the Accumulator in place and generally in race ready condition when presented to technical inspection. Inspection of incomplete vehicles may proceed with permission from the Technical Inspection Captain. Ensure Accumulator is in, and everything is connected (without HV switch and HVD). Body kit and top fire wall must be fitted	Inspect		
SI.2.2	Technical Inspection Access	The vehicle must be lifted/jacked onto stands such that all of the vehicle's wheels are at least 100 mm and no more than 300mm above the ground. It must be possible to freely rotate the vehicle's wheels without the vehicle moving. Stands must be robust, and the vehicle must be secure. Use red SCA car jack stands on the first height setting to support the car in the air. Use a tape measure to display its height off the ground from the wheels. Body Kit Stays on	Inspect		
SI.3.1	Push Bar	A pair of HV insulating gloves with leather outers, a Multimeter and fire extinguisher must be attached. If a tool is needed to open the HVD this must also be attached to the push bar. Unlock box on the push bar to display the HV gloves with leather outers, a Multimeter and a fire extinguisher. The HV inners should be tagged from Accumulator Tech and the Fire Extinguisher must be in date	Inspect		
SI.4.1	High Voltage Disconnect	The HVD must be clearly marked with "HVD" in large, high contrast lettering and should be clearly visible to a Marshal as they approach the vehicle. The HVD label must be easily distinguishable from the vehicle's other markings. Display HVD labels on Body Kit and HIP	Inspect		
SI.4.2		It must be possible to disconnect the HVD without removing any bodywork Display HVD location	Inspect		
SI.4.3		If opening the HVD is possible without the use of tools, a pilot contact/interlock line has to be implemented which breaks the current through the AIRs whenever the connector is removed Display schematic for the Shutdown Circuit and HIP, Display physical HVD	Inspect	p.g.1	
SI.4.4		In ready to race condition it must be possible to disconnect the HVD within 10 seconds. Ask the scrutineer if it is okay to fit the HVD to demonstrate. Fit the HVD and remove it once the inspector is ready. After this is done take body kit off	Ask the team to demonstrate		
SI.5.1	Tractive system protection	All tractive system connections outside of an enclosure must be appropriately insulated. Display HV Cables from the accumulator, the HIP and the MC, Display the Phase Cable Cover	Inspect		
SI.5.2		It must not be possible to touch any tractive system connections with a 100mm long, 6mm diameter insulated test probe when the tractive system enclosures are in place Ensure test points covers are on. Let the inspector probe the car, comply to their requests	Inspect		
SI.5.3		Tractive System components and containers must be protected from moisture in the form of rain or puddles. Use of tape alone is not acceptable. Heat shrink must be appropriately rated for the TS voltage and must be provided with additional mechanical protection. Display Heat Shrink datasheet and samples and say that is it only used on the phase cable cover and in the accumulator	Inspect	p.g.2	

EV CLASS - EV STATIC INSPECTION

VEHICLE VISUAL INSPECTION CONTINUED...				Reinspect	Passed
SI.6.1	Master Switches	The Tractive System Master Switch (TSMS), Grounded Low Voltage Master Switch (GLVMS) and (AV and Dual Purpose only) Autonomous System Master Switch (ASMS) on the right side of the vehicle. At the height of the drivers' shoulders. Rotary type, ON position with key horizontal. ON and OFF position must be clearly marked. Located right side of the vehicle at approx. driver's shoulder height, just behind main roll hoop. Not attached to removable bodywork. Must be easily actuated from outside the vehicle. Display the MS location and all the above details	Inspect		
SI.6.2		All master switches must be a rotary type with a red removable key/handle Display keys and switches	Inspect		
SI.6.3		GLVMS (LV Master switch) must be completely surrounded by an RED circle of min 50mm diameter Marked with international symbol (triangle with red lightning bolt on blue background). Display	LV  Inspect		
SI.6.4		TSMS (TS Master switch) must be completely surrounded by an ORANGE circle of min 50mm diameter Accompanied by the ISO 7010-W012 (triangle with black lightning bolt on yellow background). Display	TS  Inspect		
SI.6.5		The Tractive System Master Switch must have a lock or similar fitted which prevents insertion of the master key. The lock should be of the type commonly used in industry for "LOTO isolation". Use of a LOTO hasp or similar is acceptable, if necessary, provided it is secure. The key for the lock and the master keys should be in the custody of the ESO. Display lock on TSMS and the keys in the possession of the ESO	Inspect		
SI.7.1	HV warning stickers	Each housing/enclosure containing HV parts must be marked with the ISO7010-W012 symbol triangle with black lightning bolt on yellow background) If accumulator voltage is greater than 60VDC must also be Labelled as "HIGH VOLTAGE" Labelling should be on all practical external sides including top, bottom, front, rear, sides. Smaller labels accepted only if surface too small for defined size. Display Stickers on HIP, DCDC, Accumulator, Phase cable cover and Inverter (inverter will be hard to see)	Inspect Check top, sides and bottom of enclosures		

EV CLASS - EV STATIC INSPECTION

VEHICLE VISUAL INSPECTION CONTINUED...				Reinspect	Passed
SI.8.1		All tractive system wiring outside electrical enclosures must be enclosed in separate orange nonconductive conduit or use an orange shielded cable Display that the 25 mm2 ACC to HIP and the 16 mm2 HIP to DCDC are enclosed in conduit and the HIP to MC and MC to Motor cables are 50 mm2 shielded cable. Show Datasheets	Inspect	p.g.3-5	
SI.8.2		The conduit or shielded cable must be securely anchored (at least) at each end so that it can withstand a force of 200 N without straining the cable and crimp and must be located out of the way of possible snagging or damage. Take note of connections to motors, plugs carrying HV, and any entrances to accumulators, motor controllers, the TSMPs and any other HV enclosures Display boots connecting the conduct to the connector on the ACC to HIP and HIP to DCDC, and that the HV wires are routing in a way that does not show possible snagging or damage.	Inspect		
SI.8.3		Tractive system wiring must be shielded against damage by rotating and/or moving parts. All wiring must be sufficiently restrained such that it cannot come into contact with rotating and/or moving parts. Display that the HV wires are routing in a way that does not show possible snagging or damage.	Inspect		
SI.8.4		TS wires and GLVS wires are clearly separated/do not run directly next to each other/bounded together by cable rods or in the same cable channel (ALLOWED ONLY FOR PILOT CONTACTS OR INTERLOCK SIGNALS) Display that no HV wires run together with LV wires	Inspect		
SI.8.5	HV Wiring	Using only insulating tape or rubber-like paint for insulation is prohibited. N/A	Inspect		
SI.8.6		Heat-shrink type insulation used on tractive system components and cables may only be used inside rigid enclosures and must be labelled with voltage rating. Serial number or norm is also sufficient, if the team shows the datasheet in printed form. Display heat shrink datasheet and samples,	Inspect	p.g.2	
SI.8.7		No soldering in high current path including cable lugs and connectors. We do not use solder in the high current path, everything is exclusively bolted, crimped or connected using a connector.	Inspect		
SI.8.8		Electrical connections must be secure and of high quality. Connections must be made using appropriate hardware, correct sized lugs for selected cable, appropriate crimping methods etc. Electrical connections must not be able to loosen if they become hot. Electrical connections which rely on plastic or similar material being squeezed, which might soften and become loose if overheated are not acceptable. Information about the electrical connections supporting the high current path must be available at Elect Tech Inspection. Display Datasheets for HPK, Deutsch, and Surloks. Display Blue handle crimps and an example of a crimped lug, display Deutsch Crimps, HPK come precrimped. DCDC HV connector is under the Surloks	Inspect	p.g.6-8	
SI.8.9		HV wiring must be entirely within the chassis (side impact structure, rear impact zone and roll envelope) except for cables to hub motors Display Phase cable guide and that the rest of the HV wires are within the chassis	Inspect		

EV CLASS - EV STATIC INSPECTION

VEHICLE VISUAL INSPECTION CONTINUED...				Reinspect	Passed
SI.9.1	Tractive system measuring points	Two tractive system voltage measuring points and a GLVS ground point must be installed next to the master switches, right side of the vehicle, at shoulder height of the driver. Display Test Points	Inspect		
SI.9.2		The measuring points must be protected by a non-conductive waterproof housing which can be opened without tools. The use of simple plastic/rubber sealing plugs inserted into the measuring points is not acceptable as a waterproofing method. Display banana jack covers	Inspect		
SI.9.3		The measuring points must be protected from being touched with the bare hand/fingers once the housing is opened. Take of banana jack covers and display	Inspect		
SI.9.4		4mm shrouded banana jacks rated to a voltage higher than the maximum tractive system voltage must be used Display Datasheet	Ask the team to provide a datasheet	p.g.9	
SI.9.5		The TSMPs must be marked with HV+ and HV- Display markings next to test points	Inspect		
SI.10.1	GLV Ground Measuring Point	Must be positioned next to the TSMPs and must be marked with GND Display GLVMP and GND label	Inspect		
SI.10.2	GLV Voltage	Measure GLVS voltage between GLVS battery positive Must be less than 60V DC Measure using Fluke, measuring between GND and 12V	Ask team to demonstrate		
SI.10.3	Tractive System Voltage	Measure TS voltage at measurement points Must be less than 60V DC Measure using Fluke, using TSMPS	Ask team to demonstrate		
SI.10.4	Discharge System	The discharge circuit has to be wired in a way that it is always active whenever the shutdown circuit is open. If a discharge circuit is used a low resistance can be measured between HV+ and HV- whenever the tractive system is de-activated. Measure resistance between HV+ and HV- with multi-meter. Must be 2*BPR+ Dis- Charge Resistor (GLVS must be off) Use the Fluke to measure the resistance between HV+ and HV- and show the schematic for the HIP and TSAL Discharge, explain that SHUTDOWN_TSMS activates the coil of the discharge relay (datasheet attached) and disconnects the discharge resistor (datasheet also attached) when HV is on. This number must be $2*15K\Omega + 5k\Omega = 35k\Omega$ Refer alternative discharge methods to the EV Technical Inspection Captain	Ask team to demonstrate	p.g.1	
SI.11.1	Insulation Measurement Test	The insulation resistance between the GLV Ground Measuring Point and TSMPs HV+ must be greater than 500 Ohms/Volt, calculated for the maximum TS voltage. The available measurement voltages are 250 V and 500 V. All vehicles with a maximum nominal operation voltage below 500 V will be measured with the next available voltage level. All teams with a system voltage of 500 V or more will be measured with 500 V. Use the Fluke to measure the resistance between HV+ and GND. This number must be more than $500\Omega/V*453.6V = 226.8k\Omega$	Measure insulation resistance between GLV Ground and HV+		
SI.11.1		The insulation resistance between the GLV Ground Measuring Point and TSMPs HV- must be greater than 500 Ohms/Volt, calculated for the maximum TS voltage. The available measurement voltages are 250 V and 500 V. All vehicles with a maximum nominal operation voltage below 500 V will be measured with the next available voltage level. All teams with a system voltage of 500 V or more will be measured with 500 V. Use the Fluke to measure the resistance between HV- and GND. This number must be more than $500\Omega/V*453.6V = 226.8k\Omega$	Measure insulation resistance between GLV Ground and HV+		

EV CLASS - EV STATIC INSPECTION

VEHICLE VISUAL INSPECTION CONTINUED...				Reinspect	Passed
SI.12.1	Shutdown Buttons	One shutdown button, push-pull or push-rotate-pull on each side behind the driver's compartment (height approx. driver's head), one in the cockpit and easily accessible by the driver in any steering wheel position while wearing gloves and wrist restraints Display photo and positions of estops	Inspect	p.g.10	
SI.12.2		Minimum diameter of shutdown buttons on the side is 40mm. Minimum diameter of shutdown button in the cockpit is 24mm Measure using callipers	Inspect		
SI.12.3		The shutdown buttons are not allowed to be easily removable, e.g. mounted onto a removable body work Display	Inspect		
SI.12.4		All shutdown buttons marked with international symbol Display	Inspect 		
SI.12.5	Cockpit Shutdown Button	Cockpit master switch Pull-On, Push-OFF, or Twist-Pull-On, Push-OFF alongside & unobstructed by steering wheel, easily reached by driver. Minimum 24mm diameter. Marked with international symbol Display	Inspect	p.g.10	
SI.12.6	Brake Over Travel Switch	Brake over travel switch must be secured and positioned behind the brake pedal such that it will be tripped before the master cylinders bottom out or any other stops are reached. The brake over travel switch must be robustly mounted and not be bent or damaged if an over-travel occurs. Display BOTS and then photo and video of it operating	Inspect If necessary, ask team to demonstrate by bleeding the brake circuit	p.g.11	
SI.12.7	Inertia switch	The device must be mechanically attached to the vehicle. It must be possible to demount the device so that its functionality can be tested by shaking it. Mounts including double sided tape, Velcro or similar are not acceptable. Display inertia switch, demount using snips to cut the zip tie and shake to test its functionality, Remount with a zip tie.	Inspect		

EV CLASS - EV STATIC INSPECTION

VEHICLE VISUAL INSPECTION CONTINUED...				Reinspect	Passed
SI.13.1	Accelerator Pedal Position Sensor (APPS)	Accelerator Pedal must promptly return to original position, if not actuated Display by pressing accelerator pedal with hand	Inspect		
SI.13.2		At least two sensors must be fitted as APPS and must have separate supply, ground and signal lines from the plausibility detection device Display the connectors going to the pedal and how they lines are separate, display the schematic of the PEN	Inspect	p.g.12	
SI.13.3		The accelerator pedal must have a positive stop to prevent sensors from being mechanically overstressed Display Positive stop on pedal	Inspect		
SI.13.4		Two springs must be used to return the throttle pedal to the off position and each spring must work with the other disconnected Display spare accelerator pedal, show the separate springs	Inspect		
SI.13.5	Brake System Encoder	A brake pedal position sensor or brake pressure switch must be fitted to check for plausibility Display brake pressure sensors and the schematic of the PEN	Inspect	p.g.12	
SI.13.6	Brake Master Cylinders	The brake system master cylinder must be actuated directly or by a mechanical connection. Use of Bowden cables or push-pull Bowden cables is not allowed. The first 90% of the brake pedal travel may be used to regenerate brake energy without actuating the hydraulic brake system. The remaining brake pedal travel must directly actuate the hydraulic brake system, but brake energy regeneration may remain active. Display that the master cylinders are directly actuated for 100% of the brake pedal travel. We do use regen but only between 0 and 10% of the accelerator pedal	Inspect		
SI.14.1	Firewalls (EV specific requirements)	A firewall must separate the driver compartment from components of tractive system (including HV wiring). Brake parts and chassis as conductive paths are allowed to protrude through firewall. See T.1.9.3 Outboard wheel motors and associated cables and other components of the suspension members are excluded from this requirement. Display that only the rear brake line and LV wires pass through the firewall, reference rule: T.1.8.4 b. 'Grommets must be used to seal any pass through for wiring, cables, etc'	Inspect		
SI.14.2		The side of the firewall facing the tractive system must be aluminium with a minimum thickness of 0.5mm and must be deliberately earthed to the chassis ground point. Display CAD image and then display ground strap from the DCDC to the Firewall	Inspect	p.g.13	
SI.14.4		The firewall's integrity must not be compromised by forces from the driver. I.e. the driver must not sit directly against the firewall and the driver's seat must not rely on the structural integrity of the firewall unless it is adequately reinforced. Display images from CAD and FEA	Inspect	p.g.13	

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EV CLASS - EV STATIC INSPECTION

VEHICLE VISUAL INSPECTION CONTINUED...				Reinspect	Passed
SI.15.1	Team built PCBs	Where tractive system and GLV are on the same circuit board, teams must be prepared to demonstrate appropriate spacing. Separation space on the circuit boards must be clearly marked. The minimum allowable clearances are: Voltage / Over Surface / Thru Air (cut in board) / Under Conformal Coating 0-50 V DC / 1.6 mm / 1.6 mm / 1 mm 50-150 V DC / 6.4 mm / 3.2 mm / 2 mm 150-300 V DC / 9.5 mm / 6.4 mm / 3 mm 300-600 V DC / 12.7 mm / 9.5 mm / 4 mm If necessary, teams may provide manufacturer's datasheets for components demonstrating appropriate voltage ratings where the components require smaller than allowed clearances. Display the datasheet for the Conformal Coating, samples of the PCBs (without components) and the Conformal coating. Have callipers ready. Show LV/HV Separation Book	Inspect	p.g.14	
SI.16.1	Accumulator Construction and Attachment	If containers are monocoque, they must be mounted with Steel backing plates of at least 2mm thickness. N/A	Inspect		
SI.16.2		The Accumulator Container must also have a minimum number of attachment points, dependent on weight and use minimum Grade 8.8 metric 8mm bolt at each 20 kg = 4 attachments. 20-30 kg = 6 attachments. 30-40 kg = 8 attachments. >40 kg = 10 attachments. Our Accumulator is greater than 40kg (69kg), sample bolt and photo of accumulator attachment points.	Inspect	p.g.15	
SI.16.3	Accumulator Crush Zone Clearance	Ensure 25mm clearance from Side Impact Structure. Ask to see SES. Display CAD image and SES	Inspect	p.g.16	
SI.16.4		If rear mounted: At least 25mm clearance from Rear Impact Structure or any non-crushable items.N/A	Inspect		
SI.16.5		Ensure 25mm clearance of surface from the firewall. Display CAD image	Inspect	p.g.16	
SI.16.6		Non-crushable items behind Rear Impact Structure cannot pass through the structure. Display that the radiator and pumps are too large to pass through the rear impact structure	Inspect		
SI.16.7		Rear Impact protection extends to or pass the upper height of the SIS and is supported to the SIS. Display CAD image	Inspect	p.g.16	

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EV CLASS - EV STATIC INSPECTION

ENERGY METER				Reinspect	Passed
SI.17.1	Energy Meter	Energy Meter fitted and secured to the chassis in a location that does not interfere with the mechanical or electrical operation of the vehicle, in accordance with the instructions. Energy Meter must be mounted in protected and readily accessible position, mounted securely and identifiable, so that the operation light can be visually inspected, and the unit can be quickly removed in Parc Ferme. Display energy meter placement in reference to the instruction document, explain how we will remove it and that it will be easily inspected	Inspect		
SI.17.2		Confirm retaining ring on all plugs on energy meter is fully engaged (ring must be clicked over detent). Display	Inspect		
SI.17.3		Check the battery voltage cable is installed with the correct polarity (positive is white, negative is black) and the current sensor is orientated correctly (arrow shows direction of conventional current flow i.e. away from battery if installed on positive lead). Display that we have placed the energy meter is on the positive line and meets the requirements	Ask team to demonstrate		

EV CLASS - EV STATIC INSPECTION

VEHICLE GROUNDING

It is expected that all conductive components within 100mm of the Tractive system will be appropriately grounded (electrically bonded to the GLV system ground).

1. By equipotential bonding the conductive parts within the vehicle, the hazard posed by touching a voltage gradient is reduced, and
2. By ensuring a conductive path back to the chassis ground common point, the likelihood of the IMD correctly detecting the fault and shutting off the vehicle is increased, reducing the period of time for which the hazard can be present.

Scrutineers will look for any conductive components which are in close proximity (within 100mm) of any tractive system component (HV) element, which could become live in the event of a failure of a component, breach of insulation or similar either from normal operation, or in the event of a collision.

Any wire, braid or similar used for vehicle grounding must be appropriately terminated, robustly mounted, and of sufficient size and mechanical strength for its purpose.

This test involves using a Fluke 289 Multimeter on the lo-ohm setting to ensure there is a low resistance connection from the item being tested in reference to the chassis ground test point. It is acceptable to subtract the resistance of the test leads if necessary. Teams may remove paint, resin or other coverings to expose a bare conductive surface if required.

Teams also have the option of measuring resistance via method of voltage drop using a 1 amp current source if necessary.

Measurements to the conductive component should be taken within 100mm of the tractive system or as close as practical. Teams may remove body panels and covers to demonstrate compliance if required.

The pass criteria are:

a. Electrically conductive parts 300 mOhms Examples: parts made of steel, (anodized) aluminum, any other metal parts

			Criteria		Reinspect	Passed
SI.18.1	Equipotential Bonding	Firewall(s) Measure with Multimeter using GND TP and a probe	300 mOhm			
SI.18.2		Accumulator Container(s) Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.3		Components in proximity of Accumulator Container(s) Measure with Multimeter using GND TP and a probe, this would be the TS Stack, HIP and Motor	300 mOhm 5000 mOhm			
SI.18.4		Motor Controller Enclosure(s) Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.5		Components in proximity of Motor Controller(s) Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.6		Motor Casings, Mounts and Scatter Shields Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.7		Components in proximity of Motor(s) Measure with Multimeter using GND TP and a probe, this includes the left rear suspension	300 mOhm 5000 mOhm			

EV CLASS - EV STATIC INSPECTION

VEHICLE VISUAL INSPECTION CONTINUED...			Criteria		Reinspect	Passed
SI.18.8		Other HV enclosure(s) Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.9		Components in proximity of other HV enclosures Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.10		Conductive HV cable channels, cable Armor and cable shielding Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.11		Components in proximity of HV Wires and Cables Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.12		Components in proximity of HVD Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.13		Components in proximity of the Tractive System Measurement Points Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.14		Components in proximity of the Energy Meter Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.15	Equipotential Bonding	Cooling system components including heatsinks, radiators, pumps and reservoirs Measure with Multimeter using GND TP and a probe	300 mOhm 5000 mOhm			
SI.18.16		Seat Mounts, Seatbelt Mounts, Driver Controls, Pedals or items in the Drivers Area if in proximity to HV components N/A	300 mOhm 5000 mOhm			
SI.18.17		Other items:	300 mOhm 5000 mOhm			
SI.18.18		Other items:	300 mOhm 5000 mOhm			
SI.18.19		Other items:	300 mOhm 5000 mOhm			
SI.18.20		Other items:	300 mOhm 5000 mOhm			
SI.18.21		Other items:	300 mOhm 5000 mOhm			

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2024 Formula SAE-A Technical Inspection Sheet
EV FUNCTIONAL TEST

Initial Presentation Scrutineer Name:		Initial Presentation Lane Number:	
1st Reinspection Scrutineer Name:		1st Reinspection Lane Number:	
2nd Reinspection Scrutineer Name:		2nd Reinspection Lane Number:	
3rd Reinspection Scrutineer Name:		3rd Reinspection Lane Number:	

PERSONNEL			Inspection #			
Teams are required to have an Electrical Safety Officer.			Initial ins.	1st reins.	2nd reins.	3rd reins.
FT.1.1	Identify the Electrical Safety Officer (ESO)	Ask for the ESO				
FT.1.2	Only team members involved in technical inspection can be in the technical inspection bay	Ask for non-essential people to leave the area				
DO NOT PROCEED WITH TECHNICAL INSPECTION IF THE ESO IS NOT PRESENT						

INERT VEHICLE (EV & AV CLASSES ONLY)			Inspection #			
The Vehicle must be in a condition which prevents unexpected energization of the HV electrical systems or movement of the tractive system			Initial ins.	1st reins.	2nd reins.	3rd reins.
FT.1.3	Disable the HV Systems - High Voltage Disconnect (HVD)	Check the HVD is removed				
FT.1.4	Disable the HV Systems - Tractive System Master Switch (TSMS) Lock	Check the TSMS Lock is fitted and effective				
FT.1.5	(AV and Dual Purpose only) Disable the ASMS - Autonomous System Master Switch (ASMS) Lock	Check the ASMS Lock is fitted and effective				
DO NOT PROCEED WITH TECHNICAL INSPECTION IF HVD IS INSTALLED OR THE TSMS LOCK IS MISSING						

INSTRUCTIONS FOR SCRUTINEERS

This section applies to Electric Vehicles (EV) and Autonomous Vehicles (AV) and Dual Purpose Vehicles.
If an item is acceptable, initial the "Passed" column.
If an item is unacceptable, initial the "Reinspect" column and inform the team members they have not meet the requirements for that item.
Teams are allowed to take their vehicle away from technical inspection and address any issues before representing for reinspection.
Scrutineers may continue with the inspection when unacceptable items are found, provided it is safe to do so.
Teams are required to pass all items before the vehicle can proceed to the Brake Test or compete in Dynamic Events.

Scrutineers reserve the right to refuse to proceed with Technical Inspection if a sufficiently serious issue which might jeopardize the safety of the technical inspection team, event personal or any other persons is found at any time.

EV CLASS - FUNCTIONAL TEST

- ESO (Alec), Lukes, Hayward, Jackson (document hander)
- HVD Disconnected (In ESO's possession)
- TSMS Lock Installed (Keys in ESO's possession)
- Car in Race Ready Condition (accumulator installed, everything connected, firewall and body kit on
- Push Bar
- High Stands x 2
- Red SCA Jack Stands x 4
- Red toolbox and large cable crimps (blue handle)
- Spare Zip Tie
- Tech Box which samples, documents and tech bibles
- Fluke Multimeter with probes and banana jack proves
- Multiple hands to lift the car and remove the body kit
- Chungus Laptop with Candapter and Kvaser. CAN KING and BMS software open
- Impact Gun with Battery and 21mm Deep Impact Socket
- Test Resistor for IMD
- Test loom for BSPD

Ask if Car can be put on the small stands immediately after entering the bay and then ask if we are able to take the rear wheels off the car as it is rear wheel drive.

If they are happy with us to, ask if we can then remove the body kit and top firewall. Place the body kit onto the stands

EV CLASS - FUNCTIONAL TEST

EV FUNCTIONAL TEST PREREQUISITES

This section of the Technical Inspection process is intended to ensure that the vehicle's mandated safety systems function as required by the rules.

The order of testing in this section is important as the safety of some of the later tests relies on the correct functioning of systems already tested. As such there is a hold point after the testing of the safety shutdown systems. If the safety shutdown systems do not function as intended, it will be necessary to stop testing and for teams to correct any issues.

Because this section requires the vehicle to be powered on, and will require the wheels to turn under power, the vehicle must have successfully passed all previous steps before proceeding. The Scrutineer must check that the vehicle has passed all required steps before proceeding.

The Technical Inspectors will supply a Fluke 289 Multimeter and insulated banana test leads.

				Reinspect	Passed
FT.2.1	Vehicle ready for Functional Safety Test	The vehicle must have successfully passed the following inspection stages, with all reinspect items addressed and passed. - Accumulator Inspection - EV Electrical Inspection - Mechanical Inspection - Driver Egress	Check page 2 of this document and the stickers on the vehicle's nosecone		
FT.2.2	Race Ready Condition	The vehicle must be fully assembled with the Accumulator in place and generally in race ready condition when presented to technical inspection. Present car in Race Ready Condition	Inspect		
FT.2.3	Technical Inspection Access	The vehicle must be lifted/jacked onto stands such that all of the vehicle's wheels are at least 100 mm and no more than 300mm above the ground. The driven wheels must be removed - It must be possible to freely rotate the vehicle's wheels/hubs without the vehicle moving. Stands must be robust, and the vehicle must be secure. Use red SCA car jack stands on the first height setting to support the car in the air. Use a tape measure to display its height off the ground from the wheels. Body Kit Stays on	Inspect		
FT.2.4	Line of Fire	The minimum possible number of team members and Scrutineers should be in the area when testing is being conducted. Keep people away from rotating wheels, hubs or other moving parts. Check tires for debris that could be thrown or remove wheels from vehicle. Use the impact gun with a 21mm impact deep socket to remove the wheel nuts on the rear two wheels and remove the wheels.	Inspect		
DO NOT PROCEED WITH THE FUNCTIONAL SAFETY TEST IF ANY OF THE ABOVE ARE NOT COMPLETE					
FT.2.5	Driver Egress	If any of the following tests requires a driver to be in the vehicle, the driver must be in full race gear, and it must be possible for the driver to egress the vehicle safely. e.g. The vehicle must not be on high stands. We do not need a driver in the vehicle, we will be actuating the pedals from outside the car	Inspect		

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EV CLASS - FUNCTIONAL TEST					
AMS FUNCTION TEST				**Reinspect**	**Passed**
FT.3.1	Accumulator Management System Function	AMS must monitor the cell voltage of each cell Display using the candapater and BMS software on the Chungus the voltage of all 108 cells in the live data tab, ask if it okay to remove the body kit to access the expansion port on the CEN and to turn GLVMS on	Activate AMS system and show measurement data of the AMS for each cell (e.g., via laptop)	p.g.1	
FT.3.2		AMS must monitor the temperature of at least 20% of cells in pack Using the kvaser and CAN KING on the Chungus, display the max, min and average temps of the cells in the segments. Disconnect the candapater and connect the kvaser. Display a CANaMONS PCB and explain how the board connects to the thermistors on each Energus Module, converts the analogue reading into a CAN message and sends the messages the LVD on an isolated CAN network. The LVD then sends the messages on CAN 1 which is connected to the rest of the car and the BMS			
FT.3.3		A red indicator light marked "AMS" must be installed in the cockpit that lights up, if the AMS shuts down the car Point out the AMS light on the MoTeC which lights up when the AMS OK High Signal goes bad	Inspect		
TRACTIVE SYSTEM ENERGISATION TEST				**Reinspect**	**Passed**
ASK THE TEAM TO INSTALL THE HVD AND UNLOCK THE TSMS LOCKOUT. THE VEHICLE SHOULD BE ASSUMED TO BE LIVE AT ALL TIMES					
FT.4.1	GLVMS Function	TS only allowed to be powered up, when GLVS is powered up. Connect the Fluke 289 Multimeter to TSMPs and set to measure DC Voltage (600V range). Try to switch on Tractive System with GLVS Master switch in Off-Position. No voltage above 60VDC allowed at measurement points. Demonstrate whilst explaining what you are doing.	Ask team to demonstrate		
FT.4.2		TS only allowed to be powered up, when GLVS is powered up. Switch on Tractive System and then switch off GLVS Master switch. Tractive system must switch off as well - Watch measured voltage on scrutineer's Multimeter fall to below 60V DC. Demonstrate whilst explaining what you are doing.	Ask team to demonstrate		
FT.4.3	Pre-Charge Circuit	A circuit that is able to pre-charge the intermediate circuit to at least 90% of the current accumulator voltage before closing the second AIR has to be implemented. Use the graphing function of the Fluke 289 Multimeter to plot the voltage at the TSMPs during power up of the tractive system. Show that 90% voltage is reached before final AIR closes. Demonstrate whilst explaining what you are doing. Pack will be charged to 50% soc (400ish V) and listen for the second AIR to close	Ask team to demonstrate		
FT.4.4	Tractive System Voltage	The maximum tractive system voltage must be less than or equal to 600VDC at all times as measured by the Fluke 289 Multimeter. Measured Voltage: Demonstrate whilst explaining what you are doing. Should be around 400	Ask team to demonstrate		
FT.4.5	Accumulator Active Indicator	Accumulator Indicator Light or analogue voltmeter has to show if voltage above 60VDC is present outside of the accumulator container. Switch off the GLVMS. The Accumulator active indicator must continue to function even if the GLVMS is switched off or if the accumulator is removed from the vehicle. Demonstrate whilst explaining what you are doing. The AIL will remain on until the circuit has discharged below 60 VDC	Ask team to demonstrate		

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EV CLASS - FUNCTIONAL TEST

TRACTIVE SYSTEM ENERGISATION TEST				Reinspect	Passed
THE VEHICLE SHOULD BE ASSUMED TO BE LIVE AT ALL TIMES					
FT.4.6	TSAL	The TSAL must be installed immediately under the highest point of the roll hoop. The TSAL must not be on top of the roll hoop. The TSAL must not touch the driver's helmet in any seating position. Display	Inspect		
FT.4.7		The TSAL must be continuously illuminated green in colour when the vehicle GLVMS is switched on but the voltage outside the accumulator is less than 60VDC Display, may need to use the fluke to measure TS voltage to prove it is green under 60 VDC	Inspect		
FT.4.8		Switch on the Tractive System. The TSAL must flash red in colour at between 2hz and 5Hz when the voltage outside the accumulator is more than 60VDC. The TSAL may stop functioning if the GLVMS is switched off. Display the frequency of the TSAL flash using a timer	Inspect		
FT.4.9		The TSAL must be clearly visible in bright sunlight to a person standing anywhere less than 3m from the vehicle with an eye height of 1.6m. The TSAL must not be blocked by wings or other bodywork. Minor obstruction from the roll hoop is acceptable. Display	Inspect		
FT.4.10		TSAL must be non-programmable. No part of the TSAL function must depend on a programmable device. Display TSAL schematic, prepare to demonstrate the LV/HV Separation if asked.	Ask Team to demonstrate	p.g.2	
FT.4.11	Discharge Circuit	A circuit that is able to discharge the tractive system components outside of the accumulator container to less than 60V DC withing 5 seconds of a shutdown must be fitted. Use the graphing function of the Fluke 289 Multimeter to plot the voltage at the TSMPs during power up of the tractive system. Show that the voltage falls to less than 60V DC in less than 5 seconds after the TSMS is switched off. Demonstrate whilst explaining what you are doing, have a timer to time the 5 seconds. If they ask to see a schematic, p.g.1 in EV STATIC displays the discharge circuit, or the TSAL schematic in the Electrical schematic book	Ask team to demonstrate		
FT.4.12	PDOC	A red indicator light marked "PDOC" must be installed in the cockpit that lights up, if the PDOC system shuts down the car. The indicator light must be visible to the driver in bright sunlight. The PDOC may be omitted if the pre-charge and discharge circuit is designed for continuous operation in a faulted state and will not adversely affect nearby devices Point out light on MoTeC that turns on when the PDOC OK High Signal goes bad as our PDOC is not continuous. Offer to turn the light on for them by turning the car off, disconnecting the accumulator LV loom and turning the car back on. Switch the car off to reconnect. Can show HFR schematic if asked	Inspect	p.g.3	

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EV CLASS - FUNCTIONAL TEST

INSULATION MONITORING DEVICE TEST

The IMD is one of the primary methods for monitoring the health of the accumulator and tractive system.
The IMD works by continuously measuring the insulation resistance between the tractive system and the chassis. If it detects a low resistance path between the tractive system and the chassis, it will shut down the vehicle. The IMD is intended to form a detection system, providing early warning to the team that they have an insulation breakdown before a short circuit can form.
The correct function of the IMD is critical to the operational safety of the vehicle and any misbehaviour should be reported to the EV Technical Inspection Captain for investigation.

THE VEHICLE SHOULD BE ASSUMED TO BE LIVE AT ALL TIMES

				Reinspect	Passed
FT.5.1	IMD	A red indicator light marked "IMD" must be installed in the cockpit that lights up, if the IMD system shuts down the car. The indicator light must be visible to the driver in bright sunlight. Point out light on MoTeC that turns on when the IMD OK High Signal goes bad. Offer to turn the light on for them by turning the car off, disconnecting the accumulator LV loom and turning the car back on. Switch the car off to reconnect.	Inspect		
FT.5.2	IMD	The team must provide a test resistor manufactured with insulated banana plugs with an appropriate resistor in place. The resistor must have an appropriate voltage and power rating and be encased in a hard-shell enclosure. The resistor should have appropriate power rating and be installed in a hard-shell enclosure (heat shrink/tape insulation is not acceptable). Check the resistance of the test lead with the Fluke 289 Multimeter. Display The resistance should be a minimum of: R_Test = (maximum TS voltage * 250Ω/V) - (2 * BPR) Measured Resistance: Should be (453.6V*250Ω/V) – (2*15kΩ) = 83.4kΩ *BPR = the value of the Body Protection Resistors in Ohms Installed on HIP if asked show schematic, either in electrical schematic book or pg1 of EV Static.	Inspect		
FT.5.3	IMD	Activate Tractive System and connect R_Test between HV+ and GLVS ground. TS voltage as measured at the TSMPs must decrease below 60VDC in 5 sec, IMD may take up to 30s to react. Observe with the Fluke 289 Multimeter. Demonstrate whilst explaining what you are doing, if they do not have a stopwatch, use a phone to time	Check Shutdown Time with Stopwatch		
FT.5.4	IMD	Activate Tractive System and connect R_Test between HV- and GLVS ground. TS voltage as measured at the TSMPs must decrease below 60VDC in 5 sec, IMD may take up to 30s to react. Observe with the Fluke 289 Multimeter. Demonstrate whilst explaining what you are doing, if they do not have a stopwatch, use a phone to time	Check Shutdown Time with Stopwatch		
FT.5.5	IMD	Remove the test resistor. The tractive system may not automatically return to active state after the IMD test resistor was removed or a BMS error disabled it. The Driver must not be able to reactivate the tractive system Demonstrate whilst explaining what you are doing, try to turn the TSMS switch on and off, and explain that the only way to re active the TS is to power cycle LV or press the Hard Fault Reset button on the CEN which is mounted behind the firewall. Display the HFR board schematic	Ask team to demonstrate	p.g.3	

EV CLASS - FUNCTIONAL TEST					
SHUTDOWN SYSTEM TEST This section proves the correct function of all shutdown devices. The tractive system must fall below 60V within 5 seconds when the shutdown system is activated. With the Fluke 289 Multimeter monitoring the voltage at the TSMPs, have the team turn on the vehicle's LV and Tractive System then activate the shutdown mechanism. While completing this test, the items previously must continue to operate. Watch that the TSAL, Accumulator Active Indicator, precharge and discharge systems all continue to work correctly.				**Reinspect**	**Passed**
THE VEHICLE SHOULD BE ASSUMED TO BE LIVE AT ALL TIMES **TAKE CARE NOT TO OVERHEAT THE PRECHARGE OR DISCHARGE RESISTORS DURING TESTS**					
FT.6.1	Shutdown System Test	Vehicle with tractive system live --> GLVS master switch off Demonstrate whilst explaining what you are doing	Ask team to demonstrate		
FT.6.2		Vehicle with tractive system live --> TS master switch off Demonstrate whilst explaining what you are doing	Ask team to demonstrate		
FT.6.3		Vehicle with tractive system live --> Left shutdown button off Demonstrate whilst explaining what you are doing	Ask team to demonstrate		
FT.6.4		Vehicle with tractive system live --> Right shutdown button off Demonstrate whilst explaining what you are doing	Ask team to demonstrate		
FT.6.5		Vehicle with tractive system live --> Cockpit shutdown button off Demonstrate whilst explaining what you are doing	Ask team to demonstrate		
FT.6.6		Vehicle with tractive system live --> Brake over travel switch off Demonstrate whilst explaining what you are doing	Ask team to demonstrate		
FT.6.7		Vehicle with tractive system live --> GLVS master switch off Demonstrate whilst explaining what you are doing	Ask team to demonstrate		
FT.6.8		Unmount inertia switch. Activate TS and shake the switch and check if TS is shutdown. TS is not allowed to reactivate without a manual reset e.g. by the driver Demonstrate whilst explaining what you are doing, use snips to cut the zip tie to demount the inertia switch and shake it, explain that the only way to reset it is to push the switch down and is out of reach from the driver. Remount with a zip tie.	Ask team to demonstrate		

EV CLASS - FUNCTIONAL TEST

READY TO DRIVE TEST

This section tests the on-board systems which are intended to prevent the vehicle running away if a component fails.
The plausibility systems are expected to have a high degree of reliability and robustness as they may be the last line of defence from a collision.
This section will require that the team put the vehicle into drive, so the wheels and hubs will turn under power. Keep all unnecessary people outside of the test bay and ensure that people are well clear of the any rotating components.
The team may elect to have a driver inside the vehicle for this section if required. The driver needs to be in full race gear and must be able to egress the vehicle safely in the event of a fire, so pay attention to the height and stability of the vehicle and any obstructions in the inspection bay.

				Reinspect	Passed
THE VEHICLE SHOULD BE ASSUMED TO BE LIVE AT ALL TIMES					
FT.7.1	Ready to Drive	Only closing the shutdown circuit must not set the car to ready-to-drive mode. The car is ready to drive as soon as the motor(s) will respond to the input of the torque encoder/ acceleration pedal Demonstrate whilst explaining what you are doing, put the car into HV and press the accelerator pedal and explain there is no motor response as RTD is not enabled.	Ask team to demonstrate		
FT.7.2		Additional actions are required by the driver to set the car to ready-to-drive-mode e.g. pressing a dedicated start button, after the tractive system has been activated. One of these actions must include the brake pedal being pressed as ready-to-drive-mode is entered. It must be possible for the vehicle to be powered on, with the high voltage on, but with the vehicle not in drive. It is not acceptable for the action of the driver putting the vehicle in drive to simultaneously turn on the HV System and engage drive. Demonstrate whilst explaining what you are doing, explain that pressing the brake and the RTD button on the DEN will enable the car, ask they you can turn on HV and go into RTD, gentle spin the wheels.	Ask team to demonstrate		
FT.7.3		The car must make a characteristic sound, once but not continuous, for at least 1 second and a maximum of 3 seconds when it is ready to drive The sound level must be a minimum of 70dBA, fast weighting, in a radius of 2m around the car The used sound must be easily recognizable. No animal voices, song parts or sounds that can be interpreted as offensive will be accepted Demonstrate whilst explaining what you are doing. Put the car into ready to drive to display the noise. Offer to time if they do not have a stopwatch. If they wish to see a datasheet for the sounder, it can be found in the datasheet folder.	Ask team to demonstrate		
FT.7.4		Pressing the accelerator gently must cause the vehicle's wheels to rotate. Check all of the vehicle's driven wheels turn in the correct direction. Demonstrate whilst explaining what you are doing, explain we have a locked rear axle and gently spin the wheels using the accelerator (wheels off). They will spin in the right direction.	Ask team to demonstrate		

EV CLASS - FUNCTIONAL TEST

DRIVER INPUT PLAUSIBILITY CHECKS				Reinspect	Passed
THE VEHICLE SHOULD BE ASSUMED TO BE LIVE AT ALL TIMES					
FT.8.1	Torque Encoder / Brake Pedal Plausibility Check	Torque encoder is at more than 25% and brake is actuated simultaneously. The motors have to shut down. The motor power shut down has to remain active until the torque encoder signals less than 5% pedal travel, no matter whether the brake pedal is still actuated or not. 1. Ask the team to spin the motors by pressing the accelerator pedal. 2. While the wheels are spinning, ask the team to depress the brake pedal. 3. The wheels must stop turning and the torque (current) to the motors should immediately fall to zero 4. Ask the Team to release the brake pedal while continuing to hold the accelerator pedal down. The wheels must not turn. 5. Ask the team to completely release the throttle pedal and press it again. 6. The wheels may now turn. Demonstrate whilst explaining what you are doing, follow the above instructions	Ask team to demonstrate		
FT.8.2	Torque Encoder Plausibility Check	If an implausibility occurs between the values of two torque encoder sensors the power to the motor(s) has to be immediately shut down completely. It is not necessary to completely deactivate the Tractive System, the motor controller(s) shutting down the power to the motor(s) is sufficient Implausibility is defined as a deviation of more than 10% pedal travel between the sensors If three sensors are used at least two sensors have to be within 10% pedal travel, etc. 1. Check that driven axles turn by pressing the accelerator pedal 2. Disconnect at least 50% of the sensors and check that the power to the motors is shut down The sensor should be disconnected while the axles are turning. There must be no uncommanded throttle surges when the sensors are unplugged. Demonstrate whilst explaining what you are doing, follow the above instructions	Ask team to demonstrate		
FT.8.3		Repeat the above disconnecting the other throttle sensors. Demonstrate whilst explaining what you are doing, follow the above instructions	Ask team to demonstrate		

EV CLASS - FUNCTIONAL TEST

DRIVER INPUT PLAUSIBILITY CHECKS				Reinspect	Passed
THE VEHICLE SHOULD BE ASSUMED TO BE LIVE AT ALL TIMES					
FT.9.1	Brake System Plausibility Device (BSPD)	A standalone non-programmable circuit must be used on the car such that when braking hard (without locking the wheels) and when a positive current is delivered from the motor controller (a current to propel the vehicle forward), the AIRs will be opened. The current limit for triggering the circuit must be set at a level where 5kW of electrical power in the DC circuit is delivered to the motors at the nominal battery voltage. The action of opening the AIRs must occur if the implausibility is persistent for more than 0.5s. The team must devise a test to prove this required function during Electrical Tech Inspection. However, it is suggested that it should be possible to achieve this by sending an appropriate signal to the non-programmable circuit that represents the current to achieve 5kW whilst pressing the brake pedal to a position or with a force that represents hard braking. The preferred method for testing the BSPD system involves passing actual current from an external supply through the tractive system current sensor while the driver presses the brake pedal. Alternative test methods will require approval from the EV Technical Inspection Captain. The test must be an end-to-end test, meaning it is not acceptable for the team to simulate the 5kW by simulating the output of the current sensor, or using a substitute current sensor. To demonstrate, use the BSPD test loom and a power supply to put current into the coil plug on the side of the HIP. Display the BSPD circuit in the electrical schematic booklet and the image of the current sensor coiled and the current sensor. When at 1.25 A (10 turns on the sensor means that is 12.5A which 12.5A * 388.8 V = 4.86 kW) and the brake is pressed, the BSPD will fault, indicating on the MoTeC. This test can be done in or out of HV. EXPLAIN EVERYTHING YOU ARE DOING	Visual Inspection If required, ask team to show BSPD Schematic. Ask team to demonstrate	p.g.4	
FT.9.2		The Brake Plausibility Device may only be reset by power cycling the GLVS Master Switch or via a RESET button, located out of reach from the driver Display that the car will not go into HV now without power cycling GLVMS or pressing the HFR on the CEN which is mounted to the back of the firewall.	Ask team to demonstrate	p.g.3	

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EV CLASS - FUNCTIONAL TEST

				Reinspect	Passed
ENERGY METER TEST The energy meter test needs to be done by the Energy Meter Captain.					
THE VEHICLE SHOULD BE ASSUMED TO BE LIVE AT ALL TIMES					
FT.10.1	Energy Meter Test	Energy Meter Captain has laptop connected Follow instructions	Ask team to demonstrate		
FT.10.2		Switch on the GLVMS and check the datalogger will communicate with the laptop Follow instructions	Ask team to demonstrate		
FT.10.3		Switch on the tractive system and rotate the wheels such that sufficient power is delivered to the motors to register on the energy meter. Follow instructions	Ask team to demonstrate		
FT.10.4		The energy meter must show both positive voltage and correct current flow direction. Follow instructions	Ask team to demonstrate		
ASK THE TEAM TO TURN OFF THE VEHICLE, REMOVE THE HVD AND LOCK THE TSMS LOCKOUT.					
SEAL TS COMPONENTS				**Reinspect**	**Passed**
FT.11.1	Seal Tractive System components	Seal all important parts with tamper proof tape after the IMD test was passed successfully: i.e. Accumulator container, motor controller housings and any other enclosures containing Tractive System Voltage. Record items sealed:	Seal Items		