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FINAL YEAR PROJECT

PROJECT TITLE

Building a Driverless Electric Race Car for Autonomous Advancement

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Building a Driverless Electric Race Car for Autonomous Advancement

DESIGN REPORT

AV.One

Helena De Gruchy

2024

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Finally, to my best friend, Jake—thank you for your unwavering support. Your excitement in listening to my stories of AV.One, and our lunch breaks away from the workshop were invaluable in keeping me motivated to the end.

Glossary of Terms

Acronym	Definition
AIR	Accumulator Isolation Relay
AV	Autonomous Vehicle
CAN	Controller Area Network
ECU	Electronic Control Unit
EV	Electric Vehicle
GLV	Grounded Low Voltage
GLVMS	Grounded Low Voltage Master Switch
HFL	Hard Fault Latch
HFR	Hard Fault Reset
HV	High Voltage
HVD	High Voltage Disconnect
IMD	Insulation Monitoring Device
LV	Low Voltage
NU Racing	Newcastle University Racing
OKHS	Okay High Signal
PCB	Printed Circuit Board
SAE-A	Society of Automotive Engineers - Australasia
TS	Tractive System
TSAL	Tractive System Active Light
TSMP	Tractive System Measuring Point/s
TSMS	Tractive System Master Switch

Executive Summary

This report presents the comprehensive integration of electrical, mechanical, and software systems in NU Racing's first fully driverless, remotely controlled Formula-style electric vehicle, AV.One. Developed as a foundational prototype, AV.One marks a major advancement for the university's exploration into autonomous vehicle (AV) technology. Capable of remote acceleration, braking, and steering, the vehicle serves as a strong foundation for future autonomous systems development.

Originally composed of disconnected components, AV.One required extensive modifications beyond the anticipated scope; not only were goals met but major safety enhancements were achieved in addition to them.

As development of AV.One continues, the team aims to incorporate live onboard inference technology, using it as a foundational test bed to advance NU Racing's readiness for the Autonomous division of the Formula SAE-Australasia competition. Building on their outstanding results in the EV category in 2022 and 2023 (with a similar trajectory expected in 2024), the team is committed to progressing into the AV division.

AV.One is now a fully functioning driverless vehicle, capable of being driven around a marshalled race circuit via a remote controller. The result of this is a reliable and realistic platform for future autonomous research and testing that NU Racing can use to prepare for future Formula SAE-A Autonomous competitions.

(a) (b)

Figure 1
Front (a) and rear (b) views of the fully functional driverless electric vehicle, known as 'AV.One'.

Dot Point Summary

Batteries

1. Insulated batteries from metallic housing using flame-retardant thermal-insulating sheet (FR4).

High Voltage

1. Replaced faulty accumulator isolation relays.
2. Replaced HV fuse for appropriately rated one.
3. Installed additional copper bus bar so new HV fuse fits existing topology.

Low Voltage

1. Installed receiver for remote emergency-stop (e-stop).
2. Installed receiver for remote controller.
3. Designed and soldered updated versions of the Braking Electronic Node (BEN) and Steering Electronic Node (SEN) printed circuit boards (PCBs).
4. Modified existing PCBs to design the Remote Electric Node (REN) and Distribution Electronic Node (DEN).
5. Created wiring looms for the braking and steering systems.
6. Routed LV wiring from the chassis-mounted e-stops, BEN, SEN, DEN and REN to accumulator.
7. Determined connector selection.

Software

1. Wrote extensive code for the BEN, SEN, REN and LV Distribution Board (LVD).
2. Programmed the left-side motor controller.
3. Expanded Controller Area Network (CAN) communication capacity.

Topology

1. Created node layout and their mounting locations on the chassis.

Manufacturing

1. Designed and 3D-printed protective enclosures for the BEN, SEN, REN and DEN.
2. Water cut FR4 sheet and new copper bus bar.
3. Modified existing accumulator infrastructure to accommodate additional components.

1. Introduction

The Formula SAE-A competition held annually in Australia is based off the international event where university students design, build, and race their own open-wheeled, Formula-style vehicles. It aims to produce graduates with higher competency in engineering knowledge, troubleshooting and management skills that are ready to hit the ground running when they enter the workforce [1].

NU Racing is the University of Newcastle's team that competes at the Formula SAE-A competition in the electric vehicle (EV) division. The competition only defines two main conditions for the EVs: an 80kW limit on their power output, and 600V limit on their HV batteries. NU Racing have a proud tradition of applying hundreds of hours each year to produce an innovative, fast and reliable race vehicle that fits within those constraints. They also excel in the static events where they are tested on design and business skills, in addition to engineering.

Figure 2
NU Racing team at the 2023 Formula SAE-A competition with their EV.

However, the nature of the Formula SAE international competitions (simply known as Formula Student) has been shifting in the last few years to place greater importance on the autonomous vehicle (AV) division of the event. With the presence of AV technology in modern society, engineering companies are increasingly seeking graduate engineers with understanding of concepts like sensor integration and navigation algorithms. Formula Student aims to provide a platform for such graduates to emerge [1].

Although the competition held in Australia does not yet host a competitive AV division, this will shift quickly in the next few years to reflect how international events have already evolved. Of note, the 2023 Formula Student Germany competition showcased the students' impressive engineering skills when the team of the University of Applied Sciences Augsburg claimed the current world record in the Acceleration event. The achievement required their AV to cover the

75m track in 4.27s, reaching nearly 95km/h [2]. This example highlights the level of engineering excellence required to design, build, and operate Formula Student AVs.

To enter the AV division with a reliable vehicle, NU Racing first requires a platform on which they can test autonomous technology and onboard inferencing. This report details the integration of existing software and hardware into the university's first fully functioning driverless vehicle, AV.One, completed as a solo project. In alignment with the practices of NU Teams—the umbrella organisation for student-led engineering groups, including NU Racing—this project followed standardised methodologies for documentation and data management.

NU Teams utilises GitHub for its software versioning and storage, however the repository pertaining to AV.One (labelled 'Racing-AV1') was initially disorganised and missing key files related to its braking, steering and accumulator (power source) systems. Similarly, NU Teams maintains a structured database on OnShape, which is a CAD software used specifically for vehicle and component design by NU Racing. The team onboards its new members with an OnShape task. As such, it was the favourable software to design enclosures for AV.One's onboard systems because of its existing presence in NU Teams and the author's previous experience and familiarity with its layout.

As with AV.One's GitHub repository, its folder within OnShape initially lacked critical information and is still missing an up-to-date version of its accumulator design. However, both data storage locations have been extensively updated throughout this project. This includes collating information on the existing systems from their authors, who have graduated and left the university, and contributing new documentation as work was completed this year. See the 'Documentation' section of this report for further detail on the organisational framework defined this year for AV.One's GitHub and OnShape databases.

1.1. State of Vehicle at Project Commencement

Known as AV.One, this vehicle was built using the chassis, steering column, pedal box, wheels, suspension, motors and motor controllers of EV.Two, a retired NU Racing competition EV. Driverless braking and steering systems existed but were unable to be fitted to the chassis at the start of this project. The accumulator was newly commissioned and mountable in the rear of the vehicle.

The braking system consisted of the BEN in a 3D printed enclosure, electromagnetic brake booster (referred to as the iBooster) and the iBooster electronic control unit (ECU). Upon initial testing this year, it effectively applied the correct brake pressure and actuated the brake pedal.

The steering system consisted of the SEN in a 3D printed enclosure, Cytron motor driver, 12V 40W motor, and rotary angle encoder. This system was not initially functional and troubleshooting the malfunction was made tedious due to limited documentation created at the time of building the steering system.

The accumulator, which is referred to as the 'Serviceable Low-Voltage & Accumulator Box', or more simply the 'SLAB', housed the HV batteries and associated tractive system (TS) to safely distribute HV to the motor controllers. Additionally, it contained functional LV topology so the Tractive System Active Light (TSAL) correctly changed colour – solid green to flashing red – when

TS was engaged, and the brake light could turn on. There was no connection between the braking system and the brake light.

The SLAB's HV topology included a functional battery management system (BMS), 12V 18 Ah battery, HV disconnect (HVD) device, insulation monitoring device (IMD), precharge and discharge circuits. The DC-to-DC voltage converter (known simply as the DCDC) was not functional. This meant that the 12V battery could not be charged using the HV batteries. Additionally, there was no setup to charge the HV batteries using NU Racing's charger, but they held significant charge at the beginning of the project and did not require recharge throughout the year.

Upon further analysis at the start of this project, it was discovered that insufficient safety mechanisms existed to operate the SLAB without risk of HV leakage or extreme overheating. Subsequent plans for safety upgrades were initiated.

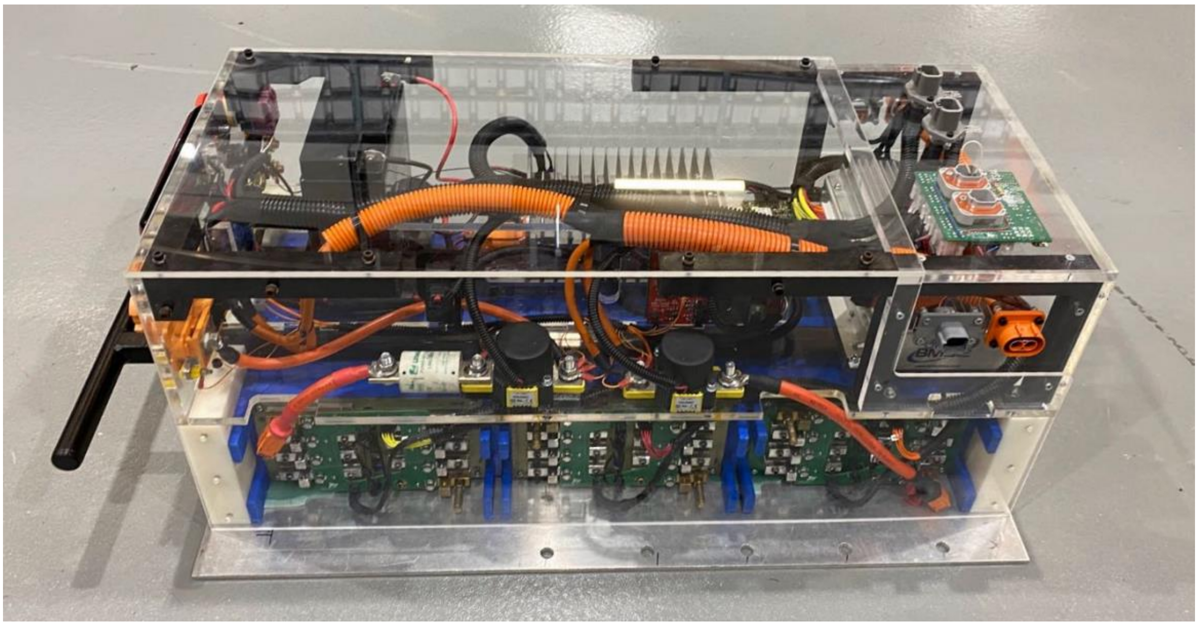


Figure 3
Accumulator (Serviceable Low-Voltage & Accumulator Box or 'SLAB') following commissioning last year.

The right motor was successfully spun forwards using a prescribed sequence of pulse-width modulation (PWM) inputs from the LVD. The left motor controller (MC) had not been programmed to operate so the left motor could not spin.

Overall, AV.One's systems could not function together as a driverless EV. This is largely due to the absence of LV wiring looms to connect systems to their power source, which is the 12V battery inside the SLAB. Additionally, there was insufficient CAN communication protocol in their software to receive messages or commands from other electronic nodes. There was no component outside of the SLAB that could activate the shutdown (SD) circuit as the wiring for the two chassis-mounted e-stops was not setup. This presented safety concerns if the vehicle's TS needed to be disengaged in the case of an emergency.

(a)  (b) 

Figure 4

(a) Front view of AV.One in its initial state at the commencement of this project.
(b) Rear view without accumulator (SLAB).

2. Scope

This Final Year Project (FYP) aims to deliver AV.One as a fully functional driverless electric vehicle, providing a platform for future testing and implementation of AV systems. Fully functioning is having the capability to accelerate, brake and steer safely around a marshalled race circuit, like the layout of the Endurance event at the Formula SAE-A competition.

The following FYP objectives in Table 1 have been devised from three main priorities:

1. Existing shortfalls in AV.One's systems.
2. NU Racing practices to improve student accessibility to the platform.
3. Competition requirements mandated by Formula SAE to increase AV safety.

The first priority was initially not included, and the relevant scope objectives did not exist. However, safety awareness led to significant scope expansion to address all shortfalls, following an initial assessment of the existing AV.One systems at the start of the year.

The second priority ensures AV.One is easy to understand for incoming students because they will be familiar with NU Racing practices in circuit design, documentation and safety procedures.

Pertaining to the third priority, the following rule (T 14.3.1) from the 2024 FSAE-A competition will be addressed in the scope:

> **'Remote Emergency System (RES): Every vehicle must be equipped with a standard RES. The RES used for FSAE-A competition is a GF2000i-codec / T53 combination from GrossFunk' [3].**

Table 1
Scope objectives for this FYP, according to main priorities.

Priority	Main Objectives	Tasks to Achieve Objectives
1	Upgrade safety within the SLAB to reduce risk of HV leakage or extreme overheating.	1. Replace ill-rated HV fuse. 2. Extend SD Circuit to outside SLAB. 3. Install thermal insulation around HV batteries.
2	Remove prerequisite for extensive knowledge of AV.One's systems to operate them.	1. Strengthen reliability of mechanical, electrical, and software components to minimise risk of malfunction or failure. 2. Create easy-to-follow troubleshooting booklets for operating AV.One.
2	Decrease troubleshooting time when a component malfunctions or fails.	1. Clearly document the systems and methods employed within AV.One. 2. Improve accessibility of components for rapid testing or replacement.
2	Integrate components to achieve full driveability and mobility.	1. Connect all systems through power and communication. 2. Securely mount them to the chassis.
2	Achieve driverless functionality.	1. Externally dictate the vehicle's basic commands using a remote controller.
3	Remotely shutdown AV.One without touching the vehicle.	1. Implement RES (separate from RC) that remotely shuts down vehicle's TS. 2. Physically integrate this device into the onboard Shutdown (SD) Circuit.

3. HV System

The upgrades and maintenance work performed on AV.One's accumulator (SLAB) during this project could not proceed without initially reviewing former FYP student reports, located in the 'Racing-AV1' GitHub within the 'Past_Reports' folder. This review aimed to thoroughly understand the HV circuit, however it became evident that some aspects would be unclear to future students working on AV.One were they to only refer to past FYP reports. To address this shortfall in knowledge transfer, a simplified topology flow chart was created this year (Figure 5). It is a visual guide that eliminates the need to revisit past reports when seeking an overview of the vehicle's HV system. It also outlines the key checkpoints addressed to be able to remotely drive AV.One, with an additional comprehensive guide found in the troubleshoot poster 'Startup Sequence' in Appendix B, which was also written during this project.

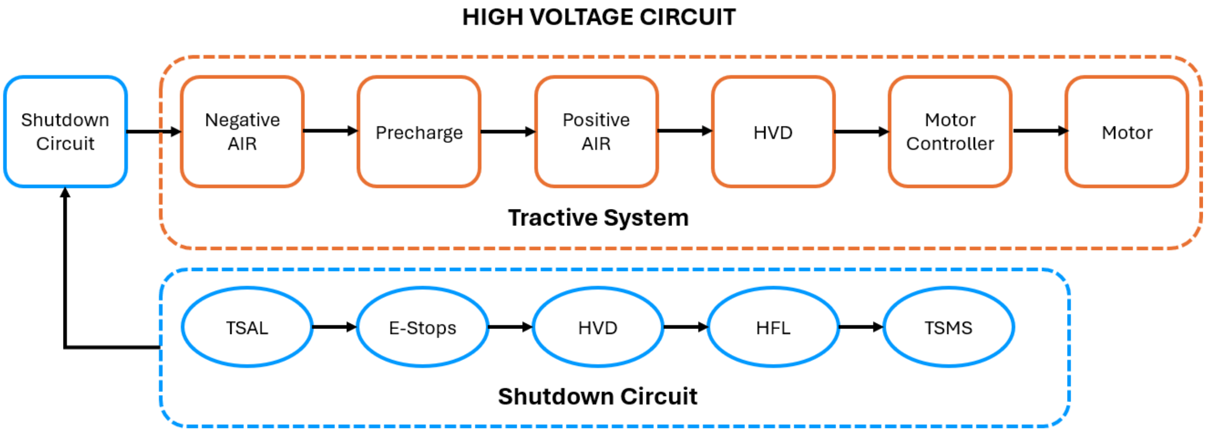


Figure 5
Electrical flow chart according to AV.One Startup Sequence. Orange indicates HV flow, and blue indicates LV (12V).

AV.One's HV circuit consists of two components: the 'safety flag', known as the Shutdown Circuit (SD), and the Tractive System, which only initiates once the safety flag is 'ready'.

3.1. Shutdown Circuit

The components of the SD circuit highlighted in Figure 5 are connected in series and must all function correctly for it to close, which is the 'ready' state of the safety flag. Closing the SD Circuit indicates the LV safety checks have been passed and the Tractive System (which carries HV to the motors) may be initiated. A brief overview of the SD Circuit is as follows: Tractive System Active Light (TSAL) must be powered (Figure 6**Figure 6**) and emergency stops (e-stops) disengaged, including the remote e-stop located on the device in Figure 7.

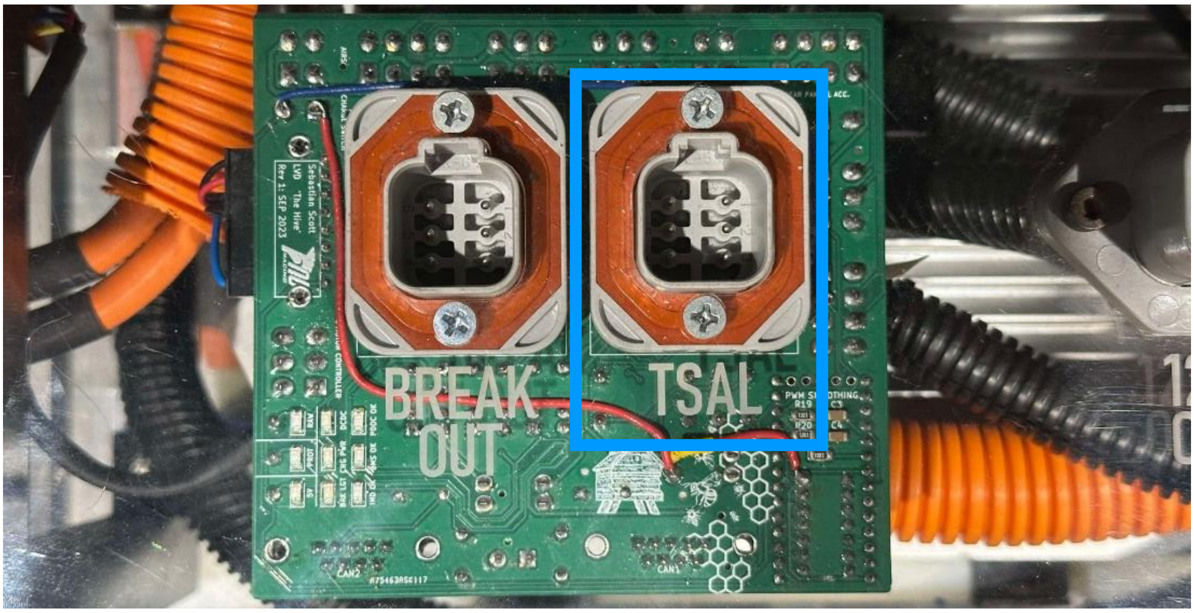


Figure 6
Blue box indicates the connector for Tractive System Active Light (TSAL) cable on top panel of accumulator (SLAB).

Figure 7
Remote emergency stop device: its transmitter (located in the SLAB) is physically integrated in the SD Circuit.

Additionally, the HV Disconnect (HVD) device must be securely attached (Figure 8) and Hard-Fault Latch (HFL) circuit closed. The HFL sequence can be found on the LVD printed circuit board (PCB), whose schematic is found on the 'Racing-AV1' GitHub within the 'LVD' folder.

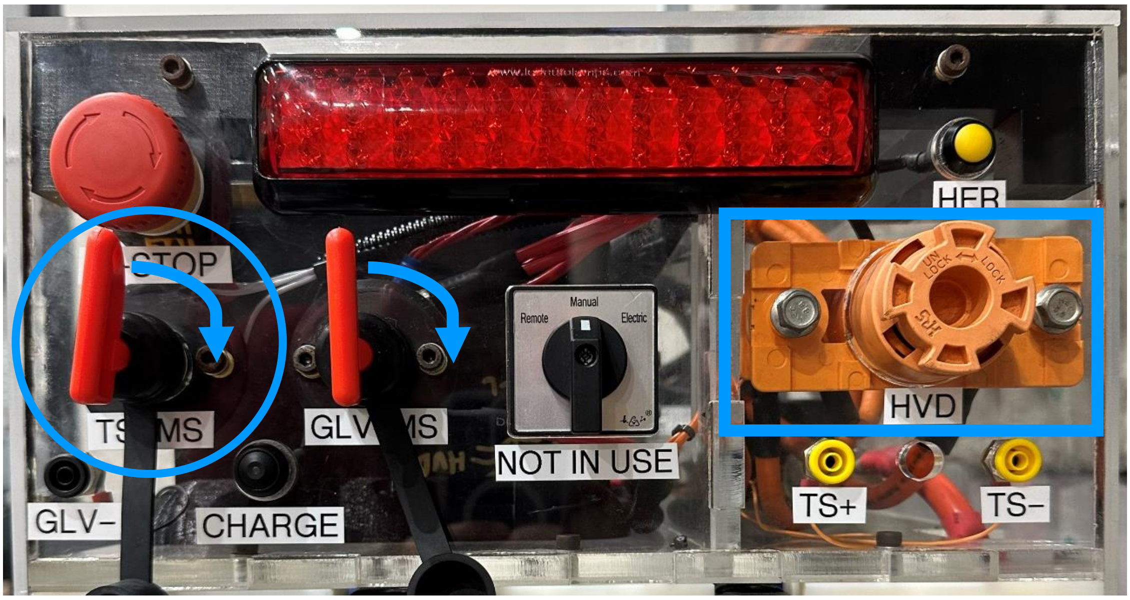


Figure 8

Rear panel of SLAB: Tractive System Master Switch (circled) with 'on' position indicated by direction of blue arrow. GLV master switch (located to right of TSMS) will already be in 'on' position at this point in the startup sequence. HVD device (blue box) must be physically connected to the SLAB to close SD Circuit.

Following all these actions, the Tractive System Master Switch (TSMS) can be switched to the 'on' position, as indicated in Figure 8. If the TSAL fails to change from solid green to flashing red (indicated by Figure 9) at this point during AV.One's startup sequence, there is likely an unclosed component in the SD Circuit. For this type of error, an in-depth troubleshooting checklist is outlined in the poster 'Shutdown Circuit' in Appendix 0.

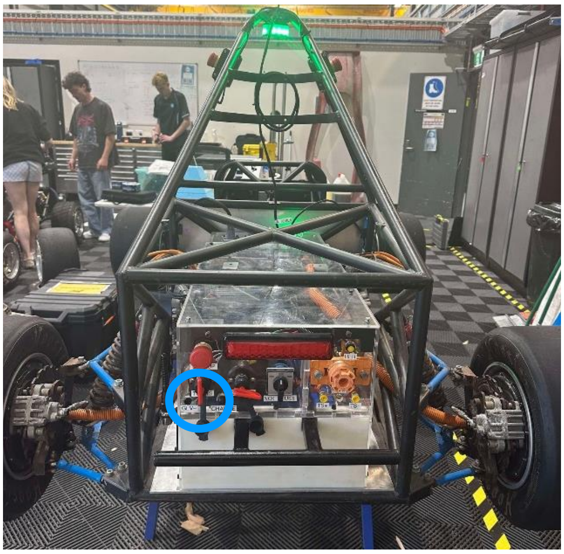
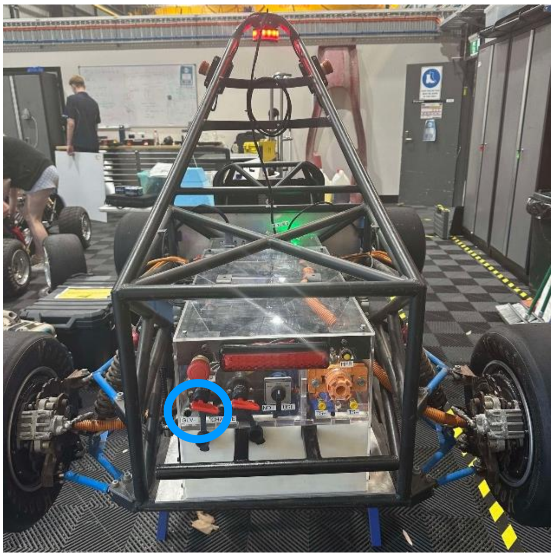
(a)  (b) 

Figure 9

TSAL changes from green (a) to flashing red (b) when TSMS (blue circle) is turned on to indicate closed SD Circuit.

3.2. Tractive System

Once the SD Circuit has closed, the Tractive System commences at the Negative Accumulator Isolation Relay (AIR) shown in Figure 10, which is a relay specifically designed for high-voltage, high-current applications.

Current is allowed to flow through this AIR into the Precharge circuit, which gradually charges the capacitors in the left and right motor controllers, to prevent damage caused by a sudden current spike. Once the Precharge board determines there has been adequate charge in the motor controller capacitors, it enables the Positive AIR to close. The HV is then able to bypass the resistor on the Precharge board, and flow through the HVD into the motor controllers and their respective motors.

Figure 10

Accumulator Isolation Relays: Labels next to them in the SLAB indicate which is positive and negative (not pictured).

3.3. Motor Controller Programming

While the right motor controller (MC) was programmed last year, the left MC had not yet been addressed at the start of this project so the left motor could not spin once HV reached it. A major challenge in the programming process was maintaining a reliable connection between the MC and the computer running the software, due to limitations in the cable's durability. The programming cable was upgraded and lengthened to enhance its robustness and user-friendliness, and Figure 11 clarifies where it attaches to the MC.

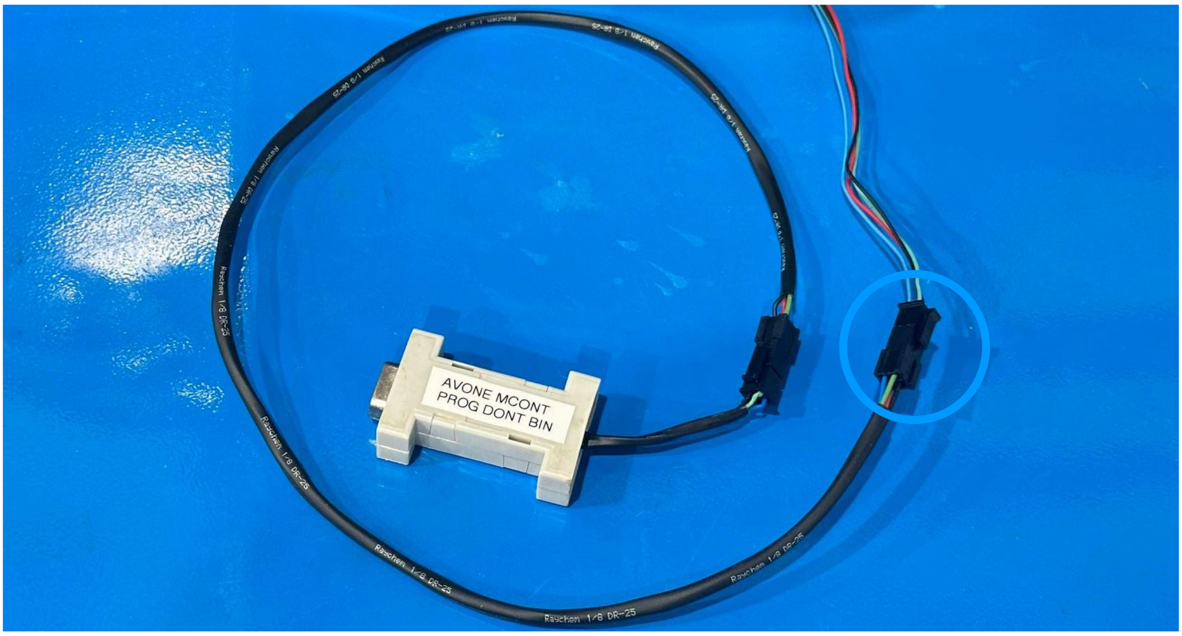


Figure 11

Programming cable connected to the left motor controller at the point circled.

The white wire labelled ‘12’ from the motor controller must be powered with 12V for the computer port to be able to connect to the MC. Current programming configuration on both the left and right MCs is shown in Figure 12. Changing a parameter will not be finalised until the ‘Write’ button is clicked, which is highlighted in a box below.

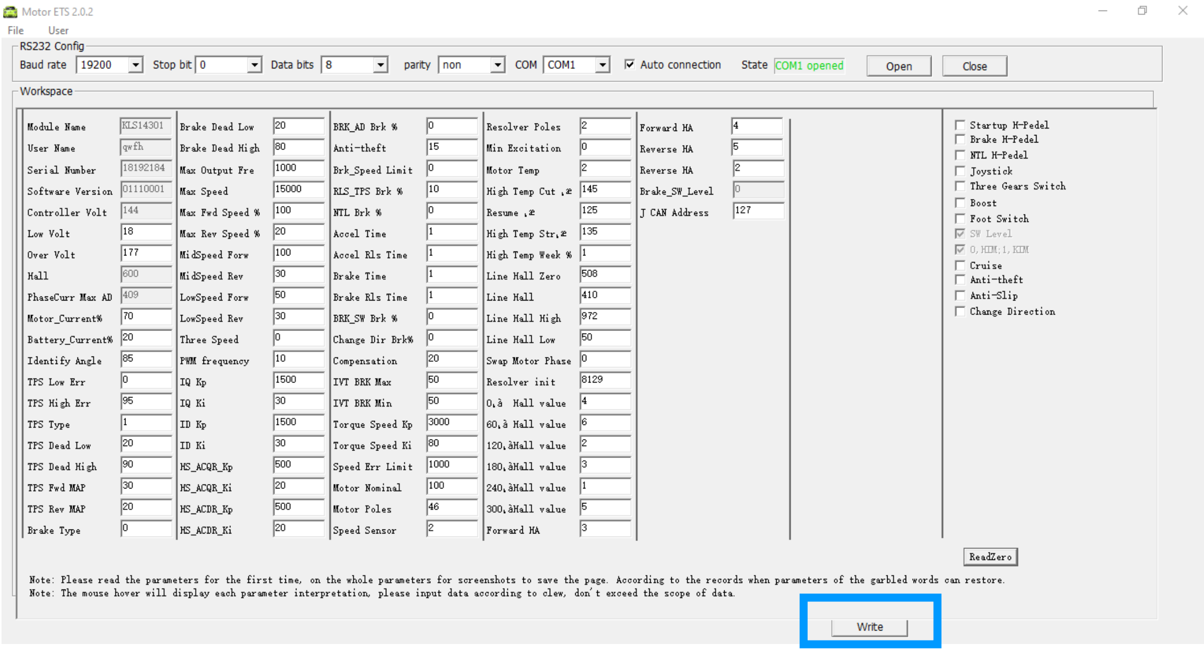


Figure 12

Kelly Motor Controller programming software showing current configuration on both motor controllers. Software is installed on NU Racing computer.

4. Safety Implementations

4.1. High Voltage Workspace

Before beginning safety upgrades on AV.One's accumulator, the HV area of TA workshop at the University of Newcastle underwent cleaning and organisation. This was essential as the project scope necessitated a safe workspace for the extensive accumulator improvements.

The following tasks were completed:

1. Unnecessary items, including furniture and debris, were removed to clear and organise the workspace.
2. A stocktake of essential safety equipment was conducted, and the following were replenished: three pairs of HV insulating gloves, leather outer gloves, and safety glasses.
3. HV-rated tools, which are defined as CAT III (600 V), were placed in clearly labelled drawers. These include spanners, sockets, multimeter and allen keys (all insulated).
4. A battery storage container (Figure 13 a) was installed for the SLAB, ensuring it is safely stored when not in use.
5. A hydraulic load-bearing trolley (Figure 13 b) was introduced to reduce injury risk when moving the heavy SLAB between the workbench, storage container and AV.One.
6. Safety posters were created to display mandatory HV procedures, which were approved by certified electrician and engineer Malcolm Sidney. These are shown in Appendix A.

(a)


(b)


Figure 13
(a) New battery storage container in the HV workspace.
(b) New hydraulic trolley to transport accumulator without injury to students.

4.2. Accumulator Improvements

4.2.1. Battery Insulation

Prior to any safety upgrades being made to the accumulator (SLAB) housing, the enclosed HV batteries sat directly over metal sheet. This was a very high-risk configuration because of the protruding battery connection fittings overhanging the uninsulated metal. Contact between any of the three connectors and the metal accumulator housing would result in the entire sheet being conductive with HV, which if touched by a human would result in serious harm. To eliminate this hazard, fire and thermal insulation in the form of FR4 Flame-Retardant Epoxy Glass Sheet (referred to as FR4) was installed on the accumulator base beneath the batteries (Figure 14 b). FR4 was chosen because it was proven to be compliant with the following Formula SAE-A rule (EV 6.2.2):

> **There must be an appropriate insulating barrier between the accumulator walls and any electrically live component within [4].**

While the FR4 sheet itself meets competition requirements, the epoxy adhesive used to secure it does not. This was deemed acceptable since AV.One is intended as a research platform rather than a competition vehicle. Nonetheless, it is notable that the FR4 material offers essential fire and thermal insulation properties, validated by its compliance with competition standards.

The FR4 sheet was water-cut to give a very precise fit to the side walls of the accumulator housing. This reinforces the insulation by eliminating any gaps where the batteries can be exposed to the metal housing.

(a)

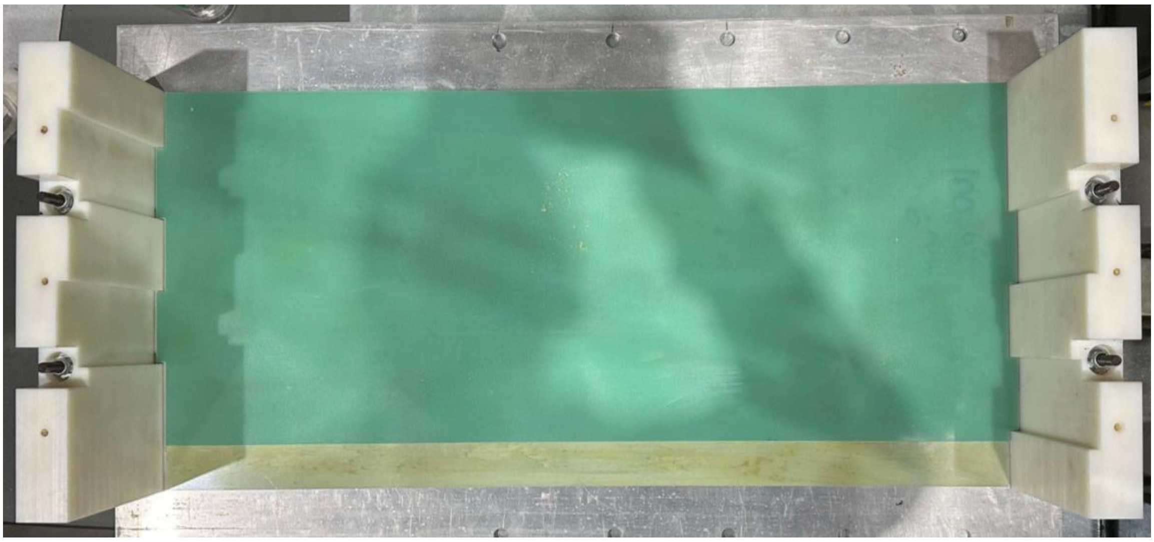

(b) 

Figure 14
(a) Exposed, uninsulated metal sheet taped off and covered in epoxy prior to FR4 being applied.
(b) FR4 sheets (narrow yellow and wide green) glued onto base of SLAB.

Following FR4 installation, the battery connectors were no longer directly above metal sheet, which greatly reduces the risk of electrical conduction (known as HV leakage) in the accumulator housing. The thinner FR4 sheet was chosen to go beneath the metal connectors so the bulky fittings could go over them with sufficient clearance from the FR4 and housing (Figure 15).

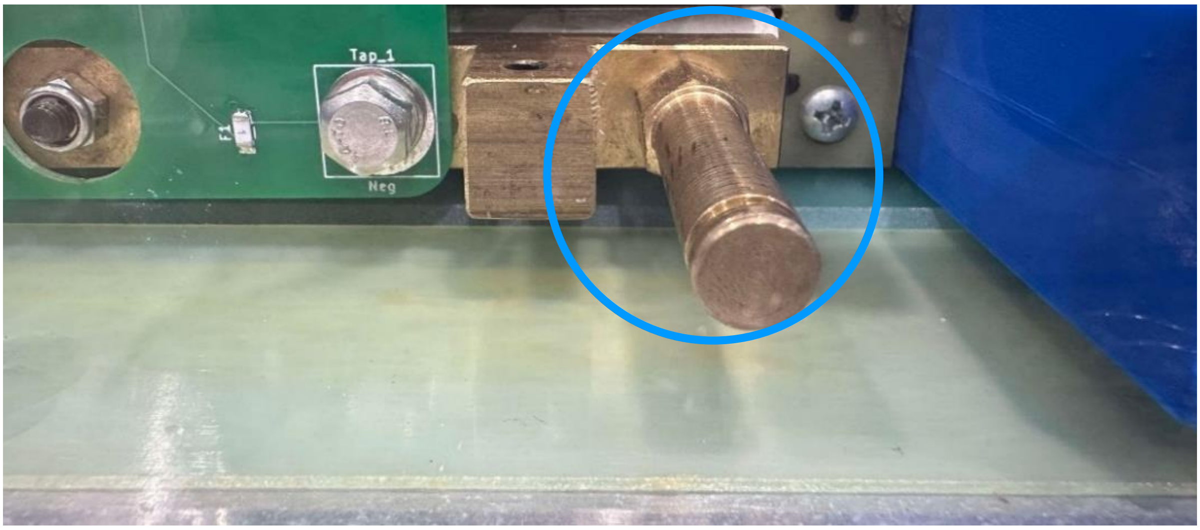


Figure 15
Sheets of varied thickness used to ensure clearance for connector fitting onto protruding battery points (circled).

4.2.2. Fuse Upgrade

To better match power requirements, the accumulator's HV fuse was downgraded from 225A to 70A. A power analysis conducted according to AS/NZS 3008 standards showed that any fuse above approximately 78A would be unable to interrupt the circuit before the HV wiring reached its current-carrying capacity, risking overheating and potential failure [3]. To accommodate the new, shorter and smaller HV fuse, a copper bus bar was water-cut to precisely fill the gap to the Positive AIR (Figure 16).

(a)

(b)

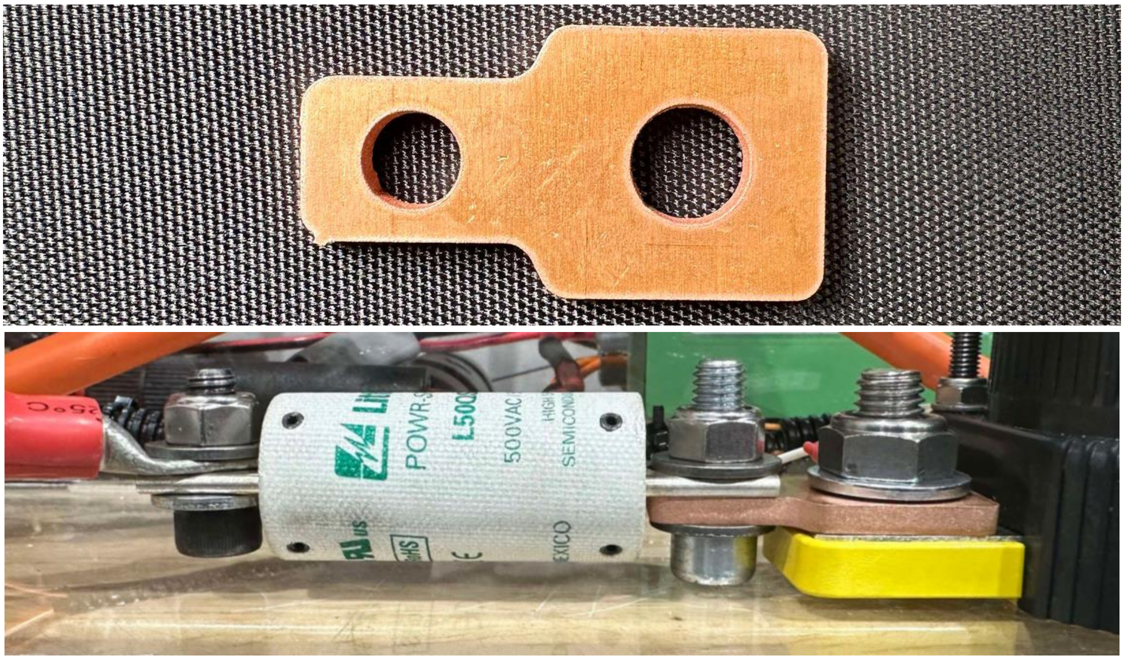


Figure 16
(a) Custom water-cut copper bus bar.
(b) New fuse connected in SLAB's HV circuit next to bus bar.

During initial attempts to spin the motors using the remote controller, the HV discharge resistor experienced severe overheating which melted the plastic mounting screws holding it to the Discharge PCB (Figure 17). The discharge resistor is designed to dissipate residual energy left in the motor controller capacitors following HV shutdown, however they heat up significantly if they are discharging for a long time. The overheating issue that arose was caused by the discharge resistor attempting to dissipate energy whilst one or both AIRs were still open and allowing continuous HV flow. This situation never occurs unless the AIRs are faulty and fused closed. It is thought that the AIRs were accidentally damaged during troubleshooting to get the motors spinning, leading to this fault and the concurrent attempt to discharge the incoming current.

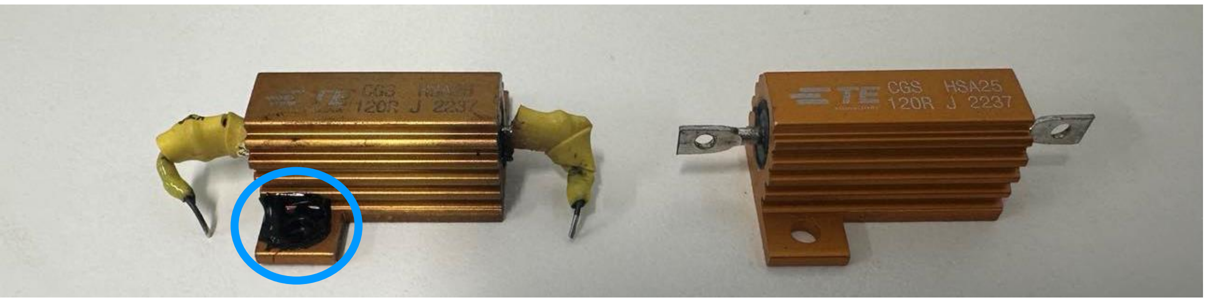


Figure 17
Damaged discharge resistor (left) and its replacement (right). The black mark (circled) is a melted mounting screw.

Following this incident, the discharge resistor was replaced and instead attached using metal screws secured with Glenloch locking nuts to ensure a heat-tolerant configuration. The faulty AIRs were replaced with the same-sized, higher-power variant (GIGAVAC GX14). The higher power is not necessary for the accumulator's requirements, however the former GX12 variant is no longer supplied to Australia so the GX14 was an appropriate replacement. An important safety lesson was learned during the incident: remain calm, disconnect HV flow by removing the HVD device at the rear of the SLAB, and if possible, safely isolate the problematic component to prevent further issues.

A bench test was conducted following the SLAB rebuild, whereby the HV batteries were removed and isolated in the battery storage container, and all remaining components were run using an alternate power supply. The purpose of bench testing was to remove the safety risk of HV battery failure and provide a fast way to disconnect power supply. The procedure outlined in the troubleshoot poster ‘HV Bench Test’ in Appendix 0 is a safe method of bench testing the SLAB.

5. Electrical Topology

5.1. LV System Improvements

Significant work was required on AV.One's LV systems to meet the scope requirements that focused on ease of use, component accessibility, and enabling driverless functionality. The LV system powers all onboard logic, making it essential for reliable communication between electronic nodes and for integrating the vehicle's driverless capabilities. Upgrades to the LV system addressed these needs by enhancing system organisation, ensuring secure connections, and improving access for maintenance and testing.

5.1.1. Electronic Nodes

5.1.1.1. BEN

The Braking Electronic Node (BEN) initiates driverless braking once it receives a brake pressure command. A PID controller is implemented on the teensy microcontroller that outputs a command to the Bosch iBooster to displace the brake pedal until the desired pressure is achieved.

The first iteration of the BEN was completed by Chris Neal in 2023; however, it required modifications for mounting to AV.One's chassis and upgrades to its PCB to better fulfill its intended function. PCB improvements included a more robust reverse polarity voltage protection circuit to align with NU Racing practices, which is a priority in the project scope. The opportunity was taken to swap the BEN's connectors from Molex to Deutsch DT for greater accessibility. Components associated with communicating on CAN Line 2 were removed as this functionality was no longer needed. The 12V high-current power supplied to the iBooster from the SLAB is now fused on the BEN PCB, rather than requiring bulky in-line fuses. This allowed for the overall BEN design to be compacted and lightened so that it can mount to the vehicle's anti-intrusion plate. Finally, pull-up resistors were added to the brake relay signals on the BEN PCB; their logic is visually displayed in Figure 18 and explained below:

1. **Common** (BRK_COM1) – the common GND terminal connected to either NC1 or NO1 based on iBooster ECU relay state.
2. **Normally Closed** (BRK_NC1) – default closed (grounded) relay. It ensures safety by connecting the braking circuit when there's no power or there is an ECU fault.
3. **Normally Open** (BRK_NO1) – default open relay. Closes when activated by the ECU, enabling power to flow only when necessary.

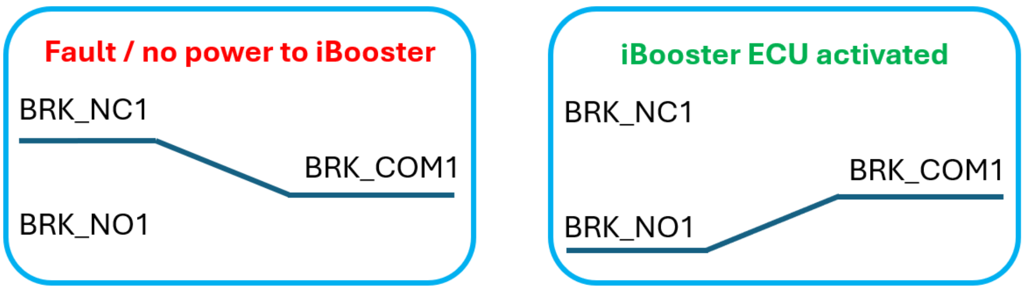
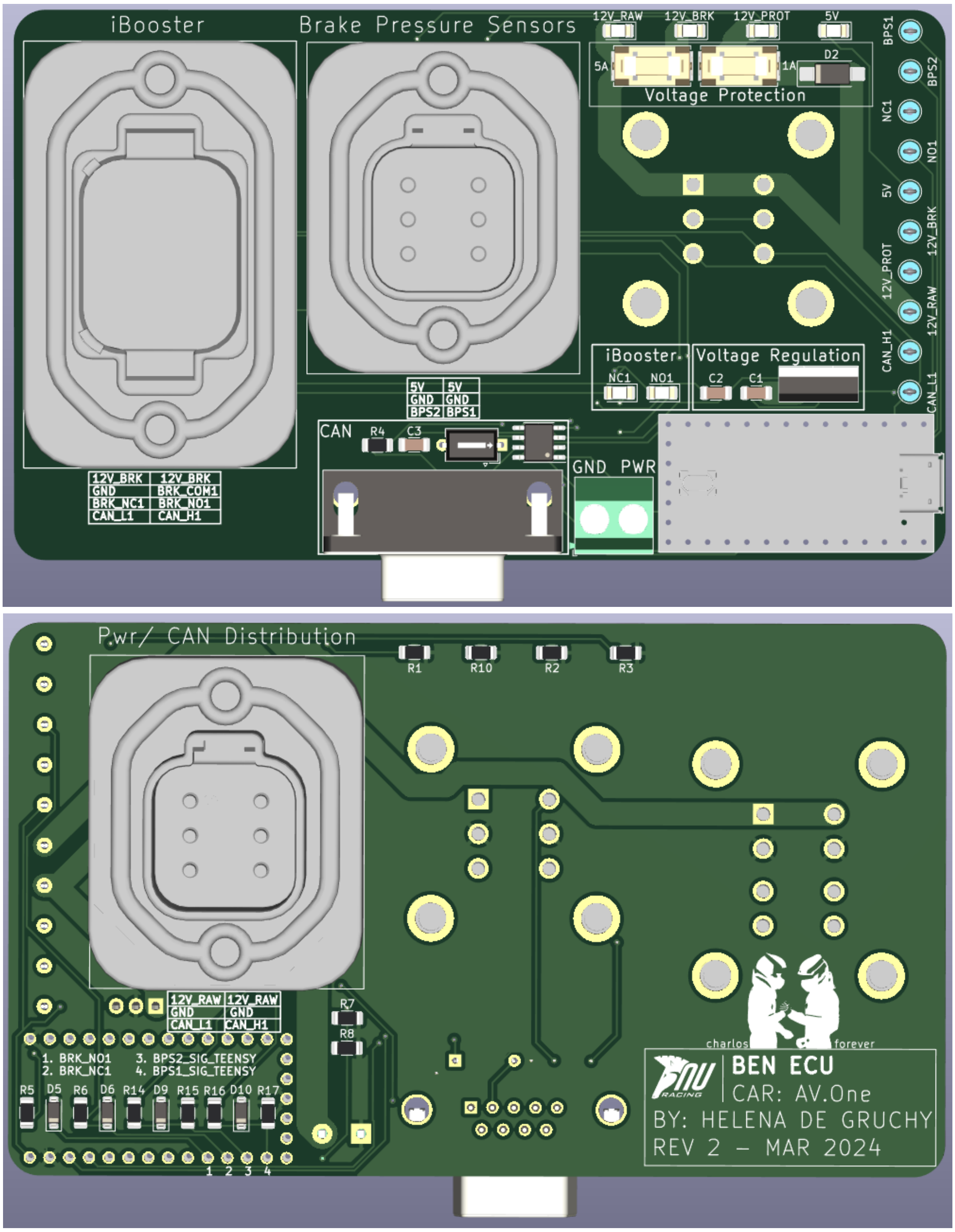


Figure 18
Current path through iBooster ECU relay according to the state of the iBooster.

Figure 19 shows KiCad software renders of the new PCB known as BEN V2.0. Sections are delineated according to their task (eg. 'Voltage Protection') using white boxes and strategic component placement, to improve readability and functional clarity.

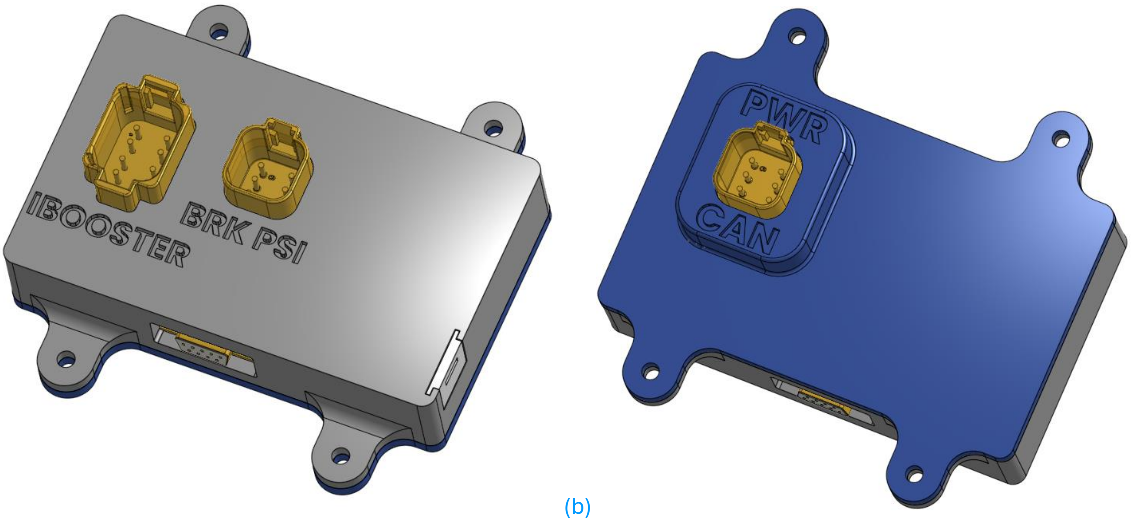
Refer to Appendix H for the new DT connector pinouts on BEN V2.0. These were incorrectly labelled on the PCB's silkscreen, so they have been covered with tape. The correct pinout is shown on Figure 19 and within BEN V2.0's folder in the 'Racing-AV1' GitHub. Since this error does not impact functionality, it was deemed unnecessary to remake the BEN V2.0 PCB.



(a)
(b)

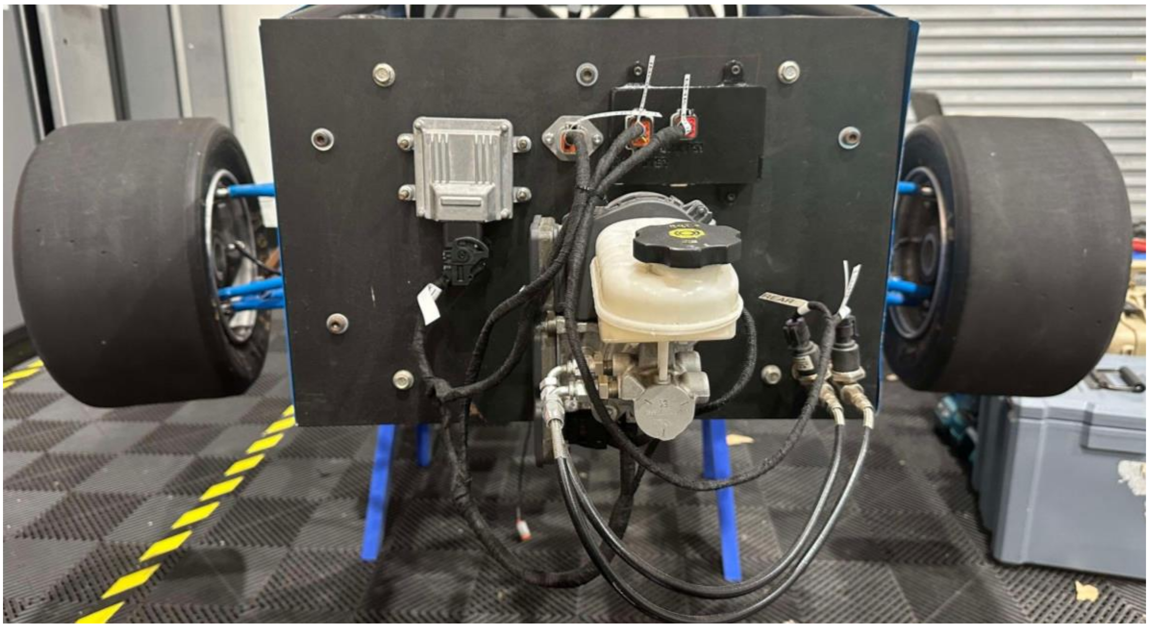
Figure 19
(a) BEN V2.0 PCB front view.
(b) BEN V2.0 PCB rear view.

Figure 20 depicts OnShape CAD software renders of the BEN enclosure. This 3D-printed structure protects and mounts the node to AV.One's anti-intrusion plate, shown in real life in Figure 21.



(a) (b)

Figure 20
(a) BEN enclosure front CAD view.
(b) BEN enclosure rear CAD view (side to face anti-intrusion plate).



(a)

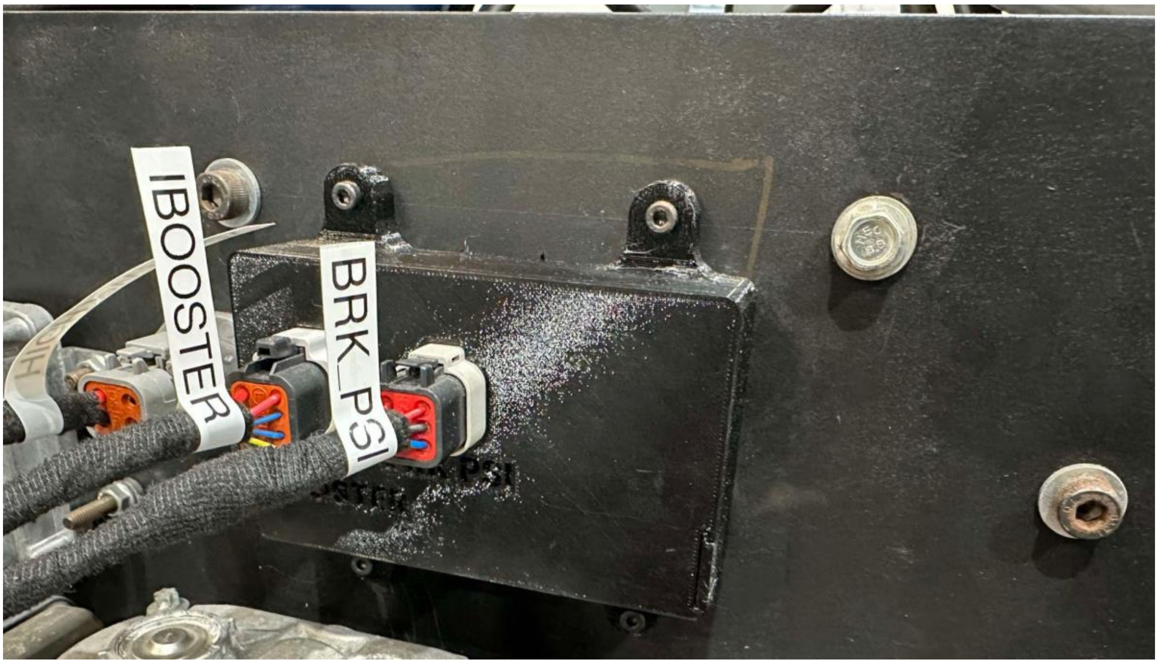
(b) 

Figure 21
(a) BEN V2.0 installed on AV.One with cleaner wiring harness connecting it to the iBooster and iBooster ECU.
(b) Closeup of BEN V2.0 mounted to anti-intrusion plate.

5.1.1.2. SEN

The Steering Electronic Node (SEN) initiates driverless steering once it receives a steering angle command. Based on actual angle data from the magnetic encoder, a PID controller is implemented on the teensy microcontroller that outputs a PWM command to the Cytron motor driver. The motor driver controls the motor, which adjusts the steering column angle by up to approximately 90° either side of vertical centre. If the motor turns the steering column in the incorrect direction, swap the position of the two motor connection cables into the motor driver (shown in blue circle in Figure 23). Never reverse the polarity of the power and GND input cables from the SLAB into the motor driver as this will cause damage; there is no inbuilt reverse polarity protection to protect it.

Attempting to operate the previous SEN, produced by Chris Neal in 2023, was tedious due to a faulty linear voltage regulator then a faulty CAN transceiver. Upgrades to SEN V1.1 include better positioning of the transceiver, so it is easier to replace should it fail again in the future. As with BEN V2.0, the swap was made from Molex to Deutsch DT connectors, and schematic sections are physically and visually delineated according to their task to improve functional clarity. The new design was not named SEN V2.0 because the functionality has not changed, so it was titled SEN V1.1 instead.

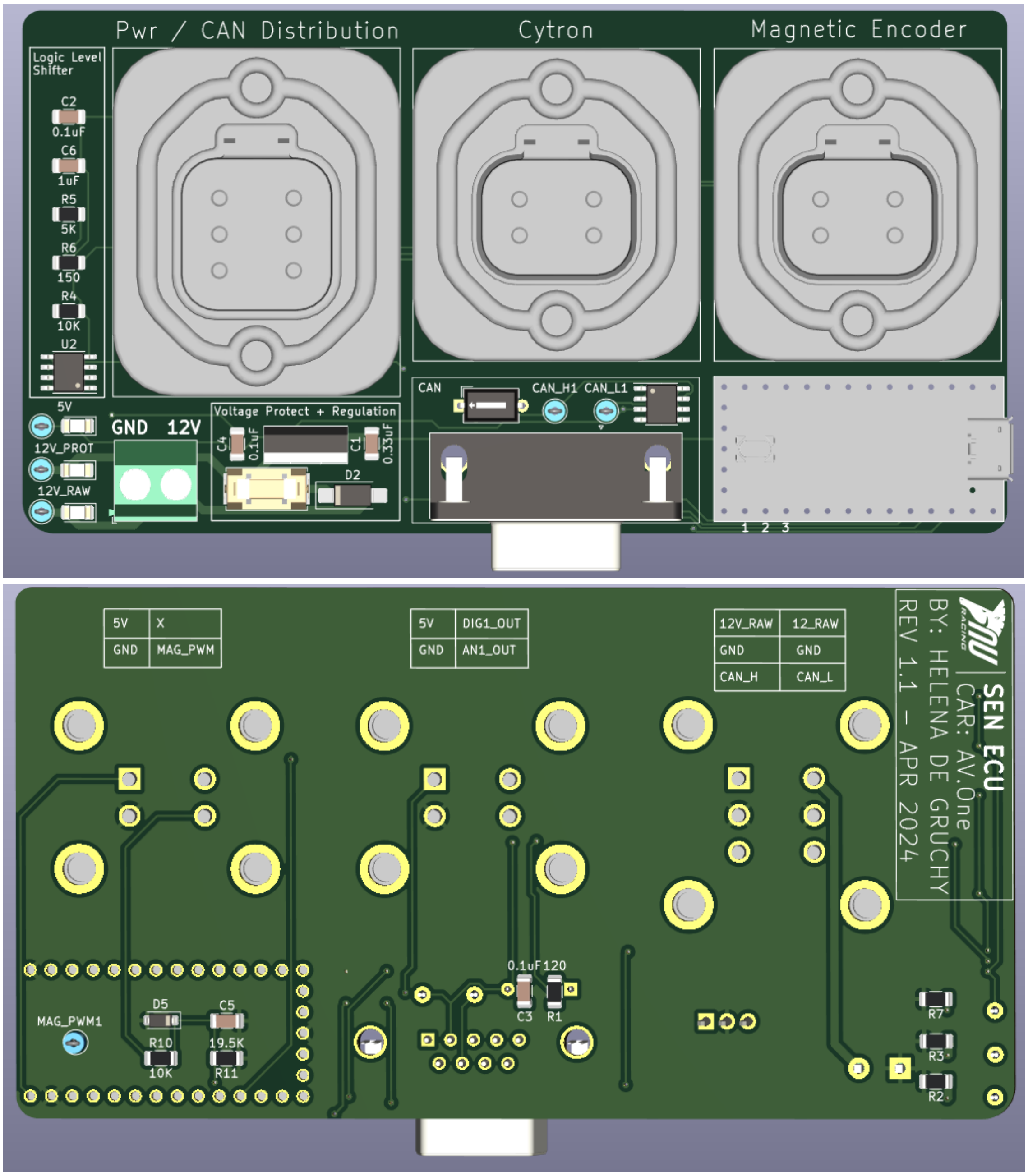
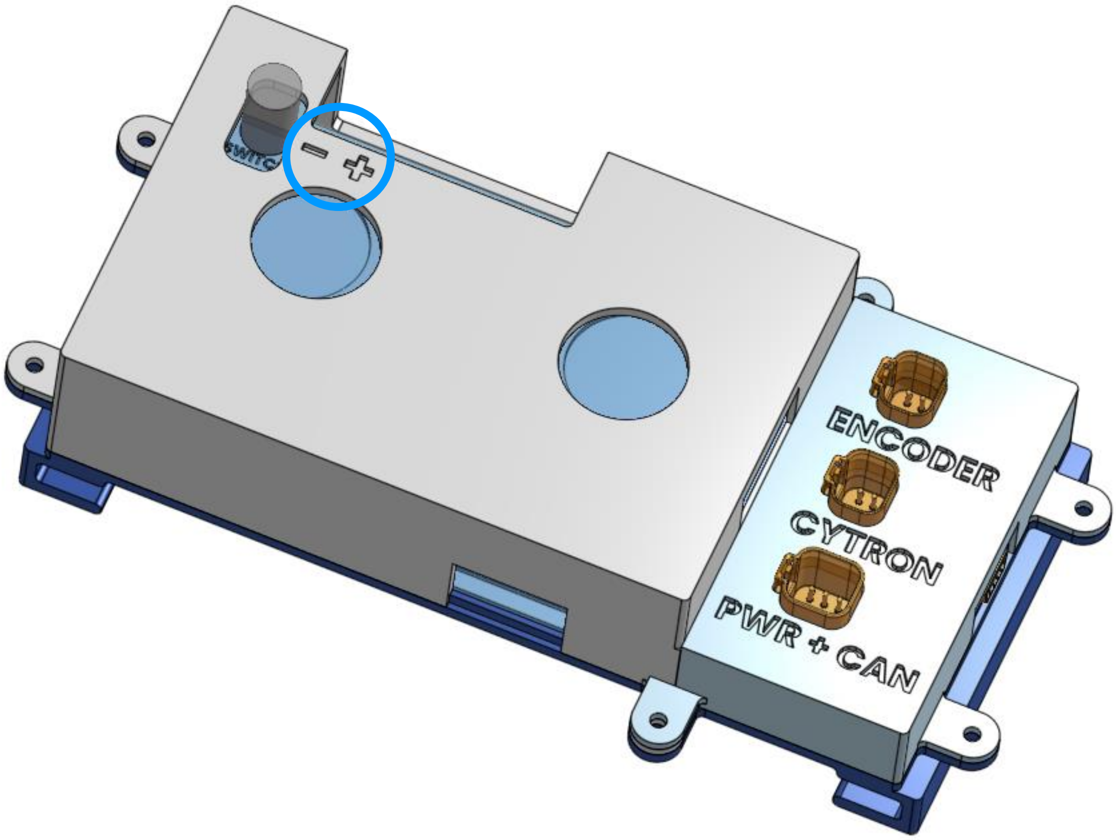
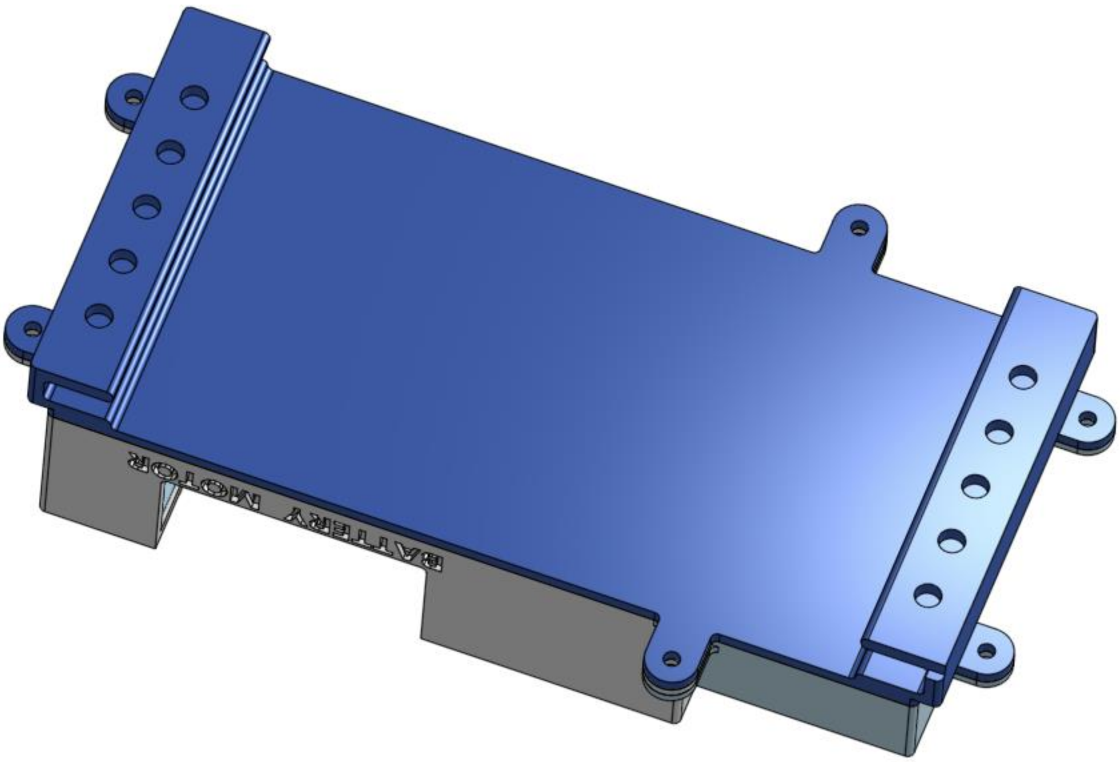
(a)
(b)


Figure 22
(a) SEN V1.1 PCB front view.
(b) SEN V1.1 PCB rear view.

The SEN and Cytron motor driver are now protected in the same enclosure, shown in Figure 23, where previously they were completely exposed and unmounted to the chassis. Figure 24 shows them mounted to the pedal box mounting bracket in AV.One.



(a)



(b)

Figure 23

(a) SEN enclosure top CAD view. Motor input cables can have their polarity reversed into the motor driver (circled).
(b) SEN enclosure bottom CAD view.

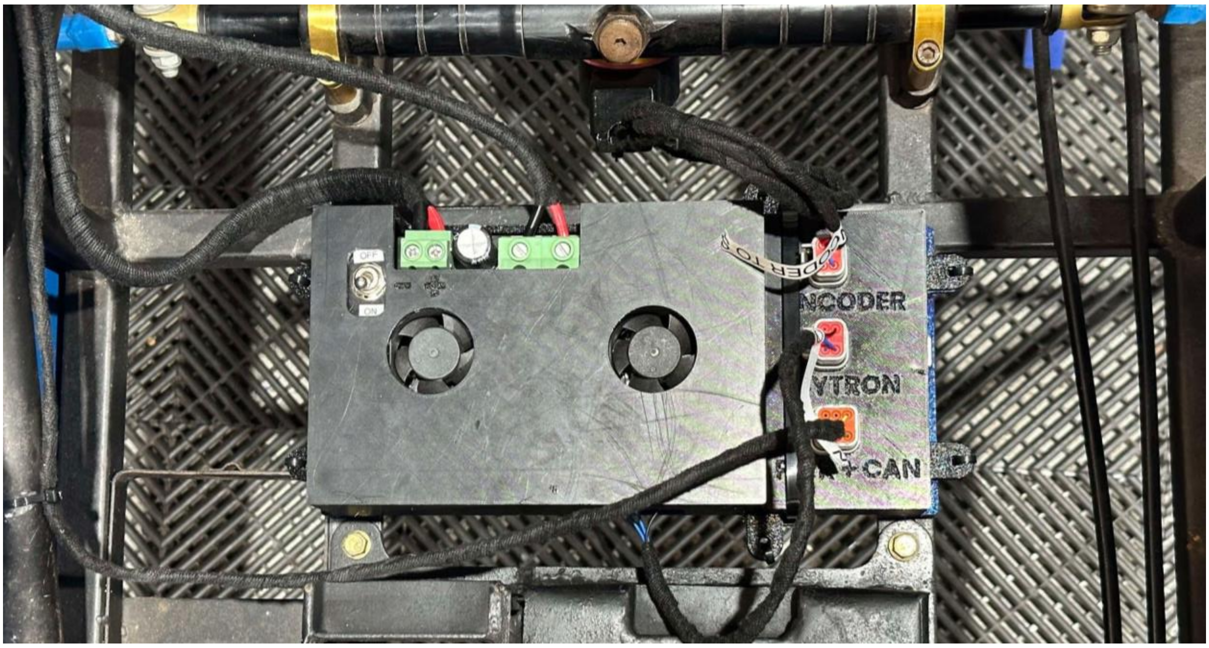


Figure 24
SEN fastened to pedal box mounting brackets.

The angle encoder mounted beneath the steering column was exposed to debris and there was significant risk of damage to the soldered wires (shown in Figure 26 a). An enclosure was designed around the angle encoder, which shields and diverts tension away from the wires (Figure 25).

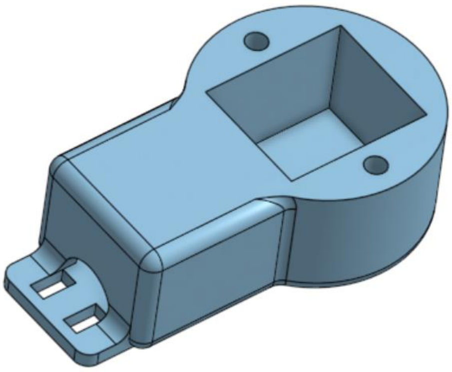


Figure 25
Steering angle encoder protective housing.

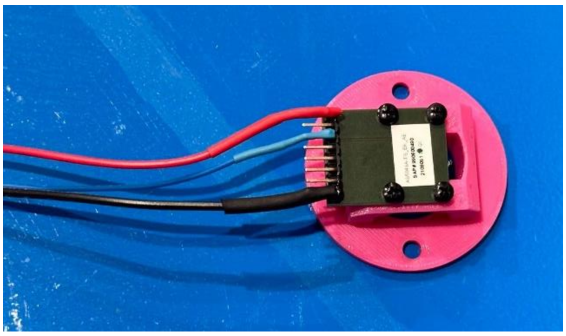
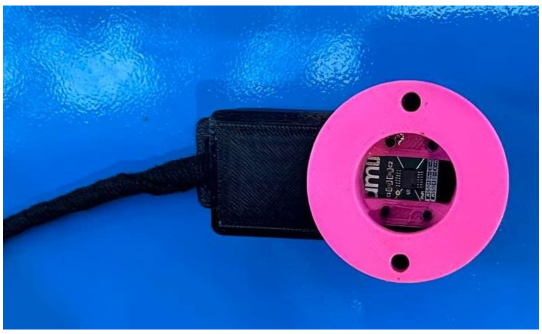
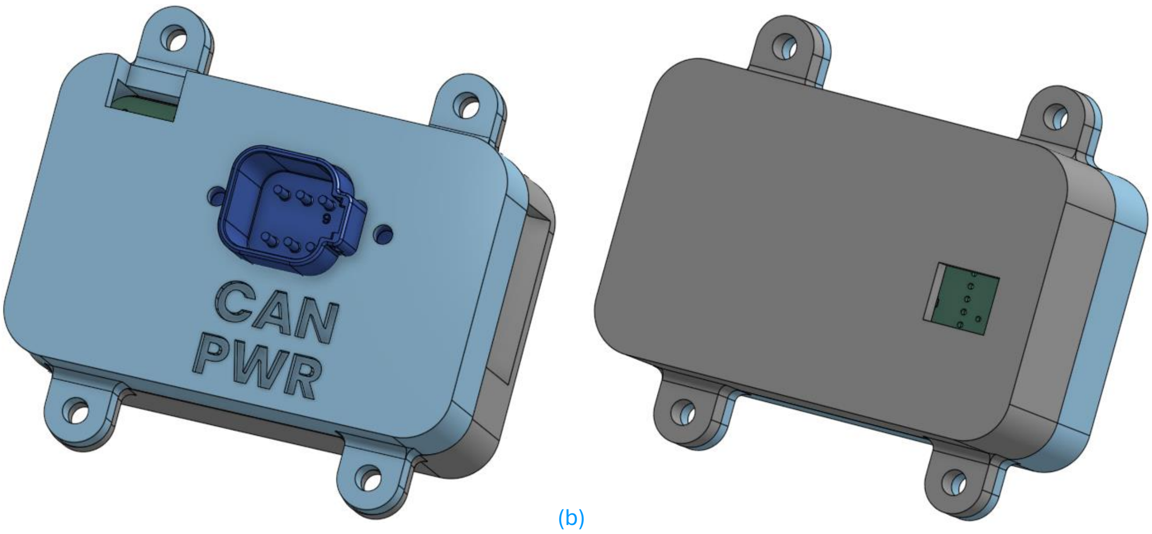
(a)  (b) 

Figure 26
Angle encoder without (a) and with (b) protective housing.

5.1.1.3. REN

The Remote-Control Electronic Node (REN) allows the remote controller's receiver to communicate via CAN protocol with the rest of AV.One's systems (see 'Data Bus Communication' for explanation of CAN). It delivers power to the receiver and translates its unique 'S-BUS' outputs into CAN messages regarding throttle, braking and steering requests. This node gives AV.One its driverless capability. The PCB was designed by NU Marine and did not require upgrades to functionality. A custom enclosure, shown in Figure 27 was created to mount the PCB to AV.One.



(a) (b)

Figure 27
(a) REN enclosure front CAD view.
(b) REN enclosure rear CAD view.

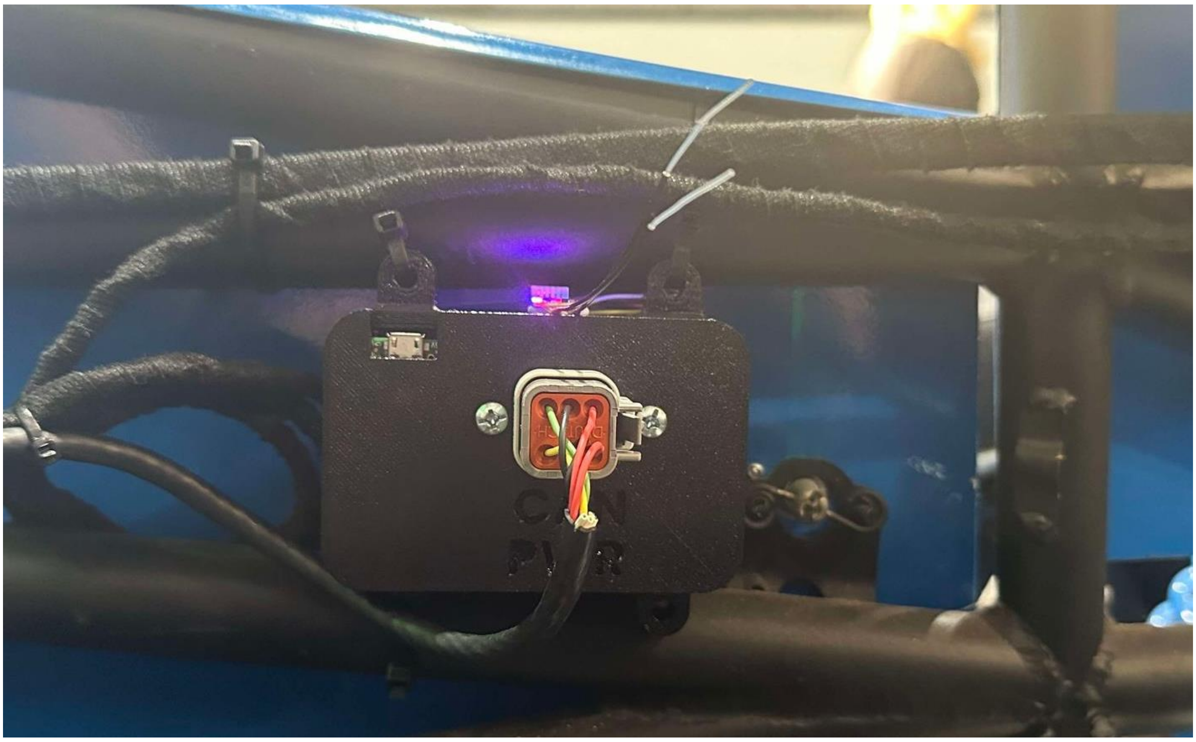
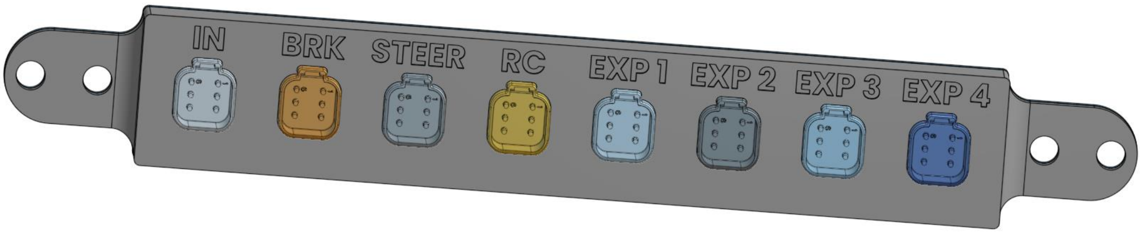


Figure 28
REN mounted to left inner panel of AV.One.

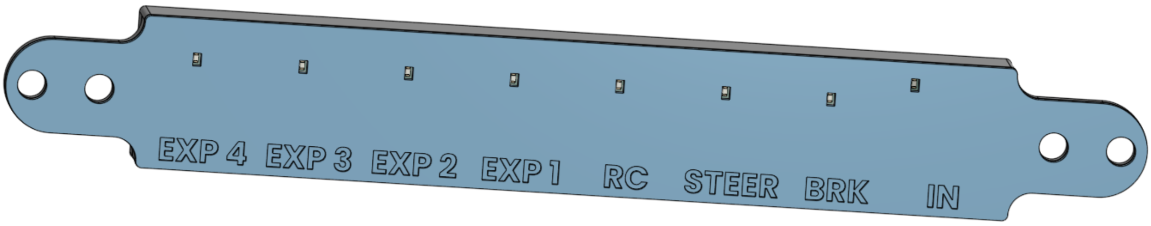
5.1.1.4. DEN

The Distribution Electronics Node (DEN) carries low-current 12V power, ground (GND), CAN High and Low (see 'Data Bus Communication' for explanation of these signals) from the SLAB to the other nodes. Previously, AV.One did not have any expansion board with similar function to the DEN, so it was impossible to connect all electronic nodes to the single power / CAN output from the SLAB (this output is labelled 'BREAK OUT' on the top panel of the SLAB).

The DEN PCB was designed by NU Marine and did not require upgrades to functionality. The enclosure in Figure 29 has been made for simple zip-tie attachment onto AV.One, with gaps to view LEDs on the rear of the PCB that indicate if power is reaching each expansion port. This assists with troubleshooting if one of the nodes were to stop functioning. The port labelled 'IN' delivers power, GND, CAN H and CAN L from the SLAB's 'BREAK OUT' output.



(a)



(b)

Figure 29
(a) DEN enclosure top CAD view.
(b) DEN enclosure bottom CAD view.

Figure 30
DEN mounted in AV.One in front of seat and beneath steering column.

5.1.1.5. Other Electronic Nodes

The remaining electronic nodes in AV.One's LV system are the Precharge, Discharge and Low-Voltage Distribution (LVD) boards. These are all housed in the accumulator (SLAB) and were commissioned last year to a functional state. For further information on them, refer to Sebastian Scott's FYP report, which can be found in the 'Past_Reports' folder within 'Racing-AV1' GitHub.

5.1.2. Software Improvements

To run all code on AV.One's electronic nodes, the following two Arduino libraries are required:

1. **Bolder Flight Systems SBUS** (Brian Taylor) – enables communication with RC receiver.
2. **PID** (Brett Beauregard) – PID controller implemented on the BEN and SEN.

Upgrades to the code was required in all electronic nodes, to enable remote controller functionality and improve performance of the systems.

5.1.2.1. Steering

Initial testing of the previous SEN revealed a lack of robustness in its code, whereby the Cytron motor driver immediately displayed 'Error 2' and would not spin the motor attached to the steering column. This was due to it receiving an immediate non-zero request (to spin the motor) from the Teensy microcontroller following power up. A conditional loop (Figure 31) was added in the script 'AV.One_SEN_V1.1' within the 'SEN' folder of the GitHub, so the PID controller does not commence for 3 seconds, or until the remote controller is armed. This allows the motor driver time to power up and clear all errors before receiving non-zero requests.

```
// only execute steering PID once 3s has elapsed since power on, or RC is ARMED
if (millis()<= 3000 || rc_armed == 0){
  out = 0;
}
else {
  // Compute PID
  myPID.Compute();
}
```

Figure 31
New conditional loop added to SEN code to prevent non-zero PID controller outputs at time of startup.

5.1.2.2. Throttle

The previous code implemented on the LVD performed a basic predetermined set of actions: motors speed up, brake light flashes three times, motors slow down back to stationary. The code has been evolved to its present state where it now converts remote-controller (RC) throttle requests into corresponding PWM signals that are sent to the motor controllers. Additionally, the brake light now illuminates when a brake command is requested by the RC. The new revision of code is in Appendix G and is largely different from initial versions.

5.1.2.3. Braking

When viewing CAN messages from the BEN, two message IDs appear that are not defined in AV.One's DBC file: ID 526 and ID 527. The first message is sent every 100 milliseconds as a custom brake command (built by Chris Neal) to the iBooster, and the system is healthy if this message is sending. The latter is an error message sent if the iBooster ECU returns a bad checksum, meaning the system is unhealthy. Refer to the iBooster User Guide in 'Datasheets_Manuals' on the 'Racing-AV1' GitHub for troubleshooting a bad checksum.

5.1.2.4. Data Bus Communication

The electronic nodes onboard AV.One communicate with one another via a Controller Area Network (CAN) data bus. Each node acts as an electronic control unit (ECU) that can receive and transmit messages. A major limitation of the separate AV.One systems prior to this project was the absence of a cohesive CAN bus communication protocol; systems were operating on both CAN Line 1 and Line 2, and at different baud rates so that none received the messages transmitted by others.

NUCAN is the NU Teams CAN library that allows for easy functionality on CAN Line 1, and all NU Racing CAN communication utilises the NUCAN library. Specifically on AV.One, CAN Line 1 operates at 500 kB/s to accommodate the iBooster ECU's specific speed requirement, set by the manufacturer. To consolidate messaging, all communications were transferred to CAN Line 1, except the Battery Monitoring System (BMS) and DCDC which run at 250 kB/s on CAN Line 2. This decision was made because the DCDC must run at 250 kB/s, and the BMS is configurable to run at different speeds so it can transmit on either CAN line. The BMS provides live cell data in the 'Orion 2' software, which can be viewed on a computer using the NU Racing CANdapter cable connected to the LVD 'BREAK OUT' port on the top panel of the accumulator. Other than the LVD board, no PCBs on AV.One are equipped with the necessary electronic components (CAN transceiver and termination resistors) to operate on CAN Line 2. It was assessed as unnecessary to utilise Line 2 anywhere except inside the accumulator (on the LVD, BMS and DCDC).

To view CAN messages being sent by a teensy, or to send messages to the teensy to test its response, the Kvaser software 'CANKing' is used in NU Teams. The troubleshooting poster 'CAN Communication' in Appendix E explains in depth how to utilise the software.

For further information on CAN Bus, refer to the NU Teams training module titled 'CAN Bus Zero-to-Hero' found here: https://training.nuteams.org/.

5.1.2.5. Serial

Earlier this year, NUCAN was updated across all NU Teams' GitHub repositories to have a condition that unexpectedly impacted AV.One's existing code. This change shuts down a Teensy microcontroller or prevents stable connection to a computer if it fails to detect the Teensy's heartbeat signal (a recurring on/off CAN message). This issue was resolved by adding a conditional loop (Figure 32) to initiate Serial only when the Teensy is connected to a computer, ensuring the code continually loops through quickly enough to maintain its NUCAN heartbeat when operating onboard AV.One.

```
if (Serial) {
  Serial.begin(9600);
  Serial.println("Serial...");
}
```

Figure 32
New conditional loop implemented in all nodes to prevent teensy shutdown and computer connection issues.

6. Driverless Implementation

To facilitate driverless capabilities in AV.One, two functionalities were developed: remote control and remote emergency stop. These implementations represent major milestones in the project, establishing foundational capabilities for a safe driverless vehicle.

6.1. Remote Emergency Stop

While AV.One was already equipped with chassis-mounted emergency stops and one e-stop on the SLAB rear panel, there was previously no ability to turn off the tractive system without touching the vehicle. The remote emergency stop system chosen is the same one deemed mandatory by Formula SAE for all vehicles competing in the autonomous division. These products were selected for AV.One as they are robust and modular, so they can be easily swapped from this prototype vehicle to NU Racing's future competition AV.

The remote e-stop transmitter is a GrossFunk T53 device that comes with two rechargeable 12V batteries and an antenna, which must be attached before battery is inserted into device to avoid damage. When disengaged, the e-stop button on the transmitter has a red light in its centre. If this light is flashing quickly, it indicates low battery, and the onboard shutdown circuit will not close.

The GrossFunk 2000i R98 Codec device is used as the onboard receiver and must also be fitted with its antenna prior to use. The receiver was installed in the SLAB on a mounting bracket that is secured using Glenloch locking nuts (Figure 34). The receiver is powered by 12V sourced from the SLAB battery, while a separate circuit has been integrated into the vehicle's SD sequence and is opened when the remote e-stop is pressed.

Figure 33
GrossFunk remote e-stop transmitter (orange), receiver (green) and associated components (excluding antennas).

Figure 34

Mounting bracket (blue box) for remote emergency stop receiver, secured inside SLAB using Glenloch locking nuts.

6.2. Remote Controller

6.2.1. Transmitter

The FrSky Taranis X-Lite Pro remote controller (RC) is AV.One's point of control. It requires multi-switch engagement to operate, so there is reduced risk of accidental throttle input from bumping the RC joystick. The procedure to operate the RC transmitter to drive AV.One is outlined in the troubleshoot poster 'Startup Sequence' in Appendix B. Below are the important controls with an explanation of their purpose:

1. **SC**: arms RC if switched up (towards display-screen side of RC). Braking and steering will not be initiated until the RC is armed.
2. **SB**: switches between autonomous (up) and RC (down) mode. Neutral position prevents any command of AV.One. RC mode is the only one currently functional.
3. **Multi-function joystick**: navigates menu, not required to control AV.One.
4. **Exit button**: if stuck somewhere within menu, easy to get out by repeatedly pressing Exit button until home screen reached.
5. **Left joystick**: controls throttle (up) and braking (down).
6. **Right joystick**: controls steering (left and right).

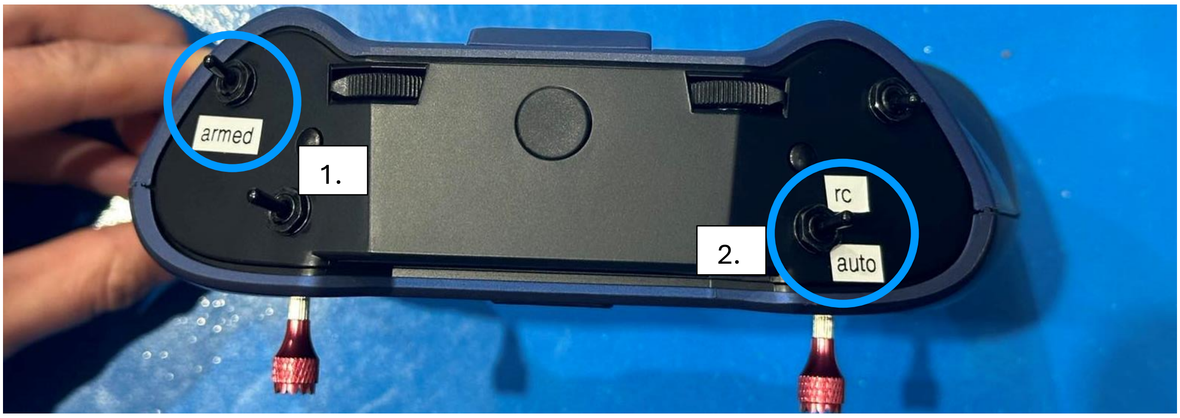


Figure 35

SC (1) and SB (2) switches shown in their unarmed and neutral position respectively.

Figure 36
Joysticks and navigation controls on the FrSky RC.

6.2.2. Receiver

The FrSky R-XSR receiver is compatible with all FrSky transmitters, so it was the ideal choice for onboard communication between the RC and AV.One's nodes. The product operates using SBUS communication, and the REN's software converts this to CAN messages readable by other nodes. For instructions on pairing a FrSky receiver to its transmitter, refer to the troubleshoot poster 'RC Binding Process' in Appendix F.

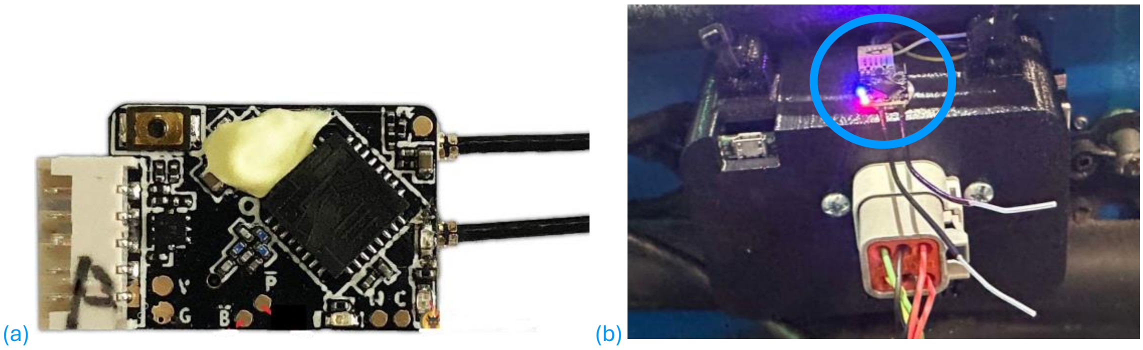


Figure 37
(a) Close-up of the R-XSR receiver. The left outport is connected to AV.One's REN.
(b) RC receiver (circled) mounted to the REN in AV.One.

7. Documentation

Each system belonging to AV.One had its own documentation structure prior to this project which made information retrieval for troubleshooting tedious, and resource management difficult. To improve this, all nodes and associated software, datasheets, manuals and past student reports have been consolidated in the GitHub repository. All CAD projects relevant to AV.One have been consolidated in OnShape.

7.1. GitHub

AV.One's GitHub repository, named 'Racing-AV1', follows a similar structure to all repositories managed by NU Racing. All folders pertaining to an electrical node (eg. BEN) are structured in the following way:

Standard Format:

- *nodeName*
  - Code
    - Archive
    - *AV.One_nodeName*
  - PCB
    - Archive
      - *archivedNodeName*
    - *nodeName*

Example:

- BEN
  - Code
    - Archive
    - *AV.One_BEN_V1.1*
  - PCB
    - Archive
      - *BEN V1.0*
    - *BEN V2.0*

When labelling code or PCB files, the versioning can be updated in two ways:

1. If **formatting improvements** were made, such as commenting code or changing layout on PCB, add .1 on the end of the version: eg. BEN V1.0 → BEN V1.1
2. If there is **upgraded** functionality or **new** components, change to next numeral: eg. BEN V1.0 → BEN V2.0

Additional folders contained in the 'Racing-AV1' repository are as follows:

1. Datasheets_Manuals: contains datasheets and manuals for key components, including:
   a. BMS
   b. DCDC
   c. Kelly MCs
   d. RC transmitter and receiver
   e. iBooster ECU
   f. Cytron motor driver
2. Past_Reports: contains all FYP and directed reading student reports related to AV.One.
3. Troubleshoot_Posters: contains troubleshoot posters found in the Appendix of this report.

7.2. OnShape

Within the University of Newcastle NU Teams' OnShape is a folder for AV.One. It has the following structure:

- AV.One
    - Mechanical
        - Chassis
    - LV Electrical
        - Distribution System
        - Brake System
        - Remote Control System
        - Steering System
    - Accumulator (SLAB)
    - Main Assembly

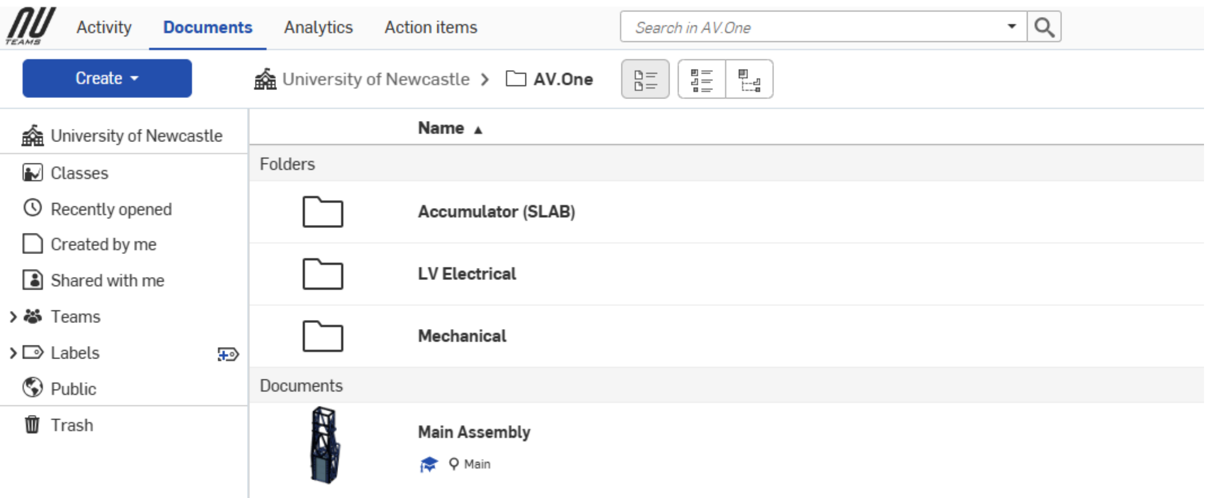


Figure 38
OnShape folder for AV.One.

8. Future Work

Prior to advancing AV.One's autonomous capabilities, a recommendation is made to improve the existing onboard systems: enable efficient charging capabilities for both the LV and HV batteries.

8.1. Battery Charging

Both the LV (12V) and HV batteries lack simplified charging methods because the current LVD version fails to send 'enable' signals to either the DCDC or BMS due to unsuitable components.

1. Once the DCDC is commissioned correctly, the 12V battery can be charged via the HV batteries (when TS is on) without connecting to an alternate power supply.
   a. Refer to Sebastian Scott's report for detail on the initial plan to enable the DCDC and how that is currently unavailable until the LVD PCB is reworked.
   b. Test Sebastian's commented code for DCDC operation on CAN Line 2 on the LVD. This code is in 'AV.One_LVD' in the 'Archive' folder of 'LVD' on AV.One's GitHub.
   c. Reconfigure BMS to operate at 250kB/s. It currently runs at 500kB/s on LVD CAN Line 2, which will interfere with DCDC CAN messages that must run at 250kB/s.
2. NU Racing's competition car has a safe and robust charger that can be used to charge AV.One's batteries. There is an existing cable that can be reworked to connect to the NU Racing charger (Figure 39).
   a. Refer to NU Racing mechatronic engineers for advice on charger setup.
   b. Troubleshoot the 'CHARGE' button on rear panel of the SLAB: when pushed in, it tells BMS to enter charge mode. However, testing this year could not achieve this.

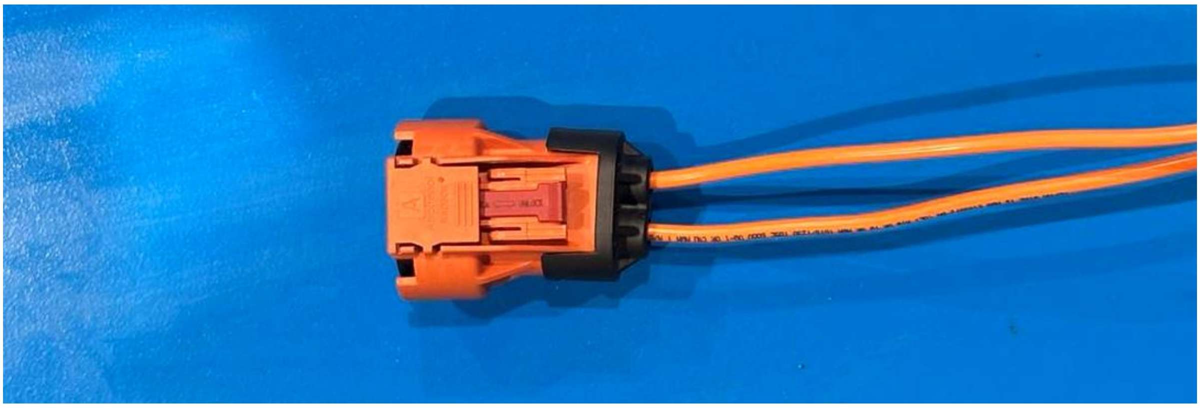


Figure 39
Existing Amphenol connector and HV-rated cable, to be repurposed for HV battery charging.

8.2. Autonomous Advancement

Now that AV.One is a functioning driverless car, with full and safe control via RC and remote emergency-stop capability, it can be equipped with autonomous technology for competition testing purposes. Important research avenues are suggested based on technology that features on most, if not all, vehicles that are currently competing in the Formula SAE Autonomous division:

1. **Perception Systems**: Implementing LiDAR, cameras, and radar assists with obstacle detection, track recognition, and localisation.
2. **Sensor Fusion**: Integrating data from multiple sensors will give accurate environment mapping and vehicle positioning.
3. **Path Planning Algorithms**: Developing algorithms to create an optimal path based on track layout, obstacles, and driving conditions will create a more robust vehicle.
4. **Vehicle Control Systems**: Implementing robust control algorithms studied in the Mechatronics Engineering program (eg. PID or MPC) will aid in managing throttle, braking, and steering. PID controllers are already implemented in the steering and braking code.
5. **Safety Protocols and Redundancies**: continue to upgrade the safe operation of AV.One through fail-safe mechanisms and real-time error handling.

For assistance with Formula SAE AV competition related topics, the University of Queensland's UQ Racing team have offered their ongoing support via email:

Madeleine Warner (madeleine.warner@uqracing.com)

James Talkington (james.talkington@uqracing.com)

9. Conclusion

This project marks a step forward in NU Racing's journey to creating a fully autonomous Formula-style electric vehicle.

Through the successful integration of electrical, mechanical, and software systems, AV.One transitioned from a set of standalone components into a cohesive, remotely controlled vehicle. Critical upgrades to the LV and HV systems, as well as improvements to safety mechanisms, component accessibility, and reliability, were achieved to fulfill scope requirements and support driverless operations.

The LV system underwent restructuring to power all onboard logic and enable seamless communication across nodes, establishing a robust platform for driverless functionality. Likewise, additions to HV safety, such as thermal insulation and multiple emergency-stop buttons, have contributed to a safer test environment.

The vehicle achieved a successful track testing day at the end of the project where it navigated an entire competition-style track circuit without errors. Following this, AV.One has fully achieved all scope objectives, and additionally operates through a tight competition layout.

With AV.One as a test bed, the team is better positioned to develop live onboard inference capabilities, aligning with the strategic goal of competing in the Autonomous division of the Formula SAE-Australasia competition. Building on NU Racing's track record in the EV category, this project represents a critical milestone in the team's transition toward autonomous racing.

Figure 40
AV.One at its track testing day following successful integration of all systems.

10. References

[1] Society of Automotive Engineers Australasia, “About Us,” SAE-A, 2024. [Online]. Available: https://www.saea.com.au/formula-sae-a.

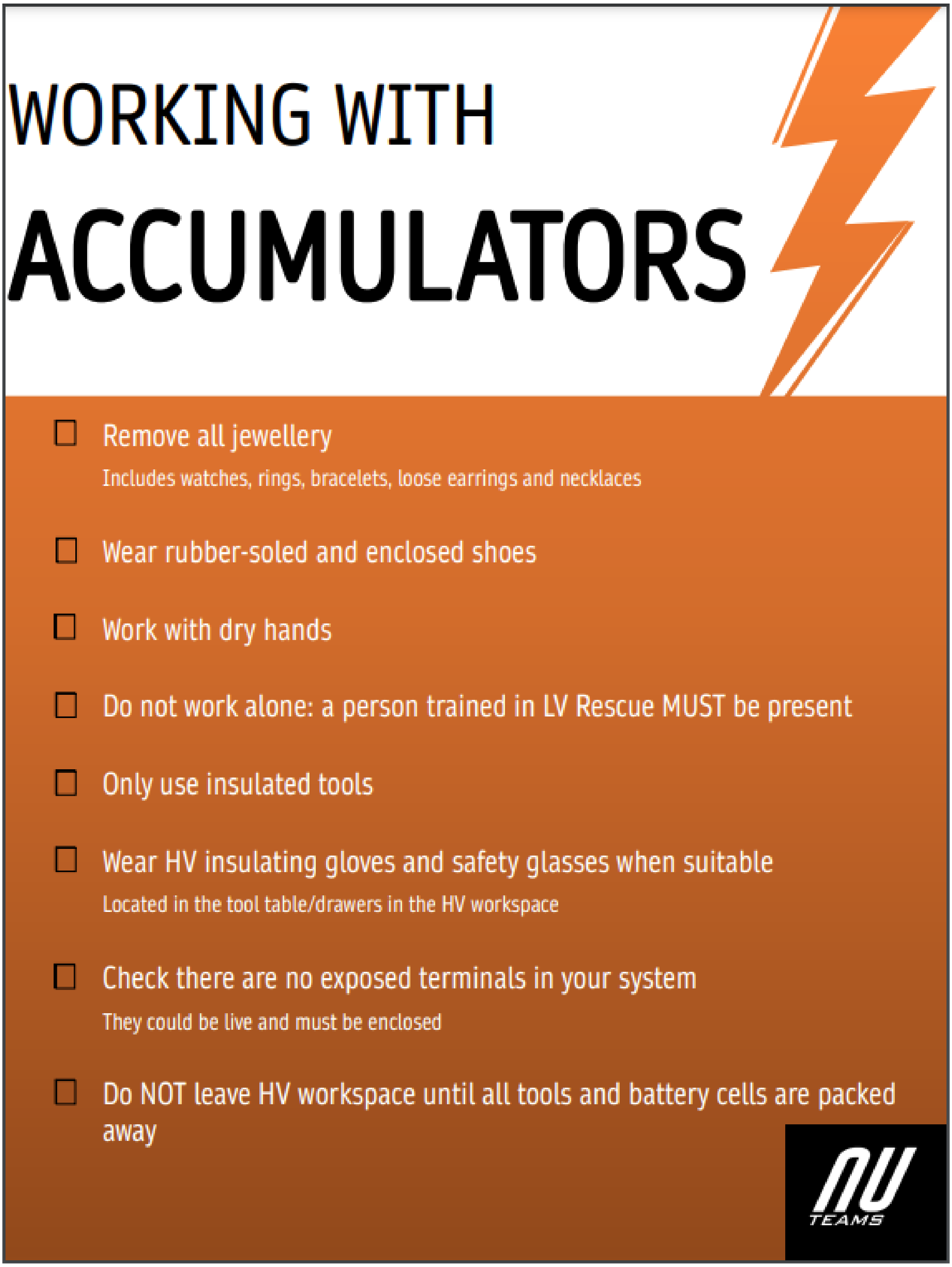
[2] Formula Student Germany, “Team Details,” FSG International Design Competition, 2023. [Online]. Available: https://www.formulastudent.de/teams/fse/details/tid/339/.

[3] European Formula Student, “Formua Student Rules 2024,” 20 01 2024. [Online]. Available: https://www.saea.com.au/content.cfm?page_id=2329080&current_category_code=24448. [Accessed 05 11 2024].

[4] jCalc Pty Ltd, “Cable Size Calculator AS/NZS 3008,” jCalc, 2024. [Online]. Available: https://www.jcalc.net/cable-sizing-calculator-as3008.

11. Appendix

A. HV Workspace Safety Posters



WORKING WITH

BATTERY CELLS

- ☐ Ensure there is a powder fire extinguisher within the HV workspace

- ☐ Report any cell drops, damage or heat exposure to your team leader and isolate the cell

- ☐ Signs of cell damage include:
  - Swelling
  - Excessive self-heating
  - Acrid or chemical smell
  - Hissing or venting sound
  - Discolouration
  - Abrasions
  - Punctures
  - Cell outputs lower or higher than its rated voltage

- ☐ If cell appears damaged, report immediately.

  If it is safe to do so:
  - Use sand buckets in HV workspace to help contain a venting cell
  - Isolate cell outside the building

NU TEAMS

B. Troubleshoot Poster – Startup Sequence

Startup Sequence

This troubleshooting poster is designed to guide the correct startup procedure for AV.One whenever it is scheduled to be operated.

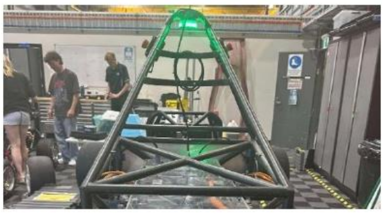
Checklist

1. Connect all cables between systems according to their labels.
2. Attach red master switches to the rear of the SLAB, in OFF (vertical) position.

3. Plug at least one motor controller (MC) orange cable into 'TS' connector on SLAB.
    a. The HV circuit will precharge too quickly if no MCs are plugged in.
    b. The 'GLV' MC cables do not need to be plugged into the SLAB for startup, however they do if the motors are going to be spun.

4. Antennas must be connected to the remote emergency-stop transmitter and receiver. Disengage / twist out e-stop button on transmitter (circled).

5. Turn GLVMS to ON position (horizontal). Check Tractive System Active Light (TSAL) turns on as solid green.



a. If no light, check 12V battery is connected in SLAB and fully charged.

b. Check LVD lights. If no lights, check 12V input is received from battery (above).

c. If TSAL is flashing red, measure for HV at measuring points (TS+ and TS-). If HV present (> 60V), immediately consult Malcolm and do not touch vehicle. If no HV present, turn off GLVMS and retry in 10 minutes.

6. Wait 20 seconds for Precharge board startup. Relay click may be heard when ready.
7. Turn TSMS to the ON position. **
8. Push Hard Fault Reset (HFR) button on SLAB. Check TSAL turns to flashing red.

a. If TSAL remains green, check lights on Precharge board then turn off TSMS.
    i. If red flashing error light on Precharge board: turn off GLVMS, restart entire sequence, wait longer at step 5.

        a. If red error light appears again, plug into Precharge teensy and read serial monitor. It will state whether precharge was too quick or slow.
    ii. If no error light: read troubleshoot poster 'Shutdown Circuit'.
  b. If TSAL turns flashing red then back to green, check LV battery is charged: low charge causes shutdown circuit to briefly cut out and precharge fails.
9. HV circuit now active and motors are ready to spin.
10. Ensure remote controller (RC) is not armed and in neutral.

11. Hold power button down on RC until dots load and RC starts up.
    a. Follow onscreen prompts to clear faults if any.

12. Switch from neutral to RC mode: RC can now steer vehicle so it can be moved.

13. Arm device: RC can now brake and accelerate vehicle using left joystick.

14. Turn off RC: switch to neutral and unarmed. Hold power button until screen blanks.
    a. If warning message appears that system is still powered, click ok.
15. To turn off AV.One, turn TSMS then GLVMS to OFF position. Check TSAL turns off.

** If startup sequence is reinitiated but GLVMS was not turned off, there is no requirement for step 7. TSAL will flash red as soon as step 6 is conducted.

C. Troubleshoot Poster – Shutdown Circuit

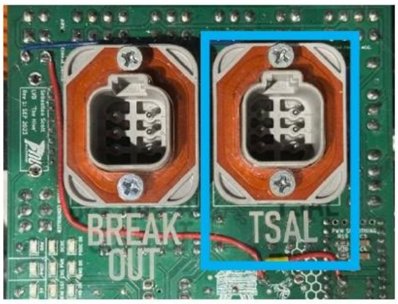
Shutdown Circuit

This poster is designed to assist in troubleshooting when the Shutdown (SD) circuit fails to close.

Symptoms include the Tractive System Active Light (TSAL) remaining green when the Tractive System Master Switch (TSMS), located on SLAB rear panel, is switched to ON position (horizontal). If the SD circuit remains open, the rest of the Tractive System cannot close and supply HV to the motors.

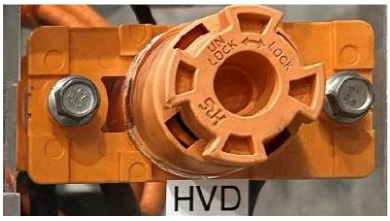
Checklist

1. Connect TSAL to the SLAB via its DT connector on the top panel (shown in blue box).



2. Twist out / disengage local emergency stop buttons (located on SLAB and chassis).

3. High Voltage Disconnect (HVD) device is firmly twisted / locked onto SLAB.



4. Untwist remote e-stop, and check its receiver is displaying correct lights in SLAB.

   a. If receiver lights are not on, check the e-stop device has orange battery inserted and red light on top of e-stop button is lit up (charge battery if red light flashing).

5. Remove SLAB lid and connect laptop to teensy microcontroller on Precharge board and watch serial monitor in Arduino during startup sequence.
   a. If unsure of the startup sequence, read its troubleshoot poster.

D. Troubleshoot Poster – HV Bench Test

HV Bench Test

This troubleshooting poster is designed to support safe bench testing of the accumulator (SLAB) high-voltage circuit after a rebuild or performance issue.

Checklist

1. Disconnect and remove HV batteries from SLAB if they are not already.
2. Disconnect BMS from within SLAB to prevent SD circuit fault.
3. Attach TSAL connector to SLAB top panel.
4. Turn on remote emergency stop transmitter, check its receiver's lights are on inside the SLAB.
5. Turn on Grounded LV Master Switch (GLVMS) and wait 20 seconds to allow Precharge startup.
6. Verify the Precharge teensy is connected to the computer's Arduino serial monitor.
7. Turn on TS master switch (TSMS). Verify an error appears on the serial monitor due to the precharge process taking too long and consequently failed: this is due to no HV present in the system.
   a. If this error is not displayed, press the Hard Fault Reset (HFR) button on SLAB.
   b. If this error is still not displayed, read the troubleshoot poster 'Shutdown Circuit' to ensure the SD circuit has been fully connected.
8. Turn off TSMS then GLVMS.
9. Turn on GLVMS and wait 20 seconds or until the precharge relay clicks audibly. Attach 60V from power supply to the correct ends of the positive and negative AIRs.
10. Turn on TSMS. Verify an error appears on the serial monitor due to the precharge occurring too quickly and consequently failed. This is due to no MCs connected.
    a. If this error is not displayed, press the HFR button on the SLAB.
11. Turn off TSMS then GLVMS.
12. Attach one or both orange HV cables from the MCs to the SLAB (no HV batteries).
13. Turn on GLVMS and wait 20 seconds or until the precharge relay clicks audibly.
14. Turn on TSMS. Verify TSAL is flashing red (representing HV present in vehicle) and >60V is measured at SLAB measuring points (between TS+ and TS-).
15. Reconnect BMS inside SLAB.
16. Motor spin or other testing may now be safely conducted.

** Ensure a person trained in LV Rescue is present during all rebuilds and testing.

*** If unsure about any components stated in this poster, refer to 'Startup Sequence' and 'Shutdown Circuit' posters for images and a more comprehensive guide.

E. Troubleshoot Poster – CAN Communication

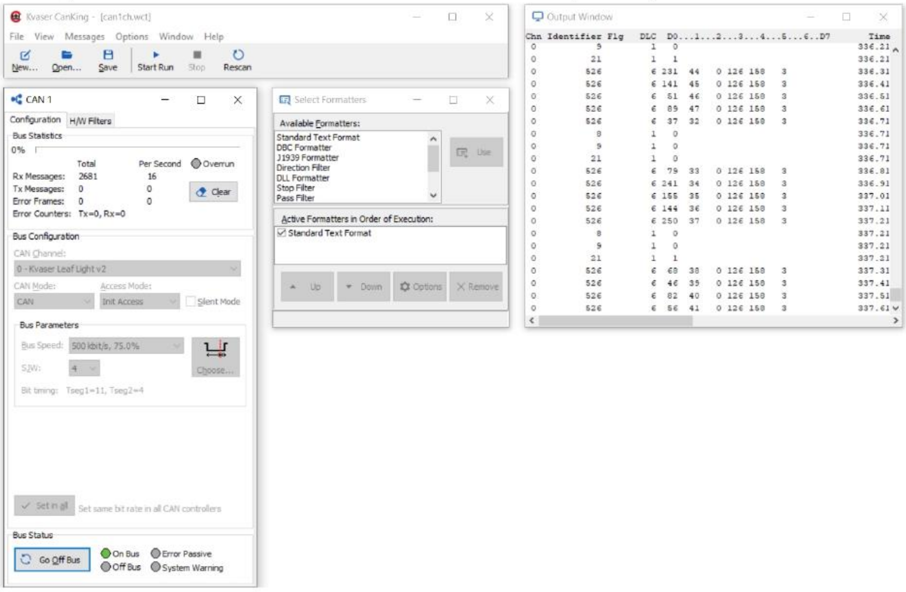
AV.One Troubleshooting

CAN Communication

This troubleshooting poster is intended to guide the setup and troubleshooting of CAN communication using Kvaser's CANKing software. After connecting a Teensy microcontroller to a PCB configured with appropriate CAN transceiver components, use CANKing to detect and send messages on different CAN lines and at varying baud rates.

Checklist

1. Connect PCB’s CAN ethernet port to computer using Kvaser Leaf Light cable.
2. In Kvaser’s CANKing software (note that for new versions of the software it will look different), open new project using template.
3. Select ‘1 CAN Channel’
4. Select ‘Kvaser Leaf Light v2’ for CAN Channel
5. Select ‘500 kbit/s’ for Bus Speed. This is correct for AV.One’s CAN Line 1.
6. Select ‘Go On Bus’ and messages should appear in ‘Output Window’. To simplify inputs, right click on the Output Window and select ‘Fixed Positions’.
7. The heartbeat message is always present when a teensy is powered and functioning correctly, and appears as changing on / off (1 then 0). The identifier can be matched to the message in AV.One’s DBC file, located in the NUCAN Github repository.
    a. The heartbeats in the image below have IDs 8 and 9.
8. To read CAN messages in ‘Output Window’ clearer, import AV.One’s DBC file: double click on ‘DBC Formatter’ in ‘Select Formatters’ window. Double click when it appears in ‘Active Formatters in Order of Execution’ window. Select folder icon to import AV.One’s DBC file from the NUCAN Github repository.



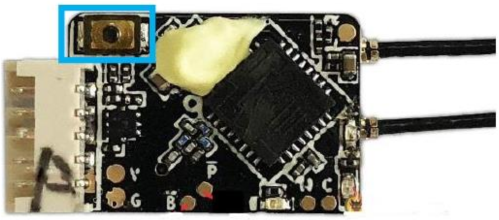
F. Troubleshoot Poster – RC Binding Process

RC Binding Process

This troubleshooting poster is intended to guide the binding process of the FrSky Taranis X-Lite Pro remote control transmitter to the FrSky R-XSR receiver.

Checklist

1. Hold down pair button (in blue box) on R-XSR receiver whilst powered off.



2. Power receiver on (<5V is adequate) whilst still holding pair button. Observe solid orange light turn on.
3. On the RC transmitter, hold multi-function joystick (in blue circle) to the right until the MODELSEL menu appears.

4. Swipe right once to SETUP menu
5. Swipe down to INTERNAL RF MODE
6. Set to ACCST D16
7. Swipe down to RECEIVER
8. Swipe right to [BND] and select it
9. Select CH 1-8 Telem ON
10. Orange light on receiver should start blinking.
11. Press Exit button continually on transmitter until back at main screen.
12. Power off receiver, wait 2 seconds, then power back on.
13. Observe constant green light now illuminated on receiver instead of orange, and signal lines shown on transmitter next to battery voltage.

G. Current Code Compiled on LVD teensy – 'AV.One_LVD_V2'

```
// AUTHOR: Helena De Gruchy 2024
// FUNCTION: Spins motors based on RC throttle request and flashes brake light when braking request is made by RC.

#include <AV1_CAN.h>  // Include the AV1_CAN library

#define BRAKE_LIGHT 2
#define THROTTLE_RIGHT 18
#define THROTTLE_LEFT 19

int pwm_value = 50;            // starting PWM value
int peak_PWM = 150;            // peak PWM value
int deadzone = 5;              // brake light does not turn on when braking below this PSI reading
float brkprs_target = 0;       // [0 - 2000 psi]
float throttle_request = 0;    // [0 - 100 %]

// CAN INITIALISATION
// Initialise NUCAN. We are sending _ messages (_), and receiving 2 (RC_BRK_REQUEST, RC_THROTTLE_REQUEST).
int numreceive = 2;
int numsend = 0;

// Tell NUCAN where to save the outputs
float *outputVar[] = { &brkprs_target, &throttle_request };
// Tell NUCAN which messages to look for on the bus
canmsg *inputmsgs[] = { &RC_BRK_REQUEST, &RC_THROTTLE_REQUEST };

void setup() {
  NUCAN_init(numsend, numreceive); // Initialize CAN 1
  pinMode(BRAKE_LIGHT, OUTPUT);
  pinMode(THROTTLE_RIGHT, OUTPUT);
  pinMode(THROTTLE_LEFT, OUTPUT);

  if (Serial) {
    Serial.begin(9600);
    Serial.println("Serial...");
  }
}

void loop() {

  // Read from the bus. Filter for messages in inputmsgs and store them in the variables in outputVar respectively.
  NUCAN_read(outputVar, inputmsgs, numreceive);

  EVERY_N_MILLISECONDS(100) {

    Serial.print("Brake PSI request from RC: ");
    Serial.println(brkprs_target);
    Serial.print("Throttle % request from RC: ");
    Serial.println(throttle_request);
    Serial.print("Throttle pwm request to motors: ");
    Serial.println(pwm_value);

    if (brkprs_target > deadzone) {
      digitalWrite(BRAKE_LIGHT, HIGH);
    } else {
      digitalWrite(BRAKE_LIGHT, LOW);
    }

    pwm_value = throttle_request + 50;       // % request scaled to between 50 - 150 PWM
    analogWrite(THROTTLE_RIGHT, pwm_value);  // send pwm command to R MC (spins backwards)
    analogWrite(THROTTLE_LEFT, pwm_value);   // send pwm command to L MC

  }

  NUCAN_heartbeat(&HB_LVD);

}
```

H. Connector Pinout – BEN V2.0

Pin number	Brake Pressure Sensors DT 6 Pin	PWR / CAN Distribution DT 6 Pin	iBooster DT 8 Pin
1	5V (BPS1)	12V_RAW	12V_BRK
2	GND (BPS1)	GND	BRK_NO1
3	BPS1_SIG	CAN_H1	CAN_L1
4	BPS2_SIG	CAN_L1	CAN_H1
5	GND (BPS2)	GND	GND (BRK_COM1)
6	5V (BPS2)	12V_RAW	BRK_NC1
7			GND
8			12V_BRK

I. Connector Pinout – SEN V1.1

Pin number	Cytron Motor Driver DT 4 Pin	Magnetic Encoder DT 4 Pin	PWR / CAN Distribution DT 6 Pin
1	5V	5V	12V_RAW
2	GND	GND	GND
3	AN1_OUT	MAG_PWM	CAN_H1
4	DIG1_OUT	X	CAN_L1
5			GND
6			12_RAW

J. Connector Pinout – iBooster ECU to BEN

Pin number (iBooster ECU)	Pin number (BEN iBooster DT)	Function
B1	2	BRK_COM1 (GND)
C1	3	BRK_NO1
D1	6	BRK_NC1
E1	5	CAN_L1
F1	4	CAN_H1
G1	1	12V_IGNITION
G4	7	GND_ECU

To reconnect COM2 / NC2 / NO2 (not required for current scope of AV.One):

Pin number (iBooster ECU)	Function
A1	BRK_NO2
A2	BRK_NC1
A3	BRK_COM2