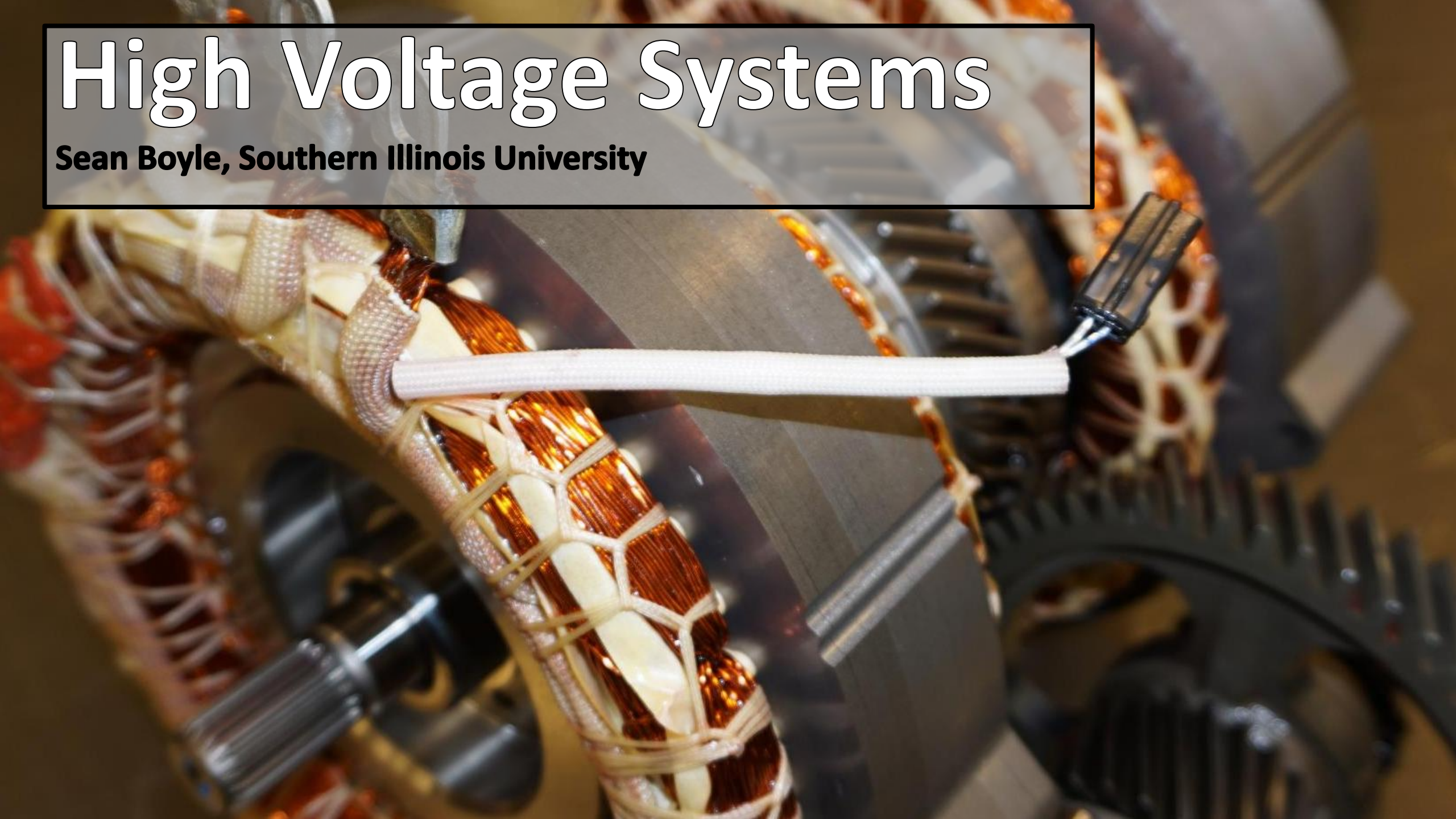


High Voltage Systems

Sean Boyle, Southern Illinois University



Meanwhile, in America...

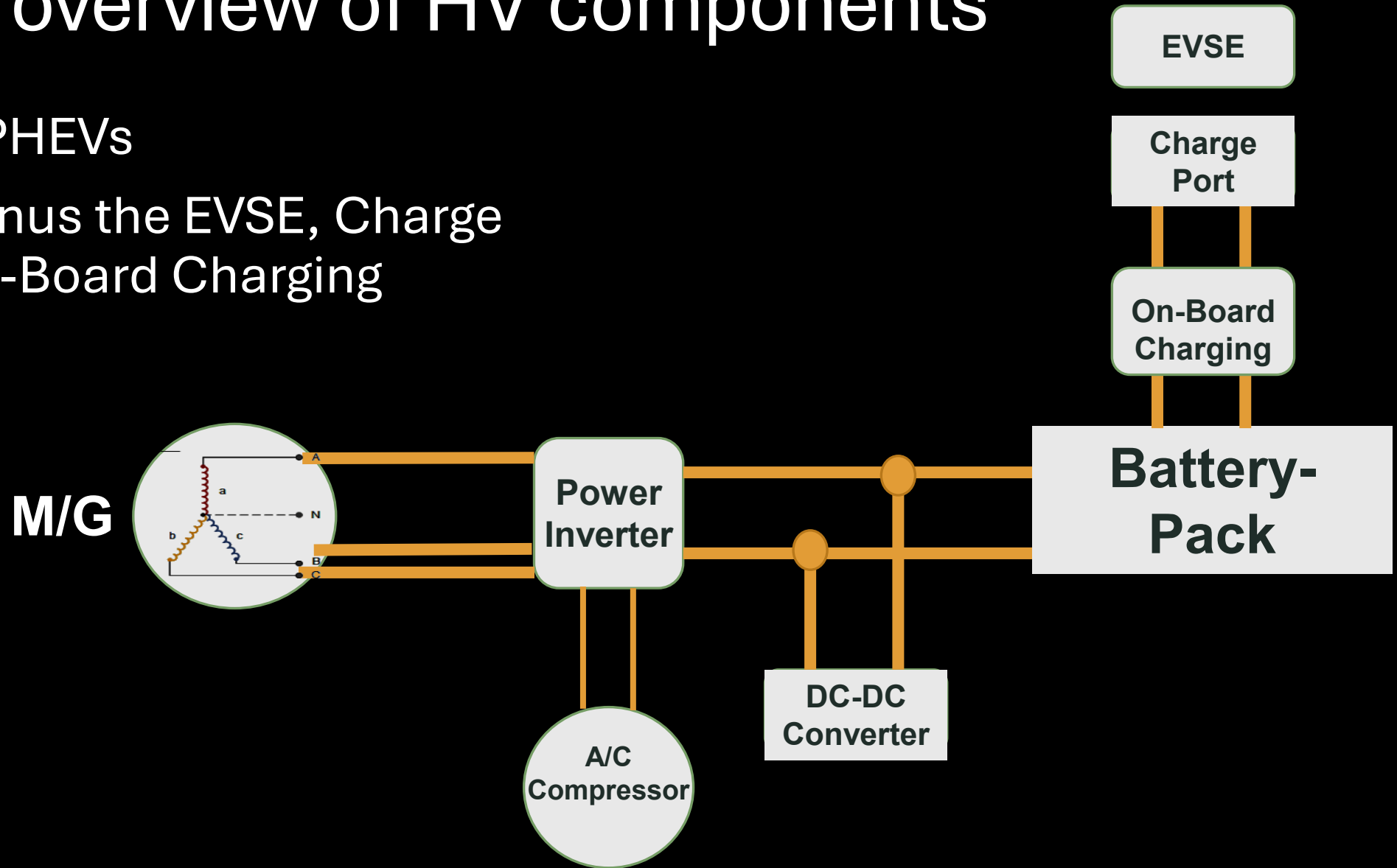


High-Level Overview



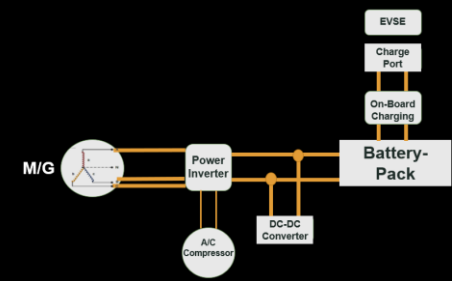
High level overview of HV components

- All EVs and PHEVs
- Hybrids – minus the EVSE, Charge Port, and On-Board Charging



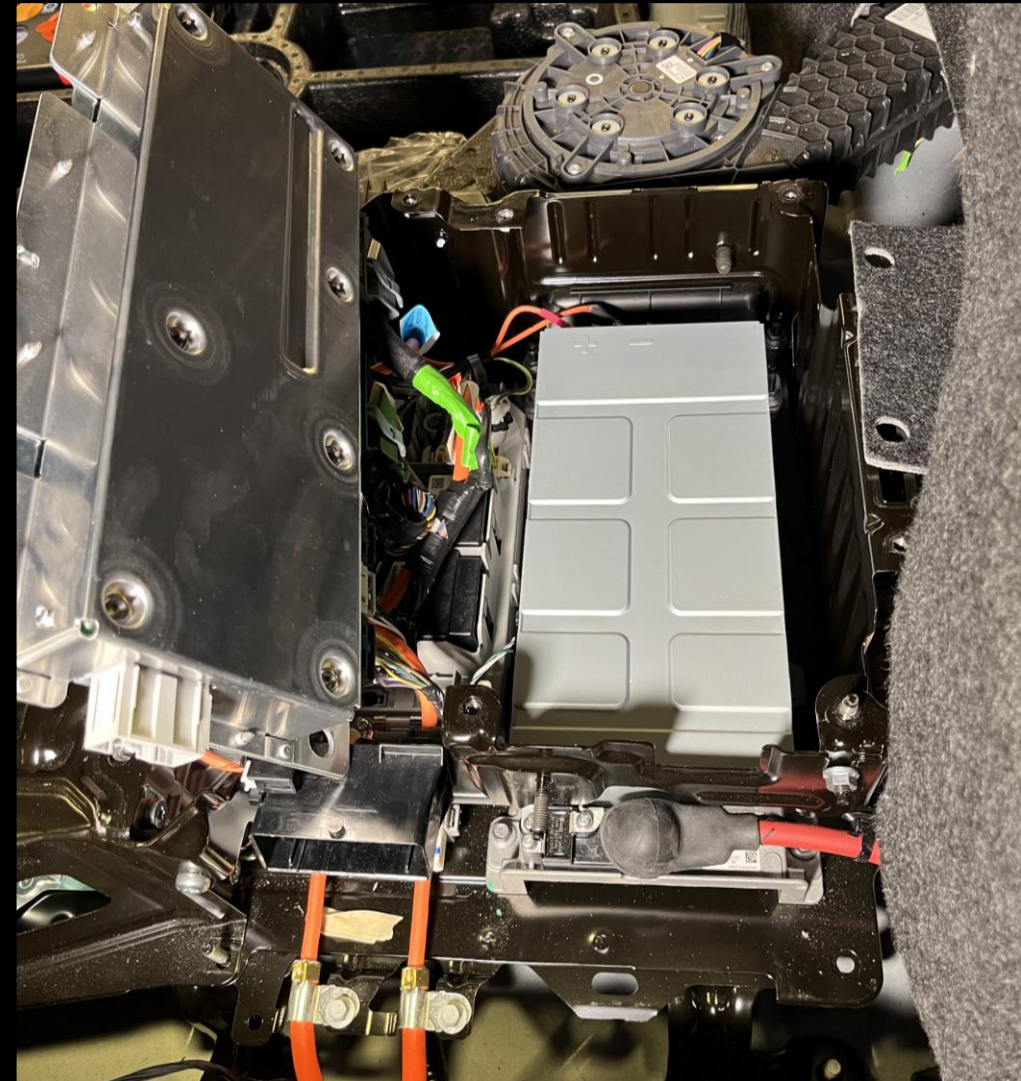
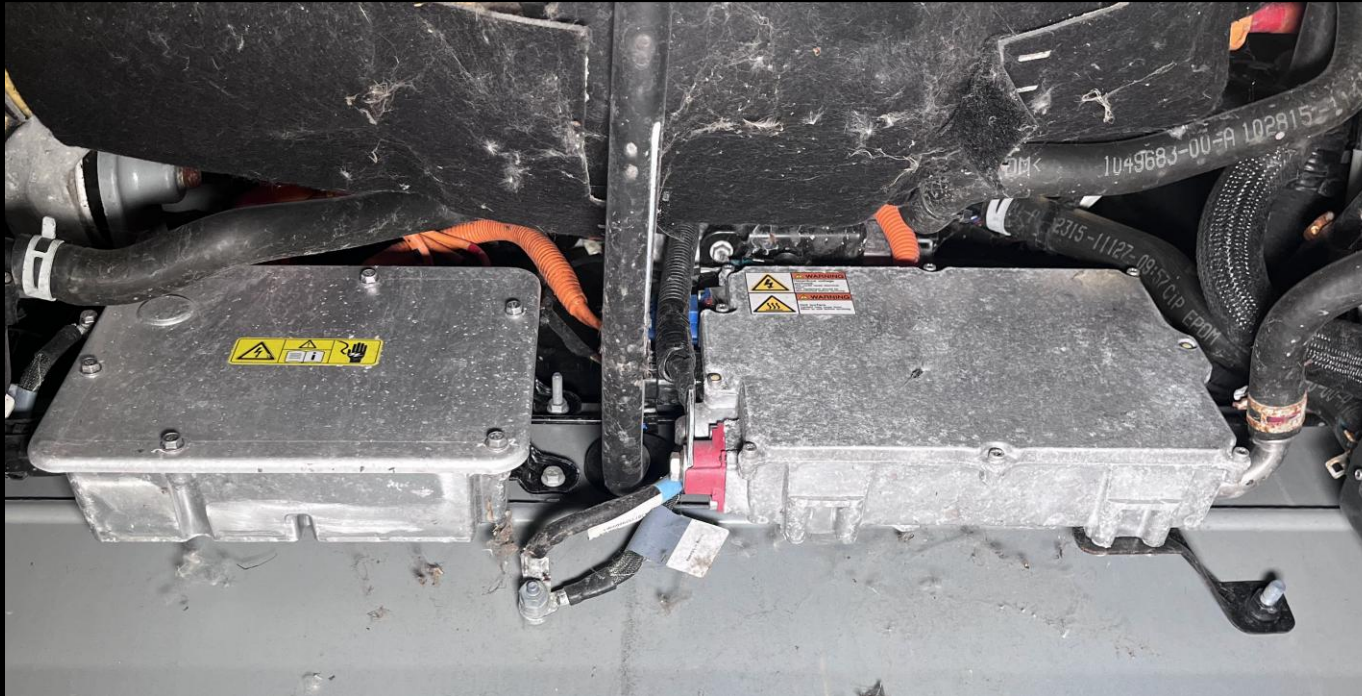
High Level – Low voltage battery

- 12-16v battery is essential to operation
- Initial system power
- Lead acid or Li ion
- If DC/DC converter is inoperative, LV battery will deplete quick



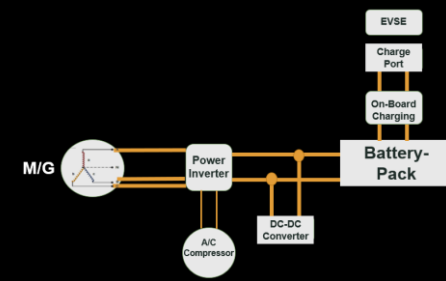
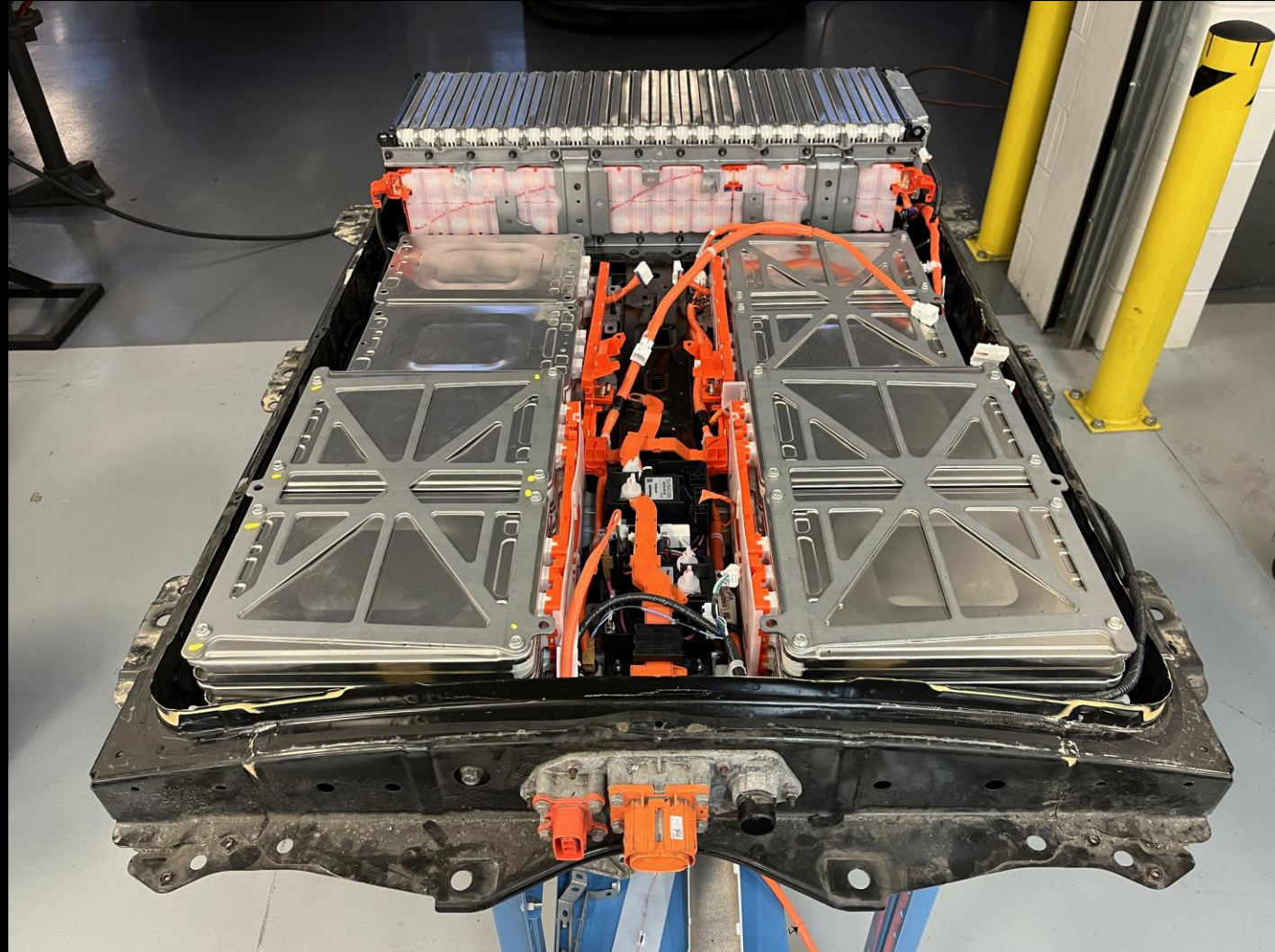
High Level – DC – DC Converter

- Takes the place of the traditional alternator
- Converts HV DC to LV DC



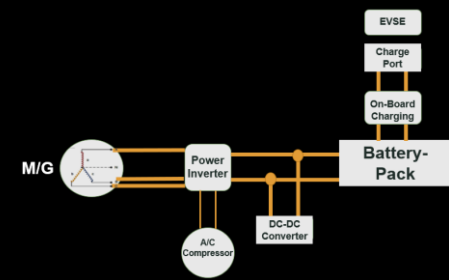
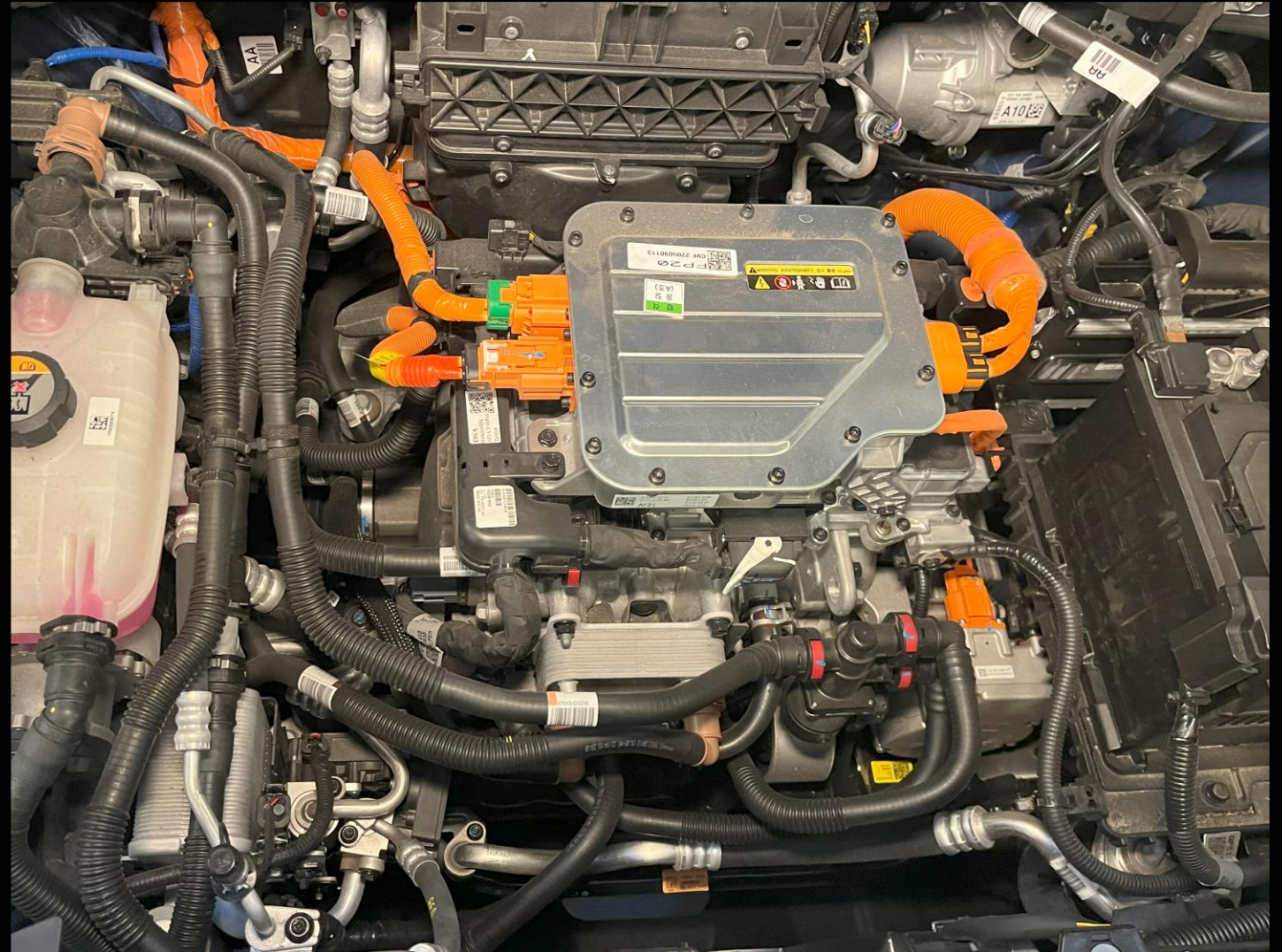
High Level – high voltage battery

- Medium hybrid – 144V
- Full hybrid – 200V +
- PHEV – 360V +
- BEV – 360V +
- Contactors
 - Make the connection between the internal battery HV and the HV components

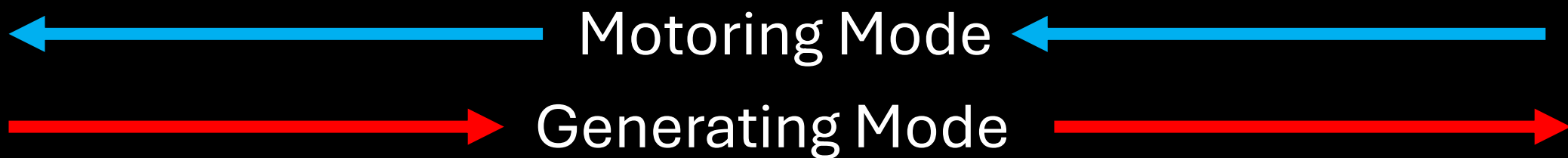
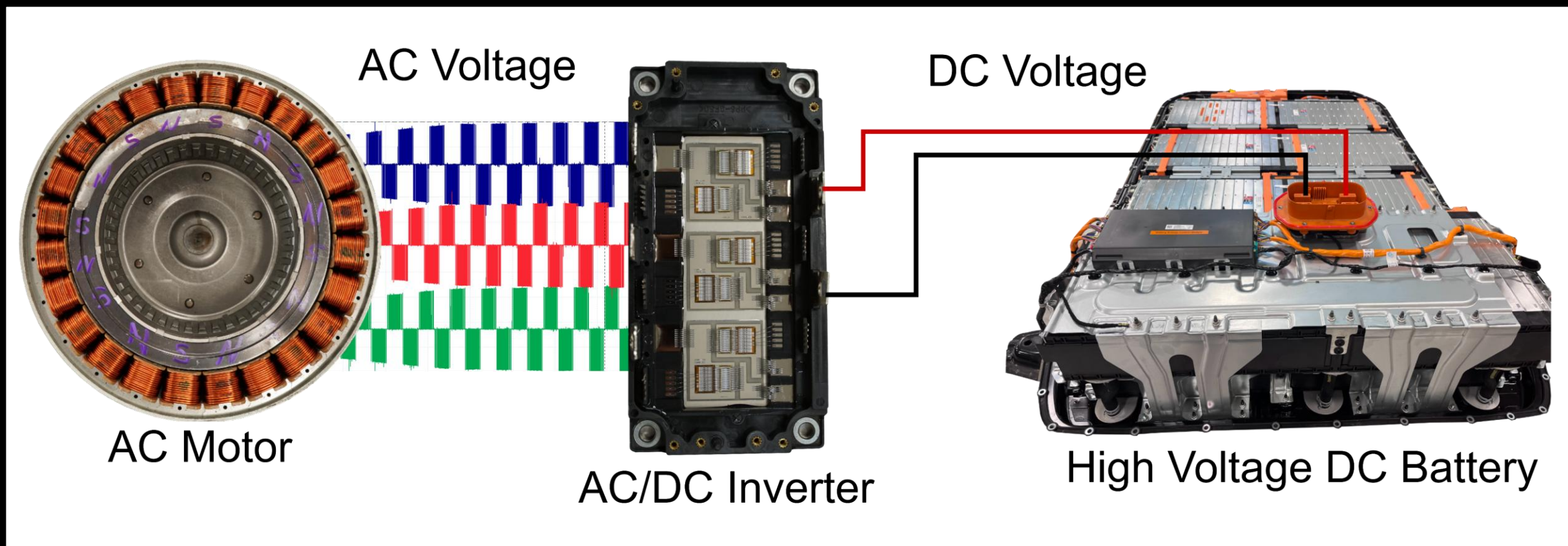
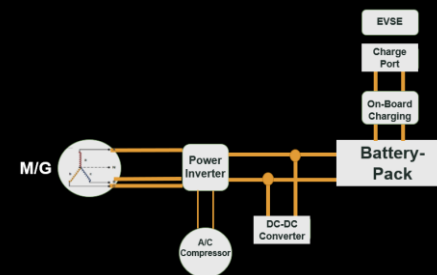


High Level – Inverter

- Converts HV DC to HV AC
- Batteries store DC
- Motors operate with AC
- High-speed transistor switching creates HV AC from HV DC



High Level – Motor



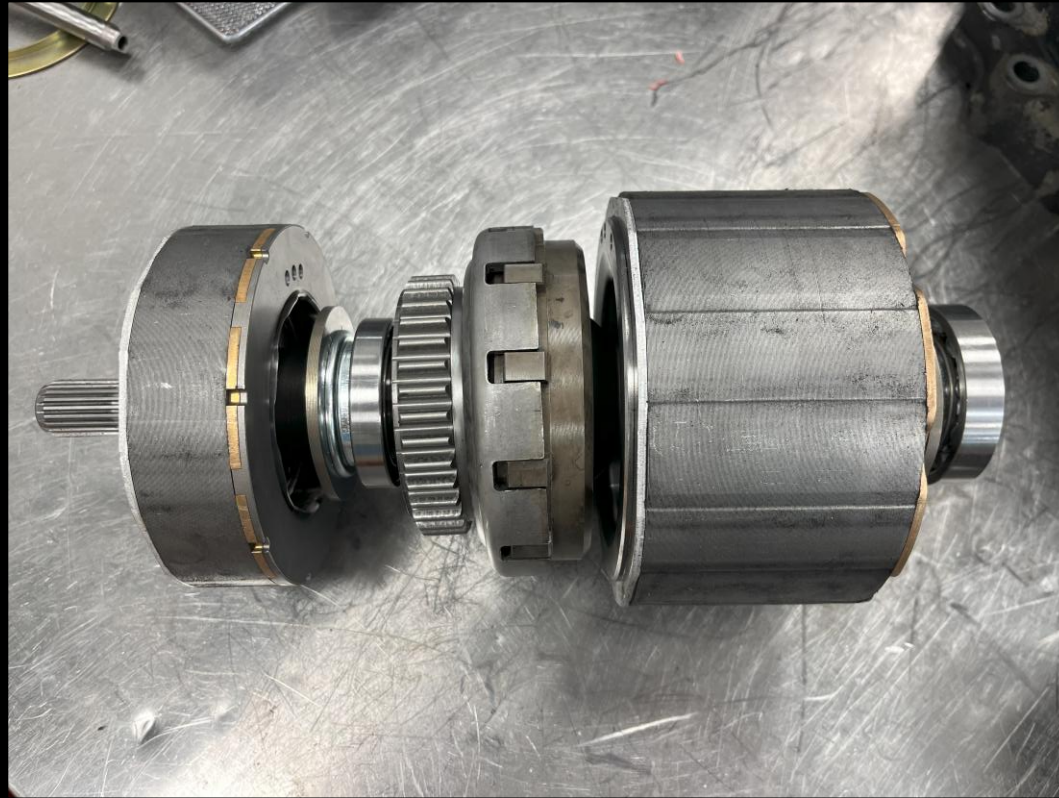
High Level – Motor

- Various Positions
 - Front of engine
 - Between engine and converter
 - Between converter and trans
 - In trans
 - Trans output
 - Stand alone rear axle



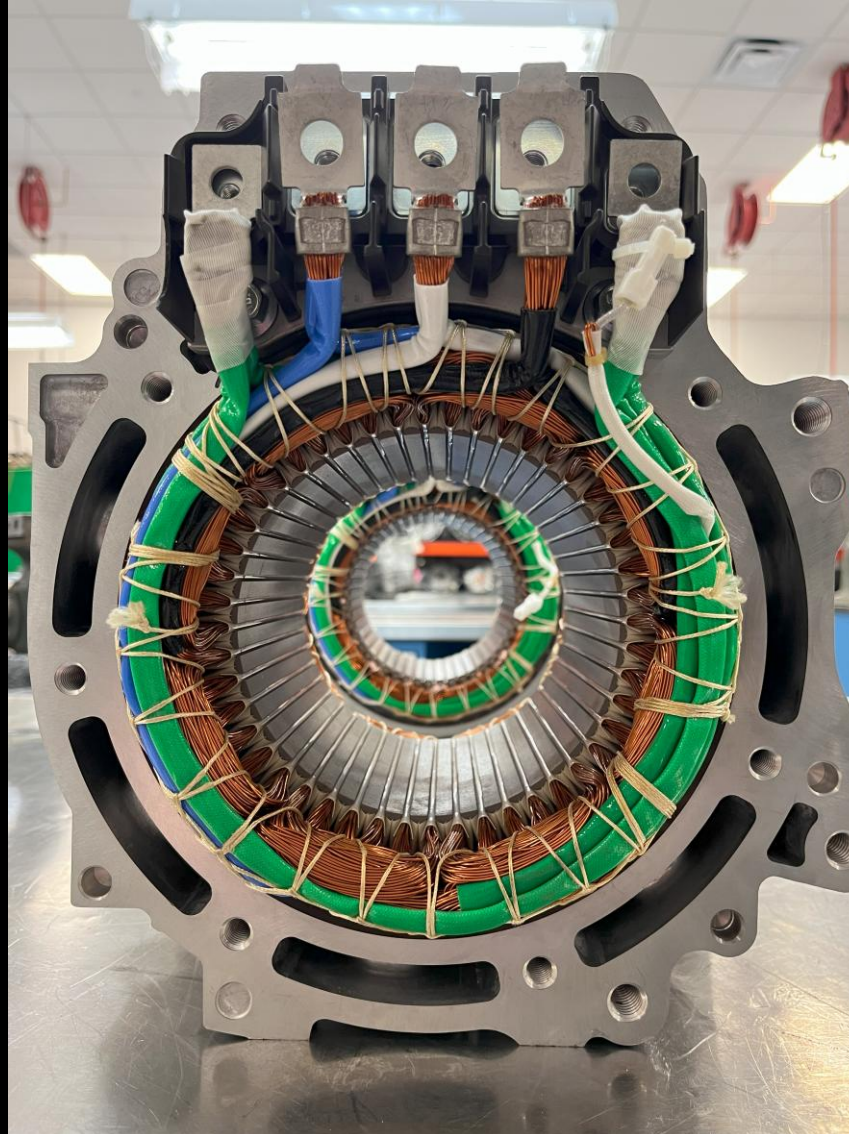
High Level – Motor

- Rotor – rotating component
 - Permanent Magnet Motor
 - Induction Motor
 - Wound Synchronous Motor
- Power split motor from Toyota Prius
 - MG1
 - MG2
 - Planetary gearset



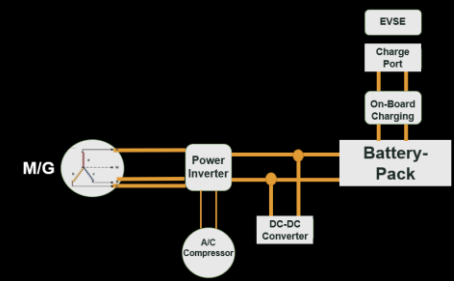
High Level – Motor

- Stator – stationary component
 - Configuration
 - Distributed windings
 - Concentrated windings
 - Winding type
 - Stranded
 - Bar



High Level – Charging - Level One

- 120-volt charging
 - 5 miles per hour of charge
- Average EV uses around 320wh per mile
- $12\text{amp} \times 120\text{v} = 1440\text{watt/hour}$
- $1440/320 = 4.5$ miles per hour of charge



High Level – Charging – Level 2

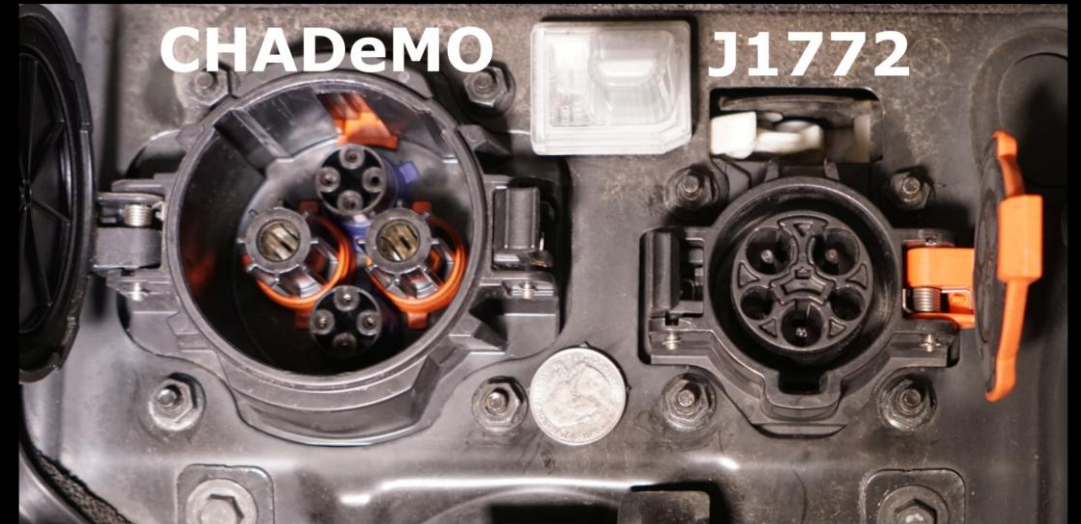
- 240-volt charging
 - 30 miles per hour of charge
- Average EV uses around 320wh per mile
- $40\text{amp} \times 240\text{v} = 9600\text{watt/hour}$
- $9600/320 = 30$ miles per hour of charge



High Level – Charging - DCFC



High Level – Charging



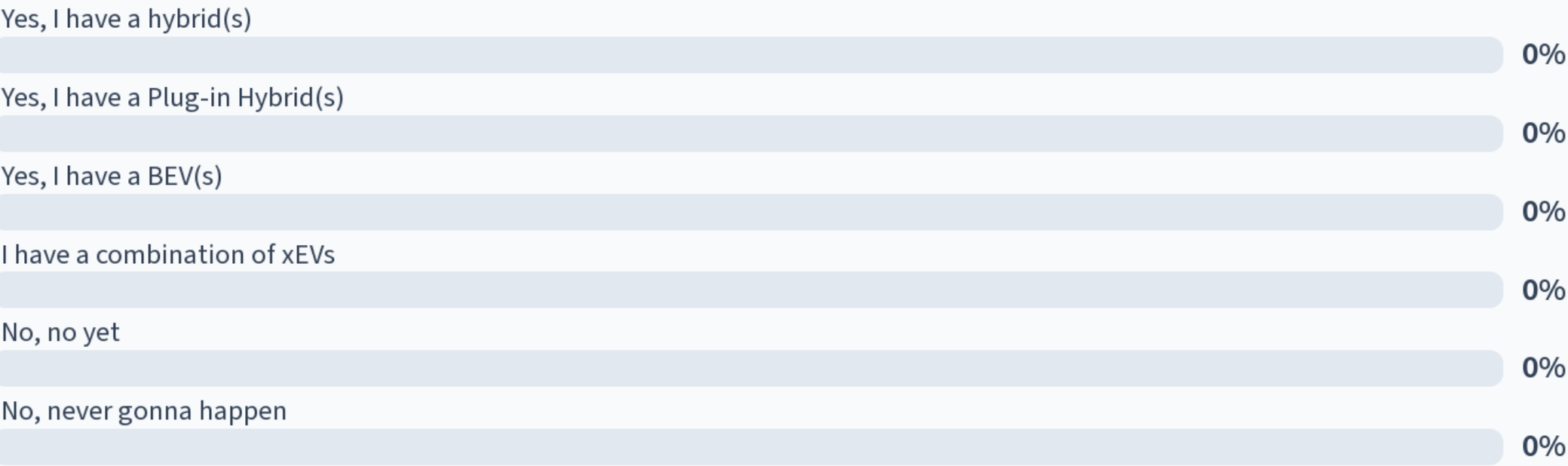
North America Charging Standard (NACS) is the US Standard (350kW capable)

Combined Charging Standard (CCS) J1772 *plus* DC charge port

SAE J1772 – Previous Level 2 standard (except Tesla)

CHAdeMO– Japanese

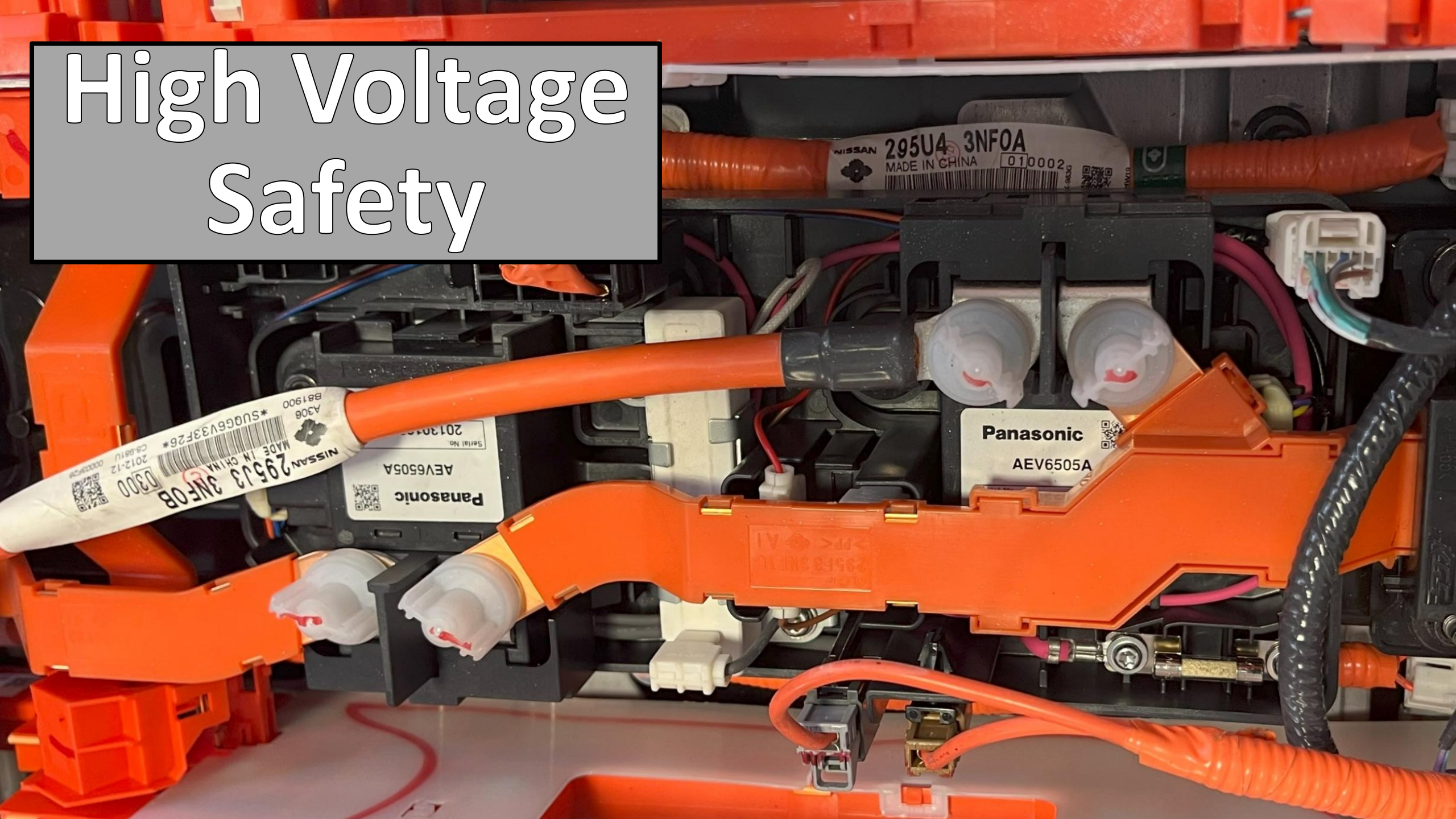
Do you have an xEV in your family?



Battery size and range



High Voltage Safety



HV Gloves

- Class 0
- Measure hands around knuckles
- Leather outers one size above rubber gloves
- Air check and visual inspection before use
- Recertify every 6 months



HV Meters

- Cat III 1000V
Meter and Leads



HV Safety

- Arc Flash Suits
 - US has no requirements
 - Some dealers are requiring suits when working in open battery packs
 - Manufacturing plants require suits and safety person
 - Shepards hook or safety rope



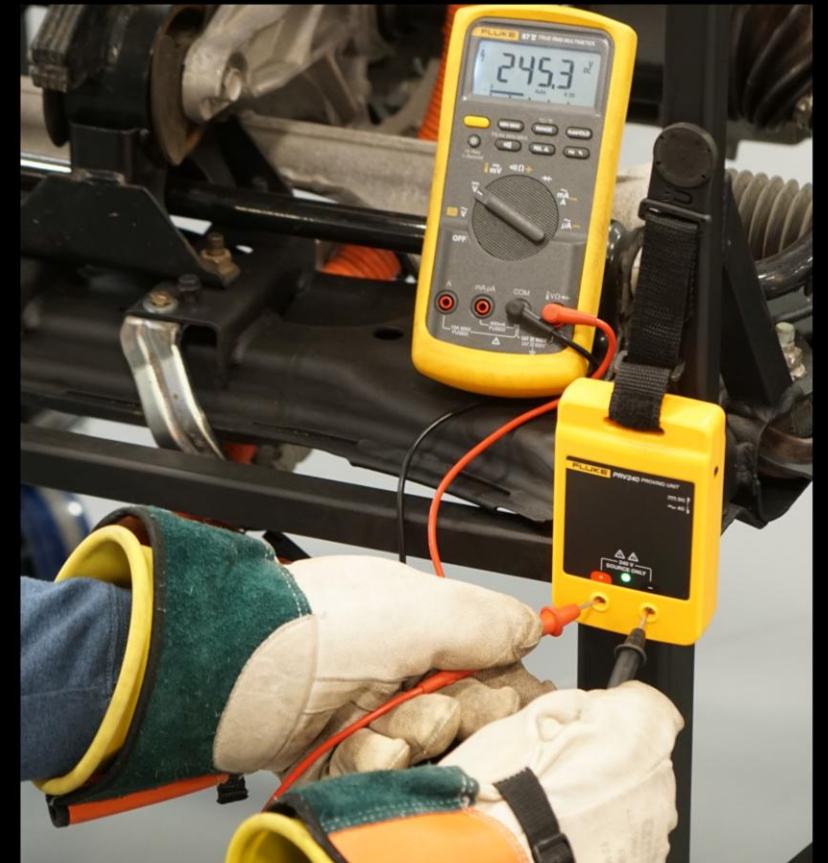
Safety Equipment

- Battery Lift Table
- Cones/Barriers



Live – Dead – Live: Fluke PRV 240

- Check to ensure the meter is actively reading and not stuck on “hold” or frozen

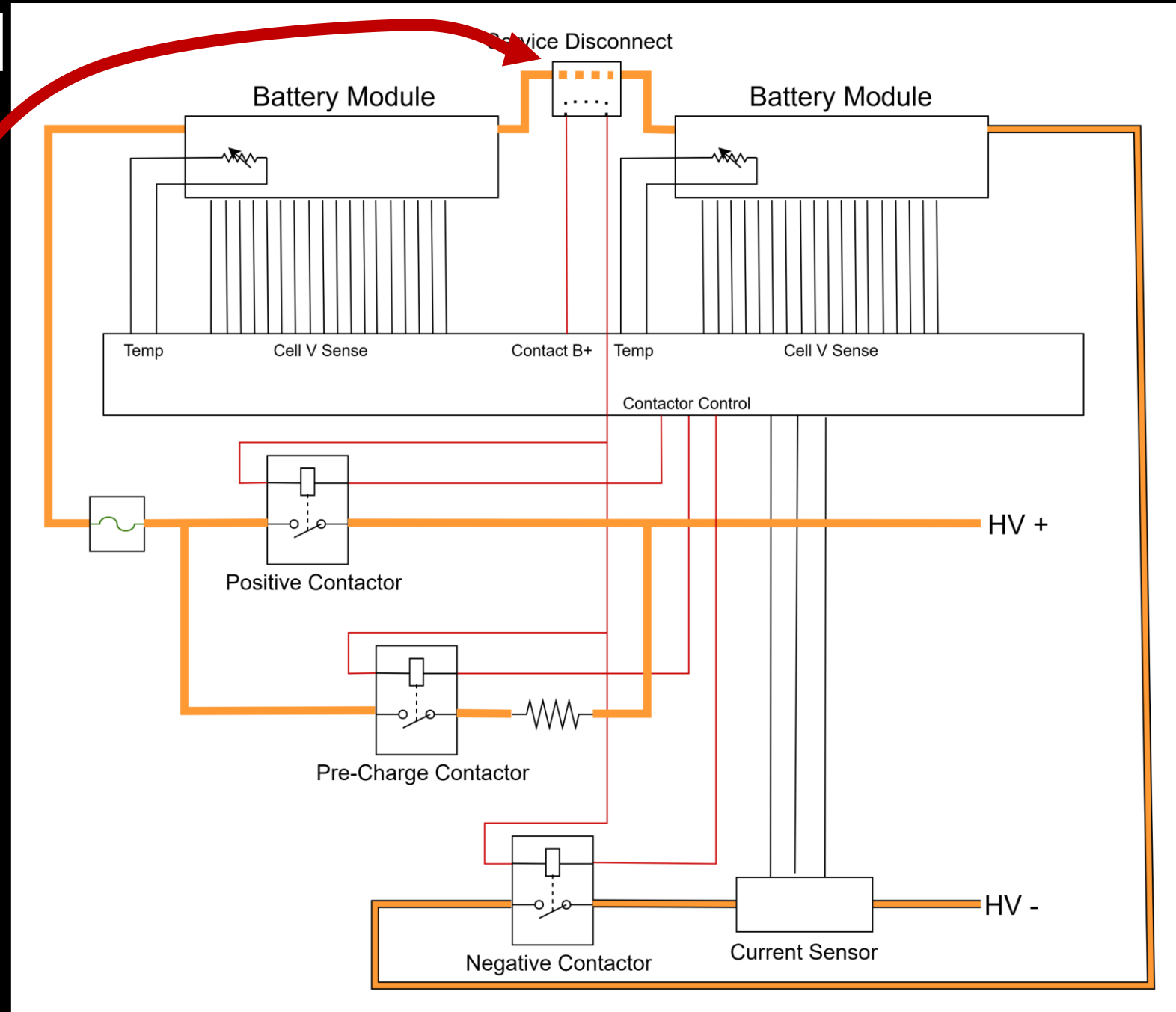


Live – Dead – Live: LV battery



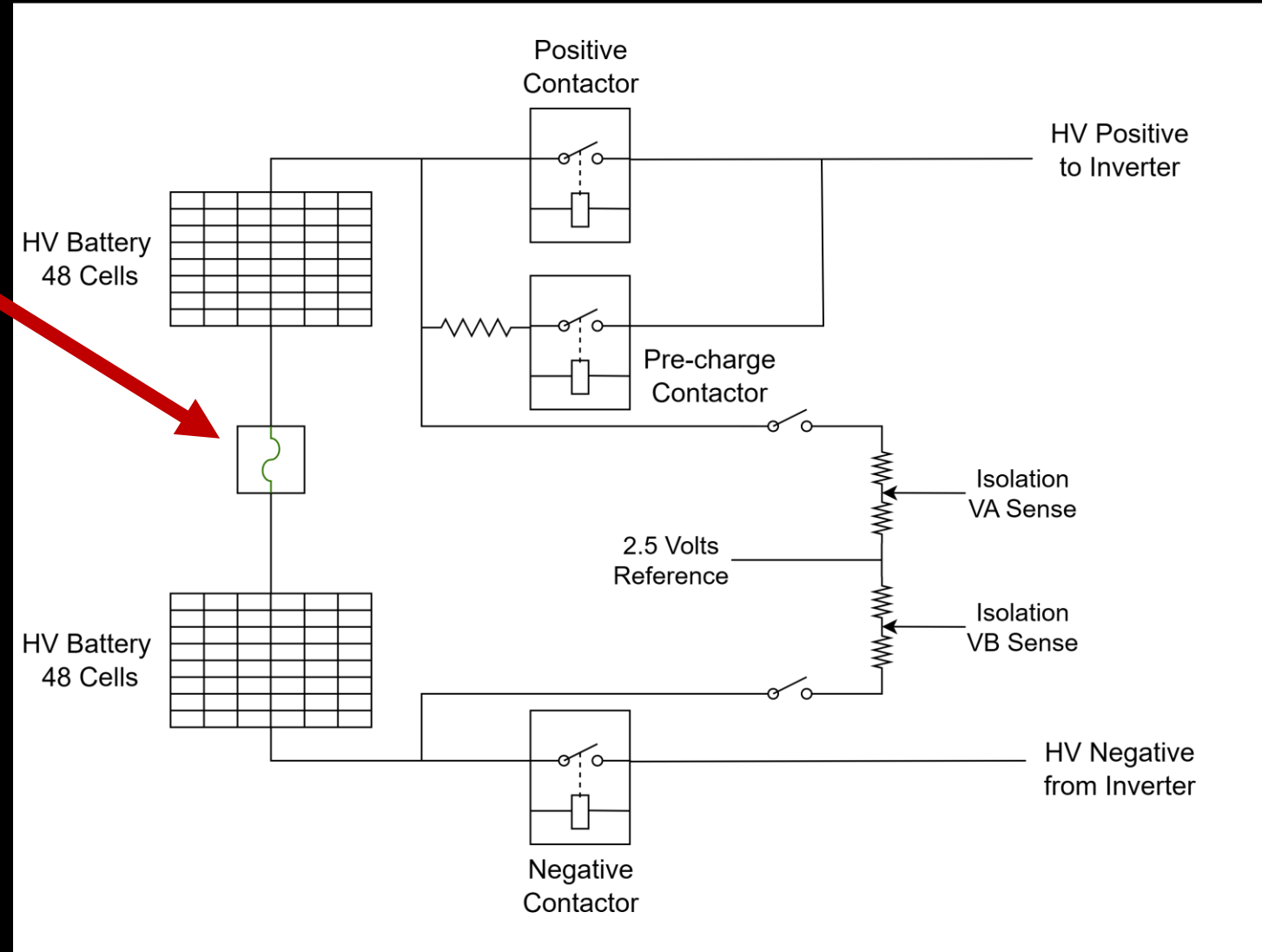
Honda CRV Hybrid

- HV disconnect splits HV battery
- Battery contactors determine if HV is available OUTSIDE of battery pack
 - Charging
 - DC/DC conversion
 - DC/AC conversion
 - HVAC



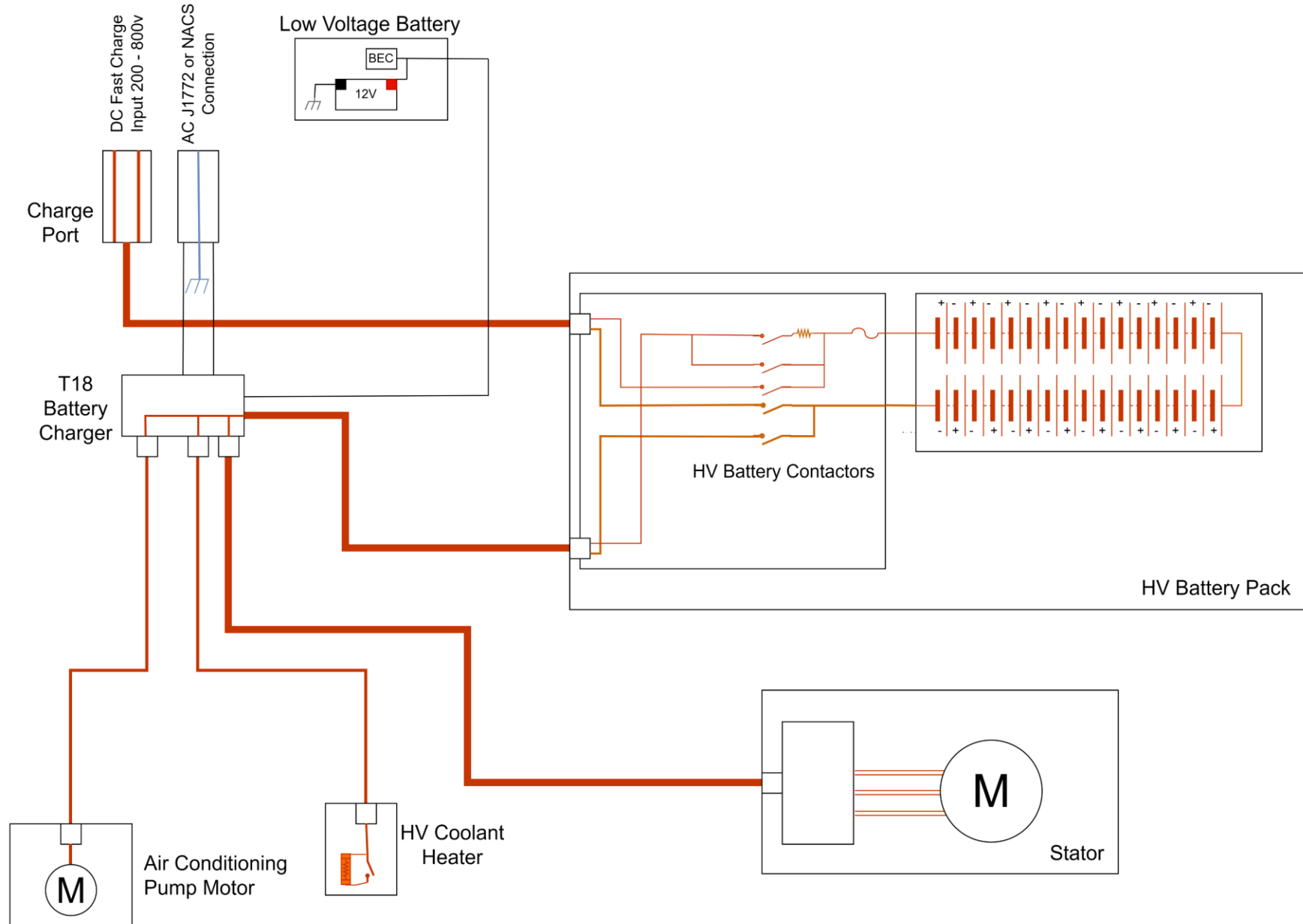
Jeep 4xe

- HV disconnect splits HV battery
- Battery contactors determine if HV is available OUTSIDE of battery pack
 - Charging
 - DC/DC conversion
 - DC/AC conversion
 - HVAC



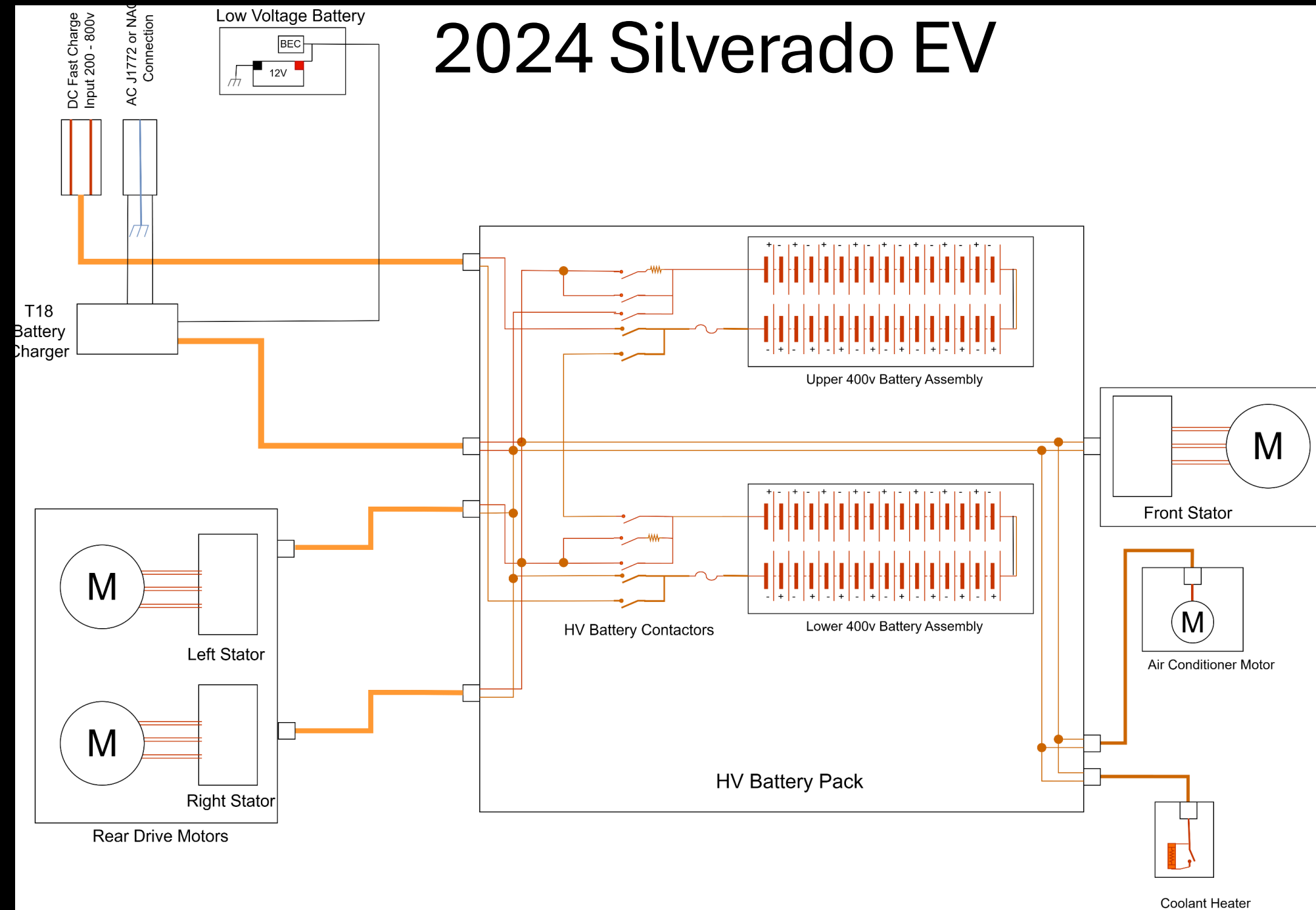
2024 Blazer EV

- Battery contactors determine if HV is available OUTSIDE of battery pack
 - Charging
 - DC/DC conversion
 - DC/AC conversion
 - HVAC



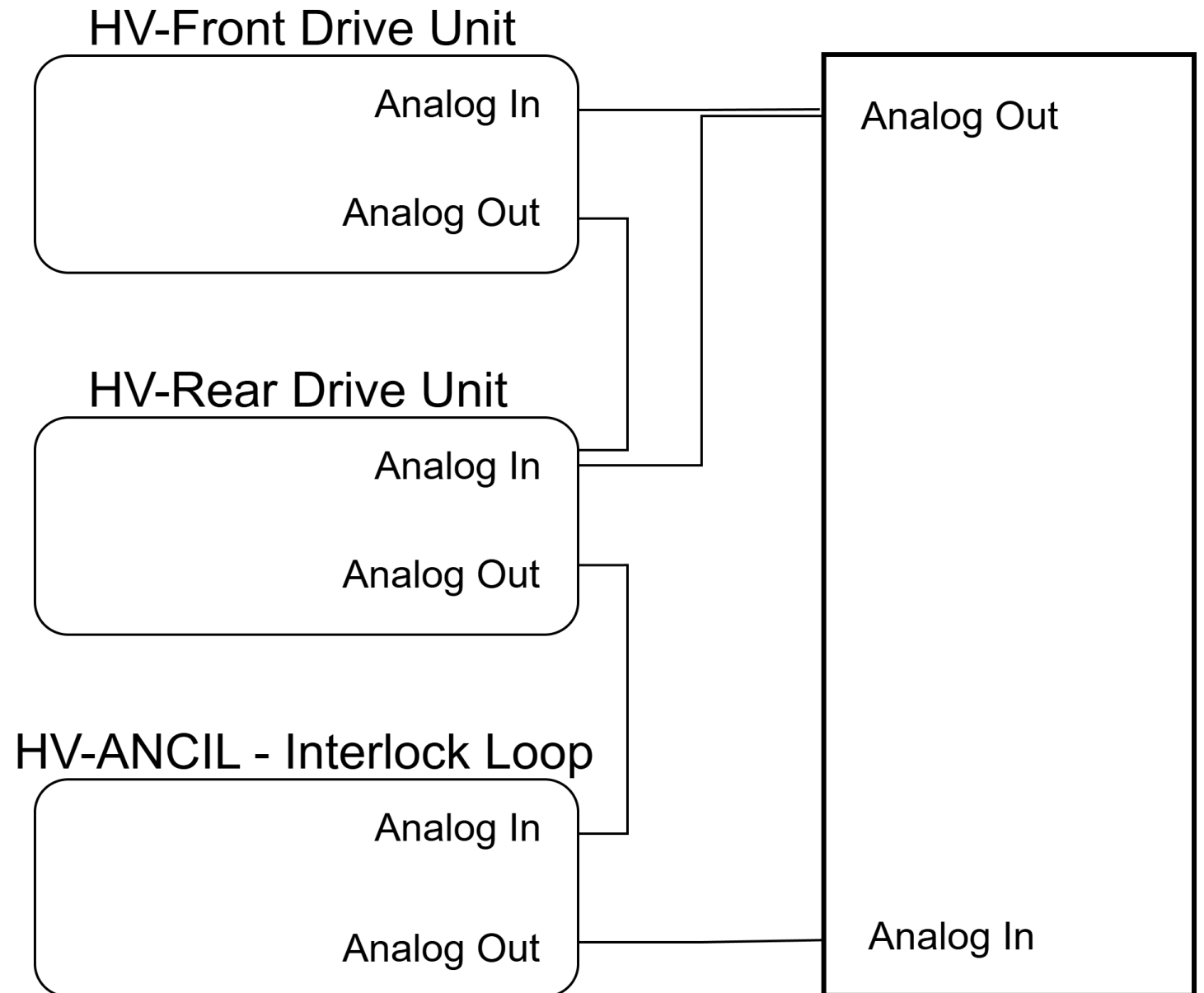
2024 Silverado EV

- HV Contactors
 - Configure battery pack to 400v or 800v
 - Allows for high KW DC fast charging



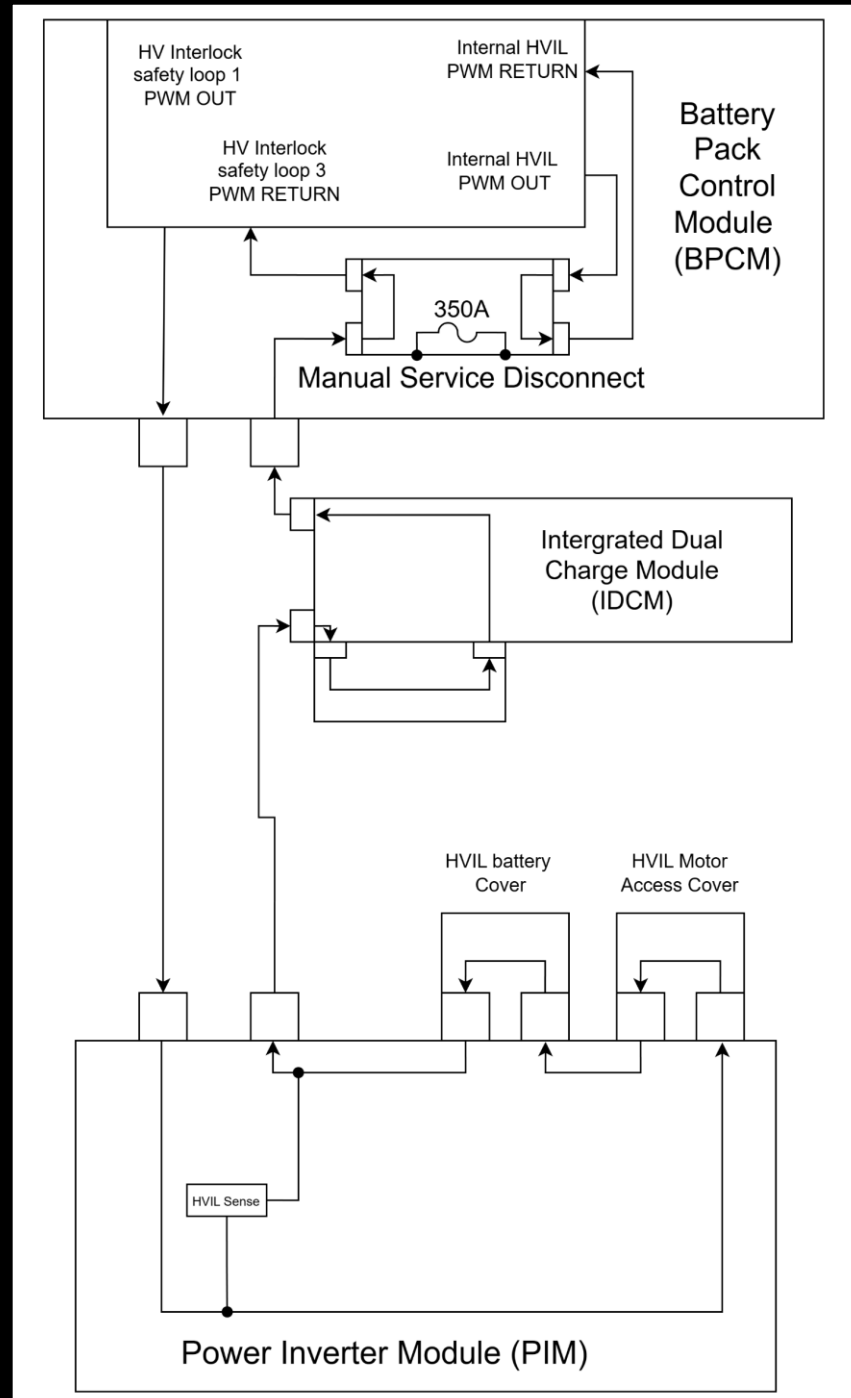
Tesla MY

- Interlock connections
 - Interruptions will inform the controller to OPEN contactors



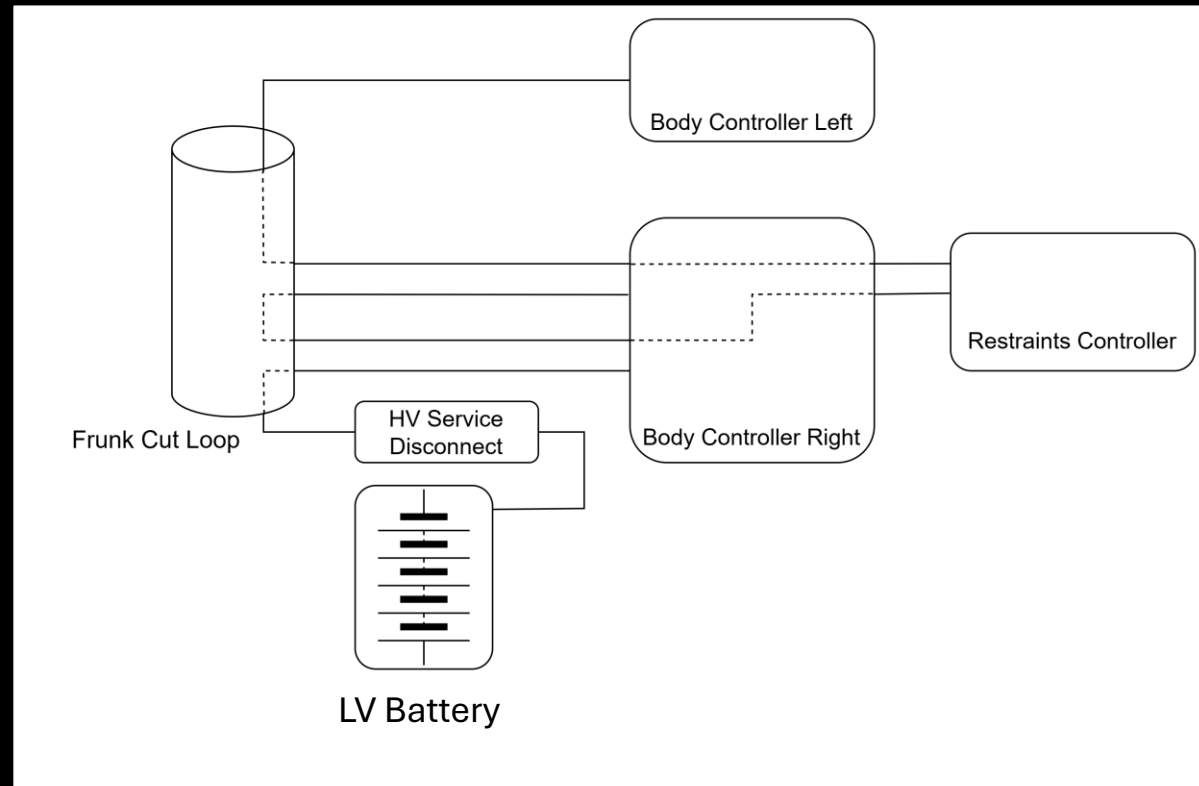
Chrysler Pacifica PHEV

- Interlock connections
 - Interruptions will inform the controller to OPEN contactors



HV and LV Disconnects

- HV Disconnect Connector
- LV Disconnect Connector



Active Isolation Testing – Measuring resistance Between HV and Chassis

Hybrid/EV Battery Pack Active Isolation Test

Diagnostic Data Display

Graphical Data Display

Line Graph

DTC Display

Hybrid/EV Powertrain Control Module 2 Data

Parameter Name	Value	Unit	Control Module
High Voltage System Isolation Test Status	Running		Hybrid Powertrain Control Module 2
Hybrid/EV Battery Pack Active Isolation Test Status	passed		Hybrid Powertrain Control Module 2
Isolation Test Resistance	3000.00	kOhm	Hybrid Powertrain Control Module 2
Battery Charging System Isolation Test Status	passed		Hybrid Powertrain Control Module 2

Parameter Name	Value	Unit	Control Module
Distance with MIL On	0	mi	Hybrid Powertrain Control Module 2
Warm-Ups Since DTC Cleared	0	Counts	Hybrid Powertrain Control Module 2
Distance Since DTC Cleared	1	mi	Hybrid Powertrain Control Module 2
Ambient Air Temperature	61	°F	Hybrid Powertrain Control Module 2

Hybrid/EV Battery Pack Active Isolation Test

Commanded State Enabled

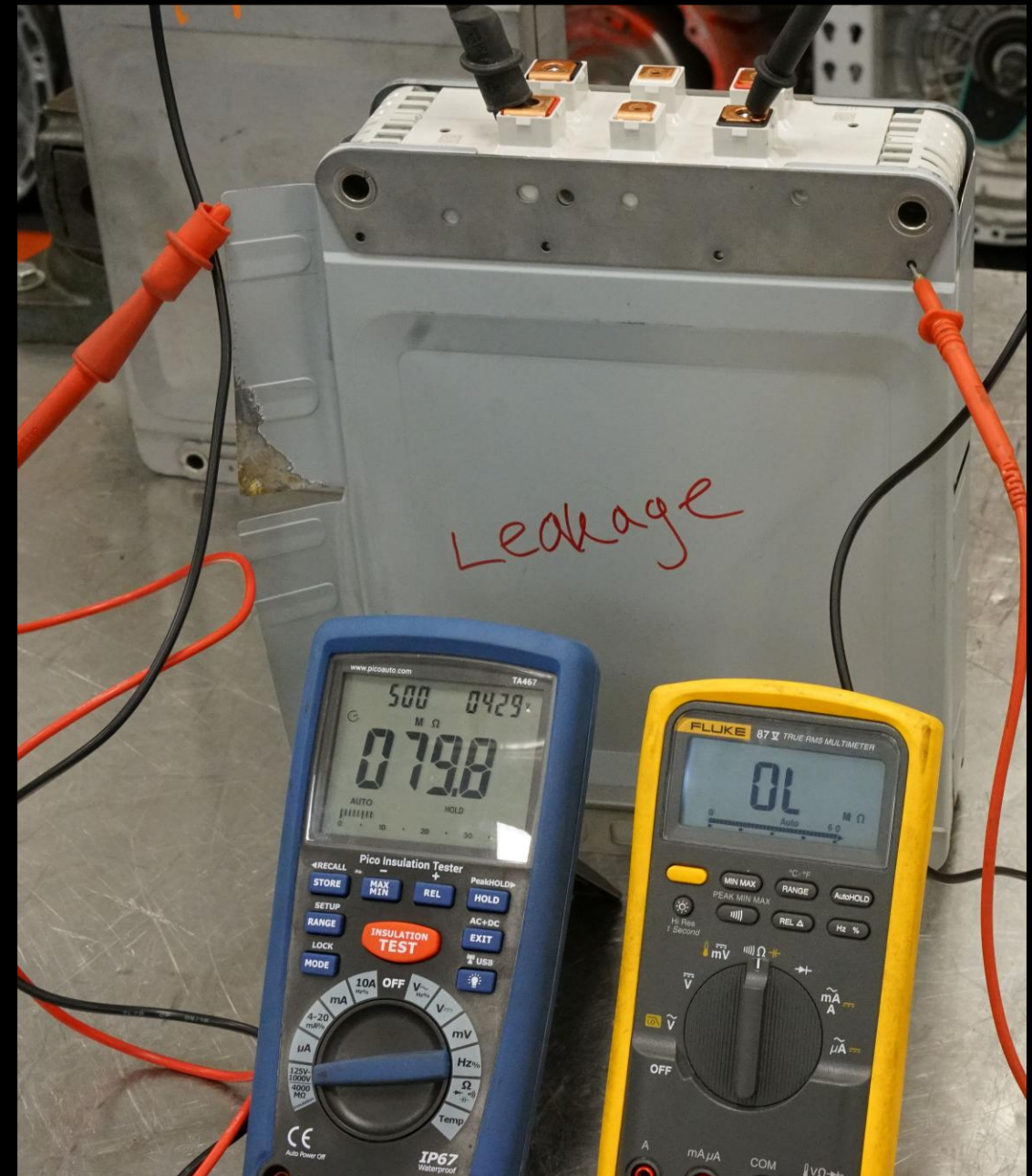
Disabled

Enabled

Release Control

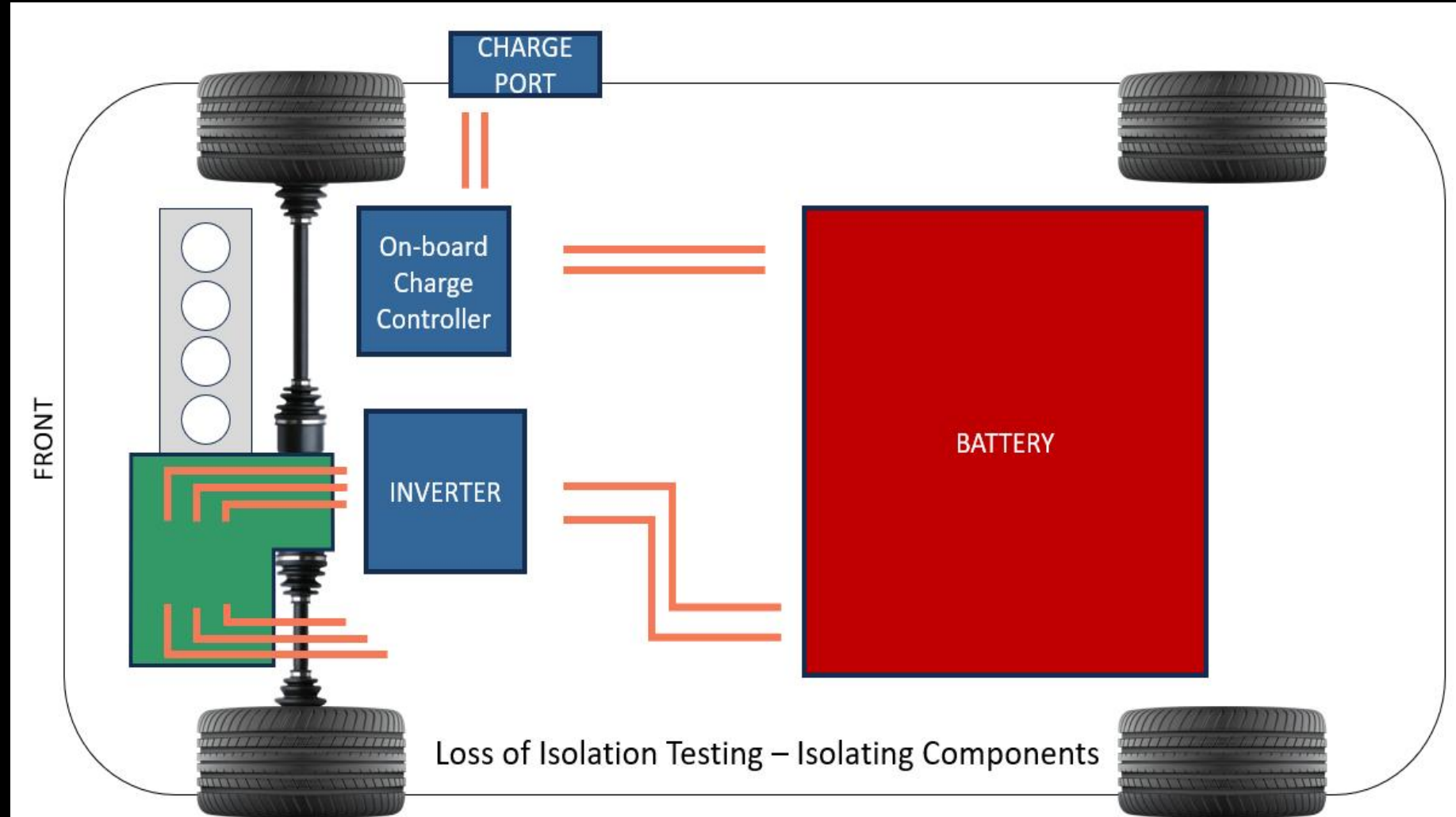
Megaohm Testing

- Check for HV leaks using HV
 - Checks for shorts that a traditional DMM might miss
 - Places 250, 500, 750, or 1000V on circuit
 - Check between circuit and ground
 - Verify with 100k ohm resistor or greater



Megaohm Testing

- Loss of isolation DTC
 - Test system with megaohm meter
 - If failed, start isolating components

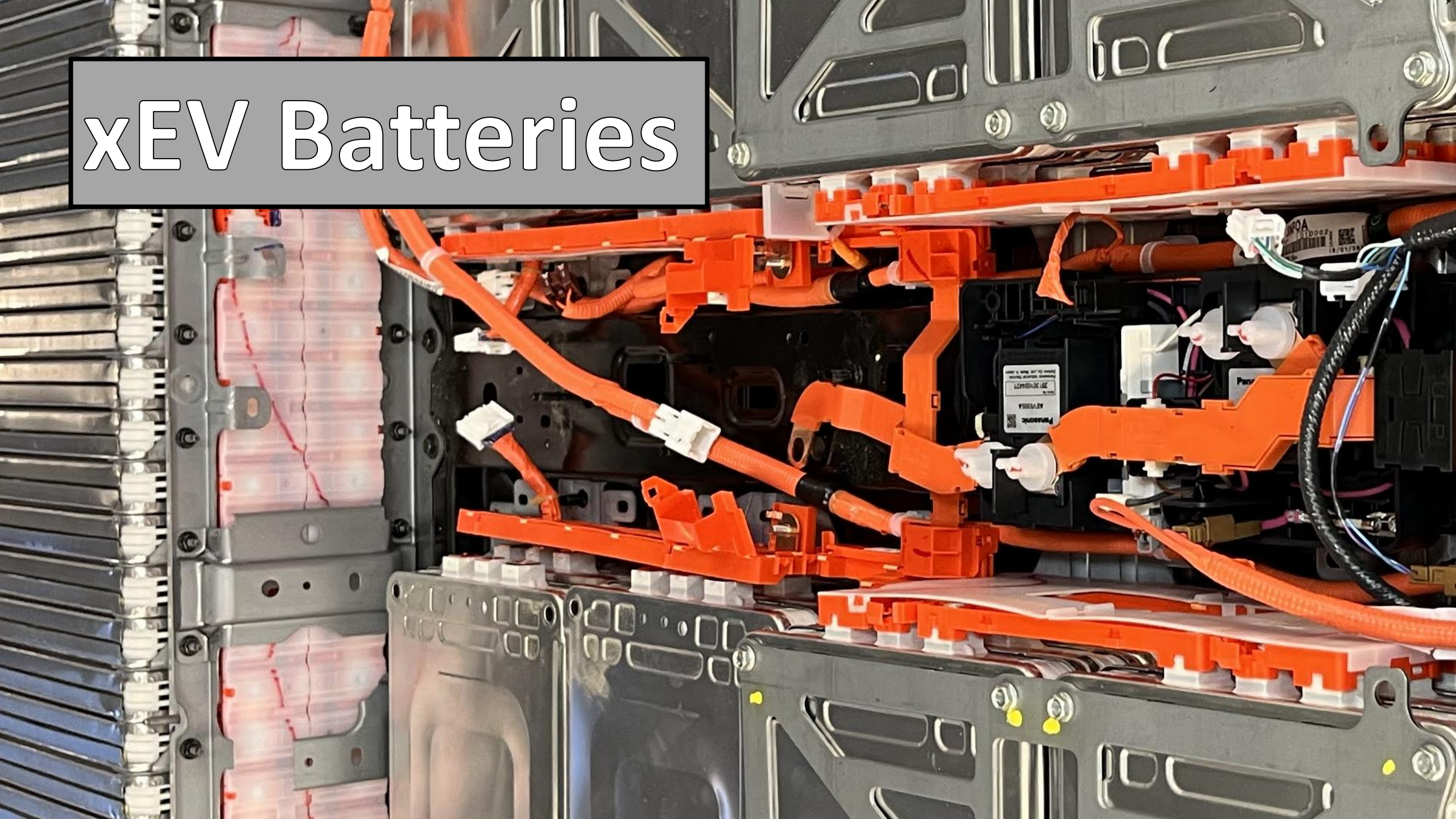


Megaohm Testing

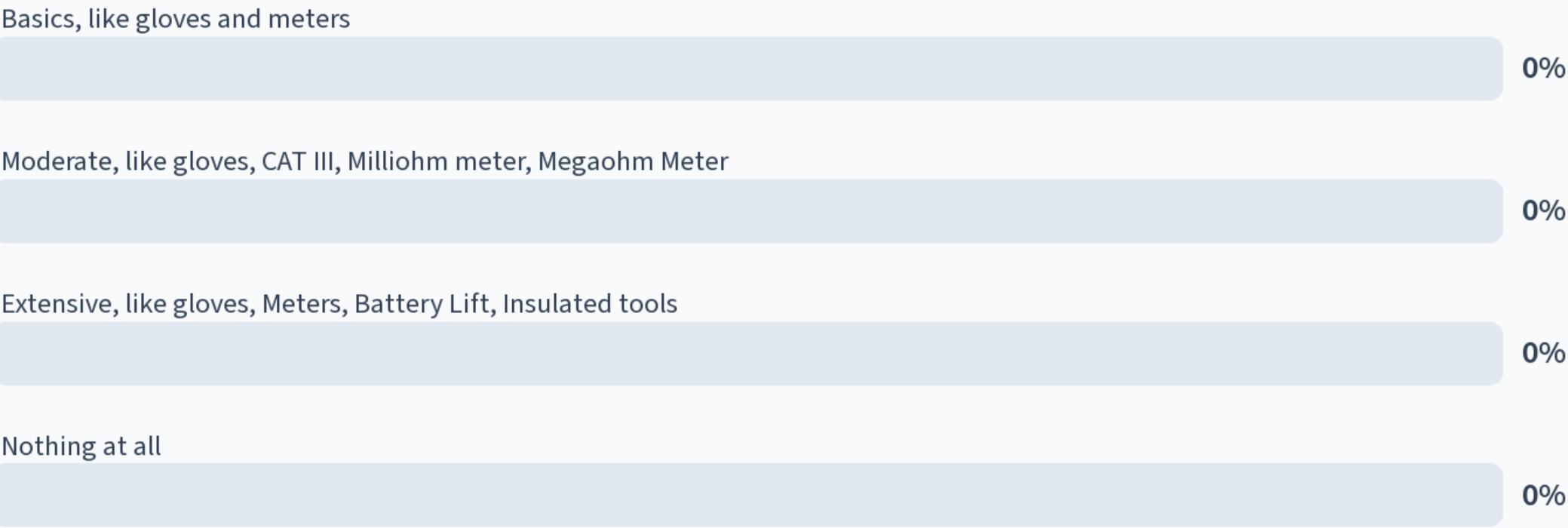
- Verify the stator windings aren't shorted to the case



xEV Batteries



How is your shop equipped with xEV safety and shop equipment?



HV battery

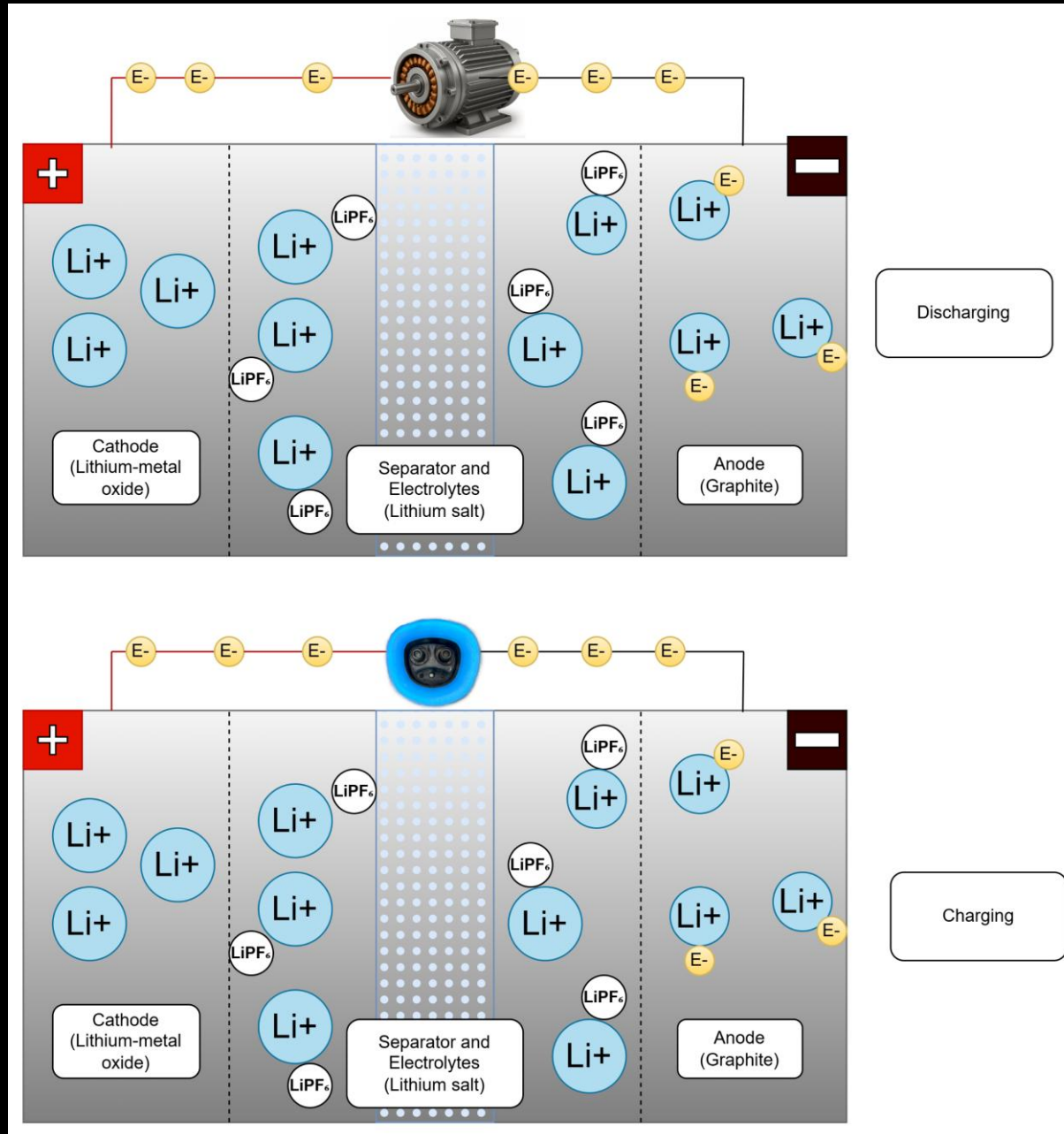
- Lithium Ion is the predominate battery technology

- LFP
- NMC
- NCA

- LMFP

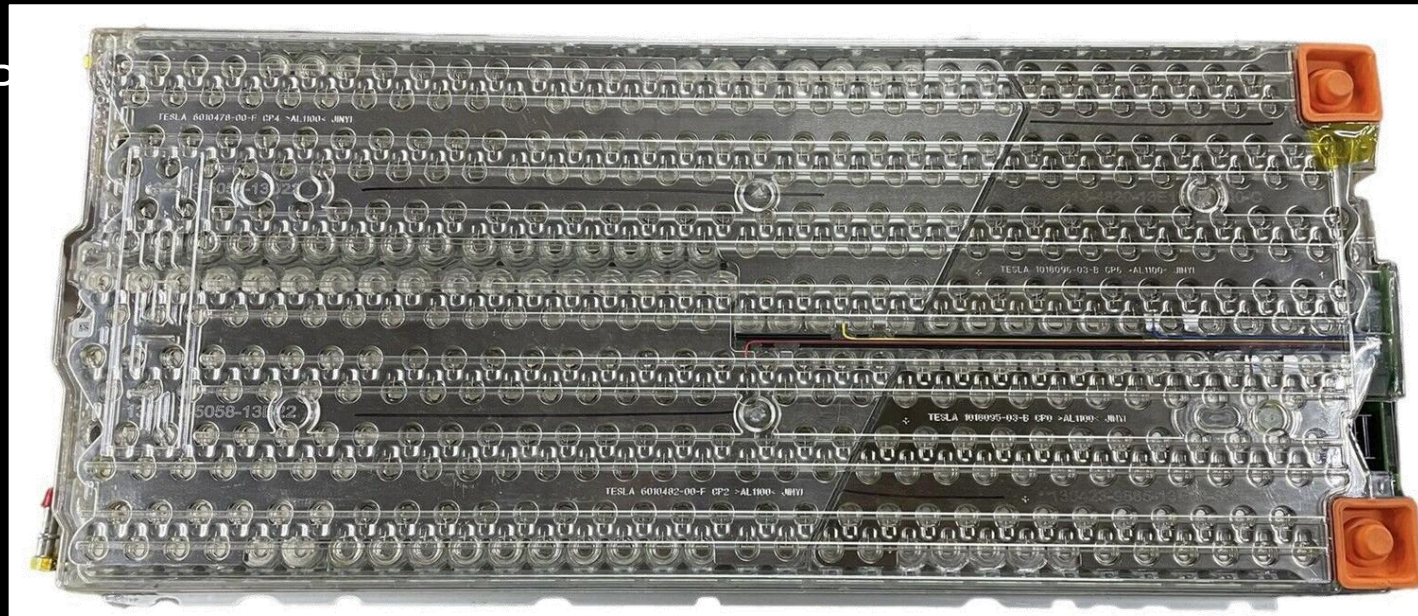
- Factors

- Cost
- Fast Rate
- Power
- Safety



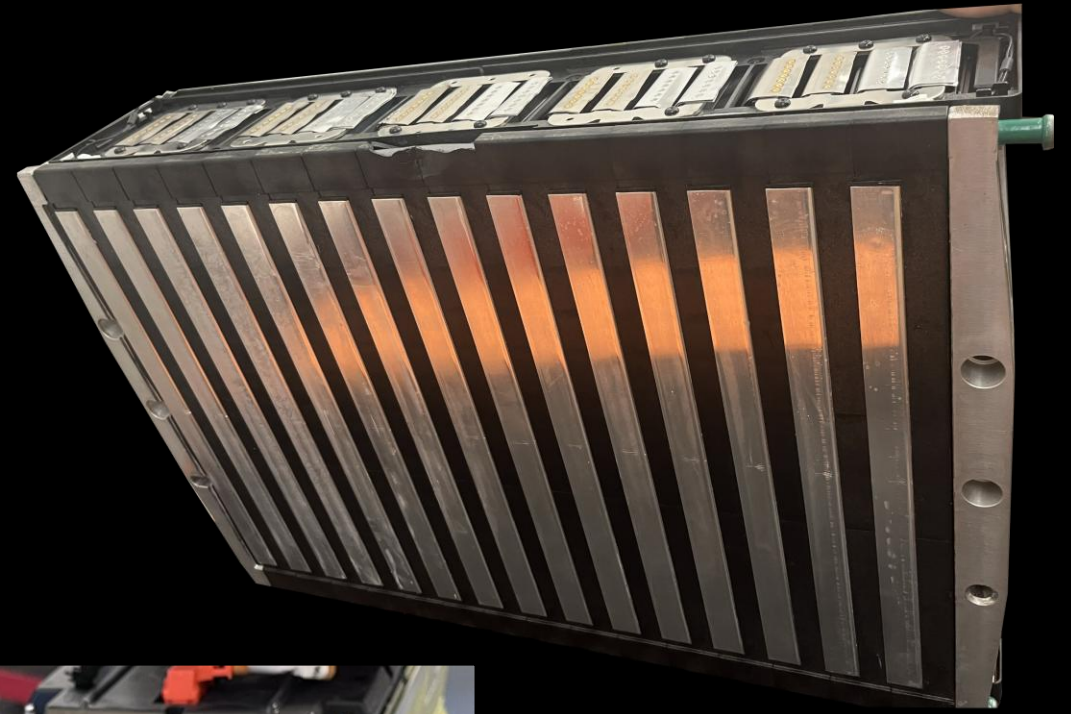
HV Battery Format

- Cylindrical format
 - Tesla, Rivian, Lucid
 - Structural
 - Lower capacity = more cells in parallel
 - 18650 – Early Tesla Model S (7104 cells) 6S74P x 16 modules
 - 2170 – Rivian R1S/T (7776 cells) 12S72P x 9 modules
 - 4680 – Cybertruck (1344 cells) 192S7P
 - 4695 – Rivian R2 (768 cells)



HV Battery Format

- Pouch format
 - GM, Stellantis, Ford, VW and many more
 - Non-structural
 - Higher capacity = less cells in parallel



PHEV HV Battery

- Lower Capacity
- Same Voltage



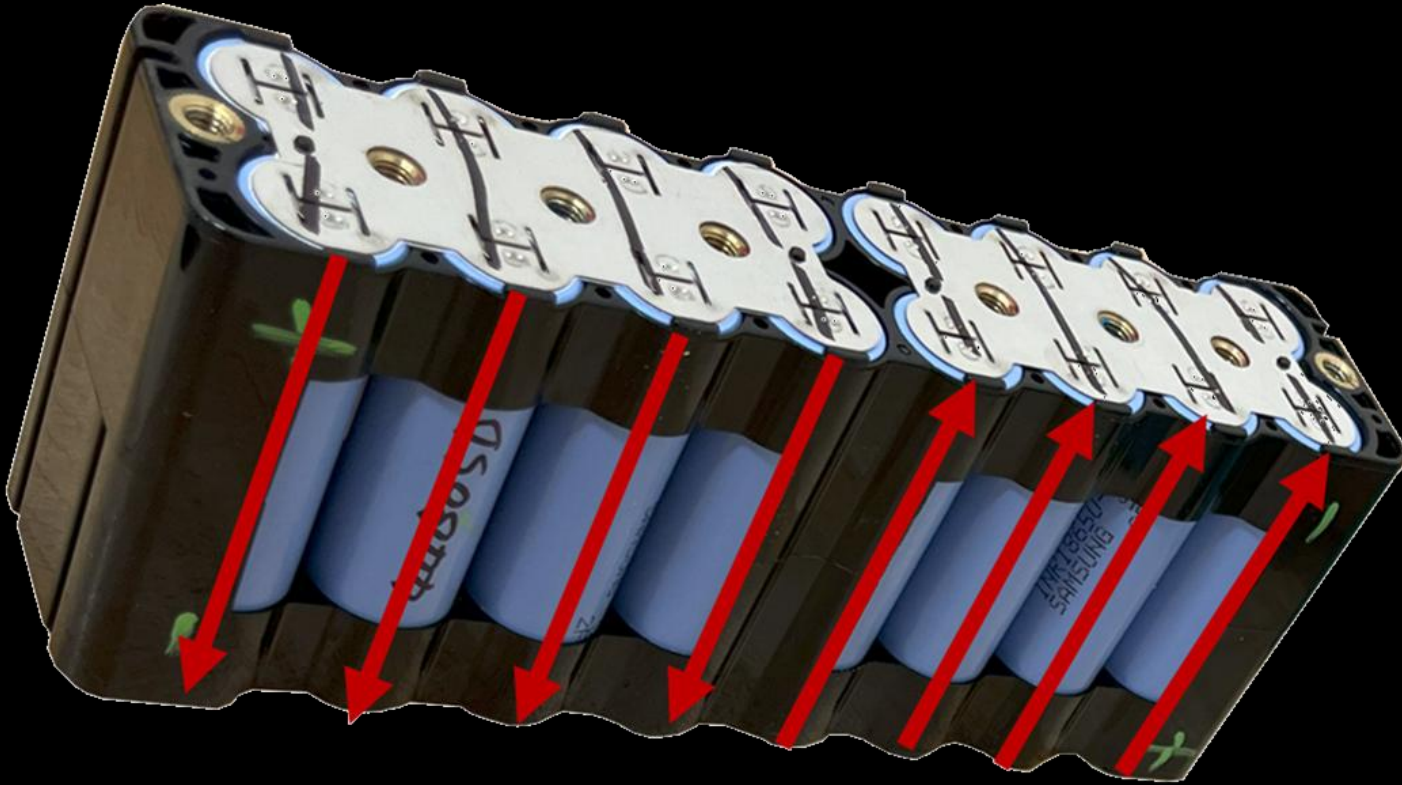
Series Connections to Build Voltage

- Voltage increases
- Amp hour stays the same



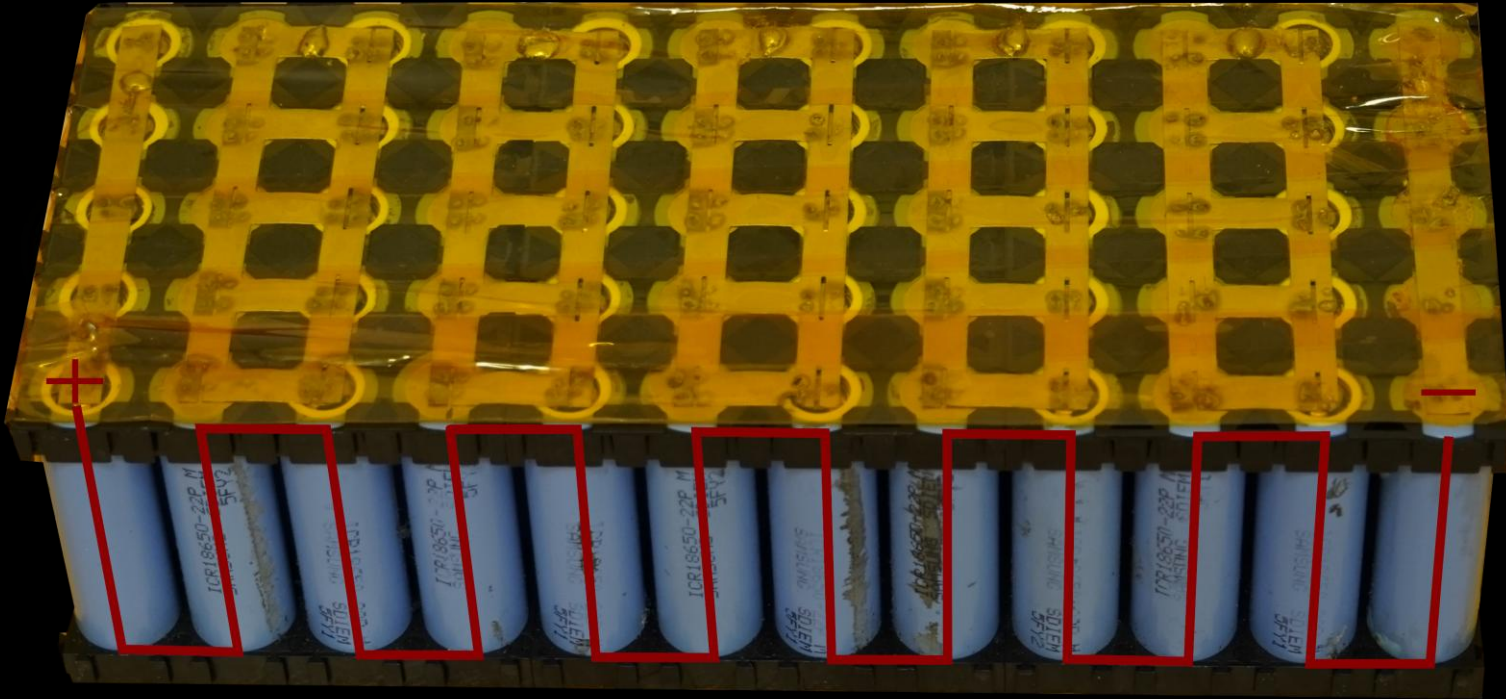
Parallel connections to increase capacity

- Voltage remains the same
- Amp hour increases



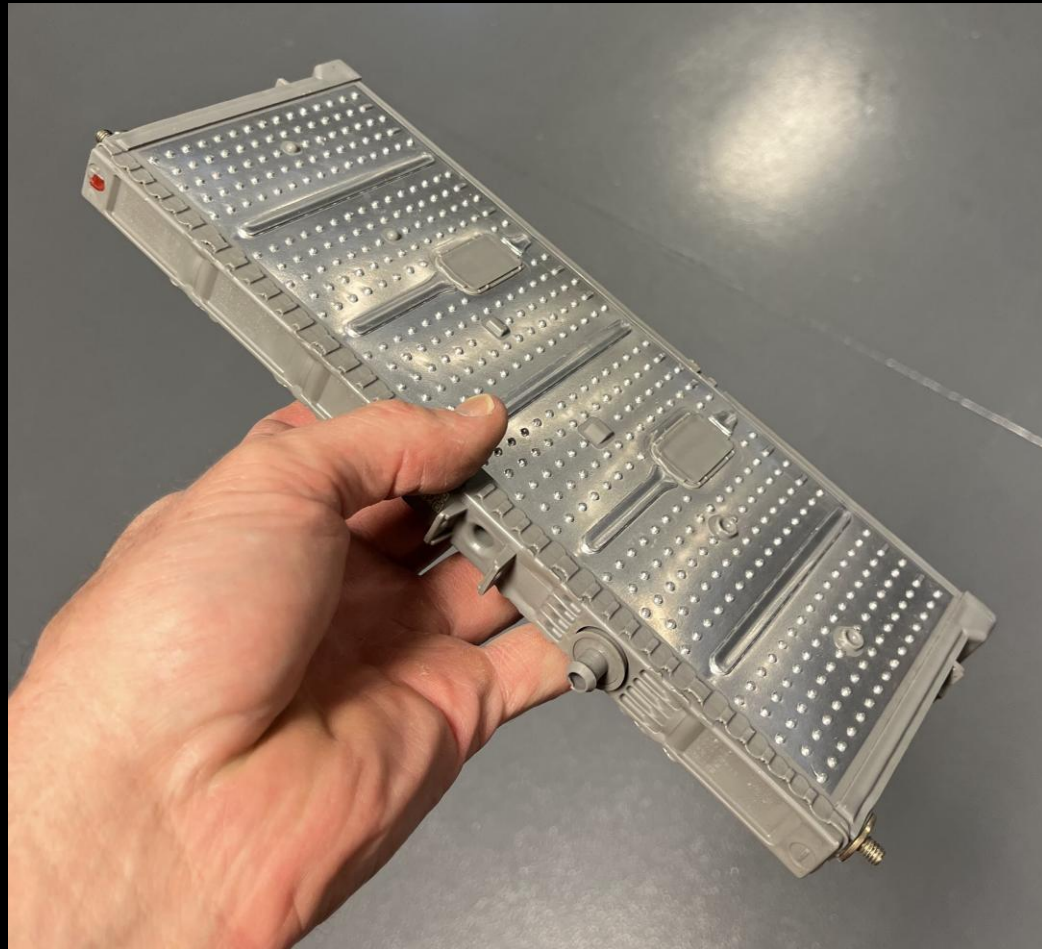
Series Parallel to increase voltage and capacity

- Voltage increases
- Amp hour increases



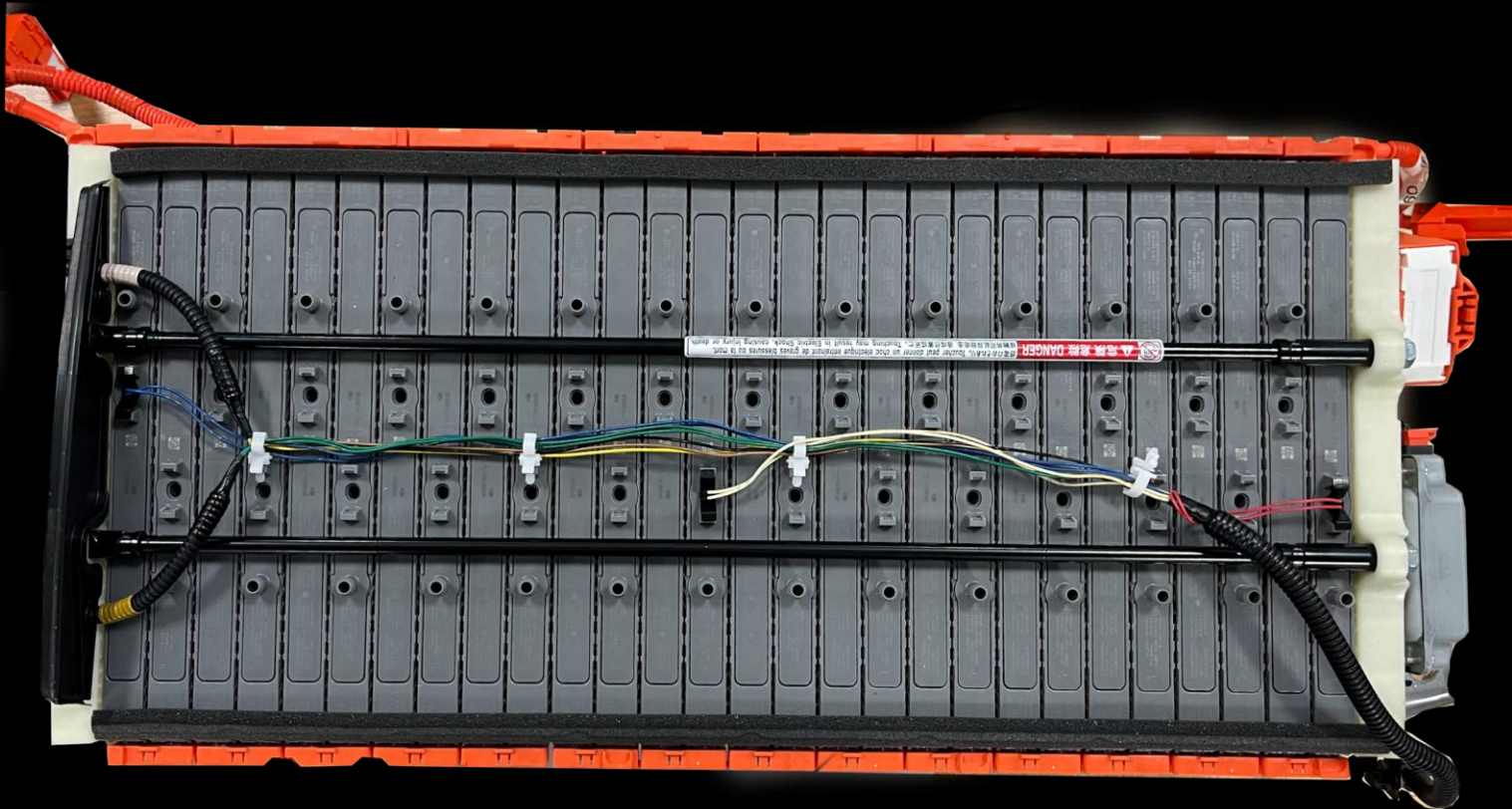
Hybrid Batteries - NiMH

- Series connections
- Cells – Modules – Blocks
 - NiMH Cells aren't balanced independently
 - Blocks are balanced



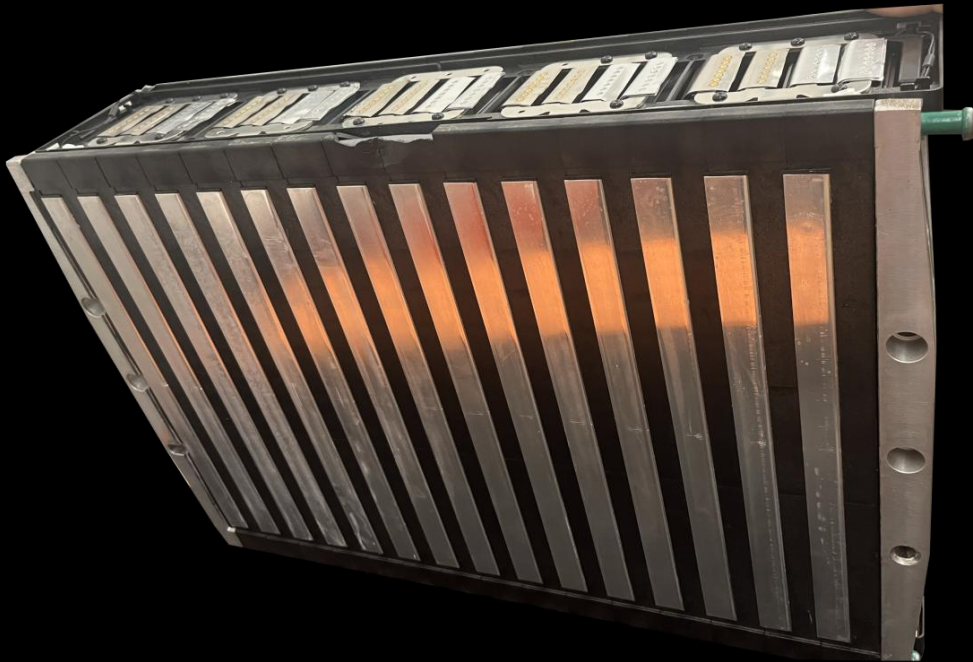
Hybrid battery

- Need high voltage but relatively low capacity



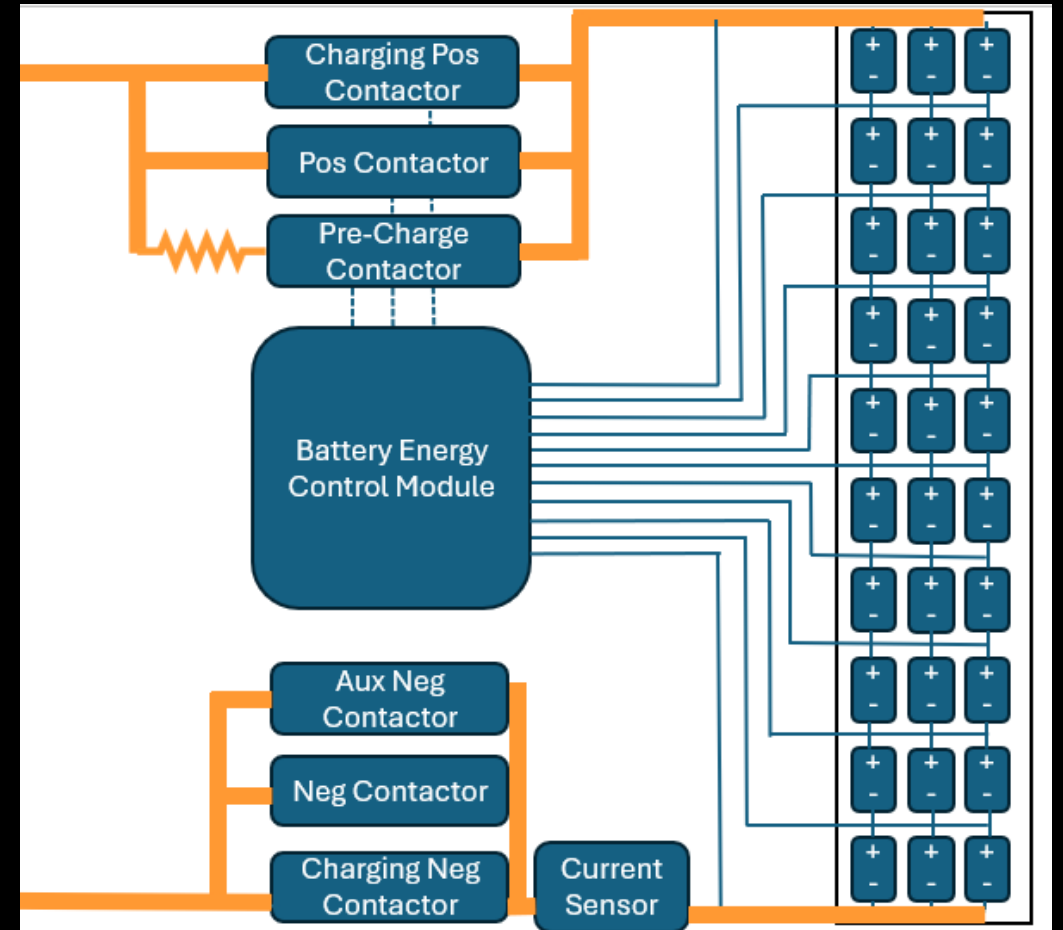
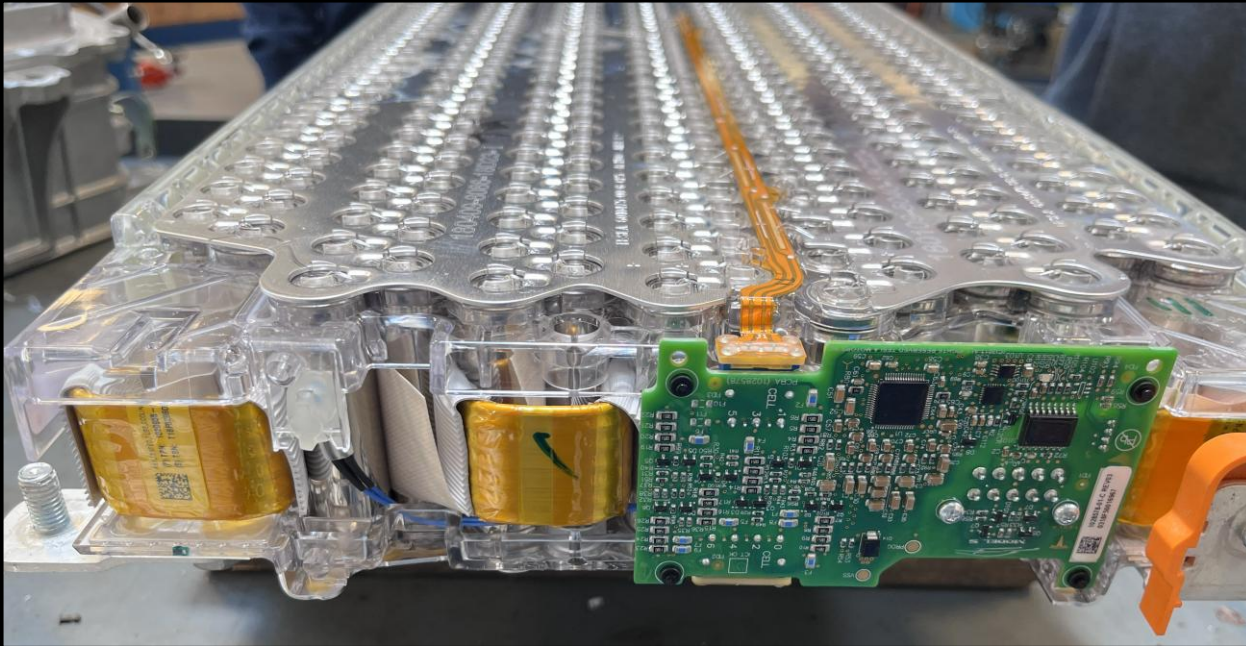
HV Battery Configuration

- Parallel connection of modules
- Cooling plates
- Battery Management System (BMS)



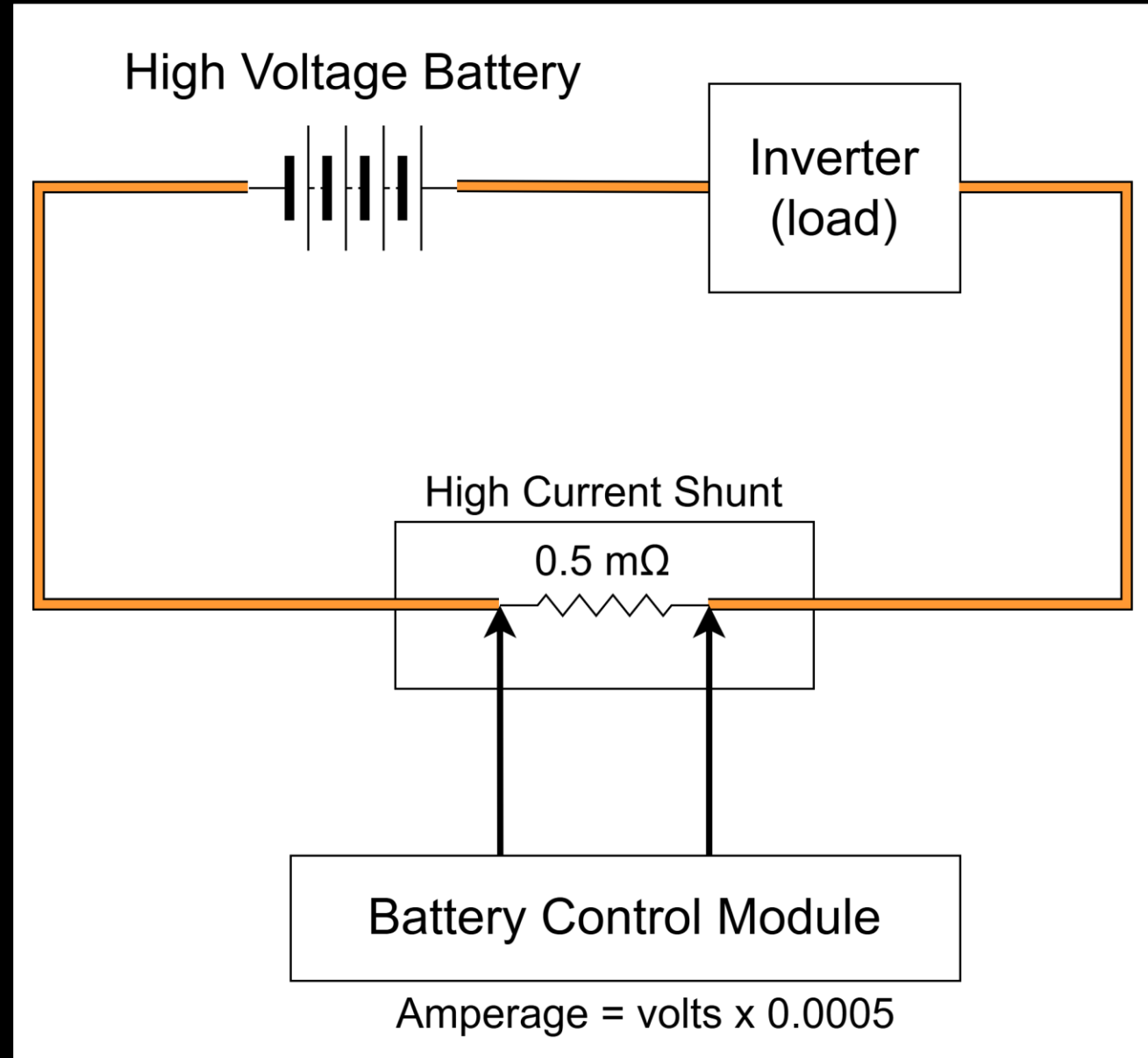
Battery Balancing

- Balance board on Model S



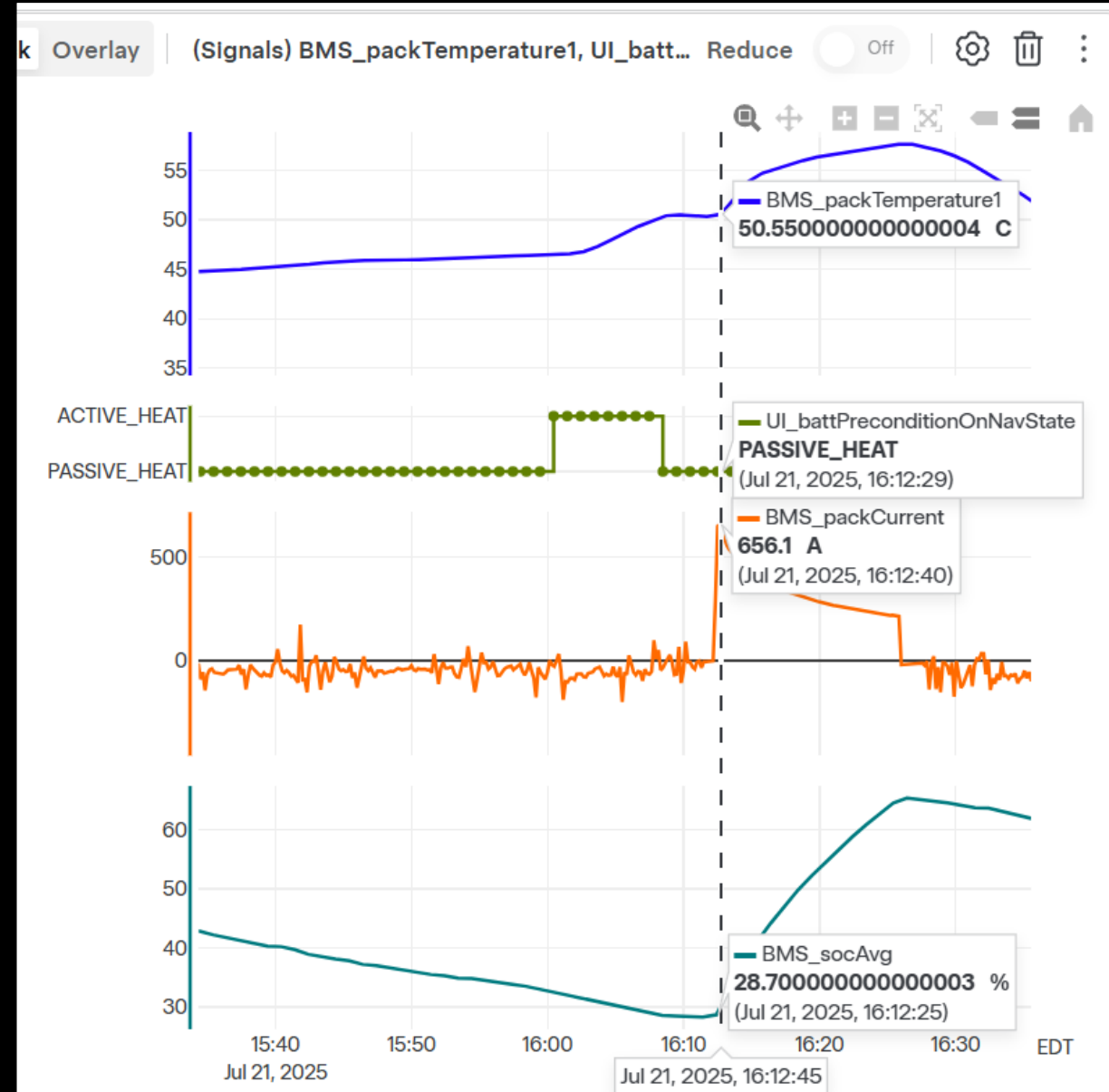
BMS -Current Monitor

- Shunt – Calculate current from voltage drop
- Hall-effect Sensor – Calculate current from sensor input

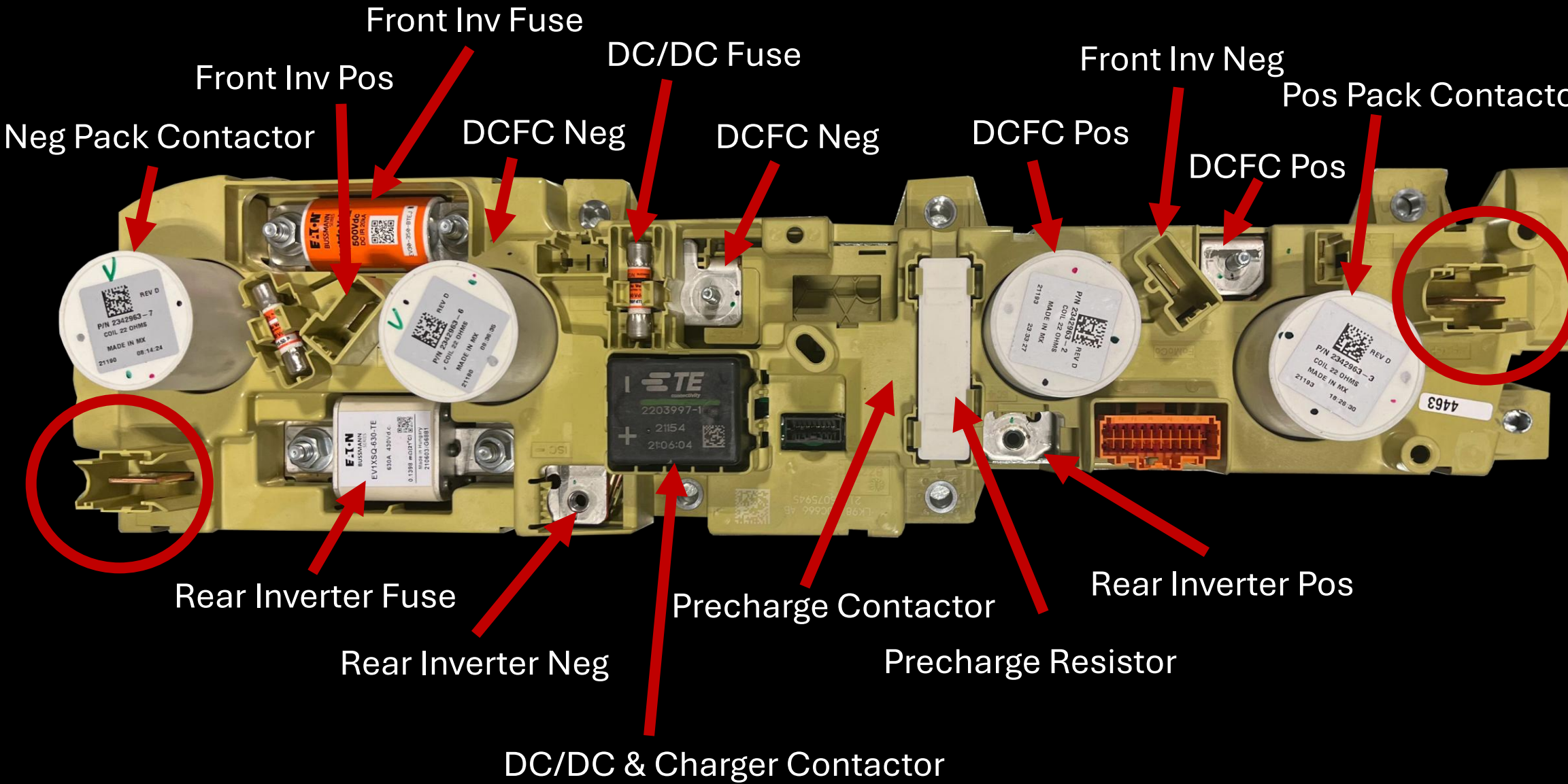


BMS – Battery Temp

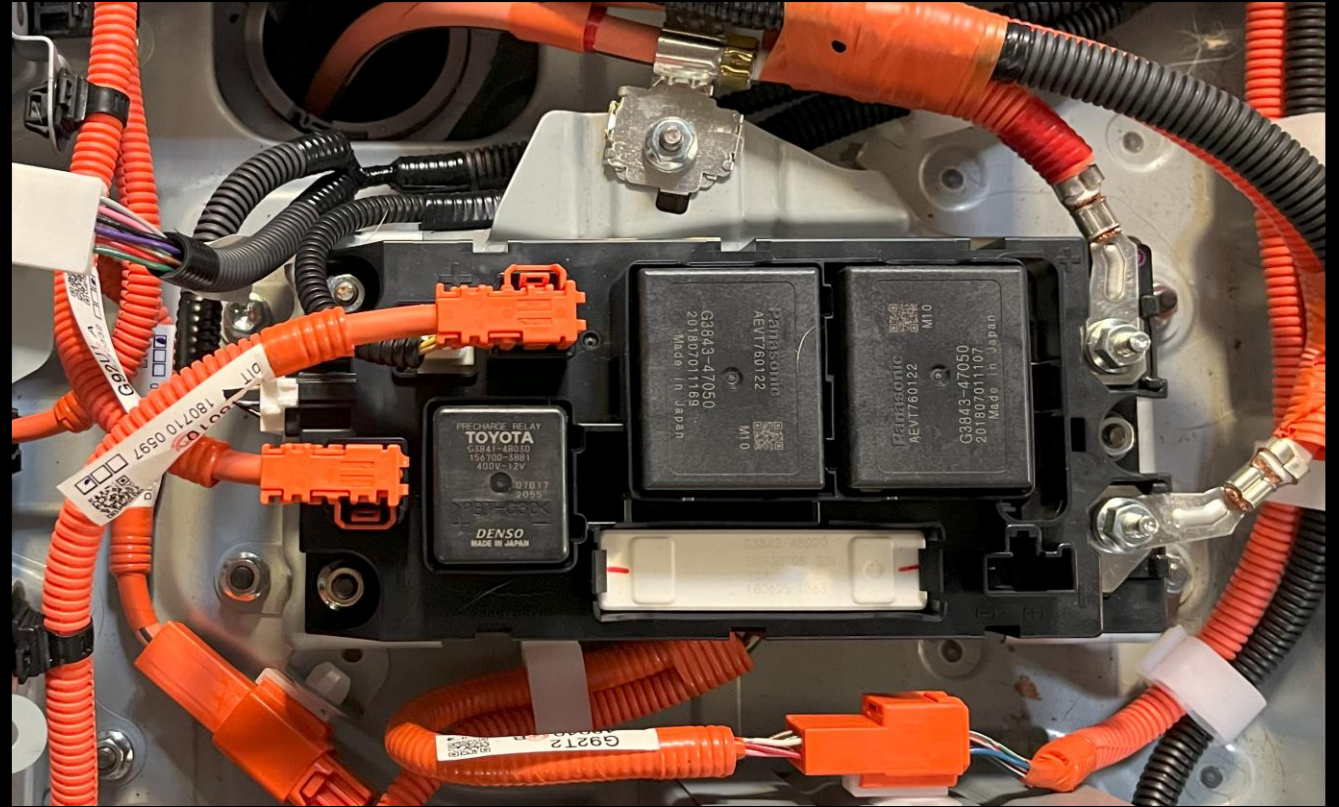
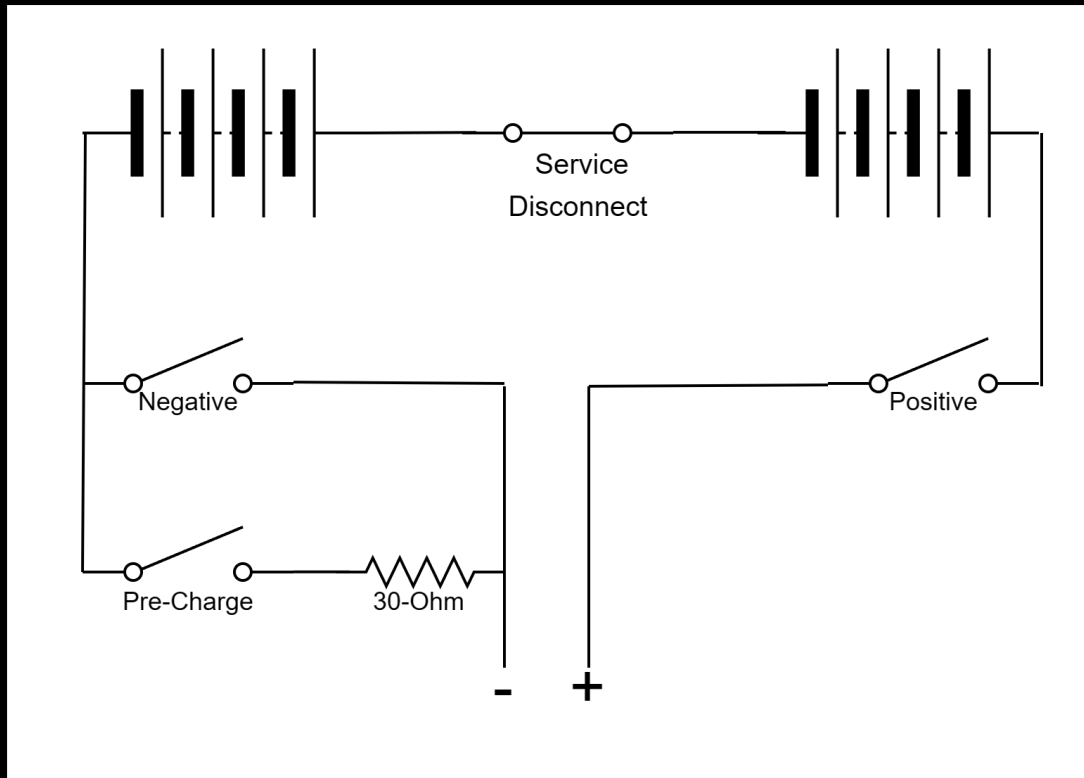
- Control cooling to maintain proper battery temp
 - Warm battery for DCFC
 - Cool battery for battery health

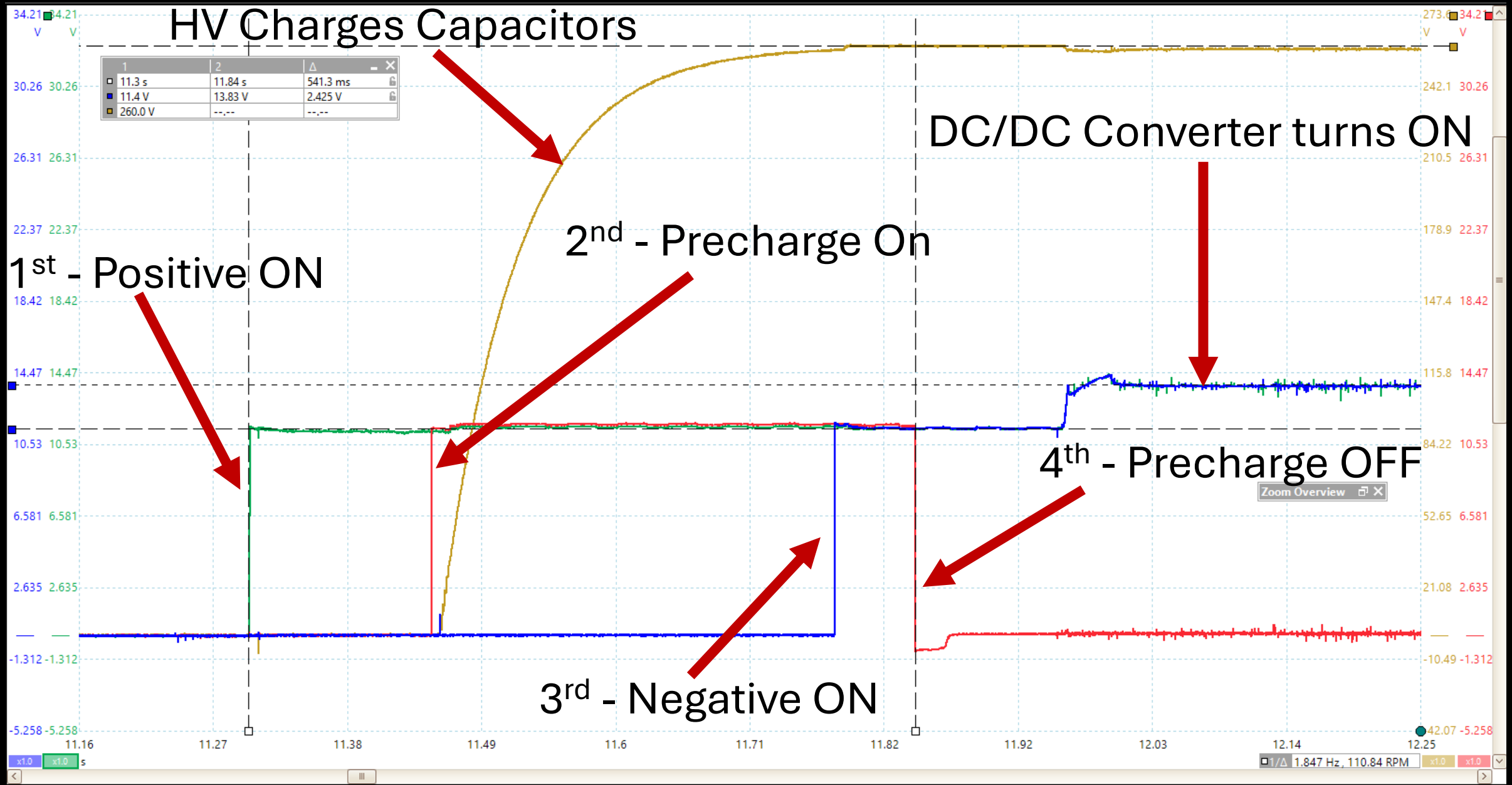


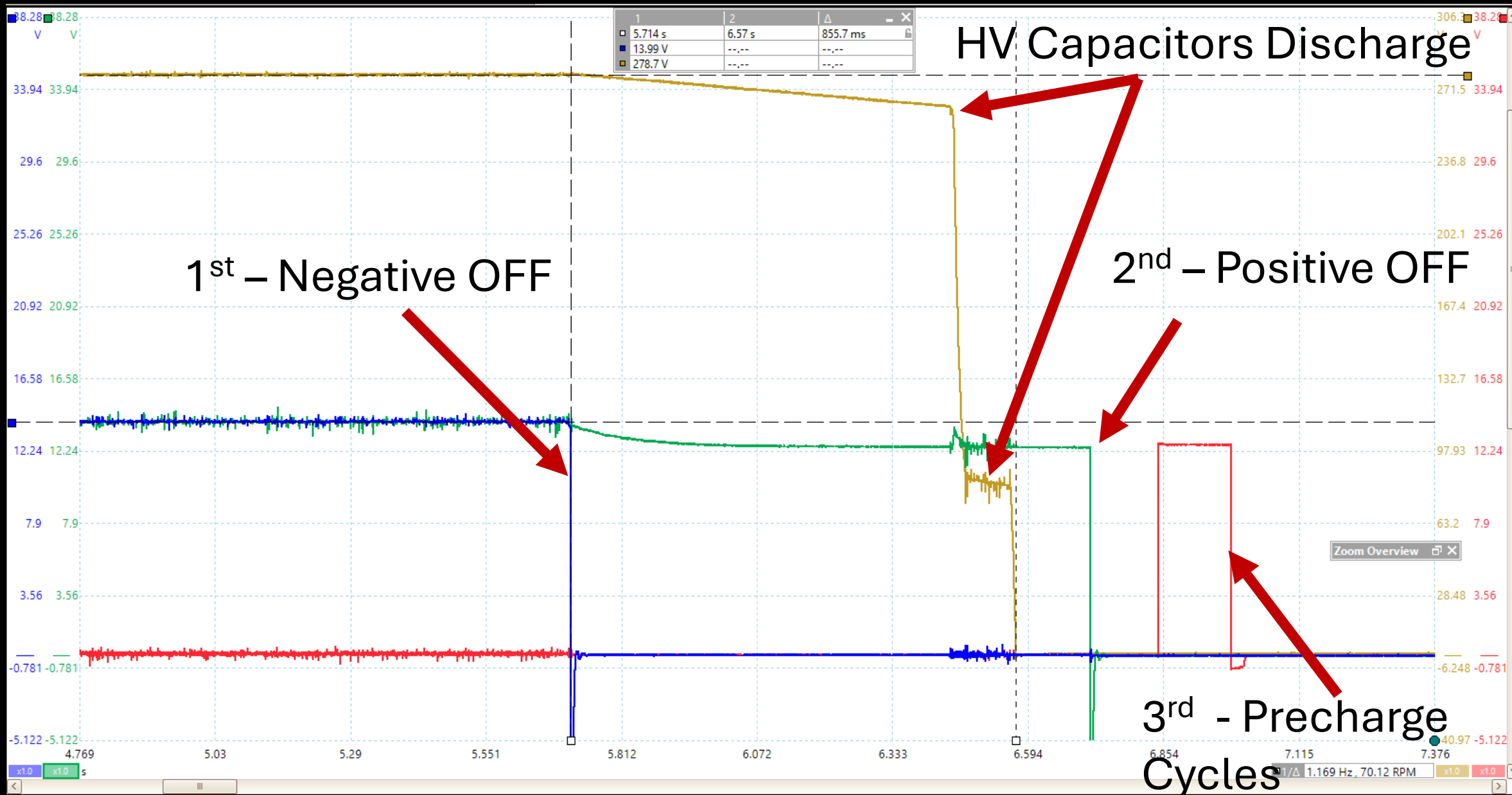
BMS – Contactor Control



Toyota Rav 4 Contactors

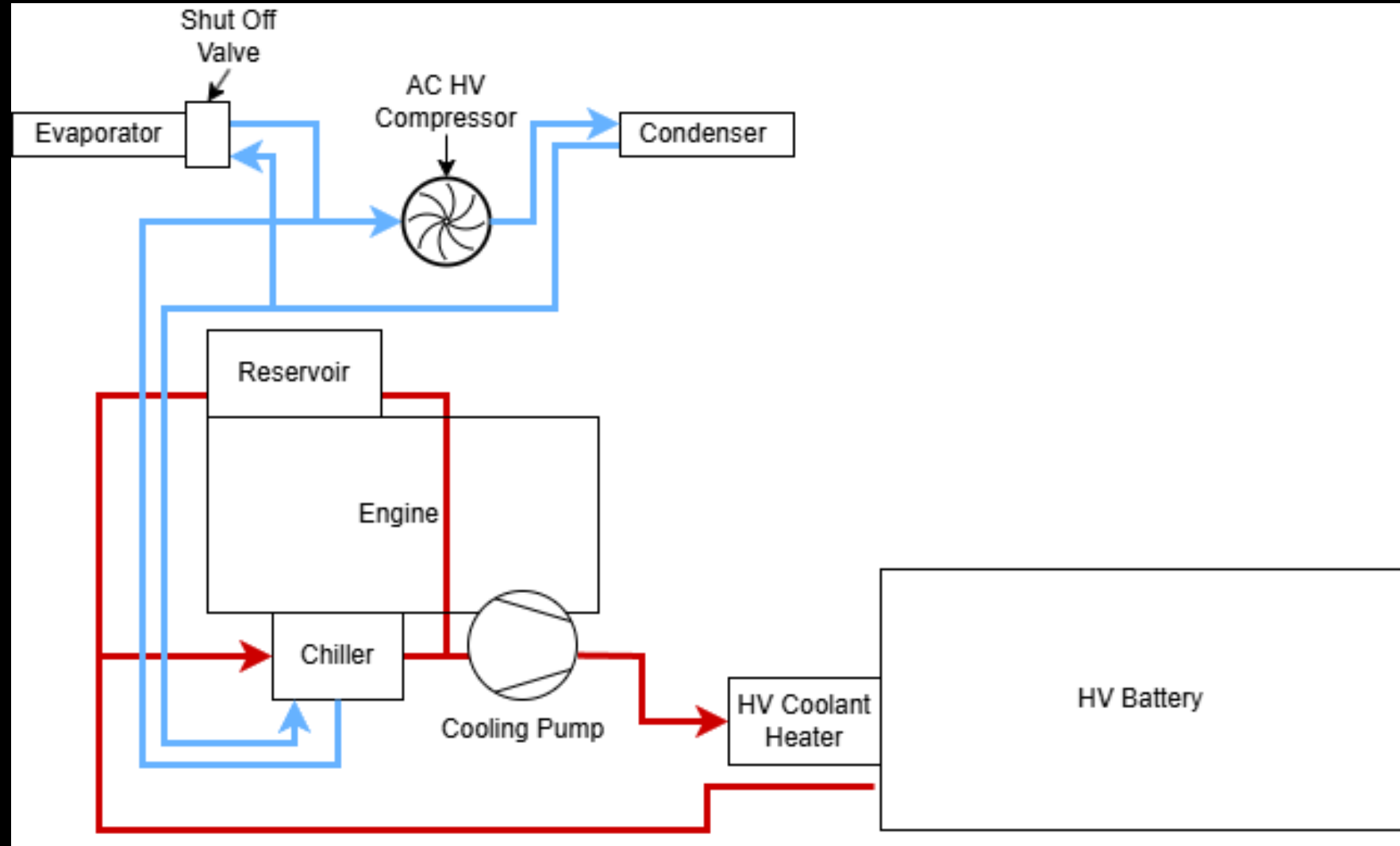






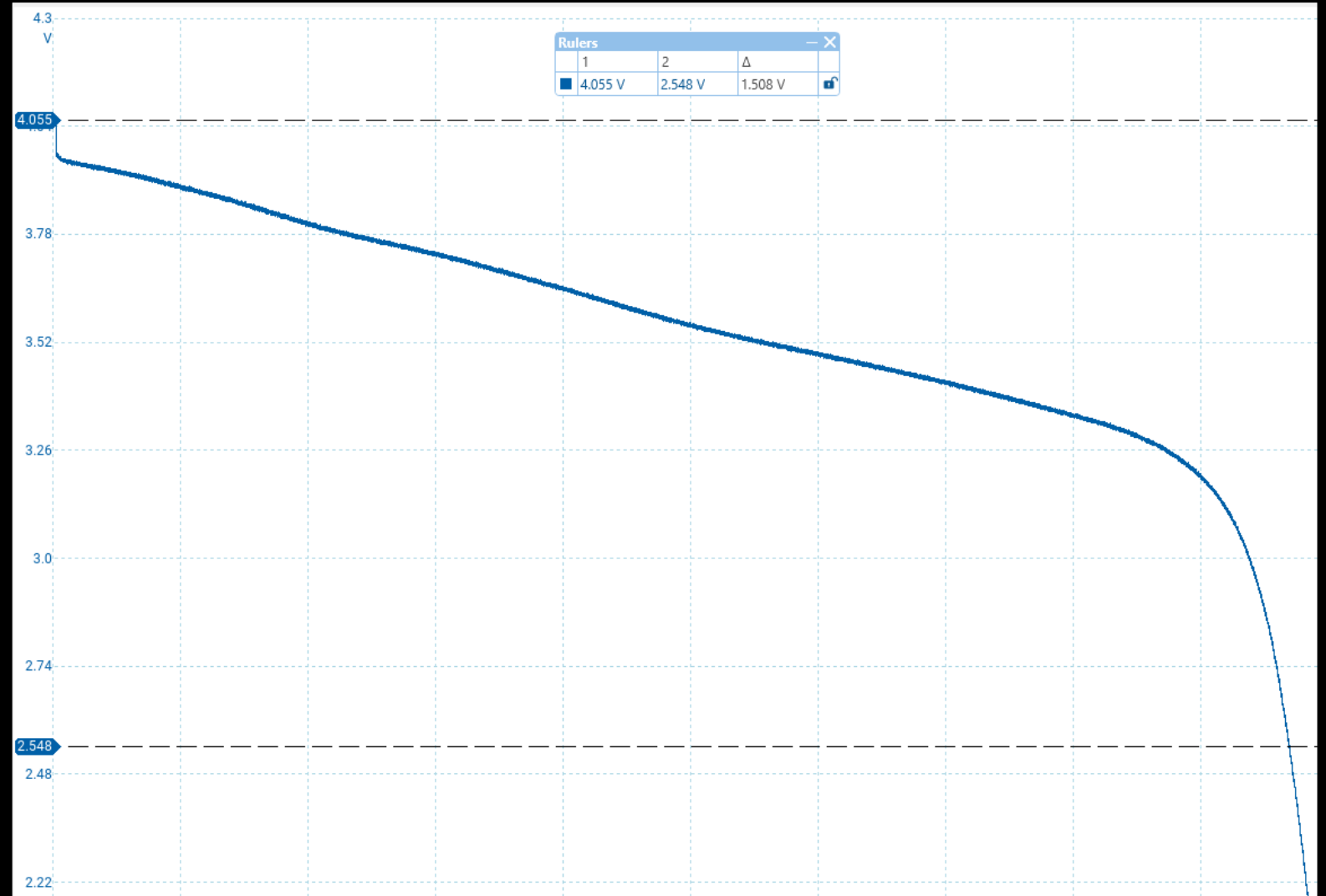
BMS - HV Battery Cooling

- Hybrid – Air Cooled
- BEV & PHEV – Liquid Cooled
- Electric Pump
- Chiller – Liquid to Refrigerant Heat Exchanger



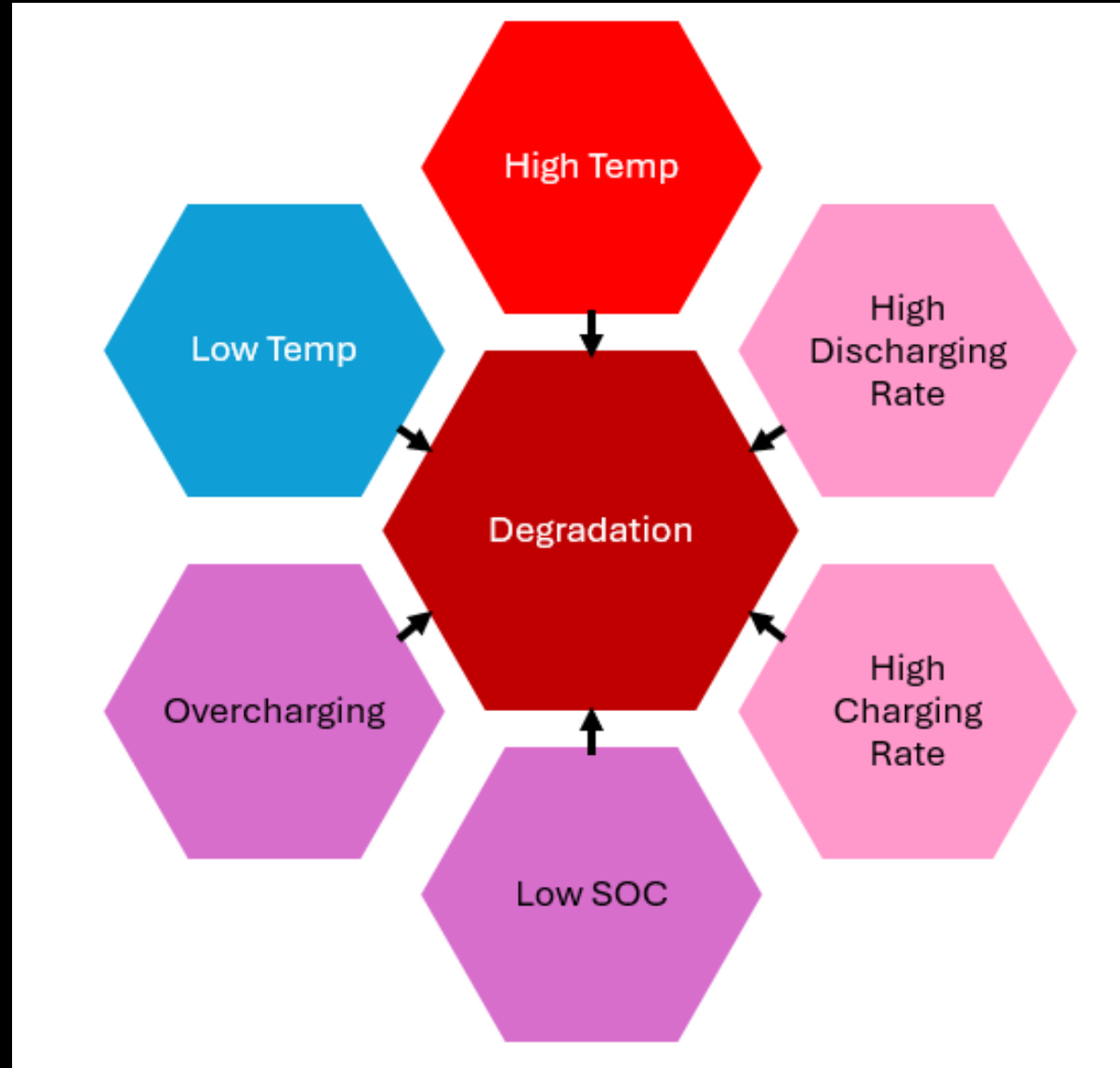
BMS – State of Charge Calculation

- Voltage slope is gradual with steep climb when charged and sharp drop when discharged



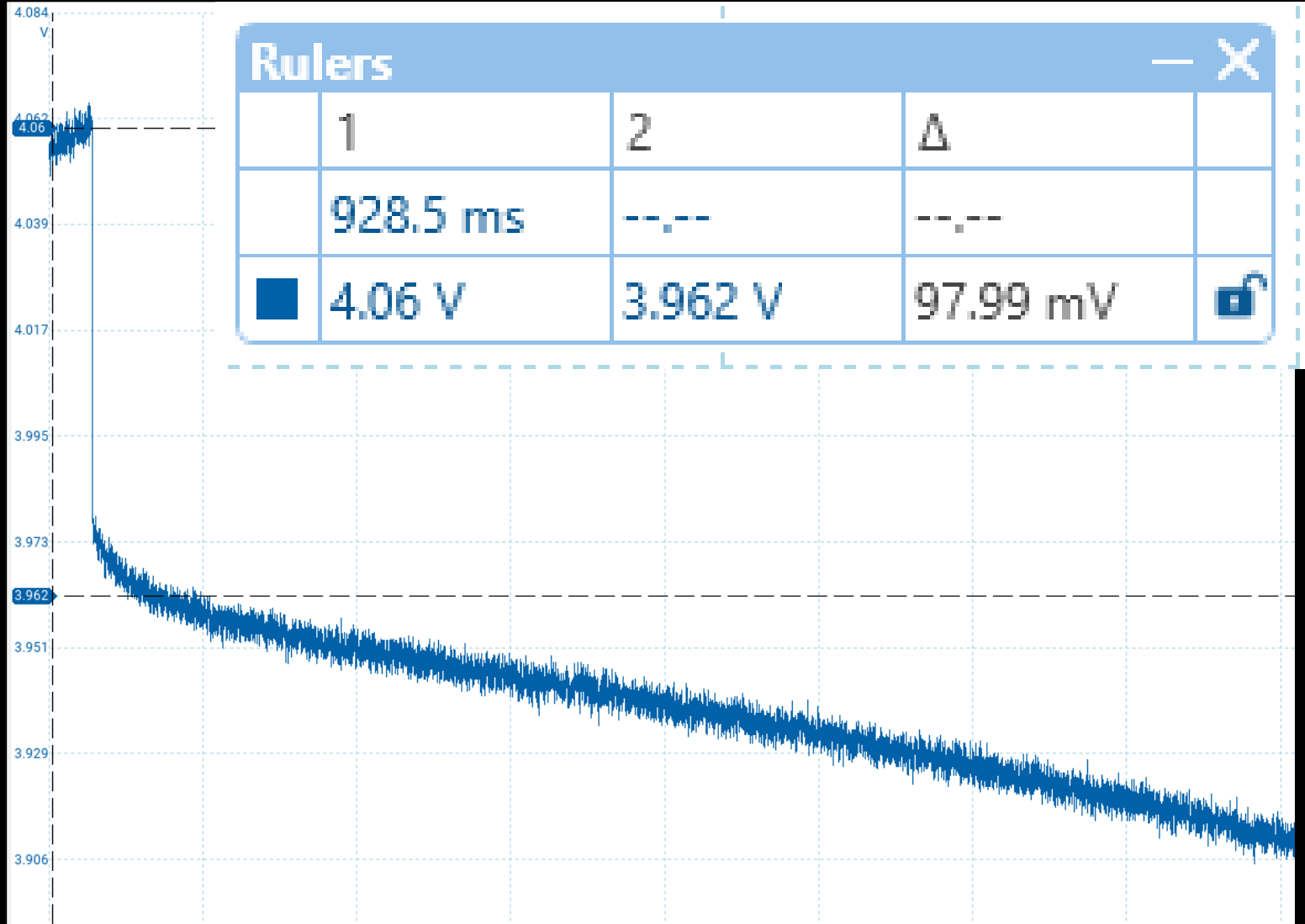
HV Battery Degradation

- High temperatures
- High SOC
- Low SOC



BMS – Calculates Internal Resistance

- Voltage drop under load divided by the current indicates internal resistance
 - Example, single cell displaying a 97mV drop while passing 2.5 amps (1c) = 39 milliohm cell resistance



Are you concerned about servicing High Voltage Batteries in your shop?

Yes, keep them out

0

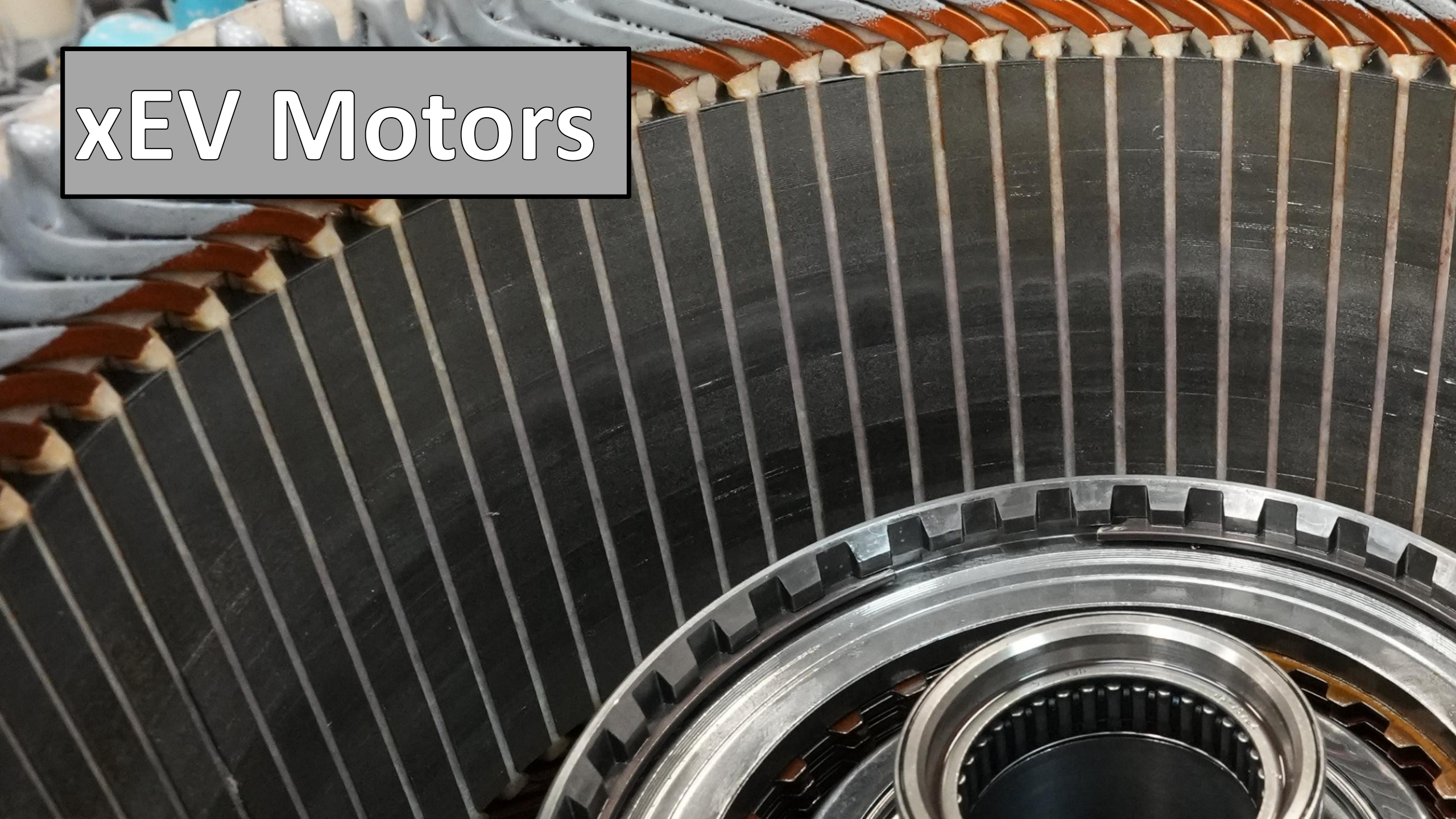
No, but only smaller, like hybrids

0

No, we welcome all xEVs

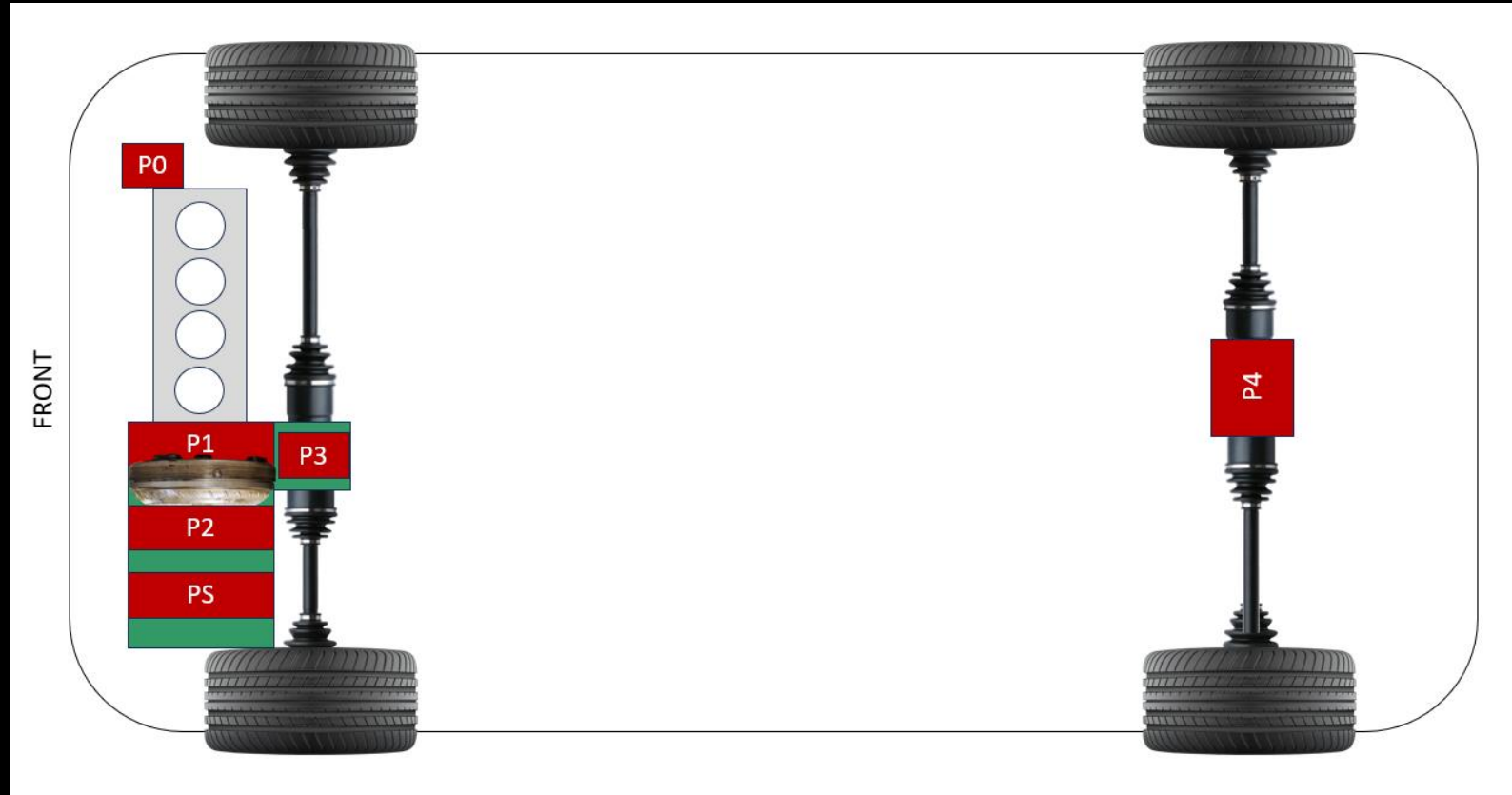
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xEV Motors



Motor Configuration

- SAE Designations
 - HEV/PHEV
 - P0 – BAS design
 - P1 – between engine and converter/flywheel
 - P2 – between converter and engine
 - PS – Two Motor/Generators in Transmission
 - P3 – After transmission
 - P4 – AWD Motor
 - BEV – Standalone



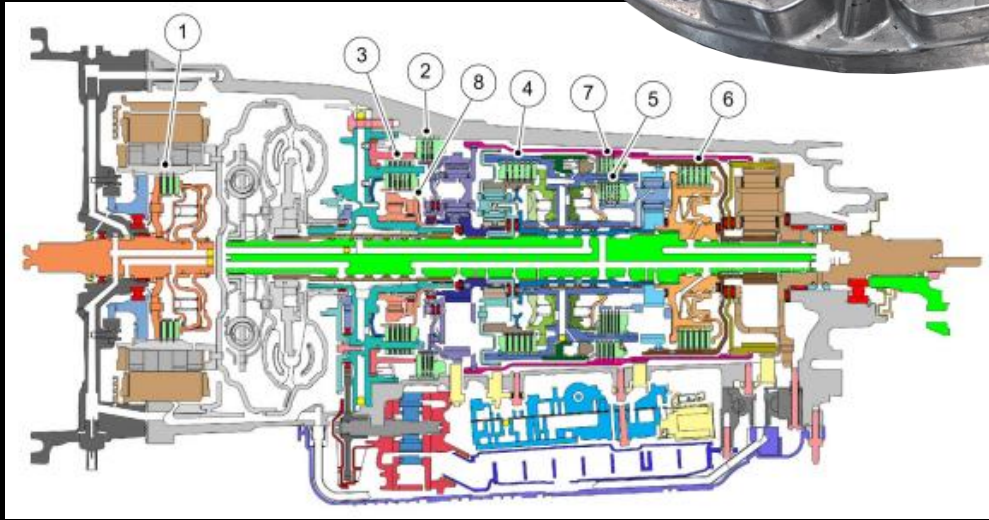
P0 – Ram eTorque

- Mild hybrid
 - Assists engine
 - Starter
 - Alternator
 - Regen



P2 – Ford F150 Hybrid

- Torque converter
- Clutch
 - Start engine
 - Alternator
 - Propel Vehicle
 - Regen



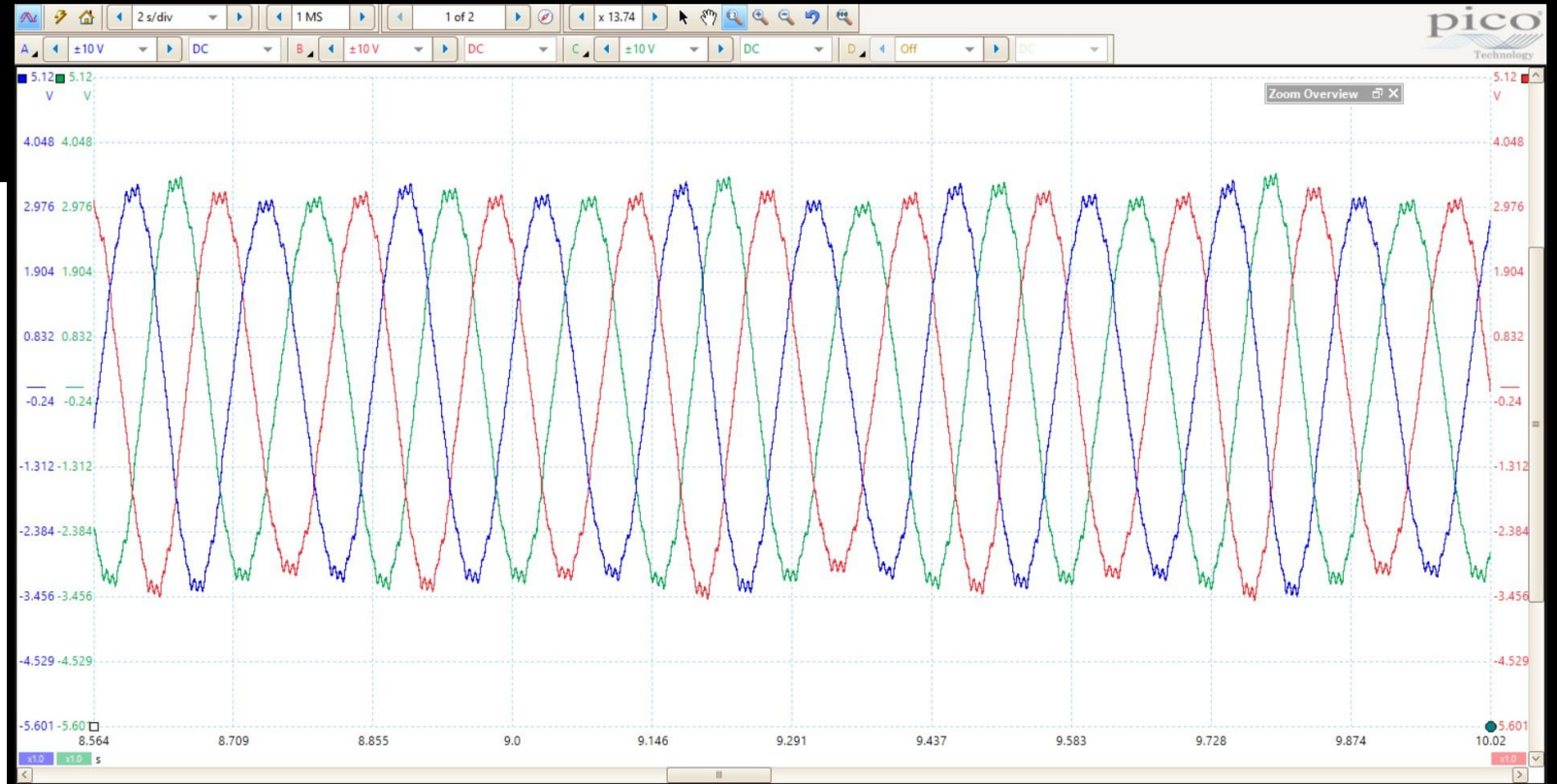
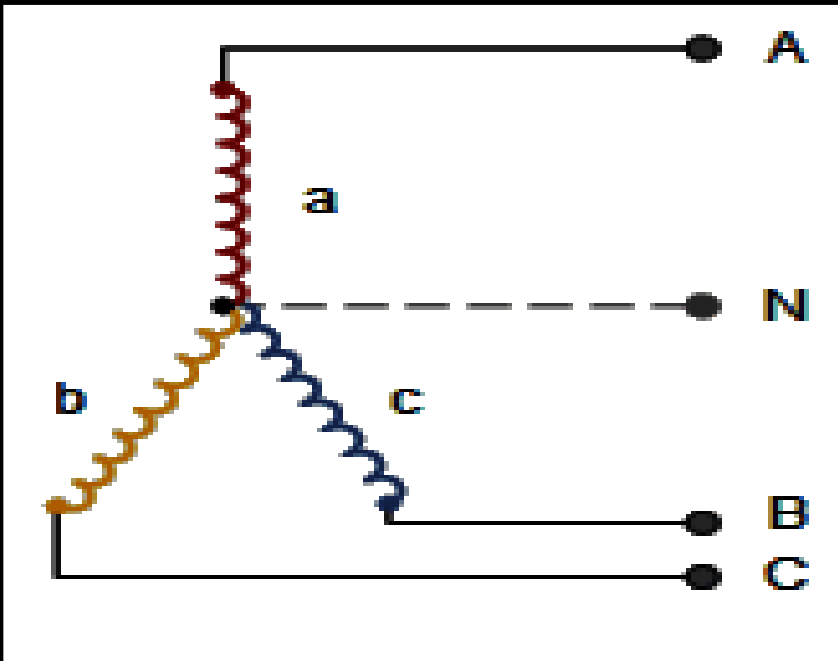
BEV

- Rotor
 - Induction Motor (IM)
 - Permanent Magnet Motor (IPM)
 - Wound Synchronous Motor (WSM)
- Stator
 - Distributed Windings
 - Bar
 - Stranded
 - Concentrated Windings



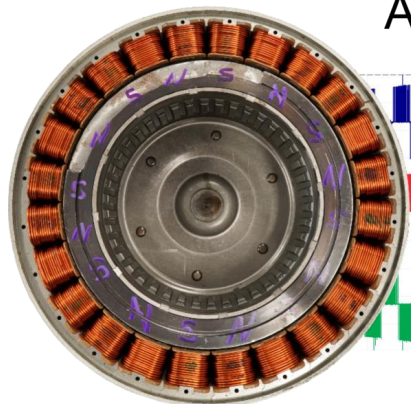
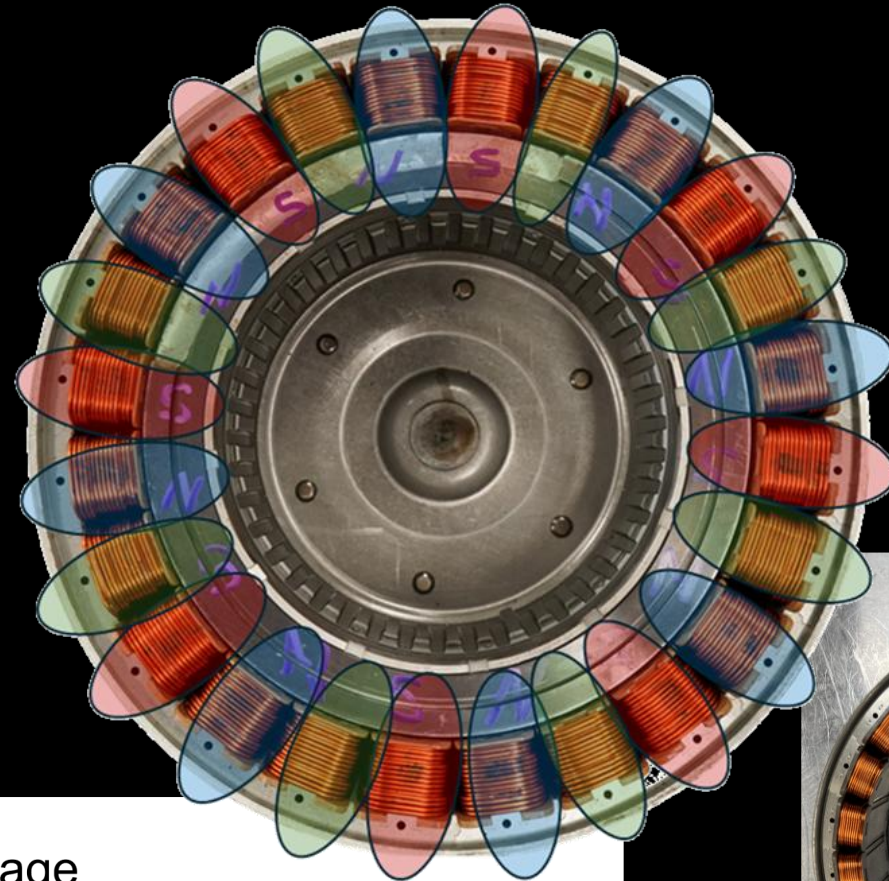
Motor – 3 Phase Operation

- Three Phases
 - 120 apart
 - Y-wound config



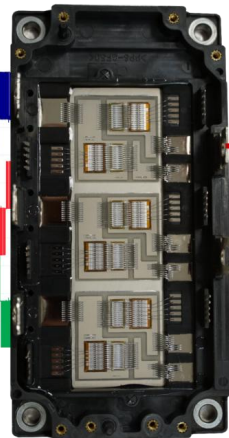
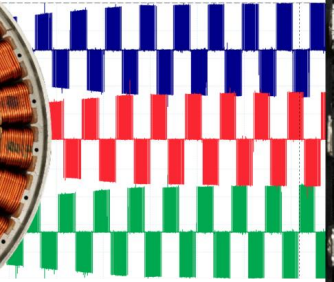
Rotating Magnetic Field

- Inverter generates a digital AC voltage to create a rotating magnetic field that switches between North and South Poles



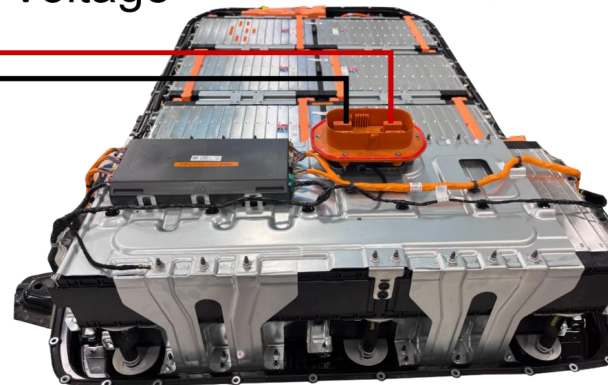
AC Motor

AC Voltage



AC/DC Inverter

DC Voltage

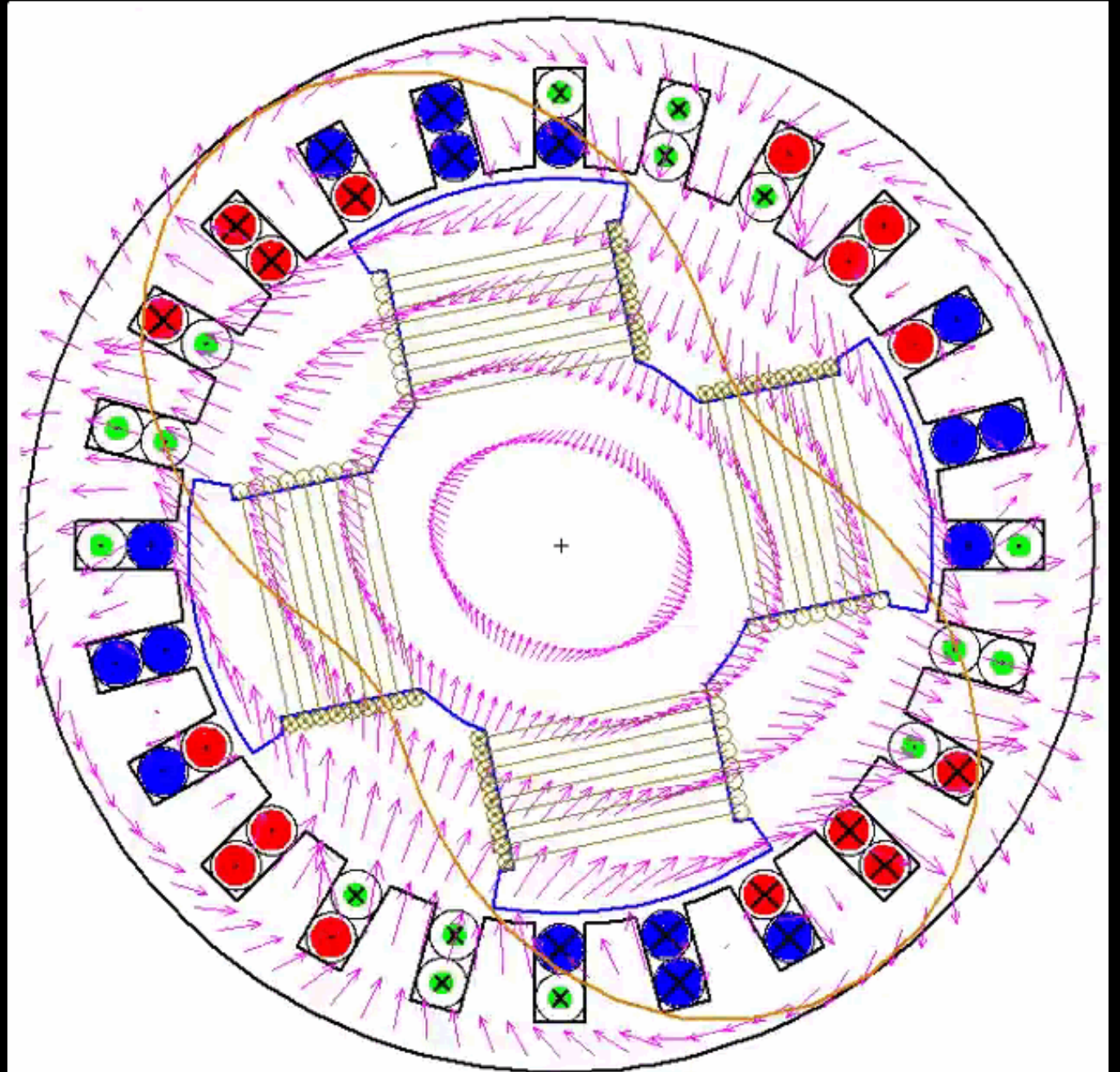


High Voltage DC Battery



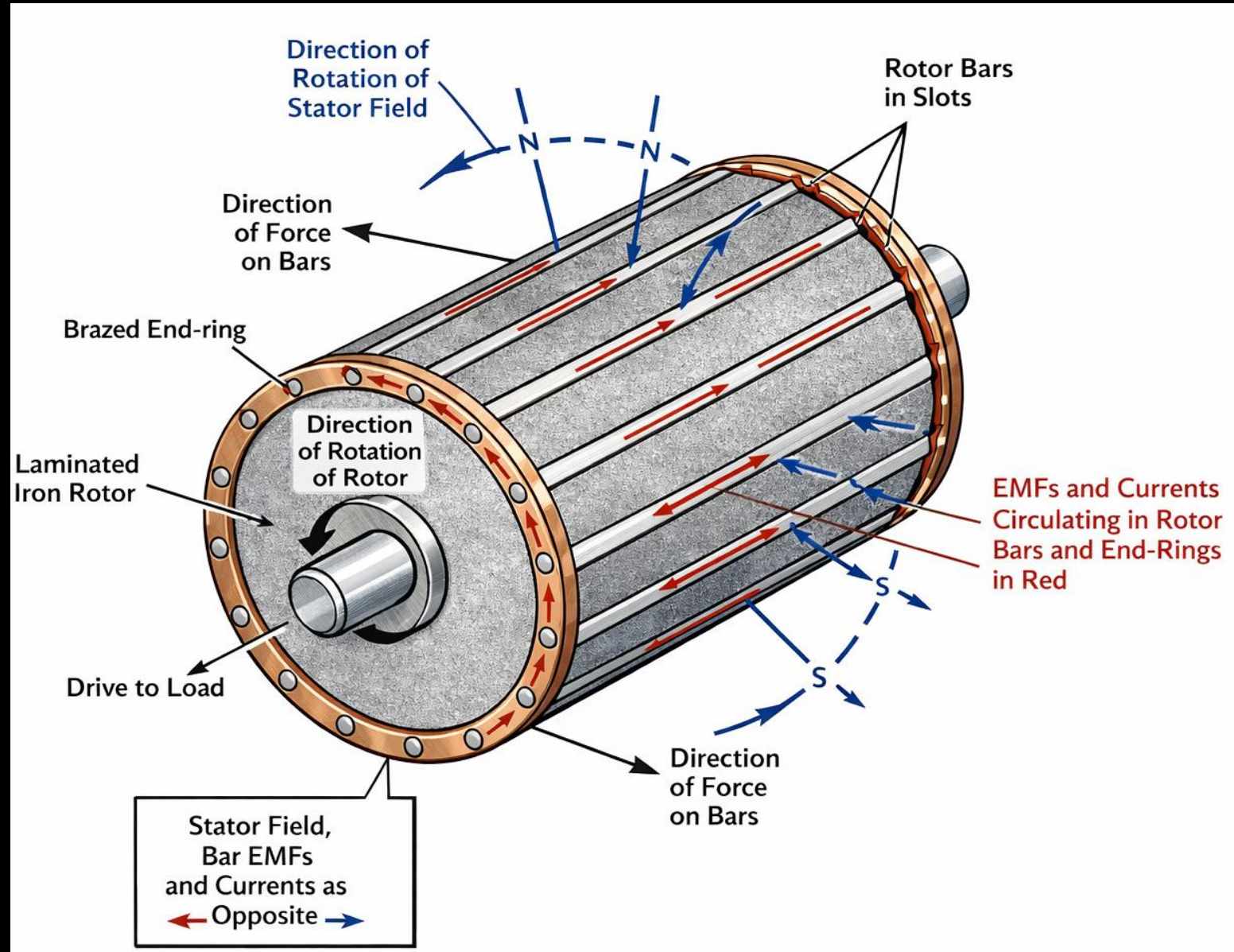
Motors - RMF

- Arrows cycling around the stator show the magnetic flux lines
- Color show the 4 sets of windings for each phase
- “X” and “O” show the current flow changes
- Magnetic force needs to lead the rotor’s magnetic field in a Synchronous Motor



Motors - Induction

- Induction does not use permanent magnets
- RMF induces current in shorting bars, which then generate a magnet field around the shorting bars
- This magnetic field reacts with the stator's RMF
- Slip speed – percent of stator RMF above/below rotor speed



Motors - IM

- Good for high speed
- Less precise control
- No rare earth materials



Wound Synchronous Motor



- Generate an electromagnetic field within the rotor via brushes
- Nissan Aryia



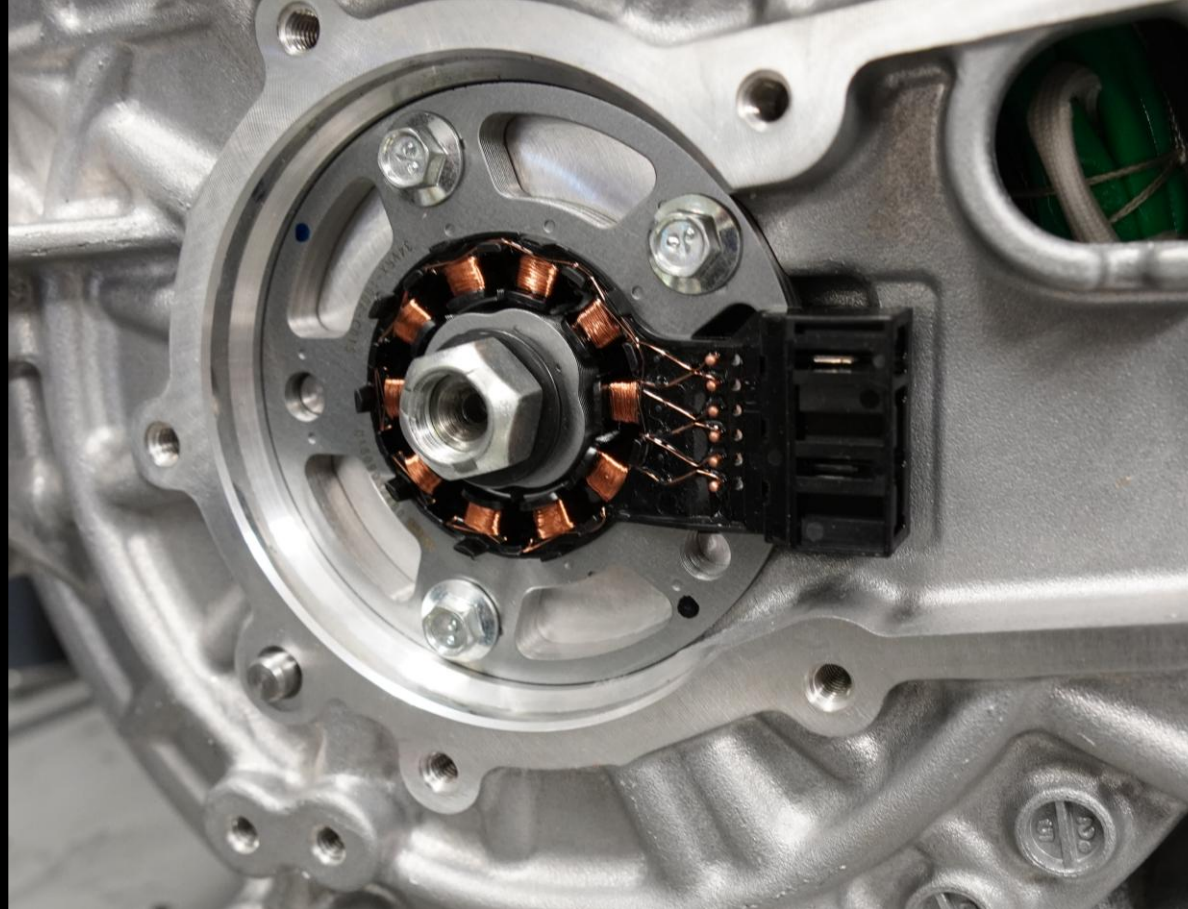
Axial Flux Motor

- Same principles, but different arrangement
- Embedded magnets in thin Rotor
- Stator Rotor Stator sandwich



Motors - Resolver

- Monitors rotor position
 - Three circuits
 - Excitation
 - Sine
 - Cosine
- Important to IPM motors to properly lead the magnets with the RMF
- Calibration



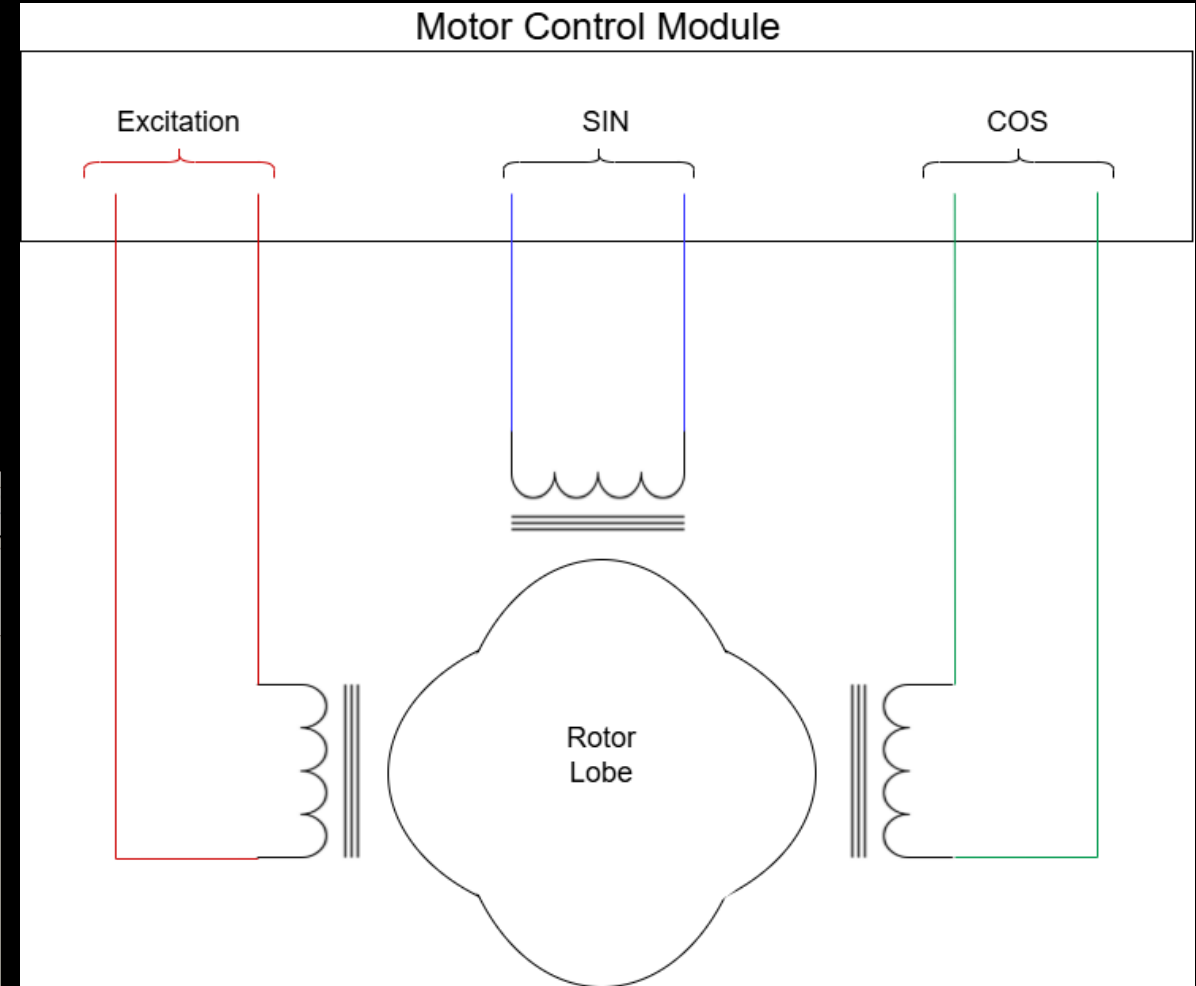
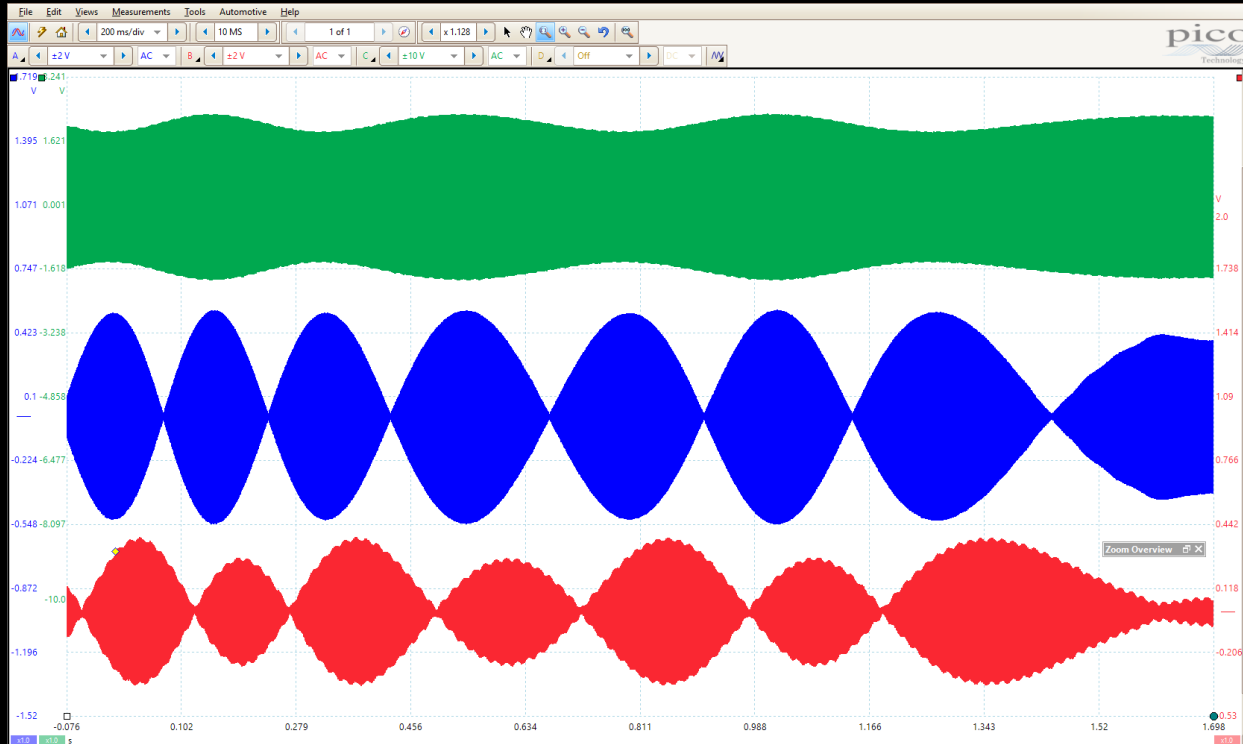
Motors - Resolver

- Non-contact
- Lobes operating within the resolver's windings change how the excitation winding influences the sine and cosine



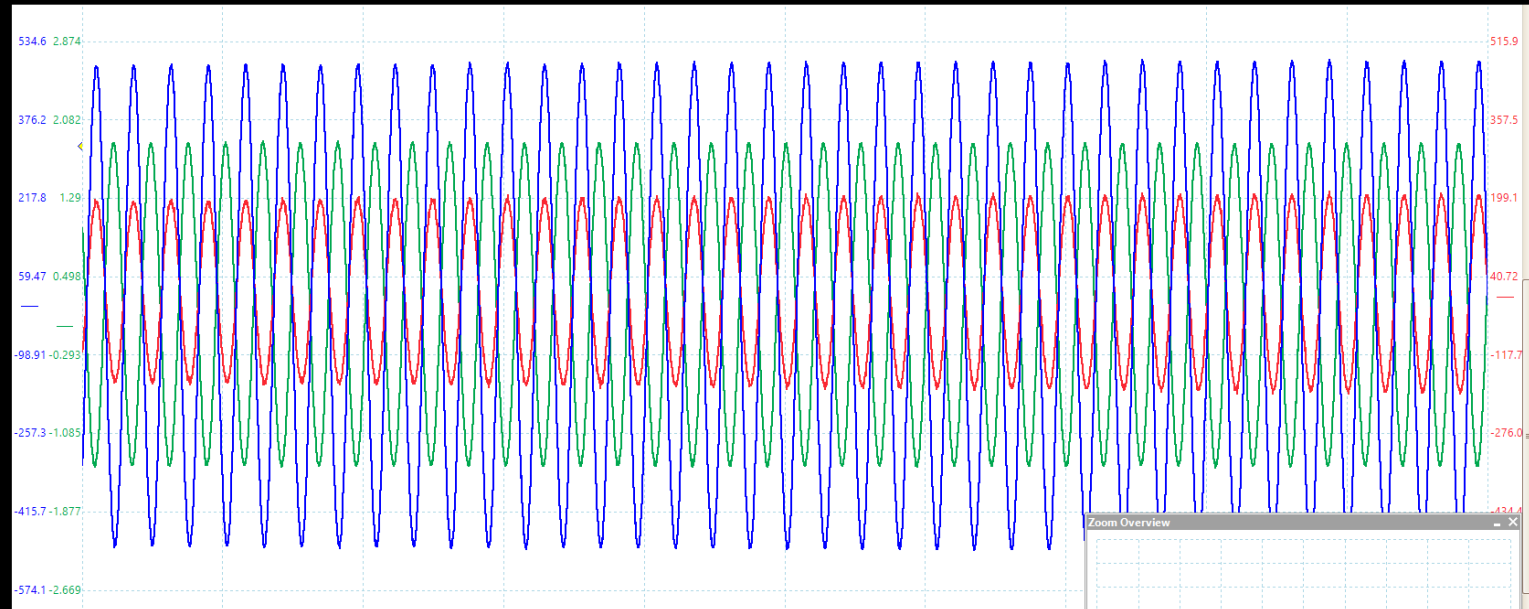
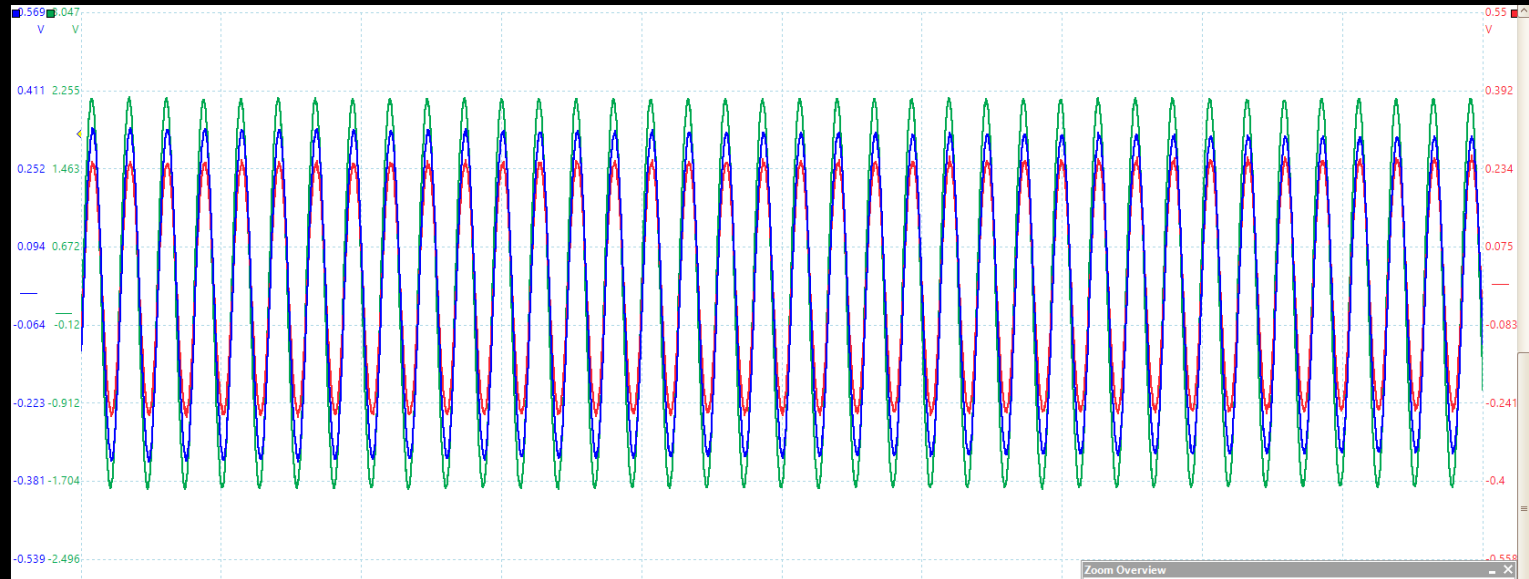
Motor - Resolver

- Green - Excitation
- Blue – Sine
- Red - Cosine



Motors - Resolver

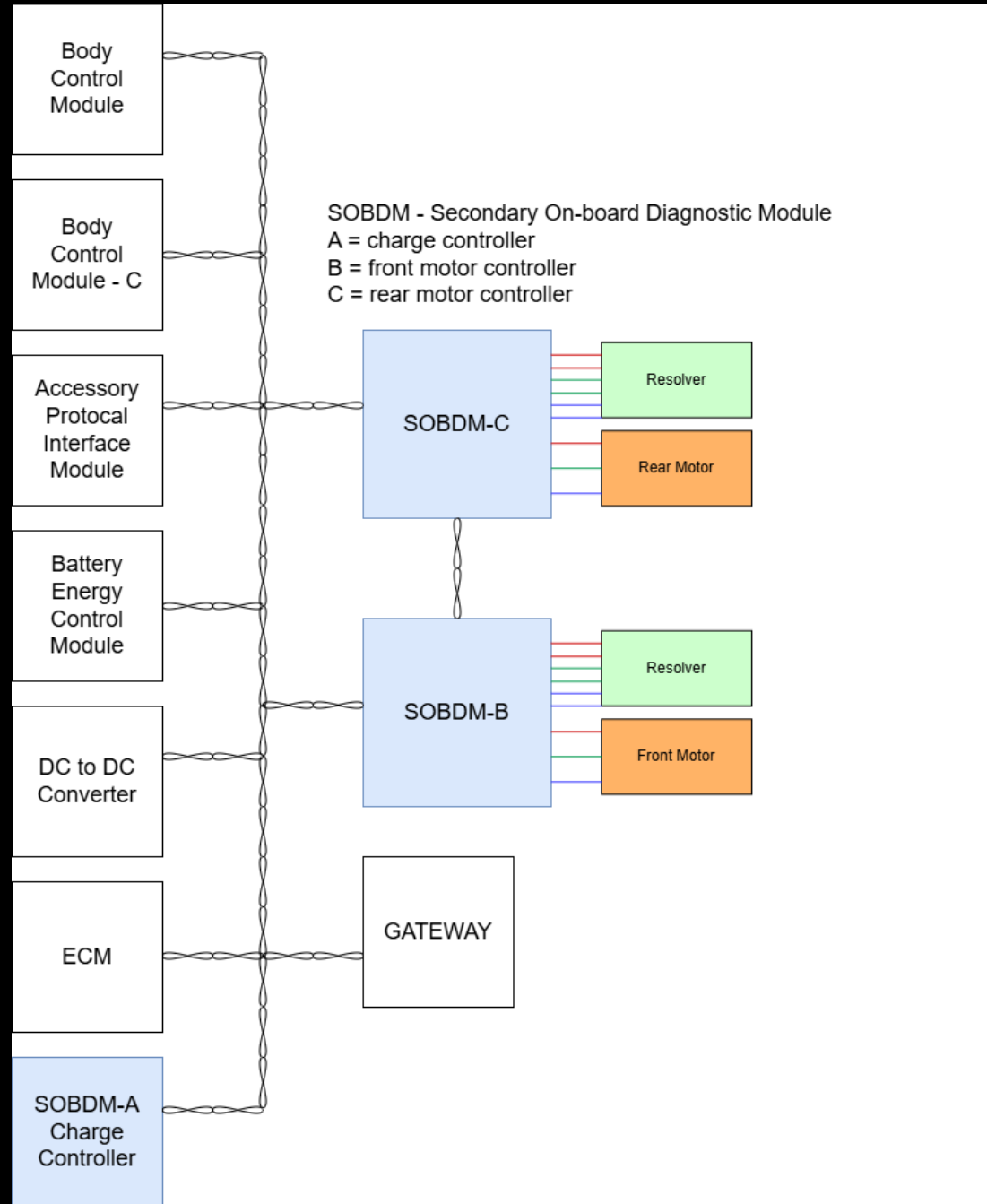
- Example rotating the motor
 - Motor control monitors sine and cosine to determine exact motor position in relation to the number of poles





Inputs/Outputs

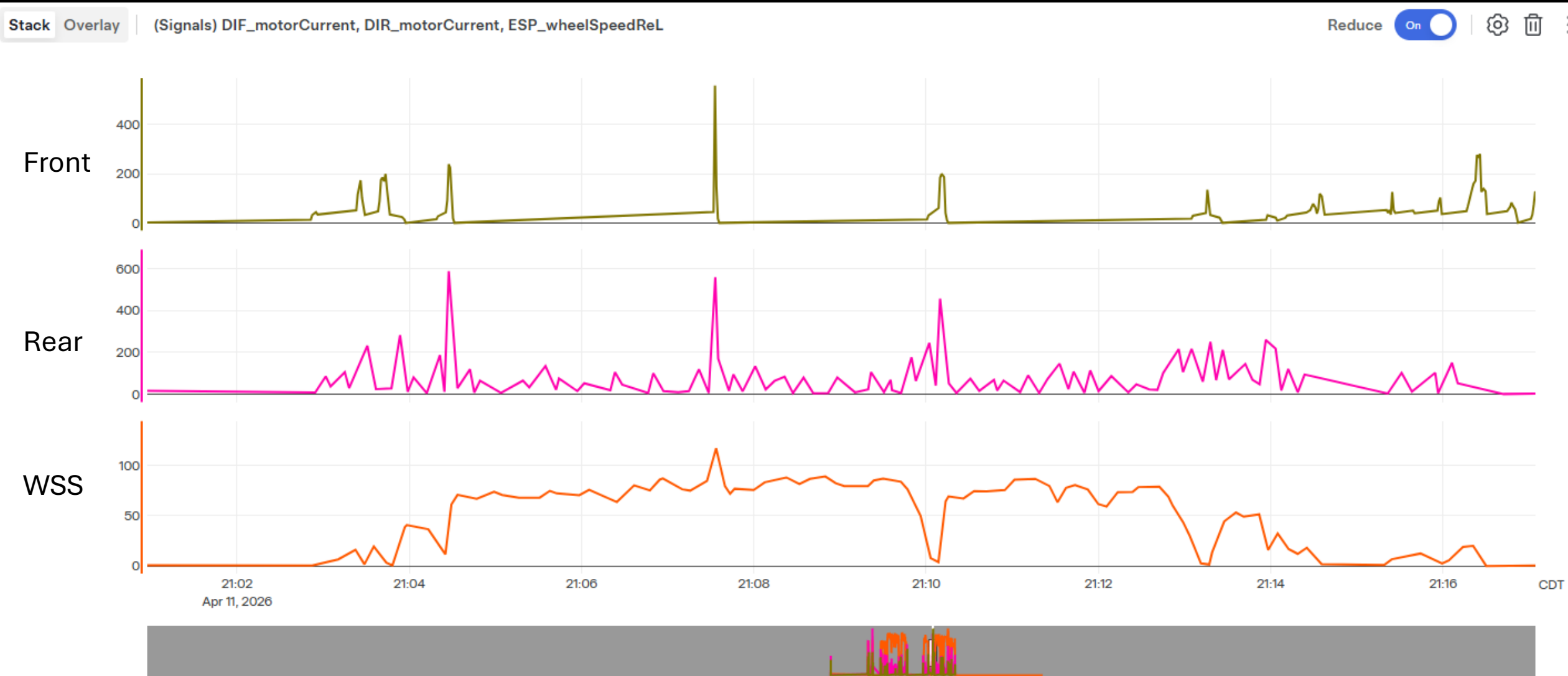
- Resolver – Position and speed
- Temperature
- Current flow
- Pump



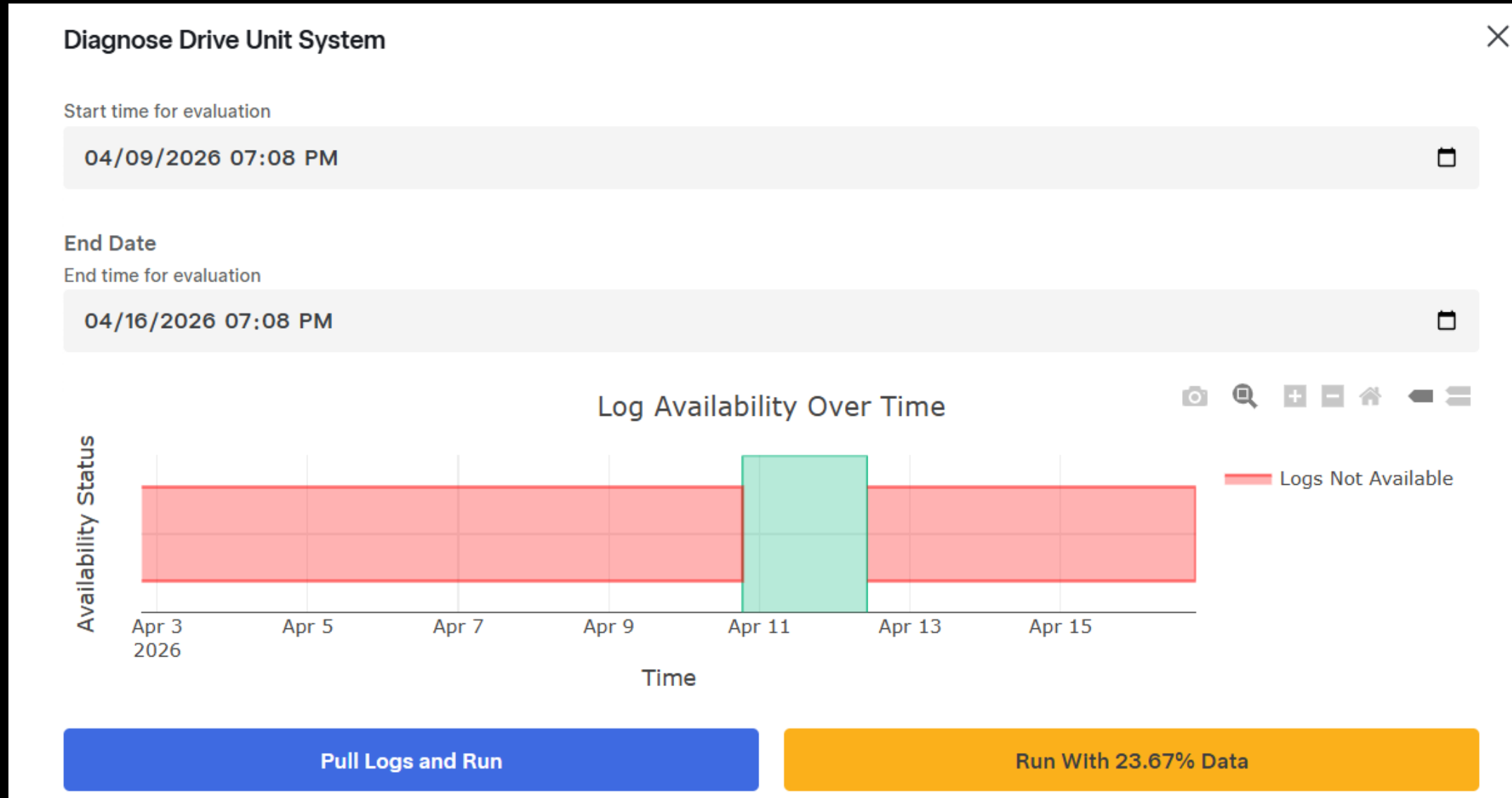
Ford Mach E Motor Data



Tesla Model 3 Motor Data



Tesla – Drive Motor Evaluation Based on Scan Data



Tesla – Resolver Learning

Front Drive Unit Resolver Error Learning



Axles and wheels will spin while in Drive.

Calibrates the resolver analog input error, which is required after an inverter swap. Before running this routine, confirm the steering wheel is straight and the drive rail is on. Run this routine while the vehicle is on the lift. After starting the routine, follow these steps to complete:

1. Shift into Drive within 10 seconds of starting the routine, and firmly press the accelerator pedal.
2. Keep the accelerator pedal pressed until the motor starts slowing down on its own.
3. After the speedometer reaches 0, press the brake and shift into Park.

Do not press the brake pedal during coast down. Brake softly to cancel the routine.



Perform Vehicle Checks

Run

PROC_DIF_X_RESOLVER-ERROR-LEARN

2026 Equinox EV Motor Data

Drive Motor Speed	0	°/s
Drive Motor Position	154	°
Drive Motor Position Sensor Offset	-6.0	°
Drive Motor Position Sensor Offset Learn Status	Learn Successful	
Drive Motor Torque Command	0.0	lb ft
Drive Motor Torque	0.0	lb ft
Drive Motor Current Command	0	mA
Drive Motor Current	0	mA
Drive Motor Magnets Strength	105	%
Drive Motor Temperature	120	°F
Vehicle Speed Sensor	0	MPH

2026 Equinox EV Motor Data

Propulsion System Status	Active	
Ignition and Start Signal	14500	mV
Drive Motor Inverter Status	Off	
Drive Motor Inverter Supply Voltage Circuit	310600	mV
Drive Motor Inverter Temperature Sensor 1	88	°F
Drive Motor Inverter Temperature Sensor 3	90	°F
Drive Motor Inverter Temperature Sensor 5	90	°F
Drive Motor Phase U Current	-0.5	A
Drive Motor Phase V Current	560	mA
Drive Motor Phase W Current	1840	mA

Ford Mach E Motor Calibration

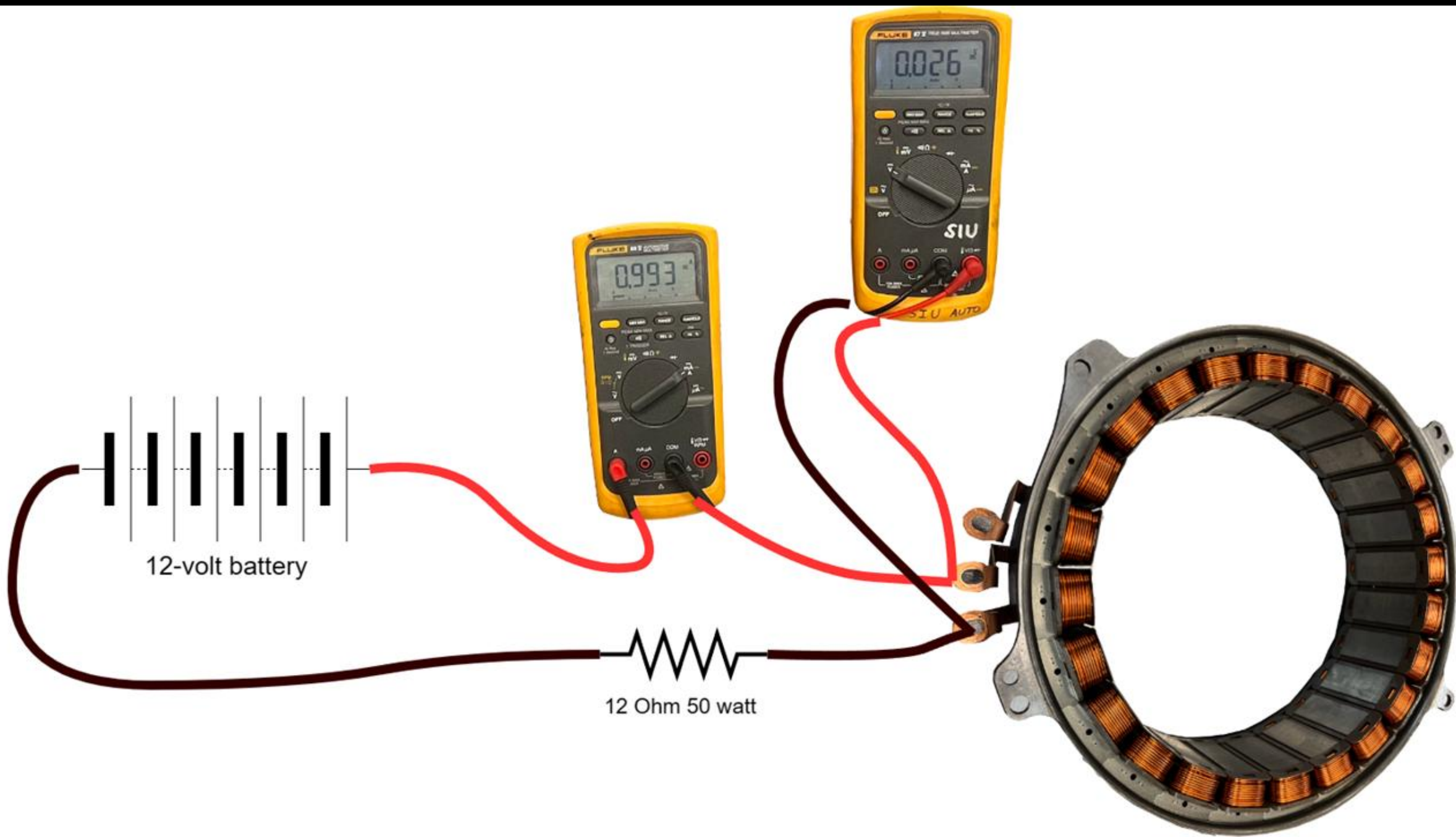
- QR code
- Service Code
- Part Number



Motor – Winding Analysis

- Milliohm meter
 - Used to check low-resistance circuits
 - DMM isn't accurate enough
 - 1 amp placed on circuit
 - Calculates resistance by using amperage and voltage drop
 - Measurements should be with 5% of each other





DIY Milliohm Meter



Megaohm Meter

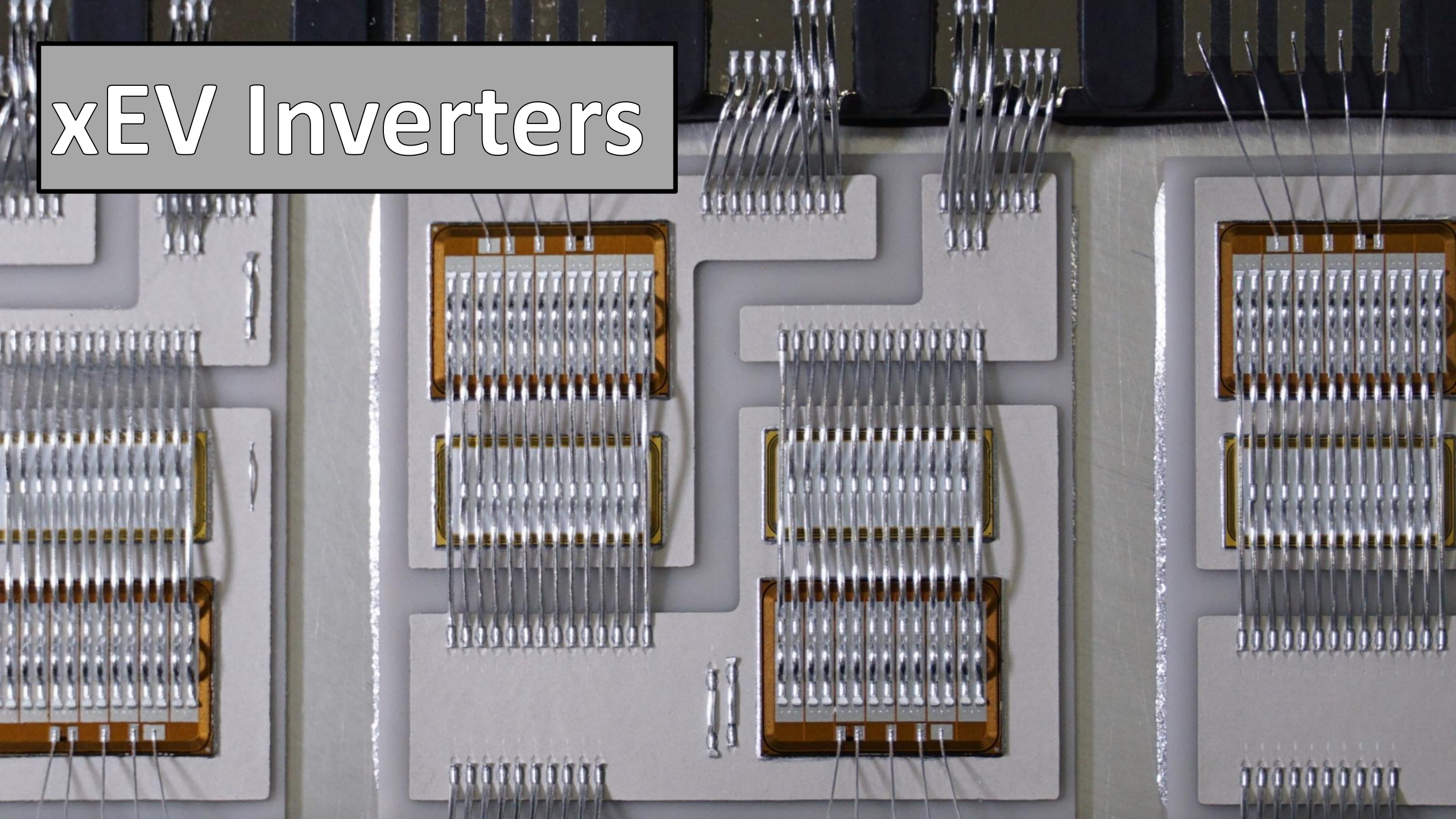
- Places high voltage in motor windings and checks for leakage to ground
- Red lead – stator winding
- Black lead – Case/Core
- Select level above operating voltage
- Press test button and wait for values to stabilize



Do you have AASRA credentials for accessing HV related service info and tool access?

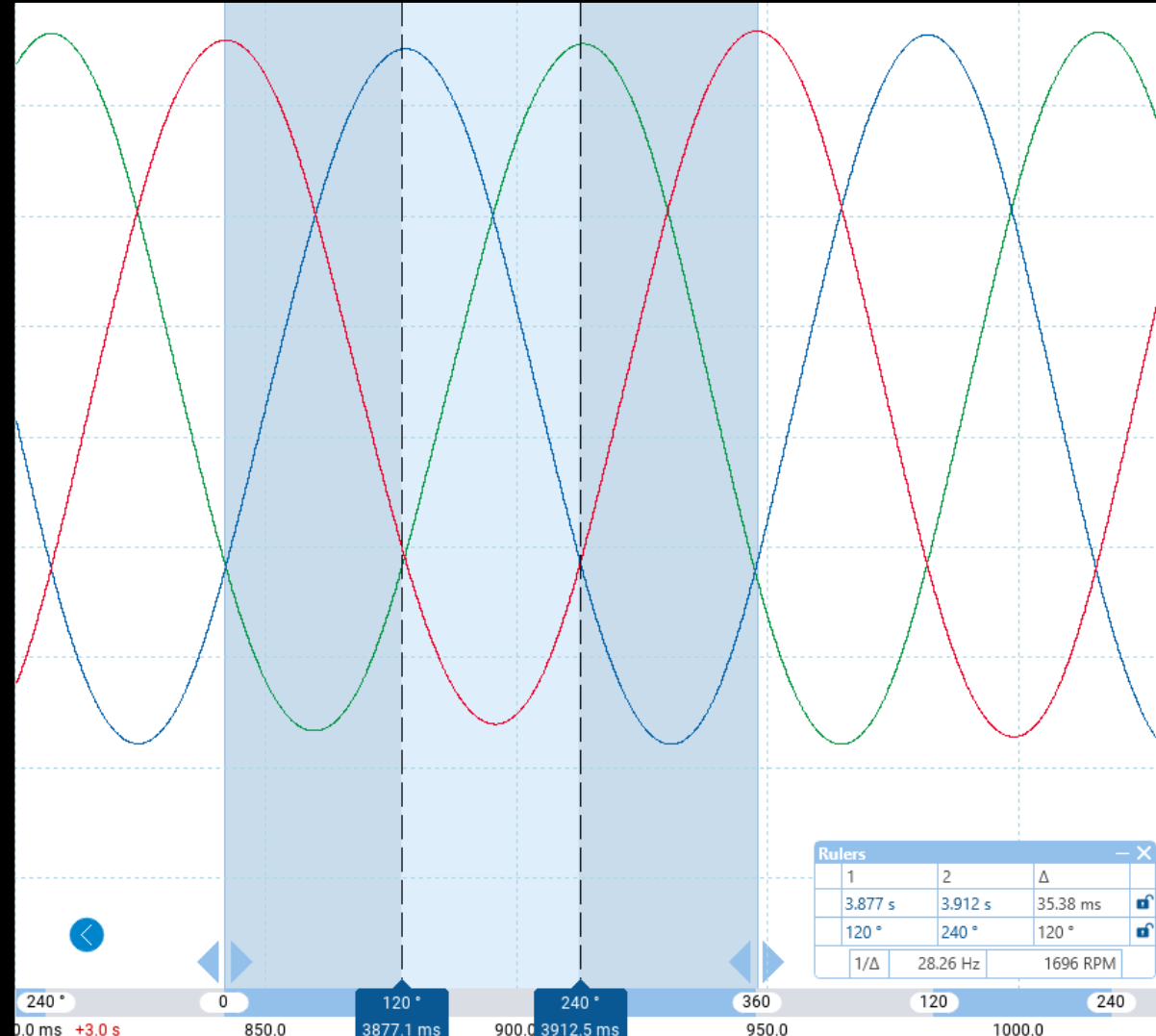
Yes, base technician	0
Yes, base plus EV safety	0
Yes, base plus vehicle security	0
Yes, base plus vehicle security and EV safety	0
No	0
No, what is AASRA?	0

xEV Inverters



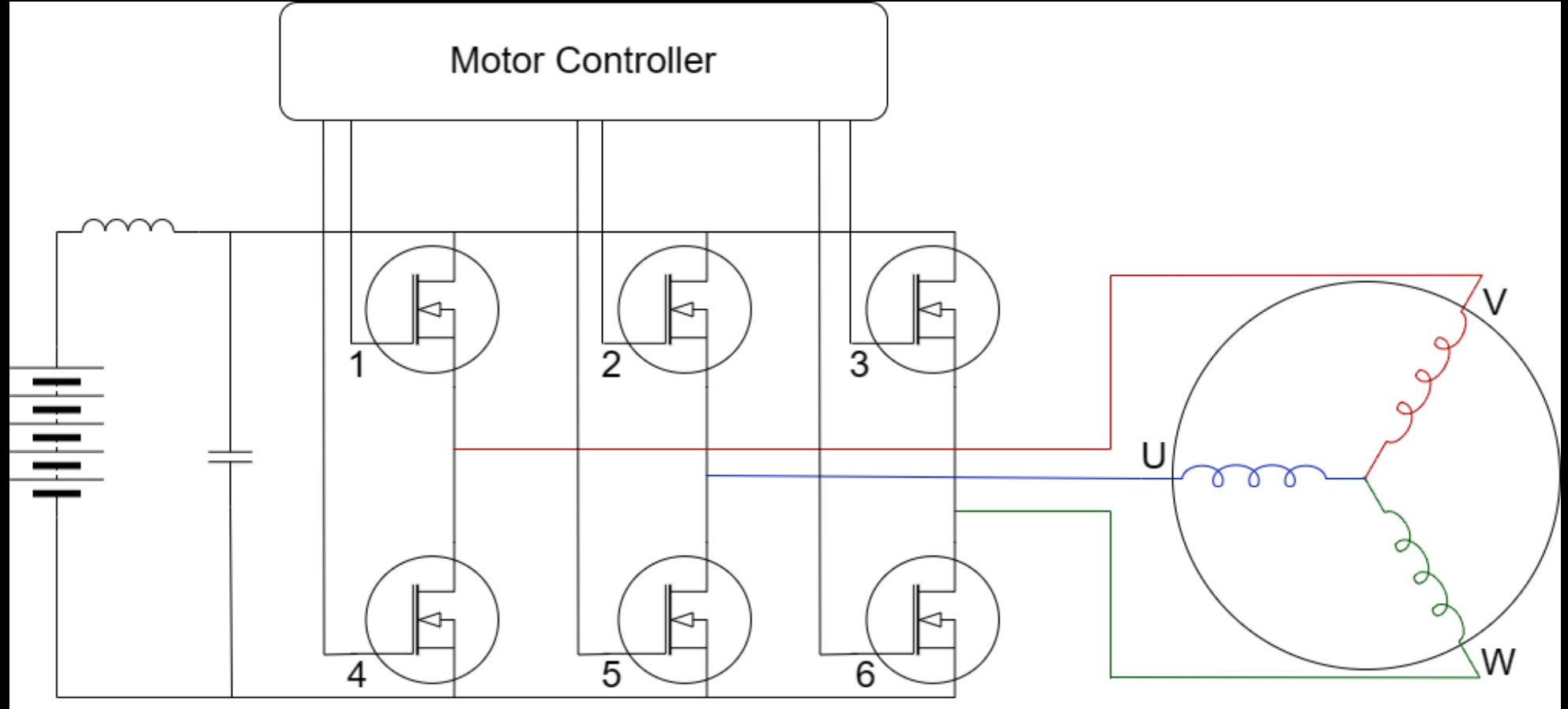
DC In → 3-Phase Out

- Inverter
 - Motoring
 - Generate 3-phase AC from HV DC
 - Generating
 - Rectify 3-phase AC into HV DC



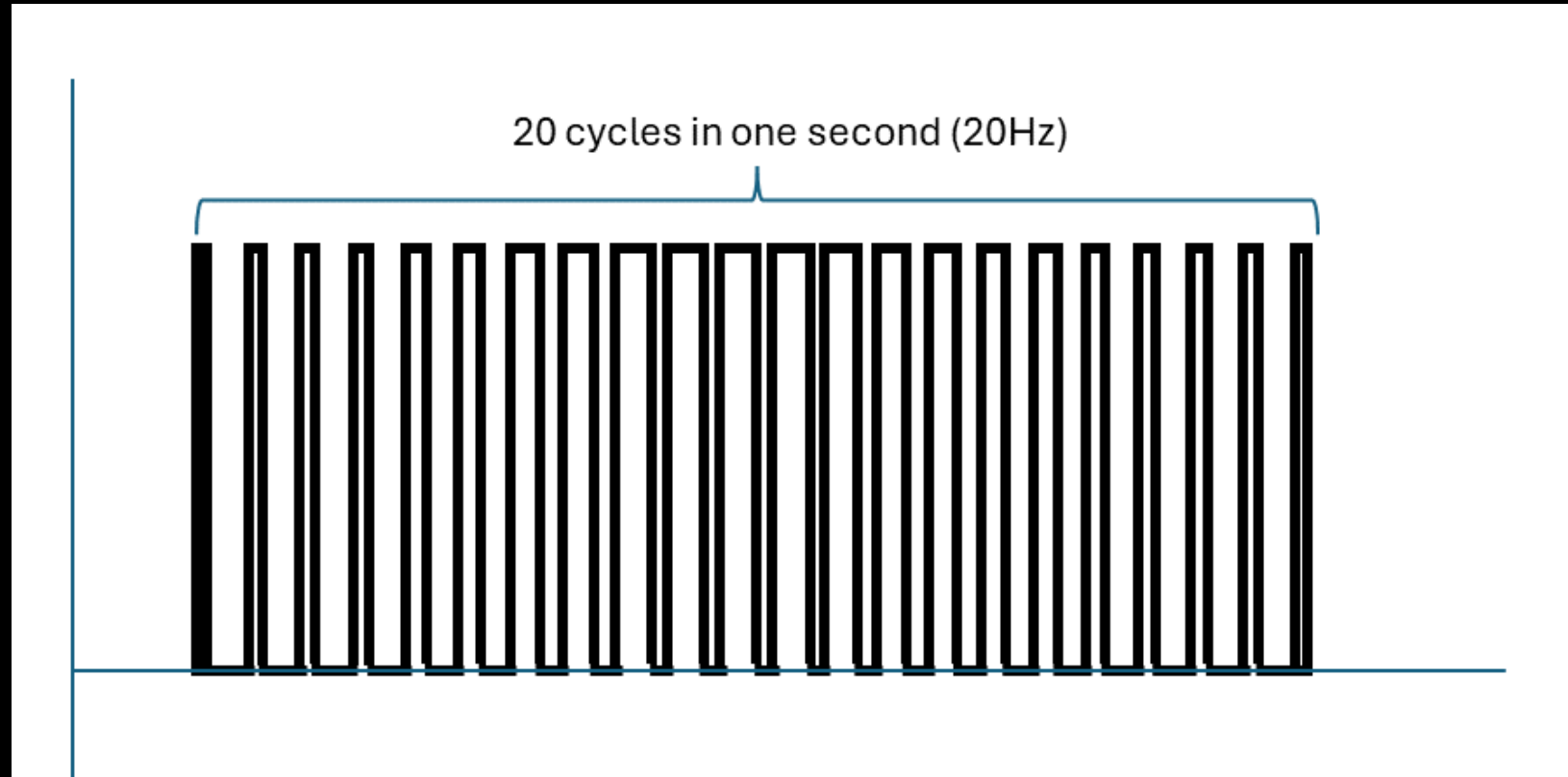
IGBT / SIC MOSFET

- Groups of 6 Transistors to generate a digital AC
- Motor windings represent the coils in the stator



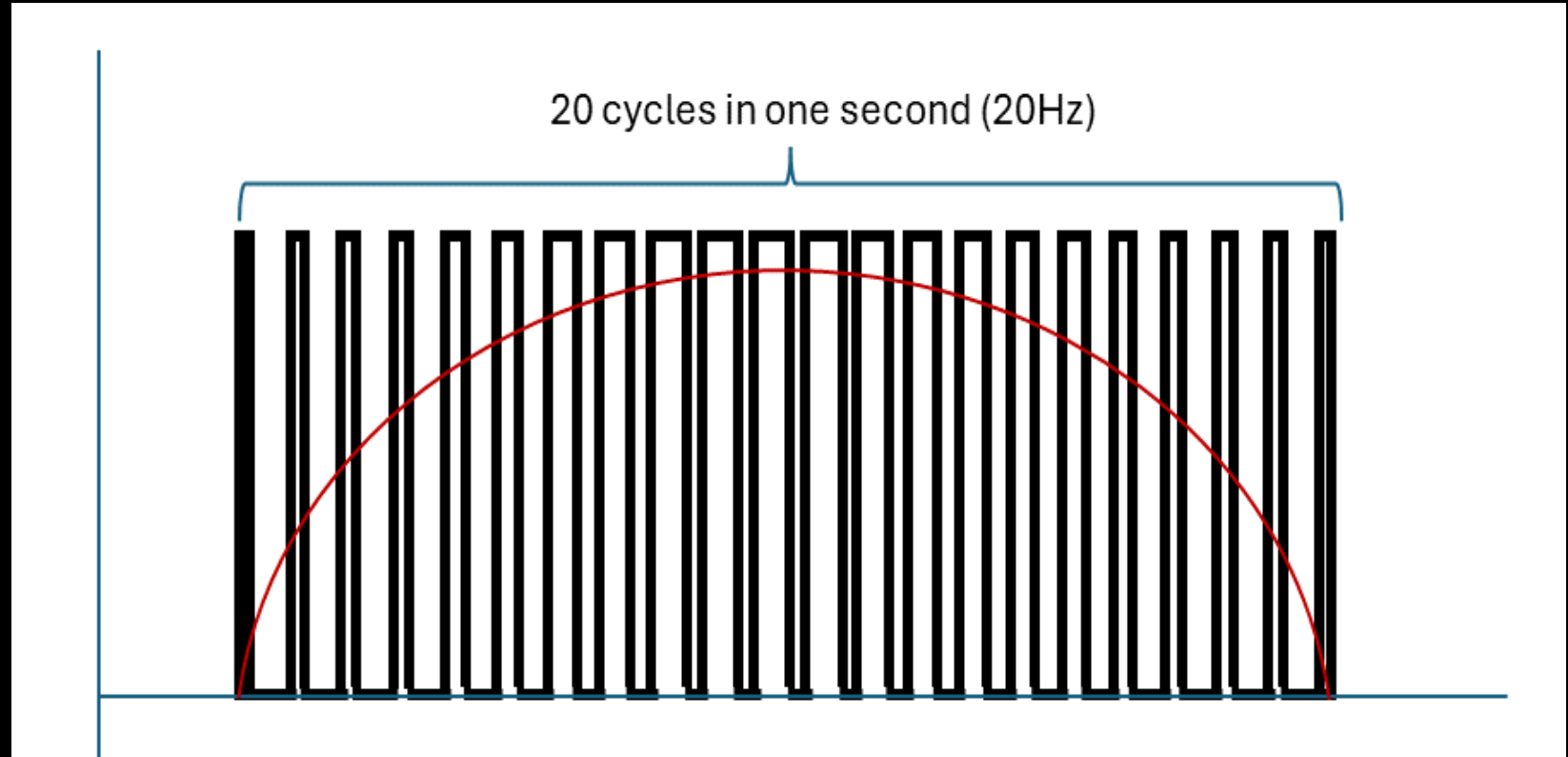
Pseudo Sine Wave

- Positive pulse between zero and HV battery voltage
 - Changing duty cycle determines the amperage



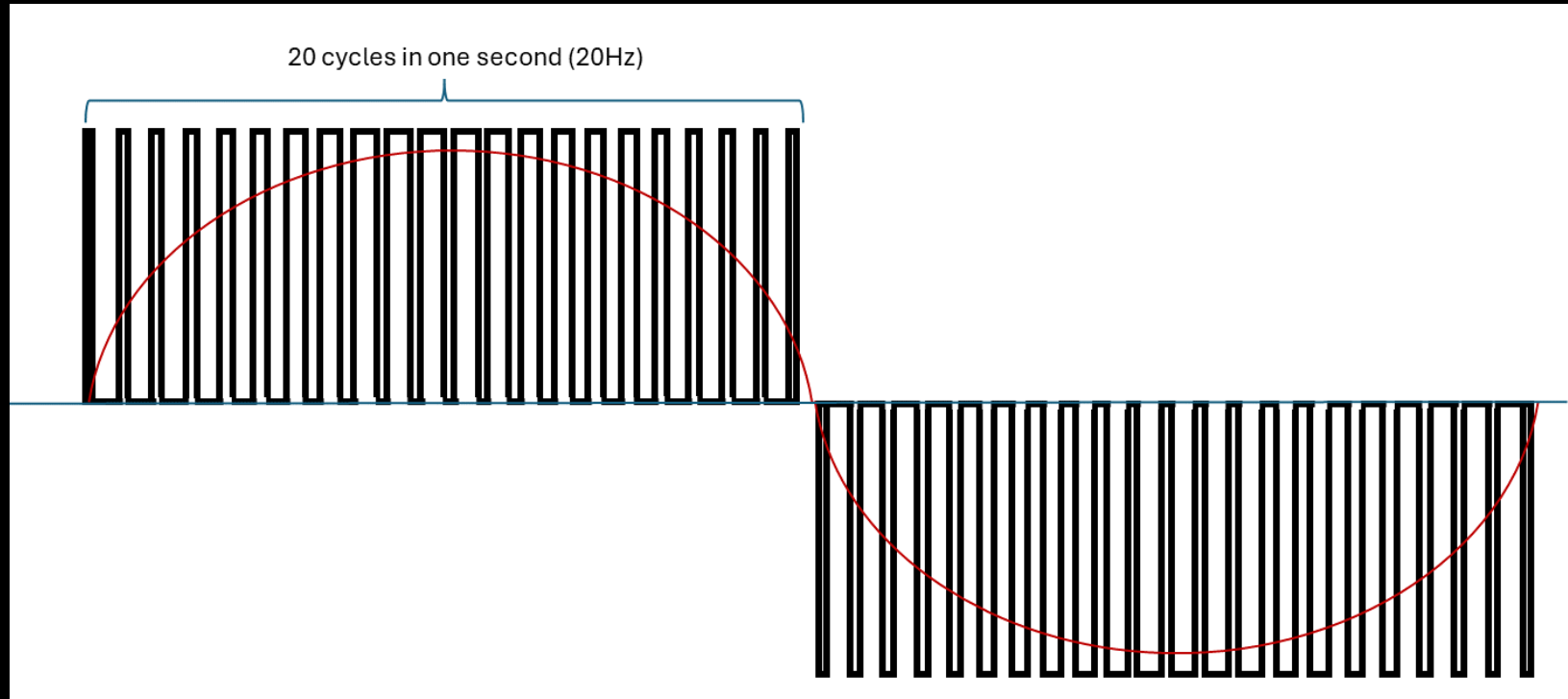
Pseudo Sine Wave

- Shorter “ON” time = low amperage
- Higher “ON” time = higher amperage
- Changing duty cycle can mimic a sine wave



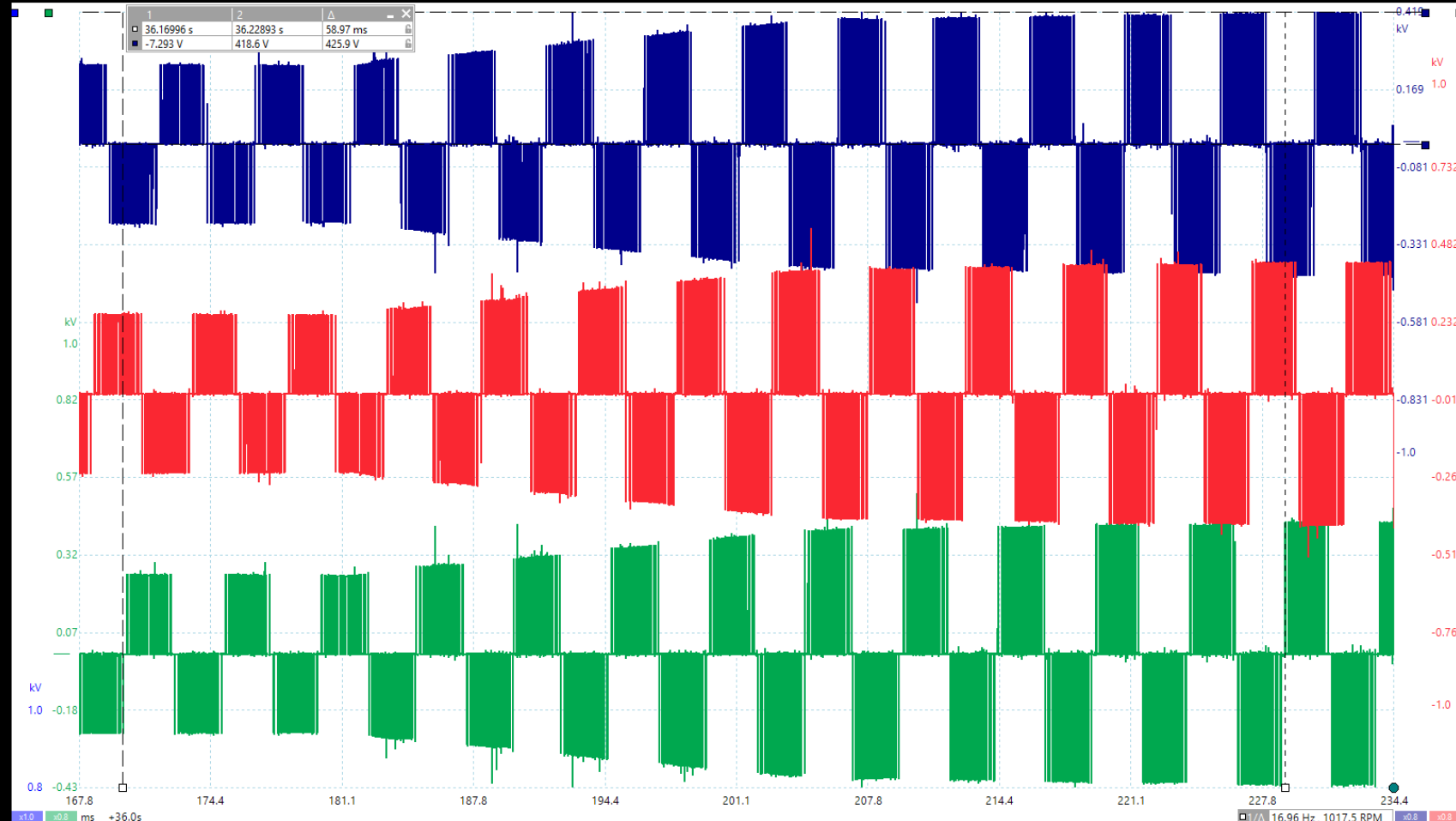
Pseudo Sine Wave

- Reverse polarity by inverting the voltage



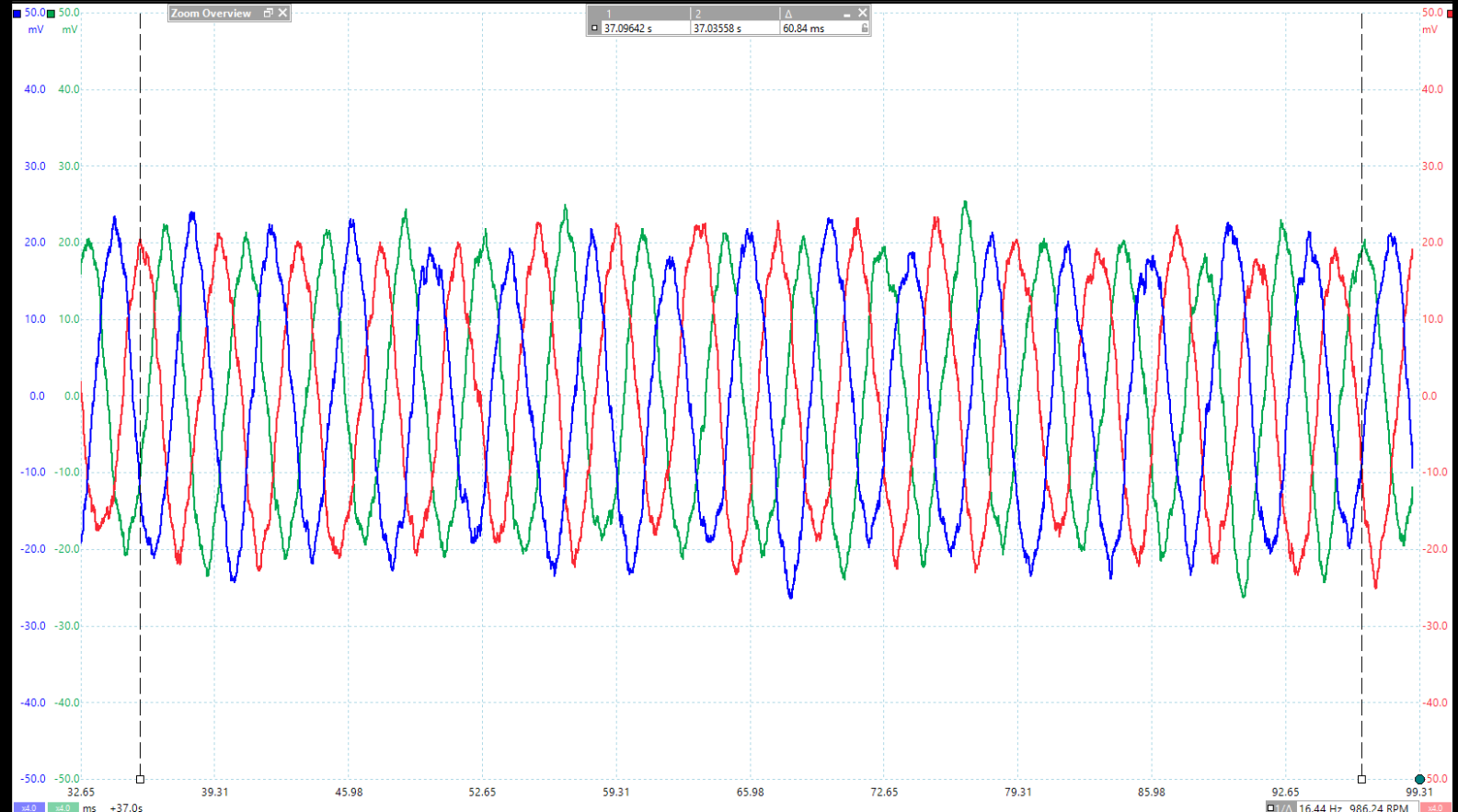
3-Phase AC Generation

- Inverter uses high speed switching
 - ~ 20kHz
- High speed switching will allow for smoother current flow
- Changing duty cycle will change amperage
- Each cycle will move the motor ONE pole



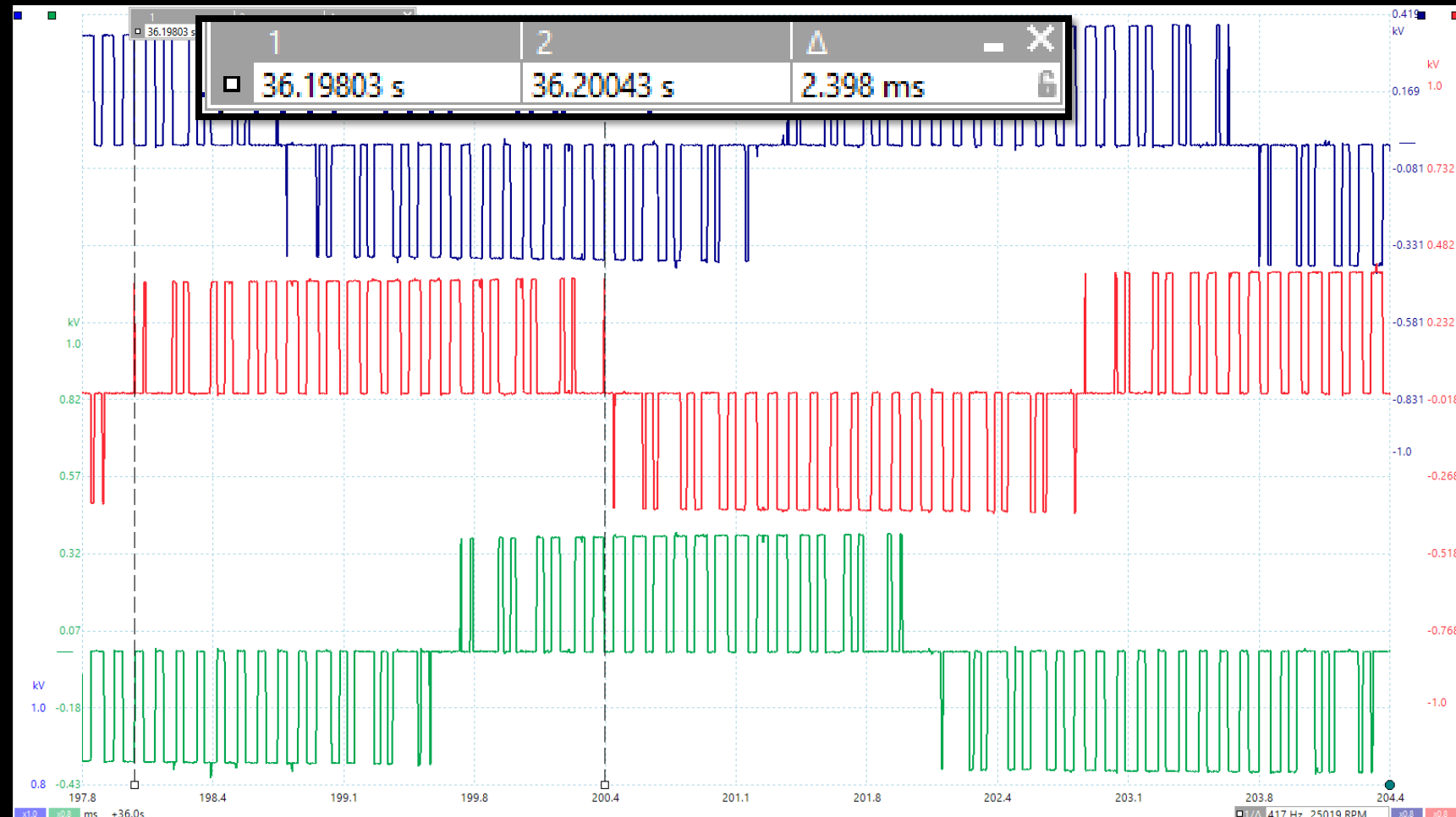
Toyota Hybrid - AC Amperage Filtered

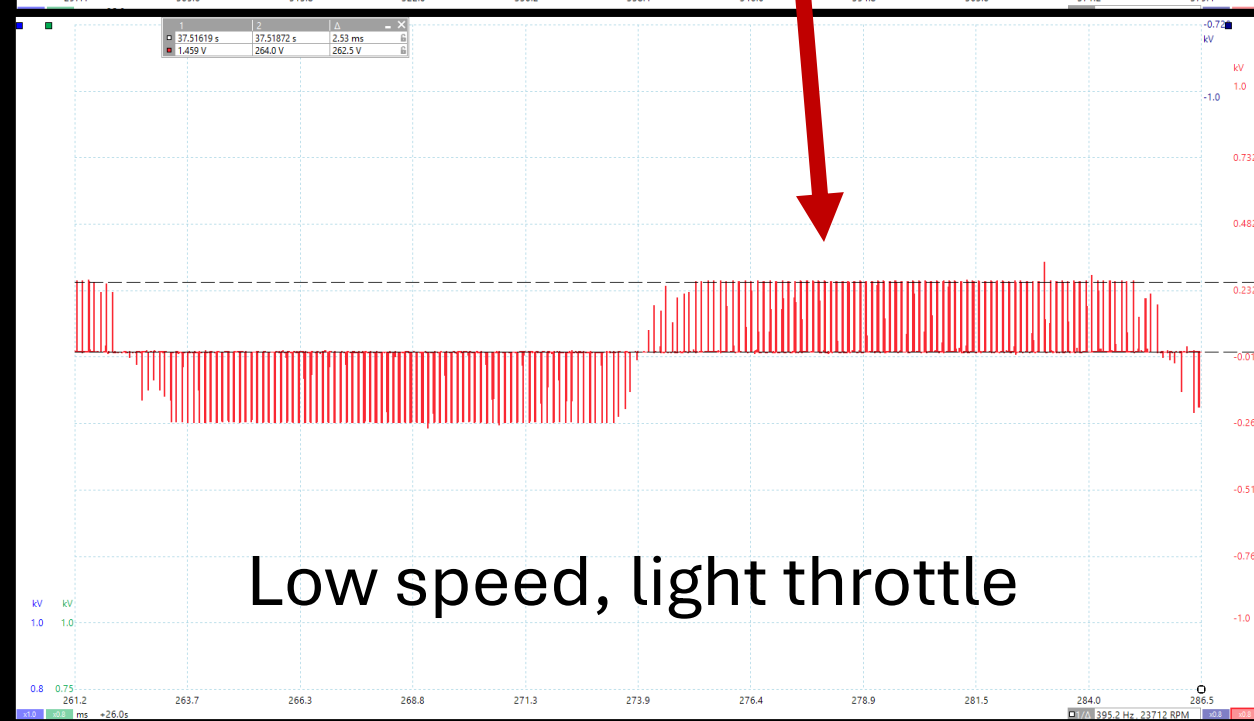
- Amperage does the work
 - Generating an electromagnetic field requires current flow



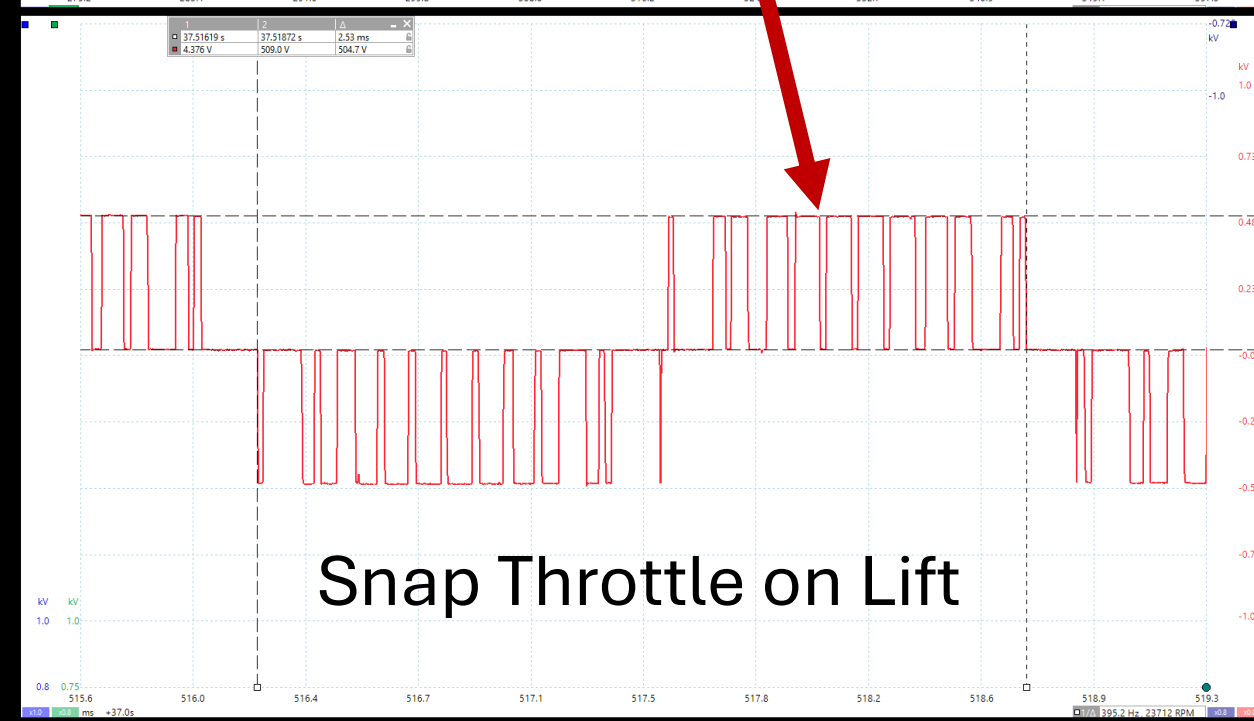
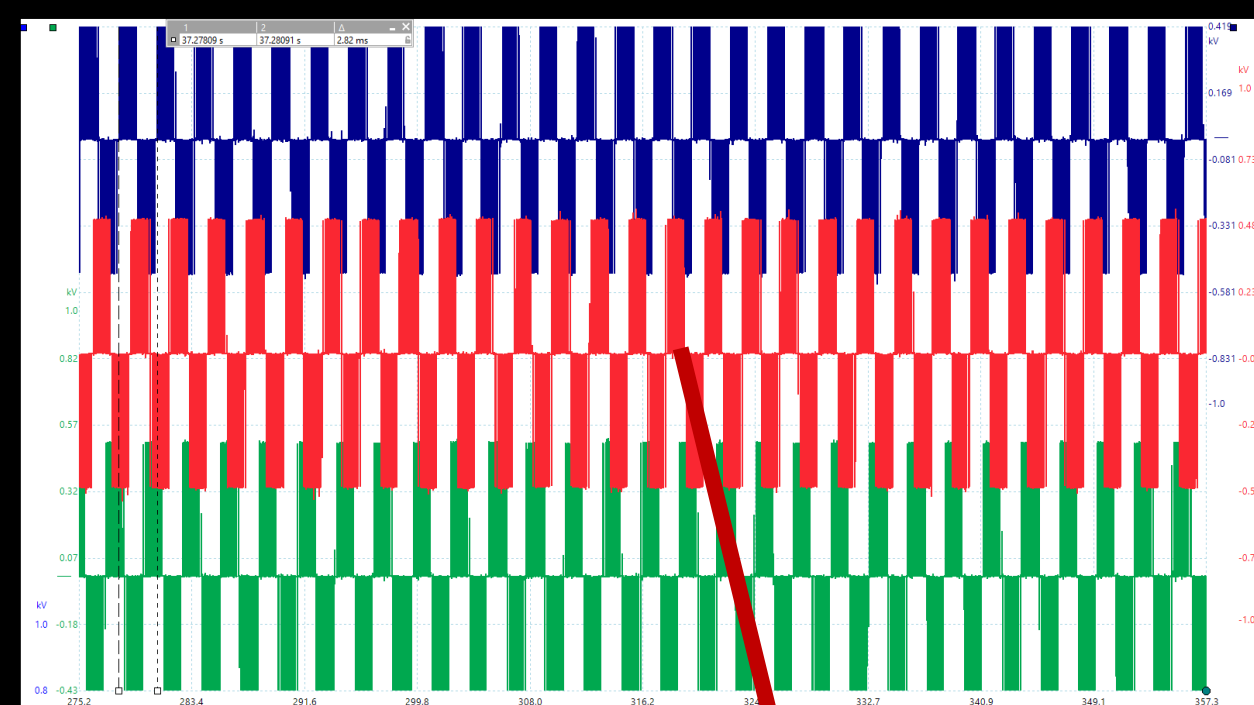
Example – Toyota Rav 4 Hybrid MG2

- This positive cycle took 2.4 ms
 - Short duty cycle to start
 - Longer duty cycle in the middle
 - Short duty cycle at the end



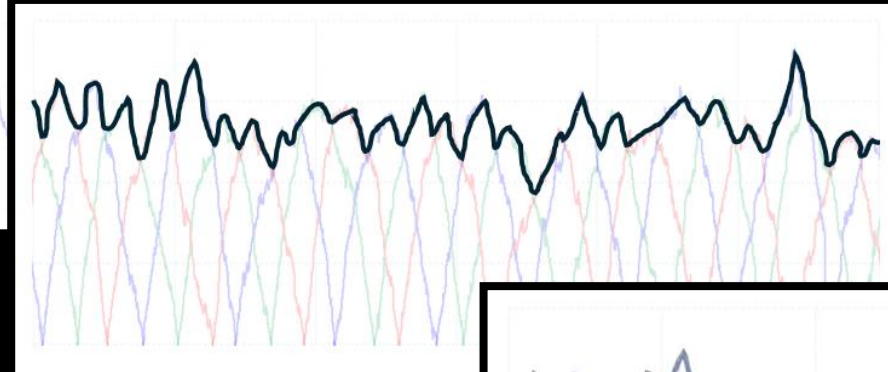
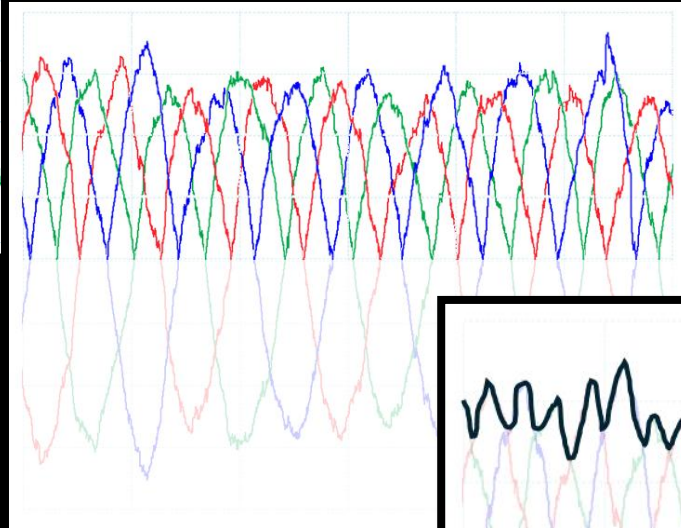
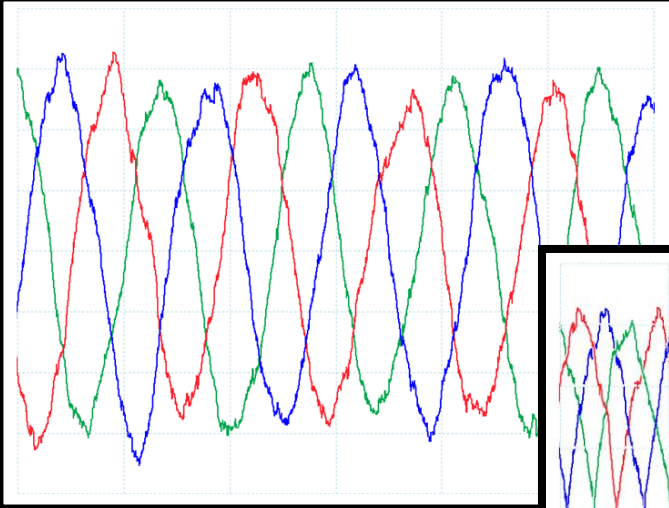


Low speed, light throttle

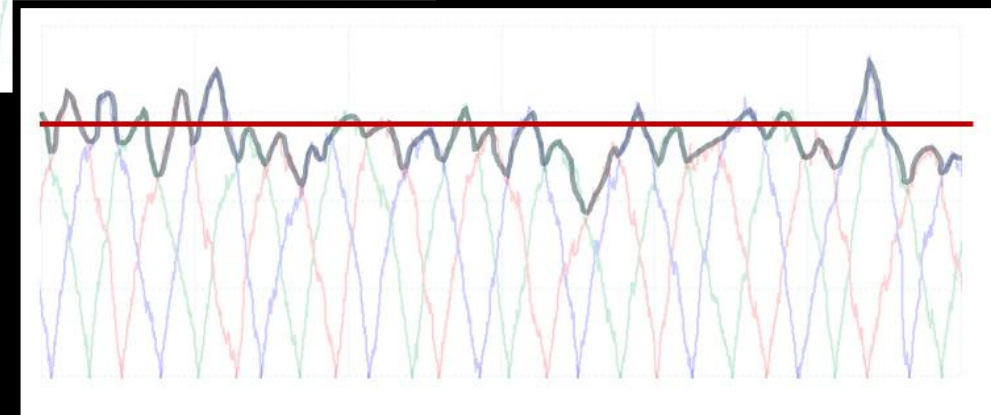


Snap Throttle on Lift

Regeneration – Filtered and Conditioned

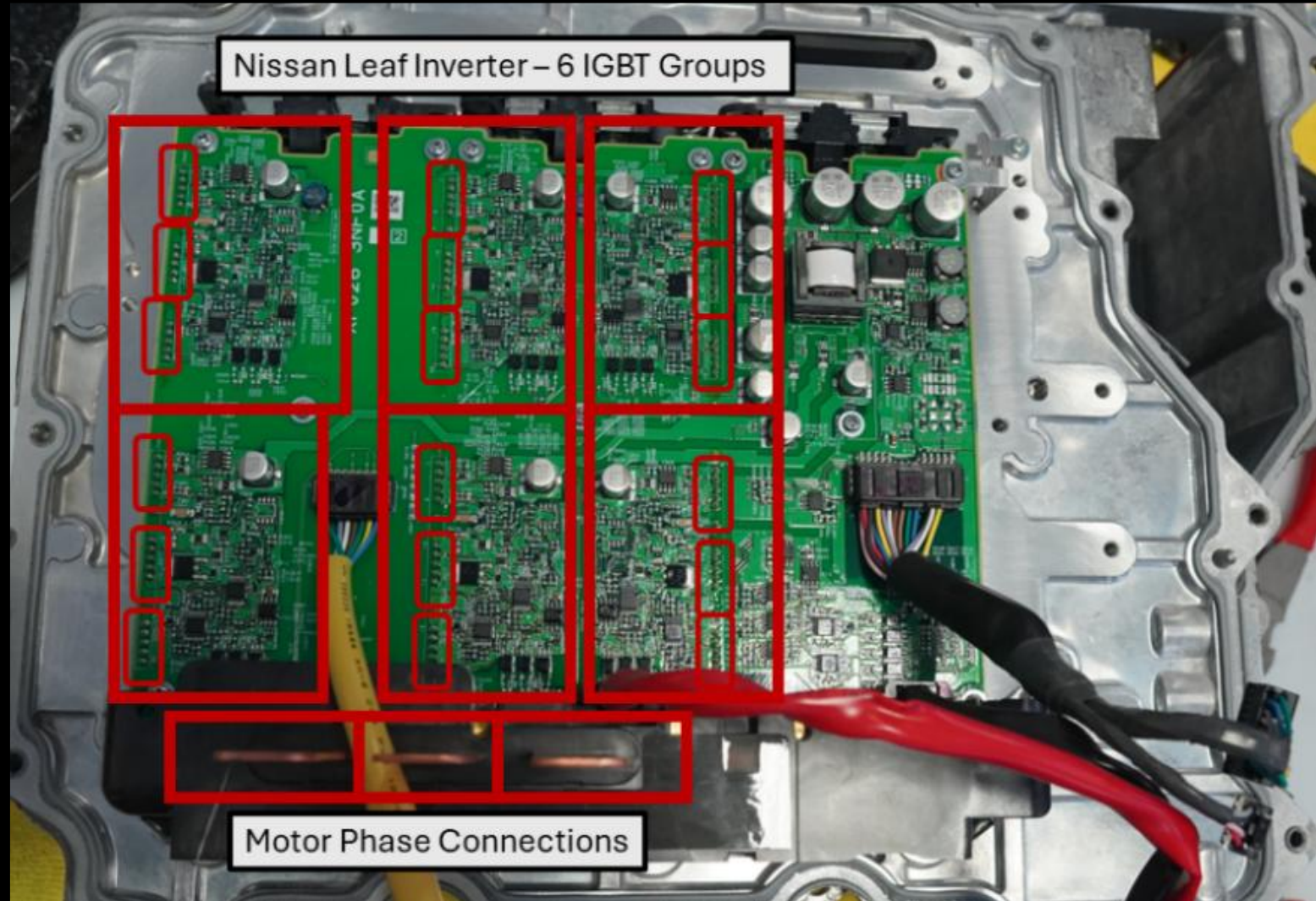


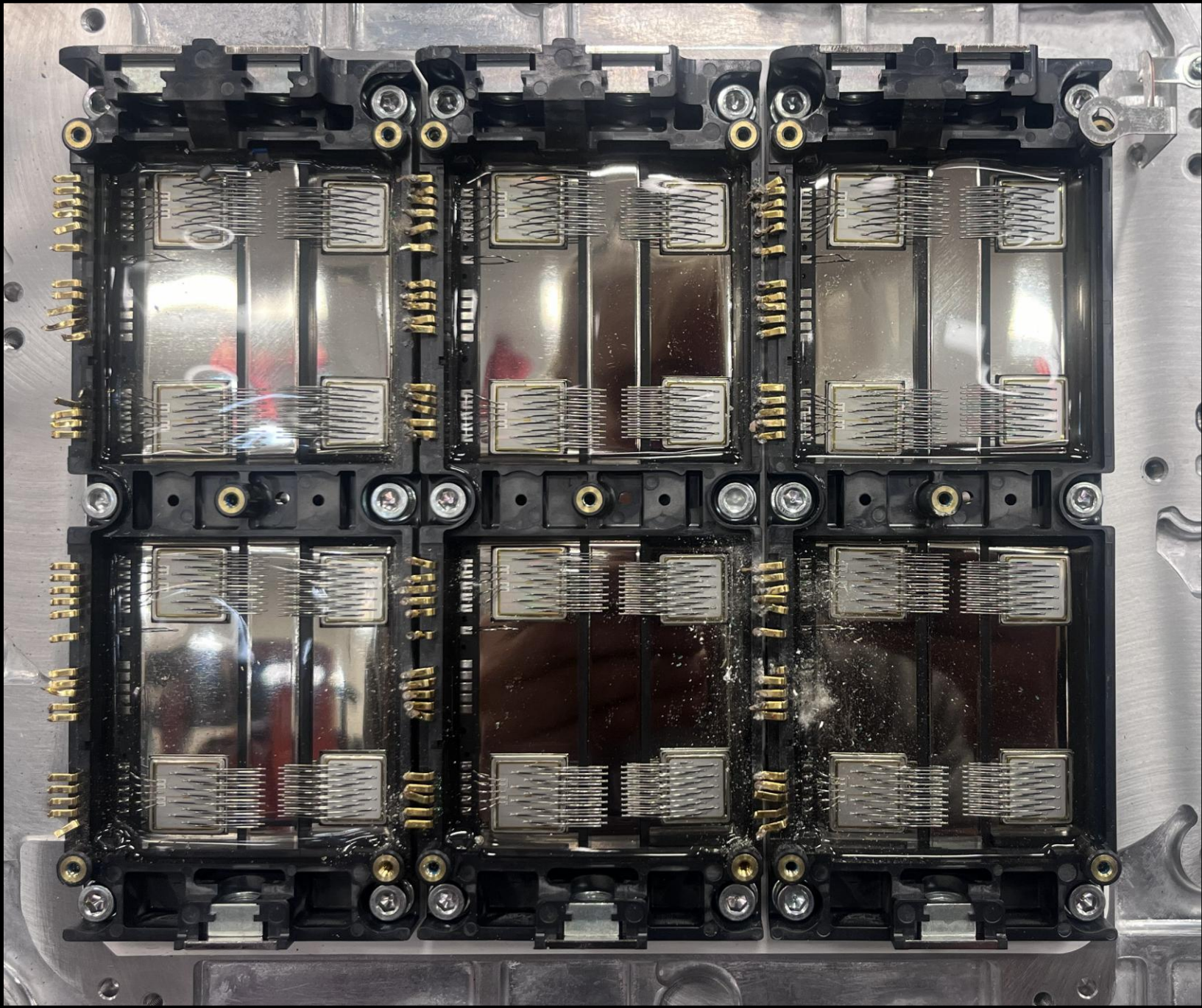
- During decel, AC is generated
 - Transistor switching can regulate the amount of regen
 - Capacitors and inductors smooth rectified DC voltage



IGBT Groups

- Parallel grouping to handle current





Inverter - Capacitors

- DC Link
 - Smooths out the peaks and valleys of AC switching



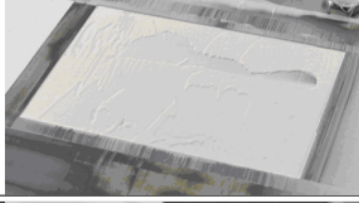
Inverters - Cooling

- Transistor switching
 - Resistance = heat
 - Ideally <160 degrees F, 70 degrees C
- Heat transfer
 - Thermal paste
 - Liquid cooling



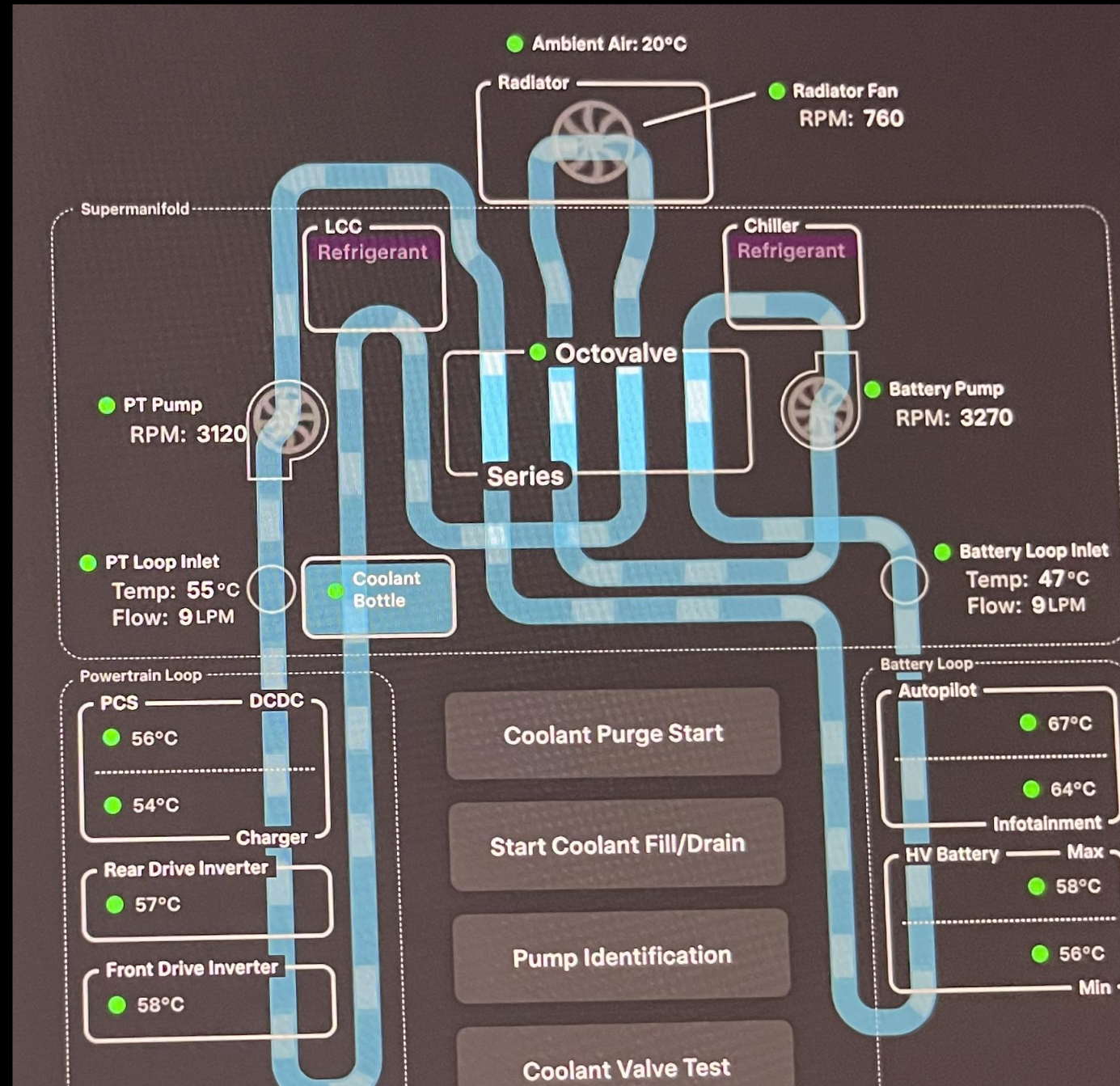
Lexus RX400h bulletin

- Example of proper thermal paste application

THE FOLLOWING STEPS ARE VITAL CONFIRM THESE STEPS ARE FOLLOWED CLOSELY CONFIRM THE CONDITION OF THE THERMAL CONDUCTIVE GREASE	
SAMPLE	CONDITION & ACTION REQUIRED
	CONDITION: Smooth surface and complete coverage. ACTION: Proceed to: SECTION X. REASSEMBLY
	CONDITION: Grease unsmooth. Metal surface of the IPM transistor NOT visible through the grease. ACTION: Proceed to: SECTION X. REASSEMBLY
	CONDITION: Grease unsmooth. Metal surface of the IPM transistor visible through the grease. ACTION: Proceed to: STEP C #2. REAPPLY GREASE TO THE NEEDED AREAS
	CONDITION: Hole or imperfection in the grease exposing the metal surface of the IPM transistor. ACTION: Proceed to: STEP C #2. REAPPLY GREASE TO THE NEEDED AREAS
	CONDITION: Foreign material in the grease. ACTION: Proceed to: STEP C #1. REMOVE FOREIGN MATERIAL FROM THE GREASE

Tesla Model 3 Cooling

- Refrigerant loop
 - Variable expansion valves
 - LCC
 - Chiller
- Coolant loop
 - Powertrain Loop
 - Battery/Computer Loop
 - Octovalve
 - LCC
 - Chiller
 - Radiator



Inverter Cooling

- Leaf cooling passages
 - Inverter
 - DC/DC converter
 - Charge controller



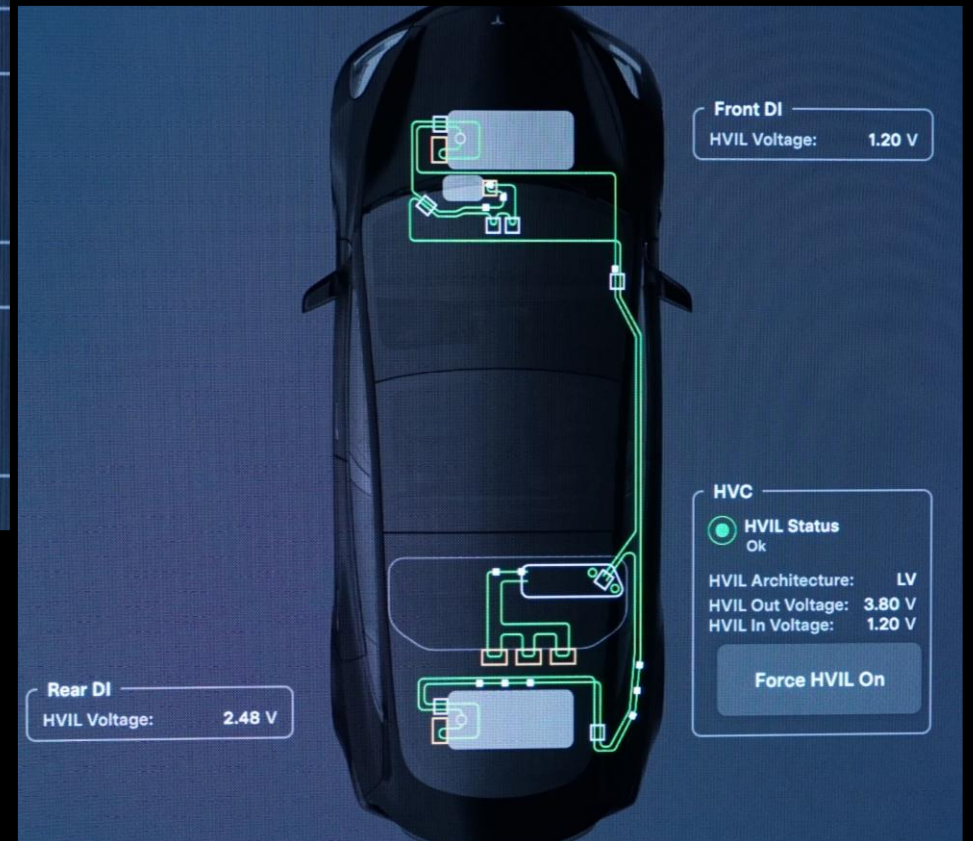
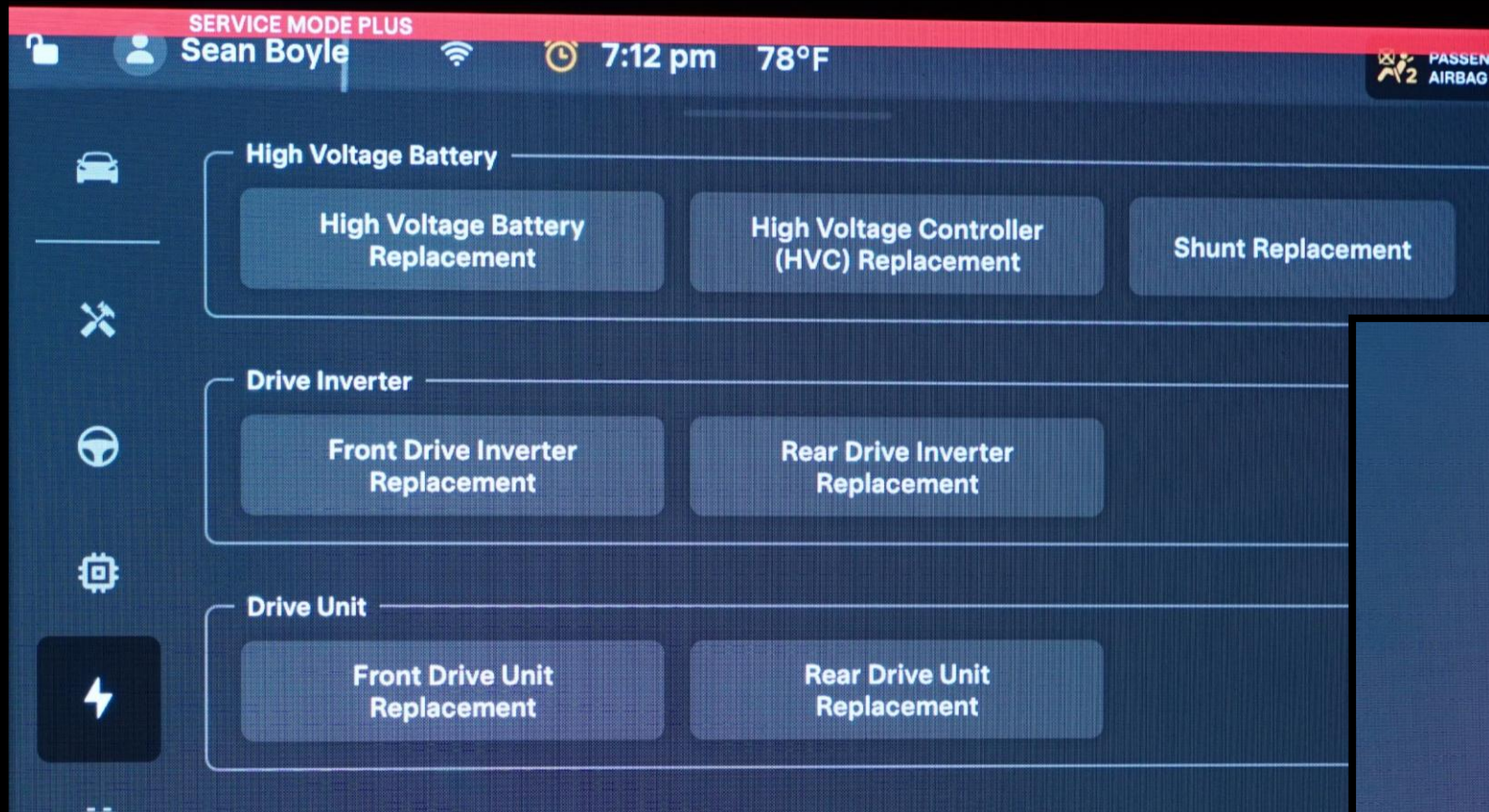
Mach-e Scan Data



Tesla Model 3 Inverter Related Actions

≡ All ▶ Actions ☰ Dashboards			
🔍 Inverter			
Action Type ≡ Model ≡ System ≡ Task Type ≡			
Front Drive Inverter (DIF) - Store Application Data Before Replacement PROC_DIF_X_STORE-DATA-APP	Backs up Drive Inverter Front (DIF) application data before replacement.	Drive Unit	ODIN
Front Drive Inverter (DIF) - Store Bootloader Data Before Replacement PROC_PMF_X_STORE-DATA-BOOT	Backs up Drive Inverter Front (DIF) bootloader data before replacement.	Wheels and Tires	ODIN
Restore Front Drive Inverter Bootloader Data after Replacement and Usage ID C PROC_PMF_X_RESTORE-DATA-BOOT-AND-WRITE-DRIVE-TYPE	Restores the Front Drive Inverter (DIF) bootloader data and configures Usage ID after a DIF replacement.	Wheels and Tires	ODIN
After DIR Replacement - Restore Application Data PROC_DIR_X_RESTORE-DATA-APP	Restores the Rear Drive Inverter (DIR) application data.	Drive Unit	ODIN
Before DIR Replacement - Store Application Data PROC_DIR_X_STORE-DATA-APP	Backs up Rear Drive Inverter (DIR) application data.	Drive Unit	ODIN
Factory DI Odometer Initialization PROC-DID_DI_VEHICLE-ODOMETER	Runs the factory Drive Inverter (DI) Odometer initialization routine.	Drive Unit	ODIN
Before DIR Replacement - Store Bootloader Data PROC_PMR_X_STORE-DATA-BOOT	Before replacing the Rear Drive Inverter (DIR), this task backs up the bootloader data.	Wheels and Tires	ODIN
Read DI Rotations PROC_DIR_X_READ-DI-ROTATIONS	The procedure reads the drive inverter rotation in the Right Drive Inverter (DIR) Electronic Control Unit (ECU).	Drive Unit	ODIN

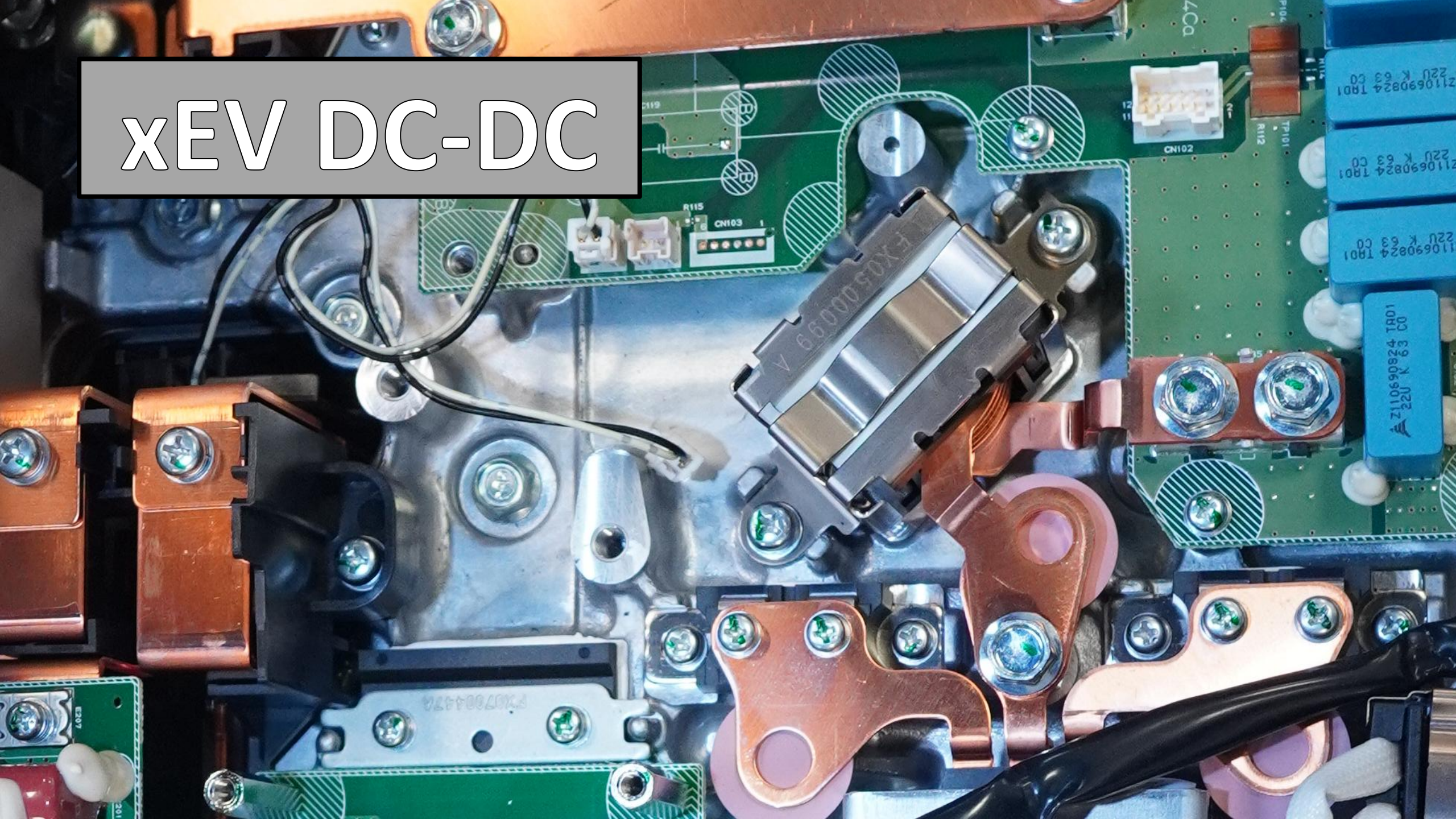
Tesla Model 3 Service Mode Plus Actions



2026 Equinox EV

Propulsion System Status	Active	
Ignition and Start Signal	14500	mV
Drive Motor Inverter Status	Off	
Drive Motor Inverter Supply Voltage Circuit	310600	mV
Drive Motor Inverter Temperature Sensor 1	88	°F
Drive Motor Inverter Temperature Sensor 3	90	°F
Drive Motor Inverter Temperature Sensor 5	90	°F
Drive Motor Phase U Current	-0.5	A
Drive Motor Phase V Current	560	mA
Drive Motor Phase W Current	1840	mA

xEV DC-DC



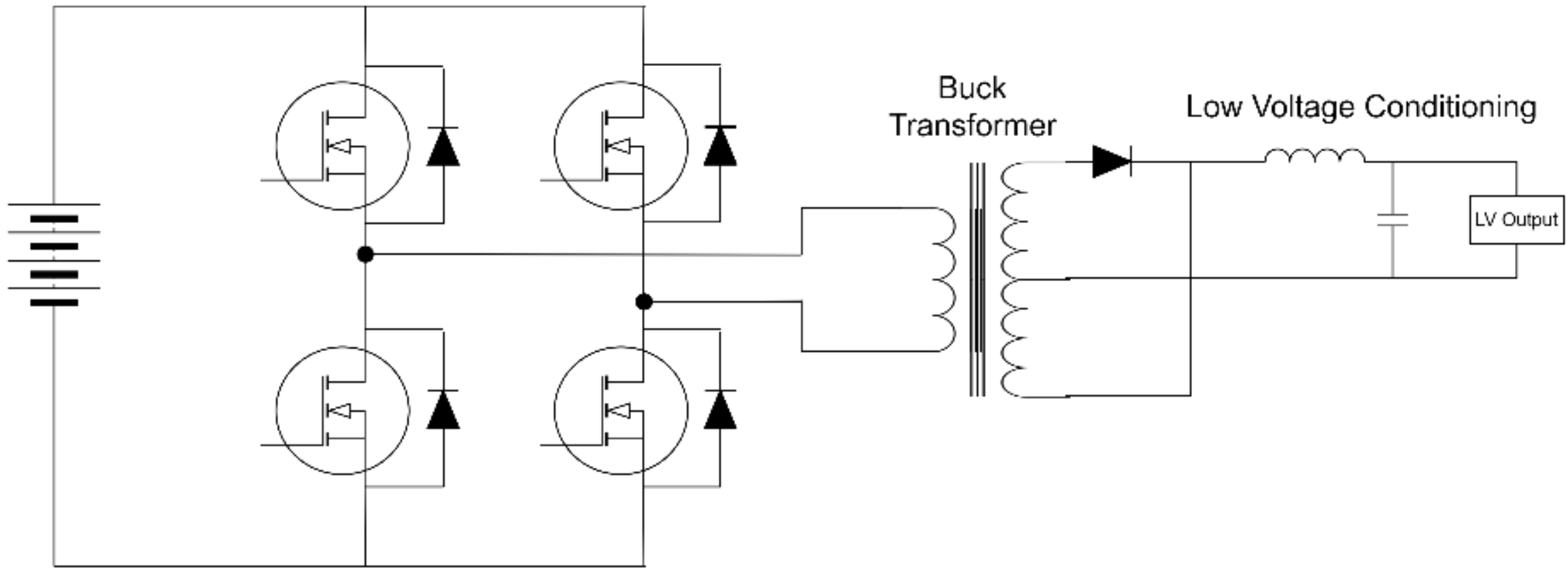
DC/DC Converter

- HV DC → LV DC
- Buck transformer



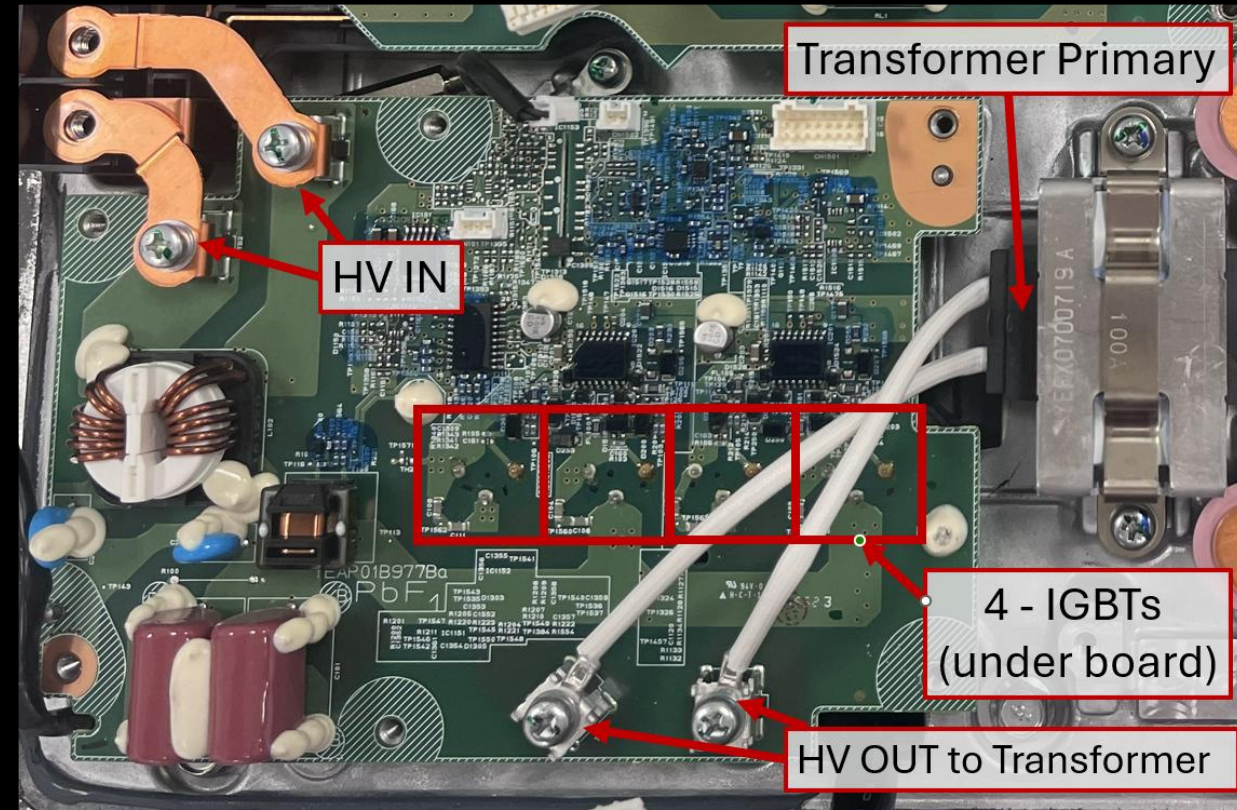
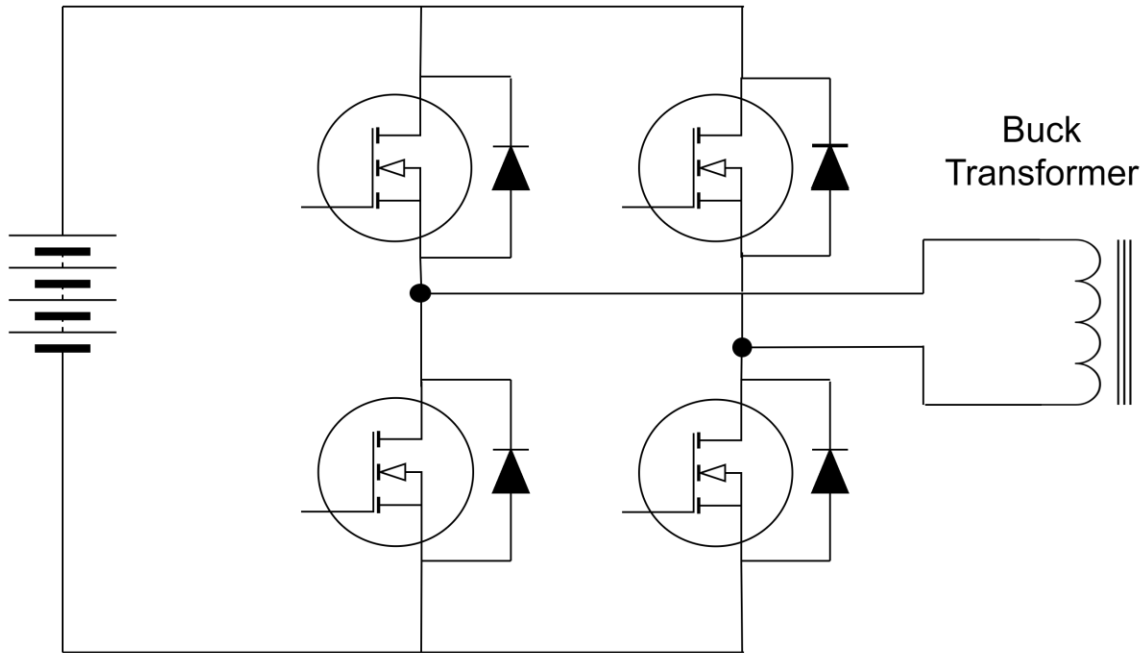
HV DC to HV AC $\longrightarrow$ Transform to LV AC $\longrightarrow$ Rectify LV AC to LV DC

HV DC to HV/HF AC

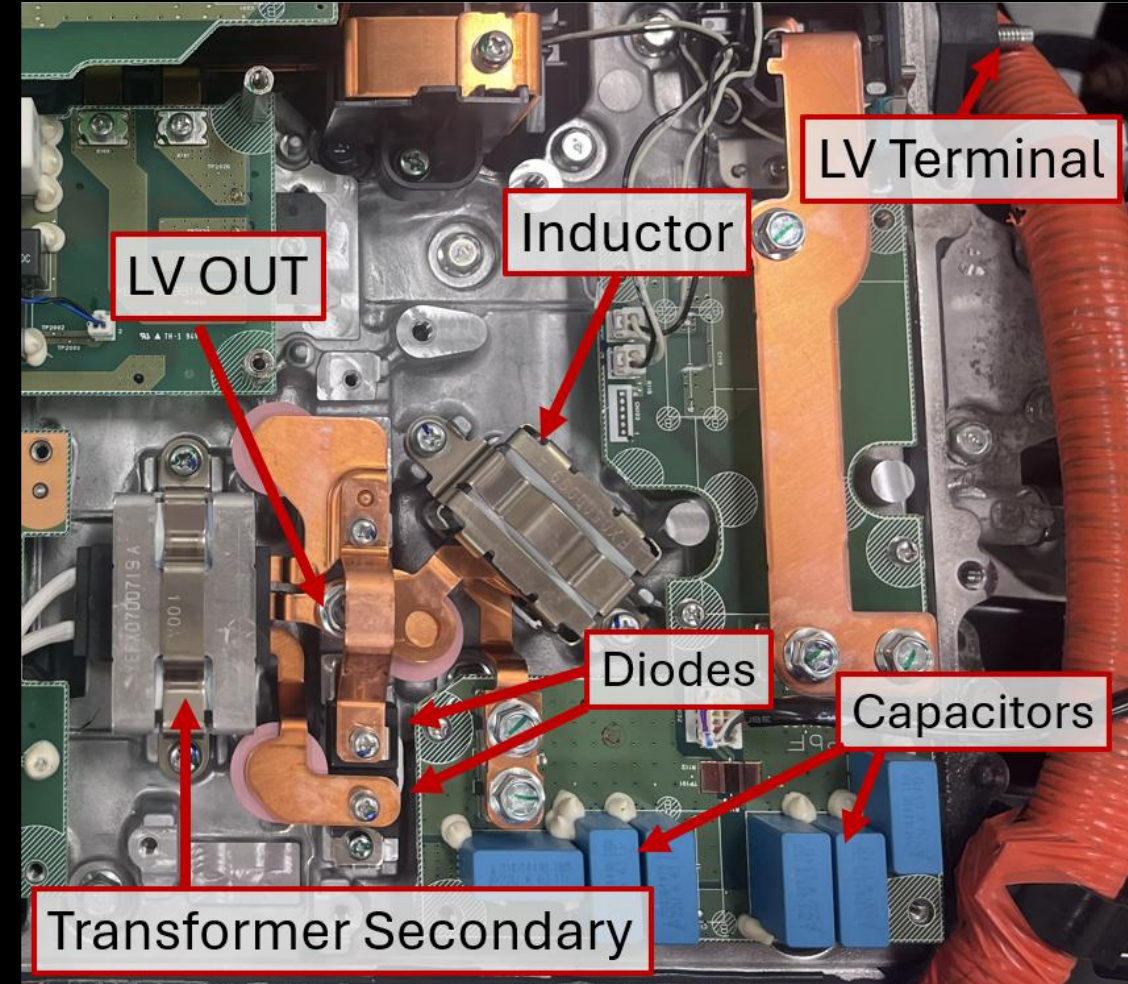
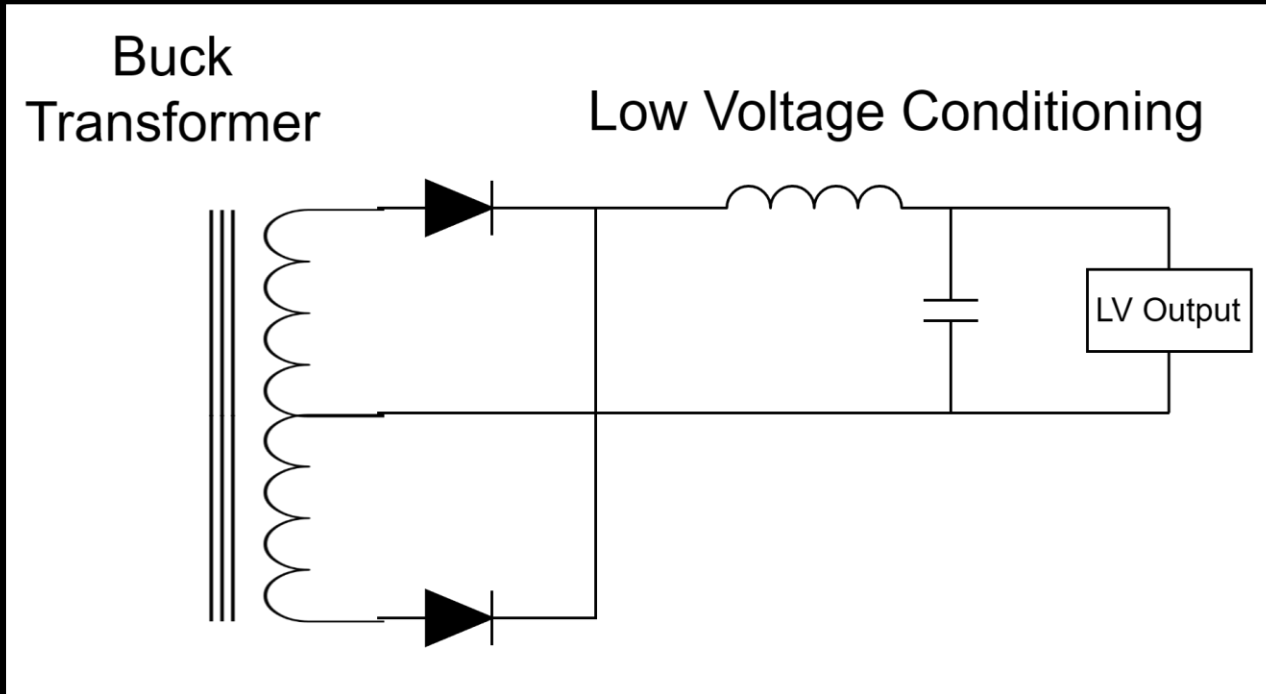


DC/DC Primary – Convert HV DC to HV AC

HV DC to HV/HF AC



DC/DC Secondary – Convert LV AC to LV DC

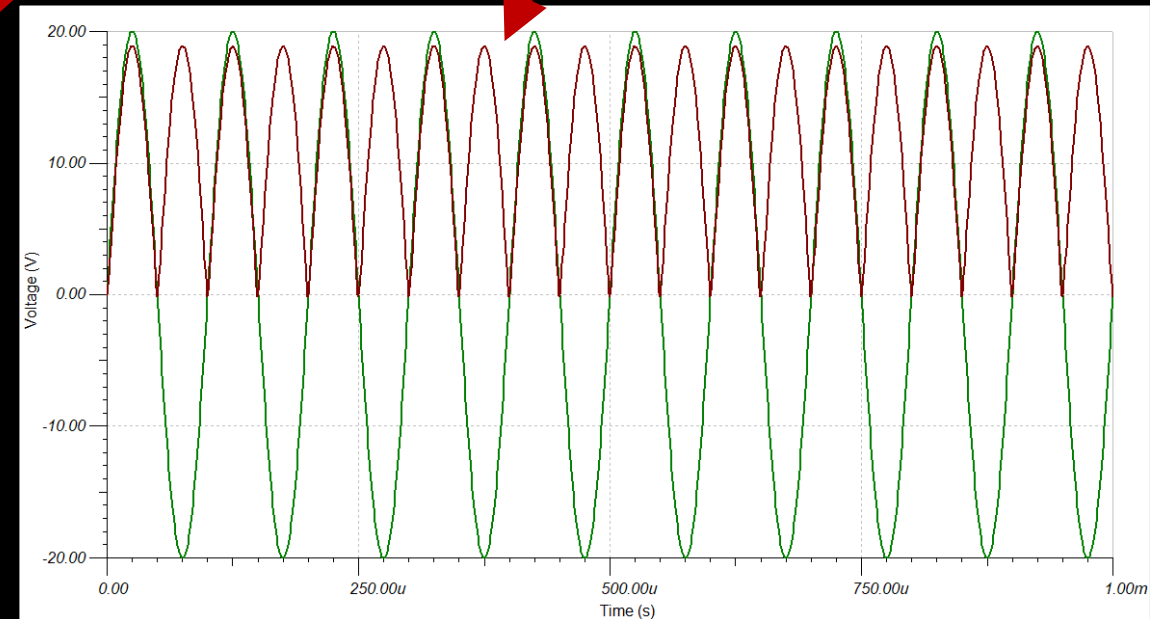
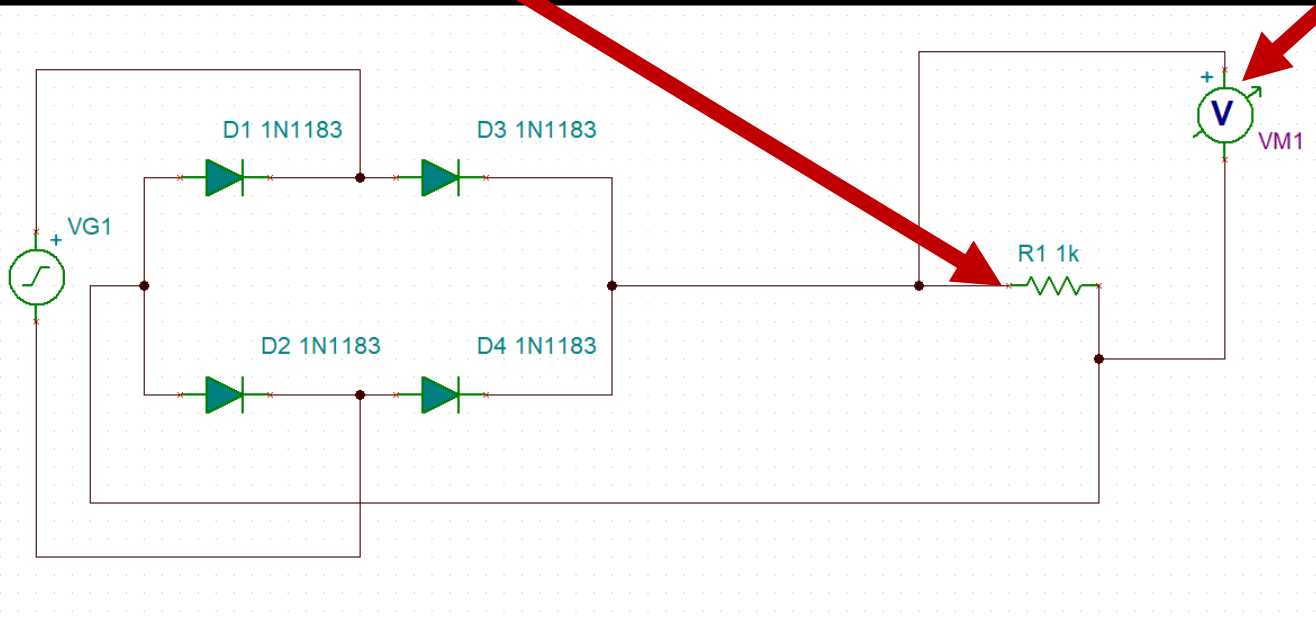


Example on rectification and filtering

- Texas Instruments TINA
- AC input rectified through diodes and no filtering/conditioning
- Load

Simulated Waveform
Green = voltage source
Red = output

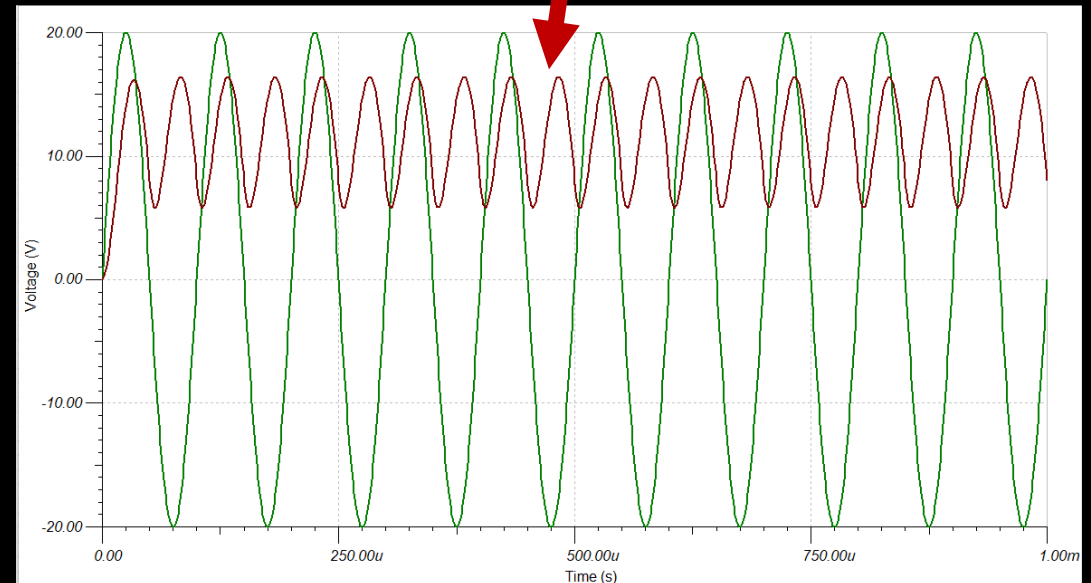
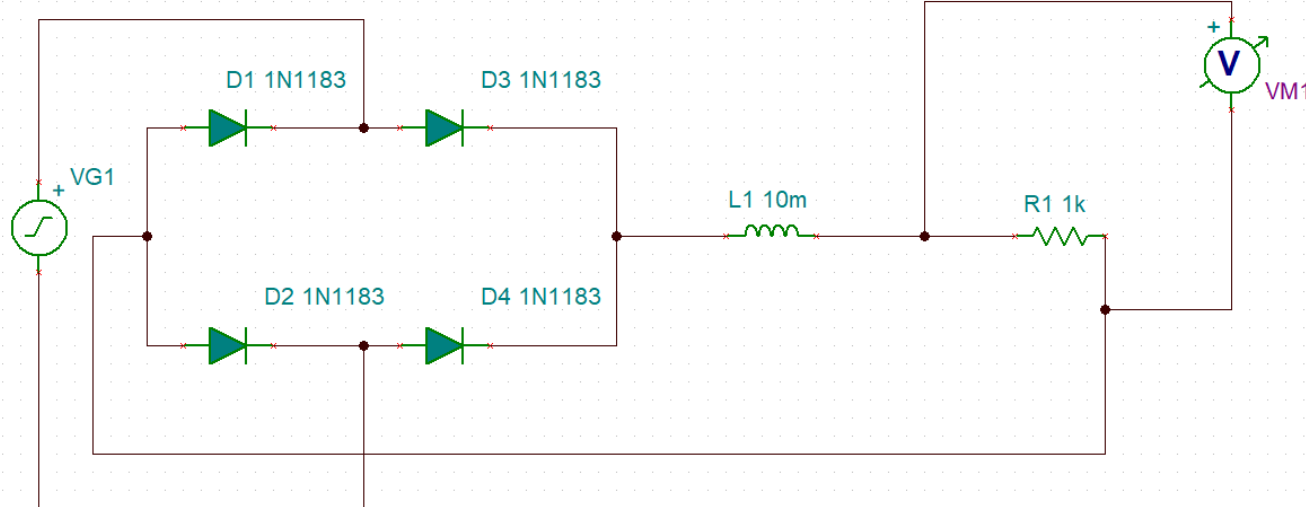
Voltmeter/scope



Example on rectification and filtering

- Inductor before load

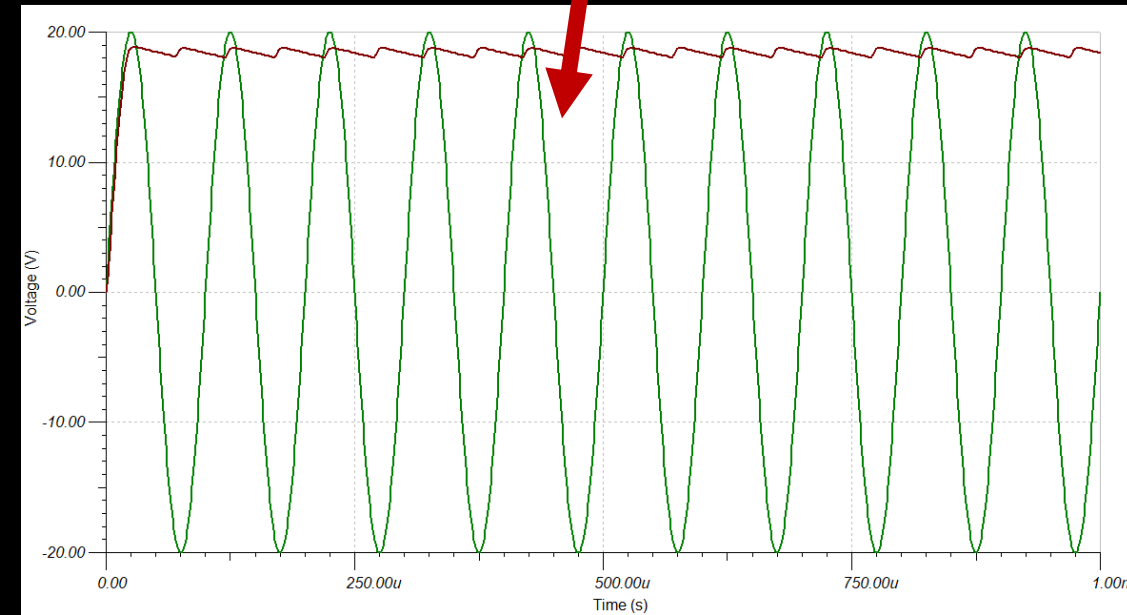
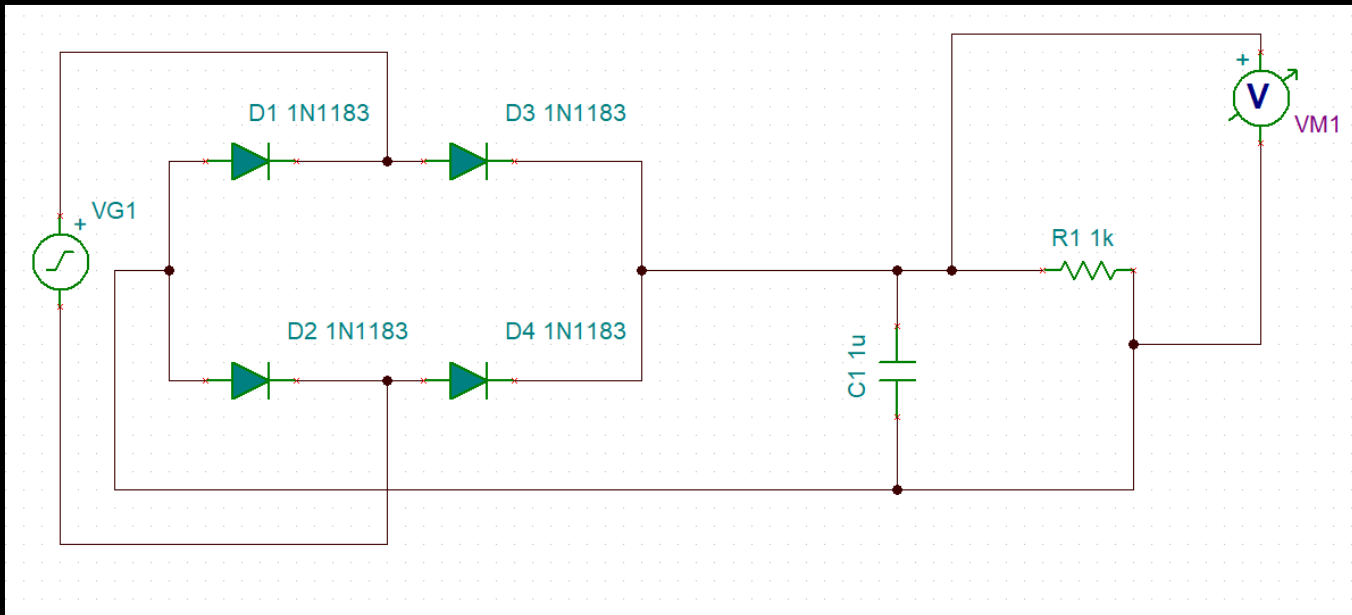
Inductors store energy in the magnetic field that results from changing current



Example on rectification and filtering

- Capacitor before the load

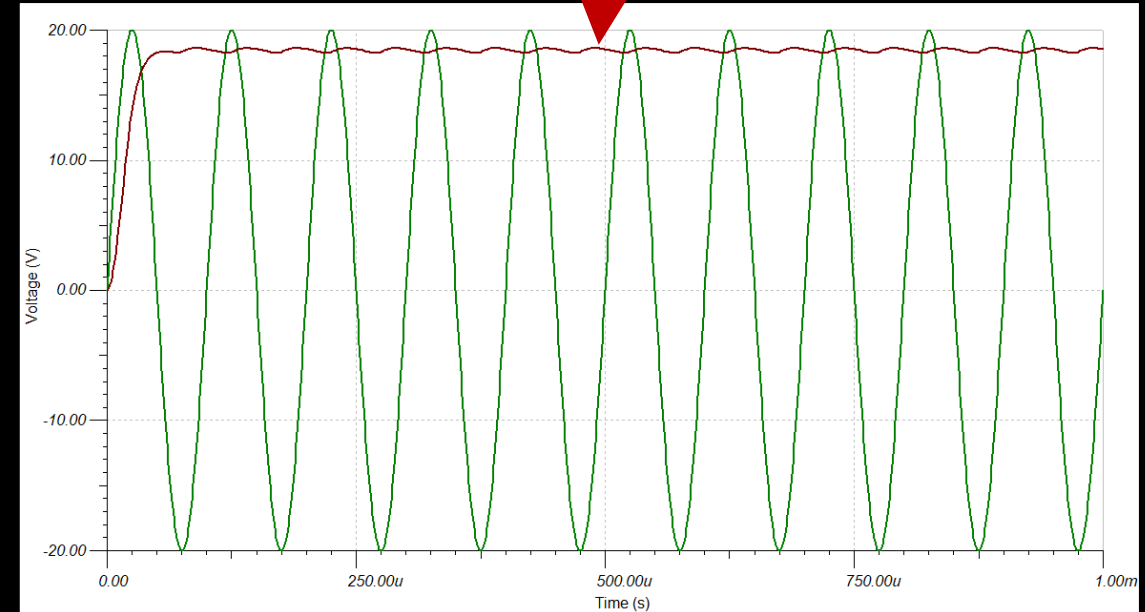
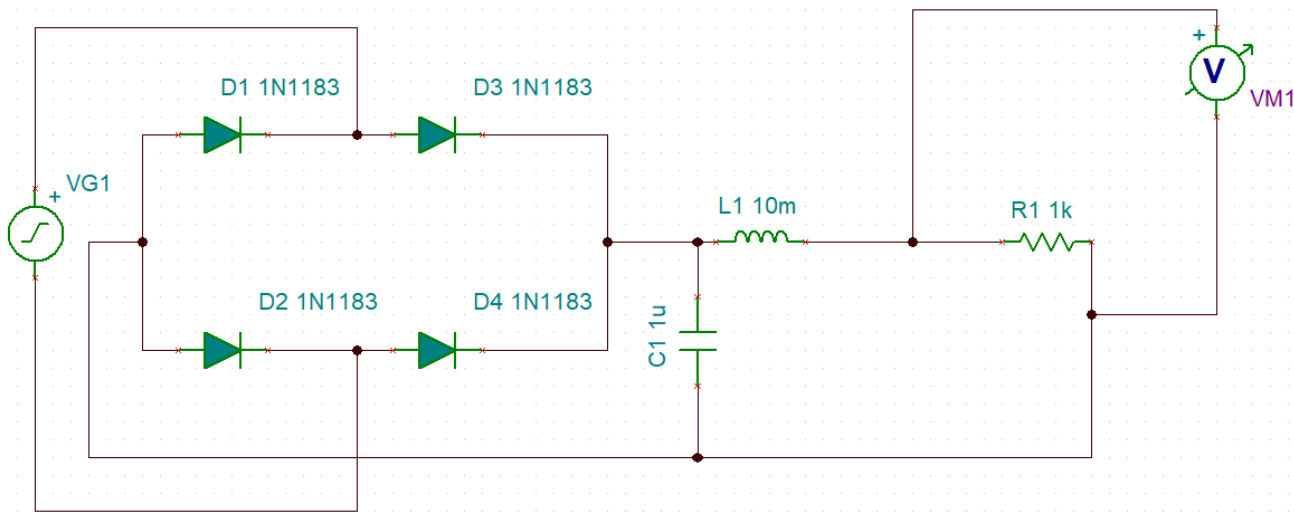
A filtering capacitor absorbs and releases energy changing voltage



Example on rectification and filtering

- Capacitor before inductor

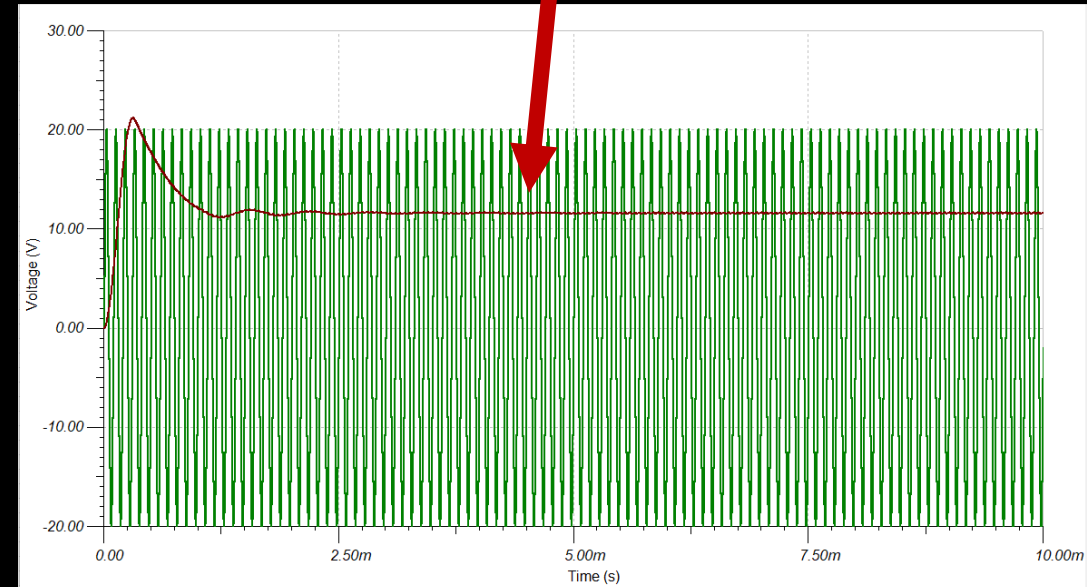
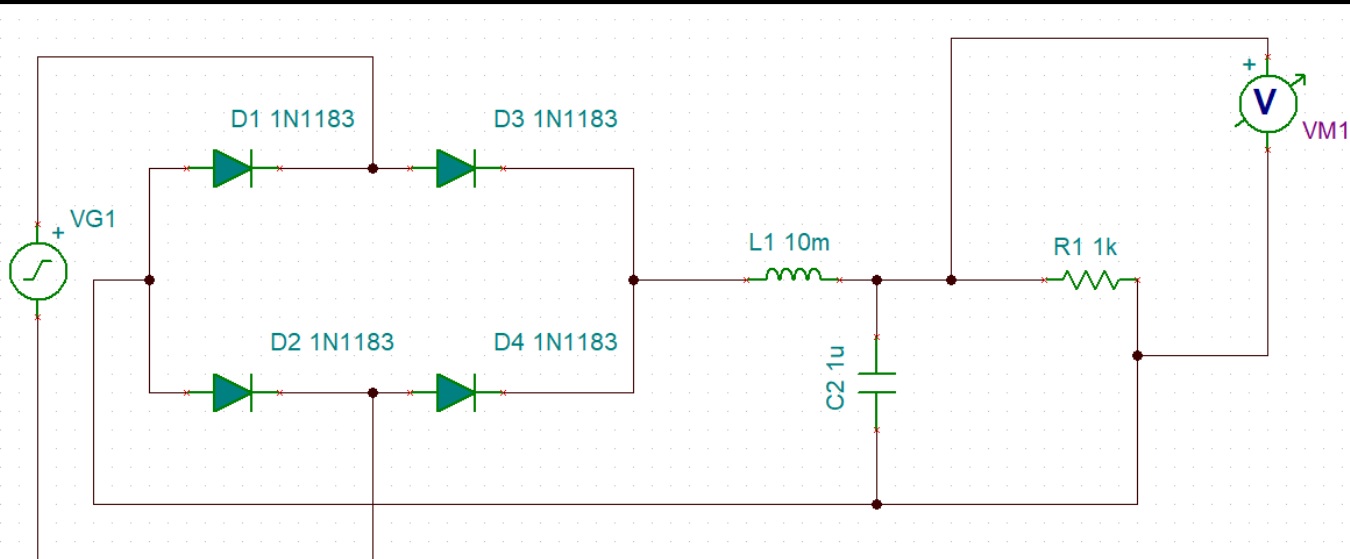
Inductor storing energy and
capacitor absorbing and releasing
energy



Example on rectification and filtering

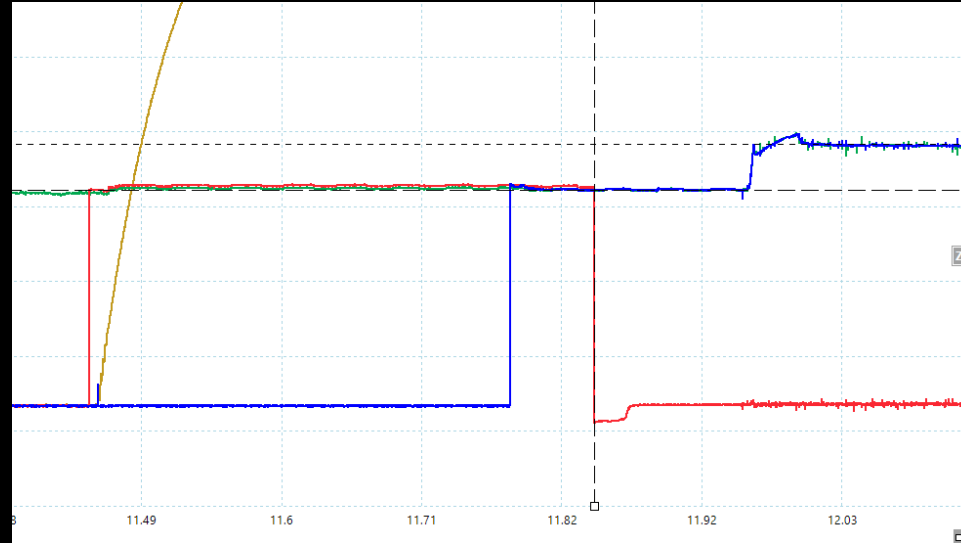
- Capacitor after inductor

Inductor storing energy and capacitor absorbing and releasing energy

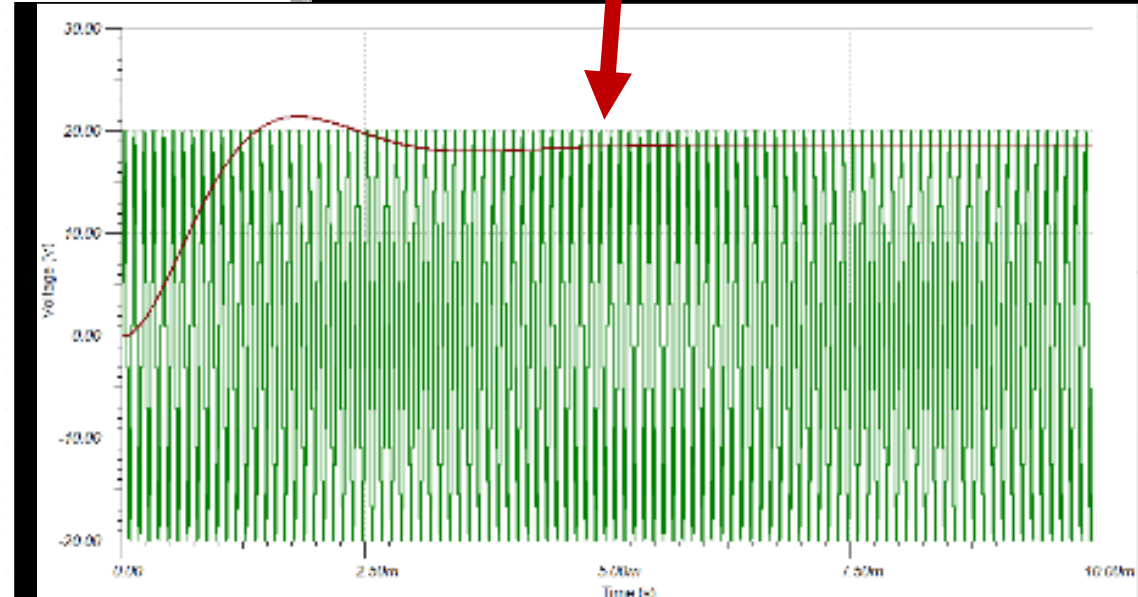
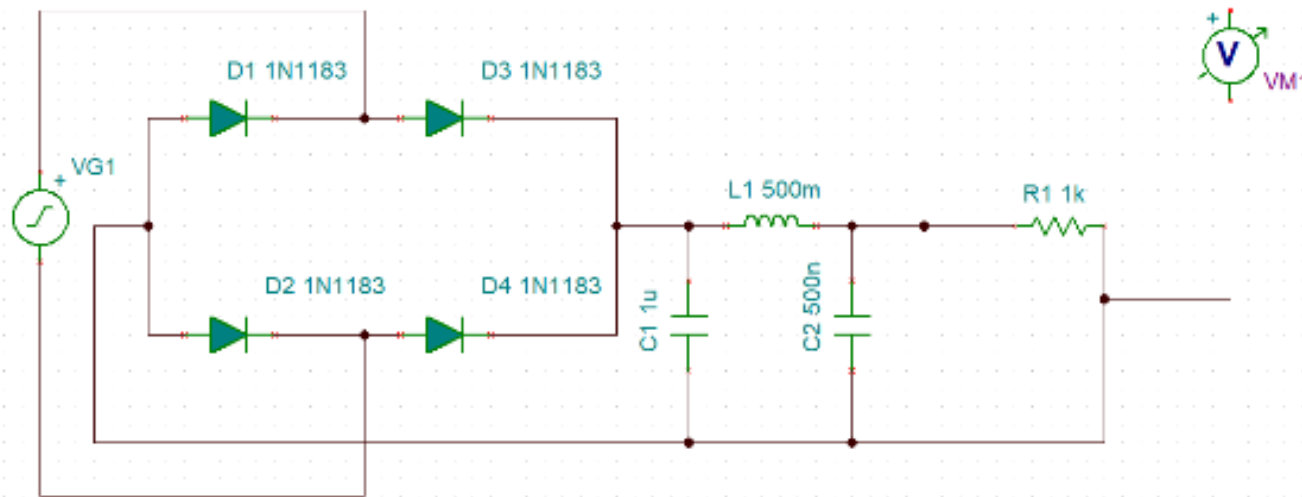


Example on rectification and filtering

- Capacitor before and after inductor

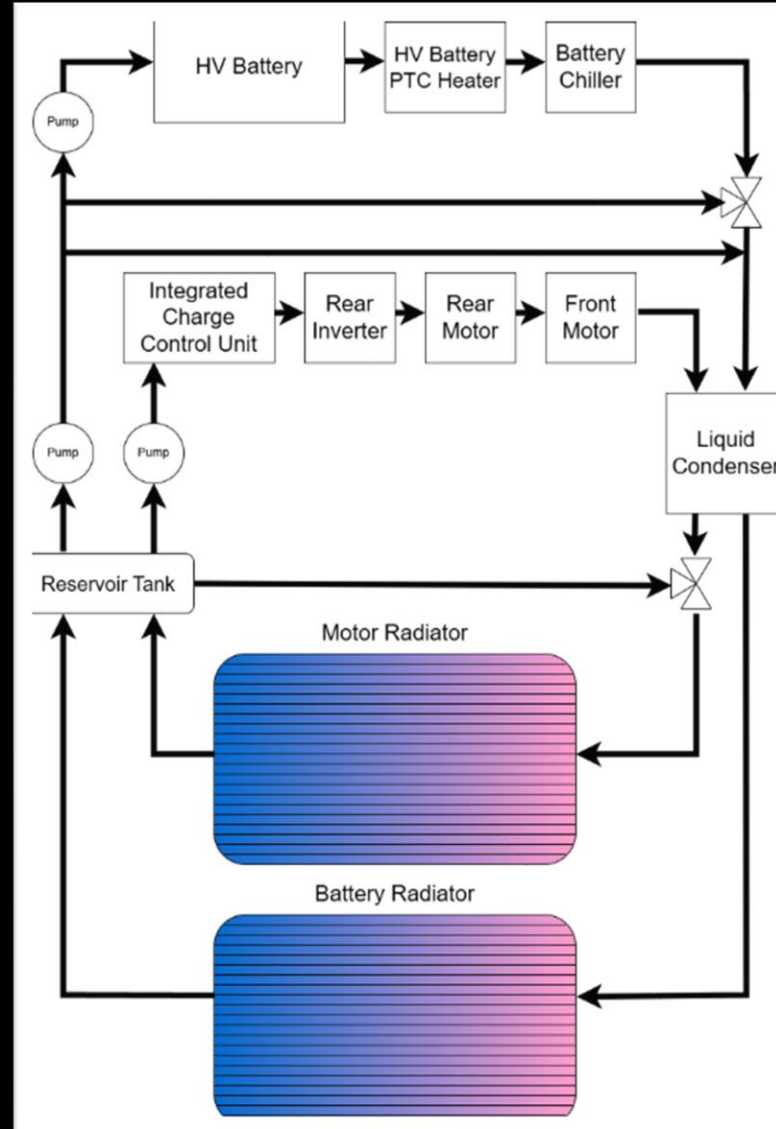


Inductor storing energy and capacitor absorbing and releasing energy



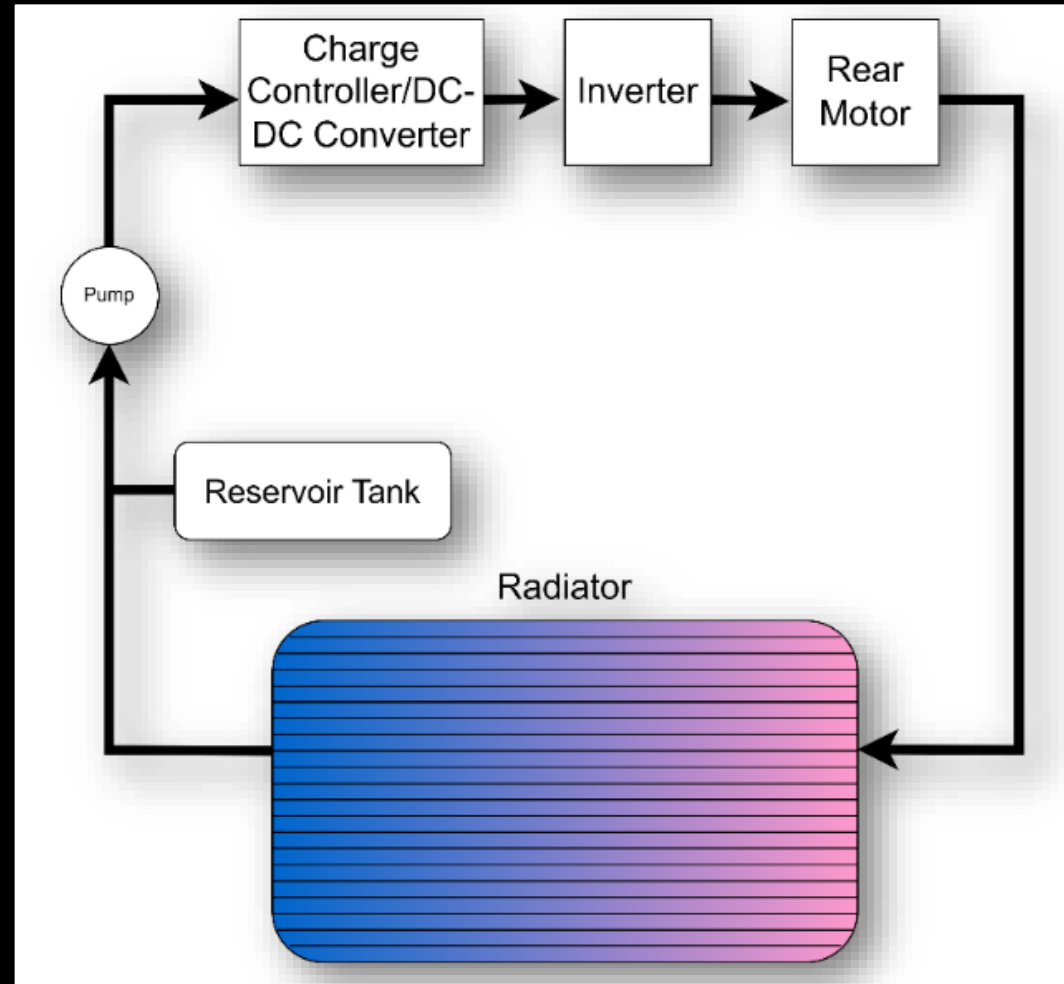
Power Electronics Cooling

- Hyundai Ionic 6
 - Inverter/converter /motor loop
 - Battery loop



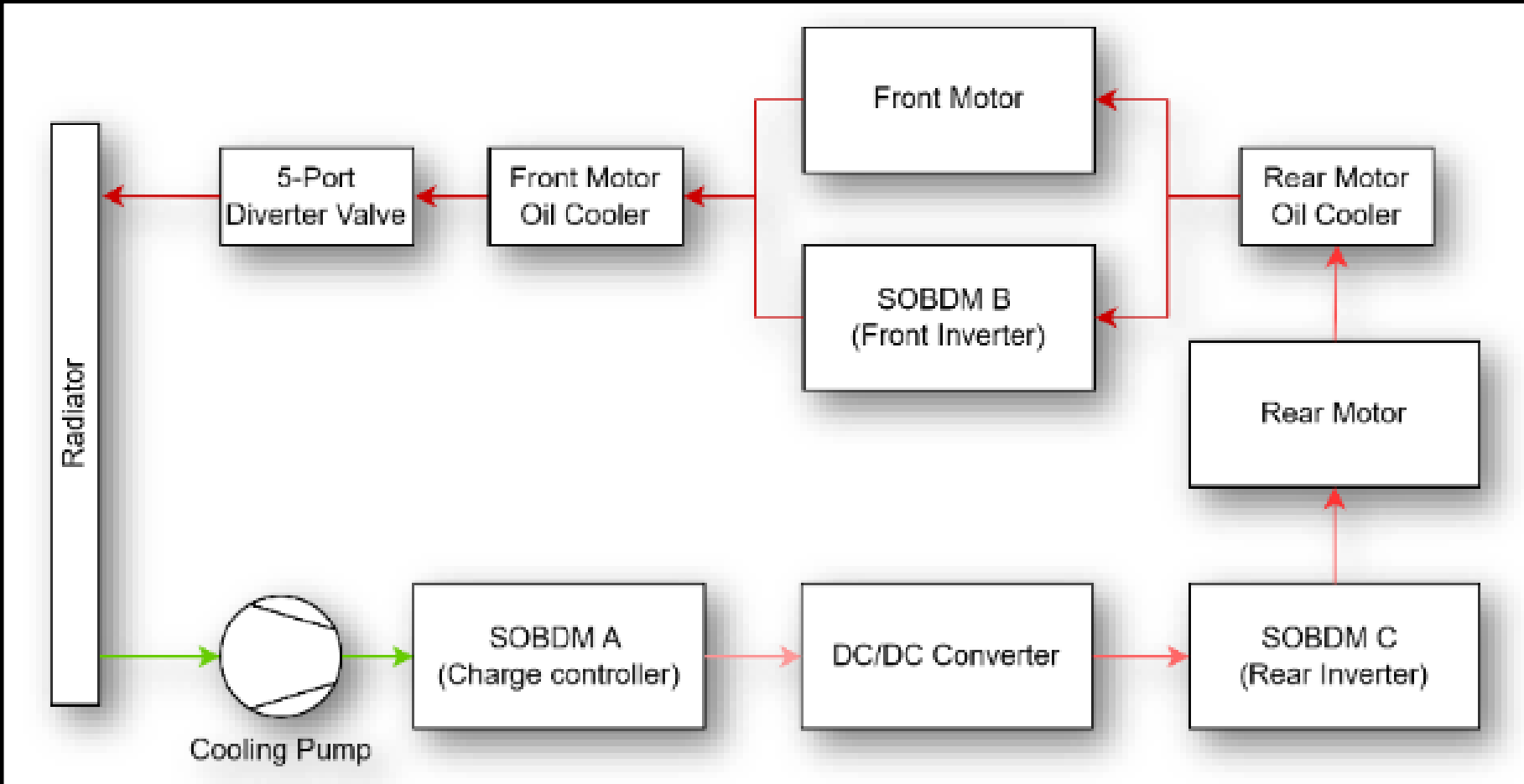
Power Electronics Cooling

- Nissan Leaf
 - Inverter/converter/motor loop



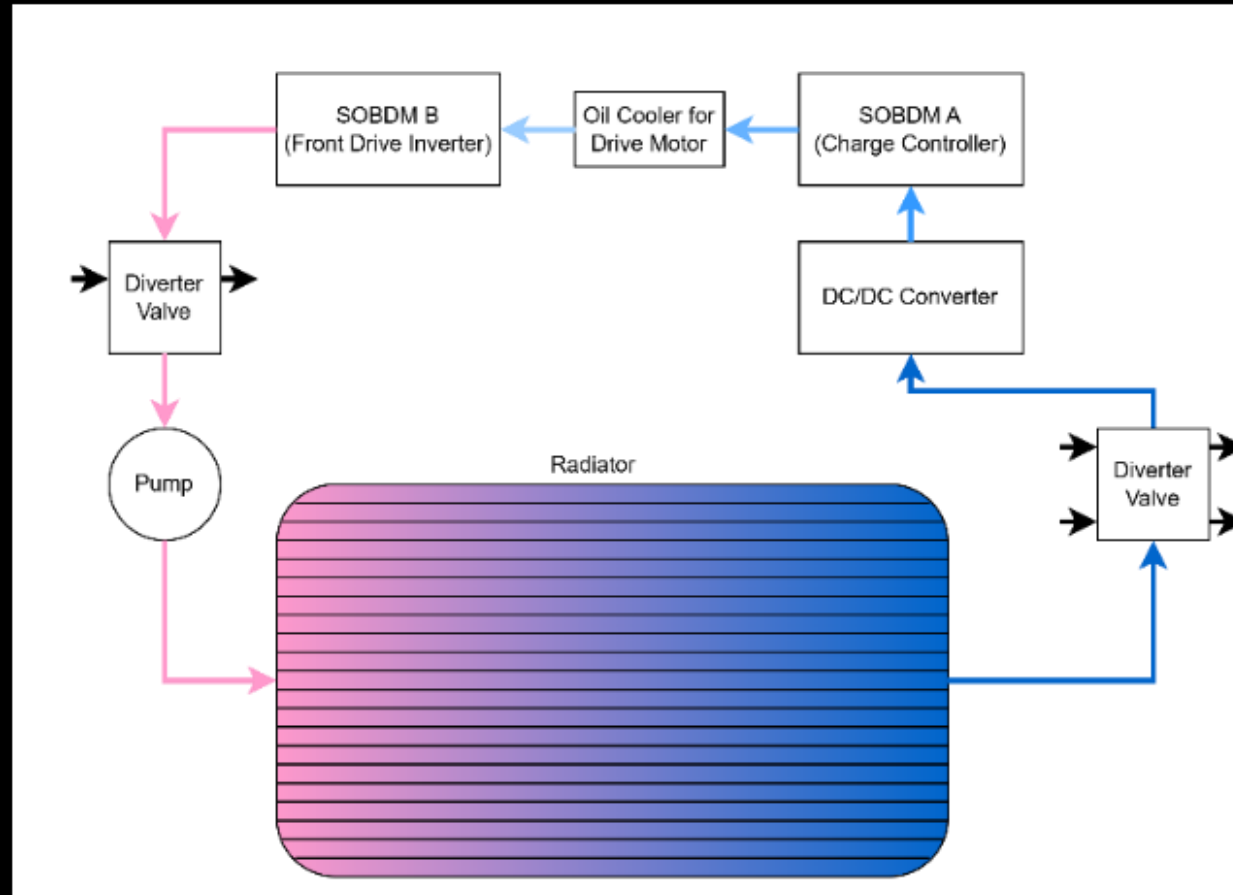
Power Electronics Cooling

- Ford Mach-E
 - Inverter/converter/motor loop



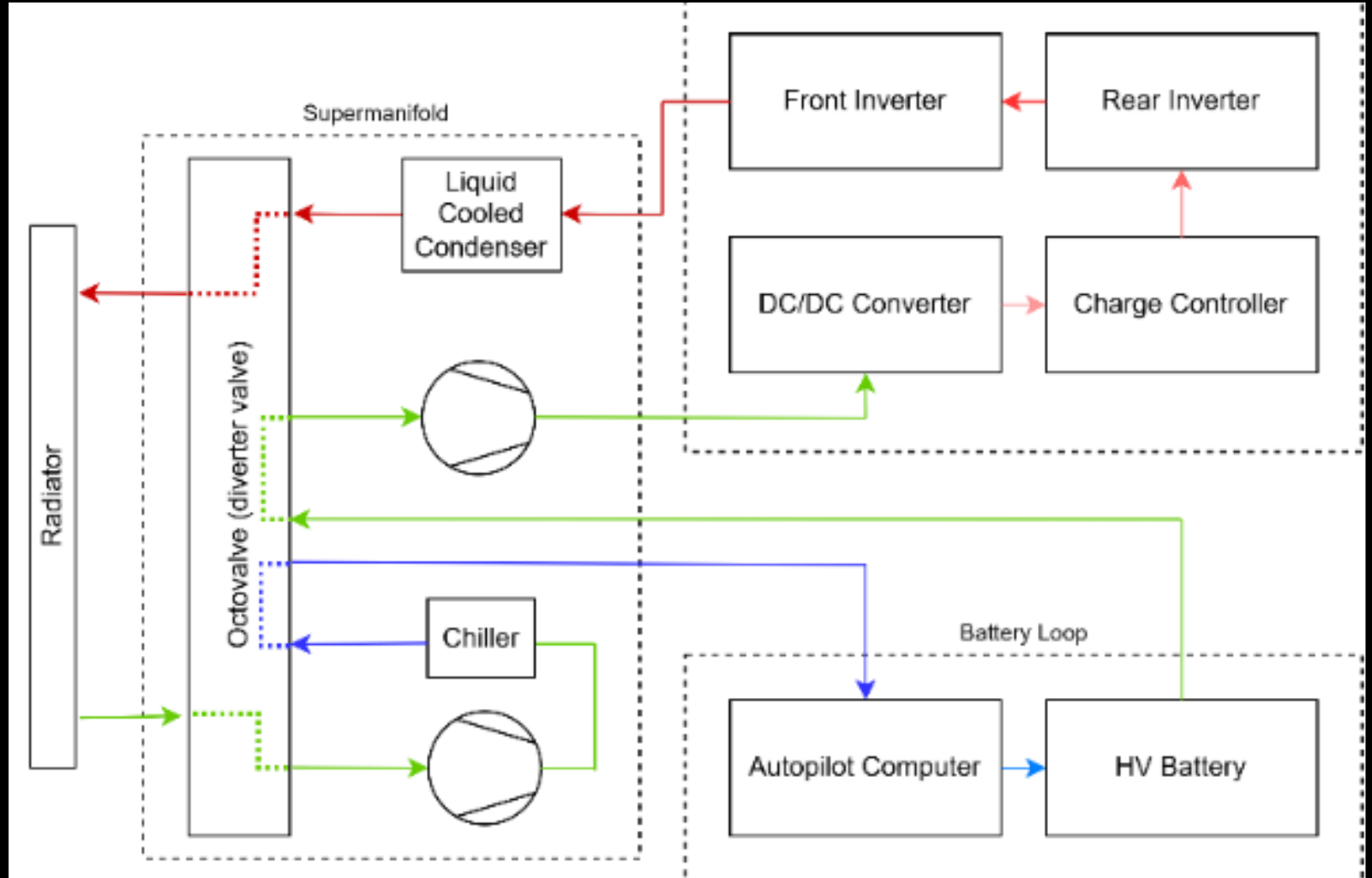
Power Electronics Cooling

- Ford F-150 Lightning
- Converter/Motor/Inverter loop



Power Electronics Cooling

- Tesla Model Y
 - Battery Loop
 - Power Electronics Loop



Does your shop have a vacuum coolant fill system?

Yes sir!

0

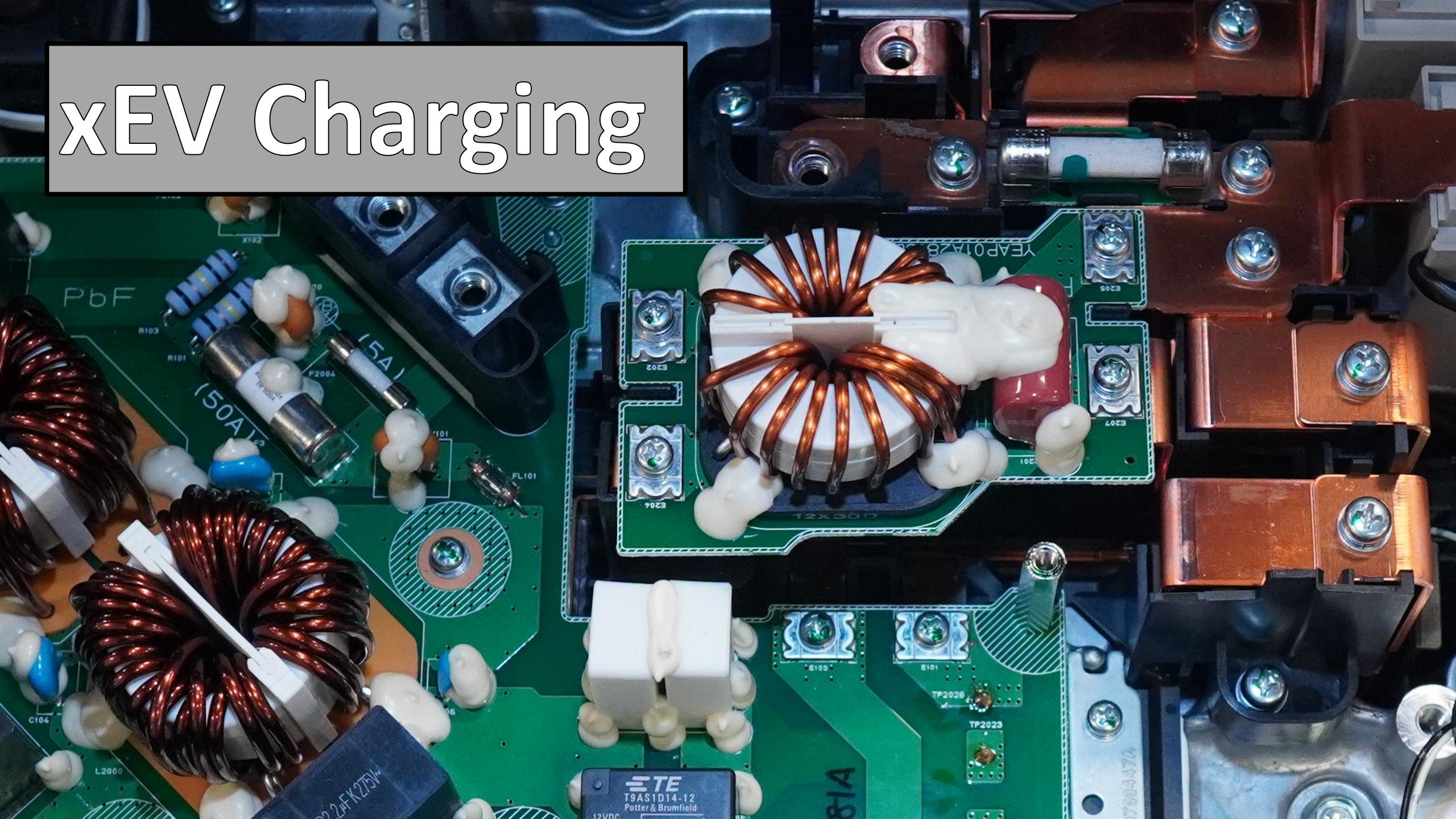
No, not yet

0

Never heard of it

0

xEV Charging

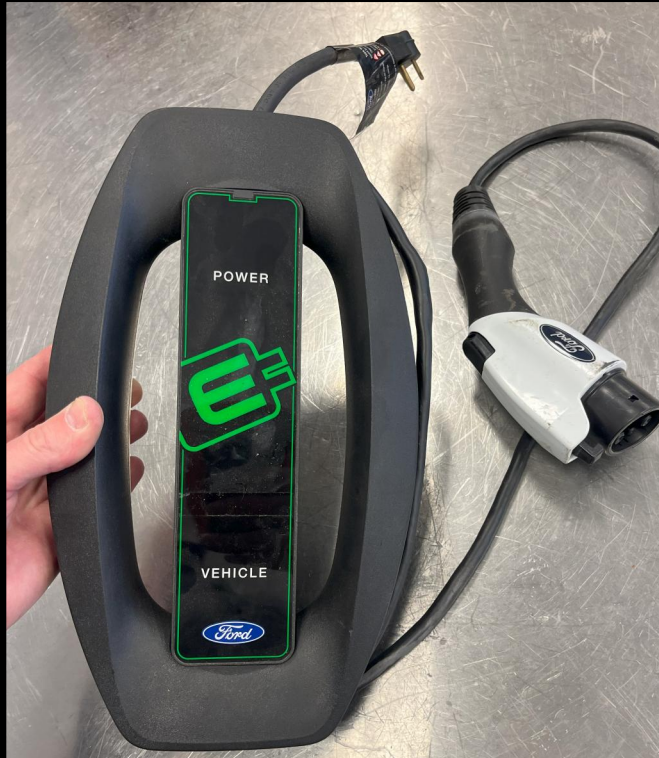


Are we going to
make house calls
to diagnose?



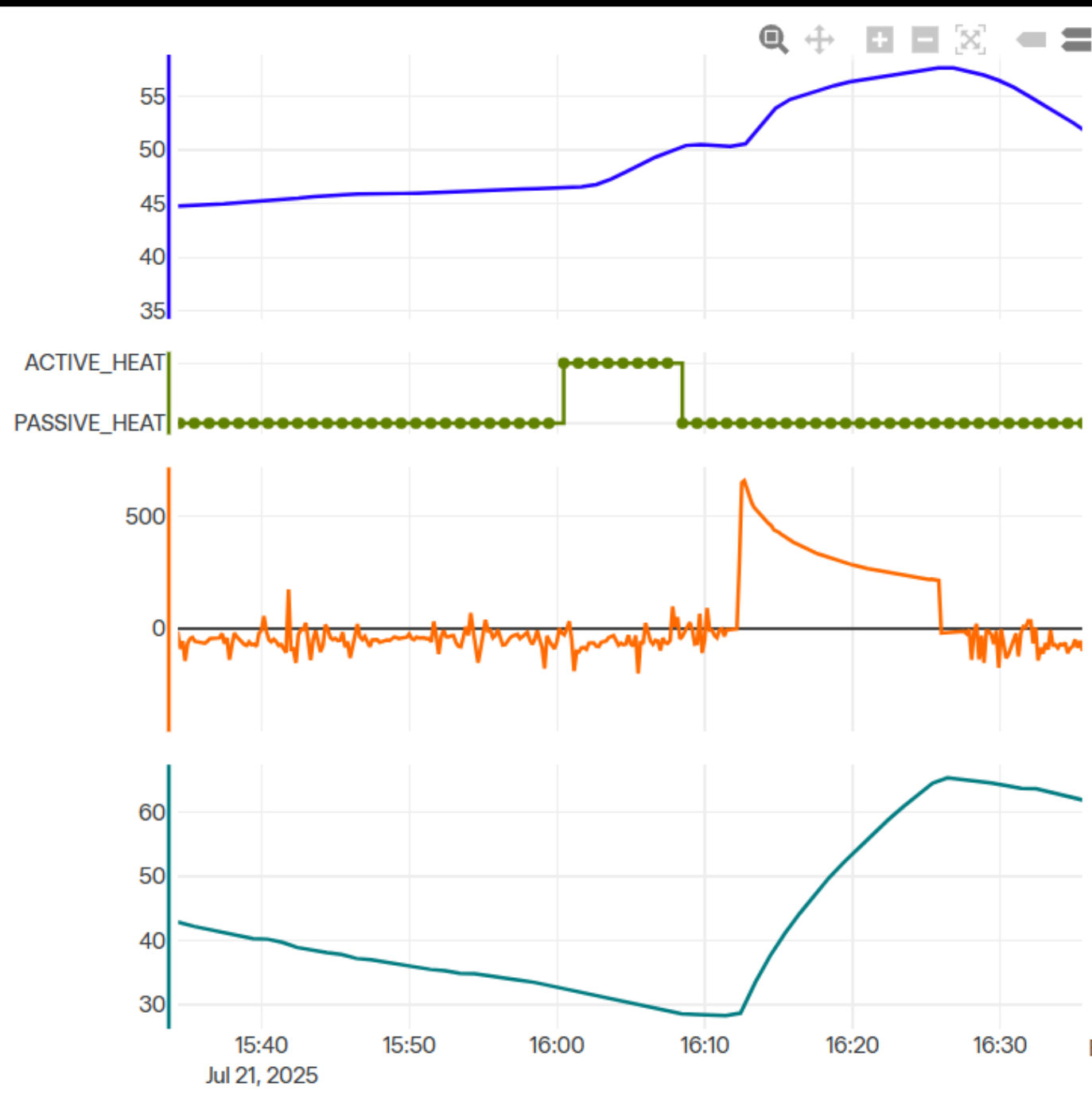
xEV charging

- EVSE or Vehicle



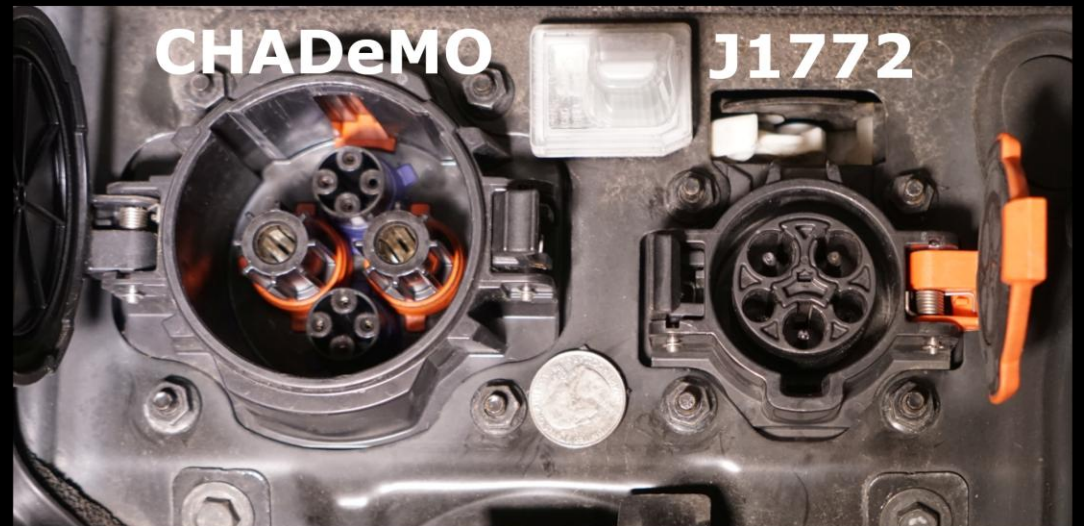
DCFC

- Battery heating
- Current demands
- Temperature monitoring

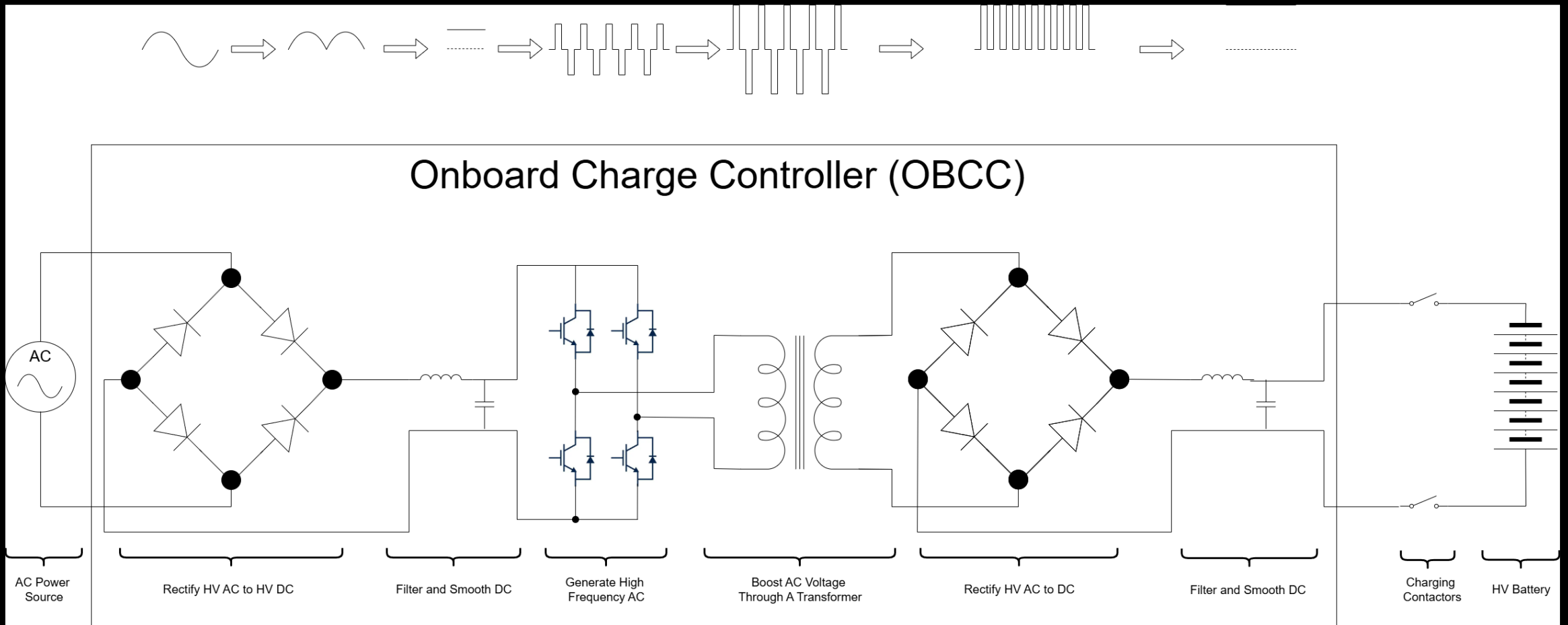


Plug standards

- North American Charging Standard (NACS)
- J1772
- Combined Charging System (CCS)
- CHADeMO – CHArge de Move – Charge for moving

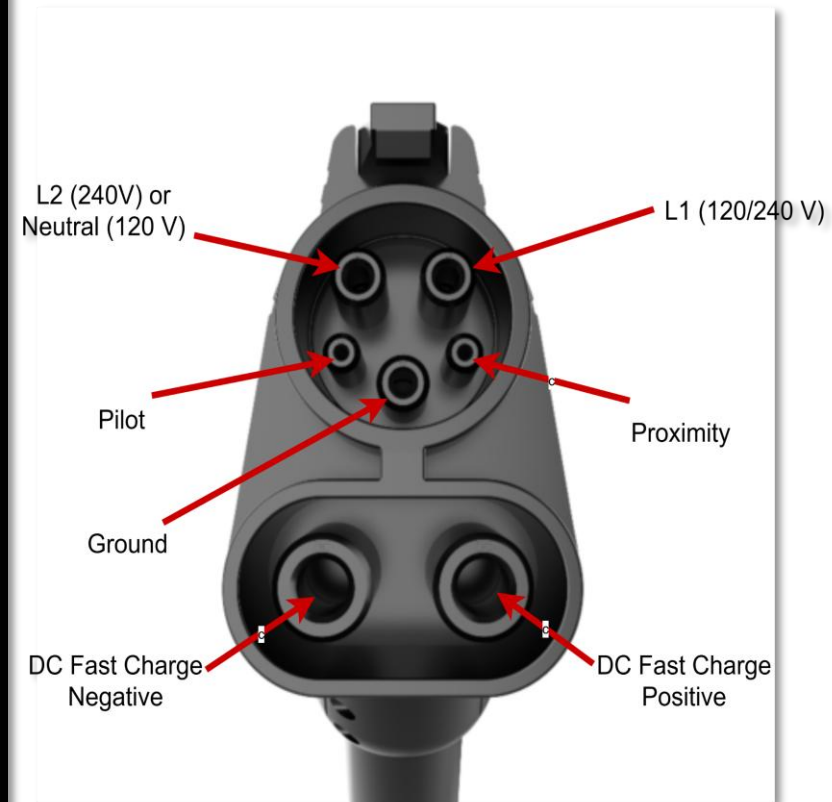
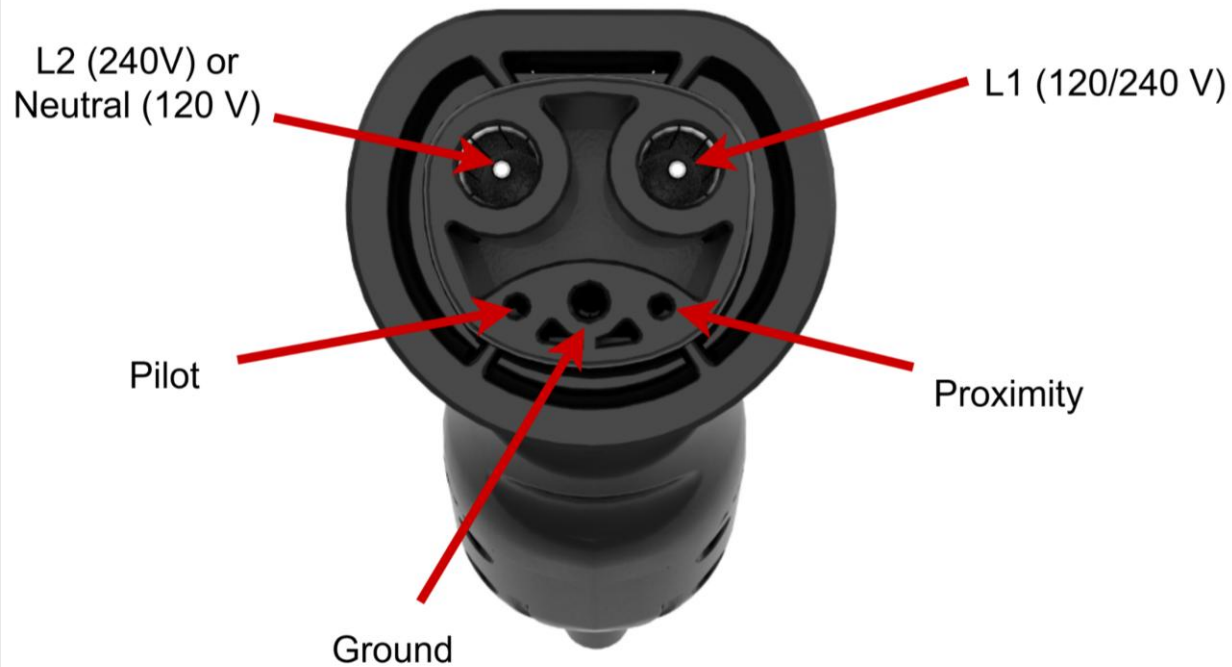


HV AC to HV DC → Transform to HV AC → Rectify HV AC to HV DC

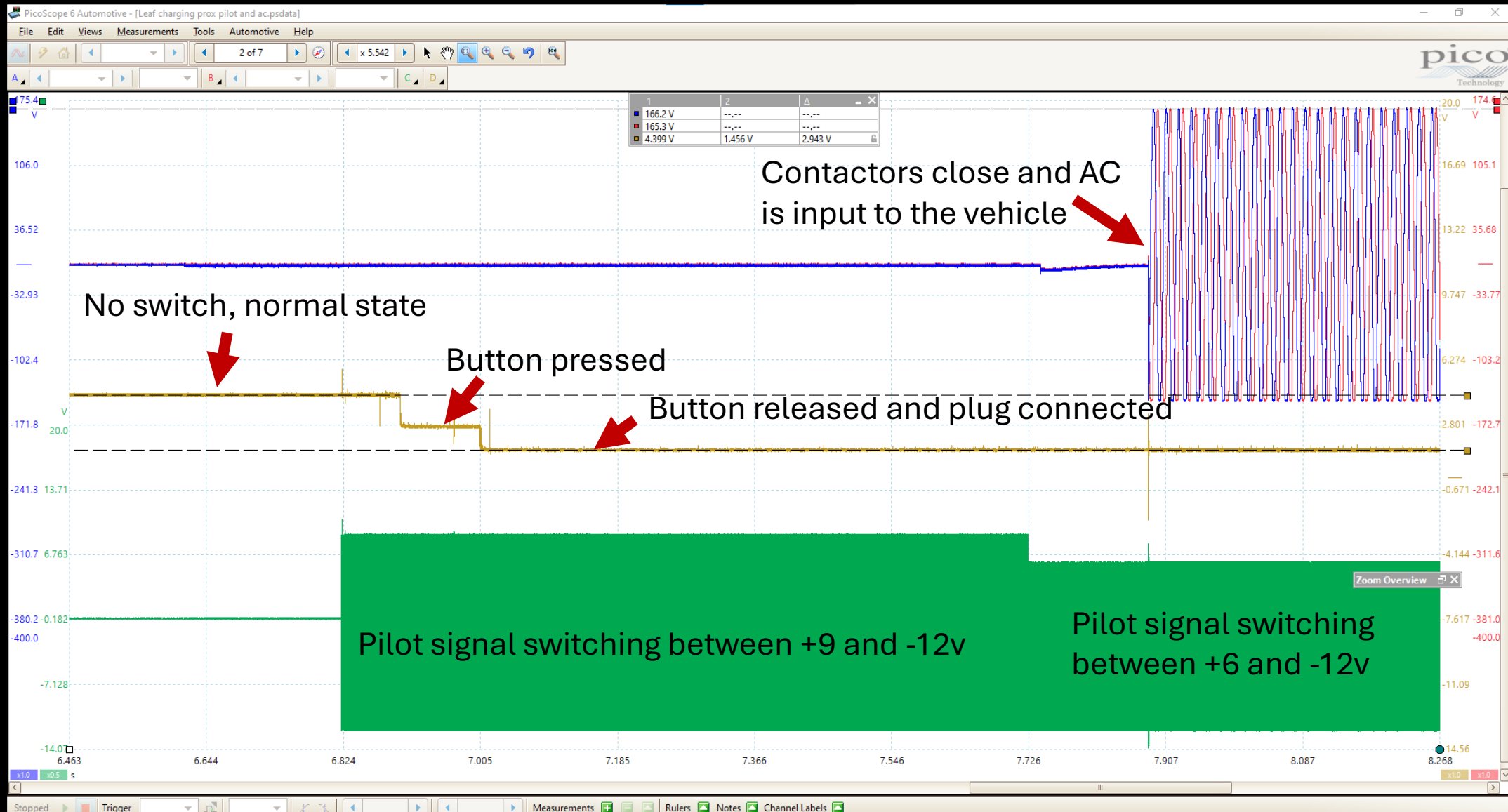


Charger connections

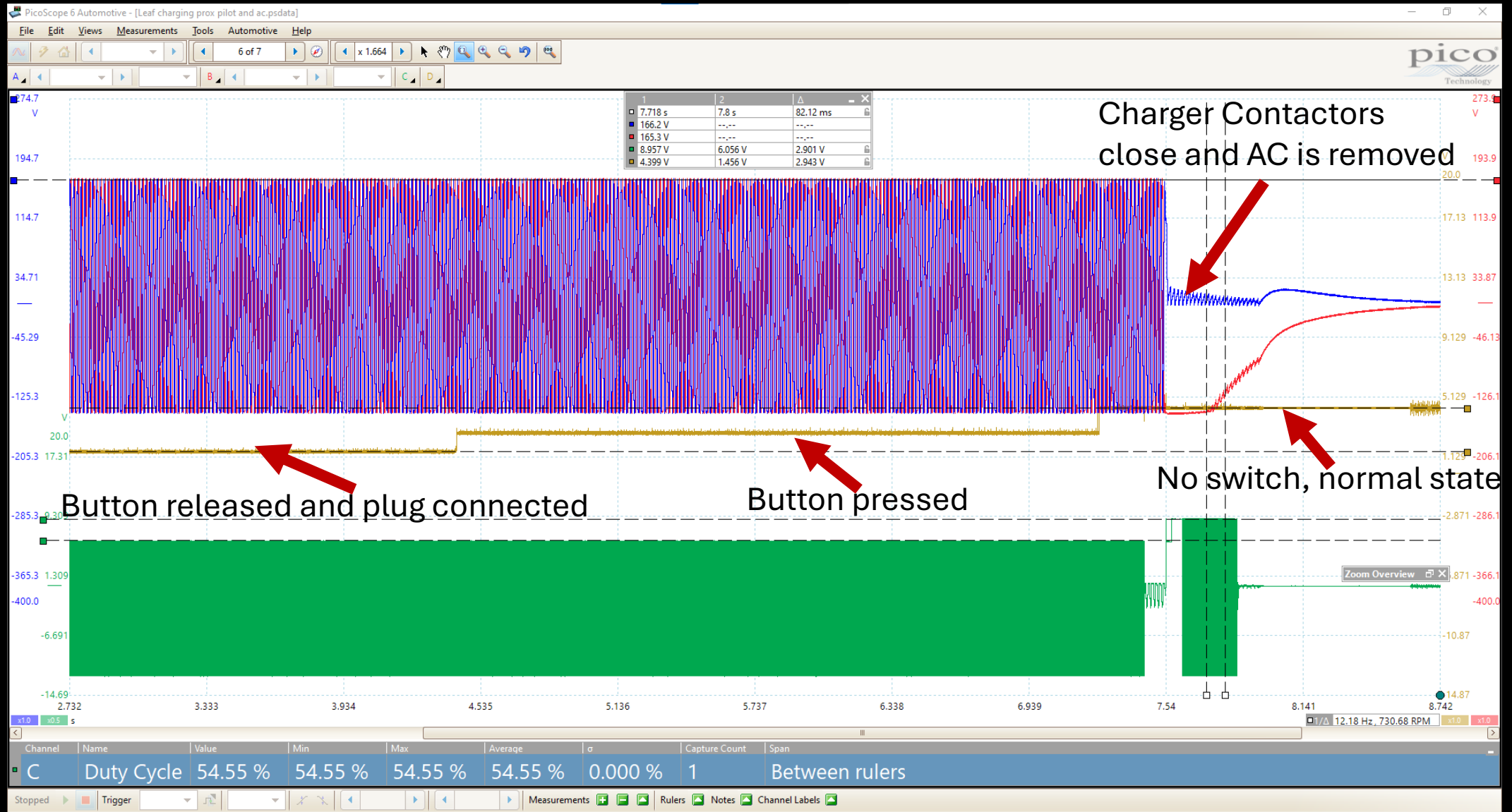
- Pilot – Charge rate
- Proximity – Switch state



Connection sequence

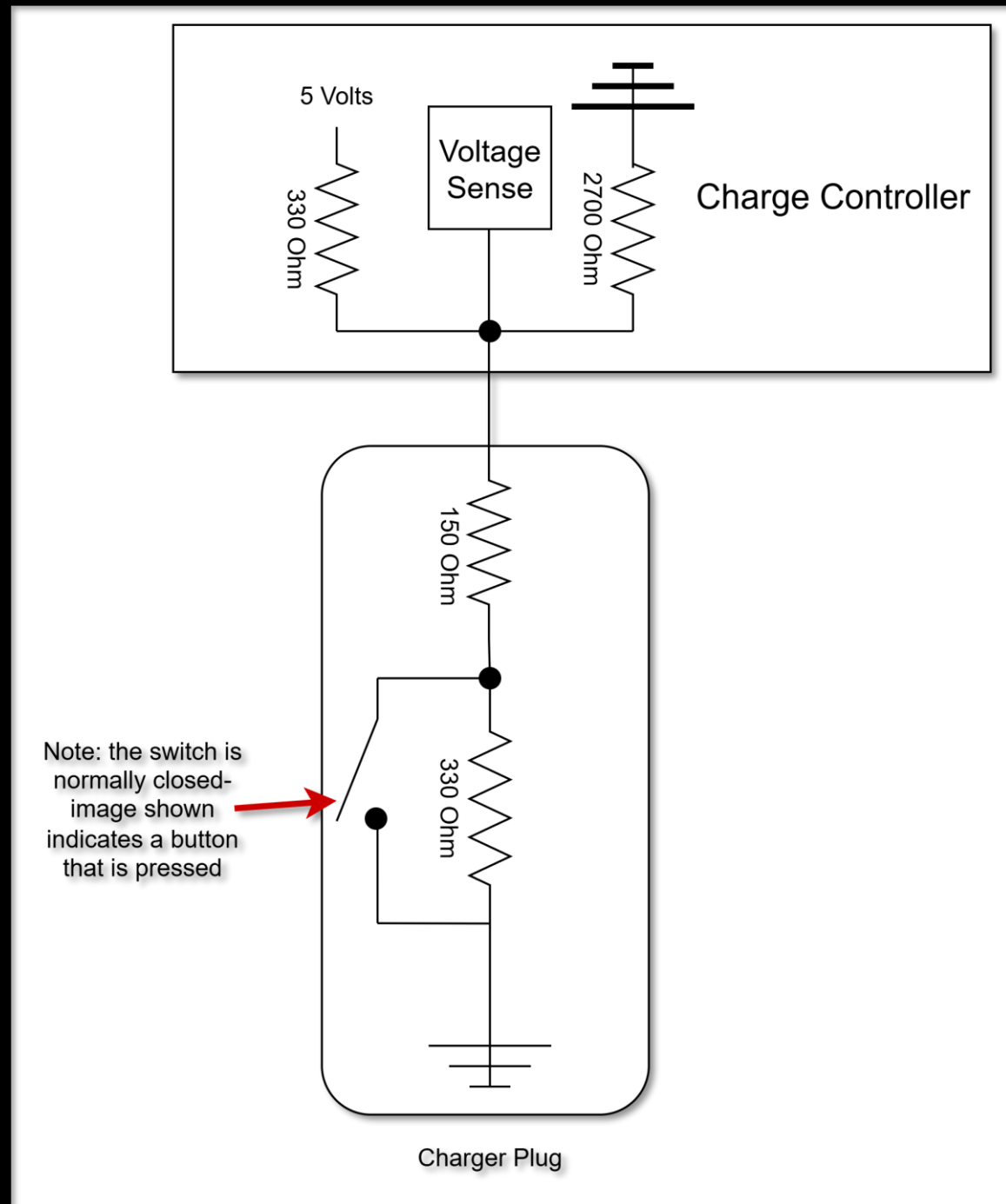


Disconnection sequence

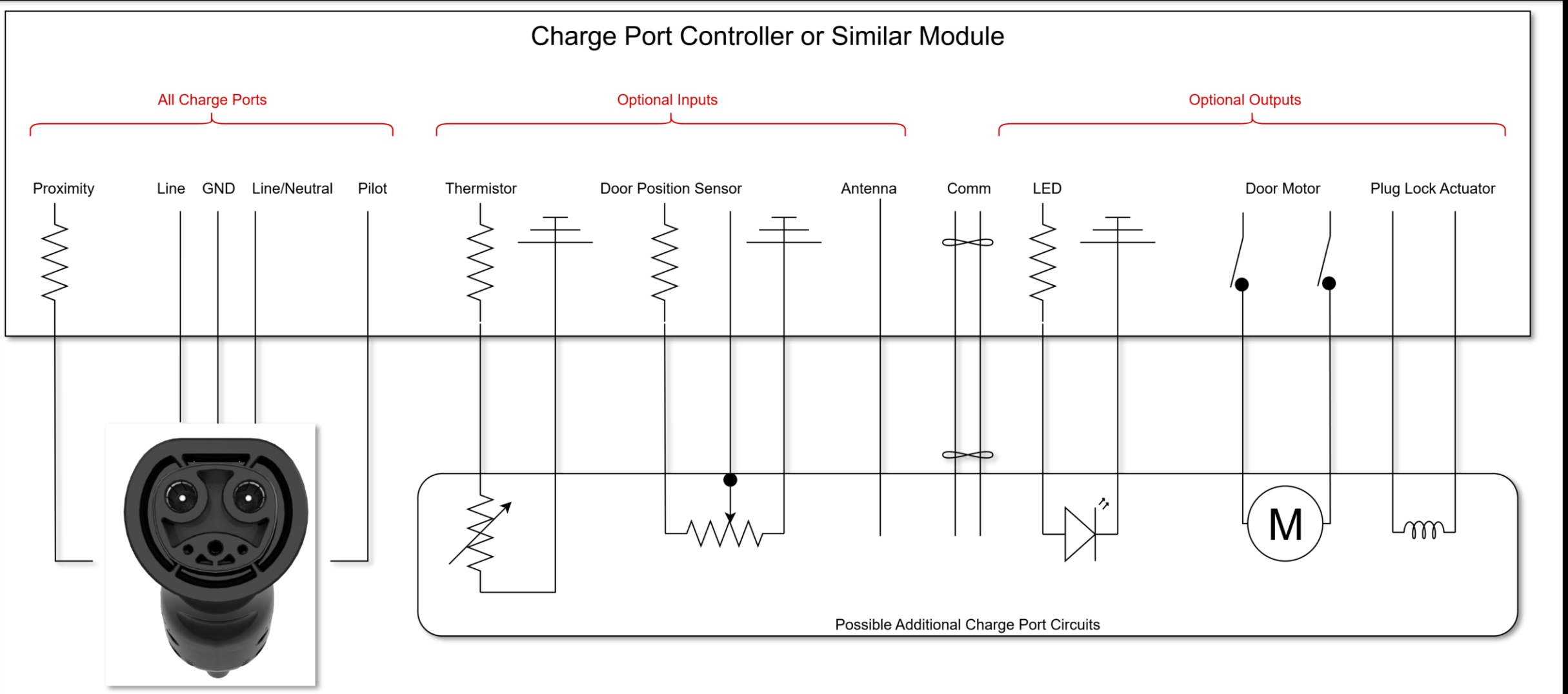


Proximity

- Disconnected
 - 2700 ohms to ground
 - ~4.4V
- Connected, button released
 - 150 ohms to ground through plug
 - (142 ohms with 2700 resistor)
 - ~1.45V
- Connected, button pressed
 - 480 ohms to ground through plug (408 ohms with 2700 resistor)
 - ~2.8V



Charge port electronics



Charge Port Data

Charge Port Data			
Parameter Name	Value	Unit	Control Module
Proximity Detection Circuit	Connected		Battery Energ...
Proximity Detection Circuit	1490	mV	Battery Energ...
Control Pilot Circuit	5900	mV	Battery Energ...
Battery Charger Coupler Lock	Unlocked		Battery Energ...
Battery Charger Coupler Lock Command	Not In Use		Battery Energ...
Hybrid/Electric Vehicle Battery AC Charger Coupler Temperature Sensor	95	°F	Battery Energ...
Hybrid/Electric Vehicle Battery AC Charger Coupler Temperature Sensor 4	91	°F	Battery Energ...
Hybrid/Electric Vehicle Battery DC Charger Coupler Temperature Sensor	77	°F	Battery Energ...
Hybrid/Electric Vehicle Battery DC Charger Coupler Temperature Sensor 2	75	°F	Battery Energ...
Charge Port Door Position Sensor	Fully Opened		Battery Energ...
Charge Port Door Position Sensor	2.2	V	Battery Energ...

2026 Chevrolet Equinox

Hybrid/Electric Vehicle Battery Accumulated Time at Range 2 State of Charge when Charging - Recent	818.03	min	Battery Energ...
Hybrid/Electric Vehicle Battery Accumulated Time at Range 3 State of Charge when Charging - Recent	479.19	min	Battery Energ...
Hybrid/Electric Vehicle Battery Accumulated Time at Range 4 State of Charge when Charging - Recent	487.49	min	Battery Energ...
Hybrid/Electric Vehicle Battery Accumulated Time at Range 5 State of Charge when Charging - Recent	1226.48	min	Battery Energ...
Hybrid/Electric Vehicle Battery Accumulated Time at Range 6 State of Charge when Charging - Recent	3627.84	min	Battery Energ...
Hybrid/Electric Vehicle Battery Accumulated Time at Range 7 State of Charge when Charging - Recent	102.57	min	Battery Energ...
Hybrid/Electric Vehicle Battery Accumulated Time at Range 8 State of Charge when Charging - Recent	0.00	min	Battery Energ...
Hybrid/Electric Vehicle Battery Accumulated Time at Range 1 State of Charge when Vehicle Off - Recent	26109.28	min	Battery Energ...
Hybrid/Electric Vehicle Battery Accumulated Time at Range 2 State of Charge when Vehicle Off - Recent	92433.35	min	Battery Energ...
Hybrid/Electric Vehicle Battery Accumulated Time at Range 3 State of Charge when Vehicle Off - Recent	17232.03	min	Battery Energ...
Hybrid/Electric Vehicle Battery Accumulated Time at Range 4 State of Charge when Vehicle Off - Recent	15983.14	min	Battery Energ...

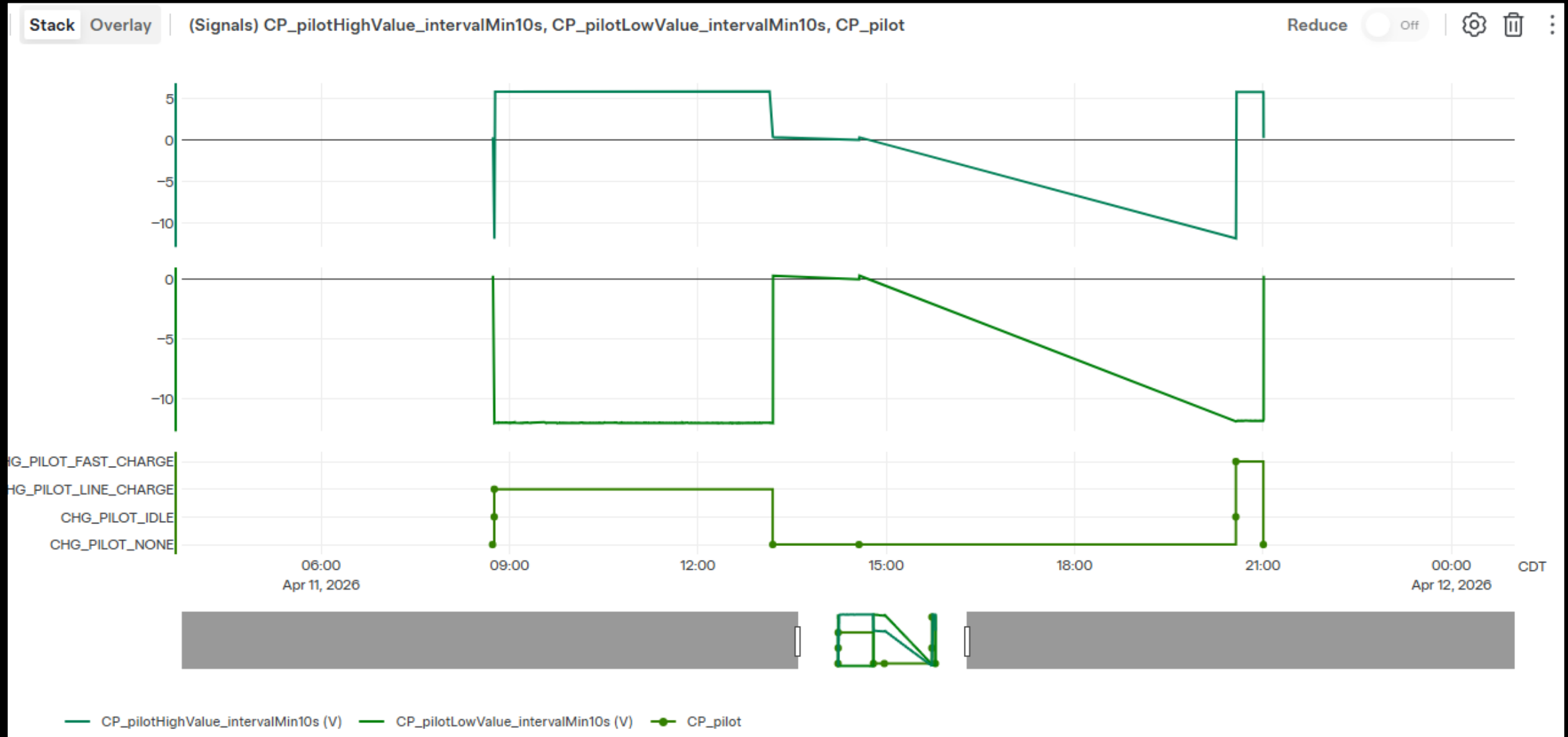
2026 Chevrolet Equinox

Hybrid/Electric Vehicle Battery Voltage Isolation Sensing Circuit	On		Battery Energ...
Hybrid/Electric Vehicle Battery Voltage Isolation Sensing Circuit	0	mV	Battery Energ...
Hybrid/Electric Vehicle Battery Pack Voltage Isolation Sensing Circuit 2	On		Battery Energ...
Hybrid/Electric Vehicle Battery Pack Voltage Isolation Sensing Circuit 2	0	mV	Battery Energ...
Battery Charger Coupler Lock	Unlocked		Battery Energ...
Battery Charger Input Voltage Sensor	205500	mV	Battery Energ...
Battery Charger DC Voltage Command	365000	mV	Battery Energ...
Battery Charger System Inhibit Reason	Not In Use		Battery Energ...
Hybrid/Electric Vehicle Battery DC Charging Positive Voltage	-700	mV	Battery Energ...
Hybrid/Electric Vehicle Battery DC Charging Negative Voltage	2000	mV	Battery Energ...
14 Volt Power Module Status	Voltage Conversion...		Battery Energ...

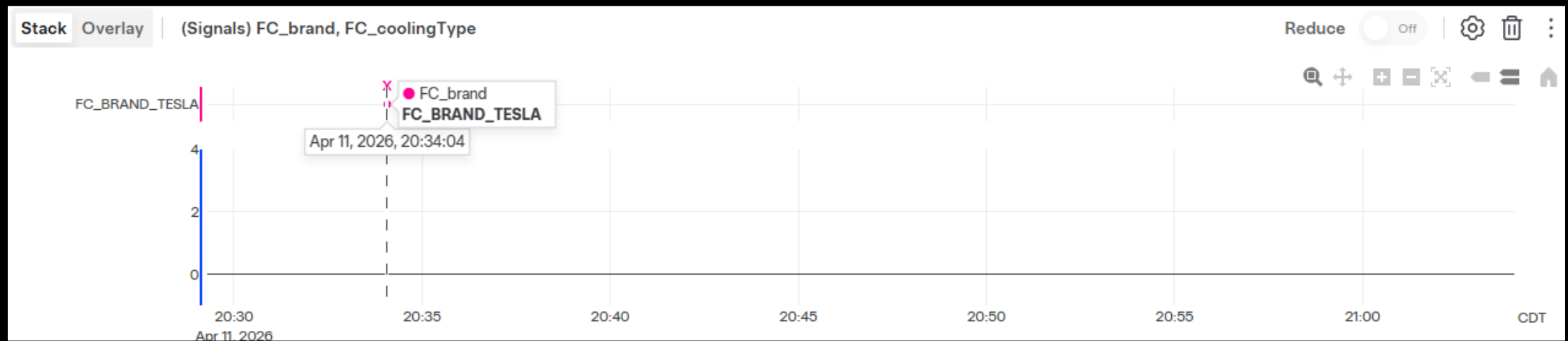
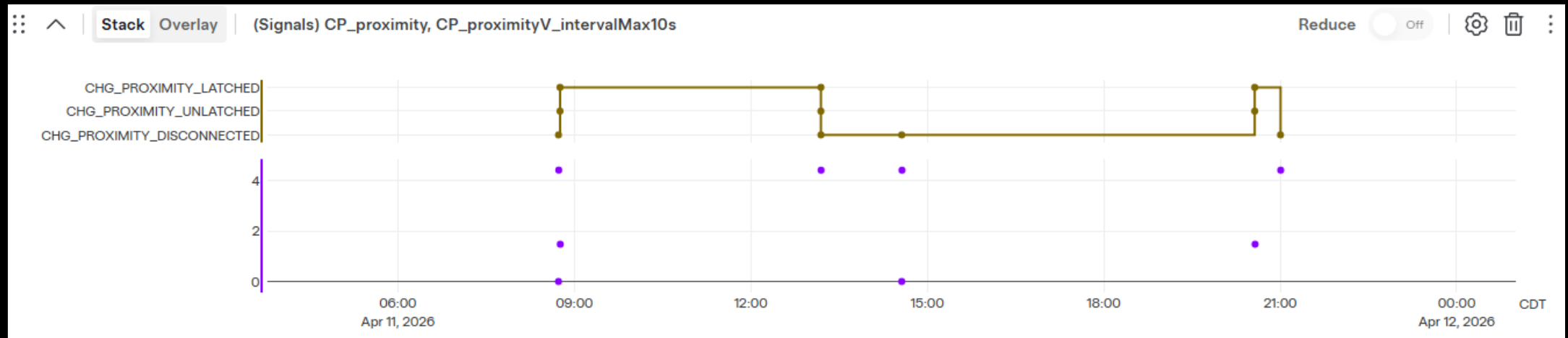
2026 Chevrolet Equinox

DC Charge History Data			
Parameter Name	Value	Unit	Control Module
DC Charge History 1 - Termination Reason	Coupler Unplugged		Battery Energ...
DC Charge History 1 - Duration	00:43:39	hh:mm:ss	Battery Energ...
DC Charge History 1 - Discharging	No		Battery Energ...
DC Charge History 1 - Charge/Discharge Duration	43.74	min	Battery Energ...
DC Charge History 1 - Vehicle Propulsion System Active	No		Battery Energ...
DC Charge History 1 - Vehicle Run/Crank Active	No		Battery Energ...
DC Charge History 1 - Vehicle OFF in Park	Yes		Battery Energ...
DC Charge History 1 - Series Charging	No		Battery Energ...
DC Charge History 1 - Series Charging Not Allowed By Vehicle	No		Battery Energ...
DC Charge History 1 - Parallel Charging	Yes		Battery Energ...
DC Charge History 1 - Thermal Conditioning Requested	Yes		Battery Energ...

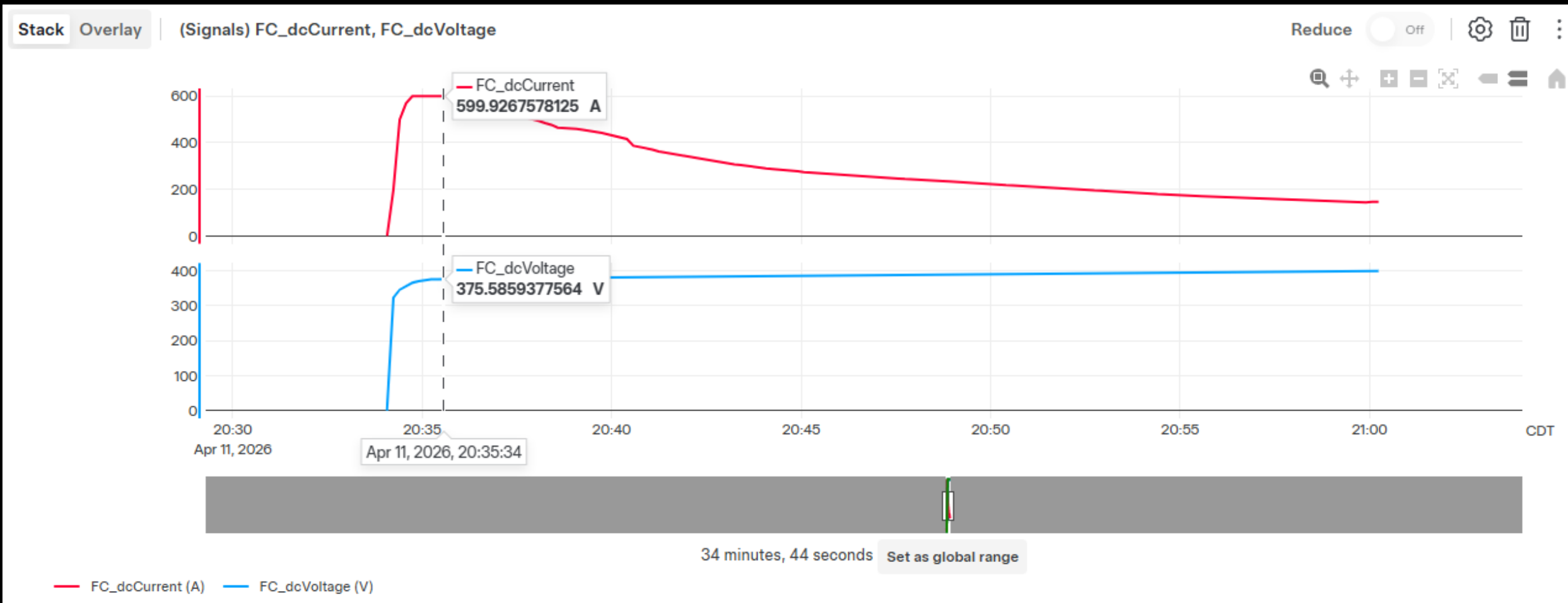
2022 Tesla Model 3 – Pilot States



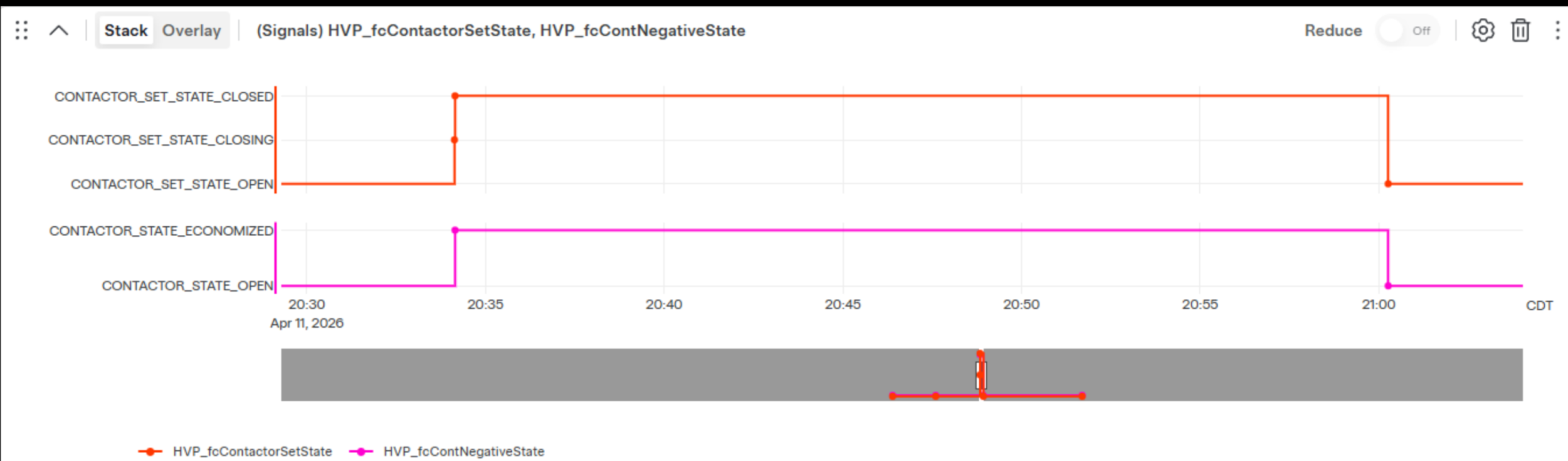
Tesla Model 3 Proximity and DCFC



Tesla Model 3 DC Fast Charge Data

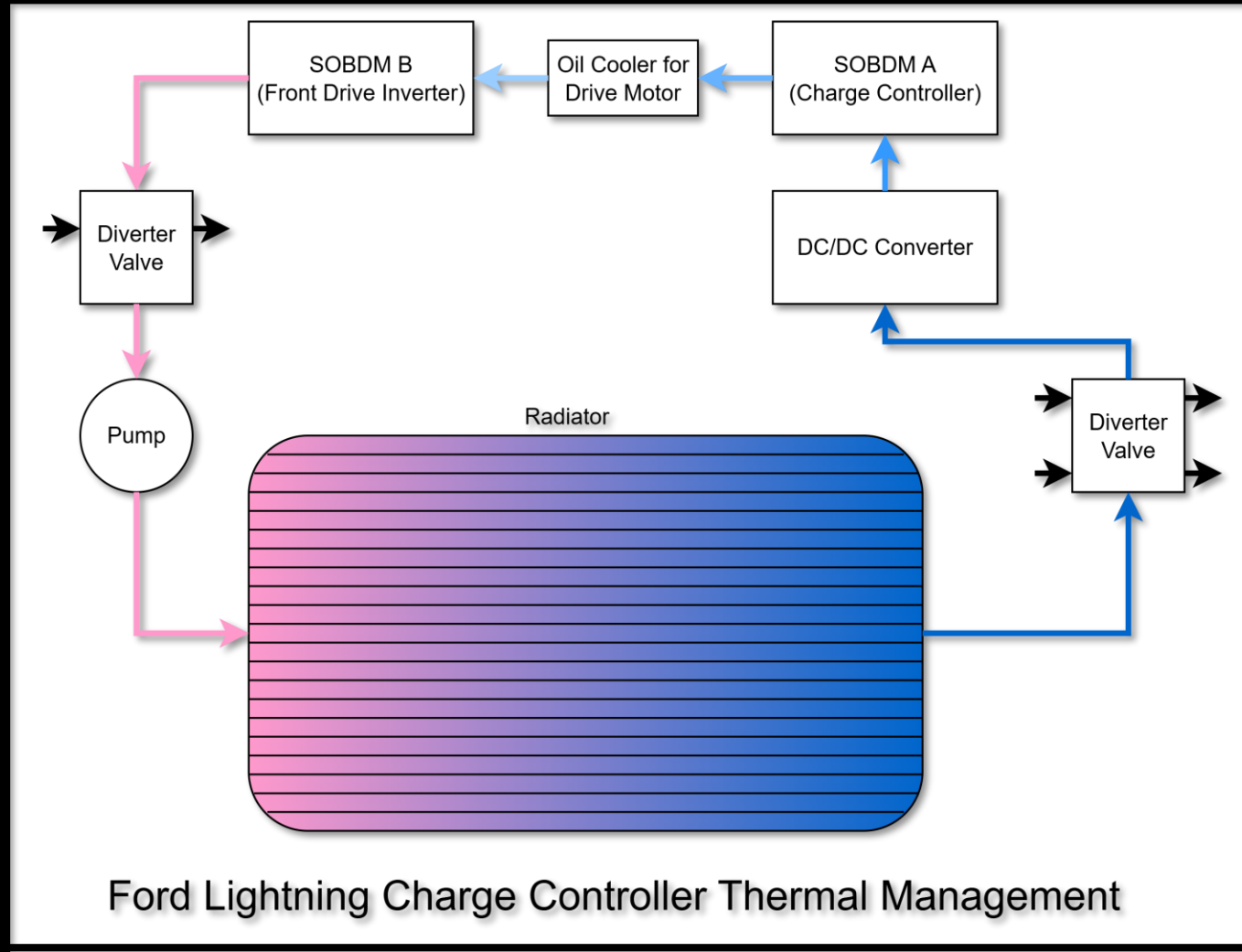


Tesla Model 3 Contactor Status



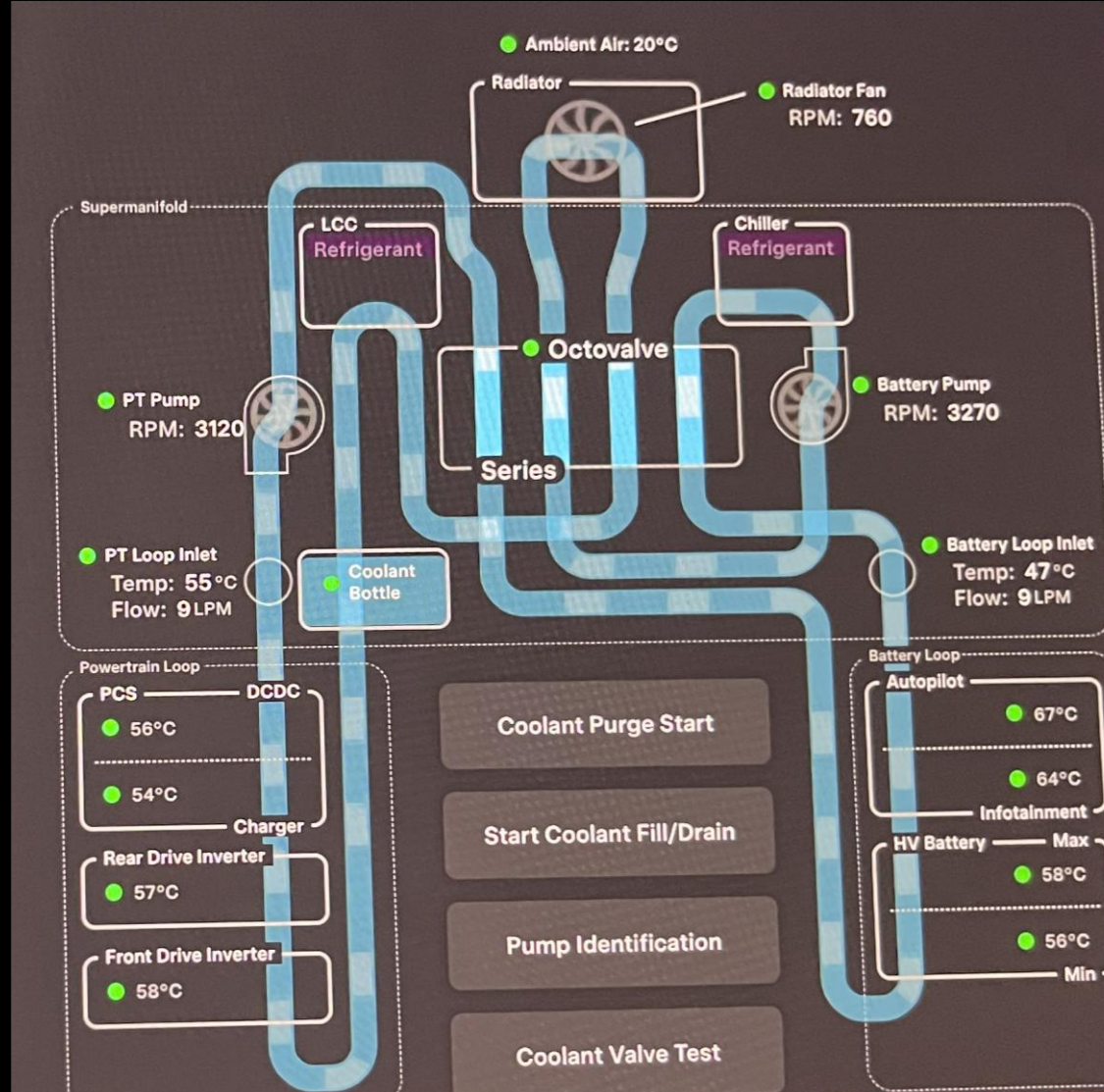
Charging Thermal Management

- Ford Lightning



Charging Thermal Management

- Tesla Model 3



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The End!

- xEV builds upon the knowledge of traditional vehicles
 - Low voltage system is essential
 - Undercar work remains unchanged
 - Trans shops lend themselves to battery and motor service
 - Need for strong electrical diagnostic skills
 - EVSE issues vs vehicle issues



POV: I get my EV
certification just to lose
money learning how to fix
electric cars 🤔❤️🔧



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🎵 POVMechnic - Original audio

A man with short blonde hair, wearing a black jacket with 'DC' and 'DPF' logos, is working on the wheel of a red car in a garage. He is wearing blue gloves and looking at the wheel. The background shows a typical garage environment with various tools and equipment.

why do you like working
on cars?