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AEM EV / Cascadia Motion Vehicle Control Unit 275 Basic Product Description

Feature descriptions and instructions for setup and calibration of a VCU275 managed system

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DANGER!

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Information

VCU275 Basic Product Description

This document is intended to provide a basic understanding of the most commonly used VU275 features. It is not a comprehensive description of all available features. It should be used as a guide for setting up a new EV application in conjunction with the VCU275 Low Voltage Harness assembly PN-30-8604 and AEM EV base calibration.

Revision History

Document Conventions

Symbol	Information
	When you see this symbol, ***PAY ATTENTION!*** This indicates that something important is about to be said that concerns your safety and the proper operation of the product. Use caution and be conservative. Use the product in the manner described.
	When you see this symbol, you are being alerted to an ***IMMEDIATE DANGER***. You MUST review these sections carefully and do everything possible to comply with installation and operation requirements or you risk injury or even death. Failure to comply with safety requirements will void all warranties and could expose you as the installer to liability in the event of an injury.

	When you see this symbol, pay attention to helpful VCU ***TUNING TIPS***.

Cautions and Warnings

Working on tractive systems (which includes but is not limited to motor(s), inverter(s), high voltage battery packs and high voltage cables) requires special experience and training. AEM EV has implemented fault detection and failsafe logic into its vehicle control units ("VCU"), however this does not mean that your VCU installation will be safe or effective, or that your VCU installation will not interfere with other systems on your vehicle and create a hazardous situation. It is the responsibility of the installer to understand the implications of each stage of tractive system installation and testing and to recognize what might be unique about your application that presents potential hazards or safety issues – and it is the responsibility of the installer to solve or address any such hazards or issues.

The following list includes basic recommended practices. ***This is not a comprehensive list; as noted below, if you are not well-versed in the appropriate installation and testing procedures, you should refer the installation and calibration to a reputable installation facility or contact AEM EV for a referral in your area.***

- When access is required near the battery pack, the cell segments must be separated by using an appropriate maintenance disconnect plug.
- When working on the battery pack or tractive system, safety goggles with side shields and appropriate insulated tools must be used.
- Always wear Class 0 gloves rated at 1000V with leather protectors.
- Only use CAT III rated digital multimeters (DMM) and test leads.
- When working on the battery pack or tractive system, work with one hand while keeping the other behind your back.
- During initial system power up and testing, the vehicle must be raised off the ground and supported appropriately. Wheels and tires should be removed.
- During the VCU firmware upgrade process, battery cell segments must be separated using an appropriate maintenance disconnect plug.
- Do not make calibration changes when the inverter pulse width modulation (PWM) is enabled.

USE THIS VCU WITH EXTREME CAUTION. MISUSE AND/OR IMPROPER INSTALLATION CAN CAUSE SIGNIFICANT DAMAGE TO YOUR VEHICLE AND PROPERTY BELONGING TO YOU OR OTHERS, AS WELL AS PERSONAL INJURY OR DEATH. IF YOU ARE NOT WELL VERSED IN THE INSTALLATION OF TRACTIVE SYSTEMS OR CONFIGURING THE CALIBRATIONS IN THE AEM EV VCU THAT ARE NECESSARY TO CONTROL THE VEHICLE, YOU SHOULD REFER THE INSTALLATION AND VCU CALIBRATION TO A REPUTABLE INSTALLATION FACILITY, OR CONTACT AEM EV FOR A REFERRAL IN YOUR AREA. IT IS THE RESPONSIBILITY OF THE INSTALLER TO ULTIMATELY CONFIRM THAT THE INSTALLATION AND CALIBRATIONS ARE SAFE FOR ITS INTENDED USE.

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Electrical Safety Insulation Monitoring

The high voltage system in an electric vehicle is designed to be ungrounded (floating) with respect to the vehicle chassis (frame). Insulation faults can cause electric shock, personal injury and even death. An insulation monitoring device (IMD) must be used to protect against these faults. See Bender https://www.benderinc.com/ for more information. Please see the Insulation Monitoring Device (IMD) 86 section for VCU calibration options.

Supported Application Overview

AEM EV VCU firmware versions are developed to support specific features. Standard support exists for the following devices, however please see the Supporting Firmware 10 section for information specific to this firmware version.

Standard Supported CAN Modules	Description
AEM PDU-8 (pn 30-8300)	AEM Eight Channel Power Distribution Unit (PDU-8)
Battery Management System	AEM EV BMS-18
Digial Current and Voltage Sensor	Isabellenhuette IVT-S Sensor 1000A <-- link to AEM part # 2500A <-- link to AEM part #
AEM CAN Keypad (pn 30-8400)	AEM EV 8-Button CAN Keypad
Cooling Pump	WP29 / WP32 BRUSHLESS ELECTRIC WATER PUMP
AEM CD Carbon Digital Dash	AEM CD Carbon Digital Dash/Logging Displays

Non CAN controlled supported hardware interface modules are identified in the following table.

Supported Hardware Module	Description
Analog Current Sensor	LEM DHAB S/137 - 500A <-- link to AEM part # 750A <-- link to AEM part # 1000A <-- link to AEM part #
Tesla Model S Parking Brake Controller	https://www.pantera-electronics.com/epbcontroller.htm

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Supporting Firmware Version

The features described in this document apply to a specific firmware version. AEM EV VCU firmware versions have a file extension of *.aemecudef*. When you install AEMCal, firmware release versions included in that build will be installed to the *C:\ProgramData\AEM\Ecudef* folder on your PC. New versions can be manually installed by dragging and dropping the *.aemecudef* file onto an open AEMCal layout page.

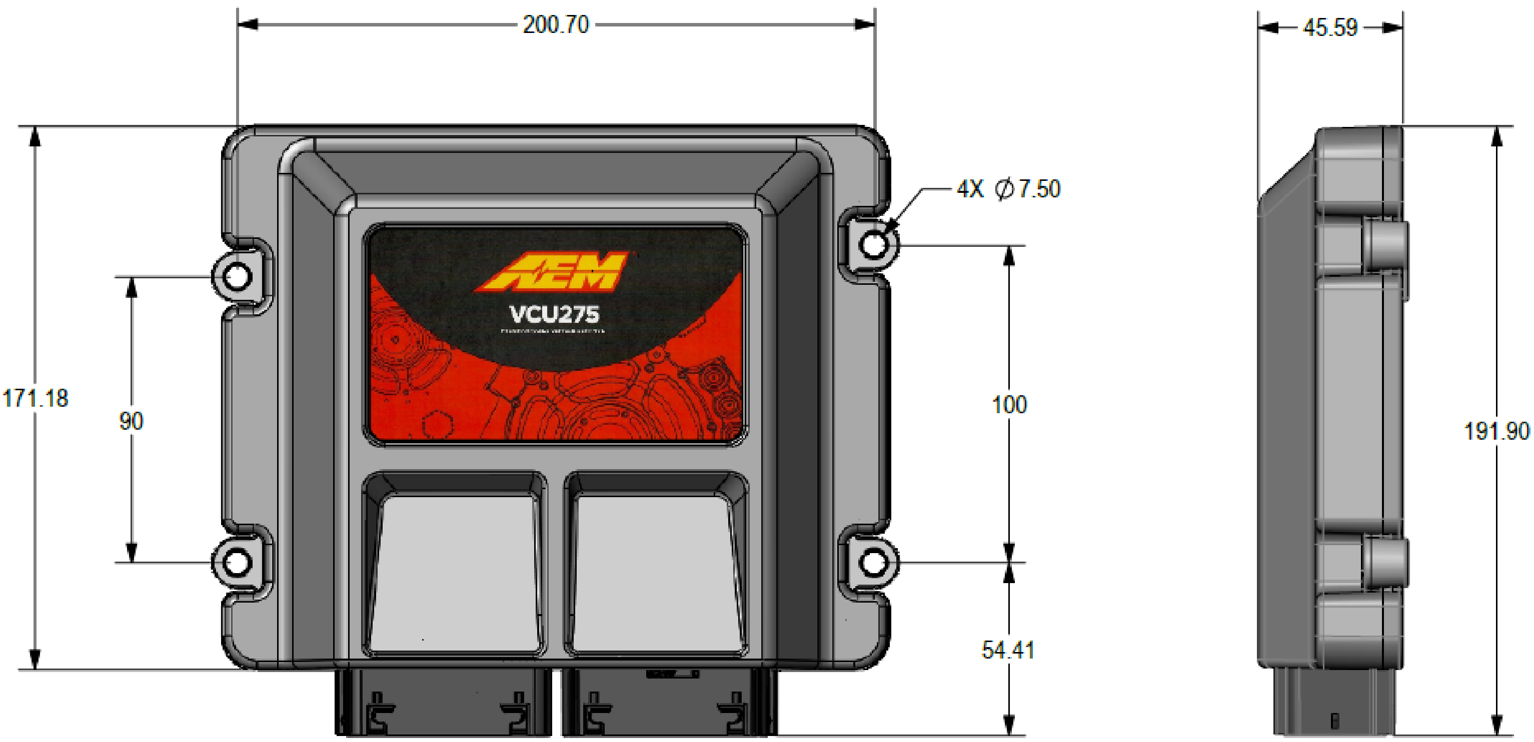
Supported applications for this firmware include:

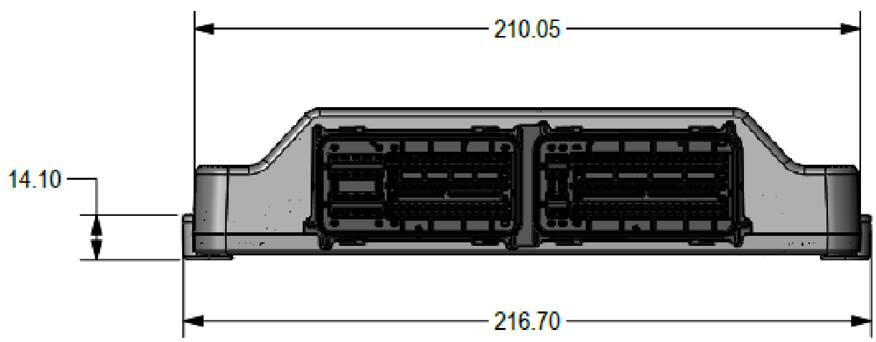
Supporting Firmware Version	VCU275_XX_xx_xxx.aemecudef
Inverters	Tesla Large Drive Unit with AEM EV Inverter Control Board, Tesla Small Drive Unit with AEM EV SDU Inverter Control Board, Cascadia CM/PM Series
Chargers*	AEM CCU, Thunderstruck TS2500, Stealth/Ovar

Direct support when used in conjunction with the AEM EV BMS-18

Hardware Overview

AEM EV Part Number	30-8001
Microprocessor	Infineon Aurix TC367, 2 Cores with EPIO to manage internal power, I/O and safety watchdog
Clock Speed	300 Mhz
Environmental	IP67
Operating Temperature	-40°C to +105°C
Operating Voltage	8V - 16V
On-State Current Draw at 13.1V (No Load)	210 mA
Off-State Current Draw	3.33 mA
Wake Switch Logic High Threshold	3.5V
Main Relay	A VCU controlled main relay is required. Main relay must be source for loads driven by lowside drivers.
Communication Channels	CAN1, 500k, Internally Terminated, PC Comms
	CAN2, 500k, Internally Terminated, Peripheral Device Comms
	CAN3, 500k, Internally Terminated, Peripheral Device Comms and Data Transmit
Internal Logging Memory	None - External logging possible with AEM Dash units with logging capability and other compatible 3rd party CAN displays and CAN data loggers.





CAN Network Configuration

At its core, the VCU is a CAN networking and logic processing hub. The following diagram describes the basic network requirements. Three separate CAN networks are represented. The network channel assignment for each device is not reconfigurable by the end user. All CAN channels in the VCU275 are internally terminated. The VCU must always be located at the physical end of a bus. All busses must be terminated with a 120 ohm resistor at the physical end. ***CAN network wiring should be twisted, shielded and assembled by a skilled harness builder familiar with vehicle networking.***

Network Summary

CAN1 – PC communication with AEMCal
CAN2 – Inverter, EMP Pump(s), PDU-8(s), AEM CD Dash Port 1
CAN3 – CAN Keypad, AEM EV BMS-18, OBC/DCDC (CCU), VCU Data Transmit, AEM CD Dash Port 2, IVT-S

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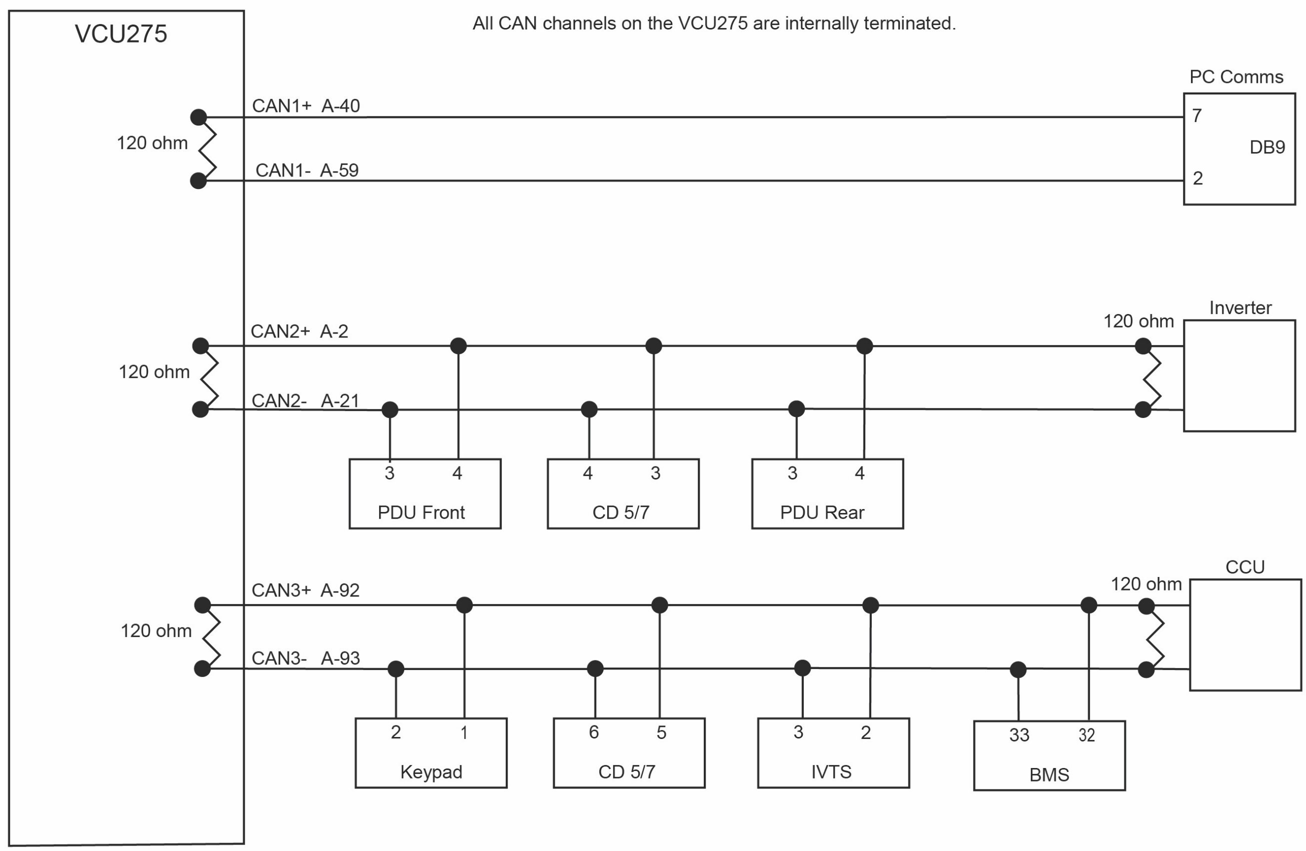

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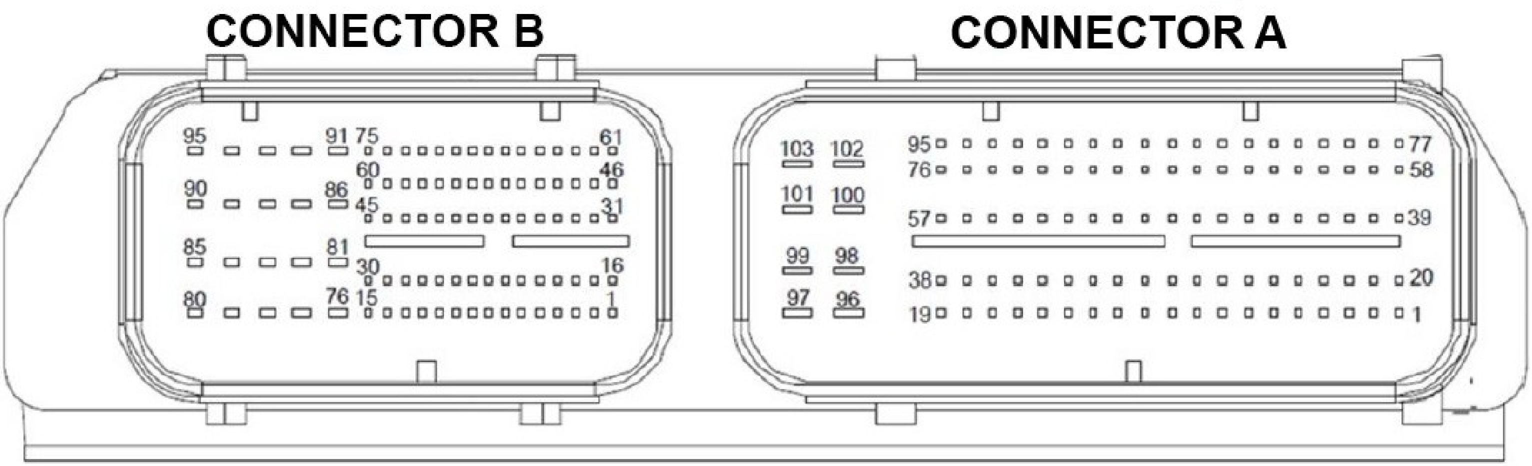
Hardware Pinout



Conn.	Pin	VCU275 Function	Type	Conditioning	Limits
A	1	N/A			
A	2	CAN2+	CAN	Internally Terminated	10mA
A	3	HVIL Main Out	LS	3k PU to MRIGN	50mA
A	4	HVIL Charge Out	LS	No PU or PD	50mA
A	5	N/A			
A	6	N/A			
A	7	BMS Discharge LS	LS	No PU or PD	350mA
A	8	BMS Charge LS	LS	No PU or PD	350mA
A	9	Sensor Power	Sensor Power		160mA
A	10	N/A			
A	11	LEM High Range	Analog	2.32k PU to 5V	10mA
A	12	N/A			
A	13	Negative Contactor Feedback	Analog	2k PU to 5V	10mA
A	14	LEM Low Range	Analog	2.32k PU to 5V	10mA
A	15	N/A			
A	16	N/A			
A	17	APP#1	Analog	301k PD	10mA
A	18	APP#2	Analog	301k PD	10mA
A	19	Brake Pressure	Analog	51k PD	10mA

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Conn.	Pin	VCU275 Function	Type	Conditioning	Limits
A	20	N/A			
A	21	CAN2-	CAN	Internally Terminated	10mA
A	22	Sensor Ground	Sensor Ground		160mA
A	23	Sensor Ground	Sensor Ground		160mA
A	24	Sensor Ground	Sensor Ground		160mA
A	25	Sensor Ground	Sensor Ground		160mA
A	26	Sensor Ground	Sensor Ground		160mA
A	27	Sensor Ground	Sensor Ground		160mA
A	28	Sensor Power	Sensor Power		160mA
A	29	Sensor Power	Sensor Power		160mA
A	30	Sensor Power	Sensor Power		160mA
A	31	N/A			
A	32	N/A			
A	33	N/A			
A	34	Reserved	Analog	7.5k PD	500mA
A	35	N/A			
A	36	N/A			
A	37	N/A			
A	38	Reverse Switch	Digital	3.3k PU to MRIGNPU	10mA
A	39	N/A			
A	40	CAN1+	CAN	Internally Terminated	
A	41	Inverter Power	LS		700mA
A	42	Drive Cooling Fan Relay	LS	No PU or PD	700mA
A	43	Sensor Ground	Sensor Ground		160mA
A	44	Sensor Ground	Sensor Ground		160mA
A	45	Sensor Ground	Sensor Ground		160mA
A	46	Pack Cooling Fan Relay	LS	No PU or PD	350mA
A	47	Sensor Power	Sensor Power		160mA
A	48	Sensor Power	Sensor Power		160mA
A	49	Sensor Power	Sensor Power		160mA
A	50	N/A			
A	51	BrakeSwitch 2	Digital	3.3k PU / 3.3k PD, Ground = On	10mA
A	52	LIN1	LIN		300mA

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Conn.	Pin	VCU275 Function	Type	Conditioning	Limits
A	53	Ignition Switch	Digital	3.3k PU / 3.3k PD, Ground = On	10mA
A	54	N/A			
A	55	N/A			
A	56	N/A			
A	57	N/A			
A	58	N/A			
A	59	CAN1-	CAN	Internally Terminated	10mA
A	60	N/A			
A	61	N/A			
A	62	N/A			
A	63	Sensor Ground	Sensor Ground		160mA
A	64	Sensor Ground	Sensor Ground		160mA
A	65	Condenser Fan Relay	LS	No PU or PD	350mA
A	66	Cooling Pump Wake	HS	Flyback Diode to MRIGN	160mA
A	67	Sensor Power	Sensor Power		160mA
A	68	Sensor Power	Sensor Power		160mA
A	69	Sensor Power	Sensor Power		160mA
A	70	Wake	Wake		500mA
A	71	Brake Switch 1	Digital	3.3k PU / 3.3k PD, 12V = On	10mA
A	72	N/A			
A	73	Reserved	SENT		10mA
A	74	N/A			
A	75	N/A			
A	76	N/A			
A	77	N/A			
A	78	Oil Pump Relay	LS	Flyback Diode to MRIGN	1A
A	79	PreCharge1 Contactor Driver	LS	Flyback Diode to MRIGN	1A
A	80	N/A			
A	81	N/A			
A	82	N/A			
A	83	N/A			
A	84	Positive1 Contactor Driver	LS	No PU or PD	2A
A	85	N/A			

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Conn.	Pin	VCU275 Function	Type	Conditioning	Limits
A	86	Negative Contactor	LS	No PU or PD	2A
A	87	AC Evap Solenoid	LS	Flyback Diode to MRIGN	1A
A	88	N/A	LS		
A	89	N/A	LS		
A	90	N/A	CAN		
A	91	N/A	CAN		
A	92	CAN3+	CAN	Internally Terminated	10mA
A	93	CAN3-	CAN	Internally Terminated	10mA
A	94	N/A			
A	95	N/A			
A	96	Chassis Ground	Ground		200mA
A	97	Battery	PERM		3A
A	98	N/A			
A	99	Battery Ground	Ground		10A
A	100	Main Relay Power	Switched Power		10A
A	101	Battery Ground	Ground		10A
A	102	Main Relay Power	Switched Power		10A
A	103	Battery Ground	Ground		10A
B	1	Sensor Power	Sensor Supply		160mA
B	2	Sensor Power	Sensor Supply		160mA
B	3	Sensor Power	Sensor Supply		160mA
B	4	N/A	Frequency		10mA
B	5	Reserved	Frequency	3k PU to 5V, Switch Low	10mA
B	6	Reserved	Frequency	3k PU to 5V, Switch Low	10mA
B	7	HVIL Charge In	Frequency	3k PU to 5V, Switch Low	10mA
B	8	N/A			
B	9	N/A			
B	10	N/A			
B	11	N/A			
B	12	Sensor Ground	Sensor Ground		160mA
B	13	Sensor Ground	Sensor Ground		160mA
B	14	Sensor Ground	Sensor Ground		160mA

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Conn.	Pin	VCU275 Function	Type	Conditioning	Limits
B	15	N/A			
B	16	Trans Brake Switch	Analog	10k PD	10mA
B	17	Heater Switch	Digital	3.3k PU / 3.3k PD, 12V = On	10mA
B	18	AC Switch	Digital	3.3k PU / 3.3k PD, 12V = On	10mA
B	19	Drive Switch	Digital	3.3k PD, 12V = On	10mA
B	20	IMD	Digital	3.3k PD, 12V = On	10mA
B	21	N/A			
B	22	Sensor Power	Sensor Power		160mA
B	23	Sensor Power	Sensor Power		160mA
B	24	Sensor Power	Sensor Power		160mA
B	25	Sensor Power	Sensor Power		160mA
B	26	Sensor Power	Sensor Power		160mA
B	27	Sensor Power	Sensor Power		160mA
B	28	Sensor Ground	Sensor Ground		160mA
B	29	Sensor Ground	Sensor Ground		160mA
B	30	N/A			
B	31	Coolant Temp	Analog	1.82k PU to 5V	10mA
B	32	Ambient Temp	Analog	1.82k PU to 5V	10mA
B	33	N/A			
B	34	N/A			
B	35	N/A			
B	36	Line Lock Switch	Analog	220k PD	10mA
B	37	Start Switch	Analog	51k PD	10mA
B	38	N/A			
B	39	HVIL Main In	Frequency	8.2k PU to MRIGNPU, Switch Low	10mA
B	40	N/A			
B	41	AC Pressure	Analog	51k PD	10mA
B	42	Manual Regen 1	Analog	470k PD	10mA
B	43	Neutral Switch	Analog	470k PD	10mA
B	44	N/A			
B	45	Park Switch	Analog	220k PU to 5V	10mA
B	46	N/A			
B	47	N/A			

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Conn.	Pin	VCU275 Function	Type	Conditioning	Limits
B	48	N/A			
B	49	N/A			
B	50	N/A			
B	51	N/A			
B	52	N/A			
B	53	N/A			
B	54	N/A			
B	57	N/A			
B	58	Brake Vacuum Press	Analog	3k PU to 5V	
B	59	Manual Regen 2	Analog	470k PD	
B	60	N/A			
B	61	AC Evap Temp	Analog	2.32k PU to 5V	
B	62	N/A			
B	63	N/A			
B	64	OBC Contactor Driver	LS	Flyback Diode to MRIGN	2A
B	65	Reserved	LS	No PU or PD	2A
B	66	N/A			
B	67	N/A			
B	68	Reserved	LS	No PU or PD	2A
B	69	MPRD	LS		2A
B	70	Reserved	LS	No PU or PD	2A
B	71	Reserved	LS	No PU or PD	2A
B	72	N/A	LS	No PU or PD	
B	73	Pack Heat Contactor Driver	LS	Flyback Diode to MRIGN	2A
B	74	Pack Chiller Solenoid	LS	No PU or PD	300mA
B	75	DCDC Contactor Driver	LS	Flyback Diode to MRIGN	2A
B	76	N/A			
B	77	N/A			
B	78	N/A			
B	79	N/A			
B	80	N/A			
B	81	Sensor Ground	Sensor Ground		160mA
B	82	N/A			

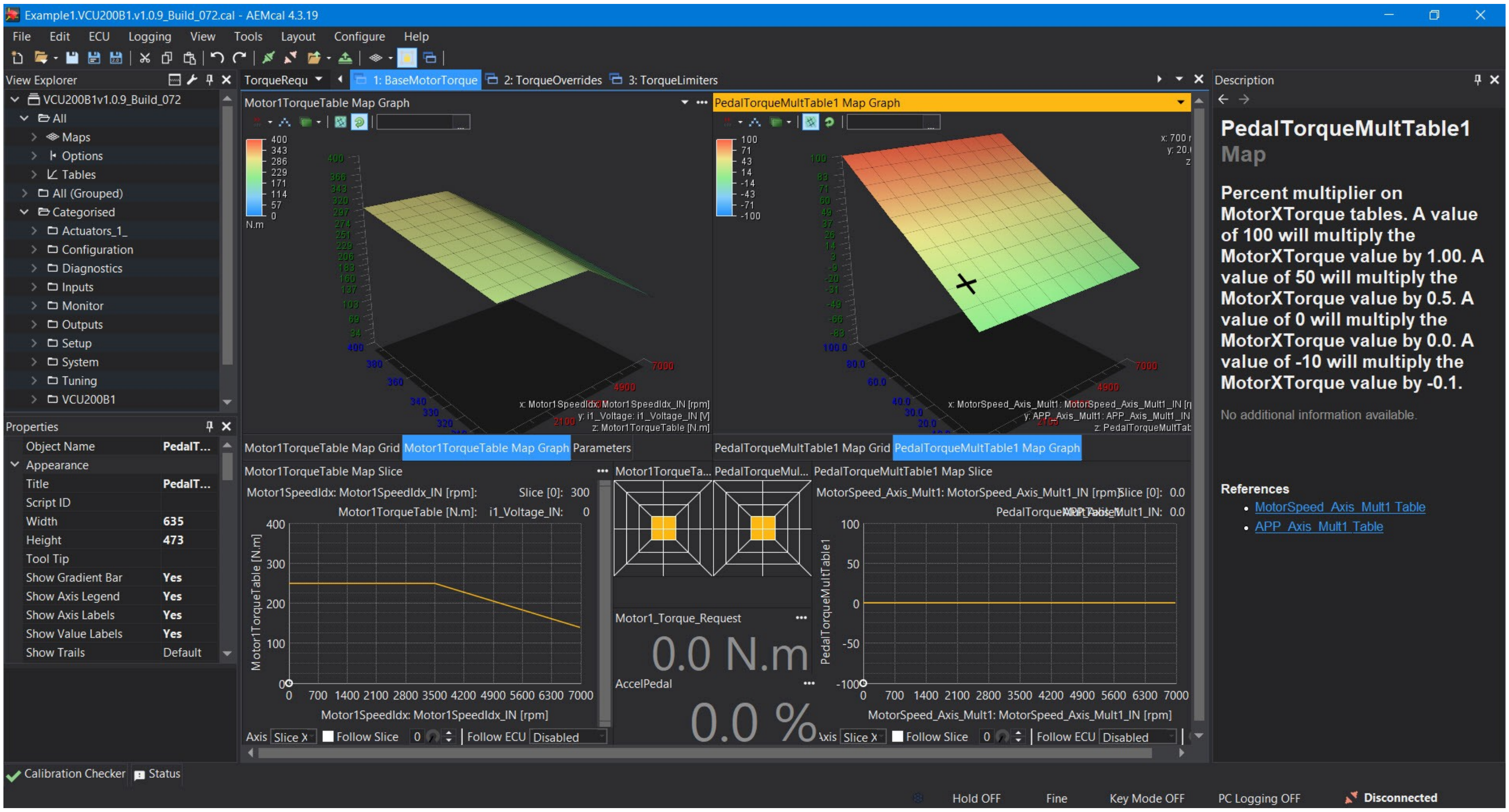
Conn.	Pin	VCU275 Function	Type	Conditioning	Limits
B	83	N/A			
B	84	N/A			
B	85	N/A			
B	86	N/A			
B	87	N/A			
B	88	N/A			
B	89	N/A			
B	90	N/A			
B	91	N/A			
B	92	Reserved	HBridge		10A
B	93	Reserved	HBridge		10A
B	94	Reserved	HBridge		8A
B	95	Reserved	HBridge		8A

Tuning Tips

1. **Pins identified as 'Reserved' in the VCU275 Function column are reserved for future VCU feature development.**
2. **Pins identified as 'N/A' are NOT available for use.**

AEMCal

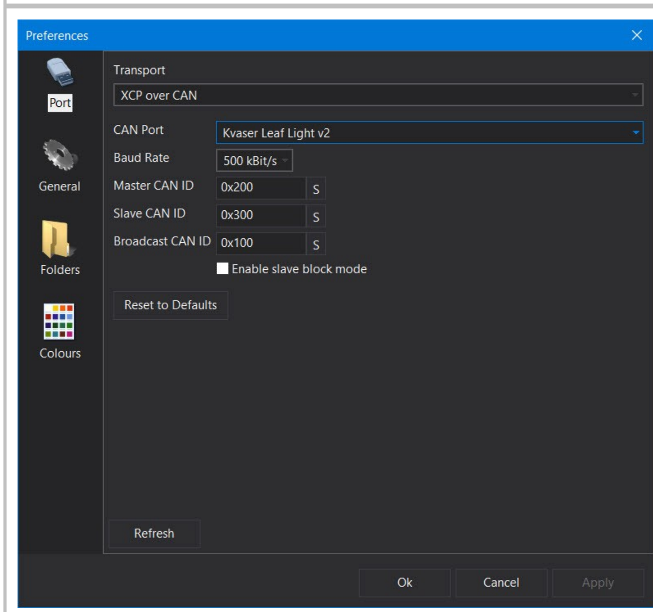
AEMCal is a tool developed specifically for calibrating the AEM EV line of Vehicle Control Modules (VCUs). See https://www.aemev.com/ for more information on the AEM EV line of products. AEMCal was developed and built on a strong foundation of professional calibration tools. It is feature rich allowing the calibrator to work quickly and efficiently. The graphical tools present calibration information in an intuitive way. Nothing is ever more than a mouse hover or right click away.



PC Connection

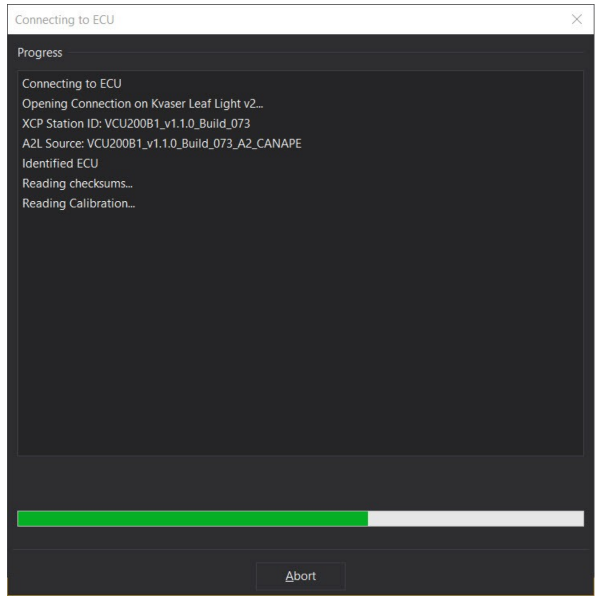
The following adapters have been validated by AEM for use with AEMCal:

- The Leaf Light HS v2 from Kvaser
- The PCAN-USB Adapter made by PEAK-System Technik



Follow the manufacturer's instructions for installing the device drivers for your chosen adapter. Once that is done, restart your PC. Your adapter should show up in the CAN Port drop down selection list shown to the left. Ensure all other settings are configured as shown.

Go to the ECU menu and select *Connect* or the Shift+F7 key combo.



The response should be similar to the example above. If not, try restarting AEMCal and repeat the same process. If the comms cable is disconnected or switched (wake) power is lost while connected, you must request a connection again using the same method.

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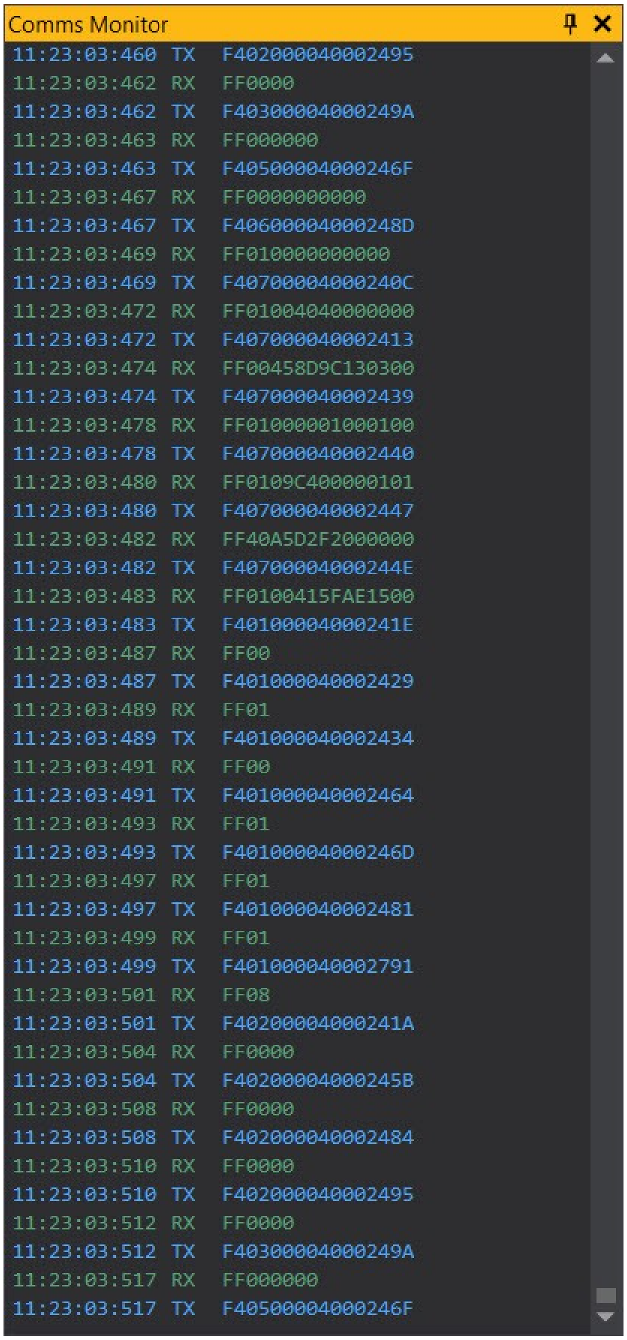
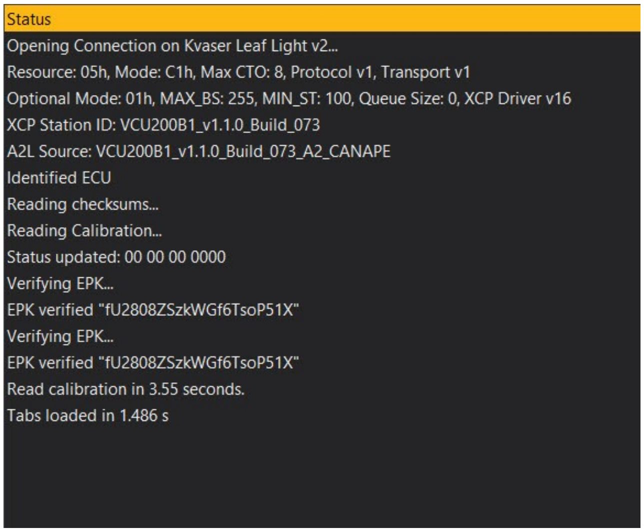


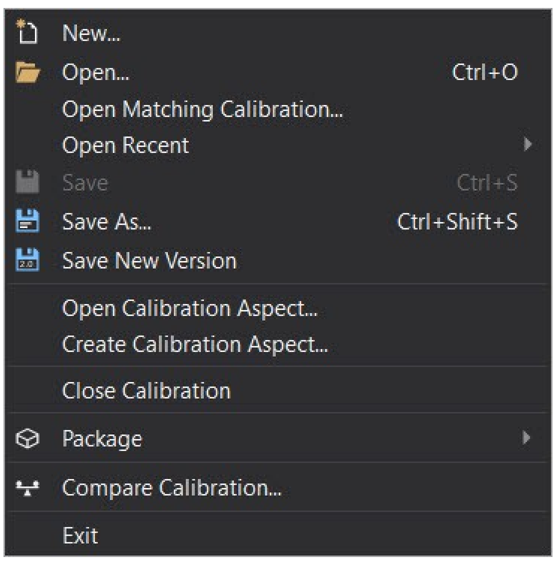
The Comms Monitor feature is helpful in diagnosing communication problems. Display the Comms Monitor from within the View menu.



The ECU Status pane will also display helpful information about the connection status.

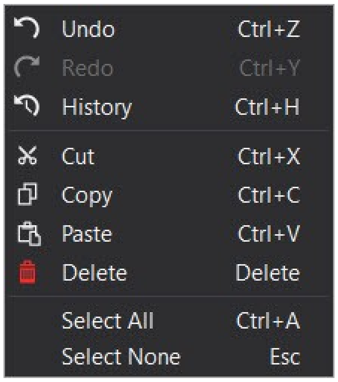
Menu Items

File Menu

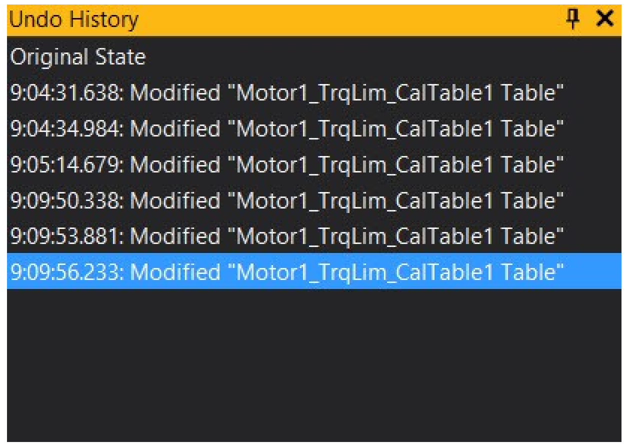


Open opens an existing calibration file.
Open Recent displays a list of recently opened calibration files.
Save saves the current calibration file.
*Save As...*saves the current calibration file with a new name.
Save New Version saves the current calibration with an incremental version number.
*Open Calibration Aspect...*opens an existing Calibration Aspect.
*Create Calibration Aspect...*creates a new Calibration Aspect.
Close Calibration closes the currently open calibration file.
*Compare Calibration...*compares a calibration with the currently open file.
Exit closes and exits the application.

Edit Menu

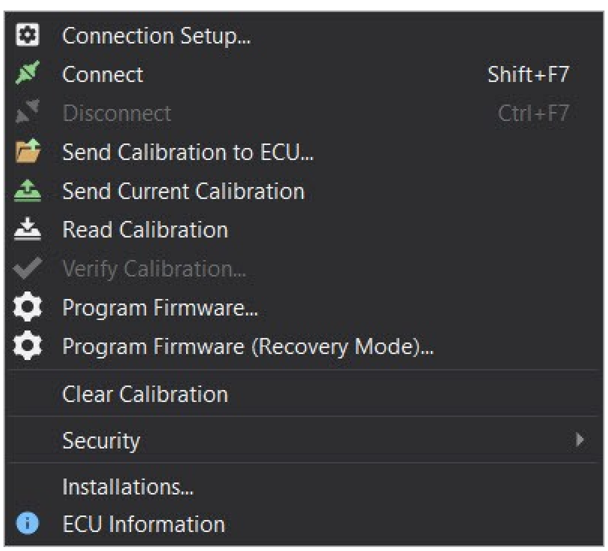


Undo/Redo are standard Windows commands for undoing/redoing data edits.
History is a running list of edits available with the Undo command.



Cut cuts the selection for pasting elsewhere.
Copy copies the selection for pasting elsewhere.
Paste pastes the selection
Delete deletes the current selection.
Select All selects all the data in the current map, table or list.
Select None or the Esc key deselects the current selection.

ECU Menu



*Connection Setup...*launches the Preferences dialog which includes the Port category which includes all USB connection preferences.
Connect or Shift+F7 connects AEMCal to the VCU hardware.
Disconnect disconnects AEMCal from the VCU hardware
Send Calibration to ECU... prompts the user to choose a compatible calibration file. AEMCal uploads the calibration data to the VCU.
Send Current Calibration will upload the calibration file that is currently open in AEMCal.
Read Calibration downloads the calibration data in the VCU hardware.
*Program Firmware...*is used to load a different firmware version in the VCU.
*Program Firmware (Recovery Mode)...*can be used in the event the previous firmware programming event failed.
*Installations...*presents a list of currently installed ecudef files.
ECU Information displays list of useful information about the connected VCU.

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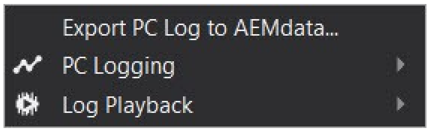
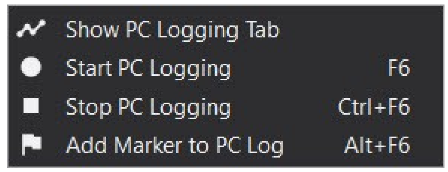
Logging Menu

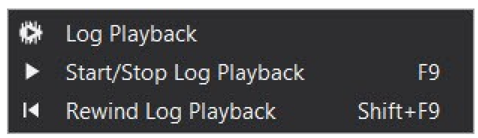


*Export PC Log to AEMdata...*selects a raw ..glo log file and allows this data to be converted and exported for analysis in AEMData.
PC Logging displays a sub menu of available PC logging options.



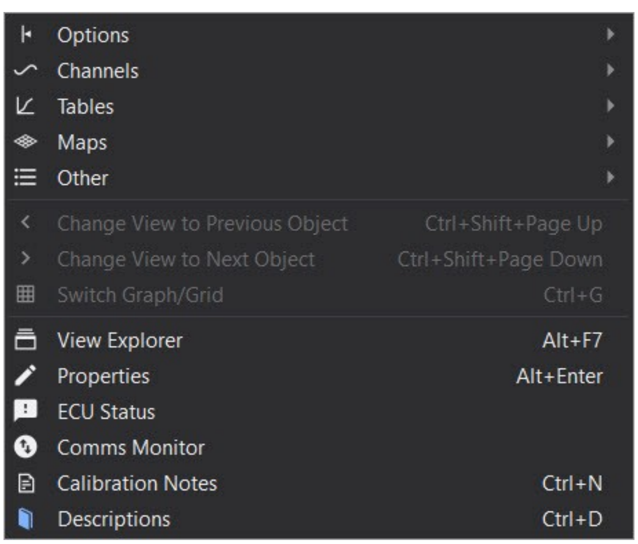
Show PC Logging Tab will open a special PC Logging Setup tab.
Start PC Logging or F6 will start the log capture.
Stop PC Logging or Ctrl+F6 will stop the current log capture.
Add Marker to PC Log or Alt+F6 will add a visual marker to the log capture at the current time stamp.

Log Playback displays additional options.



Log Playback displays the playback log transport controls.
Start/Stop Log Playback or F9 will start/stop the log
Rewind Log Playback or Shift+F9 will rewind to the beginning of the log.

View Menu



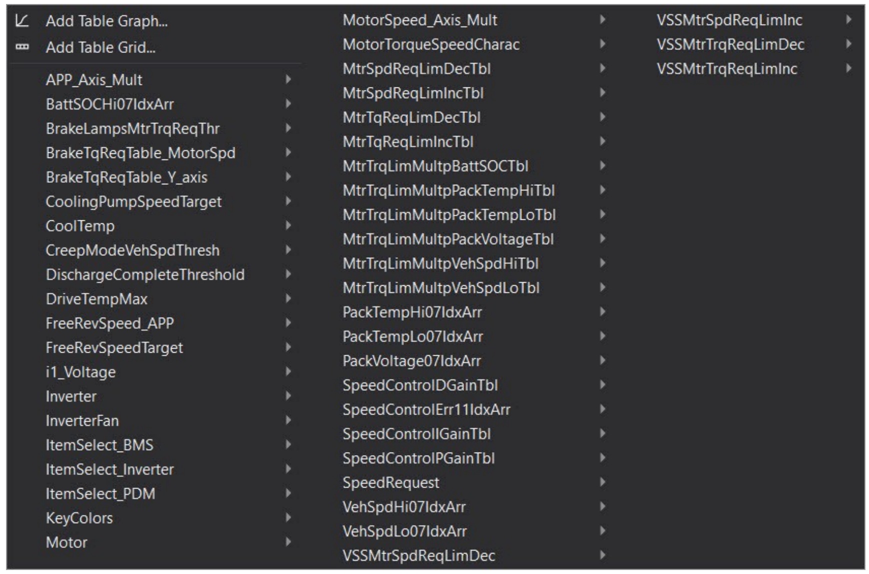
Options displays a sub menu.

Add Option Full List adds a table with a complete listing of all calibration constants (options)
Add Option Selection List allows the user to select calibration options and add them individually.

Channels displays a sub menu

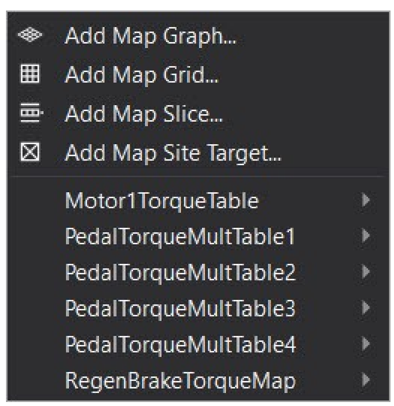
Add Channel List allows the user to select parameters and add them individually.
Add Bar Gauge... adds a Bar Gauge item.
Add Number Gauge... adds a Number Gauge item.
Add Scope... adds a Scope item.
Add Tacho... adds a Tacho item.

Tables displays a sub menu



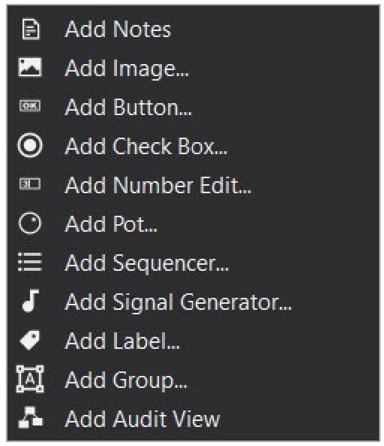
The sub menu contains a selection list of all table items in the calibration. Select either the Graph or Grid options to add the item to your layout.

Maps displays a sub menu



Select from the list of available calibration maps in either Graph or Grid format or select individual Graph, Grid, Slice or Site Target items.

Other displays a sub menu



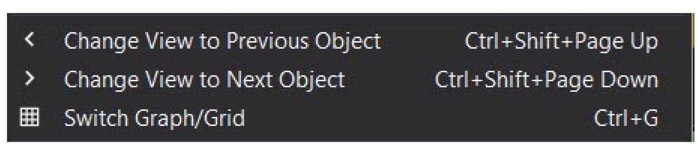
Add Notes adds an editable text box where notes can be added to the layout.

Add Image... allows the user to select an image file to add to the layout.

The following items are for use with unique scripting features that are not currently supported.

Add Button...
Add Check Box...
Add Number Edit...
Add Sequencer...
Add Signal Generator...

Add Pot... adds an interactive potentiometer control that allows calibration constants to be modified by rotating the dial.
Add Label... adds a customizable text label.
*Add Group...*adds a customizable grouping feature. Drag any other item into the group box to add.
Add Audit View is for AEM EV use only. These are tools designed to graphically explain the logic flow in the VCU firmware.

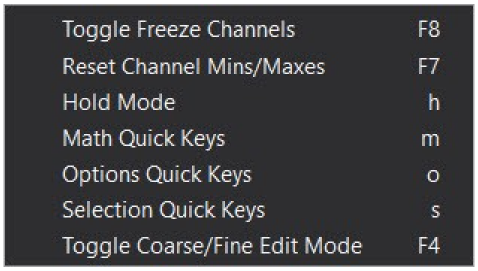


When an item like a table or map is selected in the layout, *Change View to Previous Object* and *Change View to Next Object* selects the previous or next sequential item from the list.

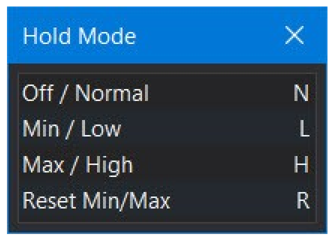
Switch Graph/Grid works with tables and maps to easily swap view type.
View Explorer displays the View Explorer panel.
Properties displays the properties panel.
ECU Status displays the ECU Status Window.
Comms Monitor displays raw communication data between AEMCal and the VCU hardware.

Calibration Notes displays a text editor where notes can be added about the calibration. The notes will appear in the file open dialog.
Descriptions displays the Descriptions Pane where information is available about most items in the VCU calibration.

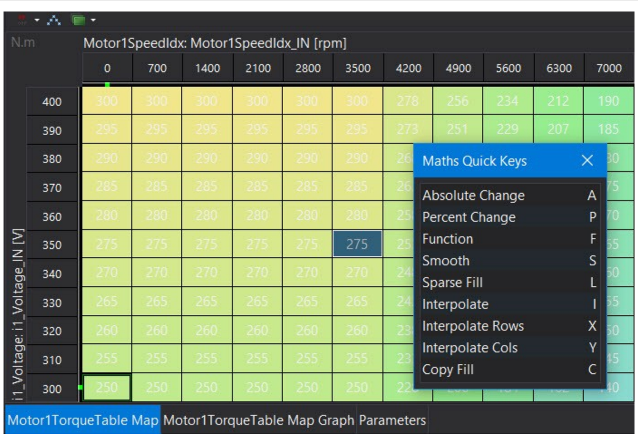
Tools Menu



Toggle Freeze Channels freezes the update of any freezable parameters.
Reset Parameter Mins/Maxes resets the parameter min/max values.
Hold Mode defines preferences for a special freeze mode. Values can be held in different states.



The *Maths, Options and Selection* quick keys are context sensitive and will spawn different features depending on the target item. In a map grid for example with keyboard focus, click the m key to bring up the math modifiers sub menu. Click the s key to selection sub menu and the o key to display the options sub menu.



The example to the left shows the sub menu displayed after hitting the m key. Now other selections are available using the new list of quick keys.

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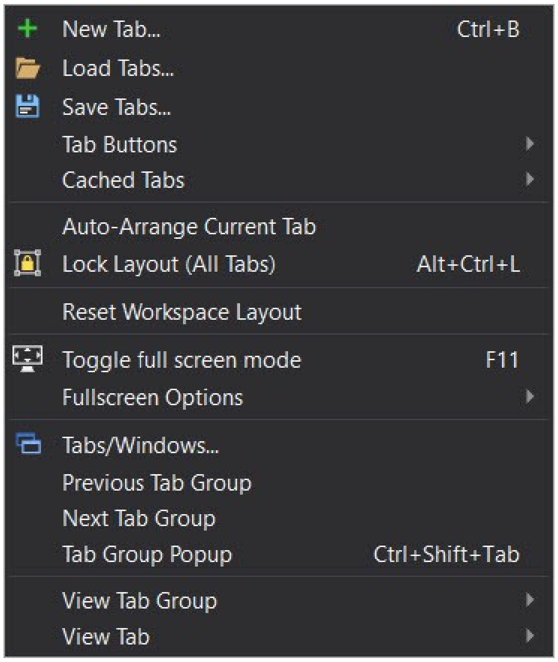
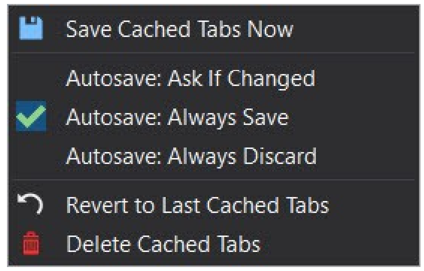
Layout Menu

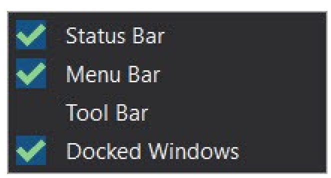


New Tab... creates a new tab
Load Tabs... loads a new tab or set of tabs
Tab Buttons allows configuration of an icon associated with a specific tab file. The icon will be added to the menu tool bar.
Cached Tabs launches a sub menu



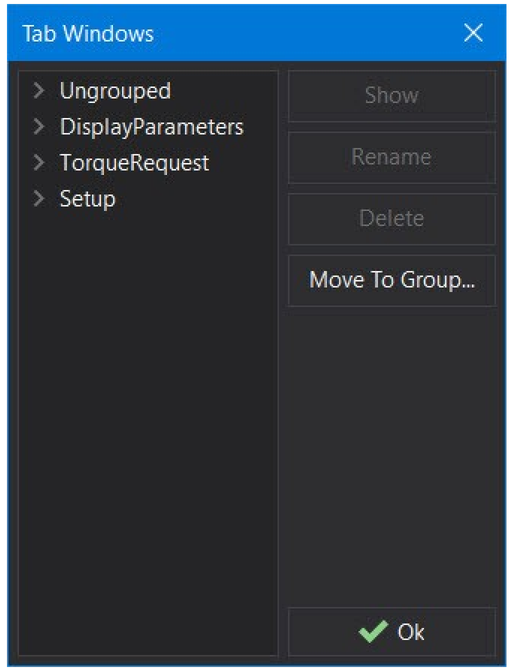
Save Cached Tabs Now makes the current layout load next time AEMCal starts.
There are three *Autosave:* preferences for tab files. *Ask If Changed, Always Save and Always Discard.* Choose the most appropriate settings for your work flow.
Revert to Last Cached Tabs reverts to the last saved tab file.
Delete Cached Tabs deletes the last view tabs files

Auto-Arrange Current Tab attempts to automatically align items in the current tab.
Lock Layout (All Tabs) locks the position of all items in the tabs.
Reset Workspace Layout resets the workspace to the default arrangement.
Toggle full screen mode and *Fullscreen Options* allow configuration of full screen view preferences.



Select which items to include when full screen mode is toggled.

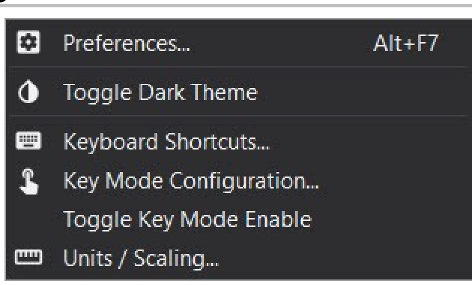
*Tabs/Windows...*launches the configuration dialog for tab group manangement



From this dialog, tabs can be organized within user configurable groupings.

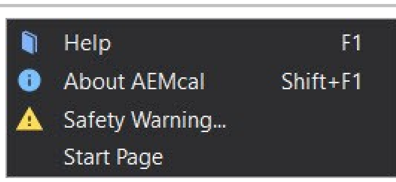
Previous and Next Tab Group moves to either the previous or next group.
Tab Group Popup displays the tab group menu.
View Tab Group and View Tab display the hot key combinations for moving between tabs and tab groups via key presses.

Configure Menu



*Preferences...*launches the global preferences dialog
Toggle Dark Theme enables or disables the dark theme
Keyboard Shortcuts... launches a dialog that allows complete customization of keyboard shortcuts
Key Mode Configuration... launches a dialog that allows customization of Key Mode editing shortcuts.
Toggle Key Mode Enable enables or disables Key Mode editing shortcuts

Help Menu



Help launches this document
About AEMcal displays information about the currently installed version.
Safety Warning... displays the safety warning message.
Start Page displays the Start Page tab.

Menu Toolbar

The menu toolbar provides a shortcut to various features. Hover your mouse over each one for a tool tip definition.

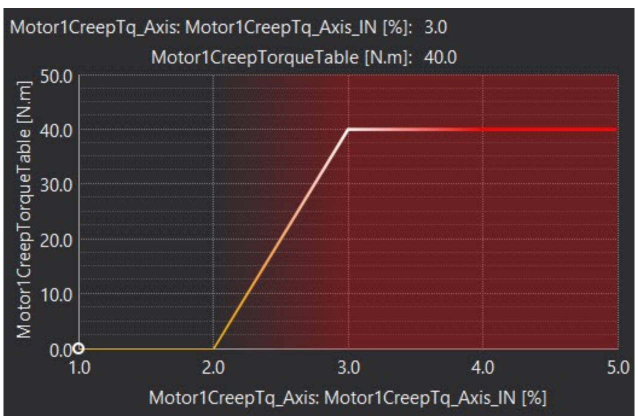
Working with Calibrations

Editing Calibrations

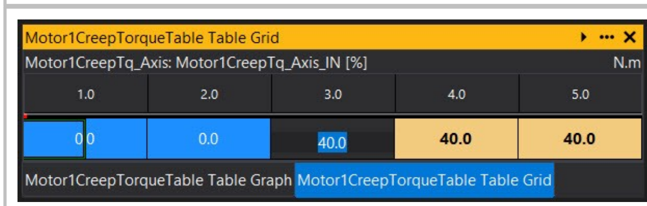
Editing Options

Simply click on the value that you wish to edit. You can then either type in a new value or use the dial or up/down controls to alter the value.

Editing Tables

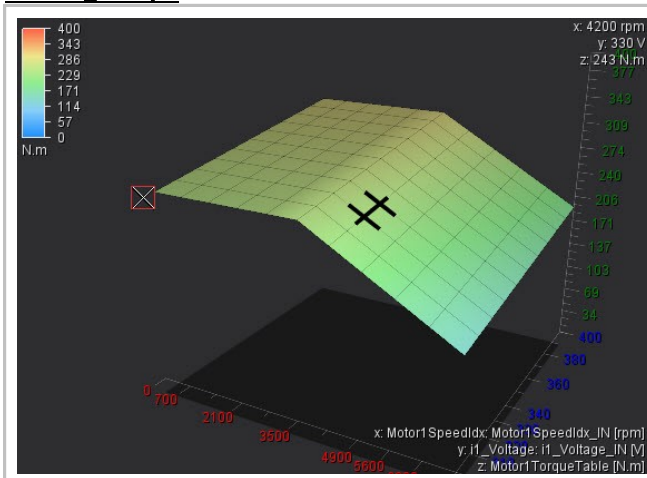


Graph Editing:
To edit a single point, move the cursor over the line on the graph and the cursor will change to a hand, which by clicking and dragging up and down will edit the current point.



Grid Editing
To select a site or range of site, click or click and drag the mouse or use left and right on the arrow keys while holding the shift key. To edit the sites use the [and] (or +/-) to increment the selected sites up or down, or type a number in to set a specific value. When online, pressing the space bar will select the site nearest to the current cursor site.

Editing Maps



There are three ways by which you can change the view of the map graph; Zoom, rotate and pan.

- Zoom increases or decreases the size of the map graph in its window. To zoom in or out, use the mouse scroll wheel.
- Rotate changes the angle which you are viewing the map graph. To rotate, hold down the Ctrl key and click and drag with the left mouse button. You can also rotate by holding the Ctrl key and using the arrow keys.
- Pan changes the position of the map graph in its window. To pan hold down the Ctrl and Alt keys and click and drag with the left mouse button. You can also pan by holding the Ctrl and Alt key and using the arrow keys.

With all of the above, also holding the shift key increases the speed at which the view changes

To select a point on the graph, click the point with the left mouse button. To select an area of points click an drag with the left mouse button. This selection can then be moved around the graph with the arrow keys.

With a point or points on the graph selected you can then edit the value of the point(s) selected. This can be done two ways:

- Incremental increase/decrease: use the [and] keys (or + and - on the keypad). Holding shift when using these keys changes the value by larger increments
- To a set value: Just start typing a number with points selected and a box will appear showing your number. Enter the correct value and press enter.

It is also possible to copy and paste a selection from another graph or grid. To do this select a point or area on another graph or grid, right click and select copy (or Ctrl+C), then select the point or area on the current graph you want to paste in to, right click and select paste (or Ctrl+V).

It is possible to change the way the map graph looks in a multitude of ways. For instance you can remove the grid, change the gradient color, or change the lighting.

To change the color of the map graph, from the Menu select: Configure > Preferences. In the preference window select the colors section. Find the option called 'Map Graph Fill'. From here you can select from many different gradients or create your own.

All other changes are made in the properties of the map graph. By default the properties window is displayed to the left of the workspace, if it is not shown you can right click on the map graph and select properties. The properties for the map graph will then be displayed. An explanation of each option is displayed at the bottom of the properties window, when the property is selected

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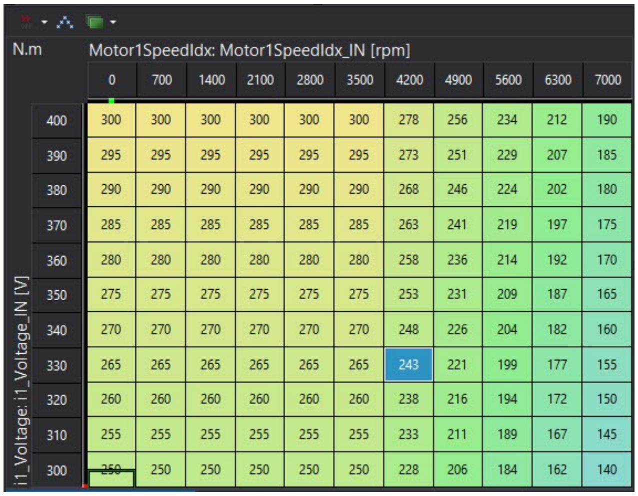


N.m / i1_Voltage: i1_Voltage_IN [V] \ Motor1SpeedIdx: Motor1SpeedIdx_IN [rpm]	0	700	1400	2100	2800	3500	4200	4900	5600	6300	7000
400	300	300	300	300	300	300	278	256	234	212	190
390	295	295	295	295	295	295	273	251	229	207	185
380	290	290	290	290	290	290	268	246	224	202	180
370	285	285	285	285	285	285	263	241	219	197	175
360	280	280	280	280	280	280	258	236	214	192	170
350	275	275	275	275	275	275	253	231	209	187	165
340	270	270	270	270	270	270	248	226	204	182	160
330	265	265	265	265	265	265	243	221	199	177	155
320	260	260	260	260	260	260	238	216	194	172	150
310	255	255	255	255	255	255	233	211	189	167	145
300	250	250	250	250	250	250	228	206	184	162	140

The map grid is a 2D representation of a map. It can be use to view and edit sites on the map. It displays the same data as the Map Graph and has much of the same functionality.

To select an area on the grid, you can either click and drag using the left mouse button, or use the arrow keys while holding down shift. Once an area is selected holding the Ctrl button down then pressing the arrows keys, will shift the entire selected area in the direction selected.

To select two non-concurrent areas (i.e. at opposite sides of the grid without the positions in between), select an area then while holding the Ctrl key, use the left mouse button to select another area.

To edit a point or group of points selected on the grid, either just start typing a number to set the selected points to a specific value, or use the + and - keys to increment up or down. To increment by a larger amount, hold down the Shift key while using + and -.

When online, pressing the space bar will select the site nearest to the current cursor site.

By displaying the state of the values on the grid you can see which sites have been edited how they have been edited. To show the state each site right click on the grid and select properties. From the Properties window set 'Color Mode' to either 'State' or 'State and Gradient'. Setting to 'State' will make each site display just its state color, setting to 'State and Gradient' will display a color for the site value and in the corner of each site display a separate color for the sites state:

The default color code for the states are as follows. These can be changed in Configure | Preferences and going to the calibration states in the colors section.
White - Unchanged - Has not been changed
Yellow - Changed - Site has been adjusted by the user
Lime - Calibrated - This state can be set either manually by the user or when the site has been calibrated using log-mapping (Auto-mapping)
Green - Calculated - Site has been calculated using a function
Grey - Pasted - Site value as been copied from another map then pasted to the current site
Blue - Optimised - Site has been set using the Optimise function

Locking certain sites in the map can be useful so that accidental changes are not made to known good values. You can do this by right clicking on the grid and selecting 'Lock Sites with Calibrated State'. When this is set any sites which have been set to calibrated can not be changed. You can also manually set states to being calibrated therefore locked, by right clicking on the grid and selecting State>'Set State to Calibrated'. To unlock the site select State>'Set State to unchanged'.

It is possible to change the way the map grid looks in a multitude of ways. For instance you can remove the change the gradient color, show sites that have been changed and display the current ECU position.

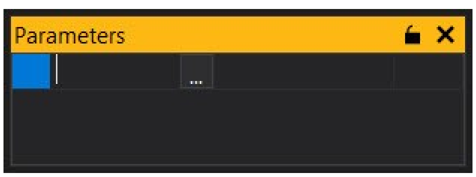
To change the color of the map grid, from the Menu select: Configure > Preferences. In the preference window select the colors section. Find the option called 'Map grid Fill'. From here you can select from many different gradients or create your own.

All other changes are made in the properties of the map grid. By default the properties window is displayed to the left of the workspace, if it is not shown you can right click on the map grid and select properties. The properties for the map grid will then be displayed. An explanation of each option is displayed at the bottom of the properties window, when the property is selected

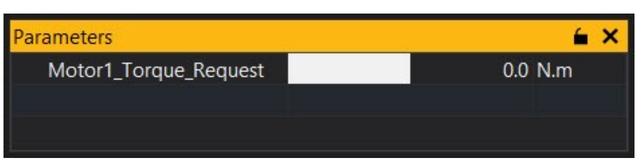
Viewing Calibration Parameters

Channel List

When a Channel list is added you be shown a blank list with a single blank entry:



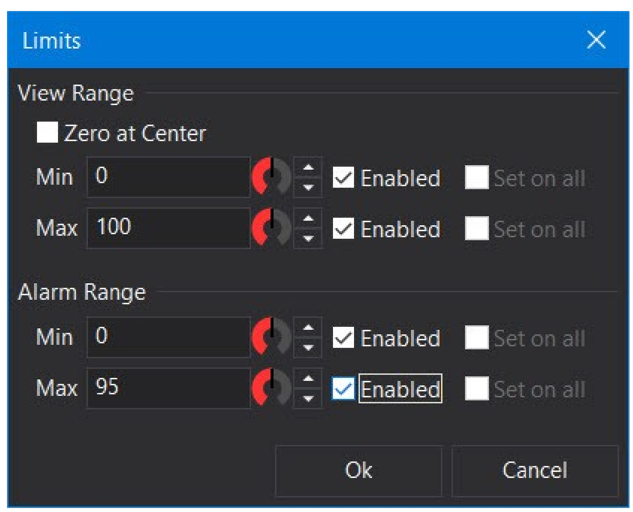
To add an channel simply start typing the name of the parameter and AEMCal will provide a list of likely options or click the '...' button and you will be shown a list of all available channels. Select the channel you want to display and click OK. This will add the selected channel to the list and provide a new blank entry from which to select another channel:

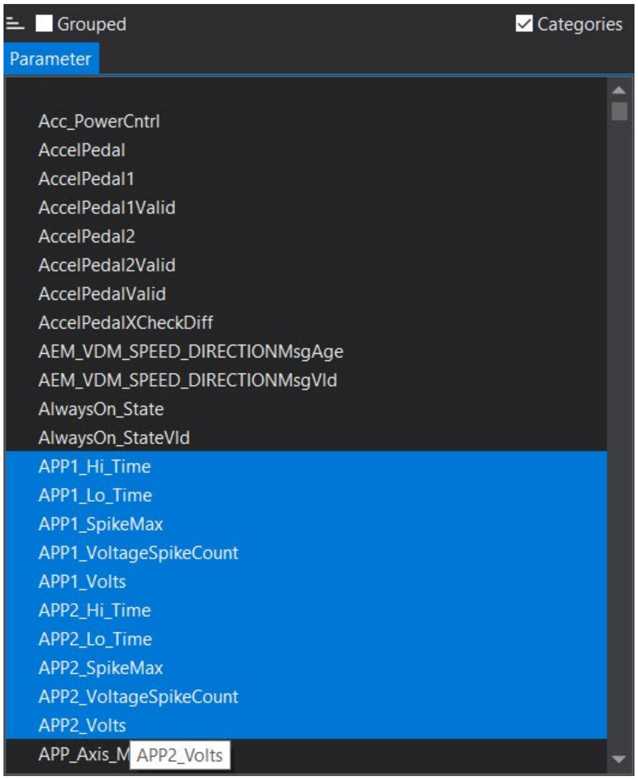


From the channel selection list you can add multiple channels. Click on the '...' button to bring up the available channels, then either click and drag over the channels, or use mouse click and either Shift or Ctrl keys to select separate items:

The Channel List provides a customizable list of available channels. This is useful to group similar channels or those which are used together. The Channel List works in the same way as the Option Selection List, just for channels not options. When the ECU is offline, the values in the channel list are greyed out.

For each channel displayed you can set up limits. This can either be to set the range of values (view range) displayed by the bar or to set warnings if the value goes above or below certain values (alarm range).





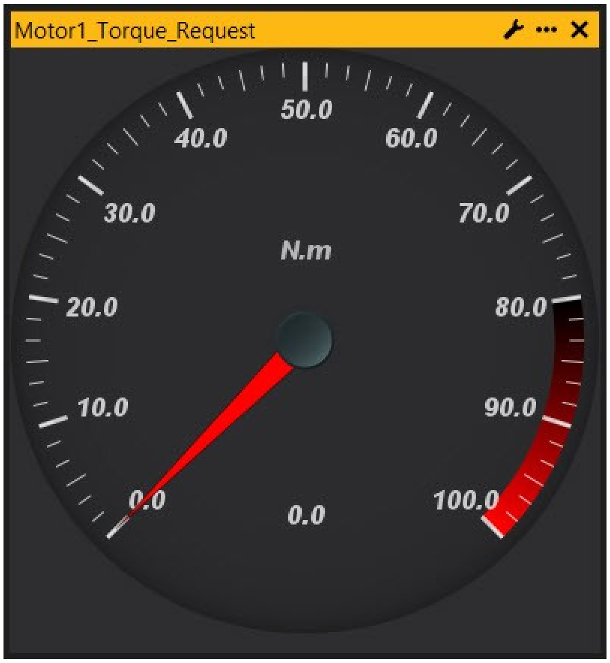
Once selected, click OK and the items will be added to your selection list.

Number Gauge

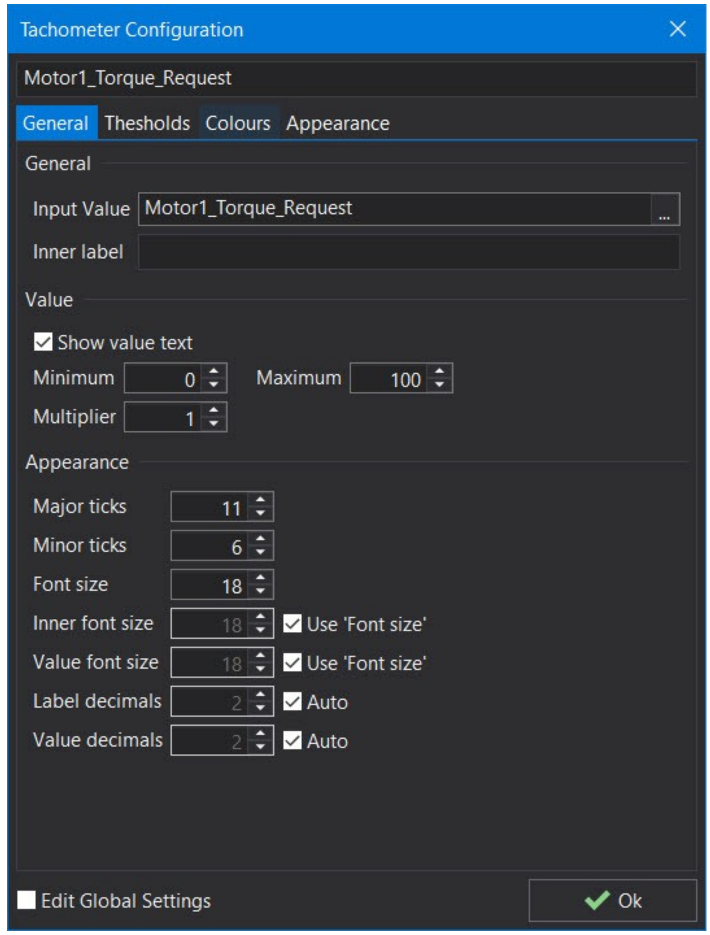
A Number Gauge provides a clear read-out of a single channel value. The numbers on the gauge will always resize to fill the size of their window. To increase or decrease the text size simply re-size the number gauge.

An alarm range can be configured. Select 'limits...' from the context (right click) menu, or 'limits' from the properties.
If an alarm limit is reached, then the color of the background will change to the color selected in your settings. The default is red.

Tacho



The Tacho Gauge provides a tacho (dial) representation of a channel. Right click on the gauge and select Configure Gauge... or select the wrench icon in the upper right hand corner. This will open the configuration options menu.



Many options are available for customization.

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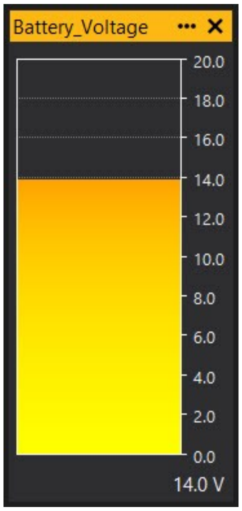
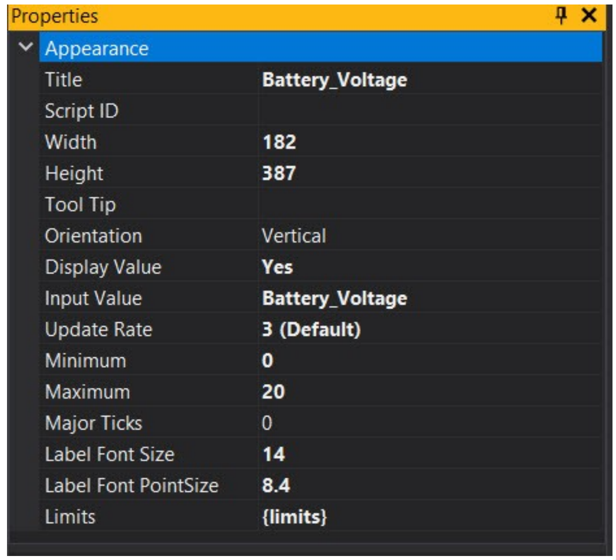
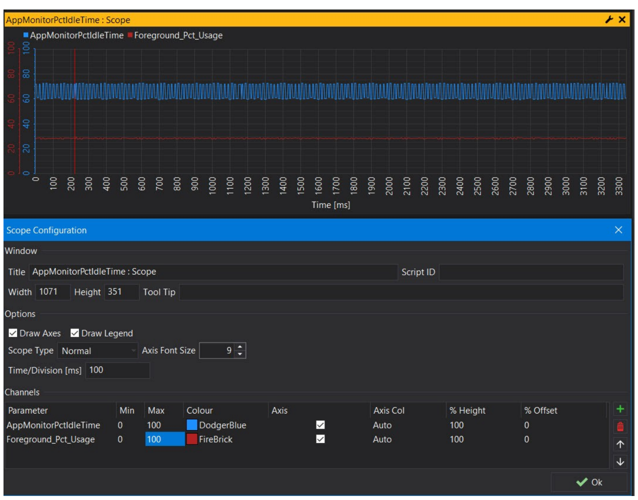
Bar Gauge



The Bar Gauge is used to display a channel value as a bar. Right click the gauge and select Properties for a list of configuration options.

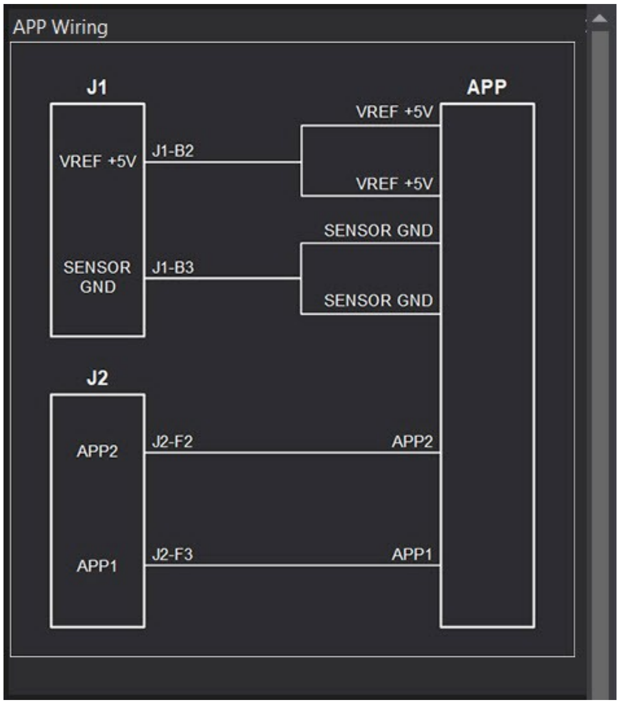


Scope

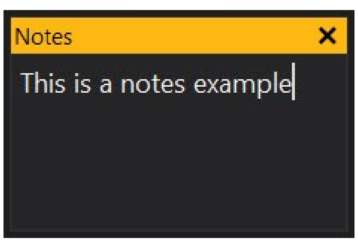


The scope displays a scope trace of a chanel value. Use the Scope Configuration pane to add channels and configure viewing preferences.

Other Tab Features



The image object allows you to place an image on your workspace. This maybe useful for display a diagram, some scanned in notes, or a company logo.



The notes object can be used to place notes in the tab areas. Select 'add Notes' when adding an object. Once you have added the note object you will be given a blank area to write in.

The notes object can be resized and the font size can be changed, by right clicking on the object, selecting 'Properties' and changing the font size property.

Note: The notes object is different to Calibration Notes as they are not stored in the calibration. They will be saved as part of your tabs file when the current tab or all tabs are saved.

The Button View provides a configurable button that may be used to execute scripts when it is clicked, and allows advanced configuration/control templates to be constructed. Button scripts should define an onClick function that is called when the button is clicked. The default script for a newly added button should contain an empty onClick function ready to be filled in.

The CheckBox View provides a configurable check box that may be used to execute scripts when it is clicked or changes state, and allows advanced configuration/control templates to be constructed. CheckBox scripts should define an onClick and/or an onChanged function that is called when the checkbox is clicked or changed state. The default script for a newly added checkbox should contain an empty implementations of these functions ready to be filled in.

The Label View is very similar to the Notes View, but is displayed as static text and is not directly editable. This is useful for developing advanced configuration/control panels.

The Number Edit View provides means to enter in a floating point number and access it from scripts. The value has no effect on the ECU and is stored in the tabs file, not in the calibration as with options/tables/maps.

The Pot View provides a mouse-adjustable dial for editing parameter and option values. Additionally it is possible to add scripting to the control in order to provide more complex control of values.

A parameter or option may be selected using the box underneath the dial. If the selected object is a map modifier then the program button will be visible. Clicking on the button will perform the same action that the virtual pot box program button does by applying the adjustment to the current map site and resetting the parameter to zero.

The label, object selector and program button visibility may be overridden by setting the appropriate properties. Additionally the text of the label may be set via the 'Label' property. If the Label property is left blank then it will be set to the name of the selected object unless a script is specified.

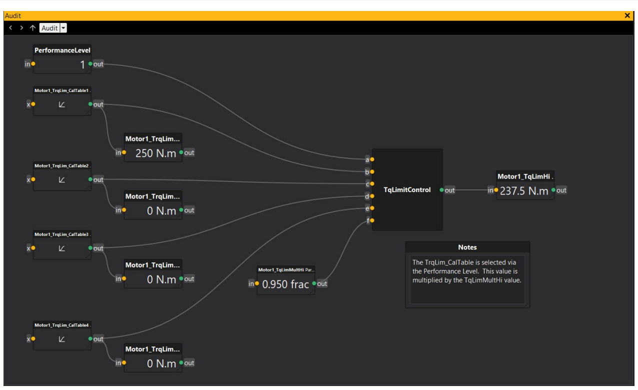
If a script is specified for the control then the object selector will be disabled since the script is mutually exclusive. To disable the script, see the 'Enable Script' property.

If the script defines a function called 'onProgramButton' then the program button will be visible and call that script function when clicked.

The Group View allows a number of other views to be contained within another movable view. This allows configuration/control panels to be created.

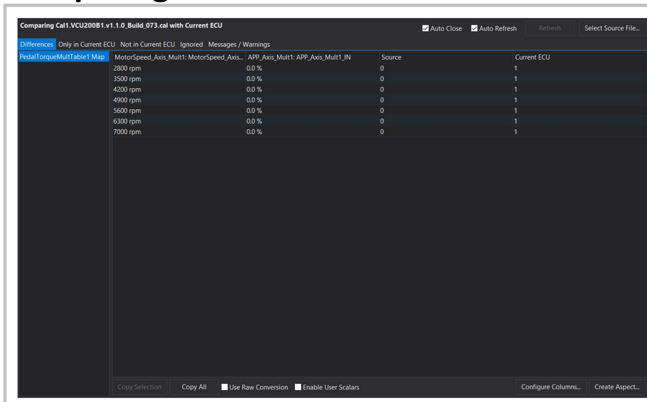
Groups can either be created by adding a new group and then adding sub-views to it, or by box-selecting some views and selecting 'Group in sub-panel' from it's context menu (right click).

For creating advanced configuration/control panels, the Group View is very useful. From the right click menu, you can select default show/hide states for the sub-window title bars and borders. Typically you'll want to hide the title and borders if you are trying to create a native looking form.



The Audit View enables the construction of node-based graphs that show a dynamic visual flow diagram between objects in the ECU (parameters, tables, maps etc).

Comparing Calibrations



Comparing calibrations enables you to compare the currently open calibration to another calibration of your choice. To compare calibrations, from the main menu select File | Compare Calibration.

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Calibration Aspects

Calibration Aspects are a way of loading/saving only a portion of a calibration file. Aspects can be used to store specific aspects of a VCU calibration. This is open-ended and can be used to load or save any combination of options, tables and maps. Aspects can be created from the current calibration by picking "Save Calibration Aspect" from the File menu. To load a calibration aspect, pick "Load Calibration Aspect" from the File menu.

Freeze Mode

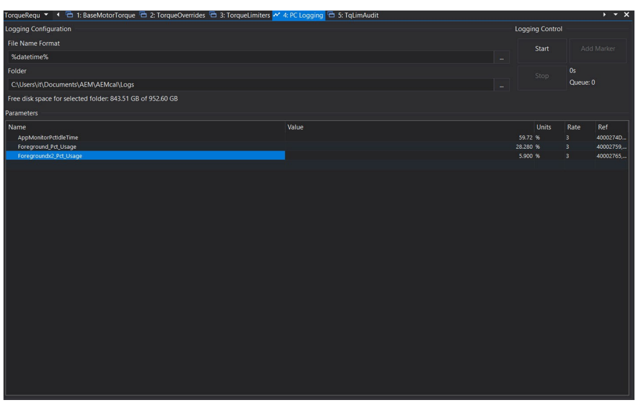
Freeze mode is available from the tools menu and by doble clicking on the 'Freeze ON/OFF' indicator in the status bar. When freeze mode is active, channel updates in the user interface stop so that you can inspect the values when freeze mode was turned on. Adding new views of channels or switching tabs may not reflect their actual state when frozen, because the channels have not been read from the VCU. PC logging still continues as normal when freeze mode is on.

Key Mode

Key Mode enables Key Mode shortcut keys. Key Mode shortcut keys are selectable in the **Configure | Key Mode Shortcuts** menu. Key Mode shortcuts can be configured to adjust specific values such as the pedal map at the current site position when online.

Options can be modified using key mode when offline.

PC Logging



PC Logging is data-logging that is done by the PC. Data is recorded and stored to the hard disk. The recorded data-log can then be either played back (see Log Playback) or can be loaded and analyzed by AEMData. PC logging can log any of the channels available in the VCU.

To access PC Logging select Logging | PC Logging.

A new tab dedicated to PC logging will then be opened, as shown. Note: Only one PC Logging tab can be opened at a time.

The log folder is where the data for the log will be recorded to while the logging is taking place. The actual viewable log file can be saved elsewhere after the log is complete. Make sure there is plenty of free space available. How much space is left is displayed below the log folder. To change the path of the log folder click the button to the right of the log folder and select a folder. The folder can also be changed in the Preferences section in the menu Configure | Preferences and selecting the folders section.

The File Name Format is the format of the name that will be given to the log file when logging has been completed.

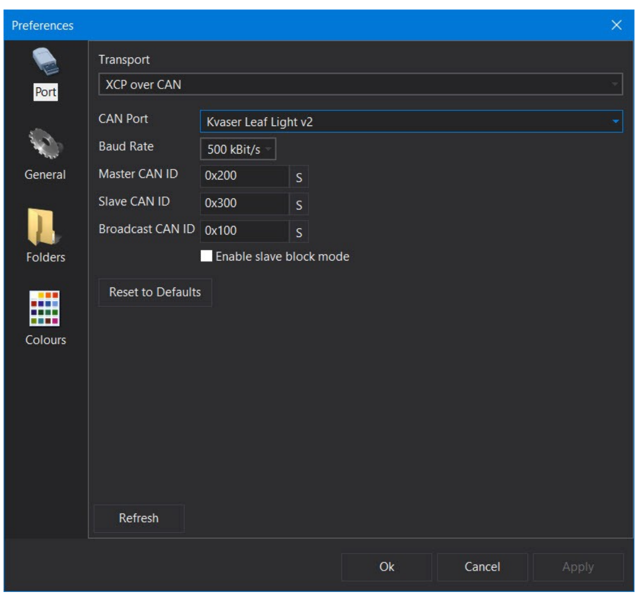
Log control is very simple, to start logging, click the Start button, to stop, click the Stop button. At any point whilst logging you can add a manual marker in the log by clicking the Add Marker button. In the log this will appear as a manual/hand marker.

Channels that are to be logged by the PC Logging are shown in the table. To add a channel click in an empty cell, then either start typing and a list will appear of close matches to what has been type, or click the '...' button to the right of the cell and a box will appear with all available channels. To add another channel repeat the process until you have everything showing that you want to log.

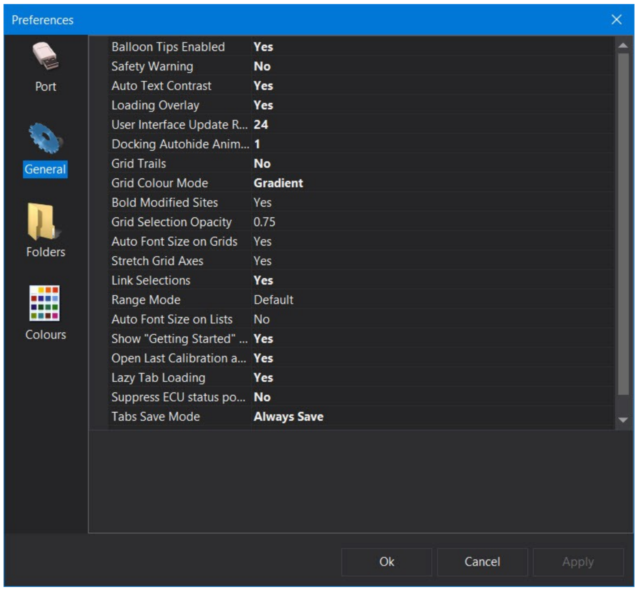
If you have a channel list and you want to log all the channels in that list, then right click on the list and select 'Add to PC logging'. All channels in that list will now be added to the list of channels to log.

If you want to log all the channels on a tab, right click on the tab name or some blank space on the tab, then click 'Add all Channels to PC Logging'. This will add all channels on the tab to PC logging, regardless of how they are displayed (parameter list, tacho, bar gauge etc).

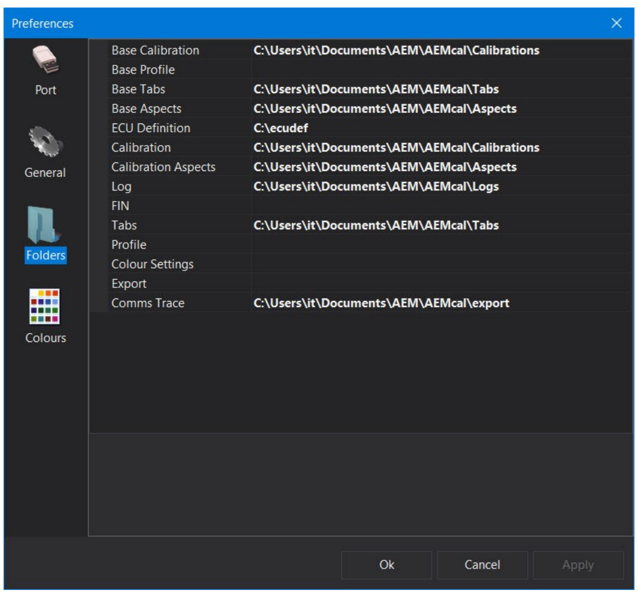
Preferences



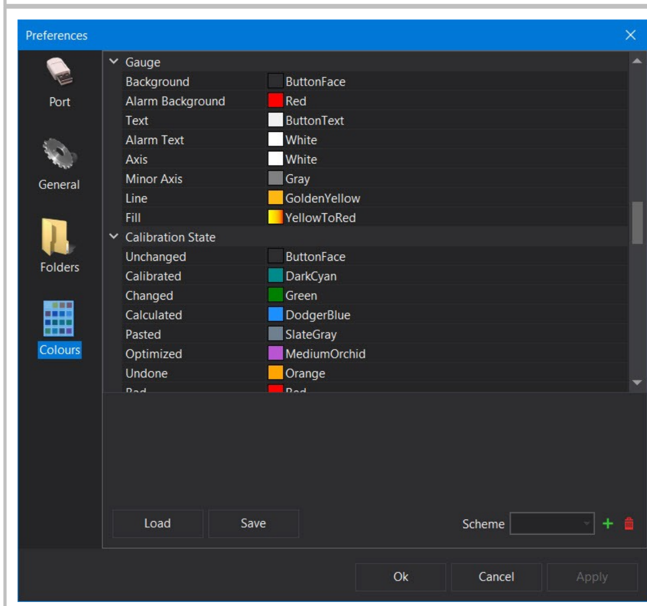
The Port preference pane is used to configure CAN communications settings. Configure as shown in the example and select your CAN to USB adapter hardware from the drop down list.



Many general preferences are available for customization.



Folder locations can also be customized.



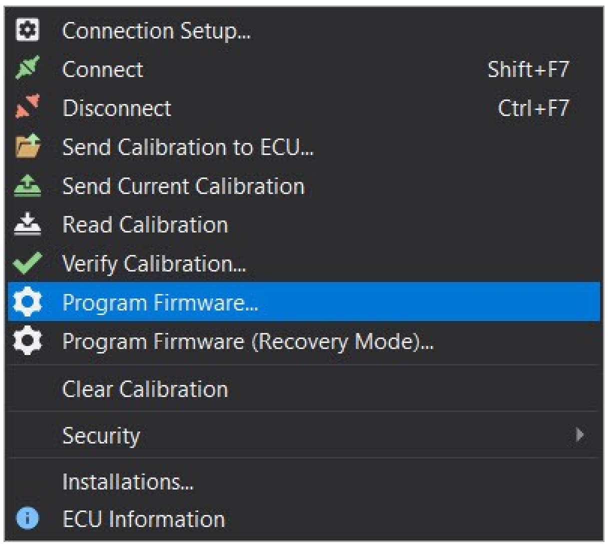
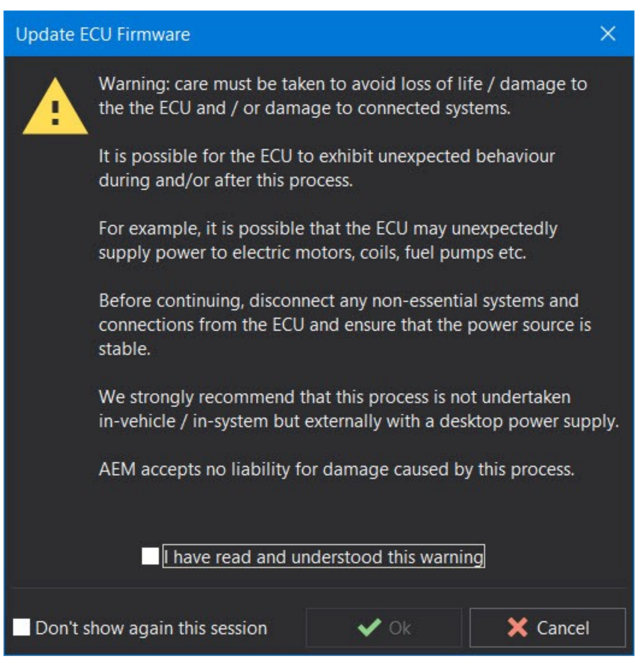
Colors are completely customizable from the Colors preferences pane.

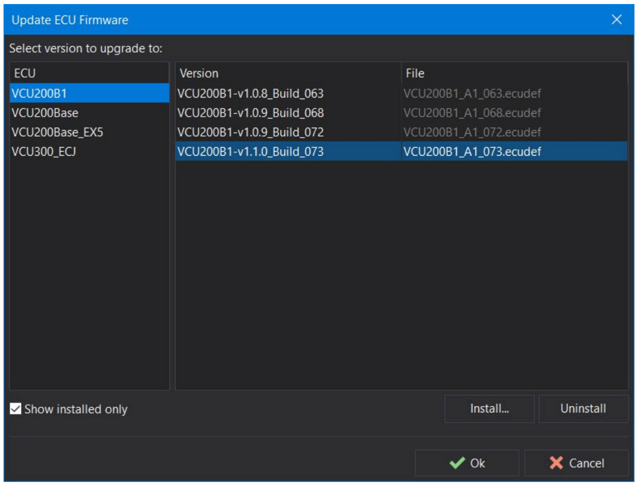
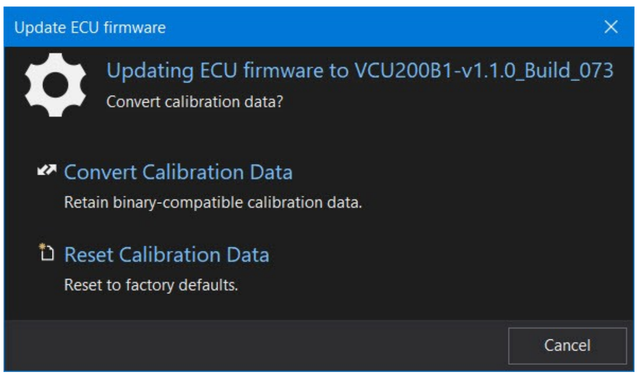
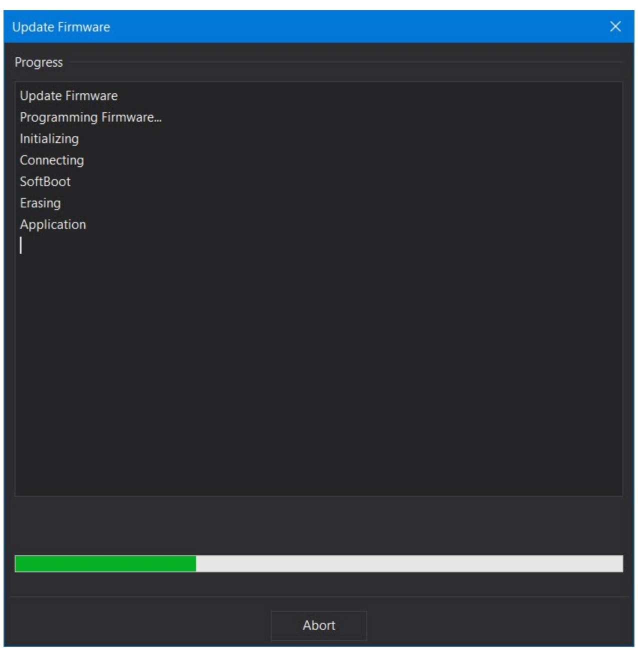
Firmware Management

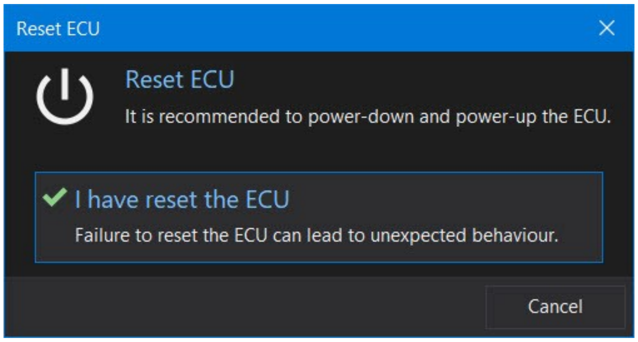
aemecudef files

aemcudef files are a package file that contains the VCU firmware and a definition file that allows AEMCal to display data properly. When you program new firmware into the VCU, you select an aemecudef file. aemecudef files have unique versions.

Upgrading Firmware

	***Before beginning the firmware programming process, ensure that the following is true:*** ***1. Battery pack segments are separated using an appropriate maintenance disconnect plug.*** ***2. The PC is connected to AC power.*** ***3. The CAN to USB adapter cable is plugged in securely and will not be disturbed during the process which can take 1 - 3 minutes depending on the VCU model.*** To begin the process, the VCU must be powered up and connected to AEMCal. Go to ECU | Program Firmware...
	Acknowledge the warning message and click OK.

	Select the ecudef file from the list of available options.
	Select to convert calibration data on the VCU or revert to AEM factory defaults contained in the new version. Choose Reset Calibration Data for new installs.
	The process will complete several steps automatically including erasing and application programming.

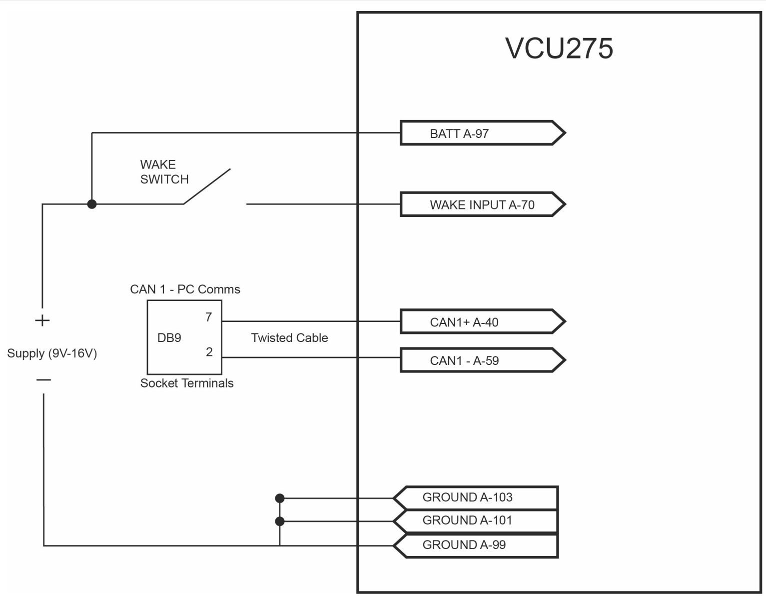


When this step is reached, turn switched power off (wake switch) and wait 10 - 15 seconds. Turn the power back on and click the acknowledgment that the VCU power has been reset. A power cycle is required each time new firmware is programmed. Once this is done, AEMCal will reconnect and display live data.

Basic Setup Guide

This section describes a basic step by step approach to configuring a VCU275 system for the first time and assumes the previous AEMCal 19 section was read and understood. It is not meant to be a comprehensive description of all features and functions. But rather it is meant to cover the most commonly used aspects. Additional information containing more detail on each topic may be found in other sections of this document.

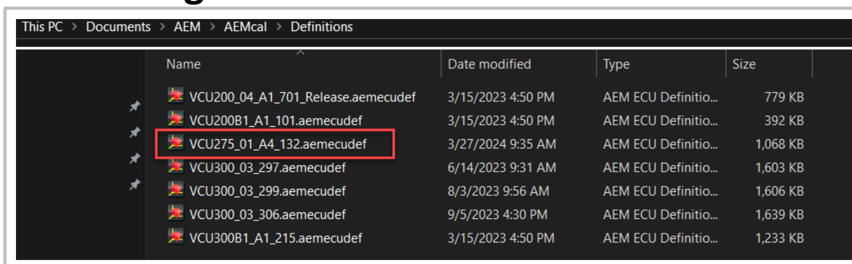
Power and Programming Harness



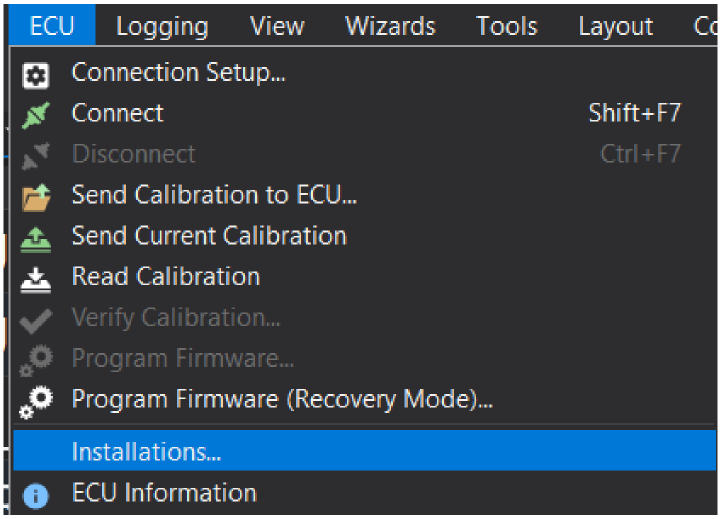
Generally, it is recommended to do all setup and initial firmware programming with a dedicated power and programming harness in a test bench environment. The schematic diagram describes how to build a dedicated power and programming harness.

The VCU communicates with the PC over the CAN1 network. A CAN to USB converter device is required. For best performance, AEM recommends the Kvaser Leaf Light V2 or Kvaser Leaf V3. Follow the manufacturers recommendations for installing hardware drivers. Connect the CAN/USB adapter to the DB9 connector. Connect the adapter to a PC USB port.

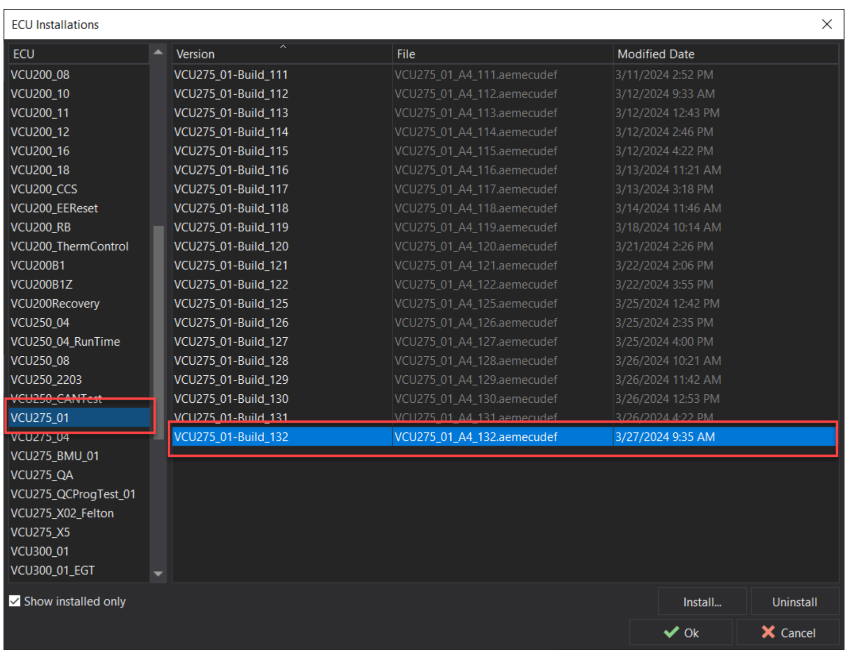
Connecting and First Firmware Flash



The VCU ships from AEM loaded with a production test firmware version. You must load a fully functional firmware version before proceeding. Application specific, production release firmware versions generally, are installed with AEMCal. In some cases, it may be necessary to manually install a new version. They will be installed in the \Documents\AEM\AEMcal\Definitions folder. The content of an example folder is shown at left. The installed files may or may not be the same. VCU275 firmware versions will be files with the format ***VCU275_XX_XX_XXX.aemecudef***.

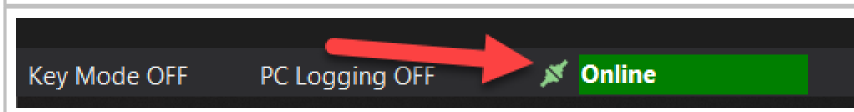


To see a listing of all current firmware versions for a given VCU, go to ECU | Installations... in AEMCal.

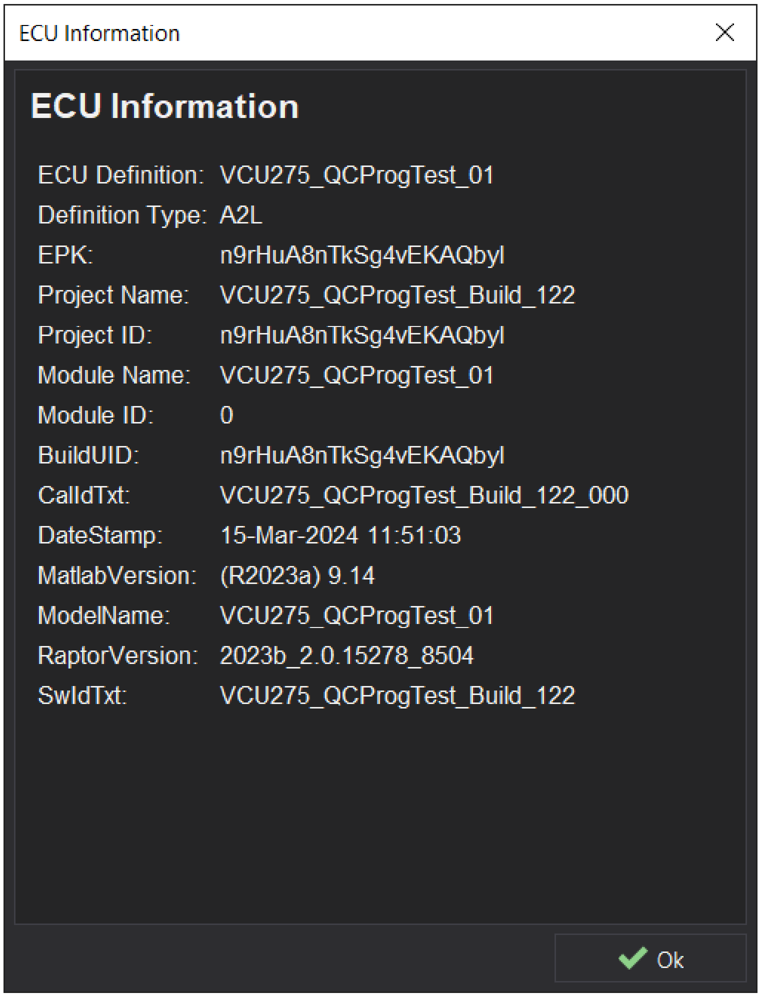


On the left hand side is a listing of all VCU build types. On the right is a listing of all versions available for each type.

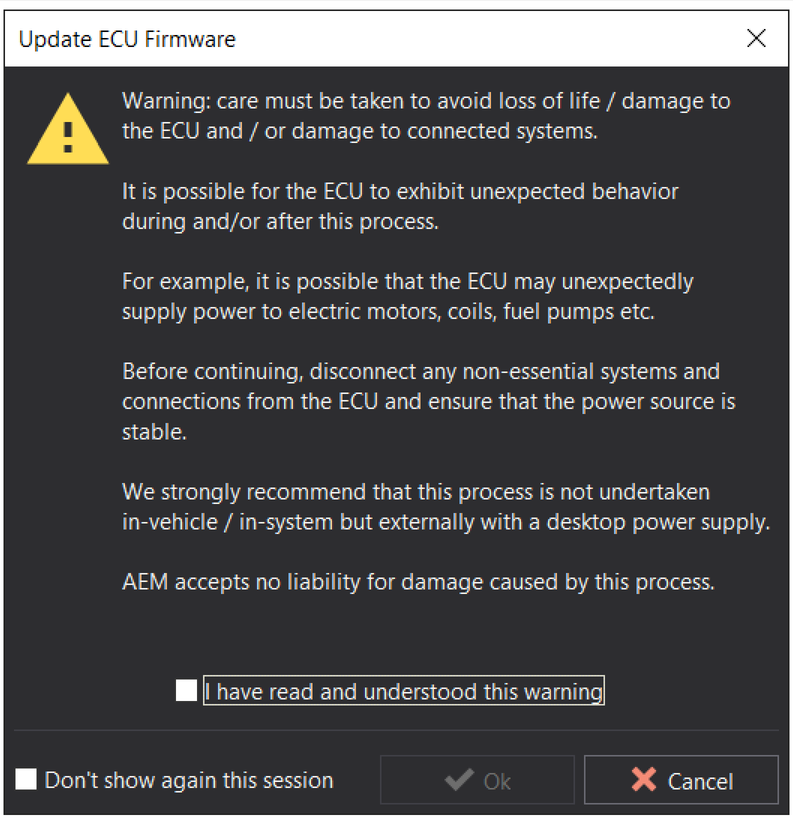
If the required version is not available in the list, drag and drop the file onto the AEMCal workspace to manually install it. Follow all pop up instructions. Close and re-open AEMCal before proceeding.



Prepare for the first PC connection by turning the 12V supply power ON. Next turn the Wake Switch ON. Click the green Connect button in the toolbar or click Shift + F7 to connect. Once connected the green Online indication should be visible in the lower right hand corner of the AEMCal workspace.



Once connected, you may also verify the base version installed on the hardware. Go to ECU | ECU Information. The information displayed should be similar to the example at left if this is a first time connection.



Before the next step, please make sure the VCU is connected to a reliable 12V power supply. Also make sure your PC is connected to AC power and NOT running on battery power. The firmware flashing process will take up to 10 minutes to complete. If it is interrupted at any point in the process, the VCU may become unresponsive and require recovery.

Go to ECU | Program Firmware...

Read the warning and click the check box to acknowledge. Click OK.

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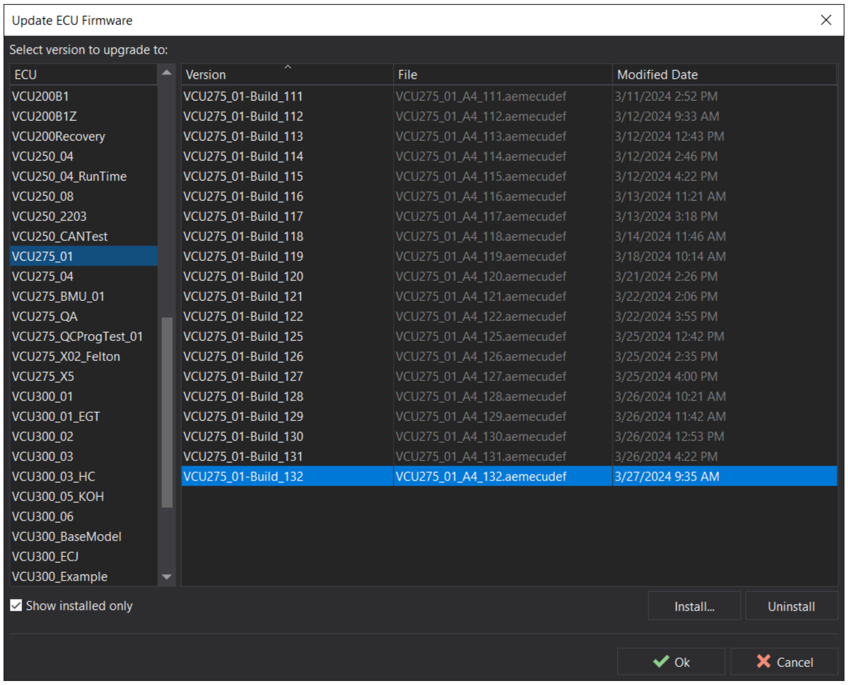
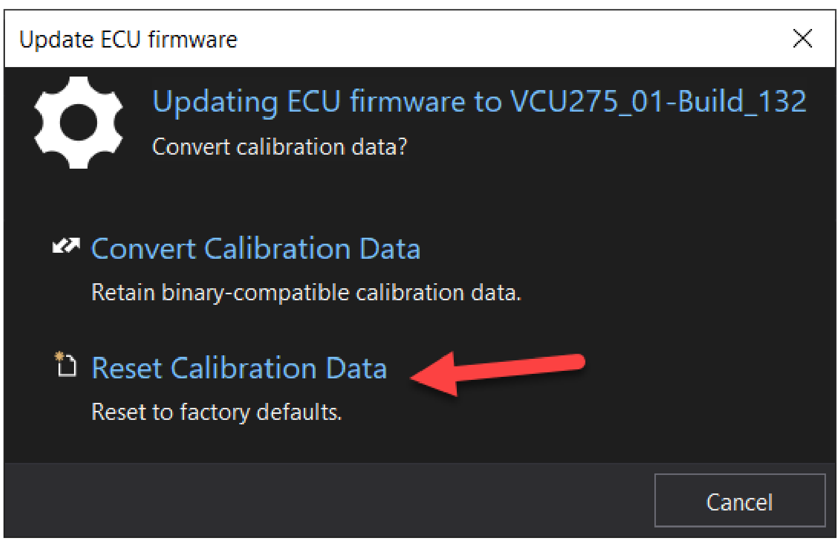


Select the latest ***VCU275_XX-Build_XXX*** from the list and click Ok.



For this initial flash, choose Reset Calibration Data.

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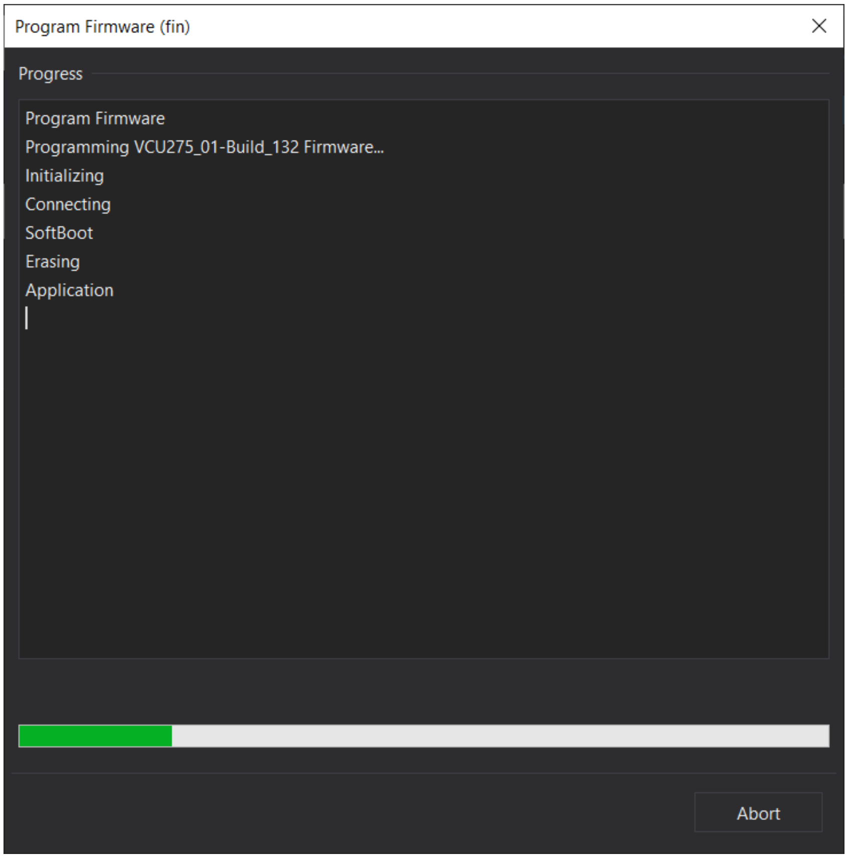
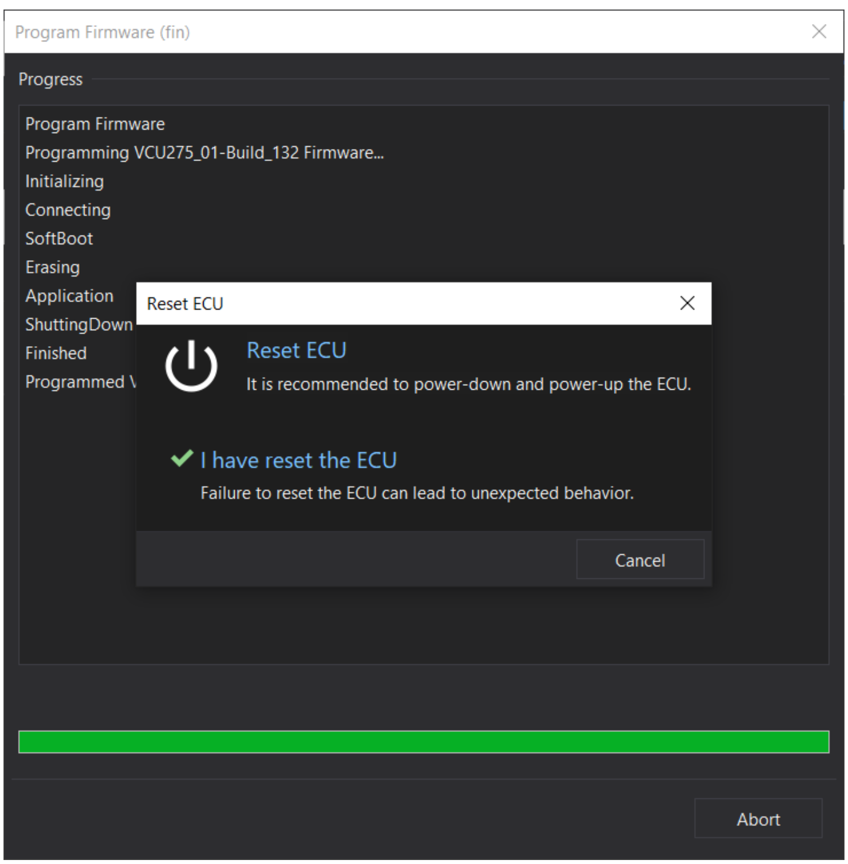


The flashing process will begin. ***This process will take approximately 10 minutes!***



When the process reaches this point, turn the Wake Switch OFF. Wait at least 5 seconds and turn it back ON. Click *I have reset the ECU*.

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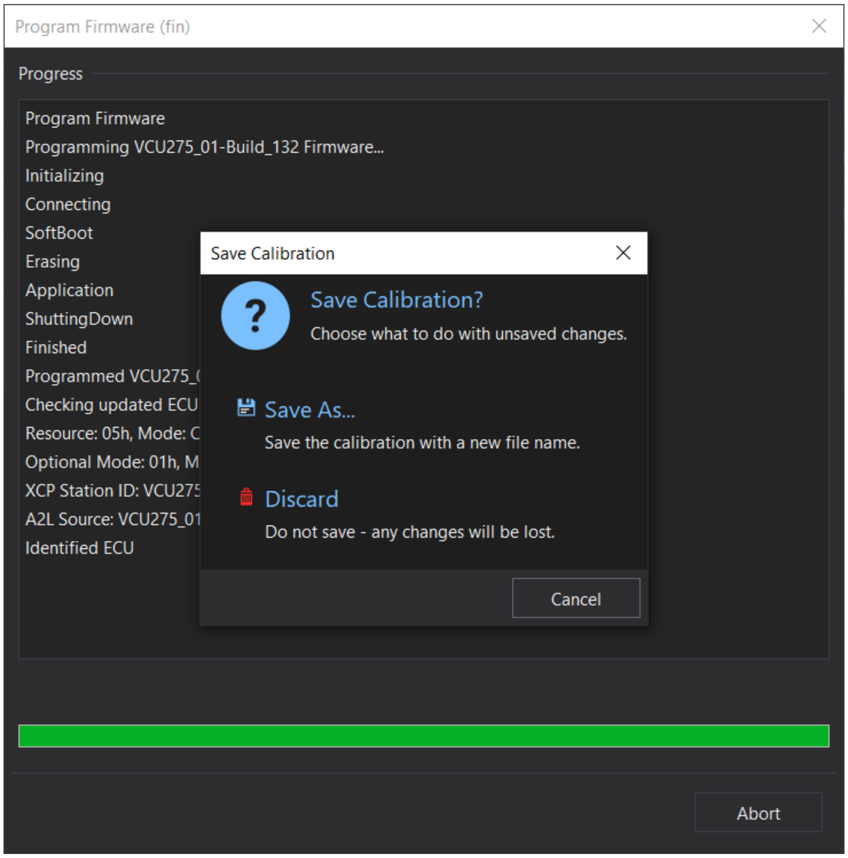
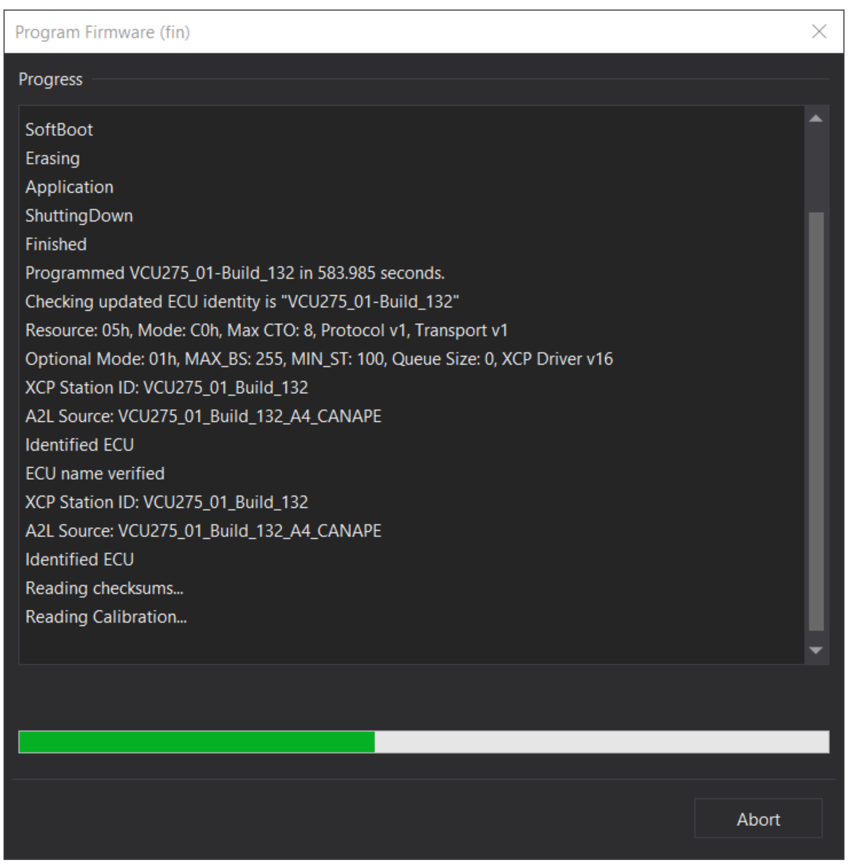
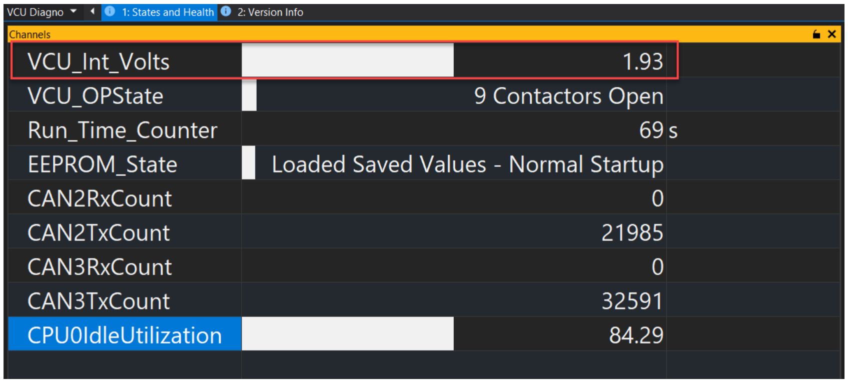


Click Discard. At this point, you do not need to save the calibration file saved in PC memory. You may need to click Discard one more time.



AEMCal will reconnect to the VCU.

Once connected, go to Layout | Open Layout... to select a working layout tab file. The AEM base layout file for the VCU275 will have a file name of the form ***BaseLayout.VCU275_XX.Build_XXX.aemcaltab***.



Go to the VCU Diagnostics group and select the States and Health tab. The example shown at left is a normal display in a test bench environment.

VCU_Int_Volts is a measure of the VCU's internal 12 volt supply. The source for this supply comes from the VCU Main Relay. See the Minimum Required Inputs 81 for more detail. A VCU_Int_Volts reading less than 2.0 volts is normal if a simple power and programming harness is used without a Main Relay.

The Run_Time_Counter should be incrementing. The EEPROM_State should be Loaded Saved Values - Normal Startup under normal conditions. CAN2 and CAN3 transmit counters should be incrementing. The CAN2 and CAN3 Rx counters will not be incrementing since there are no other CAN nodes included in this setup.

AEM Base Calibrations

AEM provided base calibrations are installed in the \Documents\AEM\AEMcal\Calibrations\Factory folder. Descriptions are below.

File name	Description
InitialStartup.VCU275_XX.Build_XXX.aemcal	Recommended initial startup calibration for new installations. Torque limits are set low.
VCU275_TeslaLDU_Sport_BMS18_CCU.VCU275_XX.Build_XXX .aemcal	Tuned base calibration for the following basic configuration: 1. Tesla Sport LDU 2. AEM BMS18 with 6x satellite groups. 3. AEM CCU 4. Default pin I/O configuration 5. 2x AEM PDU8

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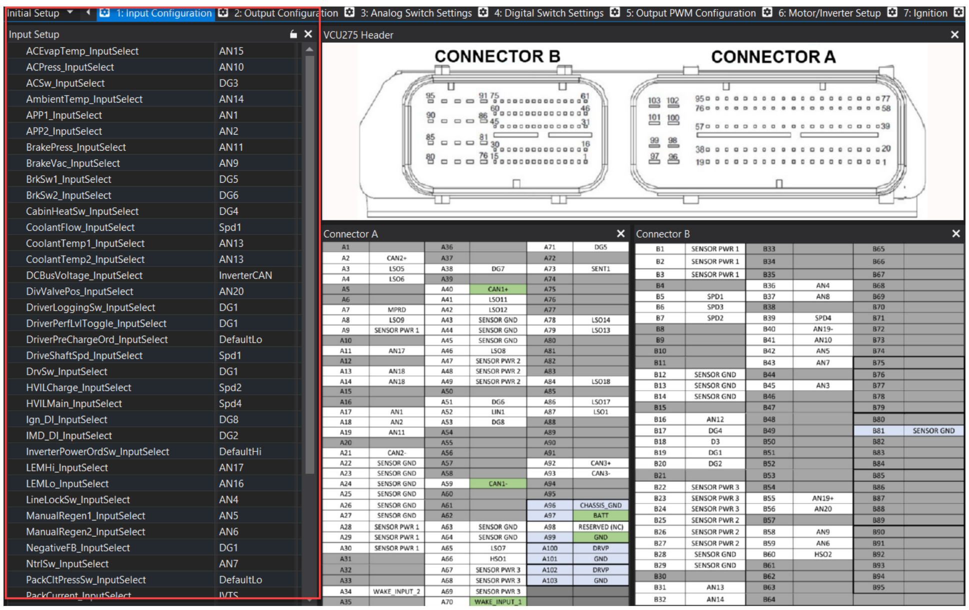
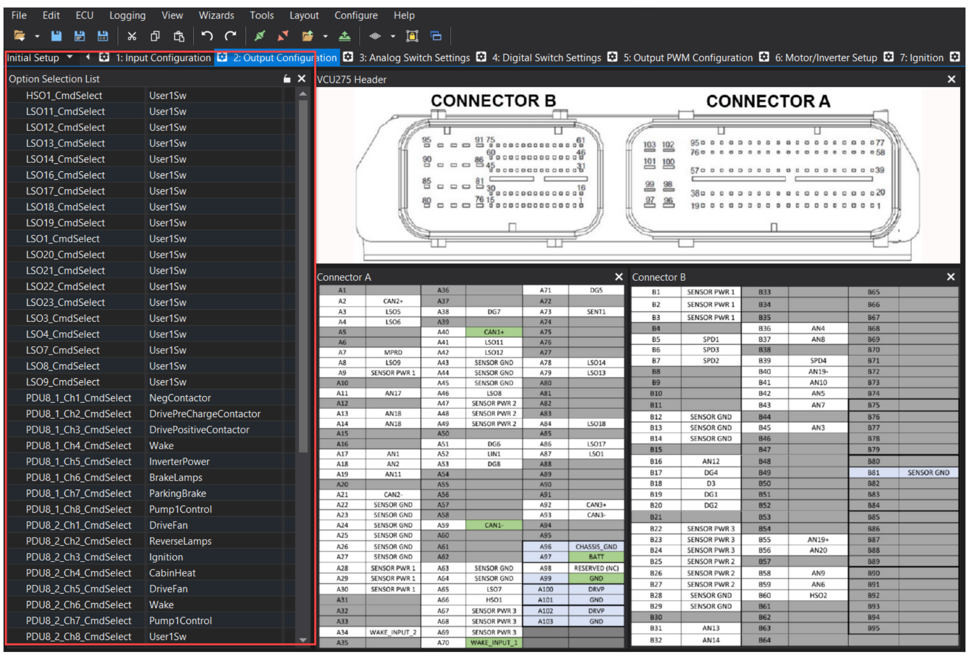
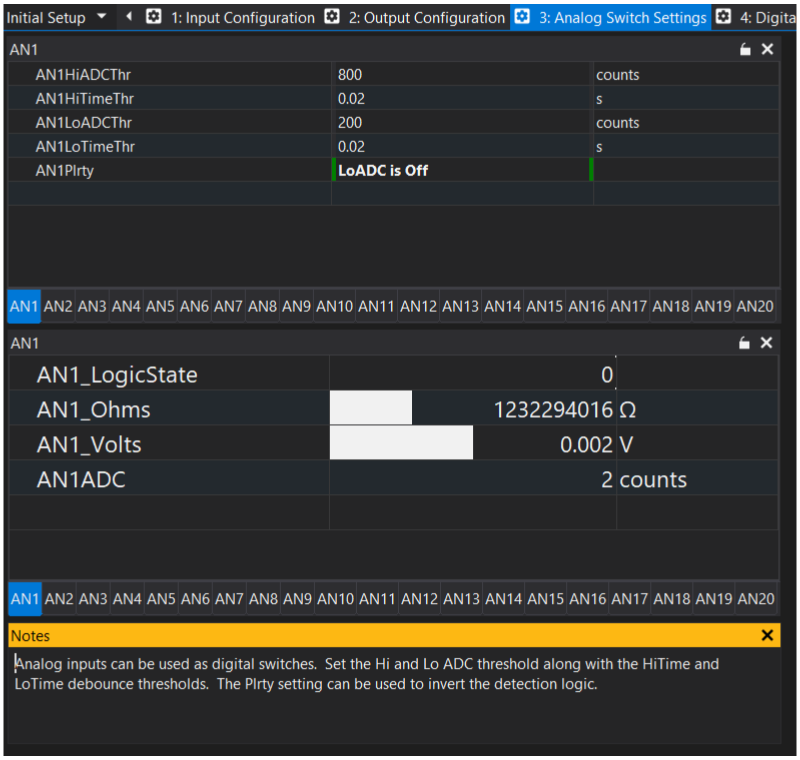
Initial I/O Setup

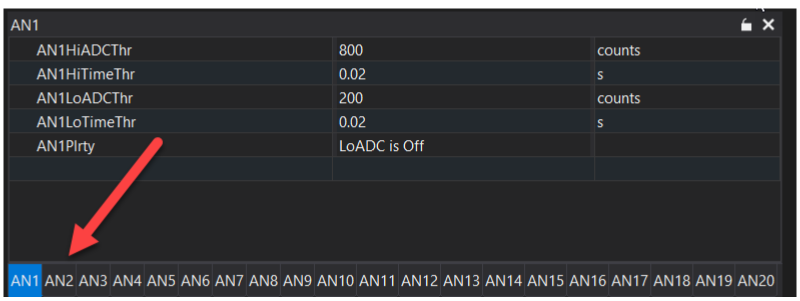


In the Initial Setup group and Input Configuration tab, assign VCU functions to input pins. AEM provided VCU base calibrations will include default pin functions. Reference the connector pinout diagram for pin locations.



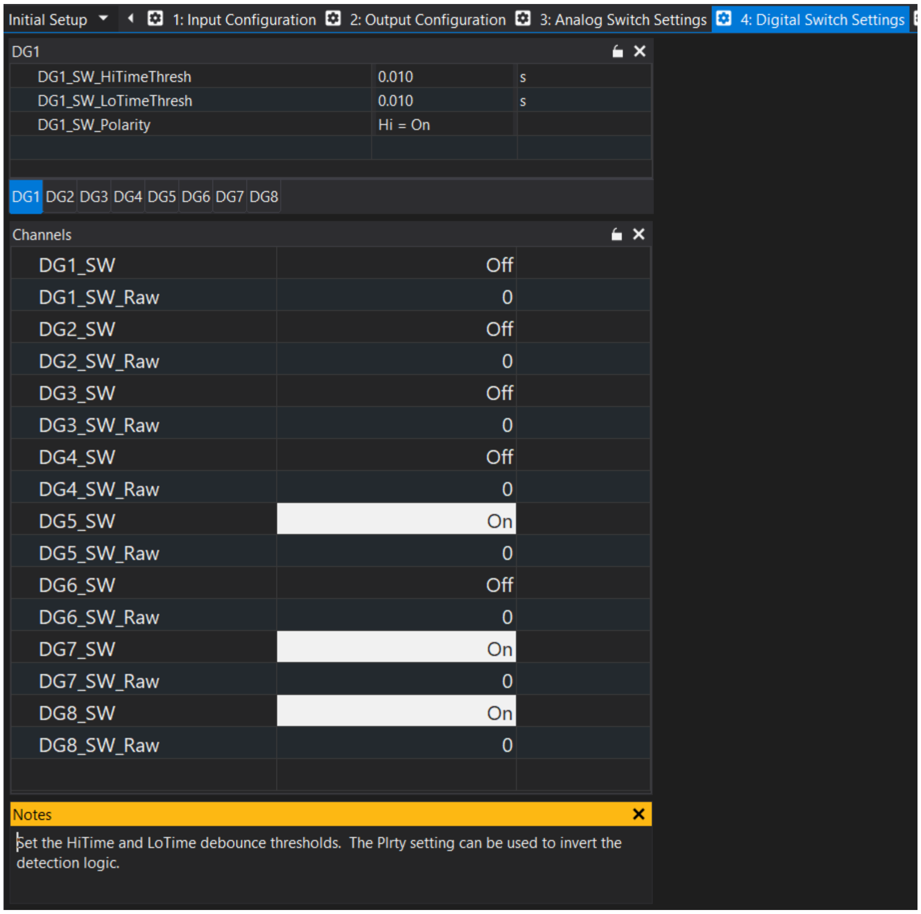
In the Initial Setup group and Output Configuration tab, assign VCU functions to output pins as well as (optional) AEM PDU8 channels. AEM provided VCU base calibrations will include default pin function assignments.





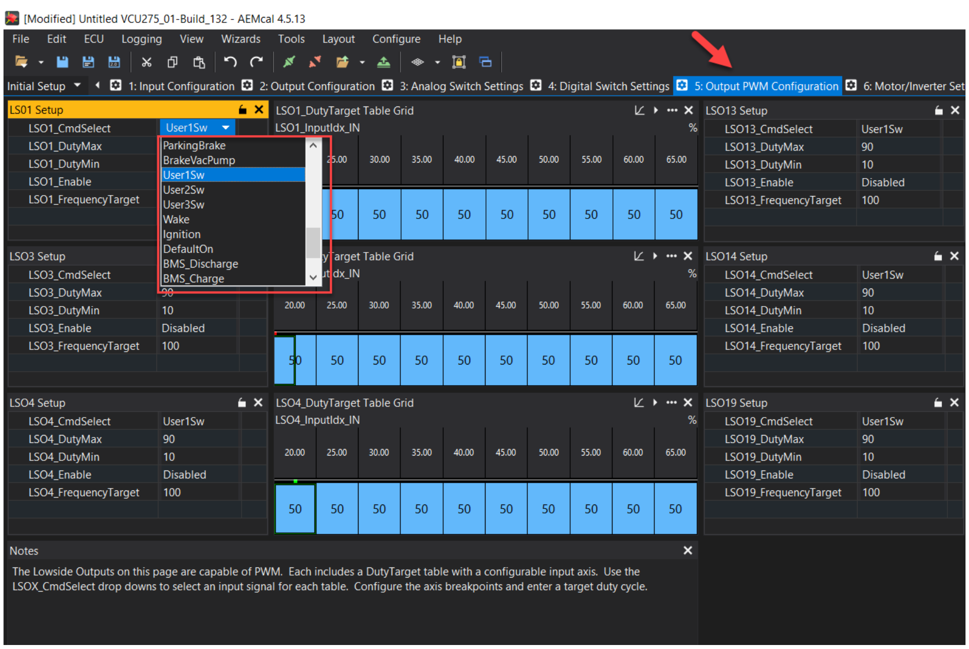
The Analog Switch Settings tab can be used to configure and monitor analog inputs used as digital switches.

Use the embedded tabs indicated by the arrow to switch between analog input settings.



The Digital Switch Settings tab can be used to configure and monitor digital input switches.

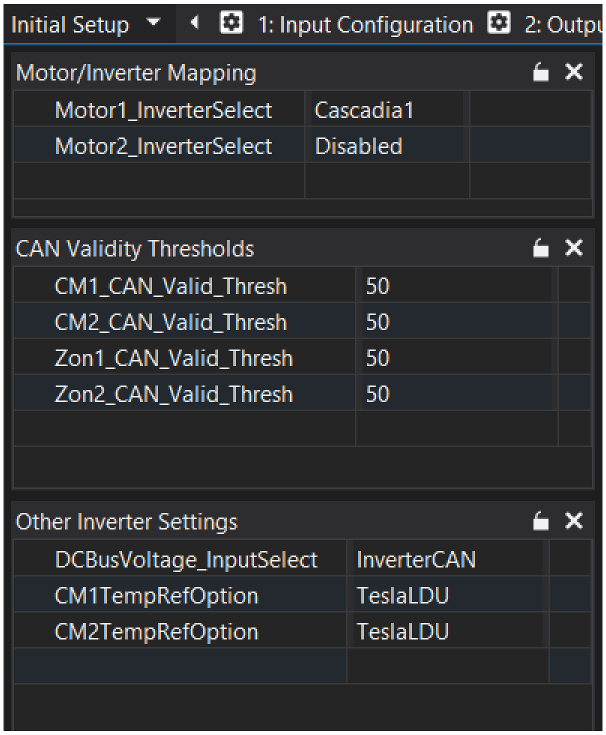
Similar to the analog input settings, use the embedded tabs to switch between digital input settings.



Lowside outputs LS01, LS03, LS04, LS013, LS014 and LS019 are configurable for pulse width modulation. Use the LS0X_CmdSelect drop downs to select the desired PWM control signal. This signal will be used as the x-axis input to the LS0X_DutyTarget table.

1. Set the LS0X_DutyMin and LS0X_DutyMax.
2. Set the LS0X_FrequencyTarget (1 Hz - 10 kHz range).
3. Set the LS0X_Enable switch.
4. Use the LS0X_DutyTarget table input axis and table values to create the desired output behavior. A duty cycle value of 0% means the output will be OFF. A duty cycle value of 100% means the output will be fully ON.

Motor/Inverter Setup



The VCU275 currently supports up to two motor control systems with the option to assign inverter interfaces to motor control features.

1. Use the MotorX_InverterSelect drop downs to assign inverter control features to motor systems.
2. Use the DCBusVoltage_InputSelect drop down to select the source for the Motor1 DC Bus Voltage signal. The InverterCAN selection is typically used. DC Bus Voltage will be received directly from the inverter CAN signals.
3. Select the preference for inverter reference temperature. Choose TeslaLDU for either Tesla LDU or SDU systems.

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Cascadia Inverter Settings

i1_DirChangeAllowed	Enable
i1_ForwardDirCmd	1
i1_FwdRPMSign	Positive
i1_Inverter_Discharge	Enable
i1_MotorDirErrorThresh	50
i2_DirChangeAllowed	Disable
i2_ForwardDirCmd	0
i2_FwdRPMSign	Negative
i2_Inverter_Discharge	Disable
i2_MotorDirErrorThresh	50

Zonic Inverter Settings

Zonic_DirChangeAllowed	Disable
Zonic_ForwardDirCmd	CCW
ZonicFwdRPMSign	Negative
ZonicMaxSpeedNeg	2000.00
ZonicMaxSpeedPos	2000.00
MotorDirErrorThresh	50
Zonic2_DirChangeAllowed	Disable
Zonic2_ForwardDirCmd	CCW
Zonic2FwdRPMSign	Negative
Zonic2MaxSpeedNeg	2000.00
Zonic2MaxSpeedPos	2000.00
Motor2DirErrorThresh	50

Additional settings are available to fine tune each inverter interface.

X_DirChageAllowed: Enables or disables motor direction changes
X_ForwardDirCmd: Defines what direction is assigned to Drive and Reverse
X_FwdRPMSign: Defines whether the forward (Drive) direction is a positive RPM or negative RPM
X_DirErrorThresh: is how much RPM sign error is allowed before the VCU disables the drive torque

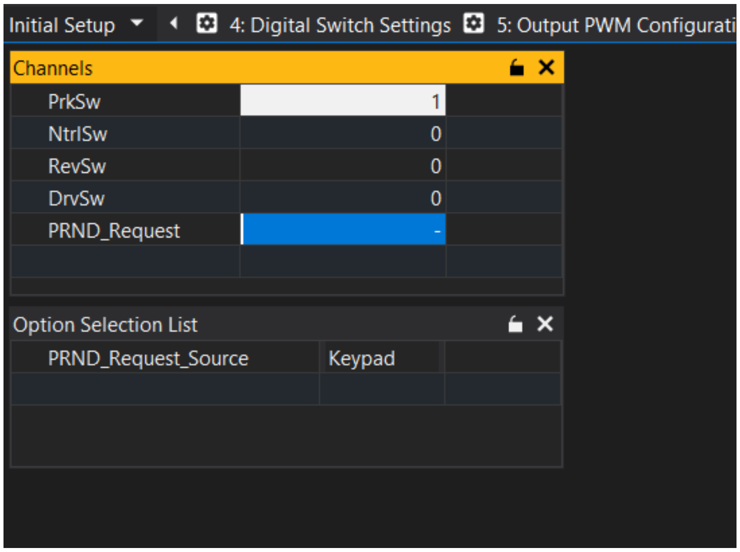
Motor1TorqueTable Map Grid

N.m — Motor1SpeedIdx_IN [rpm] (columns) / i1_Voltage_IN [V] (rows)

3D	0	6000	6500	7500	8500	9000	10000	11000	12000	14000	15000
400	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0
350	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0
340	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0
335	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0
330	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0
325	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0
320	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0
315	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0
310	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0
305	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0
300	620.0	620.0	620.0	550.0	460.0	425.0	370.0	325.0	282.8	190.0	130.0

Use the Motor1Torque table to set the motor base torque in Nm versus motor speed and DC bus voltage.

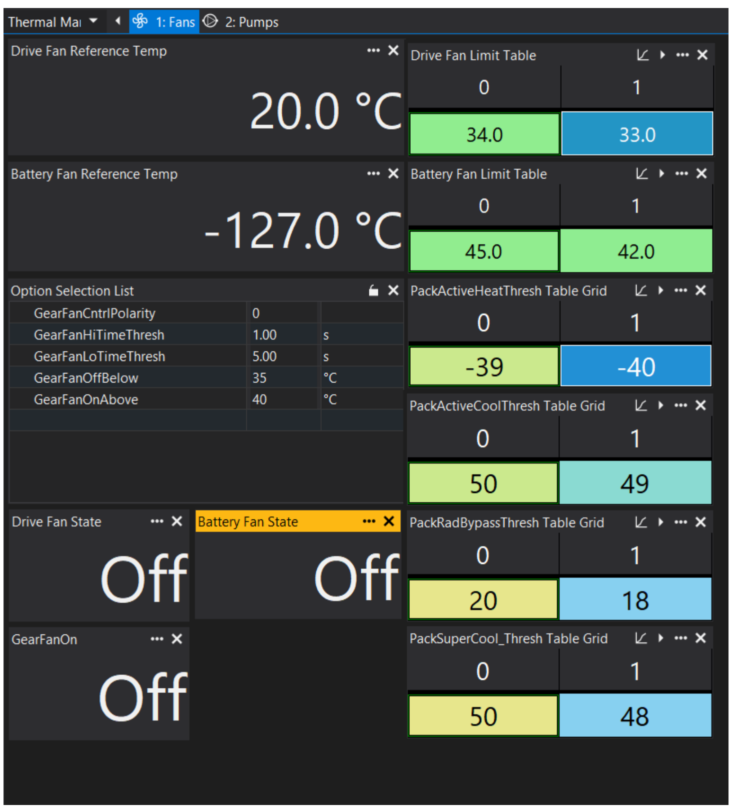
Drive Mode Detection



Use the PRND_Request_Source dropdown to select from either the AEM CAN Keypad or discrete digital switches.

The PRND_Request channel can be used to monitor the state of the input.

Thermal Management Setup



For the most basic configurations, simply set the hi/lo threshold values in the Drive Fan Limit Table. When the reference temperature is above the left most value, the output command will turn ON. The output command will turn off when the temperature is lower than the right most value.

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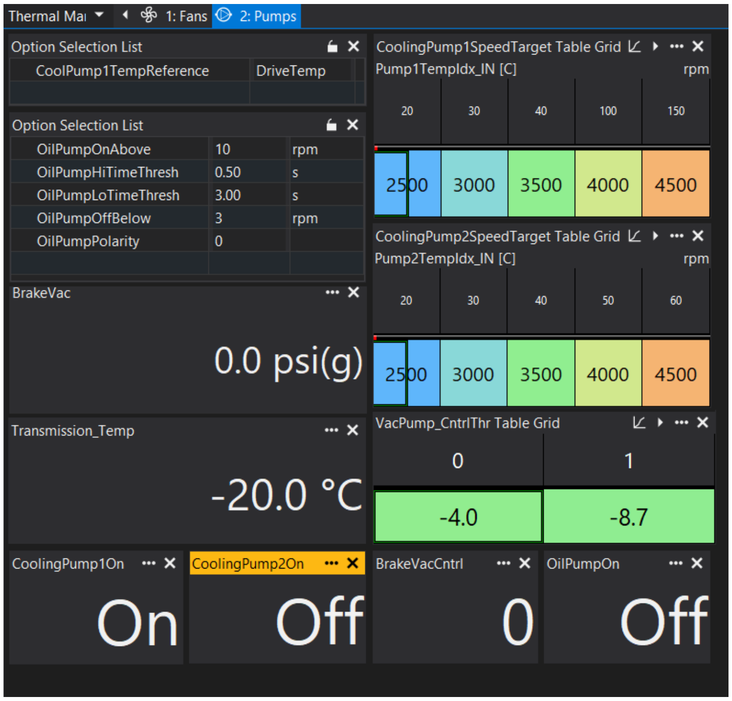
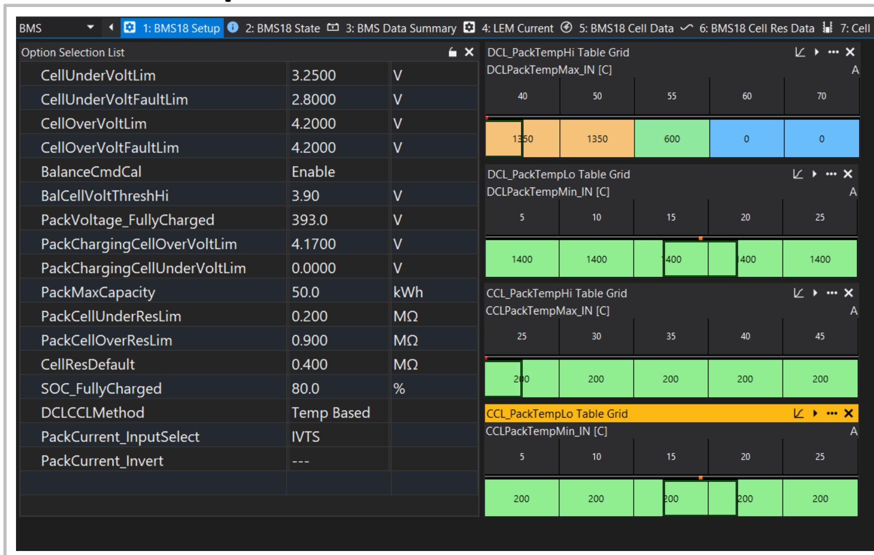


For most basic systems with a single cooling loop, the only setting necessary is CoolPump1TempReference. Choose either DriveTemp or PackTemp to control the pump control command.

BMS18 Setup and Initial Checks



BMS settings for initial testing:

1. Set CellUnderVoltLim and CellOverVoltLim to values you do not want to exceed during normal operation. Eventually, these settings will be used to calculate a predictive discharge and charge current limit.
2. Set CellUnderVoltFaultLim and CellOverVoltFaultLim to values that should result in a fault flag being set.
3. BalanceCmdCal can be used to enable or disable cell balancing.
4. BalCellVoltThreshHi is the value above which cell balancing is ON
5. PackVoltage_FullyCharged is the target pack voltage for J1772 charging.
6. PackChargingCellOverVoltLim is the value above which J1772 charging is turned OFF. If any individual cell exceeds this value, charging will be stopped.
7. PackChargingCellUnderVoltLim can be used to limit charging if any individual cell is under this limit.
8. PackMaxCapacity is the total pack capacity in kWh
9. PackCellUnderResLim and PackCellOverResLim set the normal, expected range for estimated cell resistance values. If any calculated resistance is outside this range, a fault will be set.

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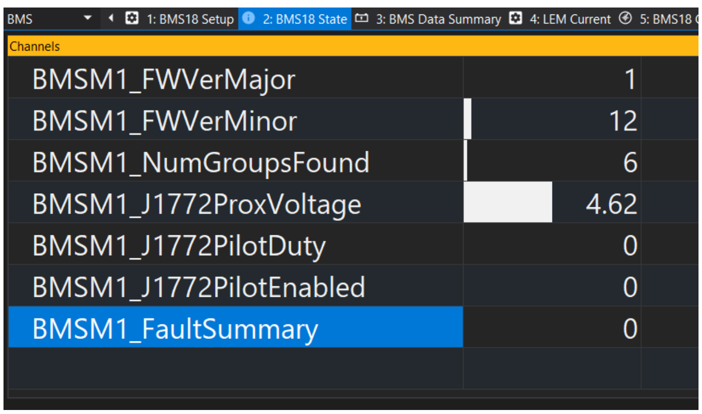
10. CellResDefault is the cell resistance value applied when no data is available or if individual cells fall outside the resistance range set by #9 above.
11. SOC_FullyCharged is an optional state of charge target for charging. Recommend using PackVoltage in the early stages of tuning.
12. DCLCCLMethod is either Temp Based or Resistance Based. Recommend using Temp based in the early stages of tuning.
13. PackCurrent_InputSelect is a choice between various options for pack current signal selection.
14. PackCurrent_Invert inverts the sign of pack current. Pack Current should be negative during charging and positive during discharging.

BMS18 States



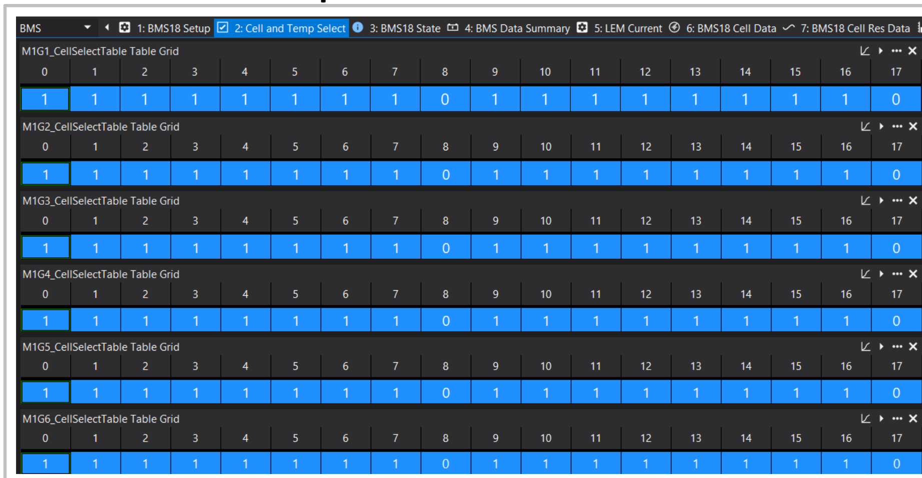
The BMS18 Master transmits a series of signals that indicate current states.

X_FWVerMajor is the major firmware version
X_FWVerMinor is the minor firmware version
X_NumGroupsFound is the number of cell groups (or satellites) that the BMS18 system has identified. This should equal the number of physical satellites in the pack.

XProxVoltage, XPilotDuty and XPilotEnabled are indicators of the J1772 plug connection state.

X_FaultSummary will indicate a value other than 0 if there are any internal BMS18 Master faults. A value of 0 is normal and indicates no faults present.

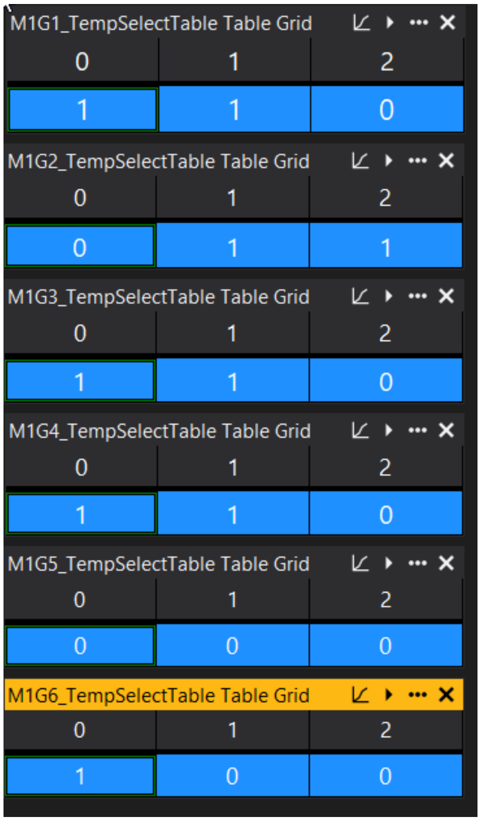
BMS18 Cell and Temp Select



The BMS18 cell and temp select tables are used to tell the VCU which cell taps and temperature sensors are physically connected to the pack.

The table axes are labeled 0 - 17 for cells 1 - 18. Enter a 1 for each cell tap that is connected to the pack.

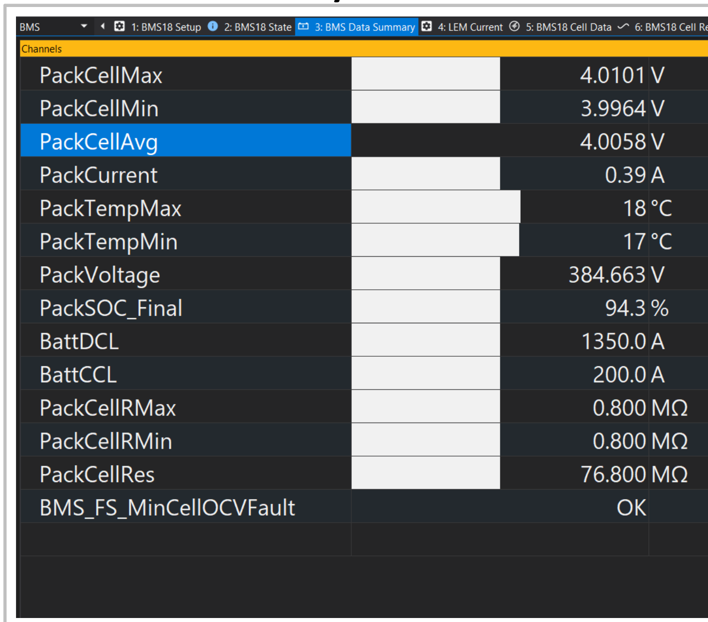
Only 6 of the 16 available tables are shown in this example.



The temp select table axes are labeled 0 - 2 for temperature sensors 1 - 3. Enter a 1 for each temperature sensor that is used in the pack.

Only 6 of the 16 available channels are shown in this example.

BMS18 Data Summary



This tab is a summary of basic BMS18 data channels.

PackCellMax is the maximum measured cell voltage.
PackCellMin is the minimum measured cell voltage.
PackCellAvg is the calculated average cell voltage across the entire pack.
PackCurrent is the measured pack current.
PackTempMax is the measured maximum pack temperature from all used temperature probes.
PackTempMin is the measured minimum pack temperature from all used temperature probes.
PackVoltage is the calculated pack voltage.
PackSOC_Final is the estimated pack state of charge based on all the existing settings.
BattDCL is the calculated discharge current limit based on all the existing settings.
BattCCL is the calculated charge current limit based on all the existing settings.
PackCellRMax is the maximum estimated cell resistance value. Default data is used when no good data is available.
PackCellRMin is the minimum estimated cell resistance value. Default data is used when no good data is available.
X_MinCellOCVFault indicates a minimum cell open circuit voltage fault.

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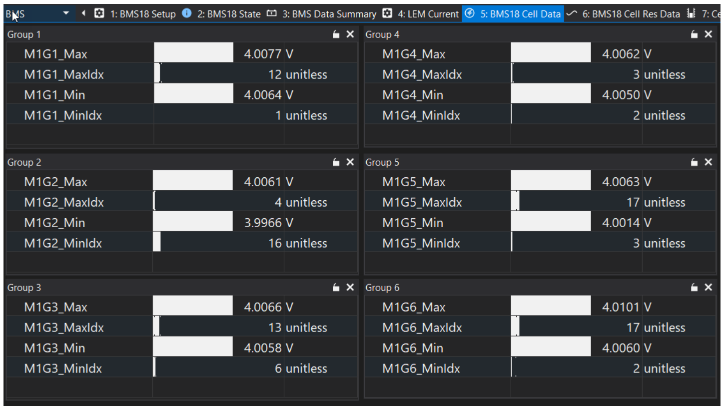
BMS18 Cell Data

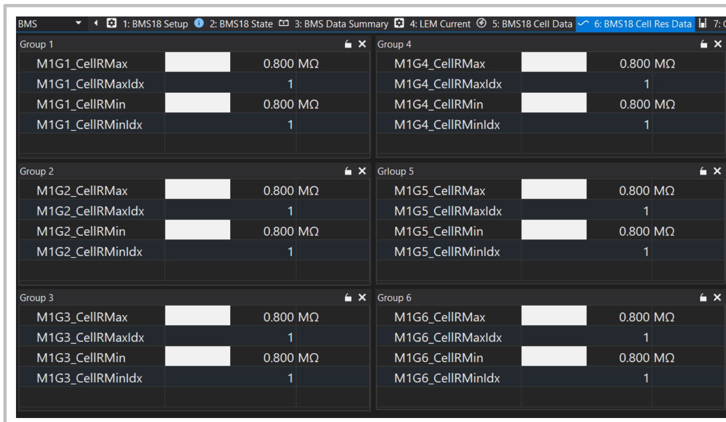


This tab provides an overview of group cell max and min values along with their indexes.

M1GX_Max is the maximum measured cell voltage for this group.
M1GX_MaxIdx is the index value of the group max cell.
M1GX_Min is the minimum measured cell voltage for this group.
M1GX_MinIdx is the index value of the group min cell.

Only 6 of the available 16 total cell groups are shown in this example.

BMS18 Cell Resistance Data

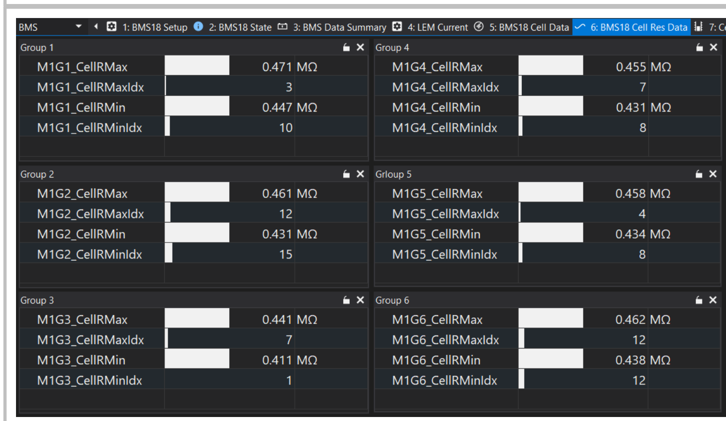


This tab provides an overview of group cell max and min resistance values along with their indexes.

M1GX_CellRMax is the maximum measured cell resistance for this group.
M1GX_CellRMaxIdx is the index value of the group max cell.
M1GX_CellRMin is the minimum measured cell resistance for this group.
M1GX_CellRMinIdx is the index value of the group min cell.

The example shows default data applied to all cells.

Only 6 of the available 16 total cell groups are shown in this example.



The example at left shows actual calculated resistance values. Resistance values are updated during J1772 charging cycles.

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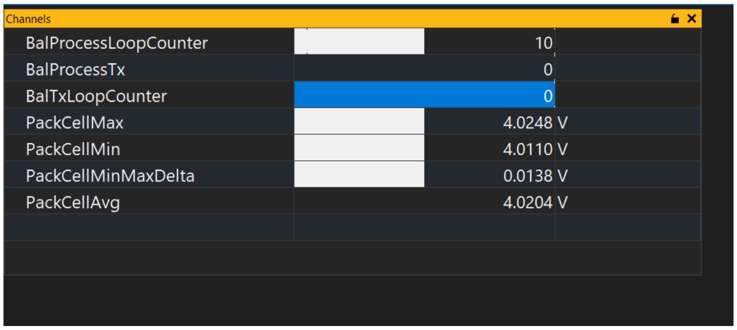
BMS18 Cell Balancing

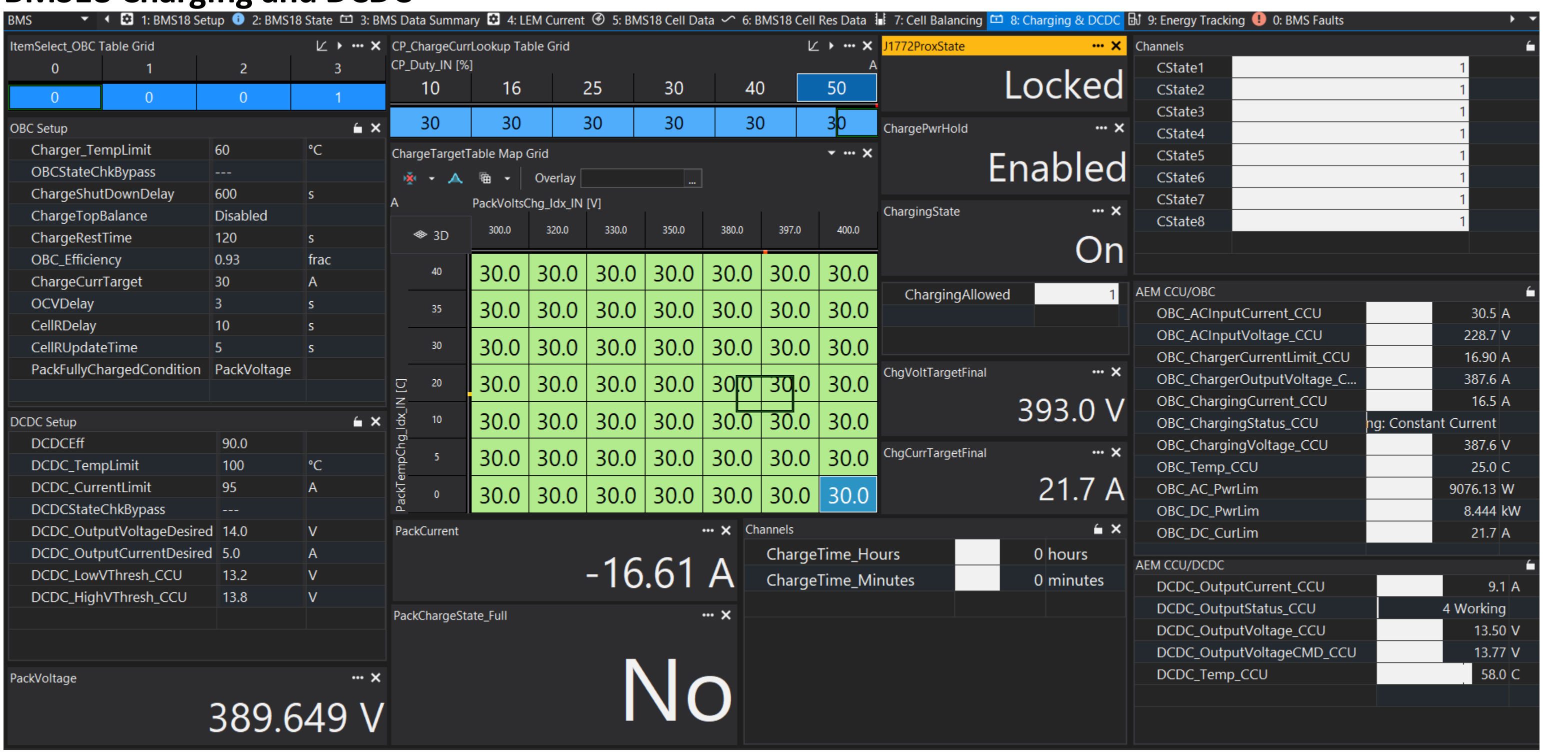


This tab is an overview of signals related to the cell balancing process.

If BalancCmdCal is set to Enable, cell balancing will commence. Any cells that are greater than the BalCellVoltThreshHi setting AND the PackCellAvg will be balanced using a process that distributes the thermal load across different zones on the BMS18 PCBs. No more than 3 cells in any group will be balanced at a time.

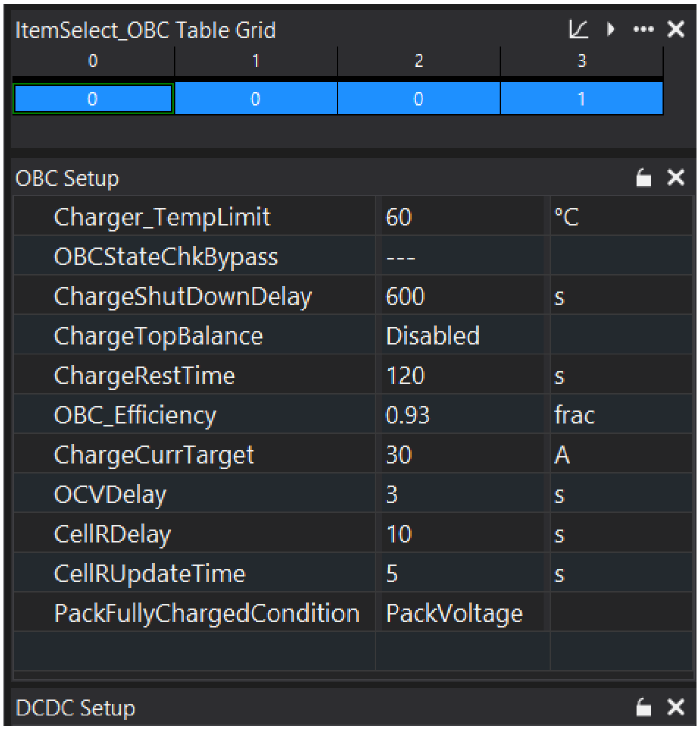
Anytime the BalProcessTx flag is indicating a 1, the balance command messages from the VCU to the BMS18 Master is being transmitted. This doesn't necessarily mean cells are being balanced. The chosen balance cells must meet the criteria listed above.

BMS18 Charging and DCDC



There are numerous settings and channels associated with J1772 charging. The following sections will attempt to highlight them.

BMS18 OBC Setup



The AEM default settings will work in most cases, especially if using the AEM CCU.

ItemSelect_OBC is a table that allows selection of different charger configurations. From left to right, the settings are Dilong, Thunderstruck TS2500, Stealth EV and AEM CCU. Enter a 1 for the desired charger interface.

Charger_TempLimit sets a maximum charger temperature. Above this value, the VCU will attempt to disable charging.

OBCStateChkBypass is for debugging new setups and can be used to bypass or ignore charger faults.

ChargeShutDownDelay is a timer that begins after the pack is fully charged. If the wake switch is OFF and the VCU was started up by connecting a charge plug, the VCU will automatically shut down once this timer expires.

ChargeTopBalance can be either enabled or disabled. If enabled, the VCU will allow for a rest period controlled by the ChargeRestTime options. It will rest and restart according to this timer indefinitely if ChargeTopBalance is enabled.

OBC_Efficiency is used to estimate a maximum DC charging current when using the AEM CCU.

ChargeCurrTarget is a simple user calibration option for charging current. The VCU will always select the minimum value from all available charge current target sources.

OCVDelay, CellRDelay and CellRUpdateTime typically do not need adjusting. They are used during charging as part of the cell resistance estimation process.

PackFullyChargedCondition can be used to select the signal used to end charging. Recommend using PackVoltage during the initial setup process.

AEM CCU/OBC

OBC_ACInputCurrent_CCU	30.3	A
OBC_ACInputVoltage_CCU	229.0	V
OBC_ChargerCurrentLimit_CCU	17.00	A
OBC_ChargerOutputVoltage_CCU	388.1	A
OBC_ChargingCurrent_CCU	16.5	A
OBC_ChargingStatus_CCU	ing: Constant Current	
OBC_ChargingVoltage_CCU	388.1	V
OBC_Temp_CCU	21.0	C
OBC_AC_PwrLim	9092.02	W
OBC_DC_PwrLim	8.456	kW
OBC_DC_CurLim	21.8	A

The example channel list at lest is mostly self explanatory. It shows an example of normal data from an AEM CCU during the charging process.

BMS18 DCDC Setup

DCDC Setup

DCDCEff	90.0	
DCDC_TempLimit	100	°C
DCDC_CurrentLimit	95	A
DCDCStateChkBypass	---	
DCDC_OutputVoltageDesired	14.0	V
DCDC_OutputCurrentDesired	5.0	A
DCDC_LowVThresh_CCU	13.2	V
DCDC_HighVThresh_CCU	13.8	V

If using an AEM CCU, these setting typically do not need adjusting.

DCDCEff is the estimated DCDC efficiency used for calculating the load on the pack from 12V systems.

DCDC_TempLimit is the maximum temperature allowed for the DCDC. The DCDC internal temperature of the AEM CCU can indicate in excess of 85 degrees C during normal operation.

DCDC_CurrentLimit is the maximum current the VCU will allow.

DCDCStateChkBypass can be used for debugging during the setup and tuning process.

DCDC_OutputVoltageDesired and DCDC_OutputCurrentDesired are NOT used with the AEM CCU. These settings are used with other 3rd party DCDC units.

DCDC_LowVThresh_CCU and DCDC_HighVThresh_CCU are used with the AEM CCU and set the high and low thresholds for 12 volt system charging.

AEM CCU/DCDC

DCDC_OutputCurrent_CCU	9.1	A
DCDC_OutputStatus_CCU	4 Working	
DCDC_OutputVoltage_CCU	13.50	V
DCDC_OutputVoltageCMD_CCU	13.77	V
DCDC_Temp_CCU	51.0	C

The example channel list at lest is mostly self explanatory. It shows an example of normal data from an AEM CCU during DCDC operation.

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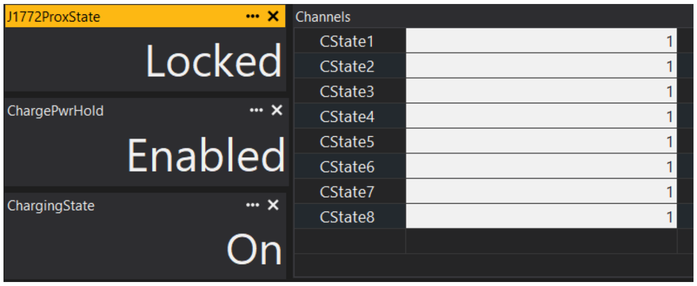
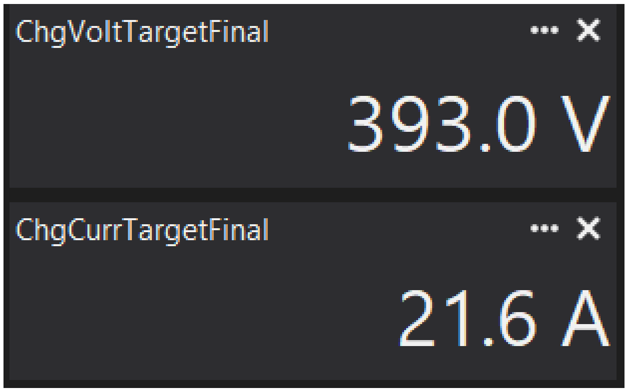
BMS18 Charging Process

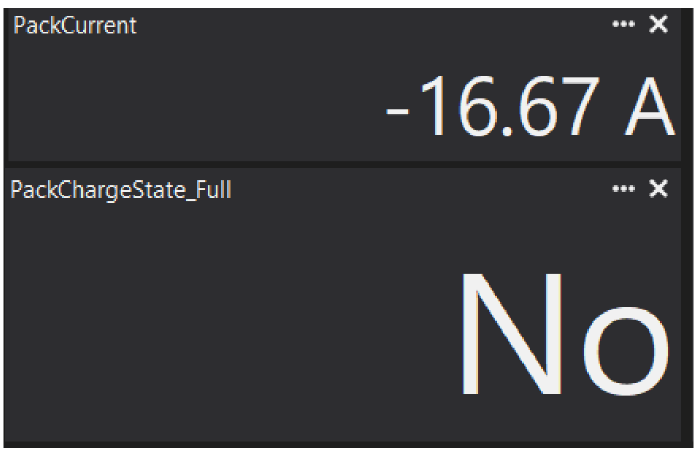


When the J1772 charge cable is connected, The J1772ProxState should indicate Locked. ChargePwrHold should be Enabled. ChargingState should be On and all CState flags should indicate 1 as shown in the example at left. This is a normal display during charging.



ChgVoltTargetFinal is the VCUs target charging voltage.

ChagCurrTargetFinal is the VCUs target charging current. This may or may not match the actual charging current. The final value is limited by the chargers capabilities.



During charging, PackCurrent should indicate a negative value as energy is being moved into the pack. PackChargeState_Full will be No until the pack is fully charged.

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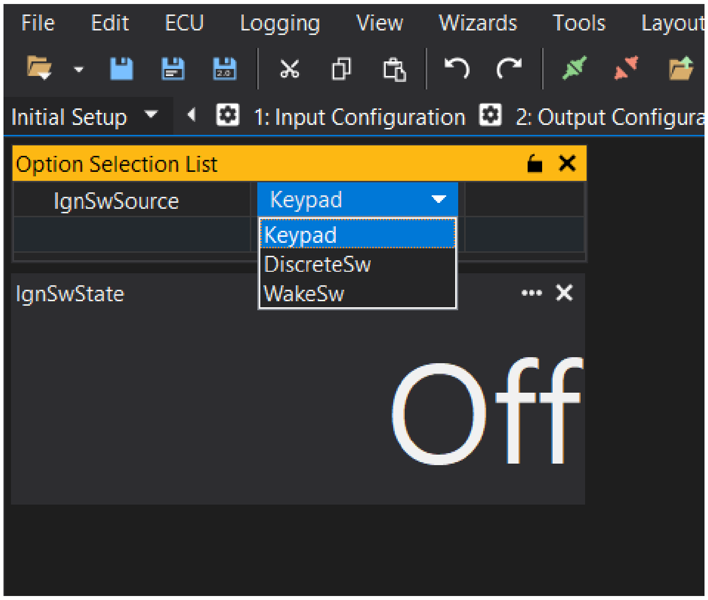
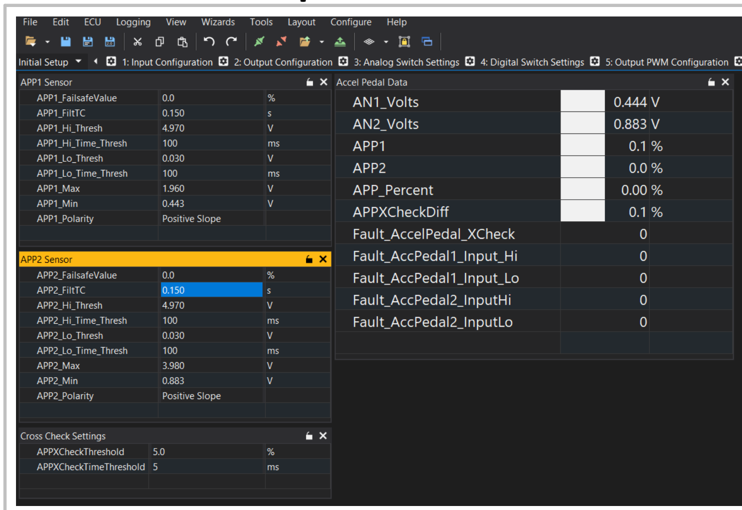
Ignition Switch Setup



The Ignition Switch input triggers the inverter pre-charge process. There are three options for the Ignition Switch input.

1. Keypad - The Ignition Switch signal will come from the AEM CAN Keypad
2. DiscreteSw - The Ignition Switch signal will come from the digital input state selected by the option Ign_DI_InputSelect.
3. WakeSw - The Ignition Switch feature will be tied to the Wake Switch input. Whenever the Wake Switch is ON, the Ignition Switch will be ON.

Accel Pedal Setup



1. If using the default AEM input configuration settings, the APP1 signal will be on the AN1 input. The APP2 signal will be on the AN2 input.
2. Monitor the AN1_Volts and AN2_Volts signals relative to the APP1_Min, APP1_Max, APP2_Min and APP2_Max calibration option settings.
3. Set the APP1_Min value very close to and just below the AN1_Volts value when the pedal is fully closed.
4. Set the APP1_Max value very close to and just above the AN1_Volts value when the pedal is fully opened.
5. Repeat this process for the APP2 settings.
6. The example screen shot at left shows typical results with the pedal fully closed.
7. Set the fault threshold values higher and lower than the Max/Min settings. These are APP1_Hi_Thresh, APP1_Lo_Thresh, APP2_Hi_Thresh and APP2_Lo_Thresh.
8. The APP1_Polarity and APP2_Polarity settings can be adjusted if the voltage from one or the other sensor input decreases instead of increases as the pedal is pushed open.
9. Generally, the rest of the APP settings can be left alone but they may be adjusted to suit particular application requirements.

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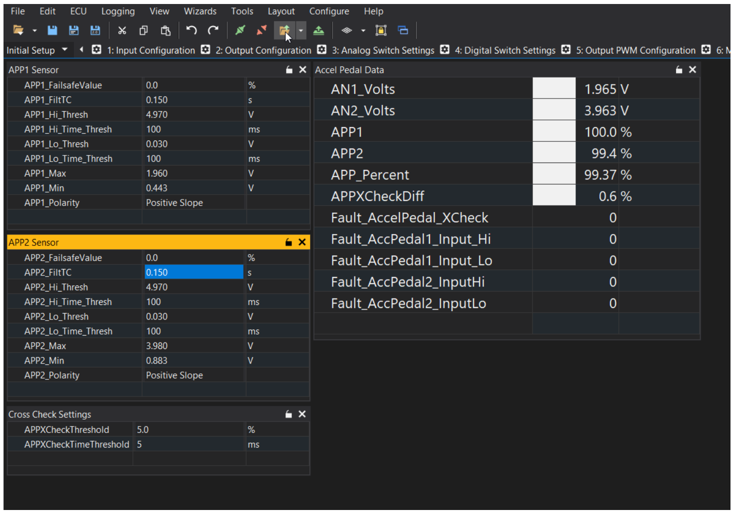
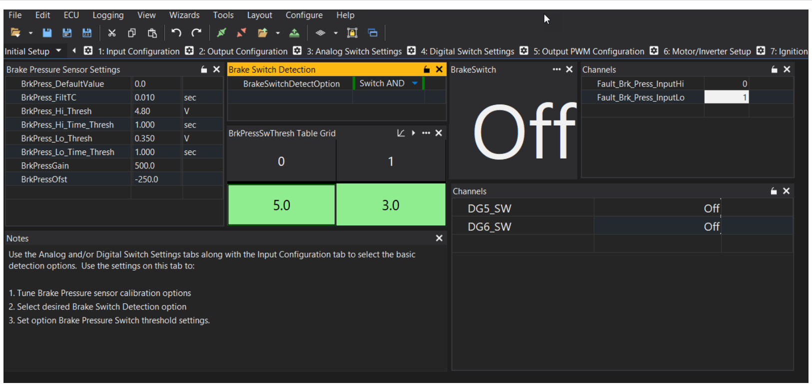


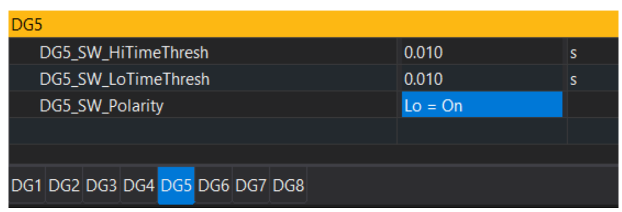
The example at left shows the APP signals with the pedal fully open.

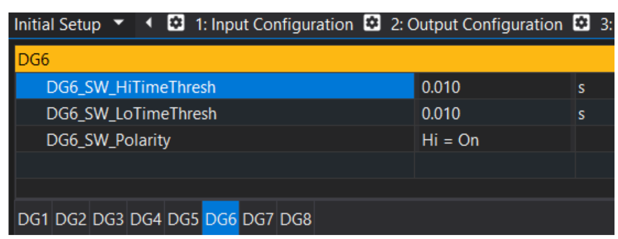
Brake Pedal Setup



AEM provided base calibrations is as follows:

BrkSw1_InputSelect	DG5
BrkSw2_InputSelect	DG6





Set the BrakeSwitchDetectOption:

Switch AND: requires both inputs to detect
Switch OR: requires either input to detect
BrakePress: uses the BrkPressSwThresh table for detection

The example screen shot at left shows DG5 and DG6 used for BrakeSwitch1 and BrakeSwitch2. Switch AND is set for BrakeSwitchDetectOption. Example shows BrakeSwitch detected as OFF.

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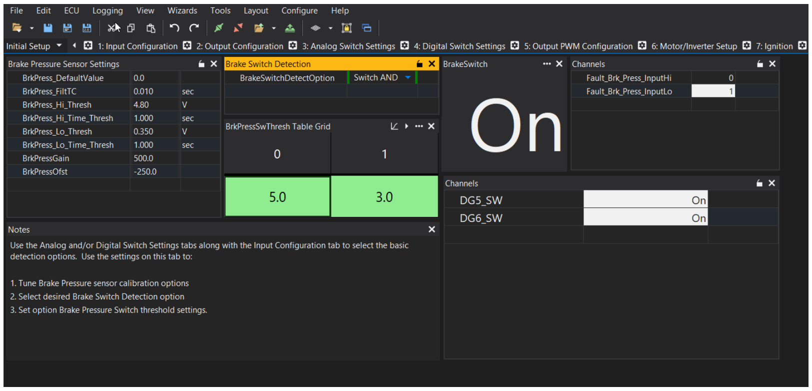
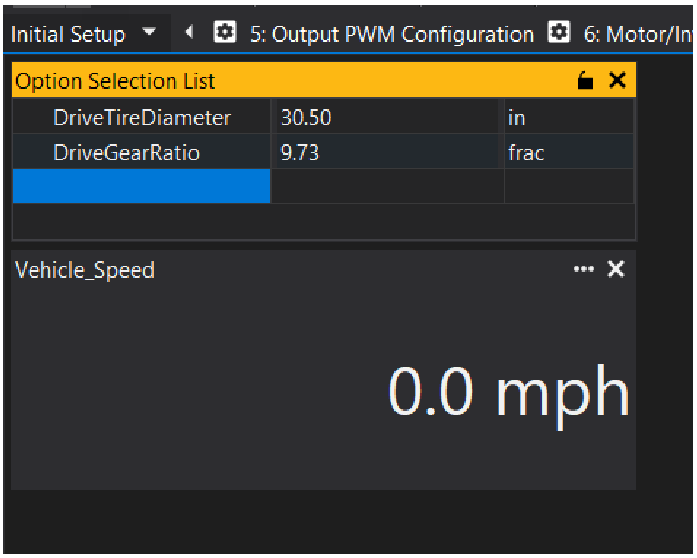


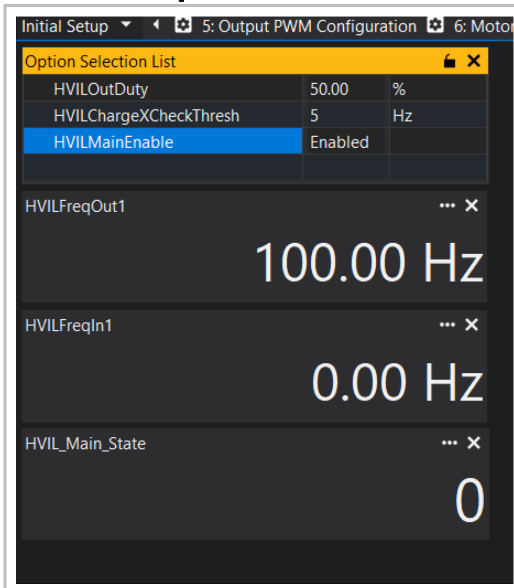
The example screen shot at left shows DG5 and DG6 used for BrakeSwitch1 and BrakeSwitch2. Switch AND is set for BrakeSwitchDetectOption. Example shows BrakeSwitch detected as ON.

Vehicle Speed Setup



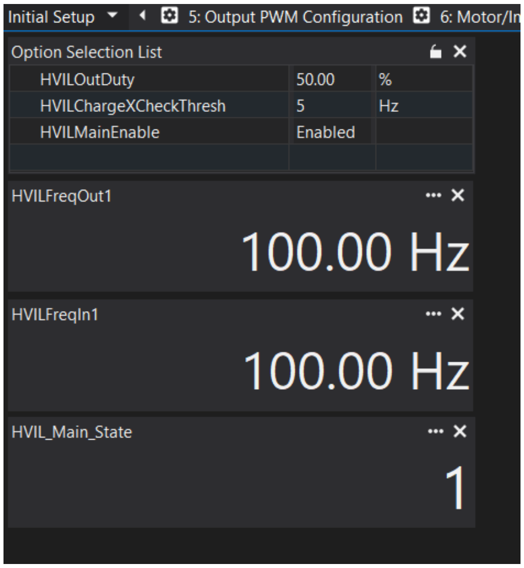
For direct drive applications, simply set the Drive Tire Diameter and Drive Gear Ration and Vehicle Speed will be calculated automatically.

HVIL Setup



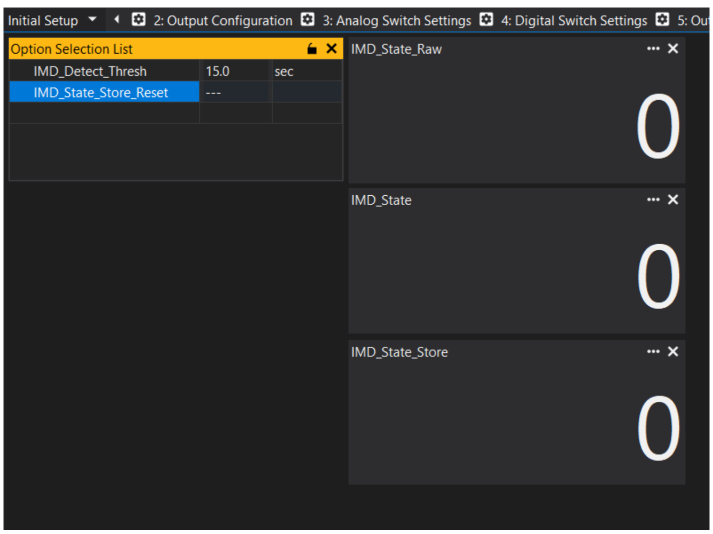
LSO5 and LSO6 are hard coded as the HVILMain and HVILCharge loop signal sources respectively. These return to

HVILMain returns to the SPD4 input. HVILCharge returns to the SPD2 input by default. These inputs may be reassigned by the user if needed.



The example at left shows the HVILMain output and input functioning as expected. The output on LSO5 is 100 Hz and the input on SPD4 is reading exactly 100 Hz which indicates a closed loop. The flag HVIL_Main_State is equal to 1 when the loop is closed.

IMD Setup

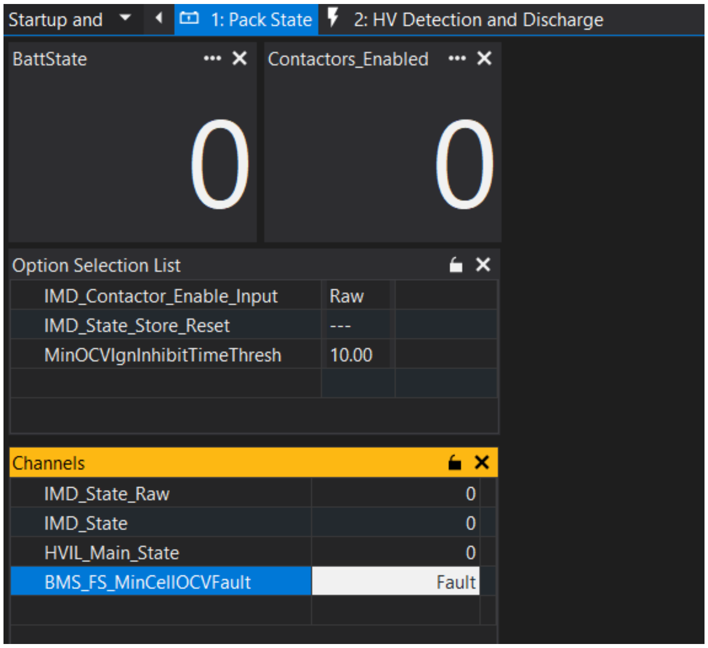


By default the IMD digital input is assigned to DG2.

Sometimes it's necessary to delay any VCU action based on the raw IMD signal just after startup. The IMD_Detect_Thresh option allows a delay. The VCU will not act on the signal until after this timer expires.

IMS_State_Raw is the state of the raw input
IMD_State is the state of the signal after the timer expires.
IMD_State_Store saves any IMD detect flags to memory. The option IMD_State_Store_Reset can be used to reset this to 0.

Startup and Shutdown Checks



Use the Startup and Shutdown layout tab group and Pack State tab.

Inverter pre-charge is prevented if the flag BattState is equal to 0.

The BattState check will fail if the following is true:

1. HVIL_Main_State is 0 indicating an open loop
2. A MinCellOCVFault is detected
3. An IMD fault is detected

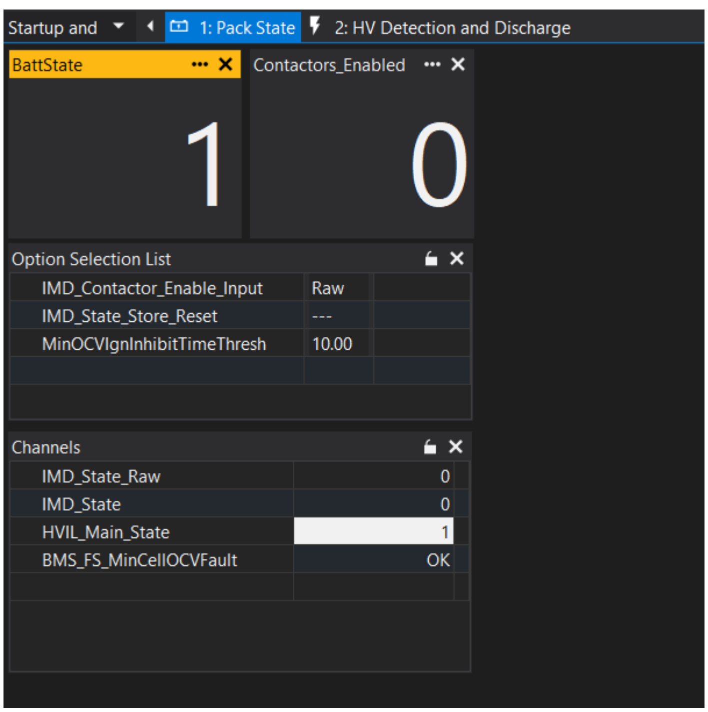
The IMD_Contactor_Enable_Input option can be used to select the VCU response to an IMD fault:

1. Raw - the VCU will react to the raw IMD signal input
2. Filtered - the VCU will react to the state of the IMD signal after the startup timer expires
3. Ignore - the VCU will ignore the IMD signal

The Contactors_Enabled flag will be true if:

1. BattState is 1
2. The Ignition Switch input is ON

The example at left shows a system that is NOT ready for start up.



The example at left shows a system that is ready for start up.

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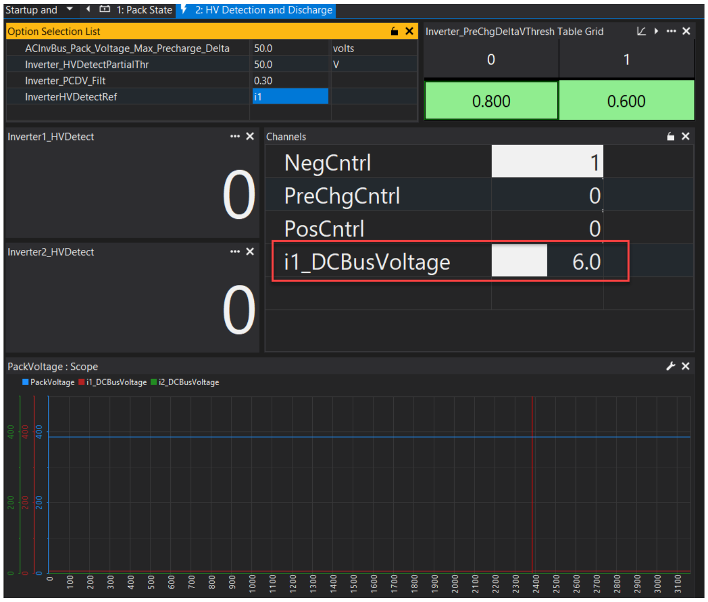
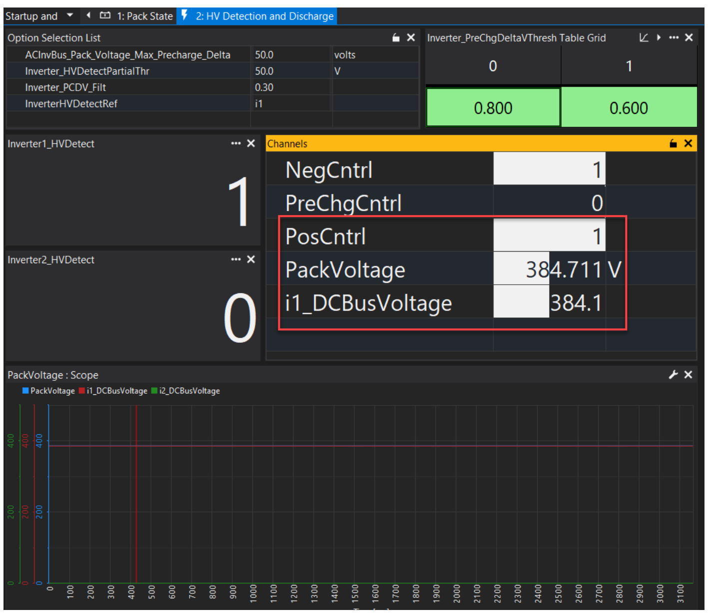


Use the HV Detection and Discharge tab.

The AEM default pre-charge settings are sufficient for most typical 400 volt applications. The example at left shows a system that is ready to begin pre-charge. The VCU is powered up and the negative contactor is ON. i1_DCBusVoltage is low.



The example at left shows the results of a successful pre-charge. The Positive Contactor is ON. i1_DCBusVoltage matches PackVoltage. The Inverter1_HVDetect flag is true.

At this point, cycle the Ignition Switch again and make sure the inverter DC Bus Voltage discharges safely.

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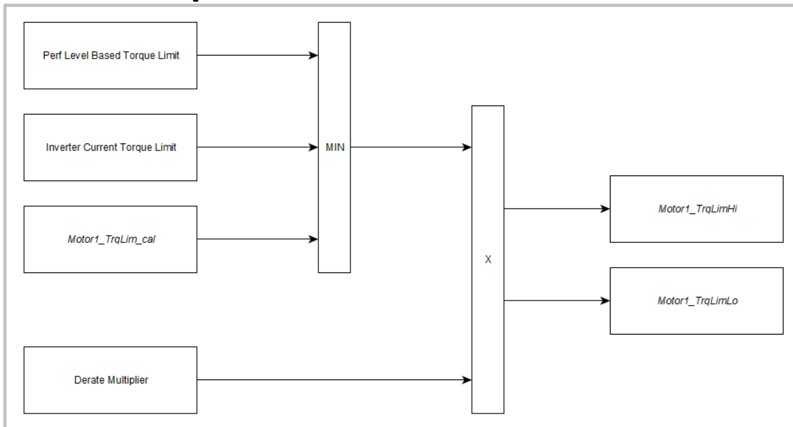
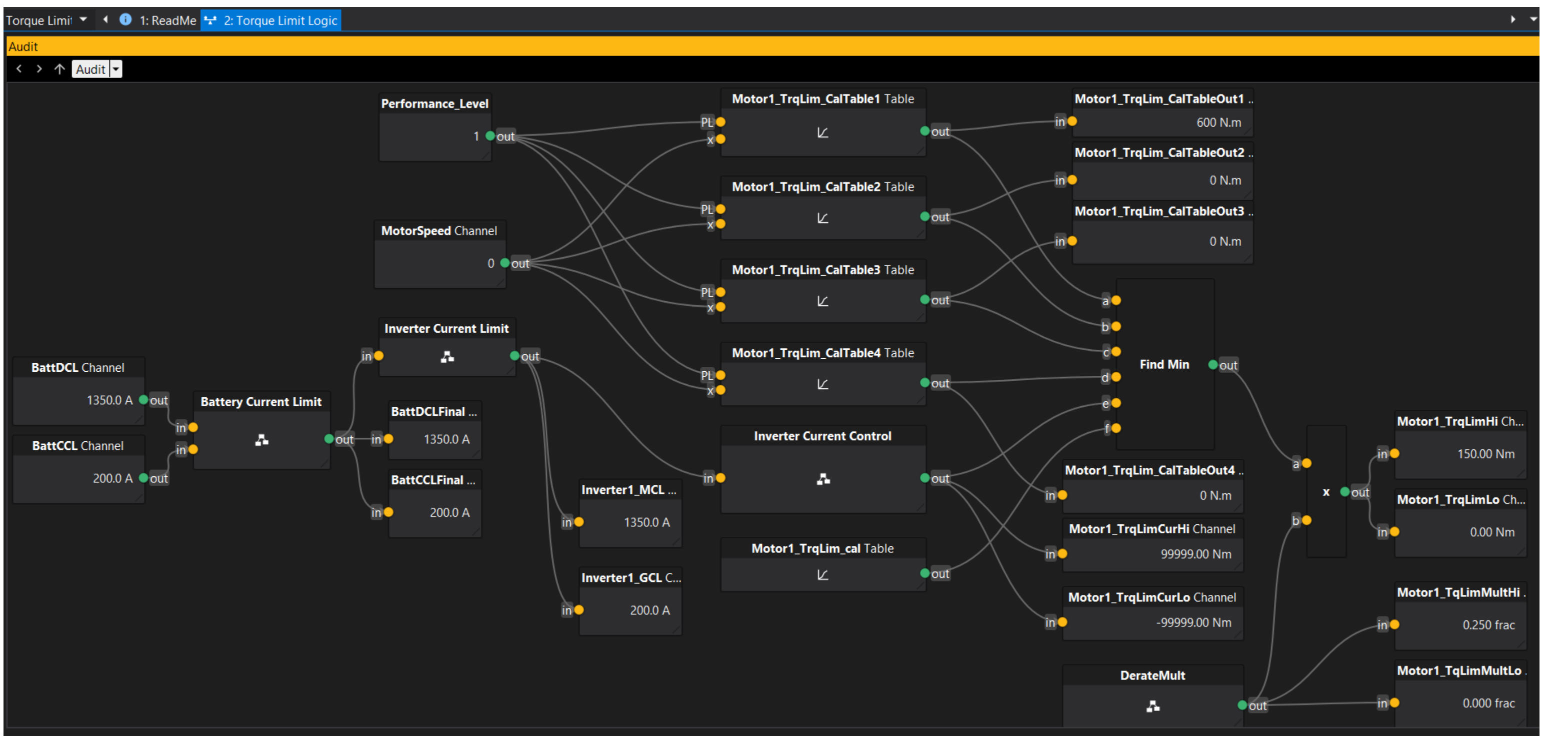
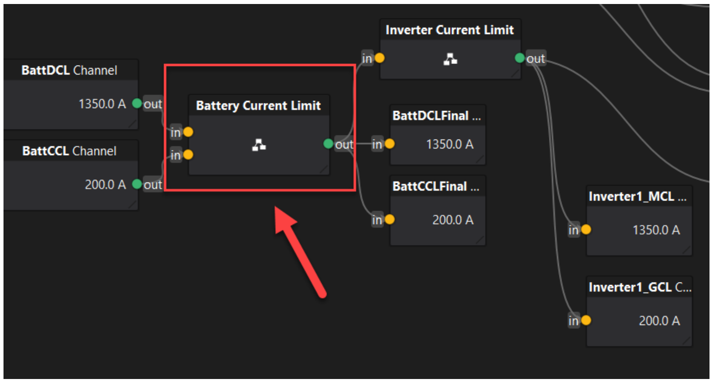
Initial Torque Limits



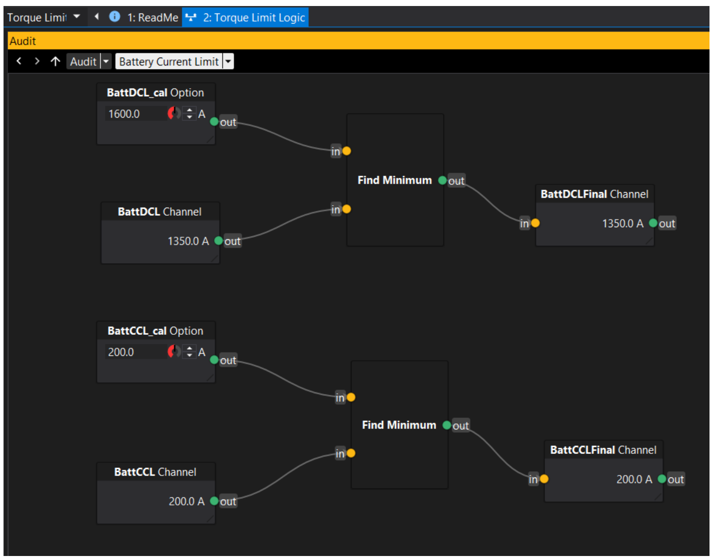
The diagram at left summarizes the basic dynamic torque limit feature.



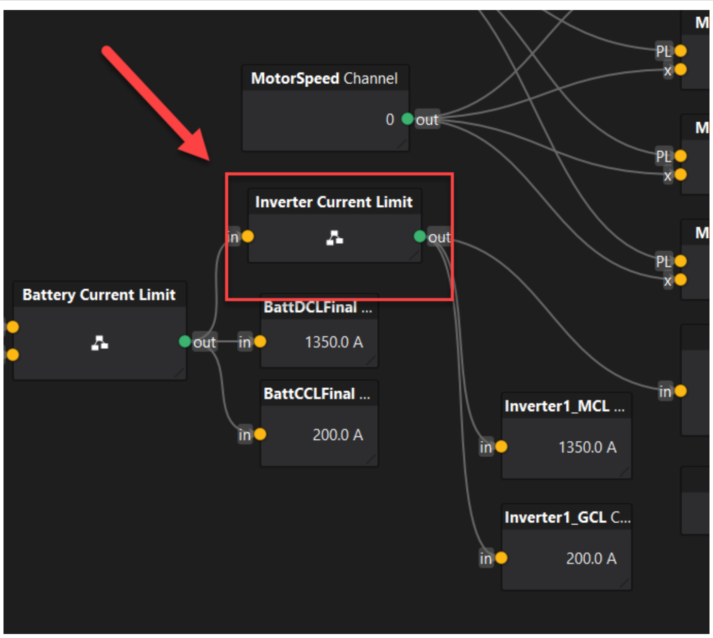
There are a lot of features associated with dynamic torque limiting. To help navigate these features, they are presented in the form of a logic flow diagram called an AEMCal Audit View. This can be thought of as an expanded version of the simplified diagram shown earlier. Measurement channels, calibration options, tables and maps can all be accessed using these interactive diagrams. When connected to the VCU live, all measurement channel data is updated real time.



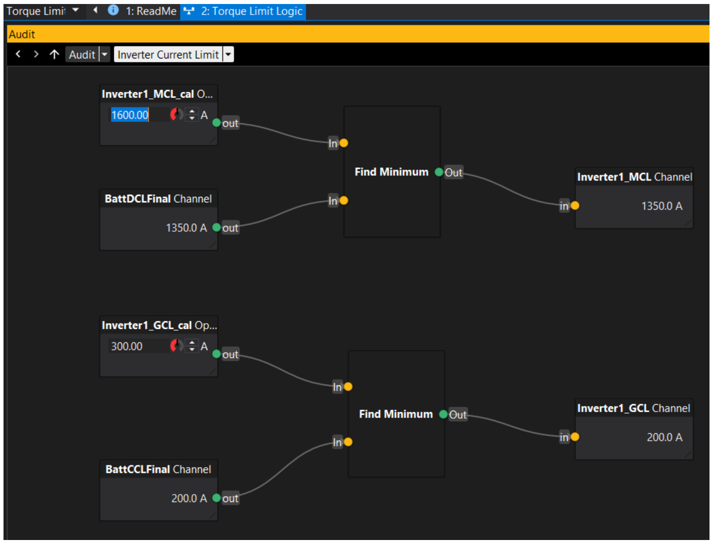
The first step in the torque limit control pathway is to establish the Battery Current Limit. Double left click or right click on the Battery Current Limit block and select Open Module to view the contents.



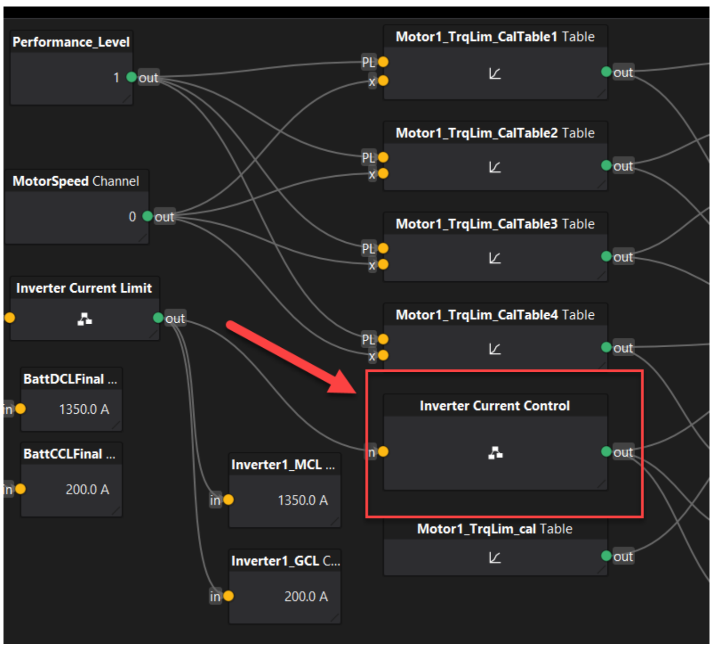
This is the first opportunity for the calibrator to optionally override the BattDCL and BattCCL signals from the BMS. The BattDCL_cal and BattCCL_cal options are compared to the BMS DCL and CCL and the minimum is chosen. The result is the measurement channels BattDCLFinal and BattCCLFinal.



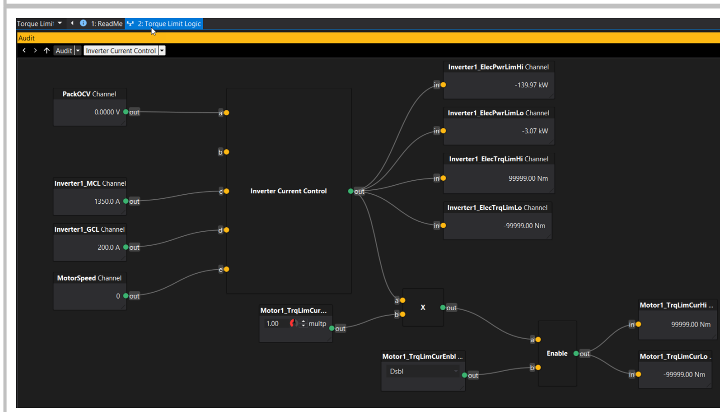
Double click or right click on the Inverter Current Limit block and select Open Module to view the contents.



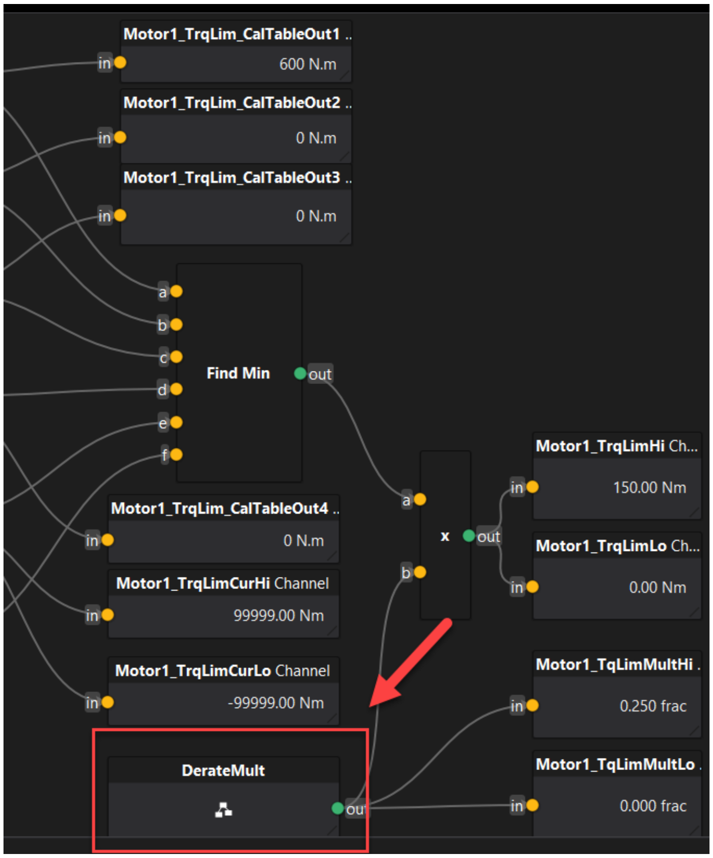
Similar to the BattDCL and BattCCL override options above, the same can be accomplished with the inverter. Use the Inverter1_MCL_cal and Inverter1_GCL_cal options. MCL stands for motoring current limit. GCL stands for generating current limit.



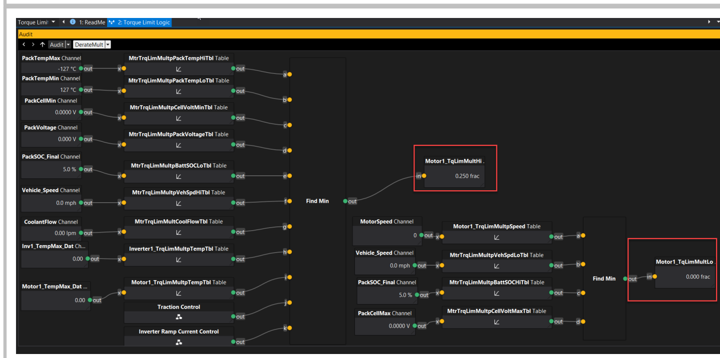
The Inverter Current Control block is a more advanced feature that is a predictive algorithm that can dynamically calculate an electrical power limit and electrical torque limit for the inverter based on the DCL and CCL signal inputs.



For new setups, recommend disabling this feature by choosing Dsbl for the option Motor1_TrqLimCurEnbl.



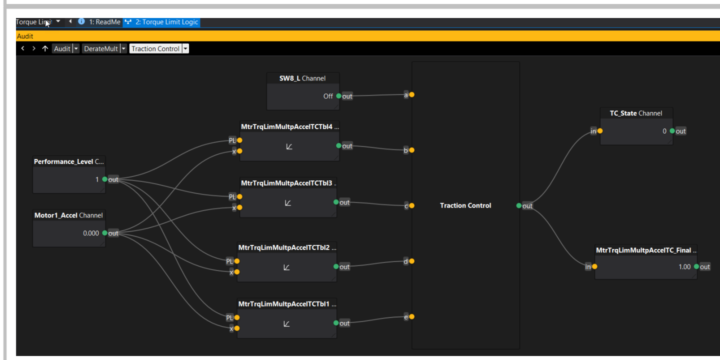
Expand the DerateMult block by right clicking and selecting Open Module.



All of the available derate multiplier tables are presented in a view that shows how they related to one another. Double click on any table to open its contents for editing.

All derate multiplier sources are compared to one another. The minimum is chosen and presented as channels Motor1_TqLimMultHi and Motor1_TqLimMultLo.

There are two additional derating features that aren't simple lookup tables. These are described below.



An optional motor acceleration based traction control feature can be used to add a derate multiplier based on the current Performance Level. In this way, multiplier levels of traction control can be applied based on driver input.

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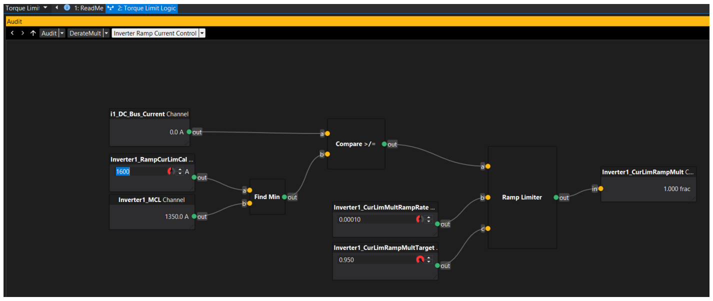
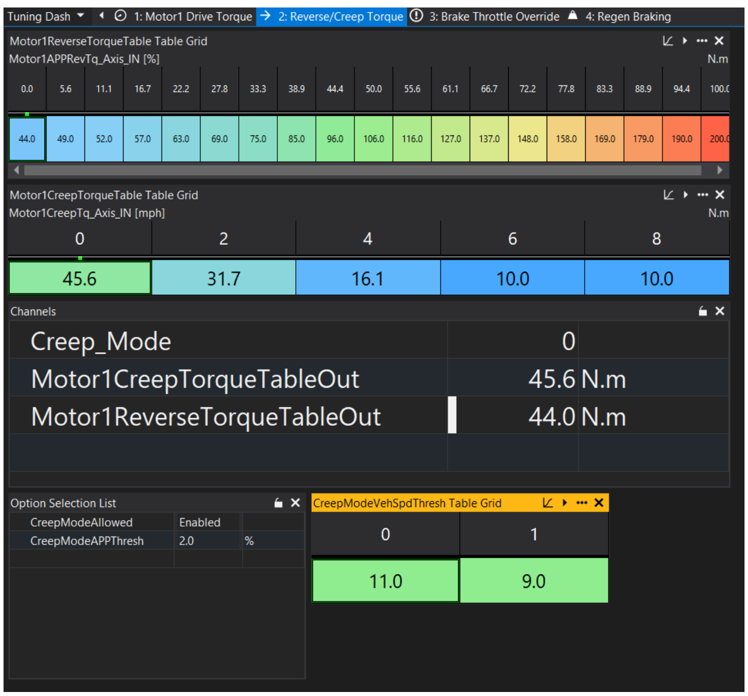


Finally, an inverter current ramp limiting feature is available.

The option Inverter1_RampCurLimCal is compared to the Inverter1_MCL channel and the minimum is chosen. This is compared to the i1_DC_Bus_Current signal. If the actual inverter current is higher, the ramp limiter is activated. The derate multiplier will ramp down at a rate set by the option Inverter1_CurLimMultRampRate to a minimum value set by the option Inverter1_CurLimRampMultTarget. Once the current falls below the threshold again, the multiplier will decay away at the same ramp rate.

Creep and Reverse



Use the Motor1ReverseTorqueTable to set a desired torque request target while in reverse.

Enable or disable CreepMode by setting the options CreepModeAllowed and CreepModeAPPThresh. Use the CreepModeVehSpdThresh table to set a vehicle speed threshold above which CreepMode will be disabled. The left most setting is the high threshold and the right most setting is the low threshold in the table.

The measurement channel Creep_Mode will indicate a 1 when CreepMode is enabled.

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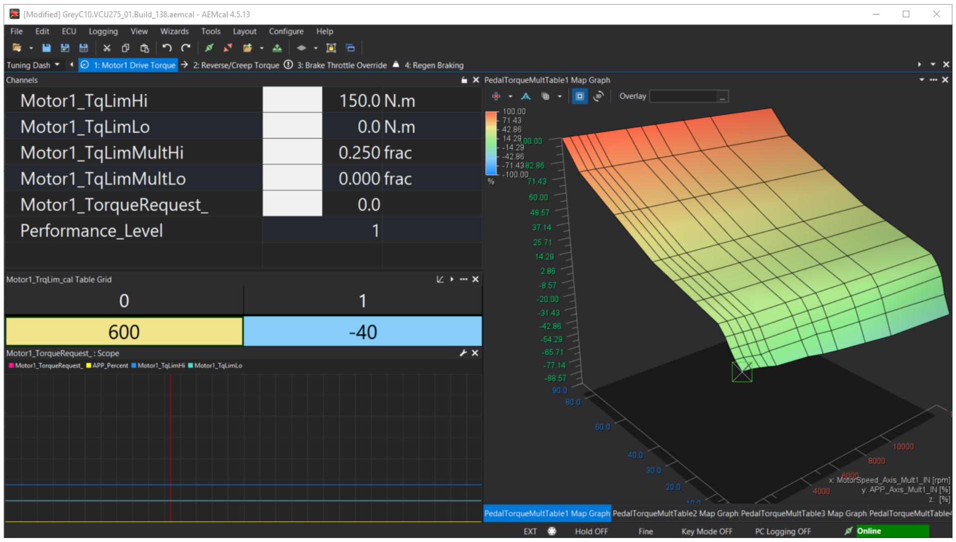
Pedal Map Tuning



Within the Tuning Dashboard group the Motor1 Drive Torque tab provides a simple overview of the most basic torque tuning tools.

For initial setup and troubleshooting, recommend setting the Motor1_TrqLim_cal table to very low values. Suggest something as follows:

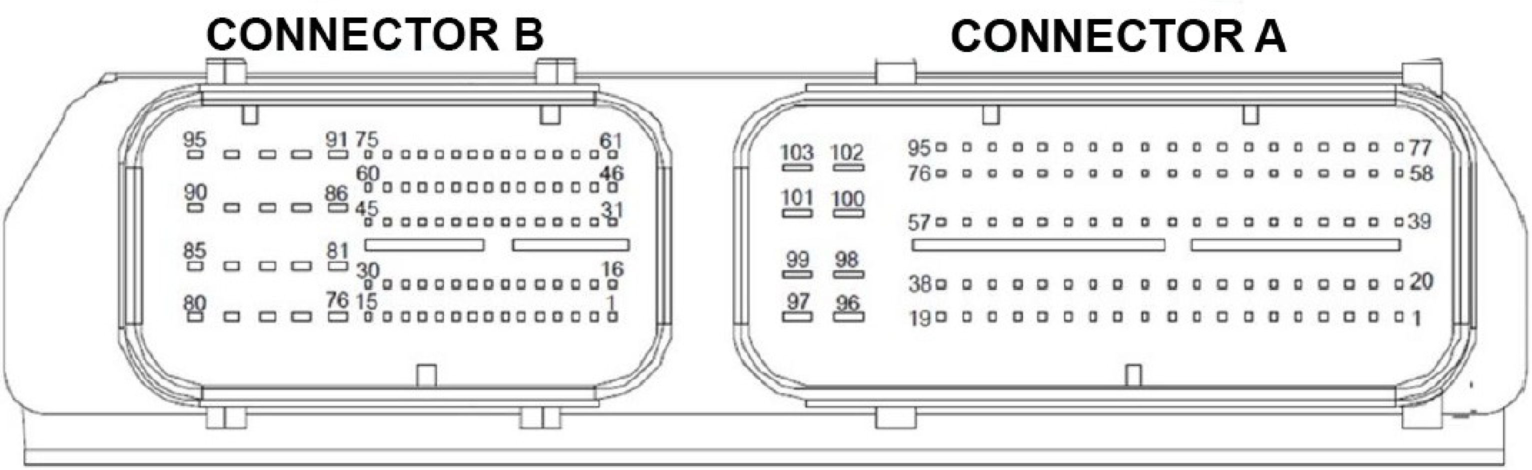
Hi thresh = 30 Nm
Lo thresh = 0 Nm

This will result in a maximum driving torque of 30 Nm and 0 Nm of regenerative braking torque.

Adjust the values in the PedalTorqueMultTable1. This multiplier is applied to the values in the Motor1TorqueTable to result in a baseline torque request in Nm. All limiters and derate multipliers are applied to this baseline value.

Inputs

Hardware Input Selection and Setup



The VCU275 allows the user to map input features to hardware pins. It is restrictive to tie VCU functions to particular pins. To make the system more adaptable, the user may select the VCU function to assign to each pin. The following table describes each generic analog and digital input along with its associated signal conditioning. Base calibrations plug and play low voltage harness assemblies provided by AEM EV will include pin function settings that match the table in the Hardware Pinout 13 section.

Name	Description	Pin Number	Conditioning
AN1	Analog Input 1	A-17	301k Pull Down
AN2	Analog Input 2	A-18	301k Pull Down
AN3	Analog Input 3	B-45	220k Pull Up to 5V
AN4	Analog Input 4	B-36	220k Pull Down
AN5	Analog Input 5	B-42	470k Pull Down
AN6	Analog Input 6	B-59	470k Pull Down
AN7	Analog Input 7	B-43	470k Pull Down
AN8	Analog Input 8	B-37	51k Pull Down
AN9	Analog Input 9	B-58	3k Pull Up to 5V
AN10	Analog Input 10	B-41	51k Pull Down
AN11	Analog Input 11	A-19	51k Pull Down
AN12	Analog Input 12	B-16	10k Pull Down
AN13	Analog Input 13	B-31	1.82k Pull Up to 5V
AN14	Analog Input 14	B-32	1.82k Pull Up to 5V
AN15	Analog Input 15	B-61	2.32k Pull Up to 5V
AN16	Analog Input 16	A-14	2.32k Pull Up to 5V
AN17	Analog Input 17	A-11	2.32k Pull Up to 5V
AN18	Analog Input 18	A-13	2k Pull Up to 5V
DG1	Digital Input 1	B-19	3.3k Pull Down

Name	Description	Pin Number	Conditioning
DG2	Digital Input 2	B-20	3.3k Pull Down
DG3	Digital Input 3	B-18	3.3k Pull Down / 3.3k Pull Up to 12V
DG4	Digital Input 4	B-17	3.3k Pull Down / 3.3k Pull Up to 12V
DG5	Digital Input 5	A-71	3.3k Pull Down / 3.3k Pull Up to 12V
DG6	Digital Input 6	A-51	3.3k Pull Down / 3.3k Pull Up to 12V
DG7	Digital Input 7	A-38	3.3k Pull Down / 3.3k Pull Up to 12V
DG8	Digital Input 8	A-53	3.3k Pull Down / 3.3k Pull Up to 12V

Tuning Tips

1. **In the Options and Channels lists below, the 'X' indicates the number of the input.**
2. **'ADC' stands for analog to digital counts. The maximum ADC count for all analog inputs is 4096.**
3. **Analog inputs with pull up resistors can be used as digital switches by shorting them to a sensor ground pin from the VCU through the switch.**
4. **Analog inputs with pull down resistors can be used as digital switches by shorting them to a sensor power pin from the VCU through the switch.**
5. **Do not connect 12 volts to any analog input pin.**
6. **The *ANXPrty* and *DGX_SW_Polarity* options can be used to invert the detection logic. The state that means ON or OFF may depend on the application.**
7. **The Hi and Low Time Threshold options can be used as software debounce filters to prevent noisy inputs from causing bad readings. The higher the threshold time, the stronger the filter at the expense of detection delays.**

Options

ANXHiADCThr: Digital sensor state high ADC threshold

ANXLoADCThr: Digital sensor state low ADC threshold

ANXHiTimeThr: Digital sensor state high time threshold

ANXLoTimeThr: Digital sensor state low time threshold

ANXPlrty: Inverts the detection logic

DGX_SW_LoTimeThresh: Raw signal must be low for this amount of time to be considered low

DGX_SW_HiTimeThresh: Raw signal must be high for this amount of time to be considered high

DGX_SW_Polarity: Inverts the detection logic

Tuning Tips

1. **Use the following InputSelect options to assign VCU functions to VCU input pins.**

APP1_InputSelect: Input pin selection for the accelerator pedal position 1 input

APP2_InputSelect: Input pin selection for the accelerator pedal position 2 input

BrkSw1_InputSelect: Input pin selection for the brake switch 1 input

BrkSw2_InputSelect: Input pin selection for the brake switch 2 input

NtrlSw_InputSelect: Input pin selection for the neutral switch input

PrkSw_InputSelect: Input pin selection for the park switch input

DrvSw_InputSelect: Input pin selection for the drive switch input

RevSw_InputSelect: Input pin selection for the reverse switch input

IMD_DI_InputSelect: Input pin selection for the IMD input

Ign_DI_InputSelect: Input pin selection for the ignition switch input

LEMLo_InputSelect: Input pin selection for the LEM current sensor low range input

LEMHi_InputSelect: Input pin selection for the LEM current sensor high range input

HeaterSW_inputSelect: Input pin selection for the heater switch input

ACSw_InputSelect: Input pin selection for the air conditioning switch input

ManualRegen1_InputSelect: Input pin selection for the manual regeneration lever 1 input

ManualRegen2_InputSelect: Input pin selection for the manual regeneration lever 2 input

BrakeVac_InputSelect: Input pin selection for the brake vacuum sensor input

DivValvePos_InputSelect: Input pin selection for the radiator diverter valve position sensor input

PackCltPressSw_InputSelect: Input pin selection for the battery pack coolant pressure switch input

ACPress_InputSelect: Input pin selection for the air conditioning pressure sensor input

AmbientTemp_InputSelect: Input pin selection for the ambient temperature sensor input

ACEvapTemp_InputSelect: Input pin selection for the air conditioning evaporator temperature sensor input

BrakePress_InputSelect: Input pin selection for the brake pressure sensor input

CoolantTemp1_InputSelect: Input pin selection for the coolant temperature 1 sensor input

CoolantTemp2_InputSelect: Input pin selection for the coolant temperature 2 sensor input

TransBrakeSw_InputSelect: Input pin selection for the transmission brake switch input

LineLockSw_InputSelect: Input pin selection for the line lock switch input

TransTemp_InputSelect: Input pin selection for the transmission temperature sensor input

CabinHeatSw_InputSelect: Input pin selection for the cabin heater switch input

User1Sw_InputSelect: Input pin selection for the User 1 switch input

User2Sw_InputSelect: Input pin selection for the User 2 switch input

User3Sw_InputSelect: Input pin selection for the User 3 switch input

StartSw_InputSelect: Input pin selection for the start switch

Channels

ANX_Volts: Measured analog voltage present at the pin

ANX_Ohms: Estimated voltage divider resistance

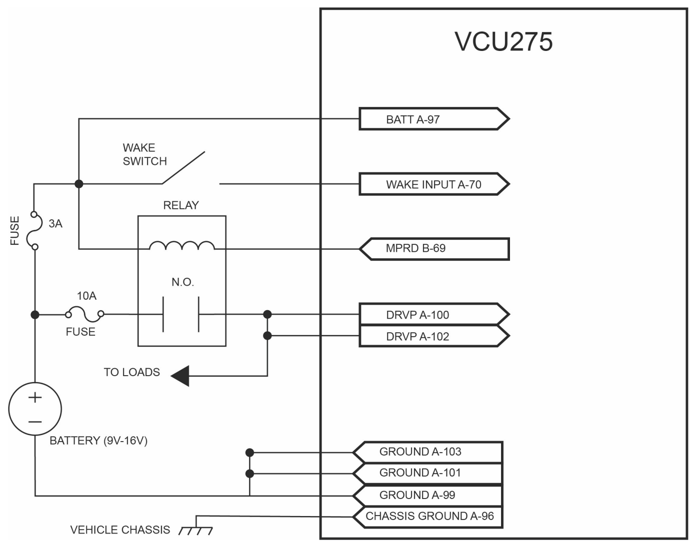
ANX_LogicState: Digital logic state of the input

ANX_Raw: Raw ADC counts measured at the pin

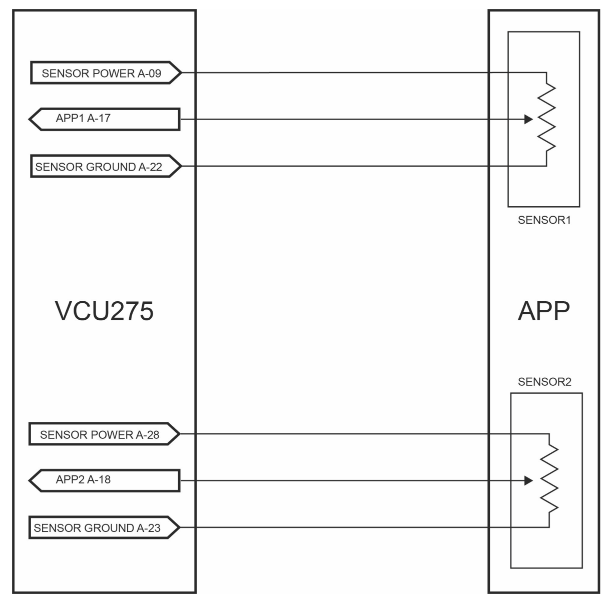
DGX_SW_Raw: Raw digital input state

Minimum Required Inputs

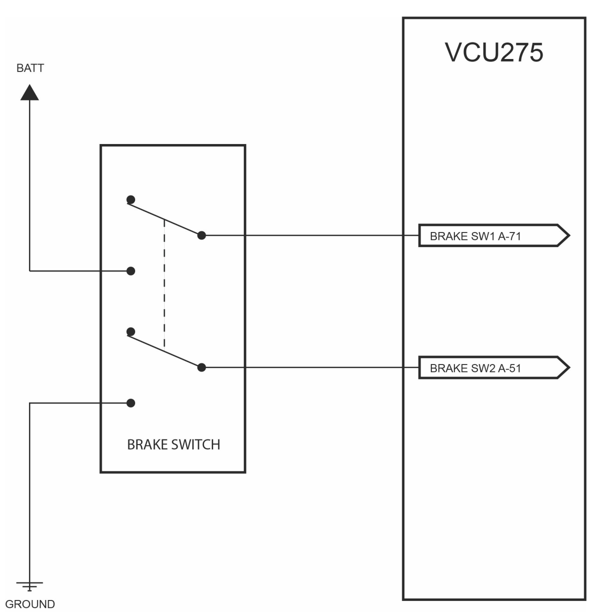
The following tables describe the minimum required inputs for proper VCU control.

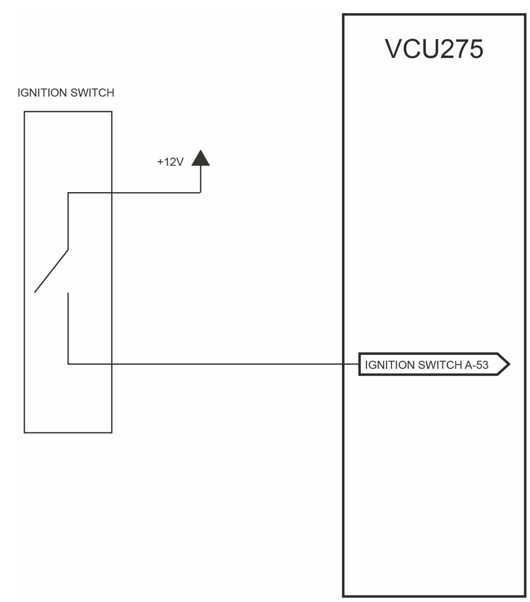


WAKE AND POWER GROUND INPUTS

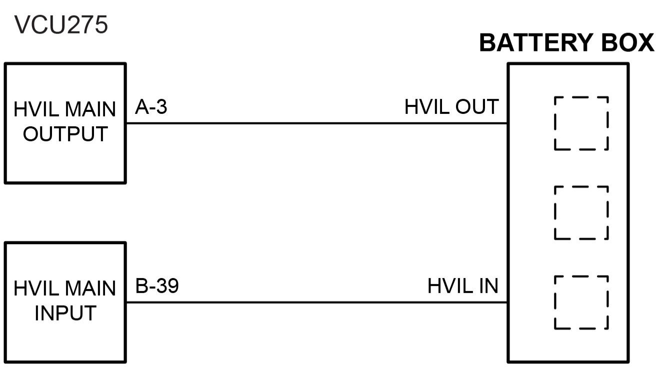


ACCELERATOR PEDAL POSITION (APP)

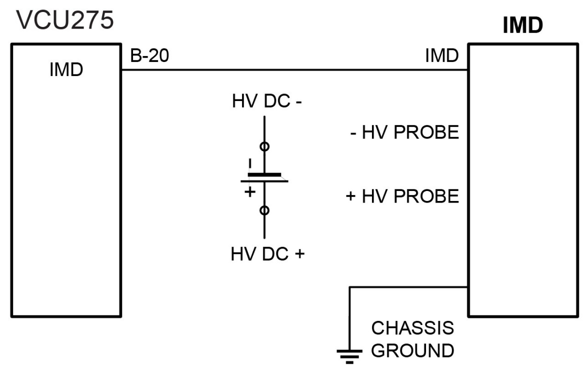




Signal polarity selectable to support both N.O. and N.C. switches Choice between AND or OR logic **BRAKE SWITCH INPUT**	Optionally inputted by AEM 8 Button CAN Keypad for direct drive applications **IGNITION SWITCH INPUT**



HVIL MAIN INPUT



IMD INPUT

Tuning Tips
1. **If you are building a custom harness from scratch, recommend starting with the wake, power/ground circuits and CAN1 PC comms only.**
2. **See the CAN Network Configuration** 11 **section for a PC comms branch schematic.**

VCU Power and Ground

The VCU power and ground inputs are used for powering internal components, such as the microprocessor, logic circuitry, RAM and high side outputs. The current usage will depend on how these circuits are used in the application. ***A good starting point for the 12V Battery+ input fuse is 10 amps.***

Channels

VCU_12V_input: VCU's internal supply voltage measurement

Tuning Tips
1. **Use the 12V output from the Main Relay for driving vehicle loads. The VCU turns this relay off when it shuts down. This ensures that when the VCU is powered down, there is no voltage feeding back into the VCU from the vehicle.**

VCU Wake and Ignition

The wake switch input is not a switched 12v power supply for the VCU. It is better described as a logic switch. When the input is high, the VCU will begin processing. When the input goes low, the VCU will continue to process and will initiate a shut down sequence when appropriate. The VCU will store nonvolatile data after the wake signal goes low. This may take a few seconds. If all power is removed from the VCU before the shutdown sequence completes, memory corruption may occur. AEMCal communications with the VCU is only possible when the wake switch is high. ***A good fuse value for the wake switch input is 3 amps.***

The Ignition Switch indicates the driver's desire to operate the vehicle. This means closing HV contactors to power up the inverter/motor and readying for a drive direction command (forward or reverse). When the vehicle outing is complete, the Ignition Switch is turned off, the inverter voltage is discharged and the contactors are opened. The VCU can optionally be configured to tie the Ignition Switch state to the Wake Switch state; however, in most instances, the Ignition Switch will be a separate input from the Wake Switch input.

Options

IgnSwSource: Source option for ignition switch input, either discrete switch or AEM CAN keypad. If WakeSw is selected, The VCU will automatically initiate the ignition sequence without needing a separate ignition switch input.

Channels

KeySw_Bgnd: Indicated state of the wake switch input

IgnSw: State of the discrete ignition switch input

IgnSwState: Final state of the ignition switch input

Tuning Tips

1. **The *VCU_12V_Input* channel should roughly match the 12V battery voltage if measured directly with a multimeter. It probably won't match exactly but there shouldn't be any large differences (greater than 1 volt for example).**
2. **The *EEPROM_State* channel displays the state of the on board memory. Under normal conditions with the wake switch on, *EEPROM_State* should indicate *Loaded Saved Values - Normal Startup.* It will indicate *Loaded Defaults - After Programming* after a firmware flash. This is also normal. Once the wake switch is cycled and the VCU saves its calibration data, the *EEPROM_State* channel should show *Loaded Saved Values - Normal Startup*.**
3. **If the VCU ever boots up in an abnormal memory state, it will prevent certain types of outputs from turning on for safety reasons.**

Accelerator Pedal Position (APP)

Dual APP sensor inputs are required for safety. Connect according to the basic schematic diagram above.

Options

APPX_InputSelect: Select desired input pin

APPX_Polarity: Option to invert the voltage slope polarity

APPX_Min: Sensor voltage calibration minimum

APPX_Max: Sensor voltage calibration maximum

APPX_Lo_Thresh: Voltage threshold for low sensor fault detection

APPX_Hi_Thresh: Voltage threshold for high sensor fault detection

APPXCheckThreshold: This is the allowable difference between the calculated APP1 and APP2 position. If the difference is greater than this limit, it will be considered a sensor or wiring error which can trigger fault actions

APPXCheckTimeThreshold: Maximum allowable time for APP1-APP2 cross check error to exist. When a cross check error is present for longer than this time a fault will be triggered

Where X = 1 or 2 depending on the APP input signal

Channels

AccelPedal: Final calculated pedal position in %

Tuning Tips

1. **With the pedal closed, monitor the channel *APPX_Volts* vs the option *APPX_Min*. Set *APPX_Min* = *APPX_Volts*.**
2. **With the pedal fully open, monitor the channel *APPX_Volts* vs the option *APPX_Max*. Set *APPX_Max* = *APPX_Volts*.**
3. **Set the *APPX_Hi_Thresh* and *APPX_Lo_Thresh* slightly outside these calibration limits. These will be your fault detection thresholds.**
4. **Use the *APPX_Polarity* options to set the appropriate slope. If the *APPX_Volts* signal increases from low to high pedal, choose *Positive Slope.* If it decreases, choose *Negative Slope*.**

Brake Switch

Dual brake switch inputs are recommended for safety. Connect according to the schematic diagram above. Brake Switch state may also be triggered by Brake Pressure value – see optional configuration settings below.

Options

BrakeSwitchDetectOption: Switch **AND**, switch **OR** or **BrakePress** options for arbitration. AEM recommends using the Switch **AND** option for safety.

Channels

BrakeSwitch: Final state of brake switch input

Tuning Tips

1. **Monitor the *BrkSw1* and *BrkSw2* channels**
2. **The final state of the *BrakeSwitch* channel will depend on the calibration option *BrakeSwitchDetectOption***
3. ***BrakeSwitch* should indicate *On* only when the brake pedal is depressed. The brake pedal switch is critical for many core VCU functions.**

Optional Brake Pressure Switch Configuration

Options

BrkPress_Lo_Thresh: Voltage threshold for low sensor fault detection

BrkPress_Hi_Thresh: Voltage threshold for high sensor fault detection

BrkPressOfst: Offset for linear transfer function

BrkPressGain: Gain for linear transfer function

Tables

BrkPressSwThresh: 1D table for using brake pressure for brake switch detection, 0 = On above setpoint, 1 = Off below setpoint

Channels
Brake_Pressure: Indicated measured brake pressure (*BrkPressGain**(volts))+(*BrkPressOfst*)

PRND

The park, reverse, neutral and drive inputs for direct drive applications may be received as either discrete switch inputs or with the AEM CAN Keypad 87 (pn 30-8400).

Options
SpdLoThr: Vehicle speed must be below this value to allow transition between neutral, drive and reverse

SpdZeroThr: Vehicle speed must be below this value to allow transition to park

Channels
PrkSw: State of the discrete park switch input

RevSw: State of the discrete reverse switch input

NtrlSw: State of the discrete neutral switch input

DrvSw: State of the discrete drive switch input

Tuning Tips
1. **Monitor the *PrkSw, RevSw, NtrlSw* and *DrvSw* channels while toggling each switch.**
2. **Remember to properly assign the pin functions using the InputSelect options. Adjust the logic polarity as needed. See the Hardware Input Selection and Setup 78 section.**

High Voltage Interlock Loop (HVIL) I/O

Use of the HVIL loop detection is a highly recommended safety feature. The HVIL circuit is a low voltage continuous loop that starts at the VCU and typically connects through each HV device's HV connector (inverter, DCDC, charger, etc). The purpose of the HVIL circuit is for the VCU to be able to detect if a HV connection has been broken or removed thus preventing the enabling of HV battery contactors to prevent possible shorting or other damage/injury. The VCU generates a 100Hz, 50% duty digital signal on its HVIL output pin and receives this same signal back on its HVIL input pin. When the input frequency equals the output frequency, the HVIL loop is detected.

It's very important to note that the VCU's HVIL circuit is low voltage only and does NOT connect directly to any HV circuits! Connecting the VCU to any HV circuits will result in severe equipment damage and possible electrical shock injury!

Options
HVILMain_InputSelect: User option to select desired frequency input

HVILMainEnable: User option to enable or disable the HVIL Main loop*HVILMainBypass*: User option to bypass the main HVIL loop detection

HVILMainXCheckThresh: User option to set the frequency difference window for HVIL loop detection.

Channels

HVILFreqIn1: Measured input frequency

HVILFreqOut1: Control output frequency

HVIL_Main_State: Final state of the main HVIL loop

Tuning Tips

1. **Monitor the channels *HVILFreqIn1* vs *HVILFreqOut1*. If these match, *HVIL_MAIN_State* should be 1, meaning the HVIL loop is detected.**
2. **For initial setup and testing purposes, the option *HVILMainEnable* can be set to *Not Enabled.* In this state, the VCU will ignore the HVIL signal.**

Insulation Monitoring Device (IMD)

The high voltage system in an electric vehicle is designed to be ungrounded (floating) with respect to the vehicle chassis (frame). Insulation faults can cause electric shock, personal injury and even death. An insulation monitoring device (IMD) must be used to protect against these faults. Suggested IMD is Bender IR155-32xx with high side (+12v) status output. Output is high when NOT faulted and goes low when insulation fault is detected.

Options

IMD_Detect_Thresh: Time threshold in seconds to filter the IMD state after VCU wake to accommodate the IMD measurement delay; suggested to start with a value of **20** and adjust as necessary

IMD_Contactor_Enable_Input: Option to inhibit initial contactor closing based on either raw or filtered IMD fault state; to not inhibit contactor closing, set to **Ignore**

IMD_State_Store_Reset: Option to clear insulation fault flags from VCU memory

Channels

IMD_State_Raw: Raw state of the IMD digital input.

IMD_State: State of the IMD digital input after the *IMD_Detect_Thresh* timer expires.

Fault_IMD: Reports the IMD fault state after delay timer expires; no insulation fault detected = 0, insulation fault detected = 1; also reported over CAN

IMD_State_Store: Flag indicating that an IMD fault has occurred and has been committed to VCU memory; can be cleared by toggling option *IMD_State_Store_Reset*

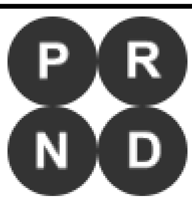
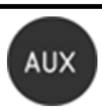
Tuning Tips

1. **Remember to choose the IMD input pin using the *IMD_DI_InputSelect* option**

Optional Inputs

AEM 8-Button CAN Keypad

The VCU currently interfaces with the AEM 8-Button CAN Keypad (PN 30-8400) for direct drive configurations only.

Icon(s)	Function
	Direct Drive Park, Reverse, Neutral, Drive inputs Radio Button functionality
	Ignition Switch Input OFF = Contactors Open YELLOW = PreCharge in process GREEN = High Voltage Contactors Are Closed YELLOW = Active Discharge in process (if supported) RED = ERROR - PreCharge failed, Contactors are open
	Performance Level Loop Toggle 1-4, on while pressed
	Slip Target (reserved for future use) Loop Toggle
	Aux Function User programmable PDU output

<u>Keypad CAN Configuration:</u>
VCU CAN channel: CAN 3
Baud Rate: 500k

	<u>Tuning Tips</u>

	1. Monitor the channel *BlinkPKP2400MsgAge*. If this counter counts up and resets periodically, the VCU is receiving CAN messages from the keypad. If it is maxed out at 65535, the VCU is NOT receiving CAN messages from the keypad. Review the keypad user manual and information in the CAN Network Configuration 11 **section.**

Pack Current and Voltage

Battery pack current and voltage sensors must be installed by experienced technicians.

Options
PackCurrent_InputSelect: Set to either **IVTS, LEM or AEM_HVPDU**

PackCurrent_Invert: Use to invert the polarity of the pack current signal. Discharge current (out of the pack) must be a positive value and charging current (into the pack) must be a negative value

Channels
PackCurrent: Final battery pack current value

PackVoltage: Final battery pack voltage value

PackCellMax: Maximum cell voltage across entire pack

PackCellMin: Minimum cell voltage across entire pack

PackCellMinMaxDelta: Voltage difference between the minimum and maximum cell values across entire pack

PackCellAvg: Calculated average pack cell voltage

IVTS

If using the IVT-S sensor from Isabellenhuette, connect it to the CAN3 network, and configure the following options:

Options
IVTS_CurrentMsgTimeoutThr: Fault timeout in seconds for IVTS CAN signal. If the VCU does not receive the CAN signal within this timeframe, the VCU will consider the connection lost and override the value. Set to a value greater than **1** second
IVTS_CurrentDfltVal: Default pack current to be used as an override in the event of a CAN timeout

Channels
IVTS_Current: Pack current signal as reported over CAN from the IVTS
IVTS_Voltage_U1: Pack voltage as reported over CAN from the IVTS

LEM Sensor

If using a LEM sensor, connect it according to the Hardware Pinout 13 section and configure the following options:

To increase sensitivity at low current measuring ranges, the DHAB sensors have two measurement signals within one housing. The VCU will blend between the two ranges in both positive (discharge) and negative (charge) current ranges.

Options

PackCurr_HiLo_BlendPoint: Maximum value of the sensor's low measurement range
PackCurr_HiLo_BlendPoint_Neg: Minimum (negative) value of the sensor's low measurement range
PackCurr_BlendStartRatio: Percentage of overlap between the low and high measurement ranges.
PackCurrLEM_FiltTC: Filter time in seconds for the low range signal
PackCurrLEM_Hi_Thresh: High threshold for fault detection. Refer to LEM datasheet for maximum voltage
PackCurrLEM_Lo_Thresh: Low threshold for fault detection. Refer to LEM datasheet for minimum voltage
PackCurrLEMSensitivity: Output sensitivity of the low range signal in mV/A. Refer to LEM datasheet for sensitivity value
PackCurrLEM1_FiltTC: Filter time in seconds for the high range signal
PackCurrLEM1_Hi_Thresh: High threshold for fault detection. Refer to LEM datasheet for maximum voltage
PackCurrLEM1_Lo_Thresh: Low threshold for fault detection. Refer to LEM datasheet for minimum voltage
PackCurrLEM1Sensitivity: Output sensitivity of the high range signal in mV/A. Refer to LEM datasheet for sensitivity value

Channels

PackCurrLEM: Filtered signal from the low range LEM current sensor
PackCurrLEM1: Filtered signal from the high range LEM current sensor
PackCurrBlendRatio: Will be between 0 and 1 within the blending window

Tuning Tips

1. **Remember to choose the appropriate InputSelect option for both the high and low range LEM signals.**
2. **For this example, we will use values for the LEM DHAB S/137 sensor capable of measuring +/- 75A on the low current range, and +/- 1000A on the high current range, suitable for a Tesla LDU system. If using this sensor, the calibration is configured with appropriate default values.**

Performance Data channel 1						
Primary current, measuring range	$I_{PM\ channel\ 1}$	A	−75		75	
Primary nominal DC or rms current	$I_{PN\ channel\ 1}$	A	−75		75	@T_A = 25 °C
Offset voltage	V_O	V		2.5		@ U_C = 5 V
Sensitivity	G	mV/A		26.67		@ U_C = 5 V
Resolution		mV		2.5		@ U_C = 5 V
Output clamping voltage min [1]	V_{SZ}	V	0.2	0.25	0.3	@ U_C = 5 V
Output clamping voltage max [1]		V	4.7	4.75	4.8	@ U_C = 5 V
Performance Data channel 2						
Primary current, measuring range	$I_{PM\ channel\ 2}$	A	−1000		1000	
Primary nominal DC or rms current	$I_{PN\ channel\ 2}$	A	−1000		1000	@ T_A = 25 °C
Offset voltage	V_O	V		2.5		@ U_C = 5 V
Sensitivity	G	mV/A		2		@ U_C = 5 V
Resolution		mV		2.5		@ U_C = 5 V
Output clamping voltage min [1]	V_{SZ}	V	0.2	0.25	0.3	@ U_C = 5 V
Output clamping voltage max [1]		V	4.7	4.75	4.8	@ U_C = 5 V

1. **Set the *PackCurr_HiLo_BlendPoint_Neg* and *PackCurr_HiLo_BlendPoint* according to the measuring range of the low current channel, e.g. -75A and 75A.**
2. **Set the *PackCurr_BlendStartRatio* to a starting value of 25%. The VCU will start transitioning to the high current measurement range at about 56A.**
3. **Configure the options in the *LEMSensor_LoRange* section and *LEMSensor_HiRange* section to suit your sensor using the information from the datasheet.**
4. **Once configured, monitor the internal 5V reference channel *VREF*. If necessary, an optional user offset for zero point adjustment is available. Set option *LEM_VSense_Ref_Option* to UserCal and adjust option *LEM_VSens_UserCal* to the measured *VREF* value to adjust the zero offset of the sensor.**
5. **Software filters are available to smooth the display of both LEM sensor inputs. Use the options *PackCurrLEM_FiltTC* and *PackCurrLEM1_FiltTC* to adjust the filter time constants for the low range and high range inputs respectively. Larger values will increase the filtering; smaller values will decrease the filtering.**

Vehicle Speed

Options – Vehicle Speed
DriveGearRatio: Final drive gear ratio

DriveTireDiameter: Tire diameter in inches

VehicleSpeedFilt: Vehicle speed signal filter; the larger the value, the more filtering is applied

Channels – Vehicle Speed
Vehicle_Speed: Speed in miles per hour

Odometer

When the vehicle speed options are properly configured, the VCU will automatically calculate a total odometer value and trip odometer value. The measurement parameters *VehOdmtr* and *VehTripOdo* can be used to monitor each signal respectively. Accumulated odometer data is reset when the VCU firmware is updated. Use the calibration option *VehOdmtrInitVal* to set an initial value.

Outputs

AEM Power Distribution Units (PDUs)

The VCU output capabilities can be expanded with the addition of AEM PDU-8 modules (pn 30-8300). The PDU-8 is a high current, lightweight module that is designed to be mounted near the devices requiring power. Its design philosophy is for multiple units to be part of a vehicle installation and to distribute the power throughout the vehicle rather than having it concentrated in a central area.

The PDU-8 is not a stand-alone device. It is designed to be operated as a satellite unit and controlled via CAN by either an AEM Vehicle Control Unit or a programmable 3rd party device that can generate the required CAN control messages. As such, the PDU-8 module itself is not programmable in any way and only carries out commands issued by other devices.

Specific PDU's are identified by grounding different combinations of configuration pins on the PDU connector. For proper function, the PDU-8 units must be configured as follows.

Unit ID	Config 1, Pin 24	Config 2, Pin 16	Config 3, Pin 10	Tx Msg 1 Address	Tx Msg 2 Address	Rx Msg 1 Address	Rx Msg 2 Address
1	O/C	O/C	O/C	0x000A0610	0x000A0611	0x000A0620	0x000A0630
2	Gnd	O/C	O/C	0x000A0612	0x000A0613	0x000A0621	0x000A0631
3	O/C	Gnd	O/C	0x000A0614	0x000A0615	0x000A0622	0x000A0632
4	Gnd	Gnd	O/C	0x000A0616	0x000A0617	0x000A0623	0x000A0633

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AEM PDU-8 / VCU Functional Pin Assignments

The VCU275 can interface with up to 4 PDU-8 units. Each of these 32 PDU-8 drivers can be configured to activate based on the logic state of any available VCU output function using the following:

Options

PDU8_X_ChY_CmdSelect: Where X = 1-4 for each of the 4 configurable PDU8 units and Y = 1-8 for each of the 8 available driver outputs.

The current list of mappable functions is as follows.

Selection Setting	Description
Inverter Power	Used to control switched 12 volt power to the inverter(s)
NegContactor	Pack negative contactor control
DrivePreChargeContactor	Drive motor inverter precharge contactor control
DrivePositiveContactor	Drive motor inverter positive contactor control
HVSafetyLight	High voltage safety light control
ShiftSolenoid	Air shift solenoid control
ACPrechargeContactor	High voltage air conditioning precharge contactor control
ACPositiveContactor	High voltage air conditioning positive contactor control
DriveFan	Drive system cooling fan control
PackFan	Battery pack cooling fan control
PackChiller	Battery pack fluid AC chiller solenoid control
DriveChiller	Drive system fluid AC chiller solenoid control
PackRadBypass	Battery pack radiator bypass valve control
Pump1Wake	Cooling pump 1 wake control
Pump1Control	Cooling pump 1 control
Pump2Wake	Cooling pump 2 wake control
Pump2Control	Cooling pump 2 control
DriveOilPump	Drive system oil pump control
GearFan	Gear fan control
CabinHeat	Cabin heat contactor control
ACEvapSolenoid	Air conditioning evaporator solenoid control
ACWake	Air conditioning wake control
ACCondenserFan	Air conditioning condenser fan control
BrakeLamps	Brake lamps control
ReverseLamps	Reverse lamps control
ParkingBrake	Parking Brake control
BrakeVacPump	Brake system vacuum pump control
User1Sw	Control based on optional User1 Switch

Selection Setting	Description
User2Sw	Control based on optional User2 Switch
User3Sw	Control based on optional User3 Switch
Wake	Control enabled if wake switch ON
Ignition	Control enabled if Ignition switch ON
DefaultOn	Control default ON

Direct Output Control

Some VCU outputs are pre-configured for certain features but most of them are fully configurable. The following outputs are hard coded for specific functions:

Output	Function
LSO2	Main Relay Control
LSO5	HVIL Main Output
LSO6	HVIL Charge Output
LSO15	Not used on VCU275

Options

LSOX_CmdSelect: Where X = 1, 3-4, 7-14, 16-23 - User option to assign a VCU function to a specific low side output pin.

HSO1_CmdSelect: User option to assign a VCU function to the high side (switched 12 volts) output.

The current list of mappable functions to direct VCU outputs is as follows.

Selection Setting	Description
InverterPower	Used to control switched 12 volt power to the inverter(s)
NegContactor	Pack negative contactor control
DrivePreChargeContactor	Drive motor inverter precharge contactor control
DrivePositiveContactor	Drive motor inverter positive contactor control
HVSafetyLight	High voltage safety light control
ShiftSolenoid	Air shift solenoid control
ACPrechargeContactor	High voltage air conditioning precharge contactor control
ACPositiveContactor	High voltage air conditioning positive contactor control
DriveFan	Drive system cooling fan control
PackFan	Battery pack cooling fan control
PackChiller	Battery pack fluid AC chiller solenoid control
DriveChiller	Drive system fluid AC chiller solenoid control
PackRadBypass	Battery pack radiator bypass valve control
Pump1Wake	Cooling pump 1 wake control

Selection Setting	Description
Pump1Control	Cooling pump 1 control
Pump2Wake	Cooling pump 2 wake control
Pump2Control	Cooling pump 2 control
DriveOilPump	Drive system oil pump control
GearFan	Gear fan control
CabinHeat	Cabin heat contactor control
ACEvapSolenoid	Air conditioning evaporator solenoid control
ACWake	Air conditioning wake control
ACCondenserFan	Air conditioning condenser fan control
BrakeLamps	Brake lamps control
ReverseLamps	Reverse lamps control
ParkingBrake	Parking Brake control
BrakeVacPump	Brake system vacuum pump control
User1Sw	Control based on optional User1 Switch
User2Sw	Control based on optional User2 Switch
User3Sw	Control based on optional User3 Switch
Wake	Control enabled if wake switch ON
Ignition	Control enabled if Ignition switch ON
DefaultOn	Control default ON
BMS_Discharge	On when the pack is in a discharge state
BMS_Charge	On when the pack is in a charge state
*Fan1Temp**	Reference temperature for Fan 1
*Fan2Temp**	Reference temperature for Fan 2
*Pump1Temp**	Reference temperature for Pump 1
*Pump2Temp**	Reference temperature for Pump 2

*LSO1, LSO3, LSO4, LSO13, LSO14, LSO19 only

Tuning Tips

1. **Before connecting a direct VCU output to any external load, review the current limitations listed in the 'Limits' column of the Hardware Pinout** 13 **table.**

Contactors

The VCU has outputs to control the main HV battery supply contactors including a negative contactor, inverter pre-charge contactor and positive contactor.

Note that parallel control logic exists for both the VCU's direct hardware output pins and the AEM PDU-8. See PDU Function Assignment 90 ***section.***

Pre-Charge Contactor

The pre-charge feature adds a resistor and another contactor across the main positive contactor. When the ignition switch is turned on, the VCU will confirm the negative contactor is closed, then close the pre-charge contactor. The rate of change of DC voltage into the inverter is monitored using CAN data reported from the inverter. When the rate reduces sufficiently, the VCU closes the positive contactor. Finally, after a brief settling time, the VCU will open the pre-charge contactor. At this point, the pre-charge process is complete.
For successful control, the following pre-conditions are required:

1. No inverter faults or lockouts
2. No IMD faults
3. HVIL Main detection
4. No Cell OCVmin faults

Options

PreChargeEnable: Select ***Enabled*** to use the VCU for inverter precharge.

DCBusVoltage_InputSelect: User option to select the source for the DC bus voltage reference used for precharge. Select between IVTS, AEM_HVPDU and InverterCAN. Generally, the InverterCAN selection is used. The signal will come directly to the VCU from the inverter over the CAN bus.

Inverter1_HVDetectPartialThr: Minimum voltage threshold the VCU expects to see after the precharge contactor is closed.

Bus_Pack_Voltage_Max_Precharge_Delta: Maximum BMS pack versus measured Bus voltage delta. The pre-charge contactor is not allowed to close unless the difference between the two measured voltages is less than this value. For non-BMS systems, set this at a value higher than maximum voltage.

Inverter1_PCDV_Filt: Software filter for the DC Bus Voltage signal to the VCU.

Tables

InverterX_PreChgDeltaVThresh: 1 x 2 table that defines the hysteresis values for threshold rate detection in volts/s

Channels

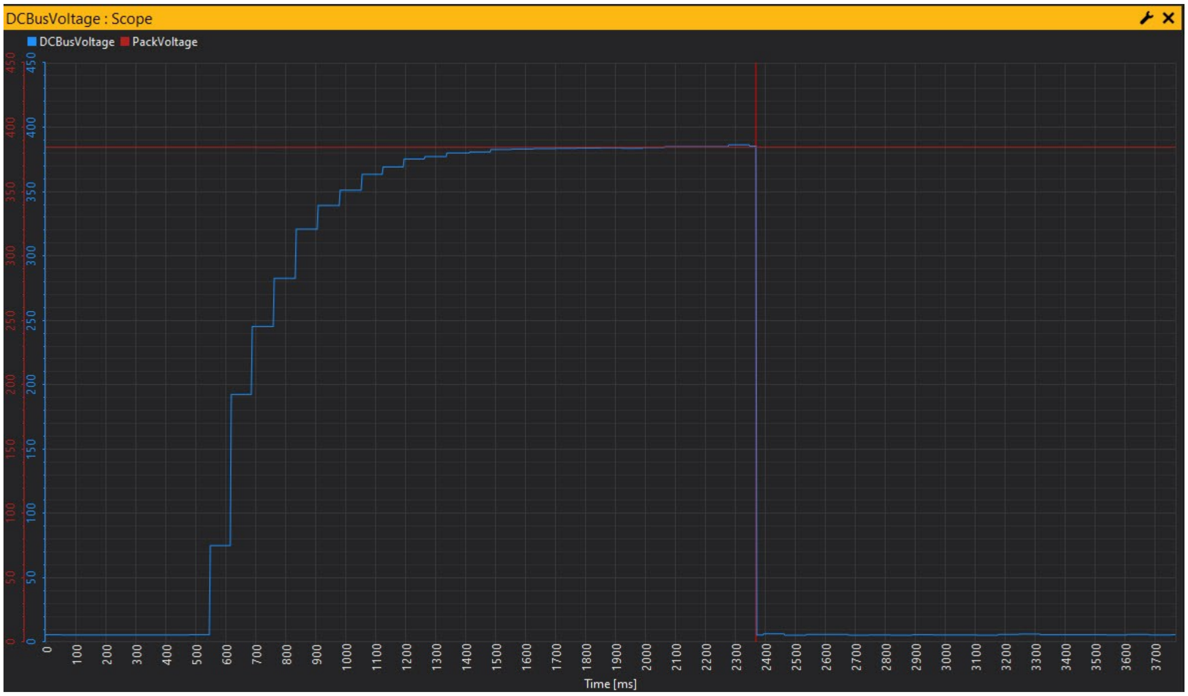
InverterX_HVDetectPartial: Will be 1 if partial high voltage is detected.

InverterXPreChgDeltaV: Inverter voltage delta V during precharge.

VCU_OpState: Helpful for debugging precharge errors.

Tuning Tips

1. **Use the AEMCal scope feature to visualize the precharge process real time.**
2. **Plot DCBusVoltage and PackVoltage. The scope will stream the data and show the process as it happens.**



Battery Management Systems

A Battery Management System (BMS) is an electronic system that manages a rechargeable battery pack. When configured properly, it can protect the battery pack from unsafe operating conditions. A BMS can also communicate state variables, limit data and detailed information about individual cells.

The VCU supports the AEM EV BMS-18 95 or other 3rd party battery management systems.

Tuning Tips

1. **Using a battery management system is highly recommended however the VCU does offer basic current limiting protection features based on reported inverter current even if a BMS isn't being used. This is accomplished by setting the table *ItemSelect_BMS* for AEM BMS-18 and setting option *DCLCCLMethod* to Temp Based which will enable discharge current limit tables *DCL_PackTempHi* & *DCL_PackTempLo*. Set these tables with fairly high values to essentially disable them and then set the discharge current limit override options mentioned in Torque Limits – Inverter Current Limiting 117 in accordance to a battery pack's known current rating.**

BMS-18

The AEM Battery Management System (BMS-18) is comprised of three components:

1. VCU
2. BMS-18 Master
3. BMS-18 Satellite(s)

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The BMS is implemented as two different Module types: the BMS Master and the BMS Satellite. Each Module is capable of measuring up to 18 cells and 3 temperatures (thermistors) but the Master also contains the CAN communication interface and J1772 charging specific connections needed for each battery pack.

The VCU communicates with the BMS via the Master Module and all battery packs need at least one Master unit. The Satellites expand the capability of the Master by an additional 18 cells and 3 thermistors per additional Satellite connected. The Satellite Modules are connected to their Master via a high-speed serial interface (isoSPI) that allows additional units to be daisy chained together, adding up to 5 Satellites for a total of 6 Modules for the VCU200 and up to 11 Satellites for a total of 12 Modules for the VCU300. The VCU275 supports up to 16 modules.

The VCU is responsible for all BMS control logic and each individual BMS module is managed as a “group”. All setup and calibration items can be modified using the AEMCal user interface.

For troubleshooting information, please see the BMS Troubleshooting Guide.

Basic Setup

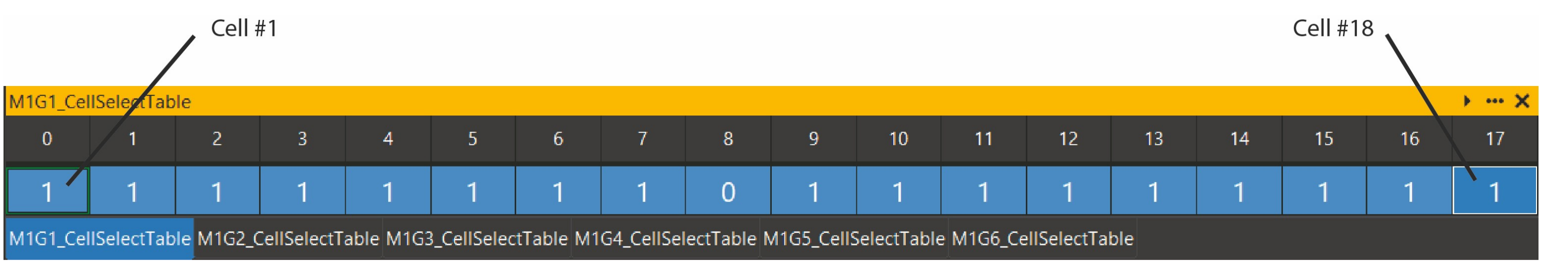
All BMS-18 modules have connections for 18 cell taps, 3 thermistors and the isoSPI channels. The Master module has additional connections for Power, CAN, and the J1772 charger connections. The Master receives its direction from the VCU over the CAN bus and it forwards them on to the Satellite units over a robust two-wire isoSPI datalink. The master only has an isoSPI output channel since it is the originator while the Satellites have both an input and an output channel.

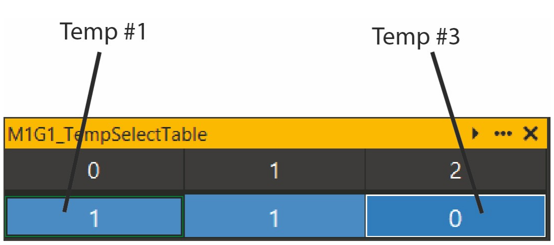
Each Module can monitor from 4 to 18 cells wired in series. The cells that are monitored by one Module is called a Cell Group. The first module in the system is always a Master and referred to as Group 1. The next module in the system is called Group 2 and would be the first Satellite immediately downstream from the Master. The next Satellite would be Group 3 and so on. The Group number assignment of a module is defined by the order in which they are attached to the Master while remembering that the Master is always Group 1.

Tables

M1GX_CellSelectTable: Use to select which cell taps are used. Enter a **1** in each desired location. Example table below. Note that position 0 in the table corresponds to cell 1 and position 17 in the table corresponds to cell 18.

M1GX_TempSelectTable: Use to select which external temperature probes are used. Enter a **1** in each desired location. Example table below. Note that position 0 in the table corresponds to external temp 1 and position 2 in the table corresponds to external temp 3.





Options

PackMaxCapacity: Define the pack maximum capacity in Watt Hours; typically cell Amp Hours X Max Pack Voltage

PackVoltage_FullyCharged: The pack will be considered fully charged above this value.

PackTempFaultMax: Option to set a pack max temperature threshold; will set the status channel flag *BMS_FS_MaxPackTempFault*

PackTempFaultMin: If the minimum pack temperature is below this value, the *BMS_FS_MinPackTempFault* will be set.

CellUnderVoltFaultLimit: Option to set a minimum allowed cell voltage; will set the status channel flag *BMS_FS_M1GXX_MinCellVoltsFault* and is reported over CAN as *Fault_M1GXX_CellV_Min*

CellOverVoltFaultLimit: Option to set a maximum allowed cell voltage; will set the status channel flag *BMS_FS_M1GXX_MaxCellVoltsFault* and is reported over CAN as *Fault_M1GXX_CellV_Max*

CellUnderVoltLim: Minimum cell voltage for DCL calculation. If the minimum cell voltage is detected below this value, the calculated DCL will be 0.

CellOverVoltLim: Maximum cell voltage for CCL calculation. If the maximum cell voltage is detected above this value, the calculated CCL will be 0.

DCLCCLMethod: User option to use either cell resistance based or temperature based charge and discharge current estimation.

Tuning Tips

1. **For a new installation, set the *DCLCCLMethod* option to *Temp Based* and set appropriate values for your application in the following 1D tables:**
   - **DCL_PackTempLo**
   - **DCL_PackTempHi**
   - **CCL_PackTempLo**
   - **CCL_PackTempHi**

Voltages

Cell Voltages

Individual cell voltages are measured by each BMS module/group which are then transmitted by isoSPI to the Master BMS unit which then transmits all cell voltages on the CAN bus to the VCU.

Channels

BMSM1_GXX_CellYY: Instantaneous cell voltage where XX = group number and YY = cell number

M1GXX_CellAvg: Average cell voltage for group XX

M1GXX_SumOfCells: Sum of all individual cell voltages for group XX. Used for pack voltage calculation

M1GXX_MinIdx: Index of the minimum cell voltage value for group XX

M1GXX_Max: Maximum cell voltage value for group XX

M1GXX_MaxIdx: Index of the maximum cell voltage value for group XX

Pack Voltage

The VCU adds all series cell voltage measurements to calculate a net pack voltage and other pack stats.

Channels

PackVoltage: Calculated pack voltage as reported by the AEM BMS-18 system

PackCellMax: Maximum cell voltage across entire pack

PackCellMin: Minimum cell voltage across entire pack

PackCellMinMaxDelta: Voltage difference between the minimum and maximum cell values across entire pack

PackCellAvg: Calculated average pack cell voltage

Temperatures

External Thermistors

The resistance of 3 thermistor inputs are sampled by each BMS module/group which are then transmitted by isoSPI to the Master BMS unit which then transmits all resistance values on the CAN bus to the VCU.

It is important that the external thermistors be used since the VCU adjusts the max allowable current (both discharge and charge) based on the cell temperatures as well as alerts the user of a critical over-temp event is occurring. The thermistors supplied with each BMS module is the Vishay NTCLE413E2103F102L. Other thermistors may be substituted so long as the temperature-to-resistance calibration values are known and enter them in the VCU software. The only limitation is that all the thermistors used in the BMS must have the same calibration.

Tables

ExtTherm_Table: Calibration table for converting external thermistor resistance to temperature

M1GX_TempSelectTable: Use to select which external temperature probes are used. Enter a **1** in each desired location. Example table below. Note that position 0 in the table corresponds to external temp 1 and position 2 in the table corresponds to external temp 3.

Options

ExtTherm_FaultHi_Thresh: High threshold for external temp sensor resistance data. Readings above this value will cause a fault flag to be set.

ExtTherm_FaultLo_Thresh: Low threshold for external temp sensor resistance data. Readings below this value will cause a fault flag to be set. The measured temperature data will be overridden by the *ExtTherm_DefaultValue*

ExtTherm_FaultTime_Thresh: If the fault condition is true for this amount of time, the fault flag will be set

Channels

BMSM1_GXX_ThermY: Measured resistance value for external thermistor Y of group XX

M1GXX_ExtThermY: Calibrated temperature for external thermistor Y of group XX

PackTempMin: Calculated minimum temperature between all external thermistor, BMSM1_GXX_ThermY signals

PackTempMax: Calculated maximum temperature between all external thermistor, BMSM1_GXX_ThermY signals

Options

M1GXX_ExtThermXX_FaultEnable: Set to Enabled for all external thermistor probes that are in use

Internal Temperatures

The temperature of the circuit board and microcontroller for each BMS modules/group are reported.

Channels

BMSM1_GXX_PCBThermY: Measured resistance value for PCB thermistor Y of group XX

M1GXX_PCBThermY: Calibrated temperature for PCB temperature Y of group XX

BMSM1_GXX_ICTemp: Reported microcontroller temperature of group XX

Pack Thermal States and Control Modes

The VCU uses the external thermistor temperature data along with user calibration settings to determine the thermal state of the pack.

Tables

PackTempStateThreshold: 1 x 2 table that defines a transition threshold with hysteresis. If both the *PackTempMax* and *PackTempMin* are above this threshold, the pack is considered warm. If both the *PackTempMax* and *PackTempMin* are below this threshold, the pack is considered cold. If the pack is warm, the *PackTempMax* value is used as the reference. If the pack is cold, the *PackTempMin* is used as the reference

PackActiveCoolThresh: 1 x 2 table that defines a transition threshold with hysteresis. If the reference pack temperature is above this threshold, the system is in active cooling mode

PackActiveHeatThresh: 1 x 2 table that defines a transition threshold with hysteresis. If the reference pack temperature is below this threshold, the system is in active heating mode

Channels

PackTempState: Cold or Warm as determined by the PackTempStateThreshold table

PackThermMode: Either Normal, Heating or Cooling. If the state is Normal, no active heating or cooling is required

Cell Open Circuit Voltage

At first look, the concept of battery open circuit voltage, or OCV, seems obvious and intuitive. Simply put, a battery’s voltage is measured while in an open circuit where there is no load on the cell so there is nothing to influence the cell voltage up or down. OCV is also known as the cell’s “resting” voltage.

Knowing a battery’s OCV is an important part of battery management because it’s representative of the battery’s capacity. Battery OCV is analogous to knowing the fuel level in a fuel tank. By knowing where between 100% capacity and 0% capacity a fuel tank is, one can roughly estimate how far a vehicle can be driven if fuel consumption rate is known.

It is very easy to quantify fuel level in a fuel tank because it is directly measured and typically changes at a slow and steady rate. The difficulty in knowing a battery’s OCV is that OCV can only be directly measured when there is no load but it is important to try and track the battery’s OCV at all times – even when under load and being discharged or charged.

The VCU uses two methods for finding a battery cell’s OCV:
1) By directly sampling the cell voltage when there is little to no load being applied
2) Calculating a cell’s OCV using a predictive algorithm

By default, the BMS logic will quickly sample all cell OCVs at wake on as this is the best time to assume the pack is at rest or very nearly so. The values are also updated as part of the charging process when pack current is closely controlled.

Once the pack is under load, the BMS calculates and adjusts the cell OCV data over time as charge leaves or enters the pack. Accurate OCV data under load is important for discharge and charging current limit calculations (DCL/CCL) as well as State of Charge or SOC.

The following equations are used to predict cell open circuit voltage while under load:

Cell OCV Max = Instantaneous Max Cell Voltage + (Pack Current * Min Cell Resistance)
Cell OCV Min = Instantaneous Min Cell Voltage + (Pack Current * Min Cell Resistance)

The quality of the predicted OCV data while under load is dependent on the accuracy of the resistance data for each individual cell which is described in the next section.

Channels

M1GXX_CellOCVXX: Measured individual cell open circuit voltage values

BMSM1_G01_CellOCV_Min: Calculated minimum cell open circuit voltage

BMSM1_G01_CellOCV_Max: Calculated maximum cell open circuit voltage

Cell Resistance

Temperature corrected, individual cell resistance data is used to track the health of the pack and to calculate charge and discharge current limits during run time. Cell resistance values are calculated real time during the charging cycle when pack current is relatively steady and within a specified range. If real time calculated cell resistance data is not available, the BMS logic uses a nominal resistance value.

Options

CellRPackCurrHi: Used with *CellRPackCurrLo*. Pack current must be greater than CellRPackCurrLo and less than CellRPackCurrHi in order to update the internal cell resistance values

CellRPackCurrLo: Used with *CellRPackCurrHi*. Pack current must be greater than CellRPackCurrLo and less than CellRPackCurrHi in order to update the internal cell resistance values

CellResDefault: Default cell resistance value to use when no data is available from the vehicle.

Channels

M1GXX_CellRXX: Individual cell resistance values in milliohms

M1GXX_CellRMin: Group minimum cell resistance

M1GXX_CellRMinIdx: Index of group minimum cell resistance

M1GXX_CellRMax: Group maximum cell resistance

M1GXX_CellRMaxIdx: Index of group maximum cell resistance

M1GXX_CellRSum: Sum of group cell resistance values

PackCellRMax: Maximum cell resistance across the entire pack

PackCellRMin: Minimum cell resistance across the entire pack

PackCellRMinMaxDelta: Difference between the pack min and pack max cell resistance

PackResistance: Total pack resistance

Cell Resistance Sampling

If you know a cells OCV and you can measure the pack current and instantaneous individual cell voltages, you can calculate each cells individual resistance using Ohm's Law where I = V/R or by rearranging this equation, R = V/I. The cells individual resistance is equal to the voltage change divided by the current. To get the most accurate data, the BMS logic calculates these resistances when the pack is being charged and the current is relatively steady. To do this, the BMS logic must know when to make this calculation during charging.

Use the options *CellRPackCurrHi* and *CellRPackCurrLo* to define this range. Remember that charging current is defined as a negative value. If your measured charging current is 8 amps for example, set these two values to -3.0 and -15.0 respectively to ensure reliable capture during charging. The BMS will only make this individual resistance calculation during charging.

Bus Bar Compensation

If bus bars or other high voltage interface cables are used to connect distributed battery modules, bus bar compensations may be necessary. These adjustments apply an offset equal to the added resistance of each interconnect bar or cable when a single BMS module is used to span more than one battery module. Up to two bus bar compensations are available for each BMS-18 module.

Options

M1GX_BusBarComp1Idx: [1 – 18] cell index where the first compensation is applied

M1GX_BusBarComp2Idx: [1 – 18] cell index where the second compensation is applied

M1GX_BusBarResComp1: Resistance compensation in milliohms. Applied to the cell index defined by *M1GX_BusBarComp1Idx*

M1GX_BusBarResComp2: Resistance compensation in milliohms. Applied to the cell index defined by *M1GX_BusBarComp2Idx*

The raw voltage channels transmitted on the CAN bus from the BMS-18 Master will not reflect the bus bar compensation values as they're only applied in post-processing in the VCU. This means that the instantaneous cell voltages, average cell voltages and sum of cell voltages from all BMS groups will show an uncompensated value in either a live dash display or data log.

Channels

M1GXX_Min: Minimum cell voltage value for group XX

M1GXX_Max: Maximum cell voltage value for group XX

Current Limits

Another important aspect of battery management is the tailoring of charge and discharge current limits to control state of charge or depth of discharge to prevent either a cell over- or under-voltage condition.

Discharge Current Limits

High power output e-propulsion drivetrains can apply incredibly high levels of load and draw hundreds of amps of current from a battery pack. The VCU offers two types or levels of current limit checks to control battery discharge. One can be thought of as an instantaneous or "short-term" discharge limit and the other a more "long-term" discharge limit where the discharge rate is reduced over time as the battery's capacity is depleted. This is done to observe a cell's depth of discharge limit and respect a cell's absolute minimum allowed voltage to prevent cell damage and maximize cell life.

The instantaneous or short-term current limit is applied and controlled through the inverter current limit subsystem. See the Torque Limits - Inverter Current Limiting 117 section. If the inverter's reported current is ever greater than the final battery DCL, the inverter current limiting ramp feature is used to reduce the live max motor torque allowed value in order to also reduce discharge current. Note that the inverter current limiting multiplier target and ramp rate options must be calibrated for optimal response.

Options

DCLCCLMethod: Setting to Temp Based will use the values of the *DCL_PackTempHi* & *DCL_PackTempLo* tables as the discharge current limit. The DCL table values will be applied as the actual live discharge current limit if less than option *BattDCL_cal*. Setting to **CellR** Based enables the long-term discharge current limit calculation using the VCU's predictive OCV algorithm and by knowing cell resistance.

Tables

DCL_PackTempLo: 1x5 table defining discharge current limits as a function of low pack temperature

DCL_PackTempHi: 1x5 table defining discharge current limits as a function of high pack temperature

CellR Based DCL

The long-term discharge current limit uses individual cell resistance data, cell open circuit voltage data and a cell under volt limit calibration option to calculate a discharge current limit based on Ohm's Law. Once every few seconds, the VCU calculates a cell's available voltage discharge capacity as the difference between the current OCV and the desired under volt limit. The discharge current available within the active calculation loop is found by dividing the cell's available voltage discharge capacity by cell resistance. It is very important to note that this value is based on a calculated discharge capacity and can result in a DCL that's much higher than a battery pack's max discharge limit – especially when cell/pack voltage is high. As the battery's capacity is depleted and OCV starts to decrease, the long-term calculated DCL will also decrease. When the long-term calculated DCL becomes less than option *BattDCL_cal* or any other lower DCL values, it will become the final live DCL target.

Options

CellUnderVoltLim: Limit minimum cell voltage for long-term DCL calculation

Channels

BattDCL: Final pack discharge current limit; the lowest value from any DCL calculators is passed through as the final DCL

Charge Current Limits

The VCU uses the same strategies mentioned above for discharge current limiting for charge current limiting (CCL). If *DCLCCLMethod* is set to Temp Based, the values of the *CCL_PackTempHi* & *CCL_PackTempLo* tables as the charge current limit. The DCL table values will be applied as the actual live charge current limit if less than option *BattCCL_cal*. If *DCLCCLMethod* is set to **CellR** Based, the charge current limit calculations are made using the VCU's predictive OCV algorithm and by knowing cell resistance.

Tables

CCL_PackTempLo: 1x5 table defining charge current limits as a function of low pack temperature

CCL_PackTempHi: 1x5 table defining charge current limits as a function of high pack temperature

Options

CellOverVoltLim: Limit maximum cell voltage for long-term CCL calculation

Channels

BattCCL: Final pack charge current limit; the lowest value from any CCL calculators is passed through as the final CCL

Direct Inverter Current Control

This feature is an optional predictive algorithm that uses the parameters listed below to calculate a live theoretical electrical power limit. This power limit is then converted to a torque limit based on motor speed. Note that direct inverter current control should not be enabled until all standard BMS18 features are set up and functioning correctly.

Reference Channels

BattPackOCVolts: Reports the final battery pack open circuit voltage value

BattPackResistance: Reports the total additive battery pack resistance

Inverter1_MCL: Final inverter motoring current limit; reports the lower of (*BattDCLFinal-HVAccCur*) and *Inverter1_MCL_cal*; see Torque Limits - Inverter Current Limiting 117

Inverter1_GCL: Final inverter generating current limit; reports the lower of (*BattCCLFinal+HVAccCur*) and *Inverter1_GCL_cal*

Tables

Inverter1_ElecPwrLim: Table that reports the VCU's live calculated inverter power limit; ***NOT A USER EDITABLE TABLE***

Inverter1_TrqLim: Table that reports the VCU's live calculated inverter torque limit; live calculated inverter power limit and motor speed are referenced to find inverter torque limit; ***NOT A USER EDITABLE TABLE***

Motor1_TrqLimCur: Table that reports the VCU's final live calculated motor torque limit; live calculated inverter torque limit is modified by the *Inverter1_MtrEffMap* value to find final motor torque limit; ***NOT A USER EDITABLE TABLE***

Option

Motor1_TrqLimCurEnbl: Option to enable or disable the direct inverter current control function; do not enable until all standard BMS18 features are functioning as expected

Motor1_TrqLimCurMultp: Mutliplier to either increase or decrease the final calculated motor torque limit value; a value of 1 makes no change, 0.9 reduces the torque limit by 10% and 1.1 increases the torque limit by 10%

Channel

VehiclePower_Battery: Total battery electrical power in kW; *VehiclePower_Battery* = *BattPackVoltage* x *BattPackCurrent*

Energy Tracking

Accurate pack current data is critical for tracking energy in and out of the battery pack. An accumulator algorithm tracks this energy flow as a function of Battery Efficiency when the measured pack current is outside a specified dead band. Battery Efficiency is a broadly applied term and a complex subject. There are several ways to express it. One of the most significant factors affecting Battery Efficiency is current. As such, the Battery Efficiency data used by the BMS is a function of pack current.

Table

BatteryEfficiencyTable: 5 x 1 table defining Battery Efficiency as a function of pack current; generally, higher current values result in less efficient transfer and vice versa.

Options

PackMaxCapacity: Battery pack max capacity in Wh; used for energy consumption and state of charge calculations.

OCVNoLoadPackCurrHi: Used with *OCVNoLoadPackCurrLo*; pack current must be greater than *OCVNoLoadPackCurrHi* and less than *OCVNoLoadPackCurrLo* for the energy accumulator to start

OCVNoLoadPackCurrLo: Used with *OCVNoLoadPackCurrHi*; pack current must be greater than *OCVNoLoadPackCurrHi* and less than *OCVNoLoadPackCurrLo* for the energy accumulator to start

The options above define a dead band. Within the dead band, the load on the pack is considered very low (nearly zero) and during this time, cell open circuit voltages are allowed to be sampled. Outside of this range, the load on the pack is considered high enough to trigger the energy accumulator algorithm.

Channels

PackCapacityConsumed: Capacity consumed in kWh since last full charge. This value will increase during discharging and decrease during charging.

PackCapacityConsumed_Outing: Capacity consumed in kWh during the current VCU wake cycle. This value will increase during discharging and decrease during charging.

PackCapacityRemaining: Remaining pack capacity equal to (*PackMaxCapacity*/1000)-*PackCapacityConsumed*.

Energy_Accum: Reports the accumulated energy in Wh since the last full charge; value will increase while discharging and decrease while charging (including during regenerative braking)

Energy_Accum_Outing: Reports the accumulated energy in Wh of the current outing; an outing is defined as a VCU wake on/off cycle; value will increase while discharging and decrease while charging (including during regenerative braking)

The Energy Tracking Process

Tracking energy in to and out of the pack is challenging. Losses and data inconsistencies can create errors. There's no one size fits all solution. The *BatteryEfficiencyTable* can be used to define the relationship between efficiency and pack current. Generally, the lower the current, the higher the efficiency and vice versa. The default settings for this table should represent a good starting point but diligent testing and trial and error is needed for the best results.

Charge tracking will never be accurate unless it is started from a known condition. That known condition is a fully charged pack. When the pack is fully charged, charge accumulators are reset and tracking can begin. Monitor the channels *Energy_Accum* and *Energy_Accum_Outing*. These reflect the accumulated energy in Wh since the last full charge and the current outing respectively. An outing is defined as a VCU wake on/off cycle. While discharging, these measurements should increase. While charging, these measurements should decrease. This includes periods of regenerative braking.

In an ideal world, the *Energy_Accum* counter will increase during periods of discharge to some value. When the charge cable is plugged in and the vehicle begins to charge, the counter will decrease and reach exactly zero at the exact point at which the pack is fully charged. This is rarely the case. However, backend VCU logic will not allow this counter to cross over and accumulate negative energy. It will always be clipped very close to zero. To optimize the tracking, monitor this behavior during charging cycles and adjust the *BatteryEfficiencyTable* until the *Energy_Accum* counter reaches zero as close as possible to the fully charged threshold. ***This will require trial and error.***

Once the energy accumulation settings are optimized, the VCU/BMS should be able to estimate the vehicle's range or distance remaining. See the Range Estimation 105 section for more information.

Energy Consumption Rates

Energy consumption rate data is calculated on a per trip (or outing) basis as well as a long-term value that is learned over time. A trip odometer value is used to calculate the short-term value. Total vehicle accumulated miles, or total odometer data is used for the long term learned consumption rate algorithm. Once enough long-term driving data is accumulated, the short-term data can be compared to see how well the vehicle is currently performing relative to the long-term data.

Options
VehTripOdoMin_Consumption: The minimum distance that must be driven before the short-term energy consumption rate data is updated; when any trip is started, the vehicle will always use a very high amount of energy to go a relatively short distance

VehicleMovingThreshold: Minimum speed above which the vehicle is considered to be moving

Channels
VehTripOdo: Distance traveled during the current outing or trip; is measured during the current VCU wake cycle

VehicleOdometer: Total distance traveled; odometer data is reset if the VCU firmware is upgraded

EnergyConsRate_LT: Long term energy consumption rate in Wh/mile; this data is a rolling average that is learned over time

PackConsumptionRate_Outing_Avg: Short term or outing-based energy consumption rate in Wh/mile

Range Estimation
Estimated range data is determined based on several different sources. When energy consumption rate data is not available, a user calibration table is used by default. This table defines the range based on pack temperature and state of charge. Once energy consumption rate data is available, the range is determined based on either short- or long-term energy consumption data combined with a pack usable capacity ratio.

Table
Range_SOC_Cal_Table: User calibration table for range vs state of charge and pack temperature; table data will be used as default when energy consumption rate data is unavailable.

Options
PackUsableCapacityRatio: Percentage of total pack capacity available for estimating range
RangeConsumption_Type: Option for using either long-term or short-term consumption rate data for determining range

Channel
DistanceRemainingEst: Estimated remaining range

The Range Estimation Process
Once the energy accumulation settings are optimized, the VCU/BMS should be able to estimate the vehicle's range or distance remaining. Keep in mind that this is an estimate and should never be relied upon in critical situations. Use the calibration option *PackUsableCapacityRatio* to define a fraction of the pack's capacity available for range estimation. A value of 0.85 means you are allowing 85% of the total capacity for estimating range.

The option *RangeConsumption_Type* can be used to choose what type of consumption rate data to use for the range estimation. The options are Short Term or Long Term. Short Term consumption rate data can be tracked by monitoring the channel *EnergyConsRate_ST*. Long Term energy consumption rate data can be tracked by monitoring the channel *EnergyConsRate_LT*. The short term data resets for every outing. The long term data is learned over time and represents an average. AEM recommends using the long term data as the reference for range estimation.

When no learned data is available, the calibration table *Range_SOC_Cal_Table* will be used as a default. This table allows the calibrator to define a range estimate to define a range estimate as a function of SOC and pack temperature. Monitor the channel *DistanceRemainingEst* for the current range estimation.

State of Charge

Battery state of charge (SOC) cannot be directly measured. Many methods exist to estimate state of charge. The AEM BMS system relies on a hybrid method that combines energy accumulation, or Coulomb counting, with user calibration data. The Coulomb counting method measures the discharging current of a battery and integrates the discharging current over time in order to estimate SOC. This method alone works well but the data may diverge over time due to pack current measurement errors or slight offsets very close to zero amps. The hybrid method employs a user defined calibration table that allows direct SOC data entry versus pack temperature and the minimum pack open circuit voltage. The values from direct Coulomb counting measurement are combined with the entries in this table using a weighted averaging algorithm. This way, depending on the application requirements, the calibrator can decide whether to prioritize OCV measurements, Coulomb counting measurements or a combination of both.

Tables

PackSOC_KFactor: 1 x 6 table of weight factor data as a function of minimum cell open circuit voltage. Used to merge energy accumulated state of charge data with user calibration table data. This is a value between 0 and 1. The higher the value, the more weight is applied to the user calibration table data. The lower the value, the more weight is applied to the energy accumulated state of charge data.

SOC_Cal_Table: 6 x 6 table of user state of charge data versus minimum cell open circuit voltage and pack temperature. This data is also used by default when no energy accumulation data is available.

Channels

BattPackSOC: Masks either *PackSOC_Final* from AEM BMS-18 or *Pack_SOC* from Orion BMS to be the observed pack SOC based on value of table *ItemSelect_BMS*

PackSOCEst: Pack state of charge based purely on energy accumulation data.

PackSOC_Final: Weighted-averaged, estimated State of Charge (SOC). *PackSOC_Final* = (*SOC_Cal_Table***PackSOC_KFactor*)+((1-*PackSoc_KFactor*)**PackSOCEst*)

Cell Balancing

To minimize heat generation in the BMS modules, the 18 cell balancing circuits have been broken into three thermal regions. No more than 1 cell from each region can be balanced at one time. Each Module can balance up to 3 cells at once. The regions are cells 1-5, cells 6-11, and cells 12-18 for each group. In addition, cells 5 and 6 will never be balanced at the same time since the balancing resistors are physically near each other. A cell will never be balanced if its voltage is less than the *PackCellAvg* value. Balancing is only allowed during a charging cycle. VCU features ensure the system honors these limitations. Once cells are selected for balancing, they will be balanced for a 60 second cycle time. After that, the system will reset and select a new group of cells to balance.

Options

BalCellVoltThreshHi: Cell voltage must be over this value to allow balancing

BalanceCmdCal: User calibration to enable/disable balancing

Channels

BMSM1_GXX_Balancing_CXX: If equal to 1, the cell is currently balancing

M1GXX_TZ1MaxCell: Thermal zone 1 max cell index

M1GXX_TZ1MaxCellVal: Thermal zone 1 max cell value

M1GXX_TZ2MaxCell: Thermal zone 2 max cell index

M1GXX_TZ2MaxCellVal: Thermal zone 2 max cell value

M1GXX_TZ3MaxCell: Thermal zone 3 max cell index

M1GXX_TZ3MaxCellVal: Thermal zone 3 max cell value

On Board Charger Support

CAN data from supported OBC and combo OBC/DCDC nodes is captured and processed by the VCU. The health and temperature states are continuously analyzed. If any parameter is abnormal or outside allowed limits, charging will be stopped or prevented from starting.

Options

Charger_TempLimit: Reported OBC on board temperature must be below this threshold to allow charge control functionality

DCDC_TempLimit: Reported DCDC on board temperature must be below this threshold to allow control functionality

DCDC_Enable: Used to Enable or Disable DCDC logic control

DCDCStateChkBypass: Can be used to bypass reported DCDC health state signals. ***Use with caution***

DCDC_CurrentLimit: Reported DCDC current must be below this threshold to allow control functionality

Channels

OBC_State_OK: Will indicate Yes when no fault flags are reported, otherwise will indicate No

OBC_Temp_OK: Will indicate Yes when reported charger on board temp is below the *Charger_TempLimit*, otherwise will indicate No

DCDC_State_OK: Will indicate Yes when no fault flags are reported, otherwise will indicate No

DCDC_Temp_OK: Will indicate Yes when reported charger on board temp is below the *DCDC_TempLimit*, otherwise will indicate No

DCDC_Current_OK: Will indicate Yes when reported charger current is below the *DCDC_CurrentLimit*, otherwise will indicate No

ChargePwrHold: When Enabled, this flag indicates the VCU power sequencing is being managed by the charging logic

DCDCPwrHold: When Enabled, this flag indicates the VCU power sequencing is being managed by the charging logic

Charge Management

The first step in charge management is determining the state of the J1772 plug or simply the “J plug”. The AEM BMS-18 Master module transmits the J1772 Proximity Voltage to the VCU. This signal is arbitrated and used to identify the J plug state. Once the J plug state is determined, this signal is combined with others to determine if the charging process should be allowed to commence.

Options

PackVoltage_FullyCharged: Sets the final pack voltage target to achieve while charging

FullChargedRangeDelta: Adjustment to account for certain on-board chargers that automatically reduce charging current near the setpoint; reduces *PackVoltage_FullyCharged* by the value set; high pack voltage threshold reported as channel PackChargeRefHi

PackVoltage_ChargeResetDelta: Defines a low pack voltage threshold to give charge allowed hysteresis; low pack voltage threshold reported as channel *PackChargeRefLo*

ChargeCurrTarget: Sets an override charge current value; final charging current is the minimum value of ChargeCurrTarget and tables CP_ChargeCurrLookup & *ChargeTargetTable*

PackChargingCellOverVoltLim: Sets the cell voltage high threshold to disable charging; if any individual cell exceeds this value, charging will be stopped

PackChargingCellUnderVoltLim: Sets the cell voltage low threshold to enable charging; if any individual cell is below this value, charging will not be enabled

ChargeRestTime: Defines the period of time for the system to pause/rest once the target charging voltage has been achieved and charging has stopped; charging will re-enable once timer expires

ChargeShutDownDelay: Defines the period of time for the system to pause once the target charging voltage has been achieved and charging has stopped; the charge process will completely stop once timer expires

ChargeTopBalance: Setting to allow automatic and continual pack charging "top off"; if enabled charging process will cycle and repeat each time charging is stopped after achieving target charge voltage; if disabled charging process will stop after achieving target charge voltage

Tables

CP_ChargeCurrLookup: 1 x 6 table of charge current versus CP Duty %; allows for the automatic detection of off-board charger current limitations

ChargeTargetTable: 7 x 7 table that provides the option of varying the charge current versus both pack voltage and pack temperature

Channels

J1772ProxState: Reports the current status of the J plug; will be Undefined, Disconnected, Proximity or Locked

CState1: Reports the OBC health and temperature states; will be 1 when OBC State is OK for charging otherwise will be 0

CState2: Currently reserved for future use; defaults to 1

CState3: Reports that the VCU Operating State is OK for charging; will be 1 if true otherwise will be 0; channel *OpState* must be 0, 1 or 14 to allow charging

CState4: Reports state of channel *PackChargeState_Full*; will be 1 if state is Yes otherwise will be 0; see options above for settings to adjust *PackChargeState_Full* conditions

CState5: Reports state of option *PackChargingCellOverVoltLim* condition threshold; will be 1 when there are no individual cell voltages above the limit otherwise will be 0

CState6: Reports state of option *PackChargingCellUnderVoltLim* condition threshold; will be 1 when there are no individual cell voltages below the limit otherwise will be 0

CState7: Reports state of pack thermal mode; will be 1 if pack thermal mode is Normal otherwise will be 0; channel *PackThermMode* must be Normal to allow charging

CState8: Reports state of J1772 Pilot Duty value to allow charging; will be 1 if Control Pilot Duty Cycle is within the normal range otherwise will be 0; VCU will inhibit charging is J plug is connected but offboard charger is disabled

PackChargeRefHi: Indicates the upper pack voltage charge threshold range; threshold set by option *PackVoltage_FullyCharged* minus option *FullyChargedRangeDelta*

PackChargeRefLo: Indicates the lower pack voltage charge threshold range; threshold set by channel *PackChargeRefHi* minus option *PackVoltage_ChargeResetDelta*

PackChargeState_Full: Indicates pack charge state; will be Yes when pack voltage >*PackChargeRefHi* and will be No when pack voltage <*PackChargeRefLo*; when Yes, resets the energy accumulation counter to zero

ChargingAllowed: If all charge allowed criteria is met, will be 1 otherwise will be 0

ChargingState: Indicates charging state as Off, On or Rest; will be Off if charging inhibited, On if charging active and Rest if charging is resting based on option *ChargeRestTime* once target voltage has been reached and charging has stopped

ChargeSum_Total: Reports the total accumulated charge in Amp Hours; will increase when discharging and decrease when charging; is adjusted by the *BatteryEfficiency* value

ChargeTime_Hours/Minutes: Reports the estimated time to charge completion based on *ChargeSum_Total* Amp Hour value and live pack current Amp value; *ChargeSum_Total [Ah]/PackCurrent [A] = ChargeTime_Hours + ChargeTime_Minutes*

The Charging Process

When the J1772 plug is connected, the charging process is initiated. If all State criteria above are met, the measurement channel *ChargingAllowed* will toggle to 1. The basic charging sequence is outline below:

1. Delay as pack load is checked and the VCU ensures the cell voltages are stable. After this check, all individual cell open circuit voltages are sampled.
2. EVSE Enable command is sent to the off-board charger. This will connect AC line voltage to the on-board charger.
3. VCU ensures the Pilot Duty Cycle is within the proper range.
4. Charging command is sent to the on-board charger along with target voltage and current. The charging current target is determined by finding the minimum from the following calibration sources:

- *CP_ChargeCurrLookup* - table
- *ChargeTargetTable* - table
- *ChargeCurrTarget* - option

5. Delay as the VCU waits for the charging current to stabilize. After this check, all individual cell resistances are calculated.
6. Charging will stop when the target voltage is reached. The measurement channel *ChargingState* will transition from On to Rest. The system will rest for a period of time defined by the calibration option *ChargeRestTime*. Once the *ChargeRestTime* timer expires, charging will begin again. *ChargingState* will transition from Rest to On. This cycle will continue indefinitely if the calibration option *ChargeTopBalance* is enabled. If *ChargeTopBalance* is disabled, the charging process will shut down after the *ChargeShutDownDelay* timer expires.

Detect System Faults

For additional troubleshooting information, please see the BMS Troubleshooting Guide.

Fault	Meaning	Calibration Options
BMS_FS_M1GXX_ExtThermX_InputHi	External thermistor resistance too high	*ExtTherm_FaultHi_Thresh* *ExtTherm_FaultTime_Thresh*
BMS_FS_M1GXX_ExtThermX_InputLo	External thermistor resistance too low	*ExtTherm_FaultLo_Thresh* *ExtTherm_FaultTime_Thresh*
BMS_FS_M1GXX_PCBThermX_InputHi	Internal thermistor resistance too high	*PCBTherm_FaultHi_Thresh* *PCBTherm_FaultTime_Thresh*
BMS_FS_M1GXX_PCBThermX_InputLo	Internal thermistor resistance too low	*PCBTherm_FaultLo_Thresh* *PCBTherm_FaultTime_Thresh*

BMS_FS_M1GXX_MinCellResFault *M1GX_CellRMinIdxDat*	Cell resistance too low …IdxDat will display which cell is currently faulted	*PackCellUnderResLim*
BMS_FS_M1GXX_MaxCellResFault *M1GX_CellRMaxIdxDat*	Cell resistance too high …IdxDat will display which cell is currently faulted	*PackCellOverResLim*
BMS_FS_M1GXX_MinCellVoltsFault *M1GX_MinIdxDat*	Cell voltage too low …IdxDat will display which cell is currently faulted	*CellUnderVoltFaultLim*
BMS_FS_M1GXX_MaxCellVoltsFault *M1GX_MaxIdxDat*	Cell voltage too high …IdxDat will display which cell is currently faulted	*CellOverVoltFaultLim*
BMS_FS_M1_SummaryFault	Internal fault detected by BMS Master	N/A
BMS_FS_M1_NumGroupsMismatchFault	Number of groups found does not match the number of enabled groups	*BMSM1GXEnable*
BMS_FS_BMS_12V_Supply_Fault	VCU measured 12 volt bus voltage below the fault threshold	*LVBusMinThresh*
BMS_FS_BMS_CAN_Fault	VCU to BMS Master CAN timeout exceeded	*MSG_0x01DD1000MsgTimeoutThr*
BMS_FS_PackCurrLEM_InputHi	Low range sensor input too high	*PackCurrLEM_Hi_Thresh* *PackCurrLEM_Hi_Time_Thresh*
BMS_FS_PackCurrLEM_InputLo	Low range sensor input too low	*PackCurrLEM_Lo_Thresh* *PackCurrLEM_Lo_Time_Thresh*
BMS_FS_PackCurrLEM_InputHi	High range sensor input too high	*PackCurrLEM1_Hi_Thresh* *PackCurrLEM1_Hi_Time_Thresh*
BMS_FS_PackCurrLEM_InputLo	High range sensor input too low	*PackCurrLEM1_Lo_Thresh* *PackCurrLEM1_Lo_Time_Thresh*
BMS_FS_ChargerFault	Fault state detected and reported by on board charger	N/A
BMS_FS_DCDCFault	Fault state detected and reported by DCDC	N/A
BMS_FS_MaxPackTempFault	Maximum pack temperature as measured by external thermistors above threshold	*PackTempFaultMax*

Control Modes

OpState

The VCU operates as a state machine with specific status indicators for the startup and shutdown process. Safety logic inhibits transitions from one state to another unless certain conditions are true. The following list of channel values is very helpful for troubleshooting unexpected behavior.

Channels

Opstate: VCU startup and shutdown state:

1 = VCU Off

2 = Waiting for Ignition Switch

3 = PreCharge
4 = HV Increase Check
5 = Main Closed
6 = PreCharge Complete
7 = Discharge
8 = PreCharge Fault
9 = Contactors Open

Drive Mode

Drive mode arbitration logic exists for safety. A transition from park to any other drive mode is not allowed unless the brake pedal is depressed and detected by the brake switch input. Charge plug detection will also inhibit transitions between park and other drive modes.

Options
Spd_ZeroThr: Vehicle speed must be below this value to allow transition to park

Spd_LoThr: Vehicle speed must be below this value to allow transition between neutral, drive and reverse

Channels
ChargePlugConnected: Charge plug detection state
Drive_Mode_State: Final state of the drive mode arbitration logic

Start Safe

Start Safe arbitration logic exists for safety. Before a non-zero torque command is allowed, certain criteria must be met. Once State Safe is true, the driver may select DriveMode 1 (reverse) or 3 (drive) and non-zero torque commands can be sent to the inverter.

Options
APPStartSafeHiThresh: Maximum allowed pedal position for transition to run mode

APPStartSafeLoThresh: Minimum allowed pedal position for transition to run mode

Channels
Start_Safe: Will be 1 when all following criteria are met:

AccelPedal must be in *APPStartSafe* threshold window

BrakeSwitch must be 1

Torque Control

One of the main functions of a vehicle control unit is to provide a torque control request to the inverter over CAN. Generally, inverters or motor controllers have their own built in safety limits. These are defined for each applicable motor type and they are established during the complex process of motor calibration. Motor calibration is not the same as VCU torque request calibration. Motor calibration data is defined in the inverter control software and establishes much lower level control parameters. VCU torque request calibration is a much higher level task. The VCU calibrator uses the tools available in the VCU calibration software to define options and tables that result in a torque request at different operating conditions. This torque request is sent to the inverter over CAN. If the resultant signal is within the torque control limits of the inverter, it will be allowed and used for control.

The VCU has three primary levels or tiers of torque control (as well as some additional secondary controls). The first tier is to establish a base torque command based on the motors available torque per rpm and voltage per accelerator pedal position. This first torque command is checked against a max torque command limit or cap. The second tier is to control or limit the torque commands rate of change or how quickly (or slowly) a change in the torque command is allowed to occur. The third tier is to then apply a decreasing multiplier to “derate” the motors output based on some other condition.

The VCU treats motoring (motor consuming current and creating torque to propel the vehicle) torque control as positive or the high or “hi” torque command. Generating (motor creating current and absorbing torque for regenerative braking) torque control is treated as negative or the low or “lo” torque command.

Important torque command channels to monitor:

Motor1_TqLimMultHi: High torque (motoring) limit derate multiplier; values range from 0-1.00; 1.00 means no derating, 0.90 means a 10% reduction, etc., applied to *Motor1_TqLimHi*

Motor1_TqLimHi: Resultant motoring torque limit based on the active high torque limit multiplier value

Motor1_TqLimMultLo: Low torque (generating) limit derate multiplier; values range from 0-1.00; 1.00 means no derating, 0.90 means a 10% reduction, etc., applied to *Motor1_TqLimMultLo*

Motor1_TqLimLo: Resultant generating torque limit based on the active low torque limit multiplier value

Motor1_Torque_Request: The final torque command that is actively sent to the inverter; motoring torque commands are positive and generating torque commands are negative

Base Torque Command

Motoring and Generating

The first step in the torque control process is to establish a base motor torque command before applying any primary torque command caps, torque command rate of change limits or torque command derate multipliers. Additional torque command requests exist for specific drive modes such as creep and reverse.

Tables

Motor1TorqueTrimTable: Placeholder for eventual torque vectoring algorithms. The x-axis is motor speed. A value of 1.00 in this table is no change. A value of 0.50 in this table would cut the Base Torque Request in half

Maps

Motor1TorqueTable: The main table for defining the base motor performance characteristics. The x-axis is motor speed. The y-axis is inverter DC voltage and the table units are Nm. This information is typically provided by the motor manufacturer

PedalTorqueMultTableX: Commonly referred to as the pedal map; map is a percent multiplier vs motor speed on the x-axis and accelerator pedal position on the y-axis. ***Both positive and negative numbers are possible which allows for basic control of regenerative braking from within the same table***. There are four of these tables available where the X in the table name is 1 -4. Each table corresponds to a different Performance Level. The Performance Level driver input is selectable using the AEM CAN keypad.

Channels

Motor1TorqueTableOut: Raw torque request target from *Motor1TorqueTable*

PedalTqMult: Final pedal multiplier. Actual table output depends on Performance Level Selection

How quickly the motoring torque command is allowed to change is set by the Torque Command Rate of Change Limits 114

Creep and Reverse

The VCU has a user selectable creep mode that allows the vehicle to "creep" forward slowly after releasing the brake from a stop without applying the accelerator pedal similar to how an ICE vehicle with automatic transmission operates. There is also a separate torque request control based on accelerator pedal position when in reverse.

Options

CreepModeAllowed: User enable for creep mode

CreepModeAPPThresh: Maximum accelerator pedal position to allow creep mode

Tables

Motor1CreepTorqueTable: Motor torque request based on vehicle speed when creep mode is active; overrides the current base motoring torque command

CreepModeVehSpdThresh: Vehicle speed thresholds for creep mode; left cell sets off above setting and right cell sets on below setting to give hysteresis

Motor1ReverseTorqueTable: Motor torque request based on accelerator pedal position when the reverse drive direction is active; overrides the current base motoring torque command

How quickly the creep or reverse torque command is allowed to change is set by the Torque Command Rate of Change Limits 114

Regenerative Braking

The *PedalTorqueMultTable* map allows for both positive and negative values which allows for basic control of regenerative braking from within the same table. In most cases controlling both motoring and generating torque commands from the main pedal map is sufficient but there is an additional optional generating torque control function.

Options

RegenAllowedCal: User enable to make optional regen braking function active

BrakingTqAxisSelect: Selectable y-axis input for the *RegenBrakeTorqueMap*; maybe either brake pressure or manual regen lever position

BrakeSwRegenReq: Sets if brake switch is required for regen brake torque command to be active

RegenPedalThreshold: Sets maximum accelerator pedal position threshold for regen brake torque command to be active

RegenVSSThreshold: Sets minimum vehicle speed threshold for regen brake torque command to be active

Tables

Motor1_TrqLimMultpSpeed: 1x2 table gives hysteresis motor speed threshold to force regen torque to zero when below; left cell sets off above speed (regen torque allowed) and right cell sets on below speed (regen torque forced to zero)

Maps

RegenBrakeTorqueMap: Optional table for fine tuning the regenerative braking feature. The x-axis is motor speed and the y-axis is selectable from either Brake Pressure or the Manual Regen Lever input using option *BrakingTqAxisSelect*. Certain activation criteria must be true for this table to work:

1. Vehicle Speed must be greater than the calibration option RegenVSSThreshold
2. If the calibration option BrakeSwRegenReq is set to Yes, the Brake Switch input must be triggered
3. The Accelerator Pedal Position must be less than the calibration option RegenPedalThreshold

4. The calibration option RegenAllowedCal must be set to Enabled

Channels
RegenBrakeTorqueMap_Output: The active regen torque command from the *RegenBrakeTorqueMap* in Nm

Brake Throttle Override

Optional safety feature that disables the torque request command if the accelerator pedal is above a certain threshold for a certain time while the brake pedal is depressed.

Options
BTO_Enabled: Yes = enabled, No = not enabled

BTO_APPThr: APP% threshold above which the function is active. This is a 1 x 2 table with hysteresis thresholds. If the APP% is above this value, the function is enabled. The left most setting is the on above threshold and the right most setting is the off below threshold.

BTO_APP_Hi_Time_Thr: APP% must be above the threshold for this amount of time in milliseconds before latching on.

Channels
BTO_APP_Hi_Time: Time in milliseconds that the APP% is above the threshold

BTO_State: State of control output. When on, the MotorTorqueRequest will be overriden to 0.0 Nm.

Torque Command Rate of Change Limits

The VCU's live torque command value is very dynamic and actively changing and with an electric motors capability of making large amounts of torque in less then one motor shaft revolution, the result can be an undesired roughness to the vehicle operation. To combat this, the VCU has user adjustable torque request rate of change limiters for both increasing and decreasing torque requests that allows for fine tuning of the torque delivery rate.

Torque Rate Limits - Performance Level

One user tunable aspect of the Performance Level function is having the capability of having different motor torque request rate of change limits per Performance Level selection (1-4).

Tables
MtrTrqReqLimIncTblX: 1x5 table that sets the increasing motor torque command rate of change limit in Nm/sec based on vehicle speed; setting all tables to the same values will effectively "disable" this feature and will ensure that the torque command rate of change limit does not change regardless of the active Performance Level selection

MtrTrqReqLimDecTblX: 1x5 table that sets the decreasing motor torque command rate of change limit in Nm/sec based on vehicle speed; setting all tables to the same values will effectively "disable" this feature and will ensure that the torque command rate of change limit does not change regardless of the active Performance Level selection
Where X = 1, 2, 3 or 4 depending on the active Performance Level selection

The Performance Level function is always active even if an AEM CAN keypad is not being used. Check channel Performance_Level to verify the active Performance Level selection.

Torque Rate Limits - Creep and Reverse

Creep and reverse both use the same torque command rate of change limit values.

Tables

MtrTqReqLimIncTbl_RC: 1x5 table that sets the increasing motor torque command rate of change limit in Nm/sec based on vehicle speed when creep or reverse are active

MtrTqReqLimDecTbl_RC: 1x5 table that sets the decreasing motor torque command rate of change limit in Nm/sec based on vehicle speed when creep or reverse are active

Torque Limits

Once a base torque command value has been made, which represents the highest possible torque request that can be made in any one instance, the torque request value is checked against several limits or caps. Some limits are based on user selection for simple on-the-fly changes in motor torque output while others are based on other operating conditions to decrease or derate the motors performance as a safety factor.

Torque Limits - Derate Multipliers

Dynamic torque limiters provide safety as well as performance optimization. All multipliers are compared and the ***minimum value is always chosen***. Derate multipliers either apply to the motoring/positive/high torque limit or the generating/negative/low torque limit. Generally, a value of 1.00 in a *TrqLimMultp* table means no change, 0.90 is a 10% reduction, 0.75 is a 25% reduction, etc. The motor rev limit function is also applied as a variable multiplier that's applied or ramped in over time.

Tables – High Torque Limit Multiplier

MtrTrqLimMultpBattSOCLoTbl: 1x7 table sets maximum allowed motoring torque command based on battery state of charge

MtrTrqLimMultpPackVoltageTbl: 1x7 table sets maximum allowed motoring torque command based on battery voltage

MtrTrqLimMultpCellVoltMinTbl: 1x7 table sets maximum allowed motoring torque command based on battery's lowest single cell voltage

MtrTrqLimMultpPackTempHiTbl: 1x7 table sets maximum allowed motoring torque command based on battery temperature when temps are high

MtrTrqLimMultpPackTempLoTbl: 1x7 table sets maximum allowed motoring torque command based on battery temperature when temps are low

MtrTrqLimMultpVehSpdHi: 1x7 table sets maximum allowed motoring torque command based on vehicle speed

Inverter1_TrqLimMultpTempTbl: 1x7 table sets maximum motoring allowed torque command based on the reported inverter temperature

Motor1_TrqLimMultpTempTbl: 1x7 table sets maximum motoring allowed torque command based on the reported motor temperature

Tables – Low Torque Limit Multiplier

MtrTrqLimMultpBattSOCHiTbl: 1x7 table sets maximum allowed generating torque command based on battery state of charge

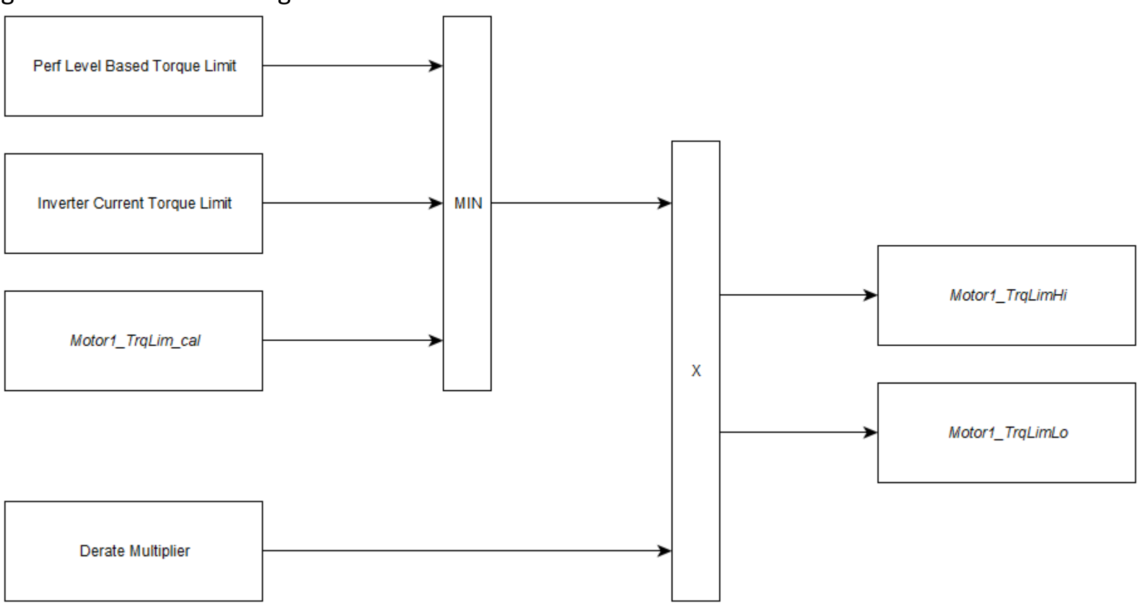
MtrTrqLimMultpCellVoltMaxTbl: 1x7 table sets maximum allowed generating torque command based on battery's highest single cell voltage

MtrTrqLimMultpVehSpdLo: 1x7 table sets maximum allowed generating torque command based on vehicle speed

Most derate tables have two channels associated with them: a status channel and a table value channel. The status channel reports that any single derate is active whenever its live table values is <1.00. This is a handy and quick indicator of whether any derate functions are currently active.

Channels
LimMultBattSOCHi_Active
LimMultBattSOCLo_Active
LimMultPackVoltage_Active
LimMultCellVoltMax_Active
LimMultCellVoltMin_Active
LimMultPackTempHi_Active
LimMultPackTempLo_Active
LimMultVehSpdHi_Active
LimMultVehSpdLo_Active
MtrTrqLimMultpBattSOCHi
MtrTrqLimMultpBattSOCLo
MtrTrqLimMultpPackVoltage
MtrTrqLimMultpCellVoltMax
MtrTrqLimMultpCellVoltMin
MtrTrqLimMultpPackTempHi
MtrTrqLimMultpPackTempLo
MtrTrqLimMultpVehSpdHi
MtrTrqLimMultpVehSpdLo

The following diagram summarizes the logic flow:



Motor Rev Limit
The VCU can apply a rev limit to prevent over speeding the motor or to limit the speed of the vehicle. The rev limiter function has two different operation types however only the ramping rev limit feature should be used with the Tesla's AC induction motors.

Options
MotorRevLimitCntrl: Set to **RampLimit** for all Tesla AC induction motors

MotorRevLimit: Sets the desired maximum motor speed to limit to

MotorRevLimitWindow: Sets the rpm threshold where the rev limit function starts to activate

RevLimMultRampRate: Sets the rate at which the rev limit derate multiplier is ramped in; a higher value will ramp in the derate multiplier more quickly and a lower value will ramp in more slowly

RevLimMultRampMax: Sets the maximum derate factor that the rev limit derate multiplier is allowed to ramp to; a lower value means larger torque reduction factor can be applied

Torque Limits - Inverter Current Limiting

The VCU has an inverter current limit ramp function that can reduce the inverter's motoring torque command to limit DC current draw in accordance with an observed Discharge Current Limit (DCL). The observed DCL may come from one of two sources: either as an internal calculation in the VCU itself if using an AEM BMS-18 or externally communicated over CAN from a third party BMS such as an Orion BMS 2. The inverter current limit ramp function becomes active anytime the inverter's reported DC current draw is greater than the live DCL value. There are optional current limit overrides that allow the user to supplant a calculated limit with user settable limits as a "backstop" should erroneous current limit values ever be calculated.

Channels

PackDCL: The VCU's calculated discharge current limit based on pack/cell data provided by the AEM BMS-18.

Pack_DCL: The discharge current limit transmitted to the VCU by an Orion BMS.

BattPackDCL: Masks either *PackDCL* or *Pack_DCL* to be the observed DCL based on value of table *ItemSelect_BMS*; gets compared to option *BattDCL_cal* and the lower value becomes the final DCL

Pack_DCLim: The final pack discharge current limit

The live battery pack discharge current limit is reported as *Pack_DCLim*. With no correction for any additional current draw from HV accessories (DCDC, HV heater, HV A/C compressor, etc) and no current limit override values applied, the VCU's inverter current limit ramp function will reduce the inverter's motoring torque command anytime inverter DC current > *Pack_DCLim*.

Options

Inverter1_CurLimRampMultTarget: Sets the torque reduction multiplier target used when inverter current limit ramp function is active; a value of **0.5** has shown to work well

Inverter1_CurLimRampRate: Sets the change in ramp multiplier per internal loop time; a value of **0.001** has shown to work well

The inverter current limit ramp function reduces the inverter's motoring torque command by applying the option *Inverter1_CurLimRampMultiTarget* to the *Motor1_TqHiLimHi* value. This is a multiplier value that should be a number less than 1 in order to reduce the maximum allowed motoring torque command. The current limit is applied progressively or "ramped" in based on the option *Inverter1_CurLimMultiRampRate*. A higher *Inverter1_CurLimMultiRampRate* value will ramp in the derate multiplier more quickly and a lower value will ramp in more slowly. When the inverter current limit ramp function is no longer actively limiting, the derate multiplier will be ramped back out to a value of 1 at the same ramp rate.

Options

Inverter1_MCL_cal: User calibration for inverter motoring current limit in Amps

Channels

Inverter1_MCL: Final inverter motoring current limit; reports the lower of (*Pack_DCLim-HVAccCur*) and *Inverter1_MCL_cal*

The inverter current limit ramp function becomes active anytime inverter DC current is greater than the value of channel *Inverter1_MCL*. The *Inverter1_MCL* channel will report the lower value of either the "net" DC current available to the inverter for motoring based on *Pack_DCLim* minus additional current draw from HV accessories (DCDC, HV heater, HV A/C compressor, etc) or the override option *Inverter1_MCL_cal*. The override is useful in the case where HV accessory load may not be accurately reported and a lower inverter motoring current limit is desired.

Options
Inverter1_RampCurLimCal: User calibration for maximum allowed inverter DC current; compares this value to channel *Inverter1_MCL* and applies the lower as the current limit

The current limit ramp function itself has its own current limit override option. The value from channel *Inverter1_MCL* is compared to option *Inverter1_RampCurLimCal* and the lower value becomes the threshold for activating the inverter current limit ramp function. This override is useful in the case where a known inverter current limit is desired regardless of the observed discharge current limit.

Option
BattDCL_cal: User calibration for battery discharge current limit; compares this value to channel *BattPackDCL* and applies the lower as the battery's discharge current limit

The observed battery pack discharge current limit (The VCU's calculated long-term battery pack discharge limit) can be supplanted with a lower current limit using override option *BattDCL_cal*. The lower value between channel *BattPackDCL* and the option *BattDCL_cal* is passed through and reported as *Pack_DCLim*. This override is useful in the case where a lower known battery discharge current limit is desired regardless of what the observed discharge current limit might be. When using the BMS-18, the VCU's long term calculated DCL based on cell OCV will typically start out at values much higher than a pack's realistic DCL. It is important to have a reasonable *BattDCL_cal* value as this will be the more "instantaneous" DCL applied until *PackDCL* decreases to be less than *BattDCL_cal* as the battery is discharged.

Thermal Management

Fan Control

Tables
FanTempLimit: Hysteresis setpoint table for Cooling Fan 1. The left most value is the on above setting. The right most value is the off below setting.

BatteryFan_TempLimit: Hysteresis setpoint table for Cooling Fan 2. The left most value is the on above setting. The right most value is the off below setting.

Channels
Fan1_State: State of Cooling Fan 1 control output

Fan2_State: State of Cooling Fan 2 control output

Fan1ReferenceTemp: Calculated maximum value between inverter 1 and 2 reported temperatures and Coolant Temp 1 and 2 inputs.

Fan2ReferenceTemp: Battery pack maximum calculated temperature

Tuning Tips
1. **Fan1 is typically used for drive system cooling**
2. **Fan2 is typically used for battery system cooling**

Pump Control

Options

CoolPump1TempReference: Selection to use either DriveTemp or PackTemp as the reference temperature.

Tables

CoolingPump1SpeedTarget: Pump 1 target speed as a function of temperature

CoolingPump2SpeedTarget: Pump 2 target speed as a function of temperature

Channels

CoolingPump1Req: Cooling pump 1 request. This will be high if IgnSwState is high, or BMSM1J1772EVSEEnable is high, or DCDC_Cmd is high, or if PackThermMode is 1 or 2.

CoolingPump2Req: Cooling pump 2 request. This will be high if IgnSwState is high.

Tuning Tips

1. **Cooling Pump 1 can be used for either drive system or battery system cooling**
2. **Cooling Pump 2 is typically used for drive system cooling only**

PWM Control

The following outputs are user configurable for PWM control. They include a flyback diode to 12v power.

Output	Pin	Limits
LSO1	A-87	6A / 10 Khz max, 1Hz min
LSO3	B-73	6A / 10 Khz max, 1Hz min
LSO4	B-75	6A / 10 Khz max, 1Hz min
LSO13	A-79	6A / 10 Khz max, 1Hz min
LSO14	A-78	6A / 10 Khz max, 1Hz min
LSO19	B-64	6A / 10 Khz max, 1Hz min

Options

LSOX_DutyMax: Maximum allowed PWM duty cycle. X = LSO number from table above.

LSOX_DutyMin: Minimum allowed PWM duty cycle. X = LSO number from table above.

LSOX_FrequencyTarget: Target PWM control frequency. X = LSO number from table above.

LSOX_Enable: Enable option for each PWM LS output.

LSOX_CmdSelect: Select desired LSOX_DutyTarget table axis input from Fan1Temp, Fan2Temp, Pump1Temp, Pump2Temp.

Tables

LSOX_DutyTarget: Target duty cycle as a function of the table input.

Phone (8am-5pm M-F PST): 310-484-2322
Fax: 310-484-0152
sales@aemev.com
tech@aemev.com

Additional Vehicle Integration

This section covers some additional vehicle integration information that may be pertinent to a user's particular vehicle application. This information is based on the setup of AEM EV's R&D test and development vehicle, a 2007 Ford Mustang GT with a Tesla LDU rear subframe grafted into the car's chassis. Following these guidelines will allow a user to implement these systems in the same way that was validated by AEM.

Parking Brake Control

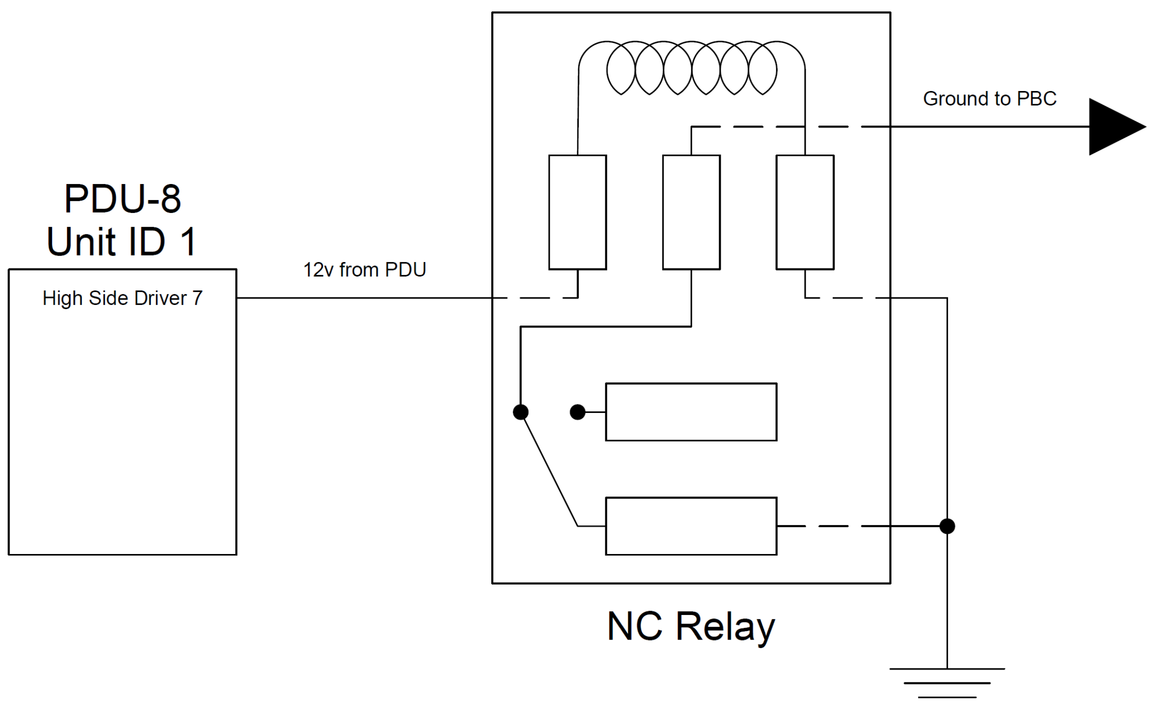
The VCU includes a parking brake control feature when combined with the AEM PDU-8. It will automatically toggle the output when the driver selects the Park Drive Mode. For use with Pantera Electronics hand lever type EBP that uses ground switch in when park brake is set on. Normally closed relay to ground is required to use PDU highside output to trigger - see schematic below.

Options

ParkBrakeLogicPolarity: Used to invert the control logic

Channels

ParkBrakeCntrl: State of the control output



Power Steering

An electric hydraulic power steering pump works well for keeping and using an already existing hydraulic power assist steering system. Electric power steering pumps from Ford/Mazda/Volvo work well. Donor vehicle applications include Mazda 3 & 5, Volvo C30, C70 & S40 and some European Ford cars.

The pump has high current, direct to 12v battery power and ground connections – protect with an appropriately sized fuse or breaker. There is also a low current connector that has a 12v pump-on logic trigger pin. This pin is trigged by a PDU output that turns on when the ignition state is active. Because the pump's turn on pin doesn't supply any circuit loading, the pins voltage will "float" when the PDU output is off therefore a pull down resistor must be used to force the pins voltage down to 0v when the PDU output is off. Use a ¼ watt rated 4.3kOhm resistor.

VCU Faults

Fault	AEMCal Measurement Name	Description	Associated Calibration Options
Brake Vacuum Pressure Input High	Fault_BrakeVac_InputHi	Voltage input exceeds high threshold	*BrakeVac_Hi_Thresh* *BrakeVac_Hi_Time_Thresh*
Brake Vacuum Pressure Input Low	Fault_BrakeVac_InputLo	Voltage input exceeds low threshold	*BrakeVac_Lo_Thresh* *BrakeVac_Lo_time_Thresh*
Brake Pressure Input High	Fault_Brk_Press_InputHi	Voltage input exceeds high threshold	*BrkPress_Hi_Thresh* *BrkPress_Hi_Time_Thresh*
Brake Pressure Input Low	Fault_Brk_Press_InputLo	Voltage input exceeds low threshold	*BrkPress_Lo_Thresh* *BrkPress_Lo_Time_Thresh*
AC Pressure Input High	Fault_ACPress_InputHi	Voltage input exceeds high threshold	*ACPress_Hi_Thresh* *ACPress_Hi_Time_Thresh*
AC Pressure Input Low	Fault_ACPress_InputLo	Voltage input exceeds low threshold	*ACPress_Lo_Thresh* *ACPress_Lo_Time_Thresh*
AC Evap Temp Input High	Fault_ACEvapTemp_InputHi	Resistance input exceeds high threshold	*ACEvapTemp_Hi_Thresh* *ACEvapTemp_Hi_Time_Thresh*
AC Evap Temp Input Low	Fault_ACEvapTemp_InputLo	Resistance input exceeds low threshold	*ACEvapTemp_Lo_Thresh* *ACEvapTemp_Lo_Time_Thresh*
Ambient Temp Input Low	Fault_AmbientTemp_InputHi	Resistance input exceeds high threshold	*AmbientTemp_Hi_Thresh* *AmbientTemp_Hi_Time_Thresh*
Ambient Temp Input High	Fault_AmbientTemp_InputLo	Resistance input exceeds low threshold	*AmbientTemp_Lo_Thresh* *AmbientTemp_Lo_Time_Thresh*
Manual Regen 1 Input High	Fault_Manual_Regen1_InputHi	Voltage input exceeds high threshold	*ManualRegen1_Hi_Thresh* *ManualRegen1_Hi_Time_Thresh*
Manual Regen 1 Input Low	Fault_Manual_Regen1_InputLo	Voltage input exceeds low threshold	*ManualRegen1_Lo_Thresh* *ManualRegen1_Lo_Time_Thresh*
Manual Regen 1 Spike	Fault_Manual_Regen1_Spike	Maximum allowable speed change per second exceeded. If voltage changes too quickly too many times, it is assumed to be a wiring or sensor fault	*ManualRegen1_VoltageSpikeThresh* *ManualRegen1_SpikeMax*
Manual Regen 2 Input High	Fault_Manual_Regen2_InputHi	Voltage input exceeds high threshold	*ManualRegen2_Hi_Thresh* *ManualRegen2_Hi_Time_Thresh*
Manual Regen 2 Input Low	Fault_Manual_Regen2_InputLo	Voltage input exceeds low threshold	*ManualRegen2_Lo_Thresh* *ManualRegen2_Lo_Time_Thresh*
Manual Regen 2 Spike	Fault_Manual_Regen2_Spike	Maximum allowable speed change per second exceeded. If voltage changes too quickly too many times, it is assumed to be a wiring or sensor fault	*ManualRegen2_VoltageSpikeThresh* *ManualRegen2_SpikeMax*
Regen Lever Cross Check	Fault_Regen_LeverXChk	Difference between signal1 and signal2 exceeds the max threshold	*RegenLeverXChkThr*
Transmission Temp Input High	Fault_Trans_Temp_InputHi	Resistance input exceeds high threshold	*TransTemp_Lo_Thresh* *TransTemp_Lo_Time_Thresh*
Transmission Temp Input Low	Fault_Trans_Temp_InputLo	Resistance input exceeds low threshold	*TransTemp_Hi_Thresh* *TransTemp_Hi_Time_Thresh*
Inverter 1 Contactor	Fault_MC1_Contactor	Fault will set if: 1. Inverter voltage is detected after the negative contactor closes and before the pre-charge contactor closes	*ContTimeThr* *Inverter1_HVDetectPartialThr* *Bus_Pack_Voltage_Max_Precharge_Delta* *Inverter1_PreChgDeltaVThresh*

Fault	AEMCal Measurement Name	Description	Associated Calibration Options
		2. Inverter voltage does not increase above the partial threshold within a certain period of time after the pre-charge contactor closes 3. Inverter voltage does not satisfy the pre-charge DC bus voltage delta V threshold	
Accelerator Pedal Position Cross Check	Fault_AccelPedal_XCheck	Difference between signal1 and signal2 exceeds the max threshold	*APPXCheckThreshold*
Coolant Temp1 Input High	Fault_Cool_Temp1_InputHi	Resistance input exceeds high threshold	*CoolTemp1_Hi_Thresh* *CoolTemp1_Time_Thresh*
Coolant Temp1 Input Low	Fault_Cool_Temp1_InputLo	Resistance input exceeds low threshold	*CoolTemp1_Lo_Thresh* *CoolTemp1_Lo_Time_Thresh*
Coolant Temp2 Input High	Fault_Cool_Temp2_InputHi	Resistance input exceeds high threshold	*CoolTemp2_Hi_Thresh* *CoolTemp2_Time_Thresh*
Coolant Temp2 Input Low	Fault_Cool_Temp2_InputLo	Resistance input exceeds low threshold	*CoolTemp2_Lo_Thresh* *CoolTemp2_Lo_Time_Thresh*
Accelerator Pedal Position1 Input High	Fault_AccPedal1_InputHi	Voltage input exceeds high threshold	*APP1_Hi_Thresh* *APP1_Hi_Time_Thresh*
Accelerator Pedal Position1 Input Low	Fault_AccPedal1_InputLo	Voltage input exceeds low threshold	*APP1_Lo_Thresh* *APP1_Lo_Time_Thresh*
Accelerator Pedal Position1 Spike	Fault_AccPedal1_Spike	Maximum allowable speed change per second exceeded. If voltage changes too quickly too many times, it is assumed to be a wiring or sensor fault	*APP1_VoltageSpikeThresh* *APP1_SpikeMax*
Accelerator Pedal Position2 Input High	Fault_AccPedal2_InputHi	Voltage input exceeds high threshold	*APP2_Hi_Thresh* *APP2_Hi_Time_Thresh*
Accelerator Pedal Position2 Input Low	Fault_AccPedal2_InputLo	Voltage input exceeds low threshold	*APP2_Lo_Thresh* *APP2_Lo_Time_Thresh*
Accelerator Pedal Position2 Spike	Fault_AccPedal2_Spike	Maximum allowable speed change per second exceeded. If voltage changes too quickly too many times, it is assumed to be a wiring or sensor fault	*APP2_VoltageSpikeThresh* *APP2_SpikeMax*
IMD State Fault	Fault_IMD	Insulation Monitoring Device is indicating an insulation fault, time delay threshold is set too low, or detection polarity is inverted	
PDU8 #1 Channel 1 Faulted	Fault_PDM1_Ch1 PDM1ErrorStatus01	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_1_Channel1_CurrentAllowed*
PDU8 #1 Channel 2 Faulted	Fault_PDM1_Ch2 PDM1ErrorStatus02	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_1_Channel2_CurrentAllowed*
PDU8 #1 Channel 3 Faulted	Fault_PDM1_Ch3 PDM1ErrorStatus03	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_1_Channel3_CurrentAllowed*
PDU8 #1 Channel 4 Faulted	Fault_PDM1_Ch4 PDM1ErrorStatus04	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_1_Channel4_CurrentAllowed*
PDU8 #1 Channel 5 Faulted	Fault_PDM1_Ch5 PDM1ErrorStatus05	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_1_Channel5_CurrentAllowed*
PDU8 #1 Channel 6 Faulted	Fault_PDM1_Ch6	Open Circuit, ErrorStatus = 1	*PDU8_1_Channel6_CurrentAllowed*

Fault	AEMCal Measurement Name	Description	Associated Calibration Options
	PDM1ErrorStatus06	Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	
PDU8 #1 Channel 7 Faulted	Fault_PDM1_Ch7 PDM1ErrorStatus07	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_1_Channel7_CurrentAllowed*
PDU8 #1 Channel 8 Faulted	Fault_PDM1_Ch8 PDM1ErrorStatus08	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_1_Channel8_CurrentAllowed*
PDU8 #2 Channel 1 Faulted	Fault_PDM2_Ch1 PDM2ErrorStatus01	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_2_Channel1_CurrentAllowed*
PDU8 #2 Channel 2 Faulted	Fault_PDM2_Ch2 PDM2ErrorStatus02	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_2_Channel2_CurrentAllowed*
PDU8 #2 Channel 3 Faulted	Fault_PDM2_Ch3 PDM2ErrorStatus03	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_2_Channel3_CurrentAllowed*
PDU8 #2 Channel 4 Faulted	Fault_PDM2_Ch4 PDM2ErrorStatus04	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_2_Channel4_CurrentAllowed*
PDU8 #2 Channel 5 Faulted	Fault_PDM2_Ch5 PDM2ErrorStatus05	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_2_Channel5_CurrentAllowed*
PDU8 #2 Channel 6 Faulted	Fault_PDM2_Ch6 PDM2ErrorStatus06	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_2_Channel6_CurrentAllowed*
PDU8 #2 Channel 7 Faulted	Fault_PDM2_Ch7 PDM2ErrorStatus07	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_2_Channel7_CurrentAllowed*
PDU8 #2 Channel 8 Faulted	Fault_PDM2_Ch8 PDM2ErrorStatus08	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_2_Channel8_CurrentAllowed*
PDU8 #3 Channel 1 Faulted	Fault_PDM3_Ch1 PDM3ErrorStatus01	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_3_Channel1_CurrentAllowed*
PDU8 #3 Channel 2 Faulted	Fault_PDM3_Ch2 PDM3ErrorStatus02	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_3_Channel2_CurrentAllowed*
PDU8 #3 Channel 3 Faulted	Fault_PDM3_Ch3 PDM3ErrorStatus03	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_3_Channel3_CurrentAllowed*
PDU8 #3 Channel 4 Faulted	Fault_PDM3_Ch4 PDM3ErrorStatus04	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_3_Channel4_CurrentAllowed*
PDU8 #3 Channel 5 Faulted	Fault_PDM3_Ch5 PDM3ErrorStatus05	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_3_Channel5_CurrentAllowed*
PDU8 #3 Channel 6 Faulted	Fault_PDM3_Ch6 PDM3ErrorStatus06	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_3_Channel6_CurrentAllowed*
PDU8 #3 Channel 7 Faulted	Fault_PDM3_Ch7 PDM3ErrorStatus07	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_3_Channel7_CurrentAllowed*

Fault	AEMCal Measurement Name	Description	Associated Calibration Options
PDU8 #3 Channel 8 Faulted	Fault_PDM3_Ch8 PDM3ErrorStatus08	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_3_Channel8_CurrentAllowed*
PDU8 #4 Channel 1 Faulted	Fault_PDM4_Ch1 PDM4ErrorStatus01	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_4_Channel1_CurrentAllowed*
PDU8 #4 Channel 2 Faulted	Fault_PDM4_Ch2 PDM4ErrorStatus02	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_4_Channel2_CurrentAllowed*
PDU8 #4 Channel 3 Faulted	Fault_PDM4_Ch3 PDM4ErrorStatus03	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_4_Channel3_CurrentAllowed*
PDU8 #4 Channel 4 Faulted	Fault_PDM4_Ch4 PDM4ErrorStatus04	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_4_Channel4_CurrentAllowed*
PDU8 #4 Channel 5 Faulted	Fault_PDM4_Ch5 PDM4ErrorStatus05	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_4_Channel5_CurrentAllowed*
PDU8 #4 Channel 6 Faulted	Fault_PDM4_Ch6 PDM4ErrorStatus06	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_4_Channel6_CurrentAllowed*
PDU8 #4 Channel 7 Faulted	Fault_PDM4_Ch7 PDM4ErrorStatus07	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_4_Channel7_CurrentAllowed*
PDU8 #4 Channel 8 Faulted	Fault_PDM4_Ch8 PDM4ErrorStatus08	Open Circuit, ErrorStatus = 1 Current Limit Exceeded, Error Status = 2 Short Circuit, ErrorStatus = 4	*PDU8_4_Channel8_CurrentAllowed*

CAN3 Data Transmit Protocol

CAN Format

CAN messages are transmitted at 500 kbps. All messages follow big-endian, CAN extended format.

Broadcast Message Definitions

0x2F0A000									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Run_Mode_State	8	2	Unsigned	1	0	0	3	unitless:	0x0 = Standby 0x1 = Indirect Drive 0x2 = Direct Drive
Drive_Mode_State	10	4	Unsigned	1	0	0	15	unitless:	0x0 = Park 0x1 = Reverse 0x2 = Neutral 0x3 = Drive
Run_Time	14	10	Unsigned	0.1	0	0	102.3	time:s	Hi Res Run Time Counter 0.1 sec resolution Loops at 100 sec
Stop_Command_State	16	1	Unsigned	1	0	0	1	unitless:	Shutdown Stop Command state

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									0x0 = Off 0x1 = On
Start_Command_State	17	1	Unsigned	1	0	0	1	unitless:	Indirect drive Start Command state 0x0 = Off 0x1 = On
OPState	18	6	Unsigned	1	0	0	63	unitless:	0x0 = VCU Off 0x1 = Waiting for Ign Sw 0x2 = Waiting for PreCharge 0x3 = PreCharge 0x4 = HV Increase Check 0x5 = Main Closed 0x6 = PreCharge Complete 0x7 = Discharge 0x8 = PreCharge Fault 0x9 = Contactors Open
MC2DischargeCmd	24	1	Unsigned	1	0	0	1	unitless:	Active Discharge Command (if applicable) 0x0 = Off 0x1 = On
MC1DischargeCmd	25	1	Unsigned	1	0	0	1	unitless:	Active Discharge Command (if applicable) 0x0 = Off 0x1 = On
MCPower	26	1	Unsigned	1	0	0	1	unitless:	Switched 12V Inverter Power 0x0 = Off 0x1 = On
MC4Enable	27	1	Unsigned	1	0	0	1	unitless:	Inverter 4 PWM Enable Command (if applicable) 0x0 = Off 0x1 = On
MC3Enable	28	1	Unsigned	1	0	0	1	unitless:	Inverter 3 PWM Enable Command (if applicable) 0x0 = Off 0x1 = On
MC2Enable	29	1	Unsigned	1	0	0	1	unitless:	Inverter 2 PWM Enable Command (if applicable) 0x0 = Off 0x1 = On
MC1Enable	30	1	Unsigned	1	0	0	1	unitless:	Inverter 1 PWM Enable Command (if applicable)

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									0x0 = Off 0x1 = On
Start_Safe	31	1	Unsigned	1	0	0	1	unitless:	Transition to Drive/Reverse allowed 0x0 = No 0x1 = Yes
MC3ContEnable	32	1	Unsigned	1	0	0	1	unitless:	Inverter 3 Contactors Allowed (if applicable) 0x0 = Off 0x1 = On
MC2ContEnable	33	1	Unsigned	1	0	0	1	unitless:	Inverter 2 Contactors Allowed (if applicable) 0x0 = Off 0x1 = On
MC1ContEnable	34	1	Unsigned	1	0	0	1	unitless:	Inverter 1 Contactors Allowed (if applicable) 0x0 = Off 0x1 = On
PumpCont_XCheck	35	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
HVIL_Charge	36	1	Unsigned	1	0	0	1	unitless:	0x0 = Open 0x1 = Closed
HVIL_Main	37	1	Unsigned	1	0	0	1	unitless:	0x0 = Open 0x1 = Closed
MC4DischargeCmd	38	1	Unsigned	1	0	0	1	unitless:	Active Discharge Command (if applicable) 0x0 = Off 0x1 = On
MC3DischargeCmd	39	1	Unsigned	1	0	0	1	unitless:	Active Discharge Command (if applicable) 0x0 = Off 0x1 = On
MC1_PosFB	40	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
MC1_NegFB	41	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
MC1_HVDetect	42	1	Unsigned	1	0	0	1	unitless:	Inverter 1 HV Detection (if applicable) 0x0 = Off 0x1 = On
MC4_DCVoltageSafeState	43	1	Unsigned	1	0	0	1	unitless:	Inverter 4 high voltage safety threshold (if applicable) 0x0 = Below Threshold 0x1 = Above Threshold
MC3_DCVoltageSafeState	44	1	Unsigned	1	0	0	1	unitless:	Inverter 3 high voltage safety threshold (if

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									applicable) 0x0 = Below Threshold 0x1 = Above Threshold
MC2_DCVoltageSafeState	45	1	Unsigned	1	0	0	1	unitless:	Inverter 2 high voltage safety threshold (if applicable) 0x0 = Below Threshold 0x1 = Above Threshold
MC1_DCVoltageSafeState	46	1	Unsigned	1	0	0	1	unitless:	Inverter 1 high voltage safety threshold (if applicable) 0x0 = Below Threshold 0x1 = Above Threshold
MC4ContEnable	47	1	Unsigned	1	0	0	1	unitless:	Inverter 4 Contactors Allowed (if applicable) 0x0 = Off 0x1 = On
MC3_PosFB	48	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
MC3_NegFB	49	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
MC3_HVDetect	50	1	Unsigned	1	0	0	1	unitless:	Inverter 3 HV Detection (if applicable) 0x0 = Off 0x1 = On
MC2_PreChgFB	51	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
MC2_PosFB	52	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
MC2_NegFB	53	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
MC2_HVDetect	54	1	Unsigned	1	0	0	1	unitless:	Inverter 2 HV Detection (if applicable) 0x0 = Off 0x1 = On
MC1_PreChgFB	55	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
Performance_Level	56	3	Unsigned	1	0	0	7	unitless:	0x1 = Performance Level 1 0x2 = Performance Level 2 0x3 = Performance Level 3 0x4 = Performance Level 4
MC4_PreChgFB	59	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
MC4_PosFB	60	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
MC4_NegFB	61	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
MC4_HVDetect	62	1	Unsigned	1	0	0	1	unitless:	Inverter 4 HV Detection (if applicable) 0x0 = Off

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									0x1 = On
MC3_PreChgFB	63	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
0x2F0A002									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
VCU_12V_Input	0	8	Unsigned	0.1	0	0	25.5	voltage:V	Measured internal VCU battery voltage
MC1_PreChg_Cmd	8	1	Unsigned	1	0	0	1	unitless:	Inverter 1 PreCharge Contactor control command 0x0 = Off 0x1 = On
MC1_Pos_Cmd	9	1	Unsigned	1	0	0	1	unitless:	Inverter 1 Positive Contactor control command 0x0 = Off 0x1 = On
VCU_5V_Output	10	6	Unsigned	0.1	0	0	6.3	voltage:V	Reserved - Not Used
MC4_Pos_Cmd	16	1	Unsigned	1	0	0	1	unitless:	Inverter 4 Positive Contactor control command (if applicable) 0x0 = Off 0x1 = On
MC3_PreChgComplete	17	1	Unsigned	1	0	0	1	unitless:	Inverter 3 PreCharge complete indication (if applicable) 0x0 = No 0x1 = Yes
MC3_PreChg_Cmd	18	1	Unsigned	1	0	0	1	unitless:	Inverter 3 PreCharge Contactor control command (if applicable) 0x0 = Off 0x1 = On
MC3_Pos_Cmd	19	1	Unsigned	1	0	0	1	unitless:	Inverter 4 Positive Contactor control command (if applicable) 0x0 = Off 0x1 = On
MC2_PreChgComplete	20	1	Unsigned	1	0	0	1	unitless:	Inverter 2 PreCharge complete indication (if applicable) 0x0 = No 0x1 = Yes
MC2_PreChg_Cmd	21	1	Unsigned	1	0	0	1	unitless:	Inverter 2 PreCharge Contactor control

									command (if applicable) 0x0 = Off 0x1 = On
MC2_Pos_Cmd	22	1	Unsigned	1	0	0	1	unitless:	Inverter 2 Positive Contactor control command (if applicable) 0x0 = Off 0x1 = On
MC1_PreChgComplete	23	1	Unsigned	1	0	0	1	unitless:	Inverter 1 PreCharge complete indication (if applicable) 0x0 = No 0x1 = Yes
SpeedMode_Allowed	24	1	Unsigned	1	0	0	1	unitless:	Indication that closed loop speed regulation is allowed 0x0 = No 0x1 = Yes
InvControl_Mode	25	1	Unsigned	1	0	0	1	unitless:	Current inverter control mode 0x0 = Torque Mode 0x1 = Speed Mode
Launch_Mode	26	1	Unsigned	1	0	0	1	unitless:	Drag racing launch control features operation state 0x0 = Off 0x1 = On
Burnout_Mode	27	1	Unsigned	1	0	0	1	unitless:	Drag racing burnout control features operation state 0x0 = Off 0x1 = On
Idle_Mode	28	1	Unsigned	1	0	0	1	unitless:	Indirect drive idle control features operation state 0x0 = Off 0x1 = On
Creep_Mode	29	1	Unsigned	1	0	0	1	unitless:	Creep mode operation state 0x0 = Off 0x1 = On
MC4_PreChgComplete	30	1	Unsigned	1	0	0	1	unitless:	Inverter 4 PreCharge complete indication (if applicable) 0x0 = No 0x1 = Yes

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MC4_PreChg_Cmd	31	1	Unsigned	1	0	0	1	unitless:	Inverter 4 PreCharge Contactor control command (if applicable) 0x0 = Off 0x1 = On
LineLock_Cntrl	32	1	Unsigned	1	0	0	1	unitless:	Drag racing line lock control features operation state 0x0 = Off 0x1 = On
TransBrake_Cntrl	33	1	Unsigned	1	0	0	1	unitless:	Drag racing trans brake control features operation state 0x0 = Off 0x1 = On
Cool_Pump_Wake	34	1	Unsigned	1	0	0	1	unitless:	Cooling pump wake control command 0x0 = Off 0x1 = On
Cool_Pump2_Cntrl	35	1	Unsigned	1	0	0	1	unitless:	Cooling pump 2 control command 0x0 = Off 0x1 = On
Cool_Pump1_Cntrl	36	1	Unsigned	1	0	0	1	unitless:	Cooling pump 1 control command 0x0 = Off 0x1 = On
OilPump1_On	37	1	Unsigned	1	0	0	1	unitless:	Oil pump 1 control command 0x0 = Off 0x1 = On
Cool_Fan2_On	38	1	Unsigned	1	0	0	1	unitless:	Cooling fan 2 control command 0x0 = Off 0x1 = On
Cool_Fan1_On	39	1	Unsigned	1	0	0	1	unitless:	Cooling fan 1 control command 0x0 = Off 0x1 = On
Cool_PumpSpdTarget	40	8	Unsigned	25	0	0	6375	angular_speed:rpm	Cooling pump 1 speed target
Brake_LampsCntrl	48	1	Unsigned	1	0	0	1	unitless:	Brake lamps control command 0x0 = Off 0x1 = On

TransBrake_Switch	49	1	Unsigned	1	0	0	1	unitless:	Trans brake switch state 0x0 = Off 0x1 = On
LineLock_Switch	50	1	Unsigned	1	0	0	1	unitless:	Line Lock switch state 0x0 = Off 0x1 = On
Inertia_Switch	51	1	Unsigned	1	0	0	1	unitless:	Inertia switch state 0x0 = Off 0x1 = On Reserved - Not Used
IMDState	52	1	Unsigned	1	0	0	1	unitless:	Insulation Monitor State 0x0 = Ok 0x1 = Fault
ShiftSol_Cntrl	53	1	Unsigned	1	0	0	1	unitless:	Drag racing air shift solenoid control command 0x0 = Off 0x1 = On
Shift_Sol2	54	1	Unsigned	1	0	0	1	unitless:	Drag racing air shift solenoid shift 2 state 0x0 = Off 0x1 = On
Shift_Sol1	55	1	Unsigned	1	0	0	1	unitless:	Drag racing air shift solenoid shift 1 state 0x0 = Off 0x1 = On
Contactors_Enabled	56	1	Unsigned	1	0	0	1	unitless:	0x0 = No 0x1 = Yes Reserved - Not Used
ChargeContactorCntrl	57	1	Unsigned	1	0	0	1	unitless:	0x0 = Off 0x1 = On Reserved - Not Used
Acc_PowerCntrl	58	1	Unsigned	1	0	0	1	unitless:	0x0 = Off 0x1 = On Reserved - Not Used
Acc_LightCntrl	59	1	Unsigned	1	0	0	1	unitless:	0x0 = Off 0x1 = On Reserved - Not Used
ReverseLamps_Cntrl	60	1	Unsigned	1	0	0	1	unitless:	State of Reverse Lamps control command 0x0 = Off 0x1 = On

ParkLamps_Cntrl	61	1	Unsigned	1	0	0	1	unitless:	0x0 = Off 0x1 = On Reserved - Not Used
HVSafetyLight_Cntrl	62	1	Unsigned	1	0	0	1	unitless:	State of HV Safety Light control command 0x0 = Off 0x1 = On
Head_LampsCntrl	63	1	Unsigned	1	0	0	1	unitless:	0x0 = Off 0x1 = On Reserved - Not Used
0x2F0A004									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
LimMult_MC1Temp_Active	0	1	Unsigned	1	0	0	1	unitless:	Active state of Inverter 1 temp limit torque derate 0x0 = No 0x1 = Yes
LimMult_MC1Curr_Active	1	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Launch_Time_Active	2	1	Unsigned	1	0	0	1	unitless:	Active state of time based launch torque derate 0x0 = No 0x1 = Yes
LimMult_DriveShaft_Spd_Active	3	1	Unsigned	1	0	0	1	unitless:	Active state of drive shaft speed based torque derate 0x0 = No 0x1 = Yes
LimMult_CellVolt_Min_Active	4	1	Unsigned	1	0	0	1	unitless:	Active state of min cell volts torque derate 0x0 = No 0x1 = Yes
LimMult_CellVolt_Max_Active	5	1	Unsigned	1	0	0	1	unitless:	Active state of max cell volts torque derate 0x0 = No 0x1 = Yes
LimMult_Batt_SOCLo_Active	6	1	Unsigned	1	0	0	1	unitless:	Active state of Low SOC based torque derate 0x0 = No 0x1 = Yes
LimMult_Batt_DCL_Active	7	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Motor1_Temp_Active	8	1	Unsigned	1	0	0	1	unitless:	Active state of motor 1 temp torque derate 0x0 = No

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									0x1 = Yes
LimMult_Motor1_SpdLo_Active	9	1	Unsigned	1	0	0	1	unitless:	Active state of motor 1 low speed torque derate 0x0 = No 0x1 = Yes
LimMult_MC4Temp_Active	10	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_MC4Curr_Active	11	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_MC3Temp_Active	12	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_MC3Curr_Active	13	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_MC2Temp_Active	14	1	Unsigned	1	0	0	1	unitless:	Active state of Inverter 2 temp limit torque derate 0x0 = No 0x1 = Yes
LimMult_MC2Curr_Active	15	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Pack_Current_Active	16	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Over_rev_Active	17	1	Unsigned	1	0	0	1	unitless:	Active state of Overrev torque derate 0x0 = No 0x1 = Yes
LimMult_Motor4_Temp_Active	18	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Motor4_SpdLo_Active	19	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Motor3_Temp_Active	20	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Motor3_SpdLo_Active	21	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Motor2_Temp_Active	22	1	Unsigned	1	0	0	1	unitless:	Active state of Motor 2 temp limit torque derate 0x0 = No 0x1 = Yes
LimMult_Motor2_SpdLo_Active	23	1	Unsigned	1	0	0	1	unitless:	Active state of motor 2 low speed torque derate 0x0 = No 0x1 = Yes
LimMult_Shift5_Tq_Active	24	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Shift4_Tq_Active	25	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Shift3_Tq_Active	26	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_Shift2_Tq_Active	27	1	Unsigned	1	0	0	1	unitless:	Active state of Shift 2 torque derate 0x0 = No 0x1 = Yes

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LimMult_Shift1_Tq_Active	28	1	Unsigned	1	0	0	1	unitless:	Active state of Shift 1 torque derate 0x0 = No 0x1 = Yes
LimMult_Pack_Voltage_Active	29	1	Unsigned	1	0	0	1	unitless:	Active state of Pack Voltage torque derate 0x0 = No 0x1 = Yes
LimMult_Pack_TempLo_Active	30	1	Unsigned	1	0	0	1	unitless:	Active state of Pack Temp Low torque derate 0x0 = No 0x1 = Yes
LimMult_Pack_TempHi_Active	31	1	Unsigned	1	0	0	1	unitless:	Active state of Pack Temp High torque derate 0x0 = No 0x1 = Yes
LimMult_Batt_SOCHi_Active	32	1	Unsigned	1	0	0	1	unitless:	Active state of High SOC based torque derate 0x0 = No 0x1 = Yes
LaunchTimer_Running	33	1	Unsigned	1	0	0	1	unitless:	Launch Timer running state 0x0 = No 0x1 = Yes
LimMult_MC4CurrRamp_Active	34	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_MC3CurrRamp_Active	35	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
LimMult_MC2CurrRamp_Active	36	1	Unsigned	1	0	0	1	unitless:	Active state of Inverter 2 current ramp torque derate 0x0 = No 0x1 = Yes
LimMult_MC1CurrRamp_Active	37	1	Unsigned	1	0	0	1	unitless:	Active state of Inverter 1 current ramp torque derate 0x0 = No 0x1 = Yes
LimMult_VehSpd_Lo_Active	38	1	Unsigned	1	0	0	1	unitless:	Active state of low vehicle speed torque derate 0x0 = No 0x1 = Yes
LimMult_VehSpd_Hi_Active	39	1	Unsigned	1	0	0	1	unitless:	Active state of high vehicle speed torque derate

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									0x0 = No 0x1 = Yes
LaunchRamp_Time	40	8	Unsigned	0.1	0	0	25.5	time:s	Launch Ramp Time Counter
Run_Time_Counter	56	16	Unsigned	1	0	0	65535	time:s	Low Res Run Time Counter 1.0 sec resolution Loops at 65,500 sec
0x2F0A006									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
AccelPedal	0	8	Unsigned	0.392157	0	0	99.9999993	fraction:%	Arbitrated Accel Pedal %
AccelPedal1	8	8	Unsigned	0.392157	0	0	99.9999993	fraction:%	Accel Pedal 1 %
AccelPedal2	16	8	Unsigned	0.392157	0	0	99.9999993	fraction:%	Accel Pedal 2 %
AccelPedalXCheckDiff	24	8	Unsigned	0.392157	0	0	99.9999993	fraction:%	Accel Pedal 1/2 cross check difference
Start_Switch	32	1	Unsigned	1	0	0	1	unitless:	State of Start Switch input 0x0 = Off 0x1 = On
Ignition_Switch	33	1	Unsigned	1	0	0	1	unitless:	State of Ignition Switch input 0x0 = Off 0x1 = On
Brake_Switch2	34	1	Unsigned	1	0	0	1	unitless:	State of Brake Switch 2 input 0x0 = Off 0x1 = On
Brake_Switch1	35	1	Unsigned	1	0	0	1	unitless:	State of Brake Switch 1 input 0x0 = Off 0x1 = On
Brake_Switch	36	1	Unsigned	1	0	0	1	unitless:	Arbitrated state of Brake Switch 0x0 = Off 0x1 = On
AccelPedal2Valid	37	1	Unsigned	1	0	0	1	unitless:	Validity state of Accel Pedal 2 input 0x0 = No 0x1 = Yes
AccelPedal1Valid	38	1	Unsigned	1	0	0	1	unitless:	Validity state of Accel Pedal 1 input 0x0 = No 0x1 = Yes

Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
AccelPedalValid	39	1	Unsigned	1	0	0	1	unitless:	Validity state of Accel Pedal 0x0 = No 0x1 = Yes
Manual_Regen	40	8	Unsigned	0.392157	0	0	99.9999993	fraction:%	Arbitrated Manual Regen Input %
Manual_Regen1	48	8	Unsigned	0.392157	0	0	99.9999993	fraction:%	Manual Regen 1 Input %
Manual_Regen2	56	8	Unsigned	0.392157	0	0	99.9999993	fraction:%	Manual Regen 2 Input %
0x2F0A008									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
ManRegen_XCheckDiff	0	8	Unsigned	0.392157	0	0	99.9999993	fraction:%	Manual Regen input 1/2 cross check difference
ParkLamp_Switch	8	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
Head_LampSwitch	9	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
Reverse_Switch	10	1	Unsigned	1	0	0	1	unitless:	Logic state of digital reverse switch input 0x0 = Off 0x1 = On
Drive_Switch	11	1	Unsigned	1	0	0	1	unitless:	Logic state of digital drive switch input 0x0 = Off 0x1 = On
Neutral_Switch	12	1	Unsigned	1	0	0	1	unitless:	Logic state of digital neutral switch input 0x0 = Off 0x1 = On
Park_Switch	13	1	Unsigned	1	0	0	1	unitless:	Logic state of digital park switch input 0x0 = Off 0x1 = On
Manual_Regen2Valid	14	1	Unsigned	1	0	0	1	unitless:	Validity state of Manual Regen 2 input 0x0 = No 0x1 = Yes
Manual_Regen1Valid	15	1	Unsigned	1	0	0	1	unitless:	Validity state of Manual Regen 1 input 0x0 = No 0x1 = Yes
Logging_Switch	16	1	Unsigned	1	0	0	1	unitless:	Logic state of digital logging start switch input 0x0 = Off 0x1 = On

Wake_Switch	17	1	Unsigned	1	0	0	1	unitless:	Logic state of the wake switch input 0x0 = Off 0x1 = On
Acc_LightSwitch	18	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
ACSwitch	19	1	Unsigned	1	0	0	1	unitless:	Logic state of digital AC switch input 0x0 = Off 0x1 = On
HeaterSwitch	20	1	Unsigned	1	0	0	1	unitless:	Logic state of digital cabin heat switch input 0x0 = Off 0x1 = On
Cooling_PumpOrdSwitch	21	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
Cooling_FanOrdSwitch	22	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
Enable_Switch	23	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
TC_State	27	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
CCSetCst	28	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
CCRsmAcc	29	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
CCOn	30	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used
CCCancel	31	1	Unsigned	1	0	0	1	unitless:	Reserved - Not Used

0x2F0A012

Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
Brake_Pressure	8	16	Unsigned	0.1	0	0	6553.5	pressure_gauge:psi(g)	Brake Pressure Value
Transmission_Pressure	24	16	Unsigned	0.1	0	0	6553.5	pressure_gauge:psi(g)	Reserved - Not Used
WheelBar_Press1	40	16	Unsigned	0.1	0	0	6553.5	pressure_gauge:psi(g)	Reserved - Not Used
WheelBar_Press2	56	16	Unsigned	0.1	0	0	6553.5	pressure_gauge:psi(g)	Reserved - Not Used

0x2F0A014

Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
Transmission_Temp	0	8	Unsigned	1	-50	-50	205	temperature:C	Transmission Temp Value
Coolant_Temp1	8	8	Signed	1	0	-128	127	temperature:C	Coolant Temp 1 Value
Coolant_Temp2	16	8	Signed	1	0	-128	127	temperature:C	Coolant Temp 2 Value
AmbientAirTemp	24	8	Signed	1	0	-128	127	temperature:C	Ambient Air Temp Value
HeaterInletTemp	32	8	Signed	1	0	-128	127	temperature:C	Reserved - Not Used

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HeaterOutletTemp	40	8	Signed	1	0	-128	127	temperature:C	Reserved - Not Used
ACPressure	56	16	Unsigned	0.1	0	0	6553.5	pressure_gauge:psi(g)	AC Pressure Value
0x2F0A016									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
BrakeVacPressure	0	8	Unsigned	0.14504	-14.696	-14.696	22.2892	pressure_gauge:psi(g)	Brake Vacuum Pressure value
Vehicle_Speed	8	8	Unsigned	1	0	0	255	speed:mph	Vehicle Speed Value
DriveShaft_Speed	24	16	Unsigned	1	0	0	65535	angular_speed:rpm	DriveShaft Speed value
DriveWheel_Speed	32	8	Unsigned	1	0	0	255	speed:mph	Reserved - Not Used
Ground_WheelSpeed	40	8	Unsigned	1	0	0	255	speed:mph	Reserved - Not Used
TC_Slip_Measured	48	8	Unsigned	1	0	0	255	speed:mph	Reserved - Not Used
0x2F0A018									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Vehicle_Odometer	24	32	Unsigned	0.01	0	0	42949672.95	distance:mi	Vehicle odometer value
0x2F0A020									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Motor1_Torque_Request	12	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Motor1 calculated torque request in Nm
Motor1_TqLimHi	16	12	Unsigned	0.5	0	0	2047.5	torque:N.m	Calculated Motor1 High Torque Limit in Nm
Motor1_TqLimLo	36	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Calculated Motor1 Low Torque Limit in Nm
Motor1_TqTable	40	12	Unsigned	0.5	0	0	2047.5	torque:N.m	Current value from Motor1TorqueTable
Motor1_TqLimMultHi	48	8	Unsigned	0.005	0	0	1.275	fraction:frac	Calculated Motor1 High Torque Limit multiplier in Nm
Motor1_TqLimMultLo	56	8	Unsigned	0.005	0	0	1.275	fraction:frac	Calculated Motor1 Low Torque Limit multiplier in Nm
0x2F0A022									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Motor1_CreepTorque	12	12	Unsigned	0.1	0	0	409.5	torque:N.m	Motor1 creep torque value in Nm
Motor1_ReverseTorque	16	12	Unsigned	0.1	0	0	409.5	torque:N.m	Motor1 reverse torque value in Nm
Motor1_TorqueTrimTable	36	12	Signed	0.001	0	-2.048	2.047	fraction:frac	Current value from Motor1TorqueTrimTable
MotorTqSpd_FeedForward	40	12	Unsigned	0.5	0	0	2047.5	torque:N.m	Reserved - Not Used

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PedalTqMult_Tbl1	48	8	Signed	1	0	-128	127	fraction:%	Current value from #1 Pedal Torque Multiplier table
PedalTqMult_Tbl2	56	8	Signed	1	0	-128	127	fraction:%	Current value from #2 Pedal Torque Multiplier table
0x2F0A024									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Motor2_TorqueRequest	12	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Motor2 calculated torque request in Nm
Motor2_TqLimHi	16	12	Unsigned	0.5	0	0	2047.5	torque:N.m	Calculated Motor2 High Torque Limit in Nm
Motor2_TqLimLo	36	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Calculated Motor2 Low Torque Limit in Nm
Motor2_TqTable	40	12	Unsigned	0.5	0	0	2047.5	torque:N.m	Current value from Motor2TorqueTable
Motor2_TqLimMultHi	48	8	Unsigned	0.005	0	0	1.275	fraction:frac	Calculated Motor2 High Torque Limit multiplier in Nm
Motor2_TqLimMultLo	56	8	Unsigned	0.005	0	0	1.275	fraction:frac	Calculated Motor2 Low Torque Limit multiplier in Nm
0x2F0A026									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Motor2_CreepTorque	12	12	Unsigned	0.1	0	0	409.5	torque:N.m	Motor2 creep torque value in Nm
Motor2_ReverseTorque	16	12	Unsigned	0.1	0	0	409.5	torque:N.m	Motor2 reverse torque value in Nm
Motor2_TorqueTrimTable	36	12	Signed	0.001	0	-2.048	2.047	fraction:frac	Current value from Motor2TorqueTrimTable
RegenBrake_Torque	40	12	Unsigned	0.5	0	0	2047.5	torque:N.m	Current value from RegenBrakeTorqueTable
PedalTqMult_Tbl3	48	8	Signed	1	0	-128	127	fraction:%	Current value from #3 Pedal Torque Multiplier table
PedalTqMult_Tbl4	56	8	Signed	1	0	-128	127	fraction:%	Current value from #4 Pedal Torque Multiplier table
0x2F0A028									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Motor3_TorqueRequest	12	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Reserved - Not Used
Motor3_TqLimHi	16	12	Unsigned	0.5	0	0	2047.5	torque:N.m	Reserved - Not Used
Motor3_TqLimLo	36	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Reserved - Not Used
Motor3_TqTable	40	12	Unsigned	0.5	0	0	2047.5	torque:N.m	Reserved - Not Used

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Motor3_TqLimMultHi	48	8	Unsigned	0.005	0	0	1.275	fraction:frac	Reserved - Not Used
Motor3_TqLimMultLo	56	8	Unsigned	0.005	0	0	1.275	fraction:frac	Reserved - Not Used
0x2F0A030									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Motor3_CreepTorque	12	12	Unsigned	0.1	0	0	409.5	torque:N.m	Reserved - Not Used
Motor3_ReverseTorque	16	12	Unsigned	0.1	0	0	409.5	torque:N.m	Reserved - Not Used
Motor3_TorqueTrimTable	36	12	Signed	0.001	0	-2.048	2.047	fraction:frac	Reserved - Not Used
Motor4_TorqueRequest	40	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Reserved - Not Used
0x2F0A032									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Motor4_TqLimHi	12	12	Unsigned	0.5	0	0	2047.5	torque:N.m	Reserved - Not Used
Motor4_TqLimLo	16	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Reserved - Not Used
Motor4_TqTable	36	12	Unsigned	0.5	0	0	2047.5	torque:N.m	Reserved - Not Used
Motor4_CreepTorque	40	12	Unsigned	0.1	0	0	409.5	torque:N.m	Reserved - Not Used
Motor4_TqLimMultHi	48	8	Unsigned	0.005	0	0	1.275	fraction:frac	Reserved - Not Used
Motor4_TqLimMultLo	56	8	Unsigned	0.005	0	0	1.275	fraction:frac	Reserved - Not Used
0x2F0A034									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Motor4_ReverseTorque	12	12	Unsigned	0.1	0	0	409.5	torque:N.m	Reserved - Not Used
Motor4_TorqueTrimTable	16	12	Signed	0.001	0	-2.048	2.047	fraction:frac	Reserved - Not Used
Launch_Torque_Multiplier	24	8	Unsigned	1	0	0	255	fraction:%	Reserved - Not Used
Launch_Torque_Time	32	8	Unsigned	0.1	0	0	25.5	time:s	Reserved - Not Used
LaunchTableSelect	45	3	Unsigned	1	0	0	7	unitless:	Reserved - Not Used
0x2F0A036									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
IdleTarget_Speed	8	16	Unsigned	0.25	0	0	16383.75	angular_speed:rpm	Reserved - Not Used
StartRamp_TargetSpeed	24	16	Unsigned	0.25	0	0	16383.75	angular_speed:rpm	Reserved - Not Used
FreeRevTarget_Speed	40	16	Unsigned	0.25	0	0	16383.75	angular_speed:rpm	Reserved - Not Used
BurnoutTargetSpeed	56	16	Unsigned	0.25	0	0	16383.75	angular_speed:rpm	Reserved - Not Used
0x2F0A038									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
LaunchTarget_Speed	8	16	Unsigned	0.25	0	0	16383.75	angular_speed:rpm	Reserved - Not Used
Motor_TargetSpeed	24	16	Unsigned	0.25	0	0	16383.75	angular_speed:rpm	Reserved - Not Used

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SpeedControl_PID	44	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Reserved - Not Used
SpeedControl_PID_Error	48	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Reserved - Not Used

0x2F0A040

Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
SpeedControl_PID_PTerm	12	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Reserved - Not Used
SpeedControl_PID_ITerm	16	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Reserved - Not Used
SpeedControl_PID_DTerm	36	12	Signed	0.5	0	-1024	1023.5	torque:N.m	Reserved - Not Used

0x2F0A046

Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
Fault_Manual_Regen1_InputHi	0	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_AccPedal2_Spike	1	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_AccPedal2_InputLo	2	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_AccPedal2_InputHi	3	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_AccPedal1_Spike	4	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_AccPedal1_Input_Lo	5	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_AccPedal1_Input_Hi	6	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_AccelPedal_XCheck	7	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_ACEvapTemp_InputLo	8	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_ACEvapTemp_InputHi	9	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Regen_LeverXChk	10	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Manual_Regen2_Spike	11	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Manual_Regen2_InputLo	12	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Manual_Regen2_InputHi	13	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Manual_Regen1_Spike	14	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Manual_Regen1_InputLo	15	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Brk_Press_InputLo	16	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Brk_Press_InputHi	17	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault

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Fault_BrakeVac_InputLo	18	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_BrakeVac_InputHi	19	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_AmbientTemp_InputLo	20	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_AmbientTemp_InputHi	21	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_ACPress_InputLo	22	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_ACPress_InputHi	23	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM1_Ch2	24	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM1_Ch1	25	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Trans_Temp_InputLo	26	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Trans_Temp_InputHi	27	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Cool_Temp2_InputLo	28	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Cool_Temp2_InputHi	29	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Cool_Temp1_InputLo	30	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Cool_Temp1_InputHi	31	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM2_Ch2	32	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM2_Ch1	33	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM1_Ch8	34	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM1_Ch7	35	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM1_Ch6	36	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM1_Ch5	37	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM1_Ch4	38	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM1_Ch3	39	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM3_Ch2	40	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM3_Ch1	41	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM2_Ch8	42	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault

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Fault_PDM2_Ch7	43	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM2_Ch6	44	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM2_Ch5	45	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM2_Ch4	46	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM2_Ch3	47	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM4_Ch2	48	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM4_Ch1	49	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM3_Ch8	50	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM3_Ch7	51	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM3_Ch6	52	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM3_Ch5	53	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM3_Ch4	54	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM3_Ch3	55	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_IMD	56	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_MC1_Contactor	57	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM4_Ch8	58	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM4_Ch7	59	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM4_Ch6	60	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM4_Ch5	61	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM4_Ch4	62	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_PDM4_Ch3	63	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
0x2F0A048									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
DG8_State	0	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
DG7_State	1	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
DG6_State	2	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF

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									0x1 = ON
DG5_State	3	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
DG4_State	4	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
DG3_State	5	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
DG2_State	6	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
DG1_State	7	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN17_State	8	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN16_State	9	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN15_State	10	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN14_State	11	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN13_State	12	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN12_State	13	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN11_State	14	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN10_State	15	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN5_State	16	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN4_State	17	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN3_State	18	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN2_State	19	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN20_State	20	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN1_State	21	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN19_State	22	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN18_State	23	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN9_State	28	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN8_State	29	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN7_State	30	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF 0x1 = ON
AN6_State	31	1	Unsigned	1	0	0	1	unitless:	0x0 = OFF

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Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
									0x1 = ON
0x2F0A050									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
EE_LD_AfterProg	7	1	Unsigned	1	0	0	1	unitless:	= 1 if Loaded Defaults After Programming
EE_LD_ErrReading	6	1	Unsigned	1	0	0	1	unitless:	= 1 if Loaded Defaults - Error Reading EEPROM
EE_LD_IncCRC	5	1	Unsigned	1	0	0	1	unitless:	= 1 if Loaded Defaults - Incorrect CRC value
EE_LD_IncEEFormat	4	1	Unsigned	1	0	0	1	unitless:	= 1 if Loaded Defaults - Incorrect EE Format
EE_LD_Manual	3	1	Unsigned	1	0	0	1	unitless:	= 1 if Loaded Defaults - Manual
EE_LSV_AfterProg	2	1	Unsigned	1	0	0	1	unitless:	= 1 if Loaded Saved Values After Programming
EE_LSV_Backup	1	1	Unsigned	1	0	0	1	unitless:	= 1 if Loaded Saved Values - Backup Copy
EE_LSV_NormStart	0	1	Unsigned	1	0	0	1	unitless:	= 1 if Loaded Saved Values - Normal Startup
EE_StoreFailed	15	1	Unsigned	1	0	0	1	unitless:	= 1 if Store Request Failed
EE_StoreInProgress	14	1	Unsigned	1	0	0	1	unitless:	= 1 if Store in Process
EE_StoreSuccess	13	1	Unsigned	1	0	0	1	unitless:	= 1 if Store Success
LimMult_CoolFlow_Active	12	1	Unsigned	1	0	0	1	unitless:	Torque Limit Multiplier applied - Low Coolant Flow 0x0 = NO 0x1 = Yes
LimMult_TCAccel_Active	11	1	Unsigned	1	0	0	1	unitless:	Torque Limit Multiplier applied - Accel based traction control 0x0 = NO 0x1 = Yes
0x2F0A064									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
BMSM1_G01_CellOCV_Max	8	16	Unsigned	0.0001	0	0	6.5535	voltage:V	Calculated maximum Cell Open Circuit Voltage
BMSM1_G01_CellOCV_Min	24	16	Unsigned	0.0001	0	0	6.5535	voltage:V	Calculated minimum Cell Open Circuit Voltage
OCV_Correction	40	16	Signed	3.00E-05	0	-0.98304	0.98301	fraction:frac	Reserved - Not Used
PackFractionConsumed	48	8	Unsigned	0.005	0	0	1.275	fraction:frac	Fraction of pack energy consumed
0x2F0A068									

Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
SOC_ChargeTarget	0	8	Unsigned	1	0	0	255	fraction:%	Current SOC charge target
MotorSpeed	16	16	Unsigned	1	0	0	65535	angular_speed:rpm	Motor Speed
0x2F0A200									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Pack_CellDelta	8	16	Unsigned	0.0001	0	0	6.5535	voltage:V	Cell voltage difference across entire pack
Pack_CellMax	24	16	Unsigned	0.0001	0	0	6.5535	voltage:V	Pack cell maximum voltage
Pack_CellMin	40	16	Unsigned	0.0001	0	0	6.5535	voltage:V	Pack cell minimum voltage
Pack_Voltage	56	16	Unsigned	0.1	0	0	6553.5	voltage:V	Pack Total Voltage
0x2F0A202									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Pack_CCLim	0	8	Unsigned	1	0	0	255	current:A	Pack Charge Current Limit
PackSOC	8	8	Unsigned	1	0	0	255	frac:%	Pack State of Charge
Pack_Curr	24	16	Signed	0.1	0	-3276.8	3276.7	current:A	Pack Current
Pack_DCLim	40	16	Unsigned	0.1	0	0	6553.5	current:A	Pack Discharge Current Limit
Pack_TempMax	48	8	Signed	1	0	-128	127	temperature:C	Pack maximum temperature
Pack_TempMin	56	8	Signed	1	0	-128	127	temperature:C	Pack minimum temperature
0x2F0A204									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
M1G1_ExtTherm1	0	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G1_ExtTherm2	8	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G1_ExtTherm3	16	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G2_ExtTherm1	24	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G2_ExtTherm2	32	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G2_ExtTherm3	40	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G3_ExtTherm1	48	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G3_ExtTherm2	56	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value

0x2F0A206

Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
M1G3_ExtTherm3	0	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G4_ExtTherm1	8	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G4_ExtTherm2	16	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G4_ExtTherm3	24	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G5_ExtTherm1	32	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G5_ExtTherm2	40	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G5_ExtTherm3	48	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G6_ExtTherm1	56	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value

0x2F0A208

Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
M1G6_ExtTherm2	0	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G6_ExtTherm3	8	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
RangeEstimate	28	12	Unsigned	0.1	0	0	409.5	distance:miles	Estimated range in miles
PackConsumptionRate	44	16	Unsigned	0.01	0	0	655.35	rate:Wh/mile	Stored outing consumption rate
CellBalanceState	51	1	Unsigned	1	0	0	1	unitless:	State of cell balancing process
MilesPerHourCharge	52	8	Unsigned	0.1	0	0	25.5	rate:Miles/Hour	Estimated miles of range gained per hour of charging

0x2F0A209

Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
EnergyConsumedOuting	8	16	Unsigned	0.01	0	0	655.35	energy:kWh	Energy consumed during the current outing
EnergyConsumedTotal	24	16	Unsigned	0.01	0	0	655.35	energy:kWh	Energy consumed since the last charge
EnergyRemaining	40	16	Unsigned	0.01	0	0	655.35	energy:kWh	Energy remaining based on pack capacity and amount consumed
BatteryPower	56	16	Signed	0.1	0	-3276.8	3276.7	power:kW	Battery electrical power

0x2F0A210

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Name	Startbit	Length [Bit]	Value Type	Factor	Offset	Minimum	Maximum	Unit	Comment
Fault_M1G1_Temp_Int	0	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G1_Temp_Ext	1	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G1_CellV_Min	2	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G1_CellV_Max	3	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G1_CellR_Min	4	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G1_CellR_Max	5	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G1_Balance	6	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_12V_Bus	7	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G3_Balance	8	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G2_Temp_Int	9	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G2_Temp_Ext	10	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G2_CellV_Min	11	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G2_CellV_Max	12	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G2_CellR_Min	13	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G2_CellR_Max	14	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G2_Balance	15	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G4_CellR_Max	16	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G4_Balance	17	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G3_Temp_Int	18	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G3_Temp_Ext	19	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G3_CellV_Min	20	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G3_CellV_Max	21	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G3_CellR_Min	22	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G3_CellR_Max	23	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault

Fault_M1G5_CellR_Min	24	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G5_CellR_Max	25	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G5_Balance	26	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G4_Temp_Int	27	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G4_Temp_Ext	28	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G4_CellV_Min	29	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G4_CellV_Max	30	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G4_CellR_Min	31	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G6_CellV_Max	32	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G6_CellR_Min	33	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G6_CellR_Max	34	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G6_Balance	35	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G5_Temp_Int	36	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G5_Temp_Ext	37	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G5_CellV_Min	38	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G5_CellV_Max	39	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_DCDC	40	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_Charger	41	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_BMS_CAN	42	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1_Summary	43	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1_NumGroupsFound	44	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G6_Temp_Int	45	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G6_Temp_Ext	46	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G6_CellV_Min	47	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_BMS_MaxPackTemp	50	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault

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BMS_MIL	51	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_LEM_LowR_InputLo	52	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_LEM_LowR_InputHi	53	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_LEM_HighR_InputLo	54	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_LEM_HighR_InputHi	55	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
BMS_NumFaults	56	8	Unsigned	1	0	0	255	unitless:	Number of detected BMS faults

0x2F0A211									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Fault_M1G8_Balance	0	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G7_Temp_Int	1	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G7_Temp_Ext	2	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G7_CellV_Min	3	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G7_CellV_Max	4	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G7_CellR_Min	5	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G7_CellR_Max	6	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G7_Balance	7	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G9_CellR_Max	8	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G9_Balance	9	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G8_Temp_Int	10	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G8_Temp_Ext	11	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G8_CellV_Min	12	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G8_CellV_Max	13	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G8_CellR_Min	14	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G8_CellR_Max	15	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G10_CellR_Min	16	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G10_CellR_Max	17	1	Unsigned	1	0	0	1	unitless:	0x0 = OK

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									0x1 = Fault
Fault_M1G10_Balance	18	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G9_Temp_Int	19	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G9_Temp_Ext	20	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G9_CellV_Min	21	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G9_CellV_Max	22	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G9_CellR_Min	23	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G11_CellV_Max	24	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G11_CellR_Min	25	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G11_CellR_Max	26	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G11_Balance	27	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G10_Temp_Int	28	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G10_Temp_Ext	29	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G10_CellV_Min	30	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G10_CellV_Max	31	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G12_CellV_Min	32	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G12_CellV_Max	33	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G12_CellR_Min	34	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G12_CellR_Max	35	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G12_Balance	36	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G11_Temp_Int	37	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G11_Temp_Ext	38	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G11_CellV_Min	39	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_MinCellOCV	45	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G12_Temp_Int	46	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G12_Temp_Ext	47	1	Unsigned	1	0	0	1	unitless:	0x0 = OK

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									0x1 = Fault
0x2F0A212									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
ChargingState	4	4	Unsigned	1	0	0	15	unitless:	State of charging process 0x0 = OFF 0x1 = ON 0x2 = Rest
ChargeTimeMinutes	8	6	Unsigned	1	0	0	63	time:minutes	Estimated charge time minutes
ChargeTimeHours	14	6	Unsigned	1	0	0	63	time:hours	Estimated charge time hours
CellRMax	28	12	Unsigned	0.001	0	0	4.095	resistance:Mohm	Estimated maximum pack cell resistance
CellRMin	32	12	Unsigned	0.001	0	0	4.095	resistance:Mohm	Estimated minimum pack cell resistance
PackResistance	52	12	Unsigned	0.1	0	0	409.5	resistance:Mohm	Estimated total pack resistance
0x2F0A214									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
M1G7_ExtTherm1	0	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G7_ExtTherm2	8	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G7_ExtTherm3	16	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G8_ExtTherm1	24	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G8_ExtTherm2	32	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G8_ExtTherm3	40	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G9_ExtTherm1	48	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G9_ExtTherm2	56	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
0x2F0A216									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
M1G9_ExtTherm3	0	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G10_ExtTherm1	8	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G10_ExtTherm2	16	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G10_ExtTherm3	24	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value

M1G11_ExtTherm2	32	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G11_ExtTherm1	40	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G11_ExtTherm3	48	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G12_ExtTherm1	56	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
0x2F0A218									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
M1G12_ExtTherm2	0	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G12_ExtTherm3	8	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G13_ExtTherm1	16	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G13_ExtTherm2	24	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G13_ExtTherm3	32	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G14_ExtTherm1	40	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G14_ExtTherm2	48	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G14_ExtTherm3	56	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
0x2F0A220									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
PackConsumptionRate_ST	8	16	Unsigned	0.01	0	0	655.35	rate:Wh/mile	Trip based energy consumption rate
PackConsumptionRate_LT	24	16	Unsigned	0.01	0	0	655.35	rate:Wh/mile	Long term average energy consumption rate
VehicleTripOdo	40	16	Unsigned	0.1	0	0	6553.5	distance:miles	Mile accumulated during the current outing
AccumCurrentOuting	56	16	Unsigned	0.001	0	0	65.535	energy:Ah	Amp-hours accumulated during the current outing
0x2F0A222									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
Fault_M1G15_CellR_Min	0	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G15_CellR_Max	1	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G14_Temp_Int	2	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault

Fault_M1G14_Temp_Ext	3	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G14_CellV_Min	4	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G14_CellV_Max	5	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G14_CellR_Min	6	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G14_CellR_Max	7	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G16_CellV_Min	8	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G16_CellV_Max	9	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G16_CellR_Min	10	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G16_CellR_Max	11	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G15_Temp_Int	12	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G15_Temp_Ext	13	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G15_CellV_Min	14	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G15_CellV_Max	15	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G13_Temp_Int	16	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G13_Temp_Ext	17	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G13_CellV_Min	18	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G13_CellV_Max	19	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G13_CellR_Min	20	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G13_CellR_Max	21	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G16_Temp_Int	22	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
Fault_M1G16_Temp_Ext	23	1	Unsigned	1	0	0	1	unitless:	0x0 = OK 0x1 = Fault
0x2F0A224									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
M1G15_ExtTherm1	0	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G15_ExtTherm2	8	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value

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M1G15_ExtTherm3	16	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G16_ExtTherm1	24	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G16_ExtTherm2	32	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
M1G16_ExtTherm3	40	8	Signed	1	0	-128	127	temperature:C	Pack temperature sensor value
0x2F0A052									
Name	**Startbit**	**Length [Bit]**	**Value Type**	**Factor**	**Offset**	**Minimum**	**Maximum**	**Unit**	**Comment**
FirmwareMajorVersion	0	8	Unsigned	1	0	0	255	unitless:	Firmware major version
FirmwareMinorVersion	8	8	Unsigned	1	0	0	255	unitless:	Firmware minor version
CalDataVersion	16	8	Unsigned	1	0	0	255	unitless:	User calibration data version

Warranty

AEM Performance Electronics warrants to the consumer that all AEM Electronics products will be free from defects in material and workmanship for a period of twelve months from the date of the original purchase. Products that fail within this 12-month warranty period will be repaired or replaced when determined by us that the product failed due to defects in material or workmanship. This warranty is limited to the repair or replacement of the AEM Electronics part. This warranty applies only to the original purchaser of the product and is non-transferable. All implied warranties shall be limited in duration to the said 12-month warranty period. Improper use or installation, accident, abuse, unauthorized repairs or alterations performed by the user on any AEM Electronics products voids this warranty.

In no event shall this warranty exceed the original purchase price of the AEM Electronics part nor shall AEM Electronics be responsible for special, incidental or consequential damages or cost incurred due to the failure of this product.

AEM Electronics disclaims any liability for consequential damages due to breach of any written or implied warranty on all of its products.

Warranty returns will only be accepted by AEM Electronics when accompanied by a valid Return Merchandise Authorization (RMA) number and a dated proof of purchase. The product must be received by AEM Electronics within 30 days of the date the RMA is issued. Warranty claims to AEM Electronics must be shipped to us prepaid (we recommend a shipping service with package tracking capability). Once your package is received by our warranty and repairs department you will be notified and provided with updates.

PROCEDURES FOR ISSUANCE OF A RETURN MERCHANDISE AUTHORIZATION (RMA) NUMBER

Please note that before AEM Electronics can issue an RMA for any product, it is first necessary for the installer or enduser to contact our technical support team to discuss the problem. Most issues can be resolved over the phone. Under no circumstances should a system be returned, or an RMA requested before our support team is contacted. This will ensure that if an RMA is needed that our team is able to track your product through the warranty process.

You can reach our Tech Support Team for support on all AEM Electronics performance products by phone at 1-800-423-0046. To contact us by email for engine management systems, email us at emstech@aemelectronics.com. For all other products, email us at gen.tech@aemelectronics.com.

AEM Electronics will not be responsible for products that are installed incorrectly, installed in a non-approved application, misused, or tampered with. In the case of AEM Electronics Fuel Pumps, incorrect polarity (+&- wires crossed) will not be warranted. Proper fuel filtration before and after the fuel pump is essential to fuel pump life. Any pump returned with contamination will not be warranted.

PRODUCTS OUTSIDE OF WARRANTY PERIOD

Any AEM Electronics product, excluding discontinued products, can be returned for repair if it is out of the warranty period. There is a minimum charge of $50.00 for inspection and diagnosis of AEM Electronics parts. Parts used in the repair of AEM Electronics components will be extra. AEM Electronics will provide an estimate of repairs and must receive written or electronic authorization from you before repairs are made to a product.