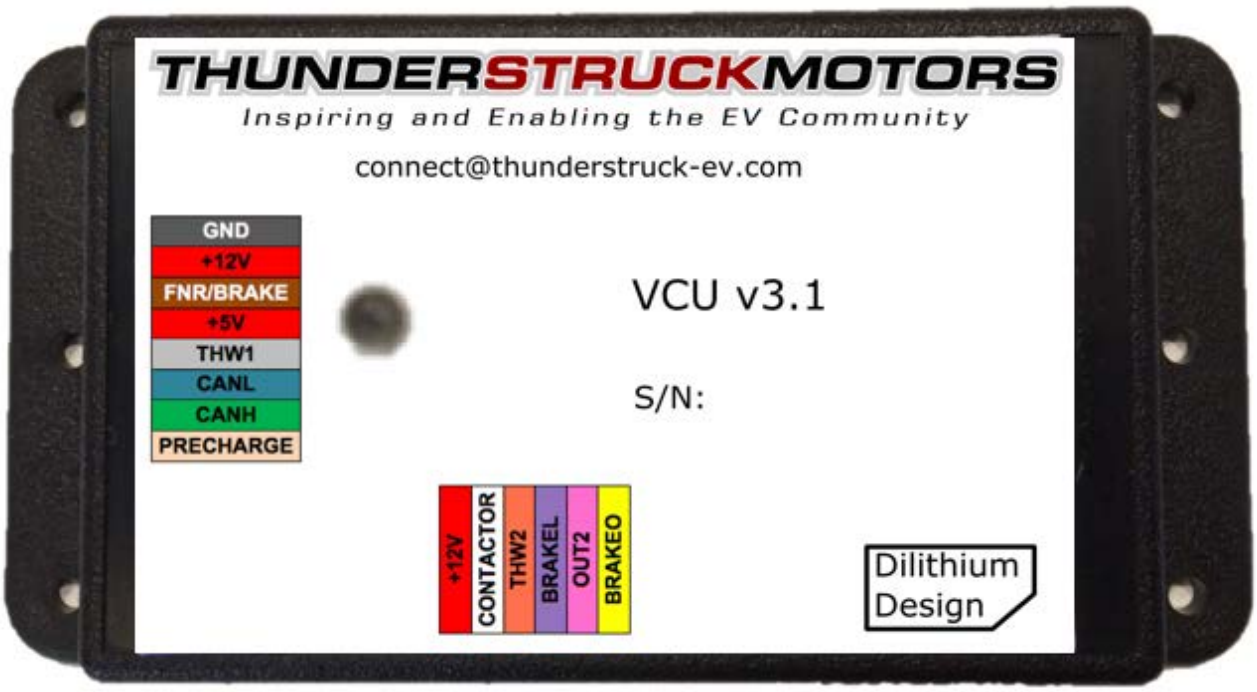
Thunderstruck Motors
Vehicle Control Unit v3.1



Document Revision 3.1.3

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Overview

The Thunderstruck Vehicle Control Unit (VCU) converts analog throttle and brake inputs into CAN messages to control either a first or second generation Nissan Leaf or a UQM PowerPhase® Inverter. This document describes how to install, configure, and troubleshoot the VCU.

This document applies to VCU 3.1 and VCU 3.0 hardware. The firmware for both versions is identical, but VCU 3.1 has a more capable interface to the CONTACTOR and PRECHARGE relays. The VCU 3.0 specific differences are described at the end of this document.

See below for a system diagram.

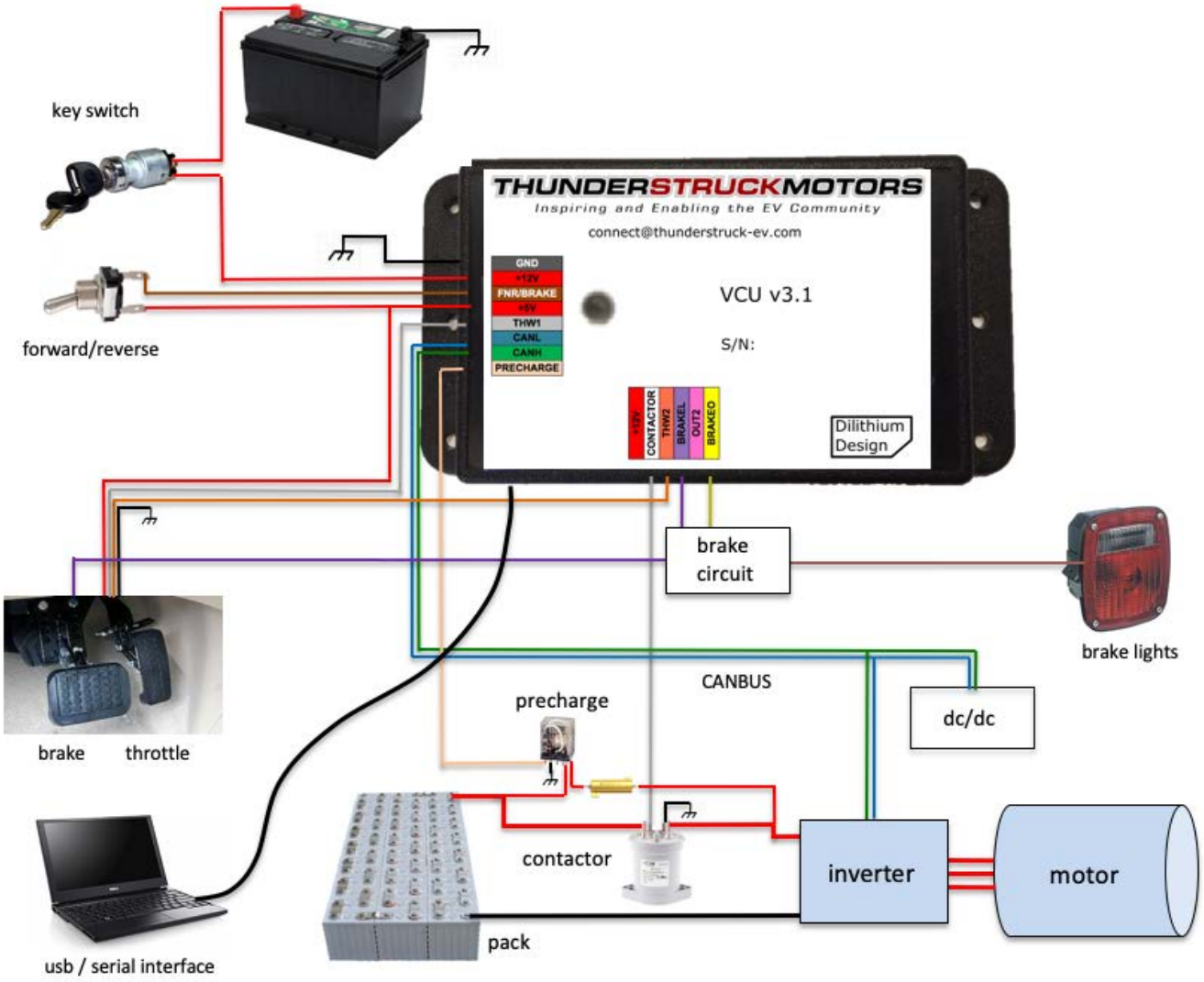


Figure 1 – VCU 3.1 System Diagram

The VCU has the following required interfaces:

- 12V Power, normally connected to an EV accessory battery through the Keyswitch.
- CAN, used to communicate between the VCU and Inverter.
- Throttle, which connects to a Hall or resistive throttle and determines the requested torque.

The VCU has the following optional interfaces:

- Precharge Control to enable a precharge relay.
- Contactor Control to enable the main contactor.
- Forward/Reverse (or Forward/Reverse/Neutral) input, to determine the direction of motor rotation for direct drive systems.
- Brake Switch, to request regeneration when the brake is applied.
- Brake Pressure Transducer, which can request variable amount of regeneration depending on brake pedal pressure.
- Brake Light output to turn the brake light on when there is braking regeneration.
- DC/DC Converter Control, which can control a DC/DC converter.

A serial port interface is used for configuration and debugging, but is not required for normal operation.

Installation and Wiring

Mechanical

The VCU is housed in a Serpac WM010I enclosure, a 4.61 x 2.32 x 0.6 plastic enclosure with mounting flanges. The datasheet can be found at http://www.serpac.com/userprints/wm010i_up_reva.pdf.

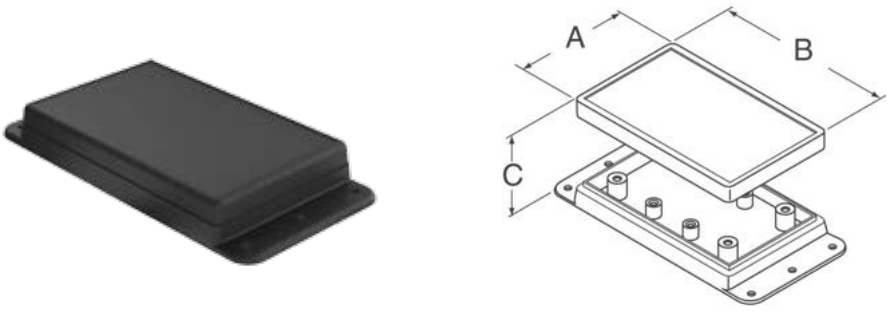


Figure 2 – VCU Enclosure

The enclosure has two connectors: “Connector A” and “Connector B”, a 3.5 mm serial port jack, and an LED. The connectors are “push-in” connectors which accept 20-24 gauge stranded or solid wire; stranded 20 or 22 gauge wire is recommended. To make a connection, strip the wire back 1/4”. Twist the wire end and insert. Be sure that all strands of wire get correctly inserted to prevent shorting between adjacent wires.

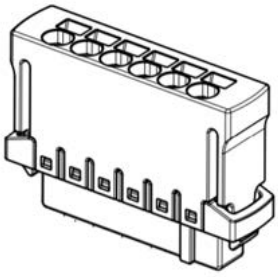


Figure 3 – Push-In Connector

Removing the wire from the connector requires a removal tool, supplied. Insert the tool into the associated slot above the wire and wiggle it in. This will collapse the spring holding the wire and the wire can be removed.

The connector part numbers are

- 8p Connector A Harting 14310813101000
- 6p Connector B Harting 14310613101000

The VCU 3.1 connector pinouts are given below:

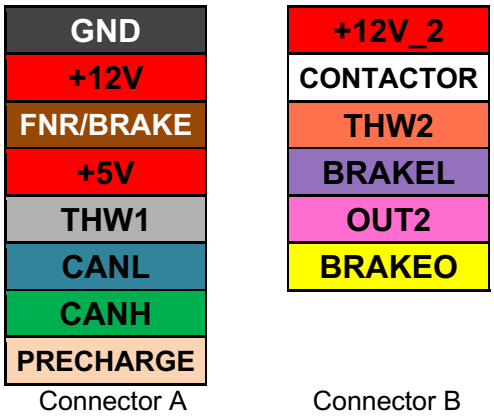


Figure 4 – VCU 3.1 Connections

Power (GND, +12V, +12V_2)

+12V and **GND** are Power Inputs and should be connected to a source of 11V-14V power (12V nominal). These inputs are usually to Keyswitch Input and Chassis Ground. The **+12V_2** input on Connector B supplies current for the contactor.

CANH and CANL

CANH and **CANL** are the CAN connections. At minimum, the CAN network must be connected to both the Inverter and the VCU. Other devices, such as a DC/DC converter, may also share the CAN network, however the CAN baud rate in the V CU is fixed at 500kpbs and all devices must operate at this rate.

A CAN network is a daisy-chain, multistation network. Normal CAN network wiring guidelines should be followed. CAN wiring should be kept short and the conductors should be twisted. Wiring should be placed

away from electromagnetic interference such as the motor, and parallel runs next to EV traction cabling should be avoided.

The CAN network must be terminated on both ends of the string by 120ohm termination resistors. Wiring stubs to non-endpoint nodes should be kept as short as possible, ideally less than a few inches. The VCU contains an internal, configurable, CAN termination resistor. By default, this termination is enabled, however this may be disabled in software.

Throttle (THW1, THW2)

THW1 and **THW2** are throttle wiper inputs. By default, the VCU assumes that a single wiper throttle and only **THW1** is used. Two-wiper throttles are used as a safety feature to prevent a single point of failure. If configured, the VCU firmware requires that the two wipers track each other and provide consistent readings.

A dual wiper throttle is configured with the command "**`set thtype dhall`**". Both throttle outputs have configured high and low settings (**`thw1off, thw1max, thw2off, thw2max`**), which determine the limit values for each wiper.

Hall throttles require power and ground connections to operate. If the throttle uses +5V power, this may be provided by **+5v**. Both **THW1** and **THW2** expect a 0 to 5v input.

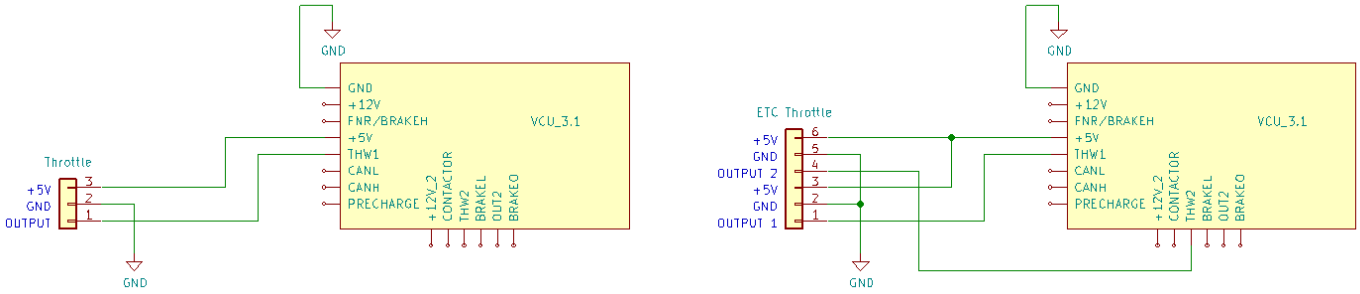


Figure 5 – Single and Dual Wiper Throttle Wiring

PRECHARGE and CONTACTOR

The VCU supports **PRECHARGE** and **CONTACTOR** outputs. The **PRECHARGE** output is switched to +12V when active and is rated to 400ma. The **CONTACTOR** output is switched to +12V and is rated to 1.5A. Note that the current for the main contactor is supplied on the **+12V_2** input, which is connected to a +12V input capable of sourcing enough current for the main contactor. If the main contactor requires more than 1.5A then an additional relay is required. See below for suggested wiring.

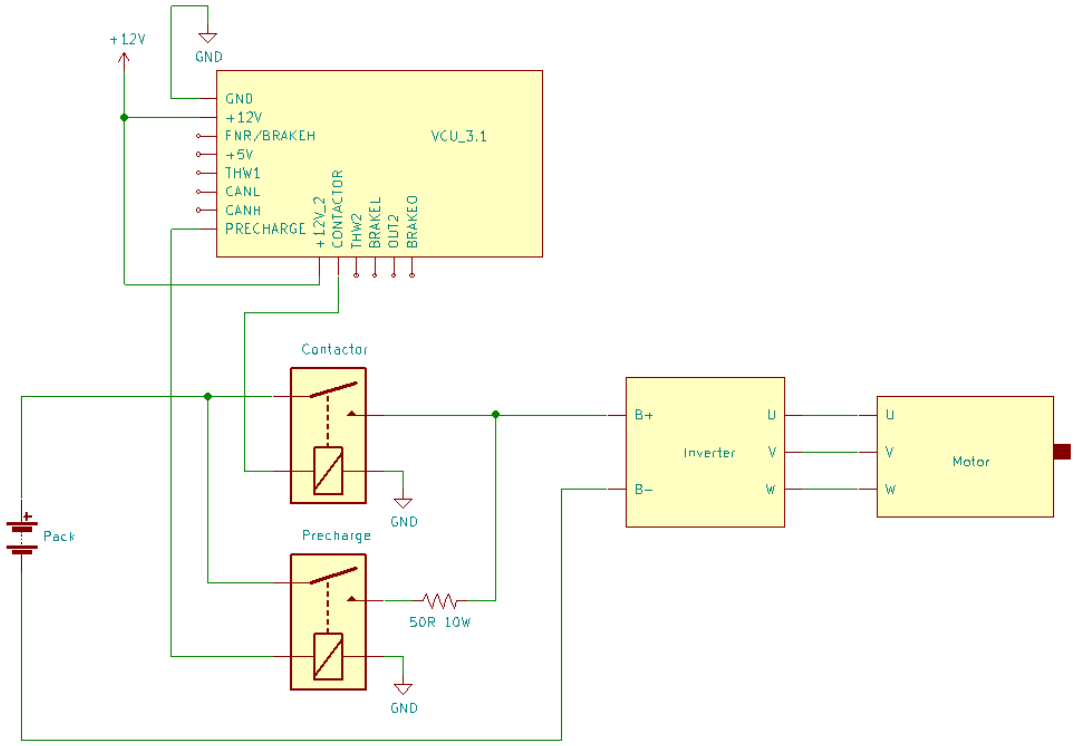


Figure 6 - PRECHARGE and CONTACTOR Wiring

FNR/BRAKE

The **FNR/BRAKE** input can be used as a direction switch (forward/reverse or forward/neutral/reverse), or used as a brake pressure transducer input.

There are two variants of the 3.1 VCU hardware. If the VCU label has the “FNR resistor” marking, then the BRAKE options is not available. The following diagram shows suggested wiring.

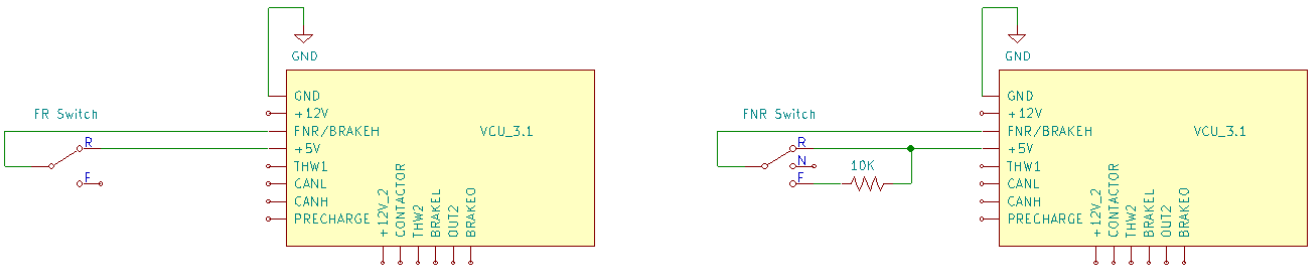


Figure 7 - Direction Switch Wiring (hardware with “FNR resistor” rework)

Non-reworked versions of the VCU can support either FR/FNR or the BRAKE input. See below for how to wire up the non-reworked versions. Note that an additional external resistor is required for FR / FNR operation.

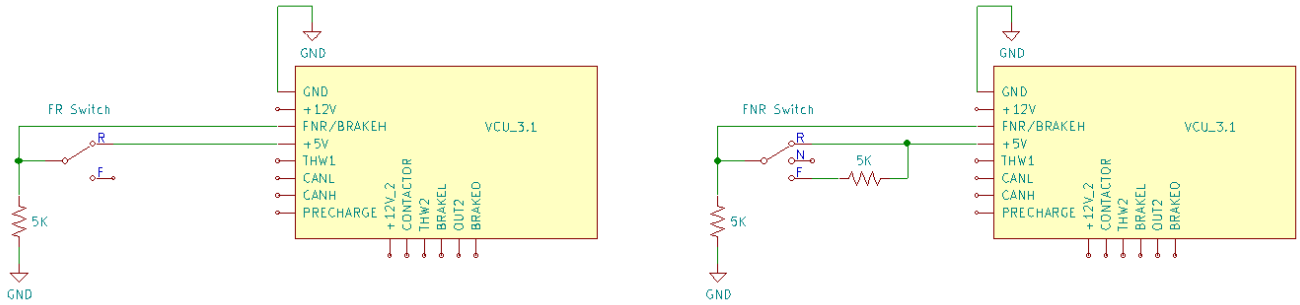


Figure 8 - Direction Switch Wiring (without the "FNR resistor" rework)

In order to configure a Forward / Reverse switch, use the command "**`enable fr`**". Once configured, if the **FNR/BRAKE** input is <= 4.0V then the requested direction is forward, and if the input is > 4.0v, the requested direction is reverse.

To configure a Forward / Neutral / Reverse switch, use the command "**`enable fnr`**". Once configured, if the **FNR/BRAKE** input is <= 1.5V then the requested direction is neutral, else if the input is <= 4.0V then the requested direction is forward, else the requested direction is reverse.

If a Brake Transducer is used, then the **FNR/BRAKE** input should be connected to the wiper input of the brake transducer. In this case, the VCU will request a variable amount of reverse torque depending on brake pedal pressure. To use this feature, the VCU must be configured with "**`set brake hall`**".

BRAKEL (Brake Light Input) and BRAKEO (Brake Light Output)

BRAKEL is a brake light input. This input connects directly to the brake light switch: it expects the input to be high impedance (or disconnected) when there is no brake and connected to +12V when the brake is applied. When the brake is on, the throttle input is ignored and the VCU requests a configurable amount of braking regeneration.

The VCU can also directly operate the brake light using **BRAKEO**. The VCU will enable the brake light if it is supplying sufficient negative torque. The **BRAKEO** output is an "open collector to ground" output that can operate a 200ma relay which can provide +12V to the brake lights.

The Brake Light Input and Brake Light Output features can be used independantly or together, as desired. However, if both features are used together, an additional relay is required.[1]

See suggested wiring diagrams below. The diagram on the left shows the wiring for just the BRAKEL connection (with the BRAKEO connection unused). The diagram on the right shows an example of using

[1] The VCU needs to distinguish between "brake light is on because the user presses the brake pedal" and "brake light is on because the VCU itself is generating negative torque".

both the BRAKEL and BRAKEO connections. The third example, just using BRAKEO, is not shown. (But if desired, would be the right side diagram with only a single relay.

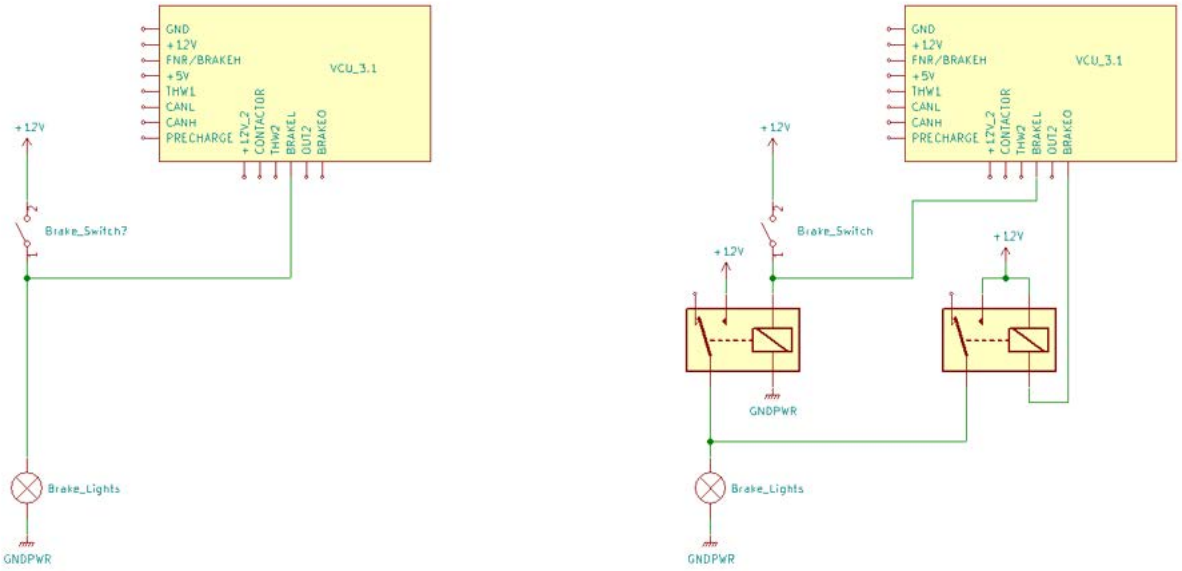


Figure 7 – BRAKE Light Input and BRAKE Light Output Wiring

OUT2

Beginning with VCU firmware release 3.1.8, the **OUT2** output is active (or "on") when the FNR switch is in "Reverse", and is inactive ("off") otherwise. This allows the OUT2 output to control a backup light.

Note that OUT2 is an "open collector to ground" output: it is high impedance (or no connection) when it is "off", and it is connected to GND when "on." This can be used to complete the circuit for a 12v automotive relay with a coil current of less than 200 ma.

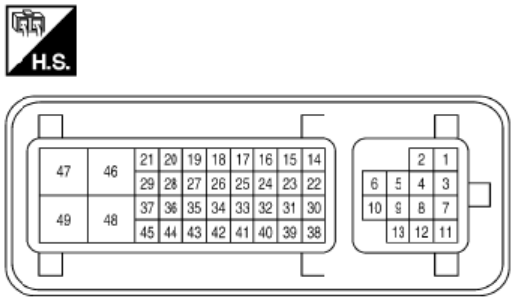
Second Generation Leaf Inverter (EM57)

This section gives basic setup and wiring information on the Second Generation Leaf Inverter.

Leaf Inverter Connections

The following pinouts found in the Nissan Leaf manual are used for the VCU setup.

Connector No.	F13
Connector Name	TRACTION MOTOR INVERTER
Connector Color	BLACK



Terminal No.	Color of Wire	Signal Name
1	–	–
2	–	–
3	–	–
4		
5	–	–
6	–	–
7	–	–
8	–	–
9	–	–
10	–	–
11	–	–
12	–	–
13	–	–
14	L	EV SYSTEM CAN-H
15	G	EV SYSTEM CAN-L
16	–	–
17	P	REZ_S2
18	L	REZ_S4
19	R	REZ_R1
20	B	REZ_S1

Terminal No.	Color of Wire	Signal Name
21	W	REZ_S3
22	–	–
23	–	–
24	–	–
25	–	–
26	–	–
27	G	REZ_R2
28	–	–
29	–	–
30	–	–
31	–	–
32	–	–
33	–	–
34	–	–
35	–	–
36	–	–
37	–	–
38	–	–
39	–	–
40	–	–
41	–	–
42	LG	IGN_SW
43	–	–
44	O	TMGND
45	Y	TM
46	G	VB1
47	B	VBGND1
48	G	VB2
49	B	VBGND2

Connect 12V power through a switch or a relay to 42, 46 and 48, and connect 47 and 49 to ground. The Leaf inverter requires about 1 Amp of 12V power, using it to run all the logic and the IGBT drivers.

CAN is found on pins 14 (CANH) and 15 (CANL).

These are used for power and control:

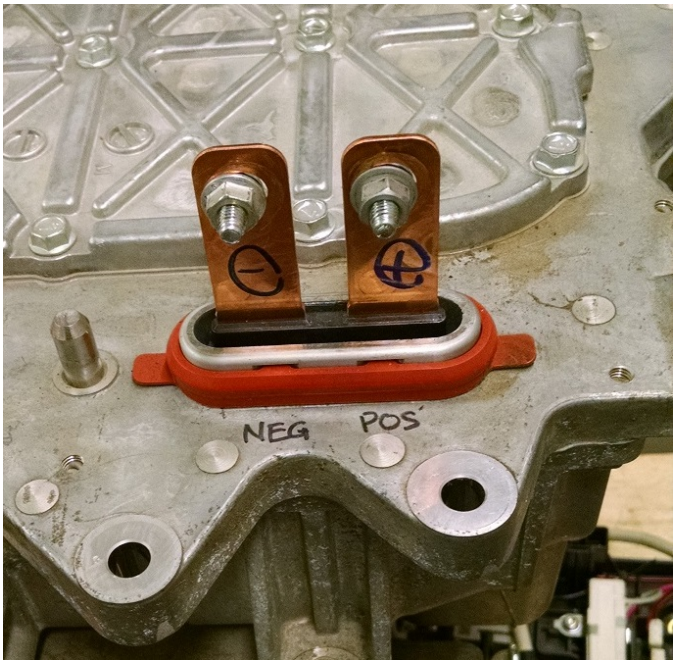
- 14: CAN-H
- 15: CAN-L
- 42: 12V switch-on signal
- 46,48: 12V power
- 47,49: Ground

These are left as-is: Do not change

- 17,18: Motor resolver S2-S4
- 19,27: Motor resolver R1-R2
- 20,21: Motor resolver S1-S3
- 44,45: Motor temperature sensor

Leaf Pack Connections

Note that the pack polarity is not labeled. With the Charger to inverter connection port open, the right-hand terminal is the pack B+, as in the following image.

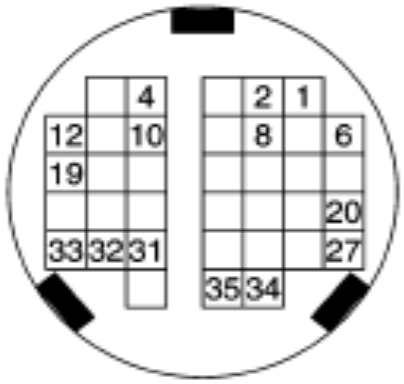


First Generation Leaf Inverter (EM61)

This section gives basic setup and wiring information on the First Generation Leaf Inverter.

Leaf Inverter Connections

The following pinouts found in the Leaf manual (tms.pdf) are used for control.



TRACTION MOTOR INVERTER

Pin #	Connection	Pin #	Connection
2, 8	12v Ground	10, 4	+12v Key Switch
12	CANH	19	CANL
33	Always On 12v		

Notes:

1) Pins 10, 4, and 33 can all be wired to the +12v Key Switch.
2) Pin numbers shown may not match numbers on mating connector – use the layout shown above.

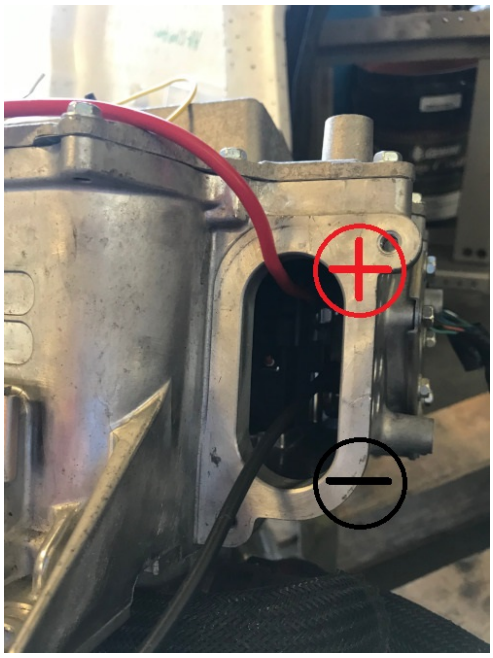
Resolver and temperature sensor wires must not be modified. They are wired by Nissan as:

1,6 – S1, S3
20, 27 – S2, S4
31, 32 – TEMP-. TEMP+
34, 35 – R1, R2

Each pair is shielded which is grounded at the inverter.

Leaf Pack Connections

The power wires are not labeled on this inverter (see image below). With the inverter oriented normally, the upper terminal is positive. Remove the side cover to access the screws holding the wire lugs in place. Wires shown are for example only and do not represent correct wire gauge or routing.



Operation Information for Both Leaf Inverters

Cooling

Cooling is essential for the inverter and motor. Coolant should flow from the inverter to the motor to keep inverter temperatures lower.

Leaf Operation

The following operations are handled by the VCU after 12V power is applied. These are required for the inverter to operate normally.

1. Switch on 12V power
2. The Inverter expects to receive CAN messages within 2 seconds of startup.
3. Finish precharging to at least 140V within 10 seconds of switching the power on. Precharging is typically complete within about 3 seconds.
4. Tests suggest that reliable inverter operation requires pack voltages above 200 volts, therefore a charged pack voltage of at least 250 volts is recommended. 4

Note that the Leaf motor controller requires a continuous stream of CAN messages otherwise it will go into a failsafe mode and the system will need to be power cycled in order to recover.

UQM and UQM Coda Inverter Setup

This section gives general information on setting up the UQM Inverter software. There are two supported UQM variations: UQM and UQM Coda, and both are configured identically.

Inverter Configuration

See the UQM manuals for additional details if provided with your system.

If you purchased your UQM inverter from ThunderStruck Motors, we will set up the inverter for operation with the VCU and bench tested the system. To access to the UQM configuration software, contact ThunderStruck Motors.

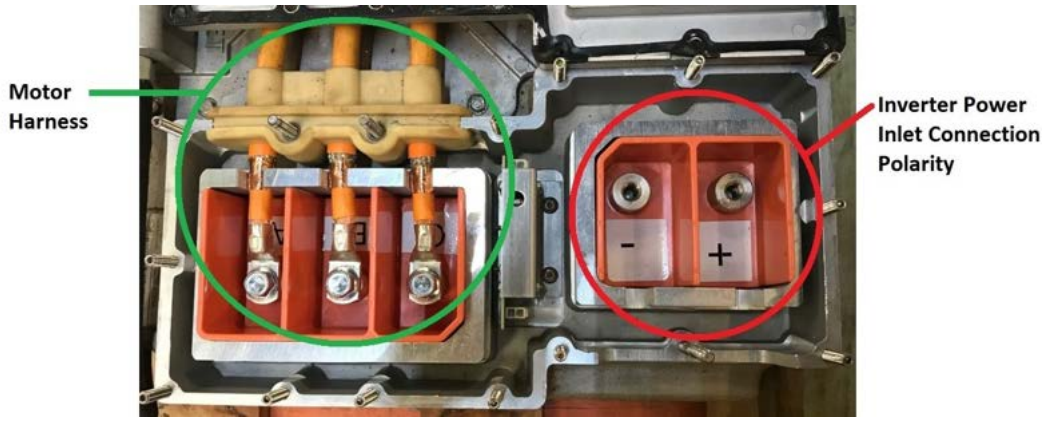
See "UQM Low Voltag Connections" below. To configure the UQM inverter, open the UQM configuration software. On the Control Tab, enable CANbus Control. On the CANbus Settings Tab, set the following:

- 11 bit identifiers
- Little Endian
- Drive Mode = Torque
- Baud Rate = 500kbps
- Transmit CAN messages = enabled
- Message "Set Enables" (**see below**)
- Timeout Period = 250 msec
- Counter = Ignore Counter
- Require Heartbeat Command = NOT enabled

For the Message "Set Enables" above, the VCU firmware requires only one message from the inverter, which is the "Watchdog Status" message. All other messages *may* be enabled but are not necessary for normal operation. If regen is required, RPM feedback must be enabled in the inverter, as the VCU uses that data in order to scale the regen level.

High Voltage Wiring

Refer to the specific UQM manual if availfor the motor/inverter set being used for your project. Typically, the motor harness will be provided with your equipment. Polarity of the traction pack connection is very important. In our experience UQM manuals may not always show this clearly. The figure below shows typical polarity.



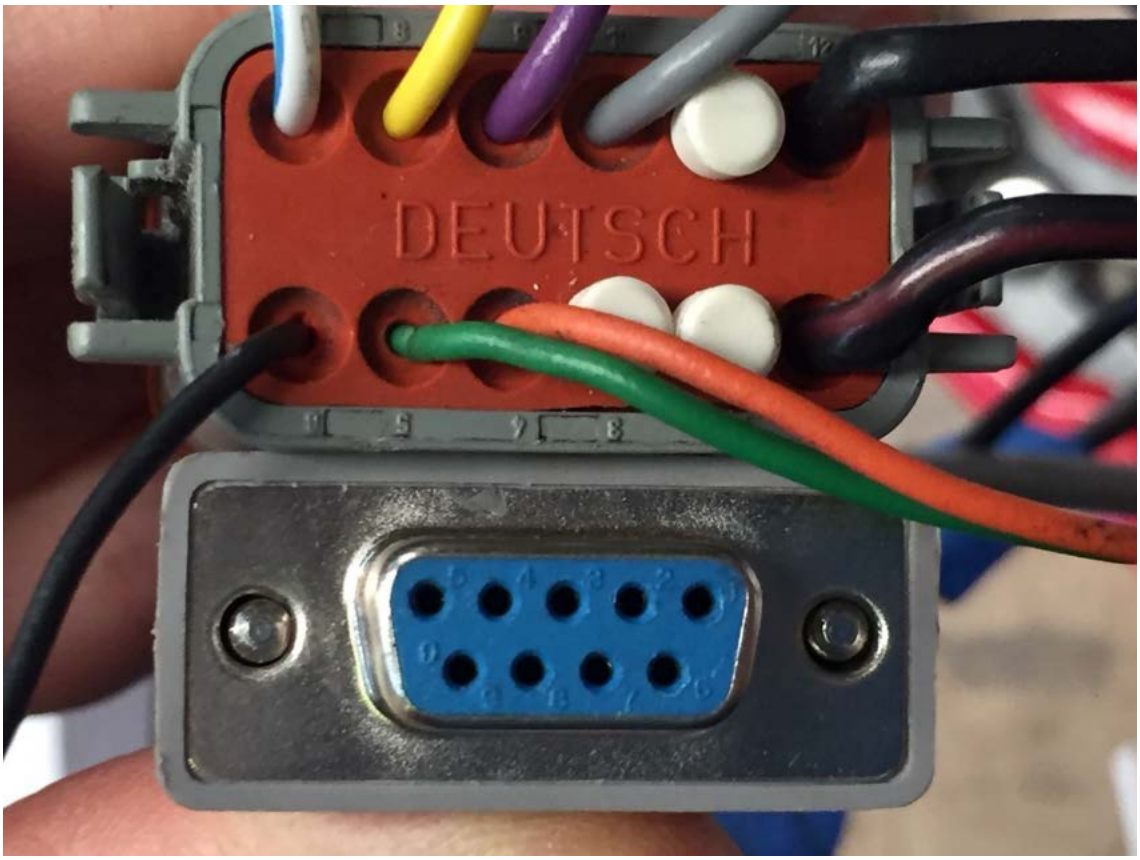
UQM Low Voltage Connections

Low voltage connections use the UQM Inverter Deutsch connector. A computer connects to the UQM via a DE-9 connector. In the image below, Deutsch pin 1 is lower right and 12 is upper right. The DE-9 pin 1 is upper right and 9 is lower left. See page 19 of the UQM user manual for complete Deutsch pinouts. In the table below, Deutsch = DT, DSub DE-9 = DE.

Deutsch Pin	Connected To	Deutsch Pin	Connected To
DT 1	12v positive	DT 7	DE 2
DT 2, 3, 11	No Connection (NC)	DT 8	DE 3
DT 4	CAN HI (VCU)	DT 9	DE 5
DT 5	CAN LO (VCU)	DT 10	12v positive (NC for UQM Coda)
DT 6	CAN common (NC)	DT 12	12v negative

Notes:

1) 120 ohm resistor installed between DT 4 and 5 (however test show this is not needed)
2) CAN HI and LO are connected to the VCU canbus
3) DT 1 and DT 10 can connect to the 12v keyswitch bus



VCU Configuration

Serial Port Drivers

The VCU uses a USB to serial port cable for configuration, firmware upgrade, and debugging. Before using the serial port, a terminal application and host drivers must be installed. See the document *Serial Port Utilities* for instructions on how to install this software. The document is available at http://www.thunderstruck-ev.com/images/companies/1/DD_SerialPortUtilities_v1.2.pdf.

Once installed, when power is applied to the VCU, the following banner message will be displayed on the serial port console:

```
******************************************************
*                Vehicle Control Unit v3.1.0         *
*       Thunderstruck Motors / Dilithium Design      *
******************************************************
vcu>
```

At this point, the VCU may be configured. Configuration is stored in non-volatile memory and retained across a power cycle. See *Command Line Interface*, below, for details on commands and syntax.

Note that diagnostics are performed automatically at startup, which results in additional output messages.

Throttle

The VCU supports throttles that output between 0 to 5v. The default throttle type in the VCU is a single wiper **hall** throttle. (This selection will also work with a resistive throttle). The throttle working range must be configured in the VCU (using **set thw1off** and **set thw1max**). To determine the correct values see throttle datasheet or use the "**measure**" command, described below. If the throttle gives a reading that is outside of the working range, it will fail its diagnostics.

The VCU also supports a dual output throttle, which may be enabled by the command (**set thtype dhall**). Dual output throttles provide redundancy: the output from the **THW1** wiper is used as the primary throttle input and the **THW2** output provides a failsafe check. In operation, the VCU requires that the two wiper outputs track together. In this case, the throttle outputs are constantly checked to make sure they track together. If they do not, then the throttle is disabled.

If the throttle type is **hall,** the second throttle wiper input, **THW2**, is not used and is available for other functions. See below, Power Takeoff.

Map

In operation, the throttle input is converted to a number between 0% (no throttle) and 100% (full throttle). Percent throttle is then converted to requested torque. By default, the mapping from throttle percent to torque is linear: 20% throttle requests 20% of the maximum configured torque (using the command **set maxtorque**). The throttle map allows the throttle response to be tuned. For example, the user may want 25% throttle to only request 10% of the torque in order to "soften" the throttle response at first.

The VCU can define up to three throttle ranges (between 0% to 100%): range1, range2, and range3. Range1 starts at 0 and ends at r1top, range2 (if configured) starts at r1top and continues to r2top, and range 3 (if

configured) starts at r2top and continues to 100. These ranges are set by the commands **set r1top** and **set r2top**.

Once a range is defined, within each range there is a weight or "scale" from 0.0 to 5.0, which determines throttle responsiveness within the range. The command **set r1scale** sets the "weighting factor" for range1 and the command **set r2scale** sets the "weighting factor" for range2. It is not necessary to set the weighting factor for range3 as the VCU computes it automatically.

By default, there is one range: **r1top** is 100, and **r1scale** is 1.00.

Brake

A brake input is optionally supported that can be used to control regenerative braking. The brake type is set using the command "**set brtype"** and can be set to one of: **none**, **hall**, or **switch**.

When a brake input is configured, the total amount of braking regeneration is set using **set brakeregen**.

If the **brtype** is set to **switch**, then if the brake is applied (the **BRAKEL** input is 12V), then the throttle input is ignored and the VCU will request the configured amount of braking regen.

If the **brtype** is **hall**, then the **FNR/BRAKE** input is used to apply a variable amout of regen (up to a maximum configured **brakeregen** value), depending on the braking pressure. As with the throttle, the working range of the a hall BRAKE input must be configured (using **set broff** and **set brmax**).

Motor / Inverter

This section describes the parameters used to control the motor and inverter.

- **inverter** sets the inverter type. It must be one of **leaf**, **leafgen1**,or **uqm**.
- **prechgminv** is an optional parameter which sets the minimum precharge voltage that must be attained before the main contactor is closed.

The following parameters determine throttle / torque response:

- **maxtorque** sets the maximum torque.
- **maxrpm** sets the RPM limit.
- **maxrpmtorque** sets the torque limit at maximum rpm
- **torquekneerpm** sets the start of rpm based torque limiting

For the UQM inverter, the **maxtorque** and **maxrpm** parameters are required and set absolute bounds for motor operation. For the Leaf, the **maxtorque** parameter is required. The Leaf motor controller has internal rpm limiting and so **maxrpm** need not be configured, unless the torqueknee feature, described next, is used. For the Coda inverter, **maxtorque** is required and is limited to 300Nm. This parameter must be within the correct range before changing inverter types.

The torque knee feature uses the parameters **maxrpm**, **maxrpmtorque** and **torquekneerpm**. This feature is used to taper the torqe as the motor rpm increases. Tapering is linear: the effect starts at the **torquekneerpm** (where the torque could be as high as **maxtorque** under full throttle) and it is limited to **maxrpmtorque** when **maxrpm** is reached.

Example:

Suppose the following settings are in place:

```
vcu> set inverter leaf
vcu> set maxtorque 2000
vcu> set maxrpm 10000
vcu> set maxrpmtorque 1000
vcu> set torquekneerpm 8000
```

Under full throttle, the VCU will initially request a torque value of 2000 Nm from the controller. When the motor rpm reaches 8000 rpm, the requested torque starts to decrease from 2000Nm and will reach a limit of 1000 Nm when the rpm reaches 10000 rpm.

The following optional UQM-only parameters are supported. See UQM documentation.

- **accellim** sets the acceleration limit
- **surgelim** sets the surge limit

If regeneration is configured, the following parameters are configured:

- **regenvmax** sets the pack voltage limit. Regeneration is limited when the pack is full.
- **idleregen** sets the amount of regeneration when the throttle is at 0%. If not used, set to 0.
- **brakeregen** sets the amount of regeneration when braking. If not used, set to 0.

These parameters set maximum values. In operation the actual amount of regen requested from the motor controller depends on several factors, including: throttle mapping, throttle position, motor rpm and on pack voltage.

The following parameters are used for automatic transmission operation. This feature is only available if a Direction Switch is NOT being used

- **idletorque** sets the maximum torque used when idle
- **idlerpm** sets the rpm target for idle

The following parameters is used for a “power takeoff” function. This feature is only available with the UQM motor.

- **maxrpm2** sets the RPM limit for power takeoff function.

DC/DC Converter

The Volt DC/DC converter is supported for UQM and UQM Coda only. A canbus ID conflict exists between the Leaf inverters and the Volt DC/DC converter.

The commands **set ddtype** and **set ddvoltage** enable the DC/DC converter.

Diagnostics

The VCU user interface provides a means for setting configurable parameters and performing various diognostic functions. When the VCU passes large text strings to the user interface, it takes processor space which can cause delays or interruptions in communication with the motor inverter. For this reason, ThunderStruck Motors does not recommend using the text interface while driving the project vehicle, unless it is on a lift and safety precautions are taken for personnel and equipment.

measure

The **measure** command can be used to measure the voltage present on the **THW1**, **THW2**, and **FNR/BRAKE** inputs. When commanded, the command repeatedly measures and prints the analog value of these inputs for up to 30 seconds. The measurement can be stopped by pressing any key.

In a similar way, the **measure** command can be used to read the value of the (digital) **BRAKEL** input.

The **measure** can be used to characterize the hall throttle and hall brake inputs at zero and full throttle. The measurements thus obtained can be used to determine the **thw1off**, **thw1max**, **thw2off**, **thw2max**, **broff**, and **brmax** configuration parameters.

can trace

CAN message tracing is available that dumps the CAN ID, message source, and raw contents. CAN message tracing is enabled sing the command **trace can**.

message trace

Message tracing is used to trace specific CAN message ids. If enabled, the message trace will present the results in a decoded form.

As an example, see below: the UQM Universal Command is being traced. This command is sent from the VCU to the inverter. The output includes timestamp, percentage throttle, requested torque, and requested RPM. In the example, the user “stepped on the gas” and one can see the requested torque proceed from -20Nm (the idleregen value) to 950Nm (the maxtorque value). Also, notice that the requested rpm limit is 0 at idle and limited to 1000rpm when the torque is nonzero.

```
vcu> trace uc
trace enabled: AF SS UC
vcu> 00:00:36.7 0% -20.0Nm 0.0rpm
00:00:36.9 0% -20.0Nm 0.0rpm
00:00:37.0 0% -20.0Nm 0.0rpm
00:00:37.1 7% 66.5Nm 1000.0rpm
00:00:37.3 7% 66.5Nm 1000.0rpm
00:00:37.4 8% 76.0Nm 1000.0rpm
00:00:37.6 9% 85.5Nm 1000.0rpm
00:00:37.8 10% 95.0Nm 1000.0rpm
00:00:37.9 10% 95.0Nm 1000.0rpm

<etc>

00:00:40.8 38% 361.0Nm 1000.0rpm
00:00:40.9 41% 389.5Nm 1000.0rpm
00:00:41.1 42% 399.0Nm 1000.0rpm
00:00:41.3 45% 427.5Nm 1000.0rpm
```

```
00:00:41.4 49% 465.5Nm 1000.0rpm
00:00:41.6 51% 484.5Nm 1000.0rpm
00:00:41.8 55% 522.5Nm 1000.0rpm
00:00:41.9 61% 579.5Nm 1000.0rpm
00:00:42.1 64% 608.0Nm 1000.0rpm
00:00:42.2 68% 646.0Nm 1000.0rpm
00:00:42.4 76% 722.0Nm 1000.0rpm
00:00:42.6 82% 779.0Nm 1000.0rpm
00:00:42.7 88% 836.0Nm 1000.0rpm
00:00:42.9 95% 902.5Nm 1000.0rpm
00:00:43.0 97% 921.5Nm 1000.0rpm
00:00:43.2 99% 940.5Nm 1000.0rpm
00:00:43.4 99% 940.5Nm 1000.0rpm

<etc>

00:00:46.0 99% 940.5Nm 1000.0rpm
00:00:46.1 99% 940.5Nm 1000.0rpm
00:00:55.3 0% -20.0Nm 0.0rpm
00:00:55.5 0% -20.0Nm 0.0rpm
00:00:55.7 0% -20.0Nm 0.0rpm
00:00:55.8 0% -20.0Nm 0.0rpm
00:00:55.9 0% -20.0Nm 0.0rpm
```

Startup Diagnostics

At power-up (and whenever throttle parameters are reconfigured), a throttle diagnostic is performed by the VCU. If an error is detected, it will be printed to to the serial port, the throttle will be rendered non-operational.

Example failure output:

```
vcu> FAULT: Throttle 1 A2D too low!
Throttle Failed; check connections and configuration ...
```

Example success output:

```
Throttle self test complete
Throttle Enabled ...
```

Operation

Startup

At startup, the **PRECHARGE** output is enabled and throttle diagnostics are performed. A 2.5 second timer is started. At the end of 2.5 seconds the VCU verifies that the throttle is at idle, and if **prechgminv** is configured, verifies that the inverter voltage is higher than the precharge minimum voltage. If these tests pass, the **PRECHARGE** output is disabled, the **CONTACTOR** output is enabled, and the VCU enters an operational state. If the throttle is not at idle or if the inverter voltage is not high enough, the VCU will print out error messages and continually retry.

Note: If the throttle diagnostics fail, then, verify throttle configuration and **THW1** and **THW2** measurement readings. If the precharge diagnostic fails, then verify the correct operation of the precharge and contactor relays.

During operation, the VCU continues to verify that the throttle readings stay within the configured ranges. If they do not, then the VCU will disable the contactor. It will then automatically retry running startup diagnostics a few times but if they continue to fail, the VCU will give up. In this state, the LED will blink in the Failed state and it will be necessary to power cycle the VCU to retry.

Direction Switch

If a “forward / reverse” or “forward / neutral / reverse” switch is configured:

- When the requested direction is Neutral, no torque will be requested, regardless of throttle position. While driving, it is always possible to switch into Neutral.
- Requests to switch to the opposite direction of the motor rotation are generally prevented. If the motor is turning at >120 RPM, then the VCU will ignore a request to switch to Reverse and will switch to Neutral instead. Similarly, if the motor is turning at < -120 RPM, then the VCU will ignore a request to switch to Forward and will switch to Neutral instead.
- It is possible to switch from Forward to Neutral and back again if the motor is moving in a forward direction. However, if the motor is moving in a forward direction, then if the driver tries to switch to Reverse, then the VCU will instead switch to Neutral until the motor RPM drops to below 120RPM.

Throttle

Percent throttle is converted to percentage requested torque based on motor RPM, requested direction, torque map, and “deadspot” (described below). The maximum torque that can be requested is the configured value **maxtorque**.

The inverter is operated in “torque mode with speed control”. A constant stream of CAN messages (the “Universal Command”) is sent to the inverter to keep it updated with current requested torque.

Braking Regen

The brake input, if active, takes precedence over the throttle. If the brake type is set to **switch**, and brake is applied, then the configured value of **brakeregen** is requested from the controller. If the brake type is set to **hall**, then depending on how hard the pedal is depressed and the motor RPM, a percentage of **brakeregen** is requested from the inverter.

Idle Regen / Throttle Braking

If **idleregen** is configured, the full amount of idleregen torque will be experienced if the motor is turning at greater than 1600rpm and the throttle is completely released.

The throttle position of 0 torque is configurable using the command **set deadspot**, which is specified in percentage. If the motor is turning at greater than 1600rpm, then a deadspot of 20 means that at 20% throttle the VCU will request 0 torque; larger than 20% throttle will request positive torque (up to **maxtorque** at full throttle), less than 20% throttle will request negative torque, and 0% throttle will request the full amount of **idleregen** torque. This feature allows the driver to brake the EV largely by using the throttle only.

In order to smooth the response, the amount of regen requested depends on throttle position and motor rpm when the motor is turning at less than 1600RPM.

The VCU supports a regen voltage limit (using **set regenvmax).** The VCU monitors inverter voltage and limits the amount of regen requested as it the inverter approaches or exceeds this limit.

Operation – Leaf (first and second generation)

The VCU recomputes torque command parameters every 100ms. These values may be traced using the command "**trace uc**".

The VCU firmware does not support rpm limits for the Leaf (**maxrpm** or **maxrpm2**). RPM limits are enforced by Leaf inverter firmware.

The VCU sends the Universal Command information to the Leaf (using the 0x1df message) every 10ms.

The VCU logs two messages from the Leaf the "nissan feedback" message (0x1da), which can be traced with "**trace nf**" and the 0x55a message which can be traced with "**trace nt**".

Leaf testing to date has been with a direct drive application and a position switch..

Operation – UQM

The VCU operates the inverter in "torque mode with speed control", up to the rpm limit configured using **set maxrpm**. The throttle mapping is used to determine "percent throttle", which in turn, is used to calculate the amount of requested torque. Note that the requested torque is a function of throttle position, rpm, and the parameters used for the torque knee feature, which can tapers the maximum available torque back based on rpm.

If regeneration is configured, the amount of requested (negative) torque is determined by throttle mapping, direction, throttle position, rpm, and pack voltage.

The VCU sends the Universal Command information to the UQM every 125ms. The UQM inverter supports additional parameters that are also sent in this command: the VCU supports configuring the **accellim**, **surgelim** parameters in the UQM Universal Command (see UQM documentation for details).

The UQM Acceleration Limits CAN command is not sent by the VCU.

The UQM Heartbeat command is sent to clear a Watchdog error, if reported from the inverter in the Watchdog Status message. If that message indicates that the Inverter has detected a watchdog error, the VCU wll recover as recommended in the UQM canbus manual.

UQM support includes configurable braking and idle regen, similar to the Leaf.

The VCU supports a second rpm limit for a "power takeoff" application. In this application, the operation of the throttle remains the same, but an alternate maximum rpm (**maxrpm2**) may be configured and used. Enabling the second limit is done by the **THW2** input and is only available if the thtype is set to **hall** (not **dhall**). If **THW2** is > 4v, then the second rpm limit is chosen.

Operation – UQM Coda

The Coda system is a modified UQM drivetrain, so its operation is mostly identical to the UQM. Both forward and regen torque are limited to 300Nm. The Universal Command is updated every 125ms, but sent to the inverter every 10ms. The Heartbeat command is sent periodically rather than in response to an error, so the Watchdog Status message will not be seen.

LED

The single green LED provides basic status. There are three blink patterns:

- **FAILED** is shown as a fast blink. This means either that the VCU diagnostics failed or that the Inverter is not communicating properly.
- **WARMUP** is shown as a slow blink.
- **RUNNING** is a solid ON.

Firmware Upgrade

See the document *Serial Port Utilities* for instructions on how to perform a firmware upgrade.
http://www.thunderstruck-ev.com/images/companies/1/DD_SerialPortUtilities_v1.2.pdf

Serial Interface

Startup Banner

When the VCU is powered up, it will print the following:

```
******************************************************
*               VCU Throttle Control v3.1.0          *
*       Thunderstruck Motors / Dilithium Design      *
******************************************************
vcu>
```

help

The **`help`** command prints out command help.

```
vcu> help
  SHow [<>|Version|Config]
        <>         - status
        version    - firmware version
        config     - configuration
  SEt  [<>|INVERTER|PRECHGMINV|REGENVMAX
        |THTYPE|THW1OFF|THW1MAX|THW2OFF|THW2MAX
        |R1TOP|R2TOP|R1SCALE|R2SCALE
        |BRTYPE|BROFF|BRMAX
        |MAXTORQUE|MAXRPM|MAXRPMTORQUE|TORQUEKNEERPM
        |MAXRPM2|ACCELLIM|SURGELIM
        |IDLEREGEN|BRAKEREGEN|DEADSPOT
        |IDLETORQUE|IDLERPM
        |DDTYPE|DDVOLTAGE]
  ENABLE [CANTERM|FR|FNR]
        canterm    - enable can termination resistor
        fr         - enable forward/reverse switch
        fnr        - enable forward/neutral/reverse switch
  DISABLE [CANTERM|FR|FNR]
  TRace [<>|HELP|CAN|OFF|UC|AL|HC|AF|SS|FC|LT|TP|WS|NF|NT|DD]
                   - enable trace
  TRace- [CAN|UC|AL|HC|AF|SS|FC|LT|TP|WS|NF|NT|DD]
                   - disable trace
  MEasure [<>|THW1|THW2|FR|FNR|BRAKE|BRAKEL]
        <>         - 'measure' help
        thw1       - measure throttle wiper1 A/D
        thw2       - measure fr switch
        fnr        - measure fnr switch
        brake      - measure brake wiper A/D
        brakel     - measure brake light input
  RESET CONFIG     - resets configuration to defaults
  UPGRADE          - performs a firmware upgrade
```

In some cases, either a full version or an abbreviated version of a command (or command parameter) can be used. This is shown in the "help" with the use of uppercase and lowercase letters. For example, the abbreviation for **show** is **sh**, and the abbreviation for **show config** is **sh c**.

show

The **show** command displays configured parameters or status.

show <>

If **show** is entered without parameters, current status will be displayed.

```
vcu> show
  thstate  : running
  thw1     : 0.03V
  thw2     : 0.07V
  brakel   : off
  brake    : 0.06V
00:08:17.3  AF/4871: -0.8Nm, 377.6V, 2.1A, 0.0rpm
00:08:16.4  TP/495: inv=26C, rot=16C, sta=19C, IGBT=26C, t=33.0secs
00:08:17.3  LT/4871: -1.8Nm, 4A, HB=100%, LB=100%, SS=0%, AD=29829
00:08:16.9  WS/985: wd=32802, sw ver=4.12.7, can ver=4
00:08:17.3  SS/1050:   error=00000000 00000000
                     history=00000000 10001000
                      status=00000000 01010000
  uptime   : 0 hour(s), 8 minute(s), 17 second(s)
```

The **thstate** values are: **warmup, self test, idlewait, prechgrel, running**, and **failed**.

The **thw1** and **thw2** values are the THW1 and THW2 wiper values as read by the VCU.

The **brakel** value is the reading at the BRAKEL input ("off" = 0, "on" =12v).

The **brake** value is the brake wiper value.

The next rows display the last message of each type received from the inverter. In this example, messages from the UQM inverter are shown. First is the timestamp of the message. Next (e.g., "AF/4871" is the message type and count. Finally, there are the decoded contents.

AF = Accurate Feedback
TP = Temperature
LT = Limited Torque
WS = Watchdog Status
FC = Fuel Cutback
SS = System Status

If no messages of a given type have been received, then nothing is printed. For more details on the contents of these messages, see the UQM inverter documentation.

The **uptime** is the VCU uptime since power on.

show version

The **show version** command displays firmware version number and build date.

```
vcu> show version
version  : v3.1.0; Nov 06 2019 11:21:19
vcu>
```

show config

The **show config** command displays configuration parameters.

```
vcu> show config
  THROTTLE
    thtype     : hall
    thw1off    : 0.75v
    thw1max    : 4.59v
  MAP
    range1     :  0..100% throttle =>  0..100% torque
  BRAKE
    brtype     : switch
  MOTOR/INVERTER
    inverter   : leaf
    maxtorque  : 950.0Nm
    brakeregen: 100.0Nm
  OPTIONS
    FNR        : enabled (Forward/Neutral/Reverse switch)
    canterm    : canterm (CAN termination resistor)
```

Configuration information is displayed in several sections:

show config THROTTLE

The **THROTTLE** section shows throttle parameters. The throttle type (**thtype**) can be **hall** or **dhall**. **thw1off** is the low value of the THW1 wiper and **thw1max** is the high value of the THW1 wiper.

If the throttle type is **dhall**, then **thw2off** and **thw2max** must be configured.

```
  THROTTLE
    thtype     : dhall
    thw1off    : 0.75v
    thw1max    : 4.59v
    thw2off    : 0.38v
    thw2max    : 2.29v
```

show config MAP

The **MAP** section defines the mapping between throttle percentage and requested torque percentage. The example above gives the default mapping. Only range1 is defined, which maps 0..100% throttle to 0..100% torque. For more detailed examples, see below “Throttle Mapping”.

In addition to the throttle mapping, the **deadspot** parameter appears here. The **deadspot** is used for throttle controlled regeneration. When forward motor rpm is high enough, the value of **deadspot** is the percentage throttle that yields 0 torque: a throttle value less than **deadspot** will request negative torque, and a throttle value greater than **deadspot** will request positive torque.

show config BRAKE

The **BRAKE** section shows the brake parameters. The brake type, **brtype**, can be **none**, **switch**, or **hall**. If the **brtype** is **none** or **switch**, no additional parameters are shown.

If **brtype** is **hall**, then the values of **broff** and **brmax** may be edited, which give the range of the brake pressure transducer. See below:

```
BRAKE
  brtype     : hall
  broff      : 0.00v
  brmax      : 5.00v
```

In operation the parameter **brakeregen** determines how much negative torque to apply when braking. If brtype is **switch**, then when the brake switch is applied, the entirety of **brakeregen** torque is requested. If **brtype** is **hall**, then a percentage of **brakeregen** is requested, depending on brake wiper position, up to a maximum of **brakeregen** when the brake is fully depressed.

show config MOTOR/INVERTER

The **MOTOR/INVERTER** section shows motor parameters. The first parameter, **inverter**, shows the inverter type. This parameter is initially set to **leaf**. The **inverter** parameter is unique in that it is the only parameter which is not changed by the command **reset config**. It must be explicitly set by the user to be changed.

The parameter **maxtorque** defines the maximum amount of torque requested from the inverter.

The value of **maxrpm** defines the highest rpm requested from the inverter. Note that the Leaf does not honor this parameter, as it has internal rpm limiting, however this parameter is used by the VCU for torqueknee operation, described below.

The UQM inverter additionally supports: **maxrpm2**, **accellim**, and **surgelim**. The **maxrpm2** parameter is used for the power takeoff feature. The **accellim** and **surgelim** parameters affect throttle reponsiveness, See the UQM documentation for more details.

The UQM inverter also supports the parameters **idletorque** and **idlerpm**, which are used for automatic transmission applications. These values define the value of requested torque when no throttle is being applied.

The parameter **idleregen** is used for throttle braking. If 0 throttle is applied, up to idleregen negative torque is requested (the amount depends upon motor rpm, and is linear from 0 to 1600 rpm, where the maximum torque is applied if the motor is turning at 1600 rpm or greater). Throttle braking also uses the **deadspot** parameter. When forward motor rpm is high enough, the value of **deadspot** is the percentage throttle that yields 0 torque: a throttle value less than **deadspot** will request negative torque, and a throttle value greater than **deadspot** will request positive torque.

The torque knee feature uses the parameters **maxrpm**, **maxrpmtorque** and **torquekneerpm**. This feature is used to taper the torqe as the motor rpm increases. Tapering is linear: the effect starts at the **torquekneerpm** (where the torque could be as high as **maxtorque** under full throttle) and it is limited to **maxrpmtorque** when **maxrpm** is reached.

show config DC/DC

The **DC/DC** section (not shown in this example) is used to define and configure a DC/DC converter. If configured, this section will show the DC/DC converter type **ddtype** and the target voltage setpoint **ddvoltage**.

show config OPTIONS

The **OPTIONS** section shows configurable options.
FNR (or FR) will appear if the Forward/Neutral/Reverse (or Forward/Reverse) switch has been enabled.

set

This command sets the configurable parameters.

set <>

If **set** is entered with no parameters, **set help** will be displayed:

```
vcu> set
  SEt [
        THTYPE|THW1OFF|THW1MAX|THW2OFF|THW2MAX
            thtype    - throttle type, one of [HALL|DHALL]
            thw1off   - THW1 reading with no throttle (from 'measure thw1')
            thw1max   - THW1 reading at max throttle (from 'measure thw1')
            thw2off   - THW2 reading with no throttle
            thw2max   - THW2 reading at max throttle
        R1TOP|R2TOP|R1SCALE|R2SCALE
            r1top     - Range1 High Limit (0 <= r1top <= 100)
            r2top     - Range2 High Limit (r1top <= r2top <= 100)
            r1scale   - Range1 Scale factor (0.01 to 5.00)
            r2scale   - Range2 Scale factor (0.01 to 5.00)
        BRTYPE|BROFF|BRMAX
            brtype    - [NONE|SWITCH|HALL]
            broff     - BRAKE reading with no brake (from 'measure brake')
            brmax     - BRAKE reading at max brake (from 'measure brake')
        INVERTER|PRECHGMINV|REGENVMAX
            inverter  = [UQM|LEAF|LEAFGEN1]
            prechgminv- minimum inverter voltage to consider precharge complete
            regenvmax - pack high voltage limit for regen
        MAXTORQUE|MAXRPM|MAXRPMTORQUE|TORQUEKNEERPM
            maxtorque - maximum available motor torque
            maxrpm    - maximum allowable motor rpm (default range)
            maxrpmtorque  - maximum torque at maximum rpm
            torquekneerpm - start of rpm based torque limiting
        IDLETORQUE|IDLERPM
            idletorque- torque at idle (used for automatic transmissions)
            idlerpm   - rpm at idle
        IDLEREGEN|BRAKEREGEN|DEADSPOT
            idleregen - (negative) torque to apply when no throttle
            brakeregen- (negative) torque to apply when braking
            deadspot  - idle regen throttle setpoint
        DDTYPE|DDVOLTAGE|
            ddtype    - dc/dc converter type, one of [none|VOLT]
            ddvoltage - dc/dc output voltage setpoint
```

THROTTLE (thtype, thw1off, thw1max, thw2off, thw2max)

The command **set thtype** sets the throttle type. Valid values are **hall** and **dhall**.
The command **set thw1off** sets the throttle 1 wiper voltage when the throttle is off.
The command **set thw1max** sets the throttle 1 wiper voltage when the throttle is fully depressed.
The command **set thw2off** sets the throttle 2 wiper voltage when the throttle is off.
The command **set thw2max** sets the throttle 2 wiper voltage when the throttle is fully depressed.

Example configuration:

```
vcu> set thtype dhall
Reinitializing Throttle
vcu> FAULT: Throttle 2 A2D too low!
Throttle Failed; check connections and configuration ...
vcu> set thw1off .6
Reinitializing Throttle
vcu> Throttle self test complete
Throttle Enabled ...
vcu> set thw1max 4.4
Reinitializing Throttle
vcu> Throttle self test complete
Throttle Enabled ...
vcu> set thw2off .4
Reinitializing Throttle
vcu> Throttle self test complete
Throttle Enabled ...
vcu> set thw2max 2.0
Reinitializing Throttle
vcu> Throttle self test complete
Throttle Enabled ...

vcu> show config
  THROTTLE
    thtype    : dhall
    thw1off   : 0.60v
    thw1max   : 4.40v
    thw1off   : 0.40v
    thw1max   : 2.00v
```

The VCU reinitializes and performs a self test whenever throttle parameters are edited.

THROTTLE MAP (r1top, r2top, r1scale, r2scale)

The following example defines two ranges. The first range is from 0 to 20% throttle, with a weighting factor of 2. The result will be that the first 20% of throttle will request 40% of the total torque. The effect of this will be that the throttle will be more responsive in the first 20% of throttle.

```
vcu> set r1top 20
vcu> set r1scale 2
vcu> set r2scale .8
vcu> show config

  MAP
    range1    :  0.. 20% throttle =>  0.. 40% torque
    range2    : 20..100% throttle => 40..100% torque
    ----------
    r1top     : 20
    r1scale   : 2.00
    r2top     : 100
    r2scale   : 0.80
```

BRAKE (brtype, broff, brmax)

The command **set brtype** sets the brake type. It can be one of **none**, **switch**, or **hall.**
The command **set broff** sets the brake wiper voltage when the brake is off. This parameter is only valid if **brtype** is **hall**.

The command **set brmax** sets the brake wiper voltage at maximum braking. This parameter is only valid if **brtype** is **hall**.

As an example:

```
vcu> set brtype hall
vcu> set broff .4
vcu> set brmax 4.5
vcu> show config

  BRAKE
    brtype    : hall
    broff     : 0.40v
    brmax     : 4.50v
vcu> set brtype switch
```

MOTOR/INVERTER (inverter, prechgminv, regenvmax)

The command **set inverter** sets the inverter type.
The command **set prechgminv** sets a minimum pack voltage before enabling the primary contactor.
The command **set regenvmax** sets a maximum pack voltage in which regen is allowed.

MOTOR/INVERTER (maxtorque, maxrpm, maxrpmtorque, torquekneerpm)

The command **set maxtorque** sets the maximum torque that the VCU will request.
The command **set maxrpm** sets the maximum rpm that the VCU will request.
The command **set maxrpmtorque** sets the maximum torque that the VCU will request at maximum rpm.
The command **set torquekneerpm** sets the rpm at which rpm based torque limiting begins.

For example:

```
vcu> set maxtorque 900
vcu> set maxrpm 6500
vcu> set torquekneerpm 4000
vcu> set maxrpmtorque 0
vcu> show config

  MOTOR/INVERTER
    Inverter  : leaf
    maxtorque : 900.0Nm
    maxrpm    : 6500
    maxrpmtorque : 0.0Nm
    torquekneerpm: 4000
vcu>
```

MOTOR/INVERTER (maxrpm2, accellim, surgelim)

The command **set maxrpm2** sets a secondary rpm limit used for the power takeoff function.
The command **set accellim** sets the accelleration limit (UQM only).
The command **set surgelim** sets the surge limit (UQM only).

MOTOR/INVERTER Automatic Transmission (idletorque, idlerpm)

The command **set idletorque** sets the amount of torque available at idle.
The command **set idlerpm** sets the target rpm at idle.

MOTOR/INVERTER Regen Configuration (idleregen, brakeregen, deadspot)

The command **set idleregen** sets the amount of braking regeneration to request when the throttle is at 0%.
The command **set brakeregen** sets the amout of braking regeneration to request when the (hall) brake is at 100% or when the (switch) brake input is ON.
The command **set deadspot** sets the throttle position of 0 torque for "throttle braking".

DC/DC Converter Configuration (ddtype, ddvoltage)

The command **set ddtype** sets the DC to DC converter type. Currently this may be set to **none** or **volt**.
The command **set ddvoltage** sets the DC to DC output voltage setpoint, entered in volts.

```
vcu> set ddtype volt
vcu> set ddvoltage 13.8
```

enable / disable

Can Termination

The command **`enable canterm`** enables the CAN termination resistor**.**
The command **`disable canterm`** disables the CAN termination resistor**.**

Forward / Reverse Switch

The command **`enable fr`** enables the forward/reverse switch**.**
The command **`disable fr`** disables the forward/reverse switch.

Forward / Neutral / Reverse Switch

The command **`enable fnr`** enables the forward/neutral/reverse switch**.**
The command **`disable fnr`** disables the forward/neutral/reverse switch.

measure

The **measure** command is a diagnostic that shows the actual value read at the VCU inputs. This command may be used to verify Throttle and Brake wiring, and to chargacterize the working range of these devices. Measure can be used with **thw1**, **thw2**, **brake,** or **brakel**. Once typed, it will repeatedly show the current input value. It can be stopped by pressing any key.

Example:

```
vcu> measure thw1
vcu> thw1= 0.44V
thw1= 0.44V
thw1= 0.44V
thw1= 0.44V
thw1= 0.44V
```

trace

The **trace** command enables various forms of message or state tracing. These commands show a timestamp (uptime) and can be useful for logging or debugging. Trace configuration is stored in EEPROM and is present after reboot.

trace <>

Trace with no parameters shows trace help.

```
      can       - trace can messages
      off       - disable all tracing
   >>UQM
      uc        - (Universal) Torque Command
      al        - Acceleration Limits
      hc        - Heartbeat Command
   <<UQM
      af        - Accurate Feedback
      ss        - System Status
      fc        - Fuel Cutback
      lt        - Limited Torque
      tp        - Temperature
      ws        - Watchdog Status
   >>LEAF
      uc        - (Universal) Torque Command
   <<LEAF
      nf        - nissan feedback
      nt        - nissan temperature
   >>DCDC
      dd        - DC DC converter
```

trace can

The **trace can** command displays canbus messages to and from the inverter. Each line gives a timestamp, the source of the message (if known), the CAN ID and CAN message contents, in hexadecimal. Note that message abbreviations are used.

```
vcu> trace can
trace enabled: can
vcu> 00:01:18.4   <<AF  0029: 1e 7d 10 8c 8e 7d 80 7d
00:01:18.4 UC>>    0025: 01 18 b8 7c 80 7d 80 7d
00:01:18.5   <<LT  002d: 03 fa fa 00 ea 02 3d 7d
00:01:18.6   <<AF  0029: 16 7d 12 8c 95 7d 80 7d
00:01:18.6   <<LT  002d: 03 fa fa 00 ea 02 3d 7d
00:01:18.7 UC>>    0025: 01 18 b8 7c 80 7d 80 7d
00:01:18.7   <<WS  002f: a5 00 68 80 a2 40 04 00
00:01:18.8   <<TP  002e: 63 63 50 53 00 63 61 5c
00:01:18.9 UC>>    0025: 01 18 b8 7c 80 7d 80 7d
00:01:18.9   <<AF  0029: 17 7d 13 8c 95 7d 80 7d
00:01:18.9   <<LT  002d: 03 fa fa 00 ea 02 3d 7d
```

trace uc, af, tp, lt, ws, fc, ss, dd, nf, nt

Individual message types can be traced using the **trace** command. Messages types can be added to the list of what is traced (using **trace)** and can be removed from the list (using **trace-**). If enabled, messages are printed in a decoded form as they are received.

The acronyms stand for the following UQM message types

AF = Accurate Feedback
TP = Temperature
LT = Limited Torque
WS = Watchdog Status
FC = Fuel Cutback
SS = System Status
UC = Universal Command

The acronyms stand for the following Leaf message types

NF = Nissan Feedback
NT = Nissan Temperature

Examples:

```
vcu> trace uc
trace enabled: AF SS UC
vcu> trace- ss
trace enabled: AF UC
```

trace off

The **trace off** command turns off all tracing.

```
vcu> tr off
all tracing now OFF
```

upgrade

The **upgrade** command is used to perform a firmware upgrade. This command will place the VCU into the serial bootloader mode, waiting for the load to begin. The VCU must be power cycled in order to leave this mode.

```
vcu> upgrade

 ***
 ***                     Starting VCU Upgrade                        ***
 *** 1) Exit from the terminal application                           ***
 *** 2) Start the bootloader and download a new .hex file            ***
 *** 3) Restart the VCU                                              ***
```

VCU 3.0 Hardware

This section describes the differences between VCU 3.0 and VCU 3.1 hardware. The figure below shows the VCU 3.0 connections.

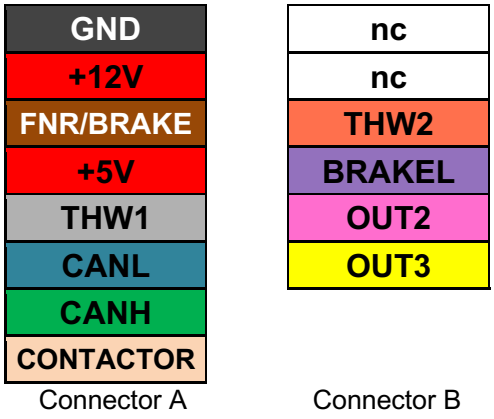


Figure 8 – VCU 3.0 Connections

Contactor and Precharge (OUT2)

VCU 3.0 Hardware supports a **CONTACTOR** output on Connector A. This output is switched to 12V when active but is only rated to 400ma. A typical main contactor requires more than 400ma to operate and so an additional relay is usually required.

VCU 3.0 also supports a **PRECHARGE** output. This is designated **OUT2** on Connector B. The **PRECHARGE** output is rated to 200ma and is an "open collector to ground" output (e.g., is grounded when active). See below for suggested wiring.

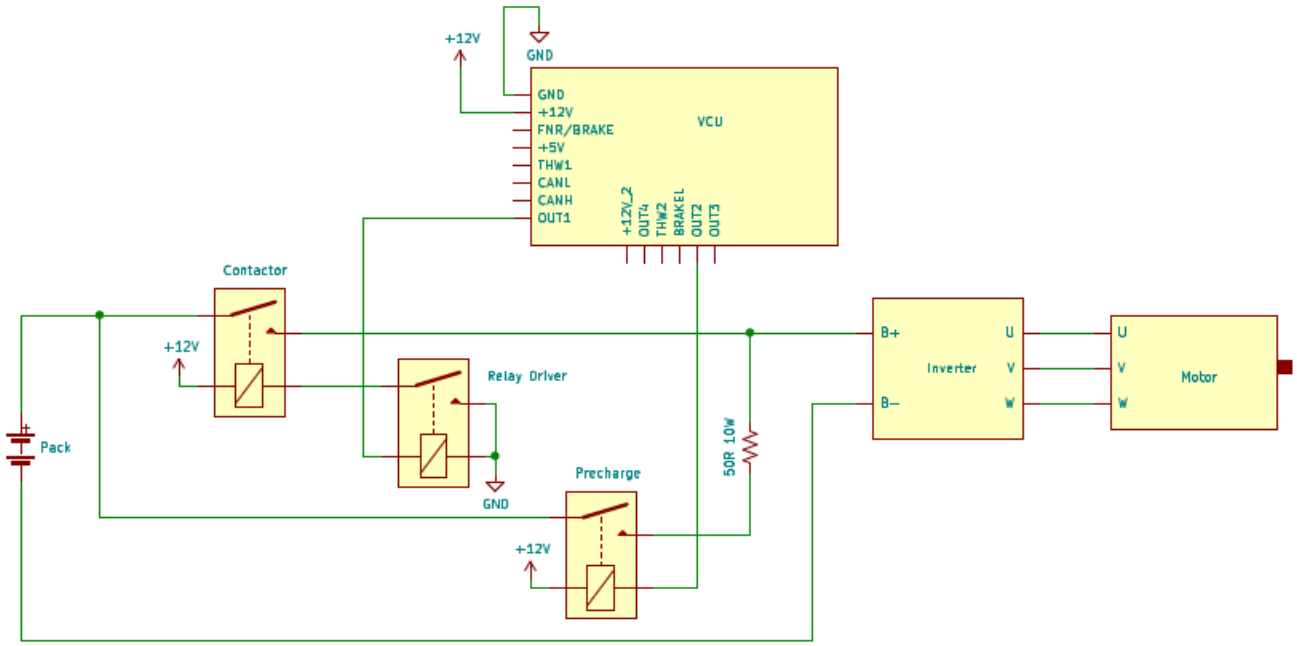


Figure 9 – VCU 3.0 PRECHARGE and CONTACTOR Wiring

Warrantee and Support

The Thunderstruck return policy is available at http://www.thunderstruck-ev.com/return-policy.html.

The Vehicle Control Unit is warranted to be free from defects in components and workmanship under normal use and service for a period of 1 year.

When failing to perform as specified during the warranty period we will undertake to repair, or at our option, replace this product at no charge to its owner, provided the unit is returned undamaged and shipping prepaid, to Thunderstruck motors.

The product is intended for non-commercial use by hobbyists. The warranty does not apply to defects arising from miswiring, abuse or negligence, accidents, opening the enclosure, or reverse engineering. Thunderstruck Motors and Dilithium Design shall not be responsible for any incidental or consequential damages.

Thunderstruck Motors and Dilithium Design reserve the right to make changes or improvements in design or manufacturing without assuming any obligation to change or improve products previously manufactured and / or sold.

For general support and warrantee issues, contact
connect@thunderstruck-ev.com

For errors in this document, or comments about the product, contact
djmdilithium@gmail.com

Document History

Rev 3.0	Oct 2018	initial document
Rev 3.0.1	Nov 2018	added automatic transmission support
Rev 3.1	Dec 2018	update to 3.1 hardware
Rev 3.1.1	Nov 2019	added torqueknee feature
Rev 3.1.2	Jan 2020	minor edits
Rev 3.1.3	Nov 2020	added support for Gen1 Leaf and UQM Coda