Tesla Model 3 Battery and EVTV Controller

http://evtv.me

INTRODUCTION

This document describes the Tesla Model 3 Battery Pack and EVTV Controller.

In 2017, Tesla Motors Inc. began delivery of the Tesla Model 3 all electric sedan. Since then it has produced over 400,000 of these vehicles at the date of this user guide, making it the largest volume production electric automobile built to date in North America and perhaps the world.

In this product, batteries are included – a 75kWh 400vdc high voltage battery pack. This provides sufficient energy storage to power the average American home for two and a half days. It was designed of course to power the Tesla Model 3 automobile for approximately 300 miles.

Tesla provides a generous warranty on the vehicle of four years or 50,000 miles, whichever comes first. But because of public perception of batteries generally, it provides an unusually generous warranty on the batteries and drive train of EIGHT YEARS OR 120,000 MILES.

But there is a bit of a repairability problem with the vehicles. Due to the high use of aluminum in body components and the very complex computer control of the vehicle, third parties are deeply discouraged from making repairs on these vehicles.

And inevitably a number of these shiny new high technology vehicles are wrecked in normal road service. Because of the high cost of Tesla authorized repair and repair of aluminum body components in general, an unusually large percentage of those wrecks are declared a TOTAL LOSS by the insurers. They are subsequently sold at salvage auctions for whatever the insurance company can get.

The prices at auction are further depressed by the high cost of repair and the unavailability of technical repair information from Tesla. Indeed Tesla is very rigorous in certifying any repaired salvage vehicle for return to service and refuses to provide software update or access to their Supercharger network for any vehicle not recertified by Tesla at a vigorous and expensive certification test.

As a result, there is essentially ZERO automotive aftermarket for often perfectly operational batteries from wrecked Tesla Model 3s. ALL VEHICLES SOLD SO FAR are still under battery warranty and will be for many years. Any Tesla Model 3 battery owner with a faulty battery or battery whose useful capacity drops below 70%, can get a brand new battery installed at no cost by Tesla.

For this reason, the often untouched batteries from salvaged Tesla Model 3 vehicles have basically zero value. A handful of hobbyists and researchers and

experimenters do trade in these batteries at prices ranging from $10,000 to $17,000 at this writing. This is actually below Tesla's COST for the batteries in many cases.

Model 3 Battery Pack
Left Side View

12v Terminals

X098 Control Connector

Charge Port
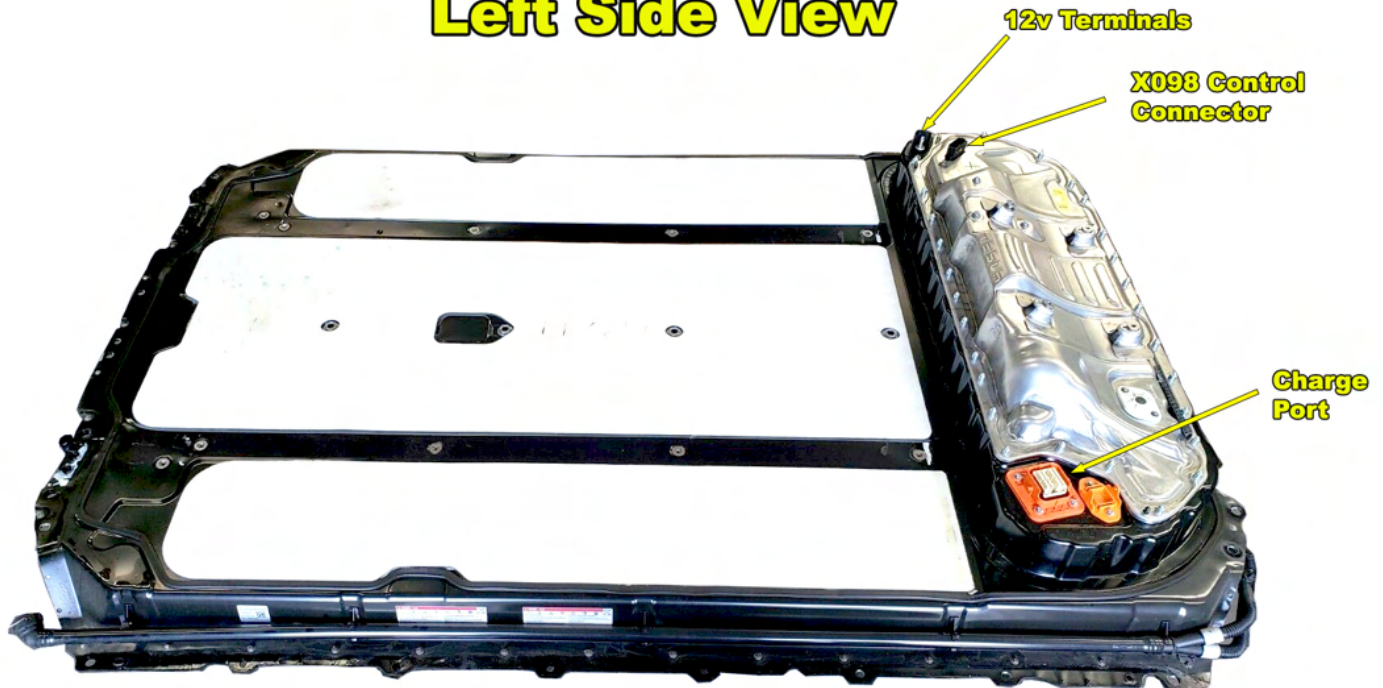
This leads to an unusual opportunity for solar energy storage. Large capacity high voltage battery storage at salvage prices. This represents an almost absurd "seam in the zone" in lithium batteries.

Lithium batteries feature ZERO maintenance and extremely long lifetimes of ten or fifteen years compared to conventional lead acid battery chemistries 3-5 years and often a 5x increase in energy storage per given weight or volume. That they are superior in every way for solar energy storage or other uses is unquestioned. The problem is they are usually five times more expensive than equivalent lead acid chemistry solutions – for new lithium batteries.

But repurposed lithium batteries from salvaged electric vehicles are available at the nominally equivalent price of lead acid cells.

There are some issues. Lithium batteries DO cram five times the energy into the same space and so represent an explosive amount of energy if mishandled. They

MUST not be either overdischarged or overcharged EVER or they are permanently damaged and further use can lead to horrendous fires or explosion.

Fortunately, Tesla has designed some extremely advanced battery management circuitry to prevent that and the success of that battery management design has resulted in an extremely low incidence of fire or explosion in their cars.

The issue there is that if you purchase a battery from a wrecked Tesla car, you can't really use it. An internal explosive fuse in the battery is almost always blown in the crash, and the internal circuitry of the battery is highly integrated with many safeties with the computer in the car. And so there is no way to simply connect the battery and use it. It will appear in all cases to be simply a dead inert battery.

Most likely, it is actually a completely serviceable nearly new battery with many years of life remaining.

EVTV has reverse engineered the vehicle to battery interface and developed a controller device to provide full access to the Tesla Model 3 battery. This device basically simulates the car to the battery and provides all messaging and connections the battery expects from the Tesla Model 3 vehicle.

To effectively do this, we must replace the pyrofuse in the battery and make a few other internal changes to the battery, while fully testing it for correct voltages and capacity. Purchasing salvaged batteries is much akin to Forrest Gump's box of chocolates, you never know what you are going to get.

And so we are offering the controller and battery as a package. Note these are still salvaged batteries and experimental controller circuitry. We are offering it to researchers and DIY builders for EXPERIMENTAL PURPOSES ONLY. We do not warrant any particular lifetime or suitability for any use whatsoever. If you are not technically trained and competent in power electronics, do not even consider a purchase. The EVER READY bunny was actually fried black in our shop and is now deceased.

WARNING

The SUCCESSFUL use of this battery and controller directly exposes the trained technician to high direct current voltages of as much as 403 vdc. **EXTREME CARE** and proper high voltage safety practices are required to avoid severe injury or death.

We are deliberately defeating Tesla's built in safety provisions to allow you access to the power and voltage available in this battery for unknown uses. And in purchasing this device you are agreeing specifically to take responsibility for all consequences arising from the use of the product.

Further, lithium batteries are inherently dangerous and cannot be MADE to be SAFE. By relying on Tesla's battery management system, and the EVTV Tesla Model 3 Battery Controller, they can be made "saf-ER" or perhaps "safe-ISH" but the inherent risk of fire or explosion of lithium batteries remains.

THE TESLA MODEL 3 BATTERY

The Tesla Model 3 battery provides about 75 kiloWatt hours of energy storage at a nominal voltage of 355 volts dc – 403vdc fully charged. The pack weighs 1054 lbs
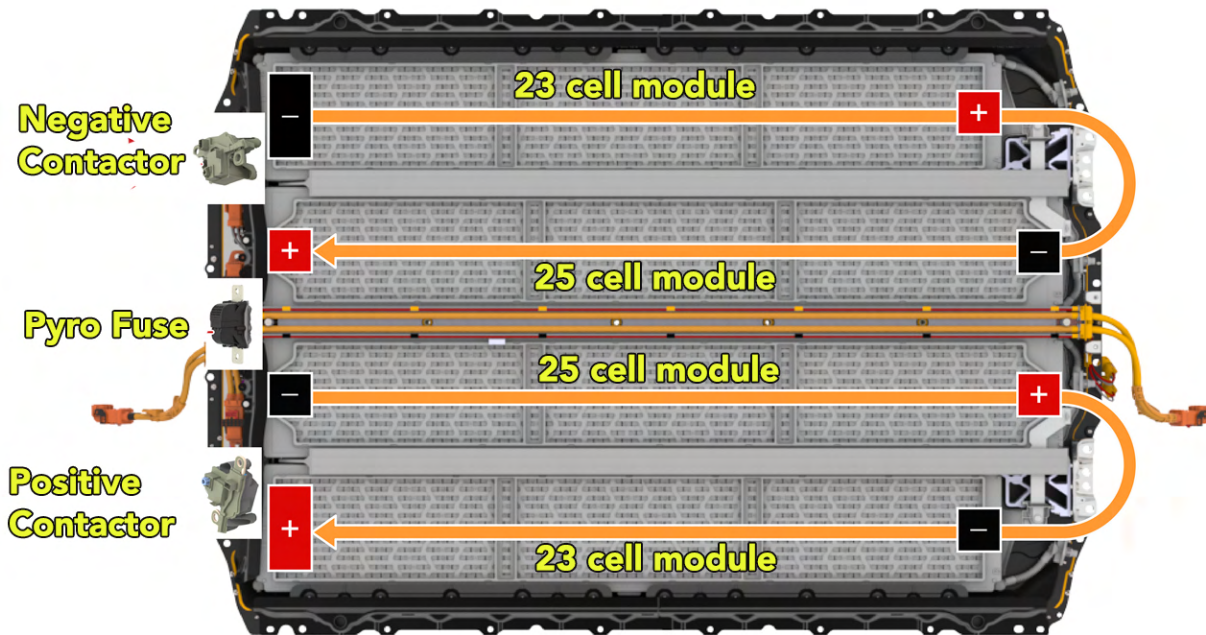
giving it an overall energy density of 73 watt-hours per pound or 161 wh/kg.

Physically, the pack is 85.75 inches long, 58.75 inches wide, and 13 inches high at it's highest point.

Internally, it consists of four battery modules connected in series. Two of these consist of 23 logical "cells" and two of 25. Each logical cell contains 46 of Tesla's 2170 battery cells in parallel. And so it consists of 96 logical cells and 4416 individual 2170 cells.

The Tesla/Panasonic 2170 cell features a carbon silicon graphite anode and a Lithium Nickel Cobalt Aluminum Oxide cathode LiNiCoAlO2. Each cell is 21 mm in diameters and 70 mm long and weighs 70 grams. With 17.3 watt hours per cell this provides 247 watt-hours per kilogram.

A coolant "channel" is woven throughout the cell modules making contact with each individual cell. Internal contactors for the negative and positive ends of the pack are provided to control access to the pack. And a "pyrofuse" connects the middle of the pack as a safety. This pyrofuse is disconnected in the event of a crash.

The pack can provide extremely high currents of up to 1150 amperes for brief periods of 10 seconds and over 400 amperes continuously.

Each cell is considered fully charged at 4.2v for a pack voltage of 403vdc. The cell is considered fully discharged at about 3.0v for a pack voltage of 288vdc.
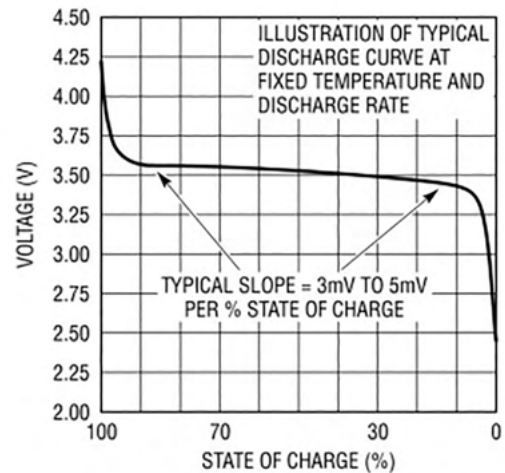
On the rear lower edge of the pack are several high voltage connectors. A connector is provided for the rear drive unit assembly and another for air conditioning heating equipment.

An optional additional high voltage connector may be available for the front wheel drive unit on AWD models. Coolant inlet and outlet connections are also located here.

Model 3 Battery Pack Connections

High Voltage Front Drive

Coolant Input

High Voltage Rear Drive

High Voltage AC/Heat

Coolant Output
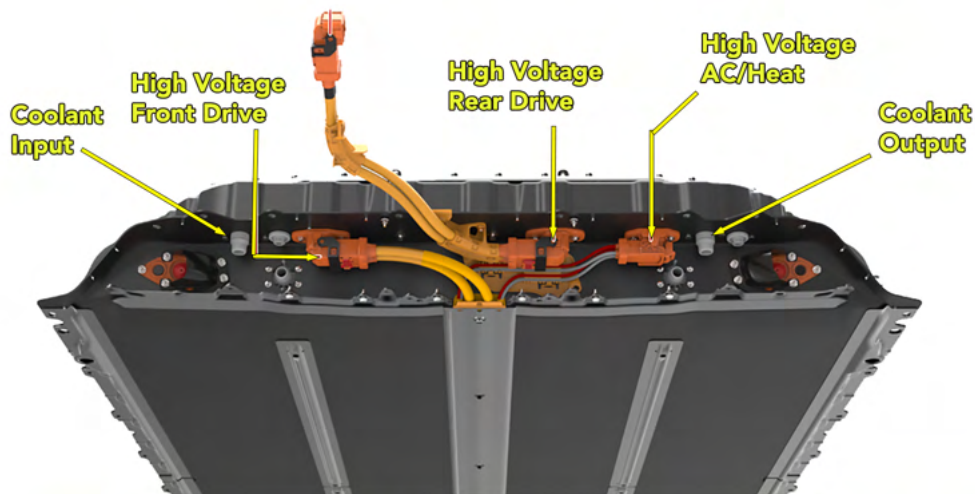
Nominal Voltage: 355vdc   Capacity: 77kWh   AH: 217

At the rear of the battery is an electronics enclosure termed "the penthouse" containing the BMS circuitry, contactors, and power conversion system.

Connector X098 provides the interface to the vehicle for 12v power and CAN messaging as well as high voltage interlock loop connections.

Two terminals are provided for higher current connections to the 12vdc battery which is charged by the PCS within the penthouse. This PCS converts high voltage to about 13.5vdc for the vehicle 12v systems.
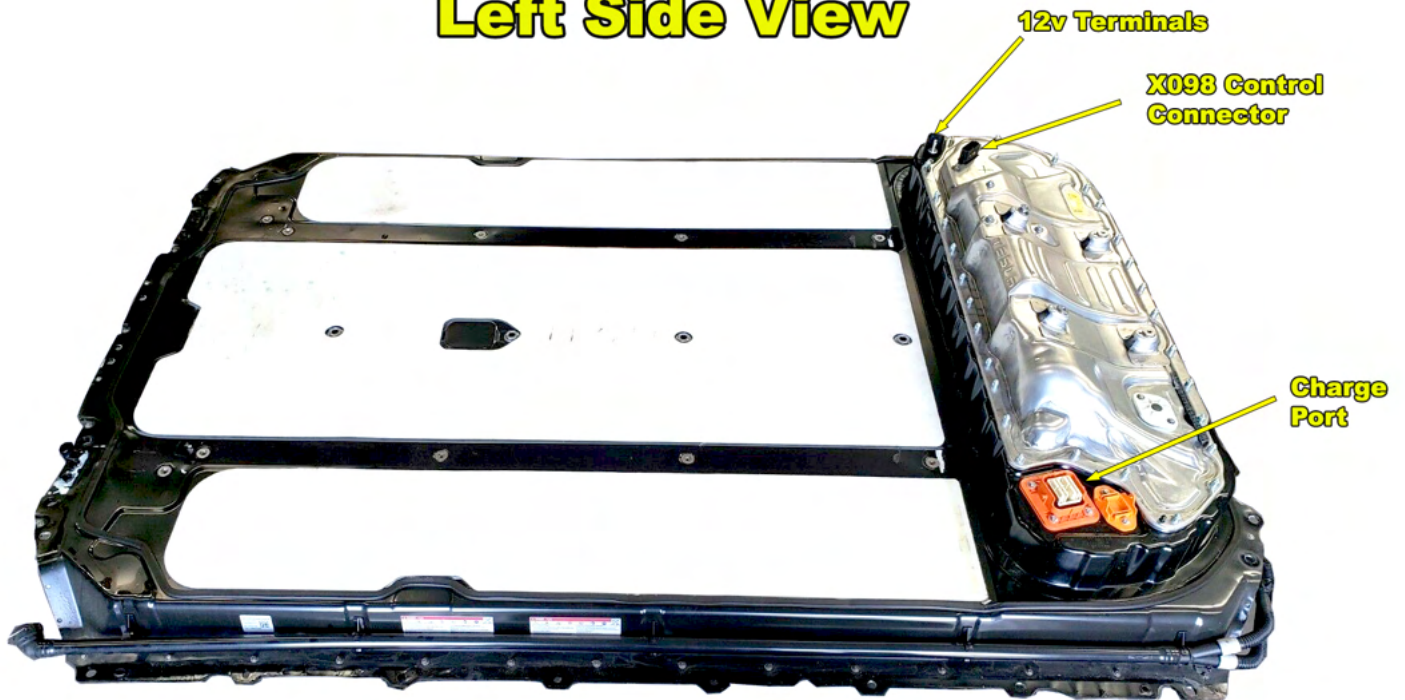
Finally, a 240vac charge port connector is normally used to charge the pack using the Tesla Model 3 charge port.

EVTV Tesla Model 3 Battery Controller

The EVTV Tesla Model 3 Battery Controller consists of a controller enclosure with connection cables for the battery and the output loads. Included is a 7-inch touchscreen display kit further described in the EVTV Battery Display User Manual.

The controller and display communications rely on the availability of a Wireless access point – a home wireless hub/router.

The controller provides a high voltage DC power connector to connect to the battery. It also provides a control connector to plug into the battery x098 control connector. And finally, it provides a positive and negative lead to connect to the PCS 12v terminals of the battery.

The functions of the controller include:

1. Provide necessary signals to the Model 3 High Voltage battery pack to cause it to close the internal contactors within the battery providing high voltage to the power connectors.

2. Receive and evaluate CAN signals from the Model 3 High Voltage Battery containing detailed information on battery operation, including total pack voltage, current, power and temperature and individual cell voltages within the pack. This information is then made available via ASCII text using the 115kbps USB port on the controller but also transmitted via WiFi to the EVTV Battery Display for a more visual presentation. This is of course much more detailed battery information than you will ever see in the Tesla Model 3 car display.

3. Control access to the high voltage battery pack via individual high voltage, high current Gigavac contactor relays on both the positive and negative connections to the pack.

4. Provide a precharge sequence to accommodate highly capacitive loads. This precharge function provides a low current (less than one amp) application of power to an external inverter, charger, or other device for a user defined period of time to "precharge" the input capacitor of the device. This avoids sudden and damaging inrush currents when full pack power is applied.

5. Provide external relay activation signals for charging, heating, or cooling. In some cases these outputs can be repurposed for inverter control operations or AC grid power switching.

6. Provides external CAN access to provide information to other equipment via CAN messages and in some cases to control external equipment such as the TCCH 6.6 kW charger.

7. Over the air updates. Like the Model 3, the controller features an OTA update process for its software. Enter **UPDATE=1** at the ASCII command line and the device will go out over the Internet and download the latest version of control software from Amazon AWS. Requires a WiFi AP with Internet connection at your location.

Note that this "controller" is specifically NOT a "Battery Management System" or BMS per se. Tesla has engineered a very capable BMS within the battery assembly. The controller more properly manages ACCESS to that system both for power and information and allows the end user to control the voltages and temperatures and currents that TERMINATE access to the device.

CONTROLLER INTERNALS

CONTROLLER MICROPROCESSOR

The heart of the Tesla Battery Module Controller is the controller electronics consisting of an EVTV ESP32 CANDue microprocessor board and a Tesla Module Controller shield.

The shield provides four switched ground MOSFET outputs capable of switching up to 2.5 amps of current at 12vdc. Typically you would use two of these to individually control a positive and negative high current high voltage contactor relay such as the Gigavac GX14.   But it provides two additional outputs to control external relays and devices or to signal other equipment. Currently one output provides a CHARGE ENABLE signal while the other is a HEAT/COOL Enable output based on temperature.

In addition to the CAN0 bus provided by the EVTV Due, it provides a second CAN1 bus.

The shield is connected to all this via a 20 pin Valu-Lok connector and harness. Four optically isolated inputs allow the shield to receive external 12v inputs. We currently use two of those to detect contactor position through the Gigavac GX14BAB auxiliary contacts and one to determine that 12v is actually available externally.

CONTACTORS

The controller uses two GIGAVAC EPIC GX16BEB contactors. These are single-pole, single-throw normally open high voltage high current relays capable of breaking current flows of several thousand amperes of current and 800 volts. These are hermitically sealed IP67 UL listed contactors mechanically rated for 1 million cycles.

These contactors are rated for 600 amperes continuous load.

The positive contactor has a 500 ohm 50 watt precharge resistor wired across the terminals.

Both contactors are wired to switched grounds from the controller board. And 12v is provided through the aux contacts to LED indicators. The RED LED indicates negative contactor closure while the GREEN LED indicates positive contactor closure.

In normal operation, on startup the controller will close the negative contactor completing the circuit between the battery and the load through the precharge resistor, which acts to limit current flow to less than an ampere. This allows the input capacitors for the load to fill before fully connecting the battery.

After a user configurable **PRECHARGE TIME**, the positive contactor is closed completing the circuit and connecting the battery to the outside system.

If at any time the controller determines that the voltage for any cell in the system exceeds the user configurable limits (**HIVOLT**, **LOVOLT**), or that the temperatures of any module exceed user-configurable limits (**HITEMP**, **LOTEMP**), the controller will disengage both contactors, isolating the battery from any load and effectively disconnecting the battery.

Precharge resistor selection is important, but not terribly critical. It is important in that the input capacitors of inverters and the output capacitors of the MPPT charge controllers can cause a huge but brief surge in current through the contactors when first connected to the battery. This current spike can reach 10000-12000 amperes but only lasts for a few microseconds before tapering to quite manageable currents. But this is sufficient to arc weld the contacts of almost any high current relay contactor. It will also most likely destroy the input capacitors of the connected equiepment.

To prevent this, the precharge resistor allows current flow into the capacitors at a much decreased rate. An ampere or two of current for five or six seconds is usually sufficient to bring the voltage up in the capacitors sufficiently to limit this current spike. You don't actually have to REACH the system voltage, just preload the capacitors to some nominal level.

The Model 3 pack has a nominal voltage of about 350 volts and a 500 ohm resistor will allow about ¾ of an ampere. If you do this for a precharge period of 8-10 seconds or so, this will be sufficient.

The precharge resistor is simply connected to both power terminals of the POSITIVE contactor. In this way, when the NEGATIVE contactor closes the circuit is completed and a small current allowed to flow.

When the POSITIVE contactor closes six or eight seconds later, the resistor is effectively bypassed and the current flows directly through the positive contactor.

CHARGER ENABLE CONNECTION

A two pin output consists of our 12vdc supply on one pin and a switched ground MOSFET output on the other.. This is configured to have the ground supplied when charging is allowed and the ground pin is floated, breaking the circuit when charging should NOT be performed.. This will be switched OFF if battery voltage exceeds user configurable voltage **CUTOFF** limits.

It will also switch back to ON if battery voltage falls below a user configurable **RESUME** voltage limit.

This signal is sufficiently powerful to operate most any external relay or contactor.

The **CUTOFF** and **RESUME** values should be selected such that hysteresis does not occur. Normally, if you charge to 4.15v for example, when you cut off the charging, the voltage of the battery will immediately fall back to a lower level. If your **RESUME** is above this level, the **CHARGE ENABLE** output will immediately energize the charge contactor. The voltage will rise and again **CUTOFF** will shut it off. This will continue to rapidly cycle indefinitely and is commonly called HYSTERISIS.

By setting the **RESUME** value somewhat lower, ie 3.90v, the charge controller will not resume charge output to the battery until the voltage falls to that lower level. You can adjust this to needs.

EVTV has also helped develop several inverters that will shift frequency of output if dry contacts are closed. By using an intermediate relay, we can close those contacts with either the CHARGE ENABLE or the HEAT ENABLE output. This frequency shift in turn can control associated grid-interactive microinverters.

If **CUTOFF** and **RESUME** are set to the SAME voltage value, when any cell reaches that value the **CHARGENABLE** output will turn on for approximately 500ms and then remain off for at least 2 minutes.

This frequency shift will cause ALL grid-interactive inverters such as the Solar Edge or Enphase inverters to CEASE providing power for a period of five minutes.

In this way, you can prevent overcharge by bumping the grid-tied inverters any time you reach your maximum charge voltage set in **CUTOFF** and effectively cycling them off for five minutes.

CAN CONNECTION

A second CAN connection is provided to communicate with inverters and other external equipment. We bring both CAN channels out using a panel mounted CAT6 RJ45 connector. Pinout is depicted below. As you can see, both CAN0 and CAN1 is available as well as 12vdc and the 12v return.

EVTV CAN OVER CAT5
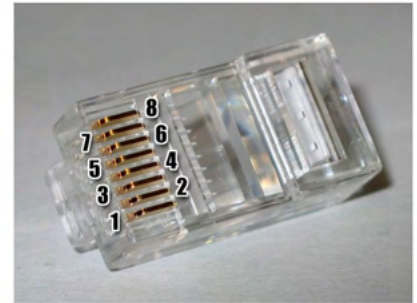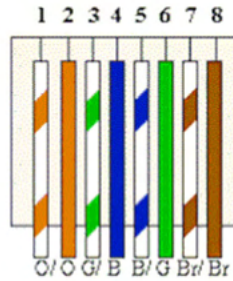
1. Orange/White   12vdc power
2. Orange   12vdc power
3. Green/White   CAN0 low
4. Blue   CAN1 high
5. Blue/White   CAN1 low
6. Green   CAN0 high
7. Brown/White   12v rtn
8. Brown   12v rtn

USB PORT

A standard USB mini-b printer port is provided on the end of the controller This is connected to the Native USB port of the EVTV Due microcontroller board .

You can connect a laptop of any operating system to this port to view the configuration and monitor screens provided by the controller software.   You will need an ASCII terminal program such as CoolTerm or Putty to do so.

Communications parameters are 115.2 kbps, 8 data bits, no parity, 1 stop bit. Your terminal program must be set to append either a line feed, carriage return, or both to all commands.

The display will be more pleasant to view if the terminal program also recognizes the FORM FEED ASCII command.

In normal operation, you would press the ON/OFF switch to initialize the system, then connect the USB cable to the port and select CONNECT on your terminal program.

Further, understand that the process of forming and transmitting a large amount of battery status data out the USB port is a processor intensive task. It puts quite a load on our little multicontroller.

This is designed to allow you to CONFIGURE your battery and to perhaps TROUBLESHOOT problems. It was never designed to produce a continuous display output. So in theory, you would connect a laptop, configure your battery to the values you desire, and DISCONNECT the USB cable. Then restart your battery.

The reason we mention this is that there have been cases where the controller fails/reboots every couple of days it would appear. But in all cases, the USB port was in continuous operation. When we have them disconnect the USB port, the same controller will operate for weeks or months on end with no hiccups.

EVTV CONTROLLER OPERATION

The EVTV Controller for the Tesla Model 3 Battery is an entirely automatic system to connect the full output of the battery to a load – typically a home solar installation.

The basic operation is extremely simple. You connect the batteries in one end and the load out the other. Set the ON/OFF toggle switch to ON and press **ON/OFF** to turn it on. After a brief pre-charge sequence, this connects the battery to your system.

To disconnect it, press **ON/OFF** again and set the toggle switch to off. You're done and that is really all the operation required. Thank you for shopping at EVTV.

The device monitors battery voltage, current and temperature hundreds of times each second, and as long as all fall within preset limits, it just works. The limits are already configured before it leaves our shop. And as long as the battery modules do net exceed certain voltage and temperature limitations, you can use the batteries at will.

BUT – how whom so ever, EVTV viewers tend toward curiosity, obsessive compulsive disorder, and an overweening desire to control everything within their purview. Not to cast aspersions on the show's host and producer and first wizard deluxe.

And so the EVTV controller provides a USB port and CAN port.

The USB port allows a serial connection for a common standard American Standard Code for Information Interchange (ASCII) terminal. While a bit shy of an iPhone application, this elderly communications technique allows a very simple interface to ANY device of any operating system, Linux, Windoze, Mac OSX, et al. But it DOES require the use of a "terminal program" such as HyperTerm for Windoze, CoolTerm for Mac OSX, or the Arduino MONITOR program, part of the Arduino IDE.

Communication parameters are 8 data bits, no parity, 1 stop bit, and nominally at 115 kbps data rate.

Any commands entered to the system must be an ASCII text line terminated with a carriage return (CR), line feed (LF) or both.

On connection, the system will send the ASCII text of the main screen several times per second. If your terminal program recognizes the ASCII Form Feed command, it will be easier to read.

There are actually three screens available, the **MAIN** screen, the **CONFIGURATION** screen, and an **AC GRID SCHEDULE** screen. You can toggle between them by entering a question mark **?** on the command line or **<** or **>** to move between them.

MAIN SCREEN

```
================================================================================
******* EVTV Tesla Model 3 Battery Controller Version 2.26 Runtime: 00 Days 04:07:24 *******
                                        Friday, March 06, 2020  17:17:28
================================================================================
 Cell 01: 4.018   02: 4.019   03: 4.019   04: 4.019   05: 4.019   06: 4.020   07: 4.018   08:4.020
 Cell 09: 4.019   10: 4.019   11: 4.020   12: 4.016   13: 4.016   14: 4.016   15: 4.016   16:4.016
 Cell 17: 4.017   18: 4.016   19: 4.017   20: 4.017   21: 4.018   22: 4.018   23: 4.018   24:4.018
 Cell 25: 4.017   26: 4.017   27: 4.016   28: 4.019   29: 4.019   30: 4.018   31: 4.018   32:4.019
 Cell 33: 4.019   34: 4.019   35: 4.020   36: 4.019   37: 4.019   38: 4.018   39: 4.018   40:4.018
 Cell 41: 4.019   42: 4.020   43: 4.017   44: 4.020   45: 4.019   46: 4.019   47: 4.018   48:4.020
 Cell 49: 4.016   50: 4.016   51: 4.016   52: 4.017   53: 4.017   54: 4.017   55: 4.017   56:4.016
 Cell 57: 4.018   58: 4.018   59: 4.017   60: 4.018   61: 4.017   62: 4.017   63: 4.017   64:4.017
 Cell 65: 4.017   66: 4.017   67: 4.017   68: 4.017   69: 4.018   70: 4.017   71: 4.018   72:4.017
 Cell 73: 4.017   74: 4.016   75: 4.014   76: 4.014   77: 4.014   78: 4.016   79: 4.015   80:4.015
 Cell 81: 4.015   82: 4.016   83: 4.017   84: 4.017   85: 4.013   86: 4.015   87: 4.015   88:4.014
 Cell 89: 4.014   90: 4.015   91: 4.013   92: 4.012   93: 4.015   94: 4.014   95: 4.014   96:4.015
  Summed Voltage:385.640v Average Cell:4.017v High Cell: 4.020v Low Cell: 4.012V

 Reported Voltage:385.170v Current:-0.215A  Power:-83 watts Temperature:20C

   Capacity:73.5 kWh  Remaining:54.4 kWh  SOC:74.0%
     Lifetime Charge:7513.273 kWh  Lifetime Discharge:6717.389 kWh
     Max System Discharge Current: -0.32A Max System Charge Current: 17.49A  (z to reset)

 Battery Internal Contactors:4 CLOSED
          Negative Contactor:ON  Reported ON
          Positive Contactor:ON  Reported ON

 Charge Enable(4):OFF      Heat Enable(5):OFF     Battery Serial Number:TG118294000SXS

 Connected to local Access Point:EVTV as IP:192.168.1.113 signal strength:-65dBm
Enter > for configuration screen
```

It is refreshed with new data each second.

TITLE BAR

```
================================================================================
******* EVTV Tesla Model 3 Battery Controller Version 2.26 Runtime: 00 Days 04:07:24 *******
                                        Friday, March 06, 2020  17:17:28
================================================================================
```

This line shows the current software version number and the runtime since the system was powered up. The runtime will rollover after about 49 days.
The version number can be used to verify you have the latest software operating anytime you upgrade the software.

If and once you connect to a local Wireless Access Point hub/router, this title bar will also display the current date and time.

In that event, the system will automatically retrieve a time mark from the National Institute of Science and Technology in Boulder Colorado using the NTP time

protocol and display the local date and time according to the Time format string entered on the **CONFIGURATION** screen.

An additional line shows the Station Set Identifier (SSID) of the Access Point, the IP number assigned to the ESP32 controller, and the current WiFi signal strength in dBm.

If this is not displayed or if you lose your connection, you can try to reconnect by enter **x** on the command line.

INDIVIDUAL CELL DISPLAY

The next set of lines shows individual cell data. It normally appears ONLY AFTER both contactors are energized.

```
Cell 01: 4.018   02: 4.019   03: 4.019   04: 4.019   05: 4.019   06: 4.020   07: 4.018   08:4.020
Cell 09: 4.019   10: 4.019   11: 4.020   12: 4.016   13: 4.016   14: 4.016   15: 4.016   16:4.016
Cell 17: 4.017   18: 4.016   19: 4.017   20: 4.016   21: 4.018   22: 4.018   23: 4.018   24:4.018
Cell 25: 4.017   26: 4.017   27: 4.016   28: 4.019   29: 4.019   30: 4.018   31: 4.018   32:4.019
Cell 33: 4.019   34: 4.019   35: 4.020   36: 4.019   37: 4.019   38: 4.018   39: 4.018   40:4.018
Cell 41: 4.019   42: 4.020   43: 4.017   44: 4.020   45: 4.019   46: 4.019   47: 4.018   48:4.020
Cell 49: 4.016   50: 4.016   51: 4.016   52: 4.017   53: 4.017   54: 4.017   55: 4.017   56:4.016
Cell 57: 4.018   58: 4.018   59: 4.017   60: 4.018   61: 4.017   62: 4.017   63: 4.017   64:4.017
Cell 65: 4.017   66: 4.017   67: 4.017   68: 4.017   69: 4.018   70: 4.017   71: 4.018   72:4.017
Cell 73: 4.017   74: 4.016   75: 4.014   76: 4.014   77: 4.014   78: 4.016   79: 4.015   80:4.015
Cell 81: 4.015   82: 4.016   83: 4.017   84: 4.017   85: 4.013   86: 4.015   87: 4.015   88:4.014
Cell 89: 4.014   90: 4.015   91: 4.013   92: 4.012   93: 4.015   94: 4.014   95: 4.014   96:4.015
 Summed Voltage:385.640v Average Cell:4.017v High Cell: 4.020v Low Cell: 4.012V
```

Current voltage for each of the Model 3 96 cells is provided, along with a calculated summed voltage, average cell, high cell, and low cell. In the battery, the cell numbers correspond as shown in the diagram below:
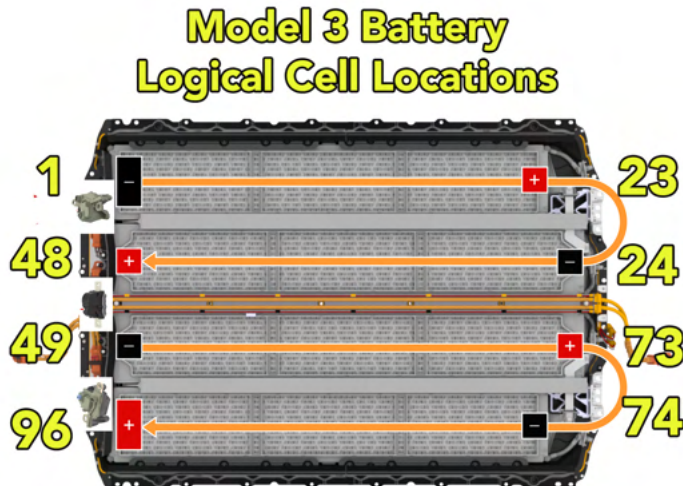
PACK SUMMARY

```
Reported Voltage:385.170v Current:-0.215A  Power:-83 watts Temperature:20C

 Capacity:73.5 kWh  Remaining:54.4 kWh  SOC:74.0%
   Lifetime Charge:7513.273 kWh  Lifetime Discharge:6717.389 kWh
   Max System Discharge Current: -0.32A Max System Charge Current: 17.49A  (z to reset)
```

Beneath the cell data is some reported pack summary data. Reported voltage and current and temperature are the most important. These are received by CAN message. Note there may be some small discrepancy between reported voltage and the SUMMED voltage of the cells. We calculate the SUMMED voltage from the individually reported cell voltages, which may not all come in at the same time. The reported voltage is a CAN message from the battery BMS indicating what it thinks the total voltage is. It is normal for a small discrepancy between these two.

Likewise, the Capacity, Remaining kWh, and SOC are reported by the battery internal BMS. The capacity is a calculated value of what the current capacity is, not the original capacity of the battery. Similarly, the amount of energy remaining in the pack and current state of charge are all reported by the battery BMS.

Lifetime charge and discharge are somewhat interesting in that the battery keeps track of this continuously and it cannot be reset. Max system charge current and discharge current, on the other hand are calculated by our controller and can be reset at any time by entering **z**   on the command line.

CONTACTOR STATE

```
    Battery  Internal  Contactors:4 CLOSED
            Negative Contactor:ON   Reported ON
            Positive Contactor:ON   Reported ON
```

One of the most important functions of Model 3 Controller is to connect, and more importantly, disconnect the pack from the load in event of a detected error in the pack. This is accomplished using two very high quality Gigavac GX14 contactor relays capable of continues currents of 350 amperes. One is provided for each battery terminal.

Additionally, there are two contactors within the Tesla Model 3 High Voltage battery. On powering up the EVTV controller, the sequence automatically begins to establish communications and actuate these internal controllers.   This requires 12vdc which is normally provided by some internal 18650 batteries in our controller. These should be recharged whenever the internal contactors close. If you encounter difficulties getting these internal contactors to close, connect a 12v source to the positive and negative terminals of the Power Control System.

The battery internal contactors should indicate OPEN, then CLOSING, then CLOSED. Once closed, we can begin the precharge sequence by closing the controller negative contactor – indicated by the red LED on the controller box.

This actually connects full battery voltage to your load. However, since the positive contactor is still open, voltage is applied via a precharge resistor that bypasses that contactor. This 500 ohm 100w precharge resistor LIMITS the current to the load to less than 1 ampere for the period of time in seconds you have set on the CONFIGURATION screen for PRECHARGE.

This is extremely important and it is imperative you fully understand how this works. Almost all loads you might connect this battery to will have a large value of internal input capacitance. DC-DC converters, chargers, inverters, all have quite large input capacitors. If we were to suddenly connect the output of the battery to such a load, an enormous but very brief current spike would result. At a minimum, this will weld the controller contactor permanently closed and could very easily result in damage to the load device by blowing up the input capacitors.

For this reason, you MUST connect the controller output to the load BEFORE turning it on and initiating precharge. Never connect anything to the controller output AFTER precharge is completed. This means you cannot have an intervening switch or circuit breaker between the controller output and your load device.

The small current through the precharge resistor is enough to bring the load device input capacitor voltage up to near the battery voltage. In this way, when the positive contactor closes *n* seconds later, no huge current spike will occur. Precharge complete is indicated by the GREEN LED.

The contactors are commanded by a switched ground output to the coils. But they also have some auxiliary contacts. 12vdc is provided to these contacts all the time. When the contactor closes, the aux contacts also close. The output of the aux contacts is actually what lights the LED.

This is also fed back to the controller as an input. In this way, we can tell if the contactor actually closed or opened.

And so you see **CONTACTOR ON,** but also **REPORTED ON**. This means we have sent the command to close the contactor and verified through the aux contacts that it did indeed close.

Why is this important? If you open a contactor carrying a high current, it is possible to draw an arc between the contacts and actually weld them together so they will not open at all. This is a potentially dangerous situation in that we have disconnected the battery pack, but one contactor didn't actually open.

And so in the event that CONTACTOR is OFF but REPORTED is ON, you will also see an advisory **POSSIBLE WELDED CONTACTOR!!!..**

Note that you can toggle the internal contactors AND the precharge sequence by entering a **C c**ommand on the command line. Similarly **1** toggles the negative contactor and **2** toggles the positive contactor.

CHARGE ENABLE

The next line of the main screen display indicates the status of two hardware outputs of the controller: CHARGE ENABLE and HEAT ENABLE. It also displays the serial number of the specific Model 3 battery.

```
 Charge Enable(4):OFF      Heat Enable(5):OFF    Battery Serial Number:TG118294000SXS
```

The **CHARGE ENABLE** output is provided to control some external charging device, a battery charger or solar MPPT charge controller for example – usually be actuating an external relay. This output consists of two pins. Pin 1 is a constant 12v and pin 2 is a switched ground. If you connect this to the coil terminals of an external relay or contactor, you can control it.

CHARGE ENABLE is a function of two **CONFIGURATION SCREEN** items, **CUTOFF** and **RESUME**. And so the output would be positive if the battery individual cell voltage is below **CUTOFF** for example 4.10 volts. Once reaching 4.1 volts, **CHARGE ENABLE** will be disabled. Cutting of the charge operation will cause the battery voltage to drop a little bit anyway. So the **RESUME** voltage is also important. The **CHARGE ENABLE** output will not re-engage until the cell voltage falls below **RESUME**. In this way, we avoid hysteresis where the output rapidly cycles on and off.

There is an obscure secondary operation for **CHARGE ENABLE**. If you set the **CUTOFF** and **RESUME** voltages to the exactly identical values, the **CHARGE ENABLE** output can be used for frequency shifting. On reaching **CUTOFF**, it will simply energize the **CHARGE ENABLE** output for 500 milliseconds. We use this as a signal to shift an inverter frequency from 60.0 Hz to 62.5 Hz for the 500ms period. This is enough to cause Enphase and Solar Edge grid-tied inverters to do a rapid shutdown for 300 seconds – five minutes.

The **CHARGE ENABLE** output can also be toggled using the **4** command on the command line.

HEAT ENABLE

Heat Enable:OFF

In addition to the CHARGENABLE output, the system also provides a second switched ground output titled HEAT ENABLE. Again, a two-pin connector with 12vdc always available and a switched ground.

The Tesla batteries are normally both cooled and heated as necessary using a liquid coolant through a circuit that actually winds through each module and contacts each cell. It is not likely you will actually need to cool the pack during normal operation. But in high loads in a high ambient temperature environment it is possible.

More likely, the pack may be in an environment where winter temperatures venture below freezing. It is EXTREMELY IMPORTANT that you NOT charge lithium batteries below 32F or 0C – basically freezing. This causes lithium plating of the anodes and irreparable damage.

For this reason, a HITEMP limit and a LOTEMP limit are provided in the CONFIGURATION screen. If the pack exceeds the HITEMP limit, the contactors will be opened and the battery disconnected from the system.

If the temperature falls below the LOTEMP limit, the pack is again disconnected from the system by opening the contactors.

But if the pack temperature rises to HITEMP LIMIT minus 3 degrees Celsius, we first engage the HEAT ENABLE output. And if the temperature drops to 3 degrees ABOVE the LOTEMP limit, we also engage the HEAT ENABLE output.

This output can be used to turn on a pump and heater for example in cold weather. Or a pump and fan system to cool the pack if the temperature rises too high.

In this way, you can apply cooling or heating to the pack only as necessary.

Heating will continue until the temperature rises to 10C ABOVE the LOTEMP limit. Cooling output will continue until the temperature falls to 10C BELOW the HIGH TEMP limit.

There are actually TWO obscure variant uses for HEAT ENABLE and actually we have found it very rare to need to cool the battery at all. But we have TWO secondary uses.

IF you set HITEMP and LOTEMP to the same value, the HEAT ENABLE output will be used as a 500ms frequency shift output when the cell voltage reaches CUTOFF.

We have also used this output to switch an external contactor applying AC grid voltage to the input of an inverter on a time of day schedule using the third screen AC GRID SCHEDULE. If you set HITEMP to ZERO, the HEAT ENABLE output will be controlled by this schedule.

HEAT ENABLE can also be toggled using the 5 command on the command line.

You can navigate to other screens using either the ?, the <, or the > keystroke command on the command line.

CONFIGURATION SCREEN.

```
========================================================================================
**********   CONFIGURATION MENU Version 2.26   Runtime: 00 Days 04:09:15  ***************
========================================================================================

GENERAL SYSTEM

   SSID=EVTV    ---WiFi SSID
   PASSWORD=usatoday    ---WiFi Password
   TIMEZONE=CST6CDT,M3.2.0/2,M11.1.0    ---Time zone TZ string
   UDPPORT=6875    ---
   CAN0SPEED=500000 Set CAN bus speed
   CAN1SPEED=250000 Set CAN bus speed
   E = 0  - Enphase Gateway Monitoring ON(1) or OFF (0)

BATTERY LIMITS AND CONFIGURATION

   AMPS=        47.00  Maximum charging amps for frequency shift
   PRECHARGE=   8.5  Number of seconds in precharge delay
   HIVOLT=      4.15 High Cell Voltage limit to open contactors
   LOVOLT=      3.00 Low Cell Voltage limit to open contactors
   FREQSHIFT=   4.10v Cell Voltage at which Frequency Shift output occurs
   CUTOFF=      4.15 Charge Enable Output Cutoff Cell Voltage
   RESUME=      3.20 Charge Enable Output Resume Cell Voltage
   SENSITIVITY= 128  Alarm sensitivity 1 (most sensitive) 254 (least sensitive)

   Enter ? or < or > to go to next screen......
```

This screen allows you to enter various configuration values used by the system. Many of these have already been discussed.   To enter a value simply enter a text line with the name of the value, the equals sign, and the numeric value. Each command line MUST end with a carriage return, line feed, or both.

GENERAL SYSTEM CONFIGURATION

SSID=EVTV

PASSWORD=usatoday

The ESP32 BMS Controller is a major upgrade to the EVTV battery controller lineup, most notably because it has WiFi communication functions. This means you can connect to your local WiFi wireless hub/router and thence to the world.

Normally to do this you need to specify the Station Set Identifier (SSID) and password for your local wireless router.

These two values can be up to 32 characters and contain any combination of upper and lower case characters, numerals, and punctuation.

If UDP is on, the ESP32 BMS Controller will attempt to connect to your wireless hub approximately 100 seconds after power-up. It will check this connection every 100 seconds thereafter, reconnecting as necessary.

TIMEZONE=CST6CDT,M3.2.0/2,M11.1.0/2

When the ESP32 BMS Controller first connects to a wireless hub, the first thing it does is attempt to connect to the NTP time server to get a National Institute of Science and Technology (NIST) time mark. This is a highly accurate time clock accessible over the Internet.

Unfortunately, time stands still for no man and worse, it is a bit hard to relate international time mark standards to local time.

The **TIMEZONE** variable allows you to specify your system timezone using the standard POSIX **TZ** variable format used by most unix-like computer systems.

The simplest form of this is something like **UTC+6** which works perfectly well to set your system to 6 hours lagging behind Universal Coordinated Time.

In our example, we are specifying that we are in the Central Standard Time zone (**CST**) of the United States, **6** hours from UTC, and that we DO observe Central Daylight Savings time (**CDT**). We then go on to specify that we change to CDT in the third month, **M3**, the second occurrence **.2** of day **.0** (Sunday) at two AM in the morning **(/2)**. Similarly we change back to CST in month 11 (November M11) on the first Sunday of the month at 2:00AM.

Who thinks this stuff up? Actually the TZ DATABASE is maintained by Paul Eggert. https://web.cs.ucla.edu/~eggert/tz/theory.html. More on the TZ database: https://en.wikipedia.org/wiki/Tz_database.

UDPPORT=6875

The controller communicates with the EVTV Battery Display by WiFi through your local WiFi Hub. But it passes CAN data using the User Datagram Protocol or UDP. This is transmitted on a specific PORT and only devices listing on that port can receive the data.

The Battery Display also has a UDP PORT setting. You simply have to make sure the UDPPORT specified on the controller matches the same port on the display. In this way, multiple displays and controllers can coexist on the same WiFi access point.

CAN0SPEED = 500000

CAN0=500

CAN speed sets the data rate for the CAN bus. Speeds must be between 33,000 bits per second and 1,000,000 bits per second. There are two CAN channels, CAN0 and CAN1. **CAN1SPEED = 250000**   is identical for CAN1

LIMITS AND CONFIGURATION

PRECHARGE= 6.50 - Number of seconds in precharge delay

On startup, the system engages the negative contactor, initiating a precharge of the input capacitors on the load equipment.   The circuit is completed through a precharge resistor across the terminals of the positive contactor. This will limit current to less than 2 amperes until the input capacitors of the device we are powering can charge to the output voltage. After a period of delay defined by **PRECHARGE** in seconds, it engages the positive contactor, connecting the battery directly to the system and bypassing this precharge resistor.

HIVOLT= 4.30 - High Cell Voltage limit for Contactor cutoff

This command allows entry of the highest allowable cell voltage. If ANY cell in ANY module reaches this voltage, even briefly, it triggers a voltage alarm and the system is disconnected. You might want this to be slightly above the charge voltage or any voltage a cell might reach during charging or balancing even briefly.

LOVOLT= 2.90 - Low Cell Voltage limit for Contactor cutoff

This command allows entry of the lowest allowable cell voltage. If ANY cell in ANY module falls below this voltage, even briefly, it triggers a voltage alarm and the system is disconnected.

Note that cell voltages can reach fairly low values during high current delivery, and that this is NOT the same as the fully discharged voltage under static conditions.

You will probably want to experiment with your system under normal full loads, and observe the cell voltages on the monitor screen. You can then set this for something slightly lower, in order to catch failing cells or surge currents beyond what you want to supply.

FREQSHIFT= 4.10 – Cell voltage for Frequency Shift Output

Cell voltage at which the Frequency Shift output will be activated for 500 milliseconcs.

CUTOFF= 4.15 - Charge Enable Output Charging Cutoff Cell Voltage

That said, Cutoff, on the other hand, does not impact contactors at all. It simply establishes the cell voltage at which we wish to discontinue charging. This value is used with CAN commands to inverters and chargers, but it is also a limit for the CHARGE ENABLE output.   This output is a switched ground that can be used to control an external contactor or circuit effecting a separate charger or charge controller.   In any cell hits the cutoff voltage, that output is disabled and so the switched ground is removed.

RESUME= 3.90 - Charge Enable Output Resume Charging Cell Voltage

Resume would be a lower voltage than cutoff that re-enables the CHARGE ENABLE output. And so we charge until reaching CUTOFF and then stop until the voltage falls to RESUME.

There is a special mode of the ESP32 controller. It uses the CHARGENABLE output to switch the Singineer controller output frequency from 60Hz to 62.5 Hz for a very brief period (500 milliseconds).

You can set this mode to occur when the battery voltage reaches **CUTOFF** by setting **RESUME** equal to the **CUTOFF** voltage. This would never be used for normal charge enable operation.

AMPS=48

A central tenet of EVTV's solar storage concept is the little known fact that an off grid inverter coupled with grid interactive inverters such as Enphase or Solar Edge will work IN REVERSE to charge the batteries from the 240vac solar power back through the off-grid inverter. Unfortunately, the power limits of the inverter still apply.

In this way, if your rooftop grid interactive solar produces MORE power than your loads, the excess power will flow BACKWARDS through the off-grid inverter, which then acts as a rectifier putting DC back into the battery.

If the power limits of the inverter are exceeded this will cause it to shut down.

We normally control the grid-interactive inverters by shifting the frequency to 62.5 Hz using the **CHARGE ENABLE** or **HEAT ENABLE** output.

AMPS let's you set the MAXIMUM power allowed to charge the batteries. And this is not because the batteries can't take it, but more likely to protect the inverter.

And so if the charge current INTO the battery exceeds the value in **AMPS** for 120 seconds, or **AMPS x 1.1** for 30 seconds, or **AMPS x 1.2** for 5 seconds, it will issue a frequency shift command for 500 ms using either **HEAT ENABLE** or **CHARGE ENABLE** as you have configured it.

AC GRID SCHEDULE SCREEN

In the summer of 2019, San Diego Gas and Electric Company has implemented a dramatic increase in the basic connection charge for electrical service to $40 per month. But more egregiously, they have introduced mandatory time of use charges for their entire customer base.

These actions are actually part of a California state law, SB327, that represents one of the most egregious examples of collusion between the utility grid operators and their regulators ever conceived.

These changes have become apparent at SG&E first because they have a relatively small customer base with a high level of residential solar – some 150,000 customers at this time. They also have more modern billing and accounting systems than some of the larger utilities.

But the much larger Pacific Gas and Electric and Southern California Edison are slated to implement this same scheme by years end.

The new SG&E rates are as follows:

EV-TOU-5

Plan	On-Peak	Super Off-Peak	Off-Peak
Time of Day	4:00 pm - 9:00 pm (Everyday)	Midnight – 6:00 am (Weekdays) Midnight – 2:00 pm (Weekends & Holidays)	All other hours
Amount	53¢	9¢	29¢

Basic service fee: $16

But note that the Basic Service Fee has risen from $16 per month to $40.

And so this isn't the future, it is the already.

PG&E has extended the battle. Facing a $10 billion lawsuit from some wildfires they have already filed for BANKRUPTCY and while how that comes out is up in the air, they have just recently cut power to 800,000 customers (some 2.5 million people) for up to two weeks in case it MIGHT cause a fire from prevailing winds and dry conditions. This likely has nothing to do with the weather or fires and everything to do with the bankruptcy and regulation. It's a bit of a "here's what we CAN do to you if you challenge us".

And of course, many of those customers DO have grid tied solar energy systems. But they are learning that without the grid, those systems don't generate ANY power, day or night. With $70,000 invested in solar on the roof, they can't make enough power to charge their cell phones.

Our solution is battery based photovoltaic solar systems that only use the grid for backup purposes. And those using that, are largely unaffected. We term it "selfish solar".

But our customers have prevailed upon us to make some concessions to the "selfish" part so they can sell power to the grid during sunny periods and "time shift" power to the 4:00 PM to 9:00 PM period when their photovoltaic panels produce negligible power output.

We can do that. So in version 2.00 we have added a THIRD screen to our main screen/config screen pair. You can still navigate between the three by entering a **?** followed by a carriage return and/or line feed.

But you can now navigate between screens bidirectionally using the **<** or **,** (comma) and the **>** or **.** (period) keys.

For our Time of Use (TOU) screen to make any sense, you DO have to have a connection to your home WiFi Access Point (AP) and that AP does have to have some sort of connection to the Internet.   The controller gets time from the Network Time Protocol (NTP) server ultimately tied to the National Institute of Science and Technology (NIST) time standard in Boulder Colorado.

And you do have to have a POSIX time string specified in the CONFIG screen so that the time displayed is equal to your local time.

Finally, you have to set the **HITEMP** value on the **CONFIG** screen to **0** (zero). This value is generally used for temperature alarms triggering the **HEAT ENABLE** output to energize in an overtemperature condition. Overtemperature has proven to be a very rare event in most installations anyway. And for TOU switching, we are going to use the **FREQUENCY SHIFT** output to control an external relay or contactors to connect AC to the system as an input.

This will work with any inverter that can be operated in UPS mode. We would normally connect the AC grid as an input to the inverter, where it would pass THROUGH the inverter to the loads. On the event of an AC power failure, the inverter automatically switches to battery output mode.

And so your external relay, using the **FREQUENCY SHIFT** output, is used to simulate grid on and grid off conditions to the inverter.

```
================================================================================
**********  EVTV Tesla Battery Module Monitor Version ESP32-2.00  Wednesday, October 16, 2019  12:38:52   ******
================================================================================
******* WIFI STATUS..connected to local Access Point:riverhouse as IP:192.168.1.152 signal strength:-62dBm ****
================================================================================

   AC grid scheduler is ACTIVATED   AC grid input is currently switched ON


================================================================================

   AC grid time 00:   ON      AC grid time 12:   ON
   AC grid time 01:   ON      AC grid time 13:   ON
   AC grid time 02:   ON      AC grid time 14:   ON
   AC grid time 03:   ON      AC grid time 15:   ON
   AC grid time 04:   ON      AC grid time 16:   ON
   AC grid time 05:   ON      AC grid time 17:   ON
   AC grid time 06:   ON      AC grid time 18:   ON
   AC grid time 07:   ON      AC grid time 19:   ON
   AC grid time 08:   ON      AC grid time 20:   ON
   AC grid time 09:   ON      AC grid time 21:   ON
   AC grid time 10:   ON      AC grid time 22:   ON
   AC grid time 11:   ON      AC grid time 23:   ON


           Enter A to toggle grid scheduler activation.
           Enter GRIDON=4 to turn grid ON at 04:00 AM
           Enter GRIDOFF=16 to turn grid OFF at 04:00 PM
           Enter GRIDALL=OFF to turn grid OFF for all time slots
           Enter GRIDALL=ON to turn grid ON for all time slots
           Enter < or > to go to other menus...
```

The first line of the TOU screen shows the software version and current local time.

The second line shows our WiFi connection status.

The third line is important.

AC grid scheduler is ACTIVATED   AC grid input is currently switched ON.

The scheduler can be toggled between **ACTIVATED** and **DEACTIVATED** by entering the **A** or **a** character.

The state of the **HEAT ENABLE** output is indicated by the AC grid input is currently switched **ON** or **OFF**.
Below this is a matrix of AC grid times. ON means the HEAT ENABLE output is energized and the grid AC is applied to the inverter. OFF then indicates the output is de-energized and the external grid relay is off with NO grid power applied to the inverter.

This matrix lists all 24 hours of the day as hour 0 (midnight) to 23 (11:00 PM). And switching occurs at the top of the hour.   So if you had times 0 through 5 set to ON

and 6 through 23 set to OFF, the grid would be applied beginning at the stroke of midnight. It would switch OFF at the top of hour 6 or 6:00 AM

To turn ON a specific time:

GRIDON=5

This would change hour 5 to ON.

To turn OFF a specific time:

GRIDOFF=5

This would change hour 5 to OFF.

To turn ALL the times ON

GRIDALL=ON

To turn ALL the times OFF

GRIDALL=OFF

In this way, you can fill out the grid to control the **HEAT ENABLE** output and thus the external relay to apply grid power or remove it from the inverter.

You would charge the batteries with GRIDON from 0 to 13 applying grid power from midnight to the top of the hour at 4:00 PM. You could then have GRIDOFF from 16 to 23 to operate solely from battery from 4:00 PM to 11:59PM. In this way, you would charge your batteries during off peak period and use the energy from the battery during the peak periods.

ADDITIONAL SECRET COMMANDS

There are a number of undocumented "secret" commands for the ESP32 BMS Controller. Well, that's not precisely true as we are documenting them here and they are not precisely secret either.

But they are rarely used, often uninteresting maintenance or development items and don't bear listing on the CONFIGURATION screen.

1 Negative Contactor

Entering a 1 toggles the negative contactor directly. If OFF sets ON and if ON sets OFF.

2 Positive Contactor

Entering a 2 toggles the POSITIVE contactor directly. If OFF sets ON and if ON sets OFF.

4 Charge Enable

Entering a 4 toggles the CHARGE ENABLE output. If OFF sets ON and if ON sets OFF.

5 Heat Enable

Entering a 5 toggles the HEAT ENABLE output. If OFF sets ON and if ON sets OFF.

d DEBUG COMMAND

Entering a lower case "d" causes an immediate jump to a debug mode where the normal screen display disappears and all CAN and UUDP CAN frames are listed instead, in the order they occur, and with a detailed time mark. Enter "d" again to return to your normally scheduled programming.

D DEBUG2 COMMAND

Entering upper case "D" simply selects a second debug mode listing mostly MQTT topic publish messages. Again, "D" to return to the MONITOR screen.

X or x Initializes WIFI

Turns on WIFI and attempt to connect to the SSID using PASSWORD configured. If successful, attempts to fetch a time.

Z ZERO

Clears max charge and discharge current values.

SOFTWARE UPDATES

The software to operate the controller is of course preloaded in non-volatile RAM memory on the controller ESP32 chip itself. And so it is available between power cycles. Your configuration parameters are likewise held in NVRAM to persist between power cycles.

One of the long held traditions in software development is to feature some code instructions that perform functions quite differently from what the programmer originally intended. These clever "features" are sometimes inaccurately termed "bugs".

Additionally, we can't really see where we want to go until we reach an altitude offered by where we've come. And so with each additional feature in software, we see additional targets of opportunity of cool things it COULD do with just a few additional lines of code.

Users often provide input regarding "bugs" that only appear in rare edge cases or at particular times. And whatever the software does, they have insights into what it might also be used to do.

And so software is often updated. With microcontrollers, this poses a significant challenge as the means to update the software are limited by the hardware.

The espressif ESP32 fortunately has a feature allowing it to hold programs in two different memory segments and either segment can be selected as the "boot" segment that is used on powerup.

It also supports wireless communications using standard Internet protocols.

EVTV is hosted on Amazon's Amazon Web Services cloud.

We've combined all of this to provide Over The Air updates much after the fashion of the Tesla vehicle. We post the latest software to the cloud any time we make a change.

You can easily "fetch" this new updated software image over the Internet wirelessly into your unused memory segment, and then designate that as the "boot" segment. As the original software is still held in the other segment, you can also "revert" to the earlier software.

To update your software at any time, simply enter the following command:

UPDATE=1

The system will automatically check to see if a wireless connection is available, locate the AWS server, and download the new image over the wireless connection.

It will also display the progress of this process and automatically reboot the controller once it has completed the download.

To revert to the previous version, enter **REVERT=1.**

TOUCH SCREEN DISPLAY

The design and concept is to have a battery that protects itself AUTOMATICALLY from every extreme of overcharge, overdischarge, temperature and the potential for a single cell failure to initiate a failure. The entire point is you don't have to be there at all and if it does its job, there's nothing to see.

You can easily perform the initial configuration and make minor adjustments in the first few days of operation using any laptop with the simplest ASCII terminal program. Thereafter, it should just run. If there is an anomaly, simply reset and restart with the ON/OFF switch and that will generally take care of the matter.

In the event you actually DO have a problem, the included software will let you quickly determine the nature of the fault.

However, we do offer a unique Display System providing very detailed information on the battery and even allowing configuration of most of the important items of battery operation on an easy to use 7-inch touch-screen display.

The EVTV Battery Monitor Display normally works over WiFi to communicate with the ESP32 controller.

For more information on this display, refer to the EVTV Battery Monitor Display User Guide.

CAN COMMUNICATIONS

The ESP32 puts out a series of CAN messages on CAN1 and has the ability to transmit them over WiFi UDP packets as well. And so it is entirely plausible for you to develop your own display, logging, and analysis system simply by receiving these messages.

The EVTV Battery Display was designed specifically for use with the ESP32 version of the EVTV Battery Module Controller which in turn is specific to providing an interface to the Tesla Model 3 Battery.

And that is the only use supported by EVTV formally.

That said, we are here providing the communications interface for the device. Batteries are batteries are batteries. And all battery management applications have most of the same features in common. ALL batteries have a state of charge, an input or output current level, a voltage level, power levels, and most provide access to individual cell voltage levels.

And so in theory, this display could be interfaced to almost any battery management system.

Essentially, the EVTV Battery Display uses the Controller Area Network (CAN) protocol 2.0A with 11 bit message identifiers. We originally configured it to use a third party CAN hat for the Raspberry Pi to receive CAN frames through the usual twisted pair CAN wired interface and indeed it can still be configured to do just that and it will work identically in all respects.

The development of the UDP WiFi interface was driven by a desire to separate the display physically from the physical battery assembly. In this way, you could have the display in the kitchen for example, while the battery itself was in an outbuilding or garage in a solar storage application. Similarly you could dash mount the display and have the battery itself elsewhere on a car or boat with no need to run hard wiring between them.

If using hardwired CAN bus connections, any device can produce the necessary CAN message and it will be received and displayed by the program. The configuration screens make no real sense or have application in other environments, but the displays can all be used quite successfully.

UDP COMMUNICATIONS

In the case of the WiFi interface, things get a little less standard and a wee bit more complicated. The Battery Display monitors for incoming UDP packets on port 6500. Any it receives will be interpreted as CAN frames.

The problem of course is there is no standard for UDP encapsulation of CAN.

In the case of WiFi interface, we simply encapsulated the raw CAN data structure we use in our own CAN libraries for the ESP32.
These are based on Collin Kidder's **esp32_can** library.
http://github.com/Collin80.

Much of this has no application of interest because it relies on our CAN libraries and we simply shuttle the entire structure peculiar to our libraries back and forth over UDP. This makes programming UDP, for us, just like programming CAN.

The basic EVTV CAN data structure is 24 bytes:

```
BYTE 0-7        The 8 data bytes.
BYTE 8-11    uint32_t Message ID     29 bit if IDEextended set, 11 bit otherwise
BYTE 12-15   uint32_t   family ID - used internally to library
BYTE 16-19   uint32_t timestamp recording when mailbox message was received.
BYTE 20         uint8_t RTR -  Remote Transmission Request (1 = RTR, 0 = data frame)
BYTE 21         uint8_t priority - only important for TX frames and not often then
BYTE 22         uint8_t Identifier Extended flag 1 eq 29-bit 0 for 11 bit
BYTE 23         uint8_t length -  number of data bytes
```

And so any UDP transmission with a raw data packet of 24 bytes on port 6500 will be received and interpreted if it is a CAN message ID of interest.

The ESP32 controller actually broadcasts these packets on the IP broadcast address (.255) on port 6500. In this way they go to ALL devices connected to the Access Point and so the controller doesn't need to know the IP number of the Battery Display or even if a Battery Display exists. The user can simply configure the Battery Controller to send UDP or not.

And so the Battery Display simply monitors its' own IP number for ANYTHING coming in on port 6500. If a message ID of interest appears in bytes 8-11 of the packet, it processes the packet.

So don't be daunted by the structure. You don't need to put ANYTHING in most of the bytes in it. The data goes in the first eight bytes. The message ID, always 11bit, follows in Bytes 8-11, and the number of data bytes actually used goes in the last byte 23. Set all the others to zero. They have to be there. But the Battery Display doesn't actually process them.

And so, you can display anything you want on the Battery Display by connecting to the AP and sending 24 byte UDP packets to port 6500 on the broadcast IP address (.255).

CAN MESSAGE IDS

Whether transmitted by actual CAN differential wire pair or by UDP packet, the CAN message definitions are identical. You will note some odd usage here and unexplained gaps in the bytes used.

We used a display interface from Andromeda Interfaces termed the EVIC. We developed software to use this with our Tesla Model S Drive units. When we started employing salvaged Tesla Battery Modules for solar energy storage, we reverse engineered the Tesla BMS communications protocol and developed a "controller" that would communicate with the Tesla BMS and control access to the batteries via contactors. It might be nice to add a display.

Andromeda offered other versions of the EVIC with interfaces or "skins" for the HPEVS AC motor and Ewert Systems ORION Battery Management System. The Orion version used the touch screen and the HPEVS did not and so Andromeda would send us the Orion version. We were replacing the software anyway for the Tesla Drive Units.

So we simply plugged in the EVIC and sent it CAN messages to drive the Orion display.. As the systems were different, we found many data pieces in the messages simply didn't apply to our system.

Andromeda Interfaces is dropping the EVIC product line. Ergo the development of the Raspberry Pi based EVTV Battery Display. The CAN messages are simply legacy remnants. But they serve well enough.

You can do similarly. By sending these messages to the EVTV Battery Display, either by CAN or by UDP Wireless packet, you can easily display most crucial battery data. And the EVTV Battery Display performs logging functions that are quite useful as well.

MESSAGE ID 0x150

Length-8 bytes

Byte 0/1

Pack Current. LSB/MSB 16-bit signed integer containing pack current. Positive values are read as charging and negative values are read as battery discharge currents.

Byte 2/3

Pack Voltage. LSB/MSB 16-bit unsigned integer representing total pack voltage x 10. Multiply your reading by 10 to preserve on digit of decimal accuracy. Example: 48.76 volts sent as 487.

Byte 4/5

Pack Ampere-Hours. LSB/MSB signed integer representing ampere-hours used from pack x 10. Almost always a negative value. X 10 to preserve one digit of decimal fractional value. Example: 114.56 amperes discharged from pack – send as -1145.

Byte 6

Maximum Battery Temperature in whole degrees Celsius. 8-bit unsigned byte representing highest cell terminal temperature currently.

Byte 7

Minimum Battery Temperature in whole degrees Celsius. 8-bit unsigned integer representing lowest cell terminal temperature currently.

MESSAGE ID 0x650

Length-1 byte

Byte 0

SOC. 8-bit integer representing SOC*2. Take SOC, double it, and round it to a hole value. Example: 77.75% x 2 = 155.5. Round to 155. On display we will divide by 2 to get 77.5. In this way, ½ digit accuracy in 8-bits.

MESSAGE ID 0x651

Length-6 bytes

Byte 0/1

Low Cell Voltage. LSB/MSB 16-bit unsigned integer representing the lowest individual cell voltage in the pack *1000. Example: lowest cell = 3.214v x 1000 = 3214.

Byte 2/3

High Cell Voltage. LSB/MSB 16-bit unsigned integer representing the highest individual cell voltage in the pack *1000. Example: highest cell = 3.274v x 1000 = 3274.

Byte 4/5

Average Cell Voltage. LSB/MSB 16-bit unsigned integer representing the average if all cell voltages in the pack *1000. Example: average cell = 3.262v x 1000 = 3262.

MESSAGE ID 0x652

Length-8 bytes

Byte 4/5

High Voltage Cutoff. LSB/MSB 16-bit unsigned integer representing the highest individual cell voltage allowed before the battery system shuts down to prevent overcharge *10. Example: High Voltage Cutoff cell = 4.20v x 10 = 42. Displayed as the high voltage tick on the voltage dial.

Byte 6/7

Low Voltage Cutoff. LSB/MSB 16-bit unsigned integer representing the lowest individual cell voltage allowed before the battery system shuts down to prevent overdischarge *10. Example: Low Voltage Cutoff cell = 3.25v x 10 = 32. Displayed as low voltage tick on voltage dial.

MESSAGE ID 0x68F

Length-8 bytes

Byte 0

Sequence Number. 8-bit unsigned integer. Message 0x68F provides individual cell voltage data for the entire battery pack. As a pack can vary from six cells to hundreds, it does this by sending a sequence of ordered 0x68F messages with six individual cell voltages in each message. As some messages may be dropped, this message provides both a sequence number and the number of six cell messages in total. In this way, we use the sequence number to retrieve the individual cell voltages in the correct order. This number will increment with each message until all cell voltages are sent, and then begin again at 0.

Byte 1

Total Modules. 8-bit unsigned integer indicating the total number of 6-cell messages in sequence. Derives from Tesla Model S modules which each have six cells.

Byte 2-7

 Cell voltage. 8-bit integer. Each byte contains the voltage of one cell-2.00v. The result should be multiplied by 100 to retain two digits of decimal fractional accuracy. Example: 3.475v = 3.475-2.00=1.47 * 100 = 147. The display adds 200 to that value =347 and divides by 100 for 3.47v.

Note that the EVTV Battery Display actually graphs the voltage levels of all cells in the battery pack. As the number of cells varies from pack to pack, how does this work?

We use the Byte 1 data from the 0x68F message to determine the number of graph bars necessary, and scale the bar width appropriately. There are display limits to this and so the maximum MODULES displayed is limited to 40 or 240 individual cells.

REVISIONS

This section provides additional notes on software changes and revisions:

VERSION 1.59 FREQUENCY SHIFT CHARGE ENABLE

Notable in this version is the provision for a frequency shift output on the CHARGE ENABLE output.

The EVTV concept of using AC coupling to charge batteries from grid-interactive or "grid-tied" inverters and microinverters proved popular and useful. This is primarily achieved with the use of the SIGINEER 15kW inverter.

It became necessary to handle the case where the batteries reached full charge OR the output of the solar array and grid tie inverters exceeded the maximum power of the inverter.

CUTOFF and RESUME are normally used to control the CHARGE ENABLE output. If the battery voltage falls below RESUME the charge enable output will be ON.   If the average cell voltage reaches CUTOFF the CHARGE ENABLE output goes OFF.

To activate the FREQUENCY SHIFT CONTROL function, set CUTOFF to the maximum average cell voltage you want to charge to. But set RESUME to the SAME voltage.
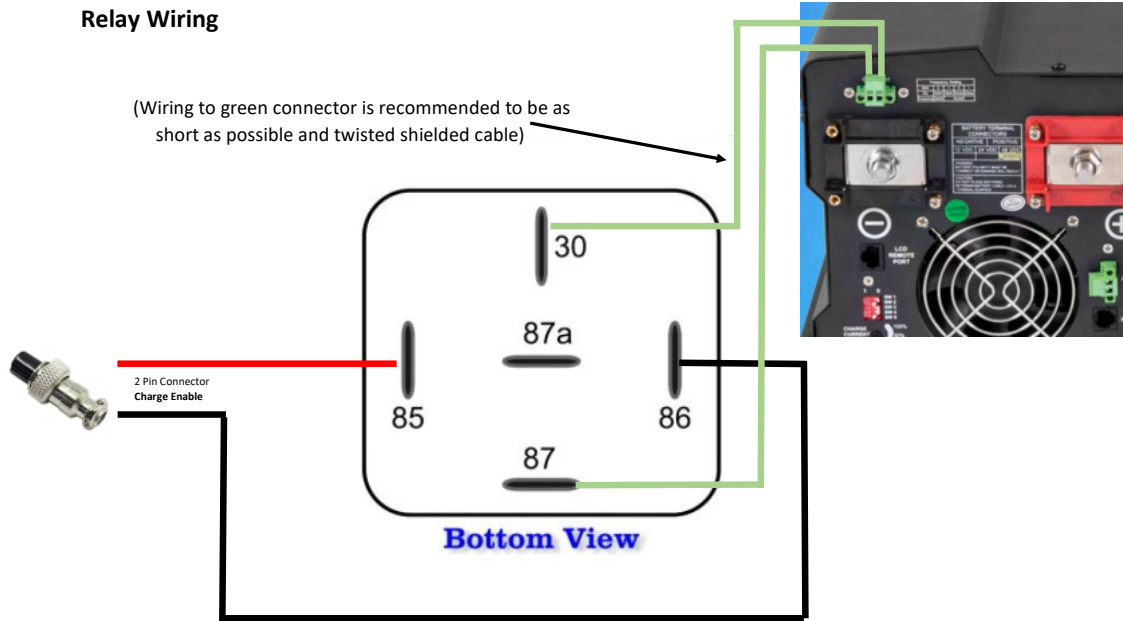
If RESUME=CUTOFF, the CHARGE ENABLE output will be off and would normally never come on. But in this special case, when you reach the cutoff voltage the CHARGE ENABLE output will be activated for 500ms or about ½ second.

We had SIGINEER add two contacts to their 15kW inverter for FREQUENCY SHIFT to switch from the normal 60Hz output to 62.5Hz.

The CHARGE ENABLE output is used to activate a normal Bosche Automotive 12v relay. The normally open contacts are connected to the Sigineer frequency shift contacts and the CHARGE ENABLE output closes the relay, shorting the two Sigineer contacts together for 500ms.

This causes a very brief shift in frequency from 60 Hz to 62.5Hz for about a half second. This will be unnoticeable by almost all electrical equipment. But grid tied inverters are required by UL1741 to perform a rapid shutdown in this event.

The result is this very brief frequency shift will shut off all grid-tied inverters – stopping the charge. These inverters have a five minute time out and will RESUME operation after that timeout period.

Relay Wiring

(Wiring to green connector is recommended to be as short as possible and twisted shielded cable)

30

87a

2 Pin Connector
Charge Enable

85   86

87

Bottom View

In this way if your batteries get full or the solar array produces too much current for the system, the controller automatically shuts the grid-tied inverters off for five minutes. During this time power output of the inverter continues without interruption using power from the batteries, and thus diminishing their charge below the cutoff level.

After five minutes, the array resumes charging and will do so for 10 or 15 minutes until the battery again reaches a fully charged state and at this point the frequency shift/shutdown is repeated.

In a properly sized system, the batteries would then begin charging as the sun rises and reach fully charged state sometime in the late afternoon. At that point it would repeatedly charge and discharge in 5 minute increments in a kind of slow motion hysteresis designed to ensure the batteries are within a five minute period of fully charged as the sun goes down and the evening begins.

Note that the relationship between CUTOFF, RESUME and CHARGE ENABLE remains the same with the exception of this edge case. And the frequency shift function only occurs in the unusual setting of RESUME=CUTOFF.

Note also the use of an intermediate relay. We use this with the Sigineer 15kW inverter but have no idea what inverter might be used in any particular installation. But ANY inverter capable of frequency shift can be used, with appropriate interface of this switched ground output to shift frequency or otherwise interrupt the grid tied inverters.

You could for example simply have all grid tied input to the house system controlled by a contactor and use this CHARGE ENABLE output with another relay to disconnect that contactor for 500ms. This will be long enough to disable the grid – tied inverters and send them into the same five minute timeout.

Note that you can toggle the 500ms CHARGE ENABLE output any time using the single character command "**f**" from the ASCII terminal console.

VERSION 1.61 AC LOAD DUMP OPERATION

Notable in this version is the provision for a grid control feature on the HEAT ENABLE output.

The HEAT ENABLE output was a brilliant concept to automatically control either heating or cooling equipment if the battery terminal temperatures approached the HITEMP or LOTEMP temperature shutoff values.

As it turns out it was a brilliant solution to something that is almost never a problem.

In solar applications the batteries are typically enclosed and in continuous operation. And so even fairly low ambient temperatures do not cause the batteries to be below freezing because of the internal activity of the batteries which generates some internal heat.

Additionally, these batteries are designed for high loads of 1100-1300 amps in a series application in a vehicle. In solar applications they are more arranged in parallel making even 300-400 amp loads less than 100 amps per module in practice. And the power load cycles of most installations are simply much much less than that – often requiring 10 to 20 amps per module on average.

And so we've never actually seen any of these batteries approach the 48C upper limit recommended by Tesla.

And so we are aware of a very few installations where the owner/designer has gone to somewhat elaborate measures to use this HEAT ENABLE output to control

heating and cooling devices of some remarkable design. We've just never heard of any of that actually being used in anger.

And so our advice, don't spend to much time and money solving a problem until you actually HAVE a problem.

But we do have an edge case that bears some explaining and a solution. It was difficult to foresee the case where we have TOO MUCH SOLAR POWER.   That sounds like a marvelous problem to have, but actually it still has to be solved. And this is MUCH more common in actual operation than temperature issues.

The heart of this is the exceeding variance in irradiance across the year. Everyone is aware you get less sun in winter than in summer, but the scale of this is poorly perceived. At summer solstice, your solar array can produce as much as 450% the amount of power produced at winter solstice. And this varies with the distance from the equator.

And so if you design your system for barely minimal requirements during the winter months and short days, you will find it surprising to face being overrun by solar power by spring.

The Sigineer inverter is a hybrid. IT can be used for battery backup of normal grid operation or grid backup of normal battery operation. And increasingly, most inverters on the market use this HYBRID concept to maximize sales in a variety of situations.

In BATTERY PRIORITY mode, the inverter normally operates from the battery. If battery state of charge decreases to some set value, it switches to AC mode and uses either the grid or a generator to recharge the batteries while it passes that source THROUGH to the normal loads of the installation.

In GRID PRIORITY mode, it normally passes the AC source through to the load and maintains the battery at 100% charge. In the event of grid failure it of course switches to battery power.

We normally use the battery priority mode and only use grid or generator as necessary during prolonged periods of overcast.

We can use the frequency shift function introduced in version 1.59 to intermittently shut off the solar power production – preventing overcharge of the batteries.

This works up to a point. But we have a largish photovoltaic array specifically to find these edge cases. And by spring, we were producing so much solar power, that the batteries were fully charged by 9:30 AM. Worse, it was producing so much current that it readily exceeded the 15kW limit of the inverter causing the inverter

to automatically fault and shut down. This had to be manually reset to resume power.

And so in the best case, within a couple of minutes of the array coming up, the system frequency shifted to disable it. Five minutes later, it came up again and again had to be immediately shut down again. And so for the majority of the day our photovoltaic array produces nothing – baking in the sun quite uselessly.

The solution is to install a pair of contactors on L1 and L2 phases on the grid input to the inverter and control those contactors with the HEAT ENABLE output.

We put the inverter in the GRID PRIORITY mode or AC PRIORITY mode. But the contactors are off/open and so no grid is available and we operate from the batteries and photovoltaics as if we were on a grid outage battery backup scenario.

In the event the batteries reach maximum state of charge, or in the event that the solar arrange current is too large for the inverter, we set HEAT ENABLE to ON energizing the two contactors and applying the grid power to the inverter.

In the case of Sigineer 15kW, it detects the grid is "back up" and after a 15 second stabilization timeout, it switches to AC pass-through to the loads and shuts off the battery powered inverter.

At the same time we set HEAT ENABLE to ON, applying the grid, we also do the normal frequency shift to shut down the grid tied inverters. And so the grid comes up in a fairly controlled and stable fashion powering the house loads. Five minutes later the grid-tied inverters come back online and any excess power is fed through TO THE GRID, and so we use the AC grid as a power dump load for the solar photovoltaic array for the rest of the day.

We use the NTP time to turn HEAT ENABLE OFF at 7:00 PM local time – removing the grid for overnight operation from the batteries. We re-enable this function at 7:00 AM. Note this does not immediately cause the HEAT ENABLE to enable grid operation. It simply resets it so it COULD do so after the batteries fully recharge any time during the day AFTER 7:00 AM.

To use this feature, simply set the LOTEMP configuration to the same temperature as the HITEMP configuration value.

Note that if HITEMP and LOTEMP are set to DIFFERENT values, the HEAT ENABLE output operates normally as originally designed.

Also note that this operation does not require a net metering agreement with the grid provider.   The grid will readily accept the excess power with a net metering meter installed or without.

With a net metering agreement, you will receive a credit from the utility company for the power you produce. But even without a net metering agreement, you can still use the AC grid as a dump load.

Also note the secret single character command "**g**" from the ASCII terminal console will toggle the heat enable output on and off for test purposes if **HITEMP** and **LOTEMP** are the same.

VERSION 2.28 FREQUENCY SHIFT OPERATION

With version 2.28 we drop the HITEMP/LOTEMP configuration items and use the rarely used HEAT ENABLE output for a frequency shift operation. In this mode, once the average cell voltage reaches a configurable value, the FREQUENCY SHIFT output is activated for 500ms.   This is usually used with a relay to close dry contacts on an inverter that supports frequency shifting. Almost all grid-interactive inverters that might be charging the batteries will then shut down for some period of time because of the brief period of the off-grid inverter being off frequency.

USE WITH SANDI INVERTERS

The Tesla Model 3 Battery Pack is nominally 73-75kWh of capacity, though they no longer specify this but rather spec their automobiles by RANGE.

It is pretty much 100% charged at 4.2v per cell (403.2v) and considered fully discharged at 3.00v per cell or 288vdc. We advise operating at a narrower range of 10% to 90% charged for longer life.

We have had some notable success at a matching DC-AC inverter from a company called **ZHEJIANG SANDI ELECTRIC CO., LTD** of Zhejiang China. They make inverters with a wide range of input DC voltages and a similarly wide range of power levels from 5kW to 200kW. We get them with input voltage range of 300-400 vdc with 240Vrms L1, L2, N, Ground output transformer appropriate for use in the U.S.

We offer a couple of models of these kind of specially modified for our needs at 20kW and 30kW power sizes.

Both the 300-400vdc of the Tesla Model 3 Battery Pack, and the 30kW of 240Vac of the inverter output, are high voltage and very dangerous. We provide these for your experimental and off-grid use and you must have the skills and experience to install and operate these high power devices in order to use them. Improper installation or operation can easily result in the destruction of equipment or death of personnel.

We like the Sandi products, which are heavy and expensive from one point of view, but offer some advantages in others.

1. High voltage DC inverters are difficult to source. Most of the hobby and residential market is for 48v, 36v, 24v and sometimes 12v battery systems which lead to very high DC currents at even modest power levels.

2. The Sandi's H-Bridge Power Switch architecture lends itself very well to using grid interactive inverters such as Enphase or Solar Edge which are very popular in the U.S. residential market. These only work with a grid waveform and can actually export power to the grid in the form of 240vac

power. In the off-grid Sandi, this means they can be used to "export" power through the Sandi inverter to charge the Tesla Model 3 Battery and indeed this works very well.

3. They are simply much less expensive than similar U.S. or German manufactured equipment.

INSTALLATION
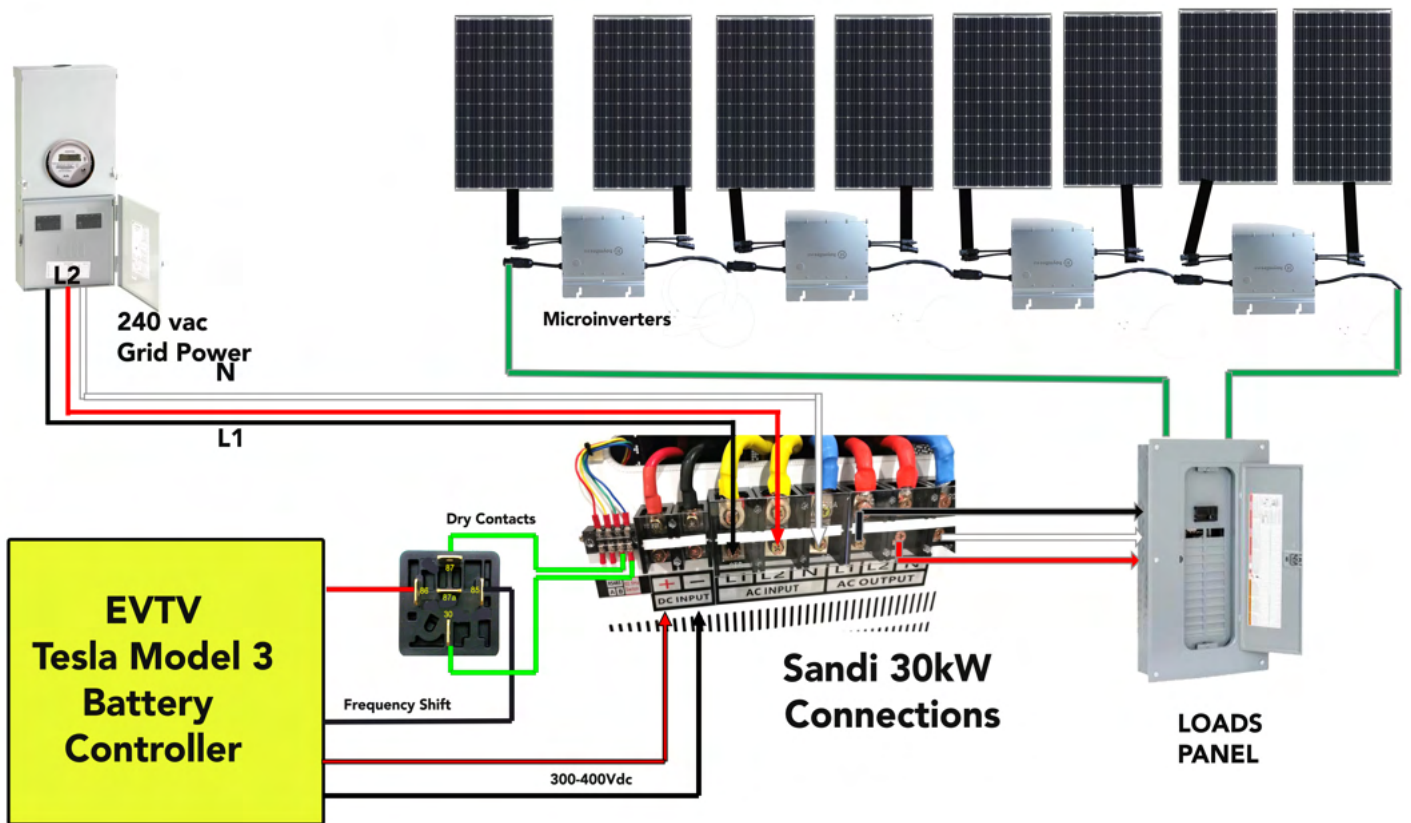
1. Connect Sandi AC Output Connections to the load circuit breaker panel, typically through the main circuit breaker of 200Amps. This should be the same loads panel your microinverters are connected to.

2. Connect Sandi AC INPUT to your grid input to the building IF DESIRED.   This is used in AC FALLBACK mode only.

3. Connect EVTV Tesla Model 3 Battery Controller DC output cables to the DC input of the SANDI panel. OBSERVE POLARITY.

4. Connect the frequency shift output of the EVTV Tesla Model 3 Battery Controller to the coil of an ordinary Bosche 12v automotive relay pins 85 and 86. Polarity does not matter.

5. Connect the Normally Open contacts of the Bosche relay (30 and 87) to the dry contacts provided on the Sandi connector panel. Polarity does not matter.

<div align="center">NOTE</div>

Some models of Sandi inverter are received by EVTV and modified to place a relay in the inverter and install a two pin matching connector. In that event, simply plug the provided FREQUENCY SHIFT cable into the EVTV Model 3 Battery Controller and to the Sandi inverter FREQUENCY connector.

STARTUP

To start the Sandi Inverter AND the Tesla Model 3 Battery it is VERY important to follow the following steps in order to prevent damage to equipment.

1. Set START switch to OFF.

2. Set AC OUTPUT BREAKER TO ON.

3. Set DC INPUT BREAKER to ON.

4. Set Power toggle switch on EVTV controller to ON.

5. Press latching POWER switch to ON (lights green)

6. Observe RED and GREEN contactor lights for 15 seconds. RED should light first, followed by GREEN about 10 seconds later.

7. Set Inverter START switch to ON.

WARNING

It is EXTREMELY important to make sure the DC INPUT BREAKER on the Sandi inverter, or for that matter ANY inverter is set to ON BEFORE energizing the EVTV Tesla Model 3 Battery Controller.

The EVTV Controller goes through a configurable PRECHARGE SEQUENCE when it is first powered up. The negative contactor closes applying DC voltage to the INPUT CAPACITORS of the inverter through a precharge resistor that LIMITS the amount of current allowed to charge the DC input capacitors. Once they have charged to the battery voltage, the POSITIVE contactor is closed bypassing the precharge resistor and applying full current to the inverter.

IF you allow the precharge to occur and THEN turn on the DC INPUT BREAKER, a very brief but very large current pulse will occur WELDING your contactors closed and lead to a very dangerous situation.

SHUTDOWN

1. Set inverter START switch to OFF.

2. Set inverter AC OUTPUT BREAKER to OFF.

3. On EVTV Controller press latching POWER switch to off (green goes off).

4. Set EVTV Controller Master Power Toggle switch to OFF.

WARNING

It is EXTREMELY important to make sure the Sandi inverter is switched off BEFORE powering down the EVTV Tesla Model 3 Battery Controller.

IF the inverter is on and substantial solar power from the microgrid inverters is currently charging the batteries, removal of the batteries from the circuit will cause a large inductive voltage in the Sandi inverter most usually destroying the switching IGBTs in the inverter in the process.

In normal operation, if the battery controller needs to disconnect the batteries because of overvoltage or undervoltage or some other condition, it will send the FREQUENCY SHIFT signal to shut down the microinverters before disconnecting the contactors. But if you manually power down the controller this does not happen.

So make sure you turn the inverter off manually, before shutting down the battery controller manually.