Prius Traction battery repair summary Part 1

This is a summery for ”Gen II Prius Individual Battery Module Replacement” 106 pages thread (and still growing) posted by “Ryousideways” Apr 24, 2013 which contains a lot of useful information and knowledge.

https://priuschat.com/threads/gen-ii-prius-individual-battery-module-replacement.125588/

This document from PriusChat wiki
https://priuschat.com/wiki/prius-high-voltage-battery-reconditioning/

Traction battery pack contains several modules blocks depends on year model. Each module block is two modules coupled in series. Each module contains six nimh cells.

---------- CAPACITY ----------
Prius battery module capacity original specification is 6500 mAh. It is important to remember that the capacity of a module is that of the weakest or lowest charged of its 6 cells. The capacity of your HV battery is then determined by the AH capacity of the **weakest** module in the pack. All of the modules should have well matched capacities.

Capacity stored in the Prius battery modules within that voltage range 7 down to 6 is minimal. Could be about 0.1 – 0.5Ah in a working packs and can be neglected in bulk tests. I’ve done hundreds of tests (many are published) conducted under electronic load of 6A. Under electronic load current stays constant during discharge. That provides better representation, accuracy and individual test results are hence comparable.
FYI: In the live test I’ve conducted on brand new pack in Prius and on the very used pack the threshold when the MTG kicks in after discharge was the same – slightly less than 7V.
Measuring Capacity below 7v is of no use for us (only for demo purposes) as that is the area where Delta V increase and that is the area which is not used by Prius.

The amount of capacity (or energy) battery provides in between, say 6 & 7 volts (even less in between 6 & 6.5) is a tiny fraction of what it provides in the range of say 7 to 8.5 Volts. Meaning that you do not have to be so much "presize" - around that area and the difference could be neglected.

Your overall battery capacity will be limited by the lowest capacity module, but your car should work fine. Problems happen when you have a bunch at 4500-5500 and one or two at 500-1500.

Your Prius will be quite happy with modules at 4 amp hours as long as they are a matched set. You will not see a noticeable decrease in performance until the modules drop to about 2.5 amp hour’s capacity

---------- LOAD TEST ----------
Module load testing is more important than capacity. Voltage readings without putting the module under load can be misleading. Load testing is one of the most critical steps so keep charging current as low as possible (2A max! pref 1A) and discharge as high as possible for best results.

You really need to do a full top balance of each module before doing this test. This means charging at a very low rate (350 mA) until the voltage stops climbing and then continue the charge for another 4-6 hours (grid charger charging). The is best achieved (time wise) with a grid charger charging all modules at once, but can also be done with at home RC car/drone hobby charger.

Once you have the battery fully charged, repeat the above discharge under load test. In your spreadsheet, you need to add an additional column that is the difference between start and end voltage. You are looking for modules with a greater difference than its peers.

1) A 35w load is not nearly enough, minimum of 55w/65w high/low beams on together (120w)
2) Time for each test must be exactly the same (minimum of 2 minutes each, down to the second)
3) You need to calculate voltage change, this is what actually tells you if the module can keep up or not.
4) Charge all the batteries up (RC charger, very low current) and run the test again to get useable results

Again, you need to then calculate the difference between starting and ending voltages. You are looking for modules with a greater difference than its peers.
Modules that have a greater difference from its peers in the above tests are candidates for replacement.

So if you compare the load test results of a nearly full and nearly empty module it's meaningless gibberish. Use your grid charger to get all the modules to 100% SOC. Then run the load test.

---------- SERIES RESISTANCE ----------
I would also determine the series resistance of each module by measuring the terminal voltage while doing a 1 amp discharge.

"stronger cell" will only dissipate excess charge as heat when and only it is overcharged and not with "parallel balancing".

A good module will have a resistance of 10-15 milliohms and your Prius ECU will report the resistance of 2 modules in series (their resistances add). You can measure module resistance of a charged module by pulling a known current and measuring the voltage drop.

You can calculate the series resistance (~ 10 to 20 milliohms in a typical module) by dividing the delta voltage by the current. High internal resistance and self discharge are the killers

Measuring internal resistance possibly the best module voltage to do this at is 7.2 volts (the nominal module voltage). The discharge voltage curve at this voltage is almost flat so that any voltage drop from discharge that takes place while taking the readings will be negligible.

Measuring voltage drop adding a load means the voltage continues to drop steadily.
Measuring the the voltage rise suffers the reverse effect as the module recovers voltage steadily rising when the load is removed.

---------- SELF DISCHARGE ----------
They should be a bit below 8v after a resting period and then exhibit a very slow self discharge rate for the next few weeks. A good module will then exhibit a very slow self discharge rate of under 0.1 volt per month.

Official Quality Testing Standards I am familiar with suggest leaving the battery for a month before you conduct capacity test (Self - discharge is factored in of course).

Another test that is useful is ascertaining the self discharge of each module which can be done by measuring the voltage of each module, leaving the battery to sit for 7 days (or longer) and then measuring again the voltage of each module.
---------- SINGLE MODULE BALANCING ----------
code p0a80 is signaled (I think) when the HV battery ECU detects a 1.2V module pair (block) difference.

Some say that a voltage difference of 0.3V between blocks is enough to set a DTC but I'm pretty sure it's much more than that - closer to 1V.

The 1.2 volt differential happens when one of the 6 cells in a module is shorted (usually due to being discharged beyond 0 volts). This is a permanent failure of that module. The 0.3 volt module pair (Battery Block)

differences can often be corrected by module balancing (getting all 6 cells to the same SOC) and equalization of all modules to the same voltage.

We are trying to slightly overcharge our modules on each cycle. This allows the cells in each module (there are 6 in series) that have a lower SOC to catch up with those with a higher SOC (which dissipate the excess energy as heat) thereby "balancing" the module.

To properly balance a module, you would overcharge it. The weaker cells will keep charging, the stronger full cells will give off the extra charge as heat....until all 6 cells are 100% charged.

Top end balance: Steady, gentle charge (0.05C; ~340 mA) continuing passed the DV point so that the out of balance cell or cells in the module can "catch up". As the full cells will convert this excess charge to heat, you want to use a very gentle charge in this phase to minimise the possibility of damage, as heat is the enemy.

Bottom end balance: Gentle and controlled deep discharge at a gentle rate (depending on the level of discharge, 1.5 A down to 7.2 V; 500 mA down to 5 V; 200 mA below 5 V) usually done in successive tranches to a lower level each time (1st discharge to 4.8 V; 2nd discharge to 3 V; 3rd discharge to 0.6 V). The reason for this is to recover lost capacity due to crystal deposits/voltage depression which will inevitably happen over time when the battery is shallowed cycled in the 40-80% range (a good thing for longevity).

---------- MODULES BALANCING ----------
Good to note this as well, don't put full charged modules back in or you will get an error from the hybrid ECU. You want to aim for around 50-60% charge (between 40-80% is fine, nominal 7.2v = 50%) and balance voltages again before install. So 7.9v is a little on the high side, I would run some better load tests and drop them all back to around 7.2-7.6v, re-pair modules based on better load test results, then re-balance everything again and do your final install.

If your modules are all at full charge, discharge @1.2A to some arbitrary voltage well above 7.2V. You only need to bleed off a couple hundred mAh. Start with your lowest capacity module and discharge 200mAh and see where that puts you. Discharge all modules to that voltage at the same current. You're not just balancing based on voltage in this case, but to internal resistance as well.

If they are in the discharged state, charge at max current (6A?) until a given voltage is attained. I would recommend it be some arbitrary voltage achieved AFTER you have put at least 1000mAh into the module.

You just can’t install a pack that is at fully charged because the computer will throw a code if the voltage it too high. The computer itself runs the battery at a 40 to 80% charge. So at 100% charge, the computer will think something is wrong.

Discharge to 7.6volts. This way, your somewhere in the 40 to 80% soc. Then do your equalization.

---------- MODULE PAIRS MATCHING & PACK REARRANGING ----------
I would match pairs based on effective series resistance, not capacity. When you do the load test you will see a delta voltage drop. Put together pairs so that all module pairs have the same total drop (sum the two module drops). That will minimize the deltaV that the Battery ECU sees under load (after you equalize the modules) and prolong the period without HV battery alarms.

I also find it very interesting that instead of seeing capacity sag in the middle of your battery pack, it appears to be quite linear across the entire pack. Given this fact I would just reverse the order in the pack (#1 becomes #28, #2 becomes #27, etc) and then load test them all to make sure you don't have any bad ones

Shuffle the modules when rebuilding center modules to the outside of the pack.

1.7amp at high SOC is not necessary and simply not a good idea.

for example 5.5AH "good" module from the fresh wreck into your pack where all others are 4AH. What would happen, you wonder? During discharge your weaker but still good 4AH modules will drop in voltage quicker than the donor 5.5Ah one and the voltage difference between pairs will increase above threshold and your Prius will throw a trouble code.
So called "shallow capacity" range of operation is not shallow enough for that situation not to occur.

Area below 7 Volts is where the difference in remaining capacity of the individual modules plays the part. That is why when capacity is high enough and pack is operated in the shallow range - things are ok, but when remaining capacity is low due to age and mileage - then high loads force modules to drop voltage below 7V - where their discharge curves are not flat - that if last long enough and repetitive – will trigger DTC (that voltage difference is above the threshold). That is why I emphasize the importance of rebuilding the pack from modules with high enough and equal capacity.

Example (voltage drops over time on load test):
0.22v, 0.25v, 0.24v, 0.23v, 0.23v, 0.24v (avg 0.235v) On reassembly I would order them 0.25, 0.22, 0.24, 0.23, 0.23, 0.24 (now you can see each pair/block averages 0.235v)

Modules with different capacities still work quite well together, as long as their discharge rates are similar.

The car cannot not see voltages within pairs. It only compares one pair to the all the others.

Matching all 28 rebalanced modules:

1. Same capacity - within about 0.2 ah
2. Same terminal voltage - within 0.05 v by controlled discharge of high modules
3. Same series resistance - within about 10% (you can pair up modules to control this further as the resistances add)

4. And all having similar low self discharge rates will result in not having to do the job again for a long time. Self discharge rate - Usually very slow in a good module; about a tenth of a volt per month (after the surface charge dissipates)

---------- MODULE CHARGING & DELTA PEAK ----------

If you have 14 chargers it will take only 3 days. If you have 1 charger it will take 42 days.
I would suggest staying at 2A for charge current (use less if doing this in ambient above 100F).

Those modules you're tickling just came out of a car getting 80A slammed into them and 120A yanked from them. Furthermore, your < 1C charge rate makes deltaV unreliable, so you need time or capacity provisions for cut-off. Furthermore, you have a much higher chance of overcharging individual cells at the lower rate if the module is significantly imbalanced. What I mean by this is that lets say 5 cells are in sync, but one cell is lagging by 20%. The voltage drop of the 5 cells when they are full will be too low trigger cut-off. This will result in an extended overcharge while the last cell catches up. If you're charging them at 1C, the voltage drop of the 5 will be enough to trip deltaV cut-off and prevent them from being over-charged.
There are basically 3 charge rates:
0.1C for 16 hours
0.3C for 5 hours (or deltaV cut-off, but not 100% reliable)
1C or higher to deltaV cut-off.
You are playing in an area of uncertainty with NiMH. I'm not at all saying they won't work, I'm saying they're

unnecessarily conservative and pose as much risk as any you might perceive from higher currents. The only low-risk option is the 0.1C charge for 16 hours. With adequate cooling, there is no downside.
The Reaktor formation charge is also an excellent tool for balancing individual modules. Unfortunately, it takes about 3.5 hours to charge a module; 1 hour at 1C, 2.5 hours at 0.1C as a topping charge.

On setting a capacity limit you need to look at the discharge figures not the charge side of things.

There are diminishing benefits after 3 charging cycles so It is not worth further cycling. Batteries have some wear out mechanisms which can limit the number of full cycle cycles each cell can take without significant capacity loss.

The Prius uses voltage and coulomb counting for state of charge and discharge, but charging from an external source directly to the battery will not be calculated

The discharge capacity readings are the real capacity of your modules. It is the discharge capacity of the last cycle that is relevant (hopefully the highest one).

"For the Delta Peak Voltage setting, its probably easier if I give you a basic explanation of what it is. When a NiCd or NiMh battery reaches full charge, the voltage hits a maximum (PEAK) value, and then "changes" (DELTA meaning change) and the voltage starts to drop or reduce as the battery starts to go into overcharge.. So this setting refers to the point at which the Batteries Voltage reaches its PEAK, and then Changes (DELTA) and starts to drop...

What a "Delta Peak" charger does is monitor the batteries voltage, and when it senses the Change in Peak voltage, the charger turns off with the battery being fully charged.. With your charger, you can adjust the point at which the charger registers the change, so as to remove the possibility of having a pack false peak, and also ensure that the pack is fully charged.. The greater value you set the Delta Peak setting at, the more your charger will overcharge your battery..

Most NiMh packs don't like to be overcharged at all, so I generally use a setting of between 3 - 6mV per cell (8mV/cellmaximum for my older packs)."

Charging/Discharging at a high rate in the middle range of SOC is not a big deal.
It's the ends of the SOC range where the problems arise (NOT TO CHARGE AT A HIGH RATE AT THE ENDS OF SOC.

---------- CHARGER SETTING ----------
Mode: Program Save then use Program Load when cycling other modules
Battery type: NiMH
Nominal voltage: 7.2V
Charge current: 2A (lower is better to prevent excessive heat buildup at high SOC)
Discharge voltage: 6V
Discharge current: 1A (use highest setting available)
Charge capacity: 7000 mAh
DCHG>CHG: 3 (more cycles if modules continue to improve)

Also go into User Set Program and set:
NiMH Sensitivity: D. Peak Default
Capacity Cutoff: on, 7000 mAh
Safety Time: off, (time doesnt matter)
Temp Cutoff: 45C (if you are using temp probes)
Waste Time: 5mins

Or more aggressive charging:
Charge at 5 amps up to 7250mAhr
Discharge at .7 aMhr down to 6 volts
DSCH<CHG for 3 cycles.
Other settings: I set the timer limit to 720 minute cut off. I also set the cool down period to 5 minutes.

Capacity cutoff = on and 7250 mah (set to 4500 on the 4th cycle to be ready for balancing)

Or:
Mode: Program Save then use Program Load when cycling other modules
Battery type: NiMH
Nominal voltage: 7.2V
Charge current: 2A (2A-5A, lower is better for heat buildup in modules)
Discharge voltage: 6V
Discharge current: 1A (use highest setting available)
Charge capacity: 7250 mAh (range 6500-7500 mAh, higher capacity should use lower charge currents)
DCHG>CHG: 3 (more cycles if needed)
Also go into User Set Program and set:
Capacity Cutoff: on, 7250 mAh
Safety Time: off, (time doesn't matter)
Temp Cutoff: 45C (if you are using temp probes)
Waste Time: 5mins

If required:

Delta peak voltage set to 20 mV the idea is to stop the peak detection from operating forcing the charger to input the 7250 mah charge before cutting out.

---------- GENERAL NOTES ----------

In selecting replacement modules you need to find modules that are of a similar capacity and charge/discharge in a similar way to the ones that are existing.

The contact between bas bar and the module is not the weakest point.
Corrosion is travelling up the voltage detective lines and what you perhaps have not seen yet:
I witnessed 5 cases so far on your model - corrosion is going all the way through to the battery comp and kills it
You can't see it unless you disconnect the orange plug and scrutinize the contacts on the computer.
When dismantle the comp - corrosion travels onto PCB and to the componentry. Dead beyond repair.

To clean bas bars - you may use phosphoric acid (aka anti rust solution) - no mechanical brushing needed and to keep them in storage and not corrode - just dump them in the motor oil.
If applying the grease - be careful for the grease to be heat resistant and dielectric.

Double checked the "stall test" guidelines - there is a set of thresholds mentioned in relation to particular DTC:
1.2V max for VMAX-VMIN
0.3V max for swith-over between CHRG/DSCH
2V max for the "swing"

---------- HOW TO START ----------

Take the battery out, let it sit 7 days. The bad ones will lose its voltage. Replace with KNOWN good modules and charge/balance the battery

Or
Label your battery modules with a permanent marker. 1 through 28.

The modules are counted from the terminal (high voltage ECU) end of the battery. The module nearest the ECU being (1) the furthest away being (28).

on the Gen II, it is the opposite. Module 1 is at the opposite end from the ECU counting back towards the ECU, making the module closest to the ECU module 28.

Toyota Tech Stream Software and any generic OBDII reader will start the count on the PASSENGER side. That is to say pair one is opposite the battery computer and pair 14 is next to the battery computer. This applies to Gen II Prius years 2004-2009. For Gen I (2001-2003) the count is in the opposite direction with pair one being next to the computer and pair 19 being on the far passenger side. I have not yet opened up a Gen III battery and do not know the direction of the count.

NHW-10 (JDM 1997-2000) Count from ECU
NHW-11 (aka GEN-I in USA only) (2001-2003) Count from ECU
NHW-20 (aka GEN-II in USA only) (2004 - 2009/2010JDM) Count towards ECU from another end.

It is better to start the load test with all modules at the same voltage for comparison.

You use the voltmeter to test the voltage of each individual cell. Record your results on a sheet of paper or excel spread sheet.

IMPORTANT: *Leave battery modules compressed in the case when charging. Otherwise they will swell.*

You may find, or will find sometimes the modules all tests perfectly, and even when you put a load on them with a light and test the voltage they still seem fine? How is this? I don't know, but in order to find out the real culprit you have to pull the battery out and disconnect/test it right after it has been used in the prius. So you want to either drive the car for a while and immediately pull out the interior and the battery, or if you already have the interior out, run the prius for about 30 to 45 minutes to get a load on and off the battery. If you let it set

over night I think the bad modules tend to try to rebalance themselves with the pack, which makes them hard to find with the voltmeter. If you run the car, stress the battery, and immediately after test the pack, it will be easier for you to diagnose. At the minimum get the pack out of the car and remove the bus bars, even then, these batteries tend to want to equalize on their own, so I would just test as soon as possible after running the car. This allowed me to find a bad module I couldn't find before.

What I did was to cycle each module 3 times D>C at 7000 mAh (first discharge tells you the state of the module coming out of the car, the second and third tells you what the total capacity is at high SOC and helps to exercise the cells back into shape). Then once that was done I would do a final D>C cycle at 4500 mAh, but make sure you discharge the cells initially so there is less than 4500 mAh when the cycle starts (usually I just discharge the cells below 4000 mAh then start the cycle again). If you don't discharge it below 4500 mAh remaining the charger will complete the cycle, but the voltages will be off considerably since the battery wasn't pulled down to the 6V minimum before the charge cycle starts. If you follow this method it makes sure they all have similar starting voltages before final balancing.

Traction battery Disassembly:
Remove bus bars
Disconnect inlet air temp sensor from far end of pack.
Remove ECU bay (3 nuts and a few connectors)
Remove two nuts holding plastic clamps to base.
Stand pack on non-ECU end facing the bottom.
Remove all mounting screws from bottom of case
Remove bottom of case
Note installation and remove temp sensor harness.
Now you have all your modules clamped between the two plastic ends.
Flip clamped modules to other end (now sitting on ECU end)
Remove 4 bolts securing top clamp
Remove/rearrange/replace modules as you see fit.

Traction battery Assembly:
Reverse of above EXCEPT
After you start and snug the clamping bolts, you need to lay the pack flat and ensure it does not rock when you put the final torque on the bolts. If you do it in the vertical position, the pack will twist.
When attaching the case bottom to the clamped pack with screws, don't just start at one end, start the extremes and work inwards in a random fashion. The idea is to get all of them started before screwing any of them down.

Then I found these threads that proved to be helpful as well:
Prius Battery rebalance thread | PriusChat
HV battery issues | PriusChat
Traction battery rebuild question | Page 6 | PriusChat

Prius Traction battery repair High Voltage Battery Reconditioning Part 2

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https://priuschat.com/wiki/prius-high-voltage-battery-reconditioning/

https://www.youtube.com/watch?v=g5KAPge-f6E&t=969s

https://www.youtube.com/watch?v=cnlEVp-v3pU&t=2655s

I completed my rebalance/recondition/cleaning of the Gen II HV battery and fan. It took me about a month, because of having to relearn soldering, acquire the correct hobby chargers and banana/alligator/wires, replacement modules. I could do it carefully, slowly again in 2 weeks, given the slow and steady DSC limitations of the multiport charger I bought.

While it's fresh in my memory, here are some things that I (30 days ago a neophyte, now an intermediate HV battery person) would note should be in a wiki or for anyone doing this for the first time:

These are my notes and not a complete HOW TO, not covering all the steps and safety concerns. Working on a car or electricity is inherently risky and you must know what to do, or at least what not to do. I suggest people review these against what they've learned elsewhere and only proceed after lots of prep with priuschat, youtube and other sources of research and knowledge.

This is a complicated but not difficult process that requires effort, planning, time and thoughtfulness. An unhurried persona can do this, particularly if you're not completely confused with batteries and basic electricity. You undertake work on your car and HV battery at your own risk. Learn more than you need to know, go slowly, test everything for voltages. These are notes to complement what you learn above in the links and on the web.

PREP / First Steps: Read the Priuschat HV battery reconditioning /balancing summary (above) and peruse individual chat threads.

Watch several shorter and several long Youtube videos on Prius battery repair, including the "Ultimate Guide" and the ElectronAutomotive removal/replacement videos (above).

Decide if you will do the whole thing, or just order and install a rebuilt HV battery. If you need your car to be back in service in less than 2 weeks, maybe you should just buy the reconditioned battery and install it. On the other hand, it's a great process to do the whole thing yourself - I'm glad I did.

PREP / Check the car's OBDII data

Find a way to check your car's battery status via the OBDII. There are different apps. I used a Bluetooth generic OBDII reader with an android phone or tablet and the paid but inexpensive Torque Pro app. I downloaded and installed the free "Prius PIDs" to Torque. That was complicated and took me a day to figure out! That will tell you what your battery's 14 banks are registering and the difference in charge between them. It will be clear which of your blocks are weak, if any aren't close to the others' voltages. You might jot down the values (Blocks and Modules are counted from the non ECU/computer side on Gen II cars)

PREP / Decide how much you'll do - Buy your supplies
If you do the whole thing, invest in the hobby chargers needed to charge 4 or more modules at once and buy/make the AC/DC 12v power supply to power the hobby chargers. Watch out for the imax and detrum fake/copy chargers. It would be much better to spend more and get a great multiport charger that can discharge quickly and can run 3 or more dsch - chg cycles...than to buy cheap iffy chargers. Source a torque wrench and figure out how it works. Ditto for a soldering iron/gun, in case you have to make your own banana clip/alligator clip leads. You can do it!
Learn how these complicated hobby chargers work - there is a crazy menu structure with some of the important settings under "User Settings" and some under NIMH Charge[x] If you can calibrate your charger, do it, otherwise know how much off it is vs your multimeter and plan accordingly.

Figure out what safe but useful reconditioning settings you will use: I used CHG @ 2.5A inputting 7250mA, no time limit, DSC to 6.0v with whatever Max DSC Amp rate you can get. I chose 3 cycles, but stopped earlier if the DSC value (the one that matters) was high enough (above 5K or the same as my other modules) I used a Turnigy 4x6s because it was the one I found online available new with an Xbox 360 power supply I carefully converted (soldering a T60 hobby connector for the 4x6s charger) to make a 12v PSU. This is geeky, I know.

DISASSEMBLY - Interior
Disassembly of the interior and the bolts holding the battery down isn't hard, but you definitely want to use some system (ziploc bags with masking tape and marker explaining to you what everything is) to store the hardware you take off. There is a lot of it and it's hard to remember where it all goes later when you put it back. The interior will all fit in the front and back seats. You can put the hardware bags or containers on the dashboard. Pull the Orange Safety plug from the HV battery before you move or open the battery. Don't lose it or forget it later!

REMOVE HV BATTERY
Note you already removed the orange safety plug above. Move the battery from the car to a place it can sit for the week(s) while you work on it. Two people with gloves (sharp edges) is best. It seems to weigh about 50-60lbs. I did it myself. I put a board (1"x4" x a couple feet) I had lying around down between the bumper and the battery. Using this I could slide the battery slowly up and out (and later in and down) without hurting myself or the battery or the bumper.) I put it on some thick towels on a table in the basement, close to a powerstrip. Read all the safety information and wear gloves especially until you understand.

RECONDITION HV BATTERY
Recording in a spreadsheet or notebook, write down what you've done and what you're going to do as the project progresses. This process has lots of steps including: purchasing replacement modules for those determined to be 'bad' (below 7v), performing multiple DSC/CHG cycles and recording the improvement/final DSC value, Finally charging all the modules to within .05V of each other, Lastly connecting the + terminals (only) and the - terminals (only) so the 28 modules are all in parallel and balance

EDIT 1/2021: PriusCamper mentions putting balloons over the vent holes (on the top) of the modules while you charge them to both contain Hydrogen Sulfide gas - and to get a sense of how much heat/stress the module is under. I wish I'd done this and recommend you do it too. - you don't want excess Hydrogen Sulfide entering enclosed spaces where you work/live.

I purchased an inexpensive ($25) Wyze wifi security camera that could send live and recorded video to my phone - and would alert me when my chargers went 'beep'. This was incredibly helpful and I suggest you consider some sort of video camera/alert thing, unless you plan to sleep and live by your battery while your chargers do their work.

Note that you should only charge modules when they are in their 'rails and white blocks' fully compressed. The compression rails and blocks can be removed from the HV battery shell, and I suggest you should do that.
Module Replacement: Replace modules that fail to grow their DSC values to be similar to your good modules. In practice none of my 4 'low voltage' modules every got better. I bought 6 modules and used 4 of them. I felt my other modules were OK.

Module Matching: Module matching seems like the murkiest/most mysterious part of all this. It's suggested to do multiple things all in synch: 1. Given that middle modules are exposed to the least venting and most heating, move these to the ends (and vice versa). 2. match modules with similar internal resistance together, 3. match pairs of two modules so that their overall total capacities are all the same. I'm not sure I did this all correctly, but I did 1 and 3...I hope.

Final fiddly adjustments: Charge/Discharge each module so that it is within .05v of all the others.

Last balance. Attach all modules' + terminals and (separately!) all - terminals, creating a very large parallel battery. I flipped every other of my modules so all the + terminals were on one side and then connected all the positives with a long thickish solder strand - flexible, conductive, easy to work with - and bolted down VERY LIGHTLY. Connect all the negatives likewise. Let sit 24 hours to balance. Then carefully disconnect, saving all your nuts. Carry out your final ordering of the modules in their rails/blocks. Tighten the rails appropriately then The modules/rail/block assembly can be put carefully back into the HV shell.

REASSEMBLY – Battery: If you did it the easy way, you already have all the modules in their rails/blocks assembly and it's separated from the HV battery case. Verify that your positive and negative terminals alternate and start in the correct position at module 1 and end in the correct position at module 28 - this is very important! Connect the 3 or so heat sensors. Originally they were on module 1, 28 and 7 on my battery. On advice I moved them all as close to the middle of the pack as I could get, since that is the part that builds heat. Carefully turn the HV battery shell and rails/block/module pack upside down. Screw in the 28 alternating bolts torquing just to 48 INCH pounds. (In fact don't trust me or any other poster on torque values EVER without triple checking...) If the holes don't line up with the modules properly, you might have to loosen or tighten the 4 bolts on the rails/white blocks a bit.

Busbars - coating / torque: Working on one side only, replace your cleaned up busbars and nuts. If you didn't already do it, you definitely want to clean the copper busbars. I put mine and the copperish nuts in a cup of white vinegar for a few hours which cleans the (basic) corrosion. Then I washed them, scrubbed them with steel wool or a Scotchbrite kitchen scrubby and washed again with baking (neutralizes) soda and water. I dried them all and then kept in a safe place - don't lose!. Before reassembly of the busbars coat them in a conductive anti corrosion coating like Noalox. Carefully use only a torque wrench to tighten the nuts back - I used 48 INCH pounds. Practice on your bad modules if you're not sure what it will feel like when the torque wrench clicks. Apply the black safety covers over the orange plastic/copper busbar assemblies. Do the other side.

Close up the battery carefully (do not connect orange safety plug - that's your last step before turning your car on again! Return battery to car, bolting everything down.

HV Battery Fan: If you didn't already do it, you definitely want to remove the white 12v fan and remove its cover and duct work for cleaning. Reportedly, HV batteries fail because of filth build up in the fan and ductwork. You've spent countless hours on this project - this is easy and you can do it: remove all the dust and build up from the fan blower (easy to remove the cover for good access). Under the sticker on the Toyota motor for the fan is likely a little metal shaft. Put 2 or 3 light motor/bearing oil drop in there and let gravity pull it down to lubricate the fan.

Do not start Prius with a fully charged battery, allow the rejuvenated battery to sit for a day before starting….read more info on this step.

Working by yourself slowly, or with the help of the Youtube videos /notes you took on where everything goes and with which fasteners, put it all back together. You may want to pause after the battery is safely attached and covered (and the 12v battery is attached again) to insert the orange safety plug to test whether all your work is GOOD. Recall the orange plug has three motions: Push in, flip up, pull down... If your car starts and the errors go away, great! If you get an error, consider checking your work. If no obvious mistakes made, try the car a second time - some have said errors clear themselves on a second restart. If all good, continue putting the car back together.

Even if something isn't quite right with your modules, you can check them with your OBDII/Torque etc solution and find out what modules are the issue. You already know how to do so much, you can carefully consider what went wrong, and resolve it, perhaps with better module balancing, module pairing, module replacement or more DSC/CHG conditioning!

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Here's a little picture you want to avoid... (lesson: work carefully, make sure you trust your hobby charger, don't attempt to 'monitor' your charging process yourself without charger control...)