

With so many manufacturers and hybrid models now out of warranty, it's a good thing that we have such detailed repair information available – except that we don't! There is rarely any detailed description of operating conditions, failure modes, known-good PID values or waveforms. And the newer the vehicle, the less likely you are to find some useful information. In the best cases you have only a symptom or code with a long flow chart. In the worst cases you're completely on your own to figure out what isn't right, and you have only your faulty vehicle as a reference. What you need is hybrid training that describes the wide variety of ways manufacturers design their systems, which gives you the ability to choose your own diagnostic path even for hybrids and hybrid-related systems that you've never worked on.

WHAT THEY HAVE IN COMMON

Our 'systems and components' approach avoids getting bogged down with 'how many Volts are in this battery' and 'how much torque that motor produces'. After all, much of the technical information available has nothing to do with successfully diagnosing and repairing vehicles. This seminar includes examples from a number of Domestic, Asian, and European hybrids, but isn't about any of them in particular. Rather, it's about identifying what they have in common and the universal ways to approach diagnosing them. Only then are specific manufacturers covered to show the different ways that these strategies play out based on available PIDs, controls and component access for direct testing.

COVERAGE: HYBRID DRIVE SYSTEMS

- *Battery Types & Stress Testing*
- *Low Battery SOC vs. Cell or Block Imbalance*
- *Isolation testing (batteries, cables & motors)*
- *Available backup plans for low HV batteries*
- *Avoiding different 'Delta SOC' definition traps*
- *PM vs. Inductive Motors, how some motor information is misleading, and when this makes a difference during diagnosis*
- *Complicated motor diagnostics & when to do it the easy way instead*
- *Identifying modules in charge of sensors, fans, contactors, pumps, and motor phase control*
- *Making sense of PID units tips for defining polarity*
- *Disabling conditions vs. fault conditions*
- *Identifying power mixing options and inferring expected behavior based on specific configurations*

COVERAGE: HYBRID-RELATED SYSTEMS

- *Forced engine operation for testing & maintenance*
- *Compression & vacuum tests @ high cranking RPM*
- *Volumetric Efficiency (VE) testing issues*
- *Drivetrain noise diagnosis*
- *Transmission lubrication, cooling & mechanical*
- *AC and DC cooling pumps, oil pumps and fans*
- *High voltage AC and DC-AC compressors*
- *HVAC-cooled & electrically heated battery packs*
- *DC-DC low voltage battery charging*
- *Motor/hydraulic brake systems & force-sharing*

BATTERY FAILURE EXAMPLE

The following pages show how it may be difficult to verify a common problem on aging hybrids – a battery imbalance or 'end of life' code. These codes often set due to calculations more complicated than just comparing available voltage PIDs. In most cases the entire battery pack will be replaced, but it still makes sense to verify the fault and find any root causes that may compromise the new batteries.

A complete repair means identifying the weak areas in the battery for inspection during replacement. It is not practical to check 'everything', so it's best to isolate fault areas *before* disassembly. Not all batteries fail the same way, so multiple tests may be required, as shown in this case. It's a Toyota case, but these battery test methods and our tests for dozens more components and systems can be used on any hybrid.

CONTACT US TODAY!

BATTERY TESTING

Gen 3 Prius P0A80 – Replace Battery!

Unless you have some other codes along with a P0A80, this code will almost certainly result in battery replacement. However, you still want to verify and document the fault, partly because you may actually find something else, but mostly because it's great evidence in case:

- The customer ever questions the diagnosis (usually because they have been to the 'internet university' and are now much smarter than you).
- Another fault that may or may not have been the root cause surfaces once the new pack is installed.
- The new battery becomes imbalanced or another fault occurs that calls your diagnosis into question.

Battery age is the most common root cause, so the new battery pack has good odds of living a long life. However, even if some other fault pops up later, documentation is your proof that the original battery pack really had failed, in addition to (or maybe related to) whatever else you find later. In other words, the charge of 'parts throwing' won't stick.

Calling Multiple Witnesses to the Stand

For battery diagnosis, you may have multiple ways to verify the fault, and none of them take very long. For every diagnosis, we recommend checking available voltage PIDs at rest, with accessory loads, and during a test drive. Additionally, use Min/MAX and Delta SOC PIDs as they are available. For this 2010 Prius we performed three tests, one of which passed, which explains the need to look at *all* available evidence.

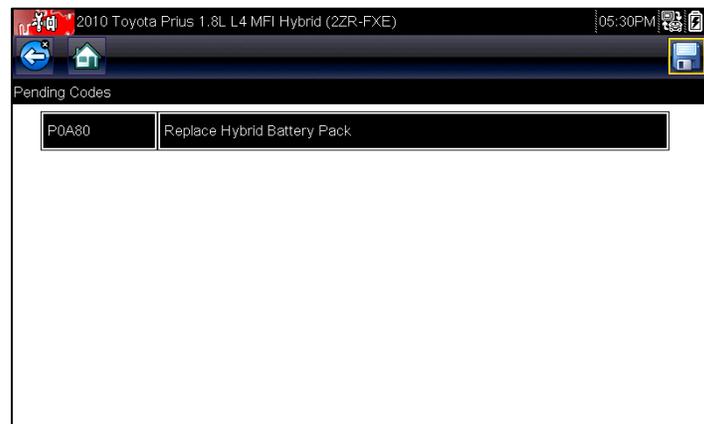
Pending (Current) P0A80

The first capture to the right shows the Pending code, which is something we like to check because it shows that the fault was detected during the last trip. That means it's not likely an intermittent fault, and should be easy to duplicate.

A discussion with the customer revealed that besides a slight loss of fuel economy, the only symptoms was an intermittent jerkiness on tip-in.

Delta SOC

Toyota uses the Delta SOC PID (from the HV ECU) as a comparison of the maximum variation in SOC between blocks. Some manufacturers use to it show the rage of SOC for the whole pack over a trip, which is of course a very large number. The Toyota version of the PID should be near 0%. This 39.5% result is about where we see many of these batteries set a code.



The screenshot shows the 'Battery Data - Delta SOC(%)' screen in the diagnostic tool. The top status bar displays the time as 05:58PM. The table below lists various battery-related parameters and their values.

Parameter	Value
Prohibit Charge for P Pos	ON
Delta SOC(%)	39.5
Batt Pack Current Val(A)	-0.02
Inhaling Air Temp (°F)	82.9
VMF Fan Motor Voltage1(V)	0.0
Charge Control Value(KW)	-3.4
Discharge Control Value(KW)	2.0
Cooling Fan Mode1	0

BATTERY TESTING

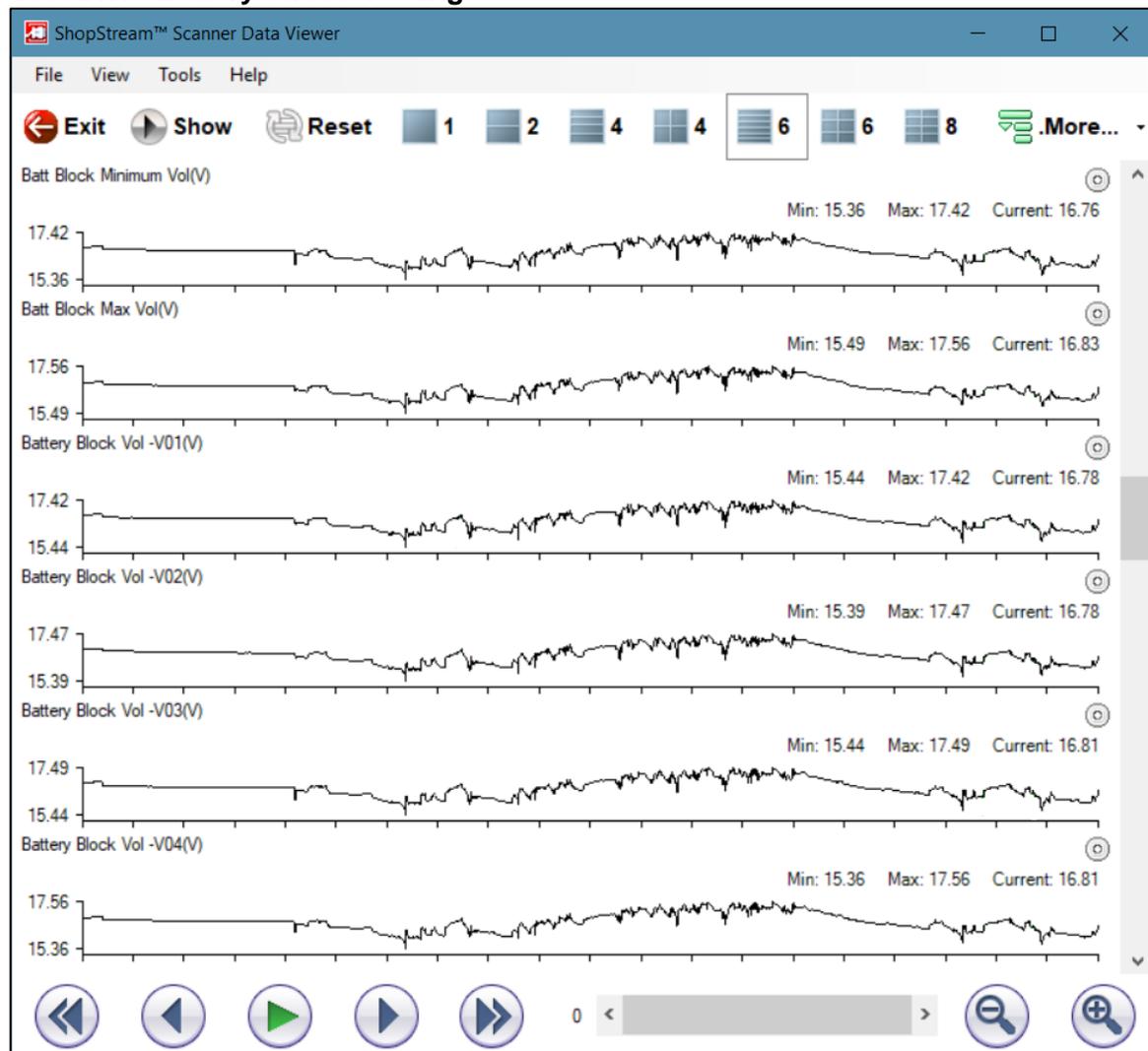
Gen 3 Prius POA80 – Replace Battery! – Continued

Test Drive & Reverse Stressing

Batteries are expensive, and PIDs are cheap, so we weren't willing to sell the high voltage battery just yet. Another great way to find a bad block is to use a lot of current during a test drive. The driving conditions that stress the batteries the most are WOT acceleration and hard acceleration in reverse gear. The ICE can't run in reverse, so it's a good way to make sure that you're only using battery power without ICE power or ICE-generated current helping out. The capture below shows the minimum and maximum voltage PIDs along with some block voltage PIDs during a test drive that involved heavy acceleration in both drive and reverse.

The minimum and maximum values for the point of greatest charge state were 17.42 Volts and 17.56 Volts. That is, when the battery was the 'fullest', the least charged block was 17.42 Volts and the most charged block was 17.56 Volts. That's only a 140-mV difference, and while we like to see 100 mV or less, this certainly doesn't indicate a failed battery.

Test Drive Battery Stress-Testing



BATTERY TESTING

Gen 3 Prius POA80 – Replace Battery! – Continued

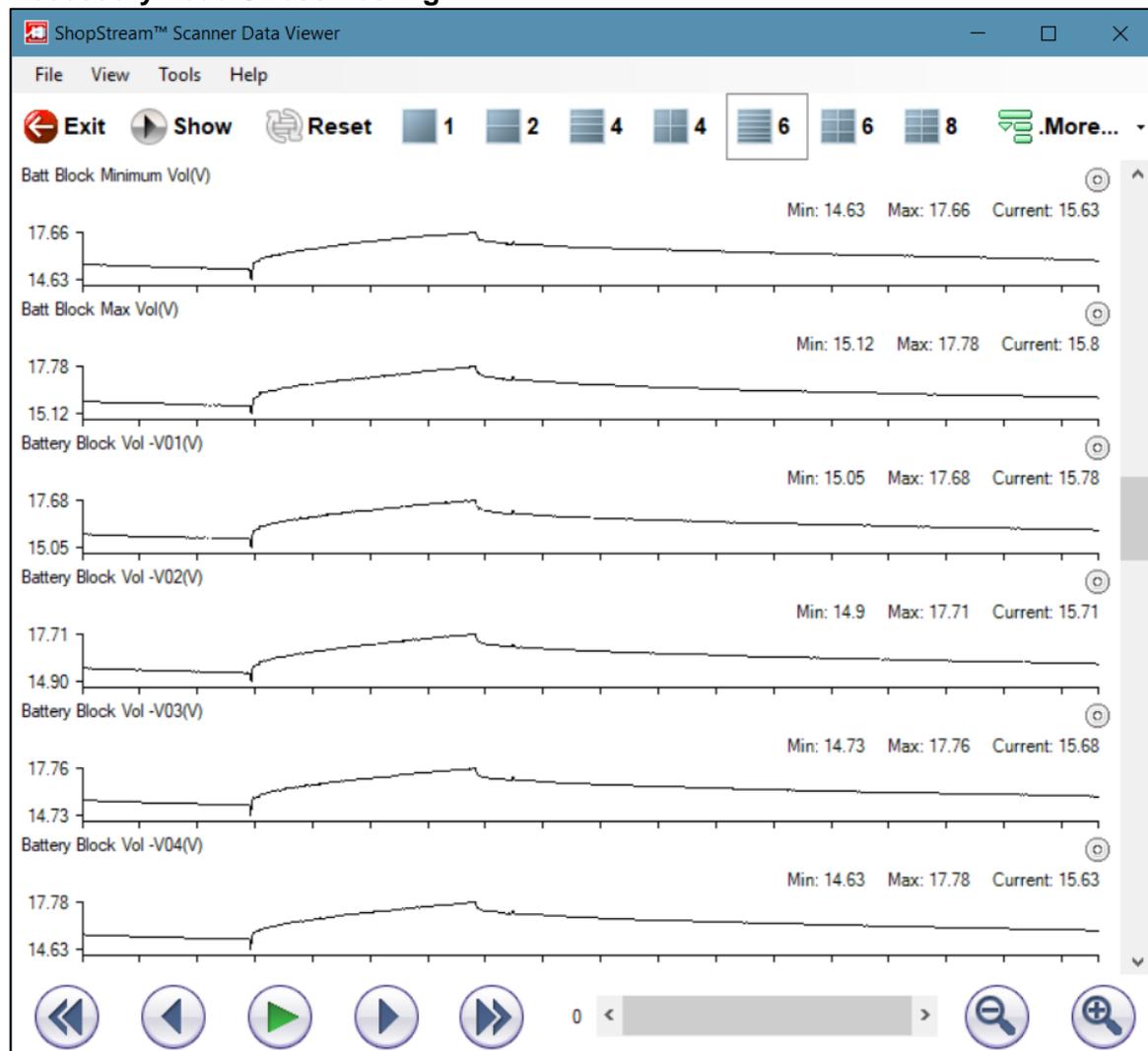
Test Drive & Reverse Stressing – Continued

In the capture on the previous page, the minimum and maximum values for the point of *lowest* charge state were 15.36 Volts and 15.49 Volts. That's only a 130-mV difference, so again, these results do not indicate a failed high voltage battery.

Accessory Load Testing

12-Volt loads are a good way to stress a high voltage battery because the current for accessories comes from the high voltage battery through the DC-DC converter. Turn on lights, fans, air conditioning (electric compressor applications) and other accessories. In the capture below, the voltage goes low in Ready mode, charges when the ICE is cycled on, and then slowly discharges again. At the lowest charge state, the lowest (minimum) block is 14.63 Volts (block 4 – bottom PID), and the highest (maximum) block is 15.12 Volts. That's a 490-mV difference. You'll often see over 1 Volt variation, but it's enough to set this code. When in doubt, un-Ready the vehicle but place it in 'Accessory' mode to prevent the ICE (and MG1 in this case) from charging the battery.

Accessory Load Stress-Testing



BATTERY TESTING

Gen 3 Prius P0A80 – Replace Battery! – Continued

Battery Data - Delta SOC(%)		72 / 2000
SOC after IG-ON(%)	54.5	
STATUS OF CHARGE MAX(%)	54.5	
STATUS OF CHARGE MIN(%)	54.5	
Inter Lock Switch	OFF	
Prohibit Charge for P Pos	OFF	
Delta SOC(%)	0.0	
Batt Pack Current Val(A)	-2.61	
Inhaling Air Temp (°F)	73.5	

Resolution

While the test drive didn't show a problem, the Delta SOC PID and accessory load stress-testing were enough evidence to sell a battery. Of course, every battery replacement should also be sold with the time needed to inspect bus bars, voltage sense connections, temperature sensor installation and calibration (when cold, PID values should match), air duct installation and alignment, fan

operation, and fan source path blockage. All were fine on this application, and a battery was a 100% fix. After installation, the Delta SOC PID showed 0% after a test drive, confirming the fix.

Key Point: *This diagnosis took well under the preliminary hour sold to the customer, and resulted in battery replacement that wasn't just a hopeful guess. Moreover, with the weak block identified, very little time was required to inspect that area of the battery after disassembly to look for debris, contamination, connection problems, sensor circuit voltage drop, or other 'surprises' that might compromise the repair. In other words, these methods balance your need to make sure it won't come back with the need to avoid wasting hours making sure it doesn't come back!*