Toyota/Lexus

12v Battery Failures - Analysis of Charging Issues - Deep Dive Analysis & Workaround

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First published: September 2025

This document may receive periodic updates for clarification and additional observations.

Contents

Disclaimer

This document has been compiled by an individual that can be described as an enthusiast with an attention for detail.

Information provided in this document is as factually correct as possible, with sources cited where available. Observations made are by the author and anecdotally by unverifiable 3rd parties.

Any recommendations followed from this document are done so at your own risk. The author accepts no responsibility for any loss or damage incurred as a result.

1. Quick Background

The number of 12v battery failures in Toyota and Lexus vehicles observed on social media platforms such as Reddit by the author of this document (/u/andy_why) appears to be abnormally high.

After an issue with the author's own vehicle, this prompted an analysis and investigation of the issue to determine if there was a common cause with the 12v batteries themselves or the way the vehicle is handling the charging or discharging of the battery.

The definition of “failure” in the context of this document refers to the 12v battery requiring a jump start or replacement in response to the vehicle being unable to start after being used in a normal way. The definition of “normal” in this context means that the vehicle is used almost daily and with no abnormal drain applied to the battery by the owner.

2. Issue Description

The 12v battery used in Toyota and Lexus vehicles is either a Flooded Lead Acid (FLA) or Absorbed Glass Mat (AGM) chemistry.

This battery is used to power all 12v systems such as lights, infotainment, power windows and liftgate, HVAC fan - just about everything electrical on the car except the hybrid system and air conditioning.

The 12v battery is required not only for these electrical systems but also to allow the high voltage hybrid battery to be switched on when the vehicle starts. A sufficient amount of power is required to complete this process.

Due to design and chemical requirements it is required that this battery be kept in a good state of health to ensure their longevity, and to keep a good state of health they must be sufficiently recharged after they are discharged by any amount.

Recharging of the 12v battery is carried out by a DC-DC converter (which replaces the alternator you would find in a non-hybrid vehicle) that converts high voltage DC from the hybrid battery into low voltage for the 12v battery.

Plate Sulfation

Any state of charge below 100% will result in chemical damage to the battery called sulfation, which begins to set in when left for a period starting at just a few days. Over weeks/months this process slowly damages the plates of the battery with hardened sulfate crystal material, leaving affected parts of the battery unable to function.

The speed at which sulfation occurs is proportional to the state of charge - a lower state of charge will form sulfate crystals more quickly than one which is at a high state of charge.

A battery held at a regularly very low state of charge, such as one where the vehicle is not driven often or has more drain on its battery from things like dashcams or regularly opening/closing electric liftgates, is likely to fail more quickly.

Comparatively, one which is at a higher state of charge because the vehicle is driven regularly and has no additional drain on its battery is less likely to fail as quickly - at least in theory.

Recently formed sulfation crystals formed from a partial discharge state which have not yet hardened are often reversible with a properly executed charging session. However, hardened sulfation, the kind that forms after the battery is in a discharge state for a prolonged period of time, is not reversible, resulting in permanent capacity loss (stored power) and reduced output power (output current) capability of the battery.

Once the battery loses enough capacity and output capability due to hardened sulfation, it can no longer function normally, resulting in insufficient power to start the vehicle. At this point the battery is classified as “failed”, requiring replacement to restore function.

The issue that appears to be occurring with Toyota and Lexus vehicles is that the 12v battery is not being sufficiently recharged by the vehicle's charging system when the car is running. The charging system does not appear to use any well established or predictable charging algorithm for FLA or AGM battery chemistries.

When using this algorithm the 12v battery does not appear to receive sufficient amounts of charge whilst the vehicle is running, resulting in the battery being unable to reach or maintain 100% state of charge. This failure to reach and maintain a 100% state of charge causes sulfate crystals to form and allows existing sulfate crystals, which are not being reversed, to eventually harden upon the battery plates. In time, observed to be only 1-2 years for many owners, the battery ends up failing through sulfation damage.

To date, this issue has been widely reported on by owners as their battery dying in an abnormally short period of time in comparison to their previous vehicles. It is affecting vehicles from around 2018 onwards (gen4+ drivetrains), and there has been no noted acknowledgement by Toyota or Lexus regarding this issue when asked. There has been no official response to this issue outside of dealer responses to the question, and dealer responses were that there are no known issues or reported problems.

Why Toyota/Lexus use this algorithm

Put simply, we don't know why this algorithm is being used.

We have known how to properly recharge a lead acid battery for decades and the technology has not changed. Older vehicles with "dumb" alternators would output 14.4v-14.6v continuously and that was sufficient to keep the battery charged and healthy for 5-10 years.

The author of this document speculates that it may be related to vehicle emissions. Charging the battery uses energy which increases CO2 emissions, so the algorithm is optimised to reduce these emissions by charging the battery only as much as it thinks is needed. This reduces emissions enough for vehicle manufacturers to pass emissions laws, but in doing this it's not treating the battery in a healthy way which is leading to premature failures.

The irony of this is that CO2 emissions are increased because the battery will need to be replaced sooner, however, this doesn't get taken into account during the vehicle's emissions testing.

3. Acceptable 12v Charging Algorithm

Before we analyse the vehicle issue we need to understand how a 12v FLA/AGM battery should be charged in order for it to remain healthy.

Both chemistries require a very similar charging algorithm with only the charging voltage varying between them.

Battery basics

A FLA/AGM battery when fully charged and resting (without any load) should have a voltage of 12.7v or higher after not receiving a charge for over 6 hours.

A voltage lower than 12.7v typically represents a state of charge under 100% or that the battery is under load.

However, it must be noted that open circuit voltage is only a guide for the battery state of charge. It does not tell you the health of the battery from a capacity point of view, only its relative state of charge. A battery may hold only 20% of its rated capacity and still show 100% state of charge at 12.7v, but can then fail to perform under load (voltage drop) or during a capacity test (runs out of energy earlier than expected).

Definition of a fully charged battery

A FLA/AGM battery is deemed to be fully charged when it has been held at a charge voltage of 14.6v (AGM) or 14.4v (FLA) for sufficient time that the charge current in milliamps drops below a set current.

Battery University defines this as decreasing to 3-5% of the C rating (C = AmpHour rating), which is 1/33 to 1/20 of C.

Some manufacturers specify 1/50 of C, and others 1/100 of C.

For the purposes of this analysis we'll go in the middle and select 1/50 of C.

For example, at 1/50 of C a 50Ah battery would be considered fully charged when its charge current drops below 1000mA (1amp) when held at its rated charge voltage.

Charging the final 10-15% state of charge

The final 10-15% of the state of charge for a FLA/AGM takes the longest amount of time to complete. Like all battery chemistries, the charge current tapers as charge acceptance drops when the battery approaches full.

It can take between 4 and 24 hours for this part of the charge to complete in an FLA/AGM chemistry. For this reason, a lot of vehicle batteries only end up charging to about 90% unless they're regularly used for many hours per day.

This means that most vehicle batteries are always in some kind of partial discharge state where sulfation can occur. The sulfation process is relatively slow at around 90% state of charge so a lot of it is reversed during the next charging session, but it does still happen and is one of the reasons most batteries eventually end up failing. The sulfation reversal process when charging doesn't reverse all of it.

Charging methods

There are multiple ways that these batteries can be charged and remain in sufficient health to ensure reasonable longevity, and the method is often chosen depending on the application that the battery will sit in and how it is expected to be charged.

Method 1: Single Step Constant Voltage Charging

- Apply a constant voltage of 14.4-14.6v. Charge current will naturally drop as the battery approaches full charge.
- Suitable for when charging is intermittent, such as in a vehicle or top-up charging. Charge current will drop as the battery approaches full, but it may never reach full charge.
- The battery should not be held at this voltage indefinitely to avoid loss of water through mild off-gassing.
- This method is used by the majority of older vehicles with "dumb" alternators.

Method 2: 2 Step Charging

- Apply a constant voltage of 14.4-14.6v.
- When charging current begins to drop, switch to a constant float voltage of 13.5-13.7v.
- Simple and suitable for applications where the battery is in standby use only such as an uninterruptible power supply that has 24/7 charging and is not subject to frequent discharges.
- Can result in under-charging if not applied continuously.

Method 3: 3 Step Charging

- **Stage 1 - Bulk:** Apply a fixed voltage of 14.4-14.6v and limit maximum charge current to the maximum allowed by the battery specification.
- **Stage 2 - Absorption:** Continue to apply the fixed voltage whilst charging current tapers to 1/50th of C.
- **Stage 3 - Float:** Once the charge current drops below 1/50th C, reduce the fixed voltage to a float voltage of 13.5-13.7v.
- Typically used in applications such as mains and solar chargers where charging and discharging is a daily occurrence.

Method 4: 5 Step Charging

- All 3 steps of the 3 Step Charging method with the following steps added.
- **Stage 4 - Stop:** After 24 hours of float charging, stop charging the battery entirely and allow it to rest.
- **Stage 5 - Top-up:** Apply a periodic (every couple of days) top-up charge for 2-4 hours at 14.4-14.6v before returning to stage 4.
- Typically used in applications such as mains and solar chargers.

Other charging methods do exist, but are typically suited to specialist applications such as battery maintainers and reconditioners. They don't apply to general charging applications.

Further reading on charging methods:
https://www.victronenergy.com/upload/documents/Datasheet-GEL-and-AGM-Batteries-EN.pdf

Acceptable charging methods for a vehicle

Only methods 1, 3 and 4 would be considered acceptable charging methods for a vehicle.

Method 2 would result in under-charging of the vehicle battery. This is due to prematurely dropping to a lower charging voltage that would result in a drop of charge current before the battery is considered full.

4. Analysis of Toyota/Lexus Charging Algorithm

This analysis will focus on the 12v charging system of Toyota and Lexus hybrids primarily, as this is the most commonly reported type of vehicle that is having issues reported on Reddit and is the vehicle type that the author has had access to. However, this issue may well expand into other brands and non-hybrid vehicles as well. This analysis does not look at other brands outside of Toyota and Lexus.

Observed Charging Algorithm

The charging algorithm observed on these vehicles varies. It is mostly unpredictable and therefore difficult to give an accurate analysis that holds true for all vehicles. Instead, observations of its behaviour are noted below with vehicles that it has been noted to apply to:

Author's observations

Vehicles observed:
(Year provided where available)

- 2x Lexus UX (2020)
- Toyota RAV4 Prime 2022

This is an observation made by the author of this document on personally owned vehicles:

- With the vehicle running the charging voltage will rise to 14.2v.
- Whilst driving, after 90 minutes:
    - The charging voltage will drop to 12.3-12.6v and remain there. As this is below the open-circuit voltage of the battery this is a state of discharge.
    - When the vehicle is put into park the charging voltage will rise back to 14.2v.
    - When the vehicle is put into drive the charging voltage will once again drop to 12.3-12.6v, again, a state of discharge.
- The 90 minute timer resets if the vehicle is turned off and restarted.
- For the RAV4 Prime plug-in hybrid, the same holds true. In addition the 12v battery does not appear to charge when the traction battery is charging, but rather it is maintained at 12.8v with a short approximately 15 minute rise to 13.0v, which is insufficient to charge the battery.

Such a charging algorithm would negatively affect the battery of any vehicle which is used regularly for more than 90 minutes at a time.

If a long journey is performed the battery is likely to end up in a partial state of discharge at the end of the journey. As a partial state of discharge causes plate sulfation, damage would begin to occur before the journey has been finished and would continue until the next start of the vehicle which resets the charging timer.

3rd party observations

Vehicles observed:
(Year provided where available)

- Toyota Grand Highlander (2025)
- Toyota RAV4 Hybrid (2020+)
- Lexus TX550h+
- Lexus ES300h
- Lexus RX450h (2025)
- Lexus UX250h (2020+)
- Lexus NH350h (2025)

These are observations made by other vehicle owners that have suffered from the same issue.

- Frequently observed with a battery voltage of 12.6-12.8v with the vehicle running. Even though 12.8v indicates close to full charge, this only applies when at rest after charging, and is otherwise an insufficiently maintained battery voltage for charging.
- A resting voltage with the vehicle off of 12.1-12.4v, representing 50-70% state of charge even after the car has been driven for several hours.
- Infrequent and unexplained rises in charging voltage between 13.0v and 14.5v for very short periods of time (seconds).
- Rarely sustains a sufficiently high charging voltage to properly charge the battery.

Such a charging algorithm would negatively affect all use cases of the vehicle.

It results in the battery receiving unpredictable charging with the potential to remain in a partially discharged state for a long period of time. As a partial state of discharge causes plate sulfation, damage would occur almost continuously over a long period of time, expediting battery failure.

Reddit Threads:

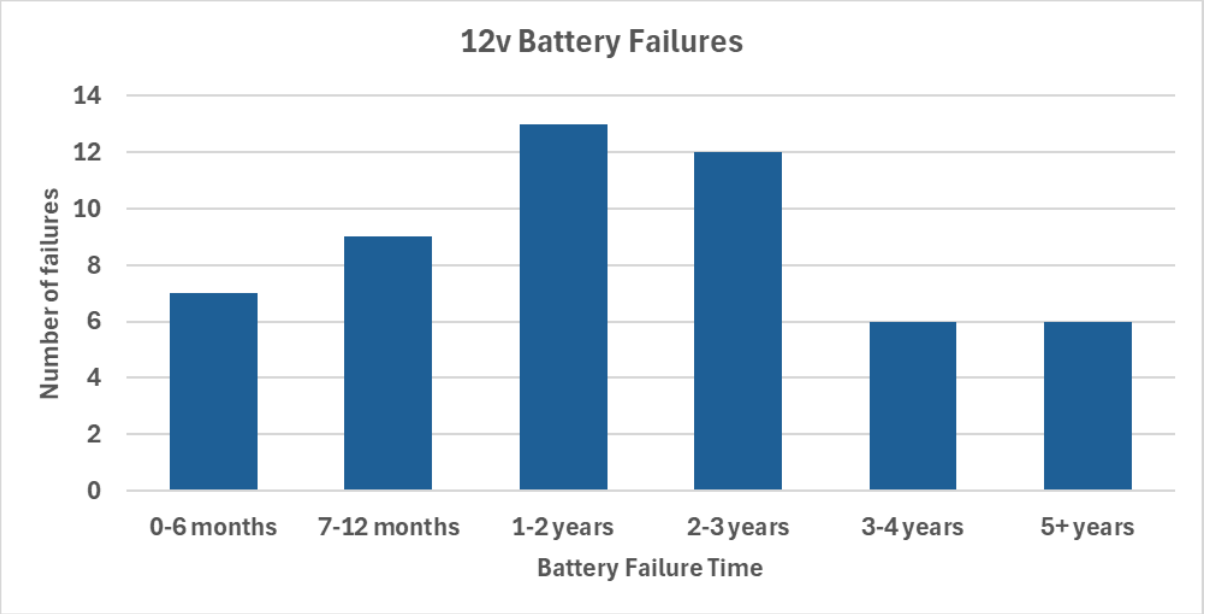
These are specific reddit threads found by the author relevant to this issue.

- https://www.reddit.com/r/ToyotaGrandHighlander/comments/1m306fj/ghhl_error_messages_and_wont_start/
- https://www.reddit.com/r/ToyotaGrandHighlander/comments/1kv5y2t/2nd_12v_battery_to_fail_in_10mo_ghhplat/
- https://www.reddit.com/r/Lexus/comments/1m0y13n/nx_350h_12v_battery_drain_issue/
- https://www.reddit.com/r/PriusPrime/comments/1j9smdv/comment/ng7d8l3/

YouTube Videos:

- https://youtu.be/DRprBX5hsMo - Trying to decode the 12V Battery in the 2022-2025 Lexus NX
- https://youtu.be/jCC06f-ofg8 - 12V Battery charging in winter for Lexus Hybrids

Online Reports:
This section compiles 53 reports from around the internet from people reporting battery failures, sourced from searching Reddit, ClubLexus, PriusChat and other sites for the length of time they have reported their battery to last before failing.



Source: *Reddit, ClubLexus, PriusChat and other forums via ChatGPT.*

This data is randomly sampled but limited due to ChatGPT's free service limits. More data is certainly available but not used in this sample.

The data demonstrates that there *may* be an increased failure rate around the 1-3 year mark, however, it is not conclusive due to the limited sample taken. It does however demonstrate that there are still quite a number of failures happening in this time frame.

Analysis of many of the threads shows that the failures are happening to a lot of people without warning through normal use of their vehicles, such as daily driving. There's nothing to suggest that it's the vehicle owner at fault.

Conclusion from all observations

- The 12v battery rarely receives, or receives for an insufficient time, a sufficient charge voltage.
- Lack of sufficient voltage over a long enough period of time means the battery can never reach 100% state of charge.
- Lack of sufficient charging voltage may result in a net discharge between journeys.
- An insufficient state of charge results in plate sulfation occurring.
- Over time, hardened plate sulfation reduces battery capacity and power capability.
- Eventually, after 12-36 months, the battery is unable to store or supply enough power to start the vehicle due to significant sulfation build up.
- A jump start is typically required to start the car.

- The battery will often fail to start the vehicle again within a short time due to the extensive plate sulfation/damage.
- Total failure soon follows requiring a 12v battery replacement.
- The owner replaces the battery and continues until the same issue occurs again 1-3 years later.

5. The charging algorithm “fail-safe” workaround

As the charging algorithm used in these vehicles is software based, this means we can’t alter it. To do so would require specialised knowledge of Toyota and Lexus systems, specialised equipment, the ability to reverse engineer software, and more. As a result it would unfortunately require Toyota/Lexus to issue a software update which is extremely unlikely to happen as they have not even acknowledged the issue.

Thankfully, there is an alternative method available to us to work around this issue that is built into the software - the “fail-safe”.

12v battery monitoring sensor

To monitor and control the charging of the 12v battery there is a sensor located on the negative terminal of the 12v battery connection. This sensor monitors voltage, current and temperature of the battery so that it can be used by the software to understand its condition, state of charge, and perform “smart” charging.

Sensor fail-safe

Unfortunately, without this “smart” sensor, the software can’t function as designed. Fortunately, if the sensor isn’t working or is disconnected, there is fail-safe software which reverts the charging system back to a “dumb” state to ensure that the battery receives some kind of charge rather than nothing.

This fail-safe “dumb” state produces a safe, fixed, continuous output voltage of around 14.1v. This voltage is sufficient enough to charge the 12v battery so that it maintains a reasonably healthy state of charge, whilst also not over-charging.

As a fail-safe it has been designed so that it can operate in this state indefinitely and remain completely safe if the sensor is not working as expected.

Sensor disconnection

To activate the fail-safe all we need to do is disconnect the sensor on the 12v negative battery terminal, as shown below.

The location of this is always on the negative terminal of the 12v battery. The battery location will vary between vehicles, but is most commonly inside the rear of the vehicle on the right side behind a plastic panel.

The 12v battery negative terminal sensor plug

This can be reverted back at any time by simply plugging the sensor back in, and disconnection does not cause any warning lights to appear on the dashboard.

Whilst the sensor plug is disconnected the Toyota/Lexus charging algorithm is bypassed and the fail-safe will be active.

Why this works

Remember:

- AGM batteries ideally require 14.6v to charge and 13.5-13.7v to float.
- FLA batteries ideally require 14.4v to charge and 13.5-13.7v to float.
- Both chemistries will receive a full charge if sustained for long enough at or above float voltage (uninterruptible power supplies work this way).

14.1v falls in the middle of the expected charge voltage and the float voltage, making it the perfect compromise.

It is 100% safe to charge both battery chemistries at 14.1v continuously because they self-regulate charge current once they reach full charge.

Is there risk of over-charging in the fail-safe state?

No. The battery self-regulates its charge current once it reaches full charge.

The only thing to be aware of is that as 14.1v is effectively both our charge and float voltage in this state, we do end up floating the battery at a higher than normal voltage once it's charged. This could (although not a certainty) result in a slightly higher loss of water from the battery electrolyte in the case of an FLA battery.

FLA batteries are not maintenance free, and do need to have their water checked and topped up every 12 months if you are maintaining it correctly. For these batteries you may find that you need to add water a little more frequently. This is normal behaviour and function of the battery, and it is not harmful to it if you keep on top of this maintenance.

In reality, watering is usually not needed this frequently and the chances of this being an issue is actually very low. However, you should be aware of this and check it as per the maintenance schedule.

AGM batteries should not be affected. They are maintenance free and therefore sealed. They have an internal recombination process which means that water from the electrolyte isn't lost unless the battery is seriously mis-treated through over-voltage, or it internally fails in a way that results in venting.

Is there still a risk of under-charging in the fail-safe state?

Yes, a slight risk, as we're using a slightly lower voltage than a proper charging algorithm would. The risk varies depending on how much the vehicle is driven and how much extra drain there is on the battery when it is not charging.

However, your battery will still be much healthier than it would be using the Toyota/Lexus algorithm. The fail-safe voltage is designed to be a safe compromise for continuous use.

Does the battery charge more slowly due to the lower voltage?

Yes, it will charge a little more slowly once it gets to the higher states of charge, but not by a lot. As long as the charging voltage is above the battery terminal voltage then current will flow and the battery will receive some charge.

The Toyota/Lexus' algorithm frequently did not bring the voltage above the terminal voltage and so no current would flow the majority of the time, and no charge would be received.

The fail-safe ensures that the battery is always receiving a voltage sufficient enough for current to flow and charge to be added.

6. Long term health

10 months of testing

In October 2024, the author of this analysis disconnected the 12v battery negative terminal sensor after replacing the 12v battery in a Lexus UX with a brand new battery following its failure. From this point it was using the fail-safe 14.1v charging voltage.

Around 10 months later in July 2025 the Lexus UX was sold but the 12v battery was retained to be put into the next vehicle (a RAV4 Prime).

Upon inspection of the battery when it was removed from the Lexus UX the battery had a terminal voltage of approximately 12.6-12.7v, representing an approximate state of charge between 90-100% according to open circuit voltage state of charge charts.

To determine the state of charge with further accuracy, a top-up charge was applied to the battery using a bench power supply set to 14.5v and a maximum of 3 amps.

Within 2 hours the charge current had dropped below 1 amp, determining the battery to be at 100% state of charge under the rule of a full charge being reached when the charge current drops below 1/50th of C.

The power delivered over this 2 hour period could not have exceeded 6 AmpHours, or 12% of the battery capacity.

Due to current taper being almost immediate upon starting the top-up charge, the delivered power was likely in the range of 3 AmpHours, or 6% of the battery capacity.

This top-up charge determined the state of charge to be at a minimum of 88%, but more realistically due to current taper it would have been nearer 94%.

This state of charge is very healthy for a car battery. As was mentioned earlier in section 3, most healthy car batteries will typically sit at around the 90% state of charge range.

Battery relocation

From July 2025, the battery now resides inside a 2022 RAV4 Prime, with the sensor plug disconnected.

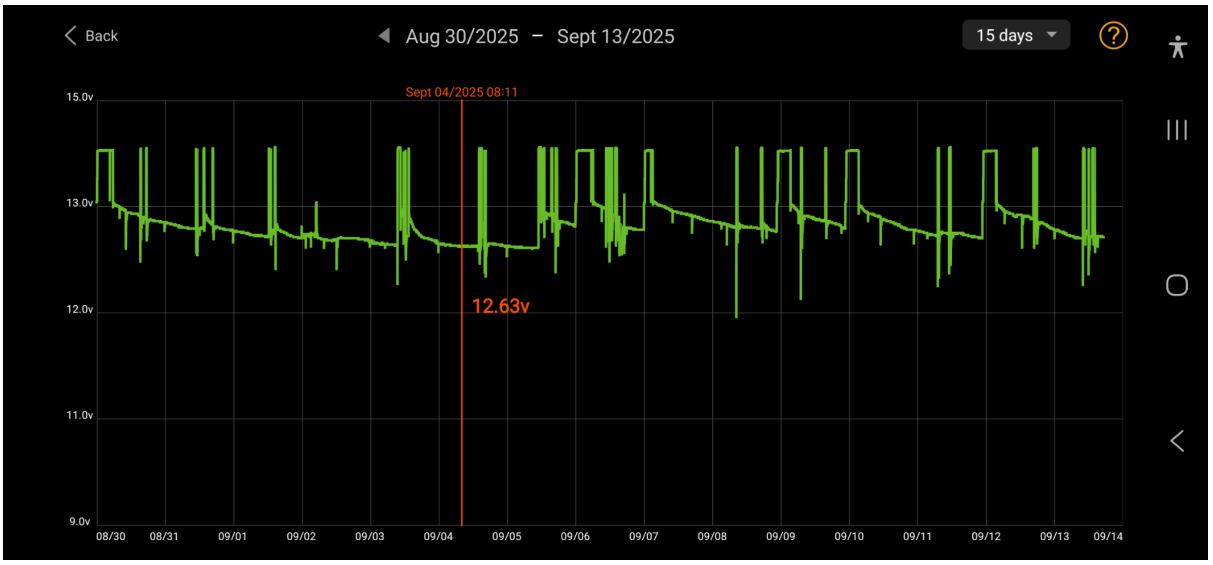
This vehicle, being a plug-in hybrid, receives 12v battery charging whenever the vehicle is turned on or the traction battery is charging, which can be up to 7 hours when fully depleted.

This allows the 12v battery to receive a healthy charging session at 14.1v for the full length of the charging period.

Upon finishing a long charging session of up to 7 hours, the battery state of charge is going to be at 100%, or very close to it.

Upon checking the terminal voltage with a bluetooth voltage logger and monitoring this over time, the voltage following a long charging session rests at 12.8-12.9v which represents 100% state of charge.

15 days of logging is shown on the graph below.



After 2-3 days unused, the surface charge dissipates and the voltage drops to around 12.6-12.7v, representing 90-100% state of charge.

Retaining 100% state of charge is unrealistic as there is some drain from the car's alarm system, etc. which will use a small amount of power.

As the battery is retaining a voltage in line with a state of charge of 90% or higher we can determine the battery is in a good state of health and is receiving a strong level of charge when charging at the fail-safe of 14.1v over the past 10 months.

10 month conclusion

The 12v battery remained healthy in both the Lexus UX over a period of 10 months of charging at 14.1v with the sensor plug disconnected, and also so far after 45 days in the RAV4 Prime.

It retained a high terminal voltage of 12.6-12.7v in line with a 90%+ state of charge.

The battery continues to appear healthy after being moved to the RAV4 Prime even with extensive charging sessions of 14.1v when the traction battery is charging.

The conclusion of this analysis therefore is that there is sufficient evidence that the 12v battery in Toyota and Lexus hybrid vehicles is more likely to remain healthy if the 12v battery negative terminal sensor is disconnected than if it were to remain connected.

It is the suggestion of the author of this analysis that anyone concerned with this issue may want to disconnect the sensor and run their vehicles in the fail-safe mode. If you do so, you should monitor it yourself to ensure it is behaving as intended.

Reminder: Any recommendations followed from this document are done so at your own risk. The author accepts no responsibility for any loss or damage incurred as a result.