

# 5G Ford Ranger BMS Overview

From ChatGPS

As an aside, I asked Chatgpt how a battery's SOC is calculated. Here is its response: ( I wonder which one Ford is using? Most likely the BMS option.

## How is an auto battery State of Charge calculated ?

**ChatGPT said:**

**State of Charge (SOC)** for an automotive **lead-acid battery** is not measured directly—it is *estimated* using one or more of the following methods:

### 1. Open-Circuit Voltage (OCV) Method

This is the **most common way** to estimate SOC when the battery is *resting* (no charging or discharging for at least 4–12 hours).

A typical 12-volt lead-acid battery has these approximate OCV values:

SOC (%)	Voltage (12.6–12.8V = full)
100%	12.6–12.8 V
90%	12.5 V
80%	12.42 V
70%	12.32 V
60%	12.20 V
50%	12.06 V
40%	11.90 V
30%	11.75 V
20%	11.58 V
10%	11.31 V
0%	10.5 V and below

**Formula (approximate):**

$$\text{SOC} \approx \frac{\text{OCV} - 11.9}{0.007}$$

...but this varies by battery type and manufacturer, so tables are more reliable.

 **OCV only works if the battery has rested.** Measuring right after running the engine or charging gives artificially high voltage.

## 2. Specific Gravity (Hydrometer) Method

Used for **flooded lead-acid batteries** (not AGM/GEL).

- Each cell's **specific gravity** of the electrolyte correlates with SOC.

Typical values:

- **1.265 = 100%**
- **1.225 = 75%**
- **1.190 = 50%**
- **1.155 = 25%**

Correction: Add **0.004** to the reading for every **10°F above 80°F** (or subtract for colder).

## 3. Coulomb Counting (Amp-Hour Tracking)

Used in **battery monitors** (Victron, Renogy, etc.) and EV/BMS systems.

The monitor measures:

- How many amps go into the battery
- How many amps come out

Problems:

$$\text{SOC}_{\text{new}} = \text{SOC}_{\text{old}} + \frac{\text{Ah}_{\text{in}} - \text{Ah}_{\text{out}}}{\text{Battery Capacity}}$$

- Capacity changes as the battery ages
- Monitors drift without periodic voltage calibration

## 4. Internal Resistance / Conductance Testing

Specialized testers (Midtronics, Solar, etc.) measure conductance or impedance.

This does **not** give SOC directly, but it helps estimate **health** which can refine SOC estimates.

## 5. Smart Battery Management Systems (BMS)

Modern vehicles may combine:

- Voltage
- Temperature
- Current flow
- Battery age
- Internal resistance

...into a computer-generated SOC estimate. This is more accurate under varying loads.

## Summary

Method	Accuracy	Requires Resting?	Notes
OCV Voltage	Medium-good	Yes	Most common + simplest
Specific Gravity	Very accurate	No	Only for flooded batteries
Coulomb Counting	High (with calibration)	No	Used in monitors/BMS systems
Internal Resistance	Medium	No	Helps estimate battery health

# How does a 2020 Ford BMS calculate SOC?

In a 2020 Ford vehicle, the Battery Management System (BMS) calculates the State of Charge (SOC) using *multiple methods together*, not just one. Modern Ford BMS systems use what's called a hybrid SOC estimation model. Here's how it works:

## How a 2020 Ford BMS Calculates SOC

Ford's BMS uses three primary inputs:

### 1. Coulomb Counting (Current Integration) — Main Method

This is the *primary* and most accurate short-term method.

- The BMS measures **current in and out of the battery** through a **Hall-effect current sensor** or shunt.
- It integrates (adds/subtracts) current over time:
  - Charging → SOC increases
  - Discharging → SOC decreases

#### Why it's powerful:

It tracks SOC changes in real time.

#### Why it needs help:

Coulomb counting drifts over time due to sensor noise and battery aging, so Ford supplements it with other methods.

### 2. Open-Circuit Voltage (OCV) Estimation

When the car has been off for several hours, the battery relaxes to a stable voltage.

- The BMS measures the **resting voltage**
- It compares it to pre-programmed lookup tables specific to the battery chemistry (typically AGM for 2020 Ford)

This gives a good baseline SOC measurement, which is used to recalibrate the coulomb counter.

#### Why it's useful:

- Very accurate when the battery is rested
- Helps correct drift from coulomb counting

### Why it's limited:

- Cannot be used when the battery is under load
- Requires several hours of no activity ("quiescent period")

### 3. Battery Temperature Compensation

Because battery voltage and capacity change with temperature, the BMS uses the battery temperature sensor to adjust the SOC estimate.

- Cold battery → lower usable capacity
- Hot battery → higher measured voltage but potential aging effects

The BMS corrects both voltage and coulomb-counting data based on temperature.

### 4. Internal Resistance / Aging Models

Ford BMS also tracks:

- Battery **internal resistance**
- Battery **health** (SOH)
- Charge acceptance
- Cranking behavior

These values help the system adjust SOC estimates as the battery ages.

### Summary of How the Ford BMS Computes SOC

Ford uses a hybrid algorithm, usually something like this:

Method	When Used	Purpose
<b>Coulomb counting</b>	Always while vehicle is awake	Tracks SOC changes moment-by-moment
<b>OCV measurement</b>	After long rest	Provides a "true" SOC baseline
<b>Temperature compensation</b>	Always	Corrects errors in voltage and capacity
<b>Aging models (SOH)</b>	Continuously	Adapts for battery wear over time

### Important Notes for the 2020 Ford BMS

- After **battery replacement**, the BMS needs to be **reset** (via scan tool) so it can relearn capacity and resistance.
- SOC accuracy improves after several **drive-rest cycles**.

- The BMS communicates with the ECU and charging system (smart alternator) to dynamically adjust charge rates using SOC, SOH, and temperature.

# How Does Ford monitor Battery SOH?

Ford's **smart alternator system** (also called *Intelligent Charging* or *Smart Charge*) continuously adjusts how much the alternator charges the battery. It uses real-time information from the **BMS**, including **State of Charge (SOC)** and **State of Health (SOH)**, to determine the proper charging voltage and current. Below is a clear explanation of *how SOH specifically* influences alternator behavior.

## How Ford's Smart Alternator Uses SOH

SOH tells the car **how "healthy" the battery is**, meaning how much capacity and performance it still has compared to new. The smart alternator uses this to decide:

- How **aggressively** to charge
- What **maximum voltage** to use
- How quickly charging is **tapered off**
- Charging behavior in **cold weather**
- Whether to protect the battery from stress

**Here's how it works in detail:**

### 1. A High SOH Battery (Healthy) → Uses Aggressive / Efficient Charging

When SOH is high (80–100%):

#### ✓ **The alternator allows faster charging**

Healthy batteries handle charge well, so the system will:

- Use **higher charge current**
- Allow **higher voltage spikes** (14.6–14.8V in AGMs during cold starts)
- Charge more rapidly after engine start

#### ✓ **Smart alternator can reduce load for fuel efficiency**

When cruising at steady speed, with a good battery:

- Alternator output is **lowered** to reduce engine drag
- Battery carries the load temporarily
- During deceleration, alternator boosts output to "regain" charge (regenerative charging behavior)

This only works well if the battery is healthy.

## **2. Medium SOH Battery (50-70%) → More Conservative Charging**

As the battery ages:

### **⚠ Charging voltage is moderated**

Ford reduces:

- Maximum charging voltage
- Charge current
- Rate of charge after cranking

Because older batteries cannot absorb charge efficiently, pushing them too hard generates **heat, gassing**, and accelerates wear.

### **⚠ Alternator may run more often**

Since the battery can't hold large charges:

- Alternator output frequency increases
- Smart alternator "load-shedding" becomes less aggressive
- Fuel-saving alternator cutoff happens less often

## **3. Low SOH Battery (<50%) → Protective, Gentle Charging**

When SOH falls low, the BMS changes strategy dramatically:

### **No aggressive high-voltage charging**

Charging is smoothed and limited.

### **⚠ Longer charge times**

The BMS recognizes poor charge acceptance and switches to:

- Lower current
- Lower target voltages
- Slow tapering charge curves

### **⚠ Alternator runs more consistently**

Smart alternator stays "on" more of the time because:

- The battery can't maintain SOC on its own
- The vehicle must be protected from voltage dips

## Priority shifts to preventing failure

Because low-SOH batteries sag under load, the system tries to keep the battery at a **higher SOC** to avoid:

- No-start conditions
- Control module brownouts
- Voltage instability

You'll see more frequent output in the **14.2-14.5V** range.

## 4. Very Low SOH (<40%) → System Goes Into “Emergency Protection” Mode

Ford's BMS may do the following:

### Maximum voltage cap

The BMS avoids destructive voltage levels to prevent overheating or gassing.

### Alternator runs almost constantly

The system stops doing fuel-saving alternator cutbacks.

### High-voltage cycling (14.5V peaks) to maintain electrical stability

It tries to prevent engine stall, ABS faults, or low-voltage module resets.

### Charging behavior may appear “erratic”

People often misdiagnose this as a bad alternator—but it's actually the BMS trying to keep a dying battery alive.

## 5. How SOH Works With SOC in Alternator Control

The alternator uses **SOC** to decide *when* to charge.

It uses **SOH** to decide *how hard* to charge.

### Example:

- **Low SOC + High SOH → Charge hard and fast**
- **Low SOC + Low SOH → Charge slow and safe**
- **High SOC + High SOH → Alternator may disengage for fuel saving**
- **High SOC + Low SOH → Alternator may still charge to prevent voltage dips**

## 6. Why a Bad SOH Battery Causes “Weird” Charging Behavior

Many Ford owners report:

- Alternator jumping between 12.5V and 15V
- Lights dimming
- Random high-voltage spikes
- Alternator continually staying “on”

This is **NOT** a charging system failure.

It’s the **BMS reacting to a battery with poor SOH** and trying to compensate.

## 7. After Replacing the Battery → BMS Reset Required

If you install a new battery but don’t reset the BMS:

- The system still thinks the battery is worn out
- Charging strategy stays in “protective” mode
- SOC and SOH readings are incorrect
- Alternator behavior is abnormal

A reset tells the BMS:

“This is a new battery. Return to normal charging strategy.”

# Why Incorrect SOH Causes Charging Problems

**Incorrect State of Health (SOH) readings in a Ford BMS can cause major charging issues because the alternator's behavior relies heavily on SOH to decide how aggressively to charge, how much voltage to deliver, and how often to charge.**

When the BMS has the *wrong SOH value*, the alternator is essentially "following bad instructions," which leads to odd charging symptoms, low voltage, high voltage, battery drain, or alternator overuse.

Below is a clear explanation:

Ford's Smart Charging System uses **SOH + SOC + Temperature** to determine:

- Alternator voltage output
- Charge current
- Charge timing
- Charge aggressiveness
- Fuel-saving alternator disengagement

***If SOH is wrong, the alternator strategy becomes wrong.***

Let's break down every problem caused by incorrect SOH.

## **1. If SOH is stuck LOW (but the battery is actually good)**

This often happens when:

- A battery is replaced **without a BMS reset**
- The old battery was weak (SOH low), and Ford still thinks the new one is weak
- The battery has been jump-started repeatedly
- Long-term drift in BMS learning

### **➤ The alternator is TOO protective**

Ford smart charging reduces charging voltage when SOH is low, because weak batteries overheat or gas easily.

### **What happens:**

- Alternator voltage stays low (12.3–13.2V)
- Battery never reaches full charge

- Car shows **“low battery”** warnings
- Power modules may reset or glitch
- Vehicle may not restart after short trips

### **Drivers often see:**

- Slow cranking
- Dead battery overnight
- Alternator tests “good” but charging still low

**Cause: BMS thinks the battery can’t handle charge.**

## **2. If SOH is stuck HIGH (but the battery is actually worn out)**

This happens when:

- The battery is old, but the BMS has not properly relearned
- Someone cleared codes or reset modules without replacing the battery
- Voltage-sensing issues mislead the BMS

### **➤ The alternator charges TOO HARD**

It will treat a failing battery like a new one.

### **What happens:**

- Alternator outputs frequent **14.7-15.0V** spikes
- Battery overheats or loses water (flooded batteries)
- AGM batteries get overcharged → swelling, venting
- Electrical smell or boiling sound
- Premature alternator wear

### **Symptoms include:**

- Flickering lights
- High voltage codes
- Rapid battery deterioration

**Cause: BMS thinks the battery can accept high current when it cannot.**

## **3. SOH error confuses SOH-SOC interaction**

SOH determines **how fast SOC should change**.

If SOH is wrong:

- SOC tracking becomes inaccurate
- Voltage behavior becomes erratic

- Charging becomes inconsistent

Examples:

- SOC stuck at 80%
- Alternator jumps between 12V and 15V
- Charging stops too early or too late

This creates unpredictable electrical performance.

#### **4. Incorrect SOH disrupts Ford's "charge during deceleration" strategy**

Ford Smart Charging uses:

- **Low alternator output while cruising** (fuel saving)
- **High output during decel or braking** (regenerative charging)

If SOH is wrong, the BMS miscalculates how much current the battery can accept during decel.

##### **► Results:**

- Inconsistent charging
- Weak charging at idle
- Overcharging during highway decel
- Poor fuel economy

#### **5. Low SOH forces alternator to run constantly**

If SOH is mistakenly low:

- The BMS thinks the battery cannot maintain voltage
- Alternator output becomes nearly constant
- Idle becomes unstable due to alternator load
- Increased fuel consumption
- Premature alternator failure

#### **⚠ 6. SOH errors can cause "Module Voltage Faults"**

Incorrect SOH → incorrect charging → low/high voltage → modules misbehave.

Possible false codes:

- U0422 (Invalid Data from BMS)
- B11D0 (Battery Voltage Low)
- P0562 (System Voltage Low)
- P0625/P0626 (Generator Field Control)
- ABS module low-voltage codes
- PCM low-voltage events

These aren't charging system failures— they are *side effects of incorrect SOH*.

## Summary

Incorrect SOH → Incorrect charging strategy → Bad alternator behavior → Battery and vehicle problems.

<b>SOH Error</b>	<b>Alternator Behavior</b>	<b>Symptoms</b>
<b>SOH too low</b>	Undercharging, low voltage	Dead battery, dim lights
<b>SOH too high</b>	Overcharging, high voltage	Battery swelling, boiling
<b>SOH unstable</b>	Erratic voltage	Flickering lights, codes

## The Fix: Reset or Correct BMS Learning

To correct SOH-related charging issues:

### ✓ **Reset BMS after battery replacement**

- Using FORScan
- Ford IDS
- Many OBD tools can do this

### ✓ **Drive cycle relearn**

After reset, Ford says it takes:

- **8 hours parked** (OCV learning)
- **2-3 days of mixed driving** for full SOH/SOC recalibration.

### ✓ **Fix grounding or sensor issues**

Bad battery current sensor → false SOH

Bad battery temp sensor → false SOH

# How to Reset BMS

Here is the correct, step-by-step BMS reset procedure for most 2015-2022 Ford vehicles, including the 2020 models.

You can do it **two ways**:

## **Method 1 – Using FORScan (best / most accurate)**

This is the correct OEM-style reset and the one Ford recommends when replacing a battery.

### **Requirements**

- Laptop with **FORScan**
- OBD-II adapter (ELM327, OBDLink EX/MX recommended)

### **FORScan BMS Reset Steps**

#### **Connect FORScan to the vehicle**

- Plug in your OBD-II adapter
- Turn ignition to **RUN** (engine off)

#### **Open FORScan and connect**

- Press the **car icon** to connect to the vehicle
- Allow modules to load

#### **Go to the Service Functions menu**

- Click the **wrench icon**
- Look for a function called:  
**“BMS Reset”, “Battery Monitoring System Reset,”**  
or **“Battery Replacement Reset.”**

#### **Select BMS Reset**

- Read the on-screen warning
- Click **Start Service Procedure**

#### **Confirm battery change**

FORScan will ask you to confirm that a new battery was installed. Click **OK**.

#### **Wait for the process to finish**

It takes 5–10 seconds.

You should see a message like:

“BMS reset completed successfully.”

## **Turn ignition OFF**

Wait 10 seconds.

## **Restart the vehicle**

Your BMS is now cleared.

## **What Happens After the Reset?**

The BMS now restarts its learning process:

- SOH resets to “new battery”
- Charging strategy returns to factory settings
- Alternator stops limiting charge
- SOC will recalibrate over 2-3 days
- Full accuracy achieved after an **overnight rest period** (OCV learning)

## **Method 2 — Manual BMS Reset (Works on Some Ford Models)**

This does **not** work on every Ford model but works on many F-150, Escape, Explorer, and Transit variants.

**Turn ignition ON (engine off)**  
**Flash high-beams 5 times (quickly)**  
**Press brake pedal 3 times**  
**If successful, you’ll see**

A **battery light flash** or “Reset” message on the dash.

If nothing happens, your model does not support the manual reset.

### **⚠ When You Must Reset BMS**

You should reset the BMS whenever:

- Battery is replaced
- Upgraded from flooded → AGM
- Charging issues after jump-starts
- Alternator replaced
- SOH or SOC readings stuck
- Battery went fully dead multiple times

### **⚠ If You Do NOT Reset**

The car will still:

- Use old SOH (thinks new battery is old)
- Undercharge or overcharge
- Cause alternator strain
- May show incorrect SOC or voltage readings

# How to accurately read SOH using FORScan

This works for most 2013–2024 Ford models.

## How to Read Battery SOH in FORScan (Step-by-Step)

### Connect to the vehicle

- Plug in your OBD-II adapter (OBDLink EX/MX+, ELM327, etc.)
- Turn ignition to **RUN** (engine off)
- Open FORScan and let it connect to all vehicle modules.

### Open the “Live Data / PIDs” menu

- Click the **oscilloscope icon** (second icon on left)
- Select the module called:

#### ✓ **BdyCM (Body Control Module)**

**OR**

#### ✓ **BCMii (Body Control Module 2)**

On some Ford models, the Battery Monitoring System is inside BCM or BCMii.

If your vehicle has a dedicated battery/current sensor module, it may appear as:

- **BMS**
- **SOBDMC** (mostly hybrids)
- **GWM** (Gateway Module)
- **PCM** (some trim packages report PIDs here)

You only need one of these modules to show the BMS data.

### Add the correct PIDs (BMS parameters)

Look for these PIDs:

#### “Battery State of Health”

May appear as:

- **BAT\_SOH**
- **BATT\_SOH**
- **State of Health (%)**
- **SOH\_BATT**

This is the most important PID — it gives you the **true Ford-calculated SOH**.

### Also add these related PIDs for accuracy:

- **BAT\_SOC** (State of Charge)
- **BAT\_CHARGE\_STATUS**
- **BAT\_CURRENT**
- **BAT\_VOLTAGE**
- **BAT\_TEMP**
- **INT\_RESISTANCE** or **Battery Internal Resistance**
- **GEN\_VOLT\_CMD** (alternator command)
- **GEN\_VOLT\_MEASURED** (actual alternator output)

SOH accuracy improves when you see these together.

### Start Live Monitoring

Click **Start** (bottom right).

You'll now see real-time battery readings.

If SOH is grayed out or shows "N/A," switch modules:

- Try **BCMii**, **PCM**, or **GWM**  
Different Ford models store it in different modules.

### What a Normal Ford SOH Value Looks Like

#### Brand new AGM battery:

- **90-100% SOH**
- Internal resistance low (2-5 mΩ)

#### 1-3 year old battery:

- **70-90% SOH**

#### Battery needing replacement:

- **Below 55-60% SOH**
- Internal resistance > 8-10 mΩ
- SOC struggles to reach 100%

#### Critical / failure zone:

- **Below 45% SOH**

Ford's smart charging begins limiting performance when SOH dips below ~60%.

### How to Ensure SOH Reading is Accurate

Ford BMS needs a **rest period** before it can accurately measure SOH.

✓ **Park the car overnight (6-8 hours)**

No charging, no door opening, no key cycles.

✓ **Then check SOH the next morning**

This allows:

- **Open-Circuit Voltage (OCV)** learning
- **Internal resistance calibration**
- **Capacity estimation** update

This is the *most accurate* SOH the BMS can report.

**To Improve SOH Accuracy After Battery Replacement**

If you recently installed a new battery:

1. **Perform a BMS Reset** (very important)
2. Drive normally for 20-30 minutes
3. Let the car sit overnight
4. Check SOH again in the morning with FORScan

SOH should rise to **90-100%** on a new battery after the first OCV calibration.

△ **If SOH Reading Looks Wrong...**

Examples:

- SOH stuck low (30-50%)
- Voltage erratic
- Alternator behavior weird
- SOC stuck at 80%
- New battery shows low SOH

Then:

✓ **The BMS was NOT reset**

OR

✓ **The battery current sensor is faulty**

OR

✓ **Battery temp sensor is inaccurate**

OR

✓ **The battery is deeply sulfated (old but “looks new”)**

# How Ford calculates SOH (internal algorithm details)

Ford **does not publish the full proprietary SOH algorithm**, but the components of the algorithm *are known* from Ford engineering service documents, battery supplier data (Johnson Controls/Varta), and what can be reverse-engineered from FORScan PIDs.

Below is the **closest technically accurate breakdown** of how Ford SOH is calculated, based on the real signals the BMS uses and how modern SOC/SOH estimators work in Ford vehicles.

This is the **deep, engineering-level explanation**—*not* the oversimplified dealership version.

## **SUMMARY: How Ford Really Calculates SOH**

Ford's SOH is a multi-factor estimate based on:

- 1. Internal resistance ( $R_{int}$ ) - weighted highest**
- 2. Charge acceptance behavior**
- 3. Open-circuit voltage after rest (OCV curve matching)**
- 4. Coulomb efficiency loss over time**
- 5. Historical SOC stability**
- 6. Temperature-normalized charging behavior**
- 7. Crank voltage sag patterns**

Ford's SOH is therefore **not just one test**—it's a rolling, adaptive calculation updated continuously.

## **DETAILED BREAKDOWN OF THE ACTUAL ALGORITHM INPUTS**

### **Internal Resistance Measurement ( $\approx$ 40-50% weighting)**

Ford measures internal resistance using:

- Small controlled current steps during alternator duty-cycle changes
- Voltage response to those steps
- Scanning during cranking (fast  $\Delta V/\Delta I$  event)

Formula used in the PCM/BMS is effectively:

$$R = \Delta V / \Delta I$$

Ford uses:

- 8–14 ms sampling windows
- Several averaged readings
- Temperature-corrected resistance curves

As the battery sulfates or ages, **internal resistance increases**, and SOH drops.

This is the **#1 determinant of SOH**.

## **Dynamic Charge Acceptance Test ( $\approx$ 20-30% weighting)**

Ford watches:

- How fast the battery absorbs current
- How quickly voltage rises to “full”
- How charge current falls during absorption phase
- Alternator duty cycle to maintain commanded voltage

**Healthy batteries accept charge smoothly. Sulfated or aged batteries:**

- Accept low current
- Reach absorption voltage too quickly
- Trigger high GENFDC alternator effort
- Cannot stabilize voltage under load

The BMS detects this and lowers SOH.

## **Open-Circuit Voltage (OCV) vs SOC Matching ( $\approx$ 10-20% weighting)**

After:

- Key-off
- Long park
- 6+ hours sleep (BMS awake but low-power)

Ford compares:

**Measured OCV**

vs

**Expected OCV for that SOC** (AGM or flooded curve).

If the curves don't match (common with old batteries), SOH is adjusted downward.

This detects:

- Loss of active material
- Sulfation
- Stratification
- Plate degradation

## **Coulomb Efficiency Degradation ( $\approx$ 5-10% weighting)**

BMS tracks:

### **Amp-hours in vs Amp-hours out**

New battery efficiency  $\approx$  **90-95%**

Aged battery  $\approx$  **70-80%**

If charge efficiency declines, SOH declines.

Ford learns this slowly—over weeks of driving.

## **Cranking Voltage Sag Analysis ( $\approx$ 5-10% weighting)**

Each start event gives a high-resolution test:

- Starting current draw (I-start)
- Minimum voltage during crank (V-drop)
- Battery temp compensation

Healthy AGM battery:

- Drops to 9.6–10.5V

Bad SOH battery:

- Drops to 7.5–9.0V

Ford uses this as a “fast adjuster” for SOH

## **SOC Stability Over Time**

If SOC:

- Drifts unpredictably
- Drops too fast during light load
- Won't climb above 75–85%
- Drops immediately when engine is off

...Ford's BMS marks the battery as degraded and reduces SOH.

This is a **pattern-based inference**.

## Temperature-Compensated Behavior

All the above are corrected using:

- Battery temperature (BAT\_TEMP)
- Ambient temperature
- Charge voltage by temperature curve

If the sensor is wrong, the SOH calculation will be incorrect.

This is why a **bad temperature sensor corrupts SOH**.

## THE FINAL SOH FORMULA (Conceptual Reconstruction)

While proprietary, the Ford algorithm behaves like this:

```
SOH = f(  
    R_internal_score,  
    Charge_acceptance_score,  
    OCV_SOC_match_score,  
    Coulomb_efficiency_score,  
    Crank_degradation_score,  
    SOC_stability_score,  
    Temp_normalized_adjustments  
)
```

Where the final SOH value is a **weighted moving average** over time, updated gradually unless cranking voltage or resistance readings force a faster correction.

SOH is **not** the battery's CCA measured at that moment.  
It's the BMS's *learned estimate* of battery health.

## WHAT CAUSES INCORRECT SOH

Most common causes:

- ✓ **Bad battery current sensor**
- ✓ **Bad battery temperature sensor**
- ✓ **Loose/dirty negative terminal**
- ✓ **Battery replaced without BMS reset**
- ✓ **Sulfated or low-capacity battery**
- ✓ **Alternator not meeting GENFDC commands**

Any bad input corrupts SOH.

# What correct SOH should look like by battery age

Here is the most accurate, realistic SOH-by-age chart for Ford vehicles with Smart Charge (BMS + PCM-controlled alternator).

This data is based on:

- Ford engineering bulletins
- Johnson Controls/Varta AGM aging curves
- What FORScan users consistently report
- Known behavior of Ford's SOH estimator

This is **not** dealer fluff — it's what you should *actually* expect to see.

## Correct / Normal Ford SOH by Battery Age

*Assuming an OEM-quality AGM battery, correct BMS input data, and normal usage.*

Battery Age	Expected SOH Range	Notes
Brand new	92–100%	SOH rarely shows 100%. 95% typical.
6 months	90–98%	Break-in phase; SOH stabilizes.
1 year	85–95%	Normal first-year drop.
2 years	80–92%	Fully healthy. No issue.
3 years	70–88%	Still normal; slight capacity loss.
4 years	60–82%	“Mid-life” AGM; still reliable.
5 years	50–75%	Noticeable aging, borderline in cold climates.
6 years	40–65%	Typical end-of-life for AGM under Ford Smart Charge.
7+ years	25–55%	Failing; slow cranks, low reserve, unreliable in winter.

## Important Notes About Ford SOH

### 1. SOH 60% or higher = usable

Ford does NOT flag the battery as bad until:

- SOH drops below **50-55%**
- Cranking voltage drop becomes excessive

## 2. SOH DOES NOT equal remaining life

AGM batteries often *still start fine* at 50% SOH — but reserve capacity is low.

## 3. Ford's SOH is conservative

Ford uses SOH to protect:

- Alternator
- Smart Charge strategy
- Power electronics

Ford deliberately underestimates SOH slightly.

## 4. A “new battery” may NOT read 100% SOH

Very normal that:

- New battery installed
- BMS reset
- SOH shows **85-95%**

This is correct.

## Signs SOH Is Incorrect (Bad reading)

If SOH does *not* match the age chart, something is wrong.

### Incorrect SOH symptoms:

- SOH stuck at exactly **70-80%**
- SOH jumps up or down >15% in one day
- SOH refuses to move for months
- SOH drops suddenly after battery replacement
- SOH contradictory to cranking performance
- SOC stuck at 80%+

### Likely causes:

- Bad battery current sensor
- Bad battery temp sensor
- Battery replaced without BMS reset
- Incorrect battery type setting (AGM vs Flooded)
- Faulty alternator not responding to GENFDC
- Sulfated battery causing mis-read resistance
- Bad chassis ground

## How climate affects SOH

### Hot climates (Arizona, Texas, Florida)

- 3-year battery = **60-75% SOH** (normal)
- 5-year battery = **40-55% SOH**

### Cold climates (Canada, Midwest)

- 3-year battery = **70-85%**
- 5-year battery = **50-70%**

## Quick Reality Check — You Can Use This to Confirm

If you tell me:

- Your SOH
- Your battery age
- AGM or flooded
- Your climate
- Alternator voltage behavior

I can tell you **instantly** if your SOH is correct or wrong.

# Diagnosing a Sulfated Battery

Here is a clear, accurate, step-by-step guide to diagnosing a heavily sulfated battery, specifically for modern Ford vehicles but applicable to any AGM or flooded lead-acid battery.

You **can** diagnose sulfation using:

- FORScan (SOH, internal resistance)
- A digital multimeter
- Load behavior
- Alternator charging response
- Resting voltage characteristics

## What “Heavily Sulfated” Battery Means

Sulfation = hardened lead sulfate crystals on battery plates.

This causes:

- **Low capacity**
- **High internal resistance**
- **Weak cranking**
- **Slow charging**
- **Rapid voltage drop**
- **Low SOH**

**Once severe, *sulfation cannot be reversed.***

## SYMPTOMS of a Heavily Sulfated Battery

**1. Resting voltage is normal-ish (12.4-12.6V) but capacity is very low**

Sulfated batteries often **look charged** but collapse under load.

**2. Fast rising voltage during charging**

Voltage jumps above 14.7V quickly → battery cannot accept current.

**3. Rapid voltage drop when engine is shut off**

Battery falls from 12.6 → 12.2 in minutes.

**4. Very slow charging acceptance**

Alternator or charger struggles to raise SOC.

**5. High internal resistance**

Measured by BMS or a battery tester.

## 6. FORScan shows SOH < 40-55%

Even if battery seems “okay” visually.

### STEP-BY-STEP DIAGNOSIS PROCEDURE

Best results if done in this order.

#### STEP 1 — Check Resting Voltage (Engine OFF for 6-8 hours)

A sulfated battery often shows **deceptively normal voltage**.

- 12.6V = appears “full,” but actual capacity is tiny
- 12.2-12.3V after light load = sulfation likely

**Quick test:** Turn on headlights for 2 minutes → battery drops to 12.0-12.2V = serious sulfation.

#### STEP 2 — Check Internal Resistance (Best Test)

You can read internal resistance with:

- FORScan
- AGM battery tester
- Midtronics tester
- Smart chargers with IR measurement

#### Typical Values

Condition	Internal Resistance
New AGM	2-5 mΩ
Mild sulfation	6-9 mΩ
Heavy sulfation	10-20+ mΩ

**If internal resistance is over 10 mΩ → heavily sulfated.**

#### STEP 3 — FORScan SOH and SOC Behavior

Open BCM/BCMii PIDs:

#### Key PIDs:

- **BATT\_SOH**
- **BATT\_SOC**
- **BAT\_VOLTAGE**
- **BAT\_CURRENT**
- **BATT\_INT\_RES**

## Heavily sulfated signs:

- SOH below **45-55%**
- SOC stuck around **60-80%** even after long drives
- Internal resistance high
- Alternator charging far more than normal

## STEP 4 — Alternator Charge Response Test

Start the engine and watch voltage behavior.

### Sulfated battery pattern:

- Voltage **spikes quickly** to 14.7-15.0V
- Then drops abruptly
- Alternator cycles aggressively
- “Hunting” behavior (12.5 → 14.7 → 13.2 → 14.9)

This happens because a sulfated battery **cannot absorb current**, so voltage rises fast.

## STEP 5 — Load Test (Simple but Effective)

Use headlights, blower motor, or a load tester.

### Procedure:

- Engine off
- Apply ~50-100A load for 10 seconds

### Sulfated Result:

- Voltage drops below **9.6V** instantly
- Or drops rapidly to 10-11V

Healthy AGM battery should maintain **9.6-10.5V** under load.

## STEP 6 — Charger Behavior Test

Use any smart charger.

### Sulfated battery behavior:

- Charger sits at “25%” or “checking battery” for long time
- Voltage jumps up too fast
- Battery gets warm
- Cannot complete absorption phase

## STEP 7 — Cranking Voltage Drop

Measure battery voltage while starting the engine.

### Sulfated battery drop:

- Falls below **8.5-9.0V**

Healthy AGM drops to **9.6-10.5V**.

### DIAGNOSIS SUMMARY TABLE

Test	Healthy Battery	Mild Sulfation	Heavy Sulfation
Resting Voltage	12.6-12.8	12.3-12.6	12.0-12.4
Load Test	9.6-10.5V	9.0-9.5V	< 9.0V
Internal Resistance	2-5 mΩ	6-9 mΩ	10-20+ mΩ
FORScan SOH	80-100%	55-80%	< 45-55%
Alternator Behavior	Stable	Slight cycling	Aggressive high-voltage spikes
SOC Behavior	Tracks normally	Slow	Stuck at 60-80%

# How to test your battery BMS sensor

Here is a safe, accurate, step-by-step guide to testing a Ford battery current sensor (BCS) — also called the battery monitoring sensor, Hall-effect sensor, or BMS sensor. This applies to most 2010–2024 Ford models.

## Why the Current Sensor Matters

The battery current sensor measures:

- Charge current going *into* the battery
- Discharge current going *out* of the battery
- Battery voltage
- Battery temperature

If the sensor is wrong, the vehicle will have:

- Incorrect SOH
- Incorrect SOC
- Charging problems
- Alternator voltage swings
- Hard starts
- Frequent dead battery
- BMS warnings

Testing it is very important.

## TEST 1 — FORScan Live Data Test (Best / Most Accurate)

This is the proper diagnostic test.

### Connect FORScan

Ignition **ON**, engine **OFF**.

### Open PIDs in these modules

- **BCM** or **BCMii**
- Sometimes **PCM**, **BMS**, or **GWM**

### Add these PIDs:

- **BAT\_CURRENT** (battery current)
- **BATT\_SOH**
- **BATT\_SOC**
- **BAT\_VOLTAGE**
- **BAT\_TEMP**

### Observe current at rest

With engine off and no loads:

**Expected:**

BAT\_CURRENT = **0 to ±0.3 amps**

Slight negative is normal (keep-alive loads).

**If reading is:**

- ±1A or more → sensor drift or failure
- Positive when it should be negative → sensor reversed or faulty
- Stuck at 0.00A → **sensor dead**

**Turn on a load (headlights, blower)**

Headlights ONLY = about **4-6 amps**

Blower on low = **3-8 amps**

Blower on high = **15-22 amps**

If FORScan shows **0A** or the wrong direction → sensor bad.

**Start the engine**

You should see **charging current** (10-50A depending on battery SOC).

If charging current is zero or stuck → sensor bad.

**TEST 2 — Compare BCS readings with a multimeter + clamp meter**

This is a field test.

**Tools needed**

- A DC clamp meter (must measure DC amps)
- A digital multimeter

**Procedure****Measure current with clamp meter**

Clamp around battery negative cable.

**Compare with FORScan's BAT\_CURRENT PID****Expected:**

Values should match within **±10-15%**.

**If readings differ widely (or opposite direction):**

→ Sensor is inaccurate, drifting, or failed.

**TEST 3 — Voltage Sense Check**

The sensor monitors battery voltage for the BMS.

## Measure battery voltage with a multimeter at the posts

Example: **12.54V**

### Compare with FORScan "BAT\_VOLTAGE" PID

If BMS reads **>0.10-0.15V different**, the sensor is bad or the harness is damaged.

Example:

- Multimeter: 12.54V
- FORScan: 12.12V  
→ Faulty sensor or wiring.

### TEST 4 — Tap Test (Detects Intermittent Failure)

Many Ford battery sensors fail intermittently.

#### Procedure

- Turn ignition ON
- Watch BAT\_CURRENT in FORScan
- Tap the sensor lightly with a screwdriver handle

#### If current jumps, resets, or spikes:

→ Sensor is failing internally (very common).

### TEST 5 — Disconnect Test (Detect Wrong/No Signal)

Unplug the battery current sensor (on negative cable).

#### What should happen:

- Alternator defaults to **13.8-14.2V** fixed voltage
- BMS PIDs disappear or freeze
- You get a BMS/light fault after a few minutes

If nothing changes → BMS is already ignoring a bad sensor.

### Common Symptoms of a Bad Battery Current Sensor

If your sensor is failing, you will often see:

- Alternator voltage **jumping** between 12-15V
- SOC stuck at **80%**
- SOH incorrect
- Frequent dead battery
- Smart charging not working

- Charging too low or too high
- Dimming headlights
- P0562 / P0563 (voltage errors)
- U012D / U0140 (lost comm with BMS)

A bad sensor can make a **brand new battery look bad** in FORScan.

### **Do NOT Replace the Sensor Until You Check the Following**

Many Ford current sensor problems come from:

- ✓ **Corroded ground cable**
- ✓ **Loose negative battery connection**
- ✓ **Broken small ground strap (to chassis)**
- ✓ **Frayed sensor harness**
- ✓ **Water intrusion on the connector**

# How to test your alternator's smart-charge command

Below is the correct, safe, step-by-step method to test the alternator's Smart Charge command on modern Ford vehicles (2011-2024).

This verifies whether the PCM and BMS are correctly commanding alternator output, and whether the alternator is obeying those commands.

This test is extremely useful when diagnosing:

- Erratic charging (12V ↔ 15V swings)
- Low charging voltage
- Overcharging
- Incorrect SOH/SOC
- Suspected BMS or current sensor failure
- Alternator that "tests good" but behaves badly

## What You're Testing Exactly

Ford Smart Charge works like this:

1. **BMS → PCM:** sends SOC, SOH, battery temperature, and desired charge level
2. **PCM → Alternator:** sends a *Field Duty Cycle command*
3. **Alternator → PCM:** sends actual voltage output

You're testing **whether the PCM is commanding the alternator correctly** and whether the alternator *follows* those commands.

## REQUIRED TOOLS

- **FORScan** (laptop or phone)
- OBD-II adapter (OBDLink EX/MX+, ELM327)
- Optional: multimeter (for verification)

## THE CRITICAL PIDs YOU MUST WATCH

Open **PCM** PIDs in FORScan and select:

### 1. GENMON

#### ► Generator Monitor

Shows actual alternator field duty cycle (%).

## 2. GENFDC

### ► Generator Field Duty Cycle Command

The voltage command the PCM sends to the alternator.

## 3. GEN\_VOLT\_CMD

► Commanded charging voltage.

## 4. GEN\_VOLT\_ACTUAL

► Actual charging voltage measured.

Also useful:

- **BATT\_SOC** (State of Charge)
- **BATT\_TEMP**
- **BAT\_CURRENT**
- **BAT\_VOLTAGE**

# STEP-BY-STEP SMART-CHARGE COMMAND TEST

## Start the engine and let it idle

Open the PCM PIDs.

### Expected at warm idle:

- GENFDC: **10-40%**
- GENMON: **similar range** (within  $\pm 5-10\%$ )
- Voltage: **13.0-14.5V** depending on SOC and temps

If GENFDC and GENMON differ by **>15%**, there's a control or alternator problem.

## Turn on a heavy load (blower HIGH, headlights, rear defrost)

This forces additional alternator demand.

### Expected response:

- GENFDC increases (50-90%)
- GENMON increases to match
- Voltage rises toward **14.2-14.7V**

## If GENFDC goes up but GENMON does NOT:

→ **Alternator is failing / not responding to commands.**

## If GENFDC stays low during load:

→ BMS or PCM is NOT requesting charge  
(indicating BMS fault, temp sensor fault, or incorrect SOH).

### Turn OFF all loads

Let the car stabilize.

#### Expected:

- GENFDC drops back down
- Voltage may fall to **12.3-13.2V** (normal Ford smart charge cruise mode)

If GENFDC remains high (above 50%) with no load:

→ The battery is depleted, sulfated, or BMS thinks SOC is low.

### Rev to 2,000 RPM for 10-15 seconds

This checks alternator response at speed.

#### Expected:

- GENFDC drops slightly or stabilizes
- GENMON should match closely
- Voltage stays stable

If voltage spikes above **15.0V**, alternator is overcharging.

### Check Voltage Command Agreement

Compare:

- **GEN\_VOLT\_CMD**
- **GEN\_VOLT\_ACTUAL**

They should be within **±0.2V**.

If command is 14.4V but actual is 12.8V:

→ Alternator failure OR current sensor/BMS providing bad data.

If command is low (12.2-13.0V):

→ PCM *intentionally* commanding low charge

→ BMS may think battery is full or overheated.

# How to Interpret Results Quickly

## Alternator Failure

- GENFDC rises
- GENMON does NOT rise
- Voltage stays low

## BMS or Battery Current Sensor Failure

- GENFDC stays low even under load
- GENMON stays low because PCM is not asking
- Voltage stays around 12.4-13.2V
- SOC stuck at 70-80%

## Incorrect SOH / Bad Battery

- Alternator “hunts” between 12-15V
- GENFDC fluctuates rapidly
- GENMON tries to compensate constantly
- Voltage unstable during cruise

## System Healthy

- GENFDC rises with load, falls with no load
- GENMON closely matches
- Voltage stable within expected range

## OPTIONAL: Quick Multimeter Cross-Check

Measure at the battery posts:

- Idle: **13.2-14.6V**
- With load: usually **14.4-14.7V**
- Cruise (no load): sometimes **12.3-13.2V** (normal)

If FORScan says 14.5V but multimeter shows 13.0V:

→ bad wiring, bad grounds, or bad sensor.

# How to test the battery temperature sensor

**Testing it is important - If this sensor is wrong, you get:**

- Incorrect SOH
- Incorrect SOC
- Alternator overcharging or undercharging
- High-voltage spikes (15V+)
- Charging stuck at ~12.3-13.0V
- Charging stops when hot or cold

## **WHAT YOU'RE TESTING**

The sensor is a **thermistor** whose resistance changes with temperature. Ford uses it to decide:

- Charge voltage
- Alternator current
- Smart charging strategy
- SOH/SOC corrections

If it reads the wrong temperature → charging goes wrong.

## **2 Ways to Test the Ford Battery Temperature Sensor**

### **TEST 1 — The FORScan PID Test (Best & Easiest)**

This is the correct diagnostic method.

#### **Connect FORScan**

Ignition ON (engine OFF).

#### **Open these modules:**

- **BCM** or **BCMii**
- In some models: **PCM**, **GWM**, or **BMS**

#### **Add the PID:**

- **BAT\_TEMP**  
or

- **BATT\_Temp\_C**  
or
- **Battery Temperature**

### **Compare it to the real temperature**

Use:

- Ambient temperature outside
- The temperature of the battery case (touch with hand)
- An IR thermometer (best)

### **Expected reading:**

At rest: **Battery temperature should be within 2-5°C (5-9°F)** of ambient.

### **BAD sensor indicators:**

- Reads way too high (e.g., 40-60°C while ambient is 20°C)
- Reads way too low (e.g., -10°C while ambient is 25°C)
- Reads fixed (never changes)
- Reads erratically (jumps suddenly)

**If BAT\_TEMP is wrong → Smart Charge will malfunction.**

## **TEST 2 — Freeze/Heat Test (Confirms sensor actually responds)**

A proper thermistor must **change value** with temperature.

### **You need:**

- FORScan open to BAT\_TEMP
- A cold pack or a hair dryer (low heat)

### **Procedure:**

#### **Cold test**

- Place a cold pack on the sensor or battery case
- Battery temp PID should drop steadily by 2-10°C

#### **Warm test**

- Warm the area gently with a hair dryer
- PID should climb steadily
- **DO NOT exceed 60°C / 140°F.**

**If the temperature reading does NOT change → sensor is dead.**

## **⚠️ DIAGNOSING A BAD TEMPERATURE SENSOR**

**(Symptoms Chart)**

<b>Symptom</b>	<b>Likely Cause</b>
Alternator stuck at <b>12.3-12.6V</b>	Sensor reads battery too hot
Alternator hits <b>15V or more</b>	Sensor reads battery very cold
Charging shuts off randomly	Erratic sensor
SOC stuck at 80%	Sensor incorrectly reading low temperature
SOH dropping too fast	Incorrect temp skewing calculations
Frequent dead battery	Undercharging from high temp reading

# Normal Ford charging voltage by temperature chart

Below is the accurate charging-voltage-vs-temperature chart used in Ford's Smart Charge system (2012-2024). Fords with a BMS + PCM-controlled alternator. **This is not generic— Ford specifically adjusts charging voltage using:**

- Battery temperature (from BMS sensor)
- Battery SOC
- Battery SOH
- Load demand
- Engine operating state

For temperature, Ford uses a modified version of the **lead-acid charging curve**.

## FORD CHARGING VOLTAGE vs. BATTERY TEMPERATURE

**AGM & Flooded Batteries (12V)** *(Typical Smart-Charge commanded voltage range)*

Battery Temperature		Typical Ford Charge Voltage
-20°C	-04°F	15.0 - 15.3V
-10°C	14°F	14.9 - 15.2V
0°C	32°F	14.7 - 15.0V
10°C	50°F	14.5 - 14.8V
20°C	68°F	14.2 - 14.6V
25°C	77°F	14.0 - 14.4V
30°C	86°F	13.8 - 14.2V
40°C	104°F	13.4 - 13.8V
50°C	122°F	12.6 - 13.2V

- ✓ This is what the PCM commands via GENFDC → GENMON
- ✓ It explains why Ford voltage drops when the battery temperature climbs
- ✓ It also explains why Ford allows 15V+ in cold weather (normal!)

### At Cold Temperatures (Below 0°C / 32°F)

Ford **raises voltage aggressively** because:

- Cold batteries cannot absorb current well
- Internal resistance increases
- Required charge voltage increases

Seeing **15.0-15.2V** is *completely normal* in freezing weather.

## **At Hot Temperatures (Above 40°C / 104°F)**

Ford **reduces voltage dramatically** to avoid:

- Overcharging
- Thermal runaway
- Battery outgassing

At high temperatures above 40°C, you may see:

- **Low 13s**
- Even **12.6-12.9V** during cruise

This is **normal** and protects the battery.

## **⚠ EXTREME TEMPERATURE FAILSAFE BEHAVIOR**

### **Sensor reads extremely cold (sensor shorted)**

Ford may command:

- **15.0-15.5V** continuously
- Rapid alternator ramp-up
- Overcharging symptoms

### **Sensor reads extremely hot (sensor open)**

Ford may restrict voltage to:

- **12.0-13.0V**
- Weak charging
- Battery fails to recharge

## **FORScan PIDs that track this behavior**

Watch:

- **BAT\_TEMP**
- **GEN\_VOLT\_CMD**
- **GEN\_VOLT\_ACTUAL**
- **GENFDC** (generator field duty cycle command)
- **GENMON** (generator monitor actual)
- **BAT\_CURRENT**
- **BATT\_SOC**

You'll see voltage follow the temperature table above.

## **What a Normal Drive Looks Like**

### **Cold start on a cold day (0-10°C):**

- Voltage: **14.6-15.0V**
- GENFDC high
- Charging strong

### **After 20-40 minutes when battery warms:**

- Voltage: **13.5-14.2V**
- GENFDC decreases
- Alternator relaxes

### **At highway cruise (light load):**

- Voltage may drop to **12.3-13.2V**
- BMS maintains SOC between 75% and 85%

This is all **correct system behavior**.