S550 Mustang Charging System - A Primer

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Traditional vehicle charging systems involved a battery, generator and voltage regulator. While these core components are still present in the S550, there are some logical advancements with improved capabilities. This primer will provide a general overview of the charging system and how it operates.

An electron is one particle of an atom which carries a negative (-) electrical charge.

Electron flow is the direction electrons take while traveling through an electrical circuit.

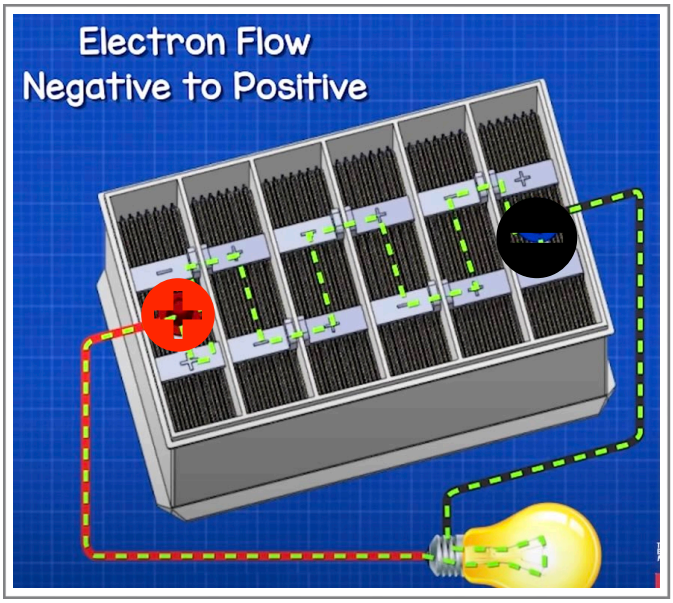
Conventional current flow is always opposite of electron flow. If electrons are traveling from North-to-South, Conventional current flow is from South-to-North.

An Ampere or Amp is the measure of the amount of electrical flow past a given point at a particular time. Current and Amps are synonymous. Current or amps could be measuring the amount of electron flow or charge carrier flow.

Voltage is a measure of electrical pressure, a difference in electrical potential and form of doing work. The higher the voltage, the greater the pressure.

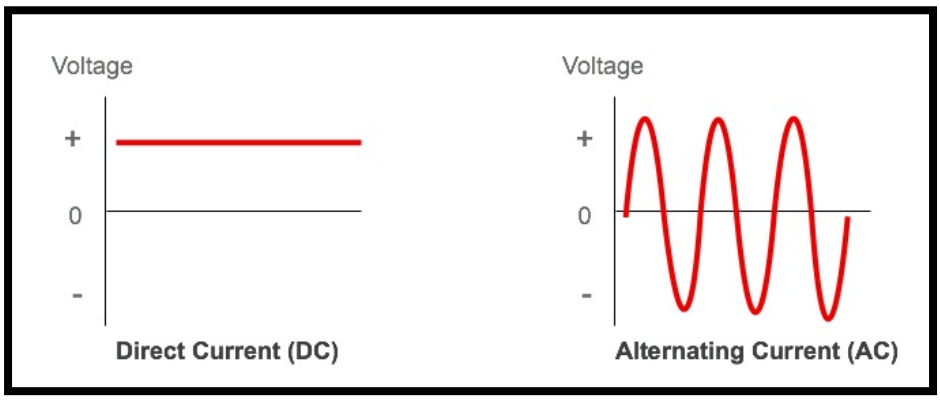
Battery (Flooded Lead-Acid)

A battery is a device which stores chemical energy, designed to produce electricity on demand. This section will focus on Flooded Lead Acid (FLA) batteries, comprised of a case, lead plates and an acid solution.



Inside the case of are a series of cells. Inside each cell are lead plates. The plates and cells are attached in-series, producing about +12 Volts of Direct Current (DC) or VDC. One can think of each cell as one battery in itself, the cells then chained together to produce an overall unit; it's much like placing multiple batteries in-series in a flashlight.

This graphic shows the differences in waveforms between DC and AC. While the DC voltage in the picture displays positive voltage, DC can easily be negative. A lead-acid battery in a vehicle will measure positive (+) voltage.



There is no inherent advantage of using positive (+) or a negative (-) system. Engineers will select one or another for a particular application.

DC voltage is of constant amplitude and polarity. AC voltage constantly varies in amplitude and polarity. Most vehicle systems use positive DC.

Logically and physically, one half of the battery is positive, the other negative. The positive end terminal is often marked with a “+” and a red protective cap. The negative end terminal is sometimes marked with a “-“. I’ve never seen a “-“ terminal with a cap, but if you do see one, it’d probably be black.

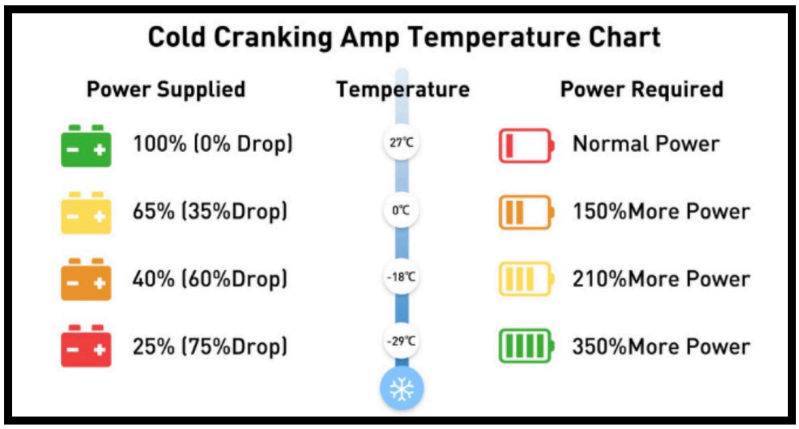
Batteries are physically sized by their assigned group type. For example, the Motorcraft BXT-96R-590, is a "96R" group type in size with "590" being the amount of Cold Cranking Amps (CCA) available. References to case types and sizes are available in this document's Appendix.

Virtually all modern vehicle systems are +12 VDC. The amperage of the recommended battery can vary by vehicle and engine type. A battery’s CCA rating gives you an idea of the power a battery can generate in specific conditions.

“CCA measures your battery's ability to start your vehicle in cold temperatures. Specifically, the amount of amperage a battery can supply at zero degrees (-17.8 C) for 30 seconds while sustaining a voltage of at least 7.2 volts. In other words, a CCA rating tells you how well your battery can work in the hardest possible conditions.”

Supplied Power	Temperature	Power Required
100% (0% Drop)	27°C / 81F	Normal Power
65% (35% Drop)	0°C / 32F	150% More Power
40% (60% Drop)	-18°C / 0F	210% More Power
25% (75% Drop)	-29°C / -20F	350% More Power

A vehicle's biggest draw on the battery will be when starting. Peak Summer and peak Winter temperatures can put excessive stress on any battery. It would not be unusual to require 250-300 amps of power to start a 5.0L. As a reference, most home service panels are rated at 100-150 amps. Small as they are vehicle batteries can generate tremendous amounts of current.



When sourcing new or replacement batteries, most owners go a bit above the minimum recommended CCA, for additional reserve.There's no specific amount over. But certainly not under the recommended CCA.

At this point, a safety PSA. When working on anything electrical, isolate that system. In the case of the home panel, turn-off the breaker fuse, or the entire panel. If the S550 or other vehicle, disconnect the negative (-) terminal, the source of the electrons. The few moments to do that can spare you and the vehicle any damage. People lose their footing. Tools slip. The only assured way of protecting yourself is to remove the source of electricity.

There is no actual distinction between breaking the negative (-) or positive (+) terminal. You are disconnecting the loop either way. However, I do believe removing the negative cable gives one some advantages. First, the (-) post is the source of electrons, and electron flow. Second, there could be charged devices in-between the negative terminal and the positive, devices which will continue to accept electrons if the (+) side of the device completes the circuit (possibly by you or a tool in an accident).

A detailed explanation of battery construction and the energy conversion process is available in the Links section.

The outside of the battery case has two terminals, a positive (+) and a negative (-). The (+) terminal is a cathode, the negative, an anode. One good way to remember is caThode and aNode, as in posiTive and Negative.

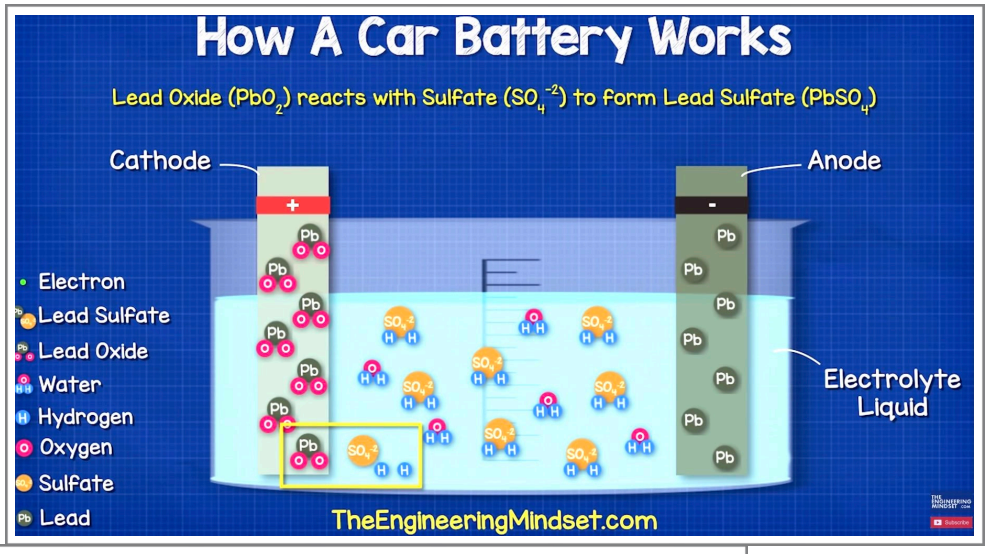
The aNode (-) terminal post and internal plates are lead. The caThode (+) post and internal plates are lead oxide. The (+) and (-) plates and terminals are never in direct contact with one another but close to one another.

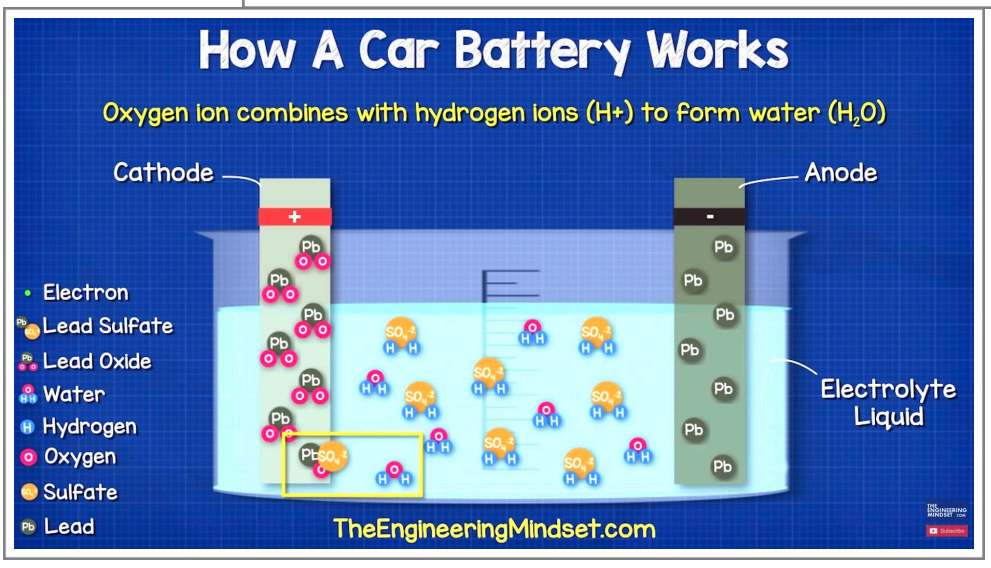
Chemical oxides (in this case, the (+) terminal and plates) are molecules with oxygen; Oxides can also be reducers; they donate electrons. When discharging, the lead oxide releases oxygen (an atom heavy with electrons), producing water and sulfate (a mineral salt) as by-products. Metal oxides act as catalysts, facilitating or accelerating chemical reactions to occur.

The electrolyte is a sulfuric acid, water solution, 1/3 sulphuric acid, 2/3 water. The battery electrolyte enables the transfer of electrons and ions from one part of the battery to another. Electrolytes allow electrical or charge flow inside a battery.

The terminals and associated plates cause the sulphuric acid to separate into hydrogen ions and sulfate ions. The hydrogen ions remain suspended in the fluid electrolyte.

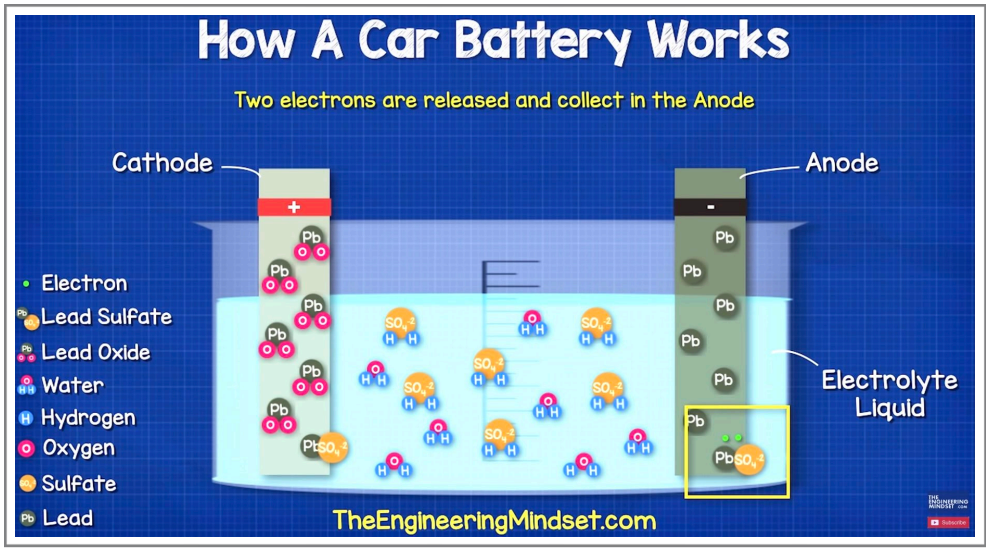
The sulfate ions that reach and attache to the (+) lead oxide terminal and plates ejects oxygen ions from those parts.



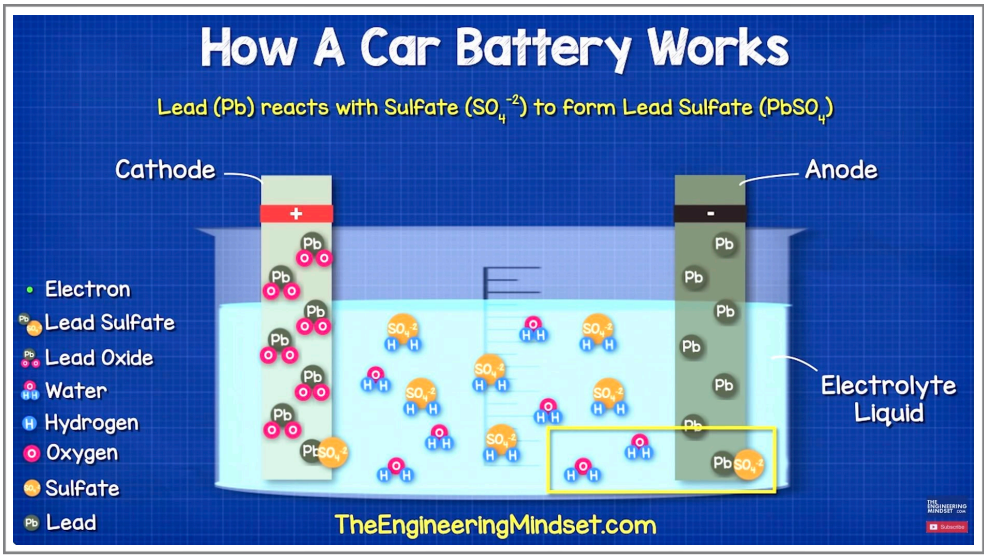


The ejected oxygen ions combine with the suspended hydrogen ions, creating water (more than what was originally in the solution).

The sulfate that reaches and attaches to the (-) lead terminal and plates ejects two electrons into the (-) plates and terminal. As with the (+) terminal and plates, a layer of sulfate builds on the surface.



Notice how one terminal becomes more positive, the other, more negative, as the process continues. A differential of potential, a form of work, has been created

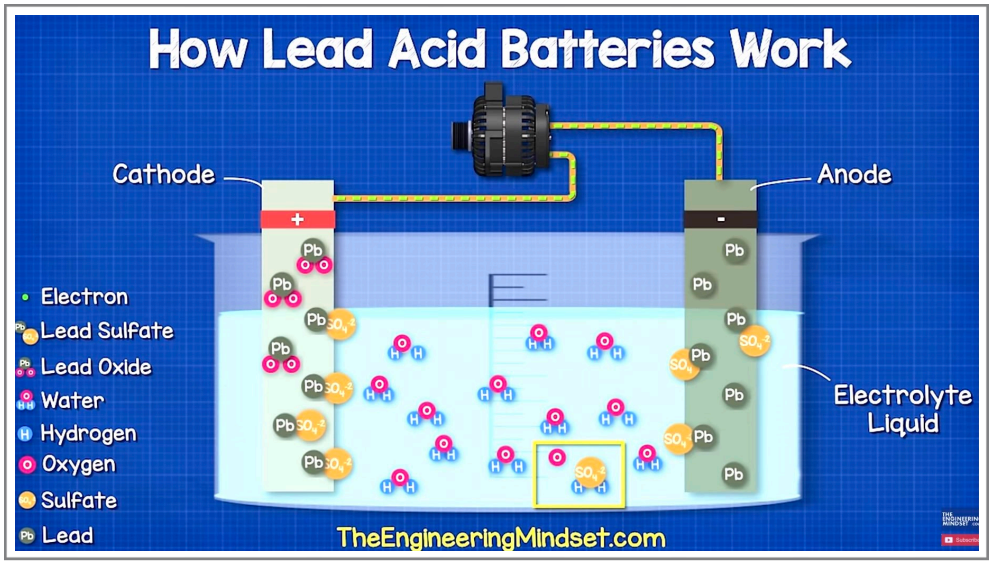


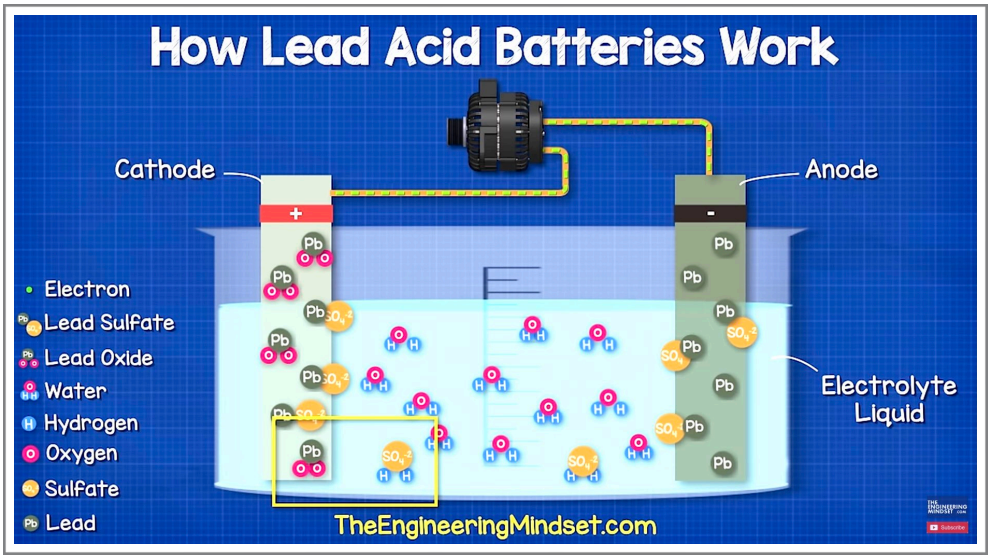
At rest, a battery is a static, chemical store of energy. While there is some electricity available, it will not flow and the battery will not create more until a circuit and load are attached.

Ultimately, the battery can become completely discharged. The electrolyte solution has a much greater concentration of water. The terminals and plates, sulfate build-up, the terminals becoming more similar.

The process described above is routinely reversed, one of the key jobs of the alternator.

When running, the alternator can produce and send electrons back through the negative terminal. The entering electrons repel the existing electrons, dissolving the sulfate, putting it all back into the electrolyte solution.





At the same time, the positive portion of the alternator circuit is increasing the amount of electrical charge on the cathode, repelling and dissolving the positively-charged sulfate.

Once back in the solution, the sulfate ions recombine with the hydrogen ions, ejecting the oxygen. The electrolyte is becoming more acidic.

The freed oxygen ions gravitate to the lead oxide on the (+) terminal.

Battery (Absorbed Glass Mat)

S550 Mustangs received Flooded Lead Acid (FLA) batteries from the factory. While capable and fulfilling requirements, FLA batteries are often taxed by vehicle and customer needs, especially in newer models with more advanced electronics. Enter the Absorbed Glass Mat (AGM) battery, also sometimes called Valve Regulated Lead Acid (VRLA) or Sealed Lead Acid (SLA) battery.

An AGM battery is a lead acid battery, with one key change: separating the lead plates inside the case are individual mats of fiberglass material. AGM batteries provide several advantages over FLAs:

- Higher voltage output - Inside an AGM battery, the individual plates can be placed closer to one another, separated by the fiberglass. More plates can then be installed, for a more powerful unit. AGM batteries discharge greater amounts of current, making it easier to start vehicle engines while providing additional power for additional electronics such as touchscreens and backup cameras

- Faster recharge rates - AGM batteries have a lower internal resistance, can absorb large amounts of current and charge up to five times faster than conventional flooded batteries

- Longer lifespans - AGM batteries can last up to three times longer than flooded batteries

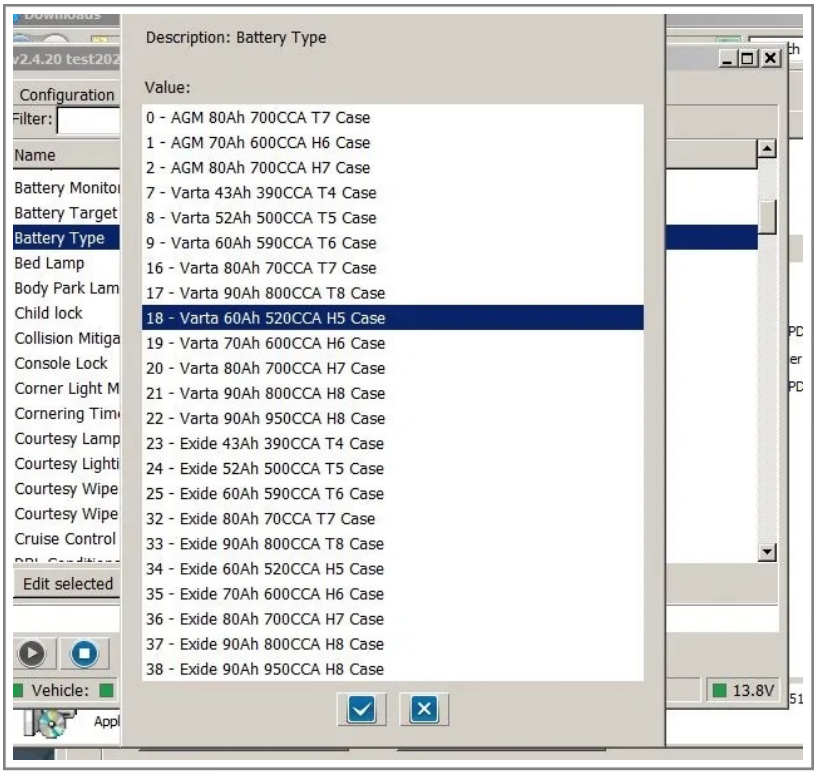
- Slower discharge rates - An AGM battery holds its charge longer when it's not being used and is more likely to be recovered if it does become completely drained

- Spill-proof - AGM batteries are spill-proof because the electrolyte is held in place by the plate separators and the battery is completely sealed. This allows you to mount an AGM battery in a variety of positions that aren't possible with a flooded option

- Weather and temperature resistance - AGM batteries do a much better job of standing up to the negative impact of extreme cold and heat

- Vibration resistance - AGM batteries are much more resistant to vibration, making them ideal for boats, personal watercraft and off-road or high-performance vehicles

- Depth of Discharge. Many AGM batteries can tolerate a greater depth of discharge when compared to an FLA, without effecting the item's lifespan. See "Deep Cycle"



Given that, a FLA-to-AGM battery change in a 6G car needs some considerations:

The S550 Mustang is programmed to work with an FLA battery. In a typical charging cycle, an AGM uses higher voltage and larger amounts of current than an FLA. The car needs to have it's as-built data in the Body Control Module (BCM) changed as a result.

This writer's research has shown 6G Mustangs and at least a few other Ford models will not auto-sense the battery type. The vehicle has to be told what has been installed, so the car's charging profile can take advantage of the upgrade.

If the Powertrain Control Module (PCM) and Body Control Module (BCM) continue to believe the battery is an FLA type, it might take longer than expected to completely charge an AGM battery, if it charges completely at all. Under-charging any battery can lead to increased sulfate accumulation and weaken the unit; this can also lead to a decreased lifespan.

Avoiding the overcharging of a battery is just as important. AGM batteries are more sensitive to overcharge events than FLA batteries and can be easier to damage. AGM batteries require a more precise charging profile than an FLA.

The next section will provide a little more detail on the stages of the charging process and help explain why an AGM mode capable battery tender is just as important as the BCM/PCM charging profile in the S550.

Battery Maintainer

A traditional battery charger is something of a blunt instrument. While capable of charging a battery with large amounts of current quickly, they are typically and all-or-nothing device. A battery tender or maintainer however, charges and conditions a battery.

There are several stages to charging a battery. We'll focus on a few: desulfation, bulk, absorption and float.

In describing the chemical reactions, sulfates were previously discussed. Routinely taking a vehicle on short trips is detrimental to the battery and the vehicle's charging system. It takes a lot of power to start a car, and time for the generator to replenish the battery. During short, consecutive drives, sulfates will develop which might not be cleared sufficiently before the next start. If heavy enough, sulfates do not later dissolve, but break up and fall to the bottom of the battery case, permanently weakening the battery. Desulfation is the process of cleaning plates in the battery.

As part of a maintainer routine, high amounts of current are driven into the battery, assisting in the breaking up and dissolving of sulfate deposits. While this process is welcome, it can cause problems in specific situations.

For batteries which have not been cared for, or have been routinely under-charged, those with large amounts of deposits, desulfation could cause those deposits to break-up. And fall to the bottom of the battery case. It's a no-win situation. The battery is degraded by the amount of deposits, but their breaking up yet not dissolving could leave the battery permanently degraded. Routinely driving the vehicle, or regularly using a maintainer, can prevent the issue from occurring.

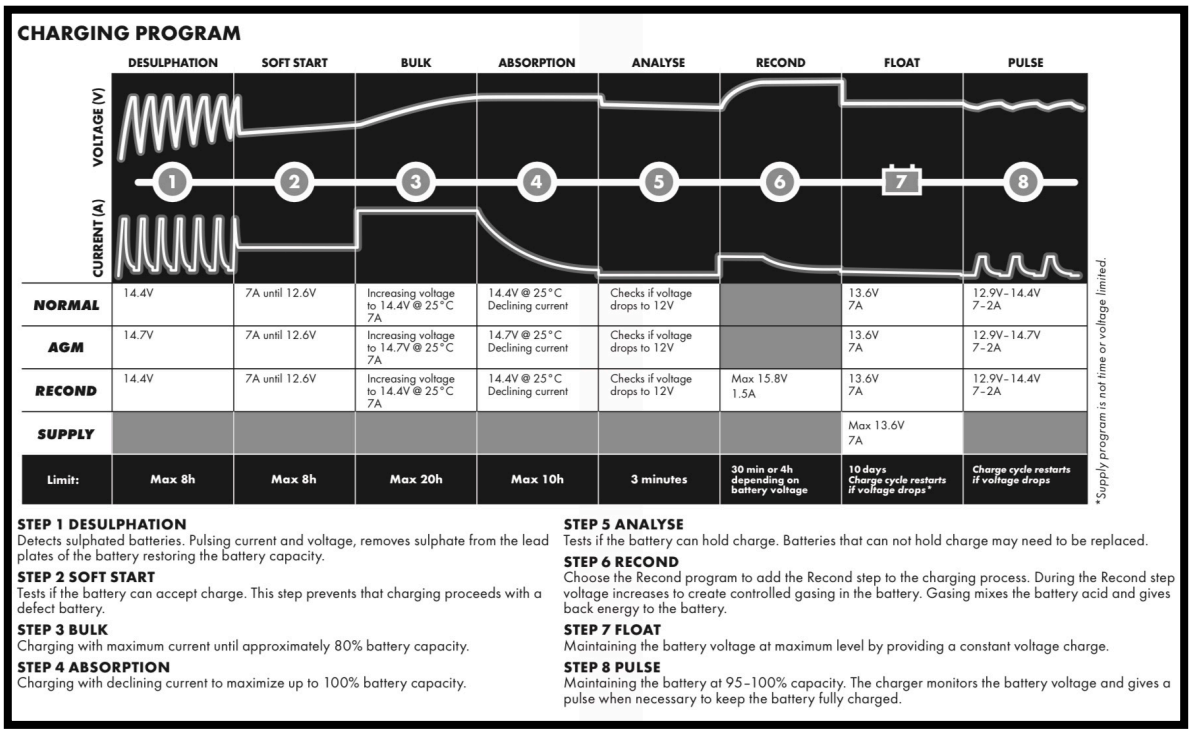
For AGM batteries, desulfation could damage the battery. Desulfation using an FLA setting could overheat an AGM battery, causing it to gas off some of the electrolyte and weakening it. If using a charger or tender, read the specifications and confirm it supports an FLA, AGM or both. Many modern units can auto-sense the type and adjust accordingly.

The bulk stage of charging is where most of the action occurs. This stage, also known as Constant Current, is when majority of the charging takes place.

The absorption stage, or Constant Voltage, is when the maintainer topping the battery off. As the electrolyte and plates hold more and more energy, it becomes more difficult to continue to add more still. A maintainer adjusts, to fill the rest.

The float stage is something of a maintenance stage. The sulfates have been cleared the battery charged. Now, as the battery naturally degrades over time, the float process adds power back, as necessary.

If the car does not see extended drives often, or is not driven often, a battery tender can enhance the life of the battery and lessen the strain on the generator. Tenders are designed with battery maintenance and longevity in mind. They have specific routines to keep at battery at peak performance.



STEP 1 DESULPHATION
Detects sulphated batteries. Pulsing current and voltage, removes sulphate from the lead plates of the battery restoring the battery capacity.

STEP 2 SOFT START
Tests if the battery can accept charge. This step prevents that charging proceeds with a defect battery.

STEP 3 BULK
Charging with maximum current until approximately 80% battery capacity.

STEP 4 ABSORPTION
Charging with declining current to maximize up to 100% battery capacity.

STEP 5 ANALYSE
Tests if the battery can hold charge. Batteries that can not hold charge may need to be replaced.

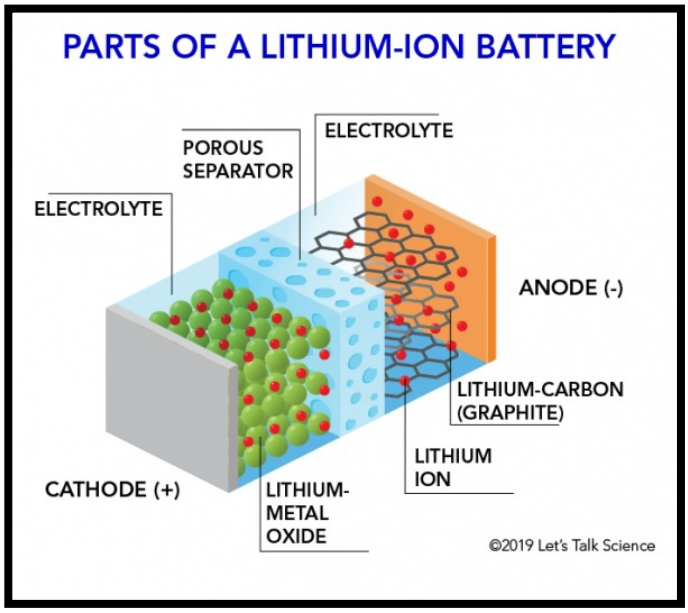
STEP 6 RECOND
Choose the Recond program to add the Recond step to the charging process. During the Recond step voltage increases to create controlled gasing in the battery. Gasing mixes the battery acid and gives back energy to the battery.

STEP 7 FLOAT
Maintaining the battery voltage at maximum level by providing a constant voltage charge.

STEP 8 PULSE
Maintaining the battery at 95–100% capacity. The charger monitors the battery voltage and gives a pulse when necessary to keep the battery fully charged.

Battery (Lithium Ion)

Lithium is a element which is widely available, light in weight and energy dense. Lithium Ion (Li-ion) batteries have an aNode (-), caThode (+), electrolyte and generate electricity. Lithium Ion batteries are not as common in ICE vehicles as traditional lead-acid ones, and their material composition is different. But the same general components and principles are the same. Different types of Lio-ion batteries can have different component materials. The following will describe activities in one type of battery.



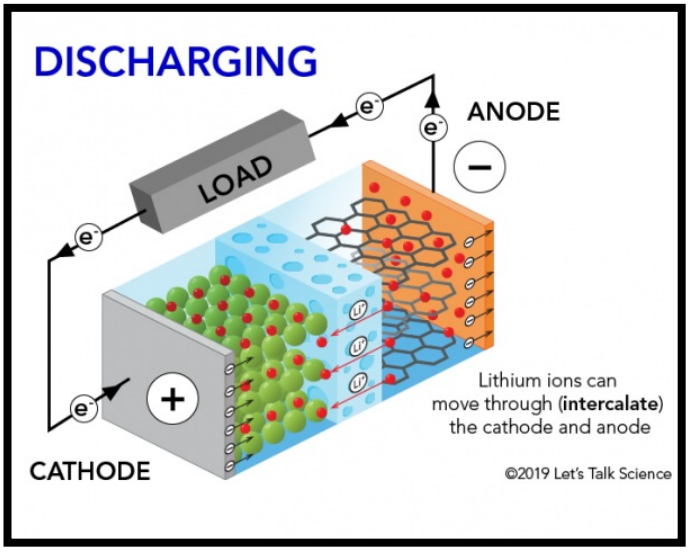
The negative section of a lithium battery holds lithium in a graphite lattice. This arrangement keeps the lithium stable until needed. “Intercalation” is a term used to describe a reversible insertion of a molecule held in a layered structure.

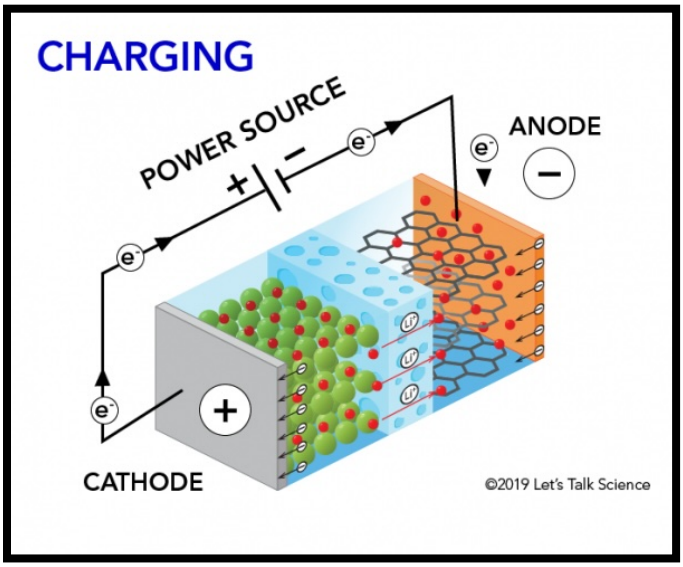
The cathode of a Lithium battery is made of a cobalt, oxygen oxide. The cobalt atoms have given up the electrons in their outer shell to the oxygen and are looking for replacements. The cobalt lattice leans (+).

The electrolyte in a Li-ion battery operates a bit different than a lead-acid one: it blocks any free electrons from crossing directly into the (+) lattice, while allowing lithium ions free movement across. Electrons in the (-) lattice can only exit the negative terminal and flow through a circuit load.

There is also a separator , preventing the lattice on either side from touching the other and causing a short circuit.

When discharging a Li-ion battery, electron flow is away from the anode and into the electrical circuit. The now lithium ions stay in the battery structure, pass through the electrolyte barrier, are attracted to and enter the cobalt lattice. Electrons recombine with those ions after passing through the circuit.





When charging a lithium battery, electrons are pumped from a power source, towards the anode lattice. The positive side of that same power source is strong enough to break the electrons away from their lithium atoms, “sucking” them back in and pushing them towards the anode. At the same time, those additional positive forces repel ions back towards the electrolyte. The ions are attracted to the gathering of electrons at the anode , move to and re-attach.

Some S550 owners have changed their factory lead-acid battery to an Antigravity Li-ion battery. The advantages are space and weight savings. The units are a direct replacement. There are some caveats when considering a lithium battery.

The most important consideration is how well the car will operate with a Li battery. A review of several 6G threads show some Members reporting no issue, while most report BCM and Battery Management System (BMS) incompatibilities. As with the AGM unit, a 6G car doesn't know a lithium battery has been installed. Unfortunately, unlike the AGM unit, there is no Lithium option in the BCM to identify that as the type now in the car.

Specific to the Antigravity unit, they have under-voltage protection. As parasitic drains lower the voltage of the Li-ion unit, the battery has intelligence to disconnect itself. The feature acts like a breaker, preventing the owner from having a dead battery.

Under voltage protection maintains a “self-jump” feature is so the owner does not have to jump-start the battery. Jump-starting a heavily-discharged battery is not safe. Li-ion units need to be brought back up slowly. Jump-starting could damage the unit. Antigravity has battery-specific help guides and more details at their web site.

With respect to battery tenders, these need to be designed to maintain a lithium unit. Using a high-powered charger or non-Li-ion tender could damage the battery.

Battery Management System

Engineers who design batteries are well-aware of certain operating conditions (extreme hot, extreme cold, taxing loads, over-charging, under-charging) which can shorten a battery's useful service life. Ford's Battery Management System (BMS) is installed to keep the battery at it's optimum for as long as possible. While monitoring conditions, BMS and the car make adjustments to the charging system in support of the battery and its health.

Flooded Lead Acid (FLA) State of Charge (SoC)

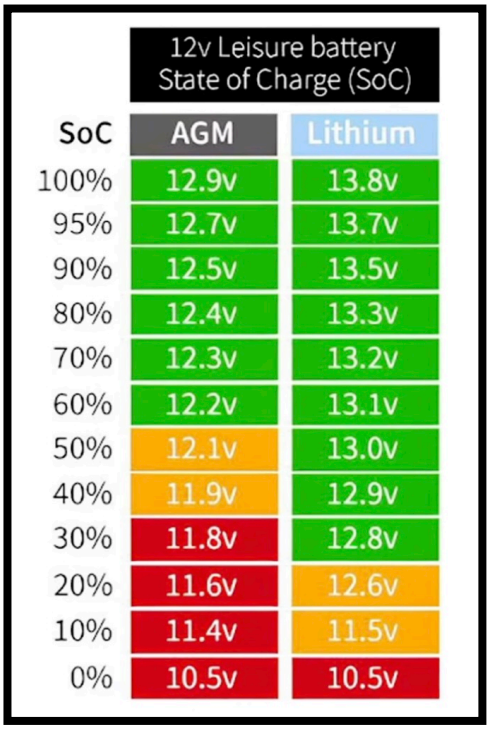
12V Battery Voltage	Volts Per Cell	State of charge
12.7	2.12	100%
12.5	2.08	90%
12.42	2.07	80%
12.32	2.05	70%
12.2	2.03	60%
12.06	2.01	50%
11.9	1.98	40%
11.79	1.96	30%
11.58	1.93	20%
11.31	1.89	10%
10.5	1.75	0%

In a new car, Ford's battery State of Charge (SoC) goal is 80%. A one hundred percent charge is not optimum. While your oven has a self-cleaning feature which operates at the device's maximum possible temperature, the oven's service life will be reduced every time that feature is used. BMS is attempting to to the same. Keeping a long-term 100% charge accelerates internal degradation of battery components.

From repeated uses and expected degradation, a battery that has been in service for some time will need a greater or longer charge than when new. BMS keeps track of all this and adjusts the alternator and charging circuits accordingly.

The charging and discharging of any battery will physically wear it out. Materials will degrade. Even when kept at their best, not all sulfates will be released. Over time, the battery has more and more difficulty maintaining a charge and producing the designed current flow.

This writer is pro-active, replacing lead-acid batteries every five years, even if they do still present well.



BMS is akin to the Oil Life Monitor (OLM); it knows how long the battery has been in the car, how often charged and discharged and adjusts the car's charging routine accordingly. Once the battery is replaced, the Owner needs to reset the BMS, to let the car know a new battery is present.

BMS resets are easy. There's a link to the procedure in this document's appendix.

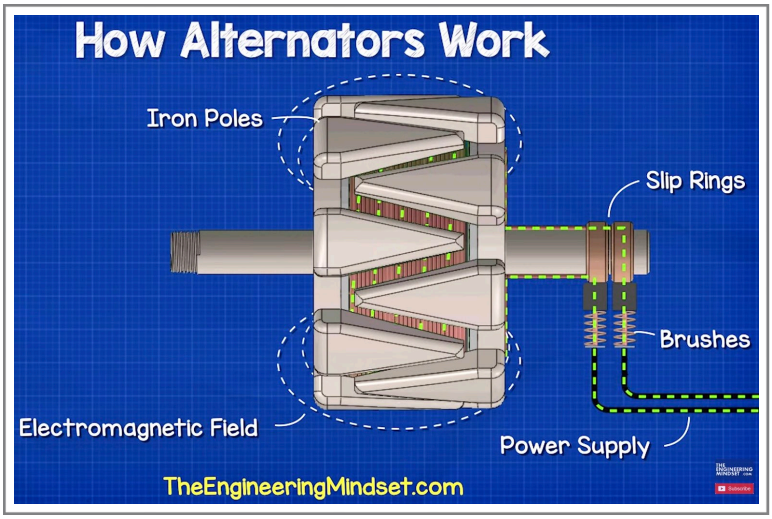
Alternator

A generator is a device that converts mechanical energy into electricity.

An alternator is a generator that produces Alternating Current (AC).

The S550 uses an alternator, but the car needs Direct Current (DC) voltage (VDC) and current, to operate the vehicle and re-charge the battery. The alternator contains three main components to produce and output DC.

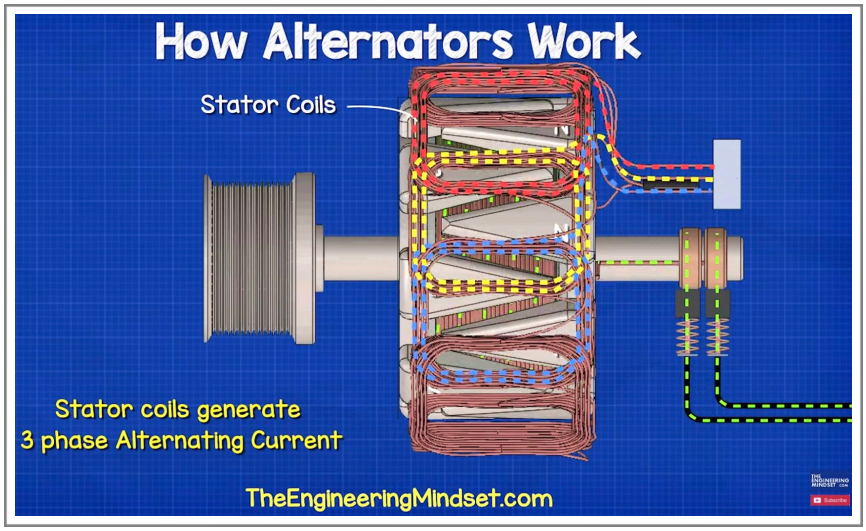
References to animated alternator videos are provided in the Links section.

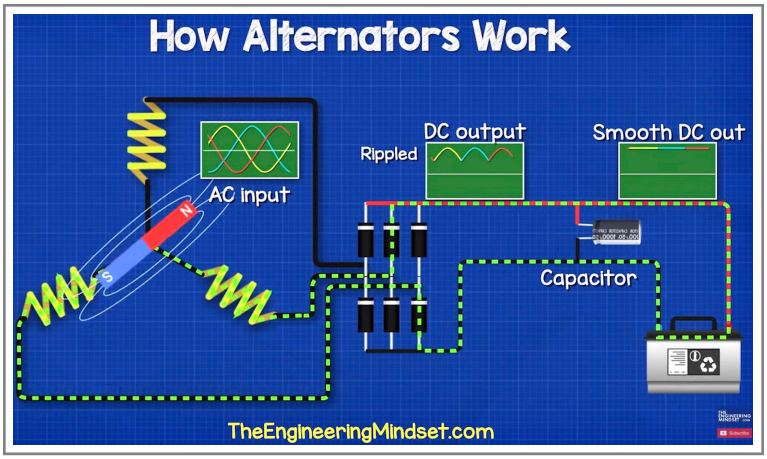


Inside the alternator is a electromagnetic rotor (magnet) and stator coil (pickup coil). This rotor is powered by the battery with a small amount of VDC. The rotor spins inside the stator coils. Once the engine is running, electromagnetic induction produces an AC signal.

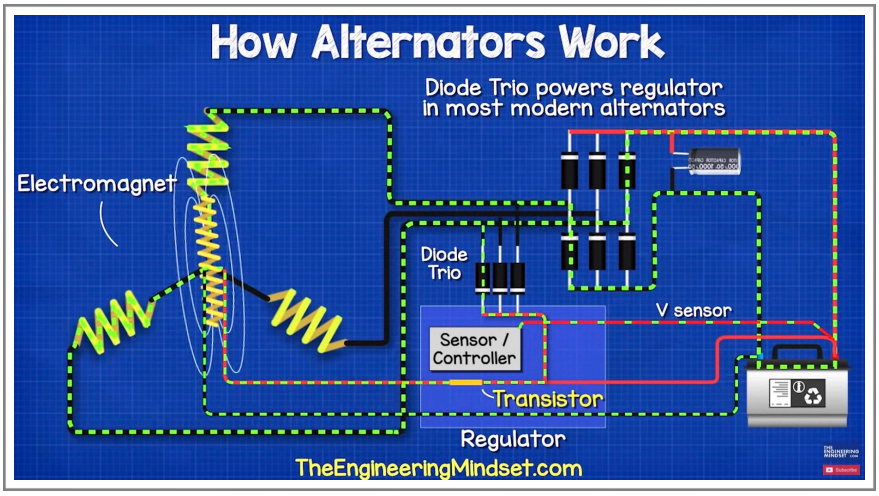
Electromagnetic Induction is the production of ElectroMagnetic Force (EMF) when there is relative motion between a magnetic field (rotor) and a conductor (stator coils).

The initial output of a alternator is VAC. A second component of an alternator produces VDC: the rectifier.





The rectifier is comprised of multiple diodes. A diode is a semi-conductor which allows current movement in one direction only. If oriented correctly, three diodes can capture and orient three-phase AC to produce VDC.

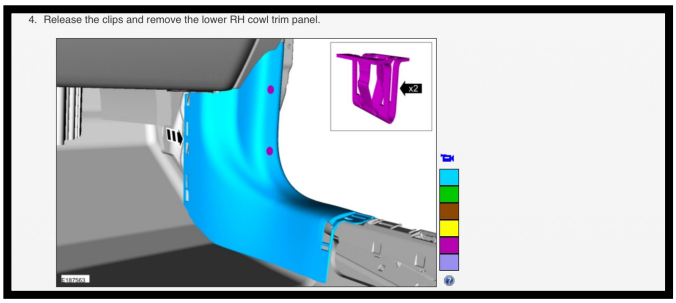


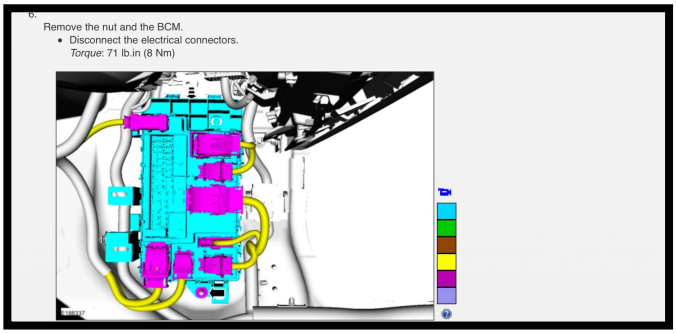
Finally, the alternator has a third major component: the regulator. As the engine's RPMs increase or decrease, so will the output voltage and current of the alternator, something we don't want. The regulator ensures the signal is always of the correct amperage and steady voltage.

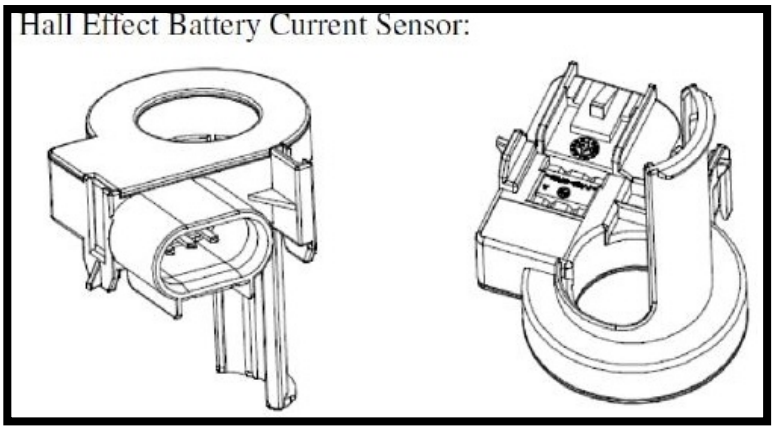
Charging Strategy

The Body Control Module-A (BCM), interior of car, near passenger side footwell, monitors and maintains the battery State of Charge (SoC). Battery charging and monitoring done by Ford's, "Electrical Energy Management", system.

A battery's SoC will be measured and charging system algorithms updated when the car is turned off. This process can take up to eight hours to ensure the highest accuracy.







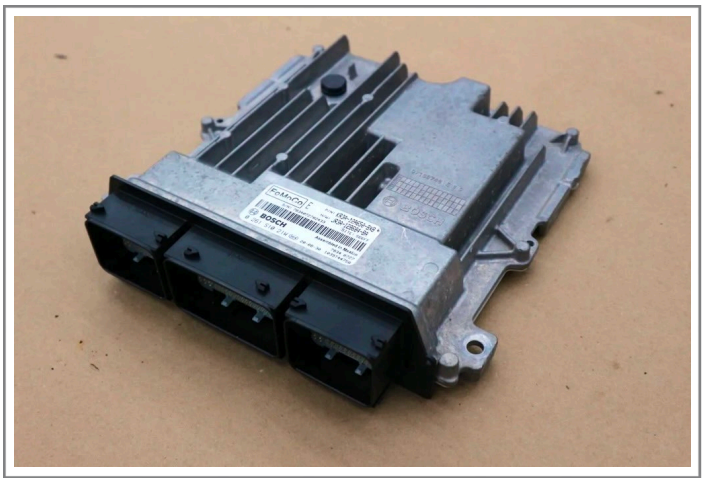
The battery is monitored via a Hall effect sensor located on the vehicle's negative battery cable. The Hall effect, "is the production of a potential difference (the Hall voltage) across an electrical conductor that is transverse to an electric current in the conductor and to an applied magnetic field perpendicular to the current."

By monitoring the Hall voltage present in the sensor, the BCM can determine at what rate the battery is charging and discharging, as well as its SoC. The presence of this sensor on the cable identifies how some electrical installations which go straight to the (-) post of the battery can confuse and interfere with the BMS.

When jump starting the vehicle, Ford recommends, at the disabled vehicle, attach the recovery negative jumper cable to the engine or a chassis mount. Not to the (-) battery terminal directly.

Load Shedding Strategy

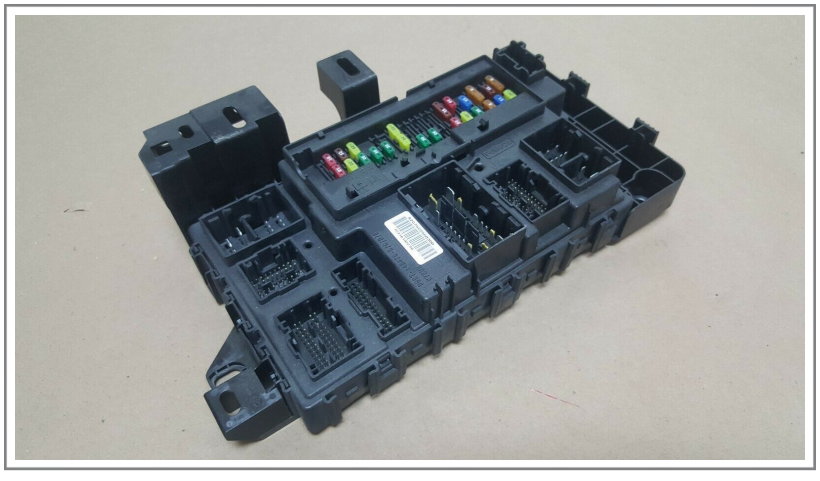
The Powertrain Control Module (PCM) (located under the hood and near the fuse panel) controls the generator and its output. In addition to the regulated voltage output of the alternator, there is a GENerator COMmunication (GENCOM) circuit; this is the method the PCM uses to direct the generator to provide a given output. In addition to generator load, the PCM receives alternator error and status conditions via the GENerator MONitor (GENMON) circuit. Both circuits use Pulse Width Modulation (PWM) signals to convey information. Ford uses the term, “Smart Charge”, for how the PCM controls the alternator. The PCM reports any system faults to the BCM-A.



During engine cranking, the PCM turns off the alternator to reduce load and increase engine cranking speed. Once running, the PCM increases alternator output to meet requirements. If the PCM senses the battery is discharging, the PCM will increase alternator output and possibly engine speed to charge the battery and prevent battery drain.

When programming modules, Ford recommends connecting an external charger, tender or running the engine while doing so. If not, there is the potential to drain a battery to a given level where load shedding will occur, the update will stop and information will be corrupted.

When the car is off, if the BCM determines the battery has discharged to concerning levels, the BCM will begin to disable the audio and navigation systems.



When the engine is running and the BCM or Power Steering Control Module (PSCM) voltage is low, load shedding will occur. Climate controlled seats, heated mirrors, steering wheels and rear window defrost functions could all be disabled.

Ford vehicles have three strategies, each more aggressive, which engage as needed: Load shed 1, Load shed 2 transient and Load shed 2 continuous.

Load shedding also helps explain why, when a driver has a failing battery that needs to be replaced, some features of the vehicle do not work correctly, if at all.

Acronyms

ABS - Anti-Lock Brake System
ACK - ACKnowledgment (See CAN message format, ISO 11898)
ACM - Audio Front Control Module (DACMC, Radio, CD, Speakers)
AGM - Absorbed Glass Mat (vehicle battery type)
AM - Amplitude Modulated
ANC - Active Noise Cancelling
APIM - Accessory Protocol Interface Module (SYNC, steering controls, radio, NAV)
BCM - Body Control Module
BCMA - BCM (Interior, right side, near floor)
BCMB - BCM (Trunk, right side, near wheel well)
BECMB - Battery Energy Control Module B (RCM, SRS. Turns off fuel in crash.)
BLIS - Blind Spot Information System
BMS - Battery Management System
CAN - Controller Area Network (See also LIN)
CCA - Cold Cranking Amps
CCM - Cruise Control Module
CIP - Consumer Interface Protocol
CPA - Connector Position Assurance (SRS, airbag connector tabs)
CRC - Cyclic Redundancy Check (See CAN message format, ISO 11898)
DAB - Digital Audio Broadcasting
DACMC - Digital Audio Control Module-C (ACM, Radio, CD, Speakers)
DCM - Door Control Module (aka DDM, PDM, Intelligent Access)
DCSM - Dual Climate Seat Module (Seating Climate Control)
DCT - Dual-Clutch Transmission (Paired, electronically-controlled manuals)
DDM - Driver Door Module (Keyless Entry)
DIAG1 - A physical link, connecting LHD and RHD DLC/GWMs
DIAG2 - A physical link, connecting LHD and RHD DLC/GWMs
DLC - DataLink Connector (OBDII, GWM, both LHD and RHD)
DSM - Driver Seat Module (Seat Memory, Power)
DSP - Audio Digital Signal Processor (DSP) Module
DTC - Diagnostic Trouble Code. The fault code/s, seen by a OBDII scan tool
ECM - Engine Control Module (PCM)
ECU - Engine Control Unit (PCM)
EOF - End Of Frame (See CAN message format, ISO 11898)
EMF - ElectroMotive Force
EMI - Electro-Magnetic Interference
FCIM - Front Controls Interface Module (Center Console Push-Button Controls)
FCDIM - Front Controls Display Interface Module (FCIM Outputs)
FDIM - Ford DIsplay Module (Screen Outputs)
FDRS - Ford Diagnostic and Repair System (Ford diagnostic and programming tool)
FLA - Flooded Lead Acid (vehicle battery type)
FM - Frequency Modulated
FMVSS - Federal Motor Vehicle Safety Standard

Acronyms (cont.)

FORScan - 3rd party diagnostic and programming tool
GENCOM - Generator Communications
GENMON - Generator Monitoring
GSM - Gear Shift Module (GT500 Only)
GWM - GateWay Module (DLC, OBDII, LHD and RHD)
HS-CAN - High-Speed Controller Area Network (1,2,3 and 4)
HSWM - Heated Steering Wheel Module
HUD - Head-Up Display Module
HVAC - Heating, Ventilation, Air Conditioning
IA - Intelligent Access (keyless entry)
ICM - Information Center Module
ID - IDentifier (See CAN message format, ISO 11898)
IPC - Instrument Panel Cluster
IPMA - Image Processing Module A (Camera, Lane Departure)
ISO - International Organization for Standardization (See CAN message, ISO 11898)
kHz - kilo Hertz (frequencies in the thousands)
LF - Low Frequency (30 kHz - 300 kHz)
LHD - Left-Hand Drive (DLC, GWM, LHD and RHD OBDII linked via DIAG1 and 2)
Li-ion - Lithium Ion (vehicle battery type)
LIN - Local Interconnect Network (low-cost, low-speed, low-reliability CAN supplement)
LVDS - Low Voltage Differential Signaling
MHz - Mega Hertz (frequencies in the millions)
MRCMA - Movable Roof Control Module, Primary (Convertible Roof)
MRCMB - Movable Roof Control Module, Secondary (Convertible Roof)
MS-CAN - Medium-Speed Controller Area Network
OBDII - On-Board Diagnostics, Gen 2 (DLC, GWM)
OCS - Occupant Classification System (Passenger Seat Only)
OCSM - Occupant Classification Systems Module (Passenger Sitting Detect)
OLM - Oil Life Monitor
PAM - Parking Assist Control Module (Backup Assist, Parking Assist)
PATS - Passive Anti-Theft System (Engine Immobilizer)
PCM - Powertrain Control Module
PDM - Passenger Door Module (Keyless Entry)
PMI - Programmable Module Installation
PSCM - Power Steering Control Module
PWM - Pulse Width Modulation
RCM - Restraint Control Module (Seatbelt, SRS, Crash Detect)
RF - Radio Frequency (all frequencies used in wireless communications)
RHD - Right-Hand Drive (DLC, GWM, LHD and RHD OBDII linked via DIAG1 and 2)
RKE - Remote Keyless Entry (IA, or Intelligent Access)
RPM - Revolutions Per Minute
RTM - Radio/Remote Transceiver Module (keyless entry, TPMS, remote start)
SCCM - Steering Column Control Module (High Beams, Turn Signals)
SCME - Seat Climate-controlled Module - E

Acronyms (cont.)

SDL - Smart Device Link (Infotainment connectivity protocol, apps, systems)
SLA - Sealed Lead Acid (vehicle battery type)
SIM - Subscriber Identity Module
SoC - State of Charge
SODL - Side Obstacle Detection Control Module LH (BLIS)
SODR - Side Obstacle Detection Control Module RH (BLIS)
SOF - Start Of Frame (See CAN message format, ISO 11898)
SRS - Supplemental Restraint System
SUMB - Vehicle Dynamics Control Module (VDM, Magneride)
TCM - Transmission Control Module (In GT500, a dedicated unit, attached to trans)
TCU - Telematics Control Unit
TCU - Transmission Control Unit (In GT500, a dedicated unit, attached to trans)
TPMS - Tire Pressure Monitoring System
TTS - Text To Speech
UHF - Ultra-High Frequency (300 MHz - 3 GHz)
VAC - Voltage Alternating Current
VDC - Voltage Direct Current
VDM - Vehicle Dynamics Control Module (Magneride)
VIN - Vehicle Identification Number
VIP - Vehicle Interface Protocol
VPWR - Vehicle PoWeR (PCM manages power needs)
VRLA - Valve-Regulated Lead Acid (vehicle battery type)
VQM - Voltage Quality Module ("smoothes" voltage to components)

Links and Site References

Alternator

Alternator Animated Video Tutorial
https://www.youtube.com/watch?v=jdSKlg80DjU

Antenna

Antenna (Roof) And What They Do
https://www.mustang6g.com/forums/threads/job-1-vs-job-2-shark-fin-roof-antenna-and-what-they-do.146941/

Antenna (Shark Fin) PN#
https://www.mustang6g.com/forums/threads/shark-fin-antenna-part.146564/

APIM

APIM - YouTube Video Showing APIM and its location
https://www.youtube.com/watch?app=desktop&v=fI03A9lbYaA

Links and Site References

Battery

Battery, Case Size/Group Cross-Reference (EUR-to-USA)

https://antigravitybatteries.com/help-center/car-battery-fitment-sizing/?srsltid=AfmBOor3J6ZNjdJgqDEN721Kxy2dipGm5k9k057LbJqTLqDVy-7CUKz8

Battery, Case Size, Physical Measurements, in Imperial and Metric

https://batterycouncil.org/wp-content/uploads/2023/10/BCI-Group-Sizes.pdf

Battery, Lead-Acid, Animation Video Tutorial

https://www.youtube.com/watch?v=VnPRX5zQWLw

Battery, Lithium-Ion, Brief Explanation

https://letstalkscience.ca/educational-resources/stem-explained/how-does-a-lithium-ion-battery-work

Battery Tender

Battery Tender, Ford (CTEK) Charging Process

https://www.youtube.com/watch?v=GXsDrRRRqcU&t=4s

BCM

BCM Location, Diagrams, with Steps on How to Replace (BCMA and BCMB)

https://www.mustang6g.com/forums/threads/bcm-replacement-help.119035/

https://www.mustang6g.com/forums/threads/2018-gauge-cluster-retrofit.74133/page-27

BCM Partial Pinout, to include Fog Lights

https://www.mustang6g.com/forums/threads/anyone-have-the-pinout-wiring-diagram-for-2018-up-fog-running-light-assembly.132859/

BLIS

BLIS, A Step-By-Step Guide To Installing
https://www.mustang6g.com/forums/threads/step-by-step-guide-to-enabling-blind-spot-information-system-blis-and-cross-traffic-alert-cta.107623/

BMS

BMS, Characteristics of Lead Acid Batteries
https://www.pveducation.org/pvcdrom/lead-acid-batteries/characteristics-of-lead-acid-batteries

BMS, The Concept of Ford's Service
https://lockdownsecurity.forumbee.com/t/m2gvh9/ford-trucks-bms-battery-monitoring-systems

BMS: How to Reset in the S550 Mustang
https://www.mustang6g.com/forums/threads/bms-reset-no-tools-required.151602/

Links and Site References

CAN

CAN Tutorials, both Document and Video (See also LIN)

https://dewesoft.com/blog/what-is-can-bus

https://www.csselectronics.com/pages/can-bus-intros-tutorials

https://www.ti.com/lit/an/sloa101b/sloa101b.pdf

https://www.youtube.com/@CSSElectronics-CAN-Logger-X000/videos

CAN in Ford, Explained In Detail, with Logical Drawings

https://www.fofusion2.com/ford_fusion_communications_network_system_operation_and_component_description_description_and_operation-2613.html (Site explains which module uses which CAN)

https://www.fordgt500.com/threads/can-bus-2020-2022-gt500.205590/

https://www.mustang6g.com/forums/threads/the-how-to-disable-the-data-link-to-ford-thread.146863/page-5#post-3007057

Links and Site References

DCT

DCT Operation (Also see TCM below)

https://www.youtube.com/watch?v=t8aGgSbtoJE

Links and Site References

GWM

GWM Location with Dash Harness Connector Layout, HSWM
https://www.mustang6g.com/forums/threads/2018-gauge-cluster-retrofit.74133/page-27

Links and Site References

IA

A- Authenticating in an Unsecured Environment

https://www.youtube.com/watch?v=KXq065YrpiU&list=PLIFyRwBY_4bTwRX__Zn4-letrtpSj1mzY

https://www.practicalnetworking.net/series/cryptography/diffie-hellman/

https://www.youtube.com/watch?v=YEBfamv-_do

A- Wireless Power Transfer (Inductive Coupling)

https://www.nemko.com/blog/wireless-power-transfer

Links and Site References

LIN

LIN Tutorial (See also CAN)

https://www.youtube.com/watch?v=TresvW4dxlc

LVDS

LVDS Tutorials

https://www.allaboutcircuits.com/technical-articles/the-why-and-how-of-differential-signaling/

https://resources.system-analysis.cadence.com/blog/msa2021-the-advantages-of-differential-signaling

https://hardwarebee.com/understanding-lvds-low-voltage-differential-signaling/

Links and Site References

Modules

Modules, Electronic, their locations

https://www.youtube.com/watch?v=uzLq5AU1rIg

MRCMA

MRCMA Detailed Document with CAN explanations and Logical Diagrams

https://www.mustang6g.com/forums/attachments/sm_22-pdf.436431/

Links and Site References

PATS

PATS, Re-Initializing, Enabling, so as to Accept New Modules (BCM, etc.)

https://www.mustang6g.com/forums/threads/engine-immobilizer-lock-pats.166144/#post-3454664

PCM

PCM, 10R80 Harness Connectors and Connections

https://www.mustang6g.com/forums/threads/looking-for-trans-pcm-connector-pinout-10r80.147871/

PCM Control Pack Reference (5.0, 5.2, Harness and Connectors)

https://performanceparts.ford.com/download/instructionsheets/FordInstShtM-6017-504V.pdf

https://www.mustang6g.com/forums/threads/leaked-2019-gt500-5-2l-supercharged-engine-wiring-cad-diagram-from-ford.95772/

PCM, Fuel Pump Schematic

https://www.mustang6g.com/forums/threads/fore-wiring-2018-gt.114303/

PCM Ignition Coil Schematic (5.0)

https://www.mustang6g.com/forums/threads/dtc-code-p0354.145419/

PCM Location, Where to Find PCM, Codes Needed by Tuners

https://www.ortizperformance.com/post/locating-your-vehicle-s-pcm-code-1996-2021-mustangs

https://lmr.com/products/ford-mustang-ecu-computer-code-location

PCM Pinout, with Specific Pin Function

https://www.mustang6g.com/forums/threads/pcm-pinout-info-for-v6-mustang-and-v8-2016.136824/

PCM Wiring, Detailed Schematic (2.3L)

https://www.mustang6g.com/forums/threads/looking-for-a-wire-from-the-ecu.107905/

Links and Site References

SODL/R

SODL SODR modules (Detailed Guide, with Photos)
https://www.mustang6g.com/forums/attachments/step-by-step-guide-to-enabling-blis-and-cta-pdf.294019/

SRS

SRSTutorial (Ford)
https://www.repairerdrivennews.com/wp-content/uploads/2023/12/On-Target.pdf

https://fordcrashparts.com/wp-content/uploads/2020/12/On-Target-2020-Vol.-4-FINAL-12-7-20.pdf

SRS- YouTube Video Showing RCM and its location
https://www.youtube.com/watch?v=-VjR8bxT_HU

SRS YouTube Video Showing OCSM and its location
https://www.youtube.com/watch?v=KYgyc7oLLtI

SRS - YouTube Video Showing APIM and its location
https://www.youtube.com/watch?app=desktop&v=fI03A9lbYaA

SYNC Update Thread

SYNC
https://www.mustang6g.com/forums/threads/official-ford-sync3-3-4-release.145436/

Links and Site References

TCM

TCM (GT500) (Also see DCT Operation above)

https://www.motortrend.com/how-to/whats-inside-tremecs-new-seven-speed-dual-clutch-transmission-new-shelby-gt500-mustang/

https://www.mustang6g.com/forums/threads/what-is-this-part-number.157159/ (GSM-specific)

TCU

TCU Location (Telematics Control Unit) (location and logical)

https://www.mustang6g.com/forums/threads/4g-modem-disabling-instructions.146860/

https://www.mustang6g.com/forums/threads/the-how-to-disable-the-data-link-to-ford-thread.146863/page-17#post-3028021

TPMS

TPMS - Federal Motor Vehicle Safety Standard

https://www.federalregister.gov/documents/2005/09/07/05-17661/federal-motor-vehicle-safety-standards-tire-pressure-monitoring-systems#h-8