Table of Contents

FIGURE 12 A conductance tester is very easy to use and has proved to accurately determine battery condition if the connections are properly made. Follow the instructions on the display exactly for best results.

However, a conductance tester is not designed to accurately determine the state of charge or CCA rating of a new battery. Unlike a battery load test, a conductance tester can be used on a battery that is discharged. This type of tester should only be used to test batteries that have been in service. ● **SEE FIGURE 12.**

TEST PROCEDURE To test a battery using an electronic conductance tester, perform the following steps.

STEP 1 Connect the unit to the positive and negative terminals of the battery. If testing a side post battery, always use the lead adapters and *never* use steel bolts as these can cause an incorrect reading.

NOTE: Test results can be incorrectly reported on the display if proper, clean connections to the battery are not made. Also be sure that all accessories and the ignition switch are in the off position.

STEP 2 Enter the CCA rating (if known).

STEP 3 The tester determines and displays the measured CCA of the battery as well as state of charge and the voltage, plus one of the following:

- **Good battery.** The battery can return to service.
- **Charge and retest.** Fully recharge the battery and return it to service.
- **Replace the battery.** The battery is not serviceable and should be replaced.
- **Bad cell—replace.** The battery is not serviceable and should be replaced.

Some conductance testers can check the charging and cranking circuits, too.

AUXILIARY BATTERY CHARGING

CHARGING PROCEDURE If the state-of-charge of a battery is low, it must be recharged. It is best to slow charge any battery to prevent possible overheating damage to the battery. Perform the following steps.

STEP 1 **Determine the charge rate.** The charge rate is based on the current state-of-charge (SOC) and charging rate. ● **SEE CHART 2** for the recommended charging rate.

STEP 2 **Connect a battery charger to the battery.** Be sure the charger is not plugged in when connecting to a battery. Always follow the battery charger's instructions for proper use.

STEP 3 **Set the charging rate.** The initial charge rate should be about 35 A for 30 minutes to help start the charging process. Fast charging a battery increases the temperature of the battery and can cause warping of the plates inside the battery. Fast charging also increases the amount of gassing (release of hydrogen and oxygen), which can create a health and fire hazard. The battery temperature should not exceed 125°F (hot to the touch).

- Fast charge: 15 A maximum
- Slow charge: 5 A maximum

● **SEE FIGURE 13.**

OPEN CIRCUIT VOLTAGE	STATE-OF-CHARGE (SOC) (%)	@60 A (MIN.)	@50 A (MIN.)	@40 A (MIN.)	@30 A (MIN)	@20 A (MIN.)	@20 A (MIN.)
12.6	100	N.A. (Fully charged)	N.A. (Fully charged)	N.A. (Fully charged)	N.A. (Fully charged)	N.A. (Fully charged)	N.A. (Fully charged)
12.4	75	15	20	27	35	48	90
12.2	50	35	45	55	75	95	180
12.0	25	50	65	85	115	145	260
11.8	0	65	85	110	150	195	370

CHART 2

Battery charging guidelines based on the state-of-charge of the battery and the charging rate.

FIGURE 13 A typical industrial battery charger. Be sure that the ignition switch in the vehicle is in the off position before connecting any battery charger. Connect the cables of the charger to the battery before plugging the charger into the outlet. This helps prevent a voltage spike and spark that could occur if the charger happened to be accidentally left on. Always follow the battery charger manufacturer's instructions.

CHARGING AGM BATTERIES Charging an absorbed glass mat (AGM) battery requires a different charger than is used to recharge a flooded-type battery. The differences include:

- The AGM can be charged with high current, up to 75% of the ampere-hour rating due to lower internal resistance.
- The charging voltage has to be kept at or below 14.4 volts to prevent damage.

Because most conventional battery chargers use a charging voltage of 16 volts or higher, a charger specifically designed to charge AGM batteries must be used. AGM batteries are often used as auxiliary batteries in hybrid electric vehicles when the battery is located inside the vehicle.

BATTERY CHARGE TIME The time needed to charge a completely discharged battery can be estimated by using the reserve capacity rating of the battery in minutes divided by the charging rate.

Hours needed to charge the battery = Reserve capacity/ Charge current

For example, if a 10 A charge rate is applied to a discharged battery that has a 90-minute reserve capacity, the time needed to charge the battery will be 9 hours.

90 minutes/10 A = 9 hours

HYBRID AUXILIARY BATTERY LOCATIONS

The location of the 12-volt auxiliary battery varies according to the make, model, and year of hybrid electric vehicle. As a general rule, the type of battery used is determined by the location such as

- An AGM battery is used when the battery is located in the trunk or near the passenger compartment area.
- A flooded-type battery is used if the battery is located under the hood.

SEE CHART 3 for a summary of the locations and type of 12-volt auxiliary battery.

AUXILIARY BATTERY ELECTRICAL DRAIN TESTING

TERMINOLOGY The **battery electrical drain test** determines if any component or circuit in a vehicle is causing a drain on the battery when everything is off. This test is also called the **ignition off draw (IOD)** or **parasitic load test.** Many electronic components draw a continuous, slight amount of current from the battery when the ignition is off. These components include the following:

1. Electronically tuned radios for station memory and clock circuits.
2. Computers and controllers, through slight diode leakage.
3. The alternator, through slight diode leakage.

These components may cause a voltmeter to read full battery voltage if it is connected between the negative battery terminal and the removed end of the negative battery cable. Because of this fact, voltmeters should not be used for battery drain testing. This test should be performed when one of the following conditions exists:

1. When a battery is being charged or replaced (a battery drain could have been the cause for charging or replacing the battery).
2. When the battery is suspected of being drained.

NOTE: Battery electrical draw can only be tested on the auxiliary 12-volt battery. It is not possible for the service technician to test the high-voltage battery pack for electrical drain.

PROCEDURE FOR BATTERY ELECTRICAL DRAIN TEST There are many different testers that can be used for battery electrical drain testing, but an inductive ammeter is one of the most commonly used.

- **Inductive DC ammeter.** The fastest and easiest method to measure battery electrical drain is to connect an inductive DC ammeter that is capable of measuring low current (10mA) around either battery cable. **SEE FIGURE 14.**
- **DMM set to read milliamperes.** The following is the procedure for performing the battery electrical drain test using a DMM set to read DC amperes.

ELECTRIC POWER STEERING

Most electric power steering units use a brush-type DC electric motor that operates on 12 volts. Some operate from 42 volts and use an electronic controller and a brushless DC motor as an actuator.

The **electric power steering (EPS),** also called electric power-assisted steering (EPAS), system includes the following components and inputs/outputs:

- A DC motor
- Reduction gear
- Torque sensor

● **SEE FIGURE 42** for an example of an EPS used on a Toyota Highlander hybrid SUV.

The electric power steering (EPS) is controlled by the EPS ECU, which calculates the amount of needed assist based on the input from the steering torque sensor. The steering torque sensor is a noncontact sensor that detects the movement and torque applied to the torsion bar. The torsion bar twists when the driver exerts torque to the steering wheel, and the more torque applied causes the bar to twist further. This generates a higher-voltage signal to the EPS ECU. ● **SEE FIGURE 43.**

The steering shaft torque sensor and the steering wheel position sensor are not serviced separately from each other or from the steering column assembly. The steering column assembly does not include the power steering motor and module assembly. The detection ring 1 and detection ring 2 are mounted on the input shaft, and detection ring 3 is mounted on the output shaft. The input shaft and the output shaft are connected by a torsion bar. When the steering wheel is turned, the difference in relative motion between detection rings 2 and 3 is sensed by the detection coil and sends two signals to the EPS ECU. These two signals are called Torque Sensor Signal 1 and Torque Signal 2. The EPS ECU uses these signals to control the amount of assist and also uses the signals for diagnosis.

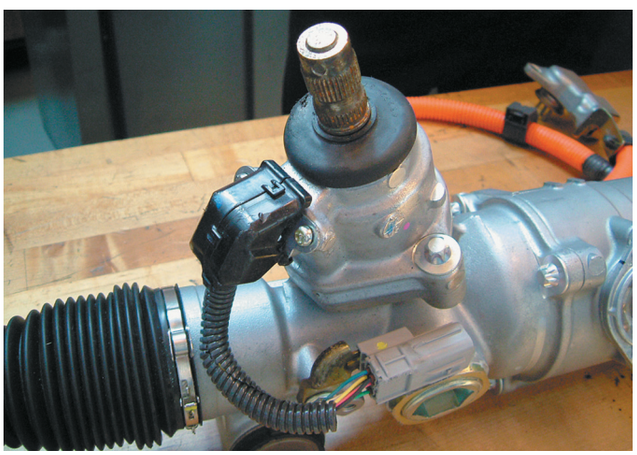

FIGURE 42 A Toyota Highlander hybrid EPS assembly.

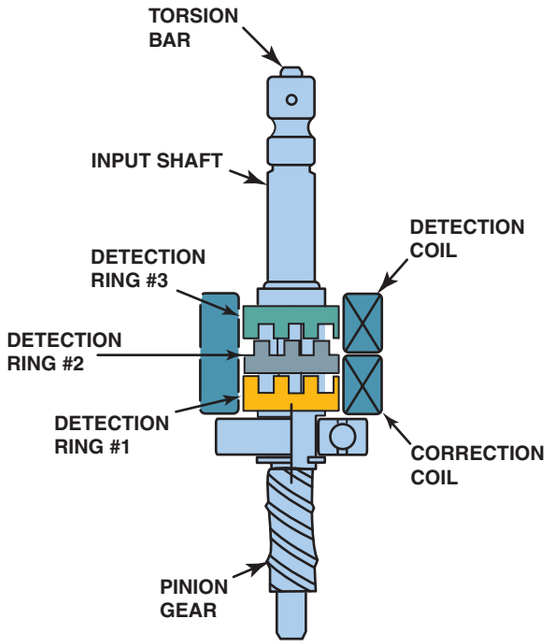

FIGURE 43 The torque sensor converts the torque the driver is exerting to the steering wheel into a voltage signal. *(Courtesy of University of Toyota and Toyota Motor Sales, U.S.A., Inc.)*

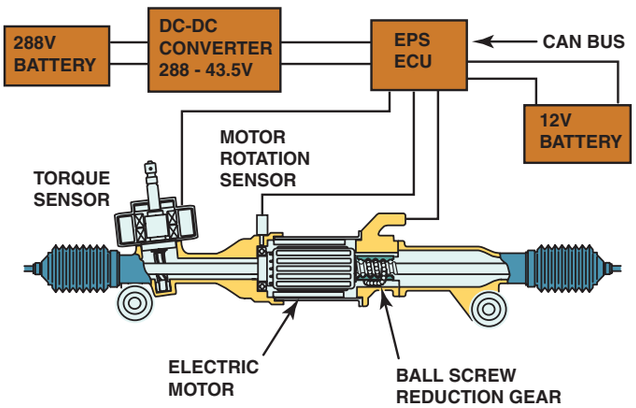

FIGURE 44 The electric power steering used in the Toyota/Lexus SUVs use a brushless DC (labeled BLDC) motor around the rack of the unit and operates on 42 volts. *(Courtesy of University of Toyota and Toyota Motor Sales, U.S.A., Inc.)*

NOTE: If the steering wheel, steering column, or the steering gear is removed or replaced, the zero point of the torque sensors must be reset using a scan tool.

The Toyota Highlander and Lexus RX 400h use a different electric power steering unit due to the larger size of the vehicles. This unit uses a concentric brushless DC motor on the steering rack. ● **SEE FIGURES 44 and 45.**

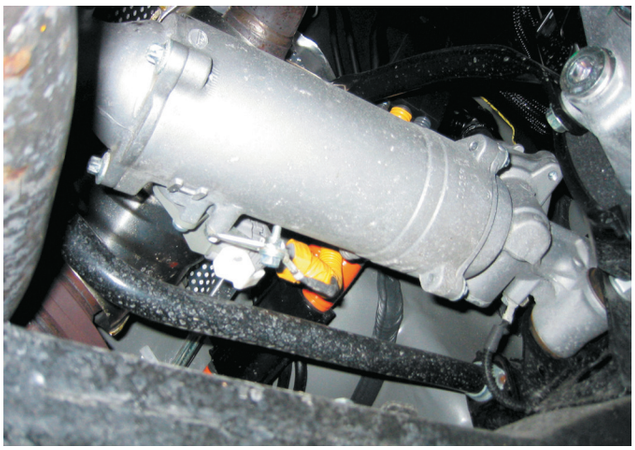

FIGURE 45 Photo of the electric power steering gear on a Lexus 400h taken from underneath the vehicle.

The Honda electric power steering uses an electric motor to provide steering assist and replaces the need for a hydraulic pump, hoses, and gear. A torque sensor is used to measure road resistance and the direction that the driver is turning the steering wheel. The torque sensor input and the vehicle speed is used by the EPS controller to supply the EPS motor with the specified current to help assist the steering effort. ● **SEE FIGURE 46.**

The motor turns the pinion shaft using a worm gear. The worm gear is engaged with the worm wheel so that the motor turns the pinion shaft directly when providing steering assist. The steering rack is unique because the tie rods are mounted to the center of the rack rather than at the ends of the rack as in a conventional Honda power steering arrangement. ● **SEE FIGURE 47.**

If a major fault were to occur, the control module will first try to maintain power-assisted steering even if some sensors have failed. If the problem is serious, then the vehicle can be driven and steered manually. The EPS control unit will turn on the EPS dash warning light if a fault has been detected. A fault in the system will not cause the malfunction indicator light to come on because that light is reserved for emission-related faults only. Fault codes can be retrieved by using a scan tool, and the codes will be displayed by the flashing of the EPS warning lamp.

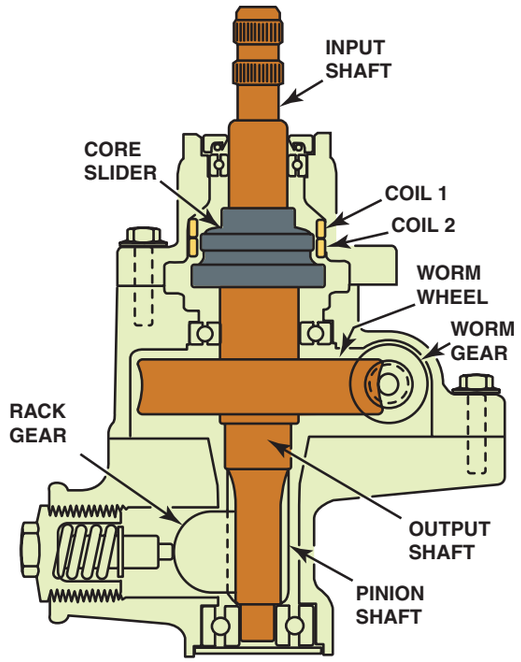

FIGURE 46 A cross-sectional view of a Honda electric power steering (EPS) steering gear showing the torque sensor and other components.

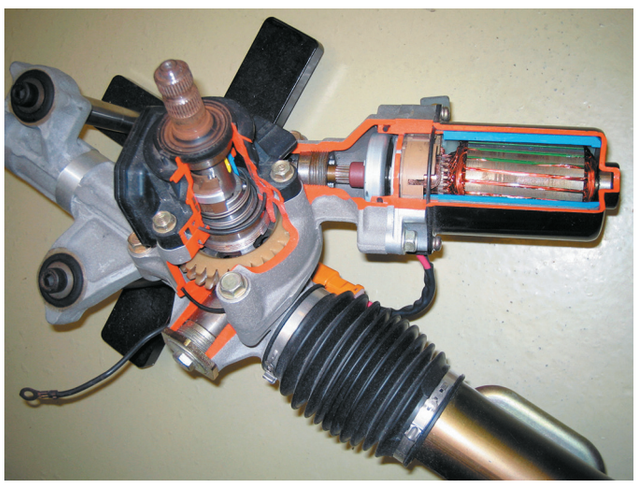

FIGURE 47 Honda electric power steering unit cutaway.

SUMMARY

1. Magnetic lines of force leave the north pole and enter the south pole of a magnet.
2. Magnetic lines of force are called flux lines.
3. Any conductor carrying an electrical current generates a magnetic field around the conductor, and a moving magnetic field across a conductor creates electricity.
4. Like poles repel and unlike poles attract.
5. A brushless DC motor is also known as an AC synchronous motor.
6. Powerful permanent magnets are used in the rotors of DC brushless motors.
7. The operation of motors is performed by the controller, which is capable of switching the voltage and/or the frequency of the current flowing through the stationary windings of the motor.
8. DC-DC converters are used in hybrid electric vehicles to convert the high-voltage battery current into a lower voltage used by the accessories and lighting systems.

3. The high-voltage cables can be easily identified by their distinctive orange color, and contact with them can be avoided.
4. The system main relays (SMRs) disconnect power from the cables the moment the ignition is turned off.

LOCATIONS OF AUXILIARY BATTERIES

● **SEE CHART 1** for a summary of the locations of auxiliary batteries.

As a rule of thumb, the auxiliary battery is usually a flood-type if it is located under the hood and an AGM-type if it is in the trunk area.

WARNING

Power remains in the high-voltage electrical system for up to 10 minutes after the HV battery pack is shut off. Never touch, cut, or open any orange high-voltage power cable or high-voltage component without confirming that the high-voltage has been completely discharged.

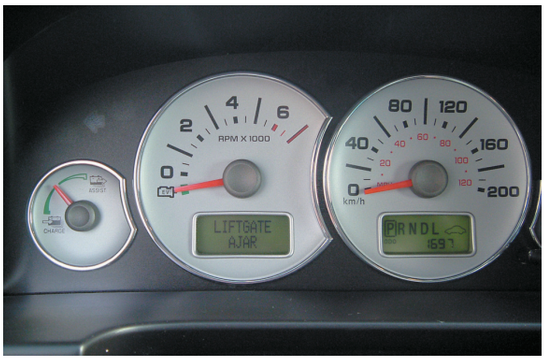

FIGURE 6 The Ford Escape Hybrid instrument panel showing the vehicle in park and the tachometer on "EV" instead of 0 RPM. This means that the gasoline engine could start at any time depending on the state-of-charge of the high-voltage batteries and other factors.

TECH TIP

Silence Is NOT Golden

Never assume the vehicle is shut off just because the engine is off. When working with a Toyota or Lexus hybrid electric vehicle, always look for the **READY** indicator status on the dash display. The vehicle is shut off when the **READY** indicator is off.

The vehicle may be powered by:

1. The electric motor only.
2. The gasoline engine only.
3. A combination of both the electric motor and the gasoline engine.

The vehicle computer determines the mode in which the vehicle operates to improve fuel economy and reduce emissions. The driver cannot manually select the mode.

● **SEE FIGURE 6.**

TECH TIP

High Voltage Is Insulated from the Vehicle Body

Both positive and negative high-voltage power cables are isolated from the metal chassis, so there is no possibility of shock by touching the metal chassis. This design is called a **floating ground.**

A ground fault monitor continuously monitors for high-voltage leakage to the metal chassis while the vehicle is running. If a malfunction is detected, the vehicle computer will illuminate the master warning light in the instrument cluster and the hybrid warning light in the LCD display. The HV battery pack relays will automatically open to stop electricity flow in a collision sufficient to activate the SRS airbags.

HYBRID VEHICLE AUXILIARY BATTERY CHART

VEHICLE	AUXILIARY BATTERY TYPE	AUXILIARY BATTERY LOCATION
Honda Insight Hybrid	Flooded lead acid	Underhood; center near bulkhead
Honda Civic Hybrid	Flooded lead acid	Underhood; driver's side
Honda Accord Hybrid	Flooded lead acid	Underhood; driver's side
Ford Escape Hybrid	Flooded lead acid	Underhood; driver's side
Toyota Prius Hybrid (2001–2003)	Absorbed glass mat (AGM)	Trunk; driver's side
Toyota Prius Hybrid (2004–2007)	Absorbed glass mat (AGM)	Trunk; passenger side
Toyota Highlander Hybrid	Flooded lead acid	Underhood; passenger side
Toyota Camry Hybrid	Absorbed glass mat (AGM)	Trunk; passenger side
Lexus RX 400h Hybrid	Flooded lead acid	Underhood; passenger side
Lexus GS 450h Hybrid	Absorbed glass mat (AGM)	Trunk; driver's side
Chevrolet/GMC Hybrid Pickup Truck	Flooded lead acid	Underhood; driver's side

CHART 1

As a rule of thumb, the auxiliary battery is usually a flood-type if it is located under the hood and an AGM-type if it is in the trunk area.

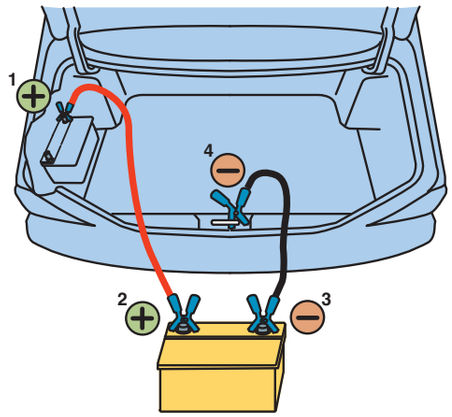

FIGURE 7 Jump starting a 2001–2003 Toyota Prius using a 12-volt supply to boost the 12-volt auxiliary battery in the trunk.

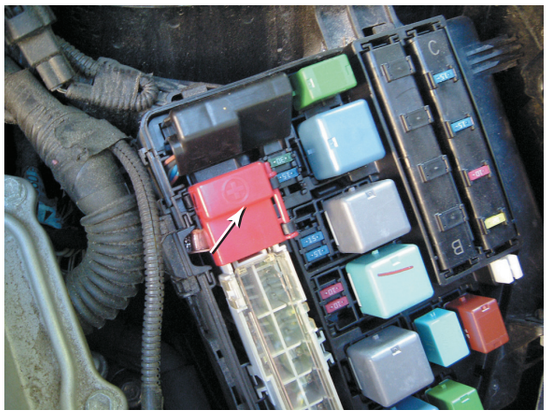

FIGURE 8 The underhood 12-volt jump-start terminal on this 2004+ Toyota Prius has a red plastic cover with a "+" sign. The positive booster cable clamp will attach directly to the vertical metal bracket.

DE-POWERING THE HIGH-VOLTAGE SYSTEM

THE NEED TO DE-POWER THE HV SYSTEM

During routine vehicle service work there is no need to go through any procedures needed to de-power or to shut off the high-voltage circuits. However, if work is going to be performed on any of the following components then service information procedures must be followed to prevent possible electrical shock and personal injury.

- The high-voltage (HV) battery pack
- Any of the electronic controllers that use orange cables such as the inverter and converters
- The air-conditioning compressor if electrically driven and has orange cables attached

To safely de-power the vehicle always follow the instructions found in service information for the exact vehicle being serviced. The steps usually include:

STEP 1 Turn the ignition off and remove the key (if equipped) from the ignition.

CAUTION: If a push-button start is used, remove the key fob at least 15 feet (5 meters) from the vehicle to prevent the vehicle from being powered up.

STEP 2 Remove the 12-volt power source to the HV controller. This step could involve:

- Removing a fuse or a relay
- Disconnecting the negative battery cable from the auxiliary 12-volt battery

STEP 3 Remove the high-voltage (HV) fuse or **service plug** or switch.

WARNING

Even if all of the above steps are followed, there is still a risk for electrical shock at the high-voltage batteries. Always follow the vehicle manufacturer's instructions exactly and wear high-voltage gloves and other specified personal protective equipment (PPE).

FREQUENTLY ASKED QUESTION

When Do I Need to De-Power the High-Voltage System?

During routine service work, there is no need for a technician to de-power the high-voltage system. The only time when this process is needed is if service repairs or testing is being performed on any circuit that has an orange cable attached. These include:

- AC compressor if electrically powered
- High-voltage battery pack or electronic controllers

The electric power steering system usually operates on 12 volts or 42 volts and neither is a shock hazard. However, an arc will be maintained if a 42-volt circuit is opened. Always refer to service information if servicing the electric power steering system or any other system that may contain high voltage.

COLLISION AND REPAIR INDUSTRY ISSUES

JUMP STARTING

The 12-volt auxiliary battery may be jump started if the vehicle does not start. The 12-volt auxiliary battery is located under the hood or in the cargo (trunk) area of some HEVs. Using a jump box or jumper cable from another vehicle, make the connections to the positive and negative battery terminals. ● **SEE FIGURE 7.**

On the 2004+ Toyota Prius vehicles, there is a stud located under the hood that can be used to jump start the auxiliary battery, which is located in the truck. ● **SEE FIGURE 8.**

NOTE: The high-voltage HV battery pack cannot be jump started on most HEVs. One exception is the Ford Escape/Mercury Mariner hybrids that use a special "jump-start" button located behind the left kick panel. When this button is pushed, the auxiliary battery is used to boost the HV battery through a DC-DC converter.