

Chevrolet Volt Battery: An Introduction

Advanced Batteries and the Chevrolet Volt

As the automotive industry transitions from cars and trucks powered primarily by petroleum to vehicles powered by electricity, the heart of this transformation will be the rapid advancement of battery technology.

When the Chevrolet Volt goes into production, targeted for late 2010, it will be powered by a battery pack that delivers up to 40 miles of gasoline- and emissions-free driving.



After extensive testing of different lithium-ion battery solutions, General Motors has a much greater understanding of lithium-ion cells, control hardware and the manufacturability of the battery components needed for the Chevy Volt's battery pack. Like today's conventional powertrains, GM believes the development and assembly of advanced batteries is a core competency. GM is rapidly building capability and resources to support this strategic decision, including assembly of the Volt's battery packs at a facility in the United States. The battery pack will include cells, major electronic components and hardware supplied by LG Chem.

GM's experience as a manufacturer — combined with the battery integration skills and the technical expertise of its suppliers — will result in battery packs that meet the Volt's quality, safety, performance and timing requirements.

Chevrolet Volt Battery: BATTERY 101

Why Lithium-ion is the Right Battery

While the majority of hybrid-electric vehicles (HEVs) on the road today use nickel metal hydride (NiMH) battery technology, the Chevrolet Volt extended-range electric vehicle (E-REV) will be powered by a 16kWh lithium-ion battery pack manufactured by GM and comprising more than 200 lithium-ion cells. Lithium-ion batteries provide nearly two to three times the power of a NiMH battery in a much smaller package.

Contrary to popular thinking, all lithium-ion chemistries are not alike. In fact, lithium-ion is a family of dozens of chemistries with different capabilities and performance characteristics. The characteristics required for automotive applications differ greatly from consumer electronics, such as laptop computers.

Lithium-ion battery chemistry is the fastest-growing and most promising battery chemistry for several reasons, including:

- Superior specific energy and power
- Long life
- High efficiency
- Durability
- Lower initial material cost and fewer replacements
- High cell voltage means fewer cells are needed to give desired voltage range
- Higher energy-to-weight ratio, an important consideration in automotive applications since excess mass affects efficiency
- Configurable into a wide variety of shapes and sizes so as to efficiently fill available space in the devices they power
- Suffers little or no memory (lazy battery) effect, which can occur when batteries gradually lose their maximum energy capacity if they are repeatedly recharged after being only partially discharged
- Encounters low loss of charge (also known as self-discharge) when not in use

Fast Facts

- The Chevrolet Volt features a 16kWh lithium-ion battery pack that weighs less than 400 pounds (181.4 kg).
- The battery pack is made up of multiple linked battery modules. All together the modules contain more than 200 battery cells.
- The battery pack is T-shaped, allowing designers to create unique vehicle designs across multiple brands. The battery's floor, or "pan", is actually part of the vehicle's structure.
- The battery modules and packs will be assembled by GM at a facility in Michigan.



- For up to the first 40 miles of driving, the Chevrolet Volt's fully charged lithium-ion battery pack powers an electric motor. Additional energy captured during vehicle braking (the Volt is equipped with Regenerative Brakes) is converted into electricity and stored in the battery pack.
- Control systems within the battery pack prevent it from discharging below its minimal state of charge.
- The vehicle seamlessly switches to Extended-Range mode once the battery has reached its minimal state of charge. In this secondary mode, a small flex-fuel powered engine-generator operates at one of several optimized speeds, turning the generator and producing the electricity needed to power the Volt's electric motor under most driving conditions.
- The battery will continue to store energy from regenerative braking and any unused electricity created during extended-range mode operation. This energy will be used to supplement the engine-generator to provide peak performance when it is required.
- The engine generator does not fully recharge the battery because the objective of the Volt is to minimize or eliminate the use of petroleum. The only way to fully recharge the battery is to plug the vehicle into an electrical outlet. The cost of energy from electricity is about 1/6 the cost of gasoline so plugging in the vehicle to charge the battery provides the lowest operating cost.

How the Battery Propels the Volt

- The Volt's lithium-ion battery is controlled so that it operates within a state-of-charge window at any given time. Controlling the battery in this way avoids fully charging or discharging the battery which can shorten the life of the battery.

Recharging the Battery

- The Chevrolet Volt battery is recharged by plugging the vehicle into a household-type electrical outlet. Recharging takes about eight hours using a 120V outlet and less than three hours on 240V.

Safety

- The LG Chem cell uses a manganese-based cathode chemistry with additives to improve battery life under high-temperature conditions.
- Numerous measures have taken to help prevent the safety issues – namely short circuiting and overheating – that have occurred in lithium-ion batteries used in consumer electronics. LG Chem's exclusive Safety Reinforced Separator consists of semi-permeable membranes separating the electrodes in the cells, which are mechanically and thermally superior to commonly used separators.
- Primary, as well as backup battery pack controls, regulate voltage, current state of charge and temperature.
- Rigorous testing of lithium-ion battery packs in GM's battery labs and on-road in early engineering development cars has not revealed any safety or performance issues.

Durability

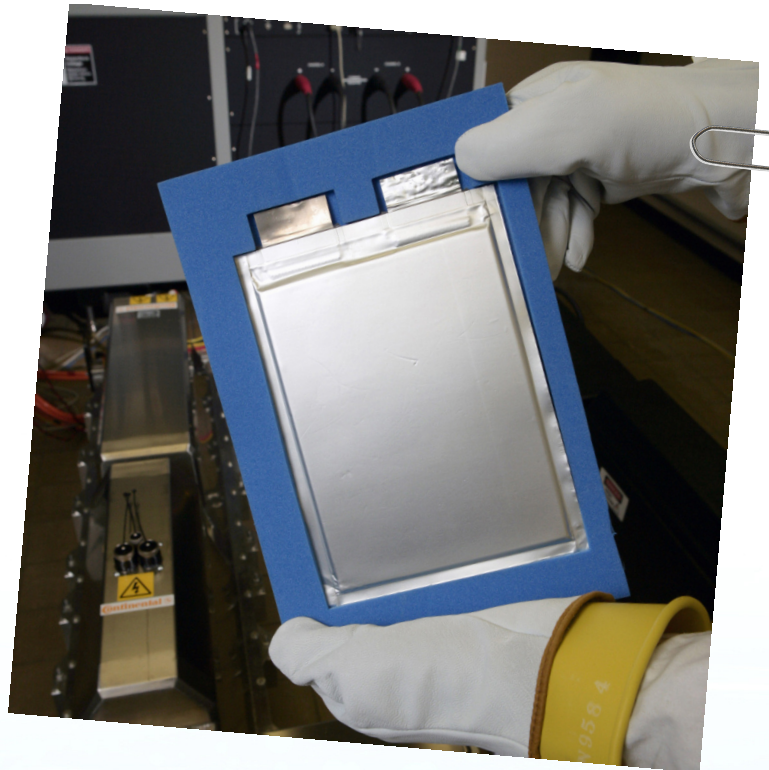
- Automotive batteries operate in a rugged and hostile environment with the expectation they will last the life of the vehicle: GM is currently testing battery packs in the lab and engineering development vehicles. This testing will help GM better understand how these packs will operate in real-world driving conditions, including extreme hot and cold weather climates and road.
- The Chevrolet Volt battery cell is encased in a polymer-coated aluminum package. This thermally efficient and safe package is designed to be more forgiving under harsh conditions and help reduce the cost and complexity of the battery cooling system.

The Battery Cell

A battery cell delivers electric current as the result of an electrochemical reaction. Electrical current is carried by lithium ions, from the positive electrode (cathode) to the negative electrode (anode) during charging, and from negative to positive during discharging. The ions are small and reside within the crystal structure of the electrode materials.

Different electrode materials have different current-carrying capacities, and this affects the storage capacities of the cells.

Each of the Volt's more than 200 cells is a "building block" within the larger battery module and pack. An individual cell is about the size of a 5-inch by 7-inch (12.7-cm by 17.7-cm) photo frame, is less than a quarter-inch thick and weighs nearly a pound.

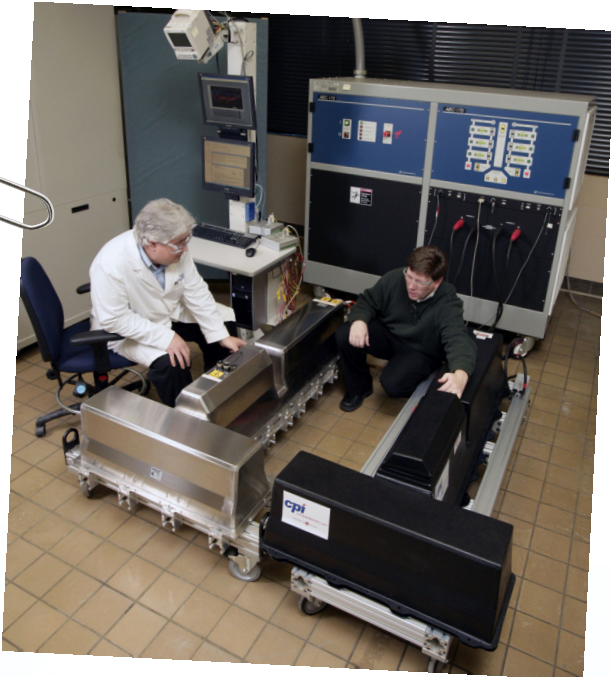


Each Volt's battery cell contains a carbon anode (the negative electrode), a manganese-based cathode (the positive electrode) and a safety-reinforced separator, which provides the medium for the transfer of electrical charge ions between the anode and the cathode inside the battery cell.

The protective polymer-coated aluminum cover encases the cell, helps prevent gas permeation and improves battery cooling efficiency. Tabs at the top of the cell are used to link the cells within the module.

The Battery Module

Numerous designs are possible for assembling cells into a battery pack for an electric or hybrid vehicle. A modular design is used in most cases, with a number of cells packaged together into a unit called a “module.” Controls are used to monitor the voltage and current of a cell to determine when to charge or discharge. Multiple modules are combined into a battery pack sized to match the requirements of the vehicle. The same modules could be used in a variety of different battery packs.



- Temperature sensors allow for inlet/outlet coolant measurement
- Manifolds and coolant lines allow for heat exchange with the cell surfaces
- Connectors allow for single point entry/exit of high voltage loads
- Battery cover/enclosure protects and insulates the pack from the ambient environment



Design

- Current layout is in the shape of a T
- Steel tray, plastic cover

Integration

- Pack is part of the vehicle structure
- Pack is an underbody-mounted component

The Battery Pack

A battery pack is the final assembly used to store and discharge electrical energy for a hybrid or electric vehicle. The Volt battery pack consists of multiple modules, configured in series, retained within an enclosure for underbody installation. Components for the control and monitoring of discharge or charge energy are also housed within the pack.

- Modules are clamped to a battery tray and joined by flexible interconnects
- Relays and mechanical assemblies allow for automated or manual control of subassembly output voltage

Looking Ahead

Future generations will produce batteries with:

- Less cost due to better use of parts commonality (less parts)
- Higher energy density, more efficient use of packaging
- Better cold-weather performance
- More efficient insulation/energy conservation
- Lower mass
- Increased power performance

Battery 101: Commonly Used Terms

(Source: *International Energy Agency*)

Advanced Technology Partial Zero Emission Vehicle (AT-PZEV):

As defined by the California Air Resources Board (CARB), a vehicle that uses electric drive components to help the industry introduce Zero Emission Vehicles (ZEVs) such as Electric Vehicles (EV) or Fuel Cell Vehicles (FCVs).

Battery cell:

The smallest, most discreet repeating unit of a battery. A cell contains an anode, cathode and electrolyte to deliver electric current as the result of an electrochemical reaction.

Note: In common usage the term “battery” is often applied to a single cell. However, it is more accurate to use the term “battery cell” when referring to a single cell.

Battery module:

A group of interconnected electrochemical cells in a series and/or parallel arrangement, physically connected in an enclosure as a single unit, constituting a direct-current voltage source used to store electrical energy as chemical energy (charge) and to later convert chemical energy directly into electric energy (discharge). The electrochemical cells are electrically connected in a series/parallel arrangement to provide the module’s required operating voltage and current levels.

Battery pack:

A completely functional system including battery modules, battery support systems and battery specific controls. A combination of one or more battery modules, possibly with an added cooling system, very likely with an added control system. A battery pack is the final assembly used to store and discharge electrical energy in a HEV, PHEV or EV.

Battery round trip efficiency: The ratio of the electrical output of a secondary cell, battery module or battery pack on discharge to the electrical input required to restore it to the initial state of charge under specified conditions.

Battery state of charge: The available capacity in a battery expressed as a percentage of rated nominal capacity.

Capacitance: The ratio of the charge on one of the conductors of a capacitor to the potential difference between the conductors.

Capacitor: A device that consists of two conductors insulated from each other by a dielectric and which introduces capacitance into a circuit, stores electrical energy, blocks the flow of direct current, and permits the flow of alternating current to a degree dependent on the capacitor’s capacitance and the current frequency.

Charge: The conversion of electrical energy – provided in the form of current from an external source – into chemical energy within a cell or battery.

Charge factor: The factor by which the amount of electricity delivered during discharge is multiplied to determine the minimum amount required by the battery to recover its fully charged state.

Charge rate: The current at which a battery is charged.

Charger: An energy converter for the electrical charging of a battery consisting of galvanic secondary elements.

Charge depletion (CD): When a rechargeable electric energy storage system (RESS) on a PHEV, EV or extended range EV is discharged.

Charge depletion (CDB): When a rechargeable energy storage system (RESS) is discharged, but it is not the only power source moving the vehicle forward. A separate fuel and energy conversion system works in tandem with the RESS to provide power and energy to move the vehicle as charge of the RESS is completed.

Charge depletion (CDE): When an RESS is discharged, and continuously provides the only means of moving the vehicle forward (all-electric operation).

Charging equalizer: Device that equalizes the battery state of charge of all the modules in an EV during charging. With this measure, the voltage of all the batteries will rise equally and the battery with the smallest capacity is not overcharged.

Controller: An element that restricts flow of electric power to or from an electric motor or battery pack (module, cell). This controls torque and/or power output, as well as helping to maintain battery life and/or temperature control.

Current: The rate of transfer of electricity. The unit of measure is the Ampere.

Cut-off voltage: The cell or battery voltage at which the discharge is terminated.

Cycle: A sequence of a discharge followed by a charge, or a charge followed by a discharge of a battery under specified conditions.

Depth of discharge: The percentage of electricity in Ampere-hours that has been discharged from a secondary cell or battery relative to its rated nominal fully charged capacity.

Direct-current motor: An electric motor energized by direct current to provide torque.

Discharge: The direct conversion of the chemical energy of a cell or battery into electrical energy and withdrawal of the electrical energy into a load.

Discharge rate: The rate, usually expressed in Amperes, at which electrical current is taken from a battery cell, module or pack.

Electrochemical cell: The basic unit able to convert chemical energy directly into electrical energy.

Energy density: The ratio of energy available from a cell or battery relative to its volume.

Equalizing charge: An extended charge to ensure complete charging of all cells in a battery.

Extended-range electric vehicle: An autonomous road vehicle primarily using electric drive provided by a Rechargeable Energy Storage System (RESS)(e.g. battery pack), but with an auxiliary onboard electrical energy generation unit and fuel supply used to extend the range of the vehicle once RESS electrical charge has been depleted. The Chevrolet Volt is an example of an extended-range electric vehicle.

Lithium ion: Lithium ion is a family of battery chemistries. Lithium-ion batteries are a type of rechargeable battery in which the lithium ion moves from the anode to the cathode during discharge and from the cathode to the anode when charging. Lithium ion is currently one of the most popular types of battery for portable electronics, with one of the best energy-to-weight ratios, no memory effect, and a slow loss of charge when not in use. Lithium-ion batteries are seen as the next enabling technology in vehicle applications.

Nickel Cadmium (NiCd): Nickel cadmium was a common battery chemistry used in many EVs of the '90s. It is no longer commonly used.

Nickel Metal Hydride (NiMH): Nickel metal hydride was a common commercial battery chemistry in the late 1990s HEVs and continues to be used today. In consumer electronics, this battery chemistry has been mostly replaced by lithium-ion battery chemistry.

Normal charging: The most common type and location for charging of a PHEV or EV battery pack necessary to attain the state of maximum charge of electric energy.

Peak power: Peak power attainable from a battery, electric machine or engine in the drive system used to accelerate a vehicle. Peak power is expressed in kW.

Power density: The ratio of the power available from a battery to its volume in liters.

Range: The maximum distance traveled by a vehicle, under specific conditions, before recharging is necessary. The Chevrolet Volt is expected to achieve an all-electric range up to 40 miles before an onboard engine generates additional electricity to extend the range several hundred additional miles.

Rechargeable electric energy storage system (RESS):

Battery packs, flywheels and ultracapacitors are examples of systems that could be repeatedly recharged from the grid, regenerative braking or an electric generator. The battery packs are later discharged in order to power an electric machine or move a vehicle.

Regenerative braking: A means of recharging the battery by using energy produced by braking the vehicle. Unlike normal friction brakes, where energy is lost in the form of heat created by friction in braking, regenerative braking reduces energy loss by returning it to the battery, resulting in improved range.

Smart charging: Computerized devices that monitor the battery so that charging is at the optimum rate and battery life is prolonged.

Specific energy (or gravimetric energy): The energy density of a battery expressed in Watt-hours per kilogram.

Specific energy (or gravimetric power density): The rate at which a battery can dispense power measured in Watts per kilogram.

State of charge: See battery state of charge.

Useable capacity: The number of Ampere-hours (or kW hours) that can be withdrawn from a battery pack. Useable capacity is less than nominal capacity.

Voltage efficiency: The ratio of the average voltage during discharge to the average voltage during recharge under specified conditions of charge and discharge.

Watt-hours per kilometer: Energy consumption per kilometer at a particular speed and condition of driving.

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