

Johnson Controls Power Solutions Lithium-ion Fact Sheet

What is lithium?

Lithium is the lightest metal found in nature, in fact only two elements have lower atomic weight – hydrogen and helium. Lithium is a popular choice for use in batteries because it has the highest electrochemical potential. Its light weight and high energy and power densities make it ideal for vehicle applications where weight affects efficiency and volume affects ease and cost of packaging.

What is a lithium-ion battery?

A lithium-ion battery is a type of rechargeable battery in which lithium ions move between the anode and cathode. Lithium-ion (Li-Ion) batteries exhibit no memory effect, a condition that causes a battery to gradually lose its maximum discharge capability after repeated cycling.

Benefits of Lithium-ion Batteries

- Ultra light weight for reduced overall vehicle weight and increased fuel efficiency.
- Zero memory effect extends the life of the battery indefinitely to move from recharge to discharge without decreasing maximum charge potential.
- Compact design maximizes space in the power train.

Lithium-ion vs. Nickel-Metal Hydride

- 30 percent smaller
- 50 percent lighter
- Two to three times the power for the same mass, greater acceleration and fuel efficiency
- Three to four times the energy for the same mass, greater electric-only vehicle range and fuel efficiency
- Two to three times faster recharge
- Enhanced cycle life (battery operating life)

Johnson Controls Lithium-ion Batteries

Johnson Controls is a full-service supplier capable of executing the entire battery system, from design to manufacturing.

- Mechanical Subsystem
- Electrochemistry/Cell
- Battery Management System Software & Hardware
- Electronics
- Electrical Subsystem
- Thermal Management Subsystem

Johnson Controls Lithium-ion Chemistry

Our Li-Ion chemistry is available in a cell portfolio ranging in amp-hour capacity from six all the way up to 45 amp-hours. Each cell regardless of Ah capacity has a nominal voltage rating of 3.6. This broad range of capacities allows us to service our customers' needs for the complete spectrum of HEV including Plug-In Hybrid Electric Vehicles (PHEVs) and even pure electric vehicles. The cell construction is a spiral wound cylindrical format. The cathode utilizes nickel cobalt aluminum (NCA) active material; the anode is graphite based. The electrolyte through which the lithium ions shuttle is an organic solution containing conductivity-enhancing salts.

Johnson Controls Lithium-ion Battery Safety Measures

Johnson Controls has purposefully built four layers of redundancy into each lithium-ion battery system to ensure safety. Safety measures have been built into the complete battery system, not just the physical cells, to create the safest environment for this technology to date.

System Software	System Hardware	Cell Hardware
<p>Measurement of battery system characteristics</p> <ul style="list-style-type: none">• Cell/Pack voltage• Temperature• Current• Device feedback• Sensor validity• If fault or failure is detected appropriate control actions is taken	<p>Electronics Hardware</p> <ul style="list-style-type: none">• Over-Voltage protection• Over-Temperature• Cell balancing circuitry• Fusing for over-current• Contactors• High voltage service disconnect <p>Mechanical Hardware</p> <ul style="list-style-type: none">• Optimized thermal management• Structural protection	<p>Key Design Features</p> <ul style="list-style-type: none">• Pressure vent• Current interrupt device• Separator materials• The system structure is also designed to contain any vented materials

Lithium-ion Automotive Battery Manufacturing: Nersac, France and Holland, Michigan, US

Johnson Controls-Saft joint venture opened the world's first manufacturing facility for lithium-ion hybrid applications, including plug-in fuel cell and electric vehicles, on Jan. 31, 2008 in Nersac, France. Lithium-ion hybrid power systems technology is considered the next generation of HEVs.

The 2009 Mercedes Benz S-class mild hybrid, the first serial production HEV to utilize lithium-ion technology, is powered by Johnson Controls cell and battery system technology.

We have announced plans for our first U.S. li-ion facility in Holland, Michigan. We expect to begin construction in late 2009, and the plant will be in operation before the end of 2010. At full capacity the plant will employ 550 people, with annual production of 15 million cells.

Lithium-ion for the Development of PHEVs

Johnson Controls-Saft is the exclusive supplier of Ford's first Plug-In Hybrid, to be available to consumers in 2012. We are also partnering with Ford and Southern California Edison (SCE) to build and test a fleet of PHEV Ford Escapes. Johnson Controls Li-Ion PHEV battery modules on bench testing at SCE accumulated the equivalent of 180,000 road miles before falling below the minimum required peak power. PHEVs can reduce petroleum fuel consumption by approximately 60 percent to 100 percent.