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AFS Trinity Power Extreme Hybrid™ System: the lower cost, higher performance plug-in hybrid alternative

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What is the Extreme Hybrid™ system?

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- US Patent 7,740,092, issued June 22, 2010 — *Method and apparatus for power electronics and control of plug-in hybrid propulsion with fast energy storage*
- Extreme Hybrid™ is an energy storage system that uses off-the-shelf energy batteries, ultracapacitors, and proprietary power electronics
- It replaces the battery pack in a Plug-in Hybrid

Extreme Hybrid™ is a system solution to the battery problem

Attributes of the Extreme Hybrid™ system

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- Uses ultracapacitors for higher power (acceleration, braking)
  Uses energy batteries for low power only (cruise)
- Battery pack is much smaller and less expensive than battery pack it replaces
- System protects battery pack from damage and greatly improves the performance of the vehicle

Extreme Hybrid™ is a system solution to the battery problem

Historical origins

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- 1994-1995 Trinity Flywheel (one of AFS Trinity's predecessors), worked with GM, Aerovironment, and LLNL on a new generation vehicular energy storage program (PNGV)
- A high power flywheel built by Trinity and powered by Aerovironment electronics was installed in a GM chassis and tested at LLNL
- The goal was to solve the problem of battery damage for electric vehicles and plug-in hybrids
- The resulting flywheel technology was not sufficiently mature to be deployed and an alternative, ultracapacitors, were 100 times more expensive than they are today
- The dual energy storage solution (batteries + ultracaps) remained unproven until AFS Trinity reduced it to practice when it revisited the problem 10 years later

The problem we are solving has existed for a long time

The Extreme Hybrid™ Powertrain

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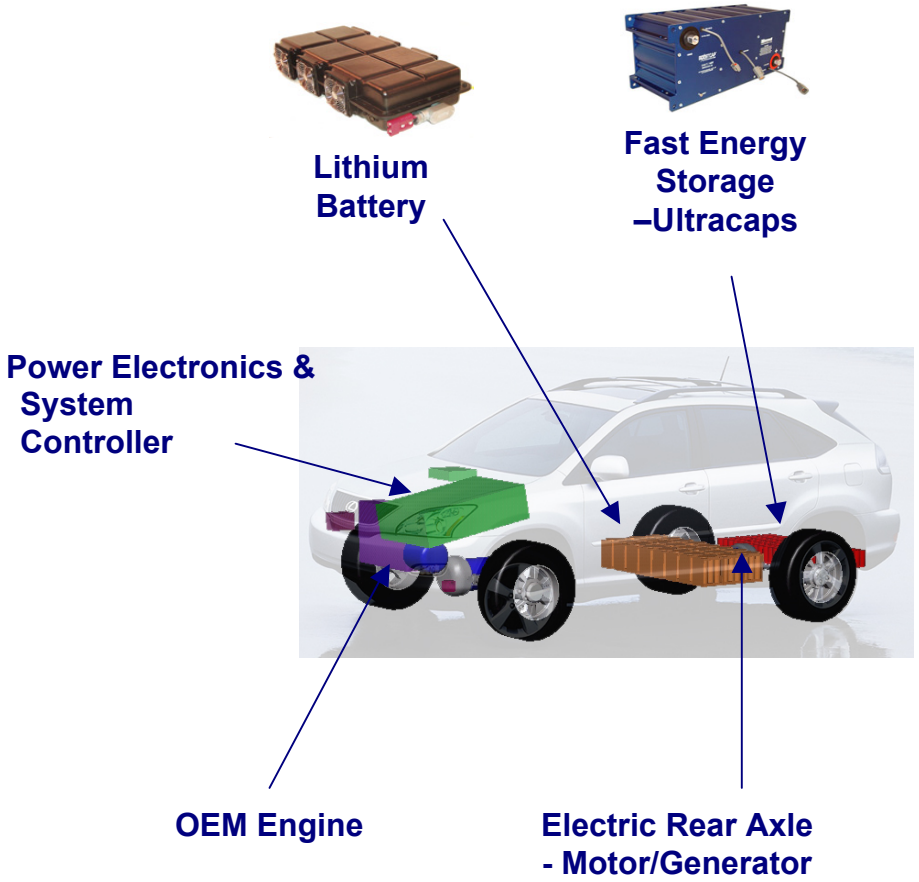

- PHEV recharged from the grid
- Platform flexibility: Series/Parallel/Power Split
- Multimode: electric only, engine only, or hybrid
- Dual energy storage
- Commercial-off-the shelf components
- AFS Trinity Patented Control and Power Electronics*

*AFST has filed six new patent applications specific to the Extreme Hybrid™ Powertrain

Patent no. 7,740,092 issued June 2010

AFST has 10 other energy storage patents, 37 other active U.S. applications and more than 50 additional international patent applications pending

Extreme Hybrid™ is more than a component or subassembly;
It enables a wide range of plug-in hybrid system solutions

Battery Testing with Ultracapacitor Protection

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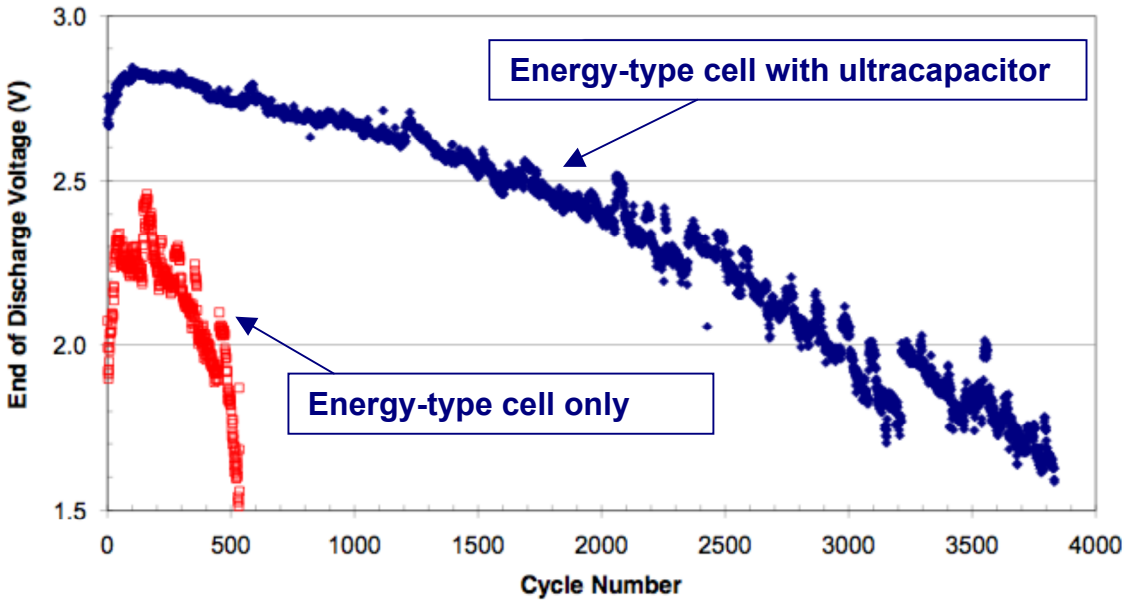
Energy Type, C2, Battery Cycle Tested with and without Ultracapacitor Protection



- Average discharge rate was C1
- C5 discharge pulses at 20% duty factor
- Cells were recharged at C/2 rate
- Depth of discharge was 80%

- Protected system is used in the Extreme Hybrid™ prototype on the road since December 2008

Life of the protected cells (up to 3,833 cycles) was 6x - 7x greater than that of the unprotected cells (481 to 611 cycles)

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An Extreme Hybrid™ Energy Storage System could cost about half what a plug-in battery pack would cost that does the same job

There are three dimensions to this cost advantage:

1) The battery pack does not need to be oversized to avoid high power operation at a low state of charge

2) Less expensive low C-rate batteries may be used
   - ❑ C2-C4 instead of more expensive C10
   - ❑ C2-C4 batteries cost 20% less

3) The Extreme Hybrid's batteries are protected against high current that can shorten battery life

A key attribute of the Extreme Hybrid™ System — *it could cost about half what a conventional battery pack would cost that can do the same job*

Ultracapacitor vs. Battery Price Trends

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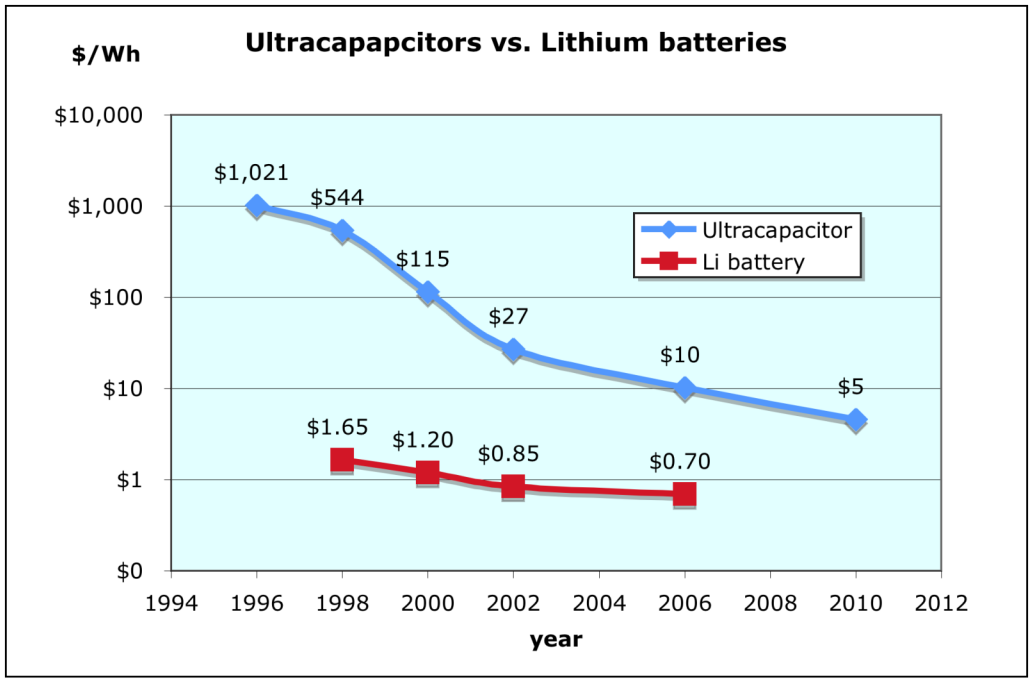

- Until recently ultracapacitors were prohibitively expensive

  Sources: Maxwell, ElectronicsWeekly.com March 1, 2006;
  DOE EERE, Tien Duong, Research Needs Transportation Perspective, April 2, 2007

- Ultracapacitor prices have come down much faster than battery prices

  The chart uses a log scale!

Since 1995 ultracapacitor prices have dropped by more than 99%
Lithium battery price progress has been much slower

1st dimension of Extreme Hybrid™ cost savings: Using fewer batteries to go the same distance

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Year	Pack cost (without Extreme Hybrid™)	Extreme Hybrid™ system cost	Savings
2010	$11,200	$8,443	24.6%
2011	$10,304	$7,639	25.9%
2012	$9,480	$6,918	27.0%
2013	$8,721	$6,271	28.1%
2014	$8,024	$5,690	29.1%
2015	$7,382	$5,168	30.0%
2016	$6,791	$4,697	30.8%
2017	$6,248	$4,273	31.6%
2018	$5,748	$3,889	32.3%
2019	$5,288	$3,543	33.0%
2020	$4,865	$3,230	33.6%

- Conventional Plug-in Battery Pack (without Extreme Hybrid™)
  16 kWh total / 8 kWh usable
  $700/kWh in 2010
  Improves 8%/yr
- Extreme Hybrid™ System
  - Battery
    8 kWh total / 8 kWh usable
    $700/kWh in 2010
    Improves 8%/yr
  - Ultracap: $1843 in 2010
    Improves 15%/yr
  - Electronics: $1000 in 2010
    Improves 15%/yr

The Extreme Hybrid™ system will be cheaper than battery-only alternatives, and its cost advantage, as a percentage of battery pack cost, is expected to continue to improve even as battery prices drop

2nd dimension of Extreme Hybrid™ cost savings: Using fewer batteries that cost 20% less

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Year	Pack cost (without Extreme Hybrid™)	Extreme Hybrid™ system cost	Savings
2010	$11,200	$7,323	34.6%
2011	$10,304	$6,608	35.9%
2012	$9,480	$5,970	37.0%
2013	$8,721	$5,399	38.1%
2014	$8,024	$4,888	39.1%
2015	$7,382	$4,430	40.0%
2016	$6,791	$4,018	40.8%
2017	$6,248	$3,648	41.6%
2018	$5,748	$3,315	42.3%
2019	$5,288	$3,014	43.0%
2020	$4,865	$2,743	43.6%

- Conventional Plug-in Battery Pack (without Extreme Hybrid™)
  16 kWh total / 8 kWh usable
  $700/kWh in 2010
  Improves 8%/yr
- Extreme Hybrid™ System
  - Battery
    8 kWh total / 8 kWh usable
    $**560**/kWh in 2010
    Improves 8%/yr
  - Ultracap: $1843 in 2010
    Improves 15%/yr
  - Electronics: $1000 in 2010
    Improves 15%/yr

With less expensive, low C-rate batteries the Extreme Hybrid™ cost advantage is even greater

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3rd Dimension of Extreme Hybrid Cost Savings: The batteries are protected against high currents that can shorten battery life

- All batteries degrade faster when subjected to high current
- In the Extreme Hybrid system the ultracaps, not the batteries, handle the high currents of acceleration and regenerative braking
- Thus, battery replacement will tend to be less frequent

Less frequent battery replacement means lower life cycle cost

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Summary:
If, for example, the 2011 Chevrolet Volt had the AFS Trinity Extreme Hybrid™ drivetrain . . .

- The cost of the Volt could be reduced by $3,500
  - Fewer batteries would be used
  - Fewer batteries would have to be recycled later
- The battery pack would be protected from aggressive driving
  - Battery life would not be reduced by high power events
- Performance is increased significantly without impacting the batteries
  - Better 0 - 60 mph acceleration
  - Better merging and passing on freeways

The Extreme Hybrid™ System increases
Plug-in Performance without compromising battery life