Building an EV

TOPIC #3

What kind of batteries do I use?

http://www.evalbum.com

http://www.diyelectriccar.com

Topics

- **What is the best car to convert?**
- **What kind of motor should I use?**
- ***What kind of batteries do I use?***
- ***What are controllers?***
- **Where can I buy the parts?**
- **Are there any books on how to do a conversion?**
- **How far can I go on a charge?**
- **How fast will it go?**
- **How much will it cost?**
- **How to make battery cables?**
- **How do I charge the batteries?**
- **How to add power brakes and power steering?**
- **How to add safety?**
- **How to add air conditioning?**
- **How about solar panels?**
- **Is there anyway to make it recharge itself while driving?**
- **How about adding a generator?**
- **How about EV kits?**

What kind of batteries do I use?

- **Lead Acid Batteries - 100+ year old technology**
  A beginners guide to Lead Acid batteries for use in EV's.

  Lead Acid Batteries are the most tried and tested battery for EV applications, the low upfront cost and their resistance to abuse means they are the battery of choice for most EV conversions. For use in any EV the only lead acid battery that should be considered is a deep cycle.

What kind of batteries do I use?

- **Flooded wet cell**: this is perhaps the most common battery type for use in most road going EV's. The most common brands being Trojan, US battery, although several others exist. These are typically used in marine, RV, golf cart, and forklift applications. Flooded wet cell batteries are composed of thick lead plates submerged in a sulfuric acid/distilled water mixture. they come in 6volt, 8v, and 12v, and, some industrial units are available in 24v or 36v.

  Flooded wet cell batteries typically have the highest AH (amp hour) rating, meaning they can go the furthest distance, but are somewhat limited at how fast they can release their energy. Since they are specifically made for deep cycling applications they tend to have a long cycle life compared to other batteries that focus more on producing amps. This makes them better suited to commuting than competition.
- Easy to recharge – Bring to 2.45 volts per cell and hold

What kind of batteries do I use?

- **AGM**: The absorbed glass mat battery is exactly that. Several lead plates are stacked with a thin fiberglass mat between each layer. This mat is saturated in an acid mixture, that completes the reaction to create voltage. AGM batteries are manufactured by Optima Orbital/Exide and Trojan as well as others

  The AGM is typically not of quite as high of an amp hour rating, as the flooded type, but has many advantages, that make it a very desirable battery as well.
  The AGM is by it's design very resistant to vibration, and even if broken open cannot leak it's acid mixture because it is held within the fiberglass mat like a sponge, that is below it's saturation point, so it will not drip.
  The AGM can be charged, and discharged at very high amps without damage to the battery. This makes the AGM well suited for competition use, as well as being suitable for commuter use.
  The AGM is a truly maintenance free battery, requiring nothing but proper charging for the life of the battery.

What kind of batteries do I use?

- **Comparison of Alternates to Lead-Acid Batteries**

The table below compares the basic lead acid batteries to other technologies below.

Battery Technology	Energy Density (Wh/Kg)	Peak Power (W/Kg)	Cycles @ DoD	Cost $US per KWh	Availability
Lead Acid	30-40	150-200	300 @ 80%	100-250	Yes
Lithium	100-150	<1000	600-1200 @ 100%	1500 - 3000	Some...
LiFePo4	100	<1000	1000 @ 80%, 2000 @ 60%, 5000 @ 20%	310 - 1200	TS have large format cells ex China
Ni-Mh	50-80	200-1000	600-1200 @ 100%	1500-3000	Small cells only
Ni-Cd	20-50	100-1000	800-3000 @ 100%	800-1000	Limited
Ni-Zn	55-65	500-800	300-500 @ 100%	150-500	Not yet

What kind of batteries do I use?

- **Lithium (Li) Based Battery Technology** Lithium batteries are planned for all the commercial EVs in design. They are known for their high power to weight density, long cycle life and relatively high power output. They are currently at high cost, and have a reputation for safety issues.

What kind of batteries do I use?

- **Lithium Iron Phosphate (LiFePo4):** Summary: Good for EV apps. Phosphate based technology possesses superior thermal and chemical stability which provides better safety characteristics than those of Lithium-ion technology made with other cathode materials. Lithium phosphate cells are incombustible in the event of mishandling during charge or discharge, they are more stable under overcharge or short circuit conditions and they can withstand high temperatures without decomposing. When abuse does occur, the phosphate based cathode material will not burn and is not prone to thermal runaway

  Some excellent test results of individual cells http://zeva.com.au/tech/LiFePO4.php and http://zeva.com.au/tech/headway/. Currently in production.

What kind of batteries do I use?

- **Lithium Cobalt Dioxide (LiCoO2), Nickel-cobalt-manganese, Nickel-cobalt-aluminum**
  Summary: Generally unsafe for EV apps due to thermal runaway issues. The cobalt manganese, and cobalt aluminum are slightly less prone to thermal runaway. The use of Cobalt is also associated with environmental and toxic hazards.
  source

What kind of batteries do I use?

- **Lithium Manganese Oxide (LiMn2O4)** Summary: Generally unsafe for EV apps, although it may be managed.
  Lithium Manganese provides a higher cell voltage than Cobalt based chemistries at 3.8 to 4 Volts but the energy density is about 20% less. It also provides additional benefits to Lithium-ion chemistry, including lower cost and higher temperature performance. This chemistry is more stable than Lithium Cobalt technology and thus inherently safer but the trade off is lower potential energy densities. Lithium Manganese cells are also widely available but they are not yet as common as Lithium Cobalt cells. Manganese, unlike Cobalt, is a safe and more environmentally benign cathode material.

What kind of batteries do I use?

- **Lithium Titanate:** Summary: Future promising technology.
  This seems to a promising technology that has been proposed by EnerDel with some successful testing. No near term production plans.

What kind of batteries do I use?

- **Battery Formats: Cylindrical, Prismatic (square), or polymer (flat packs):** Cylindrical seems to be the most popular with the standard being the 18650 which looks similar to a AA battery, but is slightly larger. 18650s have power up to about 2500 mAh. The Tesla EV has about 6500 of these 18650 cells. The next sizes up are 26650 and 38650, which look like bloated D cells. The larger sizes are probably more practical for EVs.

  The numbers associated with the round lithium cells refer to the dimensions: 18650 = aabb0, where aa is the diameter in millimeters, bb is the height in millimeters.
  Prismatic batteries are the tall square type are known to have the problem of low current rate like 3C, which may not be enough for EVs.

  Lithium polymer are generally packaged in the flat-packs. LionEV previously used these types. Polymer flat packs seem to be the cheapest (near $1/Wh), but are generally limited to 5C.

What kind of batteries do I use?

- **Battery Management Systems for lithium:** Lithium batteries should have a battery management system to manage the charge into the battery and monitor the battery life.
  Lithium batteries can not tolerate overcharging and hence should not be trickle charged.

  See the related thread about Battery Management Systems for more information.

What kind of batteries do I use?

- **Current vendors and cost:** {May need to separate distributors from manufacturers.}
  A123 does not sell to the public, but Dewalt packs can be disassembled to obtain cells. GM favorite for the upcoming Volt EV.
  Headway Unknown if there are direct sales channels to the public, buyer beware.

  Batteryspace sells a pack 30V 20Ah (10x2R Pack, 600Wh, 45A rate) for $864 (10.2KWh @ $14688)

  Ebay Ping is only selling on ebay, but offers a pack with BMS: 48V 20AH for $840, incl shipping. (10 packs = 9.6KWh @ $8400). Ping doesn't recommend series/paralleling of pack. Not sure of who manufacturers the cells, and no cell data. Here is a testimonial on a bike. Currently Ping does not sell batteries (June 2008).

  Elite Power Solutions Distributor of Thundersky LiFePo4 batteries located in Phoenix, Arizona. Sell battery/charger/BMS packages.

  EV-Power (Australia) sells packs of 18650s

  Free International Limited has a web site with prismatics

  HiPower, Shangdong China, produces li prismatic similar to Thundersky bricks.

  HuanYu Manufactures and sells cells to the public

  International Battery Distributor of what is believed to be Thundersky batteries (source).

  LiFeBATT Manufactures 40138 3.3V 10Ah cell and assembles then into modules, complete with BMS and retail pricing 14410-HPS = $3K 1440Wh ($21K/10KWh). The 144V 10Ah modules are connected in parallel to create any capacity required. For example, 7 X 14410-HPS connected in parallel = 144V 70Ah 10kWh pack. In order to preserve the life, to in excess of 3,000 cycles, LiFeBATT recommend Max Continuous Discharge of the 70Ah pack be limited to 500A and 900A peak for 10 seconds. Of course, if you need higher Amps, increase the number of parallel modules. The warranty is 3 years or 3,000 cycles, whichever the sooner, for EV applications.

  LionEV Distributor. Believe these are Chinese made. Buyer beware, there are not a lot of known users of these batteries

  K2 Energy (made by DLG batteries in Shanghai) offers a LFP200ES 12.8V 16Ahr module for $249 (10KWh @ $12.2K)

  Lithium Technology, Germany, has cylindrical cells, high power

  PHET Manufactures and sells cells to the public

  SAFT sell several cell and packs via this retailer

  Shandomg HIHON Electric has a web site with prismatics

  Tenergy sells a pack of cells: 18.5 volt 6000mAh 15C - 90+ amp Brick Style for $281 ($25/10KWh)

  Thundersky (China) Lithium: Local provider to Arizona

  Valence Technology now has large formats w/ 4 month lead time: data sheet 12V100Ah @ $1900 12V42Ah @ $860. pricing. ($15k/10KWh) 130 A continuous = $15K. *And, I don't think 130A will keep me at 65 mph.*

  YESA sells 48V 20 AH packs. I don't have pricing yet...

What kind of batteries do I use?

- **Nickel-Metal Hydride (Ni-Mh)**

  Patent Issues - Fact or Fiction
  Cobasys owns the patents associated with large-scale EV type batteries. Also known as Ovanic in GM's EV-1. Cobasys remains unwilling to produce and sell NiMH batteries in smaller quantities to individuals interested in building or retrofitting their own PHEVs. (source), see also "Who Killed the Electric Car"

What kind of batteries do I use?

- **Nickel Cadmium (Ni-Cd)** These were the first popular recharable, and had the "memory" problem of needing periodic complete discharge. The toxicity of cadmium, became an environmental issue. European Union banned Nickel Cadmium (Ni-Cd) batteries for several years. This is assumed to be un-viable technology.

  Electro Energy May have a product offering but there's no current data.

  SR Batteries sells high performance NiCd batteries. Cells are 1.2V up to 5Ah (Unmatched $19.50, $22.50 Matched). Guarantee no memory effects with their batteries. (Author has personally used this company for electric remote-controlled aircraft and can vouch for their product and customer service.) Although excellent cells, the price is extremely high for a pack large enough to power an electric vehicle.

What kind of batteries do I use?

- **Nickel-Zinc (Ni-Zn) Batteries** Ni-Zn batteries offer 500-1000 cycle charges and about half the weight of lead batteries. Evercel seems to be out of the business of selling batteries, two new companies have promising product offerings, with large scale production in 2009?
  http://www.powergenixsystems.com/technology.php
  http://www.xellerion.com/Index.htm

What kind of batteries do I use?

Firefly Battery - Composite Foam-Based Battery Technology

- Firefly's technology is an innovative material science that removes almost all limitations of current lead-acid battery products.
- Firefly Energy has developed two significant technologies that will deliver advanced battery performance for an entire spectrum of uses served by lead acid, nickel, and lithium based chemistries. The two technologies, 3D and 3D2, involve the use of a porous three dimensional material in either flooded or VRLA (valve-regulated lead acid) battery designs. Implementation of this technology successively does away with the corrodible lead grids found in conventional lead acid battery design, and allows delivery of the full power potential of lead acid chemistry for energy storage. This breakthrough delivers a formidable jump in specific power, energy, and cycle life. The resulting products possess performance parameters comparable to advanced materials (Lithium and Nickel-based) batteries, but at costs far below these high performance batteries.

What kind of batteries do I use?

- **Super Capacitors** High current, low storage, very high cycle life (up to 1 million cycles). May be best as a supplement to a low-current high storage, like a fuel cell or lithium-ion prismatic. Capacitors, unlike batteries, decrease their voltage to 0 as they are discharged requiring advanced DC to DC converters and/or controllers.

  Maxwell sells super capacitor packs in varying size.

  EEStor claims to be developing a new super capacitor cell capable of orders of magnitude increases in energy density for reduced costs. No products are offered yet and the company has been very secretive with their prototypes.

What kind of batteries do I use?

- **Safety issues:** The safety characteristics inherent to LiFePo4 technology result from the incorporation of phosphates as the cathode material. Lithium Iron Phosphate batteries (LiFePo4) are extremely stable in overcharge or short circuit conditions and have the ability to withstand high temperatures without decomposing. When abuse does occur, phosphates are not prone to thermal runaway and will not burn. As a result, LiFePo4 technology possesses safety characteristics that are fundamentally superior to those of Lithium-ion batteries made with other cathode materials.

What kind of batteries do I use?

- **Battery Management Systems (BMS)**

  Virtually all types of batteries can be damaged by excessively high or low voltages, and in some cases the results can be catastrophic. Battery Management Systems can provide battery charge protections, discharge protections, state-of-charge monitoring.

  In general, using flooded lead-acid batteries in series in EV applications can work without a BMS. A good charger can provide a float or equalization charge cycle that can effectively balance the batteries. Occasional checking and manual equalization is still required, but not on a daily basis.

  Alternative battery technologies such as Lithium and NiMh are more sensitive to over-charging and over dis-charging on a cell-by-cell basis. When the cells are used in a series, these battery technologies are generally implemented with a BMS.

Battery Management Systems

- Bypassing regulator – Passes excess current to other batteries.

- Shunting regulator – Burns off excessive current in a resistor.

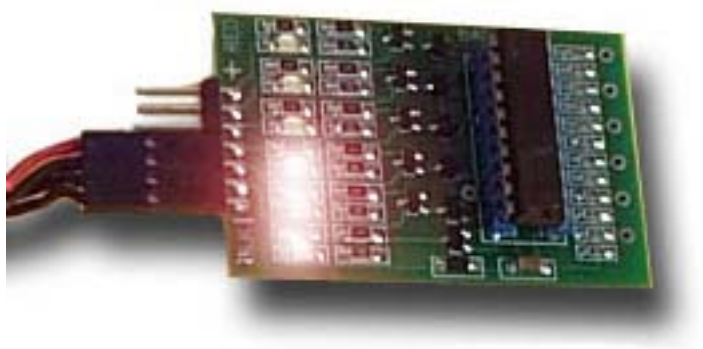
Lithium BMS

Battery Monitor

Elite Power Solutions

Battery equalizer

Astroflight Blinky



What are controllers?

DC Controllers

- Zilla Z1K-HV **($2675)**

- Curtis Model 1231 **($1,675)**

- Kelly 144V 650A **($1595)**

AC Controllers

- Azure **($3,500)**

- Evisol **($10,500 + motor)**

- AC Propulsion **($20K + motor)**

Sources:

- http://www.evalbum.com/build.html
- http://www.diyelectriccar.com/forums/showthread.php?t=669