DIY Electric Car

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DC forums: RegEdit
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Background

- 8 years IT
- 3 years IT Security
- 12 years Electronics & more
- FIRST Robotics
- Solar Power Station
- Solar Water Heater
- Rain Barrels
- Bike Generator
- Murphy Bed
- Workbench
- Voltswagon
Road Map

• EV History
• EV Acronyms
• EV Pros & Cons
• EV Uses
• EV Parts & Layout
• Open Source EV Hardware & Software
• EV Conversion Tools
• EV Conversion Steps
Car Wars (1835 - 1920)

- EVs predate ICE autos by 50 years
- 1989 – EV is first to break 100 km/h (60 mph) barrier
- EVs outsold ICE autos 10 to 1
The ICE Strikes Back (1910 - 2012)

- Cheap oil
- Electricity still limited and expensive
- Growing rural population
- 1914 - Ford chooses gas-powered autos for motorized assembly line
- 1930 - Electric tram networks bought out and dismantled by GM and Big Oil
Return of the EV (1970 - 2012)

- 1970s – Air pollution concerns and OPEC embargo
- 1990 - 2003 – California Air Resources Board (CARB) mandates
- 2008 – Tesla
- 2010 – Nissan Leaf
- 2011 – iMiEV
EV Acronyms

- A – Amps
- AH – Amp Hours
- V – Volts
- w – Watts
- wH – Watt Hours
- wH/m – wH per mile
- MPGGe – Miles per Gallon equivalent
- BEV – Battery Electric Vehicle
- NEV – Neighborhood EV
- PHEV – Plug-in Hybrid EV
- E-REV – Extended Range EV
- R-EEV – Range Extended EV
EV Pros

• Less Complexity
• Less Maintenance
• Efficiency
• Longevity
• Sustainability
• Energy Independence
• National Security
• Environmental
EV Cons

• Batteries
  – Upfront costs
  – Lower energy density
    • Weight
    • Range

• Charging Stations
  – Availability
  – Charge time
Misconceptions

- The grid can’t take it
- Same pollution, moved to the plant
- More resources/pollution
- Lithium is scarce
- EVs are slow
EV Uses

- NEV
- Business
- Racing
- Commuting
NEV

- Golf Carts
- Security/Maintenance
- Grocery Getter
- Inexpensive
- Reduced regulations
Business

- High mileage yields quick ROI
- Predictable routes
- Low maintenance
Racing

• Peak torque from 0 RPM
• Wider power band requires less shifting
Commuting

- ~80% of US commutes are under 40 miles
- No energy wasted sitting in traffic
- Typical cost ≤ $0.02 / mile
- High efficiency (MPGe)
  - Energy: gasoline energy per gallon / Wh/m
    - 33.7 kWh / 280 Wh/m = 120 MPGe
  - Economic: gas price / electric rate / Wh/m
    - $3.33 gallon / $0.08/kWh / 280 Wh/m = 149 MPGe
Voltswagen

Vehicle: 1974 Volkswagen Beetle
Range: 16-26 Miles
Speed: 70 MPH
Cost: $6000
Time: 100 Hours
EV Parts List

**Essentials**
- Donor Vehicle
- Motor & Controller
- Shaft Coupler, Adapter Plate
- Batteries & Charger
- 12V Charger/DC-DC converter
- Battery/Motor cables & connectors
- Contactor(s), Fuse(s)
- Voltmeter, Ammeter, Shunt
- Throttle

**Conditionals**
- Battery Management/Monitoring System (BMS)
- Brake/Suspension Upgrades
- SOC Gauge/monitor
- Precharge circuits

**Recommended**
- Circuit Breaker/Emergency disconnect
- Temperature sensor(s)
- Tachometer
- Inertia switch
- 12V AUX Battery
- Motor/controller cooling
- Battery Box(es) / Insulation
- AH Counter

**Optionals**
- AC
- Clutch
- Heater
- Low Rolling Resistance Tires
- Power Steering
- Solar Panel(s)
6. Refer to vehicle’s shop manual for connections to Key switch, Check Engine Light, etc.
5. Heavy gauge wire (indicated as ) should be 2/0 AWG.
4. Medium gauge wire (indicated as ) should be 10 AWG minimum with 8 AWG preferred.
3. Light gauge wire (indicated as ) should be 16 AWG.
2. Refer to documentation for installation and use details about each component (e.g., Paktrak).
Conversion Kits
Motor, Adapter Plate, Shaft Coupler

- 6.7" D&D ES-31B
- 72-144 V Series Wound DC
- Rated 12 HP, peak ~60 HP
Common Motor Options

- Warp
- Kostov
- Forklift
AC vs DC

- Easier Regen
- Runs cooler
- Even less maintenance

- Cheaper
- Greater selection
- Simpler
Motor Controller

- Curtis 1221C
- 120 V DC (nominal) 400 Amps Peak
- Aluminum finned heat sink
Motor Controller options

- Soliton
- Zilla
- Curtis
- Open ReVolt
Charger
Battery Pack

- 10 x 29DC Marine Deep Cycle Batteries
- 120 V
- 15 kWh
- 600 lbs
Battery Pack Calculations

• Range * wH/mile / 50% DOD / 60% Peukert
• 15 * 300 / .3 = 15 kWh
• Max range is 80% DOD

• Lithium
  – No Peukert
  – 70% DOD nominal
  – 80% DOD for max
Battery Options

Lead Acid
- Golf cart
- 6 V, 8 V
- 500-700 cycles

LiFePO4
- Prismatic
  - CALB, Sinopoly, Winston
- Cylindrical
  - Headway
- Pouch
  - A123
- 3.2 V
- 2000-5000 cycles
Lead vs Lithium (LiFePo4)

- Lower upfront cost
- Less sensitive
- No balancing necessary
- Easier to determine State of Charge (SOC)

- Light-weight
- Long cycle life
- High power output
- Less maintenance
- Flat discharge curve
- Better cold weather performance
To BMS, or not...

- Battery Management/Monitoring System required for some chemistries
- Active or Passive monitoring
- Distributed or Centralized
- Expensive /complicated
- Potential fire hazard
Balancing

- No two cells are identical
- Cells must be balanced to prevent damage
- Balancing matches cells at either top or bottom
- If overcharged, cell is damaged
- If overdischarged, cell can be pushed to reversal and destroyed
Discharge curve and Half-pack Bridge

- Monitor each half of pack
- Take action if imbalance passes threshold
Contactor, Precharge, & Coil Suppression

- **Precharge Resistor**
  - Prevents current surge
  - Preserves controller capacitors
  - Prolongs contact life

- **Coil Suppression Diode**
  - Prevents voltage spike
  - Usage depends on controller/contactor requirements
Accessories

• If needed, accessories may run off an auxiliary driveshaft, or be powered separately
  – Air conditioning
  – Power steering
  – Power Brakes
Open Source EV Hardware & Software

- Controller
- Charger
- Instrumentation
- Misc
Open ReVolt projects

➢ The Cougar EV Series 500 DC Motor Controller PCB & Mosfet Power PCB several versions are available on wiki.
➢ The Cougar EV Series 1000 DC Motor Controller, Mosfet Power PCB, and Mosfet Driver PCB are available on wiki.
➢ The preliminary EV SR Motor Controller PCB is on wiki, development is on going.
➢ The preliminary EV AC Motor Controller PCB is on wiki, development is on going.
➢ The preliminary EV DC LCD Instrumentation PCB - Is now on wiki !!!
➢ The preliminary EV 6Kw DC Charger Controller PCB - Was added to the wiki !!!
➢ The preliminary EV BMS Controller PCB - Was added to the wiki !!!

* Planned Future Open ReVolt projects *

➢ The EV IGBT Driver PCB - BG2A/VLA500 Interface - Coming Soon !!!
➢ The Uprising EV Series DC Motor Controller, and IGBT Driver PCB Coming Soon !!!
Electric Motor Werks
10kW 60A Open Source Charger
EV Dashboard
# EV Conversion Tools

## Essentials
- Shop manual for donor vehicle
- 2+ ton trolley jack (high clearance preferred)
- 2+ ton adjustable jack stands
- Creeper
- Sockets, Wrenches, Screwdrivers, Pliers
- Angle Grinder
- Handheld drill
- Digital Volt Meter (DVM)
- Wire strippers and crimpers
- Cable cutters and crimper
- Shop light
- Rotary tool
- Measuring Tapes

## Recommended
- Electrical Tape
- Engine hoist or transmission jack
- Clamp On Ammeter
- Drill press
- Air compressor
- Rhino Ramps
- Welding Equipment
- Safety goggles or glasses
- Latex (or similar) gloves
- Soldering Iron
- Zip Ties
- Vise

## Carry-On
- Digital Volt Meter (DVM)
- Jumper cable
- Commonly used Sockets, Screwdrivers

## Optional
- Workbench
- Box cutter, Jigsaw, Cut-off saw, Hacksaw
- Hammer, Pry Bar
- Heat gun or torch
EV Conversion Steps

• Build Requirements
• Explore the Possibilities
• Find a Donor
• De-ICE
• Eliminate Waste

• Install EV Components
  – Motor
  – Controller
  – Batteries
  – Charger
  – Accessories

• Hit the road!
• Keep on Hacking
Build Requirements

• Motivations?
• Maximize utility
• How far?
• How fast?
• Budget?
• Skills?
• Reality check
Keep it Legal

- Each state\country is different
- Some require inspections
- Some have strict requirements
- Some do not allow typical conversions
- Some don’t know what an EV is
Explore the Possibilities
EV Album

CURRENT TOTAL 3725 VEHICLES

Doug Johnson’s 1997 Ford Ranger XLT
Updated: 06/22/2012

John W Mitchell’s 1997 Saturn SC
Updated: 06/23/2012

Martin Winlow’s 2008 Vectrix VX-1
Updated: 06/18/2012

Bill Bates’s 2001 Nevcod Gizmo
Updated: 07/07/2012

thingstodo’s 1991 Chevrolet S-10
Updated: 06/16/2012

Pranav Bheda’s 1972 Volkswagen Super Beetle
Updated: 06/15/2012

Jarkko Santala’s 1987 Kawasaki GPX750R
Updated: 07/08/2012

Bruce Westlake’s 2011 Think City
Updated: 06/12/2012
Find a Donor

- Fun to drive
- Good working order (except engine)
- Aerodynamic
- Lightweight
- Cargo space
De-ICE

- Remove the engine
  - Find buyer first!
  - Jack up 2-3 feet for bottom removal
  - Engine hoist for top removal
- Drain and remove gas tank, radiator, starter, alternator, and other obsolete stuff
Eliminate Waste

• Less weight and less power draw = more range
• May be able to remove or replace non-essentials
  – Swap Fix-A-Flat for spare tire
  – Convert power steering and brakes to manual
Install EV Components

- Attach adapter plate and coupler to motor
- Install motor and controller
- Build/install battery boxes
- Install batteries and charger
- Install instruments, wiring, accessories, etc
Where to charge

- **110 V AC**
  - 20 Amps
  - 8 miles charge/hour

- **220 V outlet**
  - 50 Amps
  - 44 miles charge/hour

- **J1776-2009**
  - Level 1 120 V AC
  - Level 2 240 V AC
    - 80 Amps
    - 76 miles charge/hour

- **CHAdeMO**
  - Level 3 500V
    - 125 Amps
    - 250 miles charge/hour
Hit the road!
Sounds Great, But…

- Perpetual Motion
- Hydrogen
- Supercapacitors
- Hub Motors
- DIY Hybrid
- Solar
WARNING: EV Conversions are a very addictive/obsessive hobby. The only way to ‘finish’ a conversion is to start another.
EV Resources

- Vendors Used
  - Wilderness EV
  - KTA Services, Inc.
  - Cloud Electric
  - Sam’s Club
  - Calib Power
  - ebay
  - Lightobject
  - Chennic

- Additional Resources - chargedevs.com/Build-an-EV
Motor: $1200
Controller: $1000
Batteries: $800
Charger: $600
Adapter/Coupler: $500
Misc: $800

No longer being OPECXXON’s Bitch…Priceless