Building a Battery Car
and other technical concerns

Presented by
The Tucson Garden Railway Society,
The Tucson Botanical Garden

Nick C. Buchholz presenting

Where to start.

- Decisions-
  - What Locomotive? Trail Car?
    - In Locomotive, Tender or in Trail car?
  - R/C or fixed speed rheostat? What R/C system?
  - Battery Chemistry? Standard or DIY packs?
  - Desired max. speed? Desired run time?
  - Sound Desired? Speaker size?
- Doing it
  - Stuff you'll need
  - Stuff you'd like to have
  - Suppliers
- Circuit Diagrams

What Locomotive? Trail Car?

- Type - Steam or Diesel
  - Decide where R/C control (rheostat) will go.
  - Decide on where batteries will go.
  - Decide on access, battery swapping, charging.
- Tender, Tank engine, Trail Car
  - Decide battery geometry (size and shape)
  - Determines run-time, max speed, access.
- Purpose: Passenger, Freight, Switcher
  - Determines appropriate trail car type

R/C control or Rheostat

- R/C Control
  - Complete control over speed and direction
  - Usually can control Sound effects, lighting
  - Vender support, installation instructions
  - Minuses
    - Costly need 1 receiver per engine, possibly multiple transmitters
    - More complex wiring to control all features
    - Possibly fragile electronics boards (ESD, rough handling)

- Rheostat control
  - Inexpensive
  - Simple wiring
  - Minuses
    - No Vender support (roll your own)
    - No control over sound effects or lighting
    - Awkward changing speed and direction
    - No way to stop except "**grab it**"

R/C systems

- Airwire – 900, 9000, 5000, transmitters/decoders
  - DCC compatible - any DC or DCC Sound decoder
  - Phoenix, Soundtraxx, etc.
- Locolinc – two models 16 or 64 engines
  - Phoenix, Soundtraxx , Soundlinc
- Aristocraft – 27MHz, 75MHz,
  - Phoenix, Soundtraxx (requires Aristo accessory Board)
- Aristocraft Revolution – no experience
- RCS – no experience
- Zimo-RC – no experience
- Airplane/ R/C Car systems – no experience

Battery Chemistry

- SLA – Sealed Lead Acid
- NiCd – Nickel Cadmium
- NiMH – Nickel Metal Hydride
- Li Ion - Lithium Ion – Several chemistries
  - $LiFePO_4$, $LiMnNiO_3$, $LiMn_xNi_yCo_zO_2$, $LiCoO_2$
- Lithium Battery replacements for SLA

Battery Chemistry (cont)

Chemistry	Voltage	Energy Density	Working Temp.	Cycle Life	Safety	Environ-mental	Cost SLA=1
SLA	2.0V	>35wh/kg	-20 – 40 ℃	>200	Safe	Not good	1
NiCd	1.2V	>40wh/kg	-20 - 50 ℃	>1000	Safe	Bad	0.7
NiMH	1.2V	>80 wh/kg	-20 - 50 ℃	>500	Safe	Good	1.2-1.4
$LiCoO_2$	3.7V	>200 wh/kg	-20 - 60 ℃	>500	Unsafe without PCB or PCM	OK	1.5-2.0
$LiMn_xNi_yCo_zO_2$	3.7V	>160 wh/kg	-20 - 40 ℃	>500	Unsafe without PCB or PCM, better than LiCo	OK	1.5-2.0
$LiFePO_4$	3.2V	>120 wh/kg	-0 - 60 ℃	>2000	Safe	Good	0.15-0.25

Safe is a relative term; if you abuse your batteries they will bite you in the tender parts. The Li Ion batteries are sensitive to heat and if stressed can burst into flames.

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Battery Cost

Chemistry	Voltage	Cell type (size inches)	Capacity	Cost
SLA	12v	6 x prismatic (5.3 x 2.6 x .2.4)	3200 mAh (40 Amp)	16.95
NiCd	7.2v	6 x SubC (5.4 x 1.9 x 1.0)	2100-2200 mAh	17.95-38.00
NiMH	7.2v	6 x AA (3.4 x 2.0 x 0.6)	2200 mAh	16,95
NiMH	7.2v	6 x SubC (5.4 x 1.9 x 1.0)	4200-4500 mAh	29.95-34.95
NiMH	7.2v	6 x 4/3 AF (4.3 x 0.75 x 2.7)	4500 mAh	31.95
$LiCoO_2$	7.4v	2 x PL-544792-2C (3.7 x 1.9 x 0.6)	2500 mAh (4,2 Amp limit)	32.95
$LiMn_xNi_yCo_zO_2$	7.4v	2 x 26650 (2.3 x 1.2 x 2.9)	4000 mAh (3 Amp limit)	27.95 (w/pcb)
$LiMn_xNi_yCo_zO_2$	14.8	4 x 26650 (4.5 x 1.4 x 2.9)	4000 mAh (10 Amp limit)	59.95 (w/ 2 pcb)
$LiFePO_4$	6.4v	2 x 18650 (2.9 x 2.9 x 0.83)	2400 mAh (8.4Amp limit)	32.95

Standard or DIY packs

- Standard packs
  - Readily available, Reasonably priced
  - Nicely packaged (Safe)
  - Important for exotic chemistries (PCB included)
  - Come with or without connectors
  - No soldering required if connectors included
- DIY packs
  - Custom sizes and geometries possible
  - Custom voltage values
  - Can be cheaper
  - Selectable connectors
  - Require moderate soldering skills

Battery Geometry

- An near infinite variety to choose from
  - Over 77 individual cell size/shapes listed on
    http://www.all-battery.com/sizechart.aspx
  - Common Useful sizes AA, Sub-C, C, D
    - Commonly available in 6, 7.2, 8.4, 9.6,12 % 14.4 Volt packs
    - Capacities from 2200 mAHr (AA) to 10000 mAHr (D)
    - Geometric arrangements vary
    - D's may require more room than available.
  - Also useful A, AF, 4/3AF, F prismatic,
  - Various AA holders available to avoid soldering

Desired maximum speed

- Run engine in DC configuration
  - Run at a speed you think will make you happy.
  - Measure the track voltage at that speed.
  - Check R/C system voltage requirements
  - Check Sound system voltage requirements
  - Pick a battery voltage higher than requirements.
  - Decide on a single or multiple packs in series.

Desired Maximum Run-Time

- Run engine in DC configuration
  - Run at a speed you think will make you happy.
  - Measure the track current at that speed.
  - Grades/Long trains increase the current draw.
  - Battery mAHr 4 Current in mA $_y$ Run Time
  - Add ~1000 mA to current draw for sound systems.
  - Extending run-time
    - Use packs in parallel
    - Use switched packs to extend time
    - Use multiple identical cars
    - Just swap batteries – Assumes easy access

Sound desired

- Electronics in Battery/R/C trail car.
- Speaker in car or in engine.
- Bell/Horn/Whistle other effects
- Manufacturers-
  – Phoenix – playable horn, whistle w some R/C
  – SoundTraxx – useable with additional circuit
  – MyLocoSound – inexpensive w triggers
  – SoundLinc – designed for use with LocoLinc
  – MRC??, LGB?? Tsunami if RC is DCC?

Stuff you'll need

- Locomotive, RC unit, Batteries, Trailcar/tender
- Electrical switches – SPST, DPDT(center off),4PDT!
- Connectors – various, (Crimp tool??)
  - Molex – Tamiya, RC car plugs - **Micro-Fit 3.0**
  - Anderson Powerpole
  - Dean's connectors
- Wire 14-20 gauge (see chart at end)
- Fuses??
- Styrene, wood sheet
- Double-sided sticky tape
- Shrink wrap tubing several sizes
- Soldering station (35watt), electronics solder

Stuff you'd like to have

- Exacto or utility knife

- Twist drills, drill motor or pin vise

- Long shank screw drivers (phillips and slot)

- Wire cutters and strippers

- Heat gun (optional)

- Wire Labels or label maker

- Liquid electrical tape

- Waxed cord or cable ties

Suppliers

- Batteries
  - http://www.batteryspace.com/
  - http://www.batteryjunction.com
  - http://www.all-battery.com/
  - http://www.competitionhobbies.net
- Connectors/wire
  - http://www.digikey.com/
  - http://www.alliedelec.com
  - http://www.mouser.com
  - http://www.miniatronics.com/
  - Elliott Electronic Supply - 1301 South Tyndall Avenue
  - Radio Shack -
- RC systems
  - Airwire – CVP Products - http://cvpusa.com/
  - LocoLinc – Kiethco Inc. - http://www.locolinc.com
  - Train Enginneer, TE Revolution – Aristo-Craft Trains - http://www.aristocraft.com/
  - RCS - *www.rcs-rc.com/* - http://dnkgoods.home.mindspring.com/

Circuit diagrams

- Simple Trail Car (No RC)
- Extended Running Trail Car
- Battery Trail Car (with RC)
- Tender (with RC and sound)
- Steam Loco Battery and RC in boiler
- Diesel Loco (with RC and sound)

Current Capacity of Wire

Wire	Diameter		Ohms per		Current Capacity
gauge	Inches	mm	1000 Ft	Km	Amps in chassis
10	0.1019	2.58826	0.9989	3.27639	55
12	0.0808	2.05232	1.588	5.20864	41
14	0.0641	1.62814	2.525	8.282	32
16	0.0508	1.29032	4.016	13.1725	22
18	0.0403	1.02362	6.385	20.9428	16
20	0.032	0.8128	10.15	33.292	11
22	0.0254	0.64516	16.14	52.9392	7
24	0.0201	0.51054	25.67	84.1976	3.5

Electricity - things to remember

- Don't let the smoke out
- Don't connect the Plus and Minus wires of the battery
- Do use a wrist strap or grounding strap when handling
- There are four basic units of measurement for electricity:
    - Power, measured in Watts, commonly referred to as "P"
    - Current, measured in Amps, commonly referred to as "I"
    - Voltage, measured in Volts, commonly referred to as "V"
    - Resistance, measured in Ohms, commonly referred to as "R"
- There are a number of formulas that relate each of these four things if you know any two you can calculate the other two. Lots of folks on the Internet have easy-to use calculators that allow you to do this online - http://www.sengpielaudio.com/calculator-ohm.htm is one. The formula wheel below was on their website and presents the info in a pretty easy to understand format.

Electrical Formulae