

Electric R/C Planes Overview

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Electric R/C

- **Small or Large – Electric Power can meet your needs!**
 - **E-Flite Blade mCX Helicopter** **1 oz**
 - **ParkZone T-28 RTF** **2 lbs**
 - (Jim, Carl, Rodney, Bob, et al.)
 - **Extra 300 - 87 inch (50cc)** **18 lbs**
 - 3700 watts (5HP), 80 amps
- **Turn the page if you:**
 - Have considered trying Electric, but weren't sure where to start...
 - Own a gas/glow plane that you are thinking of converting to Electric...
 - Already fly Electric but want to move up to a larger Airplane...

Agenda

The most popular 'Electric' components are Brushless Motors, Brushless Electronic Speed Controllers (ESC's) and Lithium Polymer (LiPo) Batteries; therefore, 'Brushless' and 'LiPo' are the primary focus of this presentation.

- This presentation is an overview; it is not comprehensive. Conduct further research to obtain the necessary understanding of the components, procedures and risks.
- Read the directions on all Electric Power System Components.

1. Electric / Wet - Quick Comparison

2. Electric Power System Components:

- Motors
- Electronic Speed Controllers (ESC)
- Battery Elimination Circuits (BEC) or Receiver Battery
- Electric propellers, prop adapters
- Flight Batteries (A123, LiPo)
- Balancers, Chargers, Power Supplies

3. Sizing the Components:

- Option 1: Buy from Hobby Shops with Significant 'Electric' Knowledge.
- Option 2: R/C Forums - Find out what has worked for other people, and ask questions.
- Option 3: Do-It-Yourself with a software program or on-line tools to assist in selecting the components.
 - Rules-of-Thumb

4. Building Considerations

5. Costs

6. Web Links

Electric / Wet - Quick Comparison

	Electric	Wet
Consistent Performance - (>45F)	X	
Less Vibration - (Easier on Components)	X	
Dependency on Electricity (Field Charging)	X	
Prep Batteries for Storage	X	
Lower Cost		X
Engine Sound	**	X
Smoke	**	X
Cold Weather Flying - (<32F)		X
Fuel Storage / Clean up		X

** High Cost Add-ons Available

Power System Components:

Motors

- **Brushed**

- The windings rotate.
- Lower cost, less efficient (~ 60%), some maintenance = carbon build-up on brushes & commutator

- **Brushless**

- The magnets rotate.
- Higher cost, higher power for frame/size, more efficient (~ 80+%), no maintenance
- **Outrunner**
 - High Torque, external can spins
 - Prop planes
- **Inrunner**
 - High RPM, center armature spins
 - Electric Ducted Fans (EDF – Jets)
 - Usually requires gear-reduction for prop planes -- gears = some maintenance
- **Popular brushless brands include:**
 - AXi, E-Flite, Hacker, Hyperion, Mega, Neu, Reaper, Scorpion, Torque
 - Special mounting hardware may be required - You'll likely need a motor mount and prop adapter which can be purchased where you buy the motor.

Power System Components:

Electronic Speed Controllers (ESC)

- **Computerized Throttle**
 - Consists of a Micro Chip and Field-Effect Transistors (FET's) which convert the throttle signal into the proportionate amount of power to turn the motor.
- **Brushless motors require Brushless ESC's**
- **Low Voltage Cutoff (LVC)**
 - If you are using Lithium Polymer (LiPo) flight batteries, the ESC needs to have a LiPo cutoff setting.
 - To maintain cycle life - Time your flights! Don't fly until LVC. Consider the LVC to be a fail-safe; something you'd prefer not to use.
 - **Why:** On many ESC's, the standard LVC for LiPo's is 3 volts per cell. At this voltage, most LiPo batteries will have been depleted well beyond 80% of their capacity which significantly reduces cycle life.
- **Battery Elimination Circuit (BEC)**
 - Available on some ESC's, see the next page for more information on BEC's
- **Popular Brands Include:**
 - AirBoss, Castle Creations (Phoenix 4-12S, Thunderbird: 3S), Hacker, Jeti, Scorpion

Power System Components:

Battery Elimination Circuit (BEC)

- **Allows the primary 'Flight Batteries' to power the Receiver, Servo's, etc. by stepping-down the voltage and routing power to the receiver.**
 - Often used in smaller Electric airplanes, but are available for larger ones too.
 - Reduces the number of batteries you need to charge/connect before flight.
 - Reduces the AUV.
- **BEC Options:**
 - **BEC within an ESC**
 - Not available on all ESC's
 - Most have a very small / limited capacity
 - Many use a 'Linear' voltage regulator which causes the BEC's amp capacity to diminish at higher input voltages. This is due to excessive heat generated as the regulator works to step-down the higher input voltage.
 - **BEC**
 - Separate / stand-alone BEC device that gets wired into the primary flight battery connections.
 - Most have a higher capacity than 'BEC's within an ESC'.
 - Many use a 'Switching' power supply which can provide a constant amp output capacity as long as input voltage does not exceed the min / max.
 - Popular brands include Castle Creations, Dimension Engineering, Kool Flight Systems
 - I've used the Ultimate BEC (UBEC) made by Kool Flight Systems for several years. www.koolflightsystems.com
 - Read the directions to ensure you don't overload the BEC, wires or connectors which will result in power loss to the receiver, servos, etc.

Power System Components:

Separate Receiver Battery

- Many larger Electric setups are flown with a separate receiver battery:
 - The direct connection between the battery and the receiver removes the possibility that a BEC will fail, cutting off power to the receiver/servos.
 - It Increases the possibility that you forget to charge the receiver battery and end up with no power to the receiver/servos.
 - I use a separate receiver battery on my 87" Extra, but continue to use a BEC on my smaller planes.
- If you use a Receiver Battery and your ESC has a built in BEC, be sure to read the directions, you may need to cut one of the wires from the ESC to the receiver.

Power System Components:

Electric Props

- Hub is thinner than similar size gas/glow prop.
- Require balancing.
- Popular brands include APC-E and Xoar-Electric.
 - Note: APC also makes '**Slo-Fly**' props which have a fairly low max RPM (Maximum RPM=65,000/prop diameter (inches))

Prop Adapters are needed to mount the prop on the motor. They are available where you buy your motor and/or spinner.

Power System Components:

Flight Batteries:

– General Information:

- “S” = Series, “P” = Parallel
 - e.g. 5S2P = 5 cells in series with 2 cells in parallel (Series increases voltage; Parallel increases capacity)
- “C” = Capacity
 - 1000mAh = 1Ah (1 amp-hour)
 - » Charging a 1000mAh battery at 1 Amp (1C) rate will take about 1 hour to charge.
 - » Charging a 1000mAh battery at 2 Amps (2C) rate will take about 30 minutes to charge.
 - » Discharging a 1000mah battery at 10 Amps will deplete it in about 6 minutes (1/10 of 60 minutes)
- “C Rating” = max discharge current.
 - e.g. A 1000 mAh battery with a 20C rating should be able to provide 20 amps of current. (1Ahx20)
 - “C Rating” is usually based on 50 duty cycles. Continued use near the max ‘C rating’ will reduce cycle life.

– A123 – M1 = Lithium Iron/Phosphate (LiFePo4)

- Better power to weight ratio than NiMH or NiCd
 - But not as good as Lithium Polymer (LiPo)
 - » A123 is approx 1.3-1.4x heavier & larger than LiPo
- 2 capacities available -1100mAh or 2300mAh; “C Rating” = 30
- Full Charge Voltage = 3.6 volts per cell
 - 7S A123 voltage ~ 6S LiPo voltage ($7 \times 3.6 = 25.2 \sim 6 \times 4.2 = 25.2$)
 - » “~” Under high amp loads, a 6S LiPo with a high C-Rating will maintain voltage better than a 7S A123.
- More durable than LiPo’s
- Safer than LiPo = less risk of fire
- A123 batteries are being used by many R/C hobbyists

– LiPo = Lithium Polymer

- Better power to weight ratio than LiFePO4 (A123) or NiMH or NiCad
- **LiPo’s require special handling, charging, safety precautions - they can be a fire hazard.**
- Many capacities & “C Ratings” available
- Full Charge Voltage = 4.2 volts per cell
- Popular LiPo brands Include: CellPro, FlightPower, Hyperion, MaxAmps, Neu, Rhino, Tanic, ThunderPower, Zippy-Flightmax

Power System Components:

Lithium Polymer (LiPo) Batteries:

LiPo's require special handling, charging, safety precautions - they can be a fire hazard! Read all directions that come with chargers, balancers and LiPo batteries.

Lithium cells must be charged very differently than NiCd or NiMH.

- LiPo chargers use a CC/CV (constant current / constant voltage) protocol to charge the batteries.
- **Use a LiPo Charger, with an integrated Balancer**
 - Charge outside your house, while you are in attendance.
 - Charge/Transport/Store in a ventilated fire retardant container
 - e.g. LiPo Sack, Battery Bunker, Cinder Block, etc
 - » **IMPORTANT** – Use of a LiPo Sack or Battery Bunker does not guarantee protection of surrounding surfaces. <http://www.liposack.com/> <http://www.batterybunker.com/>

To maintain cycle life:

- Store LiPo's at approx 50% charge level
 - Most LiPo chargers have a 'storage' charge option
- Keep battery temperatures below 125 degrees
- Don't discharge beyond 80% of Capacity
 - Time your flights, don't depend on LVC
- Keep discharge rates below 80% of max amp capacity ("C Rating")
 - Use a watt meter to determine the max amps of your power system.

Power System Components:

Lithium Polymer (LiPo) Batteries (Cont):

LiPo fires have damaged houses and cars.

- **Fires have been reported when:**
 - **For illustration purposes only:**
 - **Charging:**
 - not using a charger designed for LiPo's
 - wrong cell count entered on charger
 - overcharged cell within a pack
 - using a charge rate higher than 1C
 - **Damaged:**
 - Involved in a crash or dropped
 - » Beware - you may not notice a problem until you charge them the next time.
 - Overheated > 140 degrees
 - » Excessive amp draw
 - Punctured cells
 - **Shorted:**
 - The external wires are shorted (beware of metal storage containers / wedding rings / etc.)
 - » If you're putting new connectors on the battery, don't cut or strip both wires at the same time. Finish one wire, then work on the other one.
 - **The following links contain more information:**
 - <http://www.rcgroups.com/forums/showthread.php?t=209187>
 - http://www.fmadirect.com/lipo_handbook/FMA_Lipo_Handbook_Section3.htm
 - <http://www.youtube.com/watch?v=odxR1lkfiEI>
 - <http://www.youtube.com/watch?v=ZNxLGDwGw-k>

Power System Components:

LiPo Balancers:

- A Balancer attempts to force each cell within a battery pack to be a similar voltage. It does this by consuming small amounts of energy in the higher voltage cells.
- **Use a Charger, with an integrated Balancer, specifically designed for LiPo's**
 - **A LiPo cell should not exceed 4.2 volts**
 - A charger that does not have an integrated balancer is only capable of knowing the total pack voltage.
 - A charger with an integrated balancer should know the voltage of each individual cell in the pack. Why is this important:
 - **Example:**
 - A fully charged 5S pack = 21 volts ($5 \times 4.2 = 21$ volts)
 - 4 cells at 4.0 volts and 1 cell at 5 volts also = 21 volts ($(4 \times 4) + 5 = 21$)
 - » The cell at 5 volts is a candidate for thermal runaway = fire.
 - » A charger with an integrated balancer should stop charging when/if a single cell goes above approx 4.3 volts
- There is not an industry wide standard for balance plug connectors/taps used to connect batteries to balancers; however, adapters are readily available for about \$10. See this link for more information:
<http://www.rcaccessory.com/pdf/Battery%20Tap%20Configuration%20Guide.pdf>

Power System Components:

Popular LiPo Chargers with integrated Balancers include:

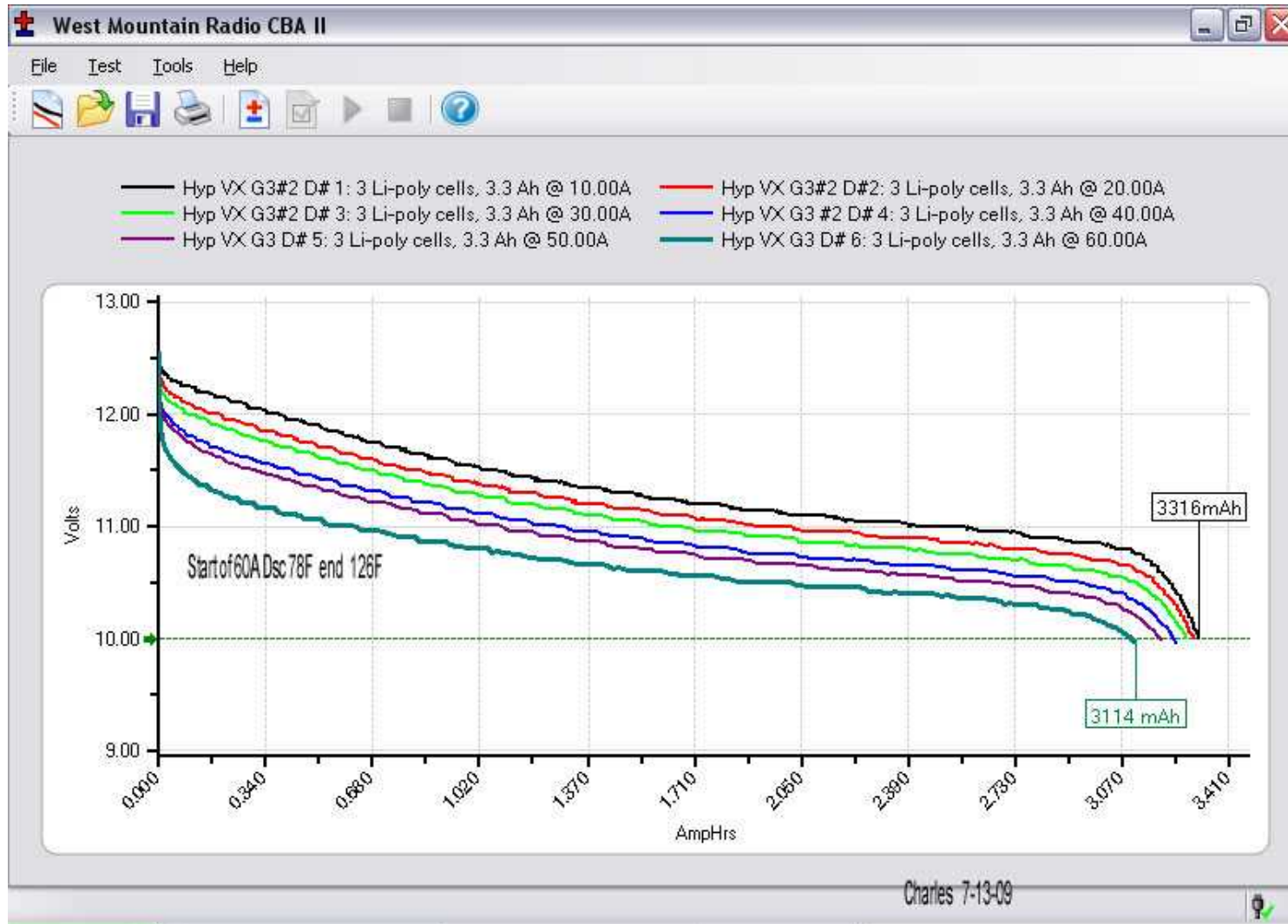
- Bantam e-Station BC6 Charger/Balancer
- FMA CellPro 4S or 10S Charger/Balancer
- Hyperion EOS0615I-DUO-III Dual Port Charger
- ThunderPower (TP) 1010C Charger + TP210V Balancer + DataPort connector

Power Supply Options Include:

- **AC at the field:**
 - Retail AC/DC Power Supplies:
 - e.g. Jetstream, Samlex SEC-series, Radio Shack, etc.
 - Converted computer power supplies
 - require experience/knowledge to do it safely
- **No AC at the field:**
 - Portable generator (e.g. Honda 1000)
 - Deep-cycle batteries = very heavy
 - e.g. marine, golf cart
 - Buy enough flight batteries so you don't need to charge at the field.

Computerized Battery Analyzer FYI Only (CBA – Graphs)

This one was created by 'everydayflyer' on RCGroups



Sizing The Components

On the next several pages I have outlined 3 Options to help you select Electric Power System Components to meet your needs. In practice, I use a combination of all 3 options, but any option can get you a good electric setup.

Option 1 = Buy from Hobby Shops with Significant 'Electric' Knowledge.

Option 2 = Read R/C Forums

- Find out what has worked for other people and ask knowledgeable hobbyists questions
- Use the 'Search' feature to help find what you're looking for...

Option 3 = Do-It-Yourself with the help of a software program or on-line tools to assist in sizing/selecting the components.

- Gives you knowledge / flexibility

Sizing The Components

Option 1: Buy from Hobby Shops with Significant 'Electric' Knowledge.

- Thinking about buying a new 'Electric' plane. These shops will provide you with a new plane and custom power system to go with it:
 - 3D Hobby Shop: www.3dhobbyshop.com Phone: 830-990-6978
 - Extreme Flight: www.extremeflightrc.com Phone: 770-887-1794
 - Atlanta Hobby: www.atlantahobby.com Phone: 678-513-4450
 - Esprit Model: www.espritmodel.com Phone: 321-729-4287
 - Hobby-Lobby: www.hobby-lobby.com Phone: 866-512-1444
- Thinking about converting an existing glow/gas plane to 'Electric'. These shops can help you decide on a power system for your current plane:
 - Atlanta Hobby: www.atlantahobby.com Phone: 678-513-4450
 - Esprit Model: www.espritmodel.com Phone: 321-729-4287
 - Hobby-Lobby: www.hobby-lobby.com Phone: 866-512-1444
 - Tell them you want help with an electric setup/conversion... Have the following information available:
 - The quality/cost range of the products you want – e.g. least cost, mid-tier, top-of-the-line.
 - The type of plane you have (name, size, weight (AUW or Airframe & Servos))
 - The type of flying you want to do (e.g. sport aerobatic, 3D, pattern)
 - The type of batteries you want to use (LiPo, A123, NiMH).
 - » If LiPo or A123 and you intend to buy a charger & balancer, then look into Bantam, FMA, Hyperion or Thunder-Power chargers with integrated balancers
 - For BEC selection - The quantity and type of servos / electronics in the plane (e.g. mini, std, high-torque, digital, etc)

Sizing The Components

Option 2: Read R/C Forums:

- Find out what has worked for other people and ask other knowledgeable hobbyists questions.
- R/C Forums have a helpful ‘Search’ feature which enables you to more quickly find things.
- Popular ‘Electric’ R/C Forums include:
 - **RCGroups:** www.rcgroups.com
 - Aircraft-Electric-Airplanes
 - » **Forums include:** Glow to Electric Conversions, Electric Warbirds, Giant Electric Conversions, etc.
 - Aircraft-Electric-General
 - » **Forums include:** Batteries & Chargers, Power Systems
 - Aircraft-Electric Helis
 - Aircraft-Electric Jets
 - **WattFlyer:** www.wattflyer.com
 - **RCUniverse:** www.rcuniverse.com
 - Electric Aircraft Universe

Sizing The Components

Option 3: Do-It-Yourself with a software program or on-line tools to assist in sizing/selecting the components.

- **MotoCalc software.** Easy to use (when compared to doing it without the software) and is filled with very helpful information. It will allow you to predict, optimize, and compare power system components:
 - I have used MotoCalc for many years; it includes a Motor Wizard, predicted in-flight analysis, opinions, side-by-side comparisons.
 - MotoCalc \$39 <http://www.motocalc.com>
- **Other software options:**
 - There is another software program named ElectriCalc. I have not used it; the last time I compared the two programs, MotoCalc contained more features.
 - ElectriCalc \$35 <http://www.hobby-lobby.com/ecalc.htm?pSearchQueryId=229730>
 - Some brands of motors have a free web-based tool to help you size/select their motor/esc to meet your needs. Go to their websites for more details.
 - e.g. E-Flite has named their motors similar to the corresponding engine size: <http://www.e-fliterc.com/PowerSystems/Motors/BrushlessCharts.aspx>
 - e.g. AXi Motor selection tool can be found at: <http://www.modelmotors.cz/axisetup/>



Sizing The Components

Do-It-Yourself (Cont.)

MotoCalc Software:

- Runs on Windows 98SE, ME, NT, 2000, XP, or Vista
- Features Include:
 - 30 Day Free Trial
 - Motor Wizard
 - » Answer questions about your plane, how you want to fly it, how long you want to fly it. The program offers suggested power systems.
 - » Already own a motor or battery? It will work with the component to try to find a viable setup.
 - Static / In-flight Predictions
 - » Scan a list of predictions to 'optimize' your set-up.
 - » Predict top speed, stall speed, flight time at various throttle settings.
 - » Compare predictions/statistics of 2 or more setups.
- The MotoCalc predictions provide a good starting point, but you'll want to test your power system with a Watt Meter before you fly.
 - I have found that MotoCalc predictions get me close; of course actual results have varied somewhat; usually resulting in me changing the prop to get the performance I'm looking for in a power system.

Note: AXi motors are contained in the MotoCalc database under 'Model Motors AXi'. Model Motors is the manufacturer.

Sizing The Components

Do-It-Yourself Rules-of-Thumb:

- **How much power do I need? What kind of performance can I expect?**
Rule-of-thumb is based on 'input' watts and can be measured with a watt meter.
 - 75 watts per pound = Trainer
 - 100 watts per pound = Sport Aerobatics
 - 150 watts per pound = 3D or Pattern
 - 200 watts per pound = Full 3D or Pattern, Unlimited Vertical
- **RTF / BNF / PNP models typically provide 75-100 watts/lb performance out-of-the-box**
 - For more power, purchase a power system upgrade, or buy the airframe only and add custom power system components
- **1HP = 746 watts**
- **Electric power is very versatile:**
 - **Volts x Amps = Watts**
 - The motor kv (rpm/volt), flight battery (# cells in series & "C rating") and prop (diam/pitch), can have a significant impact on volts & amps; therefore, watts.
- **Try not to exceed 80% of any components current carrying capacity. (Electrical components become much less efficient as you approach 100% of their current carrying capacity.)**
 - e.g. Max amps expected for the power system is 60. Buy components rated for 75 amps
 - $(60 / 80\% = 75)$
 - Stated another way... for each component (Motor, ESC, BEC, Battery, Power Supply), do not routinely operate it above 80% of it's maximum amperage rating.
 - Use a watt meter to determine the max amps of your power system.

Sizing The Components

Do-it-Yourself Rules-of-Thumb:

- **Purchase Sequence - 5 Steps:**

- 1. Select the motor, flight battery, prop to get the watts you want.**
 - The motor should be rated for the voltage and max amps**
 - The flight battery should be rated for the voltage and max amps** (C Rating)
 - » The flight battery should have the capacity (mAh) to give you the expected flight time you want.
 - Select an “Electric” prop. The prop should be rated for the max. RPM’s.
- 2. Select the ESC after you decide on the motor, flight battery, prop**
 - If you are using a brushless motor, you will need a brushless ESC
 - The ESC should be rated for the voltage and max amps**
 - If you’re considering an ESC with a built-in BEC, see 3 below.
- 3. Select a BEC or Receiver battery after you know the number/type of servos and other ‘electrical’ components in your model.**
 - The BEC should be rated for the max amps** that your electrical components will need.
- 4. Select the Charger after you’ve determined the size of batteries you expect to charge now and in the future.**
 - See next page for more information on sizing chargers
- 5. Select the Power Supply to power the charger.**
 - Do you have AC at the field?
 - See next page for more information on sizing AC/DC power supplies

** Try not to exceed 80% of any components current carrying capacity (max amps)

Sizing LiPo Chargers & AC/DC Power Supplies

Do-it-Yourself Rules-of-Thumb:

- **What size LiPo charger?**
 - The answer primarily depends on:
 1. The size batteries you expect to charge now and in the future.
 - Size = How many volts (cells in series) and how many mAh the batteries hold. The charger should have a manufacturer specification for the volts and mAh
 2. The battery manufacturers' specifications regarding the charge rate (1C, 2C, etc.) which will determine how quickly the batteries can be charged (assuming speed of charge is important to you).
 - This depends on the quality of the batteries and the charging equipment.
 - » Never exceed the manufacturers specifications
 - See how charge rate plays a role in the next bullet point.
 - **Let's assume you have purchased LiPo batteries with a Manufacturer Specification that indicates up to 2C charge rate when using a LiPo charger with an integrated balancer.**
 - Let's also assume you want to charge a 5S liPo pack that holds 5000 mAh at the 2C charge rate.
 - We'll need our equation: Volts x Amps = Watts
 - Volts = 21 (5 cells x 4.2volts = 21 volts)
 - Amps = 10Ah
 - » 5000mAh x 2C = 10,000mAh or 10Ah (amp hours)
 - 21volts x 10Ah = 210 watt output charger (gives a 2C charge rate and will take approx 30 minutes to charge)
 - » (21volts x 5Ah = 105 watt output charger (gives a 1C charge rate and will take approx 60 minutes to charge))
 - **You'll need a charger with 210 watts output** to obtain a 2C charge rate for a 5S 5000mAh LiPo (Currently there are only a handful of LiPo chargers that can deliver this much wattage.)
- **What size AC/DC power supply?**
 - Let's assume you want to buy a power supply for the charger above.
 - You should assume that the charger is only 80% efficient... that is, if it's giving you 210 watts output, you'll need to provide it with 262 watts input (210 watts / 80% = 262 watts)
 - The equation for the power supply will be: Watts / Volts = Amps
 - Watts = 262
 - Volts = 13.8 (same as lead-acid battery)
 - » On some power supplies, output voltage can be adjusted between 12 & 15 volts.
 - 262 watts / 13.8 volts = 19 amps
 - Based on the Rule-of-Thumb outlined on a previous page = "Try not to exceed 80% of any components current carrying capacity":
 - 19 amps / 80% = 23.75
 - **You'll need a 24 amp power supply**

Building Considerations

Building Tips:

1. The electrical components require airflow to dissipate heat... the cooler they run, the better they'll work and the longer they'll last.
 - Build entry and exit air vents in the plane. You must have both. It is recommended to make the exit vents larger than the entry vents.
2. Upon initial setup of a brushless Motor and ESC, you may find that the motor runs backwards.
 - This is usually corrected by changing the connection on any two, of the three wires. Some 'programmable' ESC's provide the ability to change the rotation through a program option.
3. Keep wires short between the battery and ESC. Also, keep wires short between the ESC and Motor.
 - If you need to extend wires by more than a few inches to get everything connected, contact the ESC's technical support staff for help.
 - Extending the wires can induce higher voltage spikes than the standard capacitors can handle; especially if extending the wires between the battery and ESC. You may need to add additional input capacitors to the ESC. It will depend on the specifics of your setup and the length of extension you want to make.
4. Velcro/straps are frequently used to hold batteries in place.
5. Use a **Watt Meter to test** the power system before you fly it. In-flight smoke looks spectacular, but without a muffler/oil or smoke cartridge, it's not something you want to see:
 - Are you overloading the Motor, ESC, BEC or Flight Battery?
 - Are you getting the approx 'watts' you need/expect?
 - In-Line meters, like the Watts-Up meter, are popular - remember to keep the wire leads short.
 - Eagle Tree makes a great Watt Meter / Power System Monitor called the eLogger V3.
 - You could also use a 'clamp' style amp meter.

Costs

Approximate Costs - For Illustration Purposes Only:

- **Power System (mid-tier) for a plane that has an AUW of 6 - 9 lbs.**
 - \$105 **Motor** = Scorpion 4025-12
 - \$176 **ESC** = Jeti 77 Opto ESC
 - \$45 **BEC** = Ultimate BEC - 6 volt (Or you can use a receiver battery)
 - \$12 **Prop** = Xoar Electric 16x10
 - XXX **Flight Battery** is listed below under Reusable Items
 - \$338

- **Reusable Items***:**
 - \$190 **Flight Battery** = Hyperion CX G3 (6S 5000mah 25C)
 - \$190 **Flight Battery** = Hyperion CX G3 (6S 5000mah 25C)
 - » You'll need two flight batteries for more 'continuous' flying (fly one – charge one)
 - » A similar size battery can be purchased from HobbyKing (Hong Kong) for about \$125 (Zippy-Flightmax); however the quality of the battery, mfg. specified charge rate, and customer service may not be the same as Hyperion.
 - \$25 **LiPo Sack**
 - \$170 **Charger-Balancer** = FMA Cellpro Revolectrix 10s, 10 Amp, Cell Balancing Charger
 - \$10 **6S Balance Plug Adapter** (Cellpro to Hyperion)
 - \$85 **AC/DC Power Supply** = Jetstream 25 Amp Power Supply
 - \$670 <http://www.universal-radio.com/CATALOG/hamps/5226.html>

- **Total**
 - \$1008 Look for 'combo' deals which will decrease your costs.

***** I have 4 electric planes that all use the same 6S 5000mah battery packs:**

- Pattern Plane - 68" wingspan, P-51D Mustang - 65", F-4 Phantom 40" (90mm EDF), Extra 300 - 87"(Uses two 6S packs in series for 12S 5000mah)

Web Links

- **BEC's:**

- Castle Creations <http://www.castlecreations.com/products/ccbec.html>
- Dimension Engineering <http://www.dimensionengineering.com/>
- Kool Flight Systems <http://koolflightsystems.com/ultimatebec.htm>

- **Brushless ESC's:**

- Airboss <http://www.extremeflightrc.com/html/airboss.html>
- Castle Creations <http://www.castlecreations.com/>
- Hacker <http://www.hackerbrushless.com/controllers.aspx>
- Jeti (Hobby-Lobby is U.S. Dist.) http://www.hobby-lobby.com/speed-control.htm#filterValuesRequest.filter_mid_4168=4168
- Scorpion http://www.scorpionsystem.com/catalog/speed_controllers/4s_lipo_bec/4S-Com55A-ESC/
- Principles of ESC Operation <http://www.math.niu.edu/~behr/RC/pwm.html>

- **Brushless Motors:**

- AXI <http://www.modelmotors.cz/>
 - (AXI motors can be purchased through Hobby-Lobby and other U.S. hobby shops)
- E-Flite <http://www.e-fliterc.com/PowerSystems/Motors/BrushlessCharts.aspx>
- Hacker <http://www.hackerbrushless.com/>
- Hyperion http://www.allerc.com/index.php?cPath=7_76
- Mega <http://www.megamotorusa.com/>
- Neu <http://www.neumotors.com/Site/Welcome.html>
- Reaper <http://www.reaperbrushless.com/>
- Scorpion <http://www.scorpionsystem.com/>
- Torque <http://www.extremeflightrc.com/html/torque.html>

- **Electricity:**

- <http://amasci.com/elect/vwatt1.html>
- <http://www.inspect-ny.com/electric/ElectricalDefinitions.htm>

- **Flight Batteries:**

- Lithium Iron/Phosphate (LiFePo4)**

- A123 Systems <http://www.a123systems.com/>
- MaxAmps <http://www.maxamps.com/products.php?cat=62>
- TanicPacks - A123 Packs https://www.tanicpacks.com/index.php?cPath=111_120&osCsid=675722b74cbf5a20082202ad8a744660

- A123 / LiPo Comparison <http://www.flyelectric.ukgateway.net/lithium-a123.htm>

- Lithium Polymer (LiPo)**

- Cell Pro <http://www.fmadiirect.com/index.htm>
- Flight Power <http://www.flightpowerusa.com/index.asp?page=Products/EONX30.html>
- Hyperion http://www.allerc.com/index.php?cPath=3_4_93
- MaxAmps <http://www.maxamps.com/?gclid=CPfjnvLCz50CFQjyDAodGDWnsw>
- Neu http://www.neumotors.com/Site/Battery_Specs.html
- Tanic <http://www.tanicpacks.com/>
- Thunder Power <http://thunderpowererrc.com/>
- Zippy-Flightmax, Rhino - (Hong Kong) www.hobbyking.com

- Battery Bunker <http://www.batterybunker.com/>
- LiPo Sack <http://www.liposack.com/>

- LiPo Fires
 - <http://www.rcgroups.com/forums/showthread.php?t=209187>
 - http://www.fmadiirect.com/lipo_handbook/FMA_Lipo_Handbook_Section3.htm
 - <http://www.youtube.com/watch?v=odxR1IkfiEI>
 - <http://www.youtube.com/watch?v=ZNxLGDwGw-k>

- **Hobby Shops:**

- 3D Hobby Shop www.3dhobbyshop.com
- Atlanta Hobby www.atlantahobby.com
- Chief Aircraft <http://www.chiefaircraft.com/rcmsec/Models/Model.html>
- Electric Jet Factory <http://www.ejf.com/>
- Esprit Model <http://www.espritmodel.com/>
- Extreme Flight www.extremeflightrc.com
- Hobby-Lobby www.hobby-lobby.com
- Horizon Hobby <http://www.horizonhobby.com/>
- Innov8tive Designs http://www.innov8tivedesigns.com/index.php?cPath=21_25
- Mark Twain <http://hobby1.com/store/>
- Schaefer's <http://www.schaeferhobby.com/>
- Todds Models <http://www.toddsmodels.com/>
- Tower Hobbies <http://www.towerhobbies.com/>

- Graphics <http://www.badbradgraphics.com/>

- **LiPo Chargers & Balancers:**

- Bantam e-Station BC6 Charger/Balancer <http://www.rcaccessory.com/bantame-stationbc-6bc6acdcbalancingcharger.aspx>
- FMA CellPro 4S or 10S Charger/Balancer <http://www.fmadiirect.com/>
- Hyperion EOS0615I-DUO-III Dual Port Charger <http://store.rcsupersales.net/servelet/-strse-5279/HYPERION-EOS0615I-DUO-III-dsh-DUAL/Detail>
- ThunderPower (TP) 1010C Charger + TP210V Balancer + DataPort connector <http://www.rctoys.com/rc-toys-and-parts/K-TP-1010C-210V/RC-PARTS-COMBOS-LITHIUM-CHARGER.html>

- FMA Cellpro 10s Charger Review <http://www.rcgroups.com/forums/showthread.php?t=780132&highlight=lipo+50+degrees>
- Balance Plug Adapters Xref
<http://www.rcaccessory.com/pdf/Battery%20Tap%20Configuration%20Guide.pdf>

- **Power Supplies:**

- Jet Stream <http://www.jetstream-usa.com/powersupply.shtml>
<http://www.universal-radio.com/CATALOG/hamps/5226.html>
- Samlex SEC http://www.samlexamerica.com/products/power_subcategory.asp?packagetype=3&CategoryID=2&title=Desktop

- **Props:**

- APC <http://www.apcprop.com/v/index.html>
- Xoar <http://www.xoarintl.com/>

- **R/C Forums:**

- Flying Giants: <http://www.flyinggiants.com/forums/>
- RCGroups: www.rcgroups.com
- RCUniverse: www.rcuniverse.com
- WattFlyer: www.wattflyer.com

- EZone <http://www.ezonemag.com/>

- **Software:**

- ElectriCalc <http://www.hobby-lobby.com/ecalc.htm?pSearchQueryId=229730>
- MotoCalc <http://www.motocalc.com>

- **Watt Meter:**

- Watts Up Meter <http://www3.towerhobbies.com/cgi-bin/wti0001p?&I=LXLMV0&P=FR>
- eLogger V3 <http://www.eagletreesystems.com/MicroPower/micro.htm>