INTRODUCTION TO ELECTRIC-POWERED R/C AIRPLANES

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INTRODUCTION TO ELECTRIC-POWERED R/C AIRPLANES

PART ONE

Our club members as an aggregate have possibly close to a thousand years of knowledge and experience with glow-powered airplanes. Electric power has only in recent years become a viable power source for flying airplanes at the performance level most of us want, and many club members have limited experience with them. Some may even feel a little intimidated by the new terminology and reference to electrical parameters involved with them.

It is my intention here to provide some basic information regarding the required components of electric powered airplanes and alleviate any concern about not having enough knowledge of electronics or electrical systems to put together a successful e-powered sport/aerobatic R/C plane. E-power is currently being used for everything from tiny park flyers to 12-pound aerobatic planes. Examples in this discussion will be mostly limited to sport planes of the 25 to 60 size, 2 ½ to 6 pounds or so. Members who have experience with e-powered planes may find this write up too basic. It's not intended for you.

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First, here are some of the advantages of flying e-power:

- **Clean and quiet. No oily mess to wipe off after flying and no leaking fuel tanks. Less noise than might otherwise upset the neighbors and jeopardize our field.**
- **Improved looks. No protruding cylinders or mufflers. Use any paint since fuel-proofing is not necessary. No problem with decals sticking even after flights.**
- **No needle valve adjustments, no dead sticks due to incorrect mixture.**
- **No costly fuel to buy. Cost to charge a battery is nil.**
- **No starters, starter batteries. No glow driver, no glow chargers.**
- **Possibility of multi-engine planes without the dreaded engine failure risk.**

Definitions of the required components:

Motors

- "Brushed" types. All early motors were of the type that have brushes and commutators. They are still widely used in park flyers, zaggies, small to medium size sport planes, and motor-gliders. Swapping polarity (+ and -) will reverse the motor rotation.

-"Brushless" types. Later designs are primarily of the "sensorless brushless" type that are very efficient, have only one moving part and require no routine maintenance. There are 3 wires connecting the ESC to the motor. Swapping any two of these will reverse the motor.

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ESC (electronic speed controller)

The ESC takes the place of a carburetor throttle and throttle servo. It is connected between the battery and the motor and serves the purpose of controlling the speed of the motor in relation to the transmitter throttle position.

-Two types for use with brushed motors. With and without BEC.

-Two types for use with brushless motors, also with and without BEC.

-The BEC (battery eliminator circuit) is essentially a voltage regulator that provides approximately 4.8 volts to the receiver/servos from the main battery, thus eliminating the need for a separate receiver battery.

- They are available in several power ratings and whichever type is used, it must be capable of handling the maximum current the motor will draw.

Main battery

-Most main batteries are of the NiCd (Nickel Cadmium) and NiMH (Nickel Metal Hydride) technologies. Whether NiCd or NiMH, the battery pack provides approximately 1.2 volts per cell at low current draw and typically about 1.0 volt per cell when at full power current. NiMH cells provide a little more capacity (longer run times) than NiCd for the same weight. Therefore, a 10 cell pack for example, will read about 12 volts static or with the motor at idle, but will drop to about 10 volts when at full throttle.

-The capacity of the battery pack is expressed as mah (milliamp hours), or the milliamps that can be discharged from a fully charged pack over a one-hour period. This is commonly known as the 1C rate. In our sport plane use, we typically discharge (through the motor) at 15 times the 1C rate (Therefore, a 2000 mah (2 amp hour) battery will produce power for 4 minutes (1/15 of an hour) at 30 amps with full throttle. If we fly with reduced throttle at an average of say, 12 amps, total run time could be 10 minutes. Leaving some reserve so we don't have to land dead-stick, we could fly safely for 3 to 8 minutes in the example above depending how we manage the throttle.

-Li-Poly (lithium polymer) batteries are being introduced into our hobby/sport and promise lower weight and longer flight times, but because of possible safety concerns, charging them at the field is not currently allowed at the Wingmasters flying site. See Model Aviation magazine May 2004 for a good explanation of these revolutionary new batteries.

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Gearboxes

Most electric motors operate at maximum efficiency at high and very high RPM. Since propellers operate efficiently at low RPM, gearboxes are often used to avoid this mismatch. It's not uncommon to have a motor running at 30,000 RPM with a 4:1 gear ratio providing a propeller RPM of 7,500. A fairly new motor type is designed to run at low RPM in direct mode without needing a gearbox. These "outrunner" motors are mostly of the smaller variety.

Propellers

Special propellers are often used for e-planes. They can be manufactured with thinner, more efficient cross sections since they are not subjected to the high stress loads placed on them by glow engines. Also, because of the gearing described above, it's common to see large diameter, high pitch props on e-planes. (My 40 size sport e-plane uses an APC 14X12 prop). Motor-gliders usually use folding props that reduce drag while soaring and allow belly landings without breaking the prop.

Is a great knowledge of electronics required to build and fly e-planes?

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Absolutely not. It's possible to get into e-planes easily and cheaply with small combo packages available where you don't need to know anything. But it's not difficult to build a very rewarding e-plane with straight forward, easy to understand knowledge of a few electrical parameters. For our use, really all you need is an understanding of basic DC operation and how voltage, current and electrical power relates to our requirements.

Voltage: Is the force that moves electrons through a circuit. This force increases as cells are added in series to a battery pack. For example, if you add just one cell to a 10 cell pack, you increase this force by 10 %.

Current: Is the electrons moving through the circuit and increases as the applied voltage increases. Assuming the resistance in the circuit remains the same, the 10% increase in voltage will result in a 10% increase in current.

Power: Is the product of Voltage and Current is the Power (Watts) of the system

Power = Voltage times Current.

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(Note that in the examples above we added a cell to the battery, thereby increasing the voltage by 10% and that in turn resulted in a 10% increase in current. Since power is the product of voltage and current, the addition of that one cell added 21% to our power.)

Notes: 746 Watts = 1 horsepower

1000 milliamps = 1 amp

There is a rule of thumb that says 50 watts per pound of flying weight is required to take off, fly around and land. 75 Watts per pound will provide a nice flying plane with limited aerobatics, 100 Watts per pound will provide a very quick plane with good aerobatics, and over 100 Watts per pound will do almost any maneuver you want.

Therefore, if you have a 4.5 pound e-plane operating at 15 volts and 30 amps, you have 450 Watts of power, or 100 watts per pound. That's .6 horsepower, about the equivalent of a 40 glow engine. This would be a very nice flying sport/aerobatic e-plane.

I hope this discussion has piqued some interest. If so, I will continue with some additional detail and provide information regarding costs, battery chargers, airplane designs, and the description of a very good program that can be downloaded to your PC. This program is easy to use and is great for calculating system operating parameters, flight performance predictions, and is great for quickly seeing the affects of prop choices, what happens when adding or reducing the battery cell count, etc.

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PART TWO

What sort of R/C plane is suitable for e-power?

Combo packages and those sold for e-power of course, but also many kits and ARFs designed for Glow engines can be converted to e-power.

Motor and battery technologies have improved over the last two years or so with newer/better units hitting the market almost daily. For example, just look at Tower, Hobby People, Dymond, and Hobby Lobby to see the variety of e-planes and components currently available.

If you are interested in "conventional 25 to 60 size" e-planes, the new motors and batteries can work very well at powering them. No longer must an e-plane be built so lightweight and fragile it comes apart during a hard landing.

We have a variety of e-planes flying at our site that fit into the 25 to 60 category.

A Phasor 15 powered 'Hots', a Phasor 30 powered 'Hots', a beautiful PT-19 with over 100 flights to date, a fantastic 60 size Spitfire with retracts, a Sig Cub that was converted from Glow to electric, a Somethin' Extra with a Hacker 50 motor, 3D's with incredible power-to-weight ratios, a Sig Rascal with a Phasor 45, and a couple of my "home brews" to name a few.

Several other kits and ARFs designed and available for glow engines would, in my estimation, make good e-plane conversions. (I keep seeing glow powered 'Magic Extras' from Hobby People flying at our site and can't help visualizing one with a Phasor 45 in the nose.)

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Flight prediction program for your PC.

When I become serious about converting a Magic Extra (or any other kit/ARF) to e-power, I will use a PC program called MotoCalc to optimize the power system and predict the performance. The first step would be to input the planes wingspan, wing area, airfoil type, and the estimated weight. For the Magic Extra, I would start out selecting a Phasor 45 motor or similar, probably a 16 cell NiMH battery, and maybe a 2:1 gearbox with a 14X12 APC prop. MotoCalc would compute the motor current, thrust, rate of climb, stall speed, top speed, motor and prop RPM, Input Power (Watts/ lb), flight duration at full and partial throttle settings and many other operational and flight parameters. It would be easy then to make changes to cell count, prop size, etc and rerun the program. The results of several iterations of changes could then be compared and printed for side-by-side analysis to zero in on the most optimum configuration. I would know pretty well how the plane would perform before buying or building a single component!

Details of MotoCalc use and how to obtain a free 30-day trial can be found at www.motocalc.com.

How circuit resistance affects performance

I briefly discussed voltage, current and power in the first article. Resistance to current flow in our e-plane system is also important to the overall efficiency and performance. OHM's law states that current in the circuit is determined by the voltage and resistance. (I=E/R where I is the current in amps, E is the voltage, and R is the resistance in OHMs). Since power is the product of voltage and current (Power=IE), any unnecessary resistance in the circuit will lower the current and have a detrimental affect on the power available to drive the model.

Resistance in our systems include: The internal resistance of the battery, the ESC circuitry, the motor, and the wiring and connectors that tie the system together. This total resistance is very low, typically one half OHM or less. (A system

operating at 12 volts and 24 amps means there is 1/2 OHM in the total circuit). All components must be of high quality to minimize unwanted resistance. We as the builders can minimize resistance by using wire of sufficient gauge to carry the current without loss and that is no longer than necessary, and installing high quality connectors with gold contacts, such as Deans Ultra Plugs. A desire to keep the resistance low is also the reason most of us avoid using fuses and arming switches in the system, both of which have inherent resistance.

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PART THREE

OK, so maybe you're convinced of the benefits e-power can provide, and feel a little more at home with the unique terminology. But you may still have reservations because of the cost.

In this final part, I'll make some comparisons between costs associated with g-power and e-power. As with g-power, e-power costs can vary widely between small and simple opposed to big and elaborate.

The following is a comparison between a "40 size" glow and electric

I won't include the airframe and radio system since prices for those are assumed to be equal.

Dollar values are approximate and are for good quality products.

	G-power	E-power
OS 52 4 cycle	200	na
Fuel Tank		
1 Gal. Fuel	20	na

Starter with Battery		
and Charger	60	na
Glow Ingiter		
with Charger	15	na
Throttle Servo	15	na
Fuel Pump	15	na
Phasor 45 with		
40A. ESC	na	240
Prop Adapter	na	80
Battery Pack	na	80
Battery Charger	na	100
TOTAL	$300	$450

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Note that after each 20 or 30 flights, another gallon of fuel for the G-powered plane will need to be purchased, whereas the cost of recharging the E-power battery is nil and they can go several hundreds of flights before replacement.

You're saying yeah, but I already have a bunch of engines, starter, igniter and all that other support stuff for my existing G-planes. Well, you might try what I did. I sold several engines and planes I would never use again and bought electric motors and batteries with the proceeds. Net cost to me to go electric = zero.

Consider starting with a motor-glider as a backup to your existing glow plane. I would still advise getting a good peak charger, but less expensive motors, ESCs, and battery packs are suitable for gliders. As little as 40 to 50 watts per pound is sufficient for hand launch, climbing out to find some lift, then powering off for soaring flight, only turning power back on again to regain altitude.

For example, a small and very nice flying motor glider is the Graupner Terry. It has a wingspan of 41", is a molded foam ARF, flies on a small 7 cell battery, and sells for about $60. If I recall, it does require a pair of micro servos. A large variety of motor gliders are available from Dymond, Hobby Lobby, Hobby People, Tower, and others. Approximate motor system prices for small to medium gliders are shown below.

Battery 6 to 8 cell $25 to 45

Motor with ESC $40 to 85

Whether flying Glow or E-Power, have fun. And remember when landing to keep the greasy side down.

Oh, that's right! There is no greasy side with E-Power!

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UPDATE 02/23/07

The following update is provided here since a lot of changes in product availability has occurred in the last three years. Members new to e-power are encouraged to read the original article using the following updated information.

Update to part 1:

Main battery – Li-poly battery technology continues to improve, and their use is gaining in popularity. It is still essential to charge and discharge them within their specifications and in a responsible manner. If you are unsure about your particular setup, talk to someone who is knowledgeable about them.

Gearboxes - Manufactures are providing more and more brushless outrunner motors, from very small to very large. The main advantage is that they produce high torque at low RPM, therefore can turn large props directly without need for a gearbox.

Power – With recent improvements in motors and batteries (especially L-Poly), plus lighter airframes, power/weight ratios have increased dramatically. 200 or

more watts per pound is not unheard of. That's why you see lightweight foam 3-D planes hovering.

Update to part 2:

What sort of R/C plane… - Our club members currently have about 30 Multiplex Easy Star's being flown by beginners and 'old salts' alike, some stock and some with power modifications. Also, many kits and ARF's are now provided that accommodate either gas or electric power.

Flight prediction program…-MotoCalc continues to add new motors and batteries to their extensive databases as they become available.

Update to part 3:

Costs – Added to the list of inexpensive e-planes is the ever-popular Easy Star. It is a great way to become involved with e-power.

Rex Geivett February, 2007

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ELECTRIC MOTOR CONVERSION: *Technical Note*

by Mike Woolley

My OS FS91 four stroke glow engine in my 4 Star 60 is not running and it could be the pump system. Replacing this would cost almost as much as a new motor so it is not worth replacing. I have been flying .46 size Sport electric aircraft for over ten years so I am contemplating an electric conversion. To determine the electric motor size I have used the following methodology.

The all up weight of the aircraft is 8lb 8oz or 136 oz. I have accumulated considerable static data relating thrust to motor power for Master Airscrew propeller sizes from 11x6 2 bladed to 14x9 3 bladed using the same motor-gearbox combination varying gear ratios and battery power. This eliminates some variables and the results show the efficiency of the rest of the system.

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The data shows a range of trust to power ratios of .11 to .13 oz/Watt, so I will use the lowest number a value of .11oz/Watt. I estimate that the thrust/weight ratio (T/W) of the current 4 Star 60 is just less than 1, so for estimation purposes I will use .9. The required power is then .9x136/.11 or 1112 Watts to match my present performance. The Watts to weight ratio is then 131 Watts/lb.

The 'Rule of Thumb' for determining the power required is the arcane Watts per pound definition. This is often stated as:

50 Watts/lb will give a flyable airplane.	Using my method T/W =.35
100 Watts/lb will allow mild aerobatics.	Using my method T/W=.69
120 Watts/lb will allow advanced aerobatics.	Using my method T/W =.825
140 Watts/lb preferably more gives 3D performance.	Using my method T/W =.96

In the aircraft industry T/W is a well used quantity and the above neatly ties it in to the 'Rule of Thumb'.

Using a loaded voltage of 3.3 volts for a Lipo battery, a 6S pack with a current of 56 Amps yields 1108 Watts. This can be satisfied by a 3800 20C pack.

The Maxxprod web site lists motors and Watts capability and contains very useful Amps vs Volts graphs for each motor. Their only motors fitting my requirement are Himax HC5030-390 and HC5018-530 outrunners. The HC5018-530 was power limited to 900 Watts so was not adequate. Turning to the HC5030-390 motor I plotted a 1112 watt line and also the 55 amp motor maximum current and the Volts for the RPM limit lines. My propeller size is limited to 14 inches for ground clearance. It was not possible to satisfy my requirements with this motor because of these limits. In fact I would need an 8S pack to do the job. A needless added weight which reflects on performance. However, this demonstrates how useful the Himax graphs are, and also shows the very limited range of application of direct drive motors.

I there for looked at other vendors and found a Tower Hobbies Rimfire motor advertised for .91 four stroke conversions. Unfortunately they do not provide the excellent charts like Himax but the specs look good.

Max. Constant current: 52 amps
Max Surge Current: 65 Amps
Max constant watts: 1154
Max Surge Watts: 1440
Input Voltage: 18.5-22.5 volts
Weight: 10.5 oz
Propeller size: 13x8e
RPM/V: 500

Comparing Electric vs Glow power system weights:

Weight of OS .91 motor 22oz, Onboard glow system 3 oz, full fuel 12 oz, total 37oz.

Rimfire motor 10.5 oz, 6S magnum Battery 26 oz, total 36.5 oz

ESC even trade with throttle servo.

The all up weights for both systems are comparable and the Rimfire will do the job.