# What motor do I use?

Issue 3
Article By Greg Covey

For years now, I have heard concerns about motor cost and complexity from many R/Cers wishing to try electric-powered flight. The market has responded with lower prices through competition, reduced complexity through outrunners, and even "combo" packages of matched components that work together. This has attracted more enthusiasts than ever before to try their first electric-powered ARF or glow-to-electric conversion. However, the recent increase in new motor manufacturers and inventive marketing techniques has resulted in a confused customer rather than a confident buyer. Some folks look for a complete document or database that contains all the information they seek about selecting electric power systems but become disappointed and frustrated when they cannot find it. The various numbering schemes of electric motors all seem foreign to someone used to selecting a .40-size or .60-size glow engine.

R/C hobbyists come from all different backgrounds; some are more technical and love to experiment while others may have limited time, patience, or means.

Everyone want's to get it right the first time so their effort and money is not wasted. This month's issue will address the main confusion I see now from many people wanting to try electric power. That confusion is...

What motor do I use?


### Choosing An Electric Power System

Many R/Cers wishing to try electric-powered flight are concerned with the cost of the motor and the added speed controller. The cost of paying for fuel up front, like batteries and especially expensive Lithium cells, was a foreign concept to most glow-powered R/C enthusiasts wishing to try an electric conversion. They were comfortable with paying for fuel as it was needed. Added complexity came from gearboxes, gear ratios, new mounting patterns, selecting motor and prop sizes, cell count, and series or paralleled cells. The wide dynamic range of brushless motor operation mystifies most of the glow-oriented R/Cers since a given size engine would produce a specific level of power. Each vendor proclaimed that their product was the best but shrouded specifications in various numbering schemes that were foreign to someone used to selecting a .40-size or .60-size glow engine.

Many of these areas have changed for the better. Outrunners have eliminated the need for a gearbox, reduced the prop size range to select from, and, also reduced the range of cells that could be used for a particular motor. Electronic Speed Controls (or ESCs) like the Jeti Advance PLUS line greatly simplifies programming the setup by using a tiny card that can reside in your field box. Castle Creations Phoenix line of speed controllers require no programming before flying since the standard settings will work for most applications. New Lithium cells have reduced the need to parallel cells and have increased safety by being non-combustible at high charging voltages. Lithium safety and pack longevity were further enhanced by adding taps to multiple cell packs. New chargers and devices allow for balancing during the charge cycle and the cell count was hardwired through the node connector which eliminated false guessing techniques. Automatic peak chargers for all cell types are now available. The resultant added safety and lifespan of the flight pack helped balance the cost.

What does this leave us with? The selection of the electric power system is now the biggest unknown. The question I hear from most people now is, “What motor do I use?”

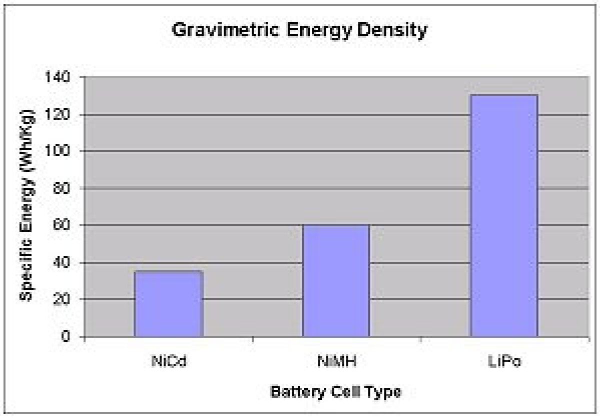
Today, you can fly a 20lb plane on an electric power system for less than $400. New ESCs allow for 12s (12-cell) Lithium packs to provide up to 7 h.p.! One of the biggest confusions for most people selecting an electric motor is, “What is a watt?” The glow guys are used to horsepower and electric power systems are measured in watts. (1 h.p. = 746 watts or about 750 watts)

Power Level in Watts equals Voltage x Current where the voltage is affected by cell count and the current is affected by prop size and throttle setting, but, these interactions are not exclusive to each other as one can affect the other. Instead of tuning a carburetor on a fueled engine by listening to the sound by ear, the wattmeter now becomes the primary tool for measuring the power of an electric motor system. Watt meters measure power input (not watts to the prop). Since brushless motors are around 80% - 90% efficient, most of the power gets to the prop.

What’s so easy about selecting an electric motor?

A general rule of thumb for electric powered flight was originated by Dr. Keith Shaw several decades ago based upon the older Astro Flight Cobalt brushed motors. The rule read something like this:

- 50-75w/lb for Cub-like planes or Trainers
- 100w/lb for Sport/Aerobatic/Pattern planes
- 150-200w/lb for 3D, EDF, or other high performance planes




Since brushless motors are more efficient than brushed motors, only 65w/lb is all that is needed for a take-off from grass, to climb well, and, to perform mild aerobatics on a .40-size trainer plane.

Swap your NiMH or NiCd battery packs for newer Lithium technology and you're flying duration doubles or quadruples, respectively. However, this increase in performance through advanced battery technology does come with an added cost.

The sequence for choosing the right electric motor is simplified by a combination of Keith Shaw's findings and today's abundance of information both on-line and in catalogs. Here is the sequence that I use to help people select the right motor class.

Choosing An Electric Power System

1) Determine the flying weight of the plane and multiply flying weight by 50, 100, or 150 depending upon plane type and expected performance (50 for Cub-like or Trainer, 100 for Sport Aerobatics, or 150 to 200 for 3D, EDF, and high performance) The result is power in watts needed from the motor at full throttle. This result determines the power class of the motor needed for your application which is a value typically displayed in the manufacturer's motor specifications. When the power level is not given, you can simply multiply the maximum current given by the number of Lithium cells with a voltage under load of 3.6v. As a comfort check, recall that 1h.p. is equal to about 750 watts so you can compare your result with the corresponding glow or gas engine recomended for the model.

2) Use Vendor Web site recommendations (most vendor sites post charts of motor power levels as well as complete recommended setups for a particular model)

3) Copy a review setup. There are many existing reviews that you can benefit from reading for your own application

4) Copy a similar size plane with similar design and wingarea. If a review uses a certain power system on a .40-size high wing trainer, it will likely work fine on your similar application.

5) Use a computer program to assist you in the motor selection process (Sid Kaufman's ElectriCalc or Stefan VorKoetter's MotoCalc). Both of these power system selection programs can give you a reasonable start or verify the merit of your existing component choices.

**Marketing Techniques**

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A scan of the top distributors of electric flight products reveals different techniques used to help customers select the right motor or power system for their application.

TOWER HOBBIES

Great Planes, ElectriFly - Offers extensive conversion charts, reviews, and step-by-step selection tools. An impressive set of tools.

HOBBY-LOBBY INTERNATIONAL, INC.

Hobby Lobby - Extensive suggestions for plane weight and flying type. Uses combo packages of match components and many reviews.

HORIZON HOBBY now, this is fun!

Horizon Hobby - Motor scheme matches glow engine equivalent or old brushed motor number. Power levels are also specified. Very useful for glow-oriented customers. Power levels are good for watts per pound rule-of-thumb.

Hobby People

Hobby People - Combo packages and suggested replacements for older brushed motors. Some motors specify peak watts output which is good for watts per pound rule-of-thumb. Short customer reviews.

## Brushed vs. Brushless

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Great Planes has a brochure on Brushless Power Systems (GPMZ0006) that is an extensive publication on their products for electric flight. If offers easy-to-use tools that help you find what you need and charts on selecting the proper motor for many of the popular top-selling glow airplanes or for converting your own plane.

ElectriFly also offers an Easy Conversion Methods page which provides links to selecting the right components for your model.

One difference between brushed and brushless motors is what rotates. In brushed motors, it's the windings that rotate. In brushless motors, the windings stay put and the magnets move. But for the most part, the names say it all. Brushed motors have brushes to carry current and spin the rotor. Brushless motors don't. A brushless electronic speed control (ESC) energizes the electro-magnetic field, which causes the motor to turn. And because of this, there's:

• No brush-to-commutator contact — the #1 source of friction, waste heat, inefficiency, wear and maintenance in brushed motors.

• No voltage drop due to arcing caused by the brush-to-commutator contact — which minimizes power losses and prevents radio noise and glitching.

• And virtually no limits on top-end speed or motor life.

When the power level is not given, you can simply multiply the maximum current given by the number of Lithium cells with a voltage under load of 3.6v. As an example, the RimFire 35-36-1500 (GPMG4625) can handle 47amps on a 3-cell LiPo pack. Multiply 47 * 3cells * 3.6v per cell to get 507 watts. Then use the watts per pound rule of thumb.

## Inrunner vs. Outrunner


The ElectriFly AMMO motor on the left is an inrunner. The outside can is stationary and it only spins the shaft on the outside of the motor. Typically, but not always, this type of motor requires a gearbox which allows them to swing larger props efficiently. Some inrunners, especially the brushless kind, can spin a larger prop directly without the need for a gearbox. On many inrunners, when a gearbox is not used, only a small prop can be used that spins very fast.

The RimFire motor on the right is an outrunner. An outrunner motor spins both the shaft and the outer case. These motors generate much more torque than a normal inrunner motor and can typically spin a larger prop without the need for a gearbox. This is sometimes referred to as direct drive since it drives a prop directly. Direct drive reduces the cost, complexity, and, added weight of using a gearbox. Outrunners also reduce the prop size range to select from and reduce the range of cells that could be used for a particular motor.

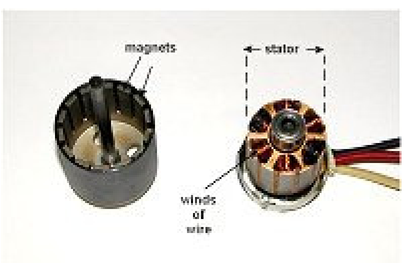
ElectriFly.com offers an on-line Electric Motor Configuration service to help you select the proper motor for your application. You can also view the Glow To Electric Conversion Guidelines PDF for hints on using larger geared inrunner motors.

Outrunners like this black Atlas 5030 series come with two prop adapters. One is for mounting the motor behind a firewall and the other is for mounting it to the front of a firewall.

Outrunner motors have come to dominate many consumer devices such as computer hard drives, CD/DVD players, and PC cooling fans. These low speed brushless DC motors are also used in direct-drive turntables, electric vehicles, and some industrial machinery. The recent increase of popularity in electric-power model aircraft has spurred demand for these outrunner motors.

Brushless DC electric motors from Wikipedia

## Understanding an Outrunner's Numbers




Most outrunners use a 6-digit numbering system like the AXI 5330/18. The first two numbers (53) represent the diameter of the stator in millimeters. The stator is the fixed part in the middle of the motor. The second two numbers (30) represent the length of magnets in millimeters. These long rectangular magnets are attached to the inside of the rotating case. The third set of two numbers (18) represents the number of wire winds, also called turns.

Other manufacturers use variations on this numbering scheme. Sometimes the second set of numbers can represent the length of the rotor or motor can instead of the magnet, or they have a letter designation to represent a size like S for Short and L for Long. In any case, I find it easiest to simply remember that bigger and longer means more power!

*Bigger and longer means more power!*

When comparing motors of similar size, there are several characteristics that you will notice. Motors with higher winds spin slower for a given voltage. Higher winds means they have lower Revolutions Per Minute (RPMs). This is also referred to as Kv in motor gain terminology. These motors spin a larger propeller at slower speeds than lower turn motors. Motors with lower winds spin faster for every volt of electricity applied. They have a higher Kv (or RPM/V). They can spin a smaller propeller at higher speeds than higher turn motors.

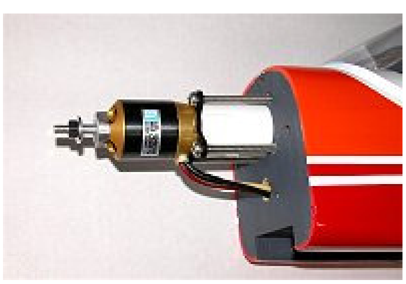
Sometimes I take advantage of the fact that lower Kv motors use thicker guage wires compared to the same size higher Kv motor. This means that you can draw more current through the motor and gain higher burst power levels for 10-20 seconds without damage to the motor. The result is an impressive fly-by or vertical climb when needed during the flight.

Example: A motor with a Kv of 1200 will turn 1200 revolutions per minute per volt applied. On a 12v supply, it will turn 12 * 1200 = 14,400 RPMs.

## Glow Conversion Example

Let's try an example using the Graupner Taxi Cup II which used to be sold in the U.S. by Hobby Lobby. Although this plane is a high wing aileron trainer, the clean design (low drag) makes it unusually fast so a pilot needs intermediate skills to fly it successfully. The manufacturer says that the plane weighs 96oz (or 6lbs) when equipped with a .40-size glow engine.

Using the middle of our rule of thumb power level for trainer-type planes, we multiply 65watts times 6lbs to get 390 watts which is about ½ h.p. The result of about 400 watts is the motor class that we need to select from for our conversion project.



The AXI line of outrunner motors has several selections in this 400 watt class, the heavier 4120 motor for 4-5 LiPo cells, and, the lighter 2826 for 3-5 LiPo cells. The AXI motors are direct drive brushless designs that are virtually maintenance-free. Since there are no brushes to wear out and no gears to lubricate or strip, the motors need no maintenance other than perhaps a yearly lubrication of the ball bearings supporting the drive shaft.

I selected the AXI 2826/12 motor because it can be powered by readily available 10-cell NiCd/NiMH packs or 3-cell Lithium Polymer (LiPo) packs. This also means that I can use an ESC with a built-in Battery Eliminator Circuit (BEC) to eliminate the complexity of using a receiver battery pack. Most

ESCs have a built-in 5v regulator that can power the receiver and servos as long as the flight pack doesn't exceed 10-cells NiCd/NiMH or 3-cells LiPo. New ESC designs are no longer limited to this 3-cell limit for using the built-in BEC. Read on!

Simply take the Lithium cell voltage under load of 3.6v, times the # of cells used, times the maximum burst current to get power class in watts.

- For the AXI 4120/14, it is 3.6v x 4 cells x 40amps = 576w.
- For the AXI 2826/14, it is 3.6v x 3 cells x 40amps = 432w.

The Jeti 40-3P ESC comes with a Battery Eliminator Circuit (BEC) which eliminates the need for a receiver battery. The BEC provides voltage to the receiver and the servos through the ESC control cable which eliminates the need for a second battery for the receiver. This convenience means that you'll never need to worry about the charge on the receiver battery again! When using a folded 10-cell NiCd or NiMH pack, the model will balance perfectly without adding and lead weight to the nose. These 10-cell packs weight about 22oz.

When you combine the AXI 2826/12 motor with either a 10-cell NiMH pack or 3-cell Lithium pack, a 40-amp ESC, and, an APC 13x10 e-prop, the resulting power system will provide about 385 watts at 37amps. Note that this power level can be easily measured with a wattmeter by plugging it in-line between the battery pack and ESC. This gives our 6lb application 385w/6lb or about 64w/lb which fits in our rule of thumb range.

My Taxi Cup II was ready to fly at 100 ounces (6-1/4 pounds) with a power system that will provide about 385 watts or about ½ h.p. The plane can perform most aerobatic maneuvers while remaining incredibly stabile in flight. My conversion to electric power was made easy by Dr. Keith Shaw's general rule of thumb.

Another solution to convert my 6lb Graupner Taxi Cup II to electric power is the E-flite Power 46 Brushless Outrunner Motor from Horizon Hobby. Not only is the correct conversion size apparent in the name of the motor, the description of the motor reads as follows:

*Ideal for 40- to 46-size airplanes 4- to 7-pounds (1.8-3.2 Kg), 25- to 40-size 3D airplanes up to 5-pounds (2.2 Kg), or models requiring up to 800 watts of power*


This technique for marketing the motor is very informative to the customer. Note that the specifications on this motor also suggest a LiPo cell count from 4 to 5 cells.

While using more than 3 Lithium cells may require the use of a separate receiver battery on some ESCs, the new 60-Amp Pro SB Brushless ESC with Switch-Mode BEC allows you to operate up to 7 analog or 6 digital standard-sized servos with the BEC on any recommended input voltage from 3s to 6s LiPo.

## Summary

The intent of this column was to arm the reader with a simple set of rules and steps to follow for selecting the right motor. When using the watts per pound general rule of thumb, choosing an electric motor can be as simple as knowing the all-up weight of your model and its desired flying style. Variations on the type of flying needed, scale prop size, and speed can be handled though the number of motor winds and battery cells used.

There is no mystery in selecting an electric power system; only confusion by the overload of choices we currently see on the market and the less than obvious specifications from various numbering schemes. While the abundance of motor manufacturers helps keep the cost down through competition, it can be intimidating to narrow the field to a few choices. We can empower ourselves by first determining the power class of the motor we need to make it an easier selection. Don't fall prey to the least expensive product on the market as quality and support can often overcome a choice based on cost alone.

Good luck on your next glow to electric conversion project! Your plane will last much longer by staying clean and flying noise-free without all the nasty vibrations. When you fly electric, fly clean, fly quiet, and fly safe!

Greg Covey

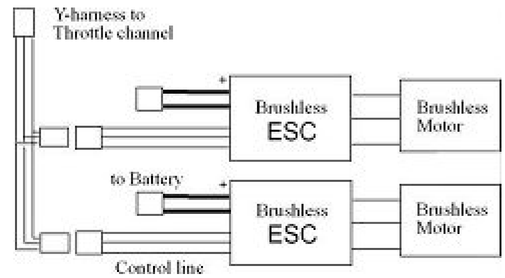
## ASK AMP'D

This section of AMP'D covers some of the questions that our readers have sent in and I thought would be interesting for others.

***Dan asks: "I was confused by your last 'Ask AMP'D' issue where you talk about using one or two***

***packs for separate motors. How do I wire two brushless motors on a plane?"***

**Greg:** Unlike brushed motors, brushless motors need one ESC per motor. You can connect both ESC's to a single throttle channel using a Y-harness or you can plug them into separate channels and use a transmitter mix from the throttle channel.




***Tim G. asks: "In your last issue, I noticed that you were using a Jeti SPIN ESC but didn't give any details on how to connect the SPIN BOX to program it. I can't seem to figure out how to get it to work?"***

**Greg:** My focus on the last issue of AMP'D was on arming the ESC. I'll admit that I was rather dissapointed in the instruction sheet that came with my Jeti SPIN BOX. Fortunitely, Hobby Lobby has a better description of the set up needed on their SPIN Brushless Speed Controls page.


The key things to know are that the longer cable with the (+ - and signal label) symbols on it connects to the ESC and if you are using an OPTO controller, a separate power supply is required like a 4.8 - 6V standard receiver battery. The shorter lead with the red connector goes to the programming box and the longer lead goes to the receiver. The short lead has a sticker on it that is marked "RX" with a circle and line thru it, which stands for "not to reciever". The battery plugs into the connector that is only labeled (+ -) for use with OPTO speed controls and the testing tool for measuring and exercising the servos.

I ended up attaching a 36" long JR extension cable to my SPIN BOX so I could more easily connect it to the short lead on the SPIN controller. I also put some Velcro® on the back of the SPIN BOX so the Rx. battery pack could be attached.

***Neal writes: In your last "Ask AMP'D", you wrote, "As long as the noisy Motor to ESC wires are short, the battery lines to the ESC can be long." I believe that this is contrary to Castle's (Castle Creations) thinking. I believe that Pat (Patrick del Castillo) wants the ESC to motor leads long and the battery to ESC short. Am I correct?***

**Greg:** Yes, you are correct. My statement appears to be contrary, but it is common to misinterpret a message, especially if it is taken out of context. The reality of which wires to make longer can be different depending upon the type of ESC used, the position of the receiver or ESC, and your definition of "long". In most cases, we only need the ESC to battery wires to be a few inches longer and it is easier to lengthen the two battery wires than extending the three motors wires, especially if the ESC must be moved out of the air flow.

Look for a consensus of opinion and examples of what works in certain situations. For example, most opto-coupled ESCs do not have any issue with longer battery wires up to 2' in length or more. When you make the battery wires longer than a foot on non-opto coupled ESCs, you run the risk of hurting the controller unless you add a decoupling capacitor across the battery wires near the controller. More detailed information about this can be read on the Schulze Tips page.

That being said, if you must run longer wires between the battery and the motor when using a non opto-coupled ESC, extending the wires to the motor is a better choice for the controller, but not always the application.

***Tom M. writes: You stated that, "Many of my ESCs also sparked when I connect more than a 5s LiPo supply to them." Shouldn't they? How do you explain this - The Spark is your Friend!***

**Greg:** Castle's position on eliminating sparks from high voltage ESCs is rather odd. The link to their FAQ section seems to promote sparking without consideration for the battery connectors or the easy solution provided by the anti-spark feature. I would continue to do what works best for you.

Ask questions by e-mailing me at greg@rcuniverse.com

# FEEDBACK

This section of AMP'D reveals some of the feedback or suggestions that our readers have sent in about previous issues.

**Greg G. writes:**

GREAT ARTICLE!!!!! I just got done with the second AMP'D issue and thought it was great. I get lots of questions about wiring arming switches and such and you've hit them all right on the head. I love the way the photos and diagrams enlarge for better viewing in the article. Whoever is formatting these articles is doing a great job. I'm working on the March column and would love to point a reference to this article if it's okay with you.

Just about the time I think electric columns have outlived their usefulness you do this. These are the kinds of practical tips that modelers can take to the shop or field and make a better and safer airplane. This just proves columns written by guys like you are still needed and I'm betting you'll get lots of good feedback on it.

When I used to have my Bristol M1C, the machine gun was attached to a sermos connector and was the arming switch. It disguised it nicely and I had a static gun and a flying gun that actually armed it.

Take care,
Greg Gimlick
Model Aviation Magazine
Park Pilot Magazine
Electric Flight Columnist

Make suggestions by e-mailing me at greg@rcuniverse.com

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