XCell Razor 600E
Power Systems Guide

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Revisions to this Manual

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For the most current version of this manual, please refer to www.miniatureaircraftusa.com, visit the Razor helicopter kit and download the power systems guide

Errata

R1.0

None identified

I. Understanding the Power System for Your Razor 600E

Introduction

So now that you've decided to fly a Razor 600E you're going to need to understand what options you have for the power system and what's important to know. This guide is intended to outline the major components of the power system and to provide some guidance as you chose what you want to use.

Miniature Aircraft USA has assembled matched power system packages as well as individual components specifically for this helicopter. For more information visit the eStore at our website.

Power System Components

This section will address the four major aspects of your power system.

Electronic Speed Controls (ESC's):

The obvious issues to be concerned about are in regards to the voltage and current handling capabilities of the ESC but there are several other features of interest as well.

After voltage/current issues, the most important feature is a good "slow start". This is absolutely necessary for a helicopter with a rotor as large as the MXR. Note that "slow start" is not to be confused with "soft start". The later is typically used in airplanes for purposes of gear box protection and is not the same thing at all.

Next is the ability of the chosen control to act as a speed governor. The decision to use an ESC equipped with a governor function allows for:

- a shallower drive ratio (numerically)
- higher voltage batteries or
- a faster turning motor

This allows for a more consistent head speed throughout the flight by using less of the available "speed" of the system initially and then using all of it later in the flight as the battery discharges.

Indeed drive ratios or voltages that may prove disastrous if used with a non-governed ESC may become usable with a governor function. By "disastrous" it is meant that the maximum head speed of the model could be exceeded which may lead to catastrophic failure of the head.

In all cases and setups, a head speed of no more than 2200 should ever be exceeded on this model with 550 to 620mm blades.

Alternately, a traditional setup method can be used, one where the drive ratio sets the maximum rpm of the rotor and the ESC is run at close to “full on” all the time.

Speed controls well suited to the Razor 600E include:

Motor	Analysis
Kontronik Jazz 55/10-32	very good governor function that allows using a deeper drive ratio
Schultze 32-55 or 32-80	very good governor function that allows using a deeper drive ratio
Master Hacker 48/77-O-heli	great overall control at a great price. It’s governor is unusable
Castle Creations HV45/85/110	feature rich controls capable of 12S voltage and governing

Motors

Since we were little kids looking past our fathers to peer under the hood of the family car, we knew by intuition that the size of the engine was in direct proportion to how much power it could make. This is true only because internal combustion engines are horribly inefficient devices and gasoline contains an incredibly high amount of energy per unit volume. The average automobile engine is on the order of 10 to 20% efficient!

If one were to make a battery capable of delivering the energy contained in a single gallon of gasoline, the battery would be MUCH larger than the car!

A battery typically used in this model (the Flight Power 5S1P 3700mAHr x 2) contain 137 W*hrs of energy…about 1/400th of the stored energy in a gallon of gasoline!

Fortunately electric motors do not work like internal combustion engines. Today’s brushless motor systems all or more than 80% efficient and the better ones are well over 90%. What this means is that the modeler should not go out and buy the largest electric motor he can find but rather, the biggest battery he can afford!

Since you can’t just crowbar any battery into the model, you have to be selective. It is recommended that for maximum performance a battery from either Flight Power or Thunder Power be chosen. Many others will work of course, but testing has shown that these two companies make the highest performance batteries available for this model.

Motors from Kohler, Kontronik, Neu, Hacker and Torcman have been tested. In all cases, a targeted head-speed of 2200 rpm has been found to produce the best performance. For less performance but more flight time, use lower drive ratios, thus slowing down the head speed and unloading the motor.

The following list details the recommended drive ratios for use with 10S packs.

Motor	Recommended Drive Ratios
Koehler Actro 24-4	From 9.47 to 10:1
Neu 1515-2Y	From 17.6 to 18.8:1
Hacker C50-15XL	From 18.8 to 24:1
Kontronik Tango 45-08	From 13.5 to 16:1
Kontronik Tango 45-06	From 11 to 13:1
Hacker A50-14/16S 10 pole	From 8 to 10:1

***Note*:** The use of a motor with more than 10 magnetic poles will mandate the use of high frequency ESC's such as the HV series from Castle Creations.

Batteries

At present, there are many batteries that will work with this helicopter. When choosing a battery one needs to look at a few different things:

A) Capacity. Most 10S setups in this helicopter will draw an average of 22 to 30 amps in a full throttle hover which means roughly 367 to 500 mA/minute… so size accordingly based upon your needs. Lower voltage setups will naturally draw more current which will shorten flight times given everything else being equal. Taking an average of the above numbers, 433mA/minute, and a typical battery, the Flight Power 3700 mA pack, one would expect to be able to hover for 8.54 minutes at full throttle. But, you need to be sure to leave power in the batteries as a safety measure, say 25%, so the actual figure would be more like 6.41 minutes.

In any event, your actual numbers will vary so TAKE MEASUREMENTS to be sure. The use of a "Whattmeter" can be most helpful here. Such devices are available through AstroFlight, Medusa Research and Eagle Tree systems to name a few.

B) "C-rate". This is the rate at which the battery can be discharged. Most batteries currently available are good for at least a 10C continuous discharge rate, many are good for much more. Most setups in this helicopter will average 25 to 30 amp average current drains with bursts as high as 80 amps. Assuming a battery of 3700 mA and using the average of the first two numbers and the third number points to a needed continuous C rating of 7.4 and a burst rating of 21.6.

C) Cost. This is always a factor and not surprisingly, higher performance (i.e. high voltage/high discharge) means higher price. However, it also means lower performance costs less. Be honest with yourself, do you need the absolute maximum power available or can you get by with something less? A modest setup on this helicopter will still have more than enough power to do 99% of the aerobatics that today's pilots can perform. Additionally, it is possible to purchase a motor/speed control that can grow as your skills do thus allowing you to setup the heli more tame now and later on change it over to a higher performance machine with just a change in the battery and/or drive ratio.

D) Weight/size. Regardless of all other factors, the battery has to fit within the confines of the space available in the helicopter and should be as light as possible.

Currently, the highest performing batteries for this helicopter are either **Flight Power** or **Thunder Power** in capacities of 3700 to 4600 mA single “P” packs. Configurations of 8S and 10S will work best but 6S and 12S may also perform satisfactorily depending on your needs. For purposes of calculations, plan on either of the named batteries being able to deliver a loaded voltage of 39 volts (for a 10S setup) in this model.

Be aware that there are many batteries from the two named vendors as well as many others that may fly the heli just as well. It is up to the modeler to explore those possibilities. The modeler is encouraged however to stay with quality batteries good for at least 15C discharge ratings. Batteries with low capacities combined with low C ratings will suffer from short life spans if flown hard.

With any Lithium Polymer battery, it has been shown that the battery will respond with higher performance levels if it’s first 12 cycles are kept gentle. Hovering the model to 3.5 volts/cell is a good way to go about this.

Drive Ratios

Your chosen drive ratio is as important as any of the other aspects discussed so far. The ratio you choose can make the difference between a high power monster and a wimp, regardless of the motor and battery chosen. It can also make the difference between being able to fly for 4 minutes or 10.

The basic methodology behind choosing a drive ratio is simple; you multiply the Kv (rpm/volt) of your motor by the Vl (loaded voltage) of your battery and then divide by the desired head-speed. However, knowing what head-speed you really want and the actual loaded Kv and nominal voltages can be somewhat elusive. Experimentation has shown that for the Razor 600E a good sport head-speed is in the 2000 rpm range and a high performance head-speed is right at 2200 rpm.

*Drive ratio=(Kv*Vl)/head-speed*

The next point to consider is whether or not you intend to use the governor function in your speed control. If you do not plan on using this function then you can just use the above formula and run your idle-up throttle curves at or very near 100% all the way across the screen (shallow “V” or “U” curves may be useful) and your normal curve as a short ramp up to something at or above 80% and then flat all the way across the screen.

However, if you do plan on using a governor function, then you can “over-drive” a bit and take advantage of a more consistent head-speed throughout the flight. This is done by targeting a higher head-speed initially and then using the ESC to pull back the head-speed so that it has “headroom” to use during high power maneuvers. Experimentation has shown that the amount of overdriving should target a head-speed about 200 rpm greater than that which you intend to run.

When doing this it is important that when first setting up and flying the helicopter you start with your throttle percentage dialed way back, perhaps as far as 70% and slowly work your way up to the head-speed you want to fly at. Also, only use flat lines in your idle-up curves…no “V” or “U” curves. As always, normal curves should be a short ramp up to a flat line across the screen.

*ESC governed drive ratio= (Kv*Vl)/(head-speed+200)*

Recommendations for Success

Never use a drive ratio that would allow under any circumstances a head speed of greater than 2450 rpm…even if you plan on using a governor. This is for the safety of yourself and everyone around you.

Even though you may be using a governed ESC to run a model that is over driven, you should strive to get a setup (drive ratio) that will allow your throttle percentages to be at or above 75%. This is to help the ESC to stay cool. Low throttle percentages combined with high current drains can be death to a model. Use low percentages only for hovering around. It has been noted that when run hot some ESC’s emit more RF noise than when run cool.

Head speed is important, having a lot of it can be fun but comes at a price. Short flight times, hotter components and shorter component lives are to be expected when turning really fast (i.e. 2100+ rpm). Conversely, using a deeper drive ratio not only slows down the head, but it unloads the motor, esc and battery thus helping to keep them running cooler and lasting longer.

The use of setups that require drive ratios greater than 15:1 (>2.5:1 in the first stage) will mandate tighter belt tensions and more attention to the drive train as a whole. This makes for a model that is of a higher maintenance nature.

The use of longer blades should be accompanied with a lower head speed. As you increase the diameter of the rotor disk, you increase the blade tip speed for a given rpm and hence the drag and current loading of the system. This model can accommodate up to 640mm blades, it is also possible to turn as small as 550mm blades. Say you were turning 600's and decided to try a pair of 640's, it would be wise to dial back your head speed at first and work your way back up until you attain the desired flight control and electrical parameters you wish. There is merit in turning a larger, slower disk… better loading and efficiency will be attained.

Generally speaking, if you want “learning to fly” kind of performance, then use 6 or 8S, target a head speed of around 1800 to 2000 rpm and use 550 to 600mm blades. If you want good “sport” performance, use 8 or 10S, target a head speed of around 2000 rpm and use 600 to 620mm blades. If you are looking to get the maximum performance possible, then use 10 or 12S, target a head speed of 2200rpm and swing 620 to 640mm blades. In all cases 95mm tail blades should be used.

Learn to take measurements! This cannot be over stressed, just because you are running the same system as someone else does not mean you will get the same results. Motors, batteries, esc’s, blades and helicopters are like snowflakes, no two are the same.

Obtain a measurement device and learn to use it. Similarly, learn to use timers and read the numbers on your battery charger. And of utmost importance and safety is to always take actual tachometer measurements and make certain that you **do not exceed the maximum of 2200 rpm on the head.**

Batteries change over time and expecting a pack to perform like new when it has 100 cycles on it is inviting disaster. As batteries age, they loose capacity which means you will loose either flight performance or time or both. If you do not plan on this you could destroy your battery unnecessarily. A great device for tracking the life cycle of your batteries is the “CBA” or Computerized Battery Analyzer made by West Mountain Radio. This device, used in conjunction with your PC, will discharge a battery at whatever rate you wish (within it's limitations), to whatever level you wish and plot the curve for you. It is suggested that you discharge at C/2 and down to 3.3v/cell. Make a plot after you get the first 12 cycles or so on your packs and then every 20 to 30 cycles. Save the curves and overlay them…bingo! Perfect life cycle data recording!

When developing a power system for your model, it is vitally important to monitor the temperatures of your power train components. Use the following guidelines to help determine if your power system is going to stand the test of time.

Motor: Usually O.K. to get as high as 200 degrees Fahrenheit so long as it stays there and does not continue to creep up. Motors that are run too hot, even once, can experience loss of magnetism (de-mag), de-bonding (glue lets go) and shorting due to burning of the laquer on the windings. Usually when a motor dies in flight, it takes the speed control with it. Initial symptoms of a dying motor (if you are given any at all) can be a sudden increase then loss in power, running hotter now than it used to and/or a burning electrical smell.

Speed control: Speed controls should be run under 140 degrees Fahrenheit. Most controls have thermal protection circuitry in them to shut them down when they get too hot. However, if this is tripped, you will be left to perform an emergency autorotation. Additionally, speed controls that are run hot (even though they may never thermal off) tend to experience failures at some point.

Speed controls will heat for three main reasons:
1. it is too small for the application,
2. running it at too low of a throttle percentage
3. being over-amped.

Some of the maneuvers a helicopter is capable of performing, especially those that quickly change the direction of the helicopter using lots of collective, can pull huge peaks in current. Most esc's will handle some of this without too much issue. However, if you're flying style incorporates a lot of this kind of flying, you may need to alter your style a little, choose a less power intense setup (deepen your drive ratio, reduce pitch etc) or get a larger speed control.

Battery: Lithium polymer batteries are somewhat a dilemma. On one hand you want to use them in a way that produces maximum power output but on the other you want to keep from overheating them. The problem is that they produce maximum power at 140 degrees Fahrenheit and are degrading at 150. The best advice is to keep them less than 130 degrees. Keep them out of the sun when not in use and do not charge them unless they are less than 100 degrees. Know your batteries. Learn their capacity as outlined above and stay off of their limits. Try to adhere to a 75% rule…if you are using 4A/Hr batts, only use 3 of them in a flight. If your battery is good for 20C, set your power train up so that it averages no more than 15C. Batteries tend to get hot from two things; over discharge (using the full capacity of the battery) and overstress (exertion past the peak C rating). A battery will warm up as it discharges and get warmer and warmer as it approaches its cycle end (dead). Stay off the limits and your battery will last a long time. Run it to those limits often and it will die in very few cycles.

Chargers and Charging batteries

This subject is NOT to be taken lightly, complacency here can lead to bad things. Models, automobiles and houses have all been lost due to the lack of proper attention being given to a charging battery.

O.K. now that you've been warned, let us say that Lithium polymer batteries are far safer today than they were in the beginning and today's charger/balancers are very nearly goof proof. But goofs are a pretty sneaky bunch and can mess up pretty much anything....

The following rules should always be observed when charging a battery:

1) Never charge a battery while still in the model, always remove the battery and check it over for any signs of physical distress after usage.

2) Never leave a battery un-attended for any time greater than 10 minutes while it is charging. Just check back every 10 minutes to see that everything is O.K. (Heating or swelling).

3) Never charge a battery that is hot, let it cool first.

4) Never leave or charge a battery in direct sunlight, this leads to elevated temperatures in the battery.

5) The use of cell balancers is very important, get one, learn how to use it and do so often.

6) Always triple check the settings of your charger before beginning a charge cycle, especially if the charger is used for other batteries.

7) It is generally accepted that charging at 1C is best. However, with the new, large, 1P batteries it is possible to charge at rates higher than 1C. Understand that doing so will take something away from the life span of the battery. This may not be very much but it is something, so charge at greater than 1C only when absolutely needed and do not leave the batteries while doing so. Never charge at more than 2.5C.

8) It is a good idea to charge batteries in a well ventilated, fire safe place. The use of clay pots, fire safes, cinder blocks, ammo cans, garage floors, and driveways are good ideas. Although not heard of very often anymore, there is still the danger of fire and protecting against it is of utmost importance.

9) Never charge packs in series unless you just flew them that way and know them to be balanced the same. Charging packs in series that are not perfectly balanced will very quickly lead to the destruction of one of the packs. This is especially important if the packs have not been used for any period of time...use a voltmeter to verify the packs as well as the individual cells are of equal voltage.

Start by only using good, well established merchandise. Batteries and chargers can be found at discounted prices, but read the label. Batteries with a C rating that is marginal or below what you really need will at very best have a short life span. We recommend and can source batteries from either Thunder Power (TP) or Flight Power (FP). For this model, we recommend the TP "eXtreme" series or the FP "EVO new formulation" cells in capacities of 3700 to 4600mAHrs.

For charger/balancers it is equally as critical to select a good model. High quality, well proven chargers can be purchased from:

- Thunder Power
- Schultze
- Orbit
- AstroFlight

The things to look for in a charger are:

1. Ability to charge lithium polymer
2. Ability to charge at least the number of cells in a single pack, in most cases, this is 5 cells.

3. Ability to handle the amount of power you need to charge a pack at equal to or greater than 1C. For example: Lets say you are planning on using the TP 4600mAHr packs, each of these is 4.6 Ahr @ 21V fully charged. To charge at 1C for the complete cycle, you need a charger good for at least 96.6 watts. If you want to charge at 2C then the charger needs to be capable of 193.2 watts…and so on.
4. Good safety protocols. The safest chargers are ones that force the user several times to verify the battery he/she is trying to charge. The most dangerous chargers are those that simply commence charging as soon as a battery is plugged in…triple checking what you are doing is the key to avoiding errors.

Cell Balancers

These days everyone makes one, most are good, others are better. Think for a minute about what a balancer does; it balances all the series cells in a pack by drawing them down to equal levels with a resistive load. None of the commercial balancers is capable of much more than a few hundred milliamps of drain. This means that if the balancer is used simultaneously with a charger to charge an out-of-balance pack, it is going to be vastly out-muscled due to the fact that the charger will be putting in current at a much higher level than the balancer can take it out. This means that a balancer can really only do its job as a stand alone unit, right?

Not any more, there are now balancer/charger combos made that work in unison with each other. By allowing the balancer to control the charger, a pack can be effectively charged and balanced at the same time. This allows the balancer to shut off the charger in the event any of the cells become so out of balance that it cannot keep up. As this is written, there is only one such “combo” made, the Thunder Power 1010C or 605C chargers and 210V or 205V feedback balancers.

But what about the high-buck charger you already have? Well, Flight Power has come to the rescue here. They are producing a unit, the “V-balancer” that goes in line between your charger and battery as well as plugs into your batteries balancing port to do the same thing as the Thunder Power solution.

This level of charger control now makes it possible to charge your batteries at greater than 1C. Note that you MUST be using a charger in conjunction with a feedback balancer to do this. NEVER charge a battery at greater than 1C with just a stand alone charger and balancer and never charge a Multi-P pack at greater than 1C, only the single P (1P) packs can do this. Always verify that your battery can do this with the manufacturer, NEVER just assume, make sure.

Summary

- Only buy good, proven equipment.
- Learn how to use it and always think before doing.
- When choosing the components of your power system, choose the system that produces the “least” amount of power you can get away with, not the most.
- Adjust head speeds to no more than 2200 rpm.
- Pay attention to the helicopter, when the power begins to fade, land and recharge.
- Fly in such a way as to allow the power system to “recover head speed”, never keep an electric heli heavily loaded continuously.
- Never fly back to back batteries, allow the power system to cool first.
- Triple check everything.

Now go enjoy your Razor 600!!