E-36 Power System Primer

By Mark Covington, with Neil Myers,
Proud Members of

Recent E-36 rule changes have breathed new life into this introductory electric motor powered event. Since electric power may be new to many Free Flighters, we hope this primer helps introduce most of the basics concepts you need to know.

CHOOSING A MOTOR

Advances in lithium polymer battery and Brushless DC Motor (BDCM) technology in the last decade gave rise to park flyers and R/C electric conversions.

BDCM motors are often more efficient at converting electricity into mechanical power than brushed DC motors. This improvement is largely due to the absence of electrical and friction losses due to brushes. The enhanced efficiency is greatest in the no-load and low-load region of the motor's performance curve. However, under high mechanical loads, BLDC motors and high-quality brushed motors are comparable in efficiency.

Categories of electric motor powered model performance have emerged based on electric power in watts per pound of aircraft weight. These range from:

- 70 watts/lb for r/c trainers
- 100 watts/lb for r/c sport aerobatics
- 150 watts/lb r/c unlimited aerobatics
- 250+ watts/lb r/c overkill, or just right for free flight power!

Some candidate motors:

From HobbyKing.com
- 1806N, 2500kv, 67 W, 19g, $9
- C20, 2050kv, 92 W, 25.5g, $9

From e-fliterc.com
- Park 250, 2200kv, 55 W, 14g, $32

From rctoys.com
- Hacker A10-7L, 2200kv, 75w, 20g, $39

From innov8tivedesigns.com
- T2008, 2000kv, 120 W, 27g, $24 (used by Frank Pollard with Graupner CAM 8x4.5 folder)

So, an E-36 weighing 135 grams should have exceptional performance with a 75 watts motor, or 225 watts/lb.
Watts are the product of potential, measured in volts, and current, measured in amps (Watts=Volts x Amps). E-36 rules limit batteries to either 6-cell Nickel Metal Hydride (NiMH) or 2 cell Lithium Polymer (LiPo) batteries. For ballpark sizing, 2 cell LiPo batteries have a nominal voltage of 7.4 volts, but closer to 8.4 volts right off a charger. Dividing the 75 watt power desired by the 8.4 volt battery, results in a current value of about 9 amps. *So, we want a brushless, 75 watt motor that can accommodate 8.4 volts and 9 amps.*

Brushless motors in the 50-90 watt range are surprisingly small, with diameters in the range of 18-25 mm (roughly 3/4" - 1"). Of course, size tends to be directly proportional to weight, so small and light is good.

Motor Kv

Another important property of brushless motors is known as “Kv.” "Kv" is the motor velocity constant, measured in RPM per volt (not to be confused with "KV," the abbreviation for "kilovolt")

Kv is a measure of the internal resistance of the motor and how fast it will turn for a given voltage or something like RPM/Volt. Motors with a higher Kv value have a lower internal resistance and will turn faster for a given voltage. .   At a simplified level, the Kv rating of a brushless motor is the ratio of the motor's unloaded RPM to the peak voltage on the wires connected to the coils. For example, a 2,000 Kv motor, supplied with 8 V, will run at a nominal 16,000 rpm. Because we will be running our propellers using direct drive (i.e. no gearbox) we want a high Kv values near 2000 or higher

Electric E-36

CHOOSING AN ELECTRONIC SPEED CONTROL (ESC)

Brushless motors have three wires. An Electronic Speed Control, or ESC, is what allows direct current (DC) from a battery to drive a three wire motor. The controller contains 3 bi-directional outputs to drive high-current DC power, which are controlled by a logic circuit. The correct phase varies with the motor rotation, which is to be taken into account by the ESC. Reversing the motor's direction may also be accomplished by switching any two of the three leads from the ESC to the motor.

Some candidate ESCs:

From stevensaero.com:

- Castle Creations Phoenix 10, $51
- Castle creations Thunderbird 09, $26
- SA Sport 10A Brushless ESC, $17

From HobbyKing.com

- HobbyKing Red Brick 10A, $6
- Birdie 10A, $8

The ESC serves as the throttle and also does the switching done by brushes in brushed motors.

As with the other components in our system, we need to select an ESC that is rated for our current limit. Fortunately, many small, light ESCs are available in the 10-12 amp range, a bit better than the expected 9 amps of the motor draw.

Otherwise, ESCs differ primarily in programmable features. Many ESCs will auto-detect the number of cells in the battery they connect to and will set their low voltage cutoff to protect the battery. In other words, the ESC will shut off a motor before a lipo battery discharges far enough to damage it. (We'll discuss batteries a bit later.)

Other ESCs may require parameters to be set by programming them. Computer-programmable speed controls generally have user-specified options which allows setting low voltage cut-off limits, timing, acceleration, braking and direction of rotation, soft start, freewheel vs. brake (useful for folder props) and can be set individually. Programmable ESCs may be programmed with a link to a PC or a dedicated programming card, or an R/C transmitter or servo tester. If you want full control, you may want a programmable ESC but they cost more than simpler auto-detecting ESCs.

CHOOSING BATTERIES

Although the E-36 rules allow either Nickel Metal Hydride (NiMH) or LiPo battery packs, we'll focus on LiPos as they have a much better energy density than NiMH, so we get more power for less weight.

Some candidate batteries:

From stevensaero.com:

- ThunderPower 325mAh, 45C, 24g, $17

From rclipos.com

- Hyperion G3 CX 450mAh 25C/45C, 30g, $12 (used by Dan Berry, Jim Jennings)
- Thunder Power G6 325mAh 45C/90C, 21g, $16 (used by Frank Pollard).
- Thunder Power G6 325mAh 65C/130C, 22g, $17 (used by Don DeLoach, Mark Covington)

From HobbyKing.com:

- Turnigy nano-tech 350mAh, 65/130C, 34g, $8 (used by Neil Myers)
- Turnigy Nano-tech 460mAh, 25C/40C, 33g, $4
- Turnigy Nano-tech 370mAh, 25C/40C, 27g, $4
- Rhino 460mAh, 20C/30C, 29g, $5 (used by John Oldenkamp, Mike Pykelny)
- Rhino 360mAh, 20C/30C, 23g, $4

Voltage

LiPo batteries have a voltage of 3.7 volts per cell, so a 2-cell pack has a nominal voltage of 7.4 volts. But hot off the charger it's closer to 8.4 volts. On the other end of their voltage scale, LiPos will be damaged if they discharge below 3 volts per cell. This is why setting the ESC's low voltage cutoff is important and *you should not leave a LiPo connected to a system if you are not using it.*

Capacity

The capacity of a battery, listed in milliampere-hours (mAh), is a measures of how much power it can store. For example, a 350 mAh battery can supply .35 amps for one hour. For the short runs E-36 demands, we don't need much capacity and larger capacity comes with greater weight. But capacity is important for the next property we need to consider, the discharge rate.

Battery Discharge Rate

The highest rate that current can be drawn from a LiPo is called its discharge rate and is stated as a multiple of the capacity, or "C." Modern LiPos have discharge rates of 20C up to 65C. Another example: a 350 mAh capacity battery with a 25C discharge rate can support a current draw of 8.75 amps (.350A x 25 = 8.75A).

Most can exceed this rate for short periods, and may list their "burst" rate as up to twice their standard discharge rate. A burst is usually considered to be under 20-30 seconds, which is longer than E-36 motor runs. So a small capacity, high discharge rate pack will serve our needs better than a larger, heavier, lower discharge rate pack that can handle the same current draw.

Battery Charging

LiPos should always be charged at a 1C or lower rate. So, our 350 mAh pack should be charged at no more than 350 milliamperes. This would take a fully discharged pack an hour to charge, but we will seldom run a pack down that far so charging won't take that long.

LiPo chargers come in a huge range of features and prices, but should allow setting the number of cells in a pack and the charging rate. The simplest may auto detect the cell number and have a fixed charge rate. If these are the only LiPos you'll ever have, a simple charger with a rate at or below your pack's capacity may suffice. But if you have a range of packs you'll want a more capable charger.

Battery Storage

LiPos discharge very little sitting on the shelf; however, they should not be stored with a full charge.
They should be stored closer to their nominal voltage.
If a LiPo ever looks puffed up, it's time to discard it.

CHOOSING ELECTRICAL CONNECTORS

At some point all these components need to be connected together to make our power system. Motors and ESCs will usually come with bare wires. Battery leads may come bare or with whatever connector the vendor chooses. Connectors must also be capable of handling the current load of our system, and we recommend that you use *polarized* connectors on batteries and ESCs to prevent reversing the connection and frying components before they ever get flown. (Polarized connectors each have a male and female pin. Unpolarized connectors put the male pins on one plug and female on the other, but that means the male pins can get flipped and plugged into the wrong female pins.)

To ensure operability between all our systems, we must all follow a standard for how connectors should be soldered to the components. If you borrow someone's battery, this should ensure it will work. (But carefully inspect it anyway to be sure.)

Deans Micro Polarized connectors can handle large current loads and are small and light. We recommend following the standard wiring described on the Deans package. It might be the most important fine print in all of electric modeling!

Battery to ESC connectors

Because polarized plugs are all identical, they must be wired up correctly. The standard for Deans Micro Polarized plugs is:
Male pin positive (+) on battery / Female pin positive (+) on ESC

ESC to Motor connectors

Motors are typically connected with three wire plug or separate barrel connectors n each wire. The standard is that the male connectors go on the ESC, which means the motor gets the female connectors.

THE WATTMETER

The best way to find the actual power of your system is to use a device called a wattmeter. It's a meter that plugs into your system, between the battery and the ESC, and measures both voltage and current simultaneously. Many modern wattmeters can also store the max wattage reading which makes it easy to find the best case power from your system. You don't have to have one but it is essential if you want to compare the relative output of different setups, such as our next topic, propellers.

CHOOSING A PROPELLER

The propeller you choose can determine whether you are getting the most out of your setup. A larger or higher pitch prop forces a motor to work harder, therefore draws more current than a smaller, lower pitch prop. E-36 will likely use props in the 6x3 to 7.5x5 range. A wattmeter is the best way to measure the effect of different props. A tachometer can be used to measure rpm, but the prop that draws the right current to get the most power will not be the highest rpm.

Electric motors are not subject to the effects of altitude as internal combustion engines are. But props are. If you're propped to draw a certain current near sea level your system will draw less at altitude because of the thinner air. You will need to run a bigger prop at altitude to draw the same current as sea level.

SUMMARY

While some may want to simply copy someone else's setup, our goal was to show you how to pick your own electric power setup. There's lots of room for optimizing. It may seem intimidating at first, but once you have a working setup we're sure you'll be taken with clean, silent, and convenient electric power. And you will never spend a single minute wiping used electrons off your model!

"Bargain Basement" Setup

The equipment John Oldenkamp and Mike Pykelny use on Oldemkamp's Joule Box E-36 is available from:

HobbyKing.com.

- C20-2050 Red Motor $7.24
- HK05518A Black ESC $6.15
- R460-20-2 460 Battery $4.67
- AM1002A Connectors $1.87

Texas Timers in the form of Hank Nystrom has a total plug and play E-36 system for sale.

- Motor
- Propeller
- ESC
- Battery
- Servo
- Timer

http://www.texastimers.com/

ADDITIONAL TECHNICAL NOTES THAT CAN HELP

Soldering

Connectors connect the components together, but we haven't addressed how the connectors are attached. Connectors must be soldered to the wires.

First, you need a soldering iron. A pen-type of 30-50 watts is sufficient. Higher wattage is better because a hotter iron takes less time to make a joint. This means less time for all the components to overheat.

It's important to keep the soldering iron tip clean. Use a small wet sponge to wipe the iron tip after each connection. Many iron holders come with a small sponge for this.

Solder should be lead free rosen-core, not acid-core. Solder is typically 60/40 lead/tin, but lead-free solder is more eco-friendly and becoming more common.

Keep the parts to be soldered as clean as possible. Paste flux can help solder flow more evenly and create a better joint.

Tinning

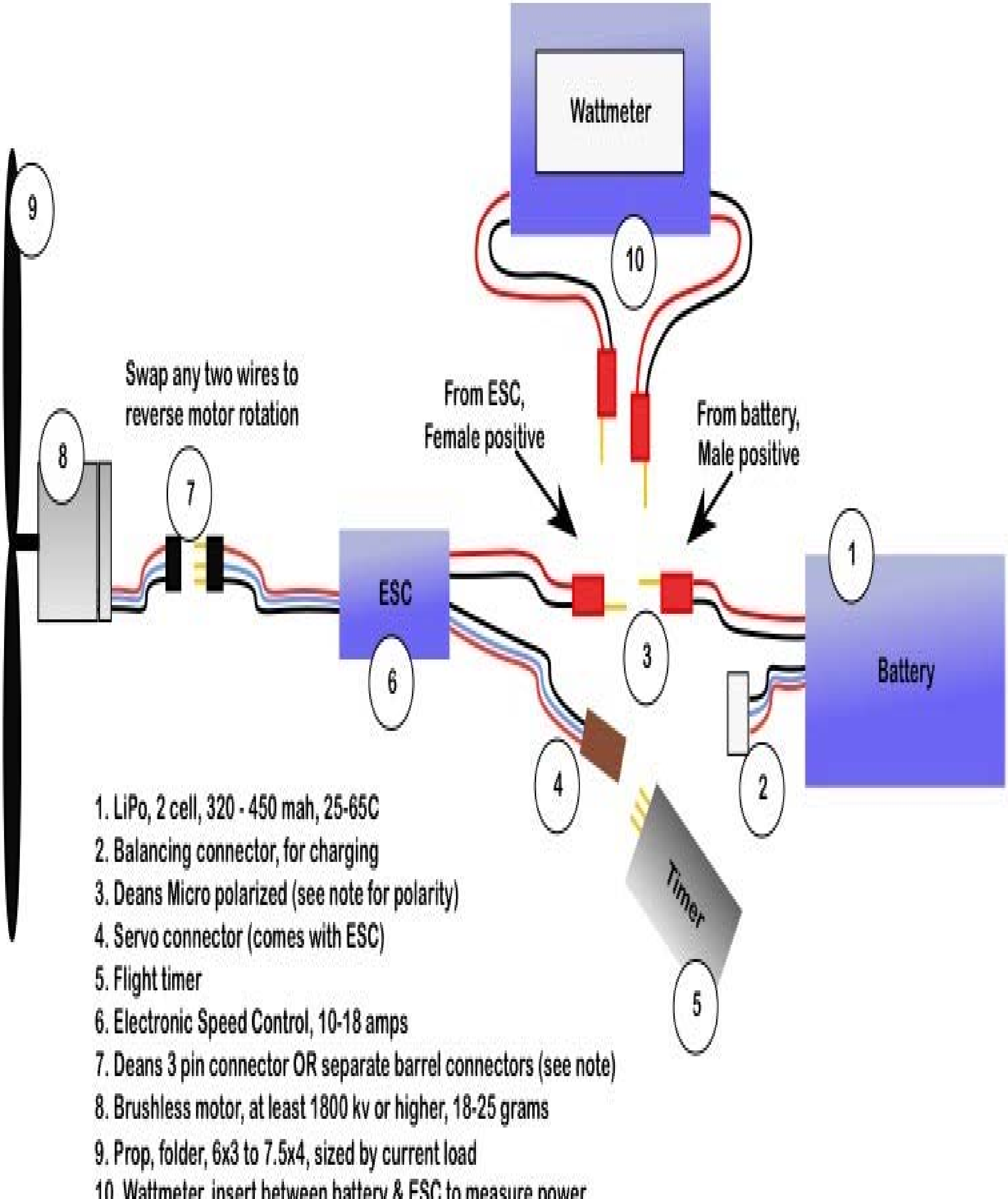
The proper way to make a connection is to coat each part with a thin layer of solder, called tinning. Then, when you solder the tinned parts together, you don't need to add more solder.
Before you begin soldering, don't forget to slide the heat shrink tubing onto the wires! Deans connectors come with small bits of rubbery tubing to cover and insulate the connections. Slide this onto the wires as far from the connection as it will go. If it's too close while you're soldering, it may shrink in place.
To tin parts, first hold the iron against the wire for a few seconds. When the wire is hot, touch the solder to the wire, not the iron. When the wire is covered in solder, remove the solder, then remove the iron.
Now hold the two tinned parts together and apply the hot iron until the solder flows between them, then remove the iron. Slide the heat shrink into place and shrink with a heat gun or flame.

Flying your E-36 in F1Q

If you want to calculate how much run you would get flying it in F1Q, do this:

1. Weigh the plane all-up (battery, tracker, rubber bands) and multiply the weight in grams by 5. This is your energy allowance in joules (watt-seconds.)
2. Hook up a watt meter to your plane, and with a fully-charged battery and the prop you intend to fly with, measure the watts when the motor reaches full speed. This is your system power.
3. Divide the energy allowance in watt-seconds by the system power in watts. The result is your allowed motor run time in seconds.
4. Write it all down on a sheet of paper for the CD to check, and show the allowed motor run time prominently on the wing so the timekeeper can see your run time. I'm guessing most E-36s will be allowed between 10 and 15 seconds.

--Bernie Crowe


Wattmeter
10
9
Swap any two wires to
reverse motor rotation
From ESC,
Female positive
From battery,
Male positive
8
7
1
ESC
3
6
Battery
4
2
Timer
5
1. LiPo, 2 cell, 320 - 450 mah, 25-65C
2. Balancing connector, for charging
3. Deans Micro polarized (see note for polarity)
4. Servo connector (comes with ESC)
5. Flight timer
6. Electronic Speed Control, 10-18 amps
7. Deans 3 pin connector OR separate barrel connectors (see note)
8. Brushless motor, at least 1800 kv or higher, 18-25 grams
9. Prop, folder, 6x3 to 7.5x4, sized by current load
10. Wattmeter, insert between battery & ESC to measure power

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