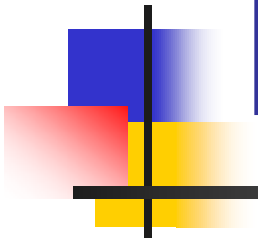


Electric Flight

The power system basics

Wayne Rademacher

Electric vs. Nitro, Equivalents

OS Max, nitro engine	HP	Weight	Nitro Propeller	Watts (746w/hp)
OS Max .10LA	.27HP @ 17000	3.95oz	7x4 - 7x5	200 watt (.27HPx 746)
OS Max .15LA	.41HP @ 17000	4.87oz	7x5 - 8x5	300 watt (.41HPx 746)
OS Max .25LA	.6HP @ 15000	6.9oz	9x5 - 10x5	450 watt (.6HPx 746)
OS Max .40LA	1.0HP @ 16000	9.5oz	10x6.5, 10.5x6 11x5	750 watt (1HPx 746)
OS Max .46LA	1.2HP @ 16000	9.6oz	11x6 -11x7	900 watt (1.2HPx 746)
OS Max .65LA	1.7HP @ 16000	18oz	12x7 - 13x8	1275 watt (1.7HPx 746)
OS Max .25FX	.84HP @18000	8.8oz	9x5 - 10x5	630 watt (.84HPx 746)
OS Max .61FX	1.9HP @ 16000	19.4oz	12x6 - 13x7	1425 watt (1.9HPx 746)
OS Max .91FX	2.8HP @ 15000	19.3oz	13x8 - 13x9	2100 watt (2.8HPx 746)
OS Max 1.60FX	3.7HP @ 9000	32.6oz	16x10-14, 18x10-12	2775 watt (3.7HPx 746)

Terminology (or what's that mean?)

Watts = volts * current

- Examples
  - 7.4v * 10amps = 74watts
  - 11.1v * 25amps = 277watts
  - 22v * 50amps = 1110watts

1 horse power = 746watts

Terminology (or what's that mean?)

Kv = The number of rpm's a motor will spin for every volt applied to motor.

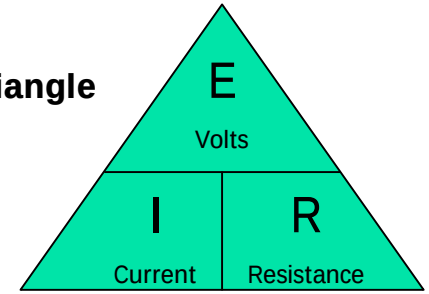
Examples

- 980Kv motor connected to a 3 cell (11.1v) battery will spin 10878rpm (unloaded)
- 1400Kv x 11.1v = 15540rpm (unloaded)
- 1400Kv x 7.4v = 10360rpm (unloaded)

Basic electronics - formulas

Ohm's law Triangle

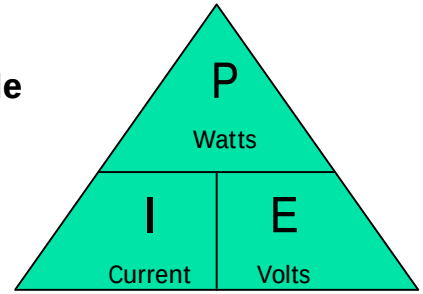
E = I * R
I = E / R
R= E / I



Place thump over the element you wish to solve. (i.e. cover "I" = E / R)

Power Triangle

P = I * E
I = P / E
E = P / I



E = **Voltage** (sometimes "V" is used instead of "E", and measured in "volts")
I = **Current** (measured in "amperes")
R = **Resistance** (measured in "ohms")
P = **Power** (measured in "watts")

Example 1

25amp motor on 3-cells

(**I**)25A*(**E**)11.1v = (**P**)277w motor

Example 2

60watt light bulb draws .5A or 500mA

(**P**)60w / (**E**)120v = (**I**).5amp draw

Example 3

60watt light bulb has 240 ohms of resistance.

(**E**)120v / (**I**).5A = (**R**)240 ohms

Inrunner vs. Outrunner

Outrunner type motor

The outside spins
i.e. outrunner

Inrunner and Outrunner are the two types of brushless RC motors.

Outrunner - brushless motor has the permanent magnets on the **outside** of the electromagnets. You can see in the picture that the outer hub holding the permanent magnets has the output shaft attached in the center.

Inrunner - The permanent magnets of inrunner brushless motors are positioned on the **inside** of the electromagnets. Inrunner brushless motors are setup very similar to old school canned motors, except the permanent magnets and electromagnets are in opposite positions.

Outrunner Brushless Model Aircraft Motors

Outrunner RC motors spin much slower and provide much more torque than inrunner motors.
The greatest benefit of an outrunner motor is the fact that a gearbox is not needed. This makes the airplane literally silent! Outrunner motors are much easier to mount. Outrunner brushless RC motors are slightly less efficient than inrunner motors. This shouldn't be a huge factor when making your decision between the two.

Inrunner motor

Only the shaft
spins

Inrunner Brushless Model Aircraft Motors

The faster a motor spins, the more efficient it is. Inrunner motors turn very fast and are more efficient than outrunner motors. Inrunner brushless RC motors require a reducing gearbox between the motor and propeller. For this reason, the output speed and torque of the propeller can easily be "***tweaked***" to facilitate different flying characteristics by using different size gears. The downside is added parts that can and do fail.
The gears get stripped, and the gearbox shafts are easily bent. It can also be an obstacle when mounting the gearbox motor combination neatly, especially under a cowling.

Basic Electric Motor Selection

Motor watts required per pound of airplane weight.

- 100w/lbs = trainer\sport (minimum)
- 150w/lbs = 3D aerobatics
- 250+w/lbs = extreme

- Examples
  - 16oz Sport airplane = 100w
  - 24oz Pylon Racer = 300w
  - 4lb Trainer = 400w
  - 8lb Sport plane = 800 – 1200w

Battery Selection

“C” discharge rating

- Battery “C” rating = The max amount of current a battery can deliver. (1C is 1 times the batteries rated current.)
  - Examples
    - 1300ma (1.3A) 12C battery can deliver (1.3A x 12) 15.6A
    - 2100ma (2.1A) 15C battery can deliver (2.1A x 15) 31.5A
    - 2100ma (2.1A) 20C battery can deliver (2.1A x 20) 42A

Balancer

- LiPo-Balancers eliminate the problem of cell imbalance, allowing your LiPo packs to reach their maximum life span.
- Traditional LiPo chargers simply terminate the charge when one cell goes above 4.25 Volts. This gradually reduces pack capacity because the imbalance slowly increases with each cycle.
- LiPo Balancers allow the charging process to continue until ALL cells have reached 4.20V while still protecting each cell from overvoltage.

Propeller Selection

Propellers can be selected two ways:

- Use the factory recommended propeller for your motor.
  - Incorrectly sized propellers can draw too many amps an burnout your motor.

- Use amp meter to determine current and rpm's for your motor.
  - Do not exceed recommended current.

Pitch Speed = (RPM x Pitch)/1056

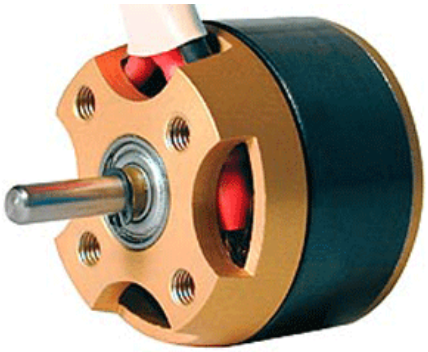
Example:

- AXI 2208-26, 3cell battery, 7x4 prop
  (15762rpm x 4")/1056 = 59mph*
  *losses will reduce this number

Typical Naming Scheme

- Typical motor numbering scheme's
  - AXI 2208/26, 1420Kv
    - 22mm diameter
    - 8mm thick
    - 26 turns of wire
    - RPM's per volt
  - Scorpion S-2208-30, 1293Kv
    - 22mm diameter
    - 8mm thick
    - 30 turns of wire
    - RPM's per volt
  - E-Flight Power 15, 950Kv
    - Equivalent to a .15cc
    - RPM's per volt

AXI 2208-26



Tiny, but BIG power for SPEED 300 to 400 class airplanes

Small and very robust but light weight (45g, 1.6 oz with 14cm long heavy-duty silicone cabling) brushless motor with rotating case suitable for all models of 300-400 size which will surprise You with very high power it can deliver. Hardened steel shaft is 3.2mm and is supported by two large ball bearings which ensures great mechanical stability. Thanks to Model Motors for using the newest materials these motors achieve in their weight category extremely high efficiency and high load possibility. A new future in AXI design is a provision for radial mounting.

- **2208-26 Factory Specifications:**
- Voltage Range 2-3xLi-Poly
- Max. Efficiency Current 5-9A
- RPM per volt 1420Kv Max.
- Efficiency 82%
- Max. loading 11A / 60 s
- No load Current / 8V 6 A
- Internal resistance 155mohm
- Dimensions 27.7x26 mm
- Shaft Diameter 3.17 mm
- Motor weight 45g
- Recommended model weight - 7 to 17.8 oz
- Propeller range:
  - 2xLi-Poly prop 8"x4.5“
  - 3xLi-Poly prop 7"x4“
  - 10 cells prop 8,5"x5"

7.4V x 9A = 67w
11.1v x 9A = 100w

11.1v x 1420Kv = 15762rpm

100w / lbs
Perfect **J**

7”x4” pitch speed
(15762rpm x 4”)/1056 = 59mph*
*losses will reduce this number

E-Flight Power 15

Key Features

Equivalent to a 15-size glow engine for sport and scale airplanes weighing 36- to 56-ounces (**2.5 to 3.5lbs**)
Ideal for size 3D airplanes 32- to 40-ounces (**2 – 2.5lbs**)
Ideal for models requiring up to 425 watts of power High torque, direct drive alternative to inrunner brushless motors
External rotor design, 5mm shaft can easily be reversed for alternative motor installations
High quality construction with ball bearings and hardened steel shaft
Slotted 12-pole outrunner design

Overview

The Power 15 is designed to deliver clean and quiet power for 15-size sport and scale airplanes weighing 36- to 56-ounces (**2.5 – 3.5lbs**), 3D airplanes 32- to 40-ounces (**2 – 2.5lbs**), or models requiring up to 425 watts of power.

Specification

Type: Brushless Outrunner Motor
Size: 15-size
Bearings or Bushings: Ball Bearings
Wire Gauge: 16
Recommended Prop Range: 10x6–13x6.5
RPM/Volt (Kv): 950
Voltage: 7.4 - 14.4V
Resistance (Ri): .03 ohms
Idle Current (Io): 2.00A @10V
Continuous Current: 34A
Maximum Burst Current: 42A (15 sec)
Cells: 8–12 Ni-MH/Ni-Cd or 3-4S Li-Po
Speed Control: 40-45A Brushless
Weight: 152g (5.4 oz)
Overall Diameter: 35mm (1.4 in)
Shaft Diameter: 5mm (.20 in)
Overall Length: 50mm (1.9 in)
Electric Prop 10x6 to 13x6.5

Sport @100watts / lb
250-350 watts

3D @150watts / lb
300-375 watts

950Kv x 7.4v = 7030 rpm
950Kv x 11.1v = 10545 rpm
950Kv x 14.4 = 13680 rpm

34A x 7.4v = 250W
34A x 11.1v = 377W
34A x 14.4v = 489W

Advanced Motor Formulas

Efficiency: Motor Efficiency = Pout/Pin, Pout = (Vin - Iin * Rm) * (Iin - Io)

Motor Kv: Kv = RPM / (Vin - Vloss), Vloss = Iin * Rm

Motor RPM: RPM = Kv * (V - Vloss), Vloss = Iin * Rm

Watts: Watts = V * Iin, Alternately $P=I^2R$ (P = I x I x Rm)

Stalled Motor: Istall = Vin / Rm

Torque constant: Torque constant: Kt=Kb x 1.345, Kb = Voltage constant (Volt/1000 RPM)

Torque Loss: Torque = Kt * (Iin - Io)

Termination: Wye = the number of winds you have performed, Delta = divide the number of turns by 1.73

Watts per Horsepower: 1 horsepower = 746 watts

Kv-Rpm constant: Kv * turns = motor constant, (ex. Kv=1090 * 32T ~= 35000 so, 35000/28T ~= 1250Kv)

Adv. Motor Formulas - Acronyms

Acronyms:

Rm = Resistance value of the motor, derived from the guage of wire used.

Pout = Power Out of the Motor expressed in Watts

Pin = Power In of the Motor expressed in Watts

Vin = Voltage Into the Motor

Iin = Current Into the Motor

Io = Noload Current of the Motor, derived from running a motor WOT without a prop at varying voltages. Io can be expressed with an associated Voltage and should be.

Kv = K value or voltage constant, the expressed value where the rpm can be surmised by a given voltage. For a 2000 Kv motor an input voltage of 10V would net 20000RPM.

Istall = The load current of a motor which is purposely stalled, hence not turning.

Kt = Torque constant (oz-In/A)

Kb = Voltage constant (Volt/1000 RPM)

Resources:

www.rcgroups.com

- Excellent source of information.

www.innov8tivedesigns.com

- Scorpion motors / kits
- Scorpion Calc – free motor calculation software

*www.**motocalc**.com*

- *MotoCalc* will tell you everything you need to know: Amps, Volts, Watts, RPM, Thrust, Rate of Climb, and much more!
- $39.00