Brushless Motors

What you need to know.

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Wayne Rademacher

Motor selection info.

Watts per pound of airplane weight.

- 100w/lbs = trainer/sport
- 150w/lbs = 3D aerobatics
- 200w/lbs = extreme

Watts = volts * current

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

Ex. 16oz sport airplane = 100w motor

746watts = 1 horse power

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)

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)

Misc. motor info.

PI*(dia./2)^2) = sectional area of wire

~ Delta > Star = .578 (.562 - .526)

~ Star > Delta = 1.73 (1.78 - 1.9)

Doubling the number of winds halves Kv (rpm/volt) and doubles Kt (torque/Ampere),

Doubling stator height halves Kv, doubles Kt and (roughly) doubles maximum power.

Kv-Rpm Constant:

Example:

The 3008-32 motor has a Kv of 1090. If you take 1090 x 32 you get 34,880. If you look at the 3008-28 motor, it has a Kv of 1253.

If you take 1253 x 28 you get 35,084. Based on these 2 numbers, you can see that the constant for the 3008 size motor is right arounf 35,000.

If you take 35,000 and divie that by the number of turns, you will get the approximate Kv of the motor.

Brushless motor construction

The basic 3-phase build

Why build?

- Fun
- Cheap
- Rewarding
- Build the perfect motor for your application.

Electronic Gearing

- Divide 360deg by number of magnets then divide by 3 phases.
  - This provides the degree of movement per step sequence.
- 6 cycle step sequences needed to complete 1 revolution of the magnetic field.
  - <u>A to B</u> / <u>C to B</u> / <u>C to A</u> / <u>B to A</u> / <u>B to C</u> / <u>A to C</u>

Examples:

<u>10 magnet</u>

360deg / 10 mag = 36deg || 36deg / 3 phase = 12deg
(12deg / step) x 6 steps = 72deg. Sequence
360deg / 72deg = 5 or 5:1 gearing

<u>14magnet</u>

360deg / 14 mag = 25.71deg || 25.71deg / 3 phase = 8.57deg
(8.57deg / step) x 6 steps = 51.42deg. Sequence
360deg / 51.42deg = 7 or 7:1 gearing

9-pole magnet options

9-pole stator basically two choices:

- 6 magnets (3:1 gearing)
  - High RPM (Kv), low torque
  - Good for Helis and ducted fans
- 12 magnets (6:1 gearing)
  - Low RPM (Kv), high torque
  - Larger propellers, 3D flying

12-pole magnet options

12-pole stator four choices:

LRK or DLRK wind

- 10 magnets (5:1 gearing)
  - Higher RPM (Kv), lower torque
- 14 magnets (7:1 gearing)
  - Lower RPM (Kv), higher torque

ABC wind

- 8 magnets (4:1 gearing)
  - Higher RPM (Kv), lower torque
- 16 magnets (8:1 gearing)
  - Lower RPM (Kv), higher torque

Wind techniques / options

- 9-pole stator can only be wound using ABC wind
  - ABC - ABCABCABC

- 12-pole stator can be wound either ABC, LRK or DLRK.
  - ABC – ABCABCABCABC (easy, need more magnets)
  - LRK – A-b-C-a-B-c (high wrap count per tooth, less to wind)
  - DLRK – AabBCcaABbcC (low wrap count per tooth, more to wind

12 stator pole wind types

Distributed LRK Winding Diagram (DLRK) for 10 or 14 Magnet Poles

	10 magnet poles	14 magnet poles	16 magnet poles
Magnetic Pattern	NSNSNSNSNS	NSNSNSNSNSNSNS	NSNSNSNSNSNSNSNS
DLRK Winding	AabBCcaABbcC	AabBCcaABbcC	ABCABCABCABC
LRK Winding	A-b-C-a-B-c	A-b-C-a-B-c	

- “A” and "a" are first phase wire S1
- “B” and "b" are second phase wire S2
- “C” and "c" are third phase wire S3
- Capital (upper case) letter means Clockwise
- Small (lower case) letter means Anti-Clockwise
- “-“ means the stator tooth not wind

Star or Delta connection?

Now, you need to make you own decision to solder the magnet wires to either Star (wye) or Delta system.

Star vs Delta

- ✓ Star (wye) system gives more torque and uses fewer amps.
  In Star system, 1.73 less turns needs to be wound to get the same power and Kv as DELTA system does.

- ✓ Delta system gives 1.73 higher power and amps draw compare to STAR system.
  In Delta system, the Kv is 1.73 higher than Star system while the Kt (Torque) is 1.73 lower

Magnet polarity

Stack all magnets together. This will assure all the magnet poles facing one end of the stack are the same polarity. Use a marker to mark the face of one of the end magnets, then move that magnet to the other end of the stack. Continue marking and moving magnets until all magnets have one face marked.

Before placing magnets inside the bell, you need to choose the number of magnet poles from the table below.

The characteristics of different magnet pole set-ups

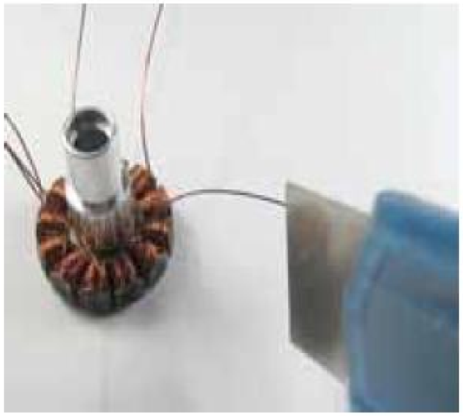
	10 magnet poles	14 magnet poles	16 magnet poles
Magnetic Pattern	NSNSNSNSNS	NSNSNSNSNSNSNS	NSNSNSNSNSNSNSNS
RPM	High	Middle	Low
Torque	Low	Middle	High

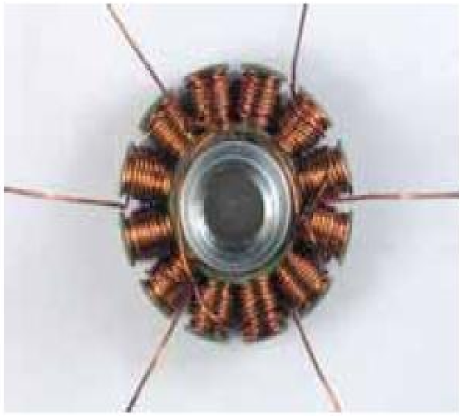
Magnet installation





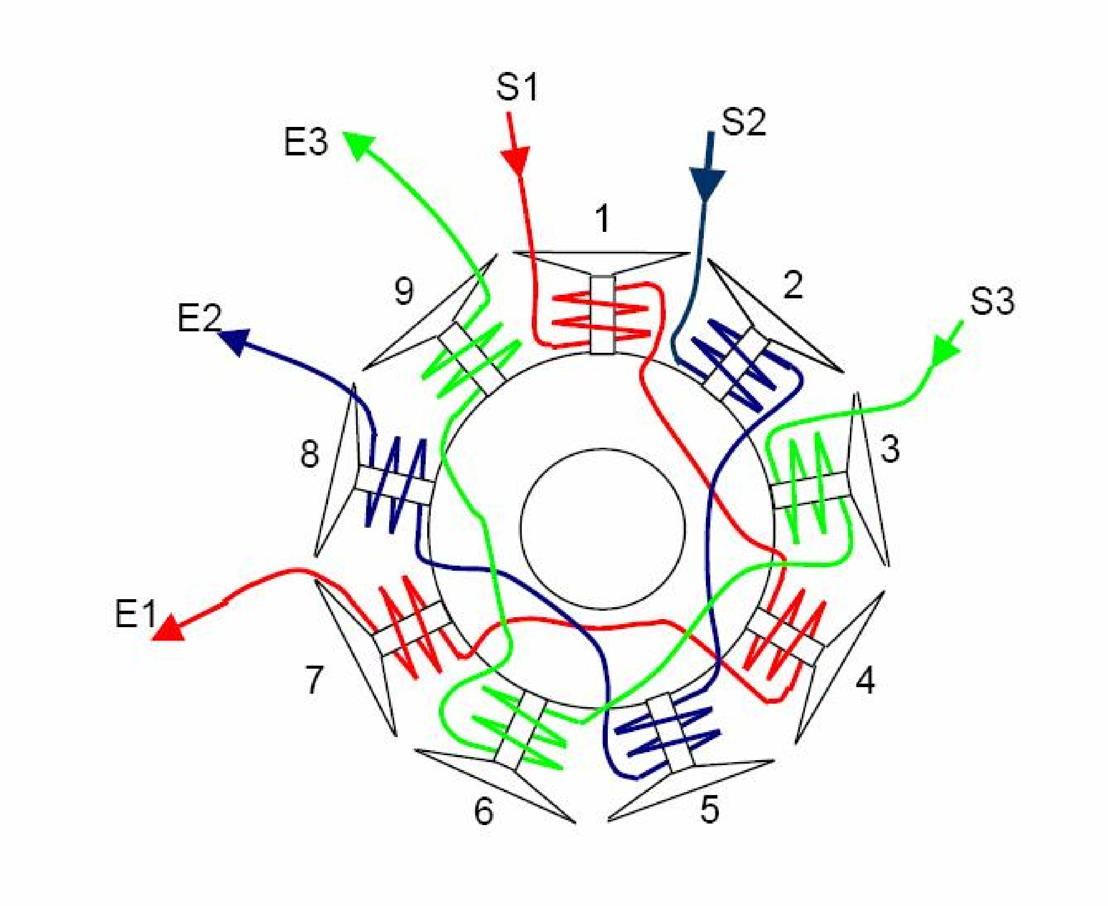
Check for shorts – Solder wires



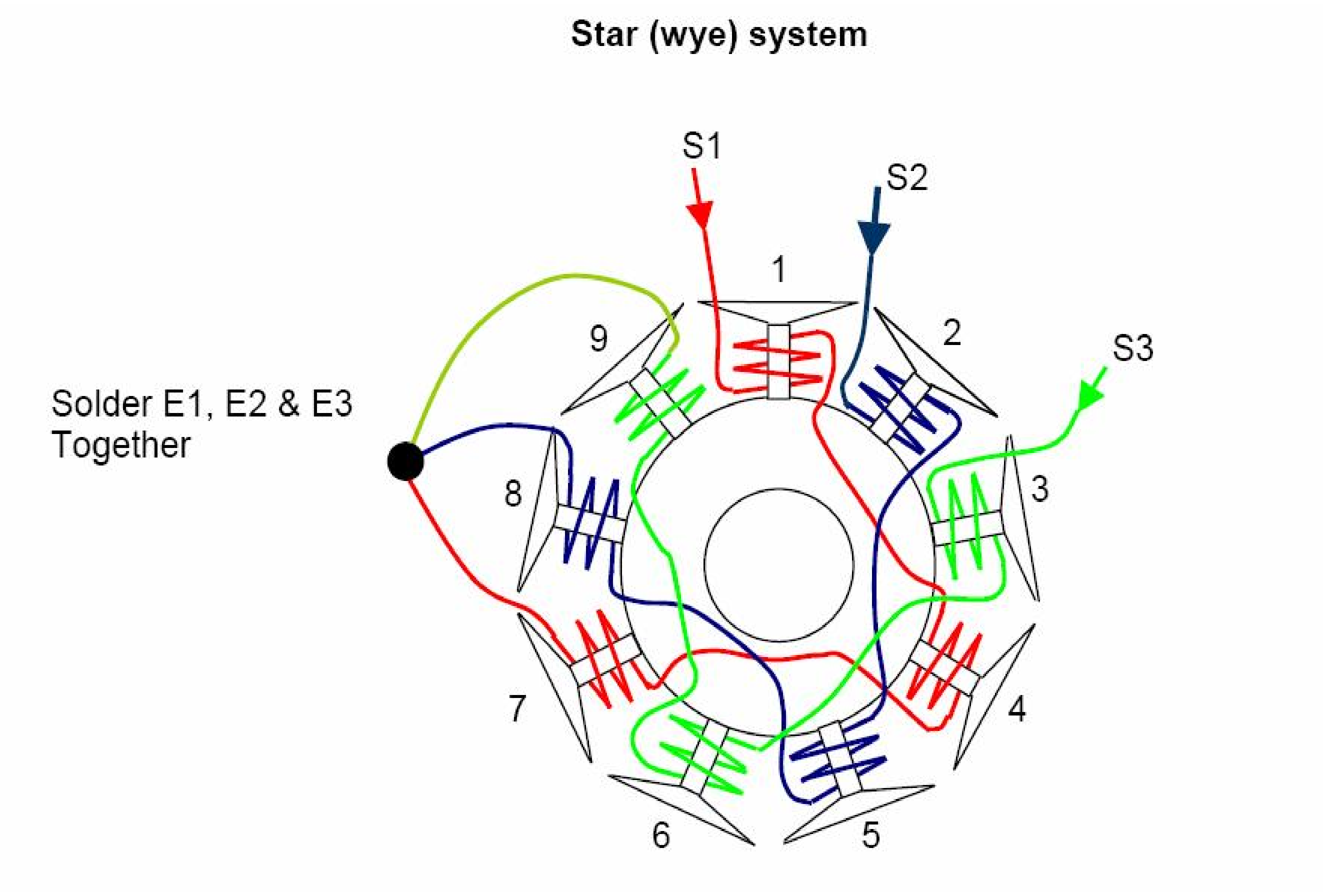


Now, check for any possible shorts between the stator and each wire or between wires S1, S2 and S3. If any shorts are found the wire should be removed and new wire installed. Attempting to run a motor with a short can damage your electronic speed control, battery, or receiver.

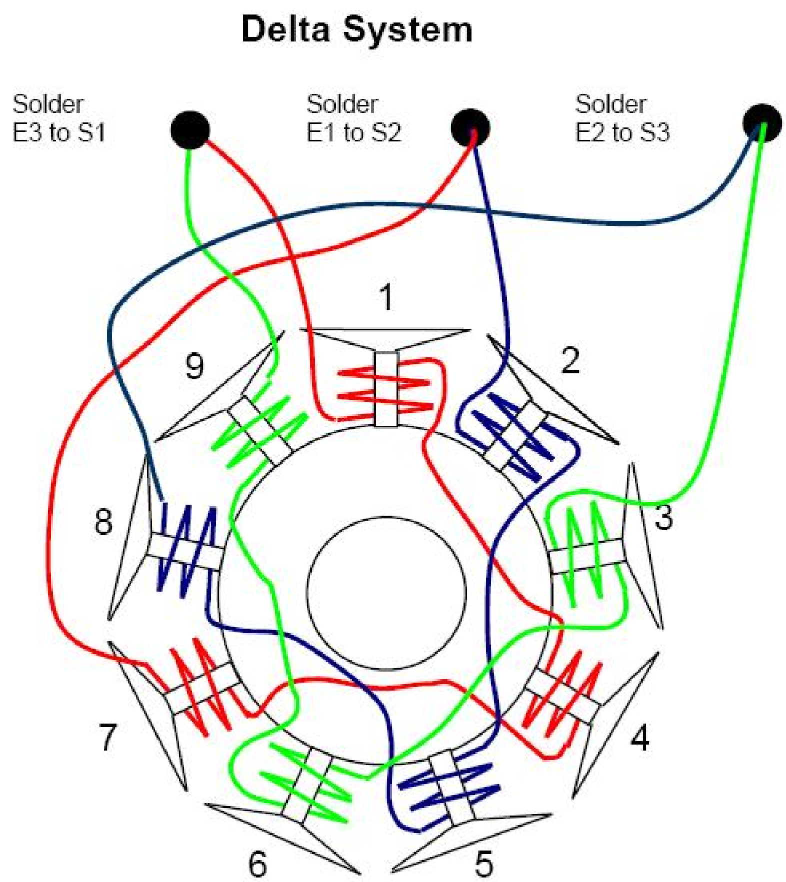
9-pole stator – ABC wind



9 pole "Star" connection



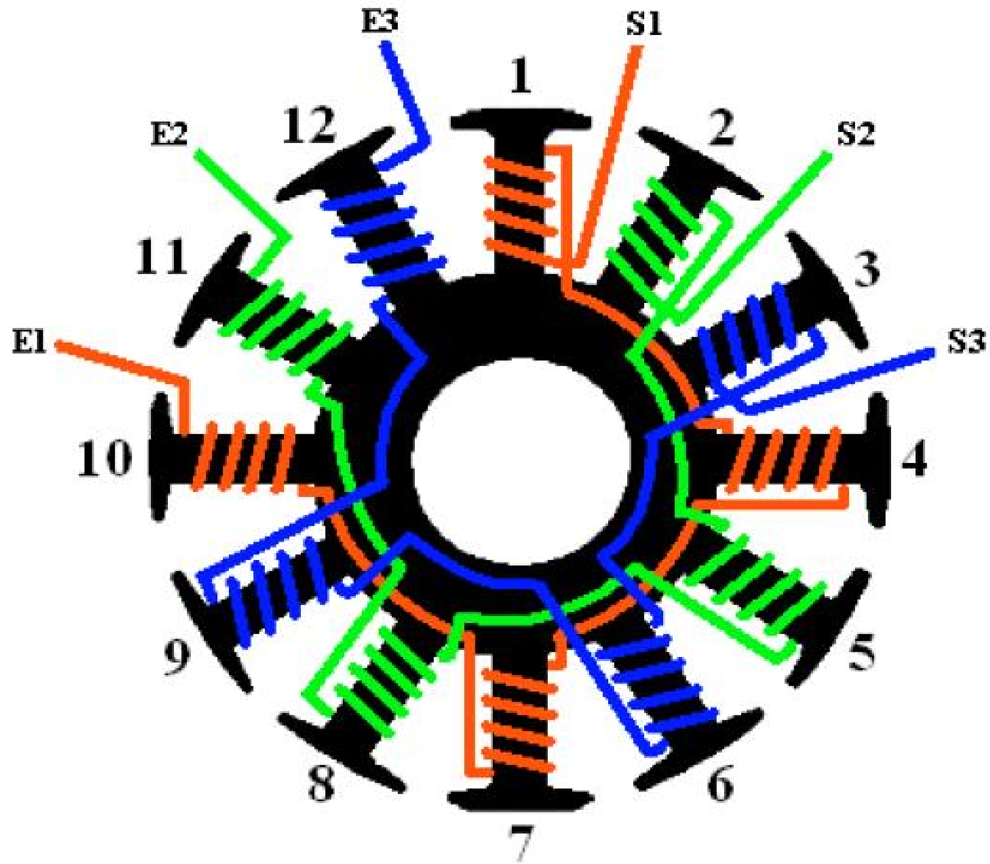
9 pole “Delta” Connection



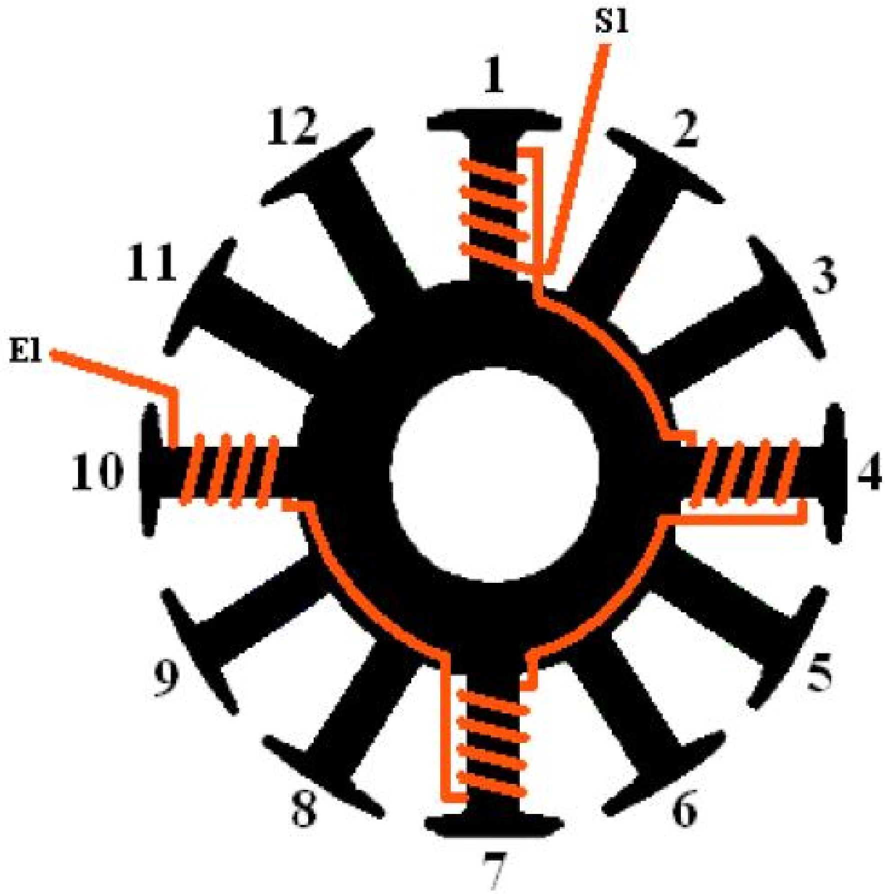
Winding: ABCABCABCABC

(For 16 magnet poles)

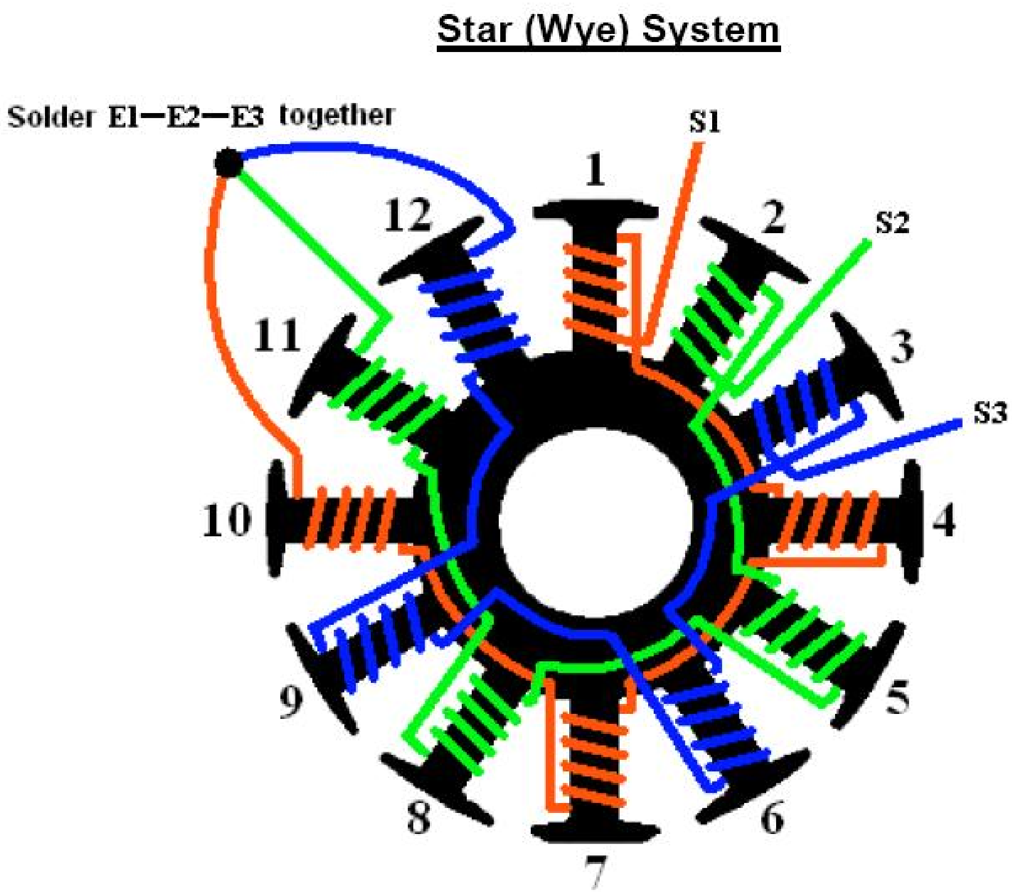
Wind magnet wire in clockwise direction on all stator teeth.



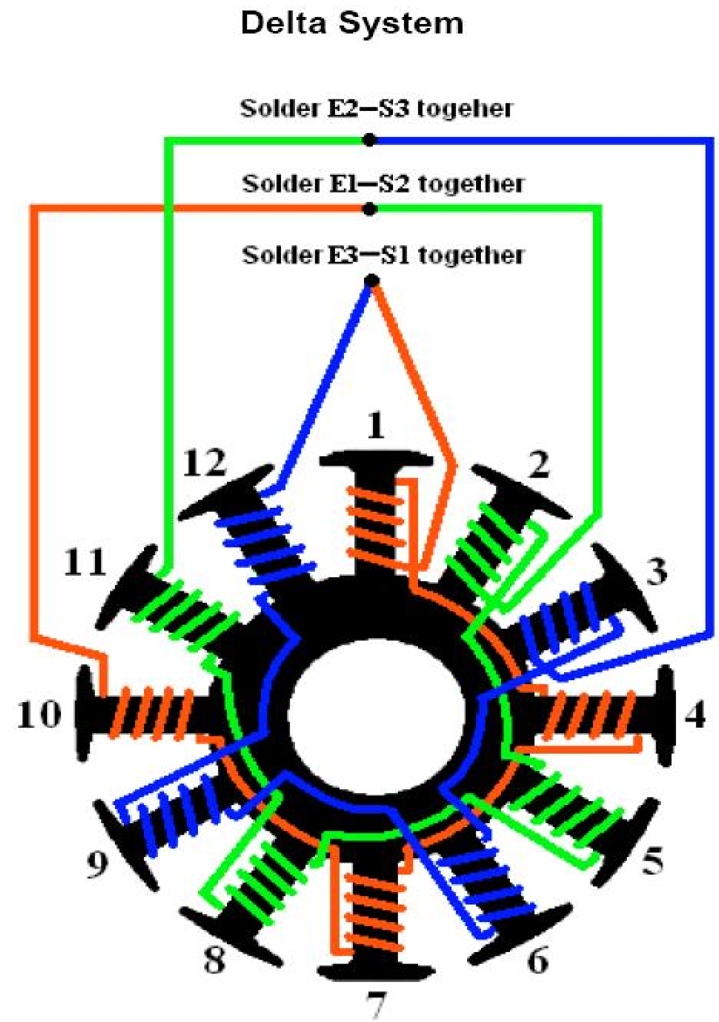
Phase A of the ABC wind 12-pole, 8 or 16-magnets



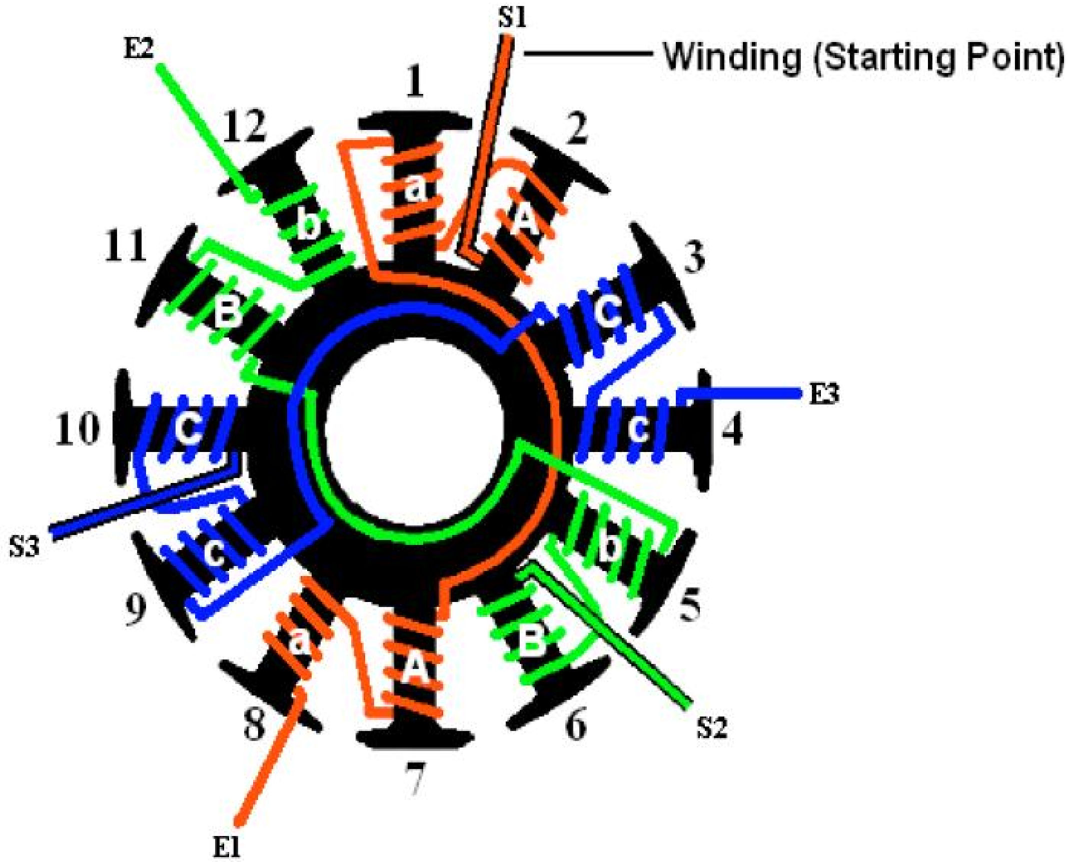
12 pole **ABC** “Star” Connection



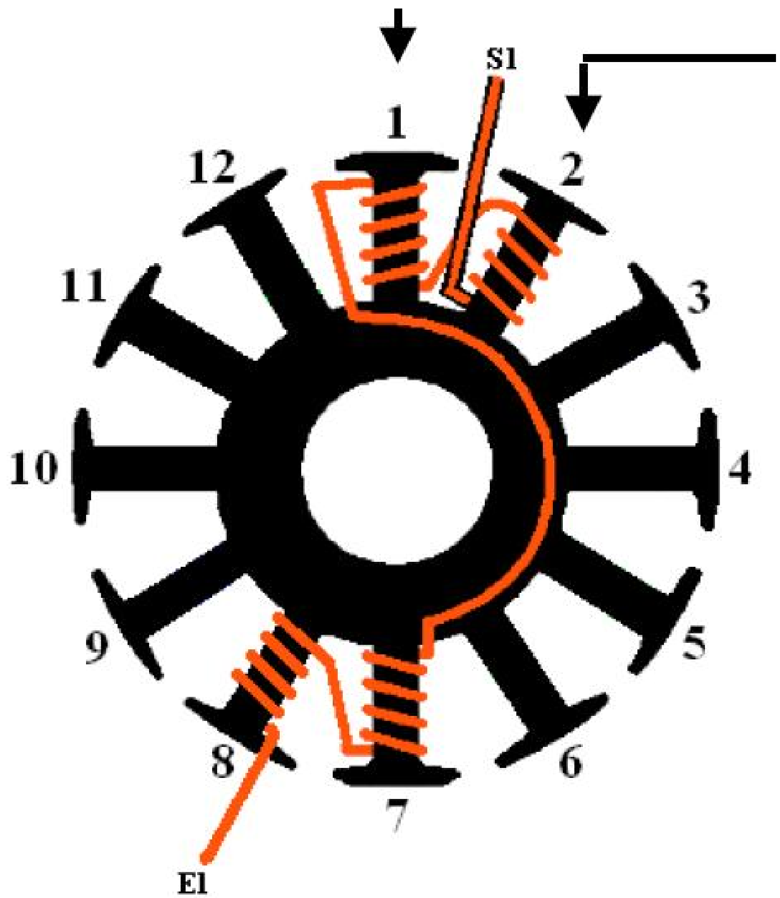
12 pole **ABC** “Delta” Connection



Distributed LRK winding diagram for 10 or 14 magnet poles.



Phase A, DLRK wind



LRK or DLRK

Delta System

Point 1: Solder S1 and E3 together
Point 2: Solder S2 and E1 together
Point 3: Solder S3 and E2 together

Note: Point 1, Point 2 and Point 3 are connected to Electronic Speed Control (ESC)

Star (Wye) System

Solder E1, E2, E3 together

Note: S1, S2 and S3 are connected to ESC.

Resources:

www.innov8tivedesigns.com
- Scorpion motors / kits

www.gobrushless.com
- Motor kits

www.komodohobby.com
- Motor kits

www.rcgroups.com
- Excellent source of information.