How to Not Blow Motors in Boosted Classes

By David Stevens – 4 June 2013

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Introduction

This article explores the reasons why motors die and provides advice on how to avoid it while still going as fast as practical. It is aimed at drivers in ñBoostedò on road classes such as 21.5 Boosted, 17.5 Boosted or 13.5 Boosted. Boosted meaning the ESC changes the motor timing during the lap to make the motor as effective, and therefore fast, as practical.

First Principle

The drivers who are on the podium are not usually blowing motors. That should give you a moment of pause. So it is very achievable to do well in races without blowing motors.

Why Motors Die

The heat inside the motor breaks down the motor internals, burning wiring and de-soldering components. Motors run internally at about 200C but on the outside of the Motor Can it is about 72C. Exceed 72C at your own risk!

Of course motors are mechanical devices with moving parts and all such things have a ñlifespanò. However, much of the time it is preventable.

Types of Failure

Single run catastrophic failure ï for example a new motor arrives and is installed, the car completes a few laps and stops dead with smoke coming from the motor.

Progressive failure ï the motor gets too hot over multiple runs until it becomes noticeably slower and uncompetitive.

The effect of both is the same. A very battered VISA card!

How to Prevent Motors Overheating

If heat is the cause of motor failure then we must monitor the motor temperature and stop it getting too hot. This is not something that can be done effectively on a race day because pulling over to check the temperature prevents a good race result. So it is vital that this is done beforehand.

When looking at dead motors Iõm often told by the driver that they were told by their mate who is quite quick to use such and such motor and ESC settings. This can work but most of the time it doesnõt. Why? Because there are many factors in motor heat including:

- How free is the drive train
- Belt tension
- Gearing
- End bell timing
- Motor brand
- ESC timing
- ESC brand
- Cooling ï heat sink / fan
- Air / track temperature
- Driving style

So it is ***very likely*** that copying another driverõs setup and putting your car on the track for the first qualifier will end in tears.

Steps for Setting Up Your Motor and ESC

Equipment used: LRP X12 21.5 brushless motor and LRP Flow ESC

- LRP motors are known for their ability to withstand heat.
- Using the same brand motor and ESC means that you know that they were designed to work together.

Step 1 – Gearing

The manufacturerõs instructions or website should have gearing recommendations for your motor. If not then check out the ñBrushless Motor Recommended Gearing Starting Pointsò from Novak (http://teamnovak.com/tech_info/view_article/26). These starting points are for Blinky ESCõs and I recommend going higher as a starting point when setting up a Boosted ESC for on road touring car as follows:

13.5 motor ï 5.5:1
17.5 motor ï 4.5:1
21.5 motor ï 4.0:1

Ask the fast guys at your local track what gearing they use and start a little higher. Eg; if you are in 21.5 and the fast guy is at 3.5:1 then Iôd start at 4.0:1. If youôre in 13.5 and the fast guy is at 5.5:1 then Iôd start at 6.0:1. Remember they are fast because theyôve done all the work described in this article already (and because they can drive well!). Just copying their settings and hoping your motor doesnôt blow is likely to hit you in the hip pocket!

For an explanation of Final Drive Ratios and how to calculate them refer to the RC Formula1 article ñA-Z of Gearing for Blinky ESCôsò (http://www.rcformula1.com.au/index.php/tech-tips/a-z-of-gearing-with-blinky-escs) or from the Main Menu of www.rcformula1.com.au > Tech Tips > A-Z of Gearing with Blinky ESCôs

So we will start with an FDR of 4.0:1.

Step 2 – End Bell Timing

Donôt change the end bell timing set by the manufacturer. We will setup the ESC to advance the timing electronically to obtain more speed in a later step. Some old hands retard the end bell timing slightly (going lower) and increase the timing more than recommended on the ESC. This can work but it may also increase the likelihood of blowing motors and is not recommended when starting out. For example; most Novak Ballistic motors come from the factory with 30 degrees of motor timing on the end bell. Some might reduce this to 25 degrees to give more Torque and allow an extra 5 degrees of timing to be added by the ESC at higher speeds (to fully understand this refer to the Appendix on page 8 which provides background information on motor timing).

Step 3 – Drive Train

Disconnect the pinion and push the car along the ground. Does it roll nice and freely? If not then check the belt tightness. The slower the class the looser the belt can be. Your belt should be as loose as possible without skipping on power from a standing start (you can hear the belt skipping). ñSkippingò means that the teeth in the belt jump / skip from one tooth to the next on the diff gear (this shouldnôt happen). A too tight belt will increase friction and motor heat.

If your car still doesnôt roll very freely then check for binding and check / replace the bearings.

A car that doesnôt roll freely makes the motor work harder than it needs to.

Step 4 – Pinion Mesh

Set the pinion mesh as described in the article on RCtek.com under the menu Tips and then ñSetting the Spur and Pinion Gear Gapò. A pinion set too tightly will burn out your motor. A pinion set too loosely will cause stripped spur gears.

Step 5 – Cooling

On an on road touring car in Australia you will almost always run a heat sink and cooling fan.

Step 6 – ESC Settings

Before you read this you may wish to skip to the Appendix (page 8) for a brief explanation of how a brushless motor works and how changing motor timing alters motor effectiveness.

The various manufacturers of ESCôs all have different setup options in order to try and differentiate themselves in the market. However, they seem to have broadly settled on two key terms:

1. **Boost Timing** ï this is timing added to the motor progressively as it accelerates. For example; if you choose 40 degrees of Boost Timing then the ESC will add timing as the motor accelerates to a maximum of 40 degrees.

2. **Turbo Timing** ï this is timing designed to be added when the motor is flat out. It might be added when you have fully depressed the throttle trigger for a period of time or when a timer in the ESC expires. For example; 7 degrees.

   Turbo timing is added to any Boost timing already applied.

For example with a 21.5 motor:

Throttle Trigger	Off	Starting to accelerate	80% throttle	Full throttle	Full throttle for say ½ a second
RPM	0	3,000	8,000	12,000	14,000
Boost Timing	0	+5	+30	+40	+40
Turbo Timing	0	0	0	0	+7
Total Added Timing					+47 degrees

The LRP Flow allows Boost Timing from 0-50 degrees and Turbo Timing from 0-10 degrees.

The Tekin RS allows Boost Timing from 0-55 degrees and Turbo Timing from 0-20 degrees.

How to blow your motor ï start with close to the top of these numbers and sit back and smell the burning! A safer course is to start with something more moderate and I suggest 40 degrees Boost and 7 degrees Turbo.

Your First Run – Taking the Temperature

Ok, so we have followed the steps above and weôre ready to hit the track.

Take the temperature of the motor using an infra red temperature gauge. Anywhere on the can is fine unless itôs a polished or highly reflective surface. Some motors are more susceptible to heat than others but as a rule of thumb at the end of a race:

Motor Temp	Comment
> 80C	Bad news, your motor has probably sustained internal damage and will be on its way out
80C	This is the highest safe temp but is not recommended over many runs
72C	This is the perfect temp and if you never exceed this then you and your motor should be very happy together for a long time
<70C	There is scope to fine tune settings looking for more speed

Warning! On your first run donôt wait for 6 minutes to take the temp. Temp after 2 minutes. If itôs say 35C then run for another minute and temp again. If itôs say 60C then temp every couple of laps.

If you reach 72C before the amount of time it normally takes for a race to run then stop and reduce your Boost or Turbo settings. Eg; if my motor was 72 degrees after 4 minutes (when setting up for a 6 minute race) then Iôd drop Boost Timing by 5 degrees. Wait for 30 minutes for the motor to completely cool and then try again.

With the FDR, Boost and Turbo Timing settings we started with above Iôd assume that the car is a little slow speed wise but it comes off well under 72C so we can start tuning it to go faster. That's why we like racing! :)

Optimising Speed

Step 1 ï start moving your gearing towards the FDR that the fast guys at your track recommend. Eg; if you are at 4.0:1 and they recommend 3.5:1 then use a pinion with one more tooth and test again. So with a 75T spur, 34T pinion and 1.8 internal ratio your FDR is (75/34) x 1.8 = 3.97. Try a 35T pinion which will take you down to 3.86. Check temps and repeat.

Step 2 ï if you get to 3.5:1 and are still under 72C after a 6 minute run then congratulations. You can now fine tune the ESC timing. Step 2 is to increase Turbo Timing to 10.

Step 3 ï if still under 72C after 6 minutes then increase Boost Timing 5 degrees at a time. Eg; we were at 40 degrees so try 45 degrees. If still ok then try 50 degrees.

Provided you are under 72C you can continue to fine tune until you are happy with the speed.

Tip - It is not recommended that you add more than 55-60 degrees total timing via ESC settings. This varies by ESC manufacturer because some use a percentage rather than degrees and some factor in end bell timing and others donôt. None of them publish detailed information and it can be difficult to relate their settings to what we know about how motors work. But be conservative and your motor will love you for it!

Another Tip - If on race day the air temperature is hotter than when you carried out your testing then consider raising the FDR or lowering the timing so that you don't over heat the motor.

Over heating the motor melts the solder inside the motor and soon afterwards the motor will probably stop working. It might just go slowly or it might grind to a halt in the middle of a race and start smoking! Motors that have over heated tend to smell (forever).

Now that you have your base setup with a car which is in the ball park speed wise and is not blowing motors you can now start listening to people in the pits for what they would recommend. But ï make the changes on a test day, make small progressive changes, and follow the testing steps above under the heading ñYour First Run ï Taking the Temperatureò each time.

How to Drive Fast

Practice!

If someone in a faster class can pick up your car and drive it as fast as the leaders in your class then the car is quick enough. The temptation is to look for shortcuts and add some timing to find a couple of tenths of a second and catch the leaders. A better way is to recognise that over time you will get faster simply by practising. The more you practice the more you accelerate the process and the faster you will be on the next race day!

Final Thoughts

Should you use a PC, a Program Card or Buttons on the ESC?

One of the strengths, and weaknesses, of programming your Boosted ESC is the granular control available. However, feedback is that many racers want a simpler setup. The good news is that a number of ESCǒs have fairly simple setup options while others allow detailed programming via a PC interface for those wanting complexity.

Before buying an ESC download the manual from the internet and make sure that itǒs programmed using your preferred method:

- PC interface
- Program Card
- Buttons on the ESC

NB: some ESCǒs like the Tekin RS have limited changes that can be made via ESC buttons but some settings, including Boost Timing, can only be changed via the PC interface. So read the manual carefully before investing your hard earned dollars.

Do Not Free Rev Your Motor!

The following is taken from the Novak website (www.novak.com):

The act of free revving *(running at high RPM under no or little load)* a brushless motor can cause damage and subsequent failure to the brushless motor and/or the speed controller.

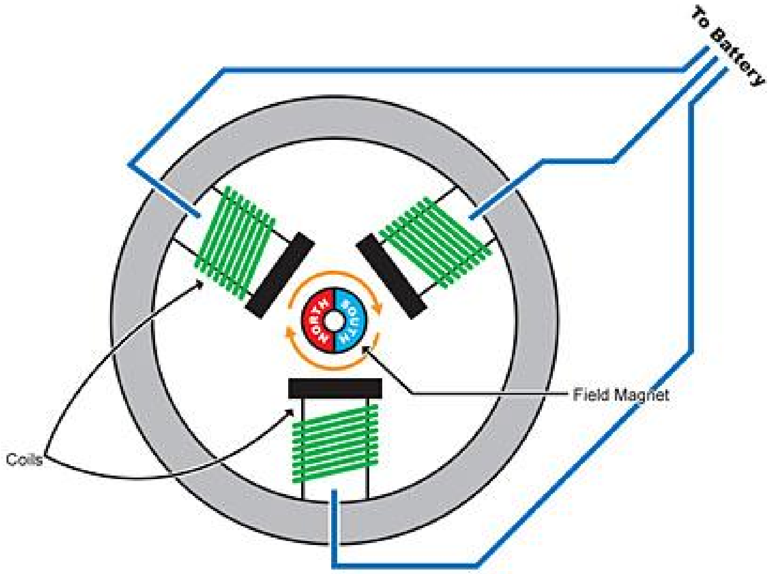
If allowed to accelerate too high, the rotor's magnet can break apart, damaging the internals of the motor. The ESC can also be damaged by the motor coming to an immediate stop from a no load high speed or by extremely-high currents experienced by applying full brakes in these conditions. The likelihood of a rotor failure is significantly increased if a brushless motor is free revved while hot, such as after a full-battery pack run.

Because brushless motors can attain such high RPMs under no (or low) load conditions, the centrifugal forces can cause the rotor to break apart.

We recommend that you NEVER free rev your brushless motor in or out of your vehicle.

Appendix – How a Brushless Motor Works

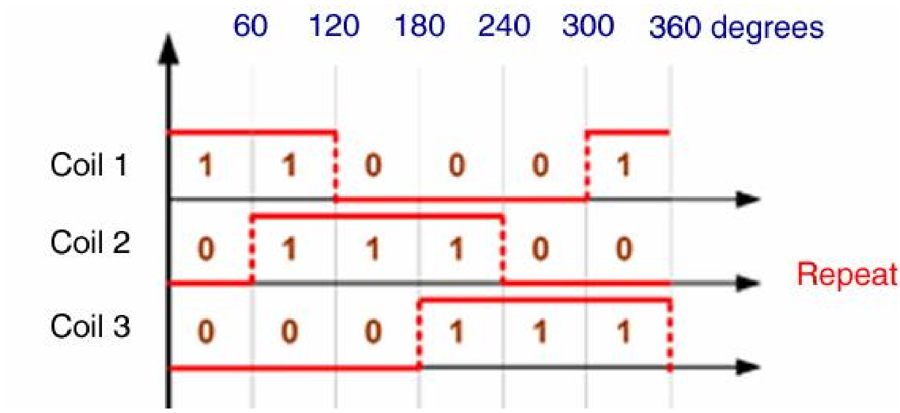
Inside a Brushless Motor – Diagram by HPIeurope.com



In a brushless motor the permanent magnets are on the rotor (red and blue on diagram), and the windings of wire (green in diagram) are on the can - or stator. Different amounts of current are supplied through three wires (blue in diagram). Basically one wire supplies positive current, one negative, and the third is ground at any given time. This makes two of the windings of wire into electro-magnets that attract or repulse the permanent magnets in the rotor which spins as a result.

The trick with a brushless motor is how does it know what current to send to each of the 3 different windings of wire (or coils)? A sensorless motor is very bad at starting up and running at low speed. This manifests as a stuttering of the motor or "cogging". A sensored motor uses Hall effect transistors as sensors to determine the position of the rotor and therefore when to energise each of the three coils. In on road racing we use sensored motors and this allows us to use the ESC to adjust the timing.

The motor can is a 360 degree circle. As the rotor rotates inside the motor power is applied to the coils every 60 degrees as shown below. 1 = power going to that coil and 0 = power off for that coil (coils are green in the first diagram above).



In classes such as 21.5 Boosted, 17.5 Boosted and 13.5 Boosted, dynamic timing is allowed. This means that the ESC can change the timing as needed to maximise the effectiveness of the motor.

Motor Effectiveness and Timing

Torque is the force that turns the motor. As RPM increases, Torque is reduced.

You need more Torque at low speeds to get the motor turning quickly. Once the motor is up to speed you need maximum RPM to maximise top speed.

Lower timing settings give more Torque and less RPM.

Higher timing settings give more RPM and less Torque.

By increasing Timing as the RPM increases you can get the best of both worlds.

NB: I have purposely used the term ñeffectivenessò because ñefficiencyò has a specific technical meaning when applied to motors.

Timing Summary

As you can see More Timing is not necessarily better. You need to provide the correct amount of Timing to the motor as RPM increases. Too much timing simply generates heat because the motor must work harder than it needs to. The incorrect amount of Timing as the motor accelerates makes the motor less effective and you donôt reach top speed as quickly as you could.

You should not give your motor more than 55-60 degrees of Timing at any stage.

By dynamically changing the timing on a brushless motor you can have a motor that has a small amount of Timing when it is running slowly, and a lot of Timing when it is running faster, giving you a fast and effective motor at all speeds.