Understanding Gear Ratios

"How can I make my car go faster?"

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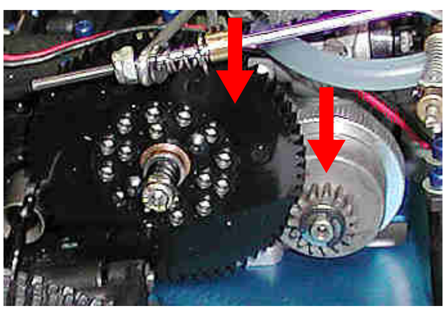
No matter what car you have, or whether you have the latest batteries and motor or high performance blue-toned engine, unless you have the right gear ratio for the track you are on, you will not get the best performance from your car. Even if you are just a sports racer who wants only to run his car up and down the street or at the local track, a basic understanding of gear ratios will help you get even more fun out of your car.

Gearing plays an enormous part in your car's ultimate performance. The most asked question in R/C cars is, "how can I make my car go faster?" Nearly as often are questions like, "why does my battery dump so soon?" and "why is my motor so hot?"

While not the only solution to those problems, there's no doubt that getting your car's gear ratio right will go a long way to resolving them.

Absolute basics



Spur and clutch bell of a nitro truck

Spur and pinion of an electric buggy

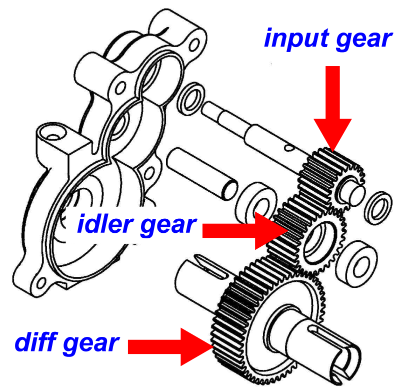
We should define the term "gear ratio" right from the start. In its simplest form, it defines the relationship between any two gears. Usually this will be the "pinion" gear (found on a motor in electric cars and on the clutch bell of a nitro car) and the "spur" gear (which more often than not is found on the drive axle of a car).

Pinion gears come in all shapes and sizes, as do spurs but for our example we'll say hat the pinion gear has 18 teeth and the spur gear has 90 teeth. You often see in car specification charts we publish in *Racing Lines* a gear ratio of 18:90. Often it is divided into its lowest common denominator which would be 5:1 after we divide the number of teeth of the pinion (18) into the number of teeth of the spur gear (90).

Spur Gear divided by Pinion Gear = Gear Ratio

90 divided by 18 = 5. What all this means is that the pinion gear must turn five times to make the spur gear turn once.

Transmission ratio



Three-gear transmission

The above example is for what we know as direct drive cars, where the pinion and spur gear mesh to transfer power to the drive axle. An example of these cars are the 1:12th scale and 1:10 scale electric pan cars.

In the case of two wheel drive off road buggies and trucks, the car is usually equipped with a transmission or an internal reduction gearbox.

Usually there are three gears in such a gearbox. At the bottom is a ball or bevel gear differential (or planet and sun) from which the output shafts protrude. Associated and Losi are good examples of the former, Kyosho, Tamiya and Traxxas the latter. At the top is the input gear and in the middle, the idler gear.

To determine the transmission ratio of cars with a three gear transmission, it is a matter of dividing the top (input) gear into the bottom (diff) gear. The idler gear plays no part. We'll stay with our nice and mathematically friendly figures and we'll say the top gear is 20 teeth and the bottom 50 teeth.

Diff Gear divided by Input Gear = Trans. Ratio

This will give us a transmission ratio of 20:50 or 2.5:1. You'll often see a figure something like this quoted by off road car manufacturers like Associated and Losi when they talk about their buggy or truck transmissions.

It's just as easy for cars with bevel gear transmision: divide the small bevels into the larger ones.

Large Bevel divided by Small Bevel = Trans. Ratio

In belt driven four wheel drive on and off road cars, divide the teeth on the diff pulley by the teeth on the top or drive pulley.

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Final drive ratio

Now that we have the gear ratio and transmission ratio worked out, we can work out the final drive ratio. To do this, you multiply the transmission ratio by the gear ratio. In our example, it is

Trans. Ratio x Gear Ratio = Final Drive Ratio

2.5 x 5 = 12.5. Thus we have a final drive ratio of 12.5:1.

So how do we use this information? Use it to be more competitive! Let's say you are at the racetrack and you have an identical car and set-up to another guy in the same race as you. He is much quicker than you so, like all racers being beaten, you wander casually over to his pit table and direcly or indirectly ask him what final drive ratio he is running. He says 13:1. Hmmmmm.

As you have seen, you have worked out your final drive ratio at 12.5:1. We'll assume here that the guy is 100% honest and not lying through his teeth like a lot of racers do to their opposition when asked to divulge some of their speed secrets.

You need to change your ratio from 12.5 to 13. You can't do much about the transmission ratio, in most cars this is fixed. Your option is to change either your pinion or spur gear. You'll have to sit back at your pit table and work out exactly what gear ratio you need to get that 13:1 ratio but it might well be worth it. Here is the formula to use:

Spur divided by Pinion x Transmission Ratio = Final Drive Ratio

Suppose your current gear ratio is 18:87 (pinion/spur). Your transmission ratio is 2.5:1. You want a final drive ratio of 13:1. Now do the math:

87 divided by 18 x 2.5 = 12.08

Now you change the spur and/or pinion numbers in your equation to see how close to 13:1 you can get. You finally hit on 17:88 for a final drive ratio of 12.94:1. Again, do the math:

88 divided by 17 times 2.5 equals 12.94:1

Of course you could have also asked your competitor what pinion gear he had on his motor and again, if he was 100% honest he'll tell you, which will save a bit of brain power (aren't you beginning to just hate this guy if he is being so honest ... like, he is telling you his set-up and more or less saying, "I'll still beat you." (Grrrr).

For those racing in the Stock motor class, be aware that of all the motors on the market, a Stock motor demands very careful selection of gear ratio. You'd be surprised just how much difference in performance there is between, say, 12.5:1 and 12.75:1. You really do need to do your homework at the track if you are into serious competition Stock class racing.

Roll-out

Roll-out simply refers to how far a car will travel for each revolution of the pinion gear. It's importance isn't so great in off road but it's absolutely vital in on road racing with foam tires. It is not used with rubber tires.

A car with a larger diameter tire will travel further than a car with a smaller diameter tire. However, the car with the larger diameter tire won't necessarily travel faster than the car with the smaller diameter. And for those wanting to really get stuck into serious competition racing, roll-out means a whole lot of experimenting.

To work out a roll-out figure, you need to know that pi = 3.14 and the circumference of the new tire (more math here):

multiply pi x tire diameter

(or you can simply mark the sidewall of the tire and roll it one revolution and measure it). So if we have a tire diameter of 90mm, the circumference is

3.14 x 90 = 282.6mm

3.14 x Tire Dia. = Circumference of tire (282.6mm)

One more bit of math and we're there! Now we have to divide 282.6mm by our final drive ratio—12.5 from our earlier example.

282.6mm divided by 12.5 = 22.6

So we now know that the car will travel 22.6mm for every revolution of the pinion gear.

How do you use this information? Throughout the day your tires are wearing down. This will affect your gearing. To maintain your optimum gearing, you'll have to change the pinion and spur (and thus your final drive ratio) to keep your roll-out consistent throughout the

Larger circumference = longer distance per axle rotation

Smaller circumference = shorter distance per axle rotation

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So you can see that depending on the diameter of the tire, the roll-out figure will vary and as a result, so will the performance of your car—both in terms of straightline speed and, in the case of electrics, lasting the entire race without dumping.

If you are to be a serious challenger for top honors in on road racing, you'll need to work up a roll-out chart. If you have a spreadsheet program such as Microsoft Excel, it is relatively painless even if it takes a while. First, you need to know the transmission ratio of your car and from there you can put into cells the various pinion and spur gear sizes you are most likely to use and play away with formulas. You'll end up with the final drive ratio. Detailed information on these charts are at the end of this article.

A lot of racers take the time to measure the diameter of their tires before and after each race. Not only does this give you an idea of tire wear but it will also help sort out your roll-out chart and, more importantly, it will eventually give you a verygood indication of what the optimum roll-out should be for your car on your track. Incidentally, tire wear is usually higher during the warmer months as traction is higher and getting the roll-out correct can be even more vital to your chances of success.

Start with a new set of tires that you know work on your track. If you can't spend an afternoon practicing at near-race speeds, then you'll have to do this during race day. Each time you put a battery through, measure your tires before and after and record them. At some time during the practice session, you'll become aware that your car is dumping sooner than it did earlier in the day (it's good policy torecord all this information also). Note the roll-out figure in your log.

At race day, you might now be able to saunter up to that friendly guy you got the earlier information from and ask him what his roll-out is. (After several heats using foam tires, asking for the final drive ratio would not be as helpful as the roll out figure.) You might get lucky and he will still give you the correct information or he might now realize you are onto something and tell you some improbable figure. Whip out the calculator and put his figures through and you'll get an idea how close you are. Keep your ears open and you'll possibly hear other racers mentioning the vital figure as well.

Gear mesh between spur and pinion

Gear mesh

This refers to the physical proximity of the spur gear to the pinion gear. You need to get the pinion gear to mesh smoothly with the spur so that you lose minimum power at this crucial point due to friction between the two surfaces.

Get the mesh too tight and you can do damage, even permanent damage, to your motor or engine. Too loose and you'll be stripping the teeth of the spur gear quickly and your car will hardly move. You need just a fraction of "rocking" movement between the two sets of teeth.

Place a piece of paper between the two sets when you first attempt to mesh them and adjust the mesh until you can just remove the paper without having to tug at it.

A final word, make certain you know what "pitch" your gears are or at least buy only the gears offered by your car's manufacturer. Technically, "pitch" refers to the number of teeth in one inch on a gear. 32, 48 and 64 pitch are the most commonly used in R/C cars. All three can be found used by manufacturers although 64 pitch is usually reserved for high-end competition electric tourers. 32 pitch is more often than not to be found in nitro cars while 48 pitch will be found in most electric tourers.

Tamiya and Kyosho are different, they use what is known as .6 module gears, a metric measurement. Be careful, because .6 module gears will not mesh with 48 pitch even though they look much the same. We'd advise you to use their proprietory gears unless you are prepared to spend quite a few dollars on replacing them with 48 pitch gears.

Brush your teeth

Your gear teeth, that is! Dirt and grit are the enemies of gears so if you are racing in a dusty environment, as you will with an off road buggy or truck, make sure you use a sealable gear cover. Most off road cars will come with one, if yours is damaged for whatever reason, don't be a tight fist and balk at paying for another because you'll end up spending more money on replacement pinion and spur gears.

On road environments are generally cleaner than off road, however it is still possible that you can pick up little pieces of grit from the track. Check after each run and carefully remove any offending particle.

Continued use of gears without ridding them of dirt and grit will soon chop them up. Your car's performance will also be reduced and we don't want that!

Other issues to consider

Of course, just having the magic roll-out figure on your car is not going to ensure instant success. Different motors, brushes, batteries and even driving styles come into it although knowing the "correct" roll-out figure often means that those differences are not as great as you would think.

No matter what anyone tells you, you cannot just put down your car and be immediately competitive. You might get a few hot laps in but those who put in the hard yards to undertake quality practice time will always rise to the top. And by quality practice time, we don't just mean driving, for although driving practice is important, understanding each component that goes into making up your competition screamer is even more important.

As you start out on your racing career, we can't urge you enough to keep a log of everyting you do and the results of that action. Ask a million questions (you'll find the answers are genereally honest and correct while you are a newbie but a little more outrageous as the replier realizes you are getting on the pace). If your final drive ratio matches the fastest car on the track but you are still slower, or are faster but your car is uncontrollable, then the gearing on your car was not really the problem. Now you must check out the motor or batteries or other part of your set-up.

Over a surprisingly short period of time you'll build up an impressive databank of knowledge which will enable you to compete on level terms with that guy with exactly the same set-up as you. Then you too can start helping other newbies!

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ARMED AND DANGEROUS

Before we get to figuring out what to do with all this information, there are a few generalities to soak up.

First, two terms will continually bob up in discussions about rear ratios: tall gearing and short gearing. Tall gearing refers to a low numerical figure (e.g. 3:1) for a final drive ratio while a short gearing refers to a high numerical figure (5:1).

Here's what to expect from different ratios in different cars:

Nitro with short gearing

Lots of acceleration, maybe excessive wheelspin and poor handling (one follows the other here), poor fuel economy and maxes out way too easily (and can go bang!).

Nitro with tall gearing

Lots of top end speed but less acceleration, less wheelspin, better fuel economy, easier handling because tires aren't breaking loose. Be careful here though, if you go too far then you will be laboring the engine out of every corner, using too much fuel as well as stressing the engine.

Electric with short gearing

Lots of acceleration, maybe excessive wheelspin and poor handling, less current draw, better run time, easier on motor.

Electric with tall gearing

Lots of top end speed, less acceleration, less wheelspin, easier handling because tires aren't breaking loose, lots of current draw, short run time, maybe motor smells bad and stops, speed controller goes "POP!"

Safety first

It's better to err by gearing nitro tall and electric short. Most car manufacturers include a recommended gear ratio chart and it is good policy initially at least to follow their guidelines. They built the car for all-round performance and some experimenting on your part will enable you to work out which way you should go.

Traction or lack of it will also influence your gear ratio selection. In cases of high traction, shorter gearing is generally the way to go while with poor traction, taller gearing usually works better.

What you are searching for is a ratio which gives you an easy driving car and the best, most consistent lap times for the full length of the race.

A few more terms

While you are on your "research" around the pit tables, you'll come across two terms racers use regularly—undergeared and overgeared.

An undergeared car has too tall a final ratio while an overgeared car has too low a final ratio. Earlier on this page we explained them a different way but they basically mean the same. An undergeared car will have too small a pinion or too large a spur gear with the reverse for an overgeared car.

TWO SPEED TRANSMISSIONS

To do justice to a two speed transmission set-up, we'd need far more space than we have here, however we'll endeavor to provide a very quick and basic guide.

Two speed transmissions are designed to deliver quick acceleration out of corners and killer speed down the straight. They do this by providing a low ratio (acceleration) and a high one (speed). There are not only two spur gears but also two pinion gears. When the car starts from the grid, the larger gears (low ratio) come into play. At a predetermined point, as the car builds speed, a small metal arm comes into play (as a result of centrifugal force) to engage the smaller (higher) ratio.

You work out your gear ratio and final drive ratio much the same as you would with a single speed tranny although you have two sets of figures to deal with. The trick is to adjust the timing of the change point to extract maximum performance. We'll leave that for another day.

MORE ABOUT GEAR PITCHES
(from Associated's Tech Help FAQ)

In the R/C hobby we use mostly 32, 48 and 64 pitch gears. The pitch has to do with the size of the tooth, not how many teeth, on the gear. 32 pitch gears are the largest pitch with fewer teeth per inch. Less teeth per inch means the teeth are larger and therefore stronger. The disadvantage is you have fewer adjustment options over a specific range of drive ratios. Also the pressure angles of the teeth as they mesh is greater so these gears tend to be less efficient and noisier. We use this pitch for our off road gas truck because of the power the engines can develop—which is enough to rip the teeth off 48 or 64 pitch gears.

With 48 pitch gears the teeth are a little smaller but still strong enough for electric off road applications. These gears are a little more efficient and quieter because the pressure angles between the teeth meshing is improved, which makes the gears more efficient and quieter. You also have a 50 percent increase in gearing options over 32 pitch gears.

64 pitch gears are more common for on road racing where you do not run into a lot of rocks. (Rocks can damage the teeth on 64 pitch gears easily.) Also the teeth on 64 pitch gears are so small that they are not strong enough for off road applications where the teeth have to be able to handle the shock loads that occur when you land after a jump. Because of improved pressure angles, again, 64 pitch gears are quieter and more efficient beyond 48 pitch gears. You again have a 50 percent increase in adjustment options over 48 pitch gears.

Roll out charts

So far as a roll out chart goes, each table in the set would be for a specific tire diameter. The set may start at 55mm and progress down to 45mm in 1mm steps. The column and row headings for each table are spur and pinion gear teeth numbers. Roll out figures can now be calculated to fill out the body of each table using the math as described earlier in the article. A driver would measure the driving wheel's diameter and consult the appropriate table. Knowing their desired roll out figure from experience, they can select a spur/pinion combination which best suits.