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FASTMATH

GEAR RATIOS

A firm grasp of gear-ratio math will allow you to fine-tune your RC vehicle's performance—specifically, its acceleration and top speed. Gear ratios determine the load on the engine, and that impacts both acceleration and top speed. Knowing the right way to alter gear ratios or other elements of a vehicle based on precise calculations can make the difference between winning and losing. Additionally, gear ratios are the basis for most other calculations related to vehicle performance, so it's good to know how to determine these ratios.

Gear ratios tell you the amount of gear reduction in the drive train. Nitro engines have far too much rpm and too little torque to be effective if the engine were hooked directly to the wheels and tires. The car would hardly go anywhere with the current tires, or you'd have to run tires that are about the size of a quarter. Much like a block-and-tackle enables mere mortals to lift tons of weight single-handedly, gear reduction in your nitro-powered vehicle's drive train multiplies torque to maximize what little torque the engine has, and it reduces crankshaft rpm to a reasonable level so the tires spin at a more appropriate speed.

**PRIMARY RATIO = SPUR
GEAR ÷ CLUTCH BELL.**

This is the ratio of the clutch-bell/spur-gear combination. It's just part of the overall gear reduction, but you must know this ratio to make most of the other calculations given in this article. To calculate this, I'll use a Kyosho Inferno 7.5 buggy as an example. Its spur gear has 46 teeth, and its clutch bell has 13 teeth. To determine the primary ratio, divide the number of teeth on the spur by the number of teeth on the clutch bell.
Inferno buggy example: 46 ÷ 13 = 3.54.
The Inferno 7.5's primary gear ratio is written as 3.54:1.
If your car is equipped with a 2-speed transmission, as many nitro touring cars are, the process is the same; you just have to calculate the ratio separately for each clutch- bell/spur-gear combination.

**TRANSMISSION/DRIVE-TRAIN RATIO =
LARGER PULLEY OR GEAR ÷
SMALL PULLEY OR GEAR.**

Like the primary ratio, the transmission or drive-train ratio is only part of the overall reduction, but you need to know this ratio and the primary ratio to make many of the other calculations. Although the drive trains on belt-driven and shaft-driven cars differ in construction, you can calculate your model's drive-train ratio in a similar way by counting the teeth of the two pulleys or gears and then dividing the larger by the smaller, assuming there is only one step of reduction in the drive train.

Inferno buggy example: The differential (diff) ring gear has 43 teeth, and the drive pinion has 13 teeth. To calculate the drive-train ratio, divide the first number by the second:
43 ÷ 13 = 3.31:1.

COMPOUND DRIVE TRAIN RATIOS =
(LARGE PULLEY ÷ SMALL PULLEY) x (LARGE PULLEY ÷ SMALL PULLEY).
Compound ratios are where there is more than one step of reduction in the drive train. In the previous example, only one gear drives another gear—just a single step of reduction. In some cases, however, there can be two or more steps of reduction, and the drive-train ratio has to be established in a different way.

The Losi Triple-XNT has a compound idler gear—two gears in one; that setup creates an additional step of gear reduction. Compound drive-train ratios are also fairly common in on-road cars. The Kyosho V-One-RR, for example, has two stages of reduction in its front drive system. The pulleys that drive the side belt have 19 and 25 teeth, and the pulleys for the front belt have 18 and 32 teeth. Calculating a compound ratio simply requires calculating each step of reduction separately and then multiplying the ratios. Using the Kyosho car as an example, the equation looks like this:

25 ÷ 19 = 1.3157985
(first step of reduction)
32 ÷ 18 = 1.7777777
(second step of reduction)
1.3157985 x 1.7777777 = 2:34:1
drive-train ratio (rounded)

The drive-train ratios in touring cars are typically the same in the front- and rear-drive systems, but there are occasionally slight differences in ratio between the front and rear. The Mugen MBX-4XR and most 1/8 on-road cars have overdrive ratios on the front drive system. In some cases, it's for extra drive in the front end to help "pull" the car through the corners; in others, it's simply to compensate for smaller-diameter front tires.

"TRANSMISSION"
RATIO = DIFF GEAR ÷
TOP SHAFT GEAR.

Transmission ratios are calculated in much the same way as on a belt- or shaft-driven car. A 3-gear transmission, such as that in the RC10GT, simply requires that you know the number of teeth on the gear of the top shaft and the number of teeth on the diff gear. Forget the idler, or middle, gear for the moment. Its size doesn't affect the transmission ratio. It only transfers power from the top gear to the diff gear, and it reverses the direction of rotation, but it doesn't play any part in the gear reduction. Top shaft gear—20 teeth.
Diff gear—52 teeth.
Transmission ratio equals:
52 ÷ 20 = 2.60:1

FINAL DRIVE RATIO =
PRIMARY RATIO x DRIVE-TRAIN RATIO.
This is an easy calculation in which you multiply the primary ratio by the drive-train ratio. The Inferno MP7.5's primary ratio is 3.5385:1, and the drive-train ratio is 3.3077:1. To calculate the final drive ratio, simply multiply the two.
Example:
3.5385 x 3.3077 =
11.70 (rounded)
The MP7.5's final drive ratio is 11.70:1.

ROLLOUT = TIRE DIAMETER x 3.14 ÷ GEAR RATIO. A tire rollout number tells how far a car rolls with one revolution of the engine. Knowing gear ratios is important and an essential element in the following equations, but only rollout takes into account the size of your tires and your gear ratio. Why is this important? Changing to tires of a different diameter will result in a higher load on the engine, and that will cause a loss of acceleration, and it could possibly increase top speed—much like installing a larger clutch bell. You may want these changes, but you may not. A rollout number quantifies exactly the effect of gear ratio and tire-diameter changes. Higher rollout numbers mean an increased load on the engine, which results in slower acceleration and faster top speed. Conversely, lower rollout numbers result in quicker acceleration and lower top speed.

You'll need to know your tire circumference; calculate this by multiplying its outside diameter by pi—3.14. Measure the tires with calipers if you can, or use a ruler. You only need to measure one tire except when the front and rear tires are of different sizes, which is typical of many nitro on-road racers. In such a case, you'll need to measure the front and rear tires. Then calculate rollout using this formula:

tire diameter x 3.14 ÷ gear ratio = rollout
Once you've calculated rollout, here's an example of where it's useful:
You're changing to a larger tire, but you want performance to stay exactly the same. Before you make any changes, you should calculate rollout to have a baseline number, and then run the numbers again with the new tire diameter plugged into the equation. Knowing you want to keep performance the same with the new tires, you'd want to determine the ratio change required to maintain that performance.

Using the MP7.5 as an example, calculate the rollout with the existing equipment:
(4 inch diameter x 3.14) ÷ 11.7
(final drive ratio) = 1.074 rollout

This tells me that for every engine revolution, the car travels 1.074 inches. If I use 4.6 inch-diameter tires instead of the 4-inch tires I currently run, which gear ratio will I need to make the car run as it did with 4-inch tires?

Step 1. First, calculate the circumference of the 4.6-inch tires.
(4.6 x 3.14) = 14.45.

Step 2. Put the new tire circumference into the equation. We don't know what the final drive ratio needs to be yet, so put an “X” in place of the ratio for now.
14.45 ÷ X = 1.074 (original rollout figure)

Step 3. Multiply both sides by X ÷ 1 to move the “X” to the right side. You now have:
14.45 = 1.074X

Step 4. Divide the tire circumference by 1.074: 14.45 ÷ 1.074 = 13.45 (rounded).

This tells us that the final drive ratio needed to maintain performance with the larger tires is 13.45:1. Examine the available clutch- and spur-gear sizes to see which combination will get a final drive ratio as close to 13.45:1 as you can get it. In this case, a 12-tooth clutch bell and a 48-tooth spur gear would be the closest possible combination (use the drivetrain ratio calculations from earlier to refigure the gear sizes for the proper ratio).

AVERAGE SPEED OVER DISTANCE = 3,600 ÷ (5,280 ÷ DISTANCE x SECONDS).

Speed is the measument of distance traveled over time; with simple math, we can calculate a vehicle's speed when we know how long it takes to travel a particular distance. You can calculate speed just for fun and bragging rights, but it's also an important number in the sections that follow. You'll need a stopwatch and an accurate measurement of the distance your car travels.

The formula for calculating speed over distance: 3,600 ÷ (5,280 ÷ distance x seconds) = mph

Example: let's say it takes my Mugen MTX-2 touring car 2.29 seconds to cover 200 feet from a running start. Divide 5,280 by 200 (number of feet), and then multiply the result by 2.29 (seconds to cover the 200-foot distance). (5,280 ÷ 200) x 2.29 = 60.456 3600 ÷ 60.456 = 59.55mph

If you want to determine your car's top speed as described in this example, you must time it over a sufficiently long distance. When a fast car travels a relatively short distance, the margin of error is much greater because it's hard to time a 60mph car accurately through a 50-foot trap. For example, it would take less than 6/10 second for a 60mph car to cover 50 feet, and that makes it very difficult to get an accurate time. Even over a 200-foot trap, a 1/10-second error in timing (at nearly 60mph) will result in a 20-plus mph margin of error.

CALCULATED ENGINE RPM =
SPEED IN MPH x
FINAL DRIVE RATIO x
336.135 ÷ TIRE DIAMETER.

Let's say you've clocked your 7.5 buggy at *40mph. At how many rpm does the engine turn?; 40mph multiplied by the final gear ratio multiplied by 336.135 and divided by tire circumference:*
40 x 11.7 x 336.135 ÷ 4.6 = 34,198rpm

ESTIMATED TOP SPEED = ENGINE RPM ÷ FINAL DRIVE RATIO x tire diameter ÷ 336.135.
If you don't want to go outside and get dirty timing your car from point A to point B, you can estimate potential top speed from the comfort of home. *To calculate estimated top speed for any vehicle, you need to know:* • final drive ratio;
• approximate maximum engine rpm (under load);
• tire diameter.

Let's calculate an estimated top speed for an 1/8 Kyosho 7.5. Assume the use of a Novarossi SBK engine with a final gear ratio of 11.70:1 and using the engine rpm from the previous calculation (34,198) and a tire diameter of 4.6 inches. Divide the engine rpm by the final drive ratio, multiply by tire diameter and then divide by 336.135. 34,198 ÷ 11.7 x 4.6 ÷ 336.135 = 40mph (rounded)

GEAR RATIO FOR TARGET SPEED =
ENGINE RPM x TIRE DIAMETER ÷
TARGET SPEED ÷ 336.135.

Want your buggy to go at 50mph but don't know the gear ratio required? With the known variables in place, just turn the equation around:
34,198rpm x 4.6 (tire diameter) ÷
50mph ÷ 336.135 = 9.36:1 final drive ratio

QUICK EQUATION GUIDE

- **Primary ratio = spur gear ÷ clutch bell**
- **Transmission/drive-train ratio = larger pulley or gear ÷ small pulley**

or

- **Compound drive-train ratios = (large pulley ÷ small pulley) x (large pulley ÷ small pulley)**
- **"Transmission" ratio = diff gear ÷ top shaft gear**
- **Final drive ratio = primary ratio x drive-train ratio**
- **Rollout = tire diameter x 3.14 ÷ gear ratio**
- **Average speed over distance = 3,600 ÷ (5,280 ÷ distance x seconds)**
- **Calculated engine rpm = speed in mph x final drive ratio x 336.135 ÷ tire diameter**
- **Estimated top speed = engine rpm ÷ final drive ratio x tire diameter ÷ 336.135**
- **Gear ratio for target speed = engine rpm x tire diameter ÷ target speed ÷ 336.135**
- **Tire diameter for target speed = Desired mph x final drive ratio x 336.135 ÷ engine rpm**
- **Lateral acceleration (G-force) = 1.227 x**

TIRE DIAMETER FOR TARGET SPEED =
DESIRED MPH x FINAL DRIVE RATIO x
336.135 ÷ ENGINE RPM.

If you know your engine's rpm, gearing and your target speed, you can calculate the tire diameter you need. *Multiply target speed by final drive ratio and then multiply that by 336.135; then divide by the engine rpm.* 50 x 9.36 x 336.135 ÷ 34189
= 4.6-inch-diameter tires

LATERAL ACCELERATION (G-FORCE) =
1.227 x (RADIUS ÷ TIME²).
Ever wondered what the acceleration of your RC car is in G-force units? If you're an automotive buff who reads auto magazines, you have likely seen "skid-pad" ratings for various high-performance cars. These ratings tell you the maximum cornering force generated in a turn before the tires break loose.

Here's how to calculate it:
$(2 \times \text{pi})^2 \times (\text{RADIUS} \div \text{TIME}^2)$ or
$1.227 \times (\text{RADIUS} \div \text{TIME}^2)$
The radius of a circle is the distance from its center to its outer edge, and "time" refers to how long it takes for the vehicle to travel completely around the circle's circumference once at the highest possible speed. The standard skid-pad radius for a full-size car is 150 feet; scaled down for 1/10-scale cars, we'll use a 15-foot radius (30-foot diameter).

I've drawn a 15-foot-radius circle on the pavement. Driven as fast as possible without straying from the circumference, my Mugen MTX-2 traveled around it in 3.5 seconds. How many G did it pull on the skid-pad?

Let's plug in the numbers:
1.227 x (15 ÷ 3.52) = 1.49

For reference, a Porsche Twin Turbo (considered one of the planet's best cornerers) pulls 0.99G on the pad. My Mugen holds its own don't you think?

You can make your own G-force calculations by chalking a circle of a particular diameter on pavement. Use a digital stopwatch to time the car and determine its maximum speed around the circle, and plug the numbers into the equation to obtain your model's skid-pad performance.

Yea; all right! It's math! But it's might useful math. How much could it hurt you to try it?