Calculating Overdrive Ratios

by Bob Ingersoll, BMT National Team

If you talk enough with an experienced 4-wheel-drive racer, the topic of "overdrive" will eventually come up. Overdrive is used to improve the front driveline of the race car. Why? Because the vast majority of 4-WD racers use a solid or "locked" axle. With no rear differential (or a locked diff) it is impossible for one rear wheel to spin faster than the other rear wheel, giving the same tire size, without one of the rear tires loosing traction. This causes the rear of the car to become loose upon hard acceleration while exiting a turn. Overdrive to the front helps to pull the car straight.

So why do 4-WD racers use solid rear axles or locked rear differentials when doing so can cause such handling problems? Because it's faster, that's why, and it also has another advantage! A locked rear allows the car to change directions faster and also lets the skilled racer steer the car not only with the front wheels, but also with the throttle.

Over my many racing years I have heard many of the racers use a 10mm difference in front to rear tire diameters (the front being smaller). In most cases, this is a good place to start. But, do you know what pulleys he us using? This is important because the pulleys determine the final drive ratio front to rear. So, if you want to really take advantage of, and learn more about "overdrive", read on!

First, there are a few important mathematical formulas and mechanical principles to remember:

- **Shaft Ratio:** When determining the shaft ratio, divide the DRIVER by the DRIVEN

  Pi: When you want to know the distance around the tire (the circumference), and you can measure the diameter of the tire, you use a "mathematical constant" called "Pi". The value of "Pi" is about 3.1416.

  Doing this stuff will be much easier if you have a calculator. When you see how useful this information is, the calculator will become a standard fixture in your toolbox. Don't round off your numbers until you're all done, or you may not be as accurate as you need to be.

Terms

TRANSMISSION SHAFT: this is the primary drive shaft. **All of your calculations will be based upon one revolution of this shaft.**
REAR DRIVER PULLEY: This is the pulley located in the center of the transmission shaft.

REAR DRIVEN PULLEY: This is the pulley that is bolted to and drives the rear axle.

LAY-SHAFT DRIVER PULLEY: This is the side belt pulley that is coupled to the transmission shaft.

LAY-SHAFT DRIVEN PULLEY: This is the side belt pulley that drives the lay shaft.

FRONT SHAFT DRIVER PULLEY: This is the pulley that is coupled to the lay-shaft and drives the front shaft pulley.

FRONT SHAFT DRIVEN PULLEY: This is the pulley that is bolted to, and drives, the front drive shaft.

Remember, the transmission shaft is the primary drive shaft. The car cannot move forwards without this shaft turning. Again, **all calculations are based upon one revolution of this shaft**.

For the examples below, I'm' going to use the pulleys that come stock with the BMT891 Austin. Once you learn how to use the formulas you can easily plug in the numbers from your own car.

When the transmission shaft makes one full revolution the 13 tooth driver pulley mounted in the center of the shaft) also makes one revolution.

The pulley that is connected to the solid rear axle is a 32 tooth driven pulley. Refer to the important formula (divide the driver by the driven). 13 divided by 32 is .406 - this tells us that for every one revolution of the transmission shaft, the rear drive shaft turns .406 turns. (Pick up your car, watch the pulleys, and turn your transmission shaft one full turn. If your ratios are similar to mine, your rear axle shaft will turn a little less than half a turn, since .406 turns is a little less than 1/2 turn.

Now, let's go to the side belt. The lay-shaft driver pulley is a 10 tooth pulley. The layshaft driven pulley is a 15 tooth pulley. Dividing driver by driven (driver/driven) means ten divided by fifteen (10/15) which is .667. So, for every one rotation of the transmission shaft, the lay shaft rotates .667 turns.

Now let's figure the front shaft ratio. The front shaft driver pulley is 11-tooth, and the front shaft driven pulley is 15 tooth. Eleven divided by fifteen (11/15) = .733

Remember that the lay-shaft only makes .667 rotations for every one of the transmission shaft, so you have to multiply .733 (the front shaft ratio) x .667 to know exactly how many revolutions the front shaft turns when the transmission shaft makes one full rotation.

.733 times .667 equals .489 - which is the fraction of a rotation that the front shaft makes when the transmission shaft makes one whole rotation.

Now, let's review to this point. If you're having difficulty following this, take your car and follow each set while you are looking at it.

Transmission shaft: one revolution

Rear Drive: .406 rotation

Front Drive: .489 rotation

Now it's time to consider the tire sizes, both front and rear, into our equations. Let's assume that the rear tire is 80mm diameter, and the front tires are 70mm diameter.

The distance the car will travel in one complete rotation of the tire, is equal to the tire's circumference (the distance around the tire). To calculate this, multiply the tire diameter by Pi:

- Front: 70mm x 3.1416 = 219.912mm

  Rear: 80mm x 3.1416 = 251.328mm

The numbers above represent how far the car will travel, for one complete turn of the tire. What we need to determine, is how far the car will move forwards for one complete rotation of the transmission shaft.

- Front: 219.912mm x .489 = 107.537mm

  Rear: 251.328mm x .406 = 102.039mm

The results calculated above are the actual distance each car will move forwards when the transmission shaft makes one rotation. As you can see, the front of the car will try to move more than the back of the car. That's overdrive!

It's easier to refer to overdrive by the actual percentage. One more formula is needed here, the formula for calculating percentage.

- Percentage = $\frac{(100) \times (\text{distance traveled by the front tire})}{(\text{distance traveled by rear tire})}$

  $= \frac{(100) \times (107.537)}{(102.039)}$

  = 105.388 %

I know all this seems to be getting pretty complicated, but it's really not and it's almost vital to your success in 4-wheel-drive racing. Think back to a time when your car seemed to be "in the zone" and "just perfect". You walked down the driver's stand with a big smile, measured and recorded the tire size, and probably saved this "special" set of tires for some future important race! But what if your important race takes place on another track and it's bumpy, so you need larger tires for all of the bumps, but you don't know the percentage of overdrive you had previously used. Well, if you did know the overdrive percentage (which we just calculated), you could easily set up your car to handle similarly as it had with the smaller tires!

Please don't become discouraged going through all of these numbers. I promise you it can make the difference from being an average racer to a consistent, good racer! Keep going through this article until you thoroughly understand how to make these calculations.

When calculating overdrive, if your answer had come out 100%, that means the front and rear tires would be traveling the same distance with one turn of the transmission shaft. If the answer had come out less than 100%, that means you would have "underdrive".

Try to figure out the overdrive percentage, using different sets of tire sizes, in each case with the rear tire diameter 10mm larger than the front. You'll see that 10mm difference doesn't give you the same overdrive, with a different set of tire diameters. That's because overdrive is an equation, not a number that is always the same.

The rest is up to you. Try some different tire diameter sizes — maybe even try some different pulleys until you achieve your best driving and handling results. It may take some practice and extra time, but eventually you will arrive at an overdrive ratio that gives you the best results for your style of racing!

Good luck, and Good Racing!