Calculating the TPM of your Speedometer Cable

When you change your rear axle ratio, or radically change your tire size (or both) you may choose to have your speedometer recalibrated to match the new number of turns your car is offering up to the speedometer cable. The idea for this monograph came from a question Jon Levine had on the MG BBS and by contributions Bud Krueger made regarding a magic formula which helps to calculate the change in speedometer accuracy. Even if I don't explain the math well enough, you should be able to follow the processes offered here to get your new TPM. I would like to thank Bud for proofing this article for me, and for adding some valuable suggestions.

Speedometers use an input from a spinning cable to advance the odometers and to spin a disk with magnetic properties to 'drag' along a needle to indicate speed. The spinning cable comes from an interface at the gearbox (transmission) that spins at a fixed rate compared to the rotation of the gearbox main shaft that spins at a fixed rotation compared to the rotation of the rear wheels. The rotation of the cable is measured in "Turns per Mile" or TPM. I first started working with this idea when I needed to have an MGB speedometer recalibrated. I discovered that TPM numbers were silk screened on the face of the speedometer. They are numbers like 1040, 1280, and 1000. Later, when doing the same process on the MG TD, Bud Krueger took a special photograph of his instrument face to show me that, yes in deed, the TD's speedometer also had a TPM value shown on the face. It is the '1600' noted by the arrow.

. 

photo by Bud Krueger

It is a simple leap to realize that if you change the rear axle gearing, or the rolling diameter of your rear tires, you will alter the TPM offered by the speedometer cable and you will either need to have your speedometer recalibrated, or a calibration box built to raise or lower the TPM of the speedometer cable back to the value expected by the speedometer head.

One additional note about speedometer accuracy: The TPM of the speedometer governs the odometer and the speedometer. Unless completely gunked up inside by dried grease, with jammed numbers, gears, or other factors, the odometer will register the correct mileage if the TPM input from the speedometer cable is correct, i.e. the tire diameters and rear axle ratios remain as the factory specified them. The steadiness and the reading of the speedometer are affected by other factors, such as the gap between the drag disk and the needle coupling and the gunk in a speedometer. Your best bet if you don't like fooling with delicate instruments is to send the instruments to a rebuilder for recalibration. He will want to know the TPM of your car if you do. The vendor I use for cosmetic restoration and for recalibration is APT Instruments. They are on-line at www.gaugeguys.com. It is not the scope of this article to describe how to repair or recalibrate an instrument.

As an aside, this was Jon Levine's original question (edited slightly for clarity):

"Does there exist a chart or equation for the conversion of the rate of rotation of the speedometer gear pinion to the MPH on the speedometer? After destroying 2 speedometer cables I removed the speedometer and lubricated the clock works, then spun with an electric drill using the remnants of the cable. I would like to check calibration of the speedometer i.e at 300 rpm x MPH"

I wrote back:

"The speedometer turns 1600 turns per mile. At 60 mph, that's one mile in a minute, so it would require 1600 turns in a minute (rpm) at 60 mph shown on the face. 300 turns in a minute would be 11.25 mph, which is not a very accurate portion of the speedometer dial.

Here are some other numbers:

20 mph is 533 rpm
30 mph is 800 rpm
40 mph is 1066 rpm
50 mph is 1333 rpm

500 rpm is 19 mph
750 rpm is 28 mph
1000 rpm is 38 mph
1250 rpm is 47 mph
1500 rpm is 56 mph"

Method one: Suitable for dealing with changing the rear axle gearing and using your original tires.

If you are already happy with the accuracy of your speedometer system and its response, you can be relatively certain that the car's tires, through the current axle, are providing the TPM output your speedometer head needs. In that case you simply need to provide the rear axle change to your technician for recalibration, or if you know your current TPM you can provide your new expected TPM.

Needed are the current axle ratio, the new axle ratio and the current TPM.

On most of our TDs the axle as delivered by the factory has 41 crown wheel teeth and 8 pinion, or 41:8, which is often stated as 5.125:1, by dividing 41 by 8. A common improvement is to give the car more comfortable high speed cruising by lowering the engine RPM required at a given road speed by raising the rear axle ratio. The common ratio is from the MGA and is 43 crown wheel teeth and 10 pinion teeth. That gives a ratio of 4.3:1. Notice that the ratio is always some kind of odd number so that the same gear teeth must make many revolutions before they contact each other again. This helps to create even wear and promotes a quiet rear end.

To calculate the new TPM of the speedometer cable, you simply have to take the new over the current axle ratio and multiply it by the current TPM. In our case that would be

4.3 / 5.125 x 1600 TPM = 1342 TPM

Our new rear end is going to allow us to travel farther on a single gearbox rotation, so the number of turns per mile our speedometer cable provides is going to be less than it was before. In this case, we will be correcting a 16% error in speedometer reading!

Method two: Suitable for dealing with changing the tire size and using the original rear axle gearing.

Something similar can be done for a change in tire size, and hence the tire rolling distance.

Needed are the current tire radius, the new tire radius and the current TPM.

Since the tire rolling distance is directly related to the tire radius, you simply have to know your tire radius. You should measure the radius of the tire on a fully loaded car with proper air pressures, from the center down to the ground, to account for the squish. In fact, some of the systems which warn of tire pressure loss on today's cars are based on the increase of rotational speed of a tire compared to the others due to its radius to the ground shrinking as air pressure is lost!

Suppose we measure our old tires at 12.55 inches from ground to center, and then measure our new tires at 13 inches ground to center. Because the new tires will roll a longer distance each revolution we expect the TPM to decrease to make the same mile. Place the smaller radius over the larger radius and multiply by the current TPM.

$12.55 / 13 \times 1600 = 1547$ TPM

In this case it is only a 3-1/2% change, or showing 58 mph at 60 mph, hardly worth recalibrating unless you have other problems with your speedometer.

Method three: Suitable for providing a TPM value when you don't know anything about your speedometer system.

This is the procedure I used when I wanted to have the MGB speedometer recalibrated, and also when I was changing the rear axle ratio and the tire diameter of the MG TD. I got it from the APT Instruments web site. It involves measuring the number of turns of the speedometer cable over a distance of 1/100 of a mile. I like this method because you can do it regardless of whether your car is operational. All you need is properly inflated tires with the approximate normal load on your car. You don't need your car in gear, you can do this test in neutral if you are pushing it.

You need two chalk marks on the pavement, your speedometer cable disconnected from the speedometer head, a flag on the speedometer cable, like a piece of tape or a hairpin, and a measuring device long enough to mark out 52.8 feet.

What we are going to do is count the number of turns the speedometer cable makes when the car is pushed 1/100 of a mile. First you need to mark off a distance of 52.8 feet or 52'9-5/8". After you disconnect the speedometer cable, place the flag on the rotating part of the inner cable. Push (or drive) the car over the entire distance making sure that you count the full and the partial revolutions of the cable. Do the test three times and write down the numbers of turns each time. Ideally, you want to start each test rolling so that the slack in the system is taken up, and there is no lag in the speedometer cable turning. It is also a good idea to not use a tire to mark the start of the test, but to use whatever part of the vehicle is over the line when you start and stop the test after the rolling start.

On my car, the measurements yielded 13.5 turns over 1/100 of a mile, or 1350 TPM. With my new rear axle, this was very close to the 1342 TPM I was expecting. My conclusion is that my new radials are ½ of 1% smaller than the original bias plies.

Method four: Suitable for providing a TPM value when you don't know anything about your speedometer system.

This method is one that Bud Krueger tossed out which I like for several reasons. First, it allows a rolling start without comparing the frame of the car to the ground, so it is easier to yield an accurate result. Secondly, you probably won't have to push the car as far! And finally, it requires more fun math, and optionally allows for a good tire radius calculation without measuring the radius directly. The description is for rear wheel drive. Just use a front tire on front wheel drive.

You need a nice chalk mark on one of the rear tires, your speedometer cable disconnected from the speedometer head, a flag on the speedometer cable, like a piece of tape or a hairpin, and either the rolling radius of your tire, or optionally, the distance the tire traveled in the six rotations (and so a measuring device long enough to measure the distance traveled.)

The formula involves a 'Magic Number' i.e. 1680, and 'N', the number of turns of the speedometer cable while the rear tire turns six revolutions and 'R' the rolling radius of your rear tire.

The formula is TPM = 1680 x N / R

When Bud offered this formula, I couldn't find a derivation of it on-line so I thought about it for a bit. It comes from:

TPM = Turns/mi = Turns of Cable / (6 tire rev x Tire Circumference) x Conversions

Where Turns is turns of the speedometer cable in revolutions and is dimensionless
Tire Circumference is in inches (2*pi*R) and the R or radius is in inches,
and Conversions are 12 in/ft and 5280 ft/mi

This yields:
TPM = Turns/mi = (Turns of Cable / (6 tire revs x 2*pi*R) in) x 12 in/ft x 5280 ft/mi

The inches and feet cancel, leaving miles, and the 6 and 2 cancel with the 12 leaving only 5280/pi which is closer to 1681 than 1680, but according to Bud, truncating to 1680 makes sense as it seems to be an industry standard; and *"in practical terms, except for digital folk, their resolution is limited by the gear sets available to them."*

Getting back to the formula:

TPM = 1680 x N / R
where N is turns of the speedometer cable in six tire revolutions, and R is the radius of the tire in inches.

Again, It would be important to measure the radius of the tire on a fully loaded car with proper air pressures, from the center down to the ground, to account for the squish. Or we can eliminate squish as Bud suggested by noting the distance traveled by the car in six tire revolutions. To do this we need to note the ground where the mark on the tire passes the first time during our rolling start, and as we count our tire revolutions and our turns of the speedometer cable (including fractions of a turn), we need to note on the ground where the sixth revolution of the tire ends. If we measure that distance for six tire revolutions, we can determine the rolling radius in inches by:

Distance traveled in feet / 6 revolutions / 2 / pi x 12 inches / feet = R inches

Also, you don't have to have the car in gear as the prop shaft will still be turning the gearbox output shaft, and the speedometer gears, in neutral as you push the car (thank goodness!)

So in my case, the distance traveled in six revolutions of the tire was 39'2-3/16", while the speedometer cable turned 10 times.

R = 39.18 ft / 6 / 2 / pi x 12 in/ft

R = 12.47 in

Which agrees closely with the actual measurement when I try to measure it statically of 12-15/32".

My TPM using Bud's formula is

TPM = 1680 x 10 / 12.47

TPM = 1347

The downside to this method is that it is difficult to measure in less than 10^{th}s of a turn, But it does show that the 1350 TPM number I gave to APT was reasonably accurate! Using the 1342 TPM available by calculation of gear ratios and my tire radius, my possible turns in six tire revolutions is 9.96 turns. It would be hard to measure the difference between 10 turns and 9.96, but I hope this helps you in your own measuring and decision-making!

One last reminder for you T-Typers from Bud:

"Be sure that the nut on the gearbox output shaft is snug. Early gearboxes depend upon this snugness to prevent the speedometer gear from slipping on the output shaft. Later gearboxes incorporate a woodruff key in the gear and shaft. Slippage can give you an erroneous N figure. Don't ask how I know!"

