A9L vs. T4M0: THE SHOWDOWN

By: Mike Wesley

Some of you may be asking why the 94-95 Mustangs seem like they are so much slower than the older cars. We've all seen them at the strip running quite a bit slower. They are heavier, but the difference in times doesn't add up to the difference in weight. What gives? Well, a lot of it has to do with the differences between the '94 - '95 Mustang EEC and the '93 or older EECs. In 1994 Ford did a major redesign of both the EEC hardware and EEC software. The end result was a much 'cleaner', 'smoother' running car. If you own one of these Mustangs or know someone who has one, you've probably heard of problems getting them to start, idle, and run like a stock 1987 to 1993 5.0 after doing some modifications. Well, you can thank the Feds and Ford for that. Ever increasing emission requirements led to major changes inside the EEC to produce better control of the powertrain. Of course this hurt the overall ability to modify the car. It became much more sensitive to minor changes. With tighter requirements for warranty, the '94 - '95 Mustang owner ended up with an engine that made the same power numbers on the dyno, but not the same numbers at the track. Let's go through some of the major differences and see if we can find the trouble spots. This will be broken down over a series of articles, because it is very complex.

PART 1 - EEC SPARK:

In the '93 and older EECs, spark advance at WOT (Wide Open Throttle) was based purely on RPM. When you went into WOT, the EEC jumped to a separate spark function to give whatever Ford thought was the best spark curve. Of course we all know they didn't really make it, because you can pick up some power by advancing the distributor. This wasn't their fault since the calibration was designed to run everywhere with different types of fuels. Everytime you went to WOT in a 93 or older car, you ran basically the same spark curve run after run. If you look at figure 1, you can see a stock WOT spark curve taken from a 93 5.0 GT 5spd.

In the '94 - '95 cars, Ford made a major change to the spark calculations. The WOT spark function was deleted and now the car uses the same spark tables for both part throttle and WOT spark calculations. The problem with this is the spark table is based on RPM and Load. The formula for Load is basically the amount of incoming air, ratioed against how much 1 cylinder can hold at standard pressure/density. You can sort of think of Load as volumetric efficiency. The EEC uses the MAF to determine Load. It is a direct measurement of how much air is entering the engine. You might be wondering what the big deal about Load is.

Well, since Load is used in the spark calculations, any change in Load will affect how much advance you get. Since the EEC uses the MAF to determine Load, any change in the MAF will change the Load calculation. Changes in the cam and anything that puts more air into the cylinders will also affect Load. Change the flow characteristics and you change Load. Let's see how this works.

To simplify the whole spark calculation, we are going to combine all the spark calculations into one table and use actual Load values seen during testing. In reality there are quite a few of them for different things. If you look at Figure 2, you'll see a spark table from a 1994 5.0 GT 5spd. When you go into WOT, the EEC will pull spark values from the top two rows of the table. Figure 3 traces a test run done with a bone stock 94 GT. Notice how as RPM increases, Load decreases and spark advances a bit. The decrease in Load is due to volumetric efficiency of the engine dropping off. A typical 5.0 is not the most efficient engine around. If you compare the spark values calculated by the 94 EEC to the 93 values, you'll see they are not too much different. Change something on the engine and it's a whole new ballgame. Let's take a MAF change as an example. Figure 4 shows a MAF transfer function for an aftermarket MAF that we tested along with the stock curve. Notice how the aftermarket MAF's curve doesn't always follow the stock curve? When the EEC looks at the aftermarket MAF and converts the voltage into airflow using a built-in lookup function, it will calculate differing amounts of Load as RPM increases. In our example, we'll use 5500 RPM and 4.6 volts out of the MAF. In our baseline car at 5500 RPM, the EEC calculated a Load of .78. Input that into the spark table and we get an advance a bit over 26 degrees. Going back to figure 4, at 4.6 volts the aftermarket MAF 'fools' the EEC into thinking MORE air is entering the engine than what really is so it calculates a higher Load. With this particular MAF on our baseline car, we saw a Load value of .91 and the resultant spark advance was 25 degrees. Wow! By changing the MAF, we lost about 1.4 degrees of spark advance! On the dyno, this particular car lost about 14HP when the aftermarket MAF was installed. Some of this was due to the loss in spark and fuel which we will get to in a later article. It looks like there is a simple fix to this by bumping the distributor up. Sounds good, and it will help get back the loss in top end spark. However, there could be a catch if we now look what happened to this car at 2500 RPM. The baseline car had a Load value of .75 @ 2500 RPM and spark was 24 degrees. After putting on the MAF @ 2500 RPM, the Load was .65, and spark was roughly 26 degrees. Hmm. We got more bottom end spark with the MAF since it 'fooled' the EEC into thinking LESS air was entering the engine. Looks good so far and the car did make more power at 2500 RPM than it did stock. Now to fix the top end spark loss, we bumped the distributor up 5.5 degrees. This included the 'normal' 4 degrees everyone puts into the car plus the extra spark to compensate for what we lost with the MAF. Now the car made up the lost power plus some on the top end and lost 10 HP at 2500 RPM. Why?

Due to what the MAF was telling the EEC, and how it changed Load and advanced the spark 2 degrees, our bump in the base advance made the total spark advance at 2500 RPM a bit over 30 degrees. Way too much advance at 2500 RPM. Figure 5 shows the relationship between torque and spark advance. The very top point in the curve is called MBT or Maximum Brake Torque spark. It's basically the amount of spark advance that produces the maximum amount of torque. If you go above or below the MBT point, you lose torque. As you continue to advance the spark, you'll reach a point in the curve called BDL spark or Borderline spark. This is the amount of spark advance where the engine just begins to knock. On a normally aspirated, low compression engine, BDL occurs at advance values higher than MBT. On high compression or supercharged engines, BDL can occur at advance values lower than MBT. Raising the octane value of the fuel moves the BDL point higher up. Going back to our low RPM example, further testing found the MBT point at 2500 RPM to be 28 degrees. Now came the question of what to do. Should we lower the base advance to get the bottom end power back and sacrifice some top end power, or leave it alone? However, should we go for the top end power, but sacrifice the bottom end? That choice is up to the owner. We opted to actually re-calibrate the EEC to run MBT spark at all RPM points by changing the spark tables. Now of course all this might go the other way depending on the MAF. It can 'fool' the EEC into lowering the Load at higher RPM which will give you more advance. It's really hard to tell what you are going to end up with.

Another thing the '94 - '95 cars do with spark is retard it during a shift. The automatic cars REALLY pull out the timing, but the 5spd cars do it also. Inside the 5spd EEC calibration is a thing called Tip-in Retard. Any time the throttle is moved from a more closed position to a more open position, it can pull out some timing. When you shift a 5spd car, most people lift off the gas during the shift. The EEC senses this, and when you push on the gas again it pulls some timing out. The older EEC didn't have this 'feature'. You lose more torque during a shift on a '94 - '95 car than a '93 or older car. Why did Ford do this?? We think warranty. Ford had to replace a zillion T-5's in the older cars. Alot of them broke due to overshifting and power shifting, but alot of them broke as a result of too much transient torque. If you could reduce the torque output of the engine during a shift, the transient torque would be lower. The trans wouldn't break as easily, and thus the Tip-in Retard was born. How much timing is pulled out during a shift varies, but it can pull out as much as 15 degrees. There is not much you can do to 'fix' this except to re-calibrating the EEC.

The '94 - '95 automatic cars have a torque modulation strategy installed in them to vary spark during shifts. When the EEC thinks it's time to change gears, it can pull out massive amounts of timing so the shift is nice and smooth. As far as we know there are two reasons for this. First is warranty. The AODE trans is not all that strong in stock form. By reducing the torque during shifts, you can extend it's life. Second is shift feel. For some reason Ford doesn't want you to 'feel' the car shift. Ever notice that just about all Ford vehicles with electronic transmissions shift like Town cars? Smooth and sloppy. Even performance vehicles like Mustangs and Lightnings have weak kneed shifting. What fun is that? The downside to this smooth, sloppy shifting is increased wear. Ford tends to slip the trans too much during gear changes slowly burning it up. Manually shift your car, and you'll see it shifts much better. During manual shifts you run through different sections of the trans control strategy. The older EECs with AODs (sometimes called DOA's) really had no idea a trans was attached to the engine. They did not spark retards during shifts and could actually shift quite well. They broke more often, but shifting was better. Adding a shift kit to a '94 - '95 car can help the shift feel by increasing fluid pressures inside the trans, but this does nothing to the engine torque loss during a shift.

So you can probably see, tuning a '94 - '95 Mustang can be tricky. The engine remained basically the same, but the brains controlling it changed. In the next article, we'll discuss the fuel system and how minor changes to the engine can have drastic effects on how the engine runs.