Part 3

Introduction: Now that you understand how to use your scan tool, the fuel trims and what they are telling you, and the proper order to switch in your mods, it's time to get into actual on-road tuning of the various sensor streams.

Mods, and what they control: CTS mod: Sets the stage for the ECU to select a leaner fuel table. A warmer engine vaporizes fuel more easily and this requires less fuel. The ECU "sees" a higher temp and selects a slightly leaner fuel table. IAT mod: Also sets the stage for a leaner fuel table but has a big effect on ignition timing. Think of your IAT as a fine-tuning adjustment for ignition timing. Higher temps shown here retard ignition timing. Lower temps shown advance it. MAP/MAF mod: Has the ability to aid the ECU in selecting a leaner fuel table, but must be in agreement with the O2 sensors for the ECU to follow through. Has the biggest effect on ignition timing. Think of your MAP/MAF as a coarse tuning control for ignition timing. Less load advances ignition timing, calls for less fuel. More load retards ignition timing, requires more fuel. Lowering the load numbers shown will ADD to the fuel trim numbers, while raising the load numbers SUBTRACTS. EFIE mod: Leans the fuel trims but must be in agreement with the other sensors, including the other O2 sensors on the vehicle. The EFIE is changing the AFR (air to fuel ratio) The ECU will always still think it's adjusting for 14.7:1. With an EFIE our goal is altering the AFR that "0" represents on the fuel trims to a higher AFR without the ECU knowing anything is different. Raising the AFR (leaning, or lowering O2 switch point) will SUBTRACT from the fuel trim numbers while lowering the AFR (richening, or raising the O2 switch point) will ADD to the numbers.

Tuning for performance: Okay, so now you know how your mods are conditioning the ECU to send less fuel. You also know what controls your ignition timing. Last, and most importantly, you know what adds to and subtracts from the fuel trim numbers. You are now ready to tune for performance. Let's not even pay much attention to the trims at this time.

Hypothetical Performance Tuning: Since I can't show you the tuning procedure I will have to step you through a imaginary tuning process to give you a better understanding of how this is done. We are going to pretend you have modified all the sensors and have everything ready to go. You have set up all your mods conservatively for the first time out. The MAP/MAF Vref is tuned from 5 volts down to 4.875V before the car is started. The car starts….we wait 3 mins before we do anything else to let the ECU do self-testing. After 3 mins we switch on the HHO. We also begin ramping up the IAT and CTS offsets. 4 mins later the IAT has reached its offset 130 degrees (30 degrees added) The CTS has reached 207 (5 degrees added). Now we switch in the EFIE, set to a switch point of 400mv. We drive the car out to the highway and begin cruising at 65 MPH.

Ignition Timing First thing we adjust now is ignition timing. Remember, the MAP/MAF adjustment you did before you started the car has advanced ignition timing, while also calling for a leaner fuel trim. We want the leaner fuel trim, but we usually do not want to advance ignition timing while using HHO. We want to retard the timing. The IAT mod has retarded the ignition timing to make up for the advance the MAP/MAF mod made, but maybe you need more or less ignition timing retard to optimize power. Best way to find out is to adjust the IAT down or up in temp 10 degrees, then breathe on the throttle and let off, breathe on the throttle and let off. What you are feeling out is initial throttle response. If the throttle response is crisper, you will feel more power and you are going the right way with ignition timing. If it's soggy you probably went the wrong way in timing. You need to raise or lower the IAT another 10 degrees and try again. Raise and lower the IAT number until you feel the most initial throttle response. This might take a while. The difference in response can sometimes be difficult to detect. It is easier to feel a difference when the vehicle is under more load, such as climbing a hill. If raising and lowering the IAT doesn't make much of a difference then reset it to the original offset (30 degrees in this imaginary case), then pull over and turn off the vehicle. Now, re-adjust your MAP/MAF offset. You can make the offset show more or less load depending on how the vehicle feels. If the vehicle feels strong, lower the MAP/MAF offset. If the vehicle feels weak, raise it closer to factory. As a general rule of thumb, never drop a 5 volt VRef lower than 4 volts, or change the load values shown more than 15%. Restart the car and follow the switch in order for your mods. With the vehicle warmed up you can switch everything in faster, but in the same order. Now, go back on the highway and repeat the IAT tuning again while trying to optimize the offset. You might need to go back and forth several times between your MAF/MAP adjustment and your IAT to optimize timing. Remember the MAF/MAP is the coarse adjustment and the IAT is your fine adjustment. Set them both for maximum throttle response, or max power. When you find the best IAT and MAP numbers you can move on to the next step.

Adjust AFR Now that you found your ignition timing "sweet spot" while using HHO, it's time to take away more fuel and reap the fuel economy benefits. With your upstream EFIE (s) begin lowering the O2 sensor switch point in 20mv increments. In other words, from 400mv drop to 380mv, wait a minute then drop to 360mv, etc… While dropping the switch point you are raising the AFR and leaning out the gasoline. Breathe on the throttle again and try to feel a difference in initial throttle response. If at any time the throttle response gets soggy or drops off you have tuned the AFR too far. Raise the o2 switch point until full power is restored. If you feel a surge in power while lowering the switch point you have likely found the sweet spot. Stop there. If there's no change in anything keep lowering the switch point until you feel a good or bad change. Once again you are trying to optimize the switch point setting for maximum power. I must stress that ANY loss of power means you have tuned too far. You might be running leaner but you'll make up for any economy you might get by stepping further on the throttle. Go back to the last switch point voltage that gives you max or full power. That's the sweet spot. There's a chance you may trigger a check engine light or "open loop" status here by tuning too far. If so clear all codes and try again until you get it.

Fine tune ignition timing: Go back and change the IAT in 10 degree increments higher and lower to see if you can optimize ignition timing even more now that you're running a leaner trim. Tune for maximum power.

Read and decipher the fuel trims- Now that you've found the switch point on your EFIE and the best IAT and MAP/MAF offsets it's time to look at your fuel trims and see how far the ECU thinks it is from "0" with your new settings. Before you do any adjustments you should compare your fuel trim numbers now with the ones you logged in your baseline, and see how much of a difference there is. If there's not much of a difference you should be able to maintain your MPG and performance gains for a long time with no problems. If there's a radical difference in the numbers DON'T PANIC. This is typical. You can get numbers back on track with a little tweaking. First, let's go over some different scenarios:

(our imaginary vehicle has one upstream and one downstream sensor, and trim numbers are averages)

Scenario 1 (good trim numbers, all is normal)

O2 sensor 1 (upstream) LTFT = +3 STFT= -1 (-2 to +7 acceptable)
O2 sensor 2 (downstream) LTFT= -3 STFT= -3 (-5 to +3 acceptable)

The above is what would be considered very good trim numbers. The upstream trims are both relatively close to zero. Slightly positive numbers on upstream LTFT is better than slightly negative. The ECU is conditioned from factory so that it would rather be adding fuel then subtracting it. Notice the downstream trims are slightly negative. This means you have properly conditioned the ECU with your mods for leaner trims and nearly any hydrocarbons read at the downstreams are too much…the ECU takes away fuel to compensate. If you are seeing positive numbers on the downstreams you probably need to mod them with an EFIE or a ½ to 1 ohm resistor in series on the ground wire. Both methods will raise the downstream readings which force a leaning action, and make them go negative.

Scenario 2 (out of balance condition too lean)

O2 sensor 1 (upstream) LTFT = +15 STFT= +18
O2 sensor 2 (downstream) LTFT= -8 STFT= -10

In this scenario the upstream O2 is saying that the mixture is way too lean and it is adding fuel to compensate. In excess of 10% signifies that there is an out of balance condition between the O2 and load sensors. In this case the load sensor reading (MAP/MAF offset) has been lowered too much. That takes away fuel but the O2 sensor sees it is missing. It adds fuel to compensate, and then the downstreams detect the added fuel and try to take it away again. To correct this scenario you could do either one of two things, or a little of both.

You could: 1. raise the MAP/MAF load offset closer to factory to subtract trim numbers.
2. lower the switch point on the EFIE to subtract the trim numbers.

You might try a little bit of both steps while maximizing for performance and power. The trim numbers would move closer to zero with either step. The trick is to find the balance between the steps while keeping your performance and getting closer to 0 on the trims.

Scenario 3 (out of balance condition too rich)

O2 sensor 1 (upstream) LTFT = -15 STFT= -18
O2 sensor 2 (downstream) LTFT= +8 STFT= +10

This is the exact opposite of scenario 2. In this case the upstream o2 sensor is telling us the mixture is way too rich, and it’s taking away fuel to compensate. Notice the downstream sensor detects the missing fuel and is adding some to keep the cat hot and in factory parameters. Usually in this scenario the EFIE setting is very low (lean) and no longer in agreement with the MAF/MAP offset. In this scenario you could do one of two things, or a little bit of both:

You could: 1. Raise the EFIE switchpoint (richen AFR), which will add to the fuel trim numbers. 2. Lower the MAP/MAF offset, which calls for less load (adds to fuel trim numbers) and will more closely match the leaner setting of the EFIE.

Once again, you would do a little of either or both steps while maximizing for performance and power. The trim numbers would move closer to zero with either step. The trick is to find the balance between the steps while keeping your performance and getting closer to 0 on the trims.

Tuning Tips Based on Specific Vehicles: Some vehicles such as many late model Fords prefer to have positive trims close to 10% instead of zero, so keep that in mind.

Late model GMs- Between 2002 and 2004 there were a handful of GM vehicles that would respond to a 5k ohm resistor between the signal wire and ground wire on the MAF sensor, thus lowering the perceived airflow into the engine by about 15%. You can try this modification. Worst case is that there will not be any change in airflow readings.

Most of the newer GM products use both MAP and MAF sensors. Regardless of whether or not you can alter the MAF reading with the 5k resistor, you should be using a MAP Adjust (LM317) circuit on the MAP VREF. Be careful as the newer MAP sensors work backwards, and require higher VREF voltage to work properly. The GM products I've worked with don't typically tolerate very much voltage change. I start with 4.90 volts (or 5.15 volts on the newer versions) and work from there. Thus far all tuning has concentrated on massaging the ECU to see things our way and comply. A more direct front-door method is to install smaller injectors to reduce total fuel flow into the engine. You can install 4.3 V-6 injectors in your 350 TBI V-8. You still have to trim the feedback system through the oxygen sensor, but this reduces the need for ECU cooperation through a MAP Adjust.

Ford

On Ford vehicles older than about 2003, MAF sensors should be altered by adding resistance to the signal wire, which is a tan wire with a medium blue tracer. Resistance values range between 175k and 330k ohms. Target the 15% reduction in gm/sec on your scan tool. On 2003 to about 2006 Fords, resistance values are much lower; ranging in the 15k to 30k range. On the newer 2006+ Fords, we've found that resistance in the MAF wires make no difference. The good news is that the MAP sensor's signal wire is a DC voltage and no longer a frequency signal. The MAP Adjust works with them just fine. You do need to raise voltage instead of reduce VREF voltage, though. Also, Ford's temperature sensors operate on a much higher resistance range. Whereas 100 ohms will make a significant difference on a Toyota, 1k ohms might make the same difference on a Ford.

Toyota

Just a few notes, many Toyotas use AFR sensors. The blue wire is the signal wire. Resistance values typically fall in the 12-18 ohm range. Usually resistance in the ground wire alters the MAF signal. Again, resistance values on many vehicles are in the 15-18 ohm range. Don't forget to address the down-stream O2 sensors from 1998 and up.

Mitsubishi

The only thing of concern on the Mitsubishis is the MAF alteration. I found that running resistance between the signal wire and ground gave the appropriate offset. Use your scan tool to determine a best value.

Honda
A couple hundred ohms of resistance on the voltage supply wire of the MAF has proven effective on the Hondas. Many Hondas use AFR sensors and like resistance values similar to the Toyotas. The MAP sensors on the Hondas will more likely work in reverse, even on many older ones. Be sure to check values as you tune your MAP Adjust.

Generic Tuning
Additionally, here are a few thoughts on generic tuning. Adjustable fuel pressure regulators allow you to cut back on fuel without the ECU knowing about it. GRreddy and Apex have Interceptor Boxes that allow you to alter the injector signal pulsewidth under a range of conditions. The ultimate control can be attained with an aftermarket stand-alone ECU. Companies like Link, Accel DFI, and even MegaSquirt can give you unlimited control of all aspects of engine operation. The down side is extensive wiring and the steep learning curve. Not only would you be trying to just modify existing fuel and spark trims, but you will have to create from scratch the entire fuel and spark mapping, along with all of the compensation factors. A good book on the subject is “How to Tune & Modify Engine Management Systems” by Jeff Hartman.