A Complete Tuning Guide

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Standard Warnings

First and foremost, I am NOT a tuner. I only have experience with my car; none of this information is guaranteed to be accurate. I wanted to learn to tune and have done lots and lots of reading regarding the topics. I put this document together mostly for myself and later decided to share with the community when I saw there was a need. A good portion of information presented here is not my own, it is information I found in various posts, articles, and books.

DISCLAIMER

While every endeavour has been made to ensure accuracy of the information:
DO NOT USE this document as a definitive resource for anything.
DO NOT tune your car using the information contained herein as the definitive resource.
DO your own research.
Make your own judgements.

A Complete Tuning Guide

Tools and Software

Must haves:

- Nice virus free laptop, to make sure all flashing software is working properly.
- RomRaider with latest definitions
- ECU Flash with latest definitions
- Wideband O_2 sensor/meter (must work with RomRaider)
- Tactrix cable

Nice to haves:

- Power converter for the cigarette lighter (in case laptop batteries die while logging)
- Old version of ECU Explorer (only for reading trouble codes)
- Airboy's spreadsheet (to help you tune and format your logs)
- Other tuning utilities found in RomRaider's tuning utilities sub forum

Prerequisite Warnings

Before you can tune, you need to know what ROMs are and how they are flashed (written) to your ECU (Engine Control Unit). This information can be found at: RomRaider/Ecuflash getting started FAQ

You also need to be OK with knowing that a bad flash can kill your car. There is no guarantee that each flash will be successful. A bad flash will disable your car. It is very unlikely, but there have been instances. **So every time you flash your car, you are taking a risk.**

From a spec sheet posted on nasioc, 16 bit ecus have a mean time to failure of 1000 flashes and 32 bit ecus can go 10000 flashes. Most flash failures can be attributed to physical connection problems, ie. poorly inserted connectors, bent pins, worn contacts, or a poor battery charge.

If something goes wrong, you will not be able to drive your car home. You car probably won't even start. Even if you have a backup ecu on hand, you probably won't be able to start your car anyway because the immobilizer system will need to be reprogrammed. To do that, you will need to get a master key from the dealer, drive the car to the dealer, and have them reprogram the immobilizer system.

Tactrix.com offers a ecu recovery service for drive by wire ecus. It's much cheaper than a new ecu and has gotten good reviews. Something to keep in mind.

You can also find a used ecu online. I've seen them for around $250, but prices vary.

Which Tables to Tune

When you first see all the tables in the ECU, you might wonder what they do and which ones you need to change. Luckily, there are descriptions for each table. Open the table and look at the description under **View→Table Properties**. I have looked through tons of tunes and noticed what tables are usually changed.

ALMOST ALWAYS CHANGED

- Target Boost
- Boost limit fuel cut
- Initial wastegate duty cycles
- Max wastegate duty cycles
- Primary open loop fueling
- Failsafe open loop fueling
- Base Timing
- Timing Advance Maximum
- CL to OL Delay
- CL Delay Max engine speed (gear)

SOMETIMES CHANGED

(In addition to previous tables, but these are on more advanced tunes)

- AVCS
- Initial Multiplier
- Rev limiter
- Requested Torque
- CL to OL transition (RPM)
- CL to OL Transition (Load)

For a basic tune, you will need to change just the necessary tables, for more advanced tunes, you can do the optional ones as well as tables not listed here. It's up to you and how much you want to experiment. Just remember to make sure the changes you make are small while experimenting

The research

Before we talk about tuning techniques, we need to know what tables do, how they are related, and their effects on the car. The following is background research. It is important to understand because the tuning techniques are based on this information.

WHAT IS BOOST

Boost is simply a positive air pressure in your intake manifold created by your turbo. The turbo pushes more air into the engine then the engine can process, so the extra air builds up pressure as more air gets squeezed into the manifold. Boost is good because having more pressure in the intake manifold means that when the intake valves opens, more air will be pushed into the cylinder. We start with boost since it lays down the ground work for the rest of the tuning process. Changing boost changes everything else which is why it must be dealt with first.

ABOUT BOOST:

Most of the info about boost and boost control comes from the Cobb Tuning Guide where they explain the Subaru stock boost control system. There is no need to repeat the information here, and therefore I suggest that you read the article before going any further.

The article is available here: Cobb Tuning Guide

After reading the article, I had some unanswered questions, mostly about how to relate the information found there to the RomRaider tables that control boost. The next section is written as a Q&A and attempts to bridge the gap.

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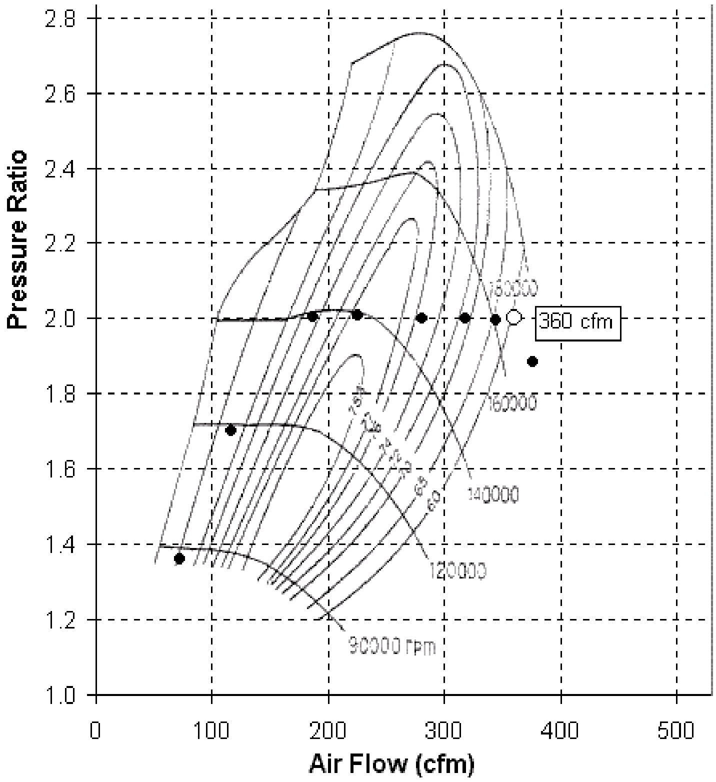
TARGET BOOST

This is where you will tell the car how much boost you want to make. You can enter any numbers you want in this table and the ECU will do what it can to help you to reach these numbers.

So why not just enter 10000psi across the board and be done with it?

A turbo has two sides; the hot side, which is connected to the exhaust and a cold side, which is connected to the intake. The cold side of the turbo compresses the ambient air and is therefore called the compressor. Now, each turbo has something called a compressor efficiency map. This is a visual graph that shows what kind of pressures the compressor is capable of. Let's take a look at the compressor map for a TD04-13G turbo:



The pressure ratio on the y-axis is how much ambient air pressure is compressed. At sea level that's 14.7psi. So if you look at the inner most ellipse at 200cfm on the x-axis, you see a 1.8. That means 1.8*14.7 = 26.46 psi, now subtract out the 14.7 and you get 11.76, which is what you would see on your boost gauge. So you can see 10000psi is a little unrealistic.

What do those circle thingies mean?

Those are a measure of how much of the energy input into the compressor is being used to compress the air and how much is used to create heat. So if you look at the inner most ellipse you see 75%. That means 75% of the energy is being used to compress the air and 25% is used to create heat.

What does that mean for me?

It means that the more psi you try to run, the hotter the air will be.

So what?

Well, the hotter the air is, the less of it there will be per cubic foot. So even though you're moving 200cfm in the 75% efficiency range at 11.25psi and 65% efficiency range at 17.7psi, there will be more air molecules per square foot at the 75% efficiency range because the air is colder and therefore denser. In other words, you are moving more air (mass) at the lower psi because of the higher efficiency range.

But won't an intercooler cool the air and make it more dense? So therefore I can run more boost at a lower efficiency?

Yes, but it can only remove so much heat. So let's do some math for a minute here to show why it's better to run a lower psi and stay at a higher efficiency range.

Here is the equation used to calculate the mass for air that is moving into your engine:

$$n(lbs/\min) = \frac{P(psia) \times V(cuft/\min) \times 29}{10.73 \times T(\deg R)}$$

P = absolute pressure coming into the engine (so atmospheric pressure + boost)
V = CFM from the map (we'll use 200 as an example)
T = Air Temp at throttle body + 460

So the only thing we don't know is the Air Temperature going into the throttle body. To figure this out we need to figure out:

1) What the air temperature will be after the compressed air leaves the turbo
2) How much the intercooler cools the air?

To figure out the air temperature after the turbo we use the following:

$$Tout = \frac{Tin + Tin \times [-1 + (Pout/Pin)^{0.263}]}{Efficiency}$$

Tin= ambient air temp + 460 (F)
Pin= atmospheric pressure - intake resistance (Psi)
Pout= atmospheric pressure + boost psi
efficiency = efficiency of the compressor. (%)

For our example we have:
Tin = 70F + 460F = 530F
Pin = 14.7psi - 0.5psi (guessed on the intake resistance)
Pout/Pin = either 1.8 for 75 % efficiency and 2.2 for the 65%
Efficiency = .75 and 65 respectively

So now

$$LowBoostTout = \frac{530 + 530 \times [-1 + (1.8)^{0.263}]}{0.75} = 188\text{F}$$

$$HighBoostTout = \frac{530 + 530 \times [-1 + (2.2)^{0.263}]}{0.65} = 257\text{F}$$

The next step is to find the thermal efficiency of the intercooler so we can estimate how much heat will be removed. To do this we will have to use the following formula:

$$ThermalEfficiency(\%) = 100 \times \frac{Tin - Tout}{Tin - Ambient}$$

Here is where we get lucky. TurboXS actually went out and tested the capabilities of the stock intercooler with the following results:

14psi max; Temp into IC 92.5C; Temp out 41.5C; IC Efficiency 73.4%
16psi max; Temp into IC 106C; Temp out 49.5C; IC Efficiency 68.1%
18psi max; Temp into IC 103C; Temp out 50C; IC Efficiency 66.3%.

Note: I've seen posts claiming that the stock unit is only about 56% efficient. So these numbers are debatable.

So to figure out our final air temperature going into the throttle body we just rearrange the equation to:

$$Tout = Tin - \frac{TE}{100} \times (Tin - Ambient)$$

So we apply this to our high and low boost numbers and get:

```
Lo boost Tout = 101.86F

Hi boost Tout = 133.58F
```

Now that we have all the parts, let's see what the final mass of air going into the engine is at both conditions:

$$LowBoostMass = \frac{(14.7 \times 1.8) \times 200 \times 29}{(10.73 \times (102 + 460))} = 25.5 \text{ (lbs/min)}$$

$$HighBoostMass = \frac{(14.7 \times 2.2) \times 200 \times 29}{(10.73 \times (133 + 460))} = 29.5 \text{ (lbs/min)}$$

Well, you can see that I'm wrong about my assumption that low boost is better. Apparently the intercooler makes a big difference with the numbers. So now the question becomes, when is it better to turn down the boost and when to leave it high?

To figure this out, I made the following →

		Compressor Map					
	2.6				65	70	
	2.4			60	72	74	65
	2.2		65	72	77	74	65
	2	60	70	76	77	74	60
CR	1.8	65	74	78	76	70	
	1.6	72	78	77	72	60	
	1.4	77	77	70	60		
		127.152	169.536	211.92	254.304	296.688	339.072
		0.06	0.08	0.1	0.12	0.14	0.16
				CFM			

		Tout - Pre IC					
	2.6				302.9514	286.312	
	2.4			298.7061	260.5884	255.4374	281.1133
	2.2		257.8897	239.6226	228.6082	235.0382	257.8897
	2	246.6414	221.4069	209.4537	207.6426	213.2227	246.6414
CR	1.8	206.3134	189.7348	183.5945	186.5839	196.5768	
	1.6	166.8542	159.4039	160.565	166.8542	186.2251	
	1.4	133.6865	133.6865	140.0552	151.7311		
		127.152	169.536	211.92	254.304	296.688	339.072
				CFM			

		Intercooler efficiecy					
	23.52	52	52	52	52	52	52
	20.58	59	59	59	59	59	59
	17.64	66	66	66	66	66	66
	14.7	73	73	73	73	73	73
	11.76	80	80	80	80	80	80
	8.82	87	87	87	87	87	87
	5.88	94	94	94	94	94	94

		Tout - post IC					
	2.6				181.8167	173.8298	
	2.4			163.7695	148.1412	146.0293	156.5565
	2.2		133.8825	127.6717	123.9268	126.113	133.8825
CR	2	117.6932	110.8799	107.6525	107.1635	108.6701	117.6932
	1.8	97.26269	93.94696	92.71891	93.31677	95.31535	
	1.6	82.59105	81.62251	81.77345	82.59105	85.10926	
	1.4	73.82119	73.82119	74.20331	74.90386		
		127.152	169.536	211.92	254.304	296.688	339.072
				CFM			

		lbs/min of airflow					
	2.6				40.929	48.35221	76.14179
	2.4			32.39475	39.87269	46.68025	52.43798
	2.2		24.95168	31.51922	38.06564	44.24426	49.90335
CR	2	17.48927	23.59733	29.66436	35.62792	41.45579	46.63804
	1.8	16.31741	21.88678	27.41926	32.86756	38.20748	
	1.6	14.89657	19.89761	24.86508	29.79313	34.59808	
	1.4	13.24863	17.66484	22.06526	26.44363		
		127.152	169.536	211.92	254.304	296.688	339.072
				CFM			

What I did here is I took those equations and applied them to the entire compressor map. What I was looking for was the lbs/min to start decreasing at a certain point, but as you can see it didn't. What this means is because of the intercooler, the more boost you make the more lbs/min will be pushed into the engine. The underlying assumption is that the intercooler efficiency is what I guessed it to be in the table. I could not find any more information on efficiency so I interpolated the data turboXS posted. Keep in mind that IC efficiency will change with location, material composition, pressure, humidity, and tons of other variables.

Ok, so I'm gonna run 22 psi on my td04! It looks like it can be done.

No, wait, there are other factors. On turbo charged cars, the air entering the throttle body should be about 110 degrees and a max of 130. You can go over this limit, but you will have to compensate with running richer fuel mixture and less timing, which will actually cost you power. Not only that but your turbo can only spin to about 190k rpm and can withstand a temperature of 950 degrees. If you try to run 22psi, the turbo is likely to fail quickly.

Oh damn, what the hell should I do then?

There never seems to be a good answer!

This is where you will have to experiment since each setup is different. But first, we should look and see what the max psi we should run is. Looking at our post IC temp chart, we see a CR of 2 around the 100 degree mark. (This is a max of 14.7 psi) But we could also try a 2.2 CR (17.5 psi) since that seems to be in the acceptable range. (Note: If you assume a 56% IC efficiency, only a 1.8 CR will be acceptable. The Tout for a 2.2CR will be about 160F) When making this decision, keep in mind that the intercooler will be less efficient on hot days and therefore you will exceed the 130 degree mark very easily running a 2.2CR. So the "best choice" would be to run a 2.0 CR (14.7PSI) so that you will be ok once it gets hot outside as well.

This seems like a lot of work to figure out one number, can't this be easier?

It can, just pick what ever CR is at the tips of the two inner most efficiency ellispes.

But the better choice would be just to ask around on the forums if you don't know.

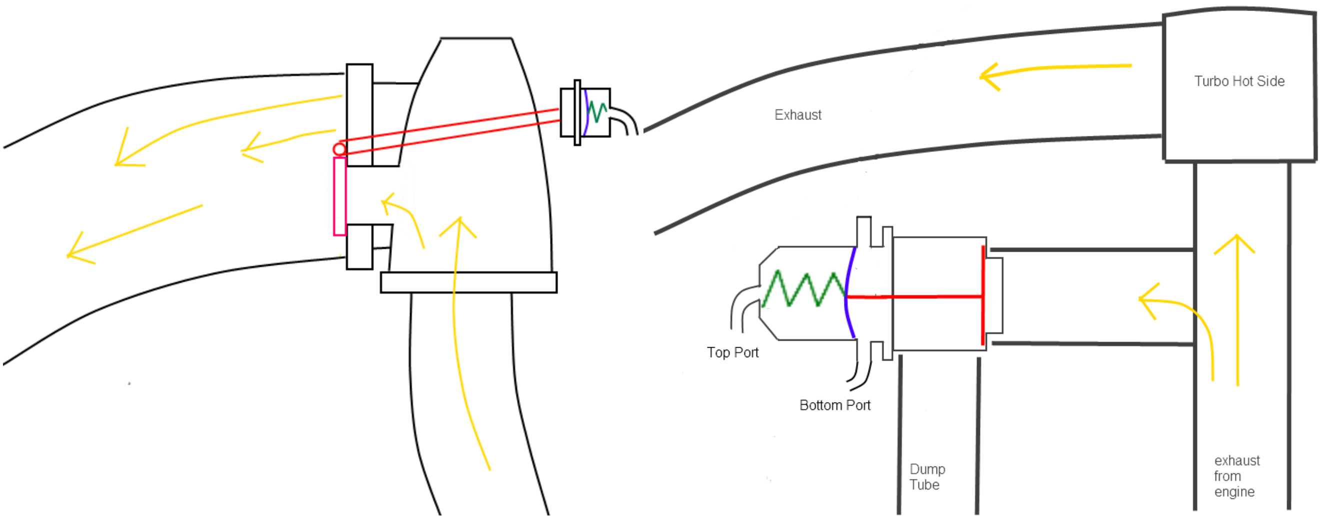
Wastegate

Introduction

Before we talk about the tables, let's talk about how the car controls boost. The wastegate controls how much exhaust gas is not used to create boost. If all the exhaust gas was always used to create boost (you didn't have a wastegate) then the turbo would always be spinning as fast as possible and making outrageous boost. You'd probably see upwards of 25 psi on a td04. Now, the stock engine isn't designed to make take that much boost, there isn't enough fuel available to be used with that much boost, the air going into the throttle body would be too hot, and the turbo would fail quickly. So the wastegate bleeds off extra exhaust gas to try and keep the turbo in its efficiency range. So at lower engine speeds the wastegate is closed to try and bring the turbine up to speed (spool), but once it's up to speed and making the desired boost, then some of the exhaust gases are directed around the turbo's exhaust wheel so the turbo doesn't make any more boost.

A wastegate is controlled by 2 things, a spring and a diaphragm. The spring has tension on it that keeps the wastegate closed and the diaphragm helps to overcome the tension of the spring and open the door. So they work against one another. The springs are rated for a psi value required to overcome the tension. The OEM spring is rated for 7 psi usually (it varies). What that means is that while you're making less than 7 psi of boost, the wastegate will always be closed. Once you exceed 7 psi, say 7.1, the wastegate will crack open, some exhaust will be bled off, and the pressure will drop to 6.9 psi. So the wastegate will close now and pressure will start building up again. This is done really fast to maintain an average pressure of 7 psi.

So here are what a stock and external wastegate setups looks like:



(not drawn to scale, just to show the ideas)

Electronic Boost Control

So now we add an electronic boost controller. The ebcs can make the diaphragm work with or against the spring. This is done by exposing the top (and bottoms in external setups) of the diaphragm to different pressures. They can be hooked up in different ways as seen in the cobb article, but the basic idea is the same. If you want to build boost and keep the wastegate closed, the ebcs makes the diaphragm work with the spring. If you want to stop building boost, the ebcs makes the diaphragm work against the spring and helps open the wastegate. So if we want to make 16psi with a wastegate spring rated for 7 psi, we would make the diaphragm work with the spring to keep the wastegate closed until we reach 16 psi, then against it and help open the gate once we get past 16. So it would work like before. You would alternate between 15.9 and 16.1 psi really fast giving you an average of 16 psi.

This finally brings us to what a wastegate duty cycle is. A WGDC is simply a percentage of a set amount of time (say a couple of milli seconds) that the diaphragm will work with the spring to build boost. So higher wastegate duty cycles means the wastegate will stay closed longer, thus making more boost.

Turbo Dynamics (32 bit)

In an ideal world, you would setup you WGDCs to reach your target boost at all times, but that doesn't always happen for a variety of reasons, so this is where TD steps in. TD adds to or subtracts from WGDC when you are not reaching your target boost values with the wastegate duty cycles you have assigned. TD comes in two forms and fixes two types of errors.
1. Immediate boost error.
2. Continuous boost error over time (small amounts of time, milliseconds not hours).

Turbo Dynamics Proportional is the immediate amount (%) applied to the initial WGDC. It's simply, boost error is X, then add Y. Turbo Dynamics Integral Positive accumulates for all positive Boost error values. So it is a temporary learning mechanism. Remember boost error = Target boost - Actual Boost. So say we are not making target boost. The ECU looks at the boost error and sees it's positive, so it says I see boost error of 5, I'll add 2%. Looks back in a couple milliseconds and says, damn! I still have a boost error of 2, I'll add another 1% to try and reach target boost (3% total now). looks back again, and either keeps adding more to the TDIP compensation, doesn't add anything, or resets the value to 0 if the conditions are no longer met. The Turbo Dynamics Integral Negative works the same way, but with a negative boost error (this means you're over boosting)

So the actual amount of WGDC actually used is:

Applied WGDC = Initial WGDC + TDP + TDI + other small corrections

Keep in mind that if Initial WGDC + TD > Maximum WGDC, then Maximum WGDC will be applied to the wastegate since it's the capped limit.

Note on TD:
The way TD works, when you first see a boost error, a lot of immediate correction will be applied and almost no cumulative correction. As time goes on and you continue doing your pull, the cumulative correction will start to add up, and the immediate correction will get smaller. Finally, most of the TD will be cumulative correction and you will have little immediate correction. This is what I’ve seen on my car when I have my WGDC dialled in correctly to make the boost I want. If can’t reach your target boost, you will see both corrections max out. If you hit target boost immediately (somehow), the cumulative will not have time to build up and you will see little of both correction.

It would seem that TD is like a bandaid for poorly tuned boost. It would make sense that if you dialled in your boost correctly, then you would never need to use TD. This is not the case. Boost is affected by temperature, humidity, elevation, air density, and a huge load of environmental conditions. TD is meant to correct for these conditions. Therefore, in an ideal world where the car is at sea level, it’s 70deg outside, and the sun is shining, you would not need TD. But during realistic driving conditions, it keeps your boost steady in a variety of weather conditions.

Fuel & Air-Fuel Ratios (AFRs)

Reference

A lot of the information about how the ecu works comes from **merchgod** from the RomRaider forums
I found it difficult to understand so I rewrote it and added extra information that will help to understand the big picture.

Introduction

Before we get to the tables, we need to discuss air fuel ratios, fueling, and air intakes. Target AFR for gasoline is 14.7:1 or 1 lambda. That means is that there are 14.7 pieces of air for 1 piece of fuel. The 1 lambda is just another scaling for the same exact thing. It's saying what percentage of the optimal air fuel ratio you are running. A 14.7:1 AFR is normally considered the best trade off between emissions, fuel economy and power production.

Unfortunately you can't run that mixture all the time. At that ratio, the air fuel mixture is very energetic. So doing things like forcing the mixture into a crammed spaced at 15 psi might have some negative consequences. It could pre-ignite or explode rather than burn. But of course the cooler the air (better intercooler), the higher the octane of gas (octane is the resistance of gas to spontaneously ignite or explode) the more abuse the AF mixture can take before something bad happens. So the closer you can get to the stoich AFR, the less abusive you can be to the air fuel mixture.

This brings us to the logical conclusion that we should try to run that stoich mixture when we're being gentle with the AF mixture (cruising on the highway), and something less energetic when we're trying to cram the most amount of air/fuel possible into the cylinder (under boost). This is the idea behind closed loop/open loop fueling.

Subaru decided to only equip our cars with a narrow band O_2 sensor. That means that our cars can only tell if we're running rich or not (simple yes or no) but they can't tell by how much. Even if we put a wideband sensor in place of the stock sensor, that wouldn't help much because the ECU wouldn't know how to interpret the signal. The ECU can only use a simple yes/no answer to determine if we are running rich or not. That means that if we want to run the stoich AFR, we use the sensor (closed loop fueling) and if we want to run some other AFR, we ignore the stock O_2 sensor and find another way to get the correct AFR.

Closed Loop

Let's start with closed loop fueling. The goal of closed loop fueling is to have the car run the stoich AFR. It does this, like it does everything else, by using guess and check. As you drive, a known amount of fuel is being used. After it is burned, the exhaust gases are analyzed by the O_2 sensor to see if there is any oxygen left in the exhaust. If there isn't, the ECU thinks you are running rich (too much fuel and not enough air, AFR lower then 14.7) so it lessens the amount of fuel it is squirting into the engine. When it sees oxygen in the air, it thinks it's running lean (AFR higher then 14.7) and adds more fuel. It does this really fast and only adjusts the fuel a little bit as needed thus giving you an avarage14.7 AFR. Easy.

Note:
For those that have widebands, you will notice that your AFRs bounce around a bit while you're in CL fueling. This is normal behaviour and is meant to help the catalytic converters.

Open Loop

There are times when we want our car to not run the stoich AFR. This would be when we are trying to make a lot of power by compressing the air/fuel mixture as much as possible before the spark plug ignites it. So what AFR should we run? A *12:1* AFR is good for power, but dangerous to the engine. It would be good for an aggressive tune on a car that you won't mind if the engine goes. The more reliable AFRs of *10.5:1 to 11:1* for a TMIC and *11:1 to 11.5:1* for an fmic are usually used on a daily driver. The tricky part is figuring out how much fuel you need since there is no feedback. This is where your

Mass Air Flow sensor comes in. The MAF is just a heated wire. The ecu tries to keep that wire heated to a certain temperature, but as air flows over the wire, it cools it. So the more air that is sucked into the engine, the more voltage will be required to keep the wire at the set temperature. So that voltage can be mapped to a given amount of grams of air per second going into the engine. So, for example, if the MAF sees 2.6 volts, then the ecu knows the engine is eating 126 grams of air per second. Knowing this, the ECU looks at what AFR you want to run, takes into account any necessary compensations, and determines an injector pulse width to give you the AFR you're looking for. The pulse width is the amount of time the injector is open and (along with the fuel pressure) determines how much fuel gets squirted into the engine. As you can see, the ECU never knows what the real AFR is while in open loop. It's up to the tuner to determine what AFR the car should be running and setup the ECU parameters to make the actual and requested AFRs match up.

CL / OL Delays & Transitions

As it turns out there are a lot of conditions that need to be met before the car will transition form CL to OL fueling. To makes things worse, there is also a delay with the transition. The basic ideas is that the ECU is designed to only transition to OL fueling if it's really, really super sure that you want to do this. There's no real explanation on why it's so difficult to make the transition, but emission requirements have been pointed out as being the culprit. To make things worse, this transition process has been responsible for some hesitation/drivability issues seen with the WRX. The ecu determines if it should go to OL fueling is by using a counter and a couple of threshold values. Once the counter exceeds the *CL to OL delay* value, the transition starts. The easiest way to look at it would be in pseudo code:

CL to OL Transition Pseudo Code:

```
While (counter < CL_to_OL_Delay) {
      If (currentRPM > CLtoOLTransition_Throttle_Value) {
            Counter = Counter + 1;
            Break;
      } elseIf (currentLoad> CLtoOLTransition_load_Value) {
            Counter = counter + 1;
            Break;
      } else {
            Counter = 0;
      }
}
```

So as you can see, if one of the conditions to get to OL is exceeded, the counter gets incremented. On the next check, if the condition is still being exceeded, increment the counter again. If it's no longer being exceeded, are any other conditions exceeded that would increment the counter? If not, reset the counter to 0. Finally, when the counter passes the CL to OL Delay value, the transition process starts.
Well almost, there are certain extreme conditions that if exceeded, you skip the whole delay process and start the transitions. These are dictated in the max/min maps. So if the ecu does not see these extreme conditions, it follows the code above, if the extreme conditions are met, the code above is skipped.

So now we finally get to make the transition. The last roadblock is the current value in the Primary Open Loop Fueling table as well as the minimum primary open loop enrichment value. The transition will only happen if the desired AFR from the POLF table is richer then the Minimum transition to OL value. (This value is usually 14 and isn't changed). If all that checks out, we go to OL fueling. So, we add these two parts to our Pseudo Code to get:

Getting past the delay counter

```
While (counter < CL to OL Delay) {
      If (any conditions are being exceeded) {
            Increment counter
      } else {
            Reset counter to 0
```

```
        }
        If (any of the extreme conditions met) {
              Forget the counter and start the transition
        }
  }
```

THE TRANSITION

```
  If (desired primary open loop value < min required value for transition) {
        Welcome to OL fueling
  } Else {
        Go back to CL fueling
  }
```

So now we are in OL. Let's sum up how the ecu operates in terms of fueling. The ecu takes the following steps in each ecu cycle:

- Reads the MAF voltage
- Looks at the MAF scaling to determine how many g/s of air are going into the engine.
- Looks up the target AFR
- Adjusts the AFR for environmental conditions
- Determines how much fuel it needs to output to give you the target AFRs
- Looks at the injector flow scaling to figure out how long the injectors need to stay open to get the right amount of fuel into the engine.
- Determines an initial pulse width
- Applies injector latency time to the pulse width
- Applies voltage to injector for duration of the pulse width and hopes for the best

So to reiterate some terms, CL to OL Delay is the counter values that need to be exceeded before the CL/OL transition happens. These will vary by year and ECU. Primary open loop fueling is map that holds the desired fueling to use when in open loop mode (no feedback). Injector Latency is the dead time of an injector (like PE would be different from stock); Or how long the injector needs to be energized before it opens and lets fuel out. The flow scaling is the estimated cc/min for the injectors being used. The MAF sensor scaling is a table that holds the relationship between volts read by the MAF and grams of air per second coming into the engine.

Timing

Reference

Majority of the information about how the ecu works comes from [Subaru's knock control strategy explained (RomRaider)] I again paraphrased a lot to make it easier to read and added information I though was useful to understand the big picture.

Knock

Knocking (also known as pinging or detonation) is when the AF mix explodes in the cylinder. Fuel isn't supposed to explode, but rather burn quickly creating an even pressure wave that drives the piston. When a car knocks, the AF explosion creates a pressure spike, whose pressure exceeds anything our engines were built to withstand. In order to withstand detonation, you'd need a cast iron engine block + a crank and bearings that can handle it = diesel car. So when the car knocks, the pressure spike is driving the piston downward much harder then it's meant to. This knocks the crank into the bearings, scoring them. Then you need a new shortblock. Not saying your engine will blow if your car ever knocks, but give it one good knock and it could be toast.

A better way to look at it is with an analogy. Say you had a fragile vase glued to a skateboard and wanted to move it as far as possible with one push. (stay with me here) If you punch the vase, the skateboard won't go anywhere and the vase will break. If you give the vase a smooth push, the skateboard will go rolling away and the vase will stay in tact. So the goal is to give the vase as hard of a push as possible, without it breaking, to make the skateboard roll away as fast as possible. The punch is like knock while the push is like regular combustion.

To get the most power out of the engine, we need the maximum pressure in the cylinder to occur once the piston is 15 degrees past TDC (top dead center), or the 12 o clock position. To accomplish this, the AF mixture is ignited early on, usually before TDC. It then gets a little more compressed as it reaches TDC, accelerating the burn. Then, after TDC, the majority of the combustion occurs, pushing the piston.

When we tune timing, we are setting the number of degrees before TDC that we want the sparkplug to ignite the AF mixture. The more advance, the sooner the AF mixture is ignited. Yes, a lot can go wrong here. Luckily, Subaru has an advanced/complicated knock system to prevent catastrophe.

One more quick note on knock. The knock sensor is an audio sensor. That means it actually listens for a certain sound in the engine. The engine can be a noisy place, so it filters out almost all sound except certain frequencies that are characteristic of knock. So if the sensor hears a sound with the specified frequency range, it reports knock. Yes, the knock sensor can pick up false knock. There have been cases where someone dropped a bolt by the sensor and didn't know it. As they drove, the bolt rattling made the knock sensor think the car was knocking like crazy. This does not happen often and it does not mean you can ignore a knock signal. This is just a limitation of the knock sensor.

Subaru Knock Control

Rather then having just 1 table for the timing value, the ECU has several that it combines to come up with the final value. The reason for this is that it gives the ECU the ability to reduce or advance timing in response to information it receives from its sensors as well as feedback it gets from the knock sensor. Therefore, we need to examine the various parameters that make up the final value. The final value is computed in the following manner:

`Total Timing = Base Timing + (IAM*Timing Advance) + Corrections + Compensations`

Base Timing: Value in the Base Timing look up table for the specified RPM/Load cell
IAM: Current value of the ignition advanced multiplier stored in ram.
Timing Advance: Value of Timing Advance look up table for specified RPM/Load cell

Corrections: Value the ECU learned from previous experiences & feedback.
Compensations: Adjustments made for intake temperature, barometric pressure, etc.

Let's look at where each of these parameters comes from and how they are determined. Base Timing comes from the base timing map in the ecu. The tuner has full control of this map. The Timing Advance value comes from a similar map, which the tuner also can change as well. So why the need for two maps if their values are just going to be added together? The answer is the IAM value. The Ignition Advanced Multiplier is there to add the full TA to the base timing if the engine is happy and only part of the TA if the engine is not too happy. Your engine is happy if the knock sensor is not hearing any knock. You, as the tuner, could very easily put in all 0s in the TA and make the Base timing Value = BaseTiming + Timing Advance. This wouldn't be a problem at all if your engine is always happy, but it's "safer" to have the two separated. They are seperate just case your car runs into trouble. In that case, the ecu can lower the IAM and thus add less TA possibly saving your engine.

IAM is also known as "Rough Correction". This is because if it is lowered, only part of the TA will be applied, and thus timing gets pulled across the board. Another way of saying this is if the car only knocks in one combination of rpm and load and the IAM is lowered, you will still not get full TA once you get out of the "danger zone" There needs to be a better way to compensate for knock that only happens in certain places.

This is where the other corrections come in. The other corrections are Feedback Knock Correction (FBKC) and Fine Learning Knock Correction (FLKC). FBKC is a timing correction that is applied mostly when you make WOT pulls and FLKC is usually applied during cruise. Let's take a look at our revised equation first.

TOTAL TIMING = BASE TIMING + (IAM*TIMING ADVANCE) + FBKC + FLKC + OTHERCOMPENSATIONS

HOW DOES THE ECU DETERMINE CORRECITONS?

Simply, the ECU adjusts 1 form of correction at a time through trail and error. This means we have 3 forms of correction (FBKC, IAM and FKLC) and we can only adjust 1 at a time. So how is this done? The ECU is setup with parameters that dictate which correction the ECU will be adjusting at any moment. To generalize, the ECU spends most of it's time adjusting the FLKC. During WOT runs or sharp changes in engine load, the ECU switches FKLC learning off and focuses on FBKC. If the ECU is adjusting FLKC and there are huge corrections (-4 degrees or more) to be made, the ECU decides it's not happy and switches to IAM correction. This is done because the ECU thinks there is something wrong with the car and this pulls timing across the board to protect the engine. This is why people say the IAM is a measure of how happy the ECU is.
Let's try to sum this up with some more pseudo code:

```
If (in fine correction) {
      If (pulled more than 4 degrees or the ECU is unhappy) {
            Goto (IAM correction)
      }
      If (Large/rapid change in engine load) {
            Goto (FBKC)
      }
} else {
      Check to see if any adjustments need to be made
      Stay in FLKC correction mode
}

If (in FBKC mode) {
      While (engine load is rapidly changing) {
            Check for knock and pull timing if needed
            When (Done) {
                  Go back to previous mode
            }
      }
}
```

```
If (in IAM correction) {
      Find optimal IAM
      Go back to FLKC mode
}
```

The ECU is set to rough correction initially. This makes sense since it finds it's optimal IAM first, then moves on to adjusting the FKLC and stays there until the IAM needs to be recalculated or you're doing a WOT run. Another thing is that the ECU seems to give FBKC priority over the other modes. So since this is the case, we'll start with that.

FEED BACK KNOCK CORRECTION

FBKC is active during the values specified in the "feedback knock correction range". During that time, the ECU is constantly listening to the knock sensor waiting to hear a knock activity. If there is no knock activity, FBKC will stay at 0. However if the ECU hears a knock event, the FBKC gets the Feedback Correction Retard Value subtracted from it. This value could be anything, but is usually, 1.4 degrees. So once the first knock event is heard, FBKC = -1.4. This means that 1.4 degrees are now subtracted from you final timing value. The ECU goes back to listening. If the correction helped, the ECU won't hear any more knock, and at that point it will slowly start adding timing back in. That means your FBKC value start going back towards 0. It only returns a little bit at a time, not the whole amount. So say pulling that 1.4 degrees did the trick, therefore as time goes on, the ECU will raise the FBKC to -1, then -.6, then -.2, then back to 0. But if at any point in time, the ECU hears another knock even, it will subtract another 1.4 degrees from whatever the current value of FBKC is. So if it hears another knock right after the first, your FBKC = -2.8. If it hears another knock a little later on when FBKC = .6, then your FBKC = -2. It does this over and over as you are making a hard pull.

At this point it would seem like a good idea if the ECU just learned when to pull timing and just do it at that load/rpm. That is a good idea, but in order to learn the ECU needs to get out of FBKC mode and into one of the other modes. But before it does this, it wants to be sure that the engine conditions are right, so there is a list of requirements that must be met first.

- Coolant temp is greater than 140F
- A/C is off or A/C was not just turned on
- If in IAM correction mode, load and RPM are within the "Rough Correction Ranges".
- If in FBKC correction mode, load and RPM are within the "Fine Correction Ranges".
- Immediate change in load is less than about +/- .05 g/rev.
- ECU is not in test mode
- ECU is not in limp-home mode due to the triggering of specific groups of CELs.
- An unknown timing compensation based on throttle change is not active (i.e. no compensation).

So the idea is that long term learning can begin once the engine conditions are steady enough to ensure that whatever knock you hear is not a fluke. So let's assume we enter IAM (rough) correction mode (this is the first mode you enter after the ECU has been reset). Once we're in, we can either adjust the IAM or not. We can adjust the IAM if the

- Current timing advance (maximum) map value > 3.9 degrees
- ECU is not in limp mode
- IAM step value is greater than 1.

So now, let's assume that the IAM can be adjusted, in order to do this, we need to do the following first (but only once every time we enter rough correction):

- ECU IAM is set to the 'Advance Multiplier (Initial)' value
- ECU IAM step value is set to 4 ("Advance Multiplier Step Value")

- ECU IAM learning delay counter set to 0
- ECU The entire FLKC table in ram is cleared.

This is done to make sure that we are not working with any previous corrections.

So now, we calculate the new IAM value by listening for knock activity. This can be summarized with the following pseudo code:

```
If (Knock) {
      Set Counter to 0
      Decrease the IAM step value in half
} else {/* There is no knock */
      If (No knock for period of 'Rough Correction Learning Delay (Increasing)') {
            Increment Counter
            If (Counter > Delay Target) {
                  Increase IAM by Advanced Multiplier Step Value
                  Set Counter to 0
            }
      }
}
```

The ecu will keep going though this procedure of trying to raise the IAM as much as possible until the ECU determines that the IAM has "settled". This means that the IAM step value <= 1 for 16bit ECUs or .25 for 32bit or IAM is 0 or maxed out. Once this is done, the ecu is ready to exit IAM correction and get back to FLKC correction.

FLKC Mode

FLKC is meant to make more precise adjustment to the timing than IAM correction mode. Rather then applying corrections across the board, it fine tunes what combination of load/rpm need adjustment. The learned values are always applied, but adjustments to the values can only be made if the following conditions are met:

- Currently in fine correction mode.
- FBKC is disabled.
- Engine speed and load are within the ranges specified by the 'Fine Correction Range' tables.
- Limp-home mode is not active.

If those conditions are met, the ecu listens for knock. If there is no knock, the ecu can add a positive correction (advance timing further). To do that, the following conditions must be met:

- (FBKC and/or negative FLKC was NOT applied during the last execution)
- If above is true, then the previous FLKC load/RPM range also has to be the same as the last range before this execution.
- The current FLKC table load/rpm range is the same as the last range.

Like the other corrections, there is a delay before which an FLKC table value can be increased ('Fine Correction Advance Delay'). This is based on a counter (similar to the FBKC counter), which is incremented when there is no knock and is cleared when FLKC table adjustments are made or the knock signal is set. This is very similar to the IAM pseudo code.

If the above are met, then the FLKC value for the current load/RPM cell is increased. However, it cannot be increased if current timing advance + FLKC is greater than the current value in the "Timing Advance (Maximum)" table. This also means that if the IAM is 16 or 1, only negative FLKC is allowed. Each increment of FLKC is .35 degrees ('Fine Correction Advance Value'). Maximum allowable correction is 8 degrees ("Fine Correction Advance Limit"). Therefore, FLKC will only be positive if your IAM is not at 100%.

However, if the ecu hears knock, the fine correction in the current FLKC cell is decreased by about 1 degree ("Fine Correction Retard Value"). So this is where the ECU spends most of its time. If it's happy and everything is good, the IAM is at 100% and the FLKC are all 0's. However, if there are problems and knock activity is heard, there is always the potential to enter back into rough correction mode. To do this, the following conditions need to be met:

- Engine speed and load must be within the ranges specified by the 'Rough Correction Range' tables.
- Timing advance (maximum) map value is greater than 4.9 degrees.
- Some FLKC value change (positive or negative) occurred last execution.
- The last FLKC applied value (|x|) is greater than 3.9 degrees (that is, the absolute correction -> ex. -4 = 4)
- The last FLKC raw difference (|y| * 2.84) is greater than last timing advance (maximum) map value.
- (IAM > 1) or (IAM <= 1 and last applied FLKC was positive).

That's it for timing.

AVCS (active valve control system)

The basic idea behind AVCS is simple; it's just a way to open the intake valve on the cylinder earlier. The higher the AVCS value is (degrees) the more advance the intake valve is given. However, the length of time the valve stays open is still the same. So what is the point of doing this? According to the Subaru article, it's to smooth idle at low engine loads, better emissions at mid engine loads, and get more power out of high engine loads. So Subaru tells us right there what to do with AVCS. At low loads, turn it off (set to 0) and at high loads turn it up. Then taper that through the middle loads.

Now, if you look at the stock WRX AVCS map, you'll notice a big jump (40 degrees) in a couple columns near the lower rpm low load range. That is there for emissions. According to Subaru, having some of the exhaust gasses flow back into the intake reduces harmful oxides in the exhaust. Furthermore, the s202 and other JDM maps don't even have that spike. So we can eliminate that right away.

What the Subaru article doesn't talk about is the relationship between AVCS and RPM. The OEM AVCS map is a 3d map broken down by engine load and rpm. So we known that the min advance should be 0 and occur at the left and max advance at the right, but what about top to bottom (low to high rpm) what happens there?

This is where things get complicated. That all depends on your exhaust/intake/turbo setup. The reason AVCS can make good power is because it increases the Volumetric Efficiency of your engine. VE is the percentage of air that is going into the engine / the amount of air that could fit. So in other words, it's how easily air flows into the engine. Another way of saying this is how much resistance the air has going into the engine. In a turbo application, the psi measured in the intake manifold is a measure of how much air is not going into the engine. So that means if the turbo is pumping out the same amount of lbs/min of air, having a lower psi is actually better since more air gets into the engine since there is less restriction.

So now this brings a problem, reversion. This is where if you give AVCS too much advance, the exhaust gases come back into the intake manifold and "pollute" your intake charge. Not only that, but they cause an extra restriction so it's harder for the turbo to move air since the pressurized exhaust gases are moving in the opposite direction of the intake charge.

This brings us to our point. The bigger your turbo and the less restriction there is in your exhaust, the more advance you can run into the higher RPM ranges. This is because the bigger turbo pushes the air harder on the intake side and the better exhaust let's the air move more freely on the exhaust side.

The key to tuning AVCS is figuring out when advancing AVCS causes more of a restriction then it helps move air into the engine. (We'll talk about this when we get to practice)

(Oh and since it changes your VE, your fuel and timing are affected....)

A Complete Tuning Guide

Tuning the car

When tuning the car, what you are really doing is finding the limits of the engine. Finding how much boost the turbo can push, how lean a fuel mixture the engine can run, and how much timing advance the engine can take. So keep in mind that the closer you come to any of these thresholds, the more likely you are to break your car. But the trade off is you'll make more power. A lot of people say the car felt the best (made most power and whatever else that means) right before the engine blew. So whatever margin of error you leave is completely up to you.

Another thing to keep in mind is that each car is different. What works for one car, might not work for another. This is why a custom tune is usually far superior to any off the shelf tune. The tune really has to be suited to the vehicle. While the practices and theory remains similar, the actual numbers will vary.

When tuning the car, you can judge progress by a number of different ways. Your goal might be max Peak power, max usable power, quickest turbo spool, or the most boost.

Max Peak Power: Getting the dyno to give you the highest possible point on your power curve.
Max Usable Power: Getting the most area under the power curve
Quickest turbo spool: Getting the turbo to push air as fast as possible as soon as possible.
Most Boost: Sacrificing all to claim you can push the most air on your turbo.

Clark Turner always says that your priority should be to tune for the most amount of usable power. Why? Simply because that is what will make your head fly into the back of your seat and keep it there. It’s nice to have a power spike, but it’s really nice to ride in a car where you find yourself wondering if the car will ever stop getting faster. So usable power will make your car move, while the other stuff just looks pretty on paper and is great for internet bragging.

When tuning, you never have complete control of all the variables being processed by the ecu. You are constantly negotiating with the ecu to get the car to do what you want. So the general format is you tell the ecu what you want the car to do (setup the base tables), tell it how to do it (setup secondary values to make the car reached the values in the base tables), then tell the ecu how to adjust for unknown environmental conditions. Then you test the setup and make sure you see the results you were looking for. If not, adjust.

Enough BS, let's get to the tuning. We will tune is the following order:

1) Establish Air and Fuel relationship
2) Tune boost
3) Tune Fuel
4) Tune timing
5) Tune AVCS
6) Retune fuel and timing

Before you start

If you changed a lot on the car, like you are going from a stage 2 car to something with a bigger turbo, you might want to do a couple things first.

- Set your WGDC map to all 0, so you only run waste gate pressure for boost.
- Set your OL fueling to ~10.2 for tmic and 10.5 for fmic to run rich
- Lower your timing in the WOT areas by about 4 degrees.

The idea behind this is to create safe conditions for you to tune in. That means if the car does not like a change you made, your engine will have a much smaller chance of getting damaged. The idea is to make everything slow and safe at first, then start adding power back in a progressive manner.

Establishing the Air and Fuel relationship

This needs to be done if anything has changed with the way air or fuel is delivered. Meaning if you threw on an intake, fuel pump, or fuel injectors, you will need to do this. The intake and the fuel systems are "tuned" to work together to give you a proper AF relationship, so changing one means, you need to update the relationship values. So if you changed something in the fuel system, you need to update the fuel parameters, if you change your intake, you will need to rescale your MAF, if you did both, you'll need to do both. That is the more difficult case. This is because if you try to tune for both at the same time, you wont know if your errors are coming from your intake or injectors. While tuning for each, you're looking at changes in the same parameters and you're never sure if the intake or fuel injectors are causing the results you are seeing. Therefore, you can only tune for 1 at a time accurately. There are 2 ways of doing this:

1) Throw on the stock intake and tune the fuel, then put on the aftermarket intake and tune the MAF.
2) Put in theoretical values for fuel, and compensate for the difference from actual values while tuning the MAF.

Ideally, you would do 1, but that can't always happen in cases where your stock air box will no longer fit in the original location. In that case you would do 2. You want to use the stock airbox because it gives the best data for tuning. Aftermarket intakes tend to spread out/disperse the data points making corrections harder to judge accurately. If the stock airbox does not fit, then you can try to use an intake that you have a good maf table for. It won’t be as good as the stock box, but much better then using theoretical values.

So let's say you have the stock intake on. If we didn't, we would just put in theoretical values and skip to the MAF tuning.

INJECTOR FLOW SCALING:

Here we will tell the car how many cubic centimetres (cc) of fuel per minute the injectors will dispense at the standard fuel pressure and density. So you are establishing the flow rate of the injectors.

There are 2 ways of doing this.

1.) Use the RomRaider Injector tool. Follow the directions and it will tell you what the cc/min are
2.) Do it by hand as described below:

Scaling by hand:

1) Find the theoretical values for your injectors. They can be found on the forums, from your manufacturer, or from Cobb's database. Cobb's db is a good starting point, but it lists the raw ECU values rather then the cc/min that RomRaider wants.
   Luckily, you can use the following to convert: `2707090 / Cobb Value = RomRaider Value`.
2) Let the car come up to temperature.
3) Once that's done, reset the ECU. You're doing this to flush any learned fuel values.
4) Turn the car back on and let the car idle and watch the AF immediate correction and AF learned correction. The sum should be <= +-5%.
5) If it's not, positive numbers mean the ECU is adding fuel; negative means the ECU is pulling fuel. Therefore, you just adjust the values as needed (up or down) by a little bit at a time.
6) So check total correction, adjust the scaling, flash map, idle again and watch the sum. Rinse & Repeat.

Again, just because you bought 850cc injectors from a member on the forums, doesn't mean that 850cc is the best value to put in for scaling, unless they came with a flow sheet that specifically told you that they are exactly 850cc. The real value could be a little less or a little more. Going through this is always a good idea if you don't have a spec sheet for your particular injectors. It can save you a lot of headaches later on.

INJECTOR LATENCY

Latency is the amount of time that it takes for the injector to fully open. It is based on battery voltage and fuel pressure. Fuel pressure changes with boost. More boost = more fuel pressure. So it is common to see larger errors when the fuel pressure is low and smaller errors when fuel pressure is high if latency is not correct.

There are 2 ways to tune latency:

1.) Use the RomRaider injector tool. Follow instructions, get your data, and enter the suggested values
2.) Do it by hand via guess and check

Tuning Latency by hand:

1.) Put in a theoretical values you found on the internet
2.) Go drive around logging your
    a. fuel corrections
    b. maf voltage
    c. FBKC to make sure you're not knocking
3.) Add an extra column to your data and calculate the volts/sec that your maf voltage is changing using the time stamp in the log and adjacent voltage values.
4.) Get rid of any lines of data where the volts/second change is > 0.2
5.) Plot your corrections vs maf voltage
6.) See if the corrections get closer to 0 as mafv gets bigger
7.) From there, figure out if you want to make a change, and in which direction. If your corrections are negative, decrease latency. If they're positive, increase latency.
8.) Flash new values to ecu
9.) Rinse and repeat until your fuel corrections is within 5% across the maf voltage range.

Note:
As you can see, this is why we need to have a good maf scaling before we tune the injectors. If you didn't have a good maf scaling, you wouldn't be able to get all the fuel corrections within 5% on the whole maf voltage range due to maf errors. In a case where you absolutely can't tune the injectors and maf separately and do not want to use theoretical values for scaling and latency, you would get as close

as you can to 0 corrections across the maf voltage table by tuning the scaling and latency. Then when you tune the maf you would bring down the rest of the corrections to bring them within an acceptable range.

MAF SCALING

Here we adjust the correlation between MAF voltage and the mass of air being pulled into the engine. For now, we will do this only up to 2.6 volts (or closed loop fueling), we'll adjust the rest after we tune boost.

There are 3 ways of doing this:

1.) Use the RomRaider MAF tool. Instructions can be found HERE
2.) Do it by hand using the more accurate way outlined HERE using THIS
3.) Do it by hand, the rough way as outlined below

Tuning the MAF by hand:

1) Drive around and collect data on a relatively flat road (flat is important). You will need about a half hour to hour of data. Log the following:
    a. AF correction
    b. AF learned,
    c. MAF voltage,
    d. CL/OL status
2) Look through your data and get rid of any rows that are in OL
3) Add a column as we did before and calculate the changes in maf voltage
4) Get rid of any rows where the changes in voltage/sec are > 0.2
5) Plot the sum of corrections vs maf voltage. A scatter plot would work best.
6) Use the plot to make corrections in you maf voltage cells
    a. Any maf cell that has a >5% error, multiply the g/s value by a correction factor.
    b. If the % correction is positive, multiply by 1+(%correction as decimal)
    c. If the % correction is negative, multiply by 1-(%correction as decimal)
    d. For example, if the sum was +10%, then multiply the value of that cell by 1.10. If it is -10%, multiply by .90.
7) Rinse and repeat.

Tuning Boost

There are two ways to get started:

1) Get a boost map from someone else and tweak it to your car.
2) Make your own boost map from scratch.

We will go with 2 since it's more involved and 1 is just a short cut for 2 anyway.
You will need to tune your Target Boost and WGDC while watching your Turbo Dynamics.

FIND YOUR MECHANICAL PROPERTIES.

1) Make sure you removed some timing, are running rich, and all your WGDCs are set to 0. You are doing this to test the mechanical efficiency of the turbo and wastegate first. So we want to see how the turbo and wastegate behave without any help from the ECU and boost controller.
2) Drive around logging your
    a. RPM
    b. Throttle Position,

    c. Relative Pressure corrected (boost)
    d. FBKC to make sure you're not knocking.
3) The boost map is a 3d map broken down by rpm and throttle position. The goal here is to try and see how your car behaves in each cell (Each rpm and throttle position value).
4) Now you need to sort the data
    a. Make a blank boost map with the same throttle and rpm values as your map
    b. Rearrange the data so that you match up each line in the log to the closest rpm and throttle position combination
    c. After you have data for each position, average the data for each cell.
    d. Graph the map and make sure all the transitions are smooth. If not, smooth them out by altering the values in the cells.
    e. Flash the map, go collect more data, and check again.

The idea behind this is since your turbo changed, your stock map no longer matches the turbo so you can't start from it and since you need a starting point, this is a good one.

TUNE TO REACH YOUR TARGET BOOST

The best thing to do for now would be to look through other people's boost maps for the turbo you are running. This is just to get a general idea of what other people are doing. Not that you will follow their lead, but you want to look though a couple maps and notice the different patterns. Like where they make max boost, what their max boost is, and the general flow of the map. It's just to give you insight into how your boost map will likely progress. We will take the boost map we made previously, add more boost to it, and adjust the WGDCs to make the car reach that boost.

1) Pick a spot in the 100% column and guess what RPM you want full boost at. Bigger turbo's spool later, but for now, this is just a guess.
2) Enter about 75% of your theoretical target boost in that cell. We're only going to try and reach 75% of our theoretical max boost for now just to make sure everything is working properly. Once everything is setup to reach this goal, getting 100% should be easy.
3) So put in the value and interpolate the table horizontally and vertically from that cell and make sure your target boost values are a smooth progression to your max boost.
4) Add a little bit of WGDC to your tables. You can make this almost like 2D map for now. So in the 0 TP load have 0 WGDC and in the 100% you can start off with 10% and interpolate horizontally.
5) I setup my min/max WGDC so that my Max WGDC = Min WGDC + Max TDIC + Max TDI + 2. I just did that to give ecu some ability to work with the WGDCs. I don't want to be hitting my max WGDCs unless the turbo is spooling.
6) You will not reach your target boost, but go out and do 3 WOT runs. You want to make them 2k rpm – redline and in whatever gear is closest to 1:1 ratio. Log the following:
    a. RPM
    b. Throttle position
    c. WGDC
    d. Turbo Dynamics Integral Cumulative and Immediate
    e. FBKC to make sure you're not knocking
7) Now look at your logs and get rid of any data that's not 100% throttle position (or very close to it)
8) Look at the TDI being added in at the RPM you want to achieve full boost. Add that amount to your 100% WGDC column.
9) Rinse and repeat.
    a. As you do this, you will start getting a better idea of how the turbo is working and that will help you find exactly where the turbo is happiest in the RPM range. Seeing how the turbo is behaving will help you confirm the RPM you want full boost at or revise it.
    b. Do this until you reach your target boost (this was set at 75% of your theoretical) at some rpm

c. Once you are hitting boost value you have in your boost map, your TDIC should start building up and your TDI should be maxed out as your spool.. Then as you hit the target boost, your TDI should drop to 0 and your TDIC should stay constant.

10) Once you confirm that everything is working properly you can raise your target boost slowly to the theoretical limit and match the WGDC as before. Keep doing this until you can achieve your target boost or you find that your theoretical target boost is unattainable.

THINGS TO WATCH FOR:

1) Boost spikes: These are just what they sound like, momentary spikes in your boost. The boost system control is fast, but not instantaneous. So sometimes it responds late causing your boost to rise rapidly until it can be controlled. This is usually caused by having too high of a WGDC too early causing you to overshoot your boost targets. Say you logged a boost spike at 4000rpm: that means that you have too much WGDC before 4000 rpm. Find the conditions that caused the boost spike (boost and tp cells) and lower the WGDC in cells prior to them.
2) Compressor Surge: Trying to make too much boost too soon can cause your compressor to surge. The surge region is on the left hand side of the compressor map. The turbo is spinning too fast and not pulling as much air as it should causing it surge or oscillate air pressure. It happens on spool up and can be heard from inside the car. If this happens, lower your target boost in that area and lower your WGDCs as well.
3) Compressor Stall: Sounds like surge, but when you lift off the throttle. This happens when the BPV or BOV fails to vent the pressure in the intake properly. The BOV or BPV is not functioning correctly and doesn’t release the air in one clean vent. It sounds like the air is vented in a couple of vents rather then one. This fluctuation in pressure causes the compressor to stall. This usually involves a mechanical fix like adjusting the BOV or cleaning the BPV.
4) WGDC > 95%: WGDCs are usually kept under 95% to preserve the wastegate. Higher values cause the wastegate to work harder and can wear out the wastegate causing it to get stuck open or closed.
5) Knock: You should not see any since we setup a rich AF and low timing, but you never know. Better be safe than sorry.
6) Turbo Limit: If you're increasing your WGDC or holding them steady and your boost is dropping, you hit the mechanical efficiency of your turbo. That or increasing boost does not = an increase in airflow (g/sec).
7) Watch your Turbo Dynamics. They tell you what the ECU is doing to achieve target boost. If log negative values, your WGDC are too high and you're over boosting. If you log positive values, the WGDC are too low and you're not hitting your target boosts. Keep doing this until your target boost values and your WGDC values give you the boost you want, your TD tables are low and positive (not adding much correction) and you're not experiencing any of the problems mentioned above.

FINE TUNING YOUR BOOST:

Basically, the same idea as above, but you're trying to get your turbo to spool quicker and hold boost longer. To do this, just add little bits of boost to the cells around your max boost cell. Then adjust your wastegate values to see if you can meet those boost targets.

So if in the pervious part I found out I can hit 20 psi on my vf39 at 4000 rpm, I would try and hit 20psi at 3800rpm and hold it to 4200rpm. I would adjust the corresponding WGDCs to see if I can hold it. I would try to extend this 20 psi as far as I can across the rpm range until I find out that adding WGDCs is not helping me come closer to the target. So what we’re doing here is “feeling” around and seeing what max boost levels we can run at what rpm.

The danger here is when you start comparing your setup to someone else’s and try to force your car to match what they’re doing. Just because some other dude can do 20psi on a vf39 from spool to redline (your really can’t), does not mean your car will. Don’t force the car to run more boost than it’s willing to, you'll run into problems (boost spikes, surges, ect). Remember, your setup is unique to your car so don't judge your progress by what someone else did. The goal is to keep your car happy.

RESCALING YOUR TURBO DYNAMICS

If you changed your boost controller to something that's more sensitive (like a 3 port prodrive, grimmspeed, or perrin), you'll notice that it takes less WGDCs to reach your target boost now. When on a stock controller you might have been running 90% WGDCs to hit your target boost, on the new controller, you might be running only 60%. This can cause your boost to fluctuate during rapid changes if you didn't update your TD tables because your ECU is still treating the boost controller like it's the stock unit.

To work with the ECU on this, you can update your TDI and TDIC tables. What I did was multiply all the values by the percent difference between the max duty cycles on the new and old controller, then dial in the rest of the numbers by hand. So if you went from 90% to 60%, your reduced your max duty cycles by 33%. So take the stock TDIC and TDI values and multiply them by 0.66. This should put in close. The go out and test again and see if your boost is still fluctuating and where. Look at what TDIC and TDC values are being used when the boost jumps around and either raise or reduce the values to calm the boost down. I ended up multiplying all the TD values by .66 and then reducing the values around 0 a little further when I switched from stock to a gm.

RESCALING YOUR TABLES:

Another thing that can be done to fine tune your boost is to rescale your boost and WGDC tables. The idea behind this is that since you have only a limited number of cells, you want to have the most resolution where the boost is changing quickly and less when it's staying constant. So if you spool between 2000rpm and 3500rpm and then holding boost steady until 6000rpm, it might be a good idea to change your scaling a bit to give you more cells during spool and less when holding steady.

As an example, say your rpm cells are spaced evenly like 1000, 2000, 3000, 4000, 5000, 6000, 7000 and you're spooling between 2k and 3.5k and holding till 6k. You can try and rescale your table so that your rpm scalings look like 1500, 2500, 3000, 3500, 4000 6000, 7000. This will give you more resolution as you spool and hit peak boost. Doing this will help prevent boost spikes since you have more control over WGDCs at peak boost rather then leaving it to the ecu to interpolate your WGDCs between 3k and 4k rpm.

Tuning Fuel

Tuning fuel simply means setting fuel target values in the primary OL fueling map and then adjusting the MAF scaling so that the actual fuel ratios match the map. Cobb's access tuner spread sheet can help out with this. It's a great tool for getting started.

We will tune fuel in 3 parts. First we will tune the middle part of the maf, then the top part of the maf, and finally lean out our map to try and hit our theoretical afr.

In case you're wondering what our theoretical afrs should be for 93 oct, 12:1 is a good power range (prone to knocking) while 11:1 more reliable. The usual settings are 10.5:1 to 11:1 for TMIC and 11:1 to 11.5:1 with FMIC. If you're not sure, ask around on the forums.

MAF MAXIMUM VALUE:

Before we tune the maf, we need to change this value. This is the highest MAF g/s value the ECU will be able to compensate for after atmospheric corrections. You want this to be about 50 higher than your max g/sec in your MAF scaling table. This just helps the ECU compensate higher MAF values in different atmospheric conditions. This is just a precaution. Raising the value doesn't change much else.

SCALE REST OF THE MAF:

You will do the same thing you did when you scaled the CL part of the MAF, except with a wideband o2 sensor. You can do this once for the middle of the MAF and again for the top part of the MAF. This works best, but takes more effort. Or you can try to be lazy and take a shortcut by not lowering your boost first. You'll see what I mean in a second.

We will scale the OL part of the MAF in 2 steps in order to be more accurate:

1.) Set all your WGDCs to 0 again
2.) Go out and do 3 pull to redline logging the following:
    1. Maf Voltage
    2. Throttle position
    3. Load
    4. Rpm
    5. Wideband o2 reading
    6. FBKC to make sure you're not knocking
3.) Now you can do this next part by hand or save yourself some time and use airboy's spread sheet along with my maf tool.
4.) Sort the data and get rid of any rows that are not near 100% throttle
5.) Find the % error in your afr in each line of the log. This is done by comparing your afrs from the wideband to the targets from the map.
6.) Next, you need to take those errors and figure out what cell in the maf scaling table they would belong to. This is done by matching up the Maf voltage in your log to the maf voltages in the map.
7.) Next, gather up all the errors that belong to each cell and find the average. This average will be used to get the correction factor for that maf cell.
8.) Your correction factor will be 100% + average %error for each cell.
9.) Apply the correction factor to each cell.
10.) Plot your MAF curve and make sure it's a smooth progression.
11.) If everything is good, flash the map, rinse and repeat until you are within 5% error for your pull.
12.) After everything is set without boost, start adding boost back in. If you made major changes to the maf scaling while doing the middle of the maf, you can guess what changes will need to be made in the upper part of the maf. Keep going through this process until your afrs are within 5% for the entire pull at full boost.
13.) Now that you have your maf table dialled in, you can start leaning out your fuel targets.
    1. Look through the OEM map; it's a good starting point. Notice the pattern in the map. Notice where the mixture is the leanest. (it should be around peak boost)
    2. Set the OL areas that are lean a little leaner. Then smooth the map.
    3. Keep making small changes and testing until you reach your theoretical target afr.

WHAT TO WATCH FOR:

1) Knock: Make sure you're not seeing any knock. You shouldn't since you pulled timing, but if you do, it might be a good indication that you don't want to run that lean in cell the you were in when the car knocked. If you do, just enrich the fuel a bit and smooth out.
2) Jagged MAF curve: If the MAF scaling curve is not smooth, you probably have a mechanical problem like a bad intake or leak somewhere. The curve can have little kinks in it, but they should just be barely noticeable when you look at the graph. And defiantly no spikes.

3) Large differences in target/measured AFRs: Means your MAF is not scaled correctly. You will need to rescale again.
4) Larger max load: You might see a load that's larger than your max load column. If you see if frequently, you might have to rescale your load again.
5) Maxing out your MAF: If your MAF voltage is increasing while your MAF value (g/sec) is pegged at 300, you maxed out your MAF. The best way to fix this would be to get a larger diameter intake (Perrin big MAF). This will force you to rescale your entire MAF. What this intake would do is cause a lower voltage values to correspond to higher air flow. If in the original intake, 4.6 volts corresponded to 300 g/sec, on the new intake, 4.6v might correspond to 400g/sec.

WIDEBAND O2 DELAY

Depending on your setup, there might be a delay between the intake and the wideband o2 readings. Especially if you're running a fmic. The maf is separated from the wideband by a couple feet of plumbing. So in areas where the maf readings are changing quickly, it might take a couple milliseconds for the air the the maf read to be processed by the engine and put through the wideband causing an offset in your log. To make the fuel tuning more accurate, you need to figure out how many row in your log separate the AFR reading from the corresponding MAF reading. To do this when scaling your maf, look for an easily noticeable dip or spike in the MAF voltage and find a corresponding reaction that spike or dip would create with the AFRs. Find how many lines the AFR reading is lagging behind the MAF reading by matching up the cause and effect. With my fmic setup, I noticed that the afr readings are 2 to 3 rows behind the maf. This was while logging minimum parameters because the more parameters you log, the more lines you will have in the log since it takes a shorter amount of time to retrieve the data.

SCALING LOAD:

It might be a good idea to rescale your load in your Primary OL fueling map if you switched from a small to a large turbo and your logs are seeing much higher loads then the current map. So if your stock map has a max load of 2.5 and you're seeing 3.6 loads in your log, it might be a good idea to rescale the OL part of the map so you can get to your WOT targets more gradually. In other words, in stock configuration, you would hit a 2.5 load and hover around there for a bit during a WOT run. While getting to that load your fuel targets would gradually drop from 14.7 to 10.06. Now with the bigger turbo you hit a 2.5 load really quick and spend more time in the 3.6 load area. If you have your fuel target (say 11) in the 2.5 load column, you're running a 11 afr from 2.5 to 3.6 load. So you'll drop to your WOT fuel target much faster. Or you're hitting your fuel target way before you hit your max load where before you were hitting your fuel target at max. Another way of looking at this is that you're setting how quickly you will drop to your WOT targets during your WOT runs. Keep in mind you don't have to do this. Some people like to run a little rich during spool, but it's all up to you.

To rescale your load:

1) Do a couple of WOT runs logging
    a. Load
    b. RPM
    c. CL/OL Status
    d. Boost (to make sure you're hitting target)
    e. Wideband o2 (to make sure you fueling is good)
    f. FBKC to make sure you're not knocking.

2) Look through your logs and find out where you are switching from CL to OL. Or look at your stock map and see at what load your fuel targets start dropping from 14.7
3) Look through your log and find the max load
4) Enter your max load in the right most column

5) Smooth from the right most column to the column where you start dropping to a richer afr.
6) Go do some more logging to double check your work. Make sure you're not knocking, are meeting your fuel targets, and no spikes in fueling error.

TIP-IN-ENRICHMENT

Up to now, we have only tuned steady throttle air/fuel calibrations. So now we need to account for rapid changes in throttle. As the throttle angle changes suddenly, there is a extra burst of air that enters the engine, so you need extra fuel to deal with the extra air. Tip-in represent an extra and separate firing of your injectors due to accommodate the extra air. You will need a wideband to tune this table properly.

Tip in divided into 3 parts: Throttle Tip in, Tip-in Boost, Tip in coolant

TIP IN COOLANT:

Most people don't mess with this, but since tip in is a separate firing of the injectors, you might want to multiply the values by (old injector size / new injector size) so you reduce the tip-in coolant values to compensate for the bigger injectors.

TIP IN THROTTLE:

1.) Set all your tip in boost corrections to 0
2.) Make sure the car is up to temp to eliminate tip in based on coolant
3.) Find a place you can drive around in an erratic manner and do the following:
    a. Log the following parameters
        i. Engine Speed
        ii. CL / OL status
        iii. Throttle
        iv. Boost Error (for reference)
        v. Wideband
        vi. Tip in throttle (change in throttle used for tip-in)
    b. Start at idle and stab the throttle down and hold it for a bit. You want to hold it down long enough for the AFRs to settle
    c. Do this for various angle changes. Small stabs to bigger stabs
    d. After you have this done, do get more date in 1^{st}, 2^{nd}, 3^{rd} and 4^{th}
    e. Now you need to sort the data
        i. Get rid of any lines where you were in OL
        ii. Get rid of any lines where your have large boost errors
        iii. For each line in the log, find the error. Your error will be (wideband-14.7)/14.7
        iv. Find the correction factor for each line. It will be (1-error)/2
        v. Find out what throttle change bin each correction factor belongs to
        vi. Put each correction factor from each into the appropriate throttle change bin
        vii. Apply the correction factors
        viii. Flash map. Rinse and repeat until your within 15%

TIP IN BOOST:

If you have a fmic, you will leave this table zeroed out. Reason behind this is that the fmic piping is much longer than the stock tmic so the boost error will have little effect on tip in. If you have a tmic, you will do the following

1.) Put back the boost error corrections your had
2.) Multiply them by a correction factor for your injectors. (old size / new size)
3.) Go out and do the same thing you did for tip in throttle, except do it in 5th or 6th gear. You want to see what happens when you have boost errors introduced.
4.) Don't get rid of any boost error lines this time and sort the logs so your corrections are now grouped into the correct boost error bin
5.) Apply corrections, reflash, and retry

Tuning Timing

Here we will adjust the timing advance maximum as well as the base timing. The timing advance (maximum) table in RomRaider is the same as dynamic advance in street tuner. When tuning, the car is most likely to knock during peak torque and therefore that is where you will be able to run the least amount of timing. Timing will increase as engine speed increases to keep up with the faster moving pistons. It will also increase as load decreased since your VE is lower so you advance timing to raise it. One thing you need to decide is what table to adjust in the ECU. You can add or subtract timing from the base timing or the timing advance. There is no clear answer what table to modify; it's a highly controversial topic. You want to have enough values in the timing advance table in case your IAM drops, but not so much that the car will not run correctly if it does drop. One of the accepted methods is to smooth out the timing advance table and make the highest values slightly higher than stock. Then tune the rest using the base timing table.

Before you start, you will also need to download the ECU Learning tool from HERE. This tool will read your stored learned knock correction values. Street tuner has a special function to do this as well. You want to repeatedly check your FLKC values and your IAM as your tune and drive.

Before you do anything, make sure your IAM is at 16 (16bit) or 1 (32 bit). If it's not, your engine isn't happy and you need to fix it. This could for just for the simple reason that every time your ecu is reset, the IAM starts off at a given value written in the initial IAM Value table. I changed mine to 1 so my IAM is maxed out from the get go. Otherwise you'll need to drive around a bit until your IAM maxes out. If it doesn't max out after a while you could either have a mechanical problem or need to adjust the timing in the trouble areas first.

IF YOU HAVE FLKC OR A NON MAXED OUT IAM:

1.) Look up timing maps for similar setups on the forums and compare
2.) Ask around if you can't find anything. Someone will help you
3.) Inspect the car and make sure everything is working mechanically and you don't have stuff rattling inside the engine bay.
4.) If you don't find your answer, drive around and collect as much data as you can about where the knocks are happening. So log your rpm and load as well as FLKC and FBKC. Then, where ever you see a knock in your log, line that up with a rpm and load cell in your timing maps. Pay attention to how many knock events occur in the area and how severe. A little knock here and there is normal, but not large corrections repeatedly.
5.) From there try lowering the timing in the areas of the timing map where you see repeated knock. Sometimes you car will knock if you have too low of timing, which is why you should compare your map to others. You don't want to get paranoid and pull too much timing.
6.) Keep working on this until your IAM is at full value and your FLKC is empty.

TUNE TIMING AT WOT

1) Before you go and start experimenting, again look through the internet or ask around to see what type if timing other people are running. Look at a couple basemaps for similar setups to give you an idea of what to expect. Look for what people run at redline and at peak torque. Peak torque will be your lowest timing and redline will usually be the highest. Then you just smooth in-between.
2) Make sure you have your conservative timing map loaded. We pulled 4 degrees last time from the original map.
3) You will be doing 3 WOT runs per iteration till redline logging your:
    a. RPM
    b. Engine Load
    c. current applied FLKC
    d. FBKC
    e. IAM
    f. Throttle Position
4) Do a couple WOT pulls logging the parameters mentioned above. If you hear you car knocking (it's audible sometimes, sounds like tinny metal balls rattling in a coffee can) get off the gas, do not finish the pull. It also helps to have someone with you watching the fbkc on the laptop so they can tell you if you're pulling timing. If you have any knock, stop the logging, you need to adjust your timing.
5) Make sure you do not have any knock being reported anywhere in your log.
6) If everything is good and you’re not seeing any knock, you can start adding timing back in. Add only a little bit at a time smooth your map.
7) You can keep adding knock until you start seeing knock show up. At that point, it’s a good idea to pull some timing to give you some overheard room. You can pull half a degree or a full degree, depends on how aggressive you want your tune to be. You are basically just feeling out the map to find the edge of knock then back off a bit once you find it.
8) You know your are done if didn't knock at all for a conservative tune and had 2 individual knock events for an aggressive tune during a full WOT pull. You will usually have a little FBKC here are there, but not consistently, so don't go crazy making sure it's always 0.

Most people want to tune to the edge of knock. That means they advance the timing as much as possible in each cell you hit during a WOT pull. Some consider this aggressive since you're just about to knock every time you do a WOT run and if something isn't right, you will knock. To me, it might seem like a good idea to pull a little bit of timing back out at this point. Just a small bit to make sure you're not always at the edge.

RESCALING TIMING LOAD

This is done the same way and for the same reason as rescaling the OL Fueling table. You will be telling the car how quickly you want to drop to your WOT timing values during a WOT pull. See the fuel map rescaling section for details.

Tuning AVCS

This idea behind advancing AVCS is to increase your VE (volumetric efficiency). Before we start tuning AVCS, we need to figure out how to calculate VE. The accepted method can be found at:

Speed Density FAQ (RomRaider)

Or the Freon's formula is the following:

```
VE = MAF(g/sec) / (2.457* A * RPM * 0.003871098 / (IAT + Temp))
A = (boost pressure + sea level pressure)/(14.7*760)
Temp = IAT in Celsius + 273.5
      or in Fahrenheit it's (5/9)*(IAT-32)+273.15
```

Another thing to look through are the test results form a member experimenting with AVCS.

AVCS Research - 03" ADM STi (RomRaider)

Those will give you a better idea on what happens when you change the values. Knowing how avcs advance will affect your VE, we can start tuning.

TUNING AVCS:

1) Reduce your timing a bit as well as add fuel. Since you are going to be increasing VE, it might cause a lean condition that leads to knocking. This is a precaution; we will fix the values later.
2) Rescale your AVCS table for load (same as OL Fueling rescaling)
3) Go out and do a WOT pull logging
    a. RPM,
    b. Load
    c. MAF (g/s)
    d. Boost
    e. IAT.
4) Calculate the VE for each line in your log
5) Group the rows into bins by the load and rpm you see
6) Take the average per bin. This will be your baseline
7) Since you don’t know exactly how VE will behave due the variations in exhaust design, turbo design, and other stuff, we will make little changes in VE and see if it got any better.
8) Make some small changes in the VE table and flash the map.
9) Go out and log again and see if the change increased your VE.
10) Keep doing this until you get the best VE
11) Retune your Fuel and Timing.

Tuning cruise

We now tuned boost, fuel, and timing to get the most power during WOT runs. Now we want to switch our focus to everyday driving.

GET A SMOOTH IDLE:

If you switched to larger injectors, you might want to raise the idle RPM by about 100 to keep the engine from stumbling.
Double check the MAF scaling at idle

TUNE YOUR MAF RPM/BOOST CORRECTION TABLE

The MAF Engine Load Compensation table is key to getting a big maf to run and idle smoothly. This table make corrections to your maf readings based on engine load and boost. This is mostly for the CL part of the maf. To tune this table, you will need to download airboy’s engine load comp mrp worksheet available in the utilities sub forum on RomRaider. Follow the instructions in the worksheet and update the table to dial in this table.

REQUESTED TORQUE:

This table establishes a relationship between the input from the gas pedal to the opening of the throttle plate. By adjusting this table, you adjust how much the throttle plate opens with a given input. The

Target Throttle Plate Position tables have the desired throttle opening angles for different requested torque inputs. Notice that they are only scaled to a given value. Meaning on my ROM, the TTPP table is scaled only to 320. So if my requested torque is more than 320, the throttle will be open 100%. There really is no tuning method for this, just make small changes and see what kind of response you get.

TUNE YOUR CRUISE VE AND TIMING

Your cruise boost and AFRs are already tuned. You can't tune for boost since during cruise you are not making much boost and the amount you do make is dictated by your wastegate and turbo, nothing in the ECU. The AFRs are in closed loop, so the ECU is automatically trying to get them to 14.7. So now you just need to make sure you are not knocking anywhere in the map while cruising and that your VE is good.

To do this, you just use the spreadsheet made by merchgod found at:

Spreadsheet to track Knock and VE (RomRaider)

You just follow the instructions in the spread sheet and it will help you figure out where you need to add or pull timing during cruise and what to do with your VE.

All Done

I guess that should take care of most things. I've read tons of threads that I pulled bits of info out of. But the RomRaider forums are a great resource, Tea Cups, merchgod, mickeyd2005, Tgui, Clark tuner, and most of the senior guys know this stuff inside and out. So it'd probably be a good idea to read their posts and listen to their advice. I tried to keep a list of the sources that contained good amounts of info. The rest of the info i found scattered throughout posts.

Some more reading

Turbocharger Compressor Calculations (Turbo Regal)
Compressor Maps (zTechz)
Heat Exchanger Theory and Intercoolers (Turbo Regal)
How intercooler's work and effect your engine (Rap Worlds)
Guide to boost controllers (SPL Parts)
Turbo dynamics and boost control explained (RomRaider)
Tuning Your Ford EFI System - Inside The Black Box (Muscle Mustangs & Fast Fords)
How Gasoline Works (How Stuff Works)
Closed Loop to Open Loop fueling transition explained (RomRaider)
Turbo Dynamics and boost control explained (Nasioc)
Subaru's Knock Control Explained (Nasioc)
Active Valve Control (Subaru Drive magazine)
Volumetric Efficiency (Wikipedia)
Let's talk AVCS tuning (Nasioc)
HOWTO: One Man's Way of Scaling a MAF (Nasioc)
AccessTUNER Tuning Guide (Cobb)
Emanage + GM Boost Solenoid (3si.org)
How to adjust the requested torque table (RomRaider)