An Introduction to Tuning

by Lynn Chamberlain, CPL Racing

Following CPL Racing's first article in this magazine, 'Evaluating Performance', we are going to study management systems and engine tuning.

Before we progress to look at what the engine management system can do in detail, it is worth mentioning that it is not the engine management system itself that provides the gains. What it does is to allow the tuner to maximize power and torque increases, given the setup of the car, by optimising fuelling, ignition timing and other variables. It should be noted that, on Honda K-Series engines, it is still possible to get worthwhile gains using a Hondata system alone, on an otherwise stock car.

Taking an example, if a good exhaust manifold is fitted to, let's say, a Honda K-Series vehicle, the gains will only be modest. Fit a good engine management system, have the car tuned by an expert and the gains in power and torque will increase considerably, as can be seen on the dyno chart in figure 1 opposite.

If tuning is not merely about the engine management system, what else is there to consider? Well, firstly, the design of the air intake and exhaust system is an essential element of tuning. Just fitting any make or design of air intake, cat-back exhaust or exhaust manifold will not necessarily mean that good gains can be achieved. To give some idea of how important the design of these parts is, at CPL Racing, we spent a year and a half optimising the design of our FN2 cold air intake system and, similarly, the exhaust manifold also took over a year before we were satisfied that we had the best design that would achieve the optimal gains. If mere fitment and cosmetic appearance were the only consideration, then both of these products could have been put to market in a matter of a few weeks.

Moving on from the air intake and exhaust, there are the inlet manifold, and camshaft profiles and so on to consider, depending upon how far you want to go in upgrading the car. As an example, too often we have seen customers purchase camshafts off-the-shelf, because it is believed that power gains are inevitable by fitting different camshafts. This is not the case, as many manufacturers produce several camshaft options , although only one, if any of them, will provide the optimum power increase. To ascertain which camshafts are the most suitable demands an extensive understanding of the camshaft profiles, what they will do to the engine and how they will perform in combination with the other modifications on the car. An experienced specialist Honda tuner will also have access to past data on an extensive range of setups, in order to analyse which combinations work best on any given vehicle.

It is not just the choice of air intakes, exhausts and camshafts that are important but the explanation above seeks to demonstrate that the act of merely purchasing performance parts and bolting them onto your car may not, in itself, increase performance, even though you may gain a psychological boost for a moment. The parts added must be correct modifications. They must work in combination with other modifications already made and, then, the power and performance of the engine should be optimised by the tuner, using a good testing facility (dyno and test cell) and engine management system.

In respect to engine management, we asked Doug MacMillan of Hondata to talk readers through this subject. Clearly, years of knowledge, experience and R&D cannot be condensed into a few magazine pages, however Doug has provided a high level summary on this complex subject.

Tuning Honda Engines

- by Doug MacMillan, Hondata

Basics of the Honda Engine – What is different.

Hondata is a US-based company founded by two New Zealanders, Derek Stevens and Doug Macmillan, both sharing a passion for racing Hondas. Our first Hondas were the mid to late-1980's Honda CRX but it was the release of the VTEC Honda CRX in 1990, with its magnificent B16a engine, that opened our eyes to the potential of tuning these units.

VTEC

VTEC (Variable Timing and lift Electronic Control) essentially gives you two engines in one, a mild-mannered, quiet, smooth-idling and torquey unit, coupled to a high RPM, screaming, rorty engine.

Essentially, what determines the characteristics of an engine is the shape of the camshaft lobes, which control the opening and closing of the valves. A camshaft lobe that opens for a short period, with medium valve lift, allows the engine to idle well with great emissions. This kind of camshaft lobe restricts the amount of air that can be drawn into the cylinder at high RPM. A camshaft that opens for a long period, with high valve lift, is great for high RPM operation and ingesting large amounts of air but, usually, it is very poor at idling.

VTEC Honda engines feature two camshaft profiles, with the ability to switch hydraulically from one to the other, at a set RPM. VTEC is not only great for power but also great for fuel economy. Many variations of Honda engines use VTEC for virtually disabling one set of intake valves, switching from a 16 to a 12-valve engine for better MPG at low RPM.

As Honda VTEC engines are essentially two engines in one, the tuning of the engine computer follows suit. All Honda VTEC engines have at least two fuel and two ignition maps, one for each camshaft profile. When the computer instructs the VTEC mechanism to shift to the high-speed camshaft, it also switches to the high-speed fuel and ignition maps.

The RPM and load point, at which the VTEC switches, on a modified engine, should be tuned on the dyno. Basically, the engine should stay on the low cam until it makes more torque on the high cam. It is a common misconception that the VTEC point is chosen by the customer, by preference. In fact, the VTEC point is dictated to the tuner by the characteristics such as exhaust manifold design, camshaft profile, induction length and so on. In figure 2, it can be seen that the VTEC (crossover) point could, in theory, be either 3,000rpm or 5,300rpm. In this particular instance, the CPL tuner set the VTEC point at 5,300rpm, as

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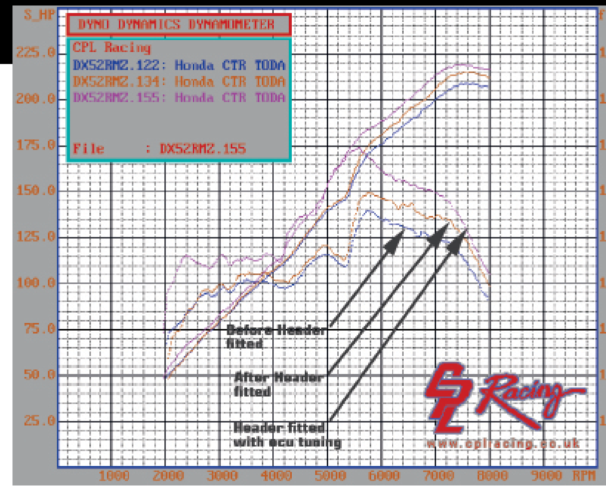

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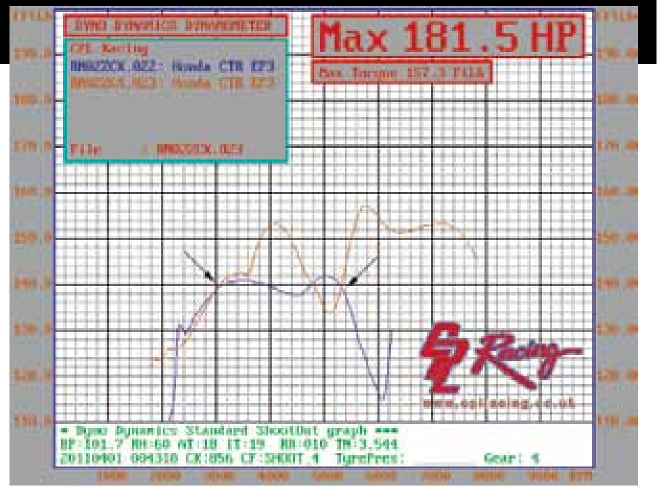


3,000 rpm was too low and would have created a torque curve of peaks and troughs.

IVTEC

The introduction of the K20 based Civic Type R added a new and exciting dimension to Honda performance, which is an ability to rotate the intake camshaft through a staggering 50 crankshaft degrees, controlling the time at which the camshaft opened the intake valve. In addition to a high-speed and low-speed cam, the entire intake camshaft could be rotated rapidly to a desired position. Think, here, of cam gears that can be adjusted 'on the fly'. As the engine characteristics vary tremendously between 0 and 50 degrees intake cam position, Honda maps the fuel and ignition for 0, 10, 20, 30, 40 and 50 degrees, for both low and high-speed cams. If you look at the mathematics, you can see that amounts to 12 x fuel and 12 x ignition maps, but do not worry, it does not take 12 times as long to tune as a conventional non-VTEC engine, although it does take maybe 2-3 times longer.

The K20 engine is the jewel in the crown of Honda production units. It responds extremely well to modifications and tuning, frequently producing more mid-range torque and top-end power than other larger naturally-aspirated four-cylinder engines.

BASICS

Firstly, it is important to understand how the Honda ECU determines the appropriate settings for the engine. For most performance engines prior to the latest Civic Type R (FN2), it uses the speed/density method of calculating these values. The ECU uses the intake manifold pressure and engine speed to index lookup tables for ignition and fuel (among other things). Other parameters such as coolant temperature, battery voltage and intake air temperature are used to compensate the table lookup values for the engine. To tune the engine, we alter the main tables (fuel and ignition) to suit the particular configuration of the unit.

A typical fuel table is shown on the next page in figure 3.

The indices used are rpm (along the bottom) and intake manifold pressure (along the side). The ECU uses interpolation to calculate values from the table, which do not fall exactly on a row or column index, for example, if an ignition table contains 20 degrees advance at 2,000rpm and 10 degrees advance at 3,000rpm, when the engine speed is 2,500rpm, the ignition advance will be 15 degrees. The interpolation actually occurs in two dimensions (engine speed and engine load).

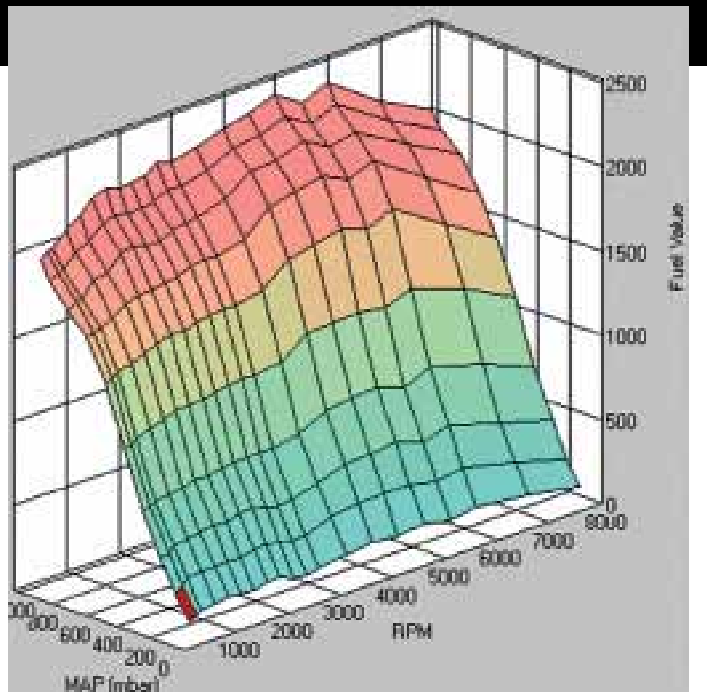
IGNITION TUNING

In general, the function of ignition timing is to ignite the mixture so that the flame front hits the piston in the region of 15 degrees past top-dead-centre, as it is descending. The more air/fuel mix there is in the cylinder, such as by forced induction, the closer the molecules are together and the faster the mixture will burn. The faster it burns, the more you need to delay the timing. In the example below, in figure 3, the ignition timing is set to 26 degrees before the piston reaches top-dead-centre at 6,400rpm (full throttle). This tells you that the engine rotates at least 37 degrees (26+15) after firing the spark, before the flame front reaches the piston.

See figure 4

The best way to determine the correct ignition advance at

3



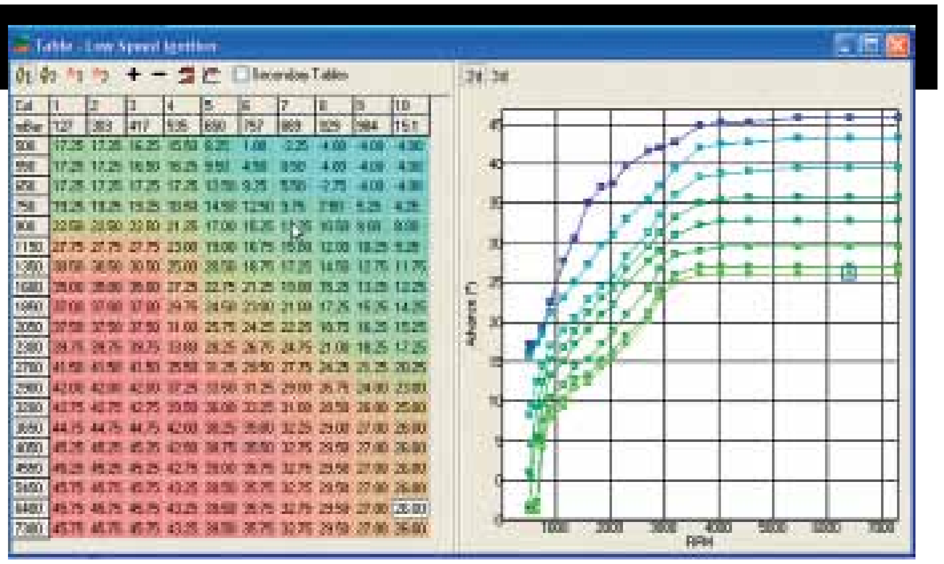
full load is by using a dyno. Generally, for naturally-aspirated engines, it is safe to set the advance near to maximum power, with the aim being to run the least amount of timing possible. A good procedure is to tune for maximum torque then retard the timing until you just start to lose power (around 1 bhp). At all times, engine knock should be monitored to make sure there is no detonation (even for a naturally-aspirated motor). If 'pinging' is audible, or the ECU shows that the engine is knocking, then it is advisable to abort the dyno run, retard timing/add fuel and restart the run.

With forced induction engines, it is important not to over-advance the ignition, otherwise the engine will be damaged in only a few seconds. Conservative ignition settings should be used, the knock sensor should be monitored and the dyno run aborted if the engine shows signs of knock, 'pinging' or detonation.

Excessive ignition advance will damage the engine. The combustion pressure and load on the engine (especially bearing stress) increase dramatically, if the engine is over-advanced. Do not believe the fallacy that 'more is better' for ignition advance. Too little ignition advance can also damage the engine by increasing the exhaust gas temperature, especially with turbo-charged engines. Do not rely on the knock sensor to retard the ignition timing if the engine detonates.

Tuning ignition advance at part-throttle is more difficult than at full-throttle, because it is difficult to determine accurately the correct settings. This should be carried out on a load bearing dyno, with good temperature control, an EGT gauge can be used to help determine the best ignition advance.

4



FUEL TUNING

Speed/density (MAP):

Speed density uses the manifold pressure sensor (MAP) to measure the intake manifold pressure, it then uses volumetric efficiency lookup tables indexed by engine speed to find the mass of air entering the engine. Other parameters, such as coolant temperature, battery voltage and intake air temperature, are used to compensate the table lookup values for the engine. To tune the engine, we alter the main volumetric efficiency tables to suit the particular configuration

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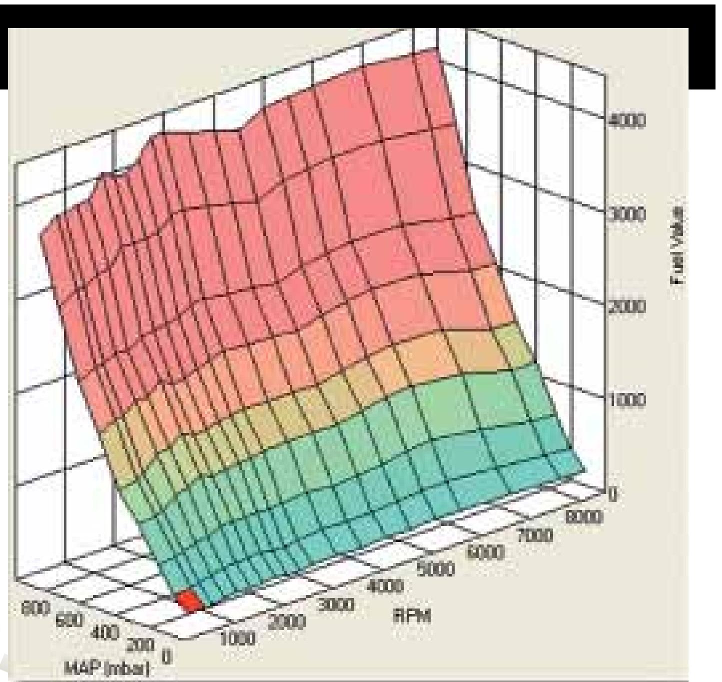


TYPICAL VOLUMETRIC EFFICIENCY / FUEL TABLE.

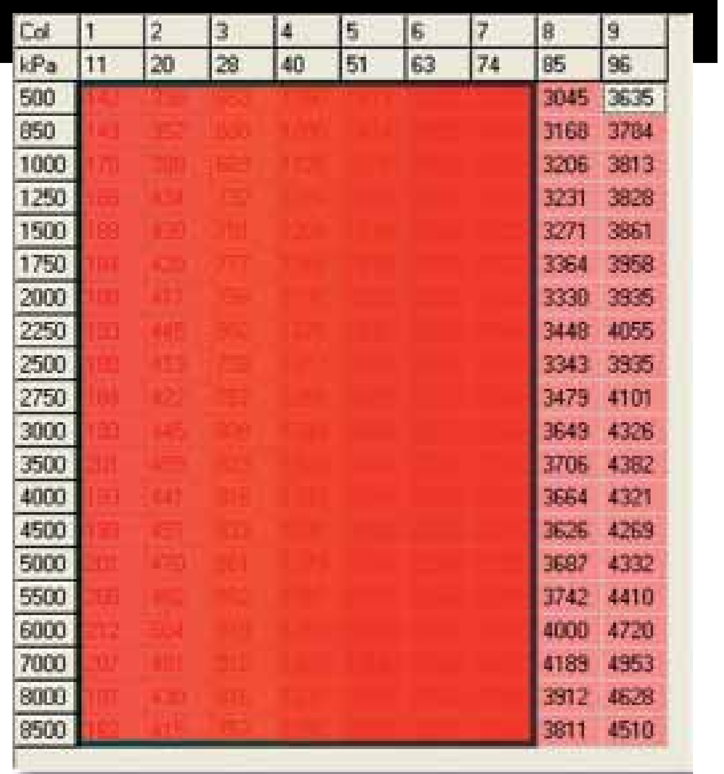
A typical volumetric efficiency/fuel table is shown in figure 5.

The indices used are RPM (along the bottom) and intake manifold pressure (along the side). The ECU uses interpolation to calculate values from the table, which do not fall exactly on a row or column index. At sea level, manifold pressure is approximately 1000mbar at full throttle. As you climb in altitude, the manifold air pressure drops at wide-open throttle. For example, at an altitude of 2km, manifold air pressure at wide-open throttle is around 900mbar, or ten per cent less than at sea level.

The fuel tables are used for both part throttle / low load / closed loop, and full throttle / high load / open loop operation.

See figure 6 - low load fuel

6



Col	1	2	3	4	5	6	7	8	9
kPa	11	20	28	40	51	63	74	85	96
500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3045	3635
850	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3168	3784
1000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3206	3813
1250	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3231	3828
1500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3271	3861
1750	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3364	3958
2000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3330	3935
2250	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3448	4055
2500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3343	3935
2750	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3479	4101
3000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3649	4326
3500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3706	4382
4000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3664	4321
4500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3626	4269
5000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3687	4332
5500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3742	4410
6000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4000	4720
7000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4189	4953
8000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3912	4628
8500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3811	4510

PART THROTTLE / LOW LOAD FUEL REGION.

This region of the fuel table should be tuned to stoichiometry (approx 14.7:1 air/fuel ratio). 14.7:1 is the ratio at which catalytic converters work best and results in the cleanest exhaust emissions.

The full load values depend on your altitude, but are typically tuned to 13:1 air/fuel ratio for maximum power.

TUNING FOR FORCED INDUCTION

We use the same principles, as above, for a naturally-aspirated engine but with a richer mixture (typically 11.5-12:1 air fuel ratio) to run cooler and less ignition timing as the mixture burns faster.

SUMMARY

Obviously, engine tuning theory is a highly detailed field of study. Resources are available, however there is no substitute for having your car professionally tuned by an expert possessing detailed knowledge of your particular engine. As mentioned in CPL Racing's previous technical feature, the quality of the testing environment itself is highly important and should simulate as far as possible 'real world' conditions. A good quality dyno and a well-designed dyno cell are key elements in tuning the car, as well as the quality of the engine management system and knowledge and skill of the tuner.

So, we have now discussed how to evaluate the performance of your vehicle and also studied the use of an engine management system. In issue 3, we shall be expanding on this and looking in further detail at optimization and tuning. ■

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