ENGINE MAPPING FUNDAMENTALS

Words and photos: Chip

Last month we covered aftermarket ECUs. This month we look at what other equipment you need and what you're aiming to avoid during mapping.

THINGS TO AVOID

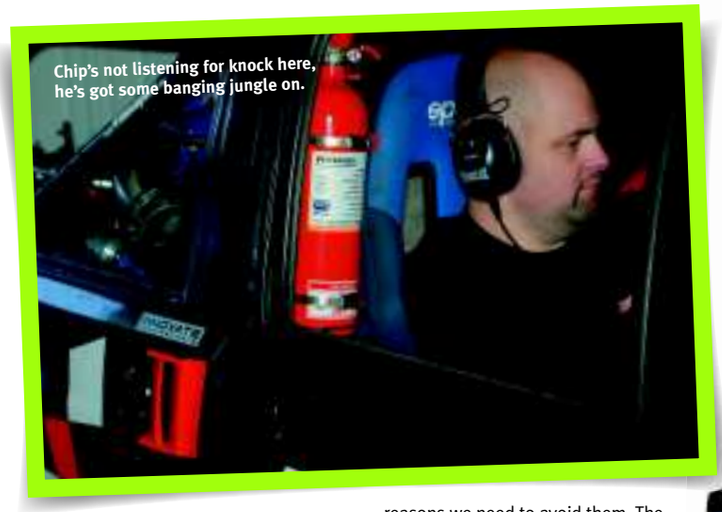
Before we start talking next month about what we want to achieve when tuning an engine, we're going to get you up to speed with the infinitely more important details of what to avoid when mapping. The two things that will kill your engine quicker than anything else are detonation and excessive exhaust gas temperature.

Detonation

Detonation, just like the name implies, is an explosion that happens inside your engine. It's a common misconception that in normal operation the fuel and air that go into our engines explodes when the spark plug fires, but this is actually not the case. When the spark plug fires, a flame starts and this flame then spreads through the fuel and air present in the cylinder as a burn. It happens incredibly quickly, but it does not happen instantaneously. The flame burns from the top downwards, making its way down the bore, consuming fuel and air as the flame front moves ever onwards, in a similar way to how a fire can spread through a forest - starting at one side and gradually working its way across to the other.

As the flame front progresses the fuel and air that it burns are taking part in an exothermic reaction, meaning that heat is generated. The other product generated by this exothermic reaction is exhaust gasses, and in doing so the combination of extra gas and extra heat creates a massive increase in pressure within the cylinder. This pressure increase is what drives the piston down the bore to turn the crank and produce power from the engine.

If the pressure in the cylinder gets too high it can cause fuel to ignite not as a result of the flame front reaching it, but spontaneously purely due to the molecules becoming so excited by pressure that a reaction occurs without the need for a flame to initiate it. When this starts to happen it generates yet more pressure and the whole reaction spirals out of control in an instant and a complete combustion cycle's worth of exhaust gas is produced in only a couple of degrees of crank rotation. Although fuelling has an effect in terms of the volatility of the mixture in the first place (a lean mixture is more likely to detonate) the key thing when tuning an engine in terms of controlling detonation is


Chip's not listening for knock here, he's got some banging jungle on.

the ignition map. By retarding the ignition (firing the spark plug later) the risk of detonation occurring is reduced and also lessened in severity when it does actually occur.

High EGTs

Exhaust gas temperature is a slightly confusing term that potentially leads you to think of gas temperatures inside the physical exhaust system on the car after they leave the engine itself, but that isn't the first point at which the temperatures become important to us. We're interested in the temperature of the gasses as soon as they start to rise within the engine.

Exhaust gas temperatures are a double-edged sword; there are two reasons we need to avoid them. The first is their effect on the detonation. As the temperature inside the cylinder increases, the pressure point at which detonation will occur is decreased as the molecules are excited not just by pressure but also by heat, so if things get too hot, detonation can occur sooner as a result of this rise in temperature. The second reason that we need to avoid excessive gas temperatures is that they can cause anything in the engine they come into contact with to become soft, or in extreme cases melt.

Pistons are made of aluminium and the melting point of aluminium is 660 degrees. The exhaust valves will be made of steel and depending on their composition, their melting point will be between 1200 and 1500 degrees. Damage to a valve can occur long before this though as the combination of heat and the hammering that they get from being opened and shut at high rpm can cause excessive fatigue, ultimately leading to failure. Another victim of high EGTs can be piston rings - the chrome can literally be separated from the rings, leading to excess wear of the cylinder bore.


High exhaust gas temperatures can cause pistons to melt and lead to piston rings becoming seperated from the piston - resulting in increased wear of the bore.

EQUIPMENT USED FOR MAPPING A CAR

Air-Fuel ratio monitoring

When we are mapping the fuelling for an engine, we need to be able to see what effects our changes are having to the air-fuel Ratio (AFR) within the engine. The air-fuel ratio is a measure of the number of parts of air to the number of parts of fuel, so for example 10:1 (very rich) or 17:1 (very lean). A wideband AFR gauge provides a digital readout of exactly what the AFR is doing in real time.

Wideband AFR gauges themselves come in two types - either a handheld device that can easily be moved from car to car when tuning, or as a permanently installed gauge. Going back a few years this was very expensive technology but these days a wideband lambda setup can be picked up for as little as a couple of hundred pounds. The reason that monitoring AFRs is so important is that a lean mixture is a major contributing factor towards excessive EGTs and often the first action to take to control EGTs when they go high is to richen up the fuel mixture.

Knock detection

The main way that we typically detect detonation when mapping a car is with our ears. When knock occurs it makes a tapping sound (referred to as 'knock') that can be heard using headphones attached to the engine. Headphones can either be in the form of a mechanical stethoscope or an electronic setup with a microphone (known as a knock sensor) attached to the engine and a set of electronic headphones for the mapper to wear.

One advantage of the mechanical setup is that you can make it easily at home using some bits of plastic tubing and a set of workman's headphones, where as typically the electronic versions will cost several hundred pounds. The disadvantages with the mechanical setup are that it is harder to move between cars because it can be awkward routing the pipework from the engine bay into the cabin and also they have no form of volume control, whereas on the electronic setups there is a volume knob on the control box.

One company right at the cutting edge of knock detection is Phormula. Their electronic knock detection kits go a couple of steps further than merely providing you with headphones to hear knock with, they give you both a digital representation of knock levels on a compact screen and also a 0-5V output giving a representation of knock that can then be fed into an ECU or a data logger. By monitoring normal background knock levels throughout the rev range on either the screen or with a data logger it becomes very apparent when detonation occurs and the level changes. This can be particularly useful if you aren't experienced at listening for knock or if you are tuning an engine where sometimes it can be difficult to be certain from listening alone if detonation has occurred or not due to the amount of valve train sounds at high rpm or other background noise.

Exhaust gas temperature monitoring

EGTs can be monitored either directly by connecting the sensor to a gauge or

by connecting the sensor into the ECU to allow you to see it on the screen while mapping. Normally the EGT probe is placed into the exhaust manifold to get it as close to the engine as possible but often on a turbo car it will be placed into the downpipe just after the turbo. If placing the sensor after the turbo, you need to allow for the fact that the exhaust gasses cool down both as a result of transferring heat into the turbo itself and also as a result of the pressure drop that occurs as the gasses exit the turbo. Typically we will work around the estimate that we have lost 100 degrees of temperature if we monitor after the turbo.

Laptop requirements

To map a car you don't need the latest high-tech laptop. The system requirements of all the aftermarket ECUs mentioned here can easily be met with a £50.00 - £100.00 second-hand laptop. Things like processor speed and hard disk size are pretty much irrelevant as the requirements in these areas are minimal; instead the things you need to be looking for are reliability and battery life. Older business machines such as IBMs and Compaqs are ideal - they are generally far better built than the cheaper makes and replacement batteries often include the option of being larger to increase the battery life. We picked up an old Compaq for £80.00 and the battery lasts a good four hours. It's taken a right battering since then, including falling off the dash of a LET-powered track day Astra onto the floor and it's still going strong despite a bit of case damage! How gutted would you be if the same thing happened to your £1000 fancy nice modern laptop?

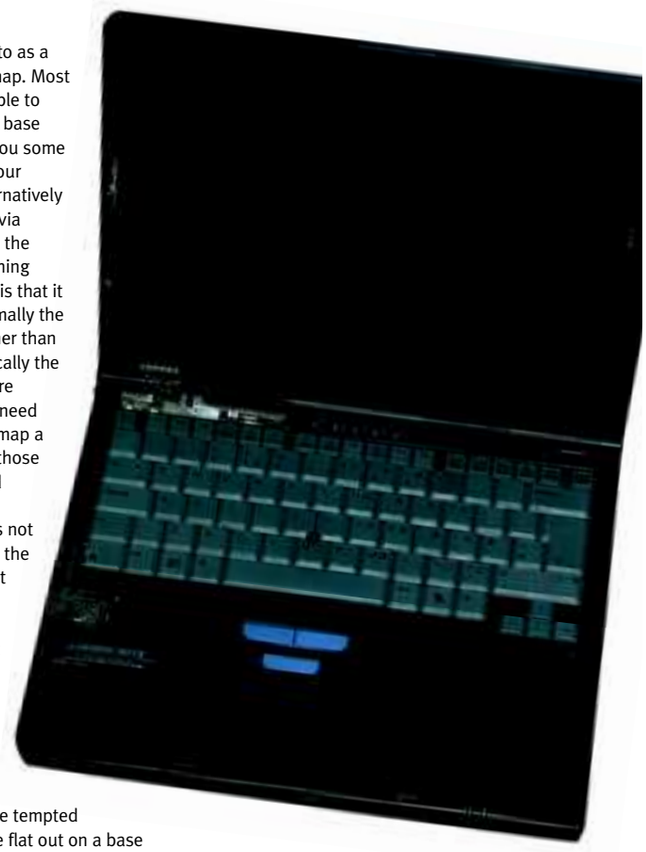
Make sure that the laptop you are looking at has the correct connection on it for the ECU you have bought. Most ECUs require a nine-pin serial port and many newer laptops won't have one of these. Adaptors can be bought but are a bit hit and miss (PCMCIA ones are typically much better than USB ones) so if you can get a laptop that has the right connection on it from the factory it means no worries about it working.

Base map

To get your car to first fire up, you need something loaded onto the ECU initially from which you can begin mapping.

This is referred to as a base or baseline map. Most suppliers will be able to provide you with a base map after asking you some questions about your application or alternatively you will find them via support forums on the internet. The key thing about a base map is that it must be safe. Normally the fuelling will be richer than you need and typically the ignition will be more retarded than you need (Chip calls a base map a footballer map as those tend to be rich and retarded too).

The base map is not about trying to get the most power or best fuel economy, it's just about getting the engine to start and to drive the car around so it can be mapped further from that starting point to get the desired end result. Don't be tempted to drive flat out on a base map without monitoring it properly, because often problems will occur if you do, and it is very important to build up gradually and map the engine as you go.



This is an exhaust gas temperature probe. Not as sexy as it sounds.

Coming up:

Issue 106:
Fuel mapping
Ignition mapping
Compensation tables
Rolling road mapping vs road mapping

Knock detection kits from the likes of Phormula are a useful and accurate way of detecting detonation.