THE EXPERT STEWART SANDERSON

Having worked as a tuner for 17 years, Stewart 'Stu' Sanderson is one of the most-respected names in the business.

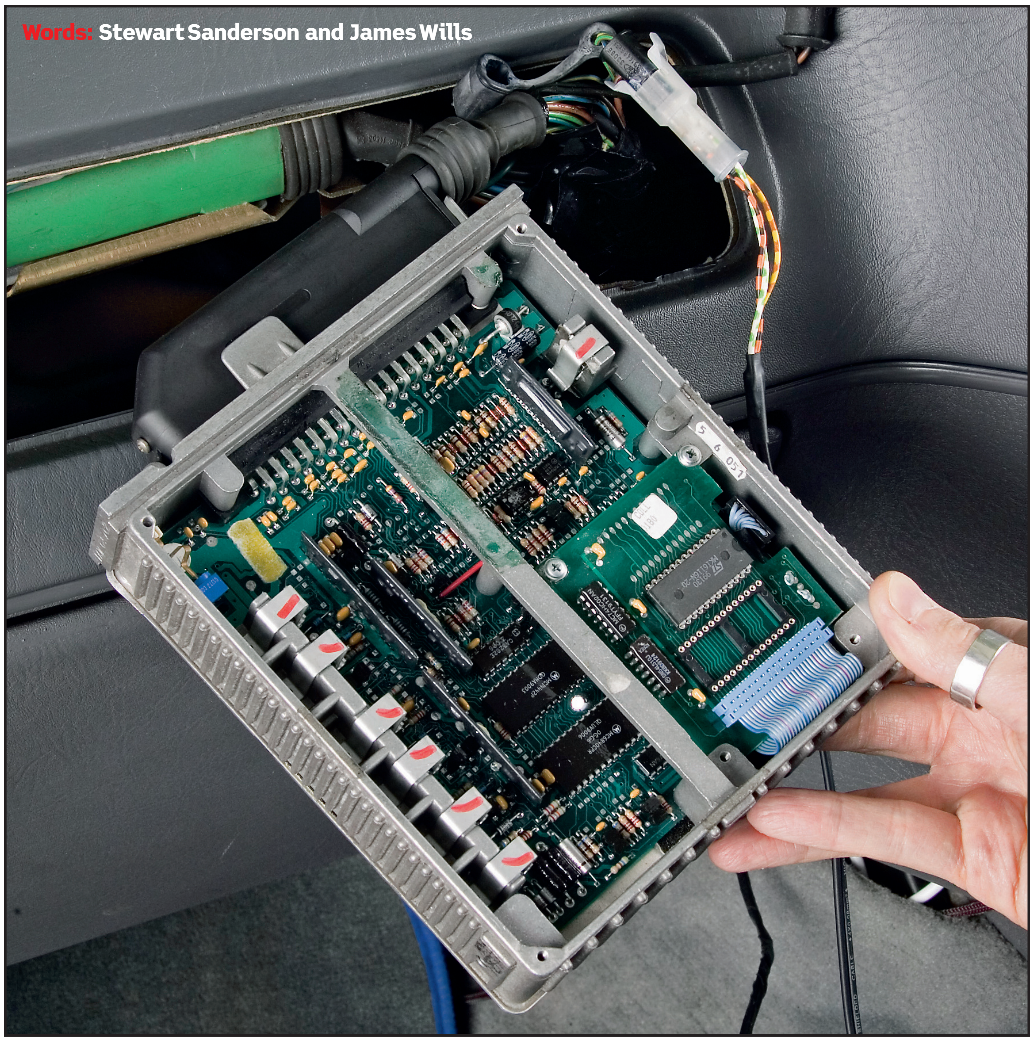
A Level 5-trained fuel-injection technician, Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

Eight years ago he joined forces with Kenny Walker and opened up Motorsport Developments near Blackpool (01253 508400, **www.remapping.co.uk**), specialising in engine management live remapping, as well as developing a range of Evolution chips which are now sold all over the world.

He is the creator and administrator of **www.passionford.com**, which he started in 2003. It has grown rapidly from a few friends contributing, to one of the biggest Ford communities on the web.

Stu's enviable knowledge of the workings of modern-day Ford performance engines means that every month he's just the man to explain how and why things work, and importantly how they can be improved.

Words: Stewart Sanderson and James Wills



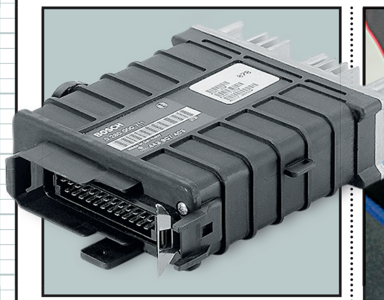
ENGINE MANAGEMENT SYSTEMS

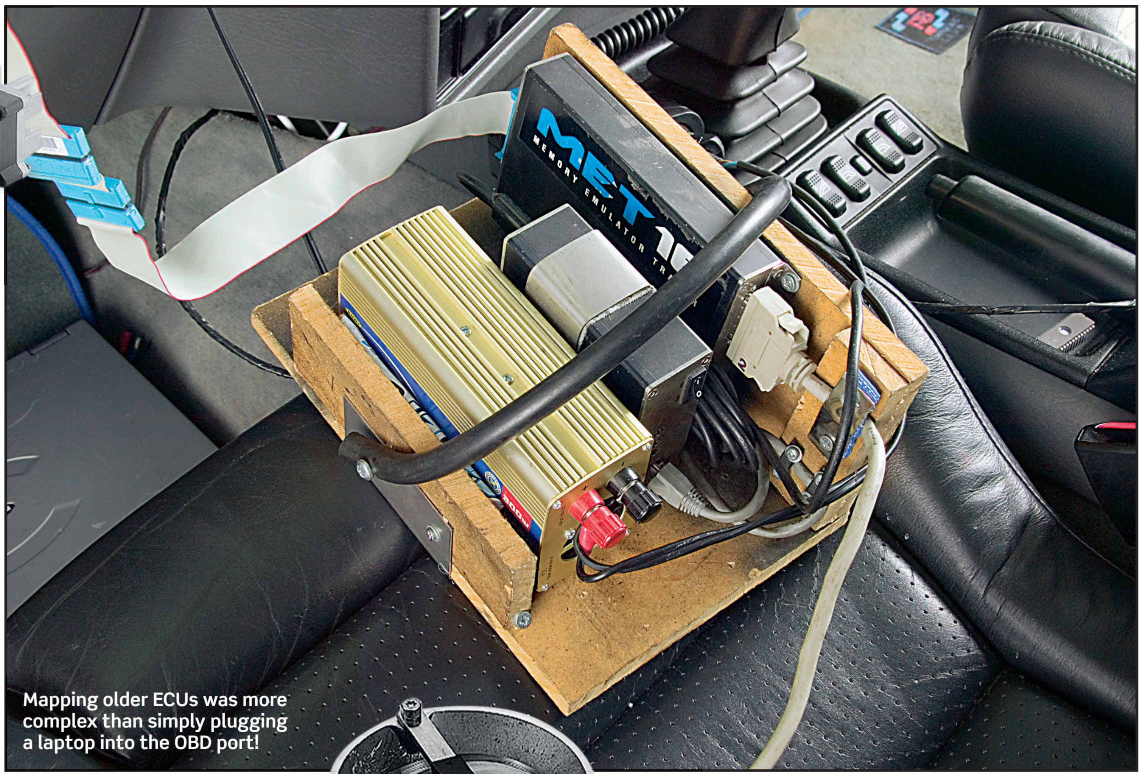
OUR EXPERT STU COMPARES OLD ENGINE MANAGEMENT SYSTEMS WITH NEW, EXPLAINING HOW THEY WORK TOO.

This month we are going to take a look at how engine management systems have evolved over the past ten or so years.

Our older readers will remember that many years ago we were using simple spring weights on a spinning shaft to control ignition advance, and simply changing the tension on the spring would alter the amount of advance across the rev range. Back in those days fuelling was nothing more than a set amount of fuel sucked though a jet from a reservoir, and we could alter the size of the jet to completely change the fuelling characteristics! Things have moved on a massive amount!

Let's now take a closer look at some of the first management systems fitted to Fords many years ago, and progress through to the more modern systems which we have today.





Mapping older ECUs was more complex than simply plugging a laptop into the OBD port!

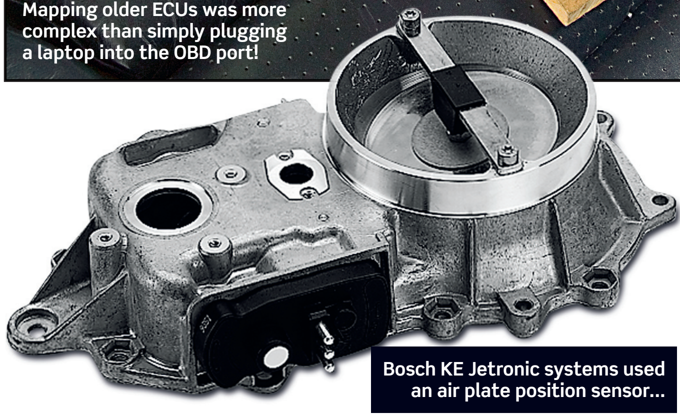
1984-1990
BOSCH KE JETRONIC

The Bosch KE Jetronic system was fitted to many makes and models of vehicle but specifically for Ford it was mainly used in the Escort RS Turbo range.

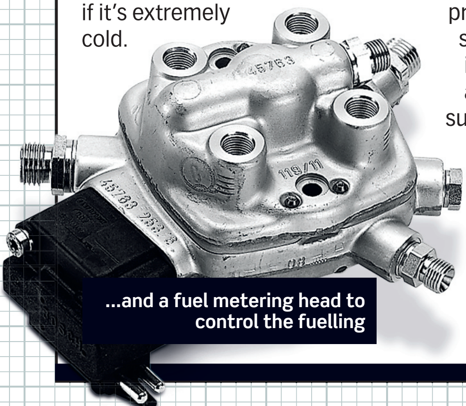
These systems have a separate fuel control ECU or 'Black Box', which takes information from a few basic engine sensors such as throttle position sensor, knock sensor, air temperature sensor, coolant temperature sensor, air plate position sensor and RPM signal to name the main ones.

Using the information, the ECU then controls the amount of fuel added by increasing or decreasing the actual fuel pressure via the electro-hydraulic pressure actuator. You will notice here that the injectors are not electronically controlled like more modern systems; they are actually mechanical pressure controlled units, meaning they open when the pressure in the line from the metering unit reaches a certain point and the variable pressure adjusts the fuel delivered.

The KE systems do not normally utilise their cold start injector as the even earlier K system did; this system increases fuelling at the metering head to enrichen the mixture for cold running and starting periods and only uses its cold start injector if it's extremely cold.



Bosch KE Jetronic systems used an air plate position sensor...



...and a fuel metering head to control the fuelling

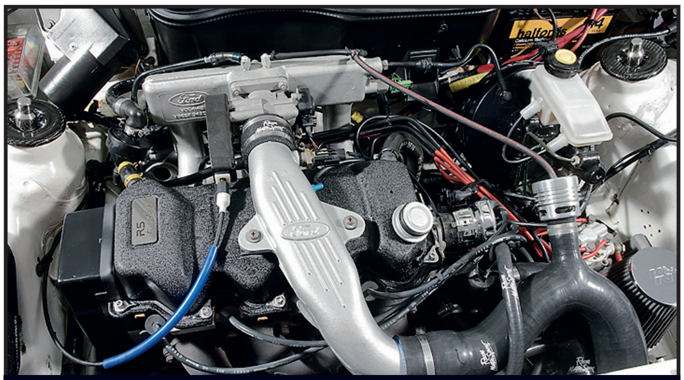
This injection system works very well if correctly set up, but finding someone who knows how they work well enough to make the required adjustments can be difficult as they are quirky by modern standards and even something as silly as a dipstick tube or filler cap not sealing properly can stop them idling properly due to the fact they meter the crankcase breather system.

This system also has lots of limiting factors which can prevent them running the sort of power everyone is asking for now, as well as having drawbacks such as being designed to start properly with a part throttle, which is something that just would not be classed as acceptable in this day and age. Diagnostics on these systems can be challenging to say the least as all sensor inputs must be manually checked because the ECU does not stream any data to assist in diagnosing faults.

1985-1990
WEBER L1-L6

The Weber range of ECUs were fitted to early Cosworth YB powered cars, and were a big step forward from the older Bosch KE systems. They used an increased number of engine sensors, giving the ECU more information and allowing it to have more control over the engine itself. These systems control both ignition and fuel systems. The injectors were electronically controlled, which opened lots of doors when it came to tuning, as the ECU is fully live-mappable, meaning all aspects of the ECU calibration can be adjusted and tweaked as necessary while running by anyone with the correct equipment and knowledge.

These ECUs can and do still perform and give results as good as almost any modern ECU if the mapping is to a high standard, but these early types of Weber ECU did lack some quite useful



The KE Jetronic system was found in Ford's Escort RS Turbo

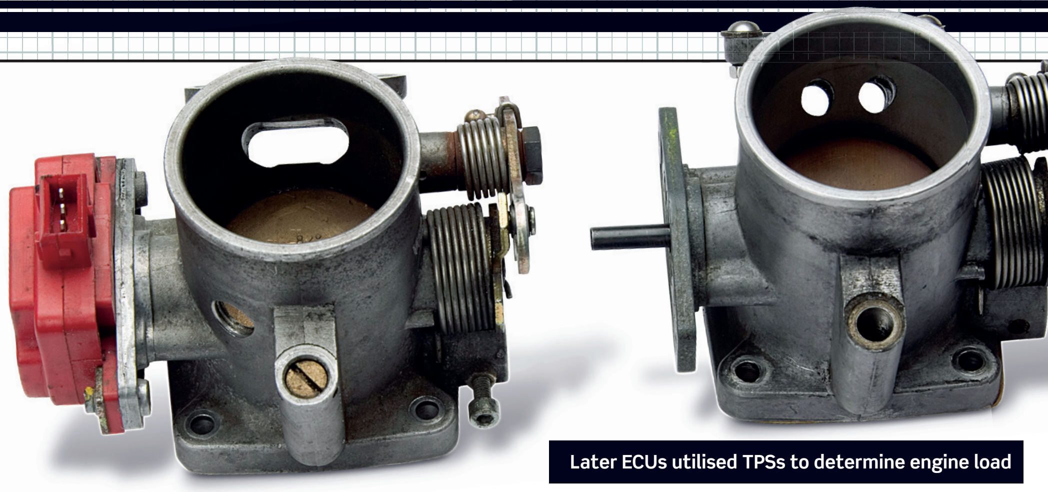
and important functions which were introduced into later systems. We will go into that in a moment though.

This Weber system uses various engine sensors such as phase sensor, crankshaft position sensor, air charge temperature sensor, coolant temperature sensor and manifold absolute pressure (MAP) sensor and throttle position sensor to name the main ones. These give the ECU enough data to allow it to reference different tables or maps in its memory, which in this case is 64kB on the L1 and L6! An absolute tiny amount of data by the standards of today's ECUs!

Because the system is fully-mappable and injectors are electronically controlled it allows a large amount of tuning to take place because the whole system can be recalibrated to suit different revs, compressions, turbos, injectors and boost pressures. Needless to say the Cosworth almost certainly wouldn't have become such an icon if these ECUs hadn't allowed the cars to be so tuneable and run such a wide range of specs and power outputs.

> **"THE COSWORTH WOULDN'T BE AN ICON IF THESE ECUS HADN'T ALLOWED IT TO BE SO TUNEABLE"**

Diagnostics on these early Weber systems involved a break out box where the sensor inputs and ECU outputs could be checked as the ECU still did not stream data to assist the diagnosis of faults.



Later ECUs utilised TPSs to determine engine load

1990-1992 WEBER L8

This later addition to the range saw a host of new features. The L8 had the ability to run closed loop fuelling as standard and the late Sapphire Cosworths used this function to meet the emission regulations of the time as it utilised a catalyst in the exhaust.

The system also had knock control which will retard ignition when any knock or detonation is detected. Other than that the L8 is very similar internally to the L6 we looked at earlier but has an expansion board fitted to increase the amount of available system memory. This means they now had 128kB ROM and were able to not only squeeze in all the software required for the closed loop and knock control, but also the system now had the ability to stream information out to a diagnostic machine. Sadly, Ford didn't utilise that feature and opted to keep the flash codes from the L6 in place, but subsequent tuners certainly utilised it, notably Pectel in the early days, and we still use it today. The ECU can literally store a code and tell us one of its sensors is faulty, as well as send the data out to us what the sensor is telling it, so we can see coolant temperature in degrees Celsius on our screen for example. Very useful.

Interestingly, the old temporary traffic light systems used a 128kB file and in fact even shared the same EPROM type as these Weber L8 ECUs!

1992-1994 WEBER P8

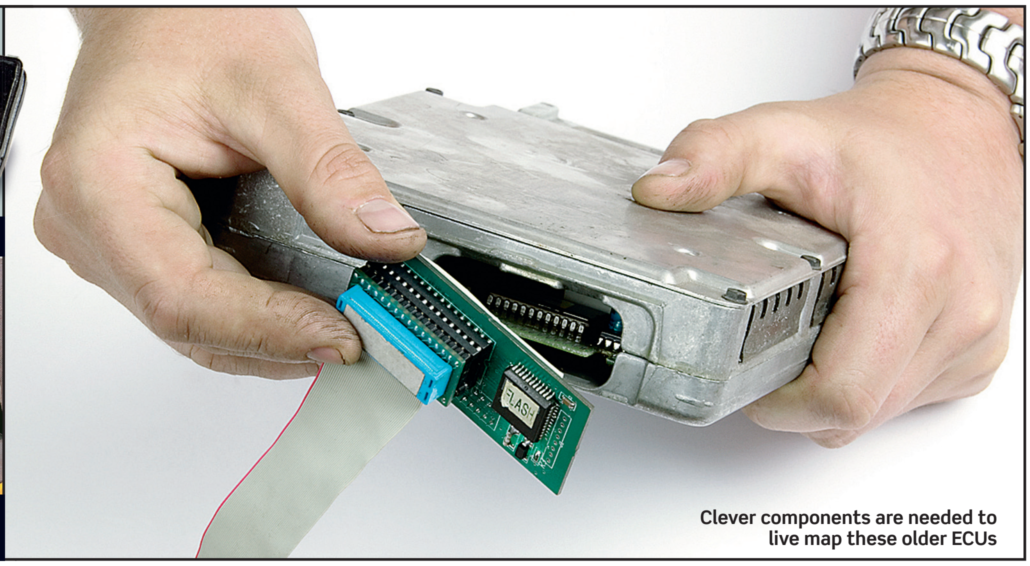
The Weber P8 is a significantly more advanced ECU and a step closer to the ECUs we see today. The P8 used an adaptive memory, which allows the ECU to self-calibrate the idle and cruise areas by using the Lambda sensor in the exhaust to measure and sample the exhaust gases while adjusting fuelling to ensure these are perfect.

The way it differs from the simple closed-loop system of the L8 ECU is that it then makes these changes permanently, until such time as the engine changes again, so it actually live maps itself over time. The knock detection in this ECU is much more advanced, and if knock or detonation is detected at certain points the ECU will remember where this knock is present and adjust the ignition advance at that point until the ECU is reset. This ability to learn was a big step forward in ECU technology and is totally standard in all modern ECUs.

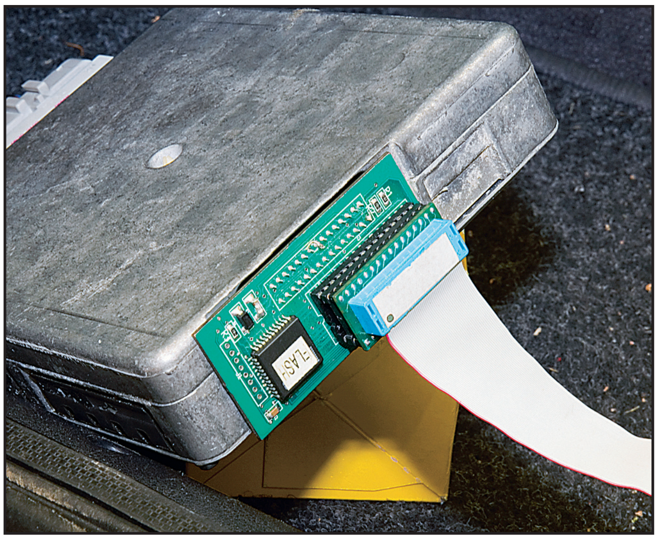
The P8 files are 256kB in size, so twice that of the L8 and four times that of an L6. However, this memory size is still absolutely tiny by today's standards! The diagnostics on these later Weber ECUs are even starting to become more advanced – they will stream data to the correct equipment,

Chip stores the vital information

MAP sensors feed the ECU info about boost pressures



Clever components are needed to live map these older ECUs



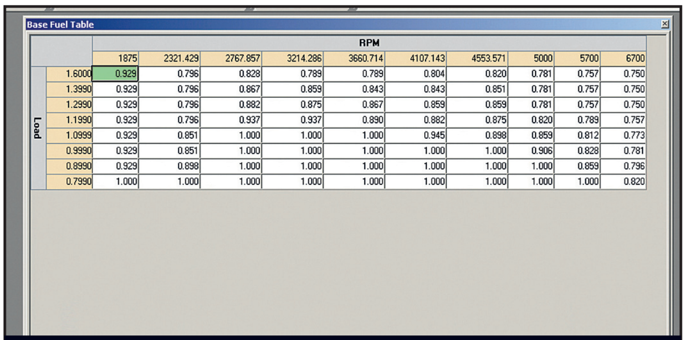
Ford's EEC ECU has been around since 1984 and is still going!

meaning sensor operation and ECU function can be seen working in real time, and fault codes can be captured by the ECU itself on a semi-permanent basis providing valuable information in the diagnosis of faults.

Again, Ford chose not to utilise this feature but tuners like ourselves have maximised its potential and can even use its DataStream to activate fuel pumps, boost solenoids, idle valves, create sparks from coils and pulse fuel injectors from our laptop. Great for diagnosing failed circuits.

time. Many of the early EEC range used an airflow meter with a flap on it that was displaced by air. It gave quite accurate information to the ECU relating to how much air was entering the engine and was therefore more accurate than the Webers, with only a MAP sensor as previously discussed.

A derivative of this airflow meter is used on almost every type of vehicle in use today, but it no longer requires the physical flap and is known as an air mass meter. The later EEC units also shared the adaptive ability of the Weber ECUs, being able to learn and make changes to the maps themselves.



Base Fuel Table

Load \ RPM	1875	2321.429	2767.857	3214.286	3660.714	4107.143	4553.571	5000	5700	6700
1.6000	0.929	0.796	0.828	0.789	0.789	0.804	0.820	0.781	0.757	0.750
1.3990	0.929	0.796	0.867	0.859	0.843	0.843	0.851	0.781	0.757	0.750
1.2990	0.929	0.796	0.882	0.875	0.867	0.859	0.859	0.781	0.757	0.750
1.1990	0.929	0.796	0.937	0.937	0.890	0.882	0.875	0.820	0.789	0.757
1.0999	0.929	0.851	1.000	1.000	1.000	0.945	0.898	0.859	0.812	0.773
0.9990	0.929	0.851	1.000	1.000	1.000	1.000	1.000	0.906	0.828	0.781
0.8990	0.929	0.898	1.000	1.000	1.000	1.000	1.000	1.000	0.859	0.796
0.7990	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.820

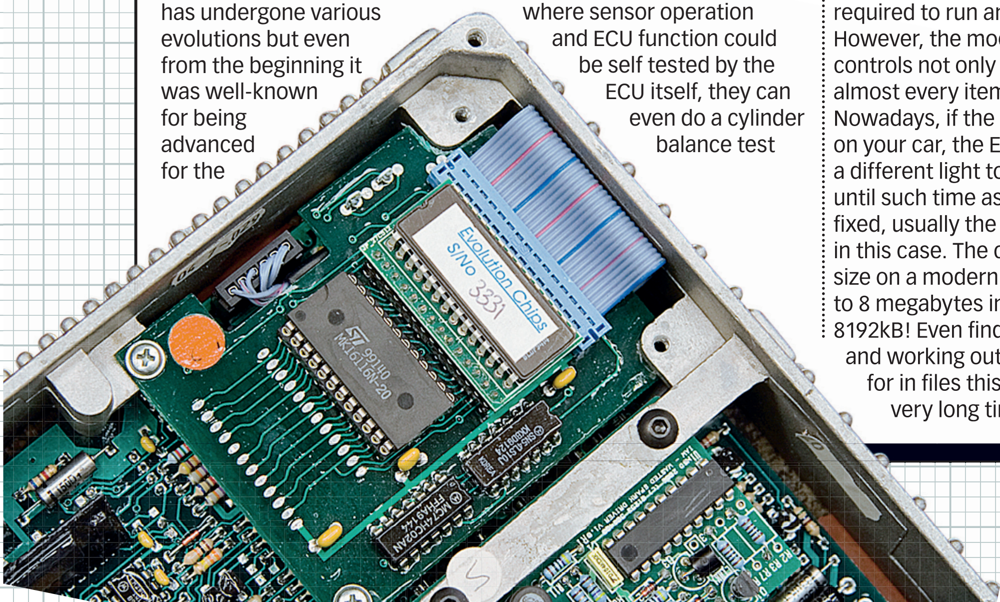
Base fuel table contains information on how long to open the injectors for any given point

> **"FORD'S OWN ECU WAS USED IN THEIR VEHICLES FROM 1984 TO CARS STILL IN PRODUCTION."**

FORD EEC

Ford's own ECU was used in the majority of their vehicles from right back in 1984 on the early Sierras to cars still in production today. It has undergone various evolutions but even from the beginning it was well-known for being advanced for the

Diagnostics again took a step forward on the later range of ECUs, fault codes could be held on a permanent basis and retrieved at any time with the correct equipment. These ECUs also had a self-test function, where sensor operation and ECU function could be self tested by the ECU itself, they can even do a cylinder balance test automatically. The equipment used to read this ECU data was becoming more popular at this point, and several types of equipment could be used meaning advanced diagnostics was possible outside of the dealer network.



MODERN ECUS

(commonly Siemens in Fords)

Modern ECUs control all manner of complex systems such as diesel particulate filters, exhaust gas recirculation systems and common rail injection systems alongside the usual systems required to run an engine. However, the modern ECU controls not only the engine, but almost every item on the vehicle! Nowadays, if the brake light fails on your car, the ECU can activate a different light to take its place until such time as the fault is fixed, usually the rear fog light in this case. The calibration file size on a modern ECU can be up to 8 megabytes in size, that's 8192kB! Even finding the maps and working out what they are for in files this size can take a very long time as there are simply so many different maps and limiters in amongst the huge files – with a modern Siemens ECU having well in excess of 1000 maps and switching functions.

The latest diagnostic systems can check almost every individual component for operation; even the electric windows, lights and car radio can be checked and operated via the diagnostic port on most vehicles. The systems are linked with CAN-bus or similar communications protocols which allow all the systems to be linked together and communicate with one another.

The sensors fitted in conjunction with these modern ECUs are more advanced than ever and there are also more of them, for example, the Weber systems from the '90s only had one knock sensor bolted to the block, so any information given from this sensor would mean a global adjustment was made to ALL cylinders, usually dropping power, whereas the modern ECU systems often utilise a knock sensor per cylinder, so that excessive knock detected on one particular cylinder can be

Modern ECUs have come a long way, and are now very powerful pieces of kit

dealt with individually, leaving the remaining cylinders performing normally and at full power.

Interestingly, modern systems are designed so that they listen for detonation constantly. They advance the timing to the point of knock and then back off, thus keeping your timing map optimised for the current conditions and fuel used. When you consider that this can happen several times per second on any one individual cylinder or on any combination of them simultaneously, it gives you some idea of the complexity of these ECUs as this is only one tiny part of what they can do. The calculations and work they perform is totally mind-blowing when you start delving into it.

ERROR MASK

When sensor faults are detected, the modern ECU is so intelligent it can simulate readings and signals for the faulty items by using data from other sources of information the ECU has available to it. For example, let's say a coolant temperature sensor has failed. Years ago this would leave us with either a very poor-running engine, or a non-runner. Not any more. What happens now is the ECU quickly inputs the last reading it had constantly, so let's say it was hot for an hour when it failed, it may substitute 90 deg C to keep the engine running fine. It will then check other systems to assess plausibility of this figure.

For example, if the water temp is at 90, the oil will usually be around 90 too. Engine run time, an engine that has been running for 2hrs should be hot, thus backing up the figure of 90. Lambda feedback, if the coolant substitution is wrong, it will affect fuel atomisation, does Lambda suggest fuelling is OK? There are many more examples, but you get the idea... the modern system can literally think for itself.

The end result of this technology is a car with a quite serious fault that drives almost as well as it did fault-free, but you now have a management light on. Sadly, people often ignore the light as it's running so well. We even see cars with the bulb removed, or tape placed over it, as "it was annoying".

SECURITY

Vehicle theft is an age-old problem and new ECUs also have technology built-in to help with these issues. The ECU holds immobilisation data and links with the key fob and alarm system meaning the system cannot be easily bypassed as earlier systems could be! The ECU also holds mileage data and the vehicle's chassis code, in order to help defeat car clockers.

THE FUTURE

Engine technology is progressing at a very fast pace, the engines of the future are most likely going to use variable compression with electronic or hydraulically-actuated valves, meaning no camshafts! Both of those systems are already in operation and proven to work well, so it's easy to see why it is very important that ECU technology also progresses and allows these new engine technologies to be integrated into our vehicles and perform as their designers intended.

Evolving technology like this is what helps our vehicles get increasingly economical and reliable. Rest assured, the manufacturers of these ECUs will keep pushing boundaries, testing, changing, spending millions of pounds to produce the best ECU they can to control future vehicles.

ECU REMAPS

Remember, no matter how good an ECU is, or how many functions it has, it is only ever as good as the instruction set controlling it! We see hundreds of cars running all sorts of ECU types, and a well-mapped £50 1985 L1 ECU can drive much better and take better care of its engine than a £3000 all-singing, all-dancing modern Siemens ECU with a poor map! The ECU can only do what it is told to do, so think wisely when choosing a remap, or buying a chip!

NEXT MONTH
MORE ON ENGINE MANAGEMENT: OE ECUS VS AFTERMARKET