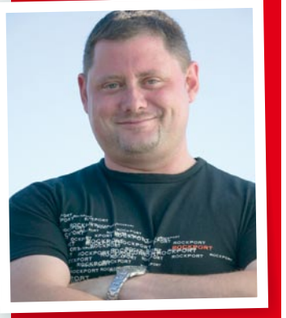
Words: Stewart Sanderson
Photos: Michael Whitestone,

WHAT IS MAPPING?

PART 3 So what actually happens at a live-mapping session then? Stu reveals all.



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, in the past Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

Then seven 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.

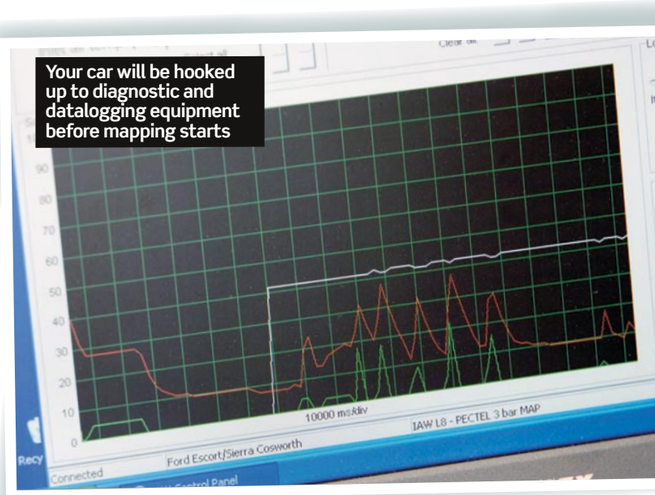
He's also jointly responsible with Webmaster, Petrucci for www.passionford.com. Started in 2003, it's grown rapidly from a few friends contributing, to one of the biggest Ford communities on the web.

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 most importantly how they can be improved.

HOPEFULLY you are fully up to speed with this series now and are fully aware of why your engine would benefit from mapping and what the mapping itself consists of. You should also have a pretty good idea what equipment is utilised to accurately perform it, as these topics were covered in some depth over the first two editions of my four-part mapping series (Fast Ford issues 253 and 254).

Once your appointment date arrives and you turn up in reception with a car ready for mapping, what happens next will depend upon one of two things: what type of car you are bringing us, and whether or not we have mapped one of them before. We map all forms of car from Audis to Porsches, but for the purpose of this article let's concentrate solely on Fords.

As you'd expect we have mapped many different types of Fords from normally-aspirated CVH and Zetec engines to the various forms of turbo diesel, through to 650-plus bhp Ford Cosworths.



Your car will be hooked up to diagnostic and datalogging equipment before mapping starts

WHAT MAP?

If you want us to map a type of engine and management that we've mapped many times before then we will have already determined where the various maps are within the ECU calibration (or chip to you), what the maps do and what is required to modify them to make the engine and management perform correctly with your various modifications.

However, if you are bringing us an engine and ECU that we have never actually mapped live before, we may have a problem because the manufacturer goes to great lengths to encrypt and hide all the maps within the ECU calibration. They really don't really like us doing what we do, so the job isn't quite as simple as it may at first appear, but we will come to that later... Let's for now assume you are bringing in a car for mapping that we have done lots of previously.

FULLY EQUIPPED

First of all, as explained in depth last month we will check your car is road legal, including tax and MoT and then hook the car up with all sorts of hardware such as air/fuel ratio monitors, dataloggers, an ECU emulator, boost gauge, multi-meters, G-meter and an emergency toolkit containing all manner of emergency tools and parts that enable us to fix common faults and make adjustments at the roadside.

Once the equipment is in the car, two of us will take it out and assess its current condition, making notes of any shortfalls in the engine and management system like hesitations on acceleration, over or under fuelling, excess fuel consumption and poor performance.

We also run a diagnostic monitor at the same time in order for us to find any faults that may exist on the engine management system; there is absolutely no point trying to map an engine management system that is actually faulty. Basically, we are giving the system a health check whilst looking for any areas where we know we can improve your car while mapping it.

After making concise notes on the current performance of the system we will return to the workshop and proceed to perform a brief set-up to ensure all engine settings are correct before hooking the emulator up to the ECU as again, there is no point mapping a car's fuelling, only to find out later the fuel pressure was too high, or low.

To briefly recount on what we covered last month, the EPROM emulator allows us to access in real-time, the precise part of the engine management calibration chip that the ECU is asking information from. For example we may only have an issue with an engine at 3000 rpm at say, half throttle — perhaps a small hesitation at light throttle — the emulator will highlight the exact part of the fuel and spark maps that the ECU is accessing when this hesitation occurs, allowing us to make relevant changes to that part of the map and only that part.

BEFORE STARTING...

The first rule of working on cars and using tools of any kind is don't ever skimp on decent protection. Goggles, gloves, ear defenders, masks and a set of overalls should be in your garage. Use them.

When using power tools, protective gear is essential — grinders and welders can make a real mess of your soft skin and bone if you get it wrong.

Never work under a car without supporting it using axle stands. A car falling on you is not something you'll be laughing about down the pub.

Mapping can be done on rollers, but MSD prefers to do it on the road

SENSORY DEPRIVATION

It is well worth bearing in mind that all the temperatures and pressures displayed within the live mapping screens are fully dependant on the sensors that output that particular data, so always ensure your management sensors are in good order before commencing mapping or the time and money may be wasted.

Removing the extra fuel from the maps of a rich running engine that had an air temperature sensor reading 40 degrees C too hot is not only a waste of time and money, it will also be dangerous to an engine if that sensor is ever replaced with one that works properly as it will start to run dangerously lean.

The golden rule here is, garbage in, garbage out.

Results are instantaneous, so we can reap the rewards instantly and move on to the next issue that needs resolving.

This form of mapping removes the immense amount of educated guesswork needed to do such a job sat at the desk with no emulator, as we will obviously be trying to guess which part of the map the ECU would be reading from when the issue occurs, burning that to a chip, and taking the car for a drive to see if it has made any difference.

This live accessing method is the emulator's main job but not its only job — our own emulation system also has the ability to simultaneously run two different calibrations and allow us to swap between each at the press of a key with the engine still running. This can be invaluable when you make a mistake — imagine accidentally deleting a fuel map at high speed. Yes, it could happen!

LIVE MAPPING

So, the emulator is all connected up and we are ready to go, so what exactly do we map when live mapping? Well, this depends exactly what modifications you have done to your engine.

A simple Fast Road camshaft, exhaust and air filter will normally just require a tweak to the fuel and spark timing maps because all you have done is adjust how much air comes into the engine under heavy load by removing a few of the manufactured-in restrictions. In these cases we can simply adjust the fuelling maps so that all throttle and load positions are running the kind of air fuel ratio that we personally wish to see.

We will also use detonation cans to help us adjust the spark advance until we are a safe way from detonation, yet still delivering good performance.

If however, you have modified the injectors, engine sensors, inlet/exhaust ports, compression ratio or maybe even the turbocharger we would have to map far more things. This can mean a week's worth of mapping work is required.

WHY A WEEK?

This is a question I have to answer on an almost daily basis and the reason is quite simple. When I map a car I want to give you a car back that performs and drives as well as an equivalent OEM-powered vehicle.

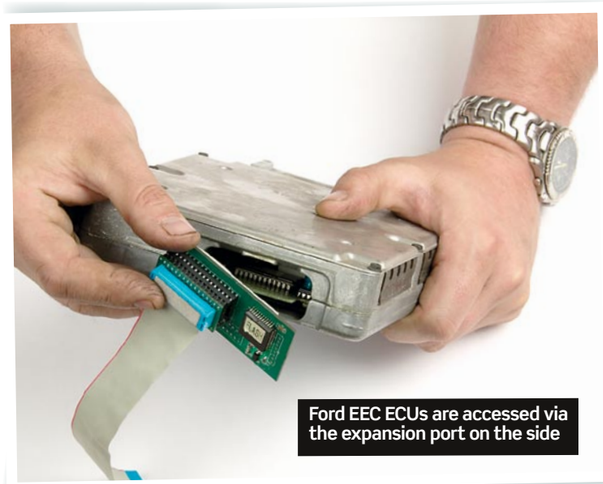
One of the failings of many mappers is that they spend far too much time trying to extract maximum power and not enough time trying to map in some refinement and economy. I absolutely cannot abide cars with engines that will not start and idle perfectly well when cold, engines that rev up and down until they get hot, or keep stalling. Almost as annoying is a car that will not drive properly when cold and tends to jerk, pop, fart and kangaroo or cut out at every junction.

The car is checked over thoroughly before it goes anywhere near the road

When we map a car it absolutely will not do any of those things and it will drive as near to a standard OEM car as it is possible to be with your particular combination of engine, modifications and management.

Going back to the question... Well, the time delay is due to the fact that once we have perfected a main fuel map with the engine hot and we are totally happy that it achieves all our aims, we can have a go at mapping the cold starting and running correction maps.

These maps are in essence an electronic version of the old choke knobs that you used to pull out on the dashboard to get your engine to run cold and had to progressively push back in as the engine warmed through. Sorry? What do you mean you're not old enough to remember that?



Ford EEC ECUs are accessed via the expansion port on the side

While Weber-Marelli ECUs are interfaced via the EPROM (chip) socket

CORRECTION FACILITY

On most EFi systems we have a small correction table within the engine calibration chip that relates only to coolant temperature and for arguments sake it is maybe 10 cells wide starting at —10 degrees C on the extreme left and going up in 10s, terminating at 100 degrees C on the extreme right.

Now, let's assume your car runs badly all the time that it is cold and let's assume for discussions sake that we have ascertained that it is due to being excessively-lean after fitment of camshafts. In this scenario, when using our emulator we will be able to see precisely which coolant multiplier the management is looking at and how much extra fuel it is delivering from the contents of that cell when the poor running occurs, and we are able to modify that data and asses the results immediately, hopefully richening up our lean engine at that temperature.

However, as you will know; most cars warm up very quickly nowadays and we don't have much testing time at each of the 10 correction sites before it moves on to the next. As an example, let's say we have just modified the multiplier that deals with the engine when it is at 20 degrees C and are now doing the multiplier that deals with 30 degrees C...

How will we know if we got them right? The only true and accurate test is to wait until the engine is back down at 20 and 30 degrees C to see if it runs correctly and exhibits a correct air/fuel ration at that point or not. If it doesn't, we can make more changes as required but will of course have to wait until the engine is at that temperature again to check our work.

Can you see the pattern emerging here? The bottom line is, to do a job correctly often takes far more time and effort than first meets the eye, as the only way to ensure success is to operate and map the engine during the actual conditions that it is to work within. So that means cold mapping should really be performed with a cold engine.

ACCESS ALL AREAS

Which actual engine management system you are using will depend on which mapping program we use to live map the engine. However, regardless of mapping program will have to hook up the emulator to your ECU in some way or other. Ford EEC systems are very simple to interface, we access these computers via an expansion port on the side of the unit.

Weber-Marelli systems are interfaced via the EPROM socket and we have to literally remove the EPROM and insert an interface cable in its place.

Let's take a look at the Weber-Marelli mapping system. Invariably for this system we will use a special mapping program that decrypts the maps and gives us masses of information and access to every map we could possibly want to adjust. As an example here is a brief list of the maps that are available within a Ford Cosworth Level I-Level 8 ECU:

Fuel injection map
Spark advance map
Boost control map
Coolant fuel adder map
Coolant spark adder map
Batter adder map
Air temperature adder map
Rev limiters
Boost limiters
Over run fuelling tables
Crank fuelling
After start fuelling
Closed loop correction level tables and switches
Knock retard look up table
Injection phasing
Injector scaling
Many transient fuel correction adjustments.

And on our latest revision of Level 8 software:
Launch control maps and switches.
Anti-lag system control maps and switches.

The Ford EEC management system uses a completely different type of software but again gives us access to various maps that will allow us to pretty much do anything we require.

These maps include the following features that are not present in the Weber system due to ECU advances and the fact it uses Mass Airflow (MAF) instead of speed density.
MAF transfer tables
Torque transfer tables

File Map Edit Analize View Emulator Window Help

RAM2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
003840	DA	DA	DA	DA	DC	DE	F7	FF	FF	FF	FF	FF	FF	FF	FF	FF
003850	AA	AA	A8	A8	A9	AF	D5	E8	FB	FF	FF	FF	FF	FF	FF	FF
003860	8F	8F	8F	90	91	93	A2	B9	BE	C2	C7	CB	CD	D1	D4	D4
003870	91	91	93	92	93	94	95	95	9B	9F	A1	A4	A7	AB	AD	AD
003880	74	75	76	76	75	74	75	76	7A	7B	7D	80	82	84	86	87
003890	58	58	58	5A	5B	5D	5F	60	63	67	6B	6F	74	77	78	79
0038A0	46	47	4B	55	56	55	57	57	57	58	57	56	57	57	57	59
0038B0	30	30	2F	3B	3E	3D	3F	3D	3C	3D	3E	3C	3B	3C	3D	3B
0038C0	1F	1F	1A	1D	1F	1F	20	1F	1E	20	20	1C	1D	20	1E	19
0038D0	08	07	08	0F	11	11	11	0F	0F	11	11	10	11	11	11	11
0038E0	04	04	04	08	08	08	08	08	08	08	08	08	08	08	08	09
0038F0	01	01	02	02	02	02	02	02	02	02	02	02	02	02	02	02
003900	00	00	00	00	00	00	00	00	00	00	00	00	01	01	01	01
003910	85	74	6A	5F	57	50	4A	44	3F	3B	37	34	31	2F	2D	2B
003920	7A	77	72	6A	63	5A	54	4F	4B	47	42	40	40	40	40	40
003930	CE	CC	C8	BD	A8	88	60	43	32	26	22	21	20	20	20	20

Figure 1: fuel map in hexdecimal format can be read by the ECU

RAM2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
003840	56026	56026	56542	63487	65535	65535	65535	65535	43690	43176	43439	54760	64511	65535	65535	65535
003860	36751	36752	37267	41657	48834	51147	52689	54484	37265	37778	37780	38293	39839	41380	42923	44461
003880	29813	30326	30068	30070	31355	32128	33412	34439	22616	22618	23389	24416	25447	27503	29815	30841
0038A0	17991	19285	22101	22359	22360	22358	22359	22361	12336	12091	15933	16189	15421	15932	15164	15675
0038C0	07967	06685	07967	08223	07712	08220	07456	07705	02055	02063	04369	04367	03857	04368	04369	04369
0038E0	01028	01032	02056	02056	02056	02056	02056	02057	00257	00514	00514	00514	00514	00514	00514	00514
003900	00000	00000	00000	00000	00000	00000	00257	00257	34164	27231	22352	19012	16187	14132	12591	11563
003920	31351	29290	25434	21583	19271	16960	16448	16448	52940	51389	43144	24643	12838	08737	08224	08224

Figure 2: fuel map in 16-bit format. This will need converting to a readable format before the map can be safely altered

Torque limiter maps for each gear
Adaptive fuel control maps
And over 200 more!

When using one of the management systems such as Weber-Marelli or Ford EEC, getting down to the job of actually mapping is a pretty straightforward process of hooking up equipment and loading software to allow us access to the maps.

The problems arise when you bring a new model that we have never mapped before. This means that due to the encryption in the ECU we will not actually have any access to the maps or even addresses of where to find them, this is where time-consuming R&D comes into the mapping arena. In cases such as this we will extract the engine calibration data from the ECU by means of either removing and reading the EPROM or extracting it via the diagnostic port on the dashboard.

Once we have the calibration program we will then load it into a very special mapping program that allows us to analyse the data on the chip in various different formats.

SHOW AND TELL

An engine calibration file in its native state is simply a computer program presented in a binary format. This format is of absolutely no use to us at the moment so we need to convert this complex looking data into a more graphical representation.

If you look at figure 1 and 2 you can see what appears to be a collection of meaningless numbers. Figure 1 is hexdecimal, and figure 2 16 bit, however if you look at figure 3 you will see exactly the same data but represented as a two-dimensional graph, this is where it starts to get interesting... The 2 dimensional view shows what appears to be a map, which is so recognised by its recurring graphical appearance.

This is just one of the painstaking ways in which we find maps in new systems and it can take many hours and even days to figure out, via an emulator, what they actually do, but once we have deciphered them we know where the key maps that we require are located and what they do, we can access them instantly the next time.

Once a calibration has been deciphered, our mapping software reassembles it on the mapping screen in a way that humans can understand and work with (see figure four). Of course, if we require access to tricky parts of the program, such as simple switches, we have to have the whole thing de-compiled professionally, and that takes time and money.

For the record, we have access to over 23,000 different ECU calibration maps at time of writing, so it's extremely rare you will bring one in that we haven't already got the information for.

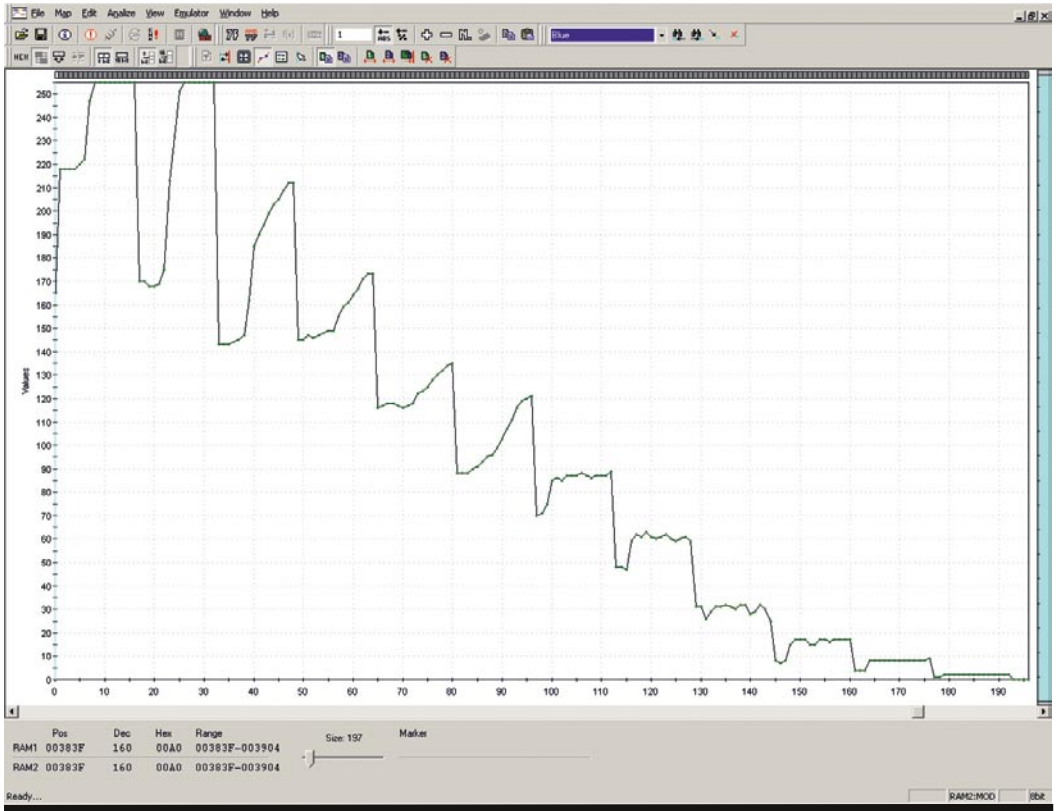


Figure 3: the 16-bit fuel data deciphered and represented as a 2D graph or 'map'

13 x 16 RPM

Load \ RAM2	800	1000	1300	1500	1800	2000	2300	2500	2700	3000	3500	4000	4500	5500	6500	7000
100	218	218	218	218	220	222	247	255	255	255	255	255	255	255	255	255
92	170	170	168	168	169	175	213	232	251	255	255	255	255	255	255	255
85	143	143	143	144	145	147	162	185	190	194	199	203	205	209	212	212
77	145	145	147	146	147	148	149	149	155	159	161	164	167	171	173	173
69	116	117	118	118	117	116	117	118	122	123	125	128	130	132	134	135
62	088	088	088	090	091	093	095	096	099	103	107	111	116	119	120	121
54	070	071	075	085	086	085	087	087	087	088	087	086	087	087	087	089
46	048	048	047	059	062	061	063	061	060	061	062	060	059	060	061	059
38	031	031	026	029	031	031	032	031	030	032	032	028	029	032	030	025
31	008	007	008	015	017	017	017	015	015	017	017	016	017	017	017	017
23	004	004	004	008	008	008	008	008	008	008	008	008	008	008	008	009
15	001	001	002	002	002	002	002	002	002	002	002	002	002	002	002	002
8	000	000	000	000	000	000	000	000	000	000	000	000	001	001	001	001

Figure 4: the fuel data is then reassembled so that it can be altered at various load and rpm points

NEXT MONTH

What maps we tend to have to change and why we need to change them for specific mods like cams, heads and turbos, as well as why fuel mixture and spark advance differ according to loads and mods.