Part3:

From this part we will teach the main tables in the ECU. Tables such as ignition, fuel, turbo, torque, load and many more.

First, we learn what tables are in ECU and to understand each table, we provide complete explanations.

Once we have learned all the tables, we will go over how to change these tables so that you can remap an ECU file.

In ECU software there are different categories like "Torque, Air Filling, Ignition Timing, Fueling, Turbo pressure, Rail pressure, Limiters" and so on.

So, in this part we start with "Engine Torque Categories". Engine torque categories are as bellows:

1- Optimal Engine Torque
2- Torque Request by driver
3- Torque Limiters

First, we talk about "optimal engine torque" and to have a complete understanding about the optimal engine torque, you should learn:

1- What is engine torque?
2- What is torque-based engine management system?
3- What is mathematical model of the engine torque or optimal engine torque?
4- What is the application of these tables in the remap and tuning?
5- Optimal engine torque in WinOLS software

And then in the next part we teach you "Torque request "

To have a complete understanding about the Torque request, you should learn:

1- Why did the mechanical throttle replace the electric throttle?
2- What is a Torque request table? And type of them.
3- What effect achieve the changes in these tables have on the vehicle's performance?
4- Torque request table in WinOLS.

And in the last part of engine torque categories, you will learn about torque limiters and their different types.

What is engine torque?

First, we will simply give the definition and concept of torque. Torque is a specialized word in the engineering fields primarily used in the vehicle industry.

Even in advertisements and introducing new products, automobile manufacturers also used torque and horsepower to show the vehicle power. the torque in general means the multiplication of force on displacement.

Torque = Force × Displacement

When we talk about the engine torque, the purpose is the piston's force in the crankshaft's crank resulting from the combustion pressure.

When the fuel and air in the engine compressed, and the ignition scintillated, the mixture of fuel and air ignited and produced the pressure that this pressure applied to the piston surface has enough force to push the piston, and the product of this force multiplied by the crankshaft length is equal to the torque in the engine.

In simple terms, the definition of torque is twisting force that speaks to the engine's rotational force and measures how much of that twisting force is available.

What is "Torque Based Engine Management System"?

Bosch first presented Torque-based engine management on the ME7 series ECU.

Nowadays, torque-based engine management is used as a standard in engine management systems. Then, it is better that understand it entirely and in simple words.

Suppose we want to describe the concept of torque-based ECU in the most straightforward possible manner. In that case, we can say that the software architecture of this ECU is defined as a mathematical model based on the engine rpm and the amount of intake air to the engine in ECU. Most of the systems are with electrical throttle. When a driver pushes the accelerator pedal, it determines not only a request for position of throttle but as a request for torque, and ECU has this possibility to manage the amount of torques demand when the driver pushes the pedal.

Simultaneously, various modules calculate the amount of requested torques, which are considered along with driver requests as a required torque percentage for the engine.

Let us review an example better to familiarize ourselves with the application of this system.

As you know, some of the engine power is always used to overcome the engine's internal friction. An idle engine always has to use torque to overcome this internal friction to stay idle. Consider the torque required to keep the engine running at idle T1.

Remember that principally the torque-based engine management has been made for the coordination between engine, gearbox, brake, etc.

One of the purposes of the torque-based engine management system is to prioritize the input and output torques. As we familiarize ourselves with the means and concept of torque-based engine management, it is better to see how this system is architected in the ECU software.
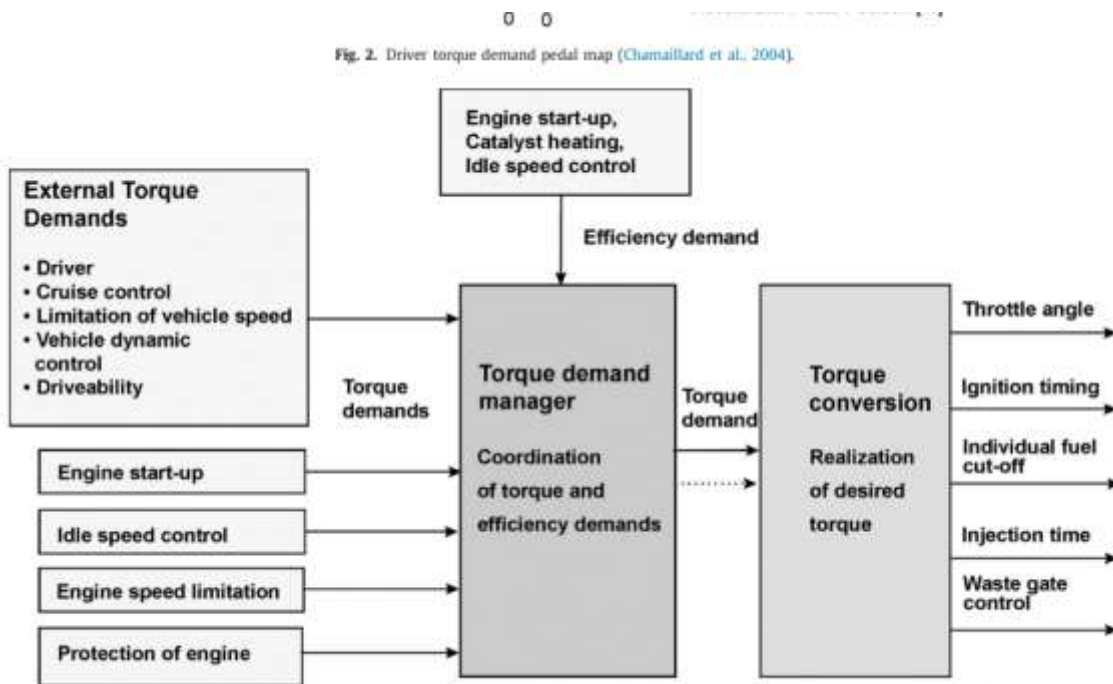
Fig. 2. Driver torque demand pedal map (Chamaillard et al., 2004).

Fig. 3. Centrally coordinated torque based control structure (Jurgen et al., 1998; Bernhard et al., 2001; Manjunath, 2003).

What is Mathematical Model of the Engine Torque or Optimal Engine Torque?

In torque-based engine management ECUs, a mathematical model of torque is defined in the case of a table in ECU at the time of ECU calibration after measuring the engine torque on a dynamometer. Engine torque is a function of various factors, e.g., intake air, Air/Fuel Ratio, temperature, ignition timing, crankshaft's crank length, etc.

For this purpose, after designing the engine, the engine prototype is fixed in the test room on the dynamometer device.

In this state, tens of sensors are installed on the engine to measure various parameters. The cause of this is that the engine's accurate torque cannot be measured with the calculations. However, by close-pack of the engine of dynamometer and

changing various parameters in different engines' rpm, the engine's output torque is accurately measured.

The torque that is measured by the dynamometer is called brake torque. During the experiments, an "Open ECU" is used.

Here, you can see "An Optimum Engine Torque" table.

OPTIMAL ENGINE TORQ #2 (%Nm)(-,-)-	5		20		40		60		90		160	
–		10		30		50		70		110		
400	2	4	8	12	16	21	25	30	39	47	70	
600	2	4	9	13	18	22	27	31	41	51	74	
800	2	5	10	14	19	23	29	33	44	55	81	
1000	2	5	10	14	20	24	29	34	46	57	83	
1240	2	5	10	15	20	25	30	35	47	59	85	
1520	2	5	10	15	20	25	31	36	49	60	88	
2000	2	5	10	15	21	26	32	37	50	62	92	
2520	2	5	11	16	21	27	32	37	51	63	94	
3000	3	5	11	16	21	27	32	37	50	63	95	
3520	3	5	11	16	21	27	32	38	50	63	95	
4000	3	5	11	16	21	27	32	38	51	64	95	
4520	3	5	11	16	22	27	32	38	51	63	95	
5000	3	5	11	17	22	27	32	38	51	64	95	
5520	3	5	11	16	22	27	32	39	51	64	95	
6000	3	5	11	16	22	27	33	39	52	64	95	
6520	3	5	11	17	23	28	33	39	52	64	95	

This table is the mathematical model of engine torque in various engine revolutions and loads.

The vertical axis is engine revolution and the horizontal axis is the cylinder air filling or engine load. The numbers in the table are the optimal engine torque in percentage of the Newton Meter.

The optimum engine torque means the torque that the engine can produce and reach it in the optimal condition.

The torque-based engine management system with this table precisely makes sense, i.e., on the basis of how much cylinders are filled with air at a given engine revolution, and how much torque the engine can produce.

We will provide another example to understand the optimum engine torque table in the ECU.

OPTIMAL ENGINE TORQ #2 (%Nm)(-,-)-										
5	10	20	30	40	50	60	70	90	110	160
2	4	8	12	16	21	25	30	39	47	70
2	4	9	13	18	22	27	31	41	51	74
2	5	10	14	19	23	29	33	44	55	81
2	5	10	14	20	24	29	34	46	57	83
2	5	10	15	20	25	30	35	47	59	85
2	5	10	15	20	25	31	36	49	60	88
2	5	10	15	21	26	32	37	50	62	92
2	5	11	16	21	27	32	37	51	63	94
3	5	11	16	21	27	32	37	50	63	95
3	5	11	16	21	27	32	38	50	63	95
3	5	11	16	21	27	32	38	51	64	95
3	5	11	16	22	27	32	38	51	63	95
3	5	11	17	22	27	32	38	51	64	95
3	5	11	16	22	27	32	39	51	64	95
3	5	11	16	22	27	33	39	52	64	95
3	5	11	17	23	28	33	39	52	64	95

(Row labels, engine revolution in rpm: 400, 600, 800, 1000, 1240, 1520, 2000, 2520, 3000, 3520, 4000, 4520, 5000, 5520, 6000, 6520)

At the engine revolution of 5000 rpm and 60% of air filling, the engine can produce 32% of torque, and when the engine revolution is equal to 6500 rpm, and the amount

of intake air to the cylinders is 160%, the amount of torque produced by the engine is 95%.

The Application of This Table in Remap and Tuning?

The increase of numbers in the table doesn't affect engine torque rise. If you set the torque percentage in engine revolution of 5000 and air filling of 60%, that has the amount of 322% Newton Meter, to the 80, it does not mean that ECU will produce 80% of the engine torque at this point.

This table needs to be increased if you raise the engine performance. Because the ECU works on a torque based control strategy، extending this table will ensure that increasing performance from ignition timing will not be limited by torque control.

You will want to make sure that "The Target Cylinder Filling Map" is raised as well as this has a direct correlation with the Optimum Engine Torque tables.

If you increase the numbers in this table without increasing the engine performance, it will lead to confusion about other parameters. For instance, when you increase this table by about 20% in Bosch's ECU for no reason, in some cases, it leads to increased fuel consumption.

The optimum engine torque map is very useful to understand the engine potential torque, and how much can we push thanks to re-mapping: In particular, we can immediately understand that the engine does not achieve the maximum torque possible in its original condition.

This table shows that this engine can produce maximum torque at 3000 to 6500 rpm.

So far, we learnt the concept of torque and optimum engine torque. And in the next part, we will teach you how to find and analyze these tables on WinOLS software…