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Thème

Optimization of the diesel engine injection performance under ECU remapping

Devant le jury composé de :

…………………	Président
………………..	Examinateur
……………...	Examinateur
Gherbi Mohammed Tahar	Encadreur

Présenté par :

- BOUBEKEUR abderrahmane
- OTHMANI abdelhalim

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I would like to sincerely thank all the people who helped us to develop and complete this thesis

Dedicates

Abstract

The rapid increase in oil consumption and emissions from vehicles Especially related to the transport sector, researchers have to present three solutions strategies to reduce all of this. Technical development in the combustion process, post-processing systems, The study and research is carried out in a dedicated section where fuel calibration strategies are researched, as vehicles' performance is improved through a discussion of this strategy, The research in the second section focuses on the level of advanced combustion technologies that include direct diesel injection. The third section is based on adapting the control function systems .The final section of this research includes an aspect of engine management including advanced engine tuning management. The quality of improving engine efficiency and reducing harmful emissions for a sustainable transportation system in general, places categorically on the strong research plan on various technologies.

Keywords : Engine techniques · Advanced chiptuning · ECU · Emission Control

Résume

L'augmentation rapide de la consommation de pétrole et des émissions des véhicules En ce qui concerne plus particulièrement le secteur des transports, les chercheurs doivent présenter trois stratégies de solutions pour réduire tout cela. Le développement technique dans le processus de combustion, les systèmes de post-traitement, L'étude et la recherche sont menées dans une section dédiée où sont étudiées les stratégies de calibrage du carburant, les performances des véhicules étant améliorées grâce à une discussion sur cette stratégie, La recherche dans la deuxième section se concentre sur le niveau des technologies de combustion avancées qui incluent l'injection directe de diesel. La troisième section est basée sur l'adaptation des systèmes de fonction de contrôle, et la dernière section de cette recherche comprend un aspect de la gestion du moteur, y compris la gestion avancée du réglage du moteur. La qualité de l'amélioration de l'efficacité des moteurs et de la réduction des émissions nocives pour un système de transport durable en général, place catégoriquement sur le plan de la recherche solide sur les différentes technologies.

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General introduction

In the field of automotive engineering, the increasing demands on automobile engines equipped with internal combustion engines with low fuel consumption, low emissions and good driving require continuous improvement of combustion processes, exhaust handling and control.

Combustion engine management includes intake system, fuel supply and injection, combustion cycles, mechanical system, turbochargers, exhaust and cooling system, and is basically created for real-time calculation. Engine control structures and development of engine control are considered in detail using various digital feed and feedback control methods, calibration, optimization and simulation tools.

As for the research goal, it is difficult to adjust the diesel engine. The knowledge of diesel in the industry is usually protected closely by those who know what they are doing, and online forums are full of half-facts and misinformation.

Practical Diesel Tuning is here to fix that and teach you how to tune diesel engines the right way. On some diesel engines, you can expect a power surge of up to 100 hp even on a mechanically stock engine without omitting the factory emissions equipment, and without compromising reliability. So we will get a high-quality supplier full of accurate and complete information.

As for the importance of this research, The technology applied to these engines, combined with the leverage incorporated into some of the diesel tunes in the factory, enables us to make it possible for our tuners to extract massive performance improvements with relative ease.

Emissions are becoming increasingly important in many markets around the world, we will discuss how these emissions systems work, and most importantly, how to produce a strong tone that keeps all emissions equipment and your engine legal.

In this research , we'll explore your options when the time comes to make diesel tuning changes. The first chapter contains state of the art of diesel engine and And the second chapter talks about the principle work of Diesel Engine Management ,The third chapter we show Engine-control method and calibration ,In the fourth chapter, we will present the experiment, design and experiment tools , In the last chapter, we did the experiment, we made the change, and we got the desired results .

Chapter I

State of the art

1. Problem statement

The importance of developing combustion technologies for advanced engine management systems in the automotive field has long been recognized. However, there are still some problems related to developing projects that suffer from the problem of delays and high costs, which can often impede work and lead to inefficiency.

First, when a constraint is not properly defined, subsequent disputes in the field are inevitable. This is what makes today's projects more technically challenging

Second, conventional methods, which are widely used as the basis for the limitations in developing combustion technologies , significantly limit our ability to formulate and develop solutions. In short, we should call for environmentally friendly vehicles and make great efforts to develop innovative engine concepts.

how become tuning performance industry formal qualification, path you can take that will make you a recognized aftermarket tuner. and improve the consumption and stringent emission norms for vehicles, like strategies namely advanced combustion techniques, after treatment systems and alternative fuels .

2. Research Objectives and Approach

The long term goal of the research is to develop a deep sense of vocation - Striving to organize and perform tasks in accordance with environmentally and health conscious, as well as sustainability expectations .Technical concepts such as direct injection helped to save fuel up to 20 % and reduce CO2-emissions. Descriptions for cylinder charge control, fuel injection, ignition, and emission volume control systems give an overview of today's engines. The aim of the present study is to improve the performance of the engine by discussing criteria and strategies for fuel injection, how to use dual fuel, mixture formation, fat burning control and the application of turbocharging and the rest of the gas. Moreover, the next section explains the main challenges of this technology. Particularly, the study has the following sub-objectives:

- The aim of this research is to provide deep understanding of the theory and experimental of modern Combustion Techniques for advance engine management systems In Automotive Sector .
- Striving to comply with and enforce quality standards .
- the development of new methods and equipment related to engineering .
- A deep sense of vocation - Striving to organize and perform tasks in accordance with environmentally and health conscious, as well as sustainability expectations.

The result of this study will be valuable to the industry practitioners and as well as related software providers in developing better practice and tools .

3. Research Methodology

This project plan deals with integration of Optimizing of diesel engine injection performance using an advanced ECU Remapping through the following stages:

3.1. Overview of advance engine management systems In Automotive Sector

Critical review of literature is necessary for exploring various diesel engine injection systems and ECU Remapping in order to understand the characteristics and the requirements of each part .

3.2. Design and development of ECU Remapping for automotive engines integration

A thorough literature review will lead to Understanding of the development requirements for the Potential Combustion Techniques for automotive engines will be identified based on a comprehensive review of current industry practices and academic researches.

3.3. Experimental validation

will be developed to verify and validate the simulation and theoretical findings. This will be based on ECU calibration is an extensive process of determining the most optimum calibration maps for engine operation and the overall experimental setup of engine dynamometer was divided into the parts:

test engine and dynamometer assembly and deduce the results .

4. History and Fundamental Principles of the Diesel Engine

4.1. History of the diesel engine

As early as 1863, the Frenchman Etienne Lenoir had test-driven a vehicle which was powered by a gas engine which he had developed. However, this drive plant proved to be unsuitable for installing in and driving vehicles. It was not until Nikolaus August Otto’s four-stroke engine with magneto ignition that operation with liquid fuel and thereby mobile application were made possible. But the efficiency of these engines was low. Rudolf Diesel’s achievement was to theoretically develop an engine with comparatively much higher efficiency and to pursue his idea through to readiness for series production.[1]

In 1897, in cooperation with Maschinen -fabrik Augsburg-Nürnberg (MAN), Rudolf Diesel built the first working prototype of a combustion engine to be run on inexpensive heavy fuel oil. However, this first diesel engine weighed approximately 4.5 tonnes and was three meters high. For this reason, this enginewas not yet considered for use in land vehicles. [1]

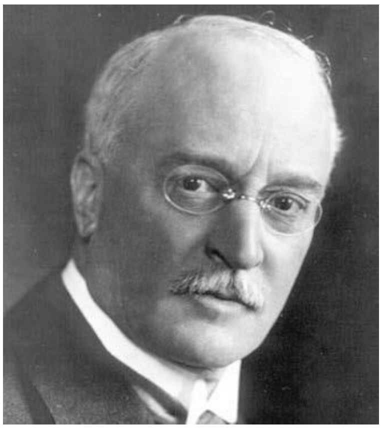


Figure 1Rudolf Diesel

4.1.1. The first diesel engine

Diesel sought out firms and factories that would build his engine. With the help of Moritz Schröter and Max Gutermuth , he succeeded in convincing both Krupp in Essen and the Maschinenfabrik Augsburg. Contracts were signed in April 1893, and in early summer 1893, Diesel's first prototype engine was built in Augsburg. On 10 August 1893, the first ignition took place, the fuel used was petrol. In winter 1893/1894, Diesel redesigned the existing engine, and by 18 January 1894, his mechanics had converted it into the second prototype. On February 17, 1894, the redesigned engine ran for 88 revolutions – one minute; with this news, Maschinenfabrik Augsburg's stock rose by 30%, indicative of the tremendous anticipated demands for a more efficient engine. On 26 June 1895 the engine achieved an effective efficiency of 16.6% and had a fuel consumption of 519 $g{\cdot}kW^{-1}{\cdot}h^{-1}$. However, despite proving the concept, the engine caused problems, and Diesel could not achieve any substantial progress. Therefore, Krupp considered rescinding the contract they had made with Diesel. Diesel was forced to improve the design of his engine and rushed to construct a third prototype engine. Between 8 November and 20 December 1895, the second prototype had successfully covered over 111 hours on the test bench. In the January 1896 report, this was considered a success.[2]

In February 1896, Diesel considered supercharging the third prototype. Imanuel Lauster, who was ordered to draw the third prototype, had finished the drawings by 30 April 1896. During summer that year the engine was built, it was completed on 6 October 1896. Tests were conducted until early 1897. First public tests began on 1 February 1897. Moritz Schröter's test on 17 February 1897 was the main test of Diesel's engine. The engine was rated 13.1 kW with a specific fuel consumption of 324 $g{\cdot}kW^{-1}{\cdot}h^{-1}$, resulting in an effective efficiency of 26.2%. By 1898, Diesel had become a millionaire. [2]

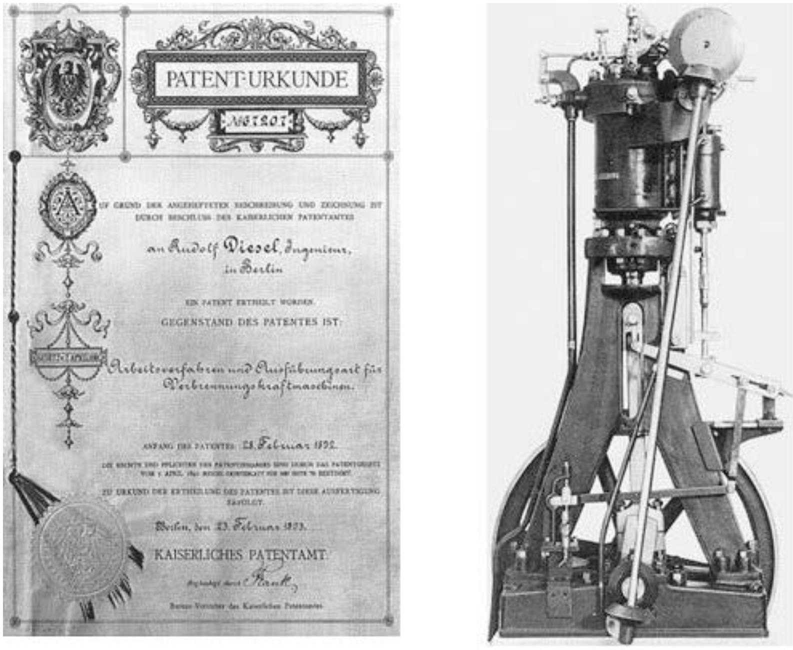


Figure 2Patent document for the diesel engine and its first design from 1894

4.2. Fundamentals of Engine Engineering

4.2.1. Introduction

Just like gasoline engines, diesel engines are, in principle, energy converters that convert chemically bound fuel energy into mechanical energy (effective work) by supplying the heat released by combustion in an engine to a thermodynamic cycle.[3]

As a function of the system boundaries of the converter represented as a ‘‘black box’’, the energy balance (Fig.3) is :

$$E_B + E_L + W_e + \Sigma E_V = 0.$$

If the energy of the combustion air relative to the ambient state is $E_L = 0$, then the energy supplied with the fuel m_B is equal to the effective work We and the total of all energy losses ∑Ev. [3]

The technical system of "diesel engine" is also part of the interconnectedness of a vast global system defined by the concepts of "resources" and "environmental pollution".

Overview Focusing on energy and economics and aiming to reduce losses, ∑Ev fails to meet today's current requirements due to environmental conditions that always impose energy and material transformation as efficiently as possible while reducing environmental pollution.

The diesel engine of our time is the result of the complex research and development that developed the diesel engine from a simple engine to a complex engine consisting of a number of subsystems .

One of the advantages of this development today is the great integration between electrical and electronic components and the shift from open control systems to closed control systems International competition makes minimum material consumption and manufacturing costs a necessity and this requires appropriate designs to work for optimal results

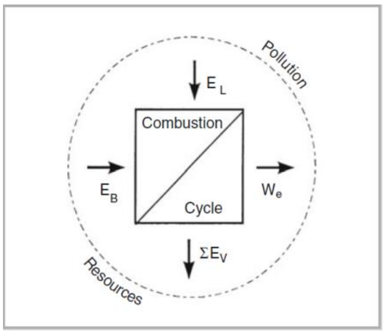


Figure 3The diesel engine as an energy converter

4.2.2. Introduction and operating cycles of Diesel engine

The modern motor vehicle engine burns a fuel to obtain power. The fuel is usually petrol (gasoline) or diesel, although liquid petroleum gas (LPG) and compressed natural gas (CNG) are sometimes used. Specialist fuels have been developed for racing car engines. Motor vehicle engines are known as ‘internal combustion’ engines (Fig.4) because the energy from the combustion of the fuel, and the resulting pressure from expansion of the heated air and fuel charge, is applied directly to pistons inside closed cylinders in the engine. The term ‘reciprocating piston engine’ describes the movement of the pistons, which go up and down in the cylinders. The pistons are connected by a rod to a crankshaft to give a rotary output .[4]

Figure 4: Internal combustion engine

a. Four-stroke engine

A **four-stroke** (also **four-cycle**) **engine** (Fig.5) is an internal combustion (IC) engine in which the piston completes four separate strokes while turning the crankshaft. A stroke refers to the full travel of the piston along the cylinder, in either direction. The four separate strokes are termed:

Intake: Also known as induction or suction. This stroke of the piston begins at top dead center (T.D.C.) and ends at bottom dead center (B.D.C.). In this stroke the intake valve must be in the open position while the piston pulls an air-fuel mixture into the cylinder by producing vacuum pressure into the cylinder through its downward motion. The piston is moving down as air is being sucked in by the downward motion against the piston.

Compression: This stroke begins at B.D.C, or just at the end of the suction stroke, and ends at T.D.C. In this stroke the piston compresses the air-fuel mixture in preparation for ignition during the power stroke (below). Both the intake and exhaust valves are closed during this stage.

Combustion: Also known as power or ignition. This is the start of the second revolution of the four stroke cycle. At this point the crankshaft has completed a full 360 degree revolution. While the piston is at T.D.C. (the end of the compression stroke) the compressed air-fuel mixture is ignited by a spark plug (in a gasoline engine) or by heat generated by high compression (diesel engines), forcefully returning the piston to B.D.C. This stroke produces mechanical work from the engine to turn the crankshaft.

Exhaust: Also known as outlet. During the *exhaust* stroke, the piston, once again, returns from B.D.C. to T.D.C. while the exhaust valve is open. This action expels the spent air-fuel mixture through the exhaust valve.

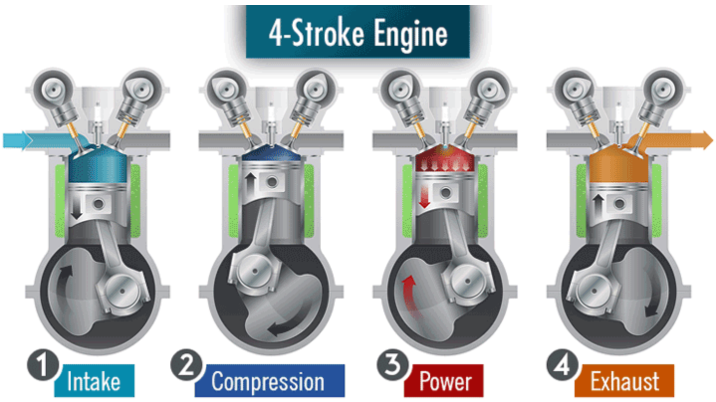


Figure 5: 4-Stroke Engine

The terms TDC and BDC are used to describe the position of the piston and crankshaft when the piston is at the end of a stroke and the axis of the piston and crankshaft bearing journals are in a straight line and at 0° (TDC) and 180° (BDC) of crankshaft revolution. To the abbreviations are added the letters ‘A’ to indicate degrees ‘after’ TDC or BDC and the letter ‘B’ to indicate ‘before’ TDC or BDC. [4]

The camshaft (Fig. 4) rotates once for the two revolutions of the crankshaft during the four-stroke cycle. The drive from the crankshaft to the camshaft hasa 2:1 ratio produced by the numbers of teeth on the driven and driver gears. Rotational data for the camshaft is usually given as degrees of crankshaft rotation and this should to be considered in relation to the four-stroke cycle. The four-stroke cycle occurs over two full revolutions of the crankshaft, which is a 720° rotational movement. [4]

Looking at the four-stroke cycle and the relationships of the crankshaft rotation, the piston position in the cylinder and the opening and closing of the valves is best observed by looking at a valve timing diagram (Fig.6). This diagram is one method of providing data for valve opening and closing positions. Valve timing data is given in engine workshop manuals as degrees of crankshaft revolution. This can be as written data or by means of valve timing diagrams. [4]

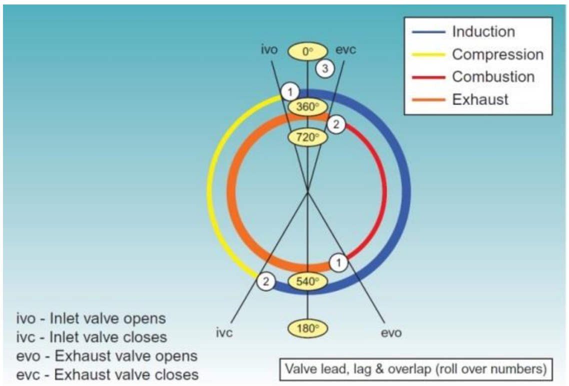


Figure 6 : Valve timing diagrams: 1, lead; 2, lag; 3, overlap

In the most popular valve timing diagram two circles, one inside the other, are used to represent the 720° of crankshaft rotation through which the crankshaft moves for a complete cycle. Each stroke is represented by an arc of 180° with induction and compression on the outer circle and combustion and exhaust on the inner circle. The valve opening and closing positions are marked and the duration of crankshaft rotation is displayed by a thicker line. [4]

4.2.3. **Engine Combustion**

b. **Fundamentals of Combustion Simulation**

Chemically, combustion is the oxidation of fuel molecules with atmospheric oxygen as the oxidant. Thus, the maximum convertible fuel mass m_B is limited by the air mass present in the engine cylinder. Using the fuel specific stoichiometric air requirement L_{min} (kg air/kg fuel) for complete combustion, the air/fuel ratio λ_V specifies the ratio of ‘‘supply to demand’’ in combustio : [3]

$$\lambda_{\mathrm{v}} = m_{\mathrm{LZ}}/(m_B \cdot L_{\mathrm{min}}).$$

The following applies to the ‘‘supply’’ of the air mass m_{LZ} of all cylinders (V_Z = z . V_Z) contained in the entire engine:

$$m_{LZ} = V_Z \cdot \rho_Z = \lambda_1 \cdot \rho_L \cdot V_H.$$

Since the density ρ_Z of the cylinder charge is usually unknown, the definitions of the volumetric efficiency λ_1 and the density ρ_L of the fresh charge directly at the inlet to the cylinder head are generally reverted to:

$$\rho_L = p_L / (R_L \cdot T_L).$$

From the preliminary fuel analysis the requirements for air derive from petroleum-derived diesel fuel (DF) is the combination of both hydrocarbons and consists primarily of carbon C, hydrogen H and sulfur S with unimportant parts of oxygen O and nitrogen N.

From this the equation for the total oxidation of the general fuel molecule CxHySz in CO2, H2O and SO2

$$C_xH_yS_Z + [x + (y/2) + z] \cdot O_2 \rightarrow$$
$$x \cdot CO_2 + (y/2) \cdot H_2O + z \cdot SO_2 + Q_{ex},$$

L_{min} ratio of air / fuel produced is identical to the oxygen content in the air and a specified number of moles

$$L_{min} = 11.48 \cdot (c + 2.98 \cdot h) + 4.3 \cdot s - 4.31 \cdot o \ \text{[kg/kg]}$$

The O_{ex} heat released during combustion corresponds to the calorific value of the Hu fuel, which can also be calculated from elemental analysis as follows with a fraction of a mass of 1 kg of fuel according to the preliminary analysis. DK reference value: L_{min} = 14.5 kg / kg).

$$H_u = 35.2 \cdot c + 94.2 \cdot h + 10.5 \cdot (s - o) \quad \text{[MJ/kg]}$$

The following approximate relation is based on the fuel density ρ_B at 15°C:

$$H_u = 46.22 - 9.13 \cdot \rho_B^2 + 3.68 \rho_B \quad \text{[MJ/kg]}.$$

From it, the following is achieved with respect to the temperature provided for the combustion cycle through "internal combustion":

$$E_B = Q_{zu} \leq m_B \cdot H_u.$$

4.3. Comparison of Engine Combustion Systems

Modern diesel engines containing the common-rail (CR) fuel injection systems, the variable geometric turbochargers (VGTs) and the exhaust gas recirculation (EGR) systems allow further improvement on the performance and reduction of pollutant emissions, noise and fuel consumption.[5]

Combustion is preceded by the preparation of usually liquid fuel to obtain a combustible mixture of fuel vapor and air. This process proceeds differently in diesel and gasoline engines (Table. 1). Internal mixture formation in diesel engines, begins with the injection of the fuel into the highly compressed and thus heated air shortly before TDC, whereas external mixture in classic gasoline engines is formed outside the working chamber by a carburetor or by injection into the intake manifold and often extends through the induction and compression stroke. [3]

The difference between engines is gasoline, which contains a homogeneous mixture of fuel / air, while diesel engines contain a heterogeneous mixture before ignition, which consists of fuel droplets of a few micrometres distributed throughout the combustion chamber. It is surrounded by fuel vapor / air mixture and is partially liquid

Combustion in gasoline engines is started by a tight spark ignition by activating an electrical discharge in the ignition plug, provided that the homogeneous air / fuel ratio of the mixture falls within the ignition limits, But diesel engines, drops surrounded by a flammable mixture, ignite automatically. There are no ignition limits in the par isotropic range (λ_V = 1) except for the fine mixture in the fuel droplets region .

Feature	Diesel engine	Gasoline engine
Mixture formation	Inside V_z	Outside V_z
Type of mixture	Heterogeneous	Homogenous
Ignition	Auto-ignition with excess air	Spark ignition within ignition limits
Air/fuel ratio	$\lambda_V \geq \lambda_{min} > 1$	$0.6 < \lambda_V < 1.3$
Combustion	Diffusion flame	Premix flame
Torque change through fuel	Variable l_V (quality control)	Variable mixture quantity (quantity control)
	Highly ignitable	Ignition resistant

Table 1: Comparison of features of engine combustion

Diesel engines require excess air ($\lambda_V \geq \lambda_{min} > 1$) for normal combustion. Consequently, the supply of energy is adapted to the engine load in diesel engines by the air/fuel ratio, i.e. the mixture quality (quality control) and, in light of the ignition limits, by the mixture quantity (quantity control) in gasoline engines by throttling that entails heavy losses when a fresh charge is aspirated. [3]

It is the type of ignition and mixture formation that determines the fuel requirements. Diesel fuel must be flammable.This is expressed by the cetane number. Uncontrolled automatic ignition does not lead to uncontrolled combustion (detonation). For this, gasoline must be flammable, that is, i t has a high octane number ,This ignition is ensured by low boiling, short chain, and therefore thermally stable hydrocarbons (C5 to C10). On the other hand, diesel fuel is distinguished by being composed of long-boiling and high-chain hydrocarbons (C9 to C30) that break apart early and form free radicals that facilitate self-ignition .

heat not being transferred between the gas and the environment. When this cycle is reversible, it is called an isentropic change of state. However, just as the real isentropic exponent depends on the state and composition of a gas, this is never actually the case in reality .[6]

4.4. THE BASICS AND DEFINITION OF ENGINE PERFORMANCE TERMS

To describe engine performance, we usually mention common features and terms describing engine performance, including cylinder pressure, crankshaft speed, fuel consumption, torque, and power at different places in the engine, powertrain, and different sets of these as shown below. These are performance parameters that are influenced by the electronic control of the engine.

In order to understand how the effect of the console is, you need to have the quantitative models of these performance variables as shown below.

4.4.1. TORQUE

Engine torque is produced on the crankshaft by the cylinder pressure pushing on the piston during the power stroke. In an IC, engine torque is produced at the crankshaft as explained below. The torque that is applied to the crankshaft is called “indicated torque T_i.” The output torque from the engine at the transmission end of the crankshaft differs from Ti due to friction and pumping losses and is called the brake torque (denoted T_b).[7]

(Fig.7) explains the different torque at different points in the transmission and shows the geometry of one cylinder in the four-stroke IC drive as it generally shows the central line of the cylinder, which is a line along the cylinder axis through the elbow shaft rotation center. The piston is connected via the connecting rod to the crankshaft and the connecting rod is connected to the piston via the piston pin that this rod can rotate around.

In (Fig.7) the piston pin is compensated from the cylinder axis by an amount indicated by δ, in order to improve the torque relative to that which will be produced with $\delta = 0$. During the power stroke, the torque is applied to the crank shaft caused by the force acting on the piston due to the pressure of the combustion chamber running through the boom, which is proportional to the crank throw R and which varies with the angular position of the crankshaft (θe). In order to distinguish it from the other torque acting on the elbow shaft, this torque is known as the indicated torque.

(Fig.7) shows the geometry of the piston, the connecting rod, and the crankshaft in a manner that allows the development of a model of the indicated torque Ti (θe) as a function of the elbow angle (θe).

In (Fig.7), the connecting rod length is denoted L_r, and the radius from the crankshaft axis of rotation to the center of the connecting rod journal is denoted R. It is this radius of the crankshaft rotation that provides the lever arm for the production of indicated torque due to the force on the top of the piston due to combustion chamber pressure ($Pc(\theta e)$). In many engines, the piston pin is located slightly off the cylinder centerline (C_L) in a plane that is orthogonal to the crankshaft axes of rotation, which benefits torque production. The piston pin offset from the cylinder C_L is denoted δ in (Fig.7) . The angle between the connecting rod plane of symmetry and the cylinder axis is denoted β. [7]

Owing to the piston offset, the indicated torque for a piston on the down stroke is given by

$$T_i(\theta_e) = \frac{p_c(\theta_e)\, AR\, \sin(\theta_e + \beta)}{\cos\beta} \quad 0 \le \theta_e < \pi$$

On the upstroke *Ti* is given by:

$$T_i(\theta_e) = \frac{p_c(\theta_e)\, AR\, \sin(\theta_e - \beta)}{\cos\beta} \quad \pi \le \theta_e < 2\pi$$

where A is the piston cross-sectional area. The factors R $[\sin(\Theta e \pm \beta)]\,/\cos(\beta)$ represent the lever arm through which torque is applied to the crankshaft.

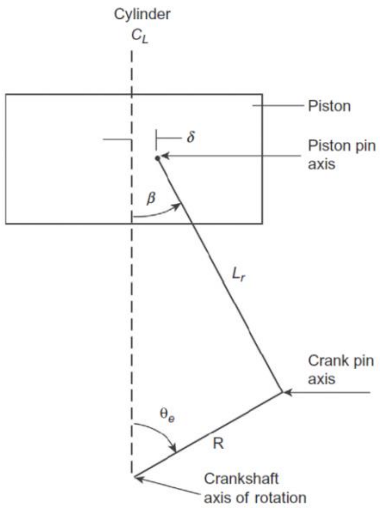


Figure 7: Schematic illustration of cylinder geometry.

In (Fig.8), the combustion chamber pressure in a representative four-stroke representative IC engine for a full drive cycle (720 ° crankshaft rotation) begins at _180 ° (BDC) to start the pressure and ends at 540 ° (BDC)) at the end of the stroke. The pressure rises suddenly after ignition (point X), due to a combustion that reaches its maximum at A. Point (y) is slightly further than TDC. .The positive working area for each cycle in the drawing is referred to as the power stroke (i.e. 0-180 degrees).

Fluctuations in the combustion chamber pressure along with the computer-related engineering factor cause the Ti to fluctuate at the angle of the crankshaft and of course over time. However, when the engine produces energy, the average time value of *Ti* (so. *Ti*) is positive

$$Ti > 0$$

There are other contributors to the total dynamic indicated torque at the crankshaft, including torques due to the reciprocating forces of the piston and connecting rod., but in general increase quadratically with rotational speed. In addition, there are contributors to the torque at the crankshaft due to internal friction of the rotating and reciprocating components as well as due to pumping of intake and exhaust gases. [7]

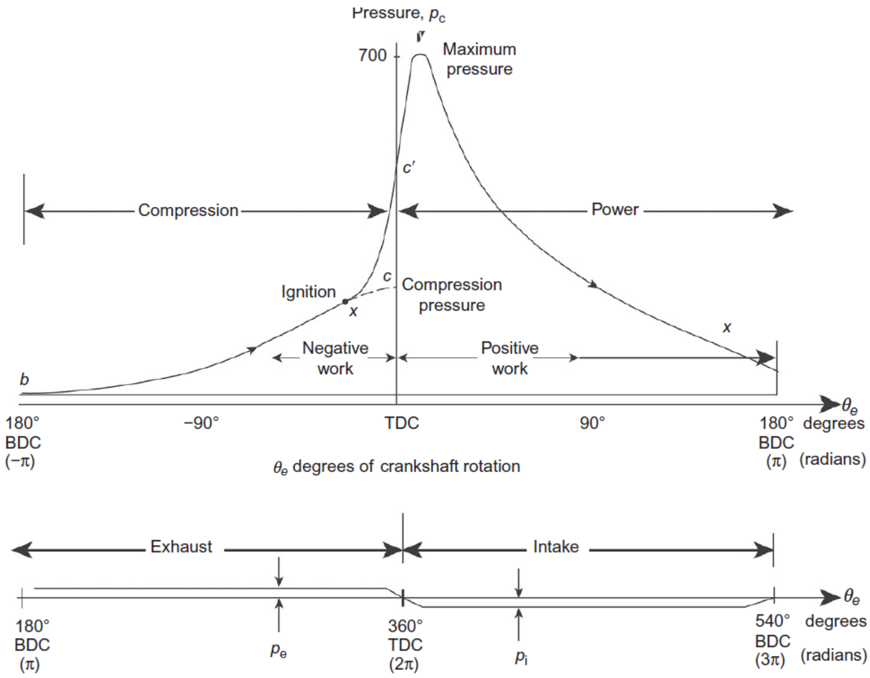


Figure 8: Exemplary plot of pc(θe).

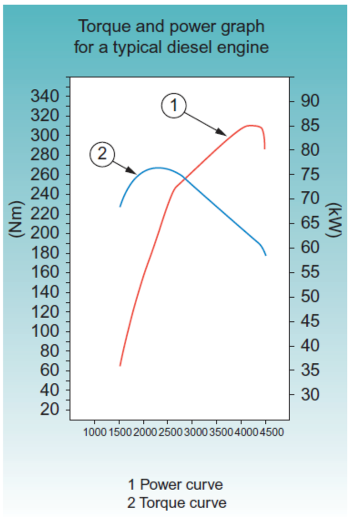
The indicated torque is the maximum available torque that is applied at each crankshaft segment for the corresponding cylinder. Typically, between each crankshaft "throw" are sleeve bearings that have friction. In addition to friction, there are negative torques applied to the crankshaft owing to the nonzero cylinder pressures p_e during exhaust and p_i during intake and a relatively large negative torque associated with compression. The time-average torque averaged over an engine cycle at the crankshaft output end is called the brake torque $\bar{T}_b$ and is given by [7]

$$\bar{T}_b = \bar{T}_c - \bar{T}_{fp}$$

The meaning of $\bar{T}_{fp}$ is the average torque associated with losses due to friction and pumping, and this is the brake torque that drives the system. The drive system provides the torque to drive the vehicle. The propulsion system includes transmission and other gear systems

4.4.2. POWER

Two common terms used when expressing engine performance characteristics are 'torque' and 'power'. Torque is an expression relating to work and is a measure of the turning force provided by the engine. Torque output can vary independently of engine speed and is a measure of the load on the engine. The SI units of torque are newton meters (Nm) and the imperial units are pounds/foot (lb/ft). Power is a derived unit and relates to the rate of work done, or the work done per unit of time. For an engine, the power is a product or torque and speed. Power output is given in kilowatts (kW) or horsepower (HP). Engine power is normally stated as measured at the fly wheel, via a dynamometer or brake, hence the term 'brake horsepower.[4]



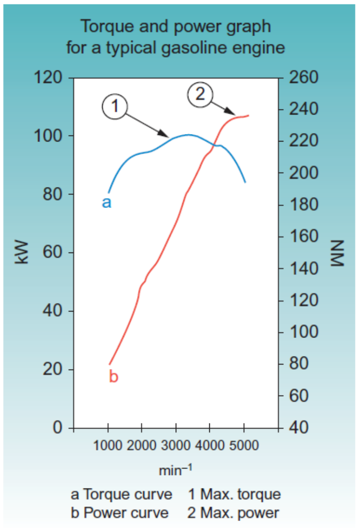


Figure 9Spark ignition (SI) engine *Figure 10Compression ignition (CI)*

One of the most important metrics for engine performance is output power. This power is related to the indicated torque applied to the crankshaft (as explained above). The instantaneous power applied to the crankshaft by the indicated torque is known as the indicated power (*Pi*(θe(t))), given by [3]:

$$P_i(t) = T_i(t)\omega_e(t)$$

Where

$$\omega_e(t) = \frac{d\theta_e}{dt} \quad \text{in rad/s}$$

The units for *Pi(t)* are N*m/sec (metric) or ft * lb/sec (English units). Normally, it is the average indicated power averaged over N engine cycles $\bar{P}(N)$ that is useful as a metric for engine available power (with θe in radians) is given by[3] :

$$\bar{P}_i(N) = \frac{1}{4\pi N}\int_0^{4\pi N} P_i(\theta_e)d\theta_e \quad N = \text{integer}$$

The appropriate unit for *Pi* is kW; although in the United States, the popular unit (with the driving public) remains horsepower (hp), where 1 hp=0.75 kW and 550 ft lb/sec. [3]

Brake force (*Pb*) is the engine output power in the crankshaft where engine power is traditionally measured with Prony brakes. This brake power (in kilowatts or horsepower) is the difference between the indicated power and the energy associated with the loss of internal energy as a result, for example, of friction and pumping of the mixture mixture and exhaust gases. The frictional force and pumping power that is computed is combined into the average cycle and is commonly referred to as $\overline{P}_{fp}$. P_b brake force is given by:

$$P_b = \bar{P}_i - \bar{P}_{fp}$$

4.4.3. FUEL CONSUMPTION

Fuel economy can be measured while the engine delivers power to the dynamometer. The engine is typically operated at a fixed RPM and a fixed brake power (fixed dynamometer load), and the fuel flow rate (in kg/h or lb/h) is measured. The fuel consumption is then given as the ratio of the fuel flow rate $\dot{f}$ to the brake power output (P_b). This fuel consumption is known as the brake-specific fuel consumption or BSFC. BSFC is a measurement of the fuel economy of the engine alone and is given by [3]:

$$\text{BSFC} = \frac{\dot{f}}{P_b}$$

The unit for BSFC is kg/(kW*h) or lb/(hp*h) in British units. By improving the BSFC of the engine, the fuel economy of the vehicle in which it is installed is also improved.[3]

In gasoline-fueled engines Air flow to the engine at any operating speed (RPM) in gasoline engines is determined by throttle angle setting. [3]

As explained above, any internal combustion must pump air/fuel into its combustion chamber. If an IC engine were a perfect air pump, then, at wide open throttle, the air volume pumped into the engine for each complete engine cycle (i.e., two complete revolutions) would be its displacement volume V_d. [3]:

$$V_d = A_p S_c M$$

where A_p is the piston cross-sectional area and *Sc* the cylinder stroke, which is the distance traveled by the piston from TDC to BDC and M=number of cylinders. Formally, the volumetric efficiency e_v is defined as the ratio of the mass of fresh mixture (i.e., air and fuel) that is actually pumped into the cylinder during an intake stroke at inlet air density to the mass of this mixture, which would fill the cylinder at the inlet air density. The volumetric efficiency for any given engine is determined empirically and varies with throttle angle, RPM, inlet pressure and temperature, and exhaust pressure (p_e). Assuming initially that all cylinders receive mixture at identical density, the definition of e_v can be expressed by.[3]:

$$e_v = \frac{2\dot{M}_i}{N V_d \rho_i}$$

where $\dot{M}_\iota$ is the air intake mixture mass flow rate (slugs/sec) (or kg/sec), N the number of revolutions/ sec, and ρi the inlet mixture density (slugs/ft3) (or kg/m3).

The variable p_i is the density of the mixture in the intake system downstream from the throttle plate in or near a cylinder inlet port. When inlet air density is defined at this point in the intake system, it provides a measurement of the air pumping efficiency of the cylinder and valves alone. It is this definition that is used for the present discussion. However, it should be noted that volumetric efficiency could be based on the air density at the input to the intake system (i.e., upstream of the throttle plate). With air density taken at this point, the volumetric efficiency is termed the overall volumetric efficiency. Unfortunately, it is not always convenient to measure the density of the inlet mixture that consists of air, fuel, and atmospheric water vapor. On the other hand, since fuel, airflow, and water vapor occupy the same volume and have the same intake volume flow rate $\dot{V}_i$, the following relationship is valid. [3]:

$$\dot{V}_i = \frac{\dot{M}_i}{\rho_i} = \frac{\dot{M}_a}{\rho_a}$$

where $\dot{M}_a$ a is the mass flow rate of dry air and p_a the inlet density of dry air. For mixtures of air, water vapor, and gaseous or evaporated fuel, Dalton's law of partial pressures states

$$p_i = p_a + p_f + p_w$$

where p_i is the total inlet pressure, pa the partial pressure of air, p_f the partial pressure of fuel, and p_w the partial pressure of water vapor.

Each constituent (denoted k) of the inlet air mixture behaves as a perfect gas such that

$$\rho_k = \frac{p_k}{RT_i}$$

where *R* is the perfect gas law constant. Also, it can be shown that

$$\frac{p_a}{p_i} = \frac{M_a/m_a}{\left[\frac{M_a}{m_a} + \frac{M_f}{m_f} + \frac{M_w}{m_w}\right]}$$

where M_k = mass of constituent *k* and m_k=molecular mass of constituent k:

$$k = a, f, w$$

The air density in the mixture p_a is given by

$$\rho_a = \left(\frac{p_i}{RT_i}\right) / \left[1 + F_i\left(\frac{m_a}{m_f}\right) + \frac{m_a}{m_w}h\right]$$

Where $Fi\left(\frac{mf}{ma}\right)$ is the fuel/air mass ratio, h the ratio of mass water vapor to the mass of air, m_a=29, and m_w =18.

In this form, it is possible to compute inlet air density from measurements of total inlet air pressure (p_I) and inlet absolute air temperature T_I and standard environmental variable measurements (e.g.,relative humidity). [3]

As presently shown, Fi is determined by the fuel control system to achieve certain engine performance requirements. As explained earlier in this chapter, the engine power is regulated by the driver via an air valve in the form of a movable throttle plate in the intake system. Linkage connects the accelerator pedal to the throttle plate such that it partially restricts airflow into the engine. Typically, the throttle plate is in the form of a circular disk that pivots about a diametric axis in a cylindrical portion of the intake manifold. Effectively, the airflow into the engine at any given engine angular speed (RPM) varies in proportion to the opening of this plate as represented by the throttle angle θ_T. This empirically determined volumetric efficiency is a convenient variable that can be used to characterize engine pumping efficiency during the development of a new engine control system and can also be used in fuel control of a production engine as explained later. [3]

4.4.4. **CALIBRATION**

The definition of engine calibration is the setting of the air/fuel ratio and ignition timing for the engine for any given operating condition. With the new electronic control systems, calibration is determined by the electronic engine control system.[7]

Electronic engine control systems rely on microprocessors or microcontrollers as described later in this chapter Diesel engine management system determines the correct amount of fuel delivery and ignition timing as a function of the driver's command (via throttle control), operating variables and other parameters under program control. In an ideal fuel control system, correct values are found from the table lookup process with interpolation, Calibration tables for any given engine configuration are found experimentally as shown below. Fuel delivery plug-in is determined from the closed-loop (CL) portion of the control as shown below.

4.4.5. **ENGINE MAPPING**

The development of any control system comes from knowledge of the plant or system to be controlled. In the case of the automobile engine, this knowledge of the plant (the engine) comes primarily from a process called engine mapping.[7]

So that we can get the engine mapping the engine is connected to a dynamic scale and runs throughout its speed and full load range. The important engine variables are measured, while quantities, such as the ratio of air / fuel and spark control, vary in a known and systematic way. Under computer control this engine mapping is performed in engine test cells that contain engine dynamics and sophisticated devices that collect data. An ideal calibration can be found as a compromise between performance and exhaust gas emissions rates permitted under federal regulations where at each operating point, calibration varies and performance is measured.

4.4.6. EFFECT OF AIR/FUEL RATIO ON PERFORMANCE

Fig. 11 illustrates the variation in the performance variables of indicated torque (T_i) BSFC and engine emissions with variations in the air/fuel ratio with fixed spark timing and a constant engine speed. In this figure, the exhaust gases are represented in brake-specific form. This is a standard way to characterize exhaust gases whose absolute emission levels are proportional to power. The definitions for the brake-specific emissions rates are[7]:

BSHC=brake-specific HC concentration

$$= \frac{r_{HC}}{P_b}$$

BSCO=brake-specific CO concentration

$$= \frac{r_{CO}}{P_b}$$

BSNOx=brake-specific NOx concentration

$$= \frac{r_{NOx}}{P_b}$$

where r_{HC} is the HC rate of flow, r_{CO} the CO rate of flow, r_{NOx} the NOx rate of flow, and P_b the brake power. The indicated torque is denoted T_i in Fig. 11. [7]

In electronic fuel control systems, the specified air / fuel ratio is a very important one It is a chemical measurement mixture. The equivalent measurement mixture (i.e. chemically correct) corresponds to the air and fuel mixture so that if combustion is ideal, all hydrogen and carbon in the fuel

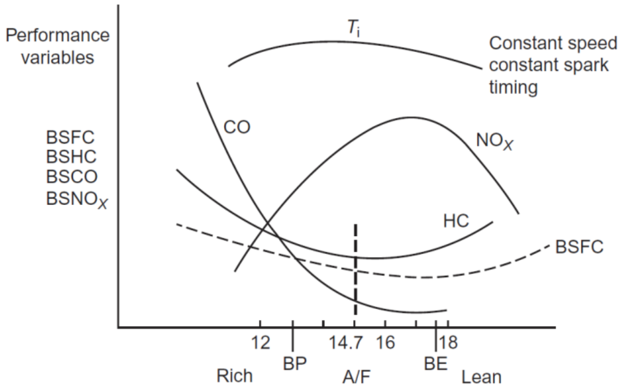


Figure 11Typical variation of performance with a variation in air/fuel ratio.

be converted by the burning process to H2O and CO2. For gasoline, the stoichiometric mixture ratio is 14.7:1. Stoichiometry is sufficiently important that the fuel and air mixture is often represented by a ratio called the equivalence ratio, which is given the specific designation λ. The equivalence ratio is defined as follows :

$$\lambda = \frac{(\text{air}/\text{fuel})}{(\text{air}/\text{fuel@stoichiometry})}$$

A relatively low air/fuel ratio, below 14.7 (corresponding to λ<1), is called a rich mixture, and an air/ fuel ratio above 14.7 (corresponding to λ>1) is called a lean mixture. Emission control is strongly affected by air/fuel ratio or by λ.

4.4.7. EFFECT OF SPARK TIMING ON PERFORMANCE

Spark advance is the time before top dead center (TDC) when the spark is initiated. It is usually expressed in number of degrees of crankshaft rotation relative to TDC. Fig. 12 reveals the influence of spark timing on brake-specific exhaust emissions with constant speed and constant air/fuel ratio for a representative engine. [7]

Note that both NOx and HC generally increase with increased advance of spark

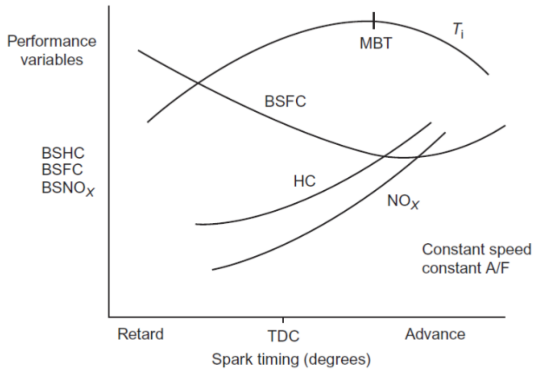


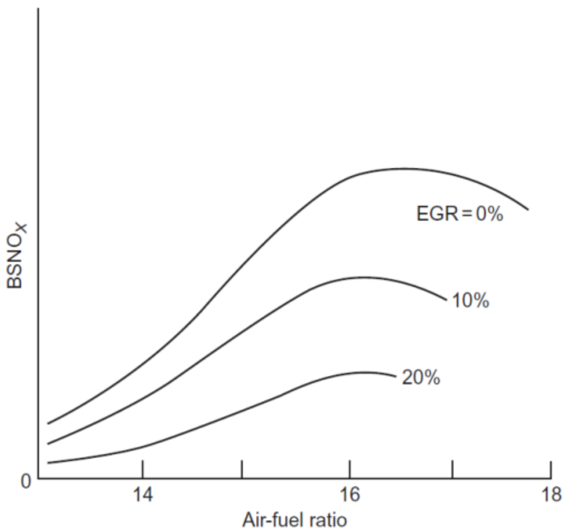
Figure 12Representative variation of performance with spark timing.

timing. BSFC and torque are also strongly influenced by timing. Fig. 12 shows that maximum torque occurs at a particular advanced timing (called advanced for mean best torque) denoted MBT. Operation at or near MBT is desirable since this spark timing tends to optimize performance. [7]

This optimal spark timing varies with RPM. As will be explained, engine control strategy involves regulating fuel delivery at a stoichiometric mixture and varying ignition timing for optimized performance. Another variable can be controlled, and thus the motor control system helps in meeting Exhaust gas mission regulations.

4.4.8. **EFFECT OF EGR ON PERFORMANCE**

Up to this point in the discussion, only the traditional calibration parameters of the engine (air/fuel ratio and spark timing) have been considered. However, by adding another control variable, the undesirable exhaust gas emission of NOx can be significantly reduced while maintaining a relatively high level of torque. This new control variable, EGR, consists of recirculating a precisely controlled amount of exhaust gas into the intake. The engine control configuration shows that EGR is a major subsystem of the overall control system. Its influence on emissions is shown qualitatively in Figs. 13 and 14 as a function of the percentage of exhaust gas in the intake. Fig. 13 shows the dramatic reduction in NOx emission when plotted against air/fuel ratio, and Fig. 14 shows the effect on performance variables as the percentage of EGR is increased. Note that the emission rate of NOx is most strongly influenced by EGR and decreases as the percentage of EGR increases. The HC emission rate increases with increasing EGR; however, for relatively low EGR percentages, the HC rate changes only slightly. Thus, a compromise EGR rate between NOx reduction and HC increase is possible in which the benefits of EGR on NOx reduction far offset the adverse effect on HC emissions. This compromise amount of EGR varies with engine configuration. [7]



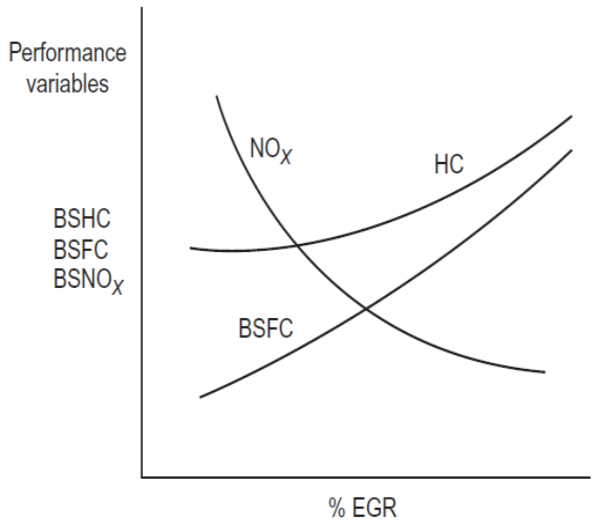


Figure 13NOx emission as a function of air/fuel ratios at various EGR%. Figure 14Influence of EGR on brake-specific performance variables.

Chapter II

Diesel Engine Management

1. Introduction

Automobile engines effectively encompass the spirit of mechatronic systems with their abundant application of electronics, sensors, actuators and microprocessor based control systems to provide improved performance, fuel economy and emission levels. The classical approach of engine-control tasks is accomplished by means of a mechanical approach, but now it is being replaced by electronic control systems. In such systems, engine performance such as power, torque, fuel-consumption and emission level, is significantly affected by the control strategies followed in the engine management system (EMS).[8] The modern spark ignition engines are generally equipped with an EMS whose task is to provide the desired output from the engine and it plays an important role in the driver's control of the vehicle. It controls the operations such as ignition, air- to-fuel ratio, idle speed and complex variable valve timing, etc., in order to reduce the emissions and improve the average fuel economy.[9] Compared with ordinary embedded systems, it requires more stringent demands on reliability, resource sharing and cost.[10] Engine management system (EMS) usually consists of various sensors to monitor the real-time operating conditions of the en- gine and actuators to control injector, spark plug, throttle, etc. The control signal sent to different actuators is accomplished by means of the EMS control system, which is comprised of a large number of control modules (control loops) in its architecture.[11]

2. Overview of common-rail systems

The demands placed on diesel-engine fuel-injection systems are continuously increasing. Higher pressures, faster switching times, and a variable rate-of-discharge curve modified to the engine operating state have made the diesel engine economical, clean, and powerful. As a result, diesel engines have even entered the realm of luxury performance sedans. [12]

Modern diesel engines containing the common-rail (CR) fuel injection systems, the variable geometric turbochargers (VGTs) and the exhaust gas recirculation (EGR) systems allow further improvement on the performance and reduction of pollutant emissions, noise and fuel consumption.[13]

The common rail fuel injection system (CR) is one of the advanced fuel injection systems and has several advantages, the most important of which is its ability to control the timing and change of injection pressure on the widest range . All of this was done by separating the pressure generation in (High Pressure Pump) from the fuel injection system , Rail here acts as a pressure accumulator.

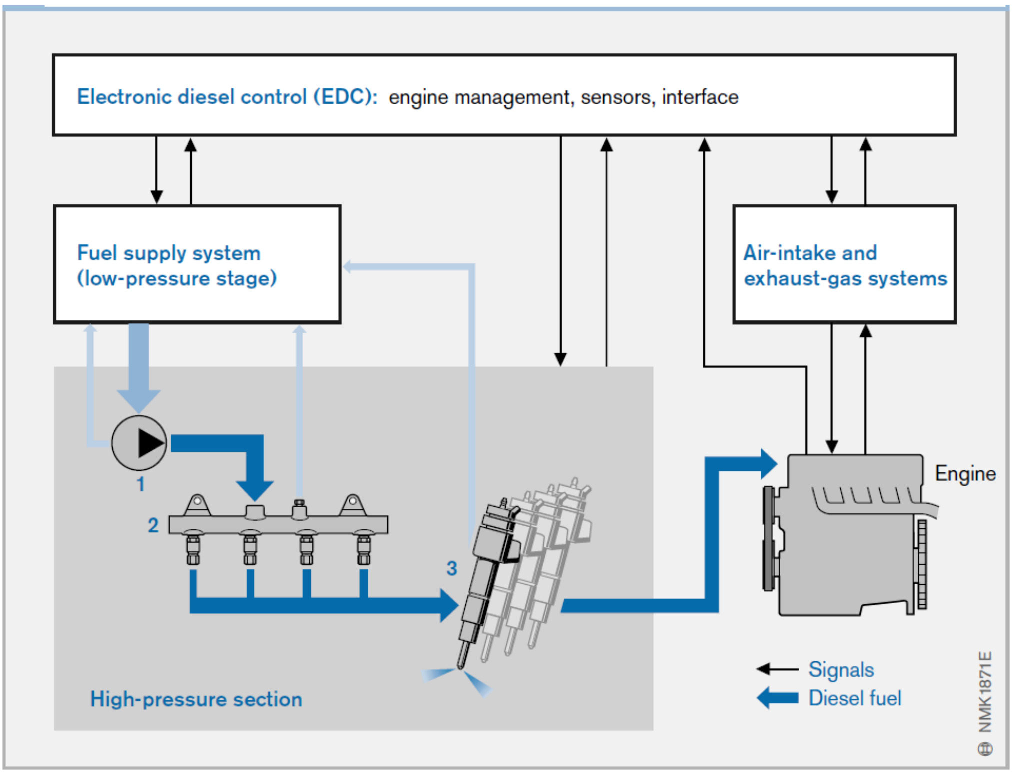


Figure 15: System modules of an engine control unit and a common-rail fuel-injection system

2.1. Areas of application

The common-rail fuel-injection system for engines with diesel direct injection (**D**irect **I**njection, DI) is used in the following vehicles[12]:

_ Passenger cars ranging from high-economy 3-cylinder engines with displacements of 800 cc, power outputs of 30 kW (41 HP), torques of 100 Nm, and a fuel consumption of 3.5 l/100 km through to 8-cylinder engines in luxury-performance sedans with displacements of approx. 4 l, power outputs

of 180 kW (245 HP), and torques of 560 Nm.
_ Light-duty trucks with engines producing up to 30 kW/cylinder, and
_ Heavy-duty trucks, railway locomotives, and ships with engines producing up to approx. 200 kW/cylinder

2.2. Design

The common-rail system consists of the following main component groups (Figs. 15) [12]:

- The low-pressure stage, comprising the fuel supply system components.
- The high-pressure system, comprising components such as the high-pressure pump, fuel rail, injectors, and high pressure fuel lines.
- The electronic diesel control (EDC), consisting of system modules, such as sensors, the electronic control unit, and actuators. The key components of the common-rail system are the injectors. They are fitted with a rapid-action valve (solenoid valve or piezo-triggered actuator) which opens and closes the nozzle. This permits control of the injection process for each cylinder.

The injectors are fed by the common fuel rail system from here on the origin of the term common rail. The most important feature of this system is the pressure in the system is variable, depending on the operating mode of the engine. Responsible for the system pressure is the pressure control valve or the metering unit . The modular design of the common rail system simplifies modification of the system to several different engines

2.3. Operating concept

The pressure-generating and fuel-injection functions are separate in the common rail fuel injection system, Injection pressure is generated independently of both the injected fuel quantity and the engine's rotational speed, Each component is controlled by the Electronic Diesel Control System (EDC)

2.3.1. Pressure generation

Pressure generation and fuel injection are separated by means of an accumulator volume. Fuel under pressure is supplied to the accumulator volume of the common rail ready for injection. A continuously operating high-pressure pump driven by the engine produces the desired injection pressure. Pressure in the fuel rail is maintained irrespective of engine speed or injected fuel quantity[12]. owing to the almost regular injection pattern, some characteristics may change such as the high pressure pump may be much smaller, Torque in the driving system can also be lower than conventional fuel injection systems. This results in a much lower load on the pump motor High pressure pump is radial piston pump The fuel injection pump is sometimes installed in commercial vehicles.

2.3.2. Pressure control

There is a relationship between the applied pressure control method and the system as the method largely depends on the type of system

c. Control on the high-pressure side

On passenger-car systems, the required rail pressure is controlled on the high-pressure side by a pressure-control valve . Fuel not required for injection flows back to the low pressure circuit via the pressure control valve. This type of control loop allows rail pressure to react rapidly to changes in operating point (e.g. in the event of load changes). [12]

High pressure control was adopted in the first common rail systems. The best location for installing the pressure control valve is the fuel rail .However, in some applications it may be installed directly on the high pressure pump

2.3.3. Control and regulation

d. Operating concept

The engine control unit detects the accelerator-pedal position and the current operating states of the engine and vehicle by means of sensors. The data collected includes[12]:

- Crankshaft speed and angle
- Fuel-rail pressure
- Charge-air pressure
- Intake air, coolant temperature, and fuel
- temperature
- Air-mass intake
- Road speed, etc.

The electronic control unit evaluates the input signals. In sync with combustion, it calculates the triggering signals for the pressure control valve or the metering unit, the injectors, and the other actuators (e.g. the EGR valve, exhaust-gas turbocharger actuators, etc.).

Injector switch times to achieve high results should be short, This is by using improved high pressure switch valves and a special control system. The angle / time system compares the injection timing, based on data from the crankshaft and camshaft sensors, with the condition of the engine (time control). Electronic diesel control system (EDC) allows accurate measurement of the amount of fuel injected.

In addition, EDC provides the ability to perform additional functions and features that can improve engine response and comfort.

e. Basic functions

The basic functions involve the precise control of diesel-fuel injection timing and fuel quantity at the reference pressure. In this way, they ensure that the diesel engine has low consumption and smooth running characteristics. [12]

f. Correction functions for calculating fuel injection

A number of correction functions are available to compensate for tolerances between the fuel injection system and the engine [12]:

- Injector delivery compensation
- Zero delivery calibration
- Fuel-balancing control
- Average delivery adaption

g. Additional functions

Additional open- and closed-loop control functions perform the tasks of reducing exhaust-gas emissions and fuel consumption, or providing added safety and convenience. Some examples are[12]:

- Control of exhaust-gas recirculation
- Boost-pressure control
- Cruise control
- Electronic immobilizer, etc.

Integrating EDC in an overall vehicle system opens up a number of new opportunities, e.g. data exchange with transmission control or air-conditioning system. A diagnosis interface permits analysis of stored system data when the vehicle is serviced.

2.3.4. Control unit configuration

As the engine control unit normally has a maximum of only eight output stages for the injectors, engines with more than eight cylinders are fitted with two engine control units. They are coupled within the "master/ slave" network via an internal, high-speed CAN interface. [12]

As a result, there is a high microcontroller processing capacity available, There are some functions that are assigned to a specific controller, for example (fuel balance control). Other units can also be allocated dynamically to one controller or another to the controllers depending on the positions (for example in order to detect sensor signals).

3. Overview of electronic control unit (ECU)

Digital technology furnishes an extensive array of options for open and closed-loop control of automotive electronic systems. A large number of parameters can be included in the process to support optimal operation of various systems. After receiving the electric signals transmitted by the sensors, the control unit processes these data in order to generate control signals for the actuators. The control program, the "software", is stored in aspecial memory and implemented by a microcontroller. The control unit and its components are referred to as "hardware". The EDC control unit contains all of the algorithms for open and closed-loop control needed to govern the Engine-management processes. [12]

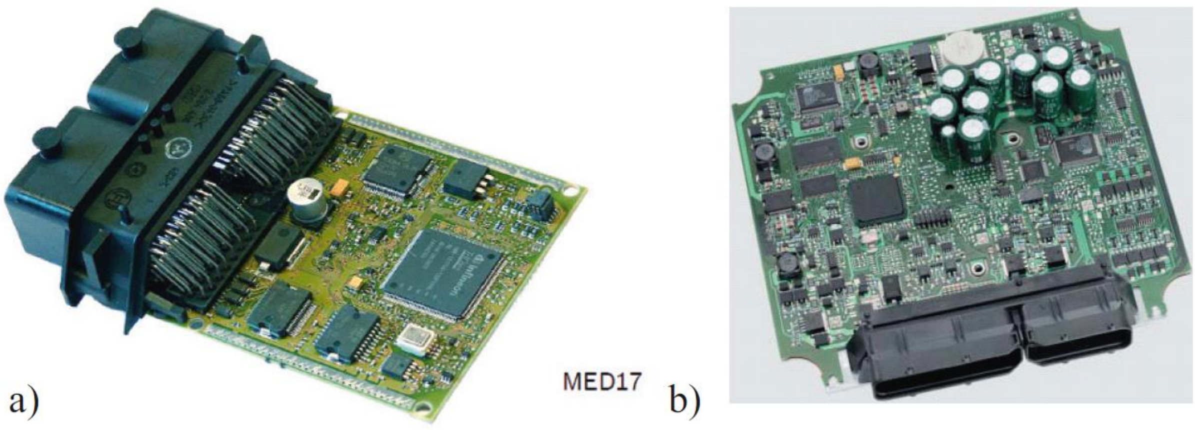


Figure 16: Examples for ECU hardware design. a Motronic MED 17, Scholl (2007). b ECU for light commercial engine, Continantal Automotive GmbH(2011)(Freescle MPC 555,40MHz, including drivers).

3.1. Operating conditions

The ECU is subjected to very high demands with respect to[12].

- extreme ambient temperatures (during normal operation from–40°C to +60...+125°C),
- violent temperature fluctuations,
- resistance to the effects of such materials as oil and fuel, etc.,
- surrounding dampness, and mechanical stresses such as engine vibrations

3.2. Design and construction[14]

3.2.1. Hardware structure

Fig. 17 depicts a block-oriented scheme for the ECU-hardware structure with connected sensors and actuators. The electronic control unit (ECU) is based on one or two microcontrollers. They consist of:

• *Microprocessor*. It contains the central processing unit (CPU) and has an own control unit for the execution of instructions from the program memory, and a unit (ALU) to handle arithmetic and logic operations. The CPU performs the flow control with address management and a command decoder. Processing happens in one cycle (10 ns for 100MHz) towards the external memory.
• *Memories*. Microprocessors operate with nonvolatile and volatile memories. Random access memories (RAM) are write/read volatile memories and part of the microprocessor as main memory. Their content is lost if the voltage is switched off. Static RAM (SRAM) retain the information until it is overwritten or the power supply is cut off. Dynamic RAM (DRAM) have a lower power consumption, but must be rewritten after reading and after certain time intervals to compensate for the self-discharge.

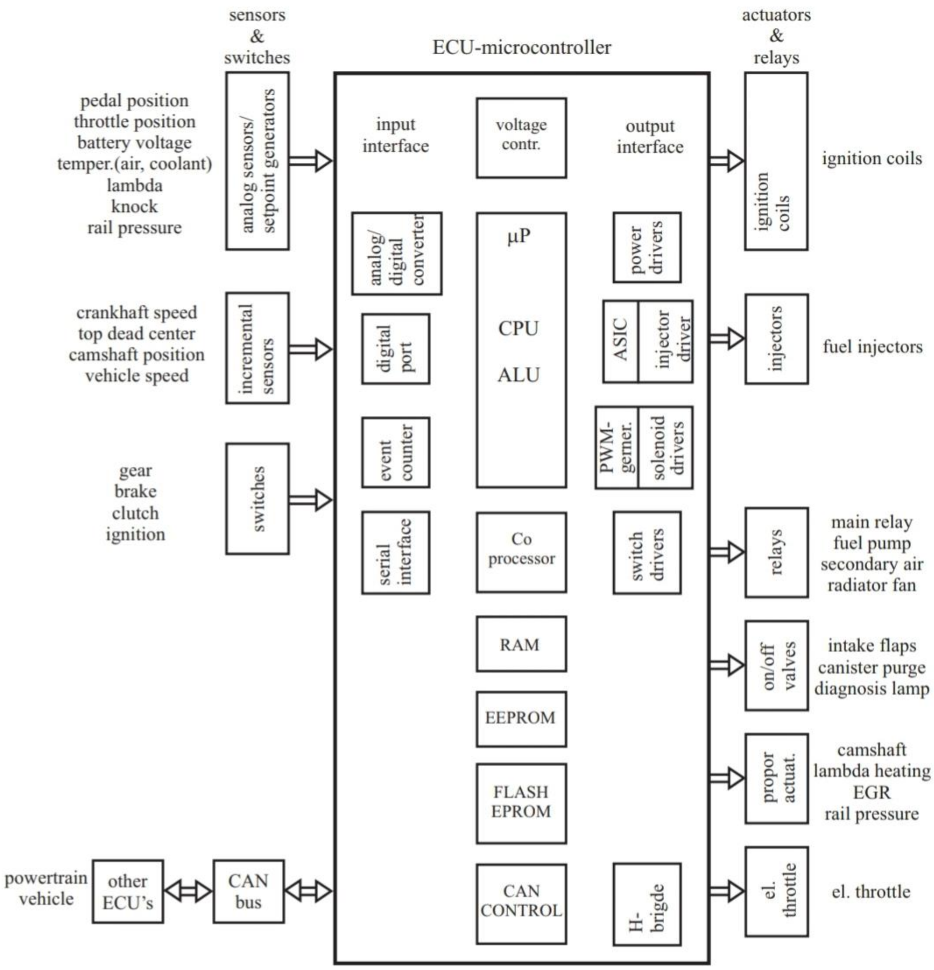


Figure 17Hardware structure of an electronic control unit (ECU) for gasoline engines.

Read-only memories (ROM) are nonvolatile. They store all programs and data that will not change and are retained even in the absence of a voltage. ROM's contain usually program code for control functions and constant data, programmed by the manufacturer. If programmed by the user, programmable read-only memories (PROM) are applied.

Some types of read-only memories can be erased and reprogrammed. Erasable read-only memories (EPROM) are erased with UV-radiation and newly programmed. Electrical erasable read-only memories (EEPROM) can be electrically erased and reprogrammed in the ECU with a separate device. An advantage is that each line of memory can be individually rewritten. A next development are Flash EPROM's. They allow the erasure, or flashing of complete memory storage by electrical pulses and reprogramming, by using a programming device. If the flash memory is part of the ECU, flashing can be applied on-board. There- fore, flash memories have become standard as they allow the modification of nonvolatile storage during the engines life-cycle.

The arithmetic unit and the control unit of a microprocessor operate via an internal bus with the different types of memories. RAM is used to store variable data. Program instructions and permanent data are hold in the ROM types. A coprocessor may be coupled through the internal bus with the main microprocessor and is at least partially used to monitor the main processor functions and for tasks of expansions. The main microprocessor is interconnected with the peripheral memories (RAM, ROM) and the input/output interfaces by the address and data bus with a parallel 8-, 16- or 32-bit structure.

• *Input interface*. The input modules provide a link between external sensors or switches and the microprocessor. They receive the analog, binary or digital input signals and transmit them to the microprocessor. The electrical analog input signals may be filtered, are converted to a uniform voltage, and pass a multiplexer, hold element and an analog-to-digital converter (ADC). Digital inputs are acquired word-wise. For incremental sensor inputs the number of signal changes is processed by counting circuits. A bus interface allows the communication with other electronic control units (e.g. by CAN-bus), as for the automatic transmission, and chassis control (ESC/TRC).

• *Output interface*. The output interface serves as a link to the actuators and relays. Based on the drivers' and sensors' inputs the microcomputer calculates the manipulated variables to the engine. The low-level signal outputs of the microprocessor are amplified by the driver stages to the level required by the various actuators. Usually the drivers may supply enough power for the actuators. In the case of large currents as for the radiator fan the driver may switch a relay. Special power drivers are required for an inductive ignition system. Based on the calculated ignition time the ignition driver stage cuts the ignition coil to generate the high voltage for the spark plugs.
The injected fuel quantity depends on the opening duration of the fuel injector and the fuel pressure. The microprocessor delivers a digital signal for the beginning and duration of the injection. In the case of high-pressure common-rail direct injection system the injection duration is very small. A special application specific circuit (ASIC) therefore generates a dynamic triggering signal to the DC/DC converter in the ECU to generate a booster voltage of, e.g. 65 V, which results in a boost current peak followed by a holding current to drive the fuel injectors.
Solenoid drivers for proportional acting electromagnetic actuators are controlled with a high frequent pulse-width-modulated (PWM) voltage. The PWM signal is, e.g. generated with a special ASIC. An H-bridge with diodes allows boost voltages for fast field changes in both directions. The position of the electrical throttle is manipulated via an H-bridge to allow a controlled DC motor speed and position change in both directions.

3.2.2. **Software structure**

The software structure of an electronic control unit for engines is highly complex. It is hierarchically and modularly organized and must comply with strong real-time requirements. The *engine control* has to be seen in connection with the overall powertrain control of the vehicle.

The *application software* operates in higher levels, and executes the engine control and some vehicle control functions. It receives the input values via the basis software functions of the input components and sends the control outputs to the basis software of the output components. The application software is in principle hardware independent. It is structured according to the main engine components like fuel system, air system, ignition, combustion, cooling, exhaust system and to the vehicle motion, and it is function-oriented. These main components comprise control function blocks like injection control, ignition control and torque control for the combustion or engine charge control and EGR control for the air system.

For the development of the software special tools are applied. They can be divided in function development tools, software implementation tools and calibration tools. The overall procedure follows a V-development scheme, which will be described in Chap. 3. The software implementation is performed either with manual programming or by automatic code generation.
The software function development begins for example by using MATLAB/ Simulink and transfer to language C with a precompiler. The C-program is then turned into machine code with special compilers. This procedure is, e.g. realized with the industrial software systems and development environments like Target Link from dSpace or ASCET from ETAS.

4. Electronic Diesel Control (EDC)

Electronic control of a diesel engine allows fuel-injection parameters to be varied precisely for different conditions. This is the only means by which a modern diesel engine is able to satisfy the many demands placed upon it. The EDC (Electronic Diesel Control) system is subdivided into three areas, “Sensors and desired-value generators”, “Control unit”, and “Actuators” [12].

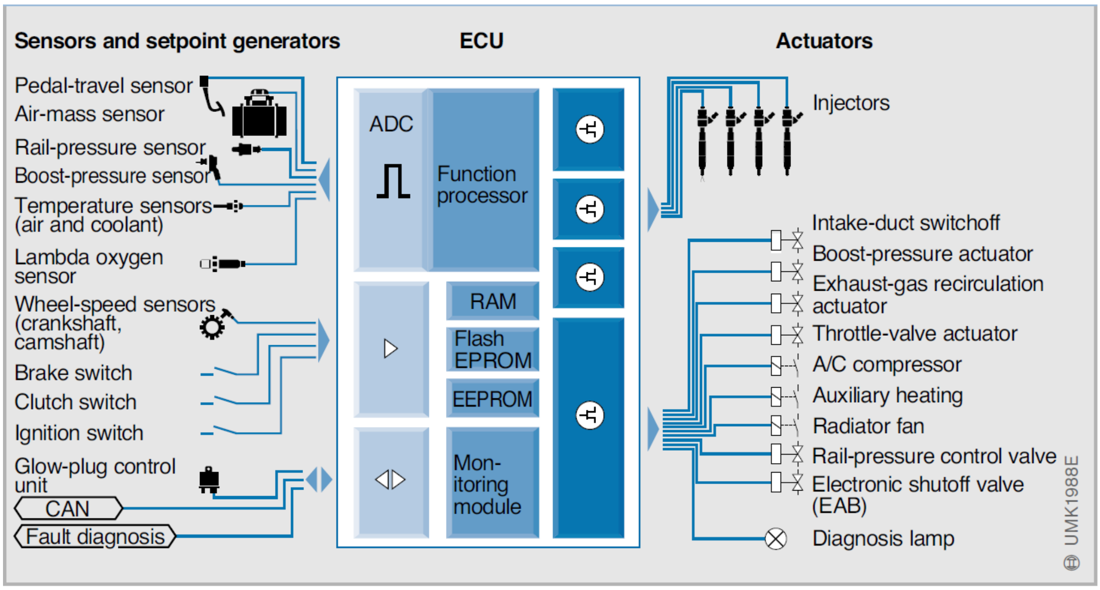


Figure 18: Main components of EDC

4.1. System overview

4.1.1. Requirements

Present-day development in the field ofdiesel technology is focused on lowering fuel consumption and exhaust-gas emissions (NOx, CO, HC, particulate), while increasing engine performance and torque. In recent years this has led to an increase in the popularity of the direct-injection (DI) diesel engine, which uses much higher fuel-injection pressures than indirect-injection (IDI) engines with whirl or pre chamber systems[12].

Due to the more efficient mixture formation and the absence of flow-related losses between the whirl chamber/pre chamber and the main combustion chamber, the fuel consumption of direct-injection engines is 10...20% lower than that achieved by indirect-injection designs[12].

In addition, diesel engine development has been influenced by the high levels of comfort and convenience demanded in modern cars.Noise levels, too, are subject to more and more stringent requirements[12].

As a result, the performance demanded of fuel-injection and engine-management systems has also increased, specifically with regard to[12]:

- High fuel-injection pressures
- Rate-of-discharge curve control
- Pre-injection and, where applicable, secondary injection

- Variation of injected fuel quantity, chargeairpressure, and start of injection to suit

4.1.2. **operating conditions**

- Temperature-dependent excess-fuel quantity for starting
- Control of idle speed independent of engine load
- Controlled exhaust-gas recirculation (cars)
- Cruise control
- Tight tolerances for injection duration and injected fuel quantity, and maintenance of high precision over the service life of the system (long-term performance

5. Remapping

means instead of just optimizing the ECU's program or 'map' to deliver the best performance or the most fuel efficiency they have to make compromises to the map to take into account these potential differing operating conditions. These could include sub-standard fuels, extremes in temperature and altitude, differing emission laws and even the possibility that vehicle may not be serviced on a regular basis and in accordance with the manufacturers recommended instructions.

ECU chip tuning is taking a read from the ECU's processing chip of the vehicles standard compromised map and adjusting various parameters within the map such as fuel pressure, boost pressure (on turbocharged applications) ignition advance and throttle pedal control amongst others to release the true performance from the engine. it is just giving the engine the performance it should have had in the first place before all the compromises were applied to the original programming. Every engine will have its own unique map and by adjusting this we can fine tune the characteristics of the engine; unleashing more power and in many cases reduce fuel consumption too.

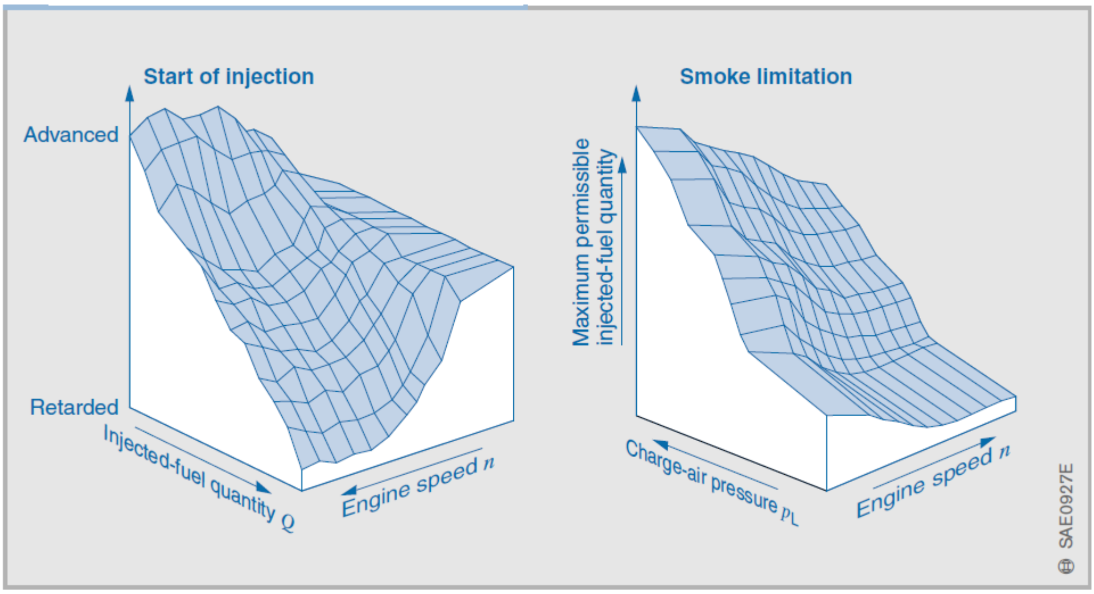


Figure 19: Data maps for start of injection and smoke limitation

Chapter III

Engine-control method and calibration

1. On the control of diesel engines

The development of sensors and actuators for diesel engines is summarized in Fig. 20. Present diesel engines need about 15–20 sensors, 5–9 main manipulated variables and an ECU with more than 100 look-up tables and many control algorithms.[14]

Today's diesel engines are characterized by high pressure (2000 bar), multiple common-rail injection, piezo-injectors, twin turbochargers or VGT chargers, high EGR rates, DeNOx-catalyst, particulate filters with regeneration, and selective catalytic reduction (SCR). [14]

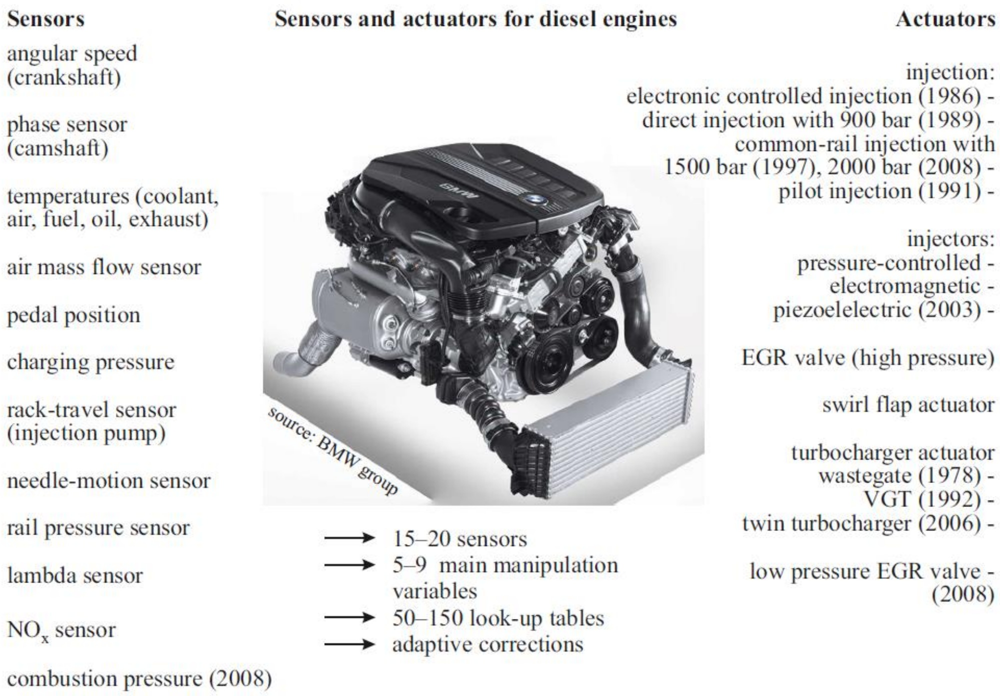


Figure 20: Sensors and actuators for diesel engines (CI).

Figure. 21. shows the basic components of a turbocharged diesel engine In diesel engines, air is sucked into the cylinders with a slight drop below the air pressure, if the turbocharger is not used and the torque is controlled by the injected fuel block. Most modern diesel engines have turbochargers in order to increase torque and power.Air charging then depends on charging pressure (booster), which is controlled by a charging pressure controller, For example by changing the position of the waste gate or the position of the variable geometry turbocharger (VGT). At low load, the diesel engine runs with a large excess air, that is, a large air / fuel ratio expressed by the excess air factor λ. Only at high loads, λ approaches 1. If it becomes too small, the diesel engine starts to smoke. Relatively high pressure ratio in cylinders combined with lower charge losses due to an inactive throttle in the intake thus good air supply leads to higher efficiency compared to gasoline engines, especially at partial loading.

The increase in thermodynamic efficiency and the increase in the production of nitrogen oxide gases due to the oxidation of nitrogen gas present in the air, is thanks to the increase in the combustion temperature, So that the combustion temperature and nitrogen oxide concentration decrease, we can recycle the exhaust gases to the intake at a cost of fuel efficiency. Modern diesel engines have the advantage of having a common rail or a unit pump injection system with pressures up to 2200 bar. Injected fuel mass into the cylinders is guided according to the drivers' throttle position by the Electronic Control Unit (ECU).

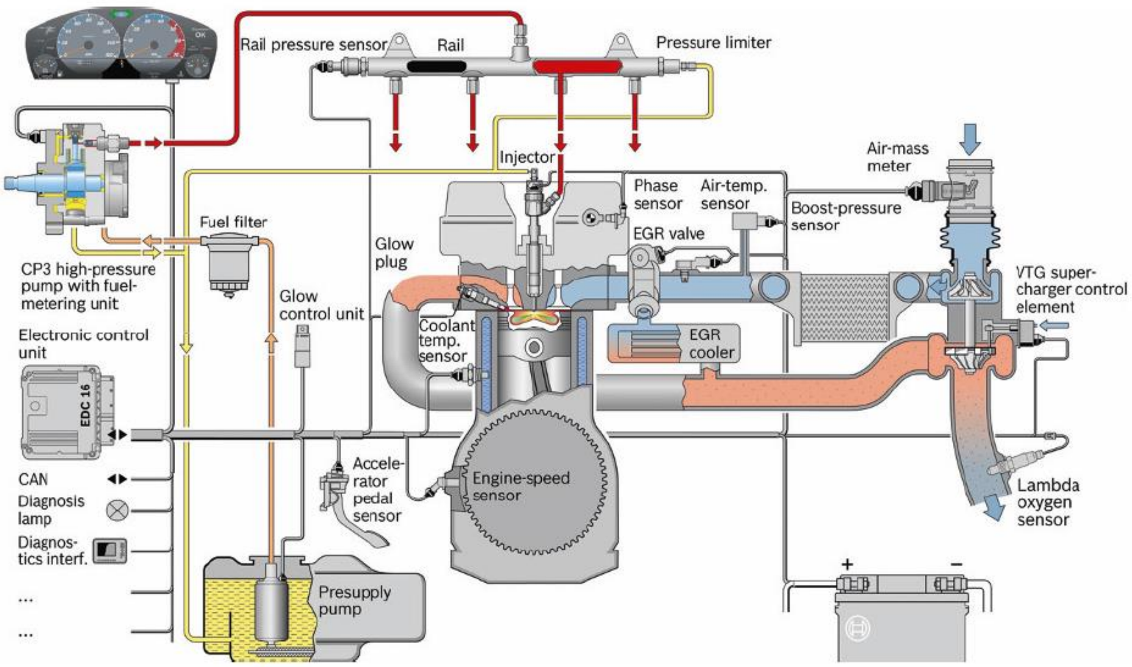


Figure 21 : Schematic of a direct injection diesel engine with VGT turbocharger, actuators,

The effect of the burning process is done in relation to the optimum fuel consumption, nitrogen oxides are used, the formation of soot and the noise generated, with multiple injections, with pulses before and after the main injection. By means of a jet valve, the rate of flow of the mass of air in the intake system is indirectly controlled (mainly diesel engines). Since the fresh gas mixture taken by the cylinders is nearly constant for a given operating point, increasing the flow rate of EGR $\dot{m}_{egr}$ leads to a decrease in the flow rate of air . This means that the ratio $\dot{m}_{egr}/\dot{m}_{air}$ has changed. The control variable of the closed air mass control loop is the measured mass flow rate and its reference value is calculated From the required reference the excess air factor λ_{ref}.

An additional feedback control is the charge pressure control ring, which manipulates either a lost gate for fixed geometry turbochargers or steering rotors for variable geometry (VGT) turbochargers. Both closed control loops are tightly bound. The fuel mass in the diesel engine is reduced by reducing the speed. This requires the use of a speed controller for the maximum speed

Otherwise, excessive speed may damage the engine. This is due to the loss of pregnancy control by suffocation. Cruise control is also applied when idling, but not during the normal operating range of diesel engines in vehicles.

The task of exhaust post-treatment is to reduce hydrocarbons, carbon dioxide, nitrogen oxides and particulate matter. Hydrocarbons, carbon monoxide and some soot are removed by an oxidation catalyst. This is done in most passenger car diesel engines.This can be followed by a nitrogen oxide storage catalyst (NSC), in which the NO2 is stored in the loading phase within 30 to 300 s in lean exhaust gas ($\lambda > 1$).

Regeneration and removal of nitrogen dioxide in rich exhaust gas (λ <1) occurs within 2 to 10 s. The removal or reduction of nitrogen dioxide with carbon dioxide and H2 in rich exhaust gas is performed by inhibiting the injection angle and throttling the intake air.Storage catalyst control requires temperature sensor and NOx sensor or sensor. The alternative is selective catalytic reduction (SCR), in which the nitrogen oxides are removed by NH3 ammonia, which stems from liquid urea. This process is constantly going, We inject the urea / water solution ("add blue") from an additional tank, and the feedback is controlled using the NOx and NH3 sensors.

The emitted soot particles can be removed by diesel Particulate Filters (DPF). They consist of porous ceramics or sintered metal and must result from the combustion of soot With oxygen in the exhaust gas and the temperature rise to at least 600 ° C, resulting in carbon dioxide regeneration begins when a standard based on a combination of increased pressure difference and storage of soot calculated from the storage model is exceeded. The exhaust temperature is then increased by means of lagging or additional lagging main injection and intake air throttle, depending on the engine's operating condition. This regeneration takes about 10 to 20 minutes and the motor is controlled so that the torque is not significantly reduced. DPF control requires pressure differential and temperature sensor.

Figure 22 shows the structure of the electronic diesel management system. It, as a control system for gasoline engines, is organized into a pyramid structure divided into high level and lower level control functions. We can combine the control functions at the top level in subsystems or units for torque control, injection and fuel control, air charge and EGR control, and emissions control. The control functions at the lower level are, for example, position control of actuators, control of vortex and flap plates.Figure 22 shows seven drivers for airflow, injection mass and angle, rail pressure, EGR flow, camshaft phase and turbocharger. Closed-loop control is usually achieved for air flow, common rail pressure, charging pressure and in some cases for exhaust gas post treatment. This is added by several feeding control functions.

Several sub-level controls are needed, such as throttle position control, injection pumps, camshaft, rotary and flip flaps, fuel and lubricant oil pressure control. For special operating conditions or situations, complementary control functions are implemented, such as smoke limit (CI) control, idle speed control, cold start control, and heating control. Most feed control functions are performed as grid-based 3D lookup tables (3D maps) or as 2D features. This is due to the nonlinear static behavior of IC motors, good interpretation and direct programming in microprocessors using fixed point arithmetic processors. Some functions are based on physical models with correction factors, but many search tables and control algorithms are calibrated after measurements on engine test benches and with vehicles. However, as engines and their variants become more complex, so do engine model-based identification, design and control methods, see next section . The automatic transmission is controlled, also the same as for gasoline engines, most often in the special transmission control unit. This concludes with the first approximation of the basic control functions of combustion engines.

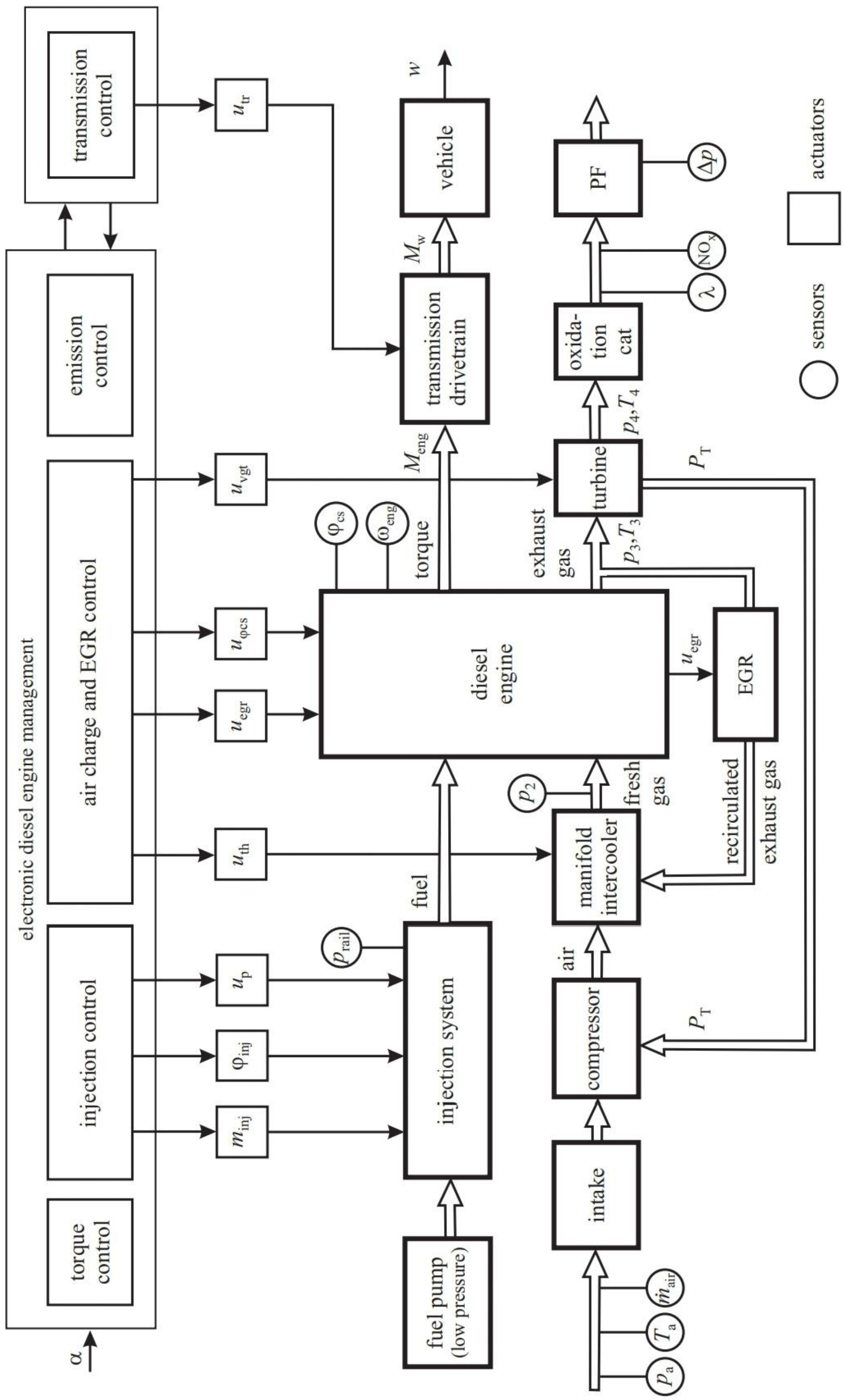


Figure 22: Control-oriented block diagram of a diesel engine with common rail injection, actuators, control subsystems and some sensors.

2. Development steps for engine control

Because of the increasing and multi-variable functions of internal combustion engines the development of the electronic management has become a rather involved task. Figure 23 gives a first impression of some development steps. The basic thermodynamic and mechanical design includes, e.g. the charging cycles, fuel injection, ignition, super charging, valve train, auxiliary drives, cooling, lubrication and exhaust gas after treatment. A prototype engine can then be equipped with selected actuators, sensors and a basis ECU, so that experiments on a test bench can be performed. A first basis control calibration with a basic control software then enables making systematic measurements on a test bench. Then the optimization of the many control functions can be started with the goal of minimizing fuel consumption and raw emissions. Advanced procedures use model-based methods, supported by different kinds of simulations and computer-aided design of, e.g. look-up tables for feedforward control and digital control algorithms for feedback control. An additional effort is designing and calibrating onboard diagnosis functions to satisfy legal requirements and to support service functions. A next step is the fine-tuning of control functions with vehicles and road tests. Then also the design of the shifted or automatic transmissions have to be taken into account. Automatic transmissions have their own ECU attached to or integrated into the transmission housing and also show an increasing extent of control and supervision functions, e.g.[15]

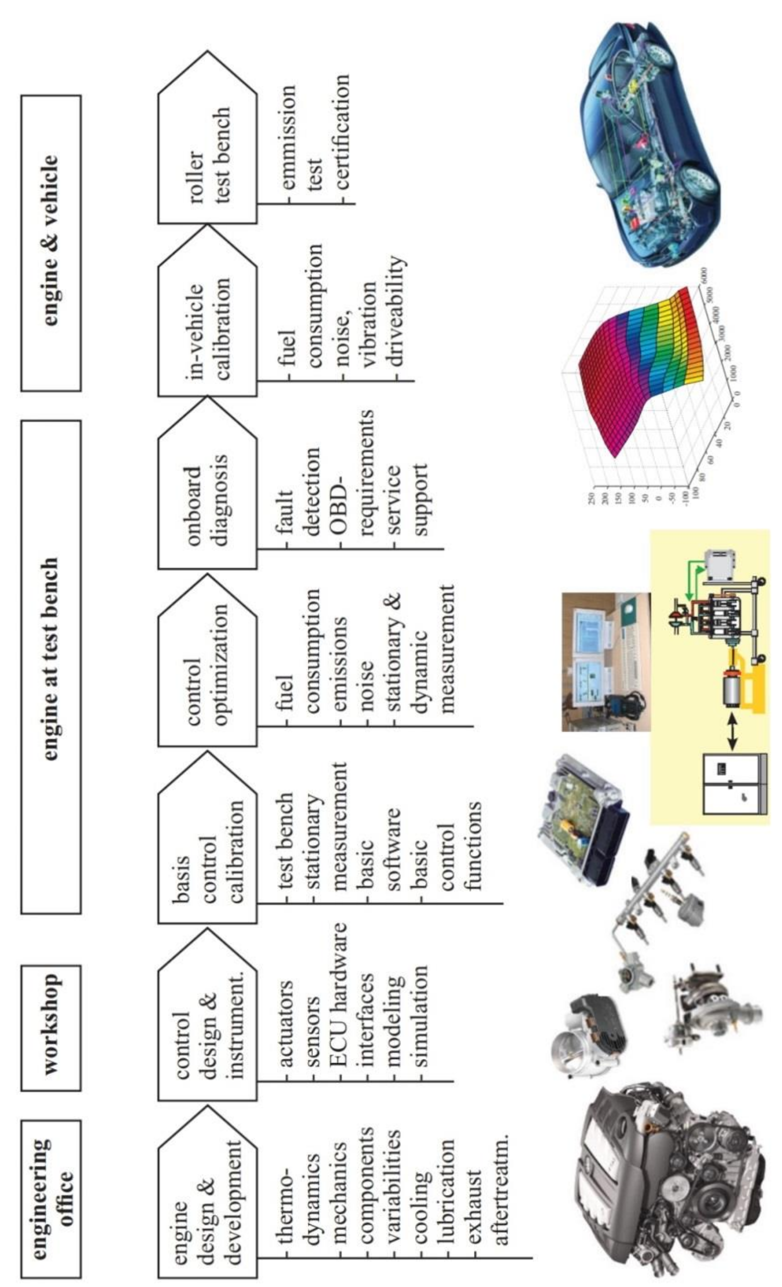


Figure 23: Development steps from basic design to test-bench tests for the control functions of internal combustion engines. Sources of figures: VW,

3. Experimental modeling of engines

Several parts of engines cannot be modeled in a theoretical way only, because the mathematical formulation of parts of the processes is not precisely known or the computational expense is too large with regard to control and diagnosis applications. This holds for example for the flame propagation, pressure and temperature development of gasoline engines and for the spray development and combustion of diesel engines, both under the influence of valve-induced turbulent flow, swirl and tumble motion. Also precise and computational simple theoretical models for the emissions depending on several manipulated variables are not available.[14]

3.1. Identification methods for the stationary behavior of nonlinear processes

3.1.1. 3.1.1 Grid-based look-up tables (maps) .[14]

The most direct way to determine the stationary behavior of a nonlinear process with one input u and one output y

$$y = f(u)$$

is to take samples in steady state for $y(k)$ and different $u(k)$ for $k = 0, 1, . . . , N - 1$ and to represent them in a graph. However, without a regression procedure the outputs $y(k)$ may be scattered because of disturbances. In the case of several inputs

$$\mathbf{u}T = [u1, u2, . . . , up]$$

$$y = f(\mathbf{u}) \quad (3.1.3)$$

the output y can be represented in a multidimensional look-up table or map. The measurements are taken for all combinations of the inputs. Grid-based look-up tables are the most common type of nonlinear static models used in practice for one or two inputs. Especially in the field of nonlinear control, look-up tables are widely accepted as they provide a transparent and flexible representation of nonlinear relationships. Electronic control units of modern automobiles, for example, contain about 100 such grid-based look-up tables, in particular for engine and emission control. In automotive applications, due to cost reasons computational power and storage capacity are strongly restricted. Furthermore, constraints of real-time operation have to be met. Under these conditions, grid-based look-up tables represent a suitable means for the storage of nonlinear static mappings.

The models consist of a set of data points or nodes positioned on, e.g. a two dimensional grid. Then, each node comprises two inputs $u1$ and $u2$. The scalar data points heights are estimates of the approximated nonlinear function at their corresponding data point position. All nodes located on grid lines, as shown in Fig. 3.1.1 are stored, e.g. in the ROM of the control unit. For model generation, usually all data point positions are fixed a priori. The most widely applied method of obtaining the data point heights is to position measurement data points directly on the grid.

If the output *y* has to be calculated for any input values *u*1 and *u*2 of a two dimensional look-up table, an interpolation has to be made. In a first step the indices of the enclosing four data points have to be selected. Then, a bilinear area interpolation is performed, For this, four areas have to be calculated.

Grid-based look-up tables belong to the class of *non-parametric models*. The model structure described has the advantage that a subsequent adaptation of single data point heights due to changing environmental conditions is easy to realize. The main disadvantage of look-up tables is the exponential growth of the number of data points with an increasing number of inputs. Therefore, grid based look-up tables are mostly restricted in practical applications to one- and two-dimensional input spaces. However, different ways do exist to extend them to multi-inputs and to use them for control .

An alternative are *parametric model representations*, like polynomial models, neural networks, or fuzzy models, which clearly require less model parameters to approximate a given input output relationship. Therefore, the storage demand of these models is much lower. However, in contrast to area interpolation, the complexity of the computation of the output is much higher, since complex nonlinear functions for, e.g. each neuron have to be computed. On the other hand, grid-based look-up tables are not directly suitable for the identification and modeling of dynamic process behavior. Therefore, other identification methods for nonlinear dynamic processes based on parameter estimation .

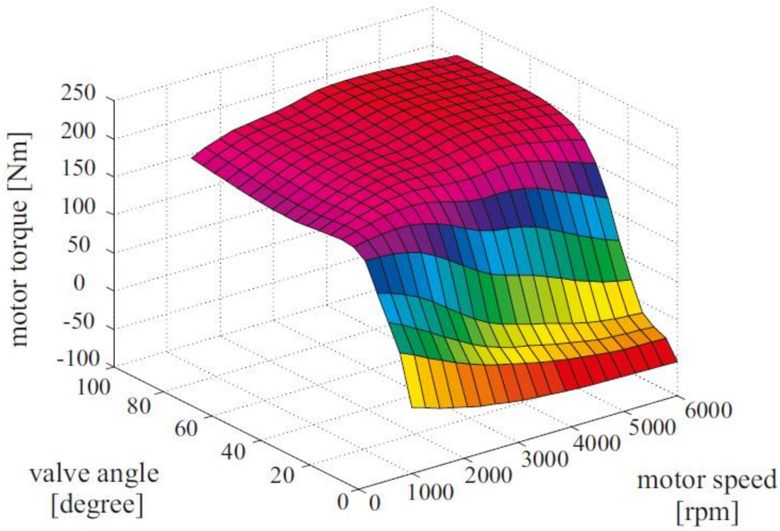


Figure 24: Grid-based look-up table of a six-cylinder SI engine.

4. Fuel supply and injection system

The fuel supply and injection system has developed to an important mechatronic system for both gasoline and diesel engines. Therefore, it is considered and modeled in some more detail. For intake manifold injection a low-pressure system is sufficient, whereas for direct injection a high-pressure system is required, which is fed by the (standard) low-pressure system.[16]

4.1. High-pressure common-rail fuel supply and injection system for diesel engines[17]

This section considers the function and modeling of a common-rail system for diesel engines in more detail. Figure .25 shows a scheme of a CR-system as it is typical for passenger car diesel engines. It accumulates the fuel under high pressure in the common-rail in order to supply the injectors time-independently and with a large scale of pressure levels. The fuel is delivered from the tank and pre-compressed by an electrical fuel pump to about 0.5MPa (5 bar). The fuel’s actual temperature is measured in the fuel filter. After filtration the fuel flows to the tooth belt driven high-pressure pump. The volume flow into the pump is controlled by the metering valve. Its supply current is measured by the ECU. In the high-pressure pump the fuel is compressed to the common rail pressure level (30-180MPa or 300-1800 bar) and then discharged to the rail. From there it is injected into the cylinders each time an injector opens.

The common rail pressure is measured by a high-pressure sensor and controlled by the pressure control valve. Its supply current is measured, too. Thus, the essential variables are:

T_f fuel temperature measured in the fuel filter

I_{mv} supply current of the metering valve

I_{pcv} supply current of the pressure control valve

n_{eng} engine speed

u_{inj} desired injection quantity

p_{cr} common rail pressure.

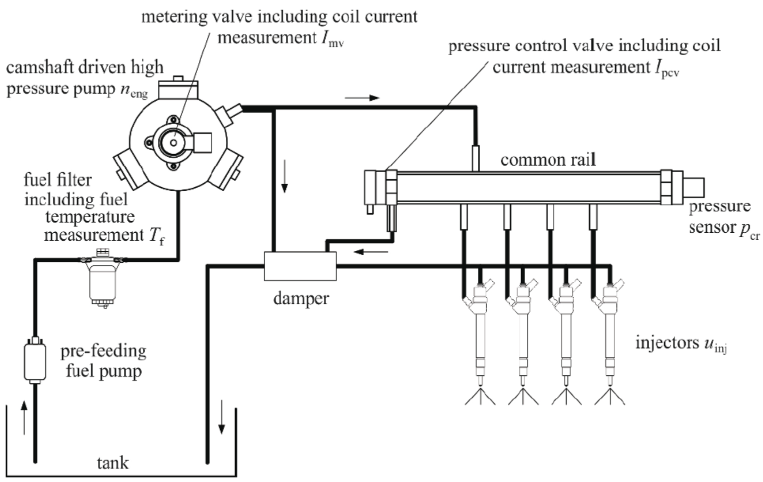


Figure 25: Scheme of the common rail injection system with measurable variables.

4.1.1. a) Common rail pressure generation

To model the dynamic behavior of the common rail pressure a lumped parameter system is assumed. The mass balance of the common rail is given by

$$\dot{m}_{\text{hpp}} - \dot{m}_{\text{pcv}} - \sum_{j=1}^{4} \dot{m}_{\text{inj},j} = \dot{m}_{\text{cr}} \qquad (4.1.1)$$

with

$\dot{m}_{\text{hpp}}$ fuel mass flow from the three pistons of the high-pressure pump into the common rail

$\dot{m}_{\text{pcv}}$ fuel mass flow through the pressure control valve 4

$\sum_{j=1}^{4} \dot{m}_{\text{inj},j}$ fuel mass flow to the four injectors

$\dot{m}_{\text{cr}}$ stored fuel mass flow accumulated inside the common rail

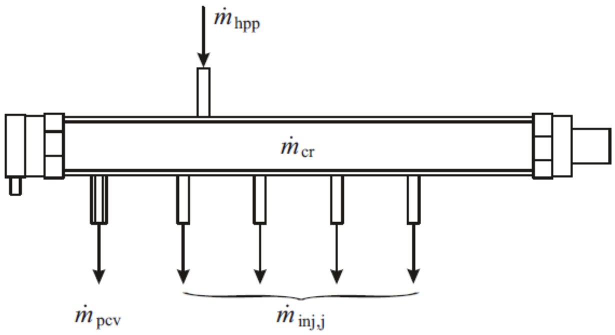


Figure 26: Mass flow into and from the common rail.

Figure .26 shows the fuel mass flow to and from the common rail. The change in the mass of fuel accumulated inside the common rod can also be expressed by changing its density. This is assuming that the common penis size remains constant

$$mcr = vcr.\frac{dpcr}{dt} \qquad (4.1.2)$$

with

V_{cr} volume of the common rail

p_{cr} fuel density.

By means of the bulk modulus E, the compressibility is expressed by

$$dp = \frac{E}{p}.dp \quad (4.1.3)$$

Applying) (4.1.1) to (4.1.3) and expressing the mass flow by means of its corresponding volume flow, it follows

$$\frac{dp_{\mathrm{cr}}}{dt} = \frac{E_{\mathrm{cr}}}{V_{\mathrm{cr}}} \cdot \left(\dot{V}_{\mathrm{hpp}} - \dot{V}_{\mathrm{pcv}} - \sum_{j=1}^{z} \dot{V}_{\mathrm{inj},j} \right) \quad (4.1.4)$$

with

E_{cr} pressure- and temperature-dependent bulk modulus

$\dot{V}_{hpp}$ volume flow through the high-pressure pump

$\dot{V}_{pcv}$ volume flow through the pressure control valve z

$\sum_{j=1}^{z} \dot{V}_{inj,j}$ volume flow to z injectors.

The flows of varying size periodically excite pressure within the common rod. As a result of this there is a special characteristic of the signal of the high pressure sensor. In fixed Operating points The signal characteristic is mainly determined by the patrol The fuel and injection processes are delivered periodical

The high-pressure pump is a three-cylinder radial piston pump, Fig.27 . The pump components are of three components concentrated around the shaft. The upward movement of the pistons of the pump elements is carried out by means of an eccentricity located on the drive shaft. The downward movement of the pistons will be carried out by the force of a return spring attached to each of the pistons. During the downward movement, the fuel floats through an inlet valve in each component of the pump. In the next step, the fuel is compressed by the upward movement of the pistons and the inlet valve is closed. Once the pressure inside the pump cylinders exceeds the pressure level inside the common rail, the vacuum valve opens and the fuel flows into the common rail. The shaft is driven by a tooth belt driven by the crankshaft. The transmission ratio between the drive shaft and the crankshaft is 2: 3. This means that during each injection, or every 180 ° C, one of the three pump elements delivers the fuel. The relationship between the angle of rotation of an eccentric shaft (unit: EA) and the crank

shaft is given by

$$x = \frac{2}{3} \varphi \qquad (4.1.5)$$

With χ rotation angle of the eccentric shaft in ◦EA.

The delivery rate of the high pressure pump is affected by the lower pressure, also affected by the throttle valve (mv metering valve), Fig.28. The metering valve is located in front of the inlet valve of the high pressure pump and controls the mass of fuel supplied by the pump. The throttle description equation describes the volume flow through the metering valve

$$\dot{V}_{\mathrm{mv}} = \alpha_{\mathrm{mv}} \cdot A_{\mathrm{mv}} \cdot \sqrt{\frac{2\Delta p_{\mathrm{mv}}}{\rho}} \quad (4.1.6)$$

with

V_{mv} fuel volume flow through the metering valve

α_{mV} flow coefficient

A_{mV} opening cross section

Δ_{PmV} pressure difference between valve inlet and valve outlet.

The volume flow delivered by pumps that are throttled at their suction side show a characteristic behavior of fuel delivery. Figure .29 illustrates the characteristic volume flow delivered by such a high-pressure pump with a constant throttling and constant common rail pressure with respect to the pump speed .

Two main areas of the pump's behavior can be identified:

(1) The volume flow raises linearly up to a limiting speed.

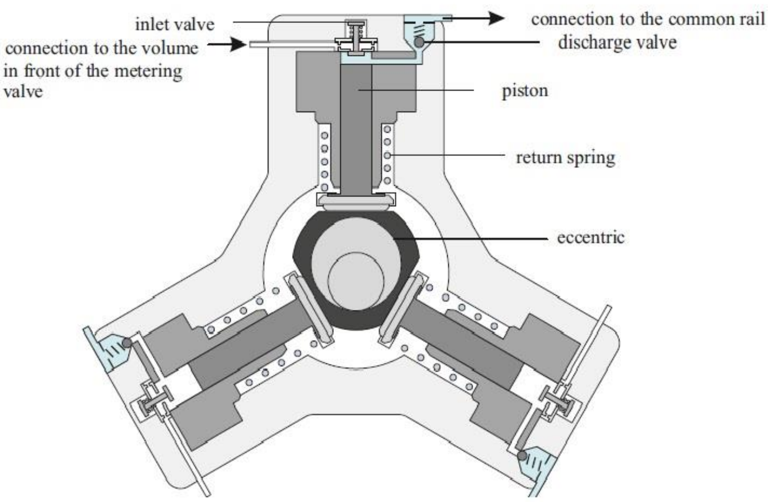


Figure 27: Sectional view of the 3-cylinder radial piston pump CP1H by Bosch.

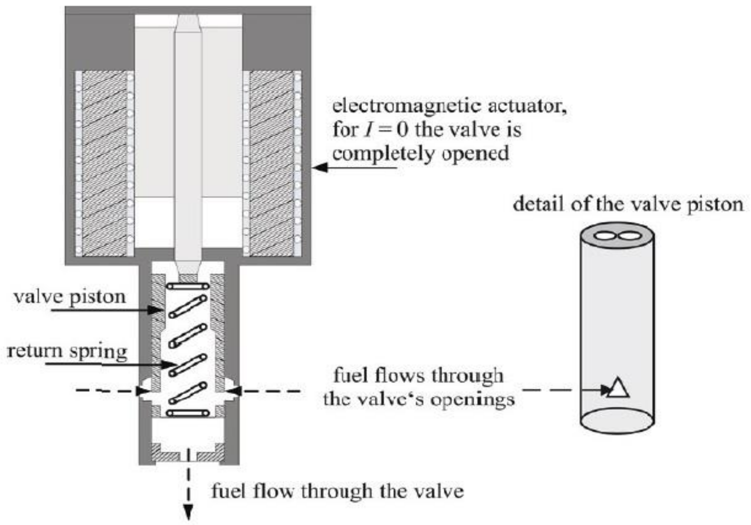


Figure 28: Fuel Supply and Injection System

(2) The volume flow decreases slightly for higher speeds.

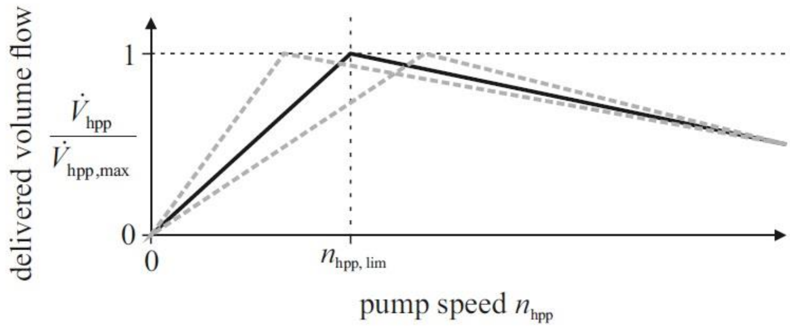


Figure 29: Illustration of the characteristic volume flow delivered by a high-pressure pump

with a constant throttling at its suction side and constant common rail pressure. The gray dashed lines indicate the influence of different restrictions in front of the high-pressure pump on the limiting speed. The smaller the restriction the smaller the limiting speed.

In order to explain this behavior, one is detailed on different stages The Delivery Cycle, For this purpose, the delivery cycle is divided into Three stages:

Stage 1: Starting at the top dead center, the piston moves down, outlet The valve closes and the pressure in the piston chamber rapidly decreases. Releasing gases from the remaining fuel, and filling the increased volume.

Stage 2 (pump speed is less than set speed): the inlet valve opens and fuel flows through the valve into the piston chamber. The inlet valve remains open until the piston chamber is completely filled with fuel in the lower dead center, and the previously released gas is dissolved again. This is true if the pump speed is less than the specified speed, Fig.29.

Stage 2 (Speed limit): The inlet valve opens and fuel flows through the valve into the piston chamber. If the pump speed is exceeded, the lower dead center is reached before the full volume of the piston chamber is filled with fuel. Thus, the previously released gas remains in the piston chamber.

Stage 3 (the pump speed is less than the set speed): the piston moves up and the pressure inside the piston chamber increases rapidly. The inlet valve closes immediately. Once the common rail pressure level is exceeded, the outlet valve opens and the compressed fuel is discharged into the common rail.

The third stage (exceeding the specified speed): The piston begins to move upward. The previously released gas is still in the piston chamber. The pressure inside the piston chamber is slowly increasing. The inlet valve remains open and the fuel flows into the chamber until the gas is completely dissolved. Thus, the maximum available volume of the piston chamber is not filled with fuel. Consequently, the volume of fuel delivered decreases.

The angle of rotation of the eccentric shaft from the bottom of the dead center up, the desired (common rail) pressure level is reached is called *non-delivery angle* xnd

Each pump element delivers a volume of fuel equal to the volume of effective fuel delivery, during each cycle, assuming a cosine curve as the volume changes, the displacement size of a given pump element taking into account

For the angle of rotation of the eccentric axis through (see Fig.30)

$$V_{\text{hpp},i}(\chi_i) = \frac{V_{\text{hpp,max}}}{2}\left(1-\cos(\chi_i)\right), \chi_i := \chi + (i-1)\frac{2}{3}\cdot 180°\text{EA} \quad (4.1.7)$$

With

$\frac{dVhpp,i}{d\chi i}$ displacement volume of the pump element *i* per $d\chi i$

$V_{hpp,max}$ cylinder capacity of one pump element .

The change of the displacement volume is found to

$$\frac{\frac{dV_{\text{hpp},i}}{d(\chi_i)}}{d\chi_i} = \frac{V_{hpp,max}}{2}\sin(\chi_i), \chi_i := \chi + (i-1)\frac{2}{3}\cdot 180°\text{EA} \quad (4.1.8)$$

with

$\frac{\frac{dvhpp;t}{d(xi)}}{dxi}$ change of the displacement volume of the pump element *i*.

If it is assumed that the fuel delivery of a single cylinder starts if the non-delivery angle is reached and ends at its top dead center (180◦EA), the fuel volume flow delivered by the pump with respect to the rotation angle of the eccentric shaft can be expressed as:

$$\frac{dV_{\mathrm{hpp}}}{d\chi} = \begin{cases} 0 & \text{for } -180°\mathrm{EA} < \chi_i < \chi_{\mathrm{nd},i} \\ \sum_{i=1}^{3} \frac{V_{\mathrm{hpp,max}}}{2} \sin\chi_i & \text{for } \chi_{\mathrm{nd},i} \leq \chi_i \leq 180°\mathrm{EA}. \end{cases}$$ (4.1.9)

The relation between the time domain and the rotation angle of the eccentric shaft can be expressed with (4.1.5) and (4.1.8) as:

$$\varphi = \frac{360°\mathrm{CS}}{60\frac{\mathrm{s}}{\mathrm{min}}} \cdot n_{\mathrm{eng}} \cdot t$$
$$\chi = \frac{2}{3} \cdot \frac{360°\mathrm{CS}}{60\frac{\mathrm{s}}{\mathrm{min}}} \cdot n_{\mathrm{eng}} \cdot t$$
$$\chi_i = \frac{2}{3} \cdot \frac{360°\mathrm{CS}}{60\frac{\mathrm{s}}{\mathrm{min}}} \cdot n_{\mathrm{eng}} \cdot t + (i-1)\frac{2}{3} \cdot 180°\mathrm{EA}$$
$$\frac{d\chi}{dt} = \frac{2}{3} \cdot \frac{360°\mathrm{CS}}{60\frac{\mathrm{s}}{\mathrm{min}}} \cdot n_{\mathrm{eng}}.$$

(5.5.22,23,24,25,) (4.1. 10,11,12,13.)

The fuel volume flow delivered by the pump is finally given by

$$\frac{dV_{\mathrm{hpp}}}{dt} = \frac{2}{3} \cdot \frac{360°\mathrm{CS}}{60\frac{\mathrm{s}}{\mathrm{min}}} \cdot n_{\mathrm{eng}} \begin{cases} 0 & \text{for } -180°\mathrm{EA} < \chi_i < \chi_{\mathrm{nd},i} \\ \sum_{i=1}^{3} \frac{V_{\mathrm{hpp,max}}}{2} \sin\chi_i & \text{for } \chi_{\mathrm{nd},i} \leq \chi_i \leq 180°\mathrm{EA} \end{cases}$$ (5.5.26) (4.1.14)

With $\frac{dVhpp}{dt}$

fuel volume flow delivered by the high-pressure pump.

Using the non-delivery angle, the difference between true and theoretical volume flow is taken into account. Figure .30. shows an exemplary illustration of the intermittent fuel delivery described in (4.1.14) . Hence, the fuel pump operates with “phase modulated control”. Therefore, the engine speed mainly determines the volume flow flowing from the high pressure pump, the metering valve opening cross section, the fuel pressure in the low pressure system, and the mass parameter of the fuel inside the piston chambers. Figure.31. shows a block diagram of the main variables influencing the generation of volume flow through a high pressure pump where plp represents the low pressure of the pre-compressed fuel.

4.1.2. b) Volume flow through the pressure control valve

The pressure control valve is an electromagnetically impelled spherical valve, Fig. 32. The volume flow through the pressure control valve, primarily depends on the opening cross section of the valve and the pressure inside the common rail, Fig. 33. The volume flow though the valve can also be expressed by means of a throttle equation and is given by:

$$vpcv = apcv.Apcv.\sqrt{\frac{2\Delta Ppcv}{P}} \qquad (4.1.15)$$

With

$vpcv$ fuel volume flow through the pressure control valve

$apcv$ flow coefficient

$Apcv$ opening cross section

ΔPpcv pressure difference between valve inlet and valve outlet (Δppcv ≈ $p$cr).

4.1.3. c) Volume flows to the injectors

By means of the z solenoid valve injectors, fuel is injected into the individual cylinders.

The initiation of the injections, their duration as well as the quantity of injections is controlled by the ECU. The injector and in particular the space around

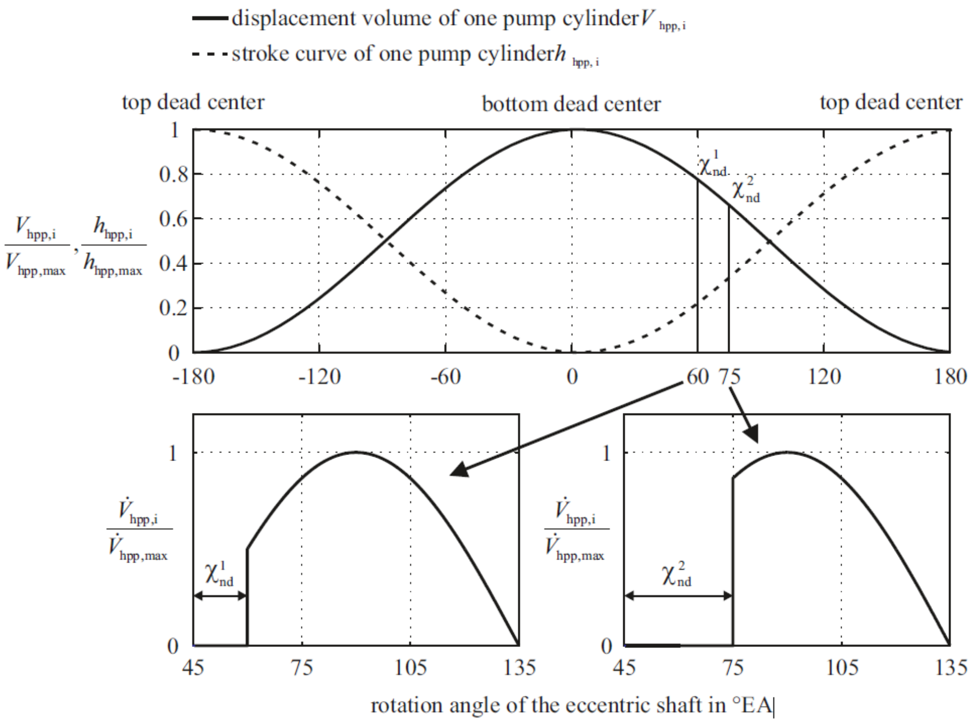


Figure 30: Illustration of the discontinuous fuel delivery of the high-pressure pump.

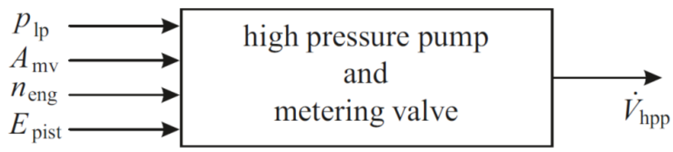


Figure 31: Main influencing variables on the generation of the volume flow through the high pressure

Pump

the injector needle and the fuel control chamber (FCC) is supplied with fuel that is directly streaming from the common rail.

We can divide the solenoid valve injector function, Fig .34, into three Operating modes:

Injector closed: The solenoid valve is not actuated. The fuel pressure levels inside the control chamber as well as on the pressurized surface are equal. The compressive force acting from the control chamber (FCC) upon the needle plus the force from the return spring exceed the pressure force that acts on the pressurized surface. Thereby the needle is pressed on the jet port.

Injector opening: After the solenoid valve is actuated, the fuel streams out of the control chamber (FCC) into the return line and the pressure decreases. The throttling in front of the control chamber is designed such that the decrease in pressure is not compensated by the feed from the common rail. After a short period of time the pressure, that acts upon the pressurized surface exceeds the opposing forces. The injector opens and remains in this position for the duration of the actuation of the solenoid valve.

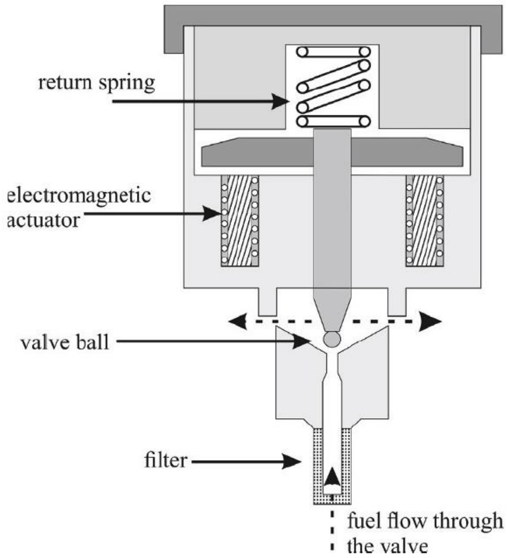


Figure 32: Sectional view of the pressure control valve.

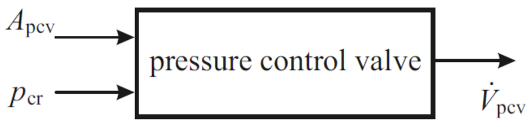


Figure 33: Main influencing variables on the volume flow through the pressure control valve.

Injector closing: As soon as the solenoid valve closes through a valve spring and therefore the volume flow through the valve is being stopped, the pressure inside the control chamber is built up again. Once the resulting compressive force, in addition to the force from the return spring, starts to exceed the opposing force, the injector closes again.

The volume flow to one of the injectors is composed of the injected and the return flow quantity, which in turn depend on the opening duration of the injectors and return flow of the solenoid valve. As a measure for the volume flow, it is feasible to use the desired injection quantity, Fig. 35. For a more detailed specification of the processes inside the injectors .

The influence of the periodic operations of the high-pressure pump and the injectors on the rail pressure and used for fault detection.

Based on the component models of the injection system a signal-flow chart for the pressure generation in the common rail can be established, as depicted in Fig. 36.

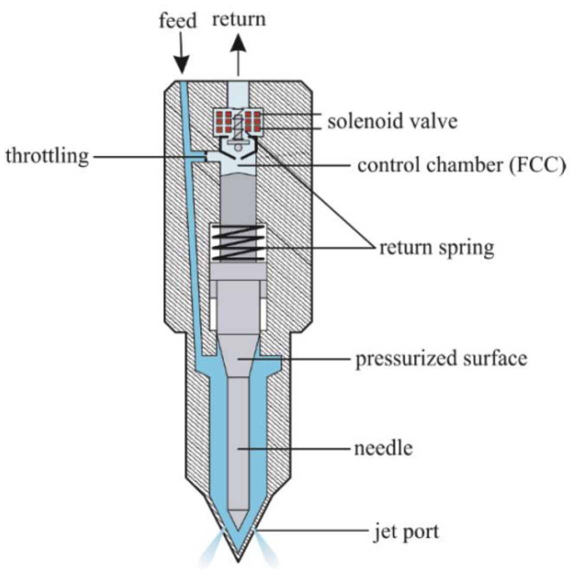


Figure 34: Setup of a solenoid valve injector.

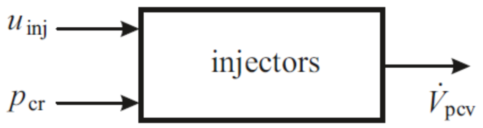


Figure35: Main influencing variables on the volume flow through the solenoid valve injector.

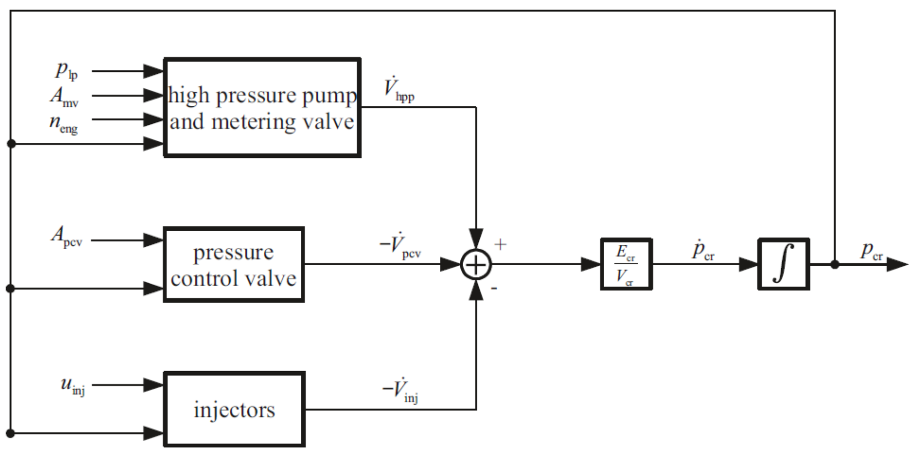


Figure 36:Signal-flow chart for the common rail pressure.

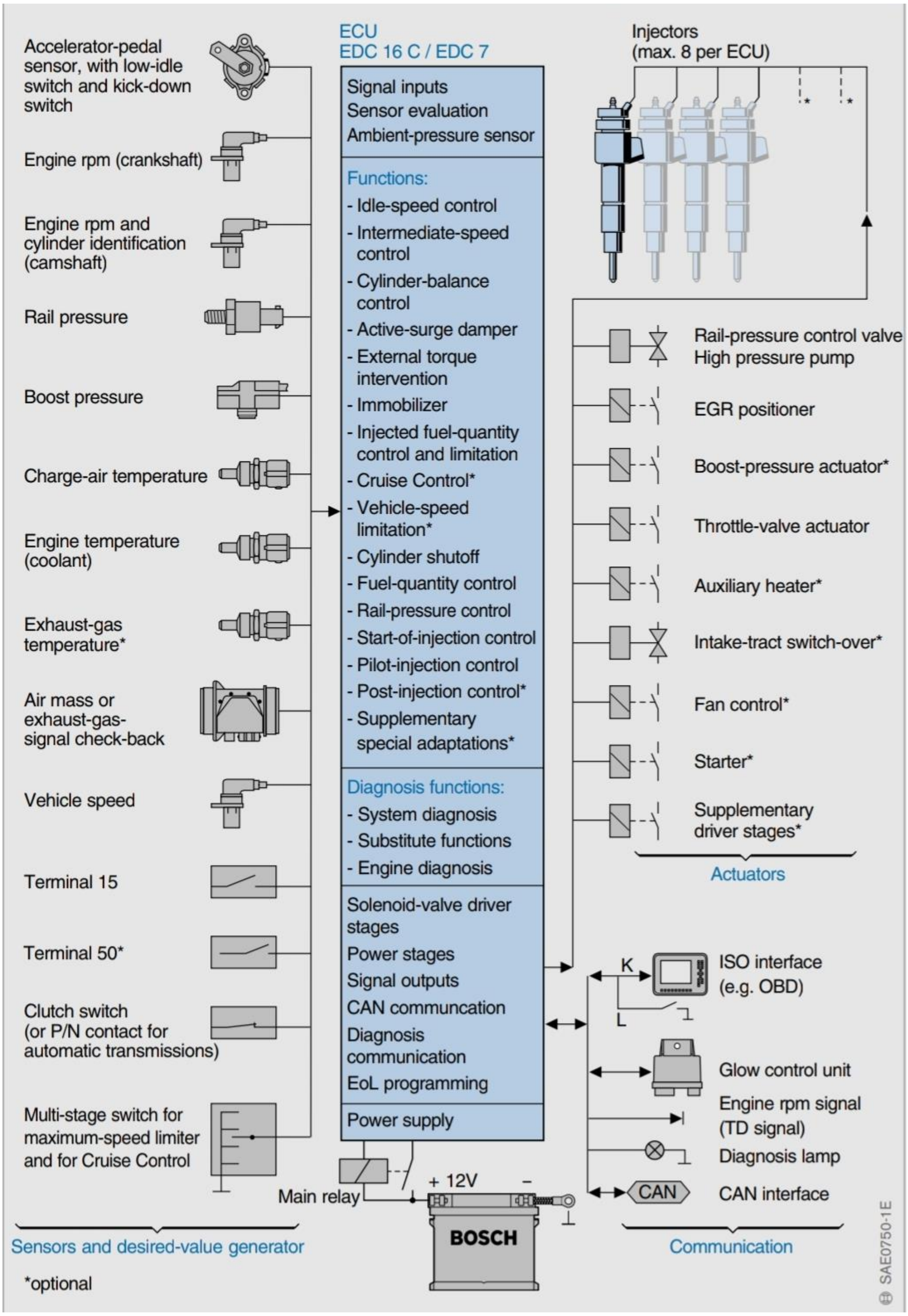


Figure 37: Overview of the EDC components for Common Rail Systems (CRS) in passenger cars

Chapter IV

Design and implementation

1. VAG EDC15P

1.1. Introduction

In modern diesel engines, the Bosch EDCxx (Electronic Diesel Control) S series is widely used and it is used by BMW, VAG, Opel, SAAB and many other companies. In this chapter the VAG EDC15P kit program described we will focus only on Volkswagen , Audi Group (VAG) applications specified in the EDC15P Type. Volkswagen, Audi, Skoda and Seat have all used these ECUs to PD engines (Pump Duse). Other EDCxx ECUs may work similarly but will differ in some details and in certain regions . In this chapter EDC15P ECU describes in detail how we can adjust the electronic control unit to better suit the devices - whether changed or not - present in the car as it will first describe the device and move to a more detailed description of the program that is running in the ECU.

1.2. Hardware

1.2.1. Overview of the board

The ECU contains a multi-layer printed ciruit board (PCB) which holds a lot of SMD components. The main component are – logically:

Main CPU, Flash program storage, SRAM memory (working memory), EEPROM (for storing mileage, immo etc) and a lot of input/output (I/O).

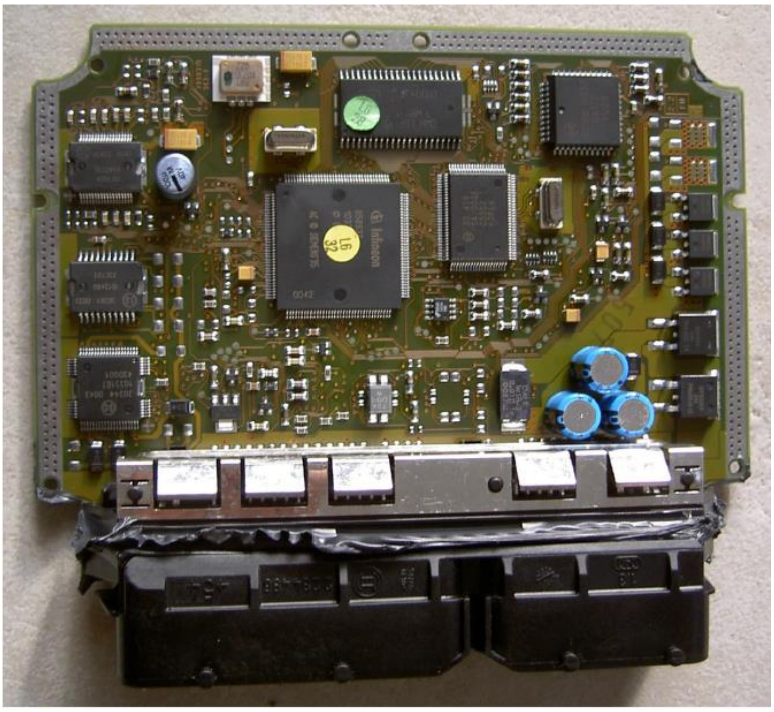


Figure 38: EDC15P board

1.2.2. **Main CPU: Infineon C167**

- 16 bit CPU

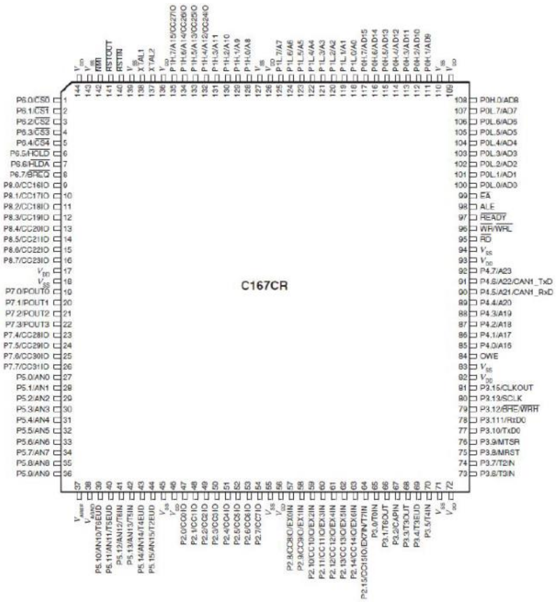


Figure 39: Infineon C167

1.2.3. **Flash eprom: Am29F400**

The flash contains the program and maps for the ECU. EDC15P has 512KB (4 Mbit) flash memory in which it can store multiple map segments for different situations (automatic gearbox, manual gearbox, etc). Switching between these segments is generally called “recoding”. Strongly DQ4 is used for boot pin (held low during startup, this will force the ECU in boot mode).

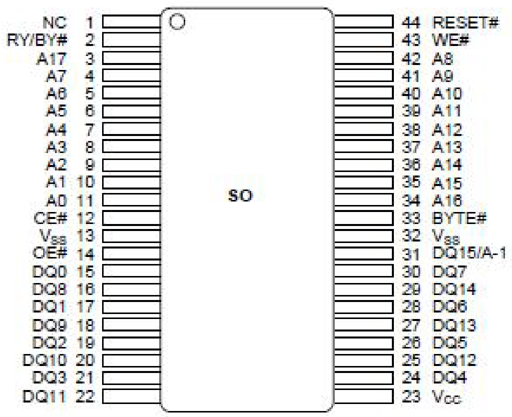


Figure 40: Flash eprom Am29F400

1.2.4. ECU Pinout

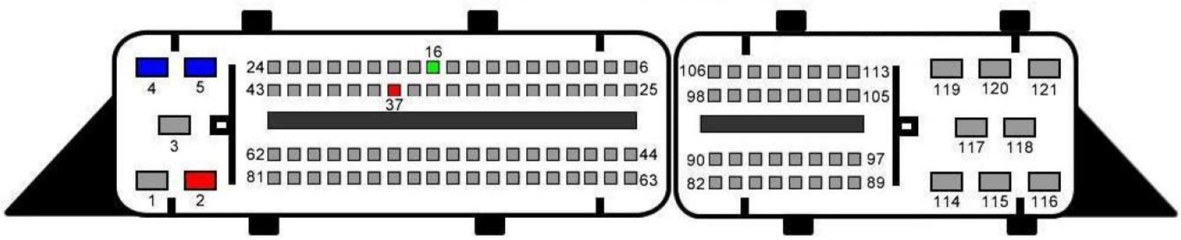


Figure 41: ECU Pinout

Pin number	Color	Description
1	Red/violet	+12V (supply voltage)
2	Red/violet	+12V (supply voltage)
4	Brown/red	Ground
5	Brown/red	Ground
6	Orange/brown	CAN-L
7	Orange/black	CAN-H
16	Orange/black	K-line diagnostics + flashing (KWP1281 + KWP2000)
37		Ignition switch (switch +12V)

Table 2: ECU Pinout

2. Tools and Software

2.1. Summary To Tuning the ECU :

STEP 1:

Plug tuner into car. Load it's software. Turn on car ignition. Press "Download Data / Read".

STEP 2:

Open ECU editing software. And open the file you downloaded from car in Step 1.

STEP 3:

Make changes to the file via HEX editing.

Example: Find and change data that correspond to: *torque, BHP, RPM to gear change ratio, etc.*

STEP 4:

Go back to tuner software, open the file from Step 4, and press "Upload to Car / Copy".

STEP 5:

A dynamometer is necessary to determine proper vehicle performance

2.2. STEP 1:

There are many tools available in the market to read and write different kinds of Engine Control Units (ECU).

The Master tools have total control and non-encrypted files are read from the ECU. The tuner can use any of these tools to safely read and write files. A good tuner would never depend on only one tool. Most of the tuners have at least 2 tools from different companies to support more cars.

Now the tuner with master tool is able to read and write files safely in our case we use the flex magicmotorsport .

2.2.1. FLEX

FLEX is an innovative tool for mechatronic workshops that fully supports the latest developments in the automotive tuning and repair market. Increase your productivity and bring your business up to the next level by adding this new customizable technology to your workplace.

Figure 42: flex tuning box

2.2.2. **Connection mode**

On line Platform for connecting the ECU

Connect your vehicle to our most advanced technology through the variety of modes offered to you. With Flex you can manage engines, transmissions, safety features and infotainment units present in your vehicle in the most efficient way possible

a. **OBD**

- Enabled access to most common OBD standards, including:
- ISO 15765:2 x CAN
- ISO 99141-2 & ISO 14230: 2 x K-LINE, 1xL-LINE
- Ethernet
- SAE J1850 PWM, VPW
- SAE J1708

b. **BENCH**

Get access on the BENCH, without having to open the control unit.

Available for:

- Engine control units
- Transmission control units

c. BOOT

In BOOT mode you will have support for all the available modes:

- BDM MPC5xx
- Bootloader C167
- Bootloader ST10F2xx
- Bootloader TC17xx
- Bootloader Nexus MPC/SPC 5xxx
- JTAG Renesas SH705x
- JTAG Renesas SH72xxx
- AUD NEC 76F00xx

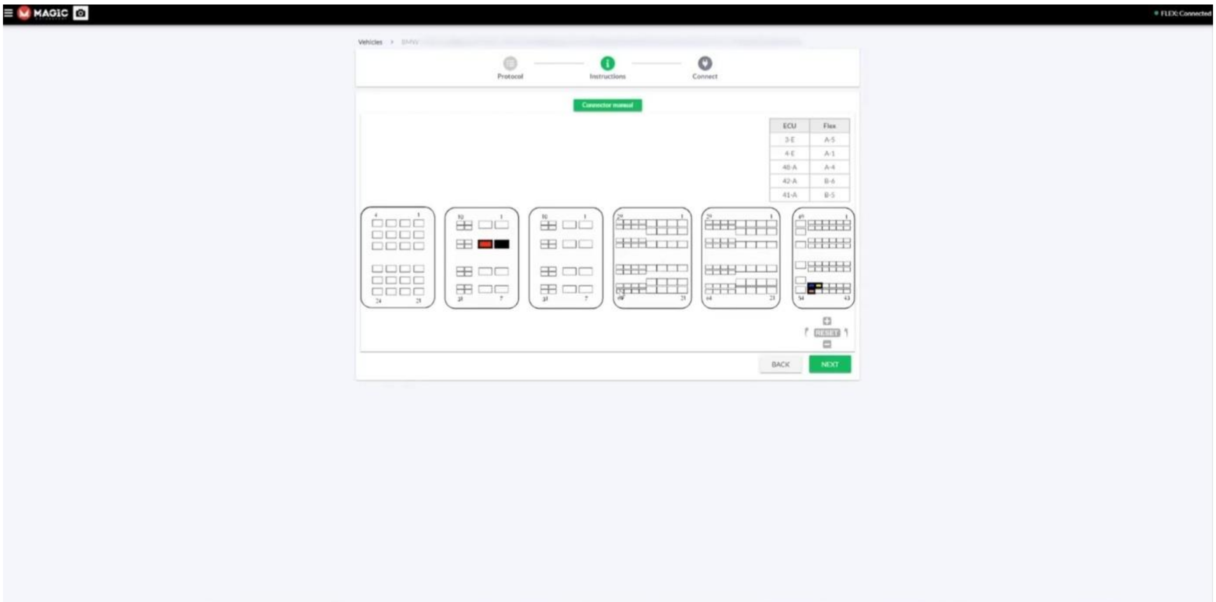


Figure 43Connector manual

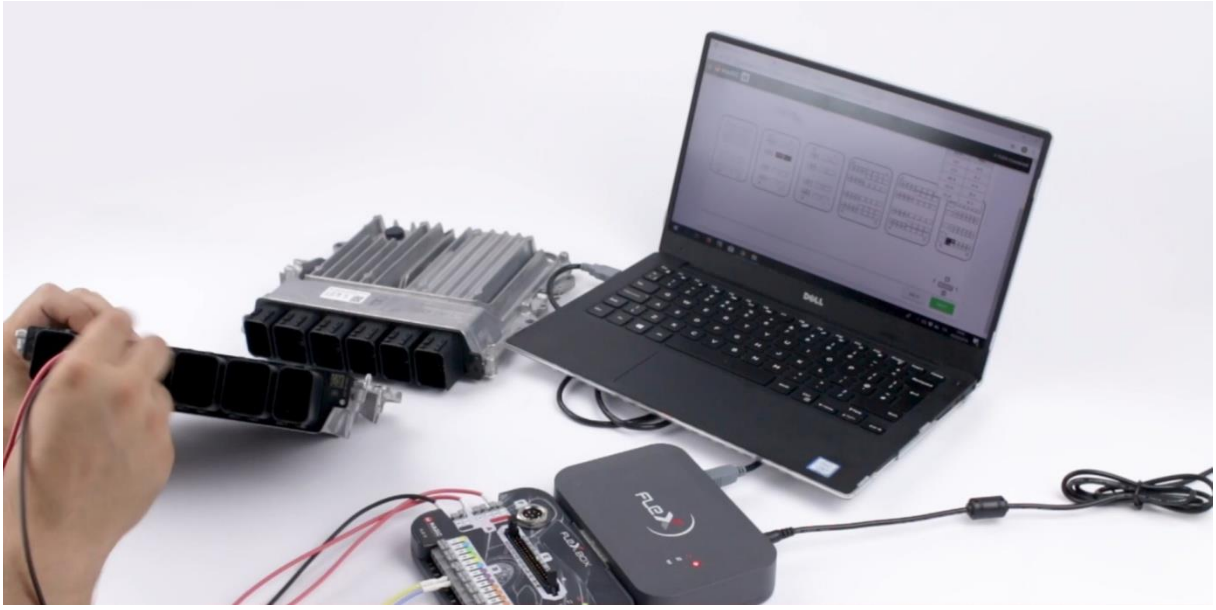


Figure 44access on the BENCH, without having to open the control unit.

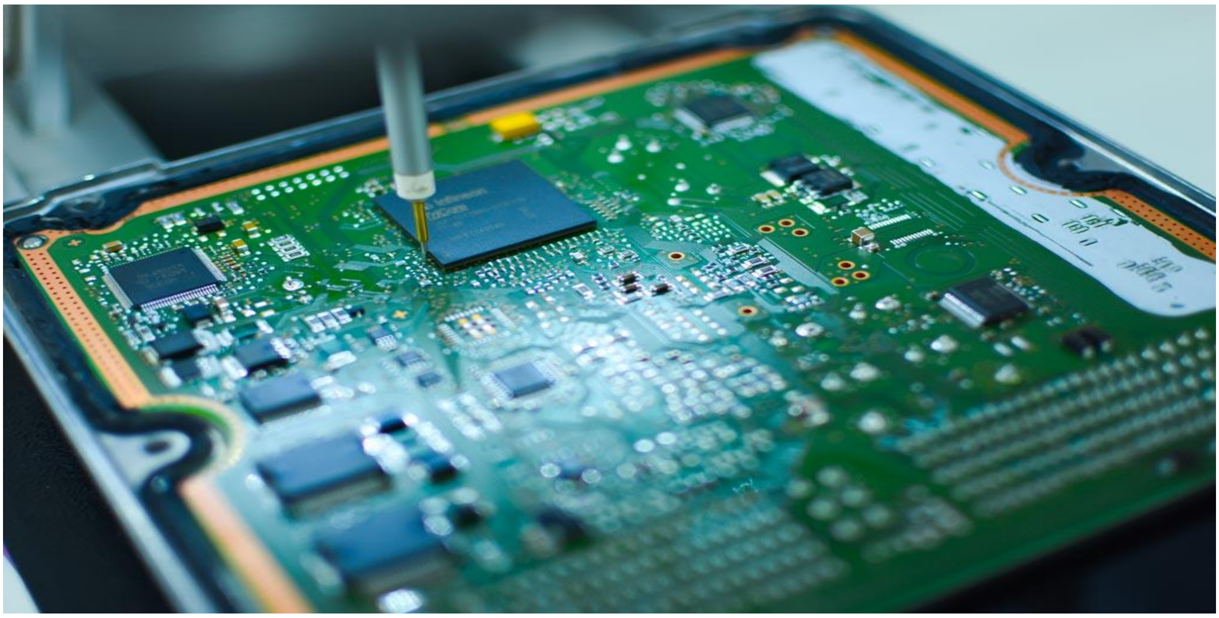


Figure 45In BOOT mode you will have support for all the available modes

2.2.3. **Reading operation**

We do full backup reading

WARNING: Always have backup of original file! If vehicle misbehaves, then upload original file from Step 1.

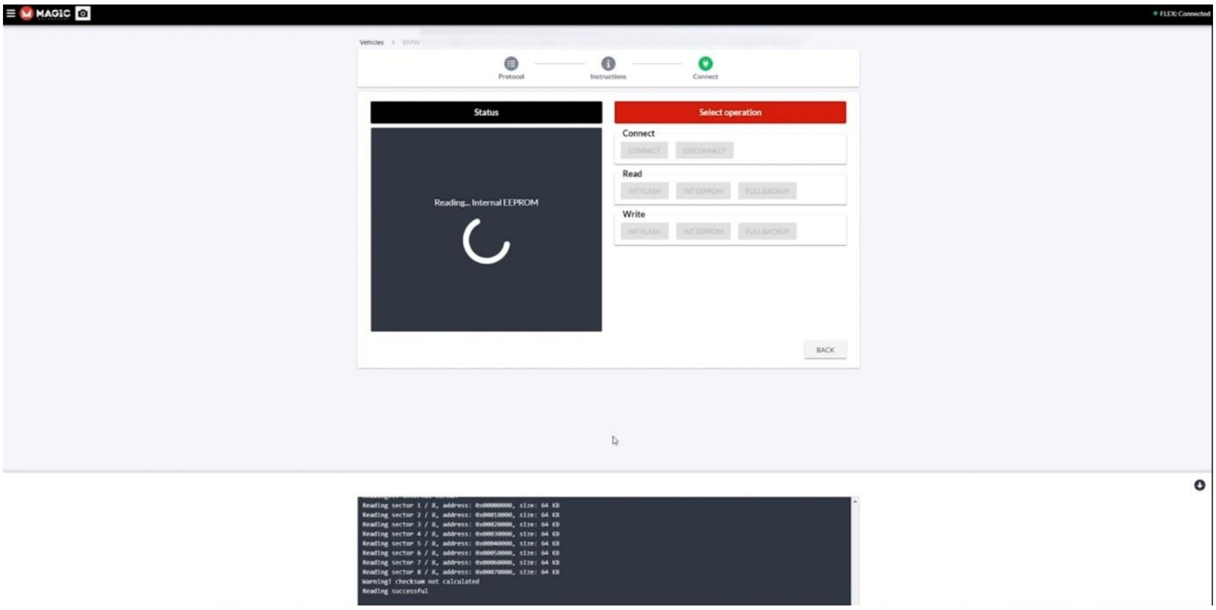


Figure 46full backup reading

2.3. STEP 2:

2.3.1. ECU editing software

Open ECU editing software. And open the file you downloaded from car in Step 1.

This is applicable only for tuners with Master tools who wants to remap on their own. There are many software available in the market which allows the tuner to identify various maps, make changes, correct the checksum etc.

a. EDC_SUITE

This is the best software to make changes in the file read from ECU. The tuner has total control here. But this software is not for newbies and for those who love spoon feeding. The tuner has to use his "brain" most of the times here. There are many options and features in this software and all the pro tuners use WinOLS, ECM titanium,,ect .

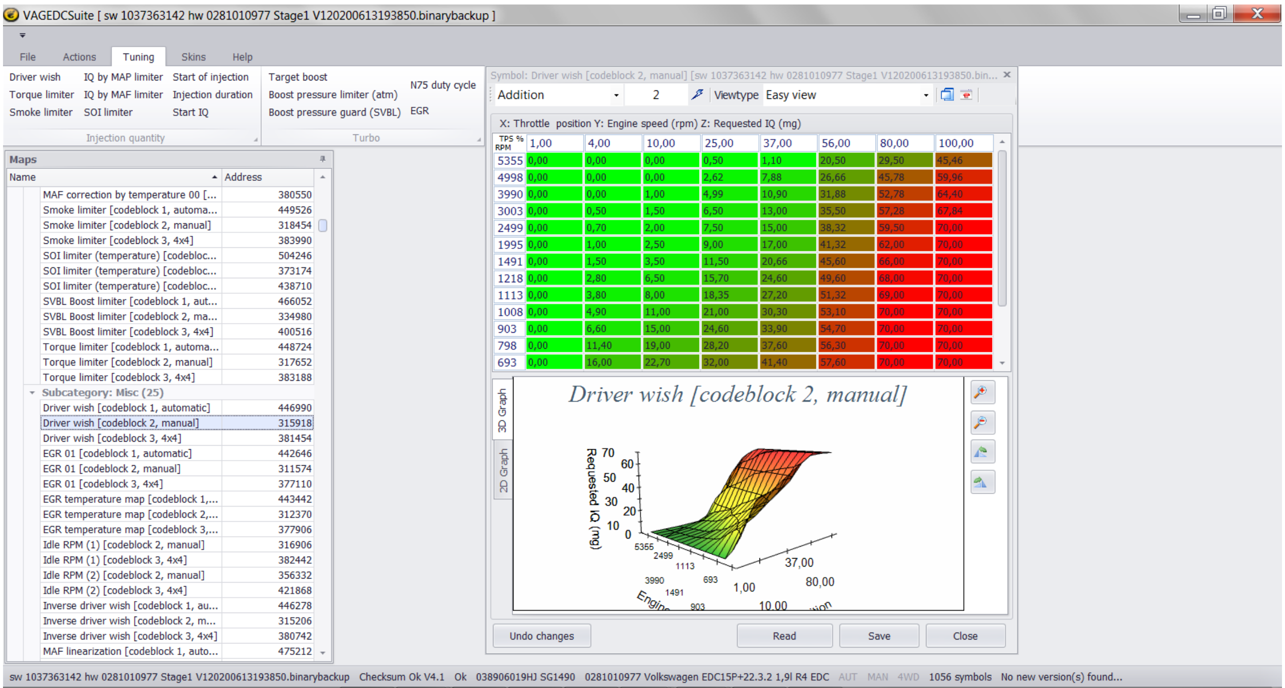


Figure 47 WINOLS software to make changes in the file read from ECU

Maps identification

There are different ECUs and the maps are not the same. It takes lot of effort for a tuner to identify all maps on his own. Basically the tuners depend on Map packs / DAMOS /A2L files to identify the various maps in ECU. These are sold for each ECU type and makes the work lot more easier. If the tuner is able to identify the required maps, half job is done.

2.4. STEP 3:

2.4.1. HEX editing

Make changes to the file
Example: Find and change data that correspond to: *torque, BHP, RPM to gear change ratio, etc.*

a. GENERAL – OPEN FILE

This option allows you to open a binary file. EDC_suit will automatically extract all the relevant information from the file after selecting it in the open file dialog.

Once the file is opened and all information is extracted the symbol list on the left hand side of the main screen will be filled with information.

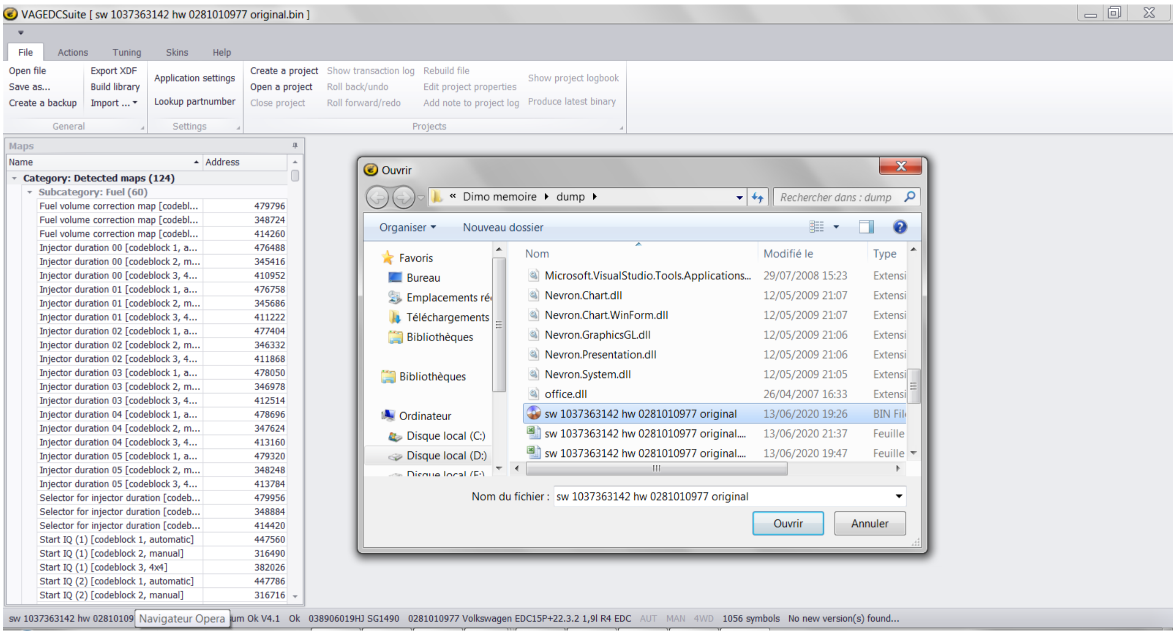
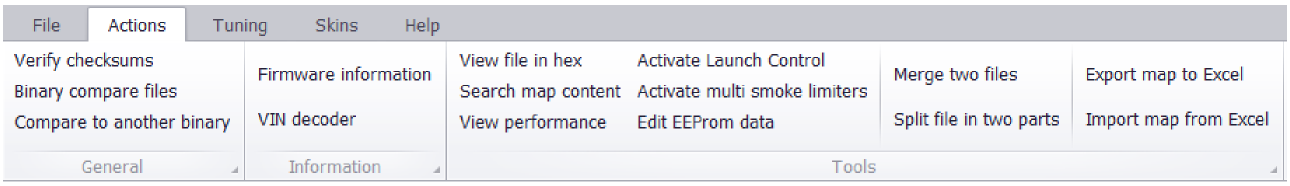


Figure 48: OPEN FILE

b. GENERAL – CREATE A BACKUP

Lets you create a backup file for the binary at this point. It is wise to create backups before you start to make big changes to your file. If a project is opened, the backup file will be stored within the project folder otherwise it will be stored in the folder where the bin file is located.

c. ACTIONS MENU



ACTIONS MENU – FIRMWARE INFORMATION

Lets you view the settings for the current binary file.

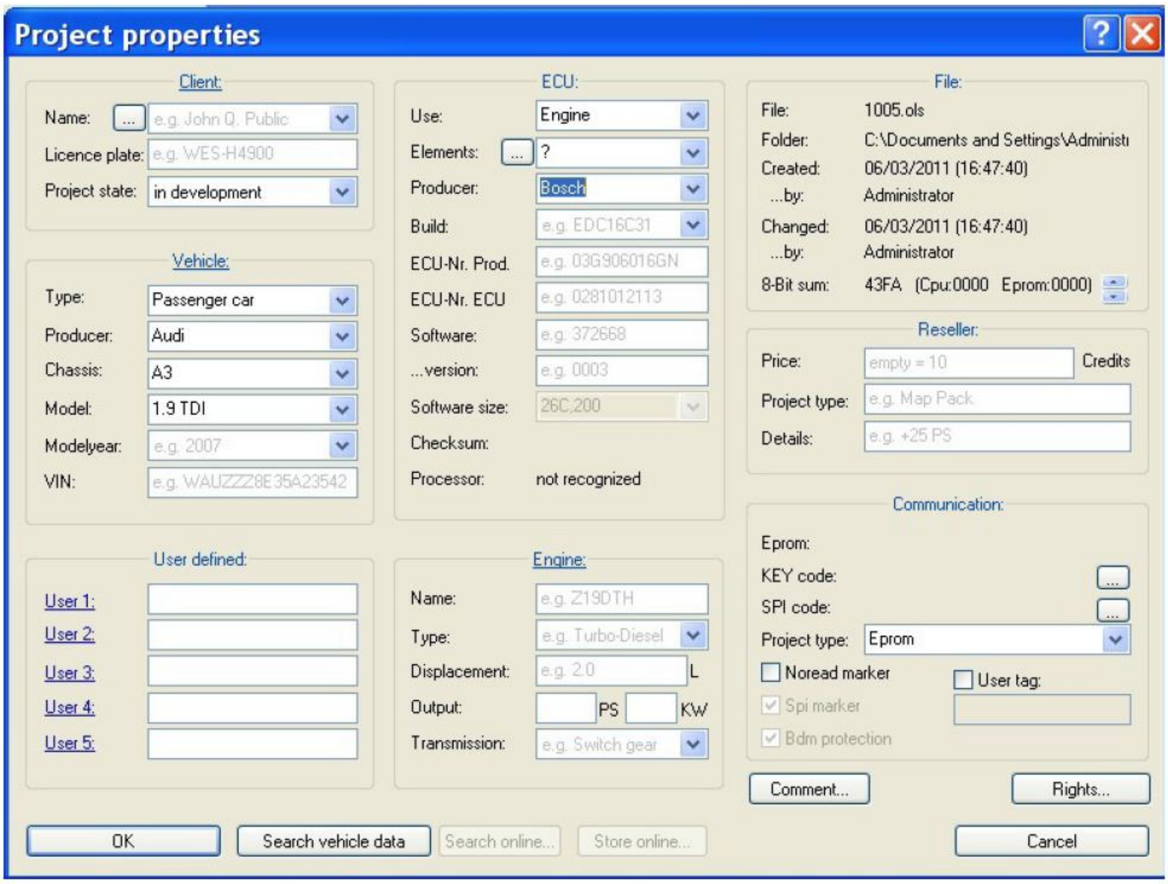


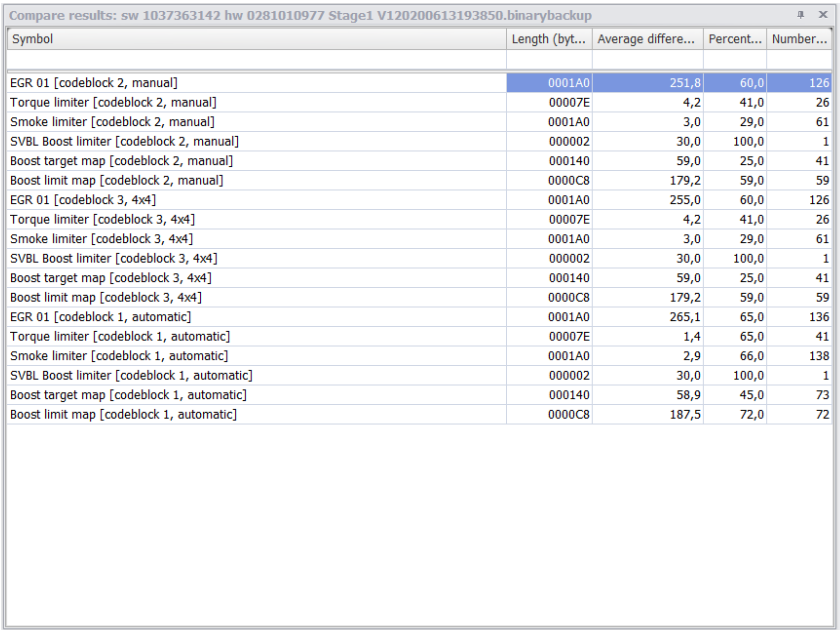
Figure 49: FIRMWARE INFORMATION Project properties

ACTIONS MENU – VIN DECODER

Lets you decode VAG VIN numbers into readable format.

ACTIONS MENU – COMPARE WITH ANOTHER BINARY

The most time-consuming thing is comparing maps for different firmware versions by hand. VAGEDC15P Suite gives you the tools to compare maps in different binaries with a click of the mouse. To do this you must first open the primary binary you want to compare. Then, select “Compare maps with other binary” from the Actions menu under Actions. Now, select the secondary binary you wish to compare the first one with. VAGEDC15P Suite will now display a list of symbols that differ in the selected binaries.



Symbol	Length (byt...	Average differe...	Percent...	Number...
EGR 01 [codeblock 2, manual]	0001A0	251,8	60,0	126
Torque limiter [codeblock 2, manual]	00007E	4,2	41,0	26
Smoke limiter [codeblock 2, manual]	0001A0	3,0	29,0	61
SVBL Boost limiter [codeblock 2, manual]	000002	30,0	100,0	1
Boost target map [codeblock 2, manual]	000140	59,0	25,0	41
Boost limit map [codeblock 2, manual]	0000C8	179,2	59,0	59
EGR 01 [codeblock 3, 4x4]	0001A0	255,0	60,0	126
Torque limiter [codeblock 3, 4x4]	00007E	4,2	41,0	26
Smoke limiter [codeblock 3, 4x4]	0001A0	3,0	29,0	61
SVBL Boost limiter [codeblock 3, 4x4]	000002	30,0	100,0	1
Boost target map [codeblock 3, 4x4]	000140	59,0	25,0	41
Boost limit map [codeblock 3, 4x4]	0000C8	179,2	59,0	59
EGR 01 [codeblock 1, automatic]	0001A0	265,1	65,0	136
Torque limiter [codeblock 1, automatic]	00007E	1,4	65,0	41
Smoke limiter [codeblock 1, automatic]	0001A0	2,9	66,0	138
SVBL Boost limiter [codeblock 1, automatic]	000002	30,0	100,0	1
Boost target map [codeblock 1, automatic]	000140	58,9	45,0	73
Boost limit map [codeblock 1, automatic]	0000C8	187,5	72,0	72

Figure 50COMPARE WITH ANOTHER BINARY

ACTIONS MENU – BINARY COMPARE

Lets you do a binary (byte-by-byte) compare of two files. This is a good tool to verify whether a programming session was successful or not. Sequences of steps would be:

1. Program ECU

2. Read file from ECU

3. Compare original and downloaded file with Binary compare.

If the result screen is empty the files are identical (successful programming)

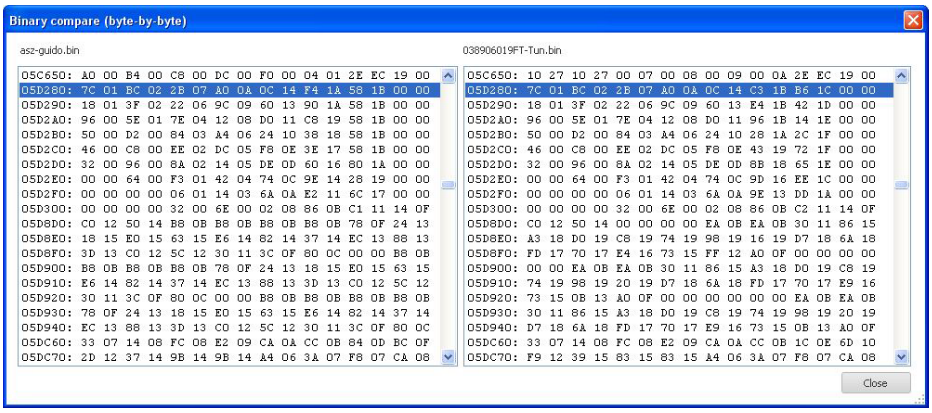


Figure 51BINARY COMPARE

a. TUNING MENU

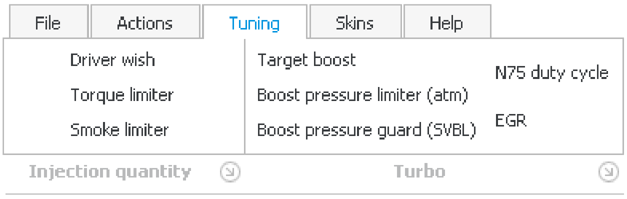


Figure 52 TUNING MENU

Lets you directly start a mapviewer with the specific map for quick access to the most imporant maps.

2.4.2. EDITING MAPS

a. HEXADECIMAL MODE

When you select “View tables in Hex” in the ribbon menu under Actions, Options all maps will be displayed in hexadecimal values. If you don’t really know how to interpret hexadecimal number, you can also switch do decimal mode by unchecking the “View tables in Hex” option. This setting will be stored and retrieved the next time the application is started. In the images below you can see the difference of viewing in hex or in decimal format.

b. COLOR INDICATORS

You can adjust how the maps are displayed to some extend. By default all maps will be displayed having color from green (low values) to red (high values). If you find this confusing you can check the “Show red and white maps” option in Actions, Options and the maps will be displayed using red only. In the images below you can see the difference in viewing in red&green and red&white.

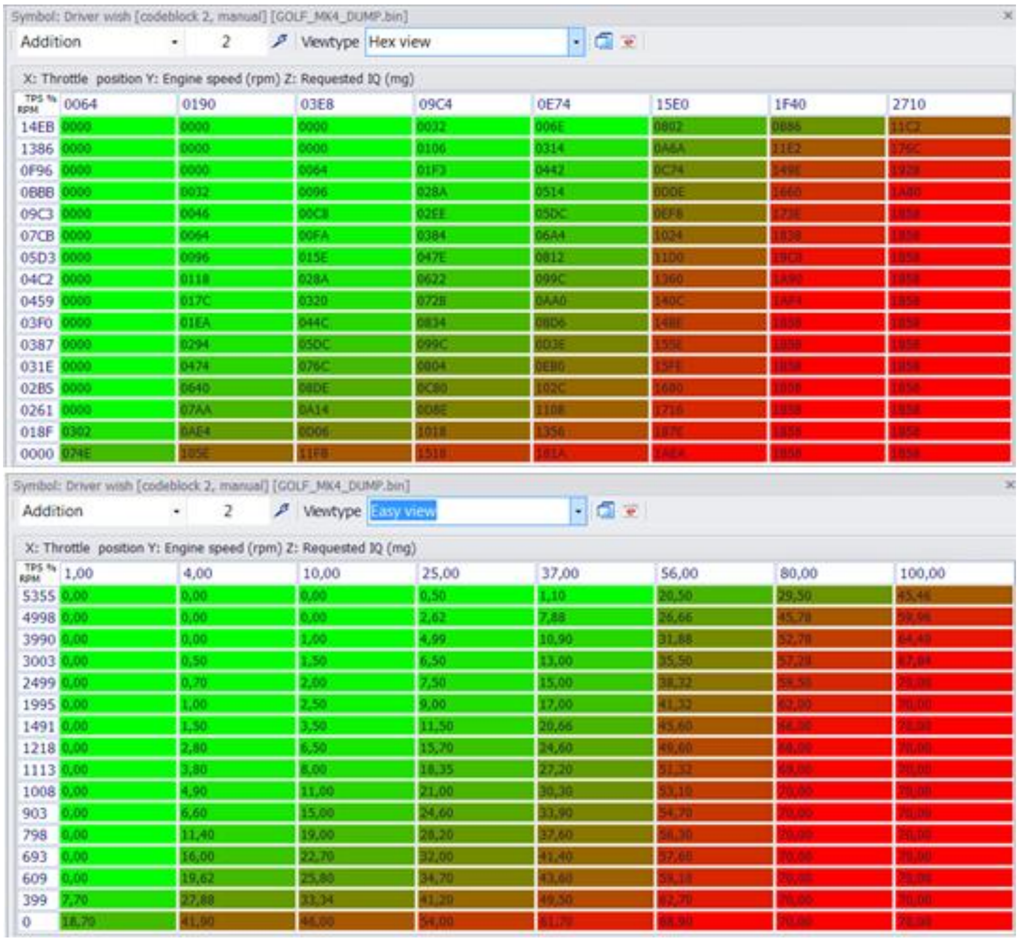


Figure 53 : EDITING MAPS View Type

2.4.3. ADJUSTING VALUES IN A MAP

To avoid that you have to adjust all values of a “large” map manually some features have been added to the map editor.

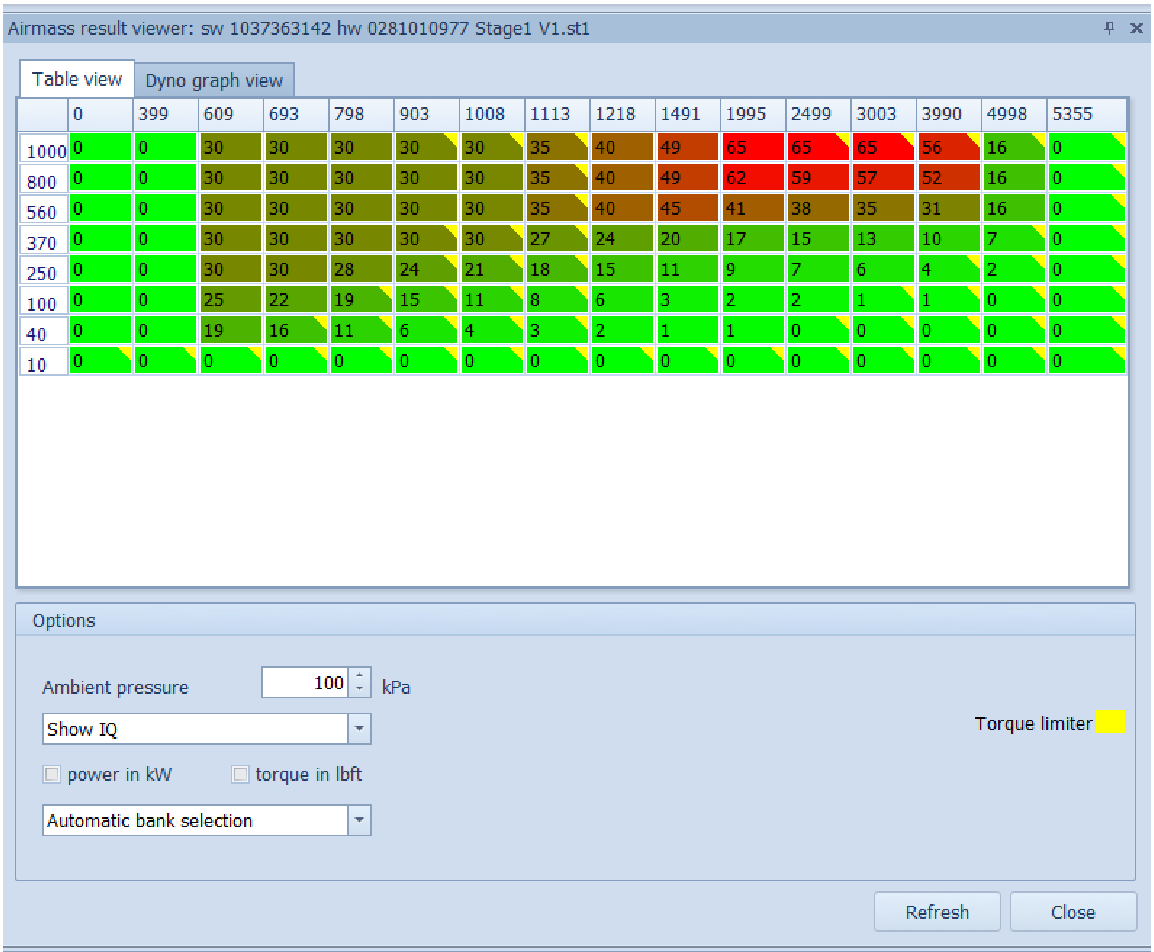
- Plus key: adds 1 to all selected cells
- Minus key: substracts 1 from all selected cells
- PageUp key: adds 10 to all selected cells
- PageDown key: substracts 10 from all selected cells
- Home key: sets all selected cells to the maximal value
- End key: sets all selected cells to the minimal values

To be able to get your work done faster you can selected one or more cells in a table and copy them to the clipboard by right clicking and selecting “Copy selected cells”.

To paste the cells select the location where you want to cells to appear – this could be in another map and even in another binary – rightclick and select “paste selected cells” and then “At original position” or “At currently selected location”.

2.4.4. ACTIONS MENU – VIEW PERFORMANCE

VAGEDC15P Suite incorporates a function to verify the final (estimated) performance results based on the most common air mass and torque limiters). The result from these calculations are shown in a table that also shows the limiter that is holding more air mass per combustion back.



	0	399	609	693	798	903	1008	1113	1218	1491	1995	2499	3003	3990	4998	5355
1000	0	0	30	30	30	30	30	35	40	49	65	65	65	56	16	0
800	0	0	30	30	30	30	30	35	40	49	62	59	57	52	16	0
560	0	0	30	30	30	30	30	35	40	45	41	38	35	31	16	0
370	0	0	30	30	30	30	30	27	24	20	17	15	13	10	7	0
250	0	0	30	30	28	24	21	18	15	11	9	7	6	4	2	0
100	0	0	25	22	19	15	11	8	6	3	2	2	1	1	0	0
40	0	0	19	16	11	6	4	3	2	1	1	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 54VIEW PERFORMANCE

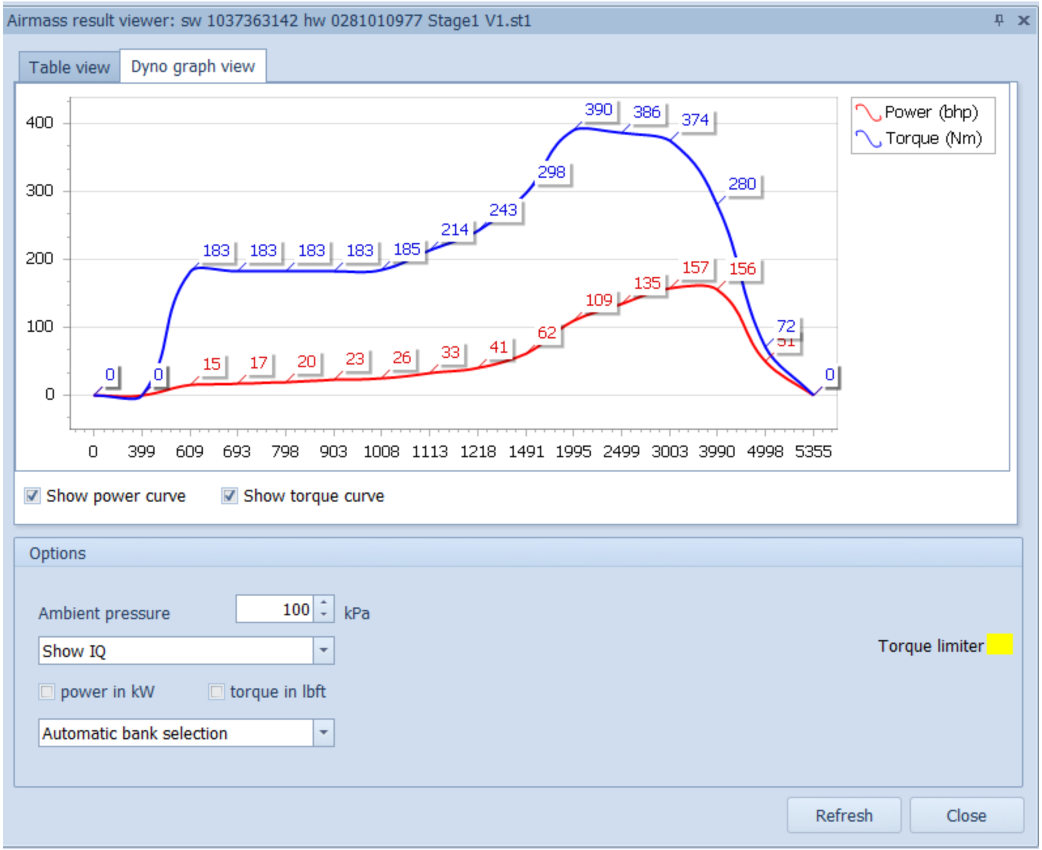


Figure 55Dyno grqph viez

2.5. STEP 4:

Writing full backup the file tuned Go back to tuner software, open the file from Step 3, and press "Upload to ECU / Copy". After that return the ECU to the car and connecting with engine connation

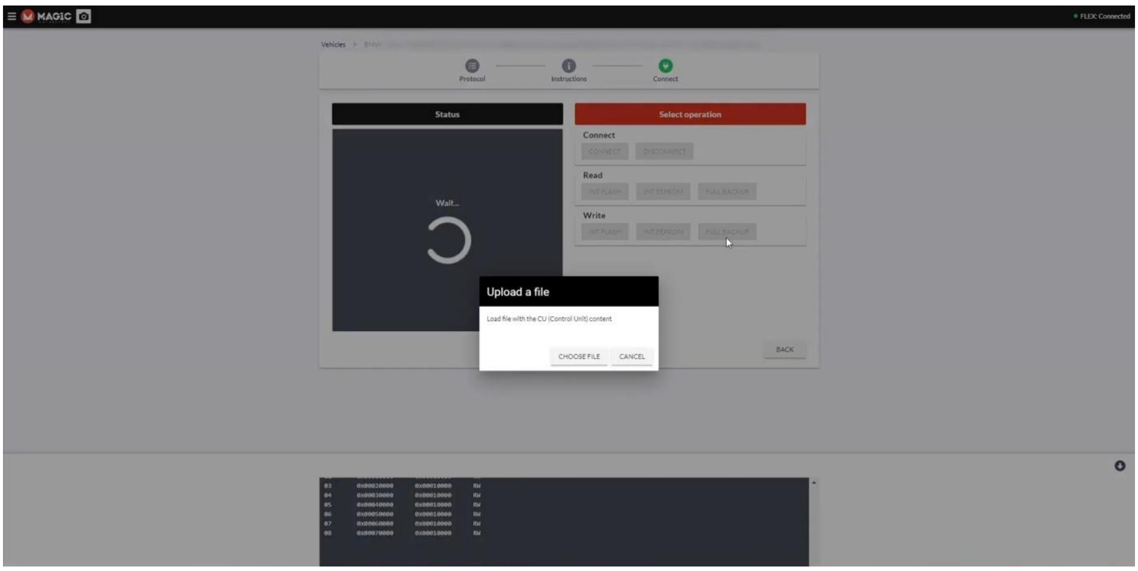


Figure 56Writing full backup the file tuned

Figure 57: ECU connecting with engine connation

2.6. STEP 5:

Dynamometer

A dynamometer is necessary to determine proper vehicle performance: for this reason, the dynoMAG line (with the exception of the 2WDI version) is equipped with an eddy current braking system, that allows the mechatronic to simulate various driving conditions. Vehicle cooling fans are provided to simulate air friction and help manage engine temperature.

Figure 58: Dynamometer

Max Power (Sweep power/Torque test)	• 1000 HP
Max Power (static functions as road simulations or steady state)	• 600 HP
Max Speed	• 360 Km/h
Axis Connection	• Electronic
Roll Diameter	• 400 mm
Roll Width	• 700 mm
Space needed	• 3470 x 1135 mm
Height	• up to 410 mm
Weight	• 1500 kg
Power Supply + Compressed Air	• Three-phase 400 VAC 16A + 6 bar

Figure 59dynoMAG 2WDF

Chapter IV

Edit file and implementation

1. Cooperation in Edit file and implementation

Our applied working conditions remotely cooperated with the center autochiptuning.sk, It is a center specialized in automobile programming and tuning , based in the country of **Slovakia**. We contacted them via their official website in order to work together. They have sent us the special program (EDC_SUITE), It is a special program for reading and editing (remapping), then we do the tuning file and sent it to them for correction . Finally, we obtained the results of the work.

Figure 60: dynamometer

Figure 61: center specialized in automobile tuning

2. Tuning EDC15P

In this chapter the basic mapping that will be needed in Simple Stage 1. The complex designations of modified devices (air mass sensors, map sensors, turbochargers, larger injectors, etc.) are not described here. It will also give a good overview of what the EDC15P range has to offer. The maps required for Simple Stage 1 are :

- Driver wish map
- Torque limiter
- Smoke limiter
- Injection duration map
- EGR map (optionally)
- Boost target map
- N75 duty cycle map (e.g. wastegate/VG control)
- Boost limit map
- Single value boost limiter

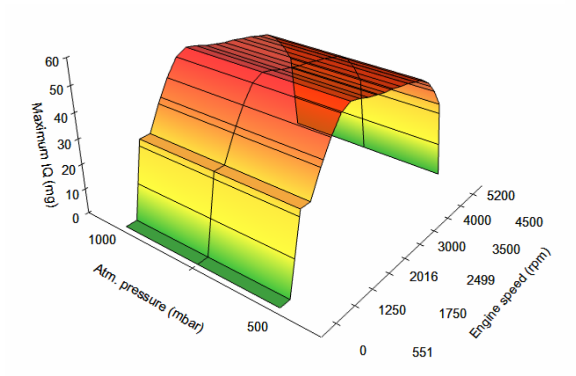


Figure 62: torque limiter

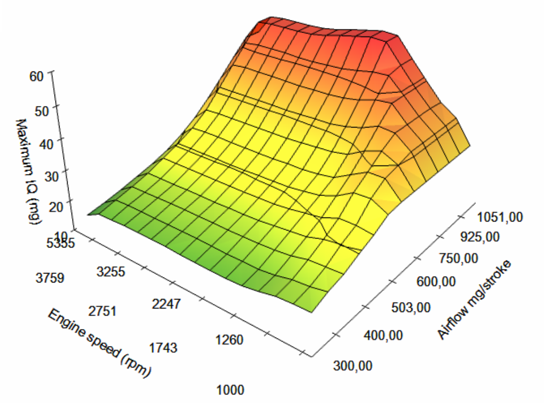


Figure 63: smoke limiter

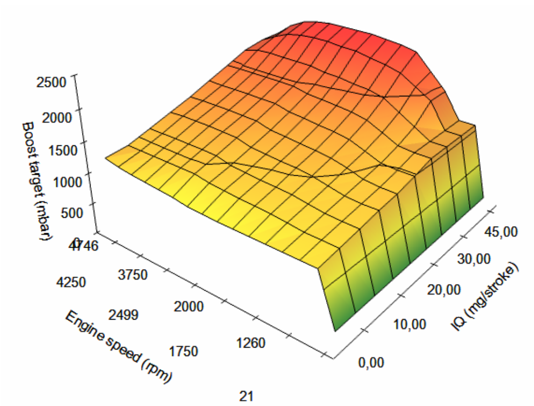


Figure 64: boost target

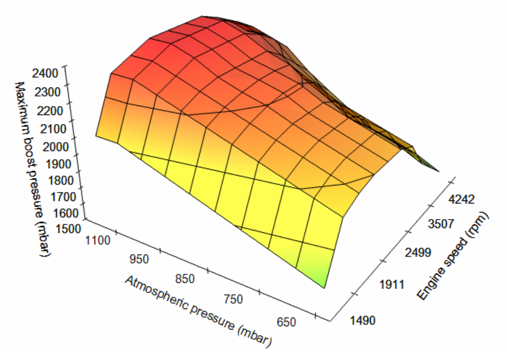


Figure 65: boost limit map

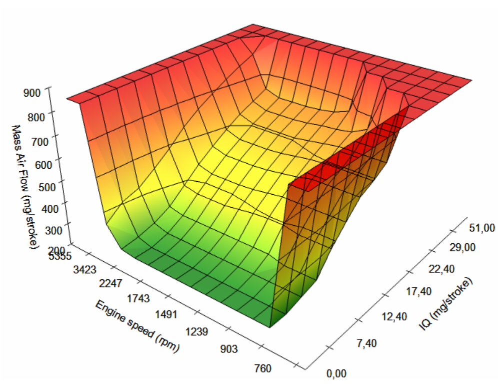


Figure 66: EGR map

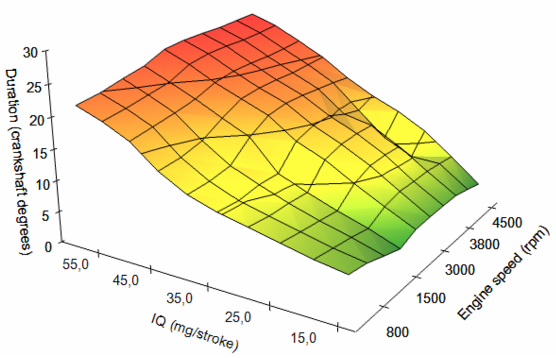


Figure 67: injection duration 00

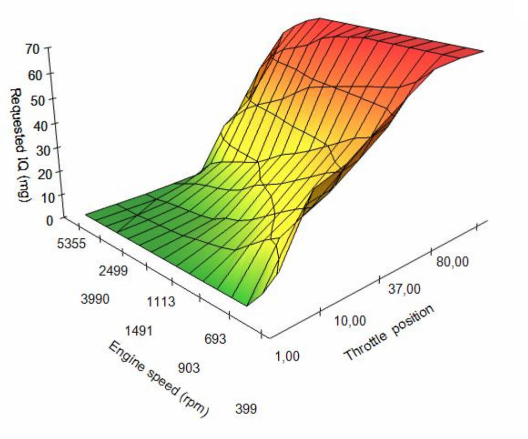


Figure 68: driver wish

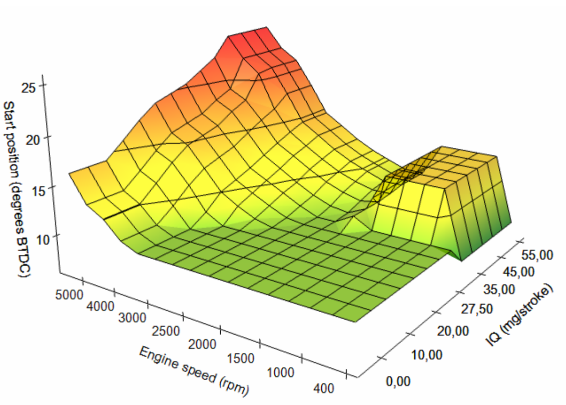


Figure 69: start of injection SOI -20

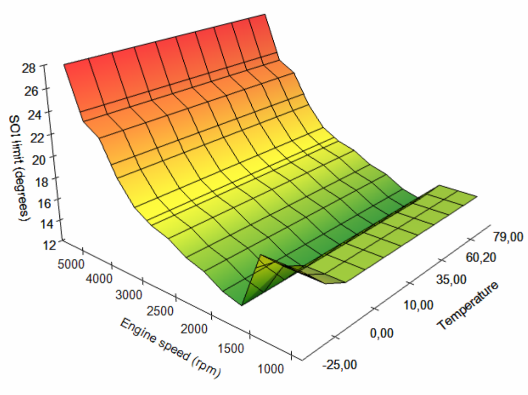


Figure 70: SOI limiter

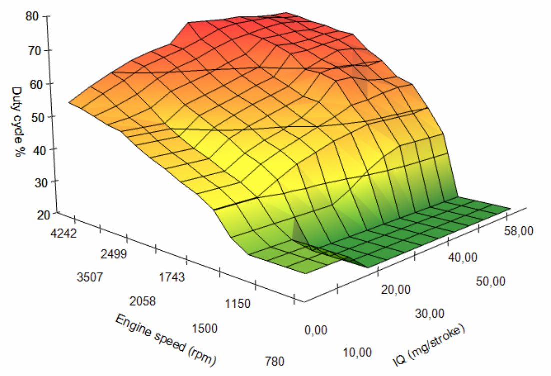


Figure 71: N75 duty cycle

3. Injection Quantity Maps

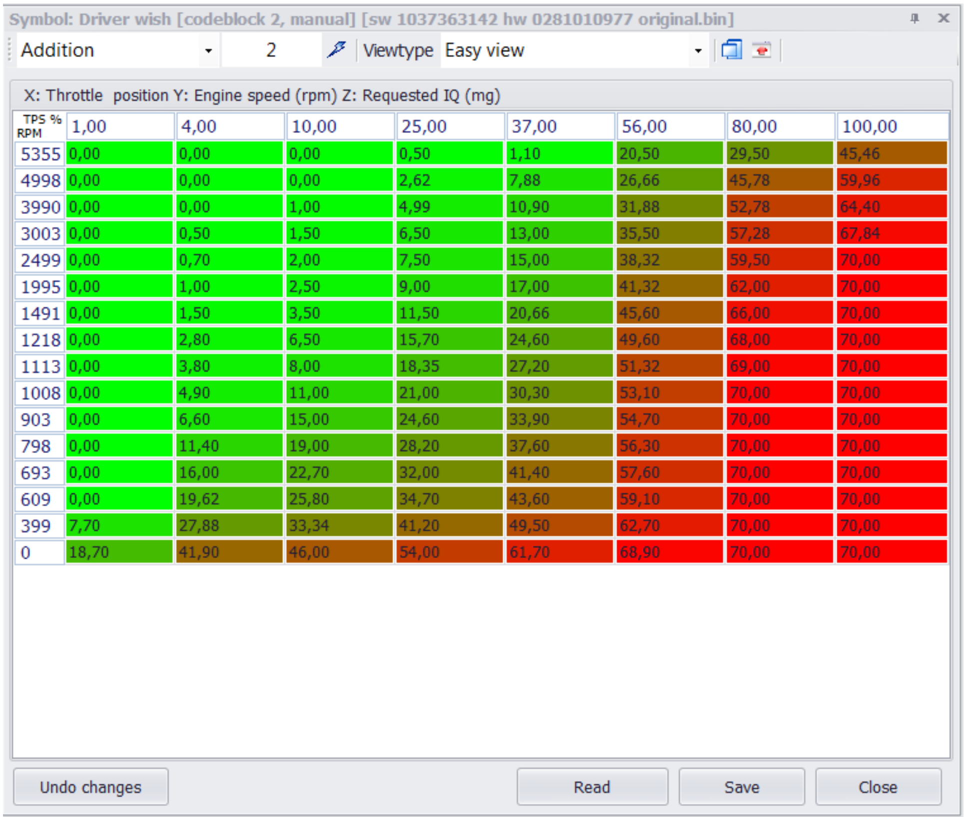
3.1. DRIVERS WISH MAPS

The electronic accelerator pedal sends a signal to the ECU showing how much the driver is pushing the pedal down.

The measurement is usually a percentage. 0 % is no push so the engine idles. 100 % is full or Wide Open Throttle. at 0 % throttle the injectors must give a fixed QUANTITY of fuel, for a fixed DURATION starting at a fixed TIME. This results in a pre-set idle speed. e.g. 900 rpm. So the idle speed has been Mapped to a specific value for MAF, QUANTITY, DURATION and TIMING

- First row (x) is Accelerator pedal. (0 - 100)

- First column (Y) is engine RPM. (0 - 5355 rpm)
- Chart data (Z) is Injection Quantity (0 - 7000) Multiply by 0.01 to see it as mg/stroke. (7000 x 0.01 = 70 mg/stroke) or in easy view (0-70) mg/stroke



Symbol: Driver wish [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

Addition 2 Viewtype Easy view

X: Throttle position Y: Engine speed (rpm) Z: Requested IQ (mg)

TPS % / RPM	1,00	4,00	10,00	25,00	37,00	56,00	80,00	100,00
5355	0,00	0,00	0,00	0,50	1,10	20,50	29,50	45,46
4998	0,00	0,00	0,00	2,62	7,88	26,66	45,78	59,96
3990	0,00	0,00	1,00	4,99	10,90	31,88	52,78	64,40
3003	0,00	0,50	1,50	6,50	13,00	35,50	57,28	67,84
2499	0,00	0,70	2,00	7,50	15,00	38,32	59,50	70,00
1995	0,00	1,00	2,50	9,00	17,00	41,32	62,00	70,00
1491	0,00	1,50	3,50	11,50	20,66	45,60	66,00	70,00
1218	0,00	2,80	6,50	15,70	24,60	49,60	68,00	70,00
1113	0,00	3,80	8,00	18,35	27,20	51,32	69,00	70,00
1008	0,00	4,90	11,00	21,00	30,30	53,10	70,00	70,00
903	0,00	6,60	15,00	24,60	33,90	54,70	70,00	70,00
798	0,00	11,40	19,00	28,20	37,60	56,30	70,00	70,00
693	0,00	16,00	22,70	32,00	41,40	57,60	70,00	70,00
609	0,00	19,62	25,80	34,70	43,60	59,10	70,00	70,00
399	7,70	27,88	33,34	41,20	49,50	62,70	70,00	70,00
0	18,70	41,90	46,00	54,00	61,70	68,90	70,00	70,00

Undo changes Read Save Close

Table 3: DRIVERS WISH MAP ORIGINAL

Symbol: Driver wish [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V120200613231802.bi...

Addition | 2 | Viewtype | Easy view

X: Throttle position Y: Engine speed (rpm) Z: Requested IQ (mg)

RPM \ TPS %	1,00	4,00	10,00	25,00	37,00	56,00	80,00	100,00
5355	0,00	0,00	0,00	0,50	1,10	20,50	29,50	45,46
4998	0,00	0,00	0,00	2,62	7,88	26,66	45,78	59,96
3990	0,00	0,00	1,00	4,99	10,90	31,88	52,78	64,40
3003	0,00	0,50	1,50	6,50	13,00	35,50	57,28	67,84
2499	0,00	0,70	2,00	7,50	15,00	38,32	59,50	70,00
1995	0,00	1,00	2,50	9,00	17,00	41,32	62,00	70,00
1491	0,00	1,50	3,50	11,50	20,66	45,60	66,00	70,00
1218	0,00	2,80	6,50	15,70	24,60	49,60	68,00	70,00
1113	0,00	3,80	8,00	18,35	27,20	51,32	69,00	70,00
1008	0,00	4,90	11,00	21,00	30,30	53,10	70,00	70,00
903	0,00	6,60	15,00	24,60	33,90	54,70	70,00	70,00
798	0,00	11,40	19,00	28,20	37,60	56,30	70,00	70,00
693	0,00	16,00	22,70	32,00	41,40	57,60	70,00	70,00
609	0,00	19,62	25,80	34,70	43,60	59,10	70,00	70,00
399	7,70	27,88	33,34	41,20	49,50	62,70	70,00	70,00
0	18,70	41,90	46,00	54,00	61,70	68,90	70,00	70,00

Undo changes | Read | Save | Close

Table 4: DRIVERS WISH MAP STAGE 1

3.2. IQ by MAP limiter

Symbol: IQ by MAP limiter [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

Addition | 2 | Viewtype | Easy view

X: Boost pressure Y: Engine speed (rpm) Z: Maximum IQ (mg)

RPM \ MBAR	800	900	1000	1100	1200	1300	1400	1600	1800	2000
5355	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
4242	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3759	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3507	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3255	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3003	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2751	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2499	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2247	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1995	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1743	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1491	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1260	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1008	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
924	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
861	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00

Undo changes | Read | Save | Close

Table 5:: IQ by MAP limiter ORIGINAL

Symbol: IQ by MAP limiter [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V120200613231...

Addition 2 Viewtype Easy view

X: Boost pressure Y: Engine speed (rpm) Z: Maximum IQ (mg)

MBAR RPM	800	900	1000	1100	1200	1300	1400	1600	1800	2000
5355	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
4242	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3759	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3507	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3255	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3003	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2751	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2499	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2247	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1995	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1743	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1491	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1260	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1008	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
924	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
861	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00

Undo changes Read Save Close

Table 6: IQ by MAP limiter STAGE 1

3.3. Start of injection

Symbol: Start of injection (SOI) -20 °C [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

Addition 2 Viewtype Easy view

X: IQ (mg/stroke) Y: Engine speed (rpm) Z: Start position (degrees BTDC)

MG/ST RPM	0,00	5,00	10,00	15,00	20,00	25,00	27,50	30,00	35,00	40,00	45,00	50,00	55,00	60,00
5000	16,2°	16,2°	16,2°	17,7°	19,3°	20,6°	21,1°	21,7°	22,7°	23,7°	25,8°	25,8°	25,8°	25,8°
4250	13,5°	13,5°	13,5°	14,9°	16,4°	17,7°	18,2°	18,7°	19,7°	20,5°	23,5°	23,5°	23,5°	23,5°
4000	12,5°	12,5°	12,5°	14,0°	15,5°	16,7°	17,2°	17,7°	18,7°	19,5°	22,0°	22,3°	22,3°	22,3°
3500	10,8°	10,8°	10,8°	12,0°	13,5°	14,6°	15,2°	15,7°	16,6°	17,5°	18,3°	19,5°	19,5°	19,5°
3000	10,0°	10,0°	10,0°	10,0°	11,0°	12,5°	13,1°	13,7°	14,5°	15,2°	15,9°	16,5°	16,5°	16,5°
2750	10,0°	10,0°	10,0°	10,0°	10,0°	11,4°	12,0°	12,7°	13,4°	14,2°	14,7°	15,3°	15,3°	15,3°
2500	10,0°	10,0°	10,0°	10,0°	10,0°	10,5°	11,1°	11,8°	12,2°	13,0°	13,5°	14,0°	14,0°	14,0°
2250	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,3°	10,8°	11,2°	12,0°	12,5°	13,0°	13,0°	13,0°
2000	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,5°	11,3°	11,8°	12,2°	12,2°	12,2°
1750	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,2°	10,7°	11,3°	11,5°	11,5°	11,5°
1500	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	11,1°	11,1°	11,1°	11,3°	11,5°	11,5°	11,5°
1250	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	15,0°	15,0°	15,0°	15,0°	15,0°	15,0°
1000	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	15,0°	15,0°	15,0°	15,0°	15,0°	15,0°
800	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	15,0°	15,0°	15,0°	15,0°	15,0°	15,0°
400	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	15,0°	15,0°	15,0°	15,0°	15,0°	15,0°
100	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	8,0°	8,0°	8,0°	8,0°	8,0°	8,0°

Undo changes Read Save Close

Table 7: Start of injection ORIGINAL

Symbol: Start of injection (SOI) -20 °C [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V12...

Addition 2 Viewtype Easy view

X: IQ (mg/stroke) Y: Engine speed (rpm) Z: Start position (degrees BTDC)

MG/ST RPM	0,00	5,00	10,00	15,00	20,00	25,00	27,50	30,00	35,00	40,00	45,00	50,00	55,00	60,00
5000	16,2°	16,2°	16,2°	17,7°	19,3°	20,6°	21,1°	21,7°	22,7°	23,7°	25,8°	25,8°	25,8°	25,8°
4250	13,5°	13,5°	13,5°	14,9°	16,4°	17,7°	18,2°	18,7°	19,7°	20,5°	23,5°	23,5°	23,5°	23,5°
4000	12,5°	12,5°	12,5°	14,0°	15,5°	16,7°	17,2°	17,7°	18,7°	19,5°	22,0°	22,3°	22,3°	22,3°
3500	10,8°	10,8°	10,8°	12,0°	13,5°	14,6°	15,2°	15,7°	16,6°	17,5°	18,3°	19,5°	19,5°	19,5°
3000	10,0°	10,0°	10,0°	10,0°	11,0°	12,5°	13,1°	13,7°	14,5°	15,2°	15,9°	16,5°	16,5°	16,5°
2750	10,0°	10,0°	10,0°	10,0°	10,0°	11,4°	12,0°	12,7°	13,4°	14,2°	14,7°	15,3°	15,3°	15,3°
2500	10,0°	10,0°	10,0°	10,0°	10,0°	10,5°	11,1°	11,8°	12,2°	13,0°	13,5°	14,0°	14,0°	14,0°
2250	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,3°	10,8°	11,2°	12,0°	12,5°	13,0°	13,0°	13,0°
2000	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,5°	11,3°	11,8°	12,2°	12,2°	12,2°
1750	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,2°	10,7°	11,3°	11,5°	11,5°	11,5°
1500	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	11,1°	11,1°	11,1°	11,3°	11,5°	11,5°	11,5°
1250	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	15,0°	15,0°	15,0°	15,0°	15,0°	15,0°
1000	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	15,0°	15,0°	15,0°	15,0°	15,0°	15,0°
800	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	15,0°	15,0°	15,0°	15,0°	15,0°	15,0°
400	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	15,0°	15,0°	15,0°	15,0°	15,0°	15,0°
100	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	10,0°	8,0°	8,0°	8,0°	8,0°	8,0°	8,0°

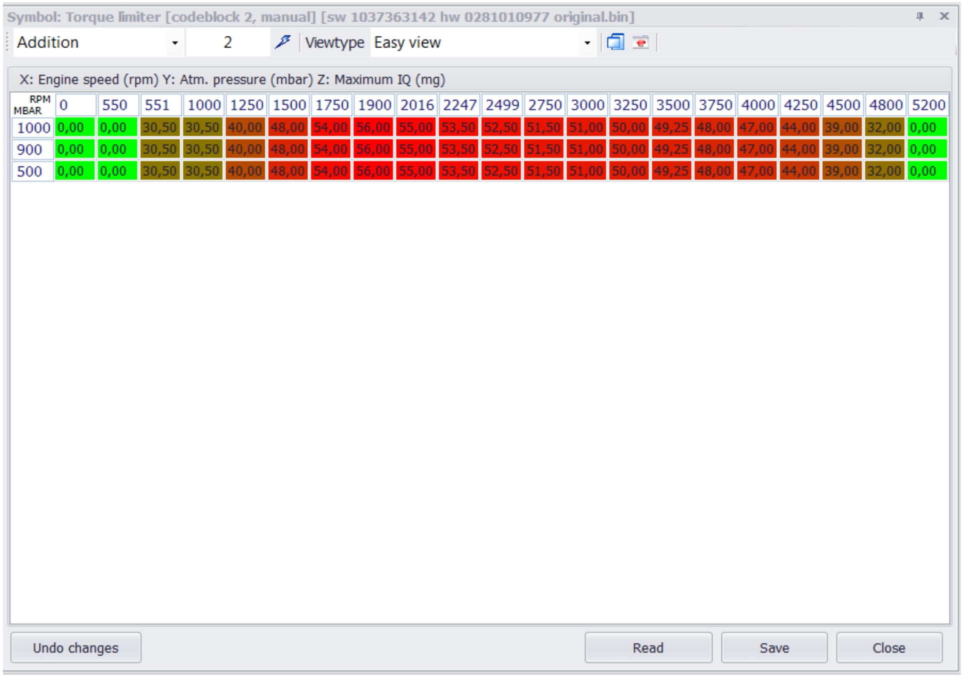
Undo changes Read Save Close

Table 8: Start of injection STAGE 1

3.4. TORQUE LIMITING MAPS

To reduce transmission and drive system components suffering greatly from low torque. Output power is restricted at low engine speeds. It also allows you to determine the torque in the case of atmospheric pressure below average (take the example of mountain heights). All this is done in order to prevent the turbocharger from overtaking.

- First row (X) is engine RPM. (0 - 5355 rpm)
- First column (Y) is Atmospheric Air Pressure (500 - 1000 mbar)
- Chart data (Z) is Injection Quantity (0 - 5100) Multiply by 0.01 to see it as mg/stroke. (5600 X 0.01 = 56 mg/stroke) or in easy view (0 - 56 mg/stroke).



Symbol: Torque limiter [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

Addition 2 Viewtype Easy view

X: Engine speed (rpm) Y: Atm. pressure (mbar) Z: Maximum IQ (mg)

RPM / MBAR	0	550	551	1000	1250	1500	1750	1900	2016	2247	2499	2750	3000	3250	3500	3750	4000	4250	4500	4800	5200
1000	0,00	0,00	30,50	30,50	40,00	48,00	54,00	56,00	55,00	53,50	52,50	51,50	51,00	50,00	49,25	48,00	47,00	44,00	39,00	32,00	0,00
900	0,00	0,00	30,50	30,50	40,00	48,00	54,00	56,00	55,00	53,50	52,50	51,50	51,00	50,00	49,25	48,00	47,00	44,00	39,00	32,00	0,00
500	0,00	0,00	30,50	30,50	40,00	48,00	54,00	56,00	55,00	53,50	52,50	51,50	51,00	50,00	49,25	48,00	47,00	44,00	39,00	32,00	0,00

Undo changes Read Save Close

Table 9: TORQUE LIMITING MAPS ORIGINAL

Symbol: Torque limiter [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V120200613231802.binarybackup]

Addition 2 Viewtype Easy view

X: Engine speed (rpm) Y: Atm. pressure (mbar) Z: Maximum IQ (mg)

MBAR \ RPM	0	550	551	1000	1250	1500	1750	1900	2016	2247	2499	2750	3000	3250	3500	3750	4000	4250	4500	4800	5200
1000	0,00	0,00	30,50	30,50	42,00	50,00	60,00	65,00	65,00	65,00	65,00	65,00	65,00	65,00	64,25	62,00	56,00	44,00	39,00	32,00	0,00
900	0,00	0,00	30,50	30,50	42,00	50,00	60,00	65,00	65,00	65,00	65,00	65,00	65,00	65,00	64,25	62,00	56,00	44,00	39,00	32,00	0,00
500	0,00	0,00	30,50	30,50	40,00	48,00	54,00	56,00	55,00	53,50	52,50	51,50	51,00	50,00	49,25	48,00	47,00	44,00	39,00	32,00	0,00

Undo changes Read Save Close

Table 10: TORQUE LIMITING MAPS SATGE 1

The Percentage difference chart shows that the axes are unchanged between 130 and 150 ECU's. The torque limiter is Atmospheric Air Pressure dependent (First column , Y - axis). It is based on three Air pressures, 500, 900 and 1000 mbars. Normal sea level air pressure is roughly 1000 mbars so the ecu 's limiting will normally be based on the last row. The other rows are designed to reduce I.Q and indirectly turbo speed at lower air pressure, This is to stop the turbo over-reving in thin air and destroying itself. For this reason the figures in the first row are always lower than the figures in the last row.

At all pressures the I.Q output for the 150 is increased over the 130 from about 1900 RPM. This is the point at which the turbocharger starts to blow. There is no point in having a higher I.Q below this 1900 RPM as their will not be enough air available.

- The 130 has a peak I.Q of 56 mg/stroke. This only increase to a maximum of 65 mg/stroke for the 150.
- the 150 injects 3 to 16% more fuel per stroke than the 130.
- The Torque map limiting the maximum I.Q to 57.50 mg/stroke.

Even if the Drivers wish requests an I.Q of 70 mg/stroke, it will be limited by the Mass Air Flow to 60 mg/stroke maximum and this will then be limited by the Torque limiter to a maximum of 56 mg/stroke.

We don't need to change the Drivers wish. It already requests up to 70 mg/stroke fuel, which is plenty.

we change the MAF limiting (smoke) map to give more I.Q at high Mass Air Flow rates and a little bit at low MAF & low rpm to make the engine pull more strongly at low rpm. Beware increasing I.Q too much at low Mass Air Flow. If you do, you will get alot of black smoke.

We change the Torque limiting map to allow more I.Q from about 1900 rpm. The peak I.Q must reduce slightly as RPM rise and the final column must be 0000. The I.Q is first limited by :

- Drivers wish (Highest I.Q).
- Next I.Q limited by MAF (Lower than drivers wish).
- Finally I.Q limited by the Torque limiter. (Lowest I.Q)

3.5. IQ LIMIT BY MASS AIR FLOW (MAF)

- First row (X) is Mass Air Flow (MAF) (3000 - 10510). Multiply by 0.1 to see it as mg/stroke. (10510 x 0.1 = 1051 mbars)
- First column (Y) is engine RPM. (861 - 5355)
- Chart data (Z) is Injection Quantity (I.Q) (0 - 6000) Multiply by 0.01 to see it as mg/stroke. (6000 x 0.01 = 60 mg/stroke)

Symbol: IQ by MAF limiter 1 [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

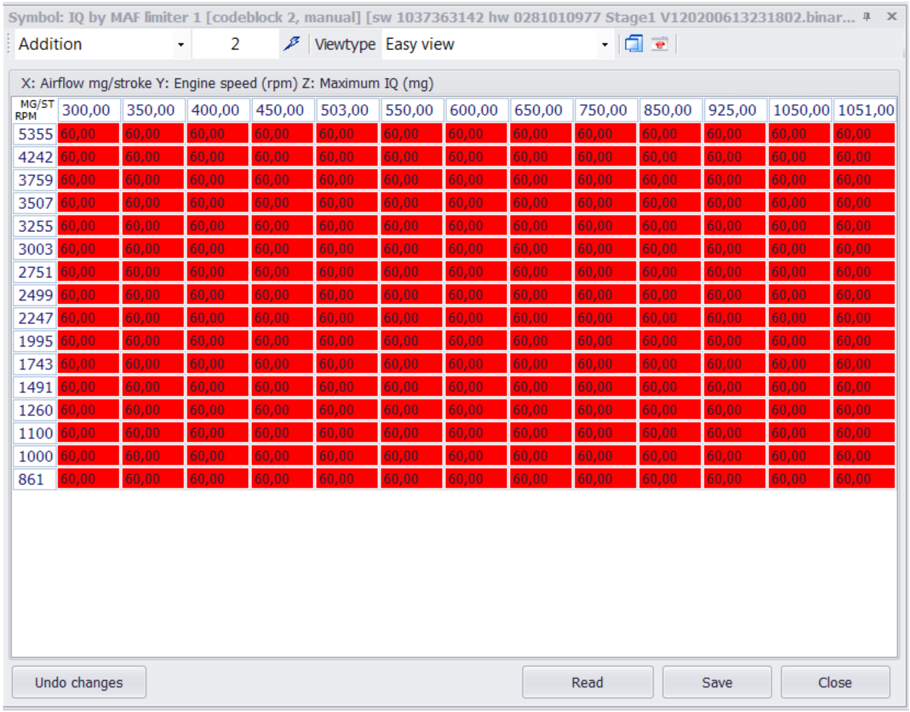
Addition 2 Viewtype Easy view

X: Airflow mg/stroke Y: Engine speed (rpm) Z: Maximum IQ (mg)

MG/ST RPM	300,00	350,00	400,00	450,00	503,00	550,00	600,00	650,00	750,00	850,00	925,00	1050,00	1051,00
5355	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
4242	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3759	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3507	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3255	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3003	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2751	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2499	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2247	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1995	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1743	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1491	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1260	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1100	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1000	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
861	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00

Undo changes Read Save Close

Table 11: IQ LIMIT BY MASS AIR FLOW (MAF) ORIGINAL



Symbol: IQ by MAF limiter 1 [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V120200613231802.binar...

Addition 2 Viewtype Easy view

X: Airflow mg/stroke Y: Engine speed (rpm) Z: Maximum IQ (mg)

MG/ST RPM	300,00	350,00	400,00	450,00	503,00	550,00	600,00	650,00	750,00	850,00	925,00	1050,00	1051,00
5355	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
4242	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3759	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3507	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3255	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
3003	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2751	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2499	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
2247	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1995	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1743	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1491	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1260	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1100	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
1000	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00
861	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00	60,00

Undo changes Read Save Close

Table 12: IQ LIMIT BY MASS AIR FLOW (MAF) STAGE 1

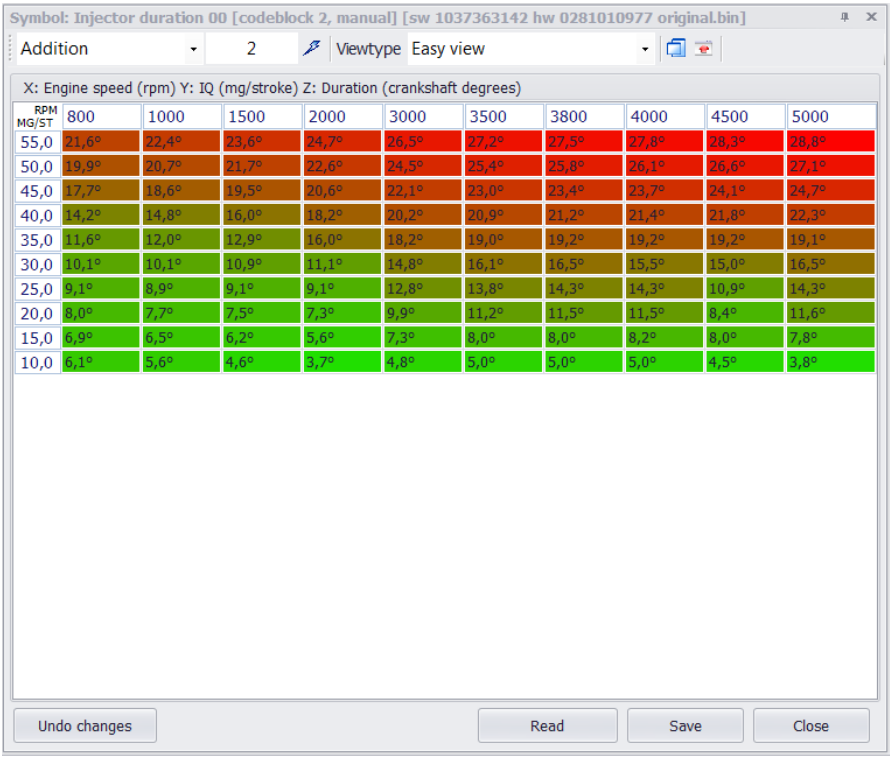
3.6. Injection duration 00

Up to a certain limit however, the amount of fuel injected determines the amount of energy produced. We can roughly estimate the torque amount to be 1.5 * X cylinders * IQ (amount injected). Injecting 60mg / stroke into a 4 cylinder engine will produce 1.5 * 4 * 60 = 360Nm of torque. Power can be calculated from torque with this formula: power (hp) = (torque (Nm) * rpm) / 7121. Injecting the same 60 mg / stroke at 4000 rpm results in 360 * 4000/7121 = 202 hp

This map tells the ECU how many degrees of the crankshaft it takes for an engine's speed to inject the required amount of fuel.

- First row (X) is I.Q (0 - 5500) Multiply by 0.01 to see it as I.Q in mg/stroke. (5500 x 0.01 = 55 mg/stroke)
- First column is engine rpm (0 - 5000)
- Chart data (Z) is Crankshaft rotation. Multiply by 0.02347 to see it as degrees of crankshaft rotation. (2901 x 0.023437 = 67.99 degrees)

If you want to see this expressed as degrees Before Top Dead Centre (BTDC) You must take the degree answer from 78. (78 - 67.99 = 10.01 degrees BTDC).


Symbol: Injector duration 00 [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

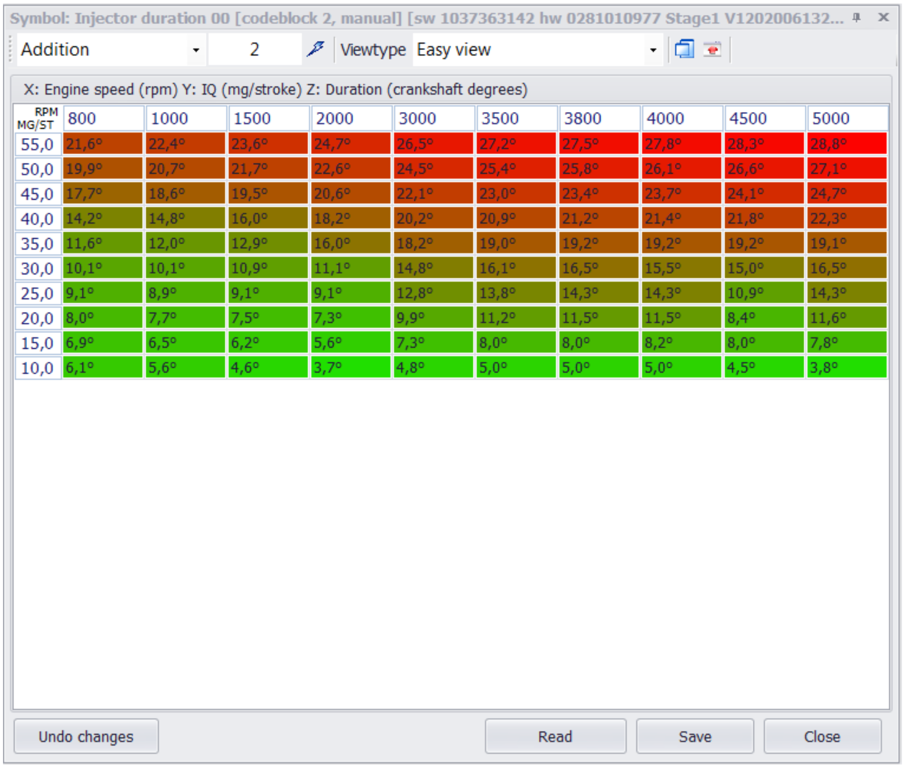
Addition 2 Viewtype Easy view

X: Engine speed (rpm) Y: IQ (mg/stroke) Z: Duration (crankshaft degrees)

RPM MG/ST	800	1000	1500	2000	3000	3500	3800	4000	4500	5000
55,0	21,6°	22,4°	23,6°	24,7°	26,5°	27,2°	27,5°	27,8°	28,3°	28,8°
50,0	19,9°	20,7°	21,7°	22,6°	24,5°	25,4°	25,8°	26,1°	26,6°	27,1°
45,0	17,7°	18,6°	19,5°	20,6°	22,1°	23,0°	23,4°	23,7°	24,1°	24,7°
40,0	14,2°	14,8°	16,0°	18,2°	20,2°	20,9°	21,2°	21,4°	21,8°	22,3°
35,0	11,6°	12,0°	12,9°	16,0°	18,2°	19,0°	19,2°	19,2°	19,2°	19,1°
30,0	10,1°	10,1°	10,9°	11,1°	14,8°	16,1°	16,5°	15,5°	15,0°	16,5°
25,0	9,1°	8,9°	9,1°	9,1°	12,8°	13,8°	14,3°	14,3°	10,9°	14,3°
20,0	8,0°	7,7°	7,5°	7,3°	9,9°	11,2°	11,5°	11,5°	8,4°	11,6°
15,0	6,9°	6,5°	6,2°	5,6°	7,3°	8,0°	8,0°	8,2°	8,0°	7,8°
10,0	6,1°	5,6°	4,6°	3,7°	4,8°	5,0°	5,0°	5,0°	4,5°	3,8°

Undo changes Read Save Close

Table 13: START OF INJECTION (SOI 00) ORIGINAL


Symbol: Injector duration 00 [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V1202006132...

Addition 2 Viewtype Easy view

X: Engine speed (rpm) Y: IQ (mg/stroke) Z: Duration (crankshaft degrees)

RPM MG/ST	800	1000	1500	2000	3000	3500	3800	4000	4500	5000
55,0	21,6°	22,4°	23,6°	24,7°	26,5°	27,2°	27,5°	27,8°	28,3°	28,8°
50,0	19,9°	20,7°	21,7°	22,6°	24,5°	25,4°	25,8°	26,1°	26,6°	27,1°
45,0	17,7°	18,6°	19,5°	20,6°	22,1°	23,0°	23,4°	23,7°	24,1°	24,7°
40,0	14,2°	14,8°	16,0°	18,2°	20,2°	20,9°	21,2°	21,4°	21,8°	22,3°
35,0	11,6°	12,0°	12,9°	16,0°	18,2°	19,0°	19,2°	19,2°	19,2°	19,1°
30,0	10,1°	10,1°	10,9°	11,1°	14,8°	16,1°	16,5°	15,5°	15,0°	16,5°
25,0	9,1°	8,9°	9,1°	9,1°	12,8°	13,8°	14,3°	14,3°	10,9°	14,3°
20,0	8,0°	7,7°	7,5°	7,3°	9,9°	11,2°	11,5°	11,5°	8,4°	11,6°
15,0	6,9°	6,5°	6,2°	5,6°	7,3°	8,0°	8,0°	8,2°	8,0°	7,8°
10,0	6,1°	5,6°	4,6°	3,7°	4,8°	5,0°	5,0°	5,0°	4,5°	3,8°

Undo changes Read Save Close

Table 14: START OF INJECTION (SOI 00) STAGE 1

Duration and SOI maps are very hard to interpret. The % difference chart for SOI 0, pd 130 vs pd 150 shows almost no difference. All ten SOI maps show the no change. But we can in other way that all ten have the X - axis change to allow more fuel to be injected. The I.Q allowed on the axis has increased from 50 mg/stroke to 55 mg/stroke. by removing the 7.5 mg/stroke column, moving all the other columns one column to the left and adding an extra 55 mg/stroke column at the end. The timing of injection is advanced slightly by moving the columns one place to the left. So more fuel can be injected by starting injection slightly earlier. This brings two benifits. More power from more fuel and more power due to advance in timing of start of injection.

3.7. SMOKE LIMITER

The smoke limiter is there to prevent excessive smoke to appear when the user depresses the accelerator pedal. Smoke is generated when the air to fuel ratio in a diesel engine are lower than 1:17. The smoke limiter tells the ECU not to inject more than the calibrated amount of fuel for any given amount of air entering the engine (air mass sensor data). If the driver wish map indicates (requests) 70 mg of air but there is only 1050 mg of air entering the engine the smoke limiter would limit the injected quantity to 55 mg of fuel for 2750 rpm.

- First row (X) is Mass Air Flow (MAF) (3000 - 10510). Multiply by 0.1 to see it as mg/stroke. (10510 x 0.1 = 1051 mbars)
- First column (Y) is engine RPM. (861 - 5355)
- Chart data (Z) is Injection Quantity (I.Q) (0 - 6000) Multiply by 0.01 to see it as mg/stroke. (6000 x 0.01 = 60 mg/stroke)

Symbol: Smoke limiter [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

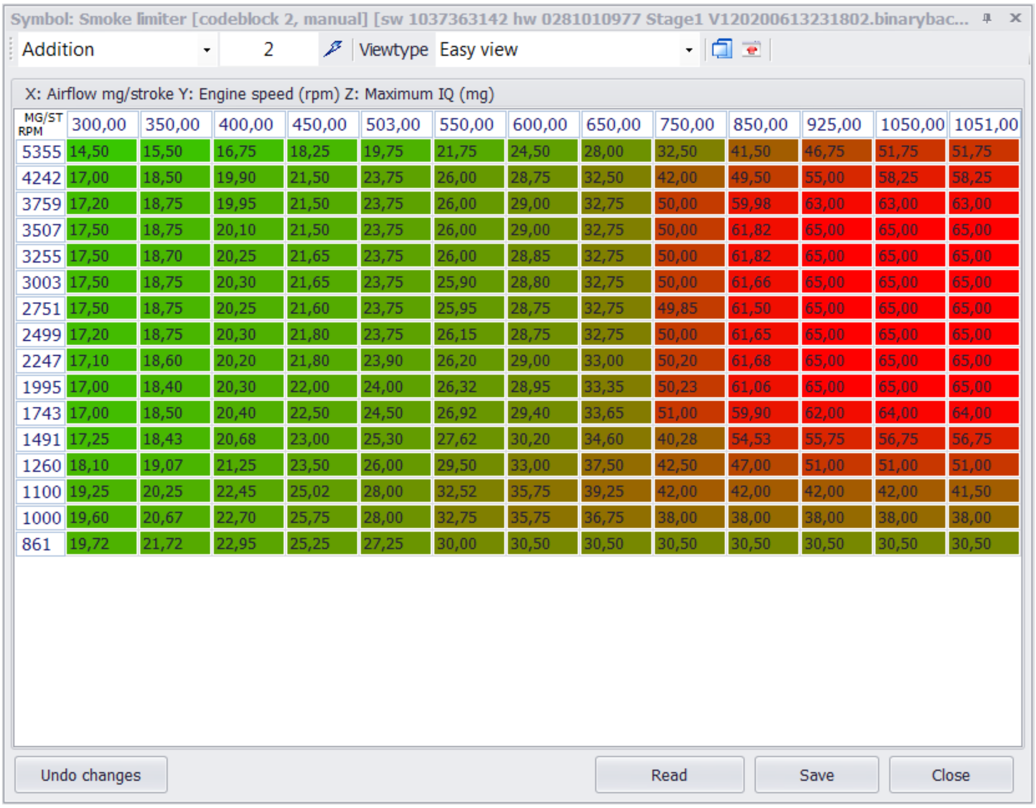
Addition 2 Viewtype Easy view

X: Airflow mg/stroke Y: Engine speed (rpm) Z: Maximum IQ (mg)

MG/ST RPM	300,00	350,00	400,00	450,00	503,00	550,00	600,00	650,00	750,00	850,00	925,00	1050,00	1051,00
5355	14,50	15,50	16,75	18,25	19,75	21,75	24,50	28,00	32,50	37,50	42,75	47,75	47,75
4242	17,00	18,50	19,90	21,50	23,75	26,00	28,75	32,50	38,00	43,50	49,00	54,25	54,25
3759	17,20	18,75	19,95	21,50	23,75	26,00	29,00	32,75	38,00	43,98	49,57	54,75	54,75
3507	17,50	18,75	20,10	21,50	23,75	26,00	29,00	32,75	38,00	43,82	49,57	54,75	54,75
3255	17,50	18,70	20,25	21,65	23,75	26,00	28,85	32,75	38,00	43,82	49,57	54,75	54,75
3003	17,50	18,75	20,30	21,65	23,75	25,90	28,80	32,75	38,00	43,66	49,25	55,00	55,00
2751	17,50	18,75	20,25	21,60	23,75	25,95	28,75	32,75	37,85	43,50	49,25	55,75	55,75
2499	17,20	18,75	20,30	21,80	23,75	26,15	28,75	32,75	38,00	43,65	49,50	57,00	57,00
2247	17,10	18,60	20,20	21,80	23,90	26,20	29,00	33,00	38,20	43,68	49,75	58,00	58,00
1995	17,00	18,40	20,30	22,00	24,00	26,32	28,95	33,35	38,23	44,06	50,50	59,00	59,00
1743	17,00	18,50	20,40	22,50	24,50	26,92	29,40	33,65	39,00	44,90	51,50	58,75	58,75
1491	17,25	18,43	20,68	23,00	25,30	27,62	30,20	34,60	40,28	46,53	51,75	52,75	52,75
1260	18,10	19,07	21,25	23,50	26,00	29,50	33,00	37,50	42,50	47,00	47,00	47,00	47,00
1100	19,25	20,25	22,45	25,02	28,00	32,52	35,75	39,25	42,00	42,00	42,00	42,00	41,50
1000	19,60	20,67	22,70	25,75	28,00	32,75	35,75	36,75	38,00	38,00	38,00	38,00	38,00
861	19,72	21,72	22,95	25,25	27,25	30,00	30,50	30,50	30,50	30,50	30,50	30,50	30,50

Undo changes Read Save Close

Table 15: SMOKE LIMITER ORIGINAL



MG/ST RPM	300,00	350,00	400,00	450,00	503,00	550,00	600,00	650,00	750,00	850,00	925,00	1050,00	1051,00
5355	14,50	15,50	16,75	18,25	19,75	21,75	24,50	28,00	32,50	41,50	46,75	51,75	51,75
4242	17,00	18,50	19,90	21,50	23,75	26,00	28,75	32,50	42,00	49,50	55,00	58,25	58,25
3759	17,20	18,75	19,95	21,50	23,75	26,00	29,00	32,75	50,00	59,98	63,00	63,00	63,00
3507	17,50	18,75	20,10	21,50	23,75	26,00	29,00	32,75	50,00	61,82	65,00	65,00	65,00
3255	17,50	18,70	20,25	21,65	23,75	26,00	28,85	32,75	50,00	61,82	65,00	65,00	65,00
3003	17,50	18,75	20,30	21,65	23,75	25,90	28,80	32,75	50,00	61,66	65,00	65,00	65,00
2751	17,50	18,75	20,25	21,60	23,75	25,95	28,75	32,75	49,85	61,50	65,00	65,00	65,00
2499	17,20	18,75	20,30	21,80	23,75	26,15	28,75	32,75	50,00	61,65	65,00	65,00	65,00
2247	17,10	18,60	20,20	21,80	23,90	26,20	29,00	33,00	50,20	61,68	65,00	65,00	65,00
1995	17,00	18,40	20,30	22,00	24,00	26,32	28,95	33,35	50,23	61,06	65,00	65,00	65,00
1743	17,00	18,50	20,40	22,50	24,50	26,92	29,40	33,65	51,00	59,90	62,00	64,00	64,00
1491	17,25	18,43	20,68	23,00	25,30	27,62	30,20	34,60	40,28	54,53	55,75	56,75	56,75
1260	18,10	19,07	21,25	23,50	26,00	29,50	33,00	37,50	42,50	47,00	51,00	51,00	51,00
1100	19,25	20,25	22,45	25,02	28,00	32,52	35,75	39,25	42,00	42,00	42,00	42,00	41,50
1000	19,60	20,67	22,70	25,75	28,00	32,75	35,75	36,75	38,00	38,00	38,00	38,00	38,00
861	19,72	21,72	22,95	25,25	27,25	30,00	30,50	30,50	30,50	30,50	30,50	30,50	30,50

Table 16: SMOKE LIMITER STAGE 1

The % difference chart shows that the axes are slightly changed. The Y axis (RPM) is very slightly altered and can probably be left as the 130 one. The X axis is altered at the upper end to allow for higher Mass Air Flow rate.

Overall you can see that the 150 has an increased I.Q at low rpm and low Mass Air Flow rate, but not at high rpm and low Mass Air Flow rate. The main change is to have higher I.Q at middle to high rpm when the Mass Air flow is high. (Last two columns)

- On the 130 map the maximum I.Q is limited to 59 mg/stroke by the MAF.
- On the 150 map the maximum I.Q is limited to 65 mg/stroke.
- the I.Q difference between 130 and 150 is only 6 mg/stroke.

3.8. SOI limiter

Symbol: SOI limiter (temperature) [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

Addition 2 Viewtype Easy view

X: Temperature Y: Engine speed (rpm) Z: SOI limit (degrees)

RPM \ °C	-25,00	-10,00	0,00	4,00	10,00	20,00	35,00	45,00	60,20	75,00	79,00
5000	27,96	27,96	27,96	27,96	27,96	27,96	27,96	27,96	27,96	27,96	27,96
4250	23,46	23,46	23,46	23,46	23,46	23,46	23,46	23,46	23,46	23,46	23,46
4000	22,48	22,48	22,48	22,48	22,48	22,48	22,48	22,48	22,48	22,48	22,48
3500	19,48	19,48	19,48	19,48	19,48	19,48	19,48	19,48	19,48	19,48	19,48
3000	17,46	17,46	17,46	17,46	17,46	17,46	17,46	17,46	17,46	17,46	17,46
2750	16,48	16,48	16,48	16,48	16,48	16,48	16,48	16,48	16,48	16,48	16,48
2500	15,96	15,96	15,96	15,96	15,96	15,96	15,96	15,96	15,96	15,96	15,96
2250	14,98	14,98	14,98	14,98	14,98	14,98	14,98	14,98	14,98	14,98	14,98
2000	14,46	14,46	14,46	14,46	14,46	14,46	14,46	14,46	14,46	14,46	14,46
1750	13,48	13,48	13,48	13,48	13,48	13,48	13,48	13,48	13,48	13,48	13,48
1500	13,01	13,01	13,01	13,01	13,01	13,01	13,01	13,01	13,01	13,01	13,01
1250	18,00	16,01	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00
1000	18,00	16,01	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00
400	18,00	16,01	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00

Undo changes Read Save Close

Table 17: SOI limiter ORIGINAL

Symbol: SOI limiter (temperature) [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V12020...

Addition 2 Viewtype Easy view

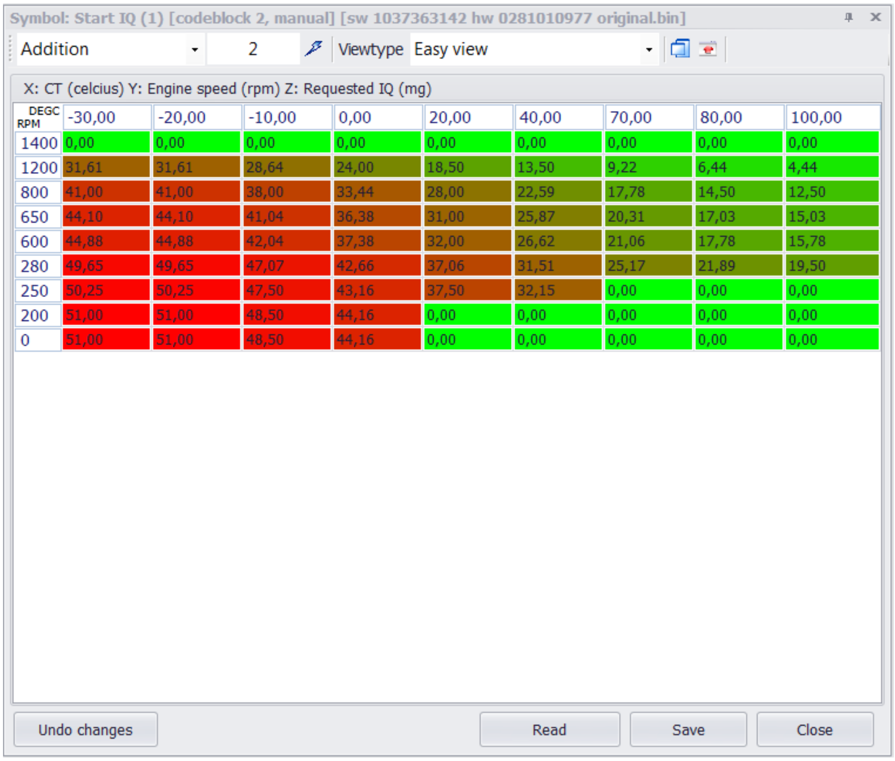
X: Temperature Y: Engine speed (rpm) Z: SOI limit (degrees)

RPM \ °C	-25,00	-10,00	0,00	4,00	10,00	20,00	35,00	45,00	60,20	75,00	79,00
5000	27,96	27,96	27,96	27,96	27,96	27,96	27,96	27,96	27,96	27,96	27,96
4250	23,46	23,46	23,46	23,46	23,46	23,46	23,46	23,46	23,46	23,46	23,46
4000	22,48	22,48	22,48	22,48	22,48	22,48	22,48	22,48	22,48	22,48	22,48
3500	19,48	19,48	19,48	19,48	19,48	19,48	19,48	19,48	19,48	19,48	19,48
3000	17,46	17,46	17,46	17,46	17,46	17,46	17,46	17,46	17,46	17,46	17,46
2750	16,48	16,48	16,48	16,48	16,48	16,48	16,48	16,48	16,48	16,48	16,48
2500	15,96	15,96	15,96	15,96	15,96	15,96	15,96	15,96	15,96	15,96	15,96
2250	14,98	14,98	14,98	14,98	14,98	14,98	14,98	14,98	14,98	14,98	14,98
2000	14,46	14,46	14,46	14,46	14,46	14,46	14,46	14,46	14,46	14,46	14,46
1750	13,48	13,48	13,48	13,48	13,48	13,48	13,48	13,48	13,48	13,48	13,48
1500	13,01	13,01	13,01	13,01	13,01	13,01	13,01	13,01	13,01	13,01	13,01
1250	18,00	16,01	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00
1000	18,00	16,01	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00
400	18,00	16,01	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00

Undo changes Read Save Close

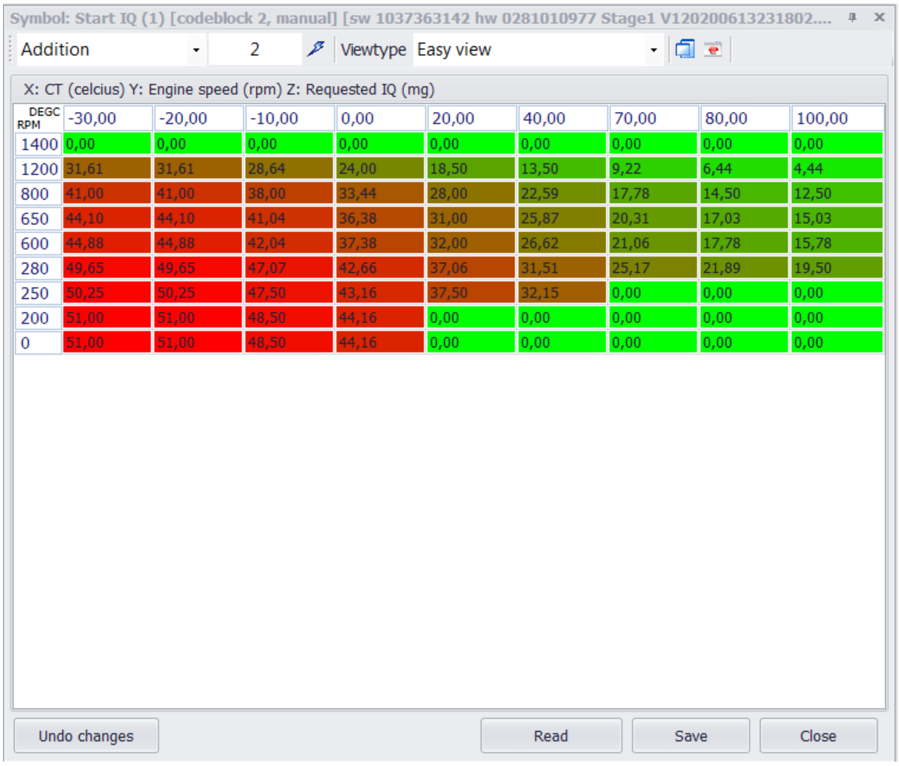
Table 18: SOI limiter STAGE 1

3.9. Start IQ 1



DEGC / RPM	-30,00	-20,00	-10,00	0,00	20,00	40,00	70,00	80,00	100,00
1400	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1200	31,61	31,61	28,64	24,00	18,50	13,50	9,22	6,44	4,44
800	41,00	41,00	38,00	33,44	28,00	22,59	17,78	14,50	12,50
650	44,10	44,10	41,04	36,38	31,00	25,87	20,31	17,03	15,03
600	44,88	44,88	42,04	37,38	32,00	26,62	21,06	17,78	15,78
280	49,65	49,65	47,07	42,66	37,06	31,51	25,17	21,89	19,50
250	50,25	50,25	47,50	43,16	37,50	32,15	0,00	0,00	0,00
200	51,00	51,00	48,50	44,16	0,00	0,00	0,00	0,00	0,00
0	51,00	51,00	48,50	44,16	0,00	0,00	0,00	0,00	0,00

Table 19: SOI limiter ORIGINAL



DEGC / RPM	-30,00	-20,00	-10,00	0,00	20,00	40,00	70,00	80,00	100,00
1400	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1200	31,61	31,61	28,64	24,00	18,50	13,50	9,22	6,44	4,44
800	41,00	41,00	38,00	33,44	28,00	22,59	17,78	14,50	12,50
650	44,10	44,10	41,04	36,38	31,00	25,87	20,31	17,03	15,03
600	44,88	44,88	42,04	37,38	32,00	26,62	21,06	17,78	15,78
280	49,65	49,65	47,07	42,66	37,06	31,51	25,17	21,89	19,50
250	50,25	50,25	47,50	43,16	37,50	32,15	0,00	0,00	0,00
200	51,00	51,00	48,50	44,16	0,00	0,00	0,00	0,00	0,00
0	51,00	51,00	48,50	44,16	0,00	0,00	0,00	0,00	0,00

Table 20: SOI limiter STAGE 1

4. Turbocharger Maps

The next area for improvement is the air supply. (Turbocharger)

The Turbocharger consists of three maps:

- A desired turbocharger pressure map
- A turbocharger control valve map.
- A turbocharger pressure limiting map
- A turbocharger Single Value Pressure Limiter.

4.1. TURBO Target boost

- First row (X) is Injection Quantity (I.Q) (0 - 5000). Multiply by 0.01 to see it as mg/stroke. (5000 x 0.01 = 50 mg/stroke)
- First column (Y) is engine RPM. (0 - 4746)
- Chart data (Z) is required boost pressure. (0 - 2350 mbars)

Symbol: Boost target map [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

Addition 2 Viewtype Easy view

X: IQ (mg/stroke) Y: Engine speed (rpm) Z: Boost target (mbar)

MG/ST RPM	0,00	5,00	10,00	15,00	20,00	25,00	30,00	35,00	45,00	50,00
4746	1200	1225	1325	1429	1530	1655	1775	1900	1950	1950
4494	1149	1225	1328	1445	1540	1645	1780	1965	2070	2140
4250	1120	1225	1330	1445	1540	1650	1780	1980	2170	2260
3990	1100	1225	1330	1445	1540	1650	1780	1970	2215	2320
3750	1080	1225	1330	1435	1530	1645	1780	1970	2235	2350
3500	1060	1225	1320	1425	1525	1645	1775	1965	2235	2350
2499	1021	1180	1260	1360	1460	1585	1725	1925	2210	2350
2247	1012	1160	1240	1340	1440	1565	1705	1915	2205	2350
2000	1002	1140	1220	1320	1415	1535	1685	1880	2155	2325
1900	1002	1130	1210	1310	1395	1515	1660	1860	2115	2300
1750	1002	1115	1195	1280	1365	1475	1610	1800	2050	2250
1500	1002	1090	1155	1225	1305	1380	1495	1650	1900	2000
1260	1002	1060	1119	1171	1225	1281	1373	1500	1750	1750
1008	1002	1058	1106	1153	1199	1265	1350	1350	1350	1350
21	1002	1052	1102	1158	1195	1265	1350	1350	1350	1350
0	198	198	198	198	198	198	198	198	198	198

Undo changes Read Save Close

Table 21: TURBO Target boost ORIGINAL

Symbol: Boost target map [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V120200613231...

Addition | 2 | Viewtype Easy view

X: IQ (mg/stroke) Y: Engine speed (rpm) Z: Boost target (mbar)

MG/ST RPM	0,00	5,00	10,00	15,00	20,00	25,00	30,00	35,00	45,00	50,00
4746	1200	1225	1325	1429	1530	1655	1775	1900	1950	1950
4494	1149	1225	1328	1445	1540	1645	1780	2065	2170	2240
4250	1120	1225	1330	1445	1540	1650	1780	2230	2270	2360
3990	1100	1225	1330	1445	1540	1650	2080	2320	2450	2450
3750	1080	1225	1330	1435	1530	1645	2080	2320	2450	2450
3500	1060	1225	1320	1425	1525	1645	2075	2315	2450	2450
2499	1021	1180	1260	1360	1460	1585	2025	2275	2450	2450
2247	1012	1160	1240	1340	1440	1565	2005	2265	2450	2450
2000	1002	1140	1220	1320	1415	1535	1985	2230	2450	2450
1900	1002	1130	1210	1310	1395	1515	1960	2210	2450	2450
1750	1002	1115	1195	1280	1365	1475	1910	2150	2400	2400
1500	1002	1090	1155	1225	1305	1380	1495	1750	2050	2150
1260	1002	1060	1119	1171	1225	1281	1373	1500	1750	1750
1008	1002	1058	1106	1153	1199	1265	1350	1350	1350	1350
21	1002	1052	1102	1158	1195	1265	1350	1350	1350	1350
0	198	198	198	198	198	198	198	198	198	198

Undo changes | Read | Save | Close

Table 22: TURBO Target boost STAGE 1

The chart data is a little different at middle RPM & I.Q. The main difference is the last column where boost is allowed to rise.

Maximum boost of 2350 mbar for the 130 is raised to a maximum of 2450 mbar in the 150. Most of the boost changes occur above 1500 rpm as this is when the turbocharger starts to spool up.

4.2. BOOST LIMITING MAP

Turbocharger boost is limited by an atmospheric air pressure map and by a single maximum Single Value Boost Limit (SVBL).

- First row(X) is engine rpm. (0 - 4494)
- First column (Y) is Atmospheric Air Pressure.(600 - 1100 mbars)

This map is designed to limit boost when the air pressure is less than ideal. (Ideal is taken as 1000 mbars.) At low air pressure, the air is thinner so the turbocharger cannot compress enough air and will spin too fast as it tries. This will damage the turbocharger bearings.

Symbol: Boost limit map [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

Addition 2 Viewtype Easy view

X: Engine speed (rpm) Y: Atmospheric pressure (mbar) Z: Maximum boost pressure (mbar)

MBAR \ RPM	1490	1743	1911	2247	2499	3003	3507	3990	4242	4494
1100	2000	2300	2350	2400	2400	2400	2400	2350	2275	2175
980	2000	2300	2350	2400	2400	2400	2400	2350	2275	2175
950	1950	2250	2300	2350	2350	2350	2350	2300	2225	2125
900	1900	2200	2250	2275	2275	2275	2275	2200	2100	2000
850	1850	2150	2200	2225	2240	2240	2225	2085	2000	1900
800	1800	2100	2150	2185	2200	2200	2150	2005	1905	1805
750	1750	2050	2100	2125	2125	2125	2075	1910	1815	1715
700	1700	2000	2050	2075	2075	2075	2025	1875	1775	1675
650	1650	1950	2000	2025	2025	2025	1975	1825	1725	1625
600	1600	1900	1950	1975	1975	1975	1925	1750	1650	1550

Undo changes Read Save Close

Table 23: BOOST LIMITING MAP ORIGINAL

Symbol: Boost limit map [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V1202006132318...

Addition 2 Viewtype Easy view

X: Engine speed (rpm) Y: Atmospheric pressure (mbar) Z: Maximum boost pressure (mbar)

MBAR \ RPM	1490	1743	1911	2247	2499	3003	3507	3990	4242	4494
1100	2000	2450	2600	2600	2600	2600	2600	2600	2600	2275
980	2000	2450	2600	2600	2600	2600	2600	2600	2600	2275
950	1950	2400	2600	2600	2600	2600	2600	2600	2600	2225
900	1900	2350	2600	2600	2600	2600	2600	2600	2600	2100
850	1850	2300	2600	2600	2600	2600	2600	2600	2600	1900
800	1800	2250	2600	2600	2600	2600	2600	2600	2600	1805
750	1750	2050	2450	2475	2475	2475	2425	2260	2165	1715
700	1700	2000	2050	2075	2075	2075	2025	1875	1775	1675
650	1650	1950	2000	2025	2025	2025	1975	1825	1725	1625
600	1600	1900	1950	1975	1975	1975	1925	1750	1650	1550

Undo changes Read Save Close

Table 24: BOOST LIMITING MAP STAGE 1

The % difference chart shows that the STAGE 1 allows slightly higher (up to 6%) boost at middle to high rpm, so the STAGE 1 is slightly less turbo limiting. So the 20 BHP increase from 130 to 150 bhp is mainly achieved by increasing the Injected Quantity slightly and increasing the turbocharger boost slightly.

4.3. SVBL boost limiter

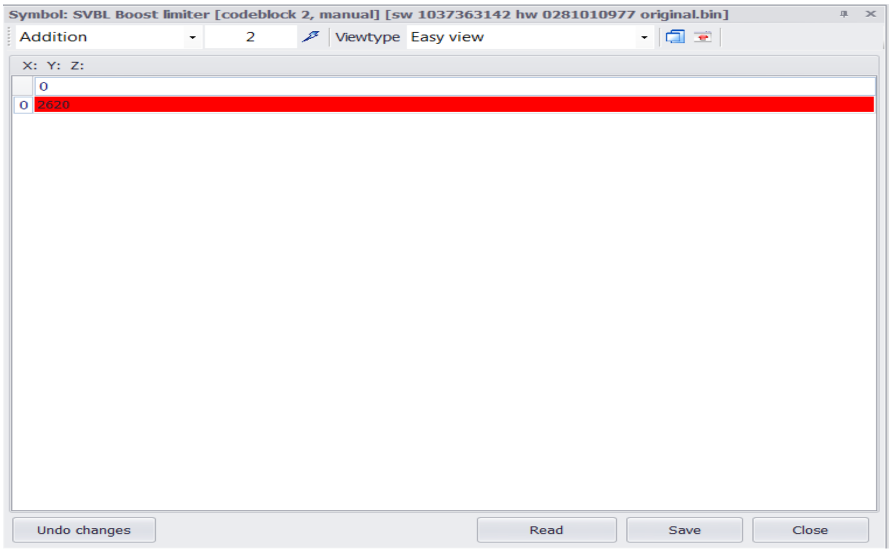


Table 25: SVBL boost limiter ORIGINAL

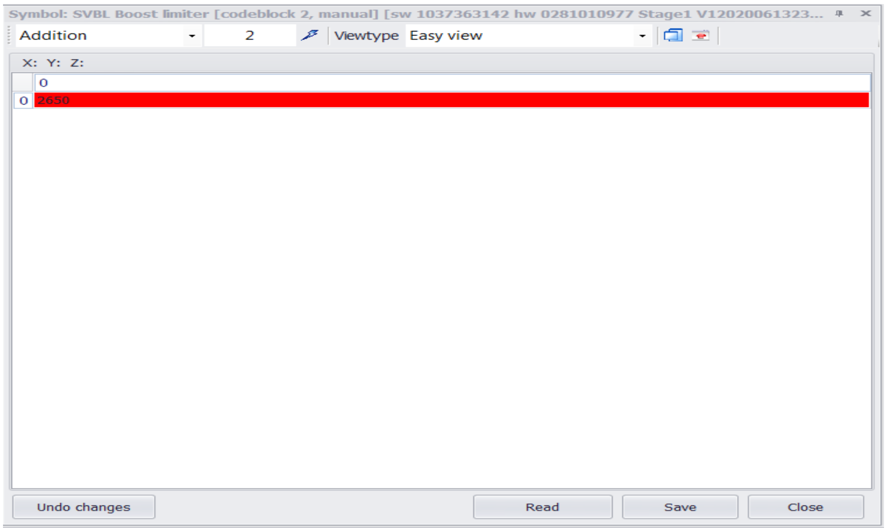


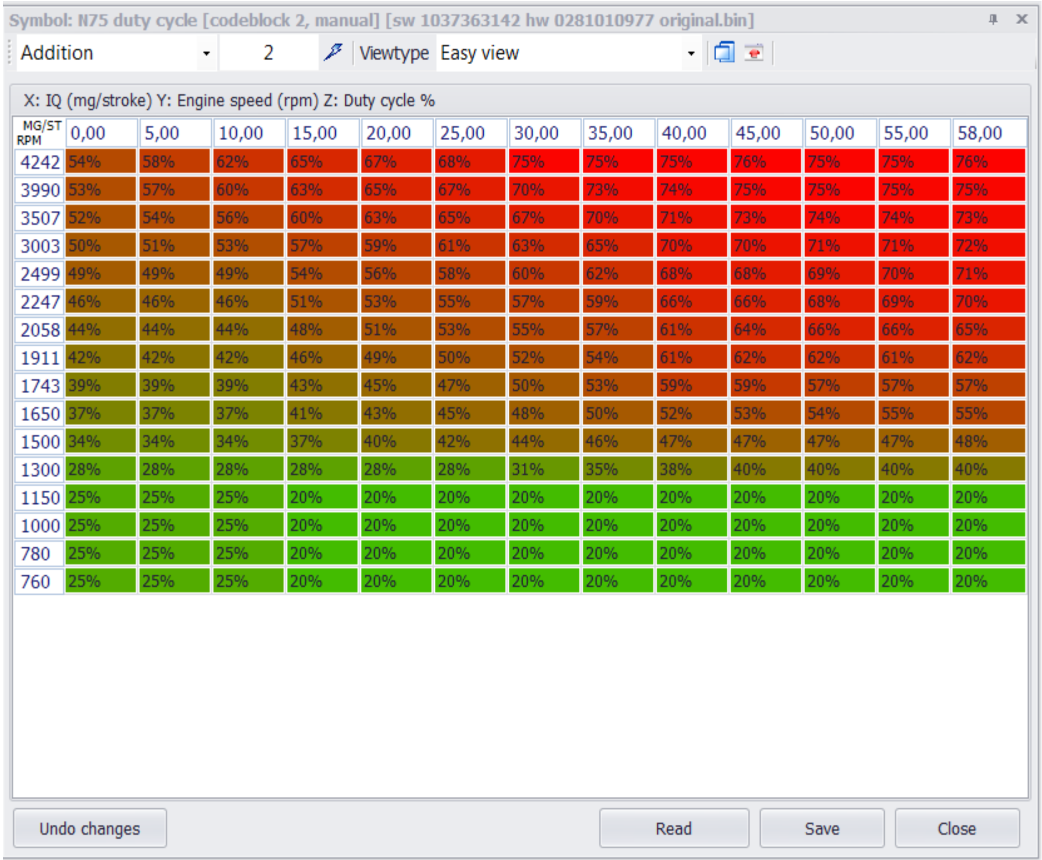
Table 26: SVBL boost limiter STAGE 1

4.4. TURBOCHARGER CONTROL VALVE MAP. (N75 % DUTY CYCLE)

This map controls the action of the turbocharger via the N75 solenoid and the turbocharger vacuum actuator.

- First row (X) is Injection Quantity (I.Q) (0 - 5800). Multiply by 0.01 to see it as mg/stroke. (5800 x 0.01 = 58 mg/stroke)
- First column (Y) is engine RPM. (0 - 4242)
- Chart data (Z) is N75 duty cycle. (0 - 8000). Multiply by 0.01 to see it as % duty cycle. (8000 x 0.01 = 80 %)

80% is turbo vanes positioned for maximum boost. Approximately 20% is turbo vanes positioned for zero boost.


Symbol: N75 duty cycle [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

Addition 2 Viewtype Easy view

X: IQ (mg/stroke) Y: Engine speed (rpm) Z: Duty cycle %

MG/ST RPM	0,00	5,00	10,00	15,00	20,00	25,00	30,00	35,00	40,00	45,00	50,00	55,00	58,00
4242	54%	58%	62%	65%	67%	68%	75%	75%	75%	76%	75%	75%	76%
3990	53%	57%	60%	63%	65%	67%	70%	73%	74%	75%	75%	75%	75%
3507	52%	54%	56%	60%	63%	65%	67%	70%	71%	73%	74%	74%	73%
3003	50%	51%	53%	57%	59%	61%	63%	65%	70%	70%	71%	71%	72%
2499	49%	49%	49%	54%	56%	58%	60%	62%	68%	68%	69%	70%	71%
2247	46%	46%	46%	51%	53%	55%	57%	59%	66%	66%	68%	69%	70%
2058	44%	44%	44%	48%	51%	53%	55%	57%	61%	64%	66%	66%	65%
1911	42%	42%	42%	46%	49%	50%	52%	54%	61%	62%	62%	61%	62%
1743	39%	39%	39%	43%	45%	47%	50%	53%	59%	59%	57%	57%	57%
1650	37%	37%	37%	41%	43%	45%	48%	50%	52%	53%	54%	55%	55%
1500	34%	34%	34%	37%	40%	42%	44%	46%	47%	47%	47%	47%	48%
1300	28%	28%	28%	28%	28%	28%	31%	35%	38%	40%	40%	40%	40%
1150	25%	25%	25%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
1000	25%	25%	25%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
780	25%	25%	25%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
760	25%	25%	25%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%

Undo changes Read Save Close

Table 27: (N75 % DUTY CYCLE) ORIGINAL

Symbol: N75 duty cycle [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V120200613231802.binaryba...

Addition 2 Viewtype Easy view

X: IQ (mg/stroke) Y: Engine speed (rpm) Z: Duty cycle %

MG/ST RPM	0,00	5,00	10,00	15,00	20,00	25,00	30,00	35,00	40,00	45,00	50,00	55,00	58,00
4242	54%	58%	62%	65%	67%	68%	75%	75%	75%	76%	75%	75%	76%
3990	53%	57%	60%	63%	65%	67%	70%	73%	74%	75%	75%	75%	75%
3507	52%	54%	56%	60%	63%	65%	67%	70%	71%	73%	74%	74%	73%
3003	50%	51%	53%	57%	59%	61%	63%	65%	70%	70%	71%	71%	72%
2499	49%	49%	49%	54%	56%	58%	60%	62%	68%	68%	69%	70%	71%
2247	46%	46%	46%	51%	53%	55%	57%	59%	66%	66%	68%	69%	70%
2058	44%	44%	44%	48%	51%	53%	55%	57%	61%	64%	66%	66%	65%
1911	42%	42%	42%	46%	49%	50%	52%	54%	61%	62%	62%	61%	62%
1743	39%	39%	39%	43%	45%	47%	50%	53%	59%	59%	57%	57%	57%
1650	37%	37%	37%	41%	43%	45%	48%	50%	52%	53%	54%	55%	55%
1500	34%	34%	34%	37%	40%	42%	44%	46%	47%	47%	47%	47%	48%
1300	28%	28%	28%	28%	28%	28%	31%	35%	38%	40%	40%	40%	40%
1150	25%	25%	25%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
1000	25%	25%	25%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
780	25%	25%	25%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
760	25%	25%	25%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%

Undo changes Read Save Close

Table 28: (N75 % DUTY CYCLE) STAGE 1

The % difference chart shows the axes are unchanged between the pd 130 and pd 150. There is little difference below 1500 RPM as the turbocharger is not working even though it is set for maximum boost (80%). At roughly 1500 rpm, exhaust pressure spools the turbocharger up to speed and boost increases.

For the 130 boost will head towards it's limit of 2350 mbars and on the 150 it will head towards it's limit of 2500 mbars. The trubocharger is already set for maximum boost so the job of the N75 Duty cycle is to change the vane angle in the turbocharger, to reduce boost. The % difference chart shows that the 150 reduces boost LESS tan the 130 and so the boost pressure is kept higher in the 150.

4.5. EGR map

The EGR (Exhaust Gas Recirculation) map determines the amount of fresh air allowed into the engine for a given injection amount and the engine speed when the EGR function is active. With the EGR system the remaining air is returned to the engine. Since this air is a pollutant and has a high temperature, we do not want this air in the engine according to the engine performance theory.

Symbol: EGR 01 [codeblock 2, manual] [sw 1037363142 hw 0281010977 original.bin]

Addition 2 Viewtype Easy view

X: IQ (mg/stroke) Y: Engine speed (rpm) Z: Mass Air Flow (mg/stroke)

MG/ST RPM	0,00	3,00	7,40	10,00	12,40	15,00	17,40	20,00	22,40	25,00	29,00	33,00	51,00
5355	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
3612	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
3423	348,30	406,70	430,00	480,00	535,00	600,00	650,00	690,00	727,00	760,00	788,00	850,00	850,00
2600	260,00	270,00	290,00	325,00	385,00	445,00	495,00	540,00	580,00	610,00	640,00	850,00	850,00
2247	250,00	250,00	270,00	310,00	370,00	425,00	475,00	515,00	555,00	585,00	615,00	850,00	850,00
1995	250,00	250,00	270,00	310,00	370,00	425,00	475,00	515,00	555,00	585,00	615,00	850,00	850,00
1743	250,00	250,00	270,00	310,00	370,00	425,00	475,00	515,00	555,00	585,00	615,00	850,00	850,00
1596	250,00	250,00	270,00	310,00	380,00	430,00	480,00	520,00	555,00	590,00	620,00	850,00	850,00
1491	250,00	250,00	270,00	310,00	390,00	440,00	490,00	530,00	565,00	600,00	630,00	850,00	850,00
1386	250,00	250,00	270,00	310,00	395,00	450,00	500,00	540,00	575,00	605,00	655,00	850,00	850,00
1239	250,00	250,00	270,00	310,00	395,00	450,00	515,00	545,00	585,00	615,00	850,00	850,00	850,00
1000	250,00	250,00	270,00	290,00	380,00	450,00	515,00	545,00	585,00	650,00	850,00	850,00	850,00
903	250,00	250,00	270,00	290,00	380,00	450,00	515,00	545,00	585,00	850,00	850,00	850,00	850,00
780	250,00	250,00	270,00	290,00	380,00	450,00	515,00	545,00	585,00	850,00	850,00	850,00	850,00
760	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
0	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00

Undo changes Read Save Close

Table 29: EGR map ORIGINAL

Symbol: EGR 01 [codeblock 2, manual] [sw 1037363142 hw 0281010977 Stage1 V120200613231802.binar...

Addition 2 Viewtype Easy view

X: IQ (mg/stroke) Y: Engine speed (rpm) Z: Mass Air Flow (mg/stroke)

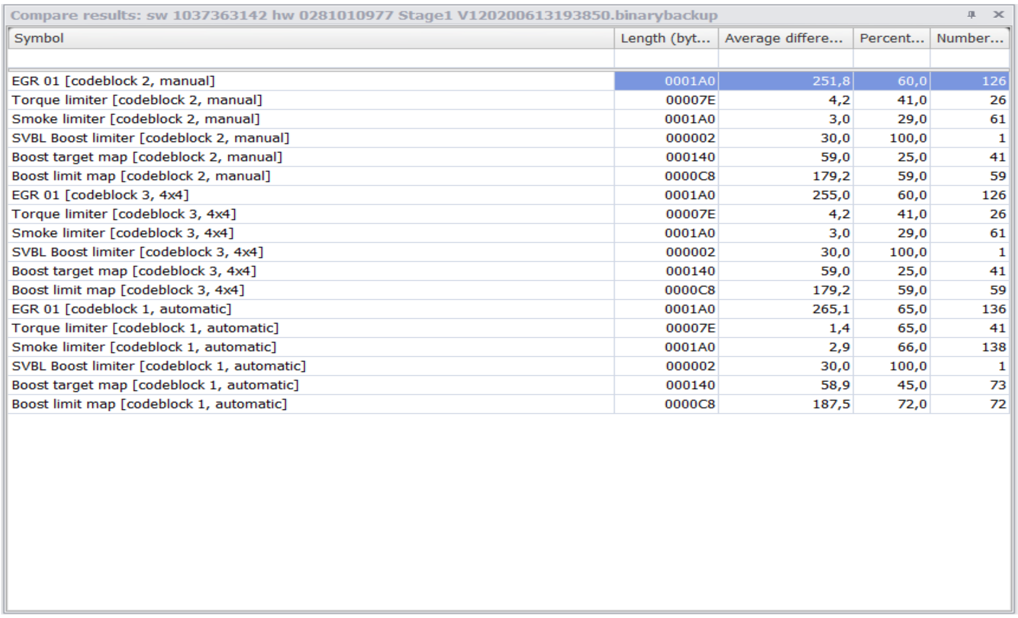
MG/ST RPM	0,00	3,00	7,40	10,00	12,40	15,00	17,40	20,00	22,40	25,00	29,00	33,00	51,00
5355	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
3612	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
3423	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
2600	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
2247	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
1995	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
1743	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
1596	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
1491	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
1386	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
1239	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
1000	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
903	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
780	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
760	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00
0	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00	850,00

Undo changes Read Save Close

Table 30: EGR map STAGE 1

5. Compare results

The software can generate a differences list between the original file and stage 1 as well and if we compare a stock file to a tuned file we can see only a few maps get edited normally.


Compare results: sw 1037363142 hw 0281010977 Stage1 V120200613193850.binarybackup

Symbol	Length (byt...	Average differe...	Percent...	Number...
EGR 01 [codeblock 2, manual]	0001A0	251,8	60,0	126
Torque limiter [codeblock 2, manual]	00007E	4,2	41,0	26
Smoke limiter [codeblock 2, manual]	0001A0	3,0	29,0	61
SVBL Boost limiter [codeblock 2, manual]	000002	30,0	100,0	1
Boost target map [codeblock 2, manual]	000140	59,0	25,0	41
Boost limit map [codeblock 2, manual]	0000C8	179,2	59,0	59
EGR 01 [codeblock 3, 4x4]	0001A0	255,0	60,0	126
Torque limiter [codeblock 3, 4x4]	00007E	4,2	41,0	26
Smoke limiter [codeblock 3, 4x4]	0001A0	3,0	29,0	61
SVBL Boost limiter [codeblock 3, 4x4]	000002	30,0	100,0	1
Boost target map [codeblock 3, 4x4]	000140	59,0	25,0	41
Boost limit map [codeblock 3, 4x4]	0000C8	179,2	59,0	59
EGR 01 [codeblock 1, automatic]	0001A0	265,1	65,0	136
Torque limiter [codeblock 1, automatic]	00007E	1,4	65,0	41
Smoke limiter [codeblock 1, automatic]	0001A0	2,9	66,0	138
SVBL Boost limiter [codeblock 1, automatic]	000002	30,0	100,0	1
Boost target map [codeblock 1, automatic]	000140	58,9	45,0	73
Boost limit map [codeblock 1, automatic]	0000C8	187,5	72,0	72

Table 31: Compare results

6. View performance

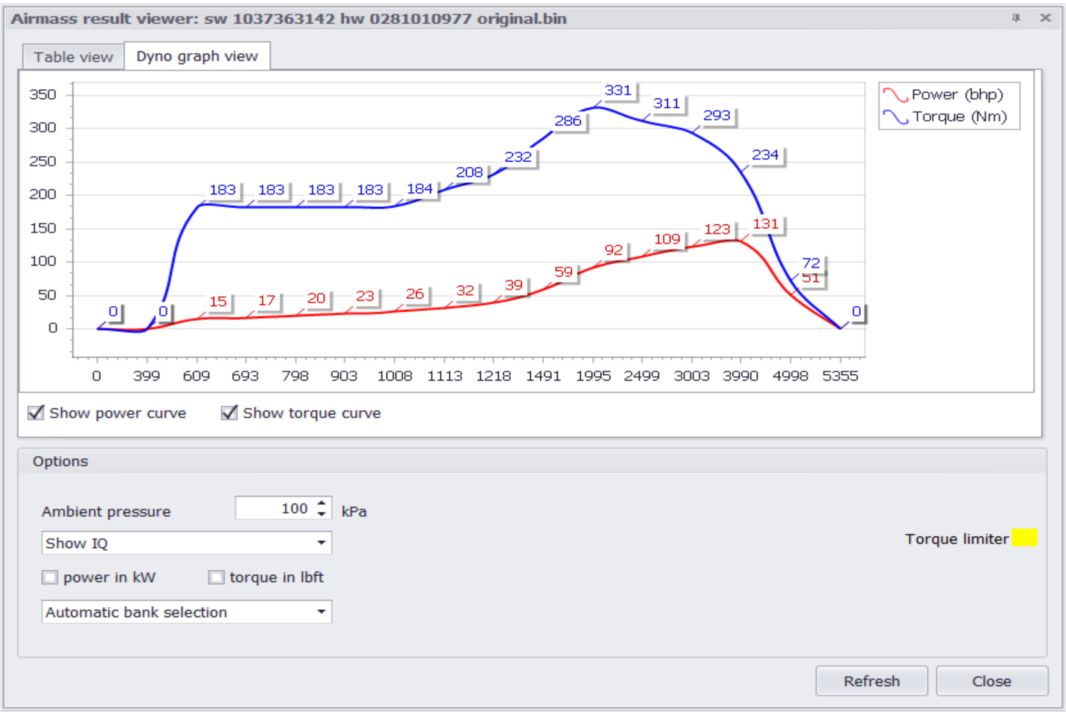


Table 32:Dyno graph view original

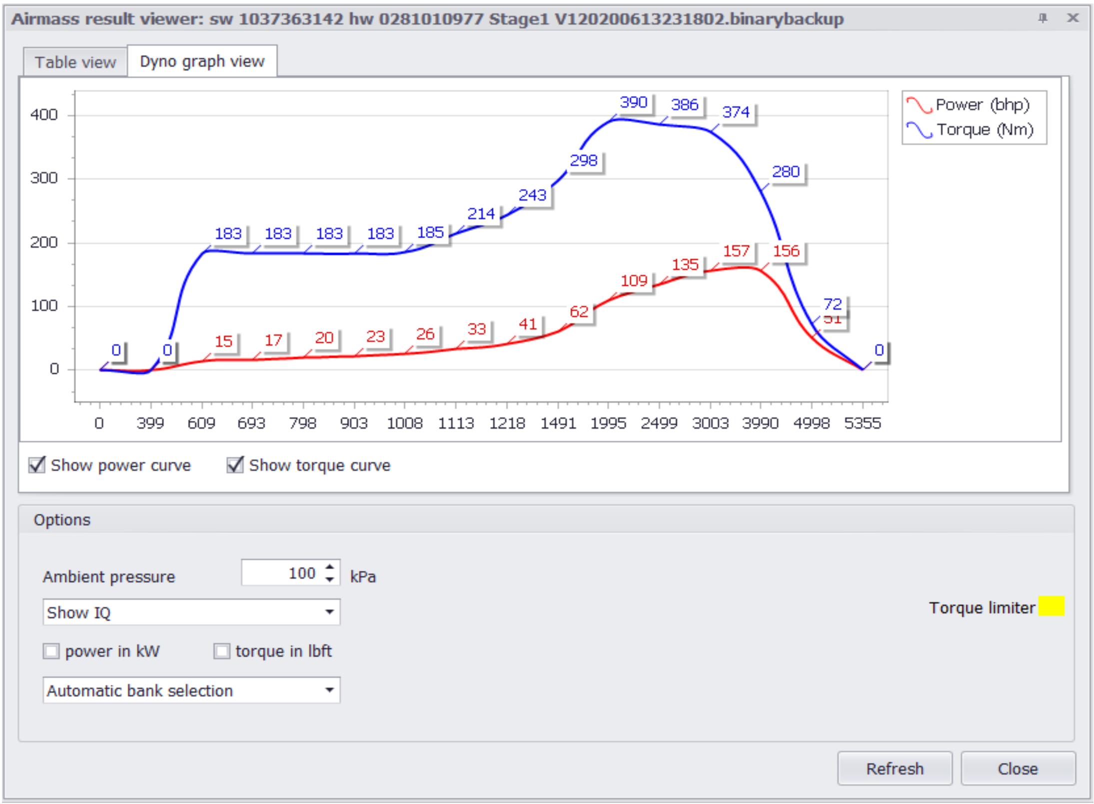


Table 33Dyno graph view stage 1

General conclusion

The process of calibrating or tuning an engine management system has ultimate goal of optimizing the engine's torque or fuel economy or emissions at every breakpoint of engine speed and loading defined in fuel and turbo tables .

The work that we did in this research is to obtain high engine performance and greater efficiency than the previous one, by determining the level of permissible changes that do not conflict with the rules of the environment

The development that diesel engine control has reached today has allowed it to open the way for changes in the level of increasing the power of engines, such as sports vehicles, and to solve some of the restrictions related to environmental laws.

Among some of the work difficulties that we faced is the difficulty of finding a workshop in order to do the experimental work, especially since the equipment in this field is very expensive, and more than all of this is the inability to move to the workplace due to the interruption of transport movement due to the conditions of the epidemic Covid 19, so we continued our work online after contacting a specialized center in the field From foreign country until the completion of the experiments, and due to the lack of time, it was not enough to complete all the experiments, but after reaching the achieved developments, we got a new performance that will enable us to adjust other parameters such as temperature and the ratio of (HC , CO , NO_x)

Finally We can say that we were able to achieve the previously established objectives, and from it the research remains subject to development in the future, and the obtained results will be a reference for many in the field of research .

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Annexes