Bosch Motorsport

ECU MS 15 Sport

Calibration Guide

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Content

1 Introduction

This is a guide explaining how to get started with calibration of the MS15 system. The following steps will be necessary and should follow in the below mentioned order. This guide does not replace the MS15 documentation but serves as a guide on how to get started with the application work. With this guide it should be possible to achieve a stable calibration, this guide does how ever not include all aspects of calibrating the MS15 system so there will be room for improvements and individual calibration.

IMPORTANT

This guide only contains suggestions and advices on how to make an engine calibration. It is not necessarily the best way or the only way to do it and it might not even fit your current hardware setup. Bosch Motorsport is not liable for any damages caused by following this guide, not to equipment or persons.

1.1 Basic information about the MS15 Sport calibration guide

EXCEL calibration help files

In some chapters there are tables and graphs showing recommendations for calibrations with a hyperlink below. All showed tables and graphs are based on excel.

The corresponding excel files are part of the installation CD. In case you want to use one of these excel files in order to individually adjust a calibration value/curve/map offline – not using Modas Sport – you can easily use the corresponding excel file. Just adjust the calibration data inside the excel file to your personal needs and copy the new data from the excel file to MODAS Sport.

All excel files are stored by the installation routine to folder “CalibrationHelp”.

MODAS Sport configurations

For most of the chapters you can find pre-defined configurations for MODAS Sport, containing the most important calibration and measurement values to perform the necessary calibration. You can individually change (add / remove) values or the way they are displayed inside the configuration.

It is recommended to use these configurations as a starting point for the different calibration actions that need to be performed.

The MODAS Sport configurations are stored by the installation routine to folder “MODASSport_Config”.

GREY MARKED parts in the calibration guide

Some parts of the calibration guide are written in grey color. These parts of the calibration guide are additional support informations that you normally do not have to take into consideration. The parts described in grey should be already well calibrated with the default calibration.

In case these parts anyway do not fit to your engine please follow the given advices to adjust them individually.

2 Naming convention

The naming convention in the MS15 is developed for ease of use and conclusiveness. In the MS15 system are two basic groups of values that you can access using the calibration tool MODAS Sport:

1) CALIBRATION labels and

2) Measurement variables.

The two types of values are distinguished by the case of the letter with which their names are written:

1) UPPER CASE for CALIBRATION LABELS and

2) lower case for measurement variables.

The naming structure of each value (CALIBRATION and measurement) is equal to the following naming conventions having three or four groups of letters separated by a '_' like this:

ffff_u(_dddd)_t

a) The '**ffff**' part is an abbreviation of the *function* which the value is a part of.

For example **fqsc** is the functions abbreviation for '**F**uel **Q**uantity **S**etpoint **C**alculation' or in plain English: *Injection quantity*.

This part of the name can be between four and six letters; normally it is four letters though.

b) The '**u**' represents the *unit* of the value, for example a '**t**' for **t**emperature or '**p**' for **p**ressure.

c) The following optional letters '**dddd**' is an extra *description* to distinguish values of the same function with the same unit from each other.

d) The't' is data *type*, for example 'w' for word (2 byte data length) or 'b' for bit.

Following there are some examples of both value types **CALIBRATION LABEL** and **measurement variable**:

<u>CALIBRATION LABELS:</u>

BIMI_PHI_BASE_MAP

BIMI = Begin of Main Injection

PHI = Physical value "Angle"

BASE = Description

MAP = Data type "Map"

This is the map containing the injection angles of the main injection depending on the engine load and engine speed.

LISC_N_BAS_CUR

LISC = Low idle set point calculation

N = Physical value “Engine speed”

BAS = Description

CUR = Data type “Curve”

This is the curve containing the low idle speed set point depending on engine temperature.

Measurement variables:

efts_t_w

efts = Evaluation Fuel Temperature Sensor

t = Physical value “Temperature”

w = Data type “word”

This is the fuel temperature in word format.

fpsc_p_w

fpsc = Fuel Pressure Setpoint Calculation

p = Physical value “Pressure”

w = Data type “word”

This is the calculated set point of the fuel pressure in the rail.

All Function abbreviations are listed in Appendix A of the MS15 documentation.

3 Before starting the engine

This chapter describes the necessary checks and calibration settings that have to be performed before the engine is fired the first time. Everything described in the following is done without injecting fuel at any time!

All actions described in the sub-chapters are mandatory to ensure a good and safe start of the engine, while fuel is injected for the first time controlled by the MS15 system.

3.1 Check electronic connections of the Harness

It is mandatory for all further actions that the electrical connections are correct. If there is a fault with an electrical connection this must be fixed before anything else is performed.

If there are doubts that the electrical connections are correct, the electrical resistance of each connection between ECU-pin and pin on the connector side to the component can be measured using a multimeter. Two pins are electrically connected if the measured resistance value is 0[Ohm]. In any other case the two pins are not connected.

The information which pin on ECU side of the harness is connected to which pin on the component side of it can be read in a harness sketch, which is provided by Bosch Motorsport.

Harness sketch MS15 Sport

Harness sketch MS15.1

Harness sketch MS15.2

3.1.1 Mandatory power supply wiring

The minimum wiring diagram gives an overview about the mandatory power supply connections (including wiring of main relais), which are necessary to supply the ECU and all actuators in the correct way.

From the following links please select the one that corresponds to your system in order to get more detailed information.

Minimum wiring diagram MS15 Sport

Minimum wiring diagram MS15.1

Minimum wiring diagram MS15.2

3.1.2 Correct connection order of the injectors

The injector plugs have to be connected in the correct order to guarantee the correct firing order. The following table helps you to find the correct connection.

The first row contains the firing order like it is labelled at the harness (in this order the SW controls the injection order).

The second row contains the real firing order using the mechanical cylinder numbers.

In the end the table shows the correct connections between harness plugs and injectors read in a column.

Example:

a) **4-Cylinder** with firing order: 1-3-4-2

Firing order based on harness-numbers	**1**	**2**	**3**	**4**	**(5)**	**(6)**
Firing order based on mechanical cylinder position	**1**	**3**	**4**	**2**	**-**	**-**

Connect cylinder plug of harness with number 1 to mechanical cylinder 1

Connect cylinder plug of harness with number 2 to mechanical cylinder 3

Connect cylinder plug of harness with number 3 to mechanical cylinder 4

Connect cylinder plug of harness with number 4 to mechanical cylinder 2

b) **6-Cylinder** with firing order: 1-5-3-6-2-4

Firing order based on harness-numbers	**1**	**2**	**3**	**4**	**5**	**6**
Firing order based on mechanical cylinder position	**1**	**5**	**3**	**6**	**2**	**4**

Connect cylinder plug of harness with number 1 to mechanical cylinder 1

Connect cylinder plug of harness with number 2 to mechanical cylinder 5

Connect cylinder plug of harness with number 3 to mechanical cylinder 3

Connect cylinder plug of harness with number 4 to mechanical cylinder 6

Connect cylinder plug of harness with number 5 to mechanical cylinder 2

Connect cylinder plug of harness with number 6 to mechanical cylinder 4

3.2 System overview

The MS15 system expects the mounting positions of sensors and actuators as shown in the following linked system overview pictures. Please select the link which corresponds to your engine design from the below standing table in order to get more detailed information.

System Overview Links			NUMBER OF TURBO CONTROL ACTUATORS		
			1	2	3
NUMBER OF CYLINDERS	4	MS15 Sport	Link01	n.a.	n.a.
		MS15.x* (Inline)		---	Link03
		MS15.x* (V-design – single rail pressure controler)	n.a.	n.a.	n.a.
	5	MS15 Sport	---	n.a.	n.a.
		MS15.x* (Inline)		---	---
		MS15.x *(V-design – single rail pressure controler)	n.a.	n.a.	n.a.
	6	MS15 Sport	Link07	n.a.	n.a.
		MS15.x* (Inline)		---	Link09
		MS15.x* (V-design – single rail pressure controler)	Link10	Link11	Link12
	8	MS15 Sport	n.a.	n.a.	n.a.
		MS15.x* (Inline)	n.a.	n.a.	n.a.
		MS15.x* (V-design – single rail pressure controler)	n.a.	Link13	n.a.

* MS15.1 or MS15.2 according to injection system of the engine.

3.3 Basic calibrations

Before the engine can be started for the first time some important calibration settings have to be done. The following sub-chapters contain the names of the concerned CALIBRATION LABELS and explain the action that has to be performed to achieve a good calibration.

3.3.1 Injection quantity

A diesel engine is basically controlled by the injected fuel quantity. The higher the injected fuel quantity, the more torque and power the engine has. A diesel engine has no throttle valve, so the engine always has the maximum amount of air in the cylinders and like this all fuel which comes to the cylinder will burn and speed up the engine. Because of this it is easily possible to over speed and damage the engine seriously in case the engine is not stopped by an external engine break function as backup – like on a dyno.

Additional to the external engine break from the dyno there are some possibilities in calibration to avoid over speeding.

The engine performance (fuel injection quantity) has to be influenced / limited by the calibration of several functions in order to avoid damage to the engine. All functions that have an influence on the injection quantity are calculated at the same time and depending on different conditions one of the function-outputs becomes valid.

Before starting the engine the first time it is very important to check and calibrate all functions correctly in order to avoid possible damages to the engine.

The target of the following sub chapters is to calibrate (limit) the different functions in a way, that it is possible on the one hand to start the engine and to reach low idle control, but on the other hand – and that is even more important - to avoid any uncontrolled over speeding or other damage of the engine! Let’s go...

3.3.1.1 Engine Start quantity (STRT)

Affected CALIBRATION LABELS:

STRT_N_OFF_CUR	Engine speed threshold to switch start to normal operation
STRT_N_ON_CW	Engine speed threshold to release start procedure
STRT_Q_MAP	Fuel quantity for start procedure

Corresponding Excel-data: Calibration_StartQuantity.xls

Corresponding MODAS-Worksheet: EngineStart.mxws

The engine has different states in which it is controlled by the MS15. One of the states is the “START”-state. During this state the engine speed is increased in order to reach the low idle speed.

STRT_N_ON_CW

To enter the start mode the engine speed has to be above the threshold STRT_N_ON_CW. The default calibration is 50[rpm], which is a good value.

Too small calibration: If the value is too low, the system could enter the start early mode due to small glitches and then tries to inject fuel although the engine is not running.

Too high calibration: If the calibration is too high, e.g. higher than the engine speed with which the starter is turning, the engine will never start, because no injections will be released.

STRT_N_OFF_CUR

The start mode is left when the engine speed (eess_n_avg_w) is greater than the coolant temperature (ects_t_w) dependant threshold.

The calibration of STRT_N_OFF_CUR has to be smaller than the low idle speed set point (LISC_N_BAS_CW), which also depends on the coolant temperature (ects_t_w).

Too small calibration: If the calibration is too small the low idle controller has to react too much to rev up the engine until it reaches the low idle set point, which will lead to an overshoot above the low idle set point and a longer time until the low idle set point is controlled.

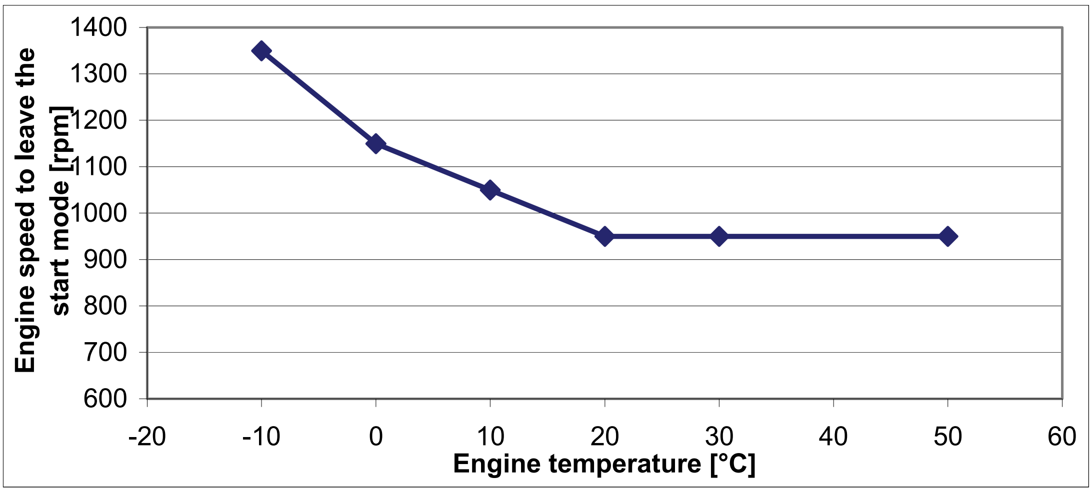
Too high calibration: If the calibration is too high, the engine is only controlled by start injection quantity coming from the map STRT_Q_MAP. If the cut out speed for example is higher than the low idle set point, the engine will rev up until the cut out speed. Afterwards the low idle controller will reduce the quantity to lower the engine speed until the low idle set point is reached, followed by undershoot of the engine. In this case the engine can stall. If the engine does not stall, the time until the low idle speed set point is reached will be longer.

Rough recommendation: (Low idle set point [rpm]) – (Start cut out speed [rpm]) = 50[rpm]

STRT_N_OFF_CUR

[°C]	-10	0	10	20	30	50
[rpm]	1350	1150	1050	950	950	950

X-axis - input: Engine temperature (ects_t_w)



Graphic 1 (Calibration_StartQuantity.xls)

STRT_Q_MAP

The map STRT_Q_MAP contains the calibration of the necessary injection quantity to rev up the engine for the first time after it is synchronized on starter speed.

To speed up the engine an open control mode is used, which injects fuel only based on engine speed (eess_n_avg_w) and coolant temperature (ects_t_w) coming from STRT_Q_MAP.

Calibration hints:

a) Depending on engine friction it may be necessary to increase injection quantity to lower revs, in order to speed up the engine sufficiently.

b) Due to increase of engine friction, injection quantity needs to be highly increased at low engine temperature.

c) The injection quantity around the start-mode cut-out speed STRT_N_OFF_CUR should slightly higher than the necessary friction quantity at low idle speed coming from LISC_N_BAS_CUR.

d) If the calibrated injection quantity is too small the engine will not speed up. There may be some visible smoke at the exhaust indicating that some kind of combustion takes place. It also might be possible to see a reaction to the injected fuel quantity in the cylinder pressure.

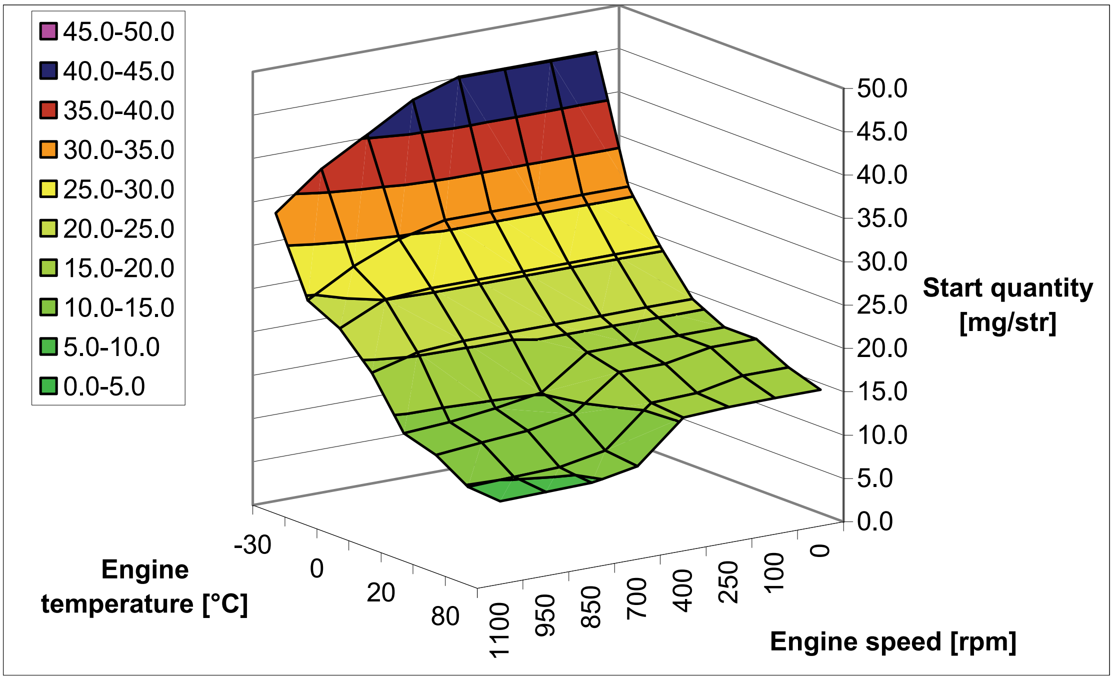
e) If the calibrated injection quantity is too high this will have an influence on the noise coming from the combustion, and the engine speed might rise too much above the low idle speed set point. The noise also is influences by the beginning of injection angle. Both – injection quantity and beginning of injection angle – always have to be adjusted depending on each other!

The following map contains a calibration proposal for a 4 cylinder 2.0l engine to give a rough estimation of the calibrated values. These values can be taken as default calibration to check the engine start. According to the above given hints the map has to be adjusted more precisely for the used engine:

STRT_Q_MAP
[mg/str]

[°C] \ [rpm]	0	100	250	400	700	850	950	1100
-30	45.1	45.1	45.1	45.1	43.4	40.3	37.4	33.2
-10	30.9	30.9	30.9	30.9	30.9	29.7	27.5	24.5
0	25.4	25.4	25.4	25.4	25.4	25.4	25.1	22.6
10	20.7	20.7	20.7	20.7	20.7	20.7	20.3	18.9
20	18.8	18.8	18.8	18.8	15.1	14.2	13.6	13.3
40	18.8	18.8	17.9	17.9	14.0	13.1	12.6	12.2
80	16.9	16.9	15.9	15.7	11.2	10.2	10.1	9.9
100	15.7	15.7	15.6	15.4	10.7	9.8	9.7	9.6

X-axis - input: Engine speed (eess_n_avg_w)
Y-axis - input: Engine temperature (ects_t_w)



Graphic 2 (Calibration_StartQuantity.xls)

3.3.1.2 Friction quantity (QFRI)

Affected CALIBRATION LABELS:

QFRI_Q_FRICTION_MAP	Friction fuel quantity map

Corresponding Excel-data: Calibration_FrictionQuantity.xls

Corresponding MODAS-Worksheet: FrictionQuantity.mxws

The friction quantity is the injection quantity the engine needs to run without load on different engine speeds. The friction quantity depends on the coolant temperature (ects_t_w) and of course on the engine speed (eess_n_avg_w).

The lower the coolant temperature ects_t_w the more injection quantity is necessary

The higher the engine speed eess_n_avg_w the more injection quantity is necessary

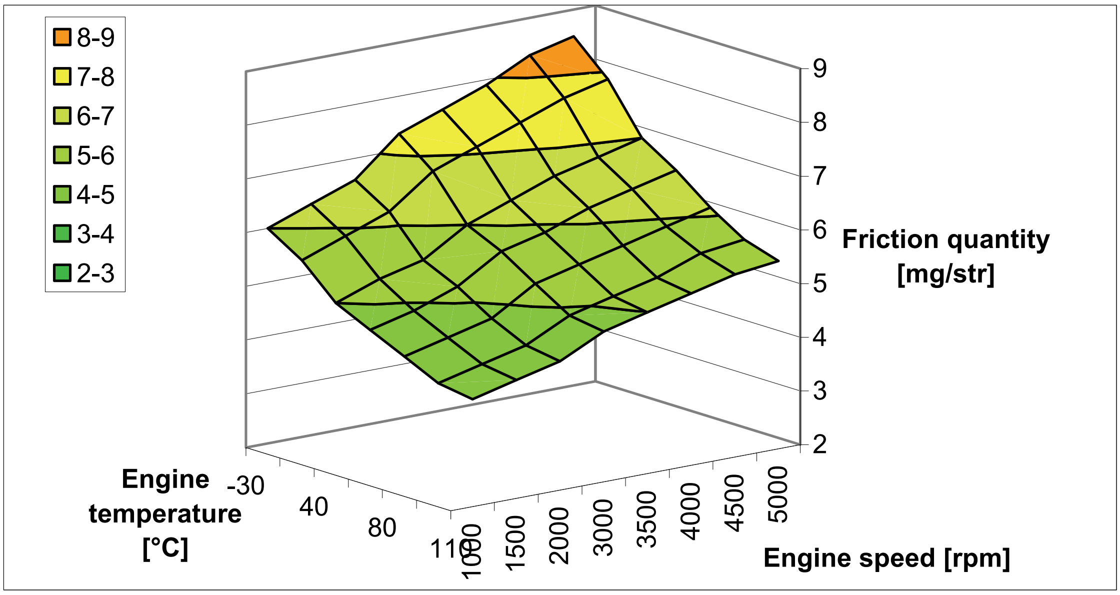
The friction quantity is calibrated in the map QFRI_Q_FRICTION_MAP.

At low idle of ~1000[rpm] the friction quantity of a warm engine is roughly about 5...7[mg/str].

QFRI_Q_FRICTION_MAP
[mg/str]

[°C] \ [rpm]	1000	1500	2000	3000	3500	4000	4500	5000
-30	6.0	6.3	6.6	7.3	7.6	7.9	8.3	8.5
0	5.6	5.9	6.2	6.8	7.1	7.4	7.7	7.9
40	5.0	5.3	5.5	6.0	6.3	6.6	6.8	7.0
60	4.7	4.9	5.2	5.7	5.9	6.2	6.4	6.6
80	4.4	4.6	4.8	5.3	5.5	5.7	5.9	6.1
100	4.1	4.3	4.5	4.9	5.1	5.3	5.6	5.7
110	4.0	4.2	4.4	4.8	5.0	5.2	5.4	5.5

X-axis - input: engine speed (eess_n_avg_w)
Y-axis input: engine temperature (ects_t_w)



Graphic 3 (Calibration_FrictionQuantity.xls)

As soon as the engine is running stable with low idle speed, the calibration of the friction quantity can be done easily using the low idle controller. The low idle speed setpoint (LISC_N_BAS_CUR) is set to the different engine speed set points of the map QFRI_Q_FRICTION_MAP. The injected fuel quantity that is calculated by the ECU to run at the desired low idle speed set point (lisc_n_w) is equal to the friction quantity for the present conditions of engine speed and engine temperature and can be calibrated in the map at the corresponding position.

3.3.1.3 Fuel limitation (FLIM)

Affected CALIBRATION LABELS:

FLIM_Q_TLIM_GMP	Fuel limit map for torque limit
FLIM_N_TLIM_ACO	Engine speed coordinates for torque limit maps
FLIM_T_TLIM_ACO	Temperature coordinates for torque limit maps
FLIM_Q_SMOKE_MAP	Smoke fuel quantity map

Corresponding Excel-data: Calibration_TorqueLimitation.xls

Calibration_SmokeLimitation.xls

Corresponding MODAS-Worksheet: Full_load_opti.mxws

The injected fuel quantity has to be limited in order to prevent the engine from

- Serious mechanical damage
- Pollution of smoke
- Over speeding

The torque limitation map FLIM_Q_TLIM_GMP is used to prevent the engine from mechanical damage. The input values of the torque limitation map are

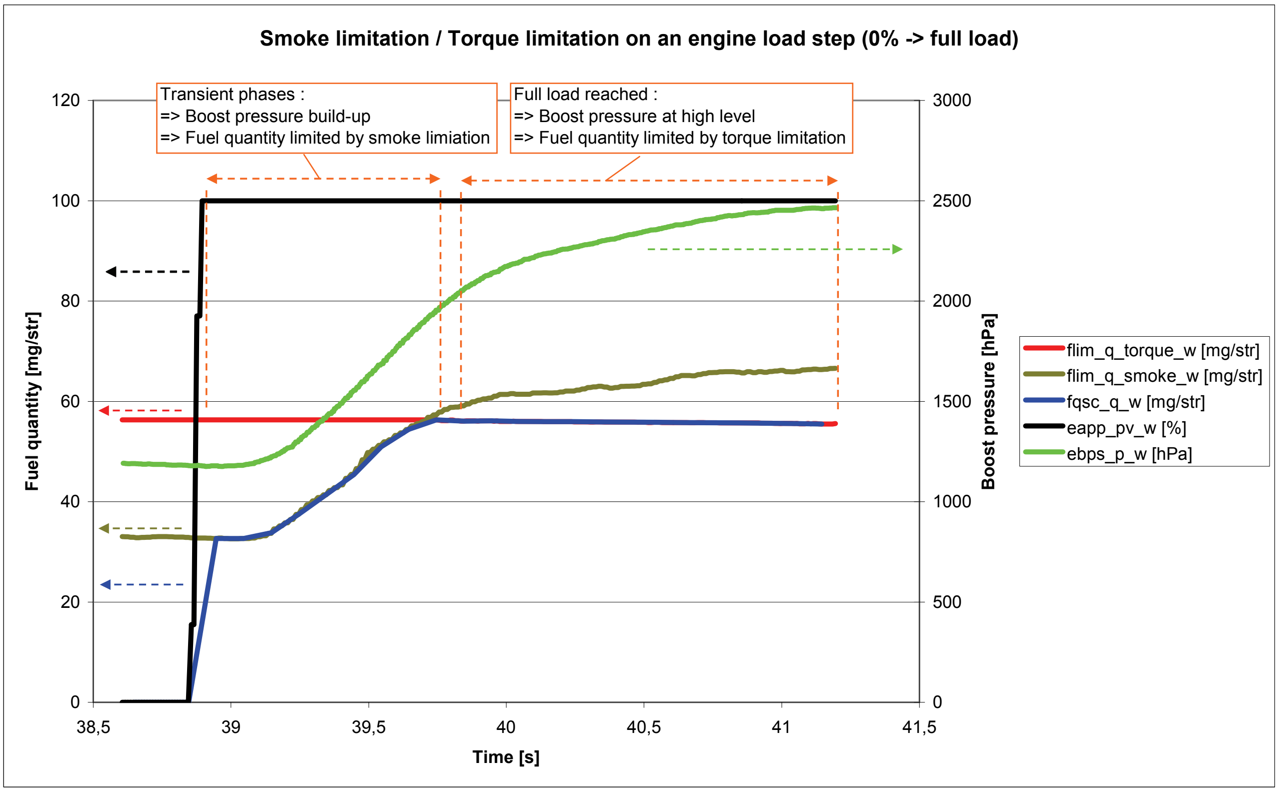
X-axis: engine speed (eess_n_avg_w)

Y-axis: boost temperature (ebts_t_w)

The smoke limitation map FLIM_Q_SMOKE_MAP is used to prevent the engine from smoke pollution especially in transient phases during boost pressure (i.e. engine air feeding) build-up. The input values of the smoke limitation map are

X-axis: engine speed (eess_n_avg_w)

Y-axis: calculated air mass flow (ciam_m_air_w)



Graphic 4

In chapter "High idle speed set point (HISP)" is a description for the base calibration of the high idle controller, which will control the fuel quantity depending on an engine speed limit in order to prevent the engine from over speeding.

TORQUE Limitation FLIM_Q_TLIM_GMP

The map **FLIM_Q_TLIM_GMP** should be limited to a small value at engine start up, for example 30[mg/str] in all points. The system is then limited to 30[mg/str] under all conditions.

Furhteron the torque limitation can be also used to prevent too high engine speeds during engine start up by simply setting the injection quantity limit to 0[mg/str] at revs e.g. >3000[rpm].

SMOKE Limitation FLIM_Q_SMOKE_MAP

To avoid smoke pollution especially in transient phases during boost pressure build-up, the injected fuel quantity can be limited by the map FLIM_Q_SMOKE_MAP depending on engine speed and calculated air mass flow.

For the first start of the engine this map should have no influence at all as it is dedicated to smoke pollution decrease during large transient phases. So it should be calibrated to a higher value than FLIM_Q_TLIM_GMP in all points.

If the engine needs more fuel than calibrated in FLIM_Q_TLIM_GMP to start it, the value needs to be increased accordingly. Make sure that the limit in map FLIM_Q_SMOKE_MAP is higher than in map FLIM_Q_TLIM_GMP until you have finished the torque calibration. Only in case of excessive smoke pollution the SMOKE-map can be used already to limit the injection quantity to avoid black smoke (probably necessary at low engine revs and high engine load).

Calibration proposal of FLIM_Q_TLIM_GMP for first engine start:

FLIM_Q_TLIM_GMP
[mg/str]

	0	500	1000	1750	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000	[rpm]
0	0,0	30,0	30,0	30,0	30,0	30,0	10,0	5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	
20	0,0	30,0	30,0	30,0	30,0	30,0	10,0	5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	
50	0,0	30,0	30,0	30,0	30,0	30,0	10,0	5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	
100	0,0	30,0	30,0	30,0	30,0	30,0	10,0	5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	
150	0,0	30,0	30,0	30,0	30,0	30,0	10,0	5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	

[°C]

Grouped axis setpoints (used also by the corresponding correction maps)
X-axis - input: engine speed (eess_n_avg_w)

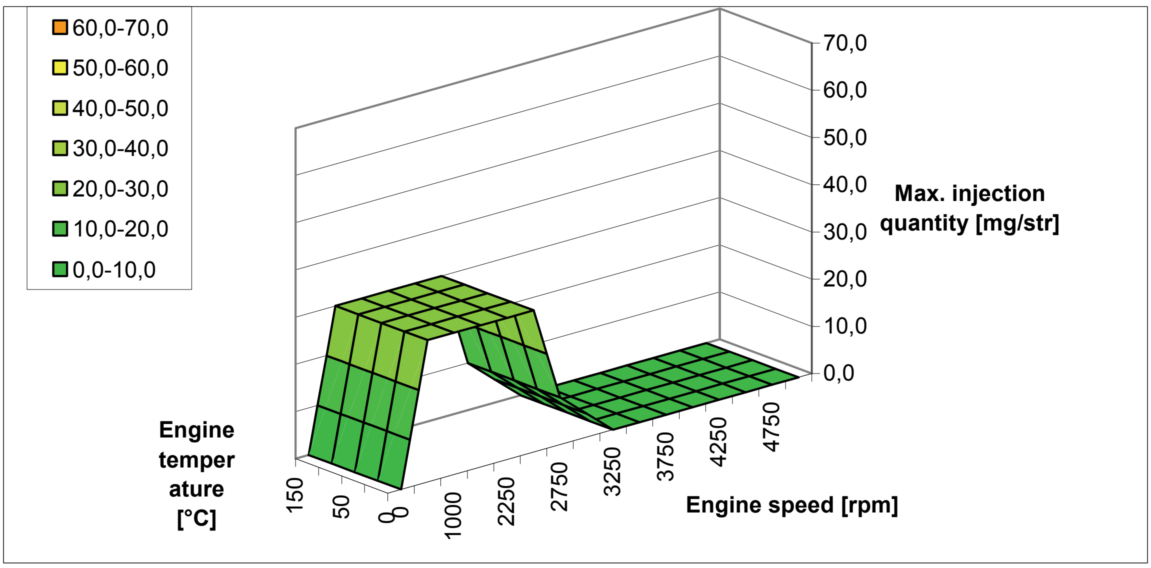
FLIM_N_TLIM_ACO

#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
[rpm]	0	500	1000	1750	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000

Y-axis - input: boost temperature (ebts_t_w)

FLIM_T_TLIM_ACO

#	1	2	3	4	5
[°C]	0	20	50	100	150



Graphic 5 (Calibration_TorqueLimitation.xls)

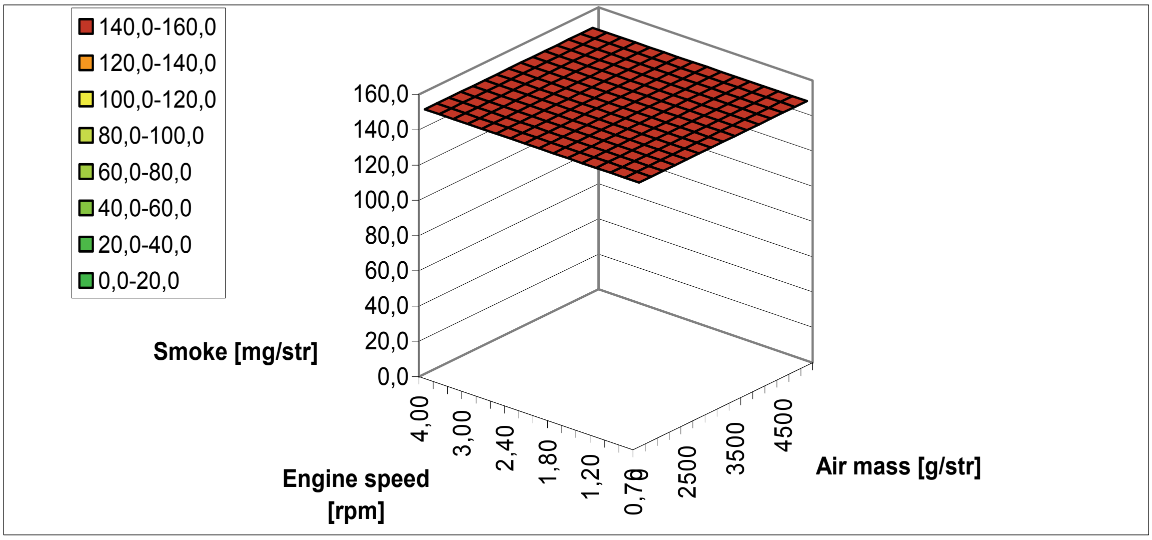
Calibration proposal of FLIM_Q_SMOKE_MAP for first engine start:

FLIM_Q_SMOKE_MAP
[mg/str]

	0	1000	1750	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000	[rpm]
0,70	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
0,85	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
1,00	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
1,20	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
1,40	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
1,60	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
1,80	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
2,00	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
2,20	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
2,40	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
2,60	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
2,80	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
3,00	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
3,25	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
3,50	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	
4,00	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	150,0	

[g/str]

X-axis - input: engine speed (eess_n_avg_w)
Y-axis - input: calculated air mass (ciam_m_air_w)



Graphic 6 (Calibration_SmokeLimitation.xls)

Basic hint: FLIM_Q_TLIM_GMP has to be calibrated by taking into consideration all the thermo mechanical requirements associated to your engine. By calibrating FLIM_Q_TLIM_GMP, the engine full load is defined. As long as the calibration of FLIM_Q_TLIM_GMP is performed the smoke limitation should be deactivated by using higher injection quantities in the map FLMI_Q_SMOKE_MAP than in FLIM_Q_TLIM_GMP. Only when the torque map is well calibrated the calibrated injection quantity in the smoke limitation map can be reduced in order to prevent the engine from black smoke in transient phases.

3.3.1.4 DRIVER DEMAND VIA PEDAL (DRIV)

Affected CALIBRATION LABELS:

DRIV_R_BASE_MAP	Driveability map

Corresponding Excel-data: Calibration_DriverDemandViaPedal.xls

Corresponding MODAS-Worksheet: Driveability.mxws

The sensitivity with which the engine reacts on the acceleration pedal depends mainly on the injection quantity that is equal to a certain position of the accelerator pedal. The more fuel is injected the more aggresiv the engine accelerates.

To achieve a comfortable behaviour of the engine to the acceleration pedal the injected fuel quantity has to be shaped via the calibration map DRIV_R_BASE_MAP.

The injected fuel quantity is the result of the multiplication of the ratio coming from DRIV_R_BASE_MAP (driv_r_map_w) and the present valid torque limited injection quantity coming from FLIM_Q_TLIM_GMP (flim_q_tlimraw_w).

To achieve a good calibration a third virtual map should be used containing the injection quantity which is the result of the multiplication of driv_r_map_w and flim_q_tlimraw_w. This injection quantity is equal to the real injected fuel quantity (as long as no other limitations are active).

The following excel sheet contains these three maps and can be used to pre-set the acceleration pedal sensitivity. As long as the shown graph, coming from the virtual map, is smooth and without any big steps, also the sensitivity of the pedal will be smooth. The overall shape of the graph must be adjusted engine individually and to the desires of the pilot(s).

The final calibration of the drivability map DRIV_R_BASE_MAP is only possible after the calibration of the torque limitation is finished. It must be done with the engine mounted in the car together based on the feedback of the pilot(s). In order to achieve also during calibration the most comfortable and sensitive response of the engine to the acceleration pedal the calibration of DRIV_R_BASE_MAP should be checked from time to time when the torque map is changed during the calibration process.

Hint: In order to adapt the engine sensitivity and power to different conditions (e.g. Circuit Racing: dry track, wet track, qualifying; or Ralley: tarmac track, gravel track, sand track) it is possible to influence the engine torque by different settings for the acceleration pedal response in a second step using different engine mappings. The selection of the engine mappings is done using a map selection switch. This is not available in MS15Sport but only in MS15.1 and MS15.2.

DRIV_R_BASE_MAP
[%]

	0	1000	2000	2500	3000	3500	4000	4500	5000	5500	[rpm]
0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	
10	100,0	24,9	16,4	13,8	12,7	11,6	10,8	10,3	10,2	10,0	
20	100,0	49,7	32,8	27,6	25,3	23,2	21,6	20,7	20,3	20,0	
30	100,0	74,6	49,1	41,5	38,0	34,8	32,4	31,0	30,5	30,0	
40	100,0	99,4	65,5	55,3	50,7	46,4	43,2	41,3	40,6	40,0	
50	100,0	100,0	81,9	69,1	63,4	58,0	54,0	51,7	50,8	50,0	
60	100,0	100,0	98,3	82,9	76,0	69,5	64,7	62,0	61,0	60,0	
70	100,0	100,0	100,0	96,7	88,7	81,1	75,5	72,3	71,1	70,0	
80	100,0	100,0	100,0	100,0	100,0	92,7	86,3	82,6	81,3	80,0	
90	100,0	100,0	100,0	100,0	100,0	100,0	97,1	93,0	91,4	90,0	
100	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	

[%]

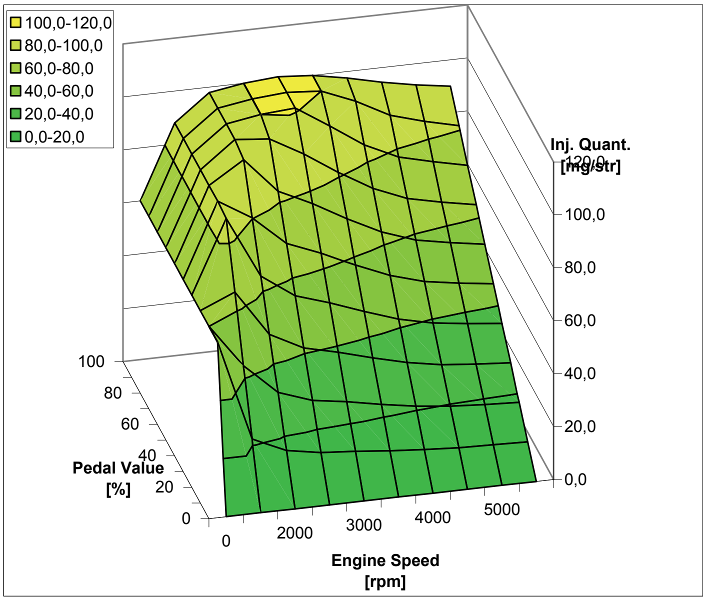
X-axis - input: engine speed (eess_n_avg_w)
Y-axis - input: acc. Pedal value (eapp_pv_w)

FLIM_Q_TLIM_GMP
[mg/str]

	0	1000	2000	2500	3000	3500	4000	4500	5000	5500	[rpm]
0	60,0	88,0	98,0	100,0	101,0	100,0	97,5	94,5	92,0	90,0	
20	60,0	88,0	98,0	100,0	101,0	100,0	97,5	94,5	92,0	90,0	
40	60,0	88,0	98,0	100,0	101,0	100,0	97,5	94,5	92,0	90,0	
60	60,0	88,0	98,0	100,0	101,0	100,0	97,5	94,5	92,0	90,0	
80	60,0	88,0	98,0	100,0	101,0	100,0	97,5	94,5	92,0	90,0	

[°C]

X-axis - input: engine speed (eess_n_avg_w)
Y-axis - input: engine temperature (ects_t_w)



Virtual Map
[mg/str] Real inj. quantity based on acc. pedal pos. (@ects_t_w = 80°C)

	0	1000	2000	2500	3000	3500	4000	4500	5000	5500	[rpm]
0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	
10	60,0	21,9	16,1	13,8	12,8	11,6	10,5	9,8	9,3	9,0	
20	60,0	43,7	32,1	27,6	25,6	23,2	21,0	19,5	18,7	18,0	
30	60,0	65,6	48,2	41,5	38,4	34,8	31,6	29,3	28,0	27,0	
40	60,0	87,5	64,2	55,3	51,2	46,4	42,1	39,0	37,4	36,0	
50	60,0	88,0	80,3	69,1	64,0	58,0	52,6	48,8	46,7	45,0	
60	60,0	88,0	96,3	82,9	76,8	69,5	63,1	58,6	56,1	54,0	
70	60,0	88,0	98,0	96,7	89,6	81,1	73,6	68,3	65,4	63,0	
80	60,0	88,0	98,0	100,0	101,0	92,7	84,2	78,1	74,8	72,0	
90	60,0	88,0	98,0	100,0	101,0	100,0	94,7	87,9	84,1	81,0	
100	60,0	88,0	98,0	100,0	101,0	100,0	97,5	94,5	92,0	90,0	

[%]

X-axis - input: engine speed (eess_n_avg_w)
Y-axis - input: acc. Pedal value (eapp_pv_w)

Graphic 7 (Calibration_DriverDemandViaPedal.xls)

3.3.1.5 Energizing time map (DINJ)

Affected CALIBRATION LABELS:

DINJ_DT_MI_MAP	Duration of main injection

Corresponding MODAS-Worksheet: Injector_MAP.mxws

The calculated injection quantity [mg/str] (fqsc_q_w) is internally converted to a temperature corrected injection volume [mm³/str] (dinj_vol_micorr_w).

The map DINJ_DT_MI_MAP contains the necessary energizing time for the injectors depending on rail pressure (efps_p_w) and temperature corrected injection volume (dinj_vol_micorr_w).

The map DINJ_DT_MI_MAP must be calibrated with correct injector depending energizing times in order to inject the calculated injection quantity as precise as possible.

The injector data to do a good calibration must be provided by the injector manufacturer.

Hint: In case the injector type is changed during the project the energizing time map needs to be updated as well with the corresponding data provided by the injector supplier. If this is not done the complete engine calibration is no longer correct and the engine can be damaged by not precise injection timings.

Hint for additional fine tuning ("nice to have" – not mandatory): For a better calibration later in the project when the engine is running stable at all points, but before the final calibration is done, the data provided by the manufacturer should be corrected using a fuel scale or flow meter on a dyno by tuning the energizing time at each possible point of the map DINJ_DT_MI_MAP as long until the fuel metering unit is equal with the Y-axis set point (= corrected injection volume dinj_vol_micorr_w).

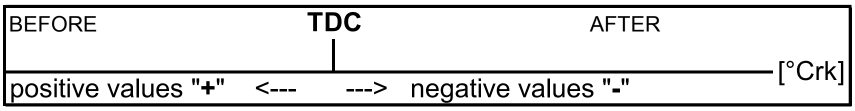
3.3.2 Begin of injection angle (BIMI)

The beginning of injection angle determines the angle before TDC (Top Dead Center) of the related cylinder at which an injection starts. The shape of the cylinder pressure curve is mainly influenced by this calibration (together with the injection fuel quantity).

The beginning of injection angle calibration has to be done very carefully, because on the one hand the engine can be easily damaged by using too big angles (early injection). On the other hand also the turbo charger can be damaged by calibrating too small angles (late injection), which will cause too high exhaust gas temperatures and poor performance of the engine.

To get the best possible engine performance it is mandatory to achieve the best possible combustion. For a good combustion of course the perfect relation between injected fuel quantity and available air mass inside the combustion chamber is mandatory. But only having the correct relation will not be sufficient. Even more important is having the correct injection timing, which is calibrated with the beginning of injection angle (using the function “Begin of Injection: Main Injection – (BIMI)”).

The beginning of injection angle is calibrated relative to TDC. **Positive** values are used to calibrate the angle at which the injection starts **before** TDC (ATTENTION: logic for positive and negative angles has the opposite sense compared to the sense of the calibration for the angle between TDC of cylinder 1 and next crankshaft gap for synchronization (see chapter “Basic settings for engine speed evaluation and synchronization”)).



The most important information to calibrate the beginning of injection angle correctly is a cylinder pressure indication! The cylinder pressure indication system is a stand-alone system and for this it is not part of the MS15 system provided by Bosch. If recommendations for a cylinder pressure system are needed, please contact Bosch Motorsport for further information.

Summary of basic information:

- The correct calibration for the beginning of injection angle is one of the most important things. A good calibration will make the engine powerful, economic and reliable.
- In case the injection angle is calibrated too early (big values) this will cause too high / early cylinder peak pressures, which can damage/crack the piston!
- In case the injection angle is calibrated too late (small values) this will cause very high exhaust gas temperatures, which may damage the turbo-charger!

3.3.2.1 Engine start beginning of injection angle

Affected CALIBRATION LABELS:

BIMI_PHI_STRT_GMP	Begin of main injection start map
BIMI_N_STRT_ACO	Definition of map axis coordinates for start (engine speed)
BIMI_T_STRT_ACO	Definition of map axis coordinates for start (temperature)

Corresponding Excel-data: Calibration_InjectionAngle.xls

Corresponding MODAS-Worksheet: EngineStart.mxws

During engine start the injection angle (bimi_phi_strt_w) is calculated based on the map BIMI_PHI_STRT_GMP with the inputs engine speed (eess_n_avg_w) and coolant temperature (ects_t_w).

The correct calibration for the angle has to be found based on the signal of the cylinder pressure indication. For engine start it is good to have the main combustion area approx. 10[°Crk] **after** TDC.

The following proposal gives a rough estimation for the first calibration. The values must be individually adjusted to the engine.

In general concerning the calibration of the beginning of injection angle it is better to start with smaller angles to get a later combustion.

BIMI_PHI_STRT_GMP

[°Crk]

	0	125	250	375	500	625	750	875	1000 [rpm]
-30	13,50	13,50	13,75	14,00	14,25	14,50	14,50	14,50	14,50
0	10,50	10,50	10,75	11,00	11,25	11,50	11,50	11,50	11,50
20	9,50	9,50	9,75	10,00	10,25	10,50	10,50	10,50	10,50
30	9,00	9,00	9,25	9,50	9,75	10,00	10,00	10,00	10,00
50	8,25	8,25	8,50	8,75	9,00	9,25	9,25	9,25	9,25
70	7,75	7,75	8,00	8,25	8,50	8,75	8,75	8,75	8,75
90	7,50	7,50	7,75	8,00	8,25	8,50	8,50	8,50	8,50
100	7,25	7,25	7,50	7,75	8,00	8,25	8,25	8,25	8,25
110	7,00	7,00	7,25	7,50	7,75	8,00	8,00	8,00	8,00

[°C]

Grouped axis setpoints

X-axis - input: engine speed (eess_n_avg_w)

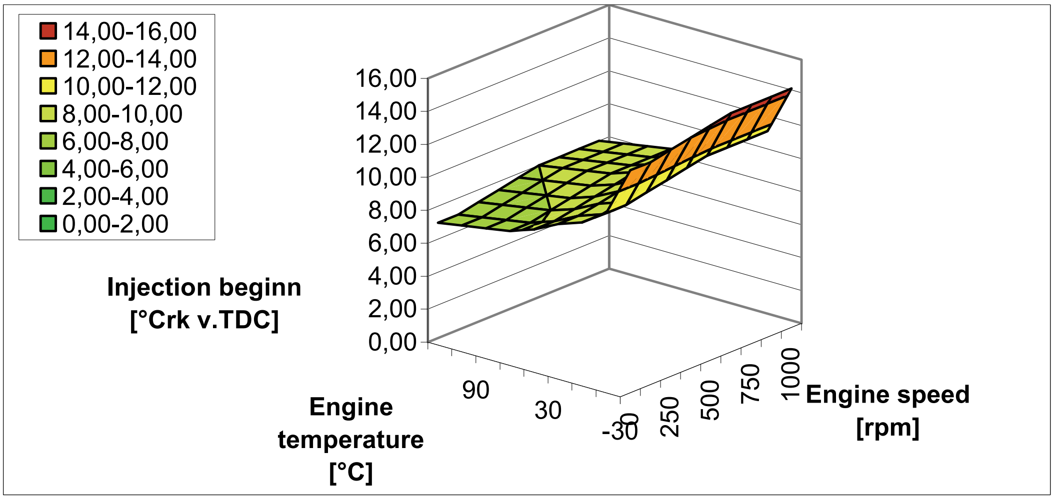
BIMI_N_STRT_ACO

#	1	2	3	4	5	6	7	8	9
[rpm]	**0**	**125**	**250**	**375**	**500**	**625**	**750**	**875**	**1000**

Y-axis - input: coolant temperature (ects_t_w)

BIMI_T_STRT_ACO

#	1	2	3	4	5	6	7	8	9
[°C]	**-30**	**0**	**20**	**30**	**50**	**70**	**90**	**100**	**110**



Graphic 8 (Calibration_InjectionAngle.xls)

Calibration hint:

- Cold engine temperatures requires bigger values for the beginning of injection angle due to combustion delay increase
- Hot engine temperatures need smaller values for the beginning of injection angle due to combustion delay decrease

Hint: The proposed calibration for BIMI_PHI_STRT_GMP has small injection begin angles in order to avoid too early injections. This calibration probably causes too late injections → pressure peak during expansion/decompression. Based on the cylinder pressure signal the injection angle has to be advanced in order to reach the above mentioned main combustion area of 10[°Crk] after TDC.

3.3.2.2 Normal operation beginning of injection angle

Affected CALIBRATION LABELS:

BIMI_PHI_BASE_MAP	Base angle map for begin of main injection
BIMI_PHI_LATEST_CW	Latest possible angle of begin of main injection
BIMI_PHI_CTCOR_GMP	Correction map coolant temperature
BIMI_SF_CTCOR_CUR	Correction curve coolant temperature
BIMI_N_ACO	Breakpoints for injection angle correction maps (engine speed)
BIMI_Q_ACO	Breakpoints for injection angle correction maps (fuel quantity)

Corresponding Excel-data: Calibration_InjectionAngle.xls

Corresponding MODAS-Worksheet: InjectionAngle.mxws

The map BIMI_PHI_BASE_MAP contains the beginning of injection angle (bimi_phi_w) based on engine speed (eess_n_avg_w) and injection quantity (fqsc_q_w).

The following table gives a proposal for calibration of this map for the first engine start.

For sure the proposal does NOT fit to every engine. In every position of the map the calibrated beginning of injection angle has to be checked very carefully based on

- the maximum allowed cylinder pressure value (given by the engine and piston manufacturer)
- the exhaust gas temperature limit (given by the turbo charger manufacturer) and
- the engine stability (to be checked with cylinder pressure measurement)

The calibration with the running engine has to be done step-by-step going through the map BIMI_PHI_BASE_MAP.

The latest possible beginning of injection angle for the main injection is limited by the calibration label BIMI_PHI_LATEST_CW. For the first engine start the latest position should be close to the TDC. The given proposal needs to be double checked later in the project. If it is possible to increase the default calibration value (to e.g. 5[°Crk]), because there is no need to inject later, this should be calibrated in this calibration label.

Default calibration: BIMI_PHI_LATEST_CW = 0[°Crk]

To avoid engine instability during state engine transition (start mode to low idle), injection angle should have a closed value between the injection angle start map BIMI_PHI_STRT_GMP and the injection angle base map BIMI_PHI_BASE_MAP. That's why the injection angle base map BIMI_PHI_BASE_MAP has values at low idle engine speed closed to injection angle start map BIMI_PHI_STRT_GMP in hot conditions (engine coolant temperature = 90°C).

To carry out a safety working engine before fine tuning of the injection angle, the default value is set to 0 on the injection angle base map BIMI_PHI_BASE_MAP outside the start and low idle areas. The values have to be specifically adjusted to the engine.

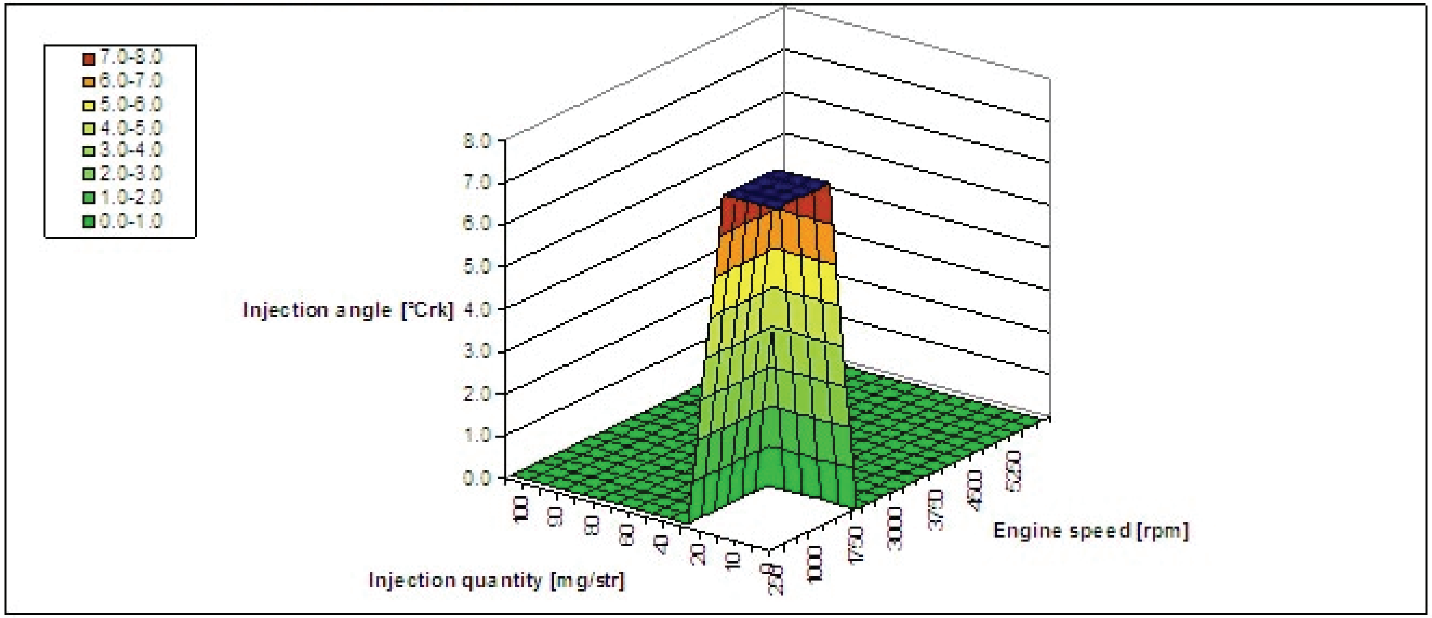
BIMI_PHI_LATEST_CW
0.0 [°Crk]

BIMI_PHI_BASE_MAP
[°Crk]

	250	500	750	1000	1250	1500	1750	2000	2500	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000 [rpm]
0	8.0	8.0	8.0	8.0	8.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	8.0	8.0	8.0	8.0	8.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	8.0	8.0	8.0	8.0	8.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	8.0	8.0	8.0	8.0	8.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	4.0	4.0	4.0	4.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
105	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[mg/str]

X-axis - input: engine speed (eess_n_avg_w)
Y-axis - input: injection quantity (fqsc_q_w)



Graphic 9 (Calibration_InjectionAngle.xls)

To take into consideration that the combustion quality changes depending on the engine temperature, there is a correction map BIMI_PHI_CTCOR_GMP with inputs engine speed (eess_n_avg_w) and coolant temperature (ects_t_w) as well as the temperature depending curve BIMI_SF_CTCOR_CUR containing factors with input coolant temperature (ects_t_w). The final corrective value is the product of the corresponding values coming from the map and the curve and is added to the base angle value coming from BIMI_PHI_BASE_MAP.

The corrective values should be disabled for the first engine start by calibrating them with neutral values. (See graphics 10 and 11). Only later during the project, when the engine is running stable in normal conditions, the calibration should be also checked for cold and hot conditions.

Grouped axis setpoints

X-axis - input: engine speed (eess_n_avg_w)

BIMI_N_ACO

[-]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
[rpm]	**0**	**250**	**500**	**750**	**1000**	**1250**	**1500**	**1750**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**	**5500**

Y-axis - input: injection quantity (fqsc_q_w)

BIMI_Q_ACO

[-]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
[mg/str]	**0**	**5**	**10**	**15**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**85**	**90**	**95**	**100**	**105**

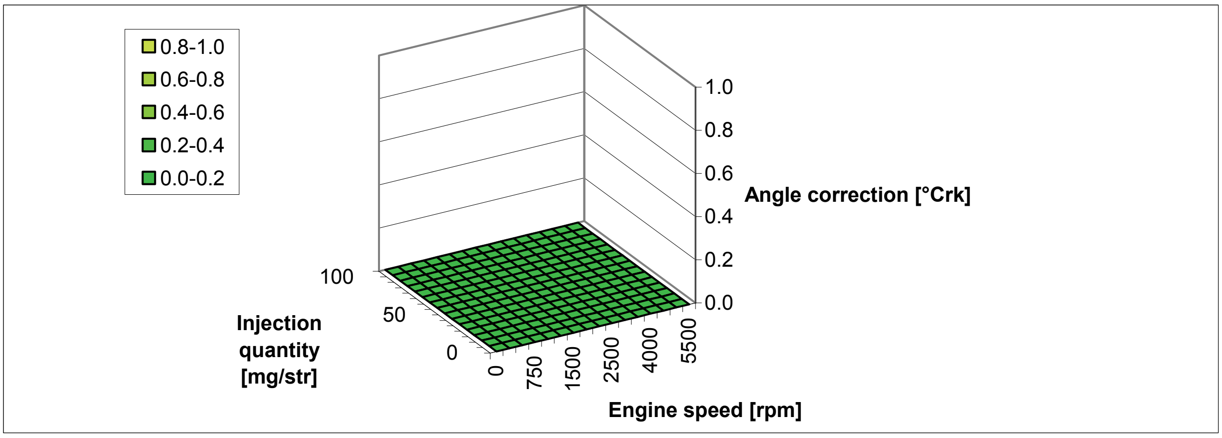
BIMI_PHI_CTCOR_GMP

[°Crk]

	0	**250**	**500**	**750**	**1000**	**1250**	**1500**	**1750**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**	**5500**	[rpm]
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
105	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
[mg/str]																	

X-axis - input: engine speed (eess_n_avg_w)

Y-axis - input: injection quantity (fqsc_q_w)

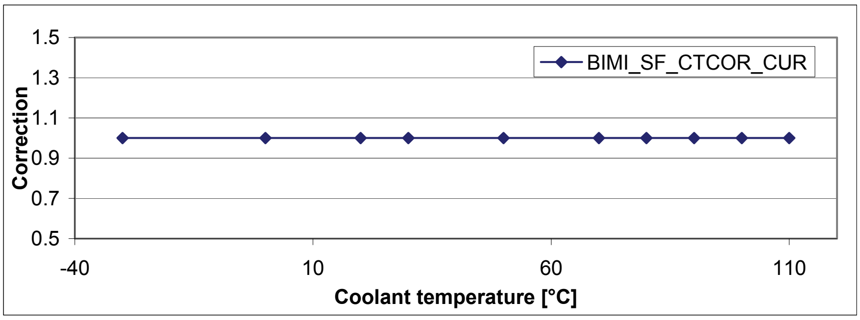


Graphic 10 (Calibration_InjectionAngle.xls)

BIMI_SF_CTCOR_CUR

[°C]	-30	0	20	30	50	70	80	90	100	110
[-]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

X-axis - input: coolant temperature (ects_t_w)



Graphic 11 (Calibration_InjectionAngle.xls)

3.3.3 Rail pressure (FPSC)

The calibration of the rail pressure function contains mainly the calibration of the rail pressure set point (fpsc_p_w) and the calibration of the rail pressure controller that regulates the high pressure pump with a closed loop control.

A good control quality of the rail pressure controller helps the engine to run stable. The rail pressure has a direct influence on the behaviour of the engine. If the rail pressure is not stable (oscillating) the engine speed probably might be not stable as well. The necessary time to inject a certain amount of fuel quantity depends directly on the level of the rail pressure. In case the rail pressure is oscillating the necessary time to inject the same fuel quantity will be different for every injection. This again will directly influence the combustion, which has a major influence to the power → changing power forced by changing injection durations will cause instability of the engine speed. Instability of the engine speed again has an influence to the beginning of injection angle and so the system is swings up ...in worse case until it becomes instable!

To avoid instability of the complete system (engine) forced by an instable rail pressure behaviour a good calibration of the rail pressure controller parameters is necessary.

3.3.3.1 Start mode rail pressure set point

Affected CALIBRATION LABELS:

FPSC_P_SPST_MAP	Base map fuel pressure set point for start
FPSC_P_H2OST_MAP	Coolant temperature correction for rail pressure during start mode
FPSC_SF_H2OST_CUR	Coolant temperature factor for rail pressure correction during start mode

Corresponding Excel-data: Calibration_RailPressure_setpoint.xls

Corresponding MODAS-Worksheet: EngineStart.mxws

The map containing the rail pressure set point during start has to be calibrated taking into account the start cut out speed and the rail pressure set point for low idle speed of the engine. The values should be close together in order to avoid big gradients/jumps while switching from START- to LOW IDLE CONTROLLER-mode.

For a good engine start it is important to have the best possible combustion conditions, which are linked directly to the level of rail pressure. The lower the level of rail pressure, the longer is the necessary injection time to inject a certain amount fuel quantity. In order to precondition the injected fuel quantity during engine start it is recommended to have the fuel in the combustion chamber as long as possible before the combustion of the injected fuel starts. For engine start though a small rail pressure set point should be used.

Calibration hint:

- If the rail pressure set point is too low, there might be no combustion at all.
- If the rail pressure set point is too high, the combustion will be very strong (heavy combustion noise).

A good value for the rail pressure set point during engine start should be somewhere between 250...600[bar]. The fine tuning – if necessary - can be done later on the running engine.

To take into consideration that the combustion quality changes depending on the engine temperature, there is a correction map FPSC_P_H2OST_MAP with inputs engine speed (eess_n_avg_w) and coolant temperature (ects_t_w) as well as the temperature depending curve FPSC_SF_H2OST_CUR containing factors with input coolant temperature (ects_t_w). The final corrective value is the product of the corresponding values coming from the map and the curve and is added to the rail pressure value coming from FPSC_P_SPST_MAP.

The corrective values should be disabled for the first engine start by calibrating them with neutral values (see graphics 12). Only later during the project, when the engine is running stable in normal conditions, the calibration should be also checked for cold and hot conditions.

To start the engine the first time the following calibration proposal should be alright.

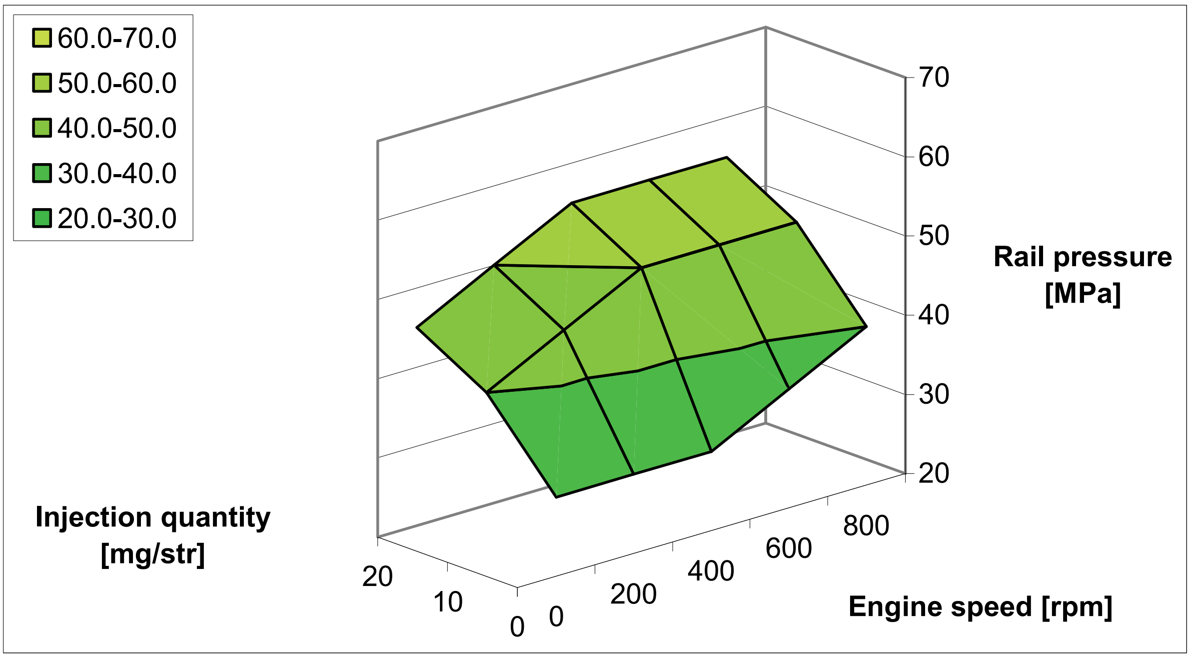
FPSC_P_SPST_MAP

[Mpa]

	0	200	400	600	800	[rpm]
0	30.0	30.0	30.0	35.0	40.0	
10	40.0	45.0	50.0	50.0	50.0	
20	45.0	50.0	55.0	55.0	55.0	

[mg/str]

X-axis - input: engine speed (eess_n_avg_w)
Y-axis input: injection quantity (fqsc_q_w)

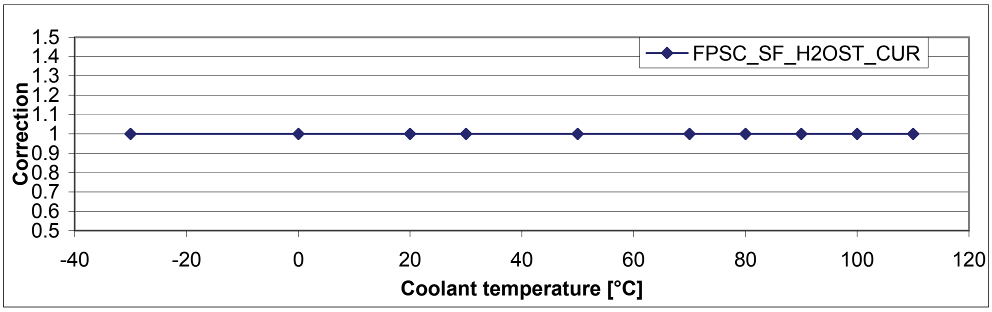


Graphic 12 (Calibration_RailPressure_setpoint.xls)

FPSC_SF_H2OST_CUR

[°C]	-30	0	20	30	50	70	80	90	100	110
[-]	1	1	1	1	1	1	1	1	1	1

X-axis - input: coolant temperature (ects_t_w)



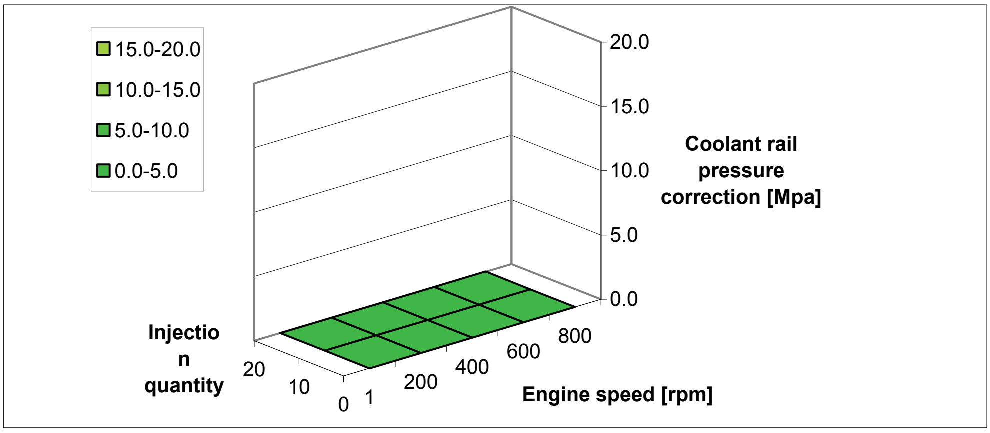
FPSC_P_H2OST_MAP

[MPa]

	1	200	400	600	800 [rpm]
0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0

[mg/str]

X-axis - input: engine speed (eess_n_avg_w)
Y-axis - input: injection quantity (fqsc_q_w)



Graphic 13 (Calibration_RailPressure_setpoint.xls)

3.3.3.2 Normal operation rail pressure set point

Affected CALIBRATION LABELS:

FPSC_P_MAX_CUR	Map max. fuel pressure
FPSC_P_MIN_CW	Min. fuel pressure
FPSC_P_SP_MAP	Base map fuel pressure setpoint

Corresponding Excel-data: Calibration_RailPressure_setpoint.xls

Corresponding MODAS-Worksheet: Rail_pressure_FMU.mxws

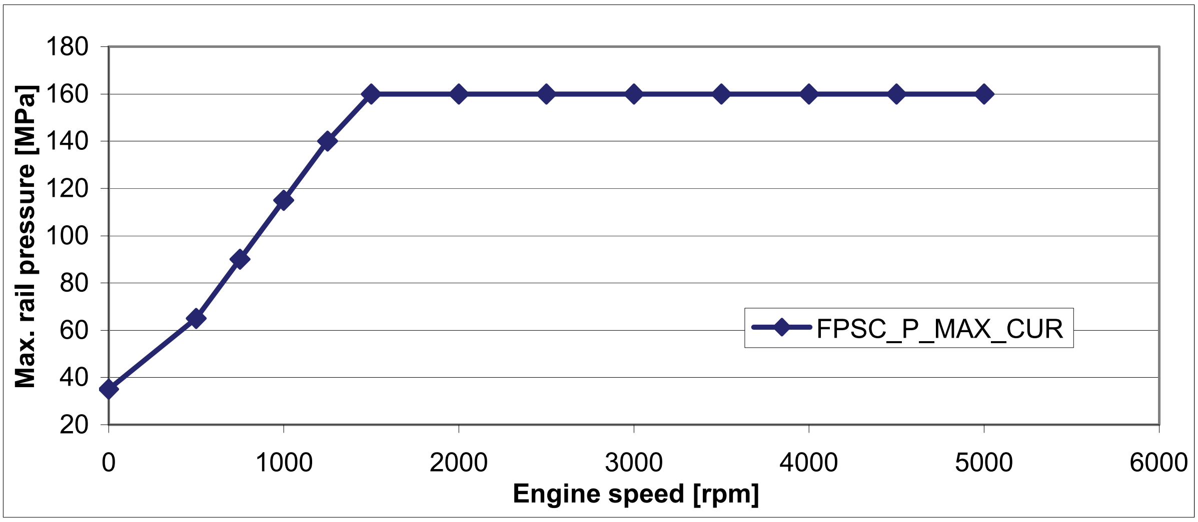
FPSC_P_MAX_CUR

The maximum allowed rail pressure set point (fpsc_p_w) is calibrated using the curve FPSC_P_MAX_CUR. The maximum rail pressure limits the rail pressure setpoint (fpsc_p_w) depending on the engine speed to avoid mechanical stress on HP-pump at low engine speed. At high engine speed, the limit is done by the injection system, so the the calibration curve FPSC_P_MAX_CUR depends on engine speed as well.

FPSC_P_MAX_CUR

[rpm]	0	500	750	1000	1250	1500	2000	2500	3000	3500	4000	4500	5000
[Mpa]	35.0	65.0	90.0	115.0	140.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0

X-axis - input: engine speed (eess_n_avg_w)



Graphic 14 (Calibration_RailPressure_setpoint.xls)

FPSC_P_MIN_CW

The minimum rail pressure set point (fpsc_p_w) depends on the rail pressure at which no combustion is possible any more. The rail pressure has to be limited to minimum that value.

Proposal: FPSC_P_MIN_CW = 25[MPa]

FPSC_P_SP_MAP

It is recommended to calibrate the rail pressure set point map FPSC_P_SP_MAP in a way that there are no big gradients of the set point in areas that are used dynamically while the engine is running. These areas are shown in the table shown below in brown marked cells.

Also the area of the low idle speed set point (LISC_N_BAS_CUR) should have a constant set point for the rail pressure. Shown in yellow marked cells

Following there is an example of a rail pressure set point map calibration for maximum rail pressure of 1600[bar].

The necessary conditions are assumed to be as follows:

Normal operating range:

- Used engine speed range under normal conditions: 2250...4500[rpm].
- Used injection quantity under normal conditions: 10...105[mg/str]

Low idle speed

- The low idle speed set point is about 1000[rpm] (depending on the coolant temperature (ects_t_w))
- The necessary injection quantity to control the engine to the low idle speed set point is 4...12[mg/str]

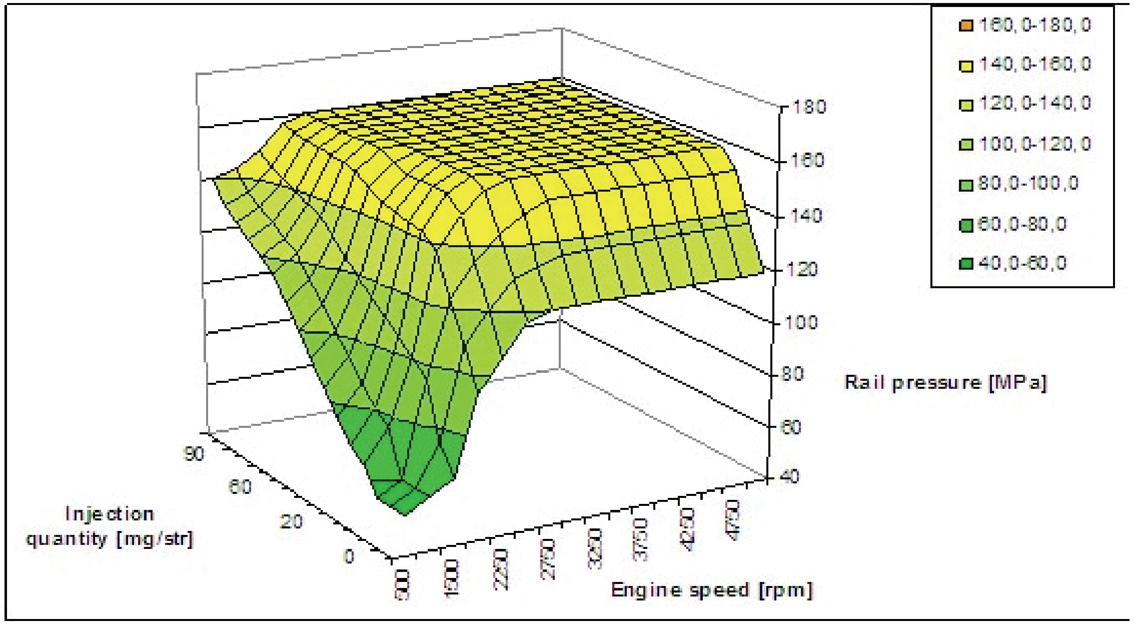
To avoid engine instability during state engine transition (start mode to low idle), rail pressure setpoint should have close values between the rail pressure setpoint start map FPSC_P_SPST_MAP and the rail pressure base map FPSC_P_SP_MAP. That's why the values coming from rail pressure base map FPSC_P_SP_MAP are close to values at low idle engine speed coming from the rail pressure setpoint start map FPSC_P_SPST_MAP in hot conditions (engine coolant temperature = 90°C).

SC_P_SP_MAP

[mg/str]	500	1000	1500	2000	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000 [rpm]
0	55,0	60,0	65,0	94,3	105,7	117,2	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0
5	55,0	60,0	75,0	108,7	120,5	130,4	133,0	136,0	136,0	136,0	136,0	136,0	136,0	136,0	136,0	136,0
10	55,0	60,0	95,0	123,2	135,2	143,7	149,5	153,3	153,3	153,3	153,3	153,3	153,3	153,3	153,3	153,3
15	64,0	76,3	100,8	137,7	150,0	157,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
20	68,0	80,4	105,3	142,6	155,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
30	76,0	87,3	109,9	143,7	155,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
40	84,0	94,2	114,4	144,8	155,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
50	92,0	101,0	119,0	146,0	155,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
60	100,0	108,1	124,4	148,9	157,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
70	108,0	115,4	130,3	152,6	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
80	116,0	122,3	134,8	153,7	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
85	120,0	125,7	137,2	154,3	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
90	124,0	129,2	139,4	154,8	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
95	128,0	132,6	141,7	155,4	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
100	132,0	136,0	144,0	156,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0
110	140,0	142,9	148,5	157,1	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0	160,0

X-axis - input: engine speed (eess_n_avg_w)
Y-axis - input: injection quantity (fqsc_q_w)

Low idle speed
normal operation mode of the engine
do not use these conditions



Graphic 15 (Calibration_RailPressure_setpoint.xls)

3.3.3.3 High pressure pump calibration

The rail pressure is controlled by the fuel metering unit (FMU) of the high pressure (HP) pump. The target of the control is to always deliver the same fuel quantity from the HP pump to the rail that is injected (fqsc_q_w) by the injectors. With this the fuel quantity balance in the rail should be well controlled and so there should be no big over- or undershoots of the actual rail pressure (efps_p_w) compared to the set point (fpsc_p_w). A pre-control MAP and a PID governor are necessary to control rail pressure.

3.3.3.3.1 Rail pressure PID governor (FPC3)

Affected CALIBRATION LABELS:

FPC3_S_CALIBRATION_MODE_CB	Enable/disable rail pressure controller calibration mode
FPC3_SF_CP_NEG_CW	Ratio to calculate P-part amplification in large negative window
FPC3_SF_CP_POS_CW	Ratio to calculate P-part amplification in large positive window
FPC3_CP_FLOWRATIO_CSTR.CPWIN	P-part small signal amplification
FPC3_CP_FLOWRATIOCSTR.WNEG	Negative window for small P-part signal amplification
FPC3_CP_FLOWRATIOCSTR.WPOS	Positive window for small P-part signal amplification
FPC3_SF_CI_NEG_CW	Ratio to calculate I-part amplification in large negative window
FPC3_SF_CI_POS_CW	Ratio to calculate I-part amplification in large positive window
FPC3_CI_FLOWRATIO_CSTR.CIWIN	I-Part small signal amplification
FPC3_CI_FLOWRATIOCSTR.WNEG	Negative window for small I-part signal amplification
FPC3_CI_FLOWRATIOCSTR.WPOS	Positive window for small I-part signal amplification
FPC3_CDT1_FLOWRATIO_CSTR.CNEG	DT1-CD-parameter neg. large signal amplification
FPC3_CDT1_FLOWRATIO_CSTR.CPOS	DT1-CD-parameter pos. large signal amplification
FPC3_CDT1_FLOWRATIO_CSTR.CWIN	DT1-CD-parameter small signal (always ZERO)
FPC3_CDT1_FLOWRATIO_CSTR.T1	DT1-T1 parameter fuel pressure controller
FPC3_CDT1_FLOWRATIOCSTR.WNEG	Negative window for small DT1-part signal amplification
FPC3_CDT1_FLOWRATIOCSTR.WPOS	Positive window for small DT1-part signal amplification
FPC3_PT1_P_CSTR.T1	T1 parameter for PT1
RMTC_S_VS100_ON_CB	Main Switch to enable remote control function RMTC
RMTC_S_FQSC_CUC	Switch to enable remote control mode for funtion FQSC
RMTC_Q_FQSC_CW	Remote control value for injection fuel quantity (fqsc_q_w)
RMTC_S_FPSC_CUC	Switch to enable remote control mode for funtion FPSC
RMTC_P_FPSC_CW	Remote control value for rail pressure set point (fpsc_p_w)

Corresponding Excel-Data: Calibration_PrailCtrl.xls

Corresponding MODAS-Worksheet: Rail_pressure_FMU.mxws

The dataset preparation contains default values for the PID governor dedicated to first engine start. At this step, the actual rail pressure (efps_p_w) and the rail pressure setpoint (fpsc_p_w) will probably be different because the PID governor isn't fine calibrated yet. The actual rail pressure (efps_p_w) may also oscillate. To adapt the governor to your injection system, see chapter "Calibration of rail pressure controller"after dataset preparation and cranking engine phase. The pre-control map is defined by the followings steps.

3.3.3.3.2 HP pump characteristic curve and pre-control map (FPC3)

Affected CALIBRATION LABELS:

FPC3_I_FLOWNORM_CUR	Norm curve to calculate current equivalent of the FMU flow ratio
FPC3_R_PRE_GMP	Pre control FMU flow ratio demand map
FPC3_N_PRE_ACO	X-Axis coordinates for FPC3_R_PRE_GMP
FPC3_Q_PRE_ACO	Y-Axis coordinates for FPC3_R_PRE_GMP

Corresponding Excel-data: Calibration_HP-Pump.xls

Corresponding MODAS-Worksheet: Rail_pressure_FMU.mxws

In order to calibrate the HP-pump characteristic curve and pre-control map only, the type of the HP-pump (only valid for Bosch HP-pumps) and some engine configuration data are needed.

The excel sheet "Calibration_HP-Pump.xls" on sheet "*Calibration_FPC3_R_PRE_GMP*" provides several drop down menus (green marked cells) to select all necessary HP-pump and engine information.

After all information are selected the Excel sheet automatically contains the good calibration for the HP-pump characteristic as well as for the HP-pump pre-control map inside the light-green marked cells

- on sheet "*Calibration_FPC3_R_PRE_GMP*" for the pre control calibration and
- on sheet "*Calibration_FPC3_I_FLOWNORM_CUR*" for the HP-pump characteristic curve.

These data just have to be copied to the corresponding CALIBRATION LABELS (named in the excel sheet) using the Application tool MODAS Sport (copy/paste from Excel to Modas is basically possible – apart from curve- and map-axis values).

Additional information:

The input of the characteristic curve **FPC3_I_FLOWNORM_CUR** is the control ratio of the HP pump (fpc3_r_reg_w), which is calculated by the rail pressure controller. The output of the curve is the necessary electrical current value (fpc3_i_w) that is necessary to deliver the desired fuel quantity with the HP-pump.

In the following there is an example of a characteristic curve for the Bosch HP pump CP3.2:

Calculation of HP pump characteristic curve based on delivery data

Selected HP-Pump: 0 (Selection is done on sheet FPC3_R_PRE_GMP_Calibration)

CP3.2 Calibration data FPC3_I_FLOWNORM_CUR

[%]	**0,0**	**0,0**	**6,8**	**19,5**	**44,1**	**68,5**	**91,5**	**96,9**	**99,7**	**100,0**
[mA]	1700	1601	1500	1399	1199	1001	800	700	600	400

PLEASE DO NOT CHANGE THIS SHEET MANUALLY - EVERYTHING IS CALCULATED INTERNALLY !!!

Graphic 16 (Calibration_HP-pump.xls – Sheet Calibration_FPC3_I_FLOWNORM_CUR)

The HP-pump pre-control map FPC3_R_PRE_GMP contains the %-flow rate of the FMU that is necessary to balance the rail pressure based on the present engine speed (eess_n_avg_w) and the injection quantity (fqsc_q_w). The more accurate the calibration in the pre-control map is (compared to the needed control command = output of rail pressure controller), the less work is required from the PID controller.

Due to changes in the fuel temperature while the engine is running, the pre-control values never can be 100% accurate in all conditions, but it helps to have an average calibration as accurate as possible to reduce the control deviation in order to limit the actual work of the PID controller.

Hint: The calibration provided by the excel file is only valid for injection synchronous fuel delivery by the HP pump.

HP-pump: CP3.2

Author: __________ Date: __________

Engine data

Strokes / Rev(HP pump)	3 Str/Rev		
Cylinder number	6 Cyl	OK !!!	
Engine design	Inline	OK !!!	
HP Pump	1 (Inline)	OK !!!	
Maximum fuel flow of HP pump:	118.0 [l/h]	@ 4000 rpm	
Flow ratio degrade over pump speed:	-5.25 [l/h]/[250rpm]		

Ratio for injection synchronous fuel delivery : 0.50 (pump speed : engine speed)

Calibration Data for FPC3_N_PRE_ACO (16 x-Axis)

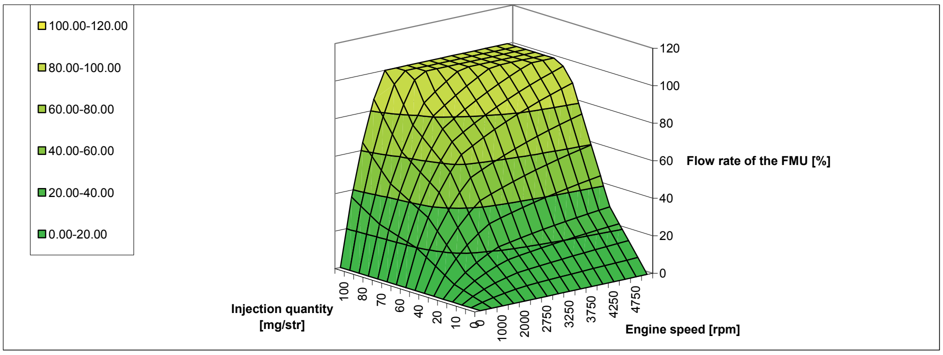
i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[rpm]	0	500	1000	1500	2000	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000

Calibration Data for FPC3_Q_PRE_ACO (16 x-Axis)

i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[mg/str]	0	5	10	15	20	30	40	50	60	65	70	75	80	90	100	110

Calibration Data for FPC3_R_PRE_GMP (16x16)
Calculation of pre control based on HP pump max fuel flow (see cell F11)

[mg/str] \ [rpm]	0	500	1000	1500	2000	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	1.65	2.91	3.90	4.70	5.37	5.66	5.93	6.17	6.40	6.61	6.81	6.99	7.17	7.33	7.48
10	0.00	3.30	5.81	7.80	9.41	10.74	11.32	11.85	12.34	12.80	13.22	13.62	13.99	14.33	14.65	14.96
15	0.00	4.94	8.72	11.70	14.11	16.10	16.98	17.78	18.52	19.20	19.84	20.43	20.98	21.50	21.98	22.43
20	0.00	6.59	11.63	15.60	18.82	21.47	22.63	23.70	24.69	25.60	26.45	27.24	27.97	28.66	29.31	29.91
30	0.00	9.89	17.44	23.40	28.23	32.21	33.95	35.55	37.03	38.40	39.67	40.86	41.96	42.99	43.96	44.87
40	0.00	13.18	23.26	31.21	37.64	42.95	45.27	47.40	49.38	51.20	52.90	54.47	55.95	57.32	58.61	59.83
50	0.00	16.48	29.07	39.01	47.05	53.68	56.59	59.26	61.72	64.00	66.12	68.09	69.93	71.65	73.27	74.78
60	0.00	19.78	34.89	46.81	56.45	64.42	67.90	71.11	74.06	76.80	79.34	81.71	83.92	85.98	87.92	89.74
65	0.00	21.43	37.79	50.71	61.16	69.79	73.56	77.03	80.24	83.20	85.96	88.52	90.91	93.15	95.25	97.22
70	0.00	23.07	40.70	54.61	65.86	75.16	79.22	82.96	86.41	89.60	92.57	95.33	97.91	100.00	100.00	100.00
75	0.00	24.72	43.61	58.51	70.57	80.52	84.88	88.88	92.58	96.00	99.18	100.00	100.00	100.00	100.00	100.00
80	0.00	26.37	46.52	62.41	75.27	85.89	90.54	94.81	98.75	100.00	100.00	100.00	100.00	100.00	100.00	100.00
90	0.00	29.67	52.33	70.21	84.68	96.63	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
100	0.00	32.96	58.15	78.02	94.09	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
110	0.00	36.26	63.96	85.82	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00



Graphic 17 (Calibration_HP-pump.xls – Sheet Calibration_FPC3_R_PRE_GMP)

3.3.3.3.3 Maximum HP pump control ratio (FPC3)

Affected CALIBRATION LABELS:

FPC3_R_MAX_CUR	Engine speed dependent maximum FMU flow ratio demand

Corresponding Excel-data: Calibration_HP-Pump.xls

Corresponding MODAS-Worksheet: Rail_Pressure_FMU.mxws

It is necessary to limit the maximum HP pump control ratio (fpc3_r_reg_w) in order to prevent large torque fluctuations on the pump drive at low engine speeds.

As long as the limitation of the control ratio does not influence the rail pressure control, it is no problem to limit the control ratio of the HP pump to small values.

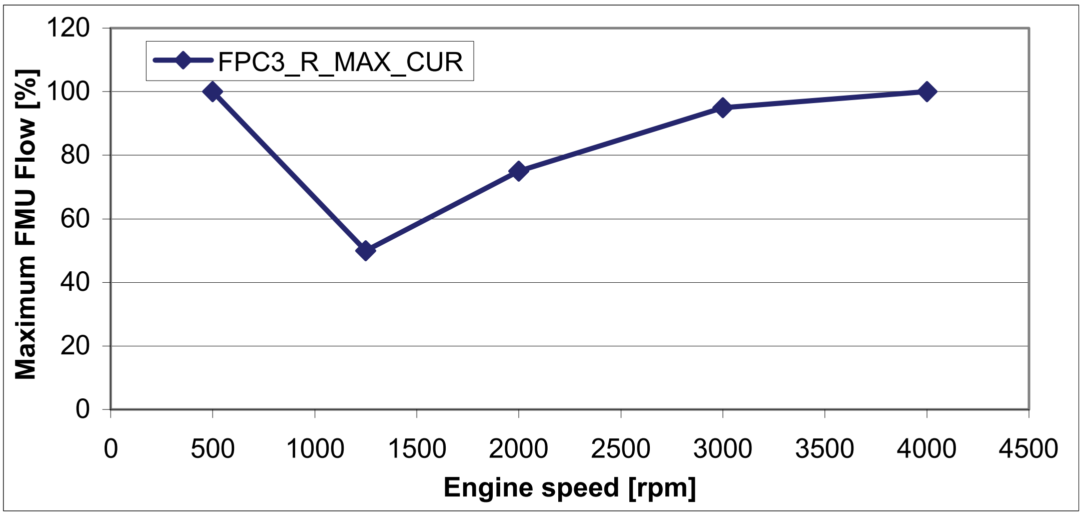
During engine start it is recommended to allow bigger control ratio values in order to pump up the rail pressure as fast as possible.

Following there is a calibration proposal for FPC3_R_MAX_CUR. This proposal has to be checked on the engine regarding the limitation at low engine speeds (eess_n_avg_w) in order to not damage the pump drive.

FPC3_R_MAX_CUR

[rpm]	500	1250	2000	3000	4000
[%]	100.0	50.0	75.0	95.0	100.0

X-axis - input: engine speed (eess_n_avg_w)



Graphic 18 (Calibration_HP-Pump.xls)

3.3.3.3.4 Minimum / maximum HP pump DC control command (FPC3)

Affected CALIBRATION LABELS:

FPC3_DC_MAX_CW	Maximum FMU duty cycle (after current controller)
FPC3_DC_MIN_CW	Minimum FMU duty cycle (after current controller)

Corresponding MODAS-Worksheet: Rail_pressure_FMU.mxws

The duty cycle (fpc3_dc_w) is limited by FPC3_DC_MIN_CW and FPC3_DC_MAX_CW. To be sure not to be limited the limitation should allow the maximum range between 0...100[%].

FPC3_DC_MIN_CW = 0[%]

FPC3_DC_MAX_CW = 100 [%]

3.3.3.3.5 HP pump control during engine start

During engine start the FMU of the HP pump is open-loop controlled with the maximum allowed ratio coming from FPC3_R_MAX_CUR, independent from the control difference between rail pressure set point (fpsc_p_w) and measured rail pressure (efps_p_w).

The HP pump control mode changes to closed loop as soon as

- Engine speed (eess_n_avg_w) is higher than the minimum engine speed (Default setting = 30[rpm])

AND

- Rail pressure (efps_p_w) has reached the rail pressure setpoint (fpsc_p_w).

3.3.4 Air System

3.3.4.1 Cylinder volume (CIAM)

Affected CALIBRATION LABELS:

CIAM_SF_CYLVOL_CW	Constant for cylinder volume
CIAM_G_ENGINE_EFFICIENCY_MAP	Engine efficiency
CIAM_D_AIR_CONST_CW	Gas constant for dry air and requantisation from hPa to N/m^2

Corresponding Excel-data: Calibration_BoostPressure_setpoint.xls

Corresponding MODAS-Worksheet: Boost_pressure.mxws

The cylinder volume has to be calibrated in order to be able to calculate the air mass flow.

Example: 4 cylinder engine with 2.0[ltr]

2,0[ltr] / 4[cyl] => 0,5[ltr/cyl]

→ CIAM_SF_CYLVOL_CW = 0, 5[dm³/str]

For dataset preparation, engine efficiency is set to 1. Added value of a fine tuning on inducted air estimation is low seeing that smoke limitation is able to run properly with an inducted air estimation calibrated roughly.

3.3.4.2 Boost pressure (BPCO)

For the first engine start the boost pressure controller is not really important. For sure later in the project a very good boost pressure control is mandatory in order to achieve the maximum engine performance. But for the first step it is mainly necessary to secure the turbo-charger from over-speeding.

The tighter closed the turbine actuator (wastegate or turbine winglets) is, the more energy the turbocharger gets from exhaust gas. More energy means more turbo speed and higher boost pressure. At first engine start, the boost pressure setpoint (bpco_p_sp_w) is defined depending on engine configuration. Additionally, the pre-control map is calibrated depending on turbocharger definition (see descriptions below).

3.3.4.2.1 Boost pressure set point

Affected CALIBRATION LABELS:

BPCO_P_BASE_MAP	Boost pressure setpoint base map
BPCO_N_ACO	Definition of MAP setpoint (engine speed)
BPCO_Q_ACO	Definition of MAP setpoints (fuel quantity)
BPCO_P_CORR_GMP	Boost pressure correction map
BPCO_SF_CORR_CUR	Boost pressure setpoint correction curve
BPCO_P_MAX_CW	Maximum boost pressure setpoint

Corresponding Excel-data: Calibration_BoostPressure_setpoint.xls

Corresponding MODAS-Worksheet: Boost_pressure.mxws

The excel sheet “Calibration_BoostPressure_setpoint.xls” on sheet “*Boost_pressure_setpoint*” provides several necessary engine information to fulfil (green marked cells).

After all information is fulfiled the Excel sheet automatically contains the good calibration for the boost pressure setpoint.

These data just have to be copied to the corresponding CALIBRATION LABELS (named in the excel sheet) using the Application tool MODAS Sport (copy/paste from Excel to Modas is basically possible – apart from curve- and map-axis values).

BPCO_P_MAX_CW:

The maximum boost pressure setpoint depends on the limits of the whole air system.

BPCO_P_BASE_MAP:

A first estimation of the boost pressure set point can be calculated based on some engine characteristics and environmental conditions (see table below).

The engine characteristics in this table must be updated to the values of your engine using the Excel file "Calibration_BoostPressure_setpoint.xls".

The resulting boost pressure set point given in the map of the Excel file can be copied to the ECU SW. Please take care that also the X- and Y-axis set points fulfil your needs.

Hints:

The resulting boost pressure set point given in the map of the Excel file "Calibration_BoostPressure_setpoint.xls" is a first estimation and it might be necessary to do some fine tuning in order to optimize it to your needs. The resulting allows just an engine air intake sufficient to run engine.

The X- and Y-axis set points of the maps in function BPCO and BIMI should have the same set points (X-axis of BIMI has more set points so the X-axis of BPCO should be a subset of the ones of BIMI).

BPCO_P_CORR_GMP and BPCO_SF_CORR_CUR:

To take into consideration that the combustion quality changes depending on environmental conditions (atmospheric pressure and air ambient temperature), there is a correction map BPCO_P_CORR_GMP with inputs engine speed (eess_n_avg_w) and atmospheric pressure (eaps_p_w) as well as the boost air temperature depending curve BPCO_SF_COOR_CUR containing factors with input boost air temperature (ebts_t_w). The final corrective value is the product of the corresponding values coming from the map and the curve and is added to the boost pressure value coming from BPCO_P_BASE_MAP.

The corrective values should be disabled for the first engine start by calibrating them with neutral values. Only later during the project, when the engine is running stable in normal conditions, the calibration should be also checked for different environmental conditions (hot and altitude conditions).

Engine characteristic data

Displacement 3.0 [l]
Cylinder number 6 [-]

Volumetric efficiency [-]

1000	1500	2000	2500	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	[rpm]
0.79	0.80	0.81	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.82	0.81	0.80	0.79	0.78	0.76	

Remark : if volumetric efficiency is unknown, set value to worst case = 0,7

Air temperature after intercooler [°C]

1000	1500	2000	2500	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	[rpm]
25	25	35	45	45	45	45	45	45	45	45	45	45	45	45	45	

Remark : if air temperature after intercooler is unknown, set value to worst case = 60°C

Min allowed lambda [-]

1000	1500	2000	2500	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	[rpm]
1.15	1.15	1.15	1.15	1.15	1.15	1.16	1.18	1.21	1.23	1.25	1.28	1.30	1.33	1.36	1.40	

Remark : if min allowed lambda is unknown, set value to worst case = 1,4

Max allowed boost pressure [bar]

1000	1500	2000	2500	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	[rpm]
1.10	1.40	1.80	2.45	2.66	2.69	2.72	2.75	2.78	2.81	2.75	2.65	2.53	2.45	2.38	2.32	

Remark 1 : 2 alternatives for max allowed boost pressure characterisation
-> advanded calculations based on charger map (supplied by T/C manufacturer), air path (counterpressure) and engine data
-> measures at engine test bench : at each engine speed, boost pressure setpoint increased step by step in order to define surge and/or overspeed limit of charger

Remark 2 : According to our recommendation about calibration of FLIM_Q_TLIM_GMP for the first engine start, engine won't be able to run at load > 30 mg/st and speed > 3000 tr/min. Consequently max allowed boost pressure can be set to 5 bar for the first engine start.

Environmental conditions

Ambient pressure 1013 [hPa]

Constants physical values

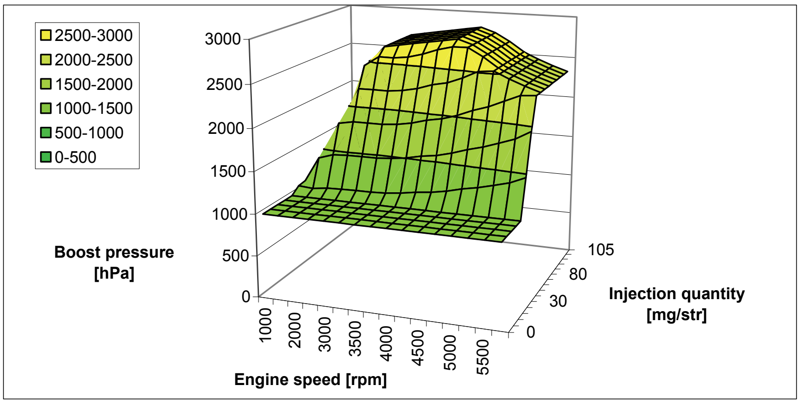
Gas constant ideal 287 [J/Kg/K]

BPCO_P_BASE_GMP

[hPa]

	1000	1500	2000	2500	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	[rpm]
0	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	
5	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	
10	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	
15	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	
20	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	1013	
30	1083	1070	1092	1100	1100	1100	1110	1129	1158	1177	1210	1255	1290	1337	1384	1463	
40	1100	1400	1456	1467	1467	1467	1480	1505	1543	1569	1614	1673	1720	1782	1846	1950	
50	1100	1400	1800	1834	1834	1834	1850	1881	1929	1961	2017	2091	2150	2228	2307	2320	
60	1100	1400	1800	2200	2200	2200	2219	2258	2315	2353	2421	2509	2530	2450	2380	2320	
70	1100	1400	1800	2450	2567	2567	2589	2634	2701	2746	2750	2650	2530	2450	2380	2320	
80	1100	1400	1800	2450	2660	2690	2720	2750	2780	2810	2750	2650	2530	2450	2380	2320	
85	1100	1400	1800	2450	2660	2690	2720	2750	2780	2810	2750	2650	2530	2450	2380	2320	
90	1100	1400	1800	2450	2660	2690	2720	2750	2780	2810	2750	2650	2530	2450	2380	2320	
95	1100	1400	1800	2450	2660	2690	2720	2750	2780	2810	2750	2650	2530	2450	2380	2320	
100	1100	1400	1800	2450	2660	2690	2720	2750	2780	2810	2750	2650	2530	2450	2380	2320	
105	1100	1400	1800	2450	2660	2690	2720	2750	2780	2810	2750	2650	2530	2450	2380	2320	

[mg/str]



X-axis input of BPCO_P_BASE_MAP: engine speed (eess_n_avg_w)

BPCO_N_ACO

[i]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[rpm]	1000	1500	2000	2500	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000

Y-axis input of BPCO_P_BASE_MAP: injection fuel quantity (fqsc_q_w)

BPCO_Q_ACO

[i]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[mg/str]	0	5	10	15	20	30	40	50	60	70	80	85	90	95	100	105

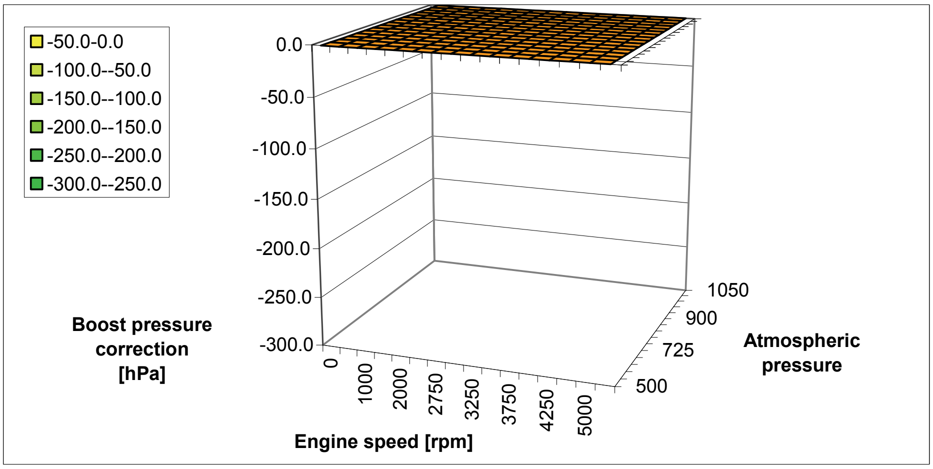
Graphic 19 (Calibration_BoostPressure_setpoint.xls)

BPCO_P_CORR_GMP
[hPa]

	0	500	1000	1500	2000	2500	2750	3000	3250	3500	3750	4000	4250	4500	5000	5500 [rpm]
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
550	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
650	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
725	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
825	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
850	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
925	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
950	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1050	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[hPa]

Y-axis input: atmospheric pressure (eaps_p_w)



X-axis input of BPCO_CORR_GMP: engine speed (eess_n_avg_w)

BPCO_N_ACO

[-]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[rpm]	0	500	1000	1500	2000	2500	2750	3000	3250	3500	3750	4000	4250	4500	5000	5500

BPCO_SF_CORR_GMP

[°C]	-20	-10	0	5	10	15	20	30	40	50
[-]	1	1	1	1	1	1	1	1	1	1

X-axis input: boost air temperature (ebts_t_w)

Graphic 20 (Calibration_BoostPressure_setpoint.xls)

3.3.4.2.2 Initial calibration for boost pressure pre-control command

Affected CALIBRATION LABELS:

BPCO_DC_PRECON_GMP	Boost pressure duty cycle precontrol map
BPCO_N_ACO	Definition of map setpoints (engine speed)
BPCO_Q_ACO	Definition of map setpoints (injection quantity)

Corresponding Excel-data: Calibration_BoostPressure_setpoint.xls

Corresponding MODAS-Worksheet: Boost_pressure.mxws

According to the recommendations below, the excel sheet “Calibration_BoostPressure.xls” on sheet “*Prectl_Calibration_engineSTRTt*” allows to prepare the dataset adapted to the turbocharger definition (green marked cells).

After all information is fulfiled the Excel sheet automatically contains the good calibration for the boost pressure duty cycle pre-control map.

These data just have to be copied to the corresponding CALIBRATION LABELS (named in the excel sheet) using the Application tool MODAS Sport (copy/paste from Excel to Modas is basically possible – apart from curve- and map-axis values).

According to our recommendation about calibration of FLIM_Q_TLIM_GMP for the first engine start, engine won't be able to run at load > 30 mg/st and speed > 3000 tr/min. So the boost pressure duty cycle precontrol map BPCO_DC_PRECON_GMP values are, in this chapter, calibrated only to carry out a proper engine running.

Depending on the turbocharger characteristic, there are two different ways to prepare dataset of boost pressure duty cycle pre-control map.

Turbocharger close to series standards (ie small turbine and small charger dedicated to engine performance optimisation at low and medium engine speeds):

The boost pressure duty cycle precontrol map BPCO_DC_PRECON_GMP is set to 50%. According to the load and speed limitation due to the calibration FLIM_Q_TLIM_GMP, this value allows a proper engine running in the limited working area for the first engine start.

Hints:

If surge or over-speeding appears, you have todecrease the value.

If the inducted air mass isn’t high enough to run correctly the engine, you have to increase the value to avoid an engine stalling.

BPCO_R_PRECON_GMP
[%]

	0	500	1000	1500	2000	2500	2750	3000	3250	3500	3750	4000	4250	4500	5000	5500 [rpm]
0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
5	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
10	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
15	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
20	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
30	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
40	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
60	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
70	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
80	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
85	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
90	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
95	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
100	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
110	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

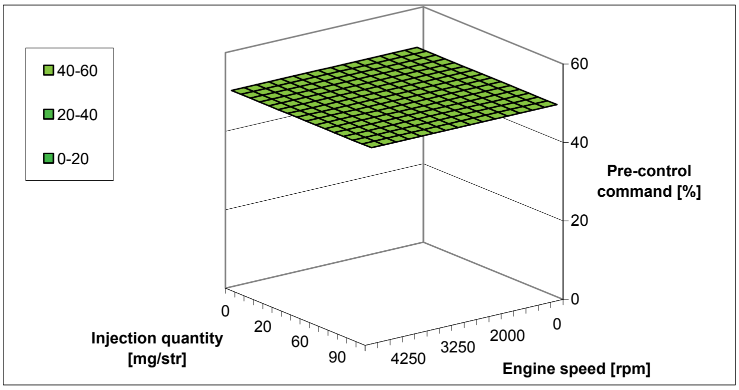
[mg/str]

Grouped axis setpoints (used also by the corresponding correction maps)
X-axis - input: engine speed (eess_n_avg_w)
BPCO_N_ACO

#	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[rpm]	0	500	1000	1500	2000	2500	2750	3000	3250	3500	3750	4000	4250	4500	5000	5500

Y-axis - input: injection quantity (fqsc_q_w)
FLIM_Q_ACO

#	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[°C]	0	5	10	15	20	30	40	50	60	70	80	85	90	95	100	110



Graphic 21 (Calibration_BoostPressure_setpoint.xls)

Turbocharger dedicated to motorsport specific use (ie large turbine and large charger adapted to maximum power at high engine speed):

The boost pressure duty cycle precontrol map BPCO_DC_PRECON_GMP is set to 100%. According to the load and speed limitation due to the calibration FLIM_Q_TLIM_GMP, this value allows a good engine running in the limited working area for the first engine start.

Hints:

If surge or over-speeding appears, you have todecrease the value.

BPCO_R_PRECON_GMP
[%]

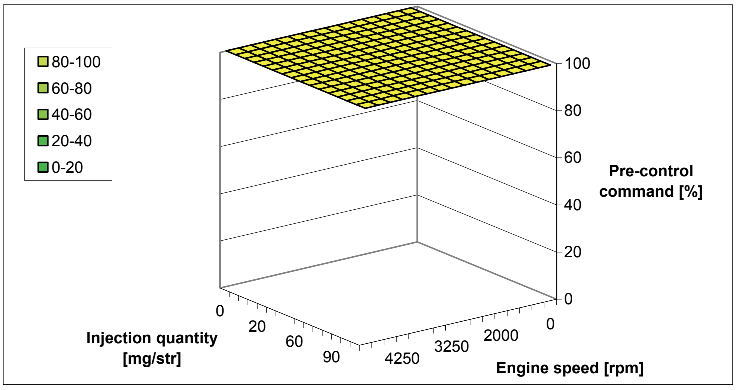
[mg/str] \ [rpm]	0	500	1000	1500	2000	2500	2750	3000	3250	3500	3750	4000	4250	4500	5000	5500
0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
10	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
15	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
20	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
30	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
40	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
85	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
95	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
110	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Grouped axis setpoints (used also by the corresponding correction maps)
X-axis - input: engine speed (eess_n_avg_w)
BPCO_N_ACO

#	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[rpm]	0	500	1000	1500	2000	2500	2750	3000	3250	3500	3750	4000	4250	4500	5000	5500

Y-axis - input: injection quantity (fqsc_q_w)
FLIM_Q_ACO

#	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[°C]	0	5	10	15	20	30	40	50	60	70	80	85	90	95	100	110



Graphic 22 (Calibration_BoostPressure_setpoint.xls)

At this step, the actual boost pressure (ebps_p_w) and the boost pressure setpoint (bpco_p_sp_w) may be different because the pre-control map isn't fine calibrated yet. To tune a fine boost pressure duty cycle precontrol map, refer to the fine tuning of boost pressure on chapter "Calibration of boost pressure pre-control map".

3.3.4.2.3 Limitation of turbocharger actuator duty cycle

Affected CALIBRATION LABELS:

BPCO_DC_MIN_GMP	Minimum duty cycle of boost pressure output
BPCO_DC_MAX_GMP	Maximum duty cycle of boost pressure output

Corresponding MODAS-Worksheet: Boost_pressure.mxws

The usable duty cycle range to control the turbocharger actuator can be limited with a minimum and maximum value. For the first engine start the duty cycle should be limited as follows (taking into consideration the min and max values in the BPCO pre control map).

Later in the project the limits may be changed if necessary in between 0[%]...100[%]

BPCO_DC_MIN_GMP = 0[%]

BPCO_DC_MAX_GMP = 100[%]

3.3.4.2.4 Boost pressure closed loop activation

Affected CALIBRATION LABELS:

BPCO_Q_GOVOFF_CUR	Fuel quantity setpoint to deactivation of closed loop control
BPCO_Q_GOVHYS_CW	Hysteresis for activating closed loop
BPCO_N_ACO	Definition of MAP setpoint (engine speed)
BPCO_S_CLOSEDLOOP_CB	Switch to enable/disable governor (closed loop)

Corresponding Excel-data: Calibration_BoostPressureCtrl.xls

Corresponding MODAS-Worksheet: Boost_pressure.mxws

To enable the closed loop control, set BPCO_S_CLOSEDLOOP_CB = 1.

At low load, boost pressure doesn't reach boost pressure setpoint in most cases. So boost pressure closed loop is not activated for low fuel injection quantity. Above the fuel injection quantity calibrated in BPCO_Q_GOVOFF_CUR (> 15[mg/stroke]), the boost pressure closed loop is activated. Below, the boost pressure runs on open loop. So it's the BPCO_DC_PRECON_ GMP map wich define the boost pressure in the air system. You can define also a hysteresis for activating closed loop (BPCO_Q_GOVHYS_CW > 1[mg/stroke]).

Affected CALIBRATION LABELS:

BPCO_P_CSTR	Boost pressure controller, P-parameter set
BPCO_I_CSTR	Boost pressure controller, I-parameter set
BPCO_DT1_CSTR	Boost pressure controller, DT1-parameter set
BPCO_OSPWND_NEG_CW	Overshoot protection activation window, negative
BPCO_OSPWND_POS_CW	Overshoot protection activation window, positive
BPCO_S_STATE_CPUC	Pointer to select the state of sensor evaluation

Corresponding Excel-data: Calibration_BoostPressureCtrl.xls

Corresponding MODAS-Worksheet: Boost_pressure.mxws

According to our recommendation about calibration of FLIM_Q_TLIM_GMP for the first engine start, engine won't be able to run at load > 30 mg/st and speed > 3000 tr/min. At this step, it's not necessary to calibrate a boost pressure governor.

So, for the first engine start, the boost pressure governor is set to 0. That means all PID parameters are set to 0. To calibrate a fine boost pressure governor, refer to the fine tuning of boost pressure on chapter "Calibration of boost pressure controller".

3.3.4.2.5 Limitation of I-part duty cycle

Affected CALIBRATION LABELS:

BPCO_DC_IMIN_CW	Minimum duty cycle of controller I-part
BPCO_DC_IMAX_CW	Maximum duty cycle of controller I-part

Corresponding MODAS-Worksheet: Boost_pressure.mxws

The minimum and maximum duty cycle coming from the I-part should be limited in order to avoid that the controller becomes too slow under dynamic conditions.

Calibration proposal (needs to be checked for every specific engine):

BPCO_DC_IMIN_GMP = -15[%]

BPCO_DC_IMAX_GMP = 15[%]

3.3.5 Cylinder number (CMOL)

Affected CALIBRATION LABELS:

CMOL_CT_CYL_CUC	Number of engine cylinders

Corresponding MODAS-Worksheet: Boost_pressure.mxws

The number of cylinders of the engine has to be calibrated in CMOL_CT_CYL_CUC.

Example: 4 cylinder engine:

CMOL_CT_CYL_CUC = 4[-]

6 cylinder engine:

CMOL_CT_CYL_CUC = 6[-]

3.3.6 Engine Speed

3.3.6.1 Low idle speed set point (LISC)

Affected CALIBRATION LABELS:

LISC_N_BAS_CUR	Curve for basic low idle setpoint speed f(coolant temperature)
LISC_N_PEDDEF_CW	Low idle speed due to defect pedal

Corresponding Excel-data: Calibration_LowIdleSpeed.xls

Corresponding MODAS-Worksheet: Low_High_idle_speed.mxws

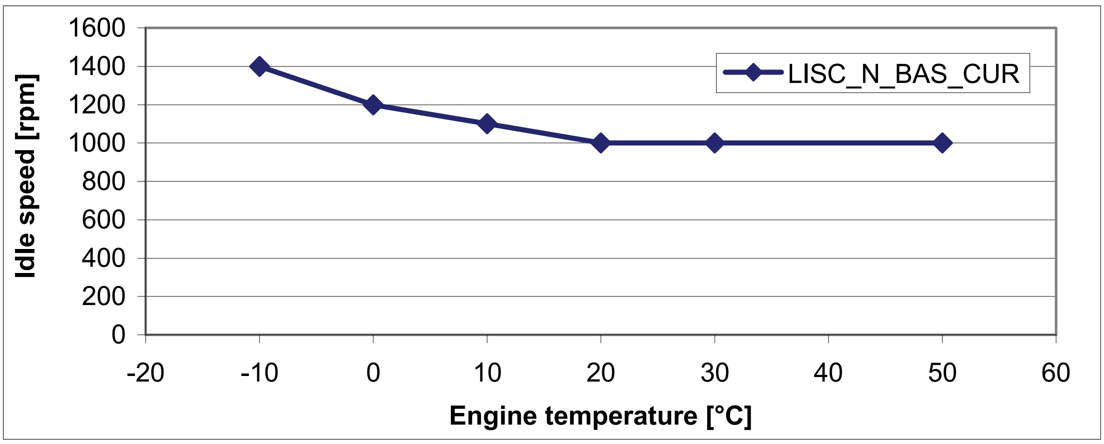
LISC_N_BAS_CUR

The idle speed is given by the coolant temperature dependent calibration curve LISC_N_BAS_CUR. The calibration of LISC_N_BAS_CUR, as stated in chapter "Engine Start Quantity (STRT)", must be greater than the start release curve (STRT_N_OFF_CUR), which also depends on the coolant temperature.

LISC_N_BAS_CUR

[°C]	-10	0	10	20	30	50
[rpm]	1400	1200	1100	1000	1000	1000

X-axis - input: engine temperature (ects_t_w)



Graphic 23 (Calibration_LowIdleSpeed.xls)

LISC_N_PEDDEF_C

This parameter is used only in case of an accelerator pedal failure. For the first engine start this should be set to the same value as the desired idle speed.

Calibration proposal for engine start:

LISC_N_PEDDEF_CW = 1000[rpm]

Later this value can be set to a higher value in order to be able to reach the box / service point in case of a pedal failure.

Normal operation mode: LISC_N_PEDDEF_CW = 2500[rpm]

3.3.6.2 low idle speed controller

Affected CALIBRATION LABELS:

LICO_PW_CSTR.CPWIN	P-part negative signal amplification (WARM)
LICO_PW_CSTR.CPNEG	P-part positive signal amplification (WARM)
LICO_PW_CSTR.CPPOS	P-part small signal amplification (WARM)
LICO_PW_CSTR.WINEG	negative small signal window (WARM)
LICO_PW_CSTR.WIPOS	positive small signal window (WARM)
LICO_PC_CSTR.CPWIN	P-part negative signal amplification (COLD)
LICO_PC_CSTR.CPNEG	P-part positive signal amplification (COLD)
LICO_PC_CSTR.CPPOS	P-part small signal amplification (COLD)
LICO_PC_CSTR.WINEG	negative small signal window (COLD)
LICO_PC_CSTR.WIPOS	positive small signal window (COLD)
LICO_IW_CSTR.CIWIN	I-Part neg. signal amplification (WARM)
LICO_IW_CSTR.CINEG	I-Part pos. signal amplification (WARM)
LICO_IW_CSTR.CIPOS	I-Part small signal amplification (WARM)
LICO_IW_CSTR.WINEG	I-Part neg. window for small signal amplification (WARM)
LICO_IW_CSTR.WIPOS	I-Part pos. window for small signal amplification (WARM)
LICO_IC_CSTR.CIWIN	I-Part neg. signal amplification (COLD)
LICO_IC_CSTR.CINEG	I-Part pos. signal amplification (COLD)
LICO_IC_CSTR.CIPOS	I-Part small signal amplification (COLD)
LICO_IC_CSTR.WINEG	I-Part neg. window for small signal amplification (COLD)
LICO_IC_CSTR.WIPOS	I-Part pos. window for small signal amplification (COLD)

Corresponding Excel-Data: Calibration_LowIdleSpeed.xls

Corresponding MODAS-Worksheet: Low_High_idle_speed.mxws

The dataset preparation contains default values for the PID governor dedicated to first engine start. At this step, the low idle speed could be instable. The low idle speed controller has to be adapted to your engine. To calibrate it, see chapter "Calibration of low idle controller "after data-set preparation and cranking engine phase.

3.3.6.3 High idle speed set point (HISP)

Affected CALIBRATION LABELS:

HISP_N_BASE_CW	High idle setpoint
HISP_N_DROOP_CW	Engine speed droop
HISP_N_TRED_CW	High idle setpoint cold engine
HISP_DT_STRT_CUR	Duration for reduced HICO-engine speed based on water temp.

Corresponding Excel-data: Calibration_HighIdleSpeed.xls

Corresponding MODAS-Worksheet: Low_High_idle_speed.mxws

HISP_N_BASE_CW

This parameter is the desired maximum engine speed (hisp_n_desired_w) the engine is allowed to run. For the first engine start this limitation should be set to a small value in order to secure the engine from over speeding.

Calibration proposal for engine start:

HISP_N_BASE_CW = 3000[rpm]

HISP_N_DROOP_CW

This label determines the cut-in engine speed (hisp_n_cutin_w) at which the high idle controller (HICO) becomes active. The cut-in engine speed (hisp_n_cutin_w) for the HICO is derived from the calculation

hisp_n_cutin_w = HISP_N_MAX_CW – HISP_N_DROOP_CW.

Starting at the cut-in engine speed (hisp_n_cutin_w) the HICO reduces the injected fuel quantity (fqsc_q_w) step-by-step until the necessary injection quantity (fqsc_q_w) to run the engine at HISP_N_MAX_CW (= hisp_n_desired_w) is reached.

The necessary injection quantity (fqsc_q_w = hico_q_w) depends on the load of the engine (fqsc_r_engload_w). In case the engine is running without load (fqsc_r_engload_w) the injection quantity (fqsc_q_w = hico_q_w) is equal to the friction quantity of this engine speed (qfri_q_w), in case there is load the HICO will control the injection quantity (fqsc_q_w = hico_q_w) accordingly.

The necessary control parameters for the HICO are calculated internally using the calibration data.

The bigger HISP_N_DROOP_CW is the smoother the control will be. Bosch requires to use always a calibration bigger than 150[rpm].

For the first engine start a big value should be taken.

Calibration proposal for engine start:

HISP_N_DROOP_CW = 600[rpm]

Later in the project the calibration of HISP_N_DROOP_CW can be set to approx. 300[rpm] (depending on engine characteristics and HISP_N_MAX_CW).

Proposal for conditions during first engine start:

HISP_N_BAS_CW is set to 3000 and HISP_N_DROOP_CW is set to 600. That means that the cut-in engine speed for the HICO (hisp_n_cutin_w) is at 2400 rpm and the max engine speed (hisp_n_desired_w) is at 3000 rpm.

The following graph gives an example for possible injection quantity limitations and shows how the injection quantity is limited due to the HICO.

All data for

TLIM – torque limitation

HICO – high idle controller

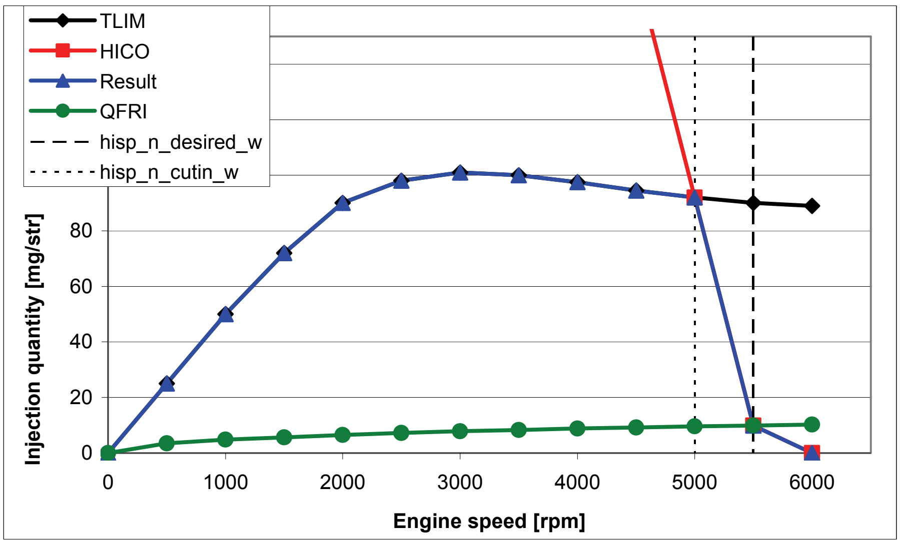
QFRI – Friction quantity

are just examples. The used curves are not available in MS15 SW. In the MS15 SW there are maps to calibrate the torque limitation (see chapter “Fuel limitation (FLIM)”) and the friction quantity (see chapter “Friction Quantity (QFRI)”). For HICO there is no curve or map at all to calibrate an injection quantity. All data are free chosen!

Example for injection quantity limitations (min and max) over the complete engine speed range

HISP_N_MAX_CW		5500 [rpm]
HISP_N_DROOP_CW		500 [rpm]
hisp_n_desired_w	5500 [rpm]	5500 [rpm]
hisp_n_cutin_w	5000 [rpm]	5000 [rpm]

The blue curve shows the resulting maximum injection fuel quantity.
The smoke limitation is not taken into consideration. The smoke limitation probably limits the max injection quantity (blue curve) at lower engine speeds before the turbo charger is producing sufficient boost pressure.



Graphic 24 (Calibration_HighIdleSpeed.xls)

HISP_N_TRED_CW

In order to prevent a cold engine during and after the engine start from harmful engine speeds (too high friction at low water and oil temperatures), the maximum engine speed for a cold engine can be reduced to the value of HISP_N_TRED_CW. The duration for which the engine speed is reduced is calibrated in the curve HISP_DT_STRT_CUR and depends on the engine temperature (ects_t_w). The higher the engine temperature is, the higher can be the maximum engine speed.

Initially the engine speed limitation for cold engines is set to 2750[rpm].

HISP_N_TRED_CW = 2750[rpm]

HISP_DT_STRT_CUR

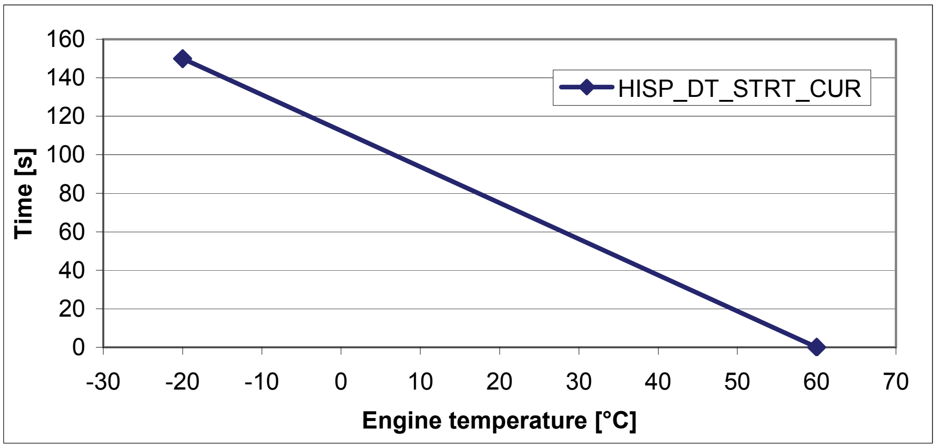
This curve determines, in seconds, how long the engine uses the HISP_N_TRED_CW value after engine start with respect to coolant temp (ects_t_w). If the engine is well prepared before its first start this calibration is not needed for the engine first fire but can be useful to increase engine longevity once the engine is installed in a vehicle.

Depending on the engine the following calibration proposal for the first engine start has to be adapted later in the project (taking also into consideration the label HISP_N_TRED_CW).

HISP_DT_STRT_CUR

[°C]	-20	60
[s]	150	0

X-axis - input: engine temperature (ects_t_w)



Graphic 25 (Calibration_HighIdleSpeed.xls)

3.3.7 Sensor calibration

The MS15 Sport provides 20 input signals to control and monitor the engine. All inputs have to be configured and calibrated individually to ensure the correct function of the engine.

The following inputs are available:

Engine speed (EESS incl. crankshaft (ECRK) and camshaft (ECAM)) (see chapter "Synchronization")

Ignition switch (EIGN) (no calibration necessary)

Reset switch (ERST)

Battery voltage (EBAT)

Acceleration pedal (EAPP)

Vehicle speed (EVSS)

PRESSURE inputs (6):

Ambient air (EAPS)

Turbo boost (EBPS)

Exhaust gas (EEGP)

Fuel (high pressure) = rail pressure (EFPS)

Fuel (low pressure) (ELFPS)

Oil (high pressure) (EOPS)

TEMPERATURE inputs (7)

Ambient air (EATS)

Turbo boost (EBTS)

Coolant water = engine (ECTS)

Exhaust gas (EEGT)

Fuel (low pressure) (EFTS)

ECU internal (EITS)

Oil (high pressure) (EOTS)

The MS15.1 has some additional inputs. The configuration of these additional inputs has to be done in the same way. To get to know which other inputs are available please refer to the MS15.1 documentation.

In the following you find the description to configure and calibrate all inputs.

3.3.7.1 Reset button (ERST)

Affected CALIBRATION LABELS:

ERST_S_ENABLE_CB	Enable flag for function evaluation
ERST_S_LOGIC_CB	Logic flag for switch signal
ERST_DT_DEB_CUC	Debounce time for transition of switch signal
ERST_SWITCH_CUC	Digital input selection of switch signal
ERST_S_RSTFUNC_CUC	Flag mask to select functions to be reset on actuation

Corresponding MODAS-Worksheet: Reset_button.mxws

In the MS15 Sport the “reset button” is used to manually reset the fuel consumption calculation after the tank was refilled during a service or pit stop.

Beside the possibility to enable the function by calibration also the electrical logic, the debounce time, the actuated function (e.g. fuel consumption), and the input pin of the ECU can be set.

The default calibration should be ok to use the reset button!

In case the function of the reset button is not ok, please check the following hints of the calibration labels contained in function ERST in order to solve the problem.

ERST_S_ENABLE_CB

To enable the function of the reset button in SW this parameter has to be set to 1. To disable the function this parameter has to be reset to 0.

ERST_S_LOGIC_CB

This parameter defines the electrical logic of the reset button (high- or low-active).

ERST_DT_DEB_CUC

This parameter defines how long the button must be pressed to detect a valid signal from a disturbance.

ERST_SWITCH_CUC

This label determines the ECU pin to which the reset button is connected.

ERST_R_RESTFUNC_CUC

This parameter is bit-coded. If bit 0 is set then the fuel consumption function is reset. All other bits (1...7) are not linked to a function in MS15 Sport.

3.3.7.2 Battery voltage (EBAT)

Affected CALIBRATION LABELS:

EBAT_DT_DEF_CUC	Time for defect recognition of battery voltage
EBAT_DT_OK_CUC	Time for intact recognition of battery voltage
EBAT_U_MAX_CW	Threshold-voltage for SRC_MAX
EBAT_U_MIN_CW	Threshold-voltage for SRC_MIN
EBAT_U_ABOVE_CW	Threshold-voltage for battery voltage above normal
EBAT_U_BELOW_CW	Threshold-voltage for low battery voltage below normal
EBAT_U_RVAL_CW	Replacement value for battery voltage
EBAT_DT_STRT_CUW	Time after start
EBAT_N_BELOW_CW	Engine speed threshold
EBAT_PT1_U_CSTR	Time constant for battery voltage
EBAT_DT_LODU_CUW	Maximum possible length of a load dump
EBAT_U_LODU_CW	Voltage threshold for load dump detection

Corresponding MODAS-Worksheet: Battery_voltage.mxws

If you use a 12 [V] system normally you do not have to change the default calibration!

In case the evaluation of the battery voltage is not ok, please check the following hints of the calibration labels contained in function EBAT in order to solve the problem.

EBAT_DT_DEF_CUC

The value placed in this parameter is the ‘debounce’ time for the voltage signal high/low fault to be set once an out of range fault is detected.

EBAT_DT_OK_CUC

The value placed in this parameter is the ‘debounce’ time for the voltage signal high/low fault to clear after set if the system is working properly again.

EBAT_U_MAX_CW

If the filtered battery voltage (ebat_u_filt_w) becomes bigger than this threshold a fault is set, and the replacement value EBAT_U_RVAL_CW is used. This parameter is used to detect a damage of the battery. The fault is shown in fmonact_d_faultnum_uc and fmonact_d_faulttype_uc. If this fault is active the replacement value EBAT_U_RVAL_CW is copied to ebat_u_filt_w.

EBAT_U_MIN_CW

If the filtered battery voltage (ebat_u_filt_w) becomes smaller than this threshold a fault is set and the replacement value EBAT_U_RVAL_CW is used. This parameter is used to detect a damage of the battery. The fault is shown in fmonact_d_faultnum_uc and fmonact_d_faulttype_uc. If this fault is active the replacement value EBAT_U_RVAL_CW is copied to ebat_u_filt_w.

EBAT_U_ABOVE_CW

Using this parameter the maximum threshold for the battery voltage under normal conditions is set. If this value is exceeded that does not mean directly that the battery is damaged, but that something is not working properly. The fault is shown in fmonact_d_faultnum_uc and fmonact_d_faulttype_uc. If this fault is active the measured battery voltage is still displayed in ebat_u_filt_w (not the replacement value).

EBAT_U_BELOW_CW

Using this parameter the minimum threshold for the battery voltage under normal conditions is set. If this value is exceeded that does not mean directly that the battery is damaged, but that something is not working properly. The fault is shown in fmonact_d_faultnum_uc and fmonact_d_faulttype_uc. If this fault is active the measured battery voltage is still displayed in ebat_u_filt_w (not the replacement value).

EBAT_U_RVAL_CW

This value is the replacement value in case the battery voltage (ebat_u_filt_w) exceeds the min or max limitations longer than EBAT_DT_DEF_CUC.

EBAT_DT_STRT_CUW and EBAT_N_BELOW_CW

The check for very low battery voltage is done only when engine speed (eess_n_avg_w) is greater than the threshold speed EBAT_N_BELOW_CW and time after start (strt_dt_off_uw) is greater than the threshold time EBAT_DT_STRT_CUW.

EBAT_PT1_U_CSTR

The raw value of the battery voltage (ebat_u_w) is filtered by a PT1 governor with the PT1 filter time EBAT_PT1_U_CSTR. The filtered output value of the battery voltage is provided in ebat_u_filt_w. This value is used for the battery voltage compensation of PWM-duty cycle. If this value is changed this may have an influence to the control of the power stages.

EBAT_DT_LODU_CUW

If a load dump is detected (ebat_s_lodu_b = TRUE) the monitoring of the power stages is disabled for the duration set with this label. As soon as the time (ebat_dt_lodu_uw) has reached the limit, the monitoring of the power stages is activated again. If the battery voltage (ebat_u_filt_w) drops below the threshold EBAT_U_LODU_CW before the time EBAT_DT_LODU_CUW is reached, then the monitoring of the power stages is enabled again at once.

EBAT_U_LODU_CW

If the battery voltage (ebat_u_lodu_w) exceeds the voltage threshold set in this parameter a load dump is detected.

3.3.7.3 Accelerator Pedal (EAPP)

The accelerator pedal calibration function is used to calibrate the 0% and 100% accelerator pedal value thresholds. The calibration function is disabled with running engine. The calibration values are stored to NVRAM as well as in the EEPROM.

The acceleration pedal contains two potentiometers which work in parallel → both potentiometers deliver a pedal value. This strategy is necessary to ensure a safe operation of the acceleration pedal also in case that one potentiometer breaks or has a fault.

The ratio between both potentiometers should be 2:1. If the ratio in your system is different, it can be calibrated in MS15 SW (see chapter "Ratio between both pedal potentiometer"). Both potentiometers are adjusted at the same time (see chapter "Pedal adjustment").

All necessary settings are done only for potentiometer 1. The corresponding calibration for the second potentiometer is calculated using the ratio value.

In normal operation and in case that the difference between the values of both potentiometers is greater than the allowed tolerance (see chapter "Fault handling for acceleration pedal") the minimum value of both potentiometers is used for the final acceleration pedal value.

In case that both potentiometers have an electrical defect the pedal value is set to 0[%] and the low idle speed set point is set to the value calibrated in LISP_N_PEDDEF_CW (see chapter "Low idle speed set point (LISC)").

3.3.7.3.1 Pedal adjustment

Affected CALIBRATION LABELS:

EAPP_S_ADJ_CUC	Manual acceleration pedal value adjustment

Corresponding MODAS-Worksheet: Accel_Pedal.mxws

Normal adjustment

While using the pre defined ModasSport configuration *AccPedal* the contained macros can be used for the pedal adjustment.

Acceleration pedal in 0[%] position

Press button “Set 0% pedal”

Acceleration pedal in 100[%] position

Press button “Set 100% pedal”

Alternative – Manual adjustment

In case the two macros are not available or do not work the pedal adjustment has to be done manually using the calibration label EAPP_S_ADJ_CUC and the following advices:

The manual adjustment has to be done in the following sequence:

- Engine speed = 0[rpm]
- Start adjustment
- Acceleration pedal in 0[%] position
- Set bit 0.
- Wait 3 sec
- Reset bit 0
- Acceleration pedal in 100[%] position
- Set bit 1
- Wait 3 sec
- Reset bit 1

Adjustment finished

To ensure that the pedal values of 0[%] and 100[%] are reached after adjustment during normal operation the corresponding voltages for 0[%] (eapp_u_low1_u and eapp_u_low2_u) and 100[%] (eapp_u_hi1_u and eapp_u_hi2_u) are changed by EAPP_U_ADJOFFSET_CW.

Lower voltage thresholds:

eapp_u_low1_u = eapp_u_adc1_w + EAPP_U_ADJOFFSET_CW

eapp_u_low2_u = eapp_u_adc2_w + EAPP_U_ADJOFFSET_CW * EAPP_R_PEDAL2_CW

Upper voltage thresholds:

eapp_u_hi1_u = eapp_u_adc1_w - EAPP_U_ADJOFFSET_CW

eapp_u_hi2_u = eapp_u_adc2_w - EAPP_U_ADJOFFSET_CW * EAPP_R_PEDAL2_CW

For testing purpose when the adjustment is finished press the acceleration pedal to 0[%], 50[%], and 100[%] and check the acceleration pedal value (eapp_pv_w). The measures values must be:

eapp_pv_w = 0[%] in case the acceleration pedal is released completely, and

eapp_pv_w = 100[%] in case the acceleration pedal is pressed completely.

In between 0[%] and 100[%] the pedal characteristic should be linear. Press the pedal to 50[%] and compare the value of eapp_pv_w – should be 50[%] as well.

Further on check the fault information displayed in eapp_s_def1_uc and eapp_s_def2_uc – must be “ok”!

If all checks are ok the adjustment was successful!

If something is wrong with the adjustment of the acceleration pedal and the checks were not successful, please read the following hints for the other calibration labels of EAPP in order to solve the problem.

3.3.7.3.2 Ratio between both pedal potentiometers

Affected CALIBRATION LABELS:

EAPP_R_PEDAL2_CW	Voltage ratio of second accelerator pedal track

Corresponding MODAS-Worksheet: Accel_Pedal.mxws

The ratio between both potentiometers of the accelerator pedal is assumed to be 2:1 (=default calibration). If the ratio is not 2:1 (= 0,5) this can be changed with the calibration label EAPP_R_PEDAL2_CW.

For example:

Voltage range of potentiometer 1: 0[V]...5[V]

Voltage range of potentiometer 2: 0[V]...2,5[V]

→ Ratio is 0,5

This ratio is used to calculate internally all values for potentiometer 2, because only the values for potentiometer 1 are calibrated.

3.3.7.3.3 Fault handling for acceleration pedal

Affected CALIBRATION LABELS:

EAPP_U_MAX_CW	Threshold voltage for SRC_MAX
EAPP_U_MIN_CW	Threshold voltage for SRC_MIN
EAPP_PV_MAXDIF_CW	Plausible range of difference of accelerator pedal values
EAPP_DEB_CSTR.DT_DEF_CUW	Timer for defect recognition of accelerator pedal
EAPP_DEB_CSTR.DT_OK_CUW	Timer for intact recognition of accelerator pedal

Corresponding MODAS-Worksheet: Accel_pedal.mxws

The minimum and maximum voltage is each calibrated only for potentiometer 1 (min: EAPP_U_MIN_CW; max: EAPP_U_MAX_CW). The limits for the second potentiometer are calculated using the value of EAPP_R_PEDAL2_CW.

If the accelerator pedal voltages (eapp_u_adc1_w / eapp_u_adc2_w) are below resp. above the thresholds a short circuit to GND resp. to Battery is detected for the specific signal line by the MS15 SW. The fault is shown in fmonact_d_faultnum_uc and fmonact_d_faulttype_uc.

The allowed maximum tolerance between the physical values of both potentiometers (eapp_pv_adc1_w and eapp_pv_adc2_w) is calibrated with EAPP_PV_MAXDIF_CW.

If the difference is bigger the accelerator pedal is classified defect and the fault is shown in fmonact_d_faultnum_uc and fmonact_d_faulttype_uc.

The time to detect a fault is set in EAPP_DEB_CSTR.DT_DEF_CUW. The signal fault is reset after the signal is intact again for the time set in EAPP_DEB_CSTR.DT_OK_CUW.

3.3.7.3.4 Automatic adjustment of accelerator pedal

Affected CALIBRATION LABELS:

EAPP_U_HI_DEFAULT_CW	Upper default threshold of accelerator pedal position track
EAPP_U_LOW_DEFAULT_CW	Lower default threshold of accelerator pedal position track

Corresponding MODAS-Worksheet: Accel_Pedal.mxws

EAPP_U_LOW_DEFAULT_CW and EAPP_U_HI_DEFAULT_CW

The adjustment of the acceleration pedal can be done automatically using default values for low and high voltage thresholds calibrated in EAPP_U_LOW_DEFAULT_CW and EAPP_U_HI_DEFAULT_CW.

It is recommended to use this method just as backup, in case the manual adjustment does not work properly. For details please refer to chapter EAPP of the MS15 documentation.

Calibration example for low and high default voltages:

Low: EAPP_U_LOW_DEFAULT_CW = 1000[mV] equal eapp_pv_w = 0[%])

High: EAPP_U_HI_DEFAULT_CW = 4000[mV] equal eapp_pv_w = 100[%]

EAPP_U_ADJOFFSET_CW

To ensure that the pedal values of 0[%] and 100[%] are reached during normal operation the corresponding voltages for 0[%] (eapp_u_low1_u and eapp_u_low2_u) and 100[%] (eapp_u_hi1_u and eapp_u_hi2_u) are changed by EAPP_U_ADJOFFSET_CW.

Lower voltage thresholds:

eapp_u_low1_u = eapp_u_adc1_w + EAPP_U_ADJOFFSET_CW

eapp_u_low2_u = eapp_u_adc2_w + EAPP_U_ADJOFFSET_CW * EAPP_R_PEDAL2_CW

Upper voltage thresholds:

eapp_u_hi1_u = eapp_u_adc1_w - EAPP_U_ADJOFFSET_CW

eapp_u_hi2_u = eapp_u_adc2_w - EAPP_U_ADJOFFSET_CW * EAPP_R_PEDAL2_CW

3.3.7.4 Vehicle speed sensor (EVSS)

Affected CALIBRATION LABELS:

EVSS_S_ENABLE_CB	Switch to enable sensor (1=with sensor, 0=without)
EVSS_CT_IMPREF_CUW	Reference number of impulses for normalization
EVSS_D_WHEEL_CUW	Wheel circumference
EVSS_V_MAX_CW	Maximum vehicle speed
EVSS_V_RVAL_CW	Replacement value for vehicle speed incase of defective VSS
EVSS_R_SHAFT_CW	Shaft ratio for vehicle speed
EVSS_PT1_A_CSTR.T1	Time constant for filtering acceleration
EVSS_PT1_V_CSTR.T1	Parameter set for filtering vehicle speed
EVSS_DT_DEF_CUW	Time for defect classification
EVSS_DT_MAX_CUW	Maximum period to recognise vehicle speed as 0
EVSS_DT_OK_CUW	Time for intact classification
EVSS_D_CHANNEL_CUC	Sensor input chanel selection (ECU PIN)

Corresponding MODAS-Worksheet: EVSS_sensor.mxws

During normal operation the vehicle speed (evss_v_w) and the vehicle acceleration (evss_a_w) are calculated based on a trigger wheel mounted on one of the wheels of the car. It is recommended to use one of the non driven wheels, in order to avoid wheel slip influences to the vehicle speed. If the sensor is mounted to a wheel of the front axle of the car, the vehicle speed may be influenced by blocking wheels and could show a smaller speed value than the real vehicle speed.

Sensor activation

If a vehicle speed sensor is mounted to the car it has to be enabled by setting EVSS_S_ENABLE_CB to 1 – to disable the sensor this parameter has to be set to 0.

Speed calculation

To be able to calculate the speed the following parameters have to be set in calibration:

Number of impulses on trigger wheel (EVSS_CT_IMPREF_CW)

Ratio of drive shaft (EVSS_R_SHAFT_CW)

Wheel circumference (EVSS_D_WHEEL_CUW)

Fault handling

The physical limitation for the engine speed (evss_v_w) to detect a failure is calibrated with EVSS_V_MAX_CW. The fault is set after the duration EVSS_DT_DEF_CUC is exceeded. The fault is shown in the failure monitor (fmonact_d_faultnum_uc and fmonact_d_faulttype_uc). If this fault is active still the measured vehicle speed is displayed.

In case of all other final defects the replacement vehicle speed EVSS_V_RVAL_CW is taken for evss_v_w.

If for the duration EVSS_DT_OK_CUC there is no error then the vehicle speed (evss_v_w) is considered valid again.

Zero-speed detection

The vehicle speed (evss_v_w) is set to “0” as soon as the time periods (evss_dt_period_w) coming from the impulses of the trigger wheel exceed the value set in EVSS_DT_MAX_CW.

In case the evaluation of the vehicle speed sensors does not work properly please check the settings of the following calibration labels as well in order to solve the problems.

Signal filtering

The vehicle speed (evss_v_w) is filtered with the value set in EVSS_PT1_V_CSTR.T1. The filtered vehicle speed (evss_v_filt_w) is the value that is used as input for other functions and that should be measured by the user.

The vehicle acceleration (evss_a_w) is filtered with the value set in EVSS_PT1_A_CSTR.T1. The filtered vehicle acceleration (evss_a_filt_w) is the value that is used as input for other functions and that should be measured by the user.

3.3.7.5 General calibration settings for temperature and pressure sensors

The strategy to calibrate a temperature or pressure sensor is always the same within the MS15 SW and so also the set of parameters for calibration of one specific sensor is always the same.

In the following there is a description of all parameters that are equal for all temperature and pressure sensors.

Some variance does occur depending on the sensor being calibrated. Refer to the software documentation for any detailed questions.

3.3.7.5.1 Sensor activation

Affected CALIBRATION LABELS:

EXXX_CFG_CSTR.S_SEN_CUW	Sensor activation flags

Corresponding MODAS-Worksheet: EXXX_sensor.mxws

EXXX_CFG_CSTR.S_SEN_CUW determines if the sensor is active or not in the system. The label is bit-coded. If the sensor is present, switch bit ‘0’ to true. If the sensor is not present in the system, switch bit ‘0’ to false.

Beside the sensor activation the label provides a small set of other settings. For details please refer to the details given in the MS15 documentation

3.3.7.5.2 Fault handling

Affected CALIBRATION LABELS:

EXXX_CFG_CSTR.U_MAX_CW	Maximum voltage threshold for electrical fault
EXXX_CFG_CSTR.U_MIN_CW	Minimum voltage threshold for electrical fault
EXXX_CFG_CSTR.D_RVAL_CW	Own replacement value for sensor
EXXX_CFG_CSTR.PHY_MAX_CW	Maximum threshold for physical fault
EXXX_CFG_CSTR.PHY_MIN_CW	Minimum threshold for physical fault

Corresponding MODAS-Worksheet: EXXX_sensor.mxws

Max voltage detection

EXXX_CFG_CSTR.U_MAX_CW is the upper voltage at which the ECU sets a fault. The value should be beyond the maximum voltage that the sensor is capable of supplying to the ECU. Generally this fault is used to diagnose an unplugged sensor.

A fault due to this threshold is displayed in the fault monitoring. Which sensor the fault has is shown in fmonact_d_faultnum_uc, the corresponding fault type in fmonact_d_faulttype_uc.

In case this fault is active the replacement value EXXX_CFG_CSTR.D_RVAL_CW is taken for calculations and displayed in the corresponding variable.

Min Voltage detection

EXXX_CFG_CSTR.U_MIN_CW is the lower threshold voltage that will set a fault. This value should be set lower than the sensor is capable of supplying to the ECU. Generally this fault is used to diagnose a short circuit fault in the sensor circuit.

A fault due to this threshold is displayed in the fault monitoring. Which sensor has the fault is shown in fmonact_d_faultnum_uc, the corresponding fault type in fmonact_d_faulttype_uc.

In case this fault is active the replacement value EXXX_CFG_CSTR.D_RVAL_CW is taken for calculations and displayed in the corresponding variable.

Replacement value in case of error detection

EXXX_CFG_CSTR.D_RVAL_CW is the 'replacement value' in case of an electrical sensor fault. It should be set at a 'normal' operating value. For example, 90[°C] would be a good value to use for the coolant temp sensor in case of a fault of this sensor.

Max physical value detection

EXXX_CFG_CSTR.PHY_MAX_CW is the physical maximum measurable point in a sensor at which a fault is set. This should correspond to a physical value that is achievable with the sensor but should not be reached during operation. For example, if the coolant temperature reached 120[°C] it would be good to have an over temp warning and possibly an engine derate to help decrease engine temperatures.

A fault due to this threshold is displayed in the fault monitoring. Which sensor has the fault is shown in fmonact_d_faultnum_uc, the corresponding fault type in fmonact_d_faulttype_uc.

In case this fault is active the measured physical value is still displayed in the corresponding variable.

Min physical value detection

EXXX_CFG_CSTR.PHY_MIN_CW works the same as the MAX fault except for the lower range of the sensor. An example of using this sensor would be for low fuel supply pressure. A derate could be desired to prevent fuel system damage.

A fault due to this threshold is displayed in the fault monitoring. Which sensor has the fault is shown in fmonact_d_faultnum_uc, the corresponding fault type in fmonact_d_faulttype_uc.

In case this fault is active the measured physical value is still displayed in the corresponding variable (not the replacement value!!!).

3.3.7.5.3 Fault / heal debouncing

Affected CALIBRATION LABELS:

EXXX_DEB_CSTR.DT_DEF_CUW	Defect delay time OK to defect for electrical defect
EXXX_DEB_CSTR.DT_OK_CUW	Defect delay time defect to OK for electrical defect
EXXX_PHYDEB_CSTR.DT_DEF_CUW	Defect delay time OK to defect for physical defect
EXXX_PHYDEB_CSTR.DT_OK_CUW	Defect delay time defect to OK for physical defect

Corresponding MODAS-Worksheet: EXXX_sensor.mxws

EXXX_DEB_CSTR.DT_DEF_CUW is the 'debounce' time for the voltage high/low fault to set once the fault is detected.

EXXX_DEB_CSTR.DT_OK_CUW is the 'debounce' time for the voltage high/low fault to clear after set if the system is working properly again.

EXXX_PHYDEB_CSTR.DT_DEF_CUW is the 'debounce' time for the physical signal high/low fault to be set once an out of range fault is detected.

EXXX_PHYDEB_CSTR.DT_OK_CUW is the 'debounce' time for the physical signal high/low fault to clear after set if the system is working properly again.

3.3.7.5.4 ECU pin selection

Affected CALIBRATION LABELS:

EXXX_CFG_CSTR.CHN_MUX	Sensor input chanel selection (ECU PIN)

Corresponding MODAS-Worksheet: EXXX_sensor.mxws

EXXX_CFG_CSTR.CHN_MUX determines which ECU pin the signal is mapped too. This label generally should not be changed.

3.3.7.5.5 Sensor characteristics

Affected CALIBRATION LABELS:

EXXX_Y_LIN_CSTR.GRAD_CW	Gradient for linear sensor calculation
EXXX_Y_LIN_CSTR.OFFS_CW	Offset for linear sensor calculation
EXXX_Y_NORM_CUR	Normalisation curve for non linear sensor calculation

Corresponding MODAS-Worksheet: EXXX_sensor.mxws

Linear sensors

Gradient: EXXX_Y_LIN_CSTR.GRAD_CW (Y = sensor type. R=ratio, P=pressure, T=temp, etc) must be set to match the slope of a linear sensor. Use this in conjunction with calibration variable EXXX_P_LIN_CSTR.OFFS_CW. This information should be supplied by the sensor manufacturer.

Offset: EXXX_Y_LIN_CSTR.OFFS_CW (Y = sensor type. R=Ratio, P=pressure, T=temp, etc) must be set to match the voltage offset of a linear sensor. Use this in conjunction with calibration variable EXXX_P_LIN_CSTR.GRAD_CW. This should be supplied by the sensor manufacturer.

Non-linear sensors

EXXX_T_NORM_CUR defines the characteristic curve of a non-linear sensor. For resistance based sensors use supplied tool "Calculation_Temperature sensor.xls" to convert the sensor characteristic curve from resistance to voltage. The characteristic curve should be supplied by the sensor manufacturer.

3.3.7.5.6 Signal filtering

Affected CALIBRATION LABELS:

EXXX_PT1_CSTR.T1	PT1 filter structure

Corresponding MODAS-Worksheet: EXXX_sensor.mxws

EXXX_PT1_CSTR.T1 is used to filter out noise in the system. Each sensor could require a different filter value to make a smooth, yet fast responding signal.

3.3.8 Basic settings for engine speed evaluation and synchronization

Affected CALIBRATION LABELS:

ECRK_D_CYLy_CSTR.PHI_GPPOS_W y = number of cylinders	Gap position data for y cylinder engine
ECAM_S_CAMPINLOGIC_CB	CAM signal logic flag

Corresponding MODAS-Worksheet: Synchronization.mxws

The engine speed is measured using the crankshaft sensor. For synchronization purpose additionally the camshaft sensor is used.

3.3.8.1 Mechanical flywheel requirements

The crank- and camshaft tonewheel have to match the following mechanical main requirements in order to be able to synchronize the engine with the MS15.

Crankshaft-requirements: 60-2 tonewheel

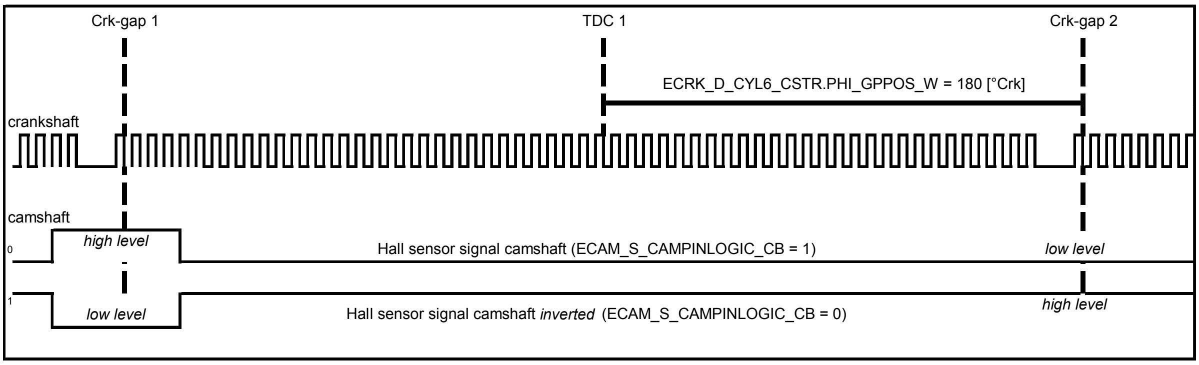
Camshaft-requirements: One tooth tonewheel (tooth = 20...25[°Cam] = 40...50[°Crk]).

Mounting requirements: The tone wheels have to be mounted to the engine so that...

The crankshaft gap (before TDC of cylinder 1 occurs) passes the crankshaft sensor at the same moment at which the tooth of the camshaft passes the camshaft sensor.

The crankshaft gap does not pass the crankshaft sensor while one cylinder is in expansion.

The following sketch gives an overview about the requirements for a 6-cylinder engine:



For more details please refer to chapter "*7.5 Evaluation of Engine Speed Sensing (EESS)*" of the MS15 documentation, where you can also find the requirements for 4- and 5-cylinder engines.

In case you match exactly the given configuration with your system (depending on the number of cylinders), you just have to check the polarity of the camshaft signal to be able to set the calibration of ECAM_S_CAMPINLOGIC_CB correct.

The default calibration of ECRK_D_CYLy_CSTR.PHI_GPPOS_W (y = number of cylinders), which contains the angle between TDC of cylinder 1 and the following crankshaft gap, fits already to these conditions.

In case the mounting conditions on the engine are different compared to the configuration given in the MS15 documentation, the calibration labels...

ECRK_D_CYLy_CSTR.PHI_GPPOS_W (y = number of cylinders)

ECAM_S_CAMPINLOGIC_CB ...have to be set accordingly.

For more details to find the good calibration of ECRK_D_CYLy_CSTR.PHI_GPPOS_W (y = number of cylinders) please refer to chapter "Synchronization setup".

4 Check of correct injection order

To ensure a safe operation of the engine the firing order of the injectors has to be correct. The connections done within chapter "Correct connection order of the injectors" have to be double checked now by controlling the injectors electrically while the engine is not running.

To control the injectors electrically the MS15 needs an engine speed signal and a rail pressure set point unequal to "0".

Using the function "Remote Control" (RMTC) it is possible to generate an internal engine speed signal although the engine is not running and also to set the set point for the rail pressure independent of all normally necessary conditions.

IMPORTANT HINT: The use of the RMTC function has to be done very carefully!!! Do not use the function without any given advices from Bosch Motorsport side (e.g. like the following description)! It is very easy to seriously damage or even destroy the engine using the RMTC function!

4.1 Use of RMTC function to check correct injection order

Affected CALIBRATION LABELS:

RMTC_S_VS100_ON_CB	Main Switch to enable remote control function RMTC
RMTC_S_EESS_CUC	Switch to enable remote control mode for funtion EESS
RMTC_N_EESS_CW	Remote control value for engine speed (eess_n_avg_w)
RMTC_S_FPSC_CUC	Switch to enable remote control mode for funtion FPSC
RMTC_P_FPSC_CW	Remote control value for rail pressure setpoint (fpsc_p_w)

Corresponding MODAS-Worksheet: RMTC_Inj_Order.mxws

Please follow exactly to the below given advices to check the correct firing order:

Engine is not running!

Set RMTC_N_EESS_CW to 700[rpm] (replacement value for engine speed (eess_n_avg_w))

Set RMTC_P_FPSC_CW to 50[MPa] (replacement value for rail pressure set point (fpsc_p_w))

Set RMTC_S_EESS_CUC to 1 (enable remote control for function EESS)

Set RMTC_S_FPSC_CUC to 1 (enable remote control for function FPSC)

Set RMTC_S_VS100_ON_CB to 1 (global enable of remote control)

Check eess_n_avg_w = 700[rpm] and fpsc_p_w = 50[MPa]

The injectors should click now one after the other in the correct firing order – to evaluate go close to the engine and listen

In case the clicks are too fast to locate the injector firing order you can reduce the engine speed in RMTC_N_EESS_CW to a smaller value (e.g. 500[rpm])

In case the injector firing order is NOT correct the connection order of the harness plugs to the injectors has to be checked (see chapter "Correct connection order of the injectors"). Change the connections to get the correct firing order.

To avoid any damage to the injectors do not run the injectors longer in the remote control mode than necessary to check the firing order!

Reset RMTC_S_VS100_ON_CB to 0 (global disable of remote control)

Check eess_n_avg_w = 0[rpm] and fpsc_p_w = 0[MPa]

Reset RMTC_S_FPSC_CUC to 0 (disable remote control for function FPSC)

Reset RMTC_S_EESS_CUC to 0 (disable remote control for function EESS)

Set RMTC_P_FPSC_CW to 0[MPa] (replacement value for rail pressure set point (fpsc_p_w))

Set RMTC_N_EESS_CW to 0[rpm] (replacement value for engine speed (eess_n_avg_w))

5 Cranking of the engine (no injection)

The engine is now “nearly” ready to be cranked for the first time. Before cranking the engine for the first time it must be checked, if there are any faults active, which have to be eliminated before (see chapter “Error check”).

After the check for errors is complete and are no faults that prevent engine cranking, the next mandatory step is the prevent fuel from being injected while the engine is cranked for the first time (see chapter “Avoid fuel injection during synchronization check”).

Now the engine is ready to be cranked for the first time, in order to check the synchronization behavior (see chapter “Check synchronization setup”).

The next calibration steps that have to be performed are described in the subsequent chapters. It is recommended to follow the sequence of the chapters to achieve a best possible calibration result.

5.1 Error check

Corresponding MODAS-Worksheet: Faults_memory.mxws

Before cranking the engine it is mandatory that there are no active faults in the system in order to ensure a safe operation. To check the correct function of all components the fault information displayed in fmonact_d_faultnum_uc and fmonact_d_faulttype_uc have to be evaluated.

If everything is fine, neither variable will show a message (= 0). In case one or more faults are active in the system they are displayed within these two variables. The information given in the variables helps to locate and solve the fault(s).

The most probable reasons for faults of sensors are:

- Sensors are enabled in SW although they are not equipped

  → Check setting for the corresponding sensor of EXXX_CFG_CSTR.S_SEN_CUW
- Wrong calibration of the minimum / maximum thresholds for the electrical / physical thresholds

  → Check setting for the corresponding sensor of...
  - ...electrical: EXXX_CFG_CSTR.U_MAX_CW and EXXX_CFG_CSTR.U_MIN_CW
  - ...physical: EXXX_CFG_CSTR.PHY_MAX_CW, EXXX_CFG_CSTR.PHY_MIN_CW
- Too short debounce times for final electrical / physical fault detection

  → Check setting for the corresponding sensor of ...
  - ...electrical: EXXX_DEB_CSTR.DT_DEF_CUW
  - ...physical: EXXX_PHYDEB_CSTR.DT_DEF_CUW

In case of other faults please refer to more detailed information provided by the MS15 documentation.

To erase faults memory by data, set the switch FMON_S_NEWAPPDATA_CB to true (1) and reset to false (0) within a time window (FMON_DT_ERASEMAX_CUC < fmon_dt_erasef_uc < FMON_DT_ERASEMIN_CUC). The faults are able to be erased after the syncronisation time FMON_DT_ON_CUW. Faults active can not be erased.

5.2 Avoid fuel injection during synchronization check

Affected CALIBRATION LABELS:

FPC3_I_FLOWNORM_CUR	Norm curve to calculate current equivalent of the FMU flow ratio

Corresponding MODAS-Worksheet: Rail_pressure_FMU.mxws

To avoid any fuel being injected during the first cranking of the engine, do the following setting in calibration for the characteristic curve of the HP pump.

FPC3_I_FLOWNORM_CUR										
[%]	**0.0**	**2.7**	**10.1**	**15.1**	**24.3**	**43.6**	**62.9**	**78.3**	**92.7**	**100.0**
[mA]	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700

Background information:

If no fuel is inside the HP fuel rail it is not possible to inject fuel by the injectors → no firing of the engine is possible!

The target in order to avoid a firing of the engine is to avoid fuel coming to the HP fuel rail. The fuel delivered to the HP fuel rail is controlled by the fuel metering unit (FMU). That means if the FMU does not deliver any fuel to the HP fuel rail the engine can not be fired!

The function logic of the FMU is, that it does not deliver any fuel, if it is controlled with the maximum current value of 1700[mA]. To avoid fuel injection the complete FMU characteristic curve is set to the maximum current value of 1700[mA] (see above) in order that no fuel comes to the HP fuel rail and so no firing is possible!

The benefit of this strategy is that there is still fuel available in the LP fuel circuit for the necessary lubrication of the turning HP pump, which would be not the case if e.g. the electrical fuel pump (EFP) would be only disconnected!

5.3 Detection of calibrated position of TDC cylinder 1

Affected CALIBRATION LABELS:

ECRK_D_CYLy_CSTR.PHI_GPPOS_W (y = number of cylinders)	Gap position data for y cylinder engine
BIMI_PHI_STRT_GMP	Begin of main injection start map

Corresponding MODAS-Worksheet: Synchronisation.mxws

The TDC position for cylinder 1 is calibrated relative to the crankshaft gap position, with the calibration label ECRK_D_CYLy_CSTR.PHI_GPPOS_W (y = number of cylinders). The position of the crankshaft gap is detected by the MS15 SW.

To ensure a good and safe operation of the engine it is mandatory that the physical position of TDC cylinder 1 is equal to the calibrated position of TDC cylinder 1.

The relation between physical and calibrated position of TDC cylinder 1 can be checked by measuring the following two signals with a transient recorder (high sample rate >10[kHz]) while cranking the engine

Cylinder 1 indication of dyno OR Cylinder pressure signal of Cylinder 1 (physical position)*

Cylinder 1 injector control signal in case begin of injection angle is calibrated to bimi_phi_w = 0[°Crk]

* If the engine dyno does not provide the possibility of “cylinder 1 detection” the physical TDC cylinder 1 position has to be determined by the cylinder 1 pressure signal. This pressure can not be measured with the MS15. To measure this signal special measurement equipment is necessary.

To measure the calibrated TDC cylinder 1 position a workaround in calibration is necessary.

→ With the calibration in the map BIMI_PHI_STRT_GMP the beginning of injection angle (during engine start) is set relative to TDC. Set the calibration map BIMI_PHI_STRT_GMP completely to “0”. With this setting the electrical control for the injector starts directly at the TDC cylinder 1 during engine start.

Now the TDC position of cylinder 1 can be displayed with a transient recorder by using a current probe to measure the electrical control signal of cylinder 1.

The physical and the calibrated position of the TDC cylinder 1 are equal, if the position of the cylinder 1 indication OR max cylinder pressure (physical) is same with the position at which the injection signal starts (calibrated).

Do the check of the correct TDC position in parallel with the first cranking of the engine for the synchronization check (see chapter “Check synchronization setup”).

5.4 Check synchronization setup

After it has been verified that there are no active errors in the system (see chapter "Error check") and after the necessary settings to avoid fuel injection (see chapter "Avoid fuel injection during synchronisation check") are performed, the engine can be cranked to measure and store the following signals with a transient recorder (high sample rate > 10[kHz]) in order to check the synchronization behaviour:

crankshaft signal

camshaft signal

Cylinder 1 indication OR cylinder pressure signal of cylinder 1 (see chapter "Detection of calibrated position of TDC cylinder 1")

injector current of cylinder 1 (see chapter "Detection of calibrated position of TDC cylinder 1")

Use the measurement to verify the calibrated position of TDC cylinder 1 by comparing the angle between the maximum of the cylinder pressure signal to the following crankshaft gap with the value calibrated in ECRK_D_CYLy_CSTR.PHI_GPPOS_W (y = number of cylinders).

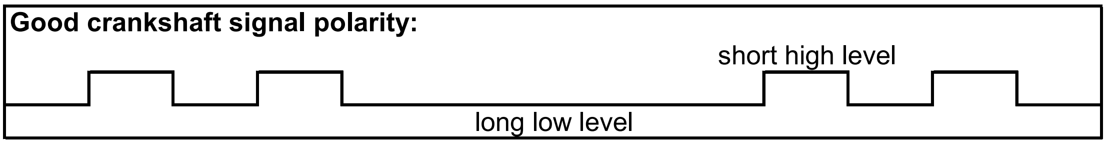
The angle can be measured by counting the crankshaft teeth. Each tooth is equal 6[°Crk] (360[°Crk] / 60[teeth] = 6[°Crk] / 1[tooth]).

If the value of ECRK_D_CYLy_CSTR.PHI_GPPOS_W (y = number of cylinders) and the degrees measured from TDC cylinder 1 to the following crankshaft gap are equal, then the calibrated TDC cylinder 1 position is equal to the physical TDC1 position, marked by the maximum of the cylinder pressure signal.

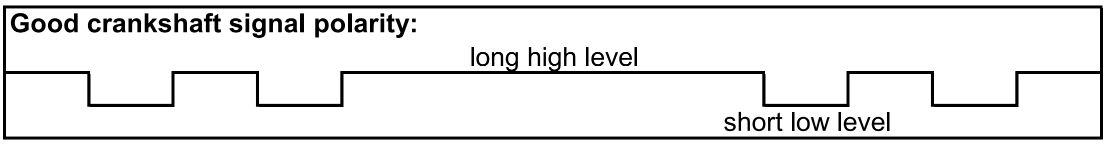
5.4.1 Check crankshaft signal polarity

The signal polarity of the crankshaft signal can be checked by the signal level in the crankshaft gap.

Good crankshaft signal polarity – long low level followed by short high level inside crankshaft gap:



Wrong crankshaft signal polarity – long high level followed by short low level inside crankshaft gap:



If the signal polarity is wrong the system will be able to synchronize, but all angles will be shifted by 3[°Crk] compared to the correct physical position of the engine.

To fix the wrong signal polarity just swap e.g. the electrical lines at the crankshaft sensor.

5.4.2 Position of segment synchronous interrupt

Affected CALIBRATION LABELS:

EESS_D_CYLy_CSTR.PHI_SEG0_W (y=number of cylinders	Position of segment synchronous interrupt
EESS_N_MIN_CW	Minimum engine speed to detect engine stop
EESS_N_ACCEL_PHASE_SEARCH_CW	Engine speed threshold to consider correct engine phase during test-injections
EESS_CT_PHASE_VERIFY_CUC	Number of revs to verify the present engine phase if detected by acceleration in WAIT_PHASE

Corresponding MODAS-Worksheet: Synchronisation.mxws

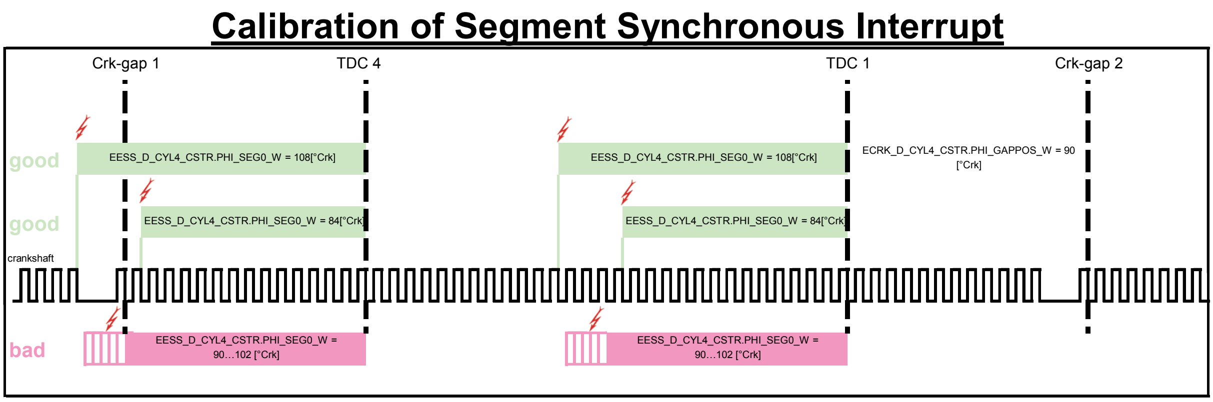
The segment synchronous interrupt is used to calculate all parameters for the injection of the following cylinder. The position of the segment synchronous interrupt is calibrated relative to the TDC position using the calibration value EESS_D_CYLy_CSTR.PHI_SEG0_W (y = number of cylinders).

It is mandatory to check that the calibrated position of the segment synchronous interrupt is not inside the crankshaft gap. In case the segment synchronous interrupt is inside the crankshaft gap the calculation of the engine speed (eess_n_avg_w) will be faulty → although the engine physically is running without oscillations the displayed engine speed (eess_n_avg_w) will show oscillations. To solve the problem...

...increase the angle EESS_D_CYLy_CSTR.PHI_SEG0_W (y = number of cylinders) until the position of the segment synchronous interrupt is at the falling edge with which the crankshaft gap begins OR

...decrease the angle EESS_D_CYLy_CSTR.PHI_SEG0_W (y = number of cylinders) until the position of the segment synchronous interrupt is at the second falling edge after the crankshaft gap!

The following picture shows examples for good and bad calibrations of the segment synchronous interrupt position on a 4-cylinder engine.



Graphic 26 (Calibration_SegSyncInt.xls)

Synchronization states of Meta-state machine (eess_s_meta_uc)

The synchronization state of the system is displayed in the Meta-state machine (eess_s_meta_uc). The system is well synchronized if the Meta-state machine is equal EESS_S_M_OK_DUC (=10).

The Meta-state machine (eess_s_meta_uc) has the following subsequent states in case all signals are ok and the synchronization works fine:

```
0 "Engine stopped"
1 "Searching valid INCs"
2 "Searching for 1st gap"
4 "wait for corr. phase, angle correct mod. 360 deg."
5 "Phase Verify after accel."
9 "runs w/o CAM"
10 "all OK"
11 "Remote controlled"
```

EESS_S_M_TIMEOUT_DUC (=0) – Engine has stopped → engine speed (eess_n_avg_w) is below EESS_N_MIN_CW.

EESS_S_M_POLLING_DUC (=1) – This is an intermediate state in which the Meta-state machine is initialized while the system is polling for the crank signal and/or the cam signal from the sensors. The state is left again as soon as valid signals from crankshaft and / or camshaft are detected.

EESS_S_M_WAIT_GAP_DUC (=2) – This is an intermediate state in which the Meta-state machine is waiting for the detection of the crankshaft gap. The state is left again as soon as the gap position is detected by the MS15 SW. When the state is left the system angle is correct modulo 360[°Crk].

EESS_S_M_WAIT_PHASE_DUC (=4) – This is an intermediate state in which the Meta-state machine is waiting for the detection of the valid camshaft signal level. After the valid camshaft signal information is found, the system angle is corrected by 360[°Crk] if necessary. Now the signals of crank- and camshaft are valid and the final state of the Meta-state machine EESS_S_M_OK_DUC (=10) is entered

In parallel to the evaluation of the camshaft signal injections are released in case the engine speed (eess_n_avg_w) is smaller than EESS_N_ACCEL_PHASE_SEARCH_CW. If the engine accelerates based on the injections to an engine speed (eess_n_avg_w) higher than EESS_N_ACCEL_PHASE_SEARCH_CW, then the present system angle (ecrk_phi_w) based on the crankshaft gap is set valid and the Meta-state machine changes to state *EESS_S_M_VERIFY_PHASE_DUC (=5)* without having the detailed information of the camshaft.

EESS_S_M_OK_DUC (=10) – This is the final state of the Meta-state machine in case the synchronization was successful.

The Meta-state machine remains in this state until the engine is stopped (eess_n_avg_w < EESS_N_MIN_CW) or until a defect crankshaft sensor is detected (ecrk_s_def_uc).

For further operation of the engine only the crankshaft signal is used. That means that the engine can be operated normally without camshaft as long as it keeps running. If the engine is stopped and restarted the camshaft signal is necessary again for a normal start procedure.

There are two additional states which are used in case that the camshaft signal is not valid. If these states are used the synchronization system has a fault or the layout is not optimized. Nevertheless the engine can be started with the MS15 system using a backup strategy for a defect camshaft signal. It is not possible to start the engine if the crankshaft system has a fault.

EESS_S_M_VERIFY_PHASE_DUC (=5) – This state is an intermediate state in which the Meta-state machine is waiting for the verification of the system angle, which was set due to an acceleration forced by the injections that were released in state *EESS_S_M_WAIT_PHASE_DUC (=4)*. If the engine speed stays above the calibrated threshold EESS_N_ACCEL_PHASE_SEARCH_CW for more than the calibrated number of crankshaft revolutions set in EESS_CT_PHASE_VERIFY_CUC, then the Meta-state machine changes to state *EESS_S_M_ALONE_DUC (=9)*.

EESS_S_M_ALONE_DUC (=9) – This is the final state of the Meta-state machine in case that the synchronization was successful without valid camshaft signal. The angle accuracy is as precise as in state *EESS_S_M_OK_DUC (=10)*.

The Meta-state machine remains in this state until the engine is stopped (eess_n_avg_w < EESS_N_MIN_CW) or until a defect crankshaft sensor is detected (ecrk_s_def_uc).

6 Fire the engine

Now all settings and checks in SW are performed to be able to start the engine for the first time. Before the start button is pressed it has to be ensured again that all necessary fluid plugs (e.g. oil, fuel, water) are connected and that the accelerator pedal (eapp_pv_w) is in 0[%]-position.

Based on the settings done in chapter 3, the engine speed (eess_n_avg_w) should reach the idle speed set point (lisc_n_w) of 1000[rpm] after the starter button is pressed.

For all calibrations done with a fired engine it is mandatory to check the cylinder pressure signal and the exhaust gas temperature in order to ensure, that they always stay in the valid range (the valid limits are given by the engine- and turbocharger-manufacturer)!!!

Further on it is important to check that some basic temperature (water, oil, etc...) and pressure (water, oil, etc...) values stay inside the valid tolerances, given by the engine manufacturer. As soon as one value is out of range stop the engine and solve the problem before proceeding with the calibration work.

Normally an engine dynamometer (dyno) provides the possibility to monitor some essential engine data and to stop the engine in case of problems. Following there is a list containing some data that should be monitored with the data including a backup strategy the dyno uses in case of problems:

Pressure signals.

Physical signal	MS15 name	Limit to monitor
Cylinder pressure	not part of MS15 SW	maximum value
Exhaust gas pressure	eegp_p_w	minimum and maximum value
Oil pressure	eops_p_w	minimum and maximum value
Low fuel pressure	elfps_p_w	minimum and maximum value
Boost pressure	ebps_p_w	maximum value

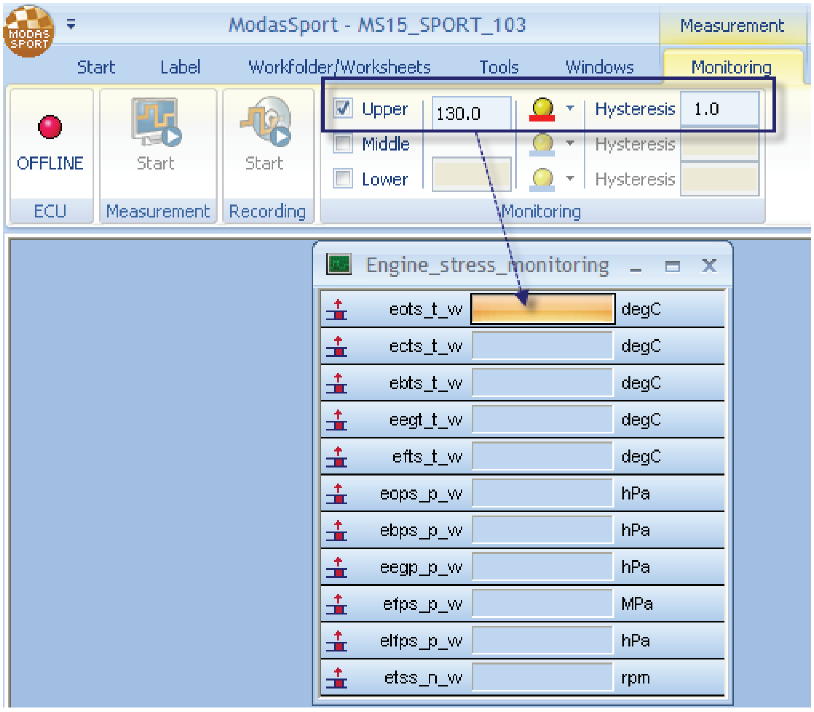
Temperature signals

Exhaust gas temperature	eegt_t_w	maximum value
Oil temperature	eots_t_w	minimum and maximum value
Coolant water temperature	ects_t_w	minimum value
Fuel temperature	efts_t_w	maximum value
Boost temperature	ebts_t_w	maximum value

Feel free to check the measure window called “Engine_stress_monitoring” which is available in all suggested MODAS-Worksheets.

Recommandation: configure the monitoring threshold accordingly to your engine requirements.

See the configuration example below:


ModasSport - MS15_SPORT_103
Measurement
Start
Label
Workfolder/Worksheets
Tools
Windows
Monitoring
OFFLINE
ECU
Start
Measurement
Start
Recording
Upper
130.0
Hysteresis
1.0
Middle
Hysteresis
Lower
Hysteresis
Monitoring
Engine_stress_monitoring
eots_t_w degC
ects_t_w degC
ebts_t_w degC
eegt_t_w degC
efts_t_w degC
eops_p_w hPa
ebps_p_w hPa
eegp_p_w hPa
efps_p_w MPa
elfps_p_w hPa
etss_n_w rpm

6.1 Engine does not reach idle speed

Affected CALIBRATION LABELS:

STRT_Q_MAP	Fuel quantity for start procedure
BIMI_PHI_STRT_GMP	Begin of main injection start map
FPSC_P_SPST_MAP	Base map fuel pressure set point for start

Corresponding MODAS-Worksheet: EngineStart.mxws

In case the engine does not start or the low idle speed set point (lisc_n_w) is not reached after the start button is pressed, check the following values to solve the problem:

Injection begin angle (bimi_phi_w) – should be equal to the data in BIMI_PHI_STRT_GMP. Please check that the position of the maximum cylinder pressure value is not too early, which could damage the piston. A good position is at about 10[°Crk] after TDC. If necessary do a fine tuning of the BIMI calibration in BIMI_PHI_STRT_GMP.

In case the position of the maximum cylinder pressure is too early the calibration of the beginning of injection angle has to be reduced at the corresponding working point in map BIMI_PHI_STRT_GMP.

In case the position of the maximum cylinder pressure is too late the calibration of the beginning of injection angle has to be increased at the corresponding working point in map BIMI_PHI_STRT_GMP.

Injection fuel quantity (fqsc_q_w) – as long as the injection fuel quantity (fqsc_q_w) is calculated in start mode (fqsc_s_uc = 243 = start procedure) the injection quantity has to refer to the calibration of STRT_Q_MAP.

When the start mode is left and the pedal command (eapp_pv_w) is 0 the control of the injection fuel quantity (fqsc_q_w) is done by the low idle controller (fqsc_s_uc = 240 = low idle governor).

In case the accelerator pedal (eapp_pv_w) is unequal to 0[%] the engine speed (eess_n_avg_w) is probably higher than the low idle speed set point (lisc_n_w) and the injection fuel quantity (fqsc_q_w) is calculated based on the driver's demand (fqsc_s_uc = 241 = driver over pedal in control).

In case no fuel at all is injected, check the fuel injection state (fqsc_s_uc). If it is equal FQSC_S_ZERO_DUC (251) then there is a request in the ECU to disable injections and the engine will not start. This needs to be fixed in order for the engine to start. In this case check the state of the central monitoring logic (cmol_s_qzero_uc) in bit form and see what bit(s) is/are disabling injection. See the software documentation for more details.

Rail pressure (efps_p_w) –as long as the system is in start mode (strt_s_uc != 0 = AFTER_START) the rail pressure (efps_p_w) must increase to the rail pressure set point (fpsc_p_w) set in FPSC_P_SPST_MAP. As soon as the start mode is left (strt_s_uc = 0 = AFTER_START) the rail pressure (efps_p_w) must become equal to the referring set point derived from the map FPSC_P_SP_MAP. Measure the control state of the HP pump (fpc3_s_mode_uc) and check the state transitions → they should proceed from FPC3_S_START_DUC (4) to FPC3_S_CNTRL_DUC (9).

If the rail pressure does not increase at all check...

- ...the HP pump control state (fpc3_s_mode_uc)
- ...the control command of the HP pump (fpsc_dc_w) as well as the HP pump current value (fpc3_i_filt_w) – remember that high current values are equivalent to low flow ratios.
- ...the low fuel pressure (elfps_p_w) – should meet the high pressure pump specification given by the manufacturer.
- ...the HP-system for leakage.

If the engine does not start although the position of the injection angle and the rail pressure are fine, it is necessary to increase the injection fuel quantity in map STRT_Q_MAP.

In case the injection fuel quantity during start is increased also the injection begin angle has to be increased (bigger value in BIMI_PHI_STRT_GMP).

6.2 Engine starts with big overshoot in engine speed

Affected CALIBRATION LABELS:

STRT_Q_MAP	Fuel quantity for start procedure
BIMI_PHI_STRT_GMP	Begin of main injection start map

Corresponding MODAS-Worksheet: EngineStart.mxws

If the engine starts with a big overshoot (>200[rpm]) in engine speed (eess_n_avg_w) before the low idle speed set point (lisc_n_w) is reached, then the injection fuel quantity during start calibrated in STRT_Q_MAP is too high. The combustion noise in this case is probably quite loud.

Reduce the calibrated injection fuel quantity in STRT_Q_MAP in order to reduce the overshoot in engine speed (eess_n_avg_w) and the combustion noise.

Please take into consideration that the beginning of injection angle calibrated in BIMI_PHI_STRT_GMP has to be reduced as well to ensure the correct position of the maximum cylinder pressure at about 10[°Crk] after TDC if the injection fuel quantity is reduced.

6.3 Calibration of low idle controller

Affected CALIBRATION LABELS:

LICO_PW_CSTR.CPWIN	P-part negative signal amplification (WARM)
LICO_PW_CSTR.CPNEG	P-part positive signal amplification (WARM)
LICO_PW_CSTR.CPPOS	P-part small signal amplification (WARM)
LICO_PW_CSTR.WINEG	negative small signal window (WARM)
LICO_PW_CSTR.WIPOS	positive small signal window (WARM)
LICO_PC_CSTR.CPWIN	P-part negative signal amplification (COLD)
LICO_PC_CSTR.CPNEG	P-part positive signal amplification (COLD)
LICO_PC_CSTR.CPPOS	P-part small signal amplification (COLD)
LICO_PC_CSTR.WINEG	negative small signal window (COLD)
LICO_PC_CSTR.WIPOS	positive small signal window (COLD)
LICO_IW_CSTR.CIWIN	I-Part neg. signal amplification (WARM)
LICO_IW_CSTR.CINEG	I-Part pos. signal amplification (WARM)
LICO_IW_CSTR.CIPOS	I-Part small signal amplification (WARM)
LICO_IW_CSTR.WINEG	I-Part neg. window for small signal amplification (WARM)
LICO_IW_CSTR.WIPOS	I-Part pos. window for small signal amplification (WARM)
LICO_IC_CSTR.CIWIN	I-Part neg. signal amplification (COLD)
LICO_IC_CSTR.CINEG	I-Part pos. signal amplification (COLD)
LICO_IC_CSTR.CIPOS	I-Part small signal amplification (COLD)
LICO_IC_CSTR.WINEG	I-Part neg. window for small signal amplification (COLD)
LICO_IC_CSTR.WIPOS	I-Part pos. window for small signal amplification (COLD)

Corresponding MODAS-Worksheet: Low_High_idle_speed.mxws

To calibrate the low idle controller please use the excel file “Calibration_LowIdleSpeed.xls”. To achieve a good calibration the control parameters must be used

The following table is an extract of the excel file "Calibration_LowIdleSpeed.xls" showing the calibration process for the low idle speed controller. The excel file contains a sheet called "Calibration" in which all necessary calculations are done that should be used to do the calibration.

1	The calibration is done with the label set for a warm engine. Hint: All low idle speed control parameters are available twice - one with C=cold one with W=warm)
2	**Start the engine**
3	Make sure that the engine temperature (ects_t_w) is above the threshold to use the parameter set for a WARM engine **LICO_T_CTTHRS_CW** (if necessary change LICO_T_CTTHRS_CW accordingly)
4	Open small signal window of P-Part completely Set **LICO_PW_CSTR.WINEG** = -500[rpm] Set **LICO_PW_CSTR.WIPOS** = 500[rpm]
5	Disable I- and DT1-Part of the low Idle controler Set **LICO_IW_CSTR.CI*** = 0[(mg/str)/(rpm/s)] Set **LICO_DCONW_CSTR.CD** = 0[(mg/str)/rpm)]
6	**START MEASUREMENT**
7	Increase P-Part **LICO_PW_CSTR.CPWIN** slowly until enginespeed starts to oscillate (use increment-values of 0,02[[mg/str]/rpm])
8	Let the engine speed (eess_n_avg_w) oscillate for ~15[s]. Then decrease the P-Part until the system becomes stable again (use decrement-values of 0,02[[mg/str]/rpm]). The P-Part value at which the system starts to be stable again is the critical P-Part Pcrit - write this value to cell "Critical gain Pcrit" on sheet "Calibration".
9	**STOP MEASUREMENT**
10	Enable I-Part of low idle controler again with default values **LICO_IW_CSTR.CI*** = default value(s) from reference page (ModasSport Short Key: Ctrl+R) **LICO_DCONW_CSTR.CD** = default value(s) from reference page (ModasSport Short Key: Ctrl+R)
11	**Stop the engine!**
12	Evaluate measured data: count e.g. 50 oscillations and measure the time. Write the overall period for all counted oscillations to cell "Time range dT" on sheet "Calibration". Write the number of counted oscillations to cell "N° of oscillations in dT" on sheet "Calibration". --> The critical frequency f_{crit} is calculated automatically based on these values.
13	Transfer all values in green cells on sheet "Calibration" to the given calibration labels.
14	**Calibration of low idle control parameters for a cold engine**
15	For the first rough calibration of the COLD engine it is COLD equal WARM

Corresponding excel file: "Calibration_LowIdleSpeed.xls" – sheet "HowTo"

After the calibration of the low idle controller is finished, please check the stability of the engine speed at low idle speed.

The MS15 SW provides a lot of more settings for the low idle controller. Only in case a stable control is not possible following the advices given in the table above it could help to have a close look to the detailed function description in the related complete MS15 documentation.

6.4 Rail pressure is oscillating in idle speed

Affected CALIBRATION LABELS:

FPC3_CP_FLOWRATIO_CSTR.CPWIN	P-part of rail pressure controller (HP pump)
FPC3_CI_FLOWRATIO_CSTR.CIWIN	I-part of rail pressure controller (HP pump)

Corresponding MODAS-Worksheet: Rail_pressure_FMU.mxws

After the engine is running in idle mode the next step is to check the rail pressure control quality. In case there are oscillations in rail pressure > 10 [MPa] amplitude they have to be reduced, because they can influence the quality of the low idle controller → result will be engine speed oscillations.

At this stage of the engine calibration the HP pump control parameters can be reduced manually in order to steady the rail pressure control quality, because right now the rail pressure control must not satisfy high dynamic conditions – it is sufficient if the rail pressure is stable in non-dynamic conditions.

The way to calibrate the rail pressure controller in order to work well under high dynamic conditions is described in chapter "Calibration of rail pressure controller".

Most probable at this stage of the engine calibration an improvement in stable conditions can be achieved by reducing the calibration of the I-part of the rail pressure controller FPC3_CI_FLOWRATIO_CSTR.CIWIN. Decrement the calibration by 0.01[%/MPa/s] steps until the measured rail pressure (efps_p_w) fits well to the rail pressure set point (fpsc_p_w). If a good calibration can not be achieved by using only the I-part the P-part FPC3_CP_FLOWRATIO_CSTR.CPWIN can be reduced as well in decrement steps of 0.01[%/MPa].

The calibration of the rail pressure control at this stage of the calibration is finished if the rail pressure (efps_p_w) oscillations are in a window smaller than the amplitude of < 10[MPa] symmetrically around the rail pressure set point (fpsc_p_w).

6.5 Updates of load/engine speeds limitaions

On the following calibration steps the engine is calibrated at different operating points. The operating points are defined by injection fuel quantity (fqsc_q_w) and engine speed (eess_n_avg_w), whereby the injection fuel quantity (fqsc_q_w) is limited at. 30[mg/str]) and the engine speed is limited at 3000[rpm] according to the aforementionned dataset preparation.

Target of the dataset updates described below is to allow engine speed (eess_n_avg_w) greater than 3000[rpm] and injected fuel quantity (fqsc_q_w) greater than 30[mg/st].

6.5.1 Updates of high idle speed set point and cut-in engine speed of high idle controller

Affected CALIBRATION LABELS:

HISP_N_BASE_CW	High idle setpoint
HISP_N_DROOP_CW	Engine speed droop

Corresponding MODAS-Worksheet: Low_High_idle_speed.mxws

To be able to perform calibration tasks described in the next chapters, it is necessary to increase the high idle speed set point in HISP_N_BASE_CW – otherwise the engine will be limited by this value. The cut-in engine speed for the high idle controller HISP_N_DROOP_CW might be adjusted to the changed maximum engine speed value as well.

Do not set the high idle speed set point HISP_N_BASE_CW to a value higher than the one your engine is capable to run at! A fault in this calibration can force serious damage to the engine!

6.5.2 Updates of injection fuel quantity limitations

Affected CALIBRATION LABELS:

FLIM_Q_TLIM_GMP	Fuel limit map for torque limit
FLIM_Q_SMOKE_MAP	Smoke fuel quantity map

Corresponding MODAS-Worksheet: Full_load_opti.mxws

To be able to perform calibration tasks described in the next chapters, it is necessary to change FLIM_Q_TLIM_GMP and FLIM_Q_SMOKE_MAP in order that the desired injection fuel quantity (fqsc_q_w) can be injected.

Do not set the calibration of the injection fuel quantity in one of the maps FLIM_Q_TLIM_GMP and FLIM_Q_SMOKE_MAP at any operating point to a value higher than the one your engine is capable to run with! A fault in these calibrations can force serious damage to the engine!

6.6 Calibration of rail pressure controller

Affected CALIBRATION LABELS:

FPC3_S_CALIBRATION_MODE_CB	Enable/disable rail pressure controller calibration mode
FPC3_SF_CP_NEG_CW	Ratio to calculate P-part amplification in large negative window
FPC3_SF_CP_POS_CW	Ratio to calculate P-part amplification in large positive window
FPC3_CP_FLOWRATIO_CSTR.CPWIN	P-part small signal amplification
FPC3_CP_FLOWRATIOCSTR.WNEG	Negative window for small P-part signal amplification
FPC3_CP_FLOWRATIOCSTR.WPOS	Positive window for small P-part signal amplification
FPC3_SF_CI_NEG_CW	Ratio to calculate I-part amplification in large negative window
FPC3_SF_CI_POS_CW	Ratio to calculate I-part amplification in large positive window
FPC3_CI_FLOWRATIO_CSTR.CIWIN	I-Part small signal amplification
FPC3_CI_FLOWRATIOCSTR.WNEG	Negative window for small I-part signal amplification
FPC3_CI_FLOWRATIOCSTR.WPOS	Positive window for small I-part signal amplification
FPC3_CDT1_FLOWRATIO_CSTR.CNEG	DT1-CD-parameter neg. large signal amplification
FPC3_CDT1_FLOWRATIO_CSTR.CPOS	DT1-CD-parameter pos. large signal amplification
FPC3_CDT1_FLOWRATIO_CSTR.CWIN	DT1-CD-parameter small signal (always ZERO)
FPC3_CDT1_FLOWRATIO_CSTR.T1	DT1-T1 parameter fuel pressure controller
FPC3_CDT1_FLOWRATIOCSTR.WNEG	Negative window for small DT1-part signal amplification
FPC3_CDT1_FLOWRATIOCSTR.WPOS	Positive window for small DT1-part signal amplification
FPC3_PT1_P_CSTR.T1	T1 parameter for PT1
RMTC_S_VS100_ON_CB	Main Switch to enable remote control function RMTC
RMTC_S_FQSC_CUC	Switch to enable remote control mode for funtion FQSC
RMTC_Q_FQSC_CW	Remote control value for injection fuel quantity (fqsc_q_w)
RMTC_S_FPSC_CUC	Switch to enable remote control mode for funtion FPSC
RMTC_P_FPSC_CW	Remote control value for rail pressure set point (fpsc_p_w)

Corresponding Excel-Data: Calibration_PrailCtrl.xls

Corresponding MODAS-Worksheet: Rail_pressure_FMU.mxws

The rail pressure controller is calibrated using one constant injection quantity of 30[mg/str] over the complete engine speed range (for small engine speeds (<2250rpm) probably smaller injection quantities have to be used!). In order to proceed with the calibration in this topic all calibrations of the previous chapters have to be finished.

The resulting rail pressure control parameters of the calibration will be valid also for full load portion, because the different injection fuel quantities are already compensated by the calibration in the high pressure pump pre control map FPC3_R_PRE_GMP.

For the different engine speed set points during the rail pressure controller calibration the same values like in BIMI_PHI_BASE_MAP and BPCO_DC_PRECON_GMP should be used.

The following table is an extract of the excel file "Calibration_PrailCtrl.xls" showing the calibration process for the rail pressure controller. The excel file contains a sheet called "Calibration" in which all necessary calculations are done that should be used to do the calibration.

(Corresponding excel file: "Calibration_PrailCtrl.xls" – sheet "HowTo")

1	**Start the engine**
2	Run engine at below given first engine speed (default 1000[rpm]). When the engine is running stable proceed with next step.
3	Disable use of speed dependent scaling factors during calibration process **FPC3_S_CALIBRATION_MODE_CB** = 1
4	Open small signal window of P-Part completely Set all **FPC3_CP_FLOWRATIO_CSTR.WINEG** = -200[MPa] Set all **FPC3_CP_FLOWRATIO_CSTR.WIPOS** = 200[MPa]
5	Set the rail pressure set point by remote control function to a fixed value that matches best the rail pressure set point (fpsc_p_w) at the present conditions. **RMTC_P_FPSC_CW** = fpsc_p_w [MPa]
6	Enable the remote function for the rail pressure set point. **RMTC_S_FPSC_CUC = 1**
7	Set the injection fuel quantity by remote control function to a fixed value that matches best the injection fuel quantity (fqsc_q_w) at the present conditions. **RMTC_Q_FQSC_CW** = fqsc_q_w [mg/str]
8	Enable the remote function for the injection fuel quantity. **RMTC_S_FQSC_CUC = 1**
9	Enable the global use of the remote control function. **RMTC_S_VS100_ON_CB = 1**
10	Check that the rail pressure set point (fpsc_p_w) is equal to the value set in **RMTC_P_FPSC_CW**
11	Check that the injection fuel quantity (fqsc_q_w) is equal to the value set in **RMTC_Q_FQSC_CW**
12	Check that the engine is running stable.
13	Wait until the rail pressure is stabilized and then disable I-Part of HP pump controler **FPC3_CI_FLOWRATIO_CSTR.CIWIN** = 0
14	Wait until the rail pressure is stabilized and then disable DT1-Part of HP pump controler **FPC3_CDT1_FLOWRATIO_CSTR.CWIN** = 0 **FPC3_CDT1_FLOWRATIO_CSTR.CNEG** = 0 **FPC3_CDT1_FLOWRATIO_CSTR.CPOS** = 0
15	**START MEASUREMENT**
16	Increase P-Part of HP pump **FPC3_CP_FLOWRATIO_CSTR.CPWIN** slowly until the rail pressure starts to oscillate heavily.
17	Let the railpressure oscillate for ~15[s] before you start to decrease the P-Part of the HP pump **FPC3_CP_FLOWRATIO_CSTR.CPWIN** again. The value at which the system gets stable again is the critical P-Part Pcrit. Write this value to the table below at the corresponding engine speed.
18	**STOP MEASUREMENT**
19	Enable I-Part of HP pump controler again with default values **FPC3_CI_FLOWRATIO_CSTR.CIWIN** = default value from reference page (ModasSport Short Key: Ctrl+R)
20	Enable DT1-Part of HP pump controler again with default values **FPC3_CDT1_FLOWRATIO_CSTR.CWIN** = default value from reference page (ModasSport Short Key: Ctrl+R) **FPC3_CDT1_FLOWRATIO_CSTR.CNEG** = default value from reference page (ModasSport Short Key: Ctrl+R) **FPC3_CDT1_FLOWRATIO_CSTR.CPOS** = default value from reference page (ModasSport Short Key: Ctrl+R)
21	Disable the global use of the remote control function. **RMTC_S_VS100_ON_CB = 0**
22	Disable the remote function for the injection fuel quantity. **RMTC_S_FQSC_CUC = 0**
23	Set the injection fuel quantity by remote control to 0 [mg/str] **RMTC_Q_FQSC_CW** = 0 [mg/str]
24	Disable the remote function for the rail pressure set point. **RMTC_S_FPSC_CUC = 0**
25	Set the rail pressure set point by remote control function to 0 [MPa] **RMTC_P_FPSC_CW** = 0 [MPa]
26	Evaluate measurement data: To get the critical frequency of the HP system count e.g. 50 oscillations and measure the time period for all counted Write both values (number of oscillations and measured time period for all counted oscillations) to the table below at the corresponding engine speed. The critical frequency f_{crit} is calculated automatically based on these values.
27	Increase engine speed to the next given engine speed point in the below standing table and then go back to step 5. In case the maximum given engine speeds can not be reached, fill-in the same values for the missing engine speeds as for the highest measured engine speed. When all engine speeds are measured go to the next step (28).
28	**Stop the engine!**
29	Transfer all values in green cells on sheet "Calibration" to the given calibration labels.
30	Check that the engine speed set points of the scaling factor curves are calibrated according to the used engine speeds: **FPC3_SF_CP_CUR** **FPC3_SF_CI_CUR** **FPC3_SF_CD_CUR** **FPC3_SF_DT1_CUR**
31	Activate use of speed dependent scaling factors again **FPC3_S_CALIBRATION_MODE_CB** = 0
32	Now the calibration of the rail pressure controler is finished!

6.7 Calibration of boost pressure controller

The boost pressure controller is calibrated after calibrating boost pressure setpoint for your engine. Then the boost pressure controller parameters (PID parameters) are identified into the small deviation window. After that, the pre-control map is fine calibrated. To finish, the boost pressure controller is calibrated outside the small window deviation.

The first step is to define the boost pressure setpoint in all operation range allowed by the engine without breaking turbocharger and according to the different mechanical stress: surge limit, maximum boost pressure allowed by the air system (air path, intercooler, and so on...), maximum temperature after charger, maximum cylinder pressure, maximum temperature before turbine and maximum turbine speed.

The second step is to calibrate the PID controller parameters using excel file "Calibration_BoostPressureCtrl.xls" into the small deviation window.

The third step is to adapt the pre-control map to your turbocharger system.

The fourth step is to calibrate the PID controller parameters using excel file "Calibration_BoostPressureCtrl.xls" outside the small window.

6.7.1 Boost pressure setpoint optimization

The aim is to have the maximum inducted air mass into the engine at full load. Doing so, you have to monitor at any operating point the:

- Charger surge
- Maximum boost pressure allowed by the system (usually no more than 3.5[bar] with series parts)
- Temperature after charger (usual series between 200[°C] and 250[°C])
- Maximum cylinder pressure
- Temperature before turbine (usual series between 800[°C] and 860[°C])
- Turbocharger speed.

A fault in these calibrations/monitoring can force serious damage to the engine!

Affected CALIBRATION LABELS:

BPCO_P_BASE_GMP	boost pressure setpoint
BPCO_DC_PRECON_GMP	Boost pressure duty cycle precontrol map

Corresponding MODAS-Worksheet: Boost_Pressure.mxws

The boost pressure setpoint optimization is calibrated using the maximum injection quantity allowed by the engine for the different engine speeds (full load). Start with the engine speed at 1000[rpm] and repeat the procedure at each 500[rpm] until the maximum engine speed of your engine. For each engine speed, the maximum boost pressure is defined by closing gradually the turbine using BPCO_DC_PRECON_GMP (increase by step of 2[%]) until to reach one limit of the mechanical stress or 100[%]. If the pre-control is set to 100[%] without reaching one mechanical stress limit, you can increase the fuel quantity injected (step by 1[mg/stroke]) to increase turbine energy. The maximum allowed boost pressure is in this way characterized.

In order to proceed with the calibration in this topic, all calibrations of the previous chapters have to be finished.

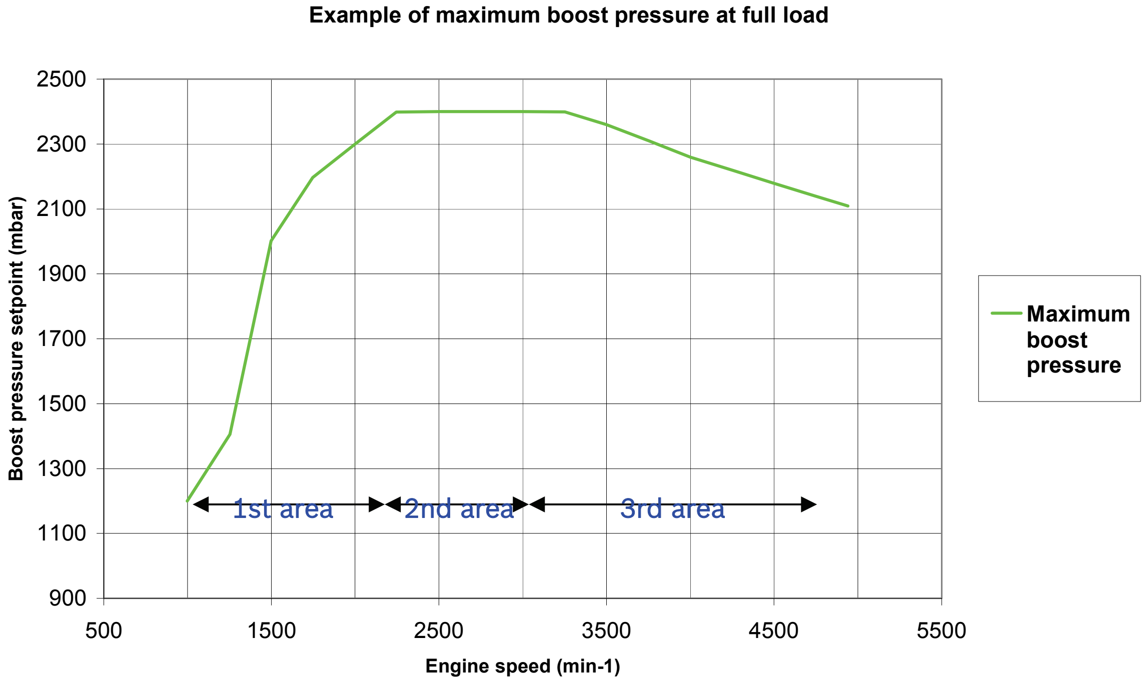
A fault in these calibrations/monitoring can force serious damage to the engine!

The following picture gives an example of the maximum boost pressure shape at full load. Three different areas are distinguished.

First area: low engine speed, maximum allowed boost pressure is set by limit of charger surge or turbine energy.

Second area: middle engine speed, maximum allowed boost pressure requirement depending basically on air system limits.

Third area: high engine speed, maximum boost pressure is limited mainly by temperature after charger and turbocharger speed.



According to the results of the maximum boost pressure, you may use excel file "Calibration_Boost_pressure_setpoint.xls" to generate the boost pressure setpoint map BPCO_P_BASE_GMP using the sheet "Boost_pressure_setpoint" by fulfilling the green cells.

For each engine speed, we recommend you to use the same engine quantity breakpoints in the three follwing maps: BIMI_PHI_BASE_MAP, BPCO_P_BASE_GMP and BPCO_DC_PRECON_GMP.

6.7.2 Calibration of boost pressure control parameters

Affected CALIBRATION LABELS:

BPCO_S_CLOSEDLOOP_CB	Switch to enable/disable the governor (closed loop)
BPCO_P_CSTR.CPNEG	Ratio to calculate P-part amplification in large negative window
BPCO_P_CSTR.CPPOS	Ratio to calculate P-part amplification in large positive window
BPCO_P_CSTR.CPWIN	P-part small signal amplification
BPCO_P_CSTR.WINEG	Negative window for small P-part signal amplification
BPCO_P_CSTR.WIPOS	Positive window for small P-part signal amplification
BPCO_I_CSTR.CINEG	Ratio to calculate I-part amplification in large negative window
BPCO_I_CSTR.CIPOS	Ratio to calculate I-part amplification in large positive window
BPCO_I_CSTR.CIWIN	I-Part small signal amplification
BPCO_I_CSTR.WINEG	Negative window for small I-part signal amplification
BPCO_I_CSTR.WIPOS	Positive window for small I-part signal amplification
BPCO_CDT1_CSTR.CD	DT1-CD-parameter
BPCO_DT1_CSTR.T1	DT1-T1 parameter boost pressure controller
BPCO_PT1_CSTR.T1	T1 parameter for PT1 for boost pressure input value

Corresponding MODAS-Worksheet: Boost_Pressure.mxws

The boost pressure controller is calibrated through an air system characterization on 4 operating points (2 engine speeds X 2 loads). For each engine speed, the fuel injection quantity has to be the maximum allowed by the engine (full load). For the other 2 operating points, the fuel injection quantity has to be medium (for example around 30-40[mg/stroke] depending on your engine). In order to proceed with the calibration in this topic all calibrations of the previous chapters have to be finished.

The resulting boost pressure control parameters of the calibration will be valid also for the whole operating range.

For each engine speed, we recommend you to use the same engine quantity breakpoints in the three follwing maps: BIMI_PHI_BASE_MAP, BPCO_P_BASE_GMP and BPCO_DC_PRECON_GMP.

The following table is an extract of the excel file “Calibration_BoostPressureCtrl.xls” showing the calibration process for the boost pressure controller. The excel file contains a sheet called “Calibration” in which all necessary calculations are done that should be used to do the calibration.

1	In order to proceed with the calibration in this topic all calibrations of the previous chapters in word file have to be finished. So you have a new boost pressure setpoint according to your engine.
2	Check at every engine parameter change the mechanical stress : charger surge, maximum boost pressure allowed by the air system (air path, intercooler and so on…), maximum temperature after charger, maximum cylinder pressure, maximum temperature before turbine and maximum turbocharger speed. A fault in these calibrations/monitoring can force serious damage to the engine!
3	**Start the engine**
4	To enable the boost pressure governor, check that **BPCO_S_CLOSEDLOOP_CB** = 1 and fuel quantity setpoint is higher than the fuel quantity calibrated in **BPCO_Q_GOVOFF_CUR**.
5	Run engine at below given first engine speed (default 1000[rpm]). When the engine is running stable proceed with next step.
6	Open small signal window of P-Part completely Set **BPCO_P_CSTR.WIPOS** = 3000[hPa] Set **BPCO_P_CSTR.WINEG** = -3000[hPa]
7	Go slowly to the chosen operating point (engine speed and fuel quantity) while adjusting turbocharger pre-control if needed. When the operating point is the full load, decrease sligthly the boost pressure and fuel quantity setpoint in order to avoid mechanical stress with the boost pressure oscillations.
8	Check that the engine is running stable.
9	Wait until the boost pressure is stabilized and then check that I-Part of boost pressure controller is disable **BPCO_I__CSTR.CIWIN** = 0
10	Wait until the boost pressure is stabilized and then check that DT1-Part of boost pressure controller is disable **BPCO_CDT1_CSTR.CD** = 0
11	**START MEASUREMENT**
12	Increase P-Part of boost pressure **BPCO_P_CSTR.CPWIN** slowly until the boost pressure starts to oscillate heavily.
13	Let the boost pressure oscillate for ~15[s] before you start to decrease the P-Part of the boost pressure **BPCO_P_CSTR.CPWIN** again. The value at which the system gets stable again is the critical P-Part Pcrit. Write this value to the relevant table on sheet "Calibration" at the corresponding operating point.
14	**STOP MEASUREMENT**
15	Evaluate measurement data: To get the critical period of the boost pressure system count e.g. 10 oscillations and measure the time period for all counted oscillations. Write both values (number of oscillations and measured time period for all counted oscillations) to the relevant table on sheet "Calibration" at the corresponding operating point. The critical period t_{crit}, the I-part and D-part are calculated automatically based on these values and the Pcrit.
16	Change the operating point to the next in the relevant table on sheet "Calibration" and then go back to step 7. In case the maximum given engine speeds can not be reached, fill-in the same values for the missing engine speeds as for the highest measured engine speed. When all operating points are measured go to the next step (17).
17	**Stop the engine!**
18	Transfer all values in green cells on sheet "Calibration" to the given calibration labels.
19	Now the calibration of the boost pressure controller is finished!

Corresponding excel file: “Calibration_BoostPressureCtrl.xls” – sheet “HowTo”

Before going on with the boost pressure controller calibration, you have to optimize the full load, see chapter “Torque limitation”. Indeed, step load from 0% to 100% is necessary to finish boost pressure controller calibration. To avoid damages on engine and to adapt the boost pressure controller to your engine, it’s better to optimize full load now. According to this remark, it’s necessary to do boost pressure and full load optimizations in parallel.

6.7.3 Calibration of boost pressure pre-control map

Affected CALIBRATION LABELS:

BPCO_DC_PRECON_GMP	Boost pressure duty cycle precontrol map
BPCO_N_ACO	Definition of map setpoints (engine speed)
BPCO_Q_ACO	Definition of map setpoints (injection quantity)

Corresponding Excel-data: Calibration_BoostPressure_setpoint.xls

Corresponding MODAS-Worksheet: Boost_Pressure.mxws

In order to proceed with the calibration in this topic all calibrations of the previous chapters and chapter "Torque limitation" have to be finished, especially boost pressure setpoint map and main injection angle map.

Open duty cycle of I-part limitation completely. Set BPCO_DC_IMIN_CW = -100% and BPCO_DC_IMAX_CW = 100%.

From 1000[rpm] to maximum engine speed by step of 500[rpm], measure bpco_dc_out_w (final output of duty cycle boost pressure) for different fuel injection quantity including full load.

Recommendation: choose the values of fuel injection quantity setpoints in the map BPCO_DC_PRECON_GMP.

Fill in the results in the BPCO_DC_PRECON_GMP map. Now the calibration of the pre-control map is finished.

Doing so, you have to monitor at any operating point the:

- Charger surge
- Maximum boost pressure allowed by the system (usually no more than 3.5[bar] with series parts)
- Temperature after charger (usual series between 200[°C] and 250[°C])
- Maximum cylinder pressure
- Temperature before turbine (usual series between 800[°C] and 860[°C])
- Turbocharger speed.

A fault in these calibrations/monitoring can force serious damage to the engine!

6.7.4 Calibration of boost pressure controller in large window

Affected CALIBRATION LABELS:

BPCO_S_CLOSEDLOOP_CB	Switch to enable/disable the governor (closed loop)
BPCO_P_CSTR.CPNEG	Ratio to calculate P-part amplification in large negative window
BPCO_P_CSTR.CPPOS	Ratio to calculate P-part amplification in large positive window
BPCO_P_CSTR.CPWIN	P-part small signal amplification
BPCO_P_CSTR.WINEG	Negative window for small P-part signal amplification
BPCO_P_CSTR.WIPOS	Positive window for small P-part signal amplification
BPCO_I_CSTR.CINEG	Ratio to calculate I-part amplification in large negative window
BPCO_I_CSTR.CIPOS	Ratio to calculate I-part amplification in large positive window
BPCO_I_CSTR.CIWIN	I-Part small signal amplification
BPCO_I_CSTR.WINEG	Negative window for small I-part signal amplification
BPCO_I_CSTR.WIPOS	Positive window for small I-part signal amplification
BPCO_CDT1_CSTR.CD	DT1-CD-parameter
BPCO_DT1_CSTR.T1	DT1-T1 parameter boost pressure controller
BPCO_PT1_CSTR.T1	T1 parameter for PT1 for boost pressure input value

Corresponding MODAS-Worksheet: Boost_Pressure.mxws

Corresponding Excel-data: Calibration_BoostPressure_setpoint.xls

For each engine speed (from 1000[rpm] to maximum engine speed by step of 500[rpm]), perform engine step load characterization: first begin with low step loads (10, 20, 30%) and then perform final validation with 100% step load.

Overshoot, undershoot have to be between 5% and 10% from the boost pressure setpoint. If it's not the case, you have to change the positive and negative ratio to calculate the different PI parameters in large window (BPCO_P_CSTR.CPNEG, BPCO_P_CSTR.CPPOS, BPCO_I_CSTR.CINEG and BPCO_I_CSTR.CIPOS). You can use excel file "Calibration_BoostPressureCtrl.xls".

Doing so, you have to monitor at any operating point the:

- Charger surge
- Maximum boost pressure allowed by the system (usually no more than 3.5[bar] with series parts)
- Temperature after charger (usual series between 200[°C] and 250[°C])
- Maximum cylinder pressure
- Temperature before turbine (usual series between 800[°C] and 860[°C])
- Turbocharger speed.

A fault in these calibrations/monitoring can force serious damage to the engine!

Now the calibration of the boost pressure controller is finished!

6.8 Calibration of friction map

Affected CALIBRATION LABELS:

QFRI_Q_FRICTION_MAP	Friction fuel quantity map
RMTC_S_VS100_CB	Main Switch to enable remote control function RMTC
RMTC_S_LISC_CB	Switch to enable remote control mode for funtion LISC
RMTC_N_LISC_CW	Remote control value for low idle speed set point (lisc_n_w)

Corresponding Excel-Data: Calibration_FrictionQuantity.xls

Corresponding MODAS-Worksheet: FrictionQuantity.mxws

The friction map contains the necessary injection fuel quantity (fqsc_q_w) to keep the engine running without load. The necessary injection fuel quantity (fqsc_q_w) changes depending on the engine speed (eess_n_avg_w) and the engine temperature (ects_t_w). The higher the engine speed (eess_n_avg_w) and the lower the engine temperature (ects_t_w), the more injection fuel quantity (fqsc_q_w) is necessary to keep the engine running.

To calibrate the friction map QFRI_Q_FRICTION_MAP the function of the low idle controller can be used. For this the low idle speed set point has to be changed by remote control to the engine speed set points of the friction quantity map QFRI_Q_FRICTION_MAP.

The calibration of the friction quantity values at low engine temperatures is difficult, because the engine heats up quite fast. So you have to take care for the good engine temperature set point. Best possibility is

The following table is an extract of the excel file “Calibration_FrictionQuantity.xls” showing the calibration process for the friction quantity.

1	**Start the engine /!\first prepare whole dataset through Application Guide /!**
2	Set first engine speed set point in friction map **QFRI_Q_FRICTION_MAP** equal to the low idle speed set point under normal conditions - default: 1000[rpm].
3	Wait until the engine speed (eess_n_avg_w) is stabilized to the low idle speed set point (lisc_n_w) and then copy the present injection fuel quantity (fqsc_q_w) to the corresponding working point in the friction map **QFRI_Q_FRICTION_MAP** - take care of the engine temperature (ects_t_w). => IMPORTANT: In case the absolute difference between the new and the old friction quantity is bigger than 30% of the old value, it is recommended to do the change of the value in two or more steps, because the friction quantity is taken as pre control for the low idle controller and too big changes may have a too big influence on the control behavior.
4	Set the low idle speed set point using the remote control function to the next engine speed set point of map **QFRI_Q_FRICTION_MAP**. **RMTC_N_LISC_CW =** next engine speed set point of map **QFRI_Q_FRICTION_MAP**
5	Enable the remote function for the low idle speed set point. **RMTC_S_LISC_CB = 1**
6	Enable the global use of the remote control function. **RMTC_S_VS100_ON_CB = 1**
7	Check that the low idle speed set point lisc_n_w is equal to **RMTC_N_LISC_CW**.
8	Wait until the engine speed (eess_n_avg_w) is stabilized to the low idle speed set point (lisc_n_w) and then copy the present injection fuel quantity (fqsc_q_w) to the corresponding working point in the friction map **QFRI_Q_FRICTION_MAP** - take care of the engine temperature (ects_t_w). => IMPORTANT: In case the absolute difference between the new and the old friction quantity is bigger than 30% of the old value, it is recommended to do the change of the value in two or more steps, because the friction quantity is taken as pre control for the low idle controller and too big changes may have a too big influence on the control behavior.
9	Disable the global use of the remote control function. **RMTC_S_VS100_ON_CB = 0**
10	Disable the remote function for the low idle speed set point. **RMTC_S_LISC_CB = 0**
11	Set the low idle speed set point by remote control function to 0 [rpm] **RMTC_N_LISC_CW** = 0 [rpm]
12	In case the last engine speed set point of map **QFRI_Q_FRICTION_MAP** was not reached yet jump back to step 4. Otherwise proceed with the next step.
13	**Stop the engine!** Calibration is finished!

Corresponding excel file: “Calibration_FrictionQuantity.xls” – sheet “HowTo”

6.9 Calibration of necessary fuel quantity limitations (Torque, HighIdle, Smoke)

The available fuel quantity limitations include torque limitation, smoke limitation, and the maximum enginee speed limiter. All these three functions must all be fully calibrated to assure that the engine won't experience mechanical failure during operation. During testing you can see which calibration parameter is limiting the fueling by observing 'fqsc_s_uc'.

6.9.1 Torque limitation

Affected CALIBRATION LABELS:

FLIM_Q_TLIM_GMP	Fuel limit map for torque limit
FLIM_N_TLIM_ACO	Engine speed coordinates for torque limit maps
FLIM_T_TLIM_ACO	Temperature coordinates for torque limit maps

Corresponding Excel-Data: Calibration_TorqueLimitation.xls

Corresponding MODAS-Worksheet: Full_load_opti.mxws

In order to proceed with the calibration in this topic all calibrations of the previous chapters have to be finished.

Seeing that the air system and fuel injection equipment are well calibrated, the goal is now to optimize the full load within the thermo mechanical stress limits of your engine.

Parameter FLIM_Q_TLIM_GMP is used for the calibration of maximum fuel quantity (full load) based on engine speed (eess_n_avg_w) and boost temperature (ebts_t_w).

To calibrate FLIM_Q_TLIM_GMP, operate the engine at full load while monitoring carefully the limits for

- Cylinder pressure (usually no more than 200[bar] with series parts).
- Somke opacity (usually no more than 4[SZ] in series engines).
- Temperature before turbine (series parts: usually between 800[°C] and 860[°C]).

Also monitor the critical engine parameters (coolant temp, oil pressure, oil temperature...).

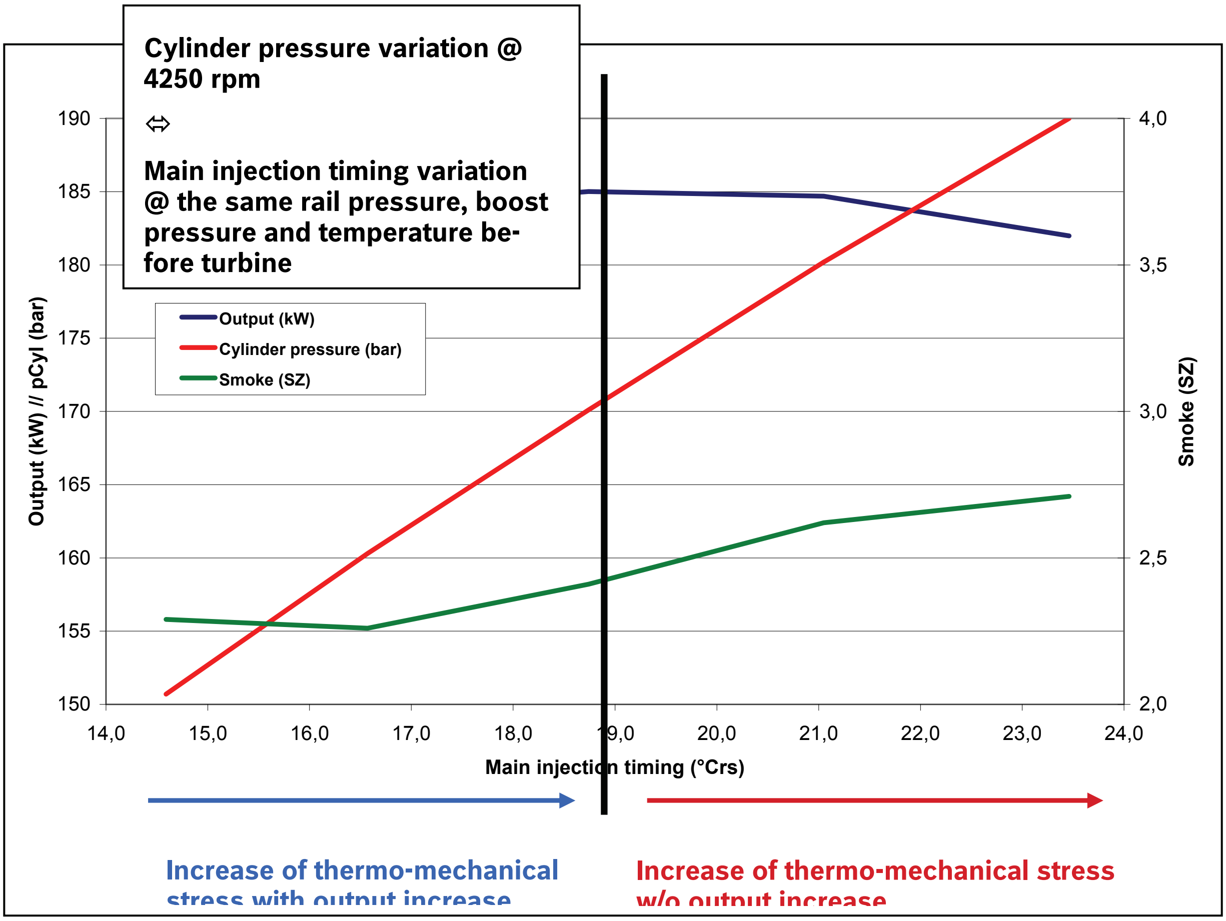
A fault in these calibrations/monitoring can force serious damage to the engine!

Be careful: don't forget to finish boost pressure controller calibration after full load optimization (go on with the chapter "boost pressure pre-control map"). Keep in mind that full load and boost pressure optimizations have to be done in parallel.

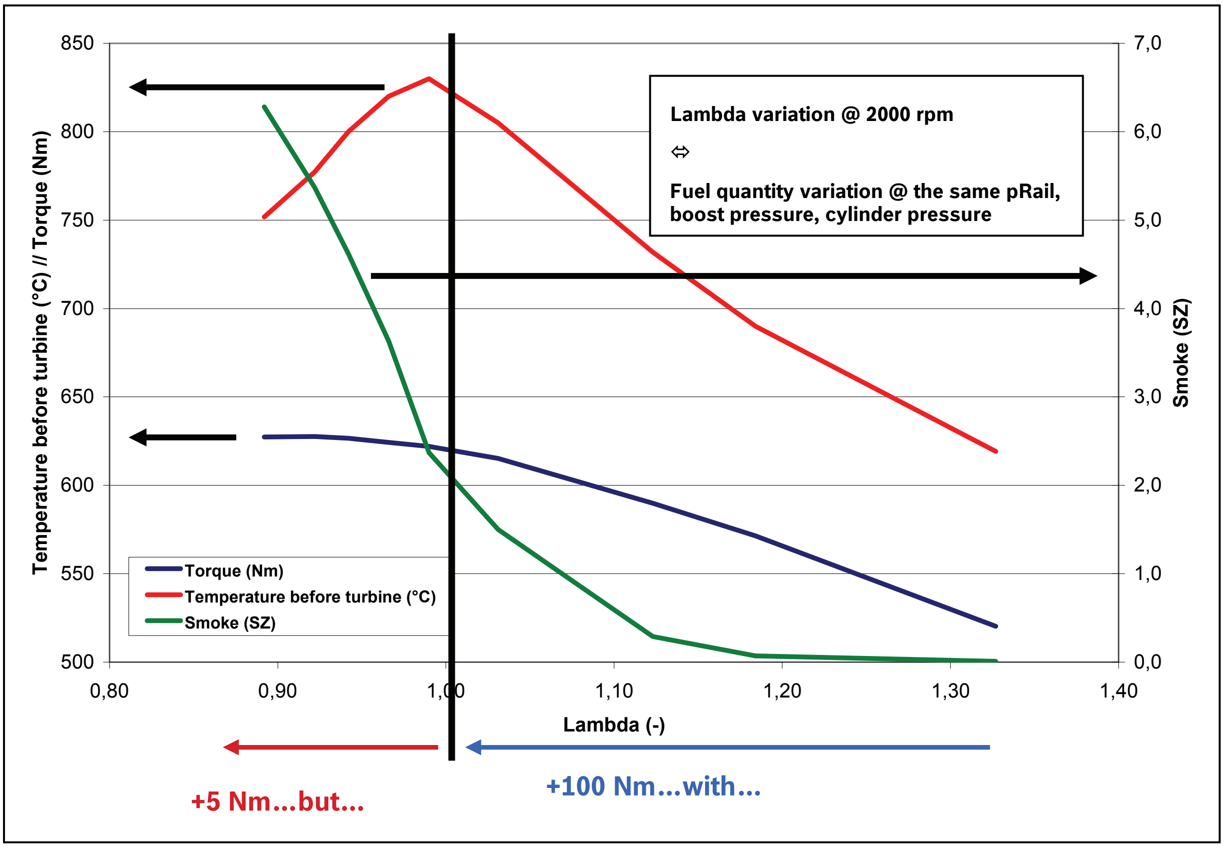
The following table is an extract of the excel file "Calibration_TorqueLimitation.xls" showing the calibration process for the torque limitation.

1	During normal operation the torque limitation is used to secure the engine from damage by too high thermo mechanical stress coming from the combustion power. The combustion power (=torque) is directly linked to the injected fuel quantity - so if the injected fuel quantity is limited, this also limits the torque of the engine.
2	The limit of maximum allowed engine torque is usually given by the following requirements: -> Rrail pressure -> Maximum cylinder pressure -> Temperature before turbine -> Boost pressure which is itself a consequence of turbocharger requirements (surge limit, charger speed limit, temperature after charger..) -> Smoke opacity **.../!\ and more/!\ ...**
3	By calibrating **FLIM_Q_TLIM_GMP,** the injected fuel quantity is limited to a level at which the maximum torque of the engine is reached without exceeding any thermo mechanical requirement.
4	As 1st approach regarding fine calibration of **FLIM_Q_TLIM_GMP**, the following steps have to be followed at each relevant engine speed : -> drive the engine in full-load at the right speed -> increase step-by-step (0,2[°Cr]) injection angle in **BIMI_PHI_BASE_MAP** until the maximum cylinder pressure target (engine manufacturer data) is reached -> increase step-by-step (0,3 [mg/str]) fuel quantity in **FLIM_Q_TLIM_GMP** until smoke opacity target and/or temperature before turbine target is (are) reached. At low engine speed, fuel injection quantity is usually limited by smoke opacity. At high engine speed, fuel injection quantity is usually limited by temperature before turbine.
5	Be careful: maximum thermo mechanical stress of your engine doesn’t mean maximum engine power and torque.
6	As 2nd approach regarding fine calibration of **FLIM_Q_TLIM_GMP**, check that the thermo mechanical stress limits reached corresponds to maximum engine power and torque. For that, the following steps have to be followed at each relevant engine speed: -> At the same relevant temperature before turbine in full load, Increase or decrease main injection angle step by step (0.2[°Cr]) in **BIMI_PHI_BASE_MAP** according to maximum cylinder pressure allowed by your engine. Check the engine power and torque variation. -> Do the same with fuel injection quantity step-by-step (0,3 [mg/str]) in **FLIM_Q_TLIM_GMP**. Check the engine power and torque variation. Doing so, you have to monitor at every parameters changing all the thermo mechanical stress defined by your engine manufacturer. A fault in these calibrations/monitoring can force serious damage to the engine!
7	The full load is calibrated when you have optimized those parameters.
8	**Important recommendation 1 :** During full load calibration the following aspects have to be monitored extremely carefully (risk of serious engine damages) : -> rail pressure -> cylinder pressure (cylinder pressure sensor(s) is (are) mandatory for this task) -> temperature before turbine (temperature before turbine sensor(s) is (are) mandatory for this task) -> air system : turbocharger speed, temperature after charger, charger surge, boost pressure (associated sensors are mandatory for this task) -> smoke opacity and/or lambda -> engine oil/water temperatures/pressures **Important recommendation 2 :** Before calibrating full load, thermo mechanical targets and their margins to the associated requirements have to be defined. Example: turbocharger speed requirement = 180 krpm => defined target = 170 krpm (10 krpm margin dedicated to boost pressure controller overshoot). By doing this, the overall thermo mechanical stress of the engine and then the maximum allowed full load level are set. **Important recommendation 3:** Before calibrating full load, the relevant controllers have to be checked (rail pressure, boost pressure...).

Important remark: 2 nd step approach is illustrated by graphics below.



Graphic 28: example of full load optimization through main injection angle variation ➔ max engine output is not reached at max cylinder pressure!!



Graphic 29: example of full load optimization through fuel quantity variation ➔the best compromise between torque / fuel consumption / smoke is not reached at the highest fuel quantity set-point!!

So the full load is now fine calibrated.

At each relevant engine speed, the main injection angle values at part load (bimi_phi_w from BIMI_PHI_BASE_MAP) can be updated with the value set during full load optimization.

However, the low idle area in the map BIMI_PHI_BASE_MAP has to be the main injection angle values defined during the low idle calibration.

Alternatively, if you want to optimize main injection angle at part load, you have to use the chapter "Adjust injection timing regarding cylinder pressure".

In order to avoid high slope in main injection angle during engine runs, the main injection angle variation have to be smooth within map BIMI_PHI_BASE_MAP.

Be careful: don't forget to finish boost pressure controller calibration after full load optimization (go on with the chapter "boost pressure pre-control map"). Keep in mind that full load and boost pressure optimizations have to be done in parallel.

6.9.2 Smoke limitation

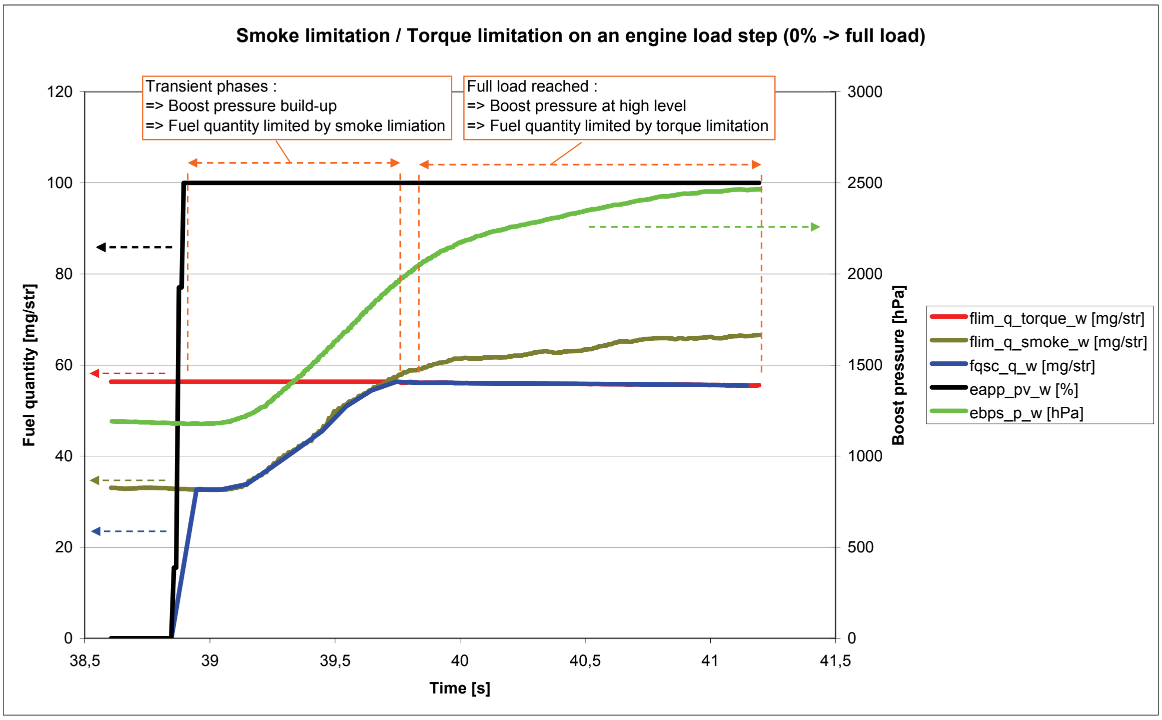
Affected CALIBRATION LABELS:

FLIM_Q_SMOKE_MAP	Smoke fuel quantity map

Corresponding Excel-Data: Calibration_SmokeLimitation.xls

Corresponding MODAS-Worksheet: Full_load_opti.mxws

Parameter **FLIM_Q_SMOKE_MAP** is used to limit the smoke opacity when the airflow is not enough to allow proper combustion of all the fuel. Usually, this limit is reached under engine transient conditions when the turbo has not built sufficient boost pressure yet (see chapter "Fuel limitation (FLIM)").



The axes for **FLIM_Q_SMOKE_MAP** are engine speed (eess_n_avg_w) and calculated air mass in the cylinder (ciam_m_air_w). If the values in this map are calibrated too large, you will have excessive smoke and poor fuel economy because of incomplete combustion. If the values are set too small, the fuel will be restricted when it isn't necessary and the turbo lag will be excessive causing poor driveability.

The following table is an extract of the excel file "Calibration_SmokeLimitation.xls" showing the calibration process for the smoke limitation.

1	In order to proceed with the calibration in this topic all calibrations of the previous chapters in word file have to be finished.
2	During normal operation, smoke limitation works as fuel quantity limitation during transient phases. Indeed, the boost pressure has not been built up during those phases. So, to have an efficient combustion without increasing smoke opacity, it's necessary to limit the fuel quantity.
3	Use sheet "Normal_Calibration". Only change **green cells**.
4	**Start the engine**
5	Run engine at full load. Start at the low engine speed point in the map and progress stepwise (by 250[rpm]) until the maximum allowed engine speed (eess_n_avg_w).
6	Check that the engine is running stable and that the engine thermo mechanical stress is ok.
7	For each engine speed, measure the air flow mass (ciam_m_air_w) and the fuel quantity (fqsc_q_w).
8	Check that the fuel quantity (fqsc_q_w) corresponds to the maximum fuel quantity (full load, flim_q_tlimraw_w or flim_q_torque) at the maximum pedal position (eapp_pv_w = 100%)
9	Write the values (ciam_m_air_w, fqsc_q_w) to the relevant table on sheet "Normal_Calibration" at the corresponding engine speed.
10	The smoke map **FLIM_Q_SMOKE_MAP** is generated automatically using the calculated lambda at full load (ciam_m_air_w and fqsc_q_w): a ratio decrease is applied on the calculated lambda at full load depending on the chosen compromise between driveability and smoke opacity. The default value of ratio decrease is set at 30% => higher values lead to higher smoke opacity and better engine driveability.
11	Calibrate the data, which are inside the light-green cells to the corresponding calibration labels, using the calibration tool MODAS Sport (copy and paste from Excel to MODAS Sport is basically possible apart from axis values of curves and maps)
12	The smoke map **FLIM_Q_SMOKE_MAP** is now calibrated.

6.9.3 High idle speed

Affected CALIBRATION LABELS:

HISP_N_BASE_CW	High idle setpoint
HISP_N_DROOP_CW	Engine speed droop

Corresponding MODAS-Worksheet: Low_High_idle_speed.mxws

To secure the engine from over speeding the engine speed can be limited with the high idle controller. The maximum allowed engine speed is calibrated with the engine temperature (ects_t_w) dependent calibration label HISP_N_BASE_CW.

The cut-in engine speed (hisp_n_cutin_w) of the high idle controller is set with the calibration label HISP_N_DROOP_CW.

The earlier the high idle cut-in engine speed (hisp_n_cutin_w) is calibrated the earlier the engine performance is limited by reducing the injection quantity. Also the high idle speed controller quality regarding under- and overshoots is better with an early high idle cut in engine speed (hisp_n_cutin_w) as soon as the high idle speed set point (hisp_n_w) is reached.

On the other side a late high idle cut-in engine speed (hisp_n_cutin_w) helps to increase the usable engine speed range, but the high idle controller quality may be bad influenced.

6.10 Adjust injection timing regarding cylinder pressure at part load

Target of the calibration is to adjust the beginning of injection angle (bimi_phi_w) until the maximum of the cylinder pressure curve is at ~10[°Crk] after TDC over the complete engine speed range using the same injection fuel quantity (fqsc_q_w) in all operating points.

To achieve an easy way of calibration the used injection fuel quantities (fqsc_q_w) and engine speeds should correspond to the axis set points of map BIMI_PHI_BASE_MAP.

Important remarks:

1/ This chapter doesn't apply to main injection angle at full load seeing that full load calibration has been already performed in chapter "Torque limitation"

2/ When you perform injection timing adjustements at part load, consider the injection angle at full load as the maximum allowed angle. Indeed, at each engine speed, main injection angle usually increases depending on injected fuel quantity (fqsc_q_w).

Affected CALIBRATION LABELS:

BIMI_PHI_BASE_MAP	Base angle map for begin of main injection
RMTC_S_VS100_ON_CB	Main Switch to enable remote control function RMTC
RMTC_S_FQSC_CUC	Switch to enable remote control mode for funtion FQSC
RMTC_Q_FQSC_CW	Remote control value for injection fuel quantity (fqsc_q_w)

Corresponding Excel-Data: Calibration_PCylinder_via_BIMI.xls

Corresponding MODAS-Worksheet: InjectionAngle.mxws

BASICS:

The behavior / shape of the cylinder pressure can be affected by two parameters: fuel quantity (fqsc_q_w) and beginning of injection angle of the main injection (bimi_phi_w).

The maximum cylinder pressure value is mainly influenced by the beginning of injection angle of the main injection (bimi_phi_w) and by the injection fuel quantity (fqsc_q_w)

Both parts (maximum cylinder pressure and shape) must be well adjusted to avoid any damage to the engine.

Problem with too high cylinder pressure:

In case the maximum cylinder pressure is too high, this can seriously damage the engine mechanics.

The maximum cylinder pressure value must be provided by the engine (and piston) manufacturer (a typical value of the maximum allowed cylinder pressure for production engines is 150...180bar).

→ Solution to avoid too high cylinder pressure: reduce the calibrated beginning of injection angle.

Problem with too much advanced position of maximum cylinder pressure:

In case the position of the maximum cylinder pressure regarding the TDC is too much advanced, this might reduce the torque of the engine, because the combustion force could start working against the normal piston movement. Additional at high engine loads the piston / engine might be seriously damaged.

→ Solution to retard the position of the maximum cylinder pressure: reduce injection angle at the corresponding working point in map BIMI_PHI_BASE_MAP.

Attention: Doing so, you have to monitor the exhaust gas temperature limits!

Problem with too late position of maximum cylinder pressure:

In case the position of the maximum cylinder pressure regarding the TDC is too late, this for sure will reduce the torque of the engine, because the use of the combustion force is not optimized (and it is already working against the compression of the other cylinders). Additional a late injection will increase the exhaust temperature, which can become a problem for the turbo charger.

And finally depending on the position of the combustion the opening / closing valves of the cylinder can be melted.

A good position for the maximum of the cylinder pressure to secure the engine at part load is at about 10[°Crk] after TDC.

→ Solution to advance the position of the maximum cylinder pressure: increase injection angle at the corresponding working point in map BIMI_PHI_BASE_MAP.

Hint: The maps, beginning of injection angle (BIMI_PHI_BASE_MAP) and pre control of the boost pressure controller (BPCO_DC_PRECON_GMP) should have the same axis set points (there are less X-axis set points for BPCO_DC_PRECON_GMP than for BIMI_PHI_BASE_MAP, so they have to be a subset).

The explanation for the calibration of BPCO_DC_PRECON_GMP is given in chapter "Calibration of boost pressure controller".

Calibration of BIMI_PHI_BASE_MAP:

For the calibration in this chapter the engine load at different engine speeds (covering the full engine speed range except for full load) must be adjusted to always the same injection fuel quantity of 30[mg/str]. The engine speeds to use are given by the X-axis set points of the map BIMI_PHI_BASE_MAP. They are going to be used one after the other (see table below).

It is recommended to use the same axis set points in the maps of function BIMI and BPCO if possible, in order to do both calibrations in the same engine operating points.

1	**Start the engine**
2	Run the engine with the engine speed (eess_n_avg_w) given by the first X-axis set point after low idle speed of the map **BIMI_PHI_BASE_MAP**.
3	Adjust the engine load using the break of the dyno until an injection fuel quantity of 30[mg/str] (fqsc_q_w) is injected. Hint: At low engine speeds an injection fuel quantity of 30[mg/str] might be not possible due to SMOKE- and/ or TORQUE-limitations. In this case adjust the engine load using the break of the dyno until one Y-axis setpoint (fqsc_q_w) of **BIMI_PHI_BASE_MAP** is matched - available default Y-axis set points: 5[mg/str], 10[mg/str], 15[mg/str], 20[mg/str], 25[mg/str].
4	Fix the injection fuel quantity (fqsc_q_w) using the remote control function to the closest Y-axis set point of **BIMI_PHI_BASE_MAP** in order to get stable injection fuel quantity conditions. **RMTC_Q_FQSC_CW** = fqsc_q_w [mg/str]
5	Enable the remote function for the injection fuel quantity. **RMTC_S_FQSC_CUC = 1**
6	Enable the global use of the remote control function. **RMTC_S_VS100_ON_CB = 1**
7	Check that the injection fuel quantity (fqsc_q_w) is equal to the value set in **RMTC_Q_FQSC_CW**
8	Change the beginning of injection angle (bimi_phi_w) at the given working point in map **BIMI_PHI_BASE_MAP** until the maximum of the cylinder pressure curve is at 10[°Crk] after TDC. For the fine calibration of the injection timing it is recommended to use increment-/decrement-steps of 0,1[°Crk]. After each calibration step wait a couple of seconds to see the influence of the calibration change to the cylinder pressure.
9	Extrapolate the calibrated angle in the present working point to the not yet calibrated adjacent cells in order to have already a good calibration forecast for working points that were not checked yet. For the extrapolation please follow the below given rules: 1) Adjacent cell with *higher engine speed* set point: *increase* calibration for beginning of injection angle 2) Adjacent cell with *lower engine speed* set point: *reduce* calibration for beginning of injection angle 3) Adjacent cell with *higher fuel injection quantity* set point: *increase* calibration for beginning of injection angle 4) Adjacent cell with *lower fuel injection quantity* set point: *reduce* calibration for beginning of injection angle
10	After the calibration of the beginning of injection angle (bimi_phi_w) in this working point is finished and the position of the maximum cylinder pressure is in the correct position of ~10[°Crk] disable the remote control function again.
11	Disable the global use of the remote control function. **RMTC_S_VS100_ON_CB = 0**
12	Disable the remote function for the injection fuel quantity. **RMTC_S_FQSC_CUC = 0**
13	Set the injection fuel quantity by remote control to 0 [mg/str] **RMTC_Q_FQSC_CW** = 0 [mg/str]
14	If the maximum engine speed is not reached yet, proceed with step 16 otherwise jump to step 19.
15	Change the engine speed (eess_n_avg_w) to the next engine speed set point given by the X-axis of **BIMI_PHI_BASE_MAP**.
16	While changing the engine speed and engine load to reach the next set point of the map **BIMI_PHI_BASE_MAP** the cylinder pressure signal(s) have to be checked the whole time for the following three cases: 1) The position of the max cylinder pressure is (much) earlier than 10[°Crk] after TDC => roughly reduce the beginning of injection angle at the present working point until the position of the maximum cylinder pressure is in the area of 10[°Crk] after TDC. 2) The position of the max cylinder pressure is (much) later than 10[°Crk] after TDC => roughly increase the beginning of injection angle at the present working point until the position of the maximum cylinder pressure is in the area of 10[°Crk] after TDC.
17	Jump back to step 3.

Corresponding excel file: “Calibration_PCylinder_via_BIMI.xls” – sheet “HowTo”

Calibration target: When the calibration work in this chapter is finished the shape of the position of the maximum cylinder pressure for an injection fuel quantity (fqsc_q_w) of 30[mg/str] (at low engine speeds for smaller injection fuel quantities) must be at ~10[°Crk] after TDC for the complete engine speed range.

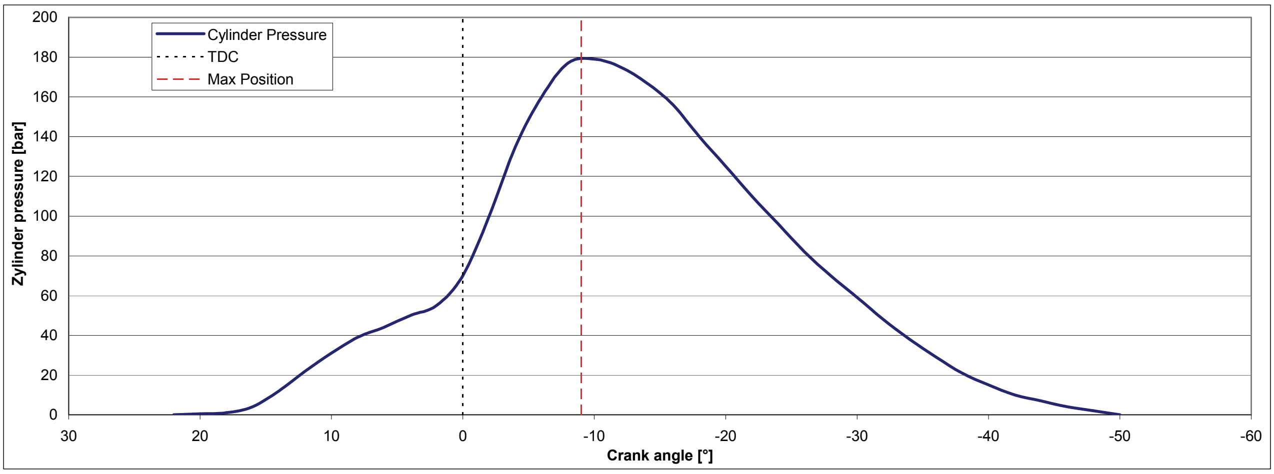
Additional the injection begin angle for the adjacent cells in map BIMI_PHI BASE_MAP are extrapolated according to the real calibrated values to ensure a safe operation of the engine.

The following picture gives an example for the shape of the cylinder pressure signal. The angle values and the level of the maximum pressure depend on the specific engine. For sure they will be different, but the shape of the signal has to be similar.

Example for cylinder pressure shape

Cylinder Pressure TDC

22	20	18	16	14	12	10	8	6	4	2	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-20	-22	-24	-26	-28	-30	-32	-34	-36	-38	-40	-42	-44	-46	-48	-50	[°Crk]
0	0.5	1	4	12	22	31	39	44	50	55	70	100	135	160	177	179	175	167	156	140	125	110	96	82	70	59	48	38	29	21	15	10	7	4	2	0	[Bar]



Graphic 27 (Calibration_CylinderPressureShape.xls)

6.11 Calibration to improve the engine performance

So far the performed calibration work should cover the following engine settings:

- Reliable engine start without big overshoots in engine speed when low idle speed set point is reached the first time
- Stable engine operation in low idle controller with small oscillations and good injection quantity pre control coming from the friction map so that there is only small PID controller interference
- Good rail pressure build-up during engine start until rail pressure set point is reached
- Accurate HP pump pre control command to have only small PID-rail pressure controller interference and to minimize the necessary rail pressure controller adaptation.
- Stable rail pressure control on rail pressure set point
- Fast reaction of rail pressure to changes in the rail pressure set point without too big over- / undershoots when the set point is reached
- Maximum boost pressure setpoint adapted to your engine configuration.
- Stable boost pressure control on boost pressure setpoint.
- Full load optimization with main injection angle, fuel quantity calibrated for your specific engine
- Smoke limitation well calibrated to ensure a fast engine reaction without high smoke opacity.
- Limitation of engine speed to the maximum allowed value in combination with a fitting cut-in engine speed of the high idle controller.

Now the calibration work proceeds in order to set up the maximum performance of the engine.

The engine calibration for performance is a mixture of the chapters

"Torque limiting"

"Calibration of boost pressure controller"

"Calibration of rail pressure controller"

While optimizing the performance calibration the following values need to be monitored very carefully to their limits.

- Cylinder pressure
- Exhaust gas temperature
- Turbocharger speed
- Torque limitation given by engine mechanics (based on material properties of e.g. crankshaft, bearing forces, etc...)
- All the others engine parameters which could have a destructive impact like coolant temperature (ects_t_w), oil pressure (eops_p_w), oil temperature (eots_t_w) and so on...

6.12 Bosch Motorsport support

Thanks to our great experience on Diesel engines, we are able to provide engineering support according to customer specific needs regarding the following aspects:

- Engine calibration: dataset preparation, first start at dyno, fine optimization at dyno or vehicle
- Software development: update specification and implementation
- Fuel injection equipment upgrade: components choice and delivery within a wide portfolio including series and sample parts
- Engine management system technical definition: engine control unit/ sensors/actuators choice and delivery within a wide portfolio including series and sample parts

Feel free to contact Bosch Motorsport at Markgröningen or your local support team (North and South America, Asia Pacific, UK, France) for further information.

Contact

Europe:
Bosch Engineering GmbH
Motorsport
Robert-Bosch-Allee 1
74232 Abstatt
Germany
Phone: +49 7062 911 79101
Fax: +49 7062 911 79104

North and South America:
Bosch Engineering North America
Motorsports
38000 Hills Tech Drive
Farmington Hills, MI 48331-3417
United States of America
Phone: +1 248 876 2977
Fax: +1 248 876 7373

Asia Pacific:
Bosch Engineering Japan K.K.
Motorsport
3-33-8 Tsuruya-cho, Kanagawa-ku, Yokohama-shi
221-0835
Japan
Phone: +81 45 410 1650
Fax: +81 45 410 1651

E-Mail: motorsport@bosch.com
www.bosch-motorsport.com

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