Infineon technologies

Automotive -Seminar

LENZ MOTORENTECHNIK GmbH

Technical basics of engines

Enginemanagement-Systems

Actuators

Sensors

Dyno (engine test bench)

Basic facts mixture formation

Mixture ratio for complete combustion = stoichiometrical ratio

14,7 kg air to 1 kg fuel

Definition of λ (Lambda-value)

$$\lambda = \frac{\text{Supplied mass of air}}{\text{stoichiometrical mass of air}}$$

λ > 1: meager mixture (redundant air)

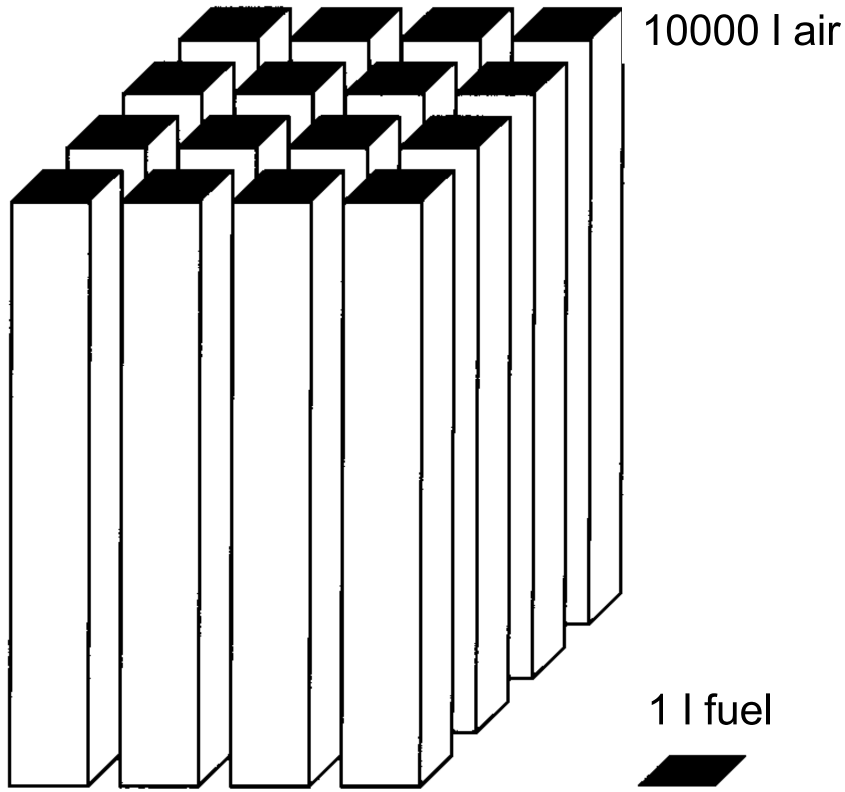
λ = 1: stöchiometrical mixture

λ < 1: rich mixture (lack of air)

λ = 0,6..1,3: operational range (ignitability)

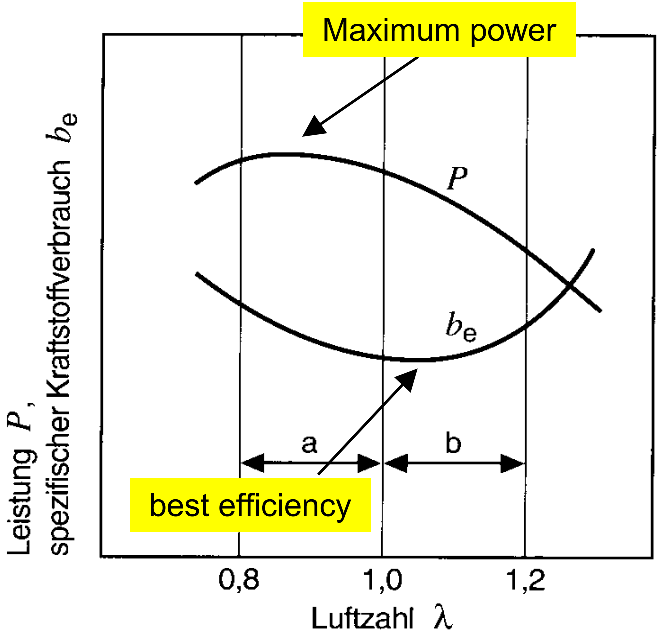
Basic facts volume ratio air-fuel

Picture 1: volume ratio air-fuel for combustion at point of minimal specific fuel consumption



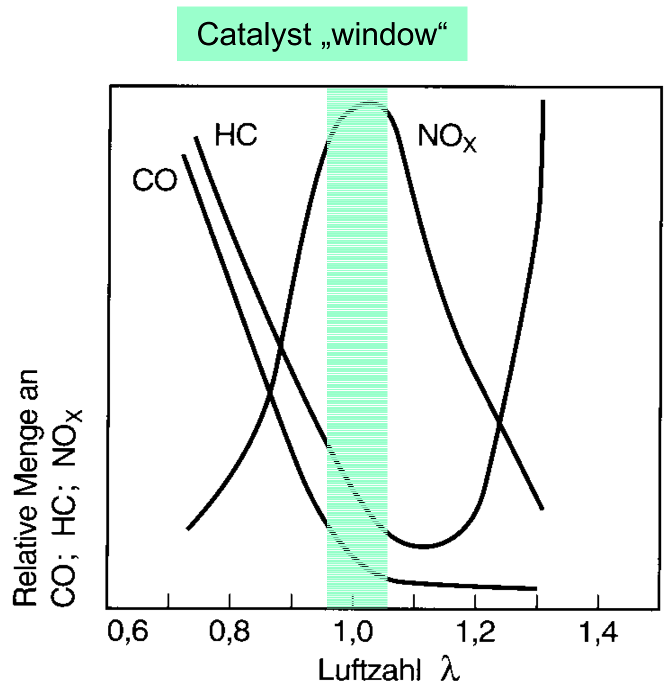
Basic facts influence of λ-value

Picture 2: Influence of λ on power P and specific fuel consumption b_e
a) rich mixture (lack of air)
b meager mixture (redundant air)



conflict power - efficiency

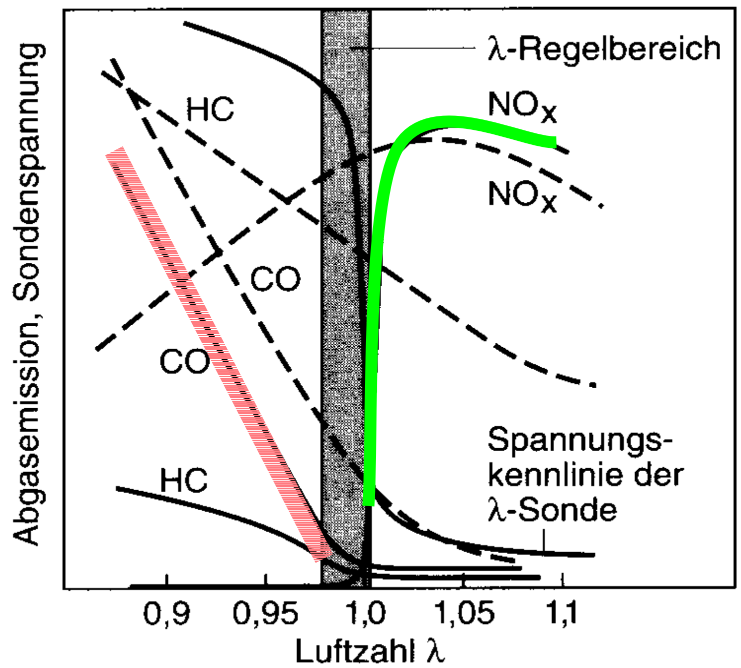
Picture 3: Influence of λ on the distribution of emissions in exhaust gas



Raw emissions before catalyst

Reduction of harmful emissions via catalyst

Picture 4: control-range of lambda-sensor and reduction of harmful emissions in exhaust gas
-------------- without catalytic conversion
________ with catalytic conversion



- best reduction of all harmful emissions only within range λ=0.98..1.01
- rich mixture: increasing CO
- meager mixture: increasing NOx
- power - consumption - exhaust gas are conflicting constraints

Requirements:

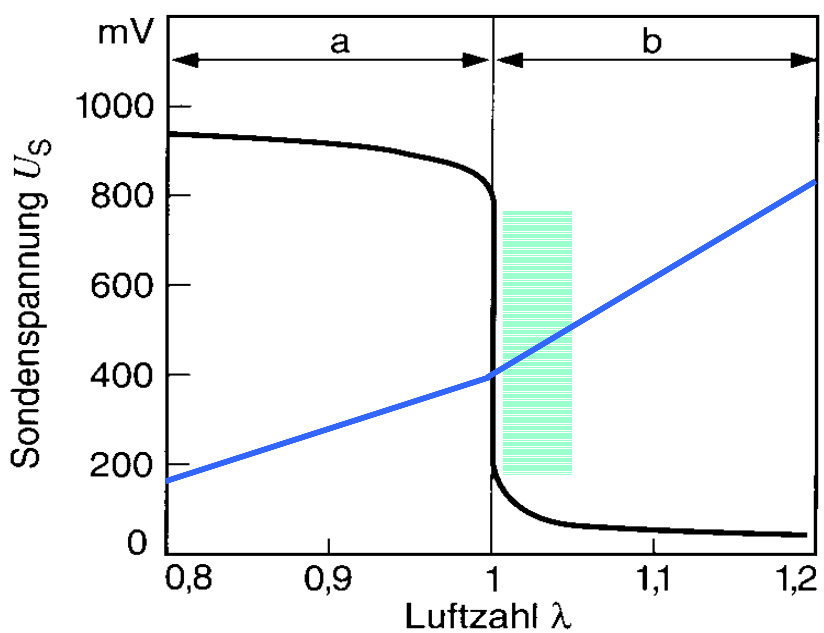
- fast startup of catalyst (exhaust gas >400°C)
- high quality of Lambda-control loop
- detection of misfiring
- monitoring function of catalyst (additional λ-sensor)

Solutions:

- broad-band catalyst, adsorbing catalyst, electrically preheated-Kat
- broad-band λ-sensor
- engine-management
- engine-construction

Basic facts λ-sensor characteristic

Picture 5: voltage-characteristic of λ-sensor at operating temperature 600°C
a) rich mixture (lack of air)
b) meager mixture (redundant air)



Problems:

- voltage-drift with temperature
- no linear characteristic
- ranges with bad resolution
- inertia: 300 ms for λ=0.8..1.2
- rapid aging

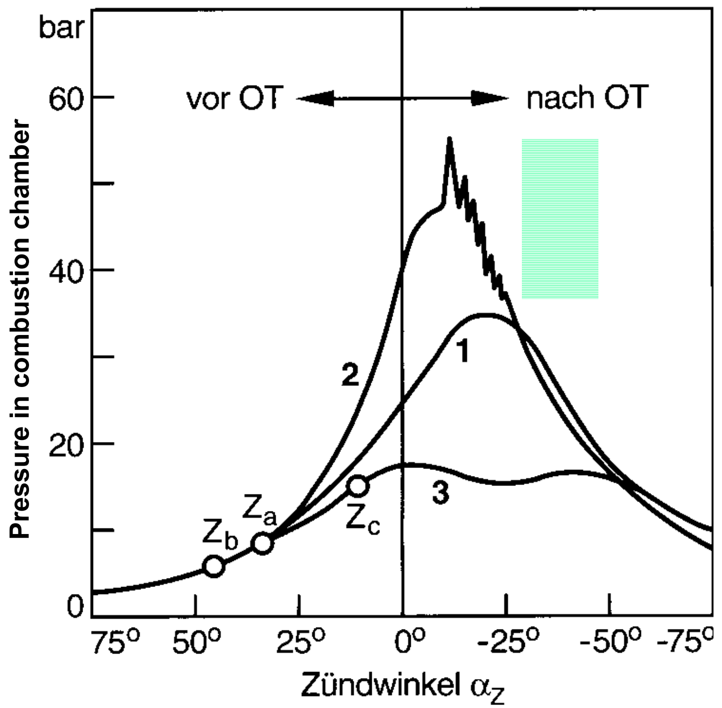
Solution:

- broad-band sensor
- linear characteristic (edge at λ=1)
- response time 10 x faster
- extended range λ=0.6..1.6

Ranges with bad resolution

Basic facts ignition control

Picture 6: pressure pattern in combustion chamber at different ignition control settings:
1) right time
2) too early (knocking combustion)
3) too late (loss of power)

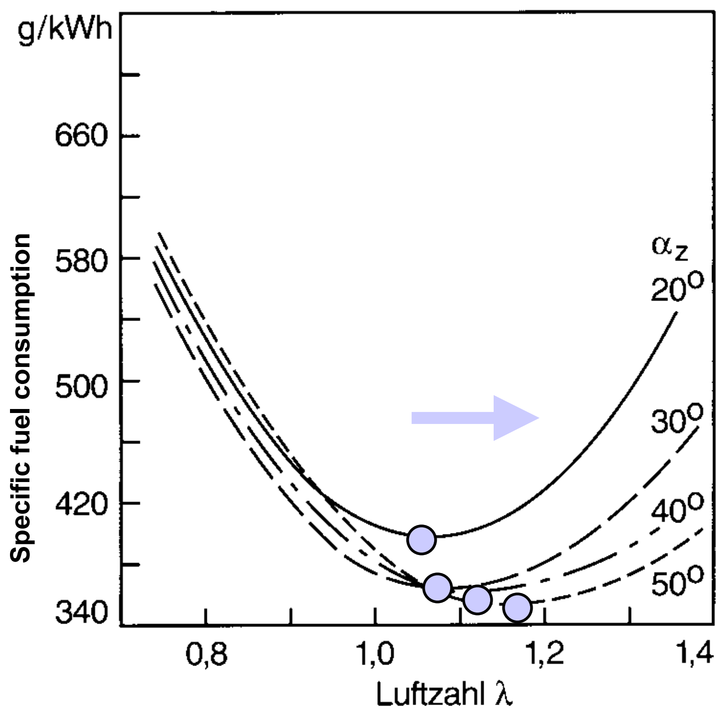


- speed of combustion depends on load (pressure) and λ-value
- ignition control depends on rotational speed
- integral on pressure pattern equals working capacity
- pressure pattern can be measured with special sensors
- ideal: flame-front-sensor (spectral colour)
- knock-sensor detects pressure-oscillations knocking-control reduces ignition control
- ideal: avoiding of knocking
- the tendency to knocking depends on constructive properties of the engine

Klopfen

Basic facts optimizing an engine

Picture 7: influence of λ-value and ignition control setting α_z to specific fuel consumption:

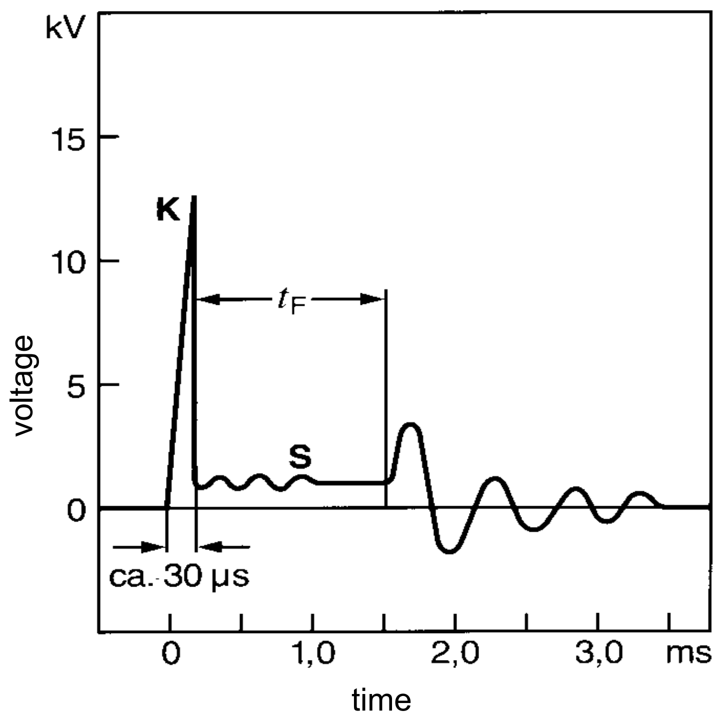


- λ-value and ignition control setting cannot be optimized independently
- the point at minimal specific consumption shifts with increasing ignition control settings towards meager mixtures.
- There is a similar behavior concerning the point of maximum power.
- Optimizing one specific operational point is a procedure with multidimensional dependancies and conflicting constraints.
- The strategy of optimizing depends on the primary orientation. (power - exhaust gas - consumption)
- optimizing the dynamic properties (changes in load and rotational speed) involves even more complicated steps.

Voltage characteristics of spark plugs

Spark plug voltage with a quiescent or only slightly turbulent mixture

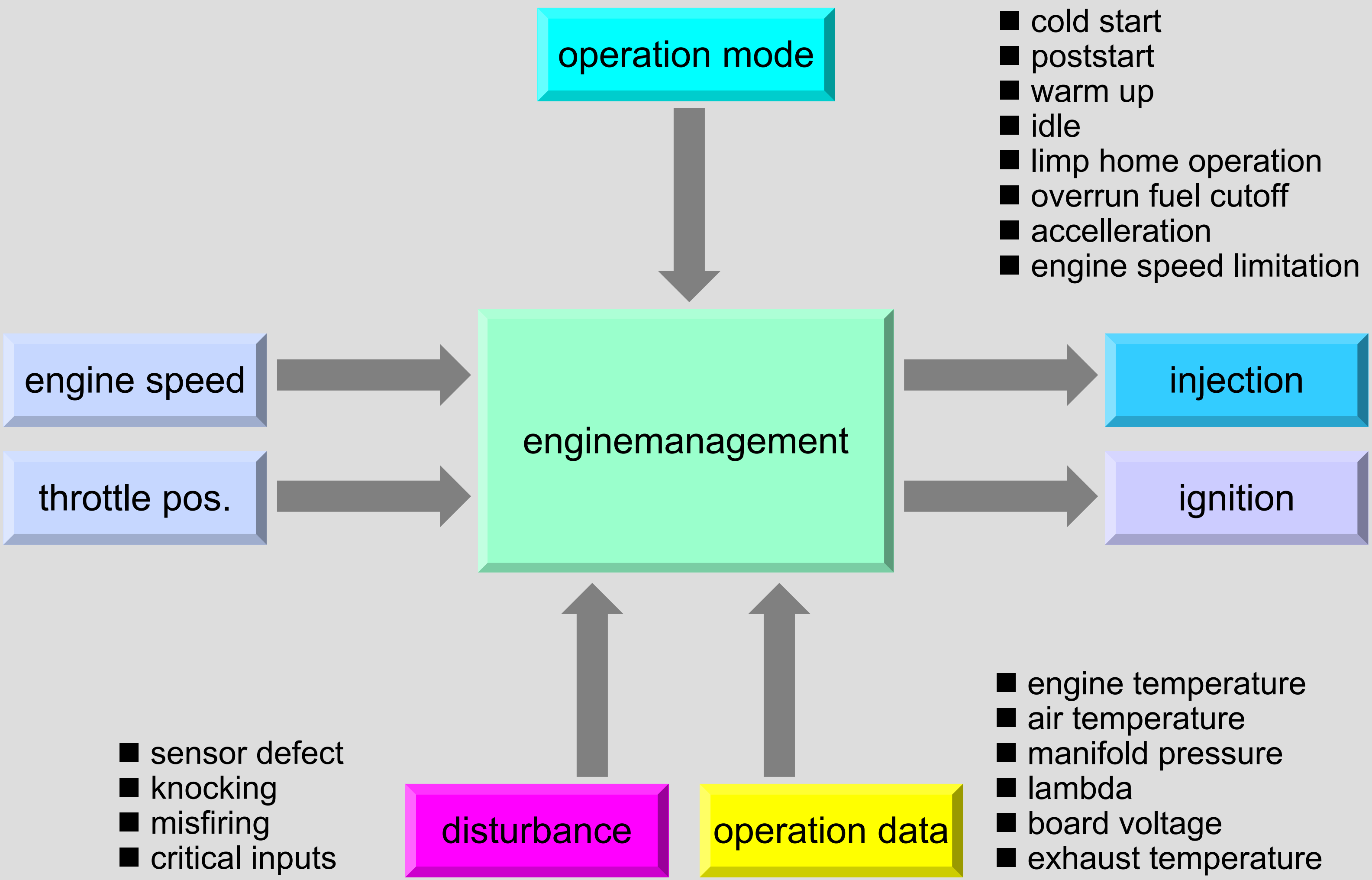
K ignition voltage, S spark voltage, t_F spark duration



Conclusions of the spark plug voltage:

- conditions in the high voltage system
- Quality of combustion
- misfiring
- knocking

Engine management - modelling



Basic functions of engine management

A engine management system outputs the required injection fuel quantity and the right moment of ignition.

Injection fuel quantity and ignition angle depend mainly on the engine speed and the throttle position (=load).

Additional inputs are temperature, pressure and the actual operation mode.

Injection fuel quantity and the right moment of ignition have to be tested on a dyno for every type of engine.

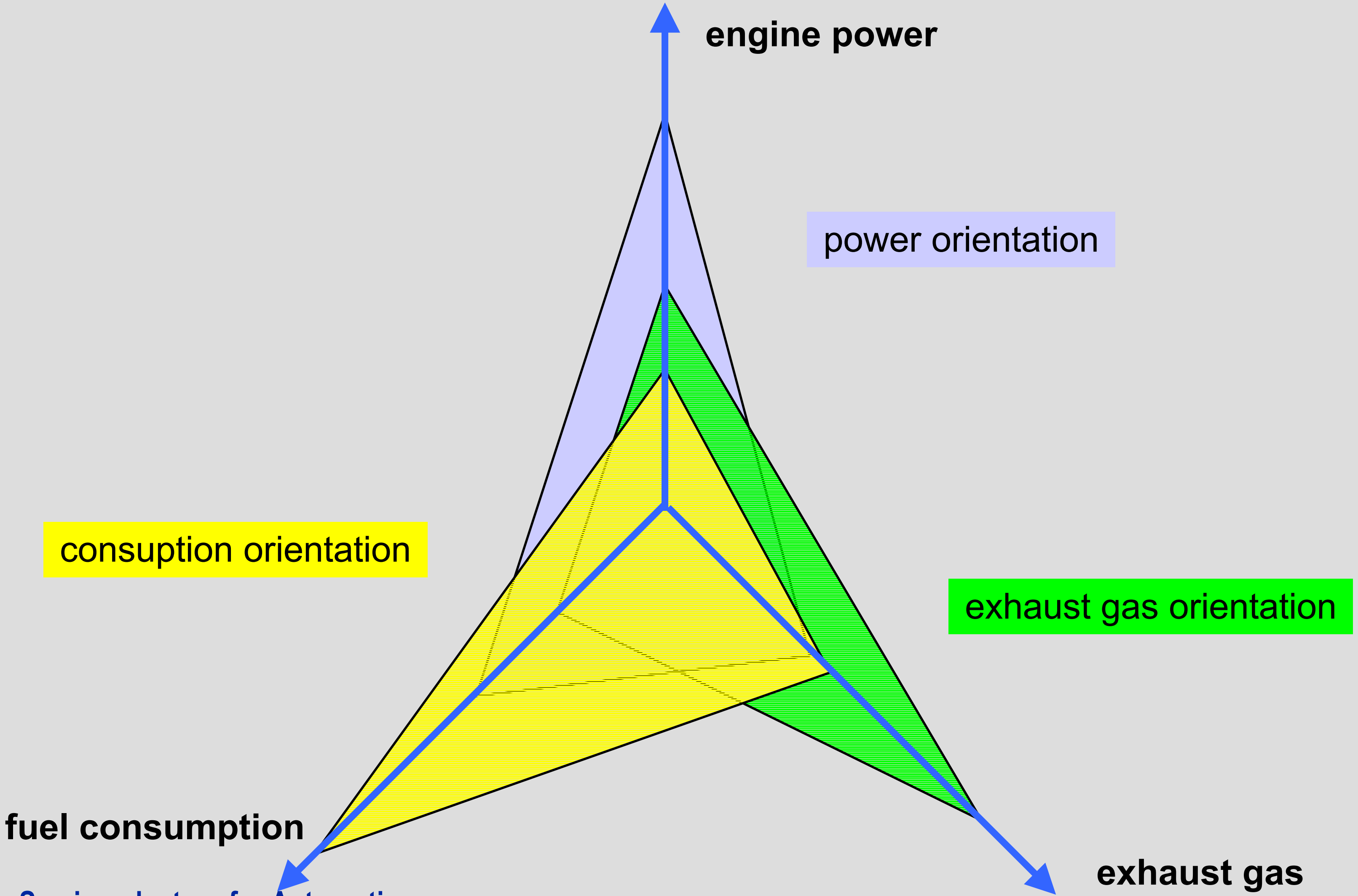
Both values depend on each other. They must be optimized relating on the kind of operation. For the criteria power, exhaust gas, fuel consumption different values will be found.

The values are evaluated for representative points of operation and are saved as a lookup table for engine speed and load.

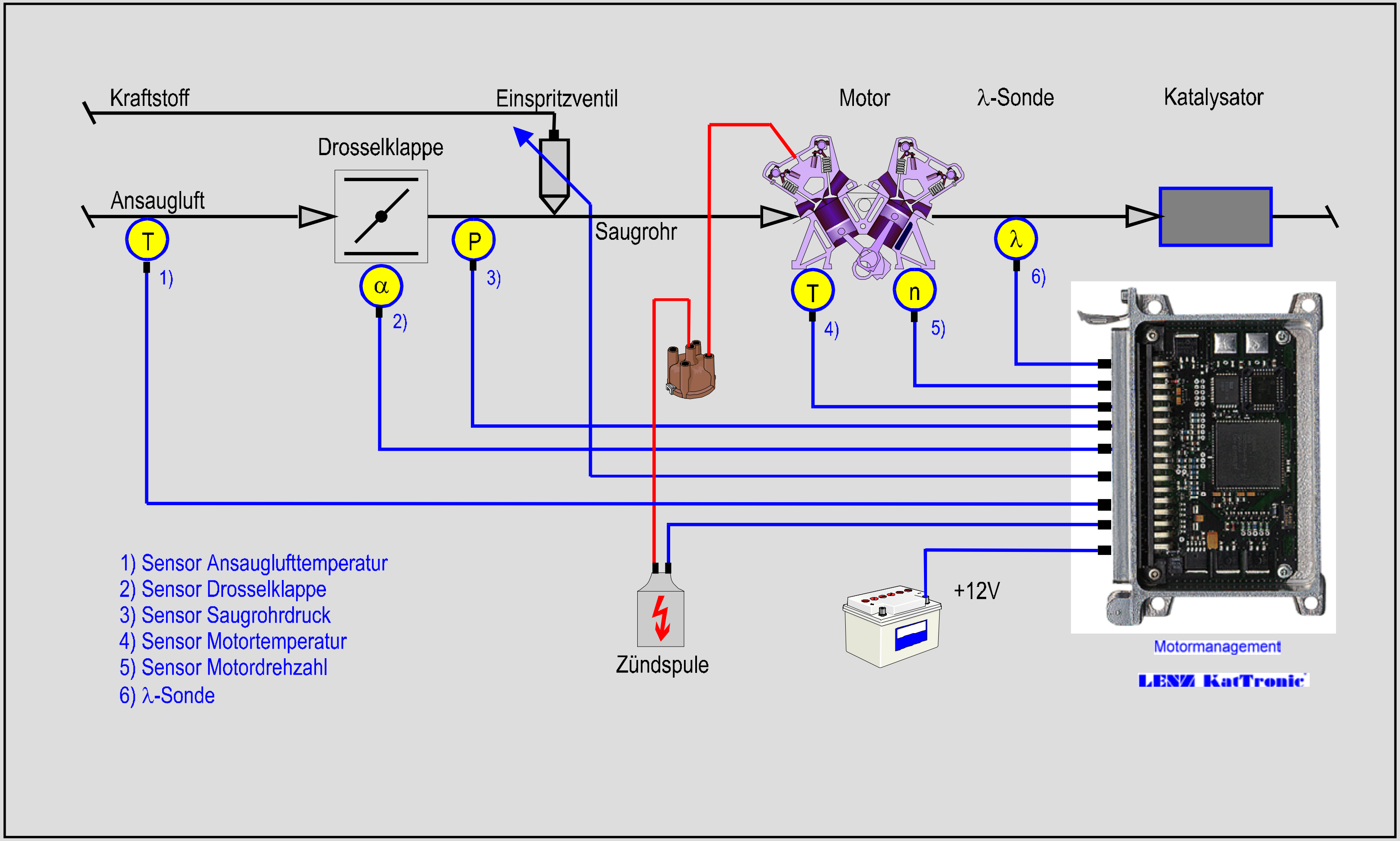
The real values are calculated with a mathematical model which is determined by the operation mode and the operation parameters.

The output values for injection and ignition are calculated with interpolation algorithms of the representative values.

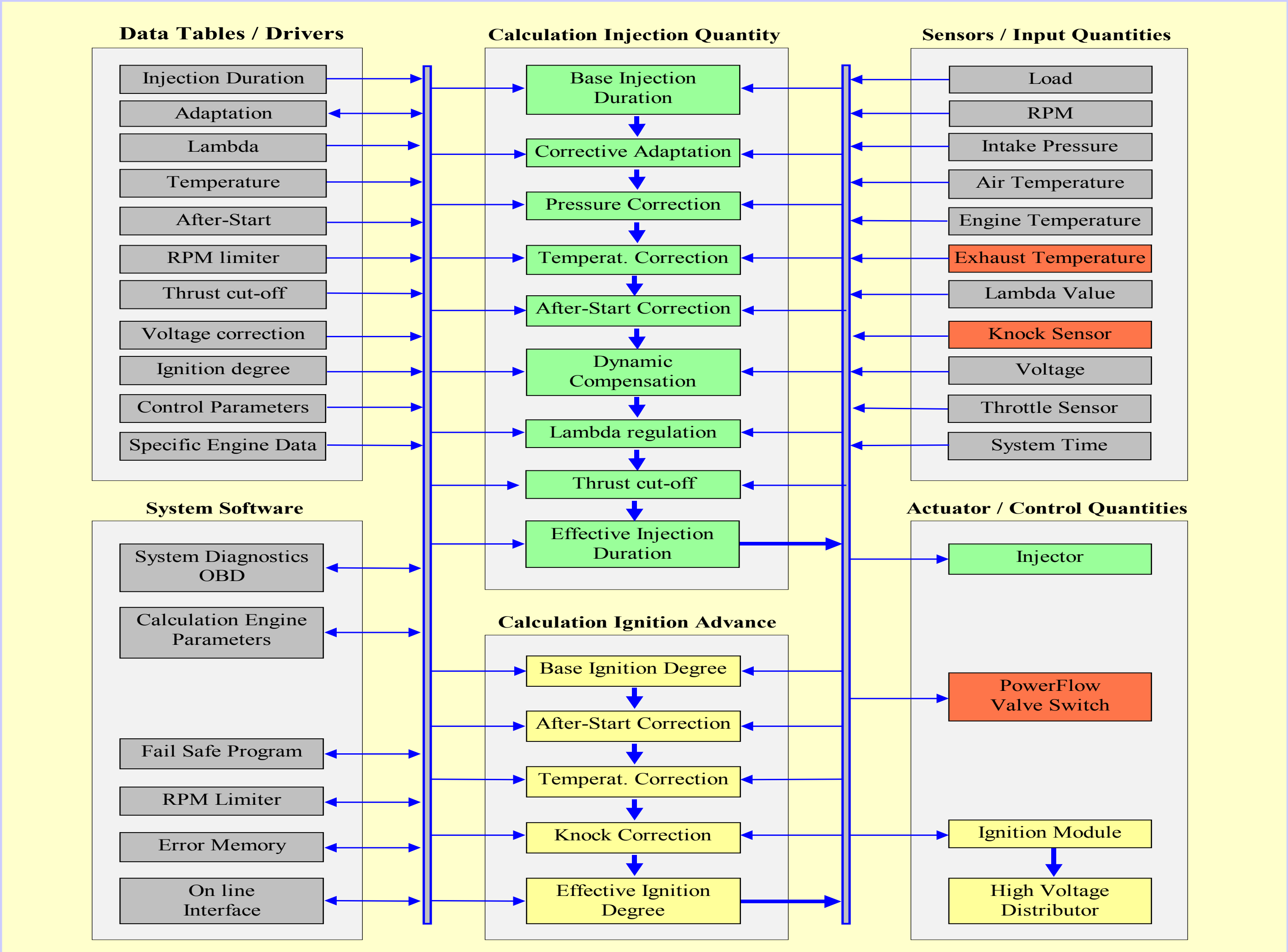
Optimizing an engine - conflicts



Engine management - System integration



Engine management - Lenz KatTronic Structure



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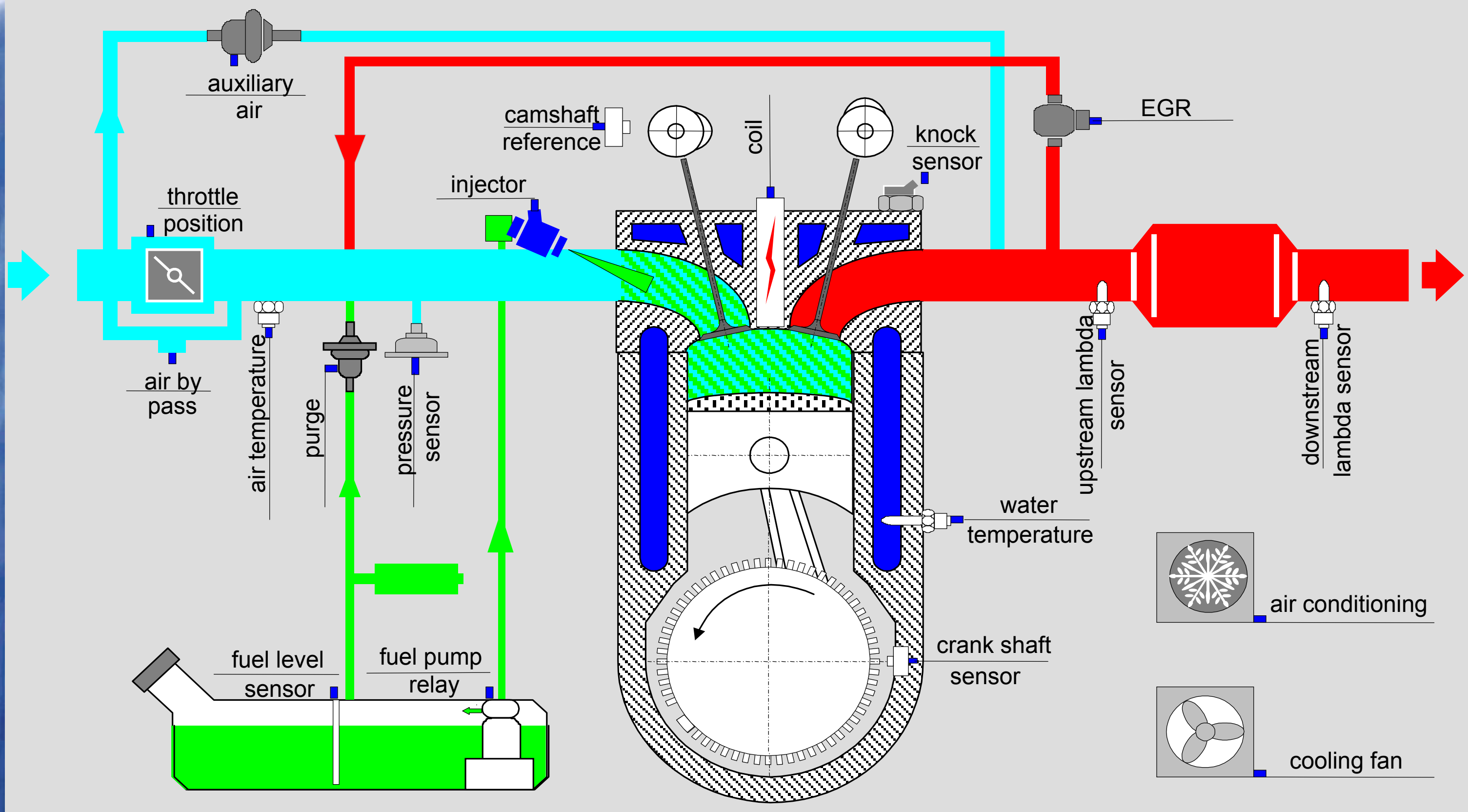
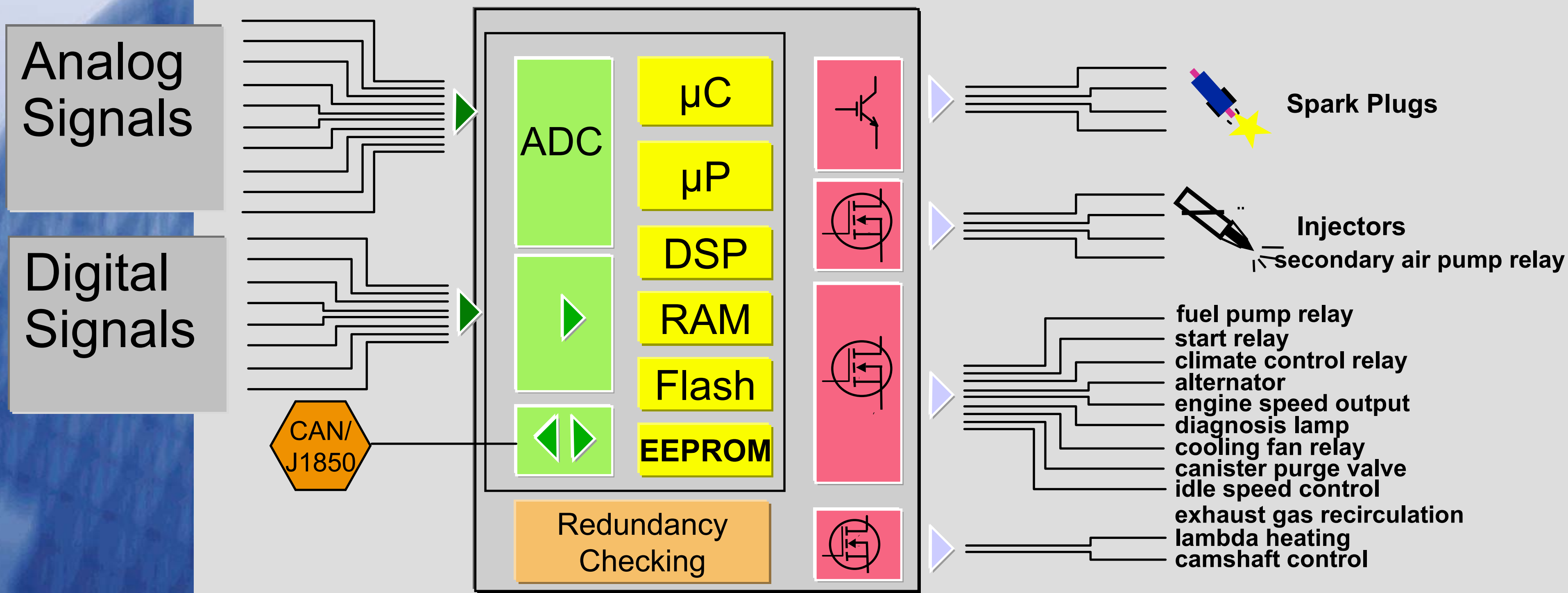
Engine management Lenz KatTronic

- developped out of the requirements of professional motorsports
- real-time - for each cycle complete calculation of output-control values
- high resolution processing of sensor-signal (hardware-PLL)
- lean and efficiently designed Software based on an 8-bit-architecture
- special algorithms for optimal dynamic performance
- operational flexibility (adaptive table-values)
- universal interfaces for sensors and actors with free definable characteristic
- build in accordance to EMI/EME-standards (SIPAD/SMD-technology)
- pin- and plug-compatible to standard-engine-controls (Bosch, Marelli, Siemens)
- modular design of engine-model for a wide range of motortypes
- on-line interface for output of Data (display/data recording)
- on-line interface for changes of operational parameters while running engine
- self-diagnostic with storage of anomal operational states

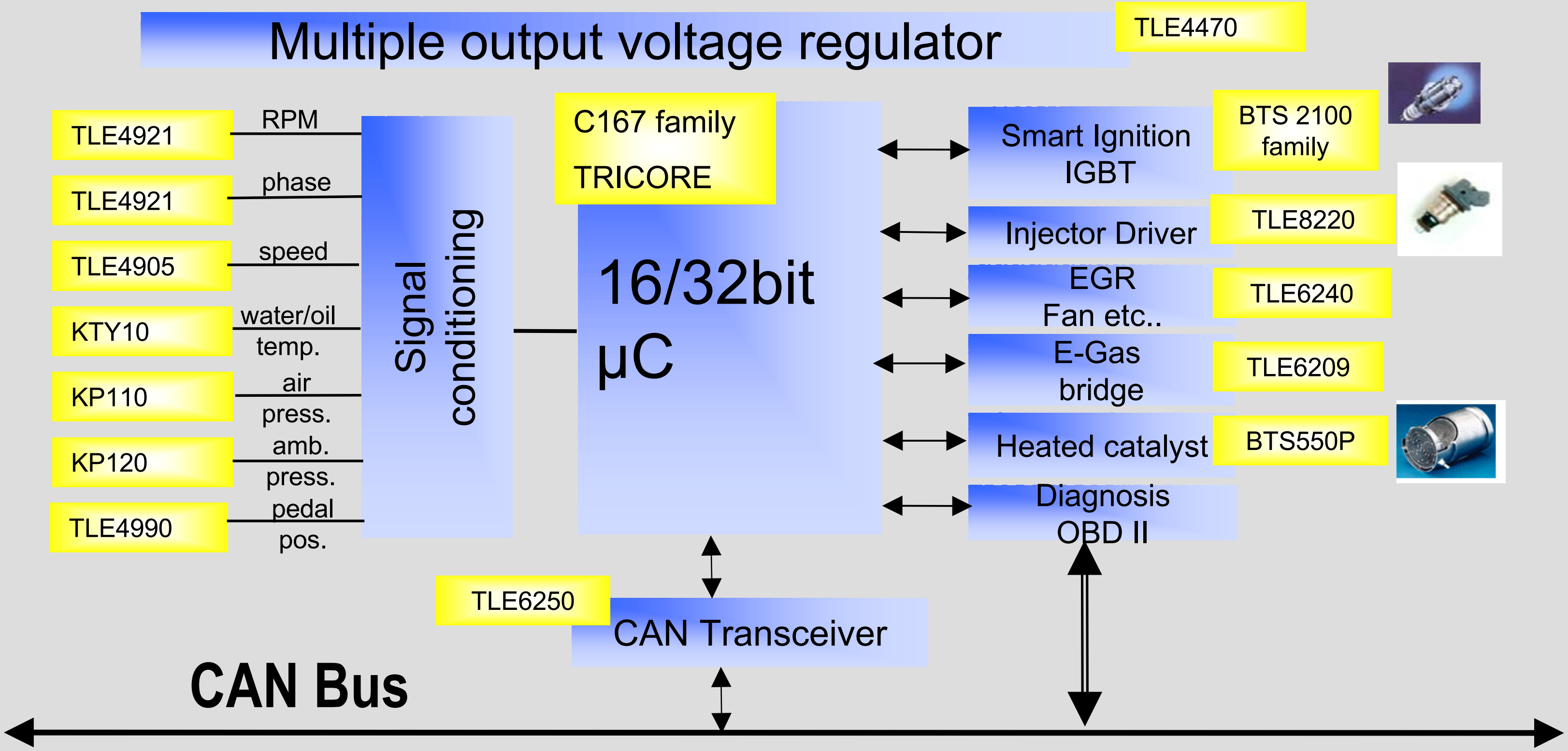
Engine management schematic



Engine management block diagram



Semiconductors for engine management



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Components for engine management

Category	Part	Short Form	Remark
Voltage Supply	TLE 4470	5V with 180mA, adjustable output with 350mA	
	TLE 4476	5V with 330mA, 3.3V with 250mA	
	TLE 4267	5V, 400mA	
	TLE 4286	5V, 10mA, in SCT 595 package	
	TLE 4250	50mA voltage tracker in SCT 595 package	
CAN transceiver	TLE 6250	high speed CAN transceiver	
MOSFETs	BUZ 1xxS,	55V/ 8..120mOhm	
	SPDxxN03	30V/ 6..23mOhm	
	SPBxxN10L	100V/ 25..40mOhm	
Smart Power Switches	TLE 62xx	(16-, 8-, 4-fold driver low side)	valve/relay driver
	TLE 5216	4-fold driver low side	valve driver
	HITFET	i.e. BTS 118	oxygen heater
	PROFET	i.e. BTS 308	fuel pump
	TEMPFET	i.e. BTS 244 Z	fuel pump

Components for engine management

Category	Part	Short Form	Remark
Smart Power Bridges	TLE 5205-2	4 A full bridge	throttle bypass
	TLE 5206-2	4 A full bridge	throttle bypass
	BTS 771	5 A full bridge	throttle bypass
	TLE 4728	2*0.7 A dual phase stepper	throttle bypass
	TLE 6209	7A, full bridge, SPI control	E-gas
Sensors	KSY44	linear GaAs Hall sensor	throttle position
	TLE 4921	dynamic differential Hall IC	cam/crankshaft
	FP410	magneto resistor	cam/crankshaft
Discretes	BCR1xx/5xx	digital transistor	
	BAS/BATxxx	Schottky diode	
System-ASICs	on request		
Microcontroller	C167CR	16bit, CAN, 10 Mips @ 20MHz	
	C167CS	16bit, 2xCAN, 2Mbit Flash, 25 Mips @ 40MHz	
	TriCore	32bit, 100 MIPS @ 50 MHz, Flash, TwinCAN	

Engine management - definition of maps

The operation parameters of an engine are mainly influenced by:

- **engine speed**
- **load (throttle position)**

The **operation point** of an engine is the combination of a certain engine speed and a load value.

To describe the **operation points of an engine,** a **fixed** number of engine speed and load values have to be defined. A certain operation parameter (e.g. time of injection or ignition angle) is stored in a look up table (map) for every combination of engine speed and load.

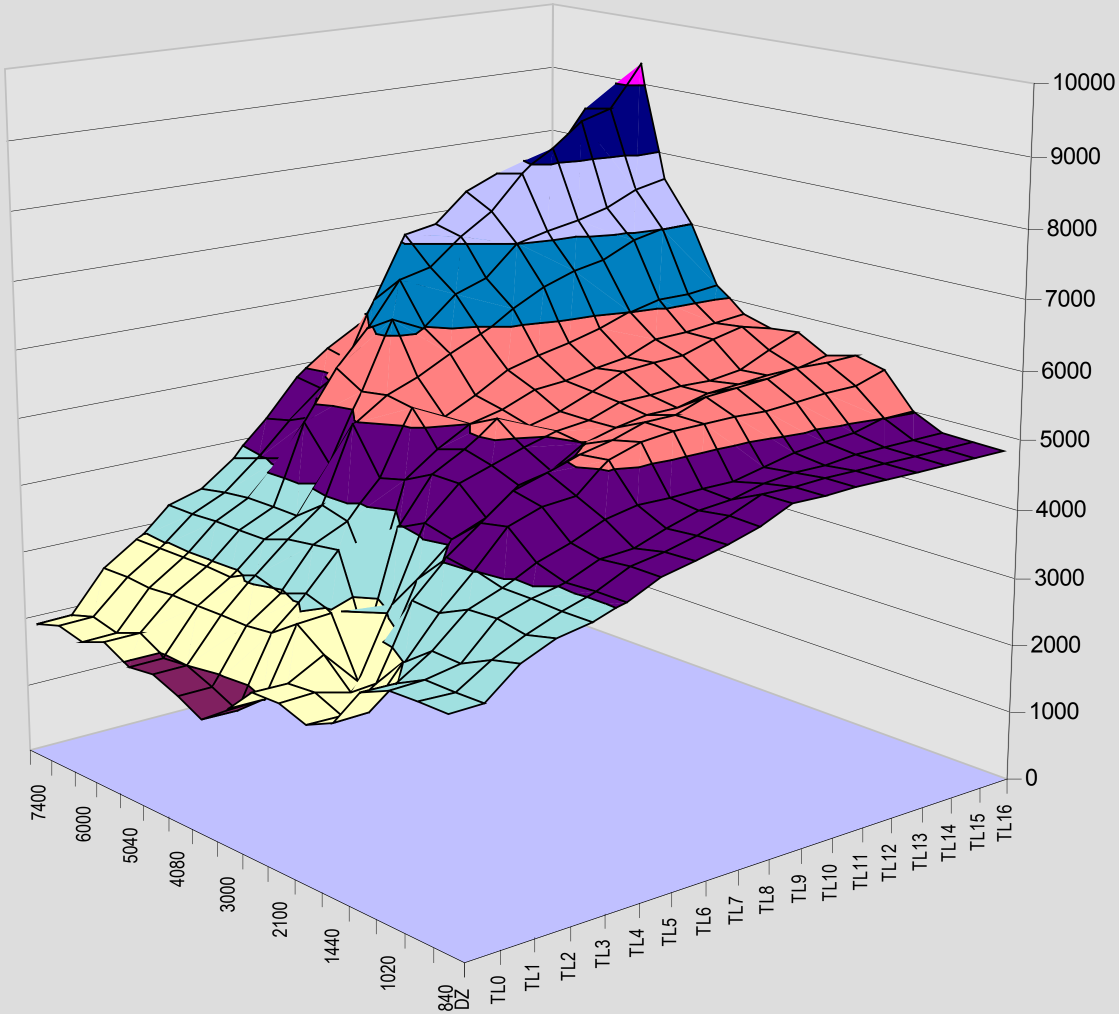
A **map or look up table** is a diagramm with three axes including the set points of an engine (z-axis) depending on the load and engine speed (x and y axis).

The values of a certain operation point are calculated by linear interpolation of the next four data points in the map.

Injection table

DZ	TL0	TL1	TL2	TL3	TL4	TL5	TL6	TL7	TL8	TL9	TL10	TL11	TL12	TL13	TL14	TL15	TL16
7200	2000	2596	2925	3333	3481	3852	4347	4903	5249	5517	5714	5908	6040	6332	6662	6955	7119
6600	2118	2596	2925	3345	3543	3955	4450	4845	5175	5838	6357	6629	6751	6901	6900	7305	7522
6000	2037	2596	2925	3358	3605	4083	4627	5265	6220	7109	7205	7608	7803	7803	8009	8600	8007
5520	2178	2611	2925	3358	3605	4753	5455	5961	6600	6708	7103	7406	7909	8207	8553	8684	9309
5040	1961	2608	2925	3358	3605	4252	5239	6205	5989	6408	6558	7001	7100	7207	7309	7505	7607
4560	1999	2631	3086	3503	3881	4981	5308	5459	5709	5909	6208	6455	6609	6702	6904	7007	7004
4080	1852	2609	2972	3548	3791	4307	5233	5008	5208	5502	5629	5703	5851	6005	6102	6100	6158
3600	1680	2666	3092	3603	2970	4394	4752	5001	5109	5303	5351	5451	5509	5706	5705	5756	5807
3000	1974	2922	2972	2426	3971	4601	4855	5206	5001	5109	5309	5508	5550	5555	5709	5809	5702
2520	2380	2643	2139	3125	4159	4607	4754	4900	5055	5109	5252	5275	5303	5301	5353	5555	5756
2100	2391	2271	2724	3617	4058	4255	4602	4708	4989	5103	5201	5205	5317	5365	5381	5400	5488
1740	2242	2555	3575	4053	4409	4760	4909	5057	5158	5309	5305	5488	5500	5538	5604	5604	5606
1440	2435	3006	3559	4009	4501	4657	4705	5102	5245	5303	5307	5300	5300	5325	5351	5371	5503
1200	3000	3315	3750	3908	4152	4303	4502	4609	4601	4605	4609	4708	4808	4852	4904	5004	5004
1020	3200	3300	3777	3923	4021	4208	4250	4402	4556	4600	4700	4750	4750	4800	4800	4800	4800
900	3200	3500	3700	3900	4040	4248	4344	4452	4596	4800	4800	4800	4800	4800	4800	4800	4800
840	3200	3600	3800	3900	4041	4248	4344	4452	4596	4800	4800	4800	4800	4800	4800	4800	4800

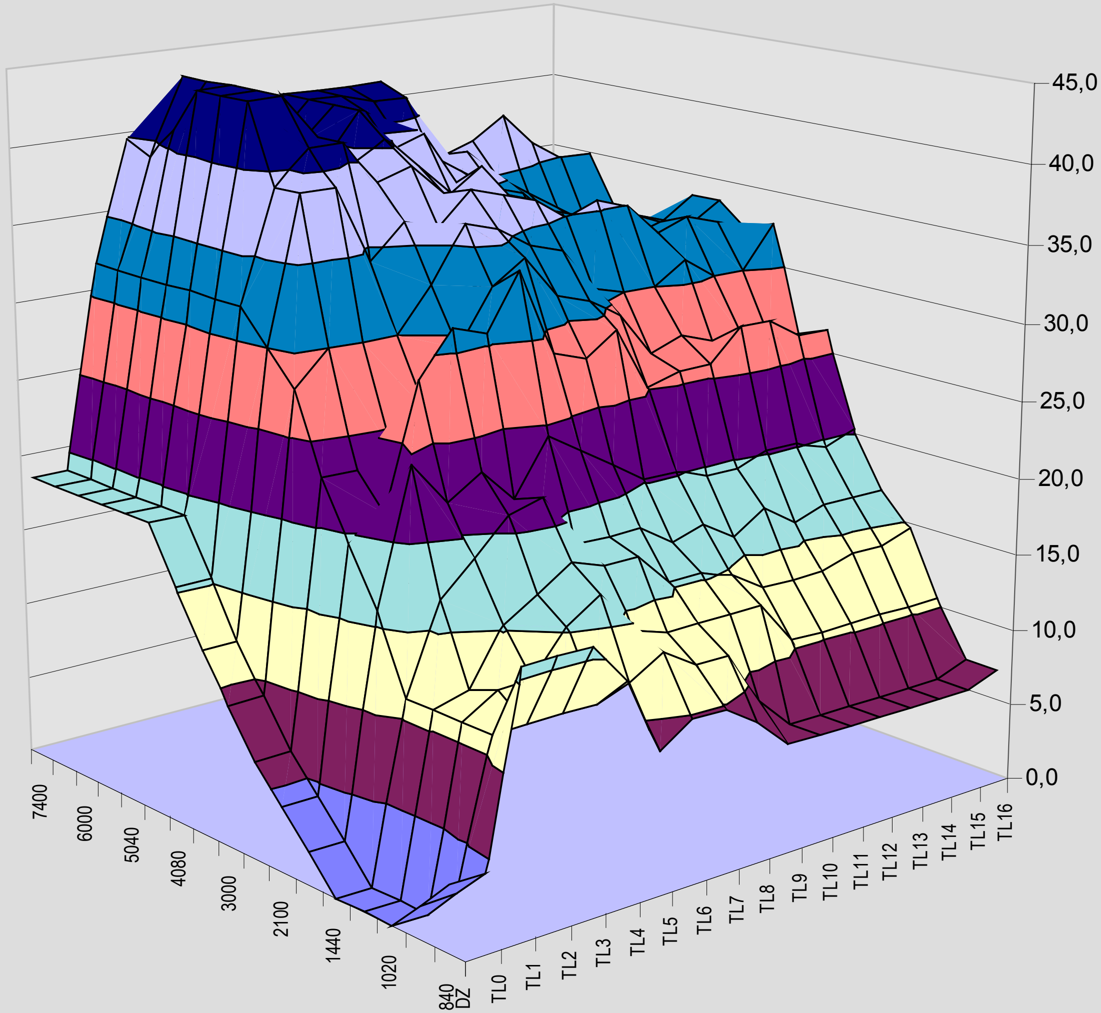
Map of injection



Ignition table

DZ	TL0	TL1	TL2	TL3	TL4	TL5	TL6	TL7	TL8	TL9	TL10	TL11	TL12	TL13	TL14	TL15	TL16
7200	18,8	32,1	39,8	39,8	39,8	39,8	39,8	39,8	37,0	35,6	32,8	29,3	27,2	25,8	25,1	25,1	27,9
6600	18,8	32,1	39,1	44,0	41,2	39,8	41,9	41,9	41,9	41,9	37,7	36,3	37,0	38,4	36,3	34,9	34,9
6000	18,8	32,1	41,2	44,0	41,2	39,8	41,9	41,9	41,2	41,2	37,0	37,0	34,9	33,5	32,1	30,7	31,4
5520	18,8	32,1	44,0	44,0	41,2	39,8	41,9	41,2	39,1	37,7	36,3	34,9	34,2	32,1	31,4	30,7	30,0
5040	18,8	32,1	44,0	44,0	41,2	39,1	41,9	39,1	39,8	36,3	35,6	32,1	31,4	30,0	30,0	31,4	30,0
4560	18,8	32,1	44,0	44,0	41,2	39,1	40,5	38,4	36,3	37,7	34,2	34,2	33,5	33,5	32,8	32,1	33,5
4080	15,3	32,1	39,1	41,2	41,2	38,4	39,1	37,0	36,3	36,3	33,5	33,5	32,8	32,1	32,8	32,1	33,5
3600	11,9	30,0	39,1	39,1	34,2	36,3	35,6	37,7	37,0	36,3	34,9	35,6	34,9	32,8	33,5	32,8	32,1
3000	9,1	27,9	30,0	30,0	30,0	32,8	36,3	35,6	34,2	33,5	30,7	30,0	30,0	31,4	30,0	30,0	32,8
2520	6,3	23,0	23,0	23,7	25,8	29,3	32,8	34,2	31,4	30,7	29,3	26,5	27,2	26,5	26,5	25,8	25,8
2100	4,2	19,5	20,9	28,6	31,4	30,7	34,2	28,6	27,9	29,3	25,1	25,8	25,8	27,9	27,9	26,5	26,5
1740	2,1	16,0	24,4	21,6	23,0	20,9	24,4	23,0	21,6	20,2	20,2	19,5	19,5	20,2	20,2	19,5	20,2
1440	0,0	11,2	16,7	18,8	20,9	21,6	18,1	18,1	18,1	16,7	17,4	16,0	17,4	16,0	16,7	16,7	16,7
1200	0,0	11,2	11,9	15,3	16,7	18,1	17,4	17,4	15,3	15,3	14,7	13,3	13,3	13,3	14,0	14,0	14,7
1020	0,0	11,2	12,6	12,6	15,3	16,7	14,0	13,3	13,3	13,3	13,3	10,5	10,5	10,5	10,5	10,5	10,5
900	2,1	11,2	11,2	11,2	11,2	11,9	13,3	11,9	11,9	8,4	6,3	6,3	6,3	6,3	6,3	6,3	7,0
840	4,2	16,0	16,0	16,0	13,3	8,4	9,8	9,8	8,4	6,3	6,3	6,3	6,3	6,3	6,3	6,3	7,0

Map of ignition



Actuators in engines

Basic types of actuators

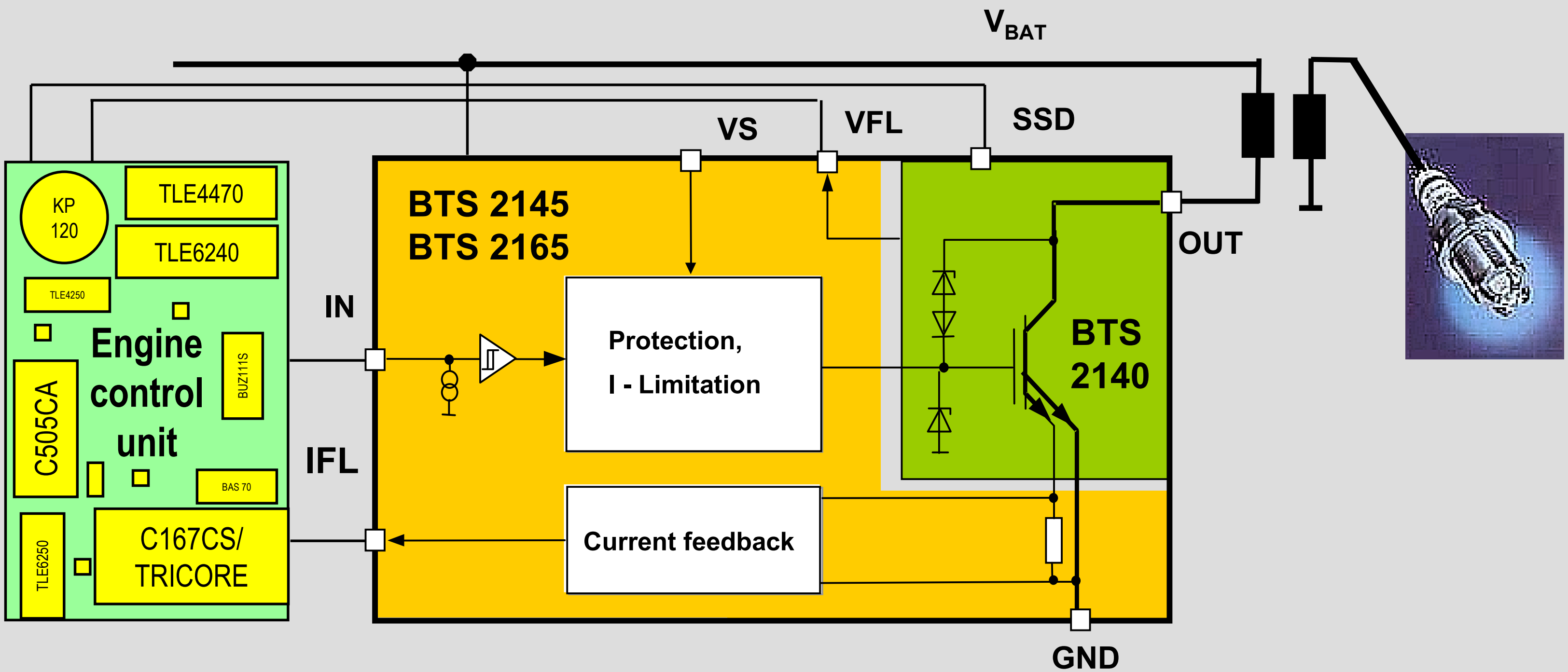
injection valves	low pressure (3-5 bar), high pressure (20-120 bar)
ignition coils + sparks	distributor with 1 ignition coil, pencil coils, integrated pencil coils
switching valves	variable intake manifold, variable cam shaft, EGR, boost pressure control
electronic throttle control	motor for throttle adjustment
air bypass valve	PWM (100 Hz)
fuel pressure control	injection quantity is controlled by pressure
variable turbine	turbine is adjustable by electrical components
electro-hydraulical power steering	pressure control with electrical pump
electrical FAN / waterpump	controlled by map
EGR	proportioning valve
integrated starter/alternator	mounted on the crankshaft

Actuators in engines

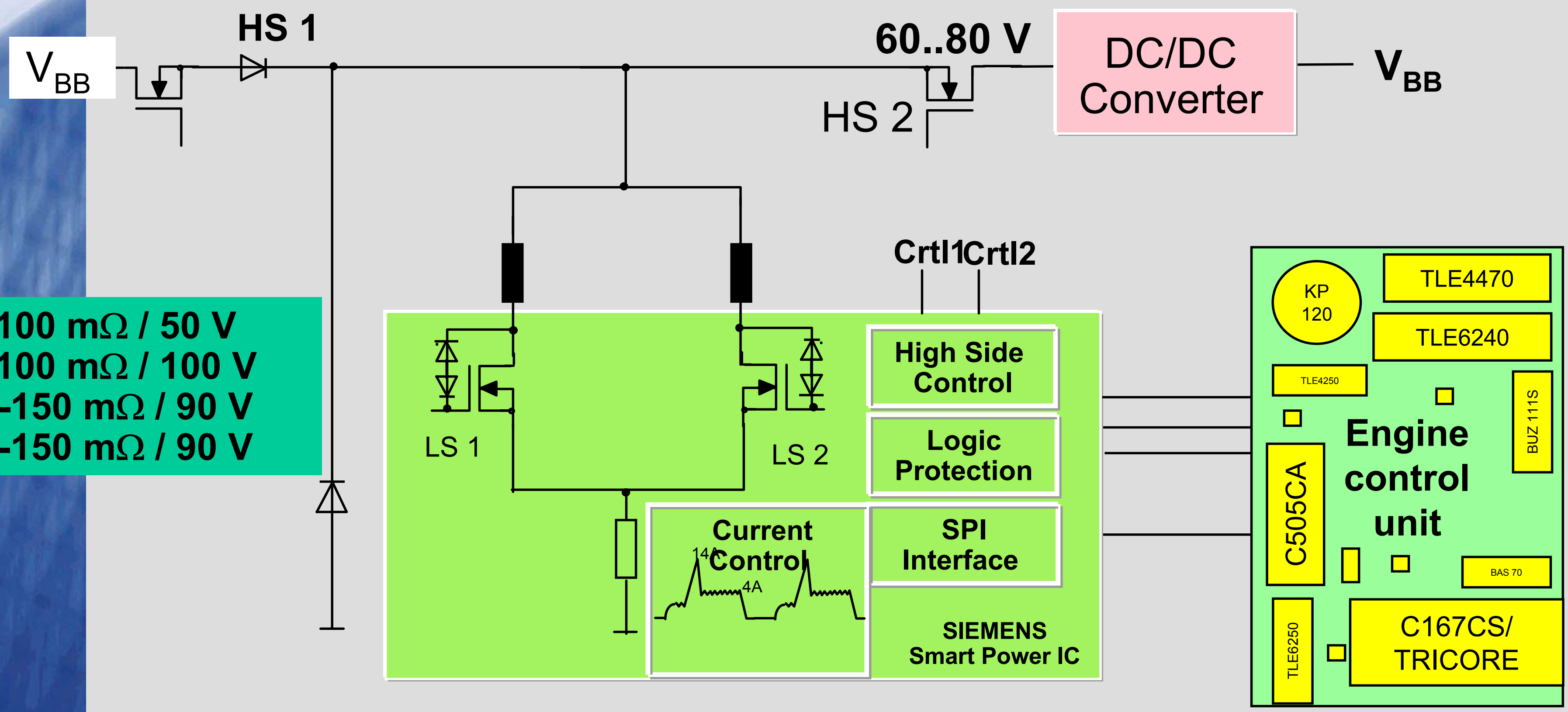
Actual requirements

- low cost
- low energy consumption
- minimal size
- insensitive to sweep radiation (EMV)
- insensitive to specific environment (temperature, vibration, chemical resistance)
- resistance to aging
- minimal response time
- connectable to bus-systems
- self-diagnostic
- degree of accuracy / drift / hysteresis
- uncoupling power-supply from control
- integrated position-indication
- supply-voltage 42 Volt

Smart ignition IGBT



Gasoline direct injection



HS1: 60-100 mΩ / 50 V
HS2: 40-100 mΩ / 100 V
LS1: 100-150 mΩ / 90 V
LS2: 100-150 mΩ / 90 V

Sensors for engine management

Basic sensor types

revolution speed sensors	inductive, hall effect, capacitive
position sensors	inductive, hall effect, capacitive
phase signal sensors	inductive, hall effect, capacitive
angle / rotation sensors	potentiometer, hall effect (incremental) GMR
air mass sensor (load sensor)	MAF (hot-film-sensor, ultrasonic receiver)
temperature sensors (engine/air)	NTC, silicon sensors
temperature exhaust gas	NCN, PT100
pressure sensors	piezoresistive, silicon sensors (micro-mechanical) absolut-, relative-, differential- pressure
knock sensors	piezo-sensors (knock signal 7-14 KHz)
lambda-sensor	galvanic oxigen-measurement

Sensors for engine management

Conditions

changing temperatures	engine	-40°C...+125°C standard
		-50°C...+150°C mounted at the engine
		exhaust gas up to +1000°C
vibrations		over 10 g at frequencies from 10 Hz to 20 KHz
pollution		with oil, water, salts
EMI / EME		high voltage, distributor, ECUs, electronics
used over years		

Sensors for engine management

Requirements

- The engine management processes sensor signals in real time. It outputs the right, theoretical control values for each combustion
- Resulting problems using sensors
  - delay times, response times
  - failure, plausibility of signal
  - charakteristics
  - temperature drift
  - aging (drifting, response time)
  - pollution
  - mesurement of alternative signals, instead of the real data
  - system related disturbance
  - measurement of the sum of input signals instead of a single signal
- Consequence: inexact process data

Sensors for engine management

Requirements

- Pressure, temperature, engine speed and engine position are measured simply. They have no special requirements to the sensors
- Exeption: the measurement of the pressure in the combustion chamber needs high time- and angle-accuracy.
- There are no sensors in mass production for the measurements of
  - quality of the combustion
  - elements of the exhaust gas
  - misfiring
  - early knock detection
- Indirect measurements are used, which are unavoidable inexact.:
  - remaining oxigen in exhaust gas = lambda-value = quality of exhaust gas
  - load measurement = cooling capability of air mass = supplied air mass

Sensors for engine management

Lambda-sensor

- dead time 50 ms (= 5 strokes at 6000 U/min) + response time
- temperature drift
- aging (drifting of parameters, longer response time)
- rapid characteristics
- integration of measurement
- system related failures
- quality of lambda control is limited
- elements of exhaust gas are not seperately measured

Sensors for Engine management

knock-sensor

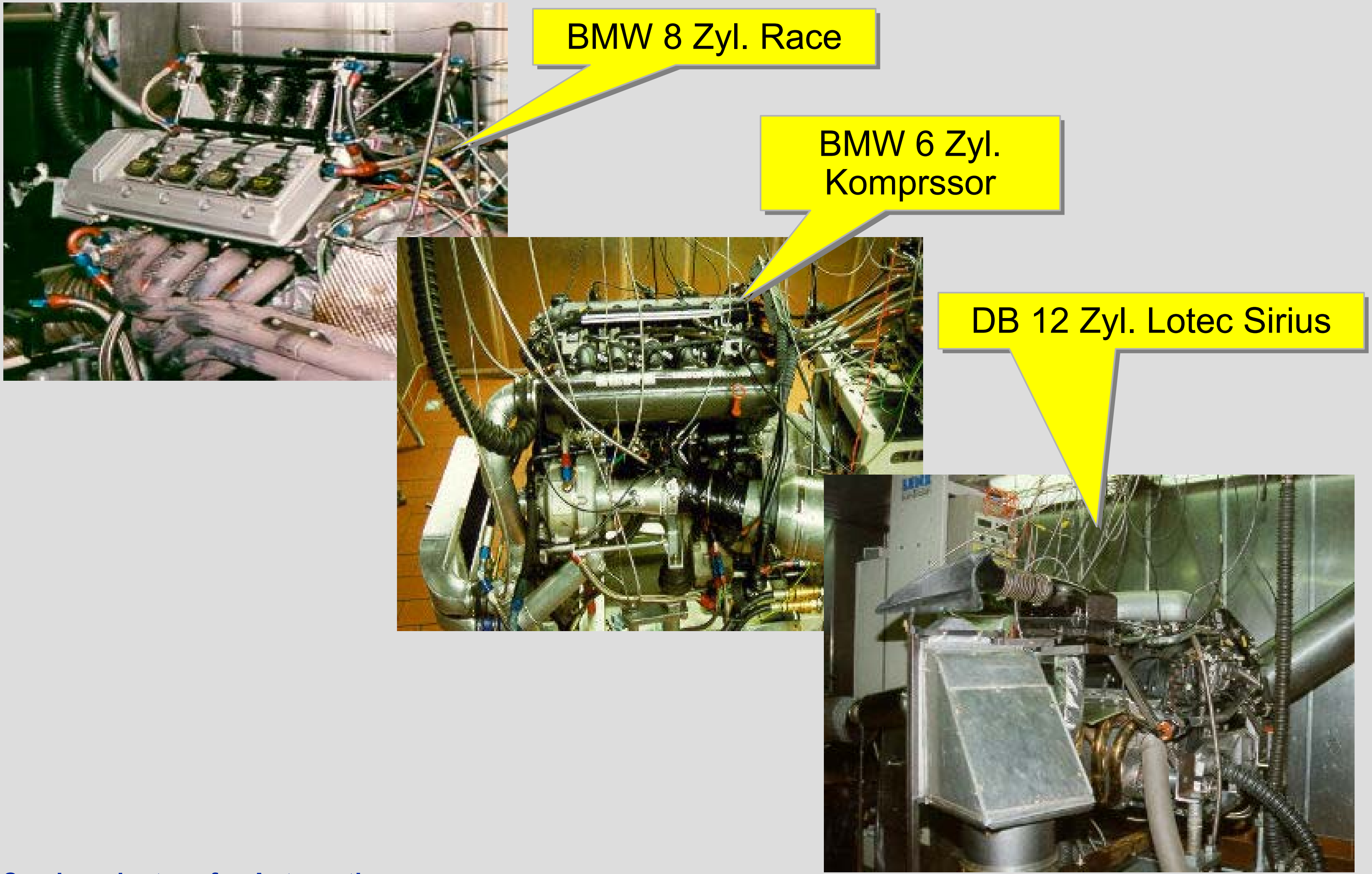
- characteristic sound conducted through solids within frequency-range 7-14 KHz indicates knocking combustion
- no early detection of knocking combustion
- irregularities in combustion process early indicate tendency to knocking
- characteristic patterns of ingition voltage or combustion pressure indicate future knocking
- decreasing ignition control reduces efficiency
- decreasing ignition control is difficult to apply to engines with high compression ratio

Sensors for Engine management

actual developments

- New sensortypes for
  - humidity
  - oxygene
  - flame-front (optical sensor)
- broadband-Lambda
- sensors integrated in spark-plug or ignition-coil
- combined sensors
  - air pressure + humidity
  - lambda + exhaust temperature
  - fuel pressure + temperature
- active sensors: integrated conversion of data and amplification
- smart sensors: self disgnostic, self calibrating, connectable to bus (e.g. CAN)
- extended signalprocessing up to complex real-time-analysis

Engine test bench by Lenz Motorentechnik



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