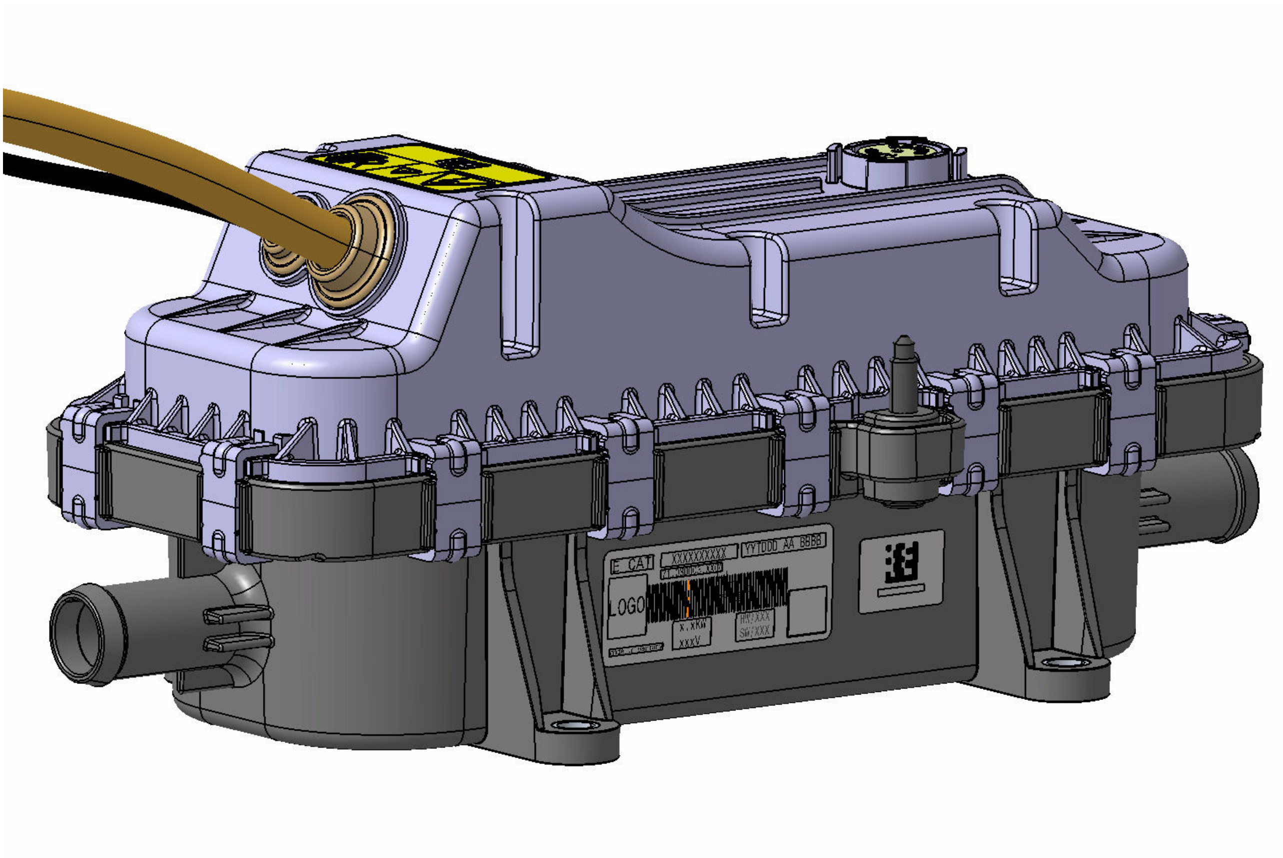
	Technische Dokumentation/ Technical Documentation confidential	QFB 300206 Revision: A Seite/Page 1 von 15 Ersteller/Abt. Author/Dept.: K.Walz/CEV

Electrical Specification
Standard Coolant Heater

This is an extract out of Eberspaecher catem Standard Coolant Heater Specification - Version 07.05 – 08.11.2010



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1 Functions

1.1 System description

The main functions of the coolant heater with integrated electronic device are:

- To heat the liquid media using the electrical energy available on vehicle board
- To be connected to the automotive electrical architecture (alternator, battery, loads and engine management)
- To be implemented in the passenger or engine compartment
- Failure feedback
- Internal diagnostic with a high level safety concept
- Heating performance according to power request via PWM

1.2 General characteristics

- **General**

Parameter	Description	Condition	Min	Typ	Max	Unit
$P_{n\ el.}$	maximum Power	Nominal conditions: (U_n = 350V, $T_{coolant}$ = 0℃, $\dot{m}_{coolant}$ =20l/min)	5400	6000	6600	W
Weight		Without coolant	2500	2600	2700	g

- **Temperatures**

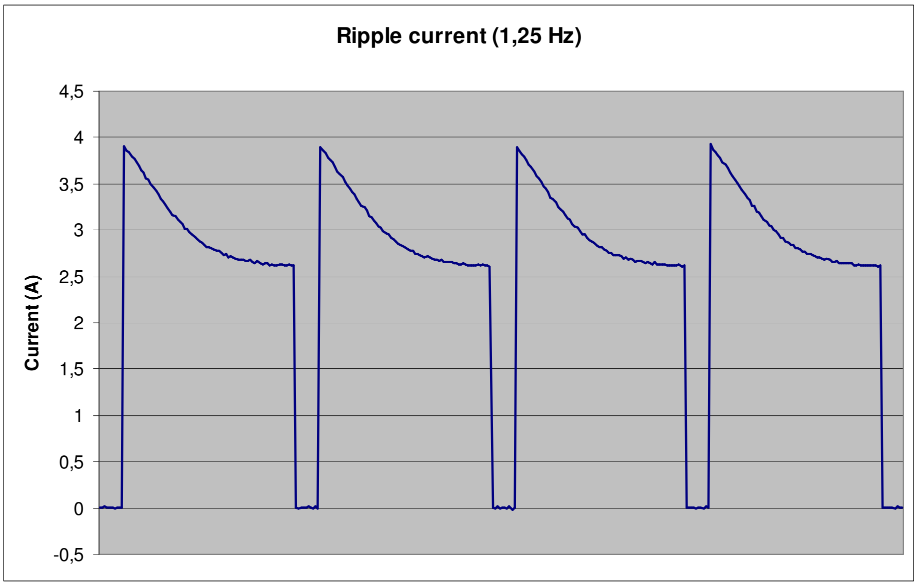
Parameter	Description	Condition	Min	Typ	Max	Unit
$T_{storage}$	Storage temperature		-40		125	℃
$T_{operating}$	Operating temperature (ambient)		-40		125	℃
T_{medium}	max coolant temperature	max. input pressure 1,5 bar.	-40		100	℃

- **Low voltage**

Parameter	Description	Condition	Min	Typ	Max	Unit
$U_{Kl\ 15}$	Voltage supply		9	13,2	16	V
$U_{Kl\ 31}$	Ground			0		V
$I_{Kl\ 15}$	Current supply		50	60	70	mA

- **High voltage**

Parameter	Description	Condition	Min	Typ	Max	Unit
$U_{HV+/HV-}$	Voltage supply		250	350	450	V
$U_{peak\ HV+,HV-}$	Voltage supply	Peak on HV for a duration of 400 ms			550	V / ms
dU / dt	Voltage supply	slew rate			100	V/ms
$I_{HV+,HV-}$	Current supply	nominal conditions	0		20	A
$I_{HV+,HV-max}$	Inrush current	nominal conditions			30	A
I_{off}	stand by current				800	µA
I_{ripple}	ripple current (1,25 Hz)	nominal conditions		3		A



Ripple current is due to the low frequency PWM-heater leg.

- **Others**

Parameter	Description	Condition	Min	Typ	Max	
HR	Humidity		5		95	%
R_{ios}	Electrical insulation resistance	according to ISO 16750-2	50			MΩ
C_X	X-capacity	from HV+ to HV-		200		nF
C_Y	Y-capacity	From HV+ / HV- to shield/GND		3,8		nF
$T_{Discharge}$	Discharge time	after disconnecting HV		4		s
IP-Protection				6K9K		
ESD Protection	Robustness against ESD		-8KV		+8KV	

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1.3 Heating performance

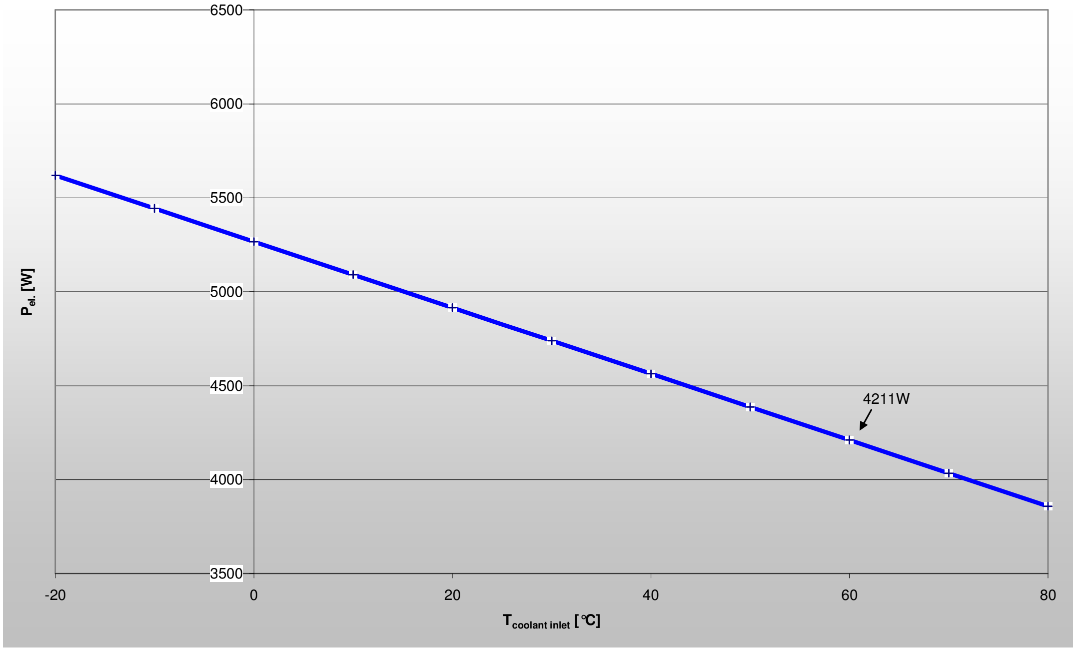

Figure 1a: Power characteristic trend at nominal voltage supply (U=350V) and 10l/min

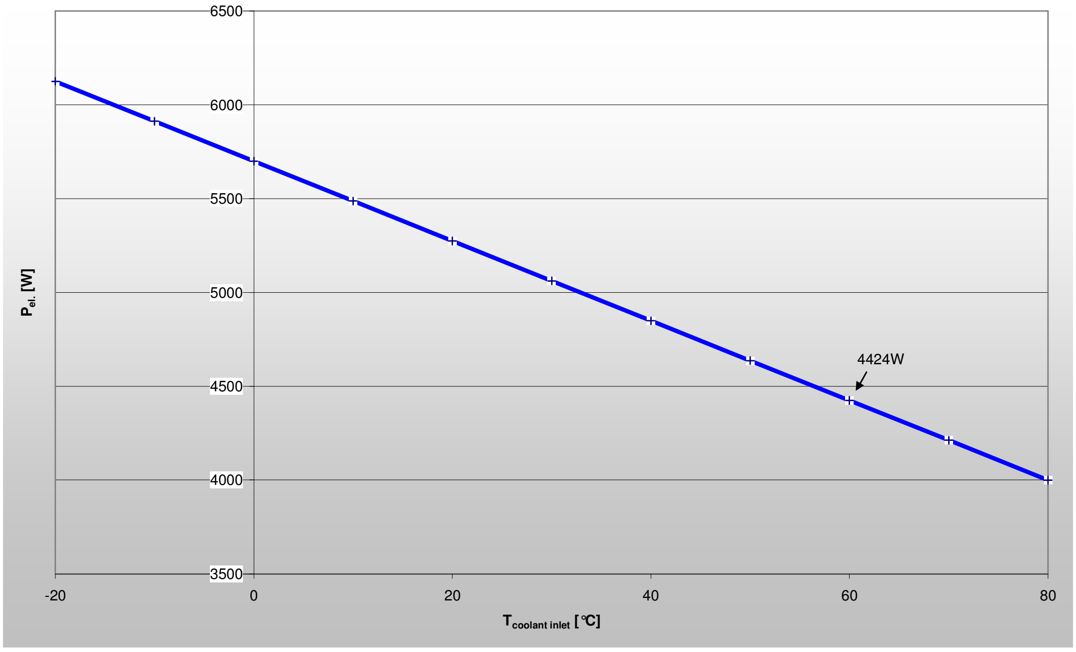

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Figure 1b: Power characteristic trend at nominal voltage supply (U=350V) and 15l/min

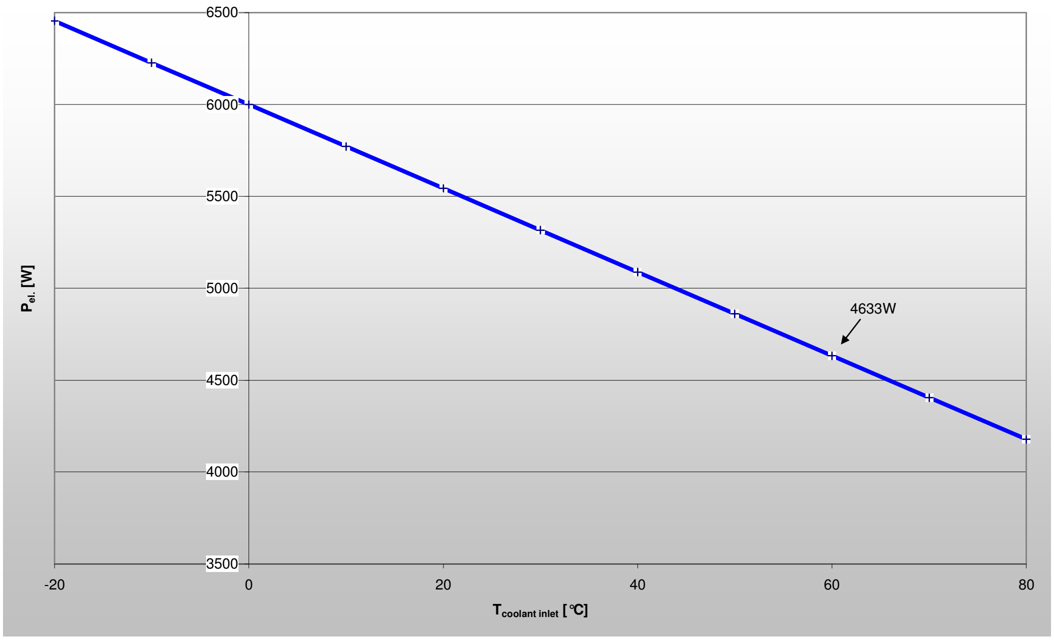

Figure 1c: Power characteristic trend at nominal voltage supply (U=350V) and 20l/min

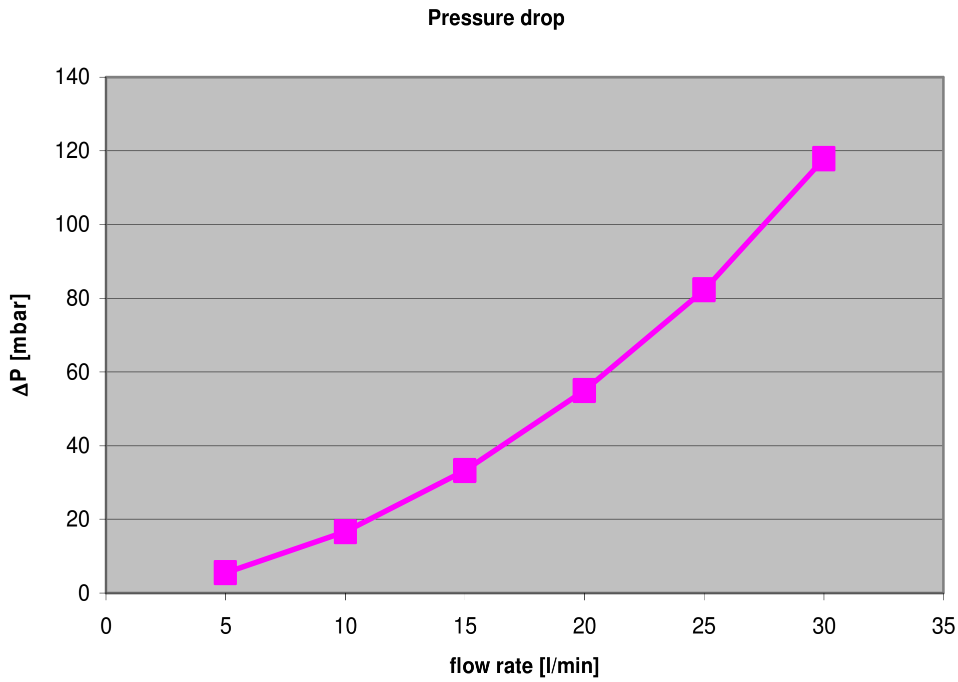

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Figure 3: Typical pressure drop of coolant heater under nominal condition.

1.4 Control

1.4.1 Block diagram / Electrical interfaces

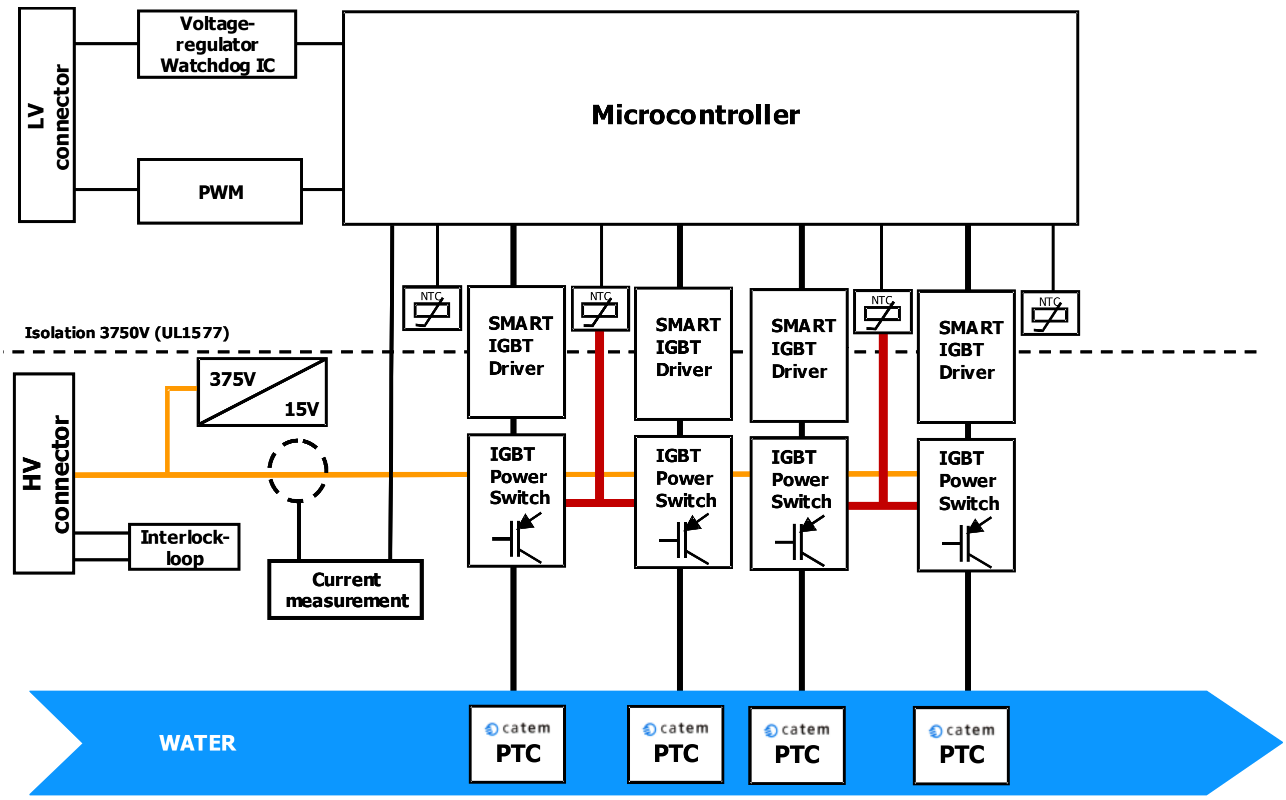

Figure 4: Block diagram of electrical architecture

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1.4.2 PWM

An active–low PWM-signal is used to control the heater power.

Diagram: Duty Cycle / Heating

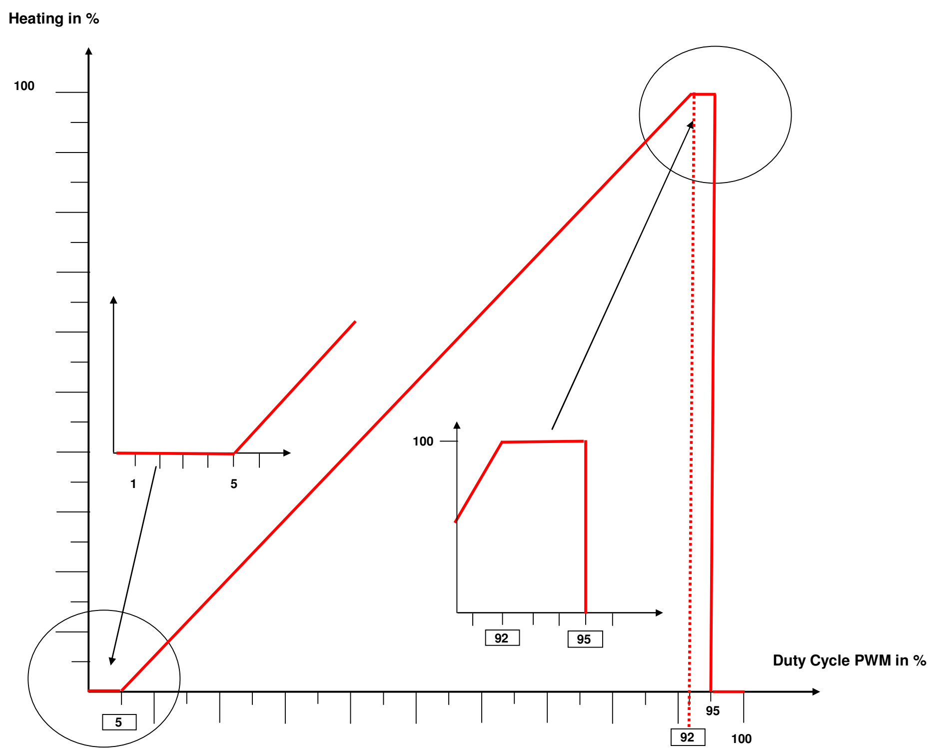

Figure 5: Relation between input and output duty cycle

0% to 5% > Output off
5% to 92% > Output 0% to 100%
92% to 95% > Output 100%
95% to 100% > Output off

Note: the heater has a ramp-up function. New power requests will not be transferred instantly to output power, 260 milliseconds per percentage change. This means, to get from 0% to 100% it takes ~26 seconds. This function is implemented to prevent high inrush currents and abrupt current changes on the HV-bus.

1.4.3 Check for valid input signal

The PWM input signal is checked for its duty cycle and frequency. The duty cycle ranges near 0%-5% and 95%-100% are defined to switch the heater off due to the possibility of a short circuit of the input signal to ground or U_{KL15}. The frequency is valid from 40 to 300Hz, other frequencies will not start the heater or switch it off.

1.4.4 Controlling without causing ripple current

It is possible to operate the heater without causing ripple current on the HV-bus. When the following requests are set there's no PWM-signal (and therefore no ripple current) on any heater-leg.

Request	Approx. resulting power at nom. conditions
16 %	750 W
27 %	1500 W
38 %	2250 W
49 %	3000 W
60 %	3750 W
71 %	4500 W
82 %	5250 W
92-95 %	6000 W

1.4.5 PWM-Input signal

Parameter	Description	Condition	Min	Typ	Max	Unit
f_{PWM}	Frequency input		40		300	Hz
PWM	type			active-low		
High level	detection level			0,7* U_{Kl15}		V
Low level	detection level			0,3* U_{Kl15}		V
allowed ripple voltage	noise on PWM-line				0,5	V_{peak}
Signal current		Open collector circuit at the ECU	20			mA

In case of insufficient PWM signal, the heater won't work at all. Take care to eliminate disturbances on the PWM-line.

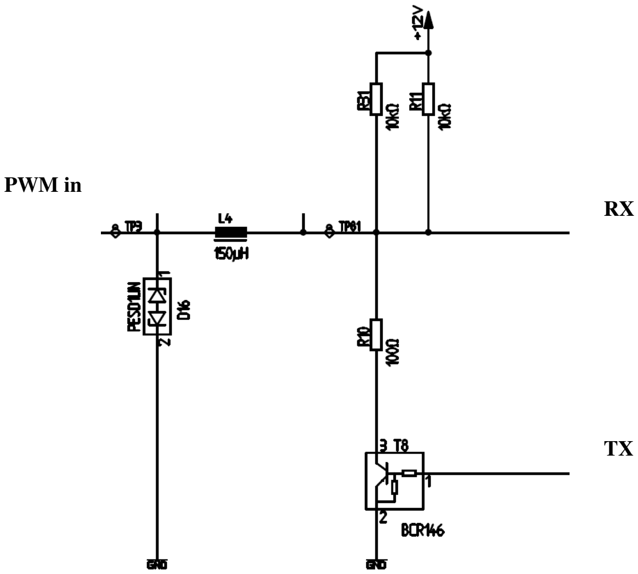

Figure 7: Internal signal processing of the "heater-exchange-request" signal.

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1.4.6 Ramp-up function

The heater has a ramp-up function. New power requests will not be transferred instantly to output power, 260 milliseconds per percentage change. This means, to get from 0% to 100% it takes ~26 seconds. This function is implemented to prevent high inrush currents and abrupt current changes on the HV-bus.
In the following graph you can see the current curve during ramping-up.

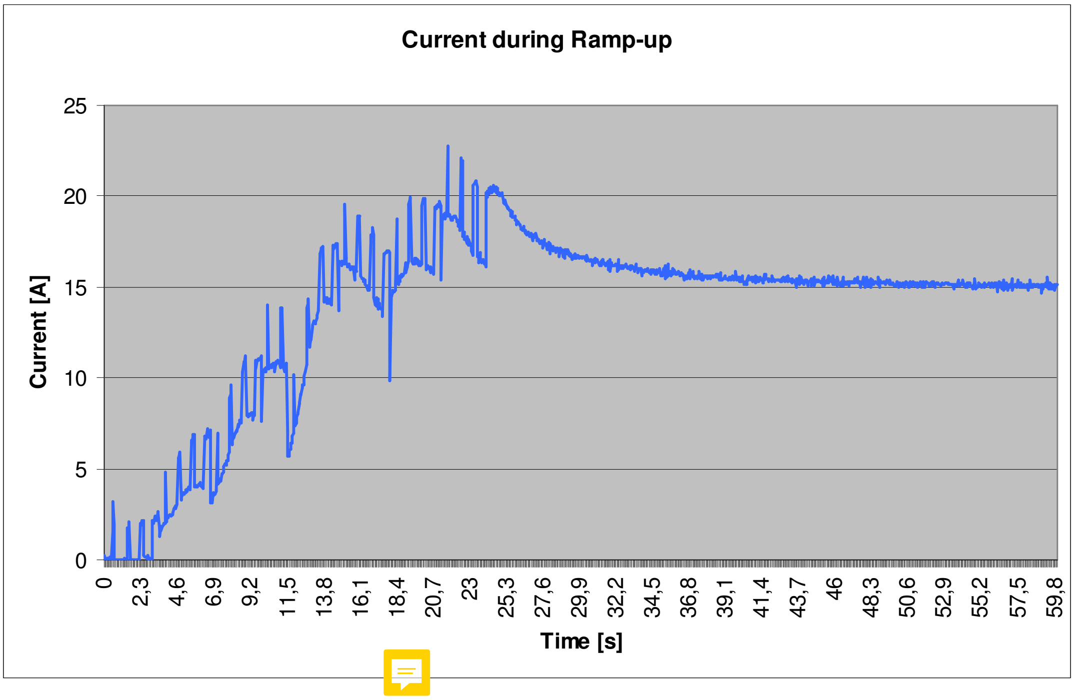

Figure 7: Current curve during ramp-up condition.

1.4.7 Active HV-bus discharge

It is possible to use the coolant-heater for active HV-bus discharging. This may be interesting in case of service or crash of the vehicle. In this case, it is recommended to leave an active power request when the battery is switched of. This allows to lower the HV-bus voltage to less than 50 volts.

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1.5 Integration

1.5.1 Mechanical integration

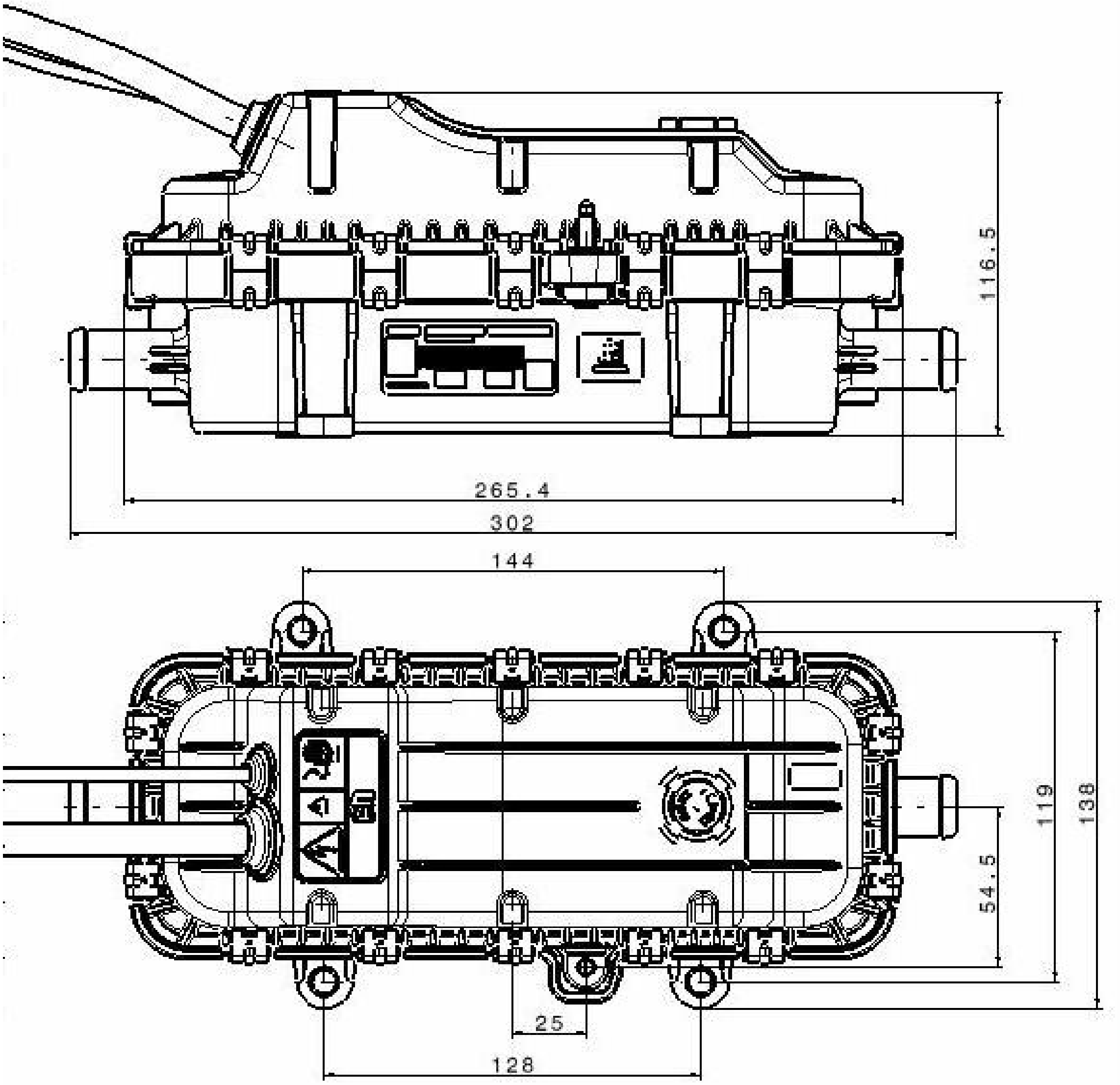


Figure 6: Drawing of the serial design of the coolant heater

1.5.2 Coolant hose connection

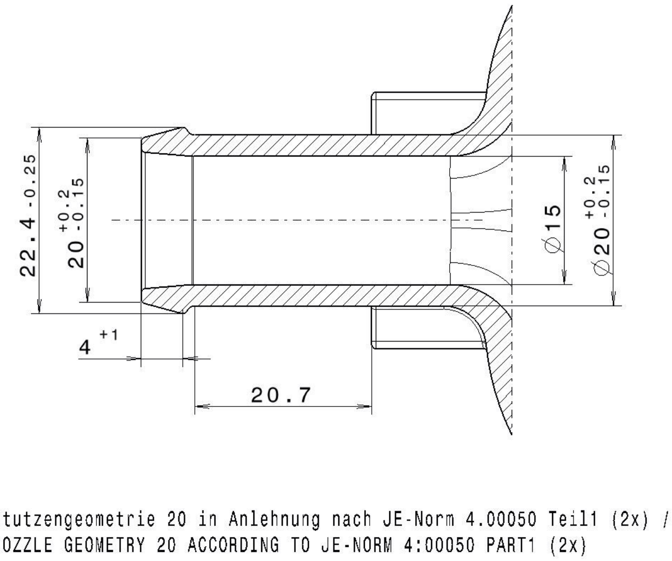


Figure 7: Drawing of the serial design of the coolant hose connection

⚠ **Attention: Protection cap has to be removed before assembly.**

1.5.3 Electrical integration

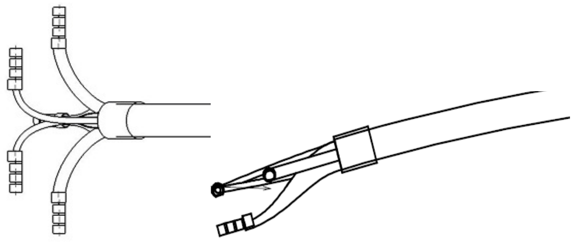
Demands of the heater:
- PWM signal controls the heater.
- +HV / -HV High Voltage supply of the heater circuit
- Power supply LV KL_{15} (ignition) , KL_{31} (ground)
- Interlock signal line bridged inside the heater (passive interlock)

Demands on the electric system of the vehicle:
- The heater has to be integrated in to the insulation monitoring device of the vehicle to detect:
  - Fault voltage
  - Fault current
  - Leakage current
  - Interlock function of the high voltage cable

- Voltage power supply has to be fused
- HV supply has to be fused separately with a 40 A fuse
- It must be assured that no reverse polarity is applied to the HV voltage supply
- Over and under voltage shutdown has to be done by the car
- Medium flow must be guaranteed during the operation of the heater

HV-Wiring with cable end splices:

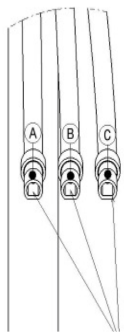
HV-Wires: 4,0 mm²
Interlock-Wires: 0,35 mm²
Length: 1 m



PIN	Signal	Color / Farbe
1	HV +	red / rot
2	HV -	blue / blau
3	Interlock	white / weiss
4	Interlock	blue / blau
5	shield / Abschirmung	black / schwarz

LV-Wiring with cable end splices:

LV wires: 0,35 mm²
Length: 1 m



PIN	Signal	Color / Farbe
A	+ 12 V	red / rot
B	GND	black / schwarz
C	PWM	green / grün

Figure 8: Drawing of the wiring harness of HV and LV.

<u>**Options:**</u> assembly of custom HV and LV connectors / adaptive cable-length

1.5.4 General Installation requirements

The installation position of the heater in the vehicle must be chosen under attention of the following requirements:

- It must be assured that no reverse polarity is applied to the HV voltage supply
- No influence through inappropriate chemical substances
- Protection of inappropriate mechanical forces / impact
- Minimum distance to surrounding parts is 30mm for air circulation
- It should be assured that no air-bubbles are floating into the heater
- If there's no coolant flow the heater may enter its over temperature-protection

⚠ **Attention: Voltage supply has to be deactivated for installation or removal of the heater!**

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1.6 Safety

1.6.1 Over temperature on PCB

There are three temperature sensors (NTCs) which are used for temperature monitoring in order to switch off or reduce power in case of over temperature on the PCB.

One sensor is placed near the Microcontroller, two others near the power transistors.

As a temperature of more than 110℃ is reached on any of the NTCs, the heater will reduce its output power to 12,5% until a temperature of 105° is detected. If the temperature rises above 115℃ anyway, the whole heater is switched off until the temperature drops below 85℃ on every NTC.

To avoid overheating in case of defect of temperature sensors, they are permanently checked for a plausible signal level. In case of a defect temperature sensor the heater will be switched off.

1.6.2 Short circuit detection

The IGBT driver is monitoring short circuits by desaturation detection. In case of a failure the heater circuit will be switched off. The reaction time of the driver on shorts is less than 10µs, thus the IGBT is protected from damaged due to overload.

1.6.3 Current limitation

If the current consumption exceeds 20A for five seconds, overload is detected and heater leg 2 is switched off for five seconds. If you have low coolant temperatures and low HV supply voltage, it may happen that this protection is active, which will result in current variation of ~4A when heater leg 2 is switched off and on. When the coolant is heated up, the toggling should stop and the heater has a stable current consumption again.

1.6.4 Over-Current detection

If the current consumption exceeds 30A for a 80 milliseconds duration, all heater legs are switched off an the heater performs a soft-reset. Subsequently, the start-up check is executed in order to identify the defective heater-leg.

1.6.5 Start-up check

After power on or a reset of the PTC heater, the heater waits for a power request, i.e. a duty cycle of more than 5% at the PWM input. Once this duty cycle is detected, a start-up check is executed.

First the total current is measured with all heater legs deactivated. If the current measurement exceeds a defined value the heater is not operational, hence this fault indicates a short-circuit in the hardware or leakage current.

If the first check is successful the heater legs are pulsed one by one and the consumed current is measured. If the current is out of a specific range the heater recognizes this as overload or open load. The corresponding heater leg will not be operated. The remaining heater legs work normally.

HV voltage out of the specified range or cut-off during start-up test can cause problems. Voltages below 20V volts may lead to too low currents during start-up check and can cause that an “electronic defect” is detected.

See also 4.6.5 Failure feedback

1.6.6 Watchdog

An external hardware watchdog IC is applied. It will restart the microcontroller in case that it has hung up.

1.6.7 Failure feed back

Due to PWM control, only one failure can be communicated, the “heater exchange request”:
By forcing the PWM input to GND it is signalized that the heater should be replaced because of an electrical defect.

The following conditions / failures can lead to a heater exchange request:

- defective current sensor (signal out of specified range)
- defective AD converter (same values on all channels)
- failed startup-test (open load / short circuit)
- desaturation detection (due to short circuit on heater-legs)
- over-current detection
- thermistor error (monitors internal temperature sensors / shorted to LV + or -)
- EPROM defective

1.6.8 Active HV-bus discharge

The coolant heater can also be used for active discharge of the vehicles HV-bus. This might be interesting in case of accident or service of the car. To discharge the HV-bus just leave an active request while disconnecting the battery / power supply. This will result in lowering the bus voltage down to ~ 50V. The resulting voltage depends on the height of the active request and the vehicles bus characteristic.

Note: You mustn’t turn on HV while a PWM request is still active. This may result in turning the coolant-heater inoperative, due to detected over-current.

1.7 Maintenance

The heating element is maintenance-free. It shall not be disassembled.

1.8 Flammability

Material flammability according FM.VSS 302.

1.9 Recycling

The end-of-life vehicle regulation of 2000/53/EC fulfilled.

1.10 Identification

The heating element is labeled with the high voltage warning sign to indicate potentially fatal voltages. Label according IEC 417K A includes manufacturer data and is applied for identification and traceability.

1.11 General behavior

If high voltage is interrupted during active PWM request, the heater may turn inoperative. If high voltage is interrupted you need to set the PWM request to 0% before turning on HV again. Else the heater may detect over-current.

If failures are detected continuously, the heater may set the heater exchange request and turn inoperative. This can't happen accidentally. Failures have to be detected at least 10 times before the heater turns inoperative.

If the heater is inoperative and the "heater exchange request" is not set, try if a hard-reset (low-voltage disengaging) fixes the problem. If the problem is still present, the heater will set the "heater exchange request" after its internal tests failed several times.

The heater guarantees safe operation under specified normal operation and environment conditions.

1.12 Recommendation for general storage

Due to electronic components, Eberspaecher catem is recommending to avoid no longer than 1 year without 12 V supply. In other case specific protection packaging is recommended.