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CC-DA/ECR5	FR5CPEC	0265K60532

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1. General product description

The present technical customer documentation describes FR5CPEC, for which the Robert Bosch GmbH has the assigned responsibility. In addition, it contains noncommittal descriptions of components and functionalities, which are not in the responsibility of Robert Bosch GmbH, but nonetheless determine or influence the behavior and performance of the particular vehicle type series.


1.1. Main functions and properties of the product

1.1.1. Principle

The FR5CP radar sensor and control unit (SCU) contains a FMCW radar transceiver operating in the globally harmonized frequency range of 76.0 - 77.0 GHz. It senses targets by emitting many short frequency modulated waves using the transmit antennas while receiving waves reflected by targets using the receive antennas. Distance and relative speed are determined via beat frequency (due to travelling time of the waves) and phase differences between ramps (due to change of distance in short time). By using the antenna diagram the angles of departure and arrival of the radar waves can be determined.

Using the Bosch chirp sequence radar modulation, the FR5CP allows unambiguous determination of relative speed in a single measurement cycle. Therefore, no complex object models are needed for ambiguity resolution.

The radar reflections (strength, distance and relative speed, angular direction, and derived values) are basis for building a comprehensive model of the sensed environment.

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1.1.2. Block diagram

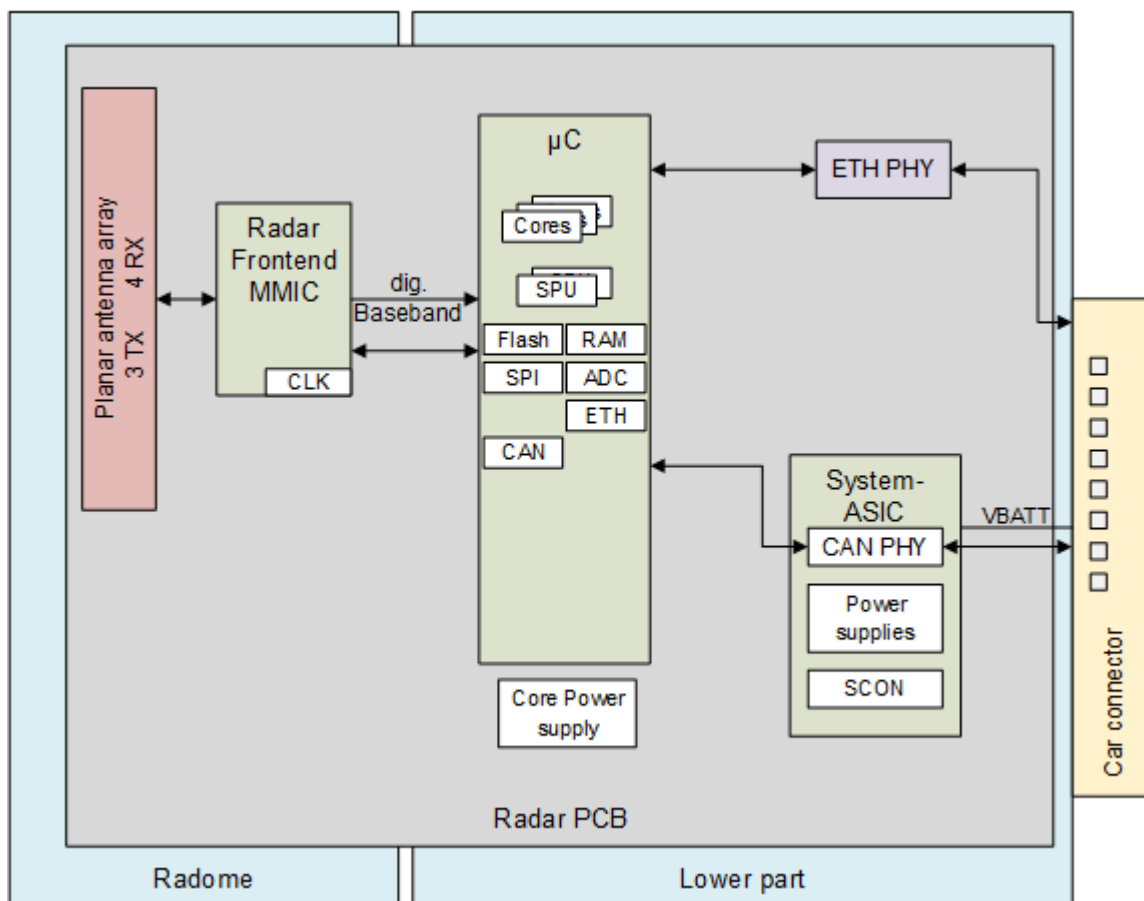



Figure: Block diagram

The FR5CP sensor is a highly integrated ECU with a single printed circuit board and highly integrated components:

- Highly integrated microcontroller (μC) with multi-core architecture and dedicated radar signal processing unit (SPU), Flash and RAM memory, peripheral units as well as safety features.
- Highly integrated Radar Frontend MMIC in modern SiGe technology for frequency generation (VCO, PLL and sequencer), power amplifiers (PA) and receiver including mixer, analog frontend processing, ADC and digital frontend processing with digital baseband interface to the microcontroller as well as clock generation and safety features.
- Planar antenna array with three transmit antennas and four receive antennas
- A System-ASIC with power supplies for internal voltages (except microcontroller core power supply), a safety controller (SCON) with watchdog functionality and electrical vehicle interface (CAN-transceiver).
- Ethernet PHY for 100Base-T1 automotive ethernet interface

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1.1.3. Preliminary Assembly concept

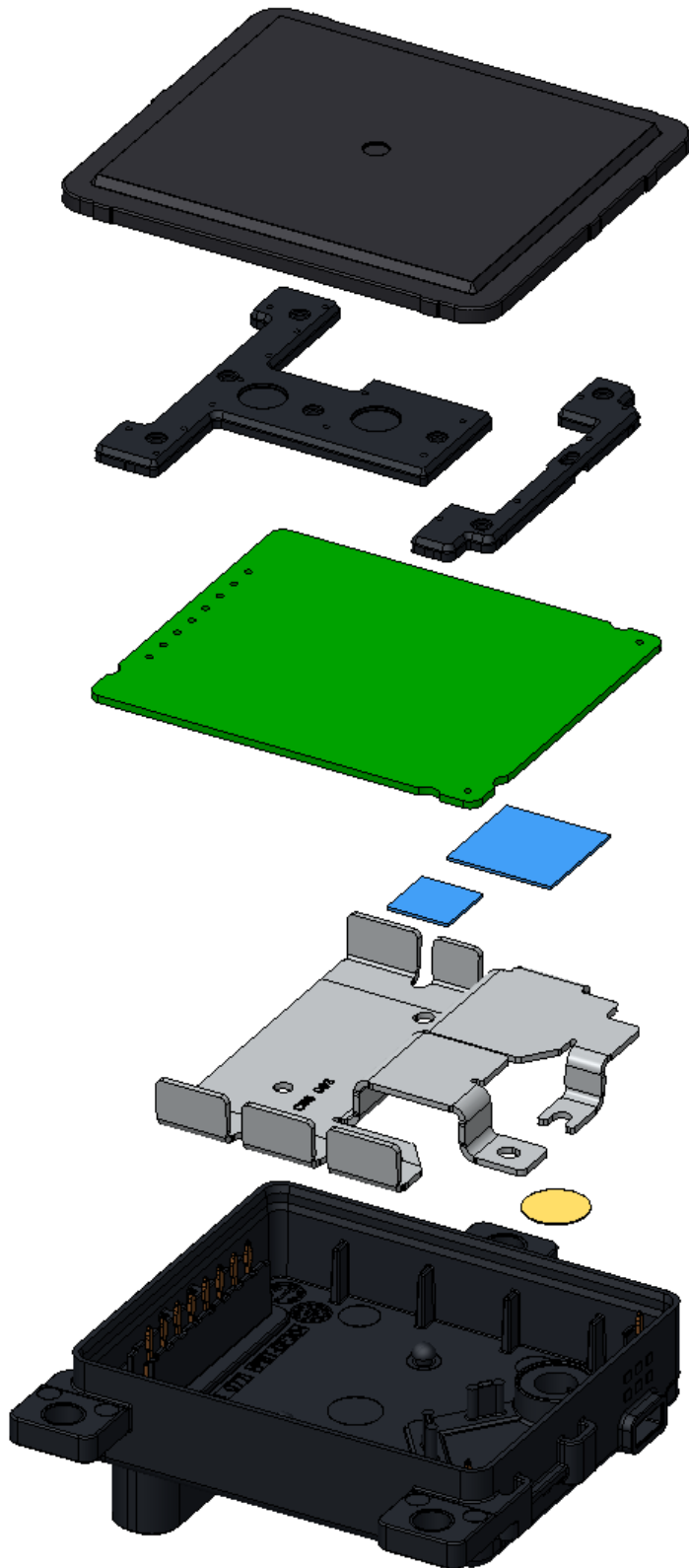



Figure: Assembly concept

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With only 3 main components (radome, PCB, lower housing), the assembly of the FR5CP SCU is quite simple and is focusing to robust and cost effective mass production.

1.2. Labeling of the product

The radar devices provides information about:

- part-number
- series-number
- hardware and software version
- barcode information
- production date
- radar emission release information
- customer information

1.2.1. Radio Frequency Homologation

1.2.1.1. Phrases and Markings

The following phrases and markings are part of the radio frequency homologation and have to be reproduced in the vehicle user manual.

1.2.1.1.1. *Australia*

1.2.1.1.2. *Qatar*

1.2.1.1.3. *South Africa*

1.2.1.1.4. *Singapore*

1.2.1.1.5. *Ukraine*

1.2.1.1.6. *Serbia*

1.2.1.1.7. *Moldova*


1.2.1.1.8. *Mexico*

1.2.1.1.9. *Phillipines*

1.2.1.1.10. *Indonesia*

1.2.1.1.11. *Brunei Daressalam*

1.2.1.1.12. *Jordania*

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1.2.1.1.13. United Arab Emirates

1.2.1.1.14. Morocco

1.2.1.1.15. Malaysia

1.2.1.1.16. South Korea

1.2.1.1.17. Brazil

1.2.1.1.18. Taiwan

1.2.1.1.19. China

1.2.1.1.20. Hong Kong

1.2.1.1.21. Japan

1.2.1.1.22. Europe

1.2.1.1.23. USA

Once FCC approval is granted for FR5CPEC, the following FCC ID has to be included in the vehicle user manual and labelled on the product.

FCC ID: NF3-FR5CPEC

The following warning text for RF equipment has to be included in the vehicle user manual:

User Manual statement according to §15.19

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:


- 1. this device may not cause harmful interference, and*
- 2. this device must accept any interference received, including interference that*
- 3. may cause undesired operation.*

User Manual statement according to §15.21:

Changes or modifications made to this equipment not expressly approved by Robert BOSCH GmbH may void the FCC authorization to operate this equipment.

User Manual statement according to §15.105:

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial

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environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

RF Exposure Information according 2.1091 / 2.1093 / KDB 447498 / OET bulletin 65:

Radio frequency radiation exposure Information:

This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance of 20 cm between the radiator and your body. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

1.2.1.1.24. Canada

Once Canada approval is granted for FR5CPEC the following ISED certification number, PMN and HVIN has to be included in the vehicle user manual and labelled on the product on the product.

IC: 3887A-FR5CPEC

HVIN: FR5CPEC

PMN: Front Radar 5 Car Plus Ethernet CAN

The following warning text for RF equipment has to be included in the vehicle user manual:

RF equipment according to RSS_GEN in English and French language

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device must not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

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RF Exposure Information according to RSS-102 in English and French language:

This equipment complies with FCC and IC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance of 20 cm between the radiator and your body. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

Cet équipement est conforme aux limites d'exposition aux rayonnements IC établies pour un environnement non contrôlé. Cet équipement doit être installé et utilisé avec un minimum de 20 cm de distance entre la source de rayonnement et votre corps. Ce transmetteur ne doit pas être placé au même endroit ou utilisé simultanément avec un autre transmetteur ou antenne.

1.2.1.1.25. Argentina

1.3. Dimensions and weights

Outside dimension:

Box volume, total Length (depth in X-direction) = 18.7 mm

Detailed dimensions see offer drawing.

Outside dimension:

Box volume, total Width = 62.6mm


Detailed dimensions see offer drawing.

Outside dimension:

Box volume, total Height = 72mm

Detailed dimensions see offer drawing.

Maximum weight of complete SCU (w/o heating) w/o mounting device and poka yoke element >80gr.

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1.4. Power consumption / power output

This section describes the power consumption of the SCU for different operating states.

Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
P_RF_on	operating power consumption	- RF on, approx. 30% duty cycle - COM Interfaces ON - Processing Unit: M - VBATT=14V +/- 5%	-	4		W

Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
P_RF_off	operating power consumption	- RF off - COM Interfaces ON - Processing Unit: M - VBATT=14V +/- 5%	-	2,5		W

1.5. General remarks for service, repair and maintenance

Repair and maintenance of the product is not allowed


Sensor can't be opened without damaging.

In case of service the Sensor needs to be replaced.

1.6. Information on disposal and recycling

All Materials are released regarding the following regulations:

- ELV (Altautorichtlinie) and GADSL (BBM)
- RoHS
- REACH

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2. System description

2.1. Vehicle integration interfaces

This chapter describes the requirements for all parts mounted in front or around the sensor, like painted bumper, unpainted cover and emblem/radome, regarding RF integration at 77 GHz with FR5plus radar sensors.

Values are marked with t.b.c. or t.b.d. showing that they have to be confirmed or defined during the development process.

As product development is an on-going process, we reserve the right to make amendments in line with technical progress.

The radar sensor performance should be influenced as low as possible by the installation behind a fascia. Therefore the two-way radar loss by the fascia should be as low as possible and the reflection attenuation must fulfill the requirements listed below.

Vertical misalignment will cause additional attenuation reducing the maximum range.

Horizontal misalignment will cause reduced detection at higher azimuth angles.

Ghost target detection caused by interference signals of multiple reflection at fascia and metallic parts of the vehicle must be avoided. A simulation can be offered to evaluate the risk and the need of using absorber material to suppress this unwanted signal. Because the threshold of detection is very low, a high attenuation is required. Plastic material can only achieve high enough attenuation, if carbon black is added.


2.1.1.1. Radar Cone

Radar Cone for PLUS Family

The radar cone describes the zone where the fascia has to be optimized. Any parts of the vehicle inside the radar cone may influence the radar performance. Cables, brackets, bars etc. should not touch the radar cone. The fascia in this zone may not have bends and edges as well as changes in thickness or material or painting.

Based on the footprint on the top side of the radar PCB the cone is characterized by a vertical and a horizontal opening angle. The footprint is centered regarding to the sensor housing. A CAD model of the radar cone is available.

The footprint for radar cone has the following dimensions: (W x H) 55 mm x 55 mm

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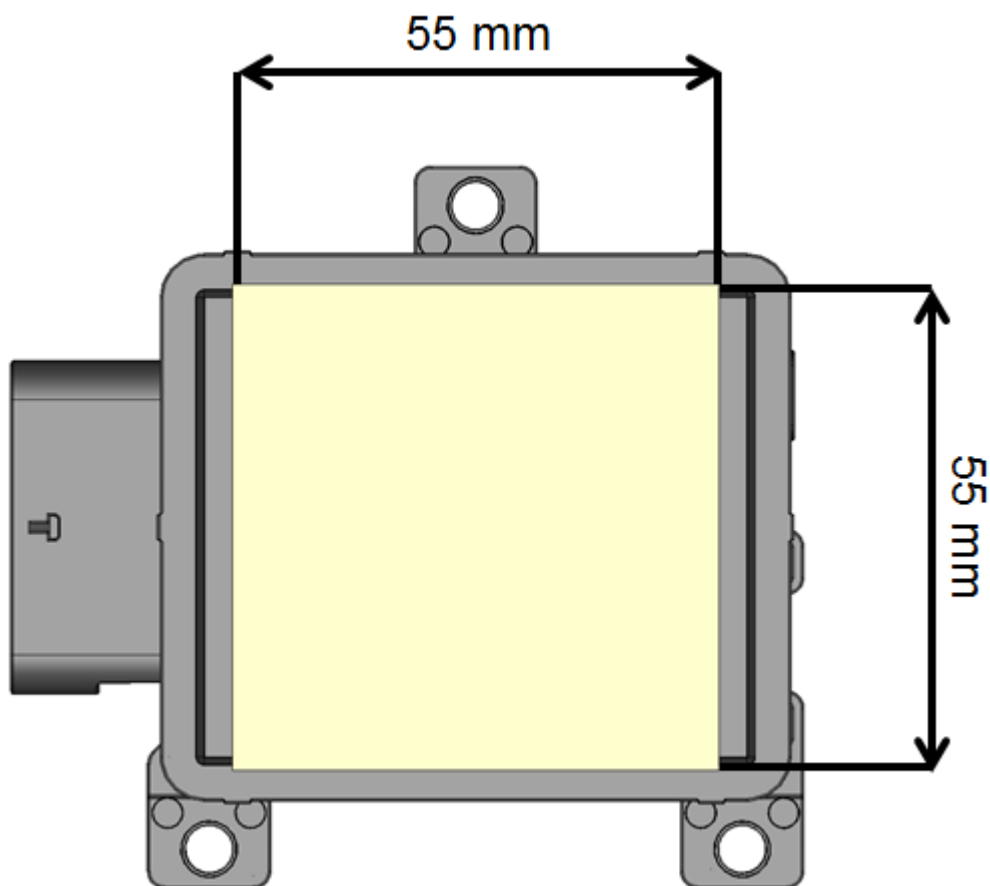


Figure: Footprint of the radar cone. For better visibility the footprint is shown on top of the sensor housing.


Radar cone definition for covered installation (FR5CP):

The horizontal opening angle depends on the angle range that is evaluated by the sensor in azimuth and elevation, whereby the opening angle of the radar cone has to be larger than the angle range that is evaluated. For covered integration the radar cone is 10° larger than the used angle range that is evaluated by the sensor.

Radar cone:

- $\pm 70^\circ$ ⁽¹⁾ in horizontal direction (not including misalignment)
- $\pm 20^\circ$ in vertical direction (not including misalignment)

⁽¹⁾ Valid for angle measurement range of $\pm 60^\circ$

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2.1.1.2. Fascia design guidelines

Material

Material with low dielectric constant (ϵ_r) and low dielectric loss factor $\tan\delta$ at 77 GHz should be used. Recommended are materials based on polypropylene (PP) and polymethyl methacrylate (PMMA), while materials like polycarbonate (PC) and acrylonitrile butadiene styrene (ABS) are still ok. The material shall be homogenous, compounds including glass fiber, carbon fiber or metal particles are not recommended.


The fascia shall be designed for radar transparency. The thickness shall be a multiple of the half wavelength (in the material) to minimize the influence of the fascia. The quality criteria of radar transparency is the reflection coefficient of the radome/fascia. Tolerances of the overall thickness and the dielectric constant of the used material influence the amount of reflection at the radome/fascia. Additional influence occurs due to curvature of the fascia. Therefore the radius has to be as large as possible. With sharp edges the negative influence will increase significantly. Not allowed are ribs, structures and steps changing the thickness of the radome/fascia.

Painting

The layer structure of the painting, typically made of three painting layers consisting of primer, base coating and clear coating, will increase the effective permittivity value $\epsilon_{r,eff}$ and dielectric loss factor $\tan\delta$ of the painted plate used as fascia.

Fascia Classification (FR5CP)

The two-way radar loss caused by fascia should be as low as possible. High losses decrease the sensor performance regarding range and angle estimation. Therefore it is recommended to achieve a two-way radar loss below 3 dB.

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Classification of reflection caused by the fascia

1.	Reflection coefficient <-15 dB is achieved when fascia has optimized thickness within a tolerance of ± 0.1 mm and permittivity within a tolerance of ± 0.02 . Dielectric loss factor $\tan \delta$ shall be < 0.01 . With such low reflection a vertical tilt angle of 0° is possible. This is the case for unpainted or a single e.g. black paint cover. Also well designed emblems without air gap inside may be usable.
2.	Reflection coefficient <-10 dB is achieved when fascia has optimized thickness within a tolerance of ± 0.2 mm and permittivity within a tolerance ± 0.02 . Dielectric loss factor $\tan \delta$ shall be < 0.03 . With such reflection a vertical tilt angle of 0° must be avoided.
3.	Reflection coefficient <-6 dB is achieved when fascia has optimized thickness within a tolerance of ± 0.2 mm and permittivity within a tolerance of ± 0.2 . Dielectric loss factor $\tan \delta$ shall be < 0.05 . With such reflection a vertical tilt angle of $> 18^\circ$ is required. This is the case for painted bumper especially when various colors are used.
4.	Reflection coefficient >-6 dB is achieved when fascia has no optimized thickness or a painting with high metallic content is used. The attenuation will exceed the maximum allowed limit.

The examples described in the classification of reflection are derived from evaluation of flat plates with constant thickness and homogeneous material. Deviations from this situation may cause a change in classification and the vertical tilt angle of fascia has to be increased.

Surface Properties of the fascia

The surfaces of the fascia shall not exceed an average roughness height of $20 \mu\text{m}$ (corresponding to ISO 1302 class N10; VDI 3400 class 45).

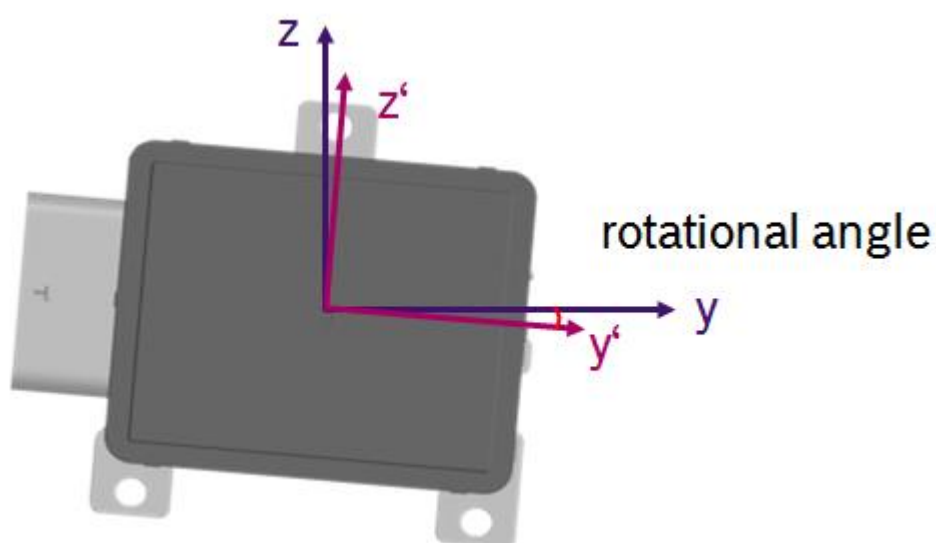
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2.1.1.3. Installation Hints

To enable the full performance of the radar sensor, it is recommended to use the following installation hints and guidelines for the RF integration of the sensor.

Sensor rotation around radome normal (FR5CP)

The sensor shall not be rotated more than 1.5° around the normal of the radome surface.



Maximum angle between radar cone and fascia

The angle α between the radar beam inside the radar cone and the fascia may not be larger than 70° anywhere inside the radar cone.

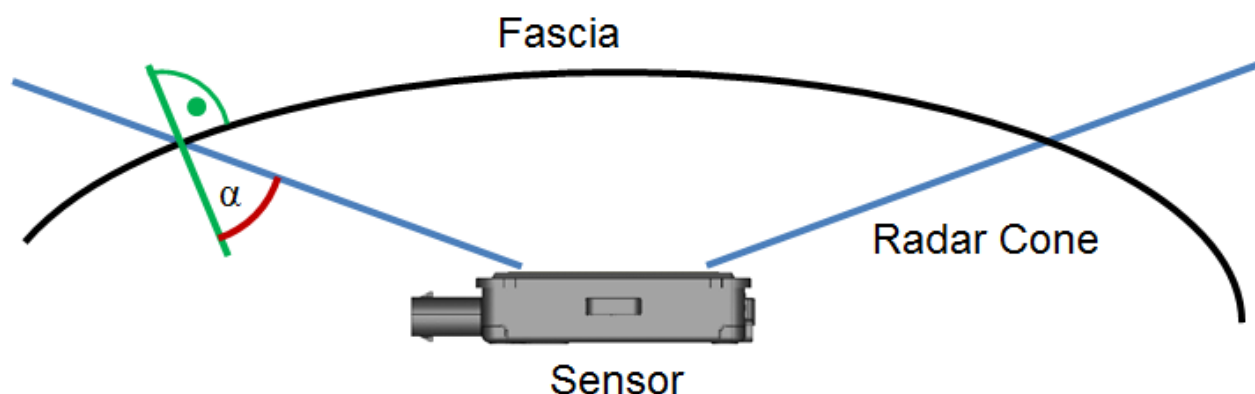



Figure: Maximum angle between fascia and radar cone

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Minimum distance between sensor and fascia

The minimum distance between the sensor radome and the fascia or any other part of the vehicle may not be smaller than 5 mm.

This is valid for fascia parts fulfilling the following requirements.

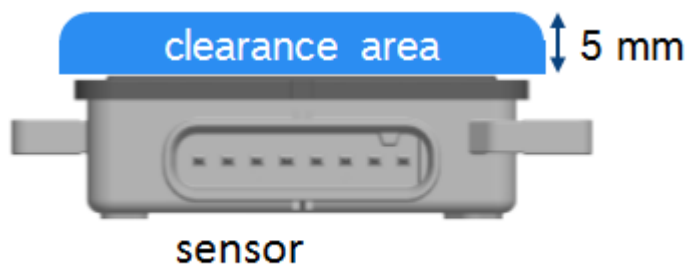


Figure: Minimum distance above sensor radome

Vertical tilt of fascia (FR5CP)

The vertical tilt angle between the sensor normal and the surface normal of the fascia shall be in the range according to the following table.

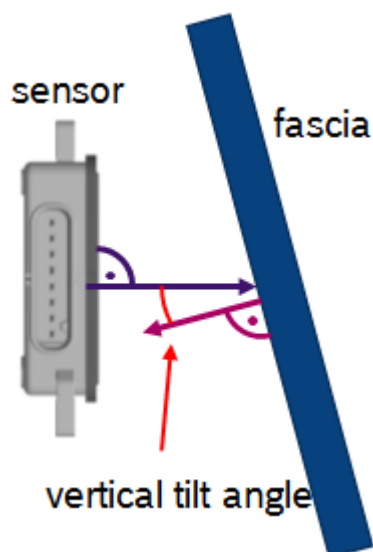



Figure: vertical tilt angle of fascia to sensor normal

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Minimum vertical tilt	reflection coefficient	max. tolerance thickness	tolerance ϵ_r	$\tan\delta$	application
	<-15 dB	± 0.1 mm	± 0.02	<0.01	unpainted, (black) painting, embleme
>8°	<-10 dB	± 0.2 mm	± 0.02	<0.03	unpainted, (black) painting, embleme
		± 0.1 mm	± 0.2	<0.03	painted bumper
>18°	<-6 dB	± 0.2 mm	± 0.2	<0.05	painted bumper

Table: minimum vertical tilt angle of fascia to sensor normal

Curvature of fascia for FR5CP

Curvature of the fascia may influence the radar performance, especially with low vertical tilt angles. The minimum radius of the curvature shall be according to the following rules:

- R > 350 mm, no significant influence expected
- R < 350 mm, significant influence possible, has to be evaluated
- R < 200 mm, significant influence expected, not recommended

Absorber around the sensor


It is highly recommended to use a cone made of absorber material around the radar cone of the sensor to prevent ghost targets. The design of the absorber cone must fulfill the following design guidelines (reflection from outside the radar cone, multipath reflection).

Reflection from outside the radar cone

Reflections from structures located outside the radar cone have to be avoided.

Furthermore interference signals picked up by the sensor antennas should be avoided by keeping a minimum distance (d) of 5 mm to 10 mm for parts in front of the sensor.

Even with compliance to the radar cone, reflections at parts outside the radar cone may disturb the received signal. Reflections at parts causing an interference signal to the receiving antenna and reflections at parts getting to the receiving antenna after a second reflection at the fascia (multipath reflection).

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Closed surfaces of brackets and masks made of metal or high reflecting material need a tilt angle being arranged that the reflection is not received by the receiving antennas of the sensor.

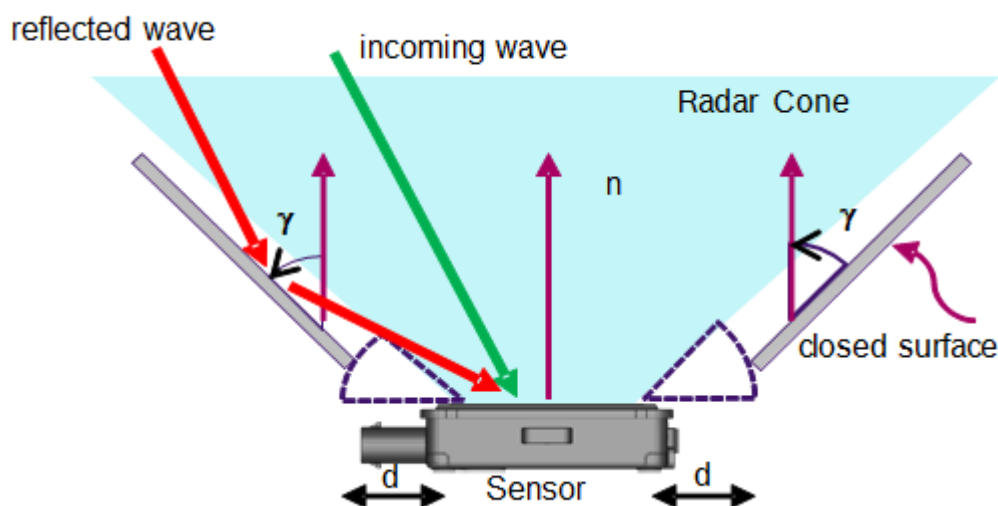


Figure: Reflection at bracket or mask

For closed surfaces (masks) in azimuth, the angle γ between mask surface and the normal vector \underline{n} of the sensor shall be above 75° for parts outside of the radar cone.

For closed surfaces (masks) in elevation, the angle γ between mask surface and the normal vector \underline{n} of the sensor shall be above 20° for parts outside of the radar cone.

Multipath reflection

Reflections of incoming signals at bracket or shielding absorber are coming back to the sensor if reflection at the bumper occurs. The figure below shows the situation which should be avoided. The worst case happens if the combination of the vertical tilt angles of shielding and bumper is $\gamma_1 = \gamma_2 / 2$. For a low interference signal the condition shall be:

$$\gamma_1 > \gamma_2 / 2 + 10^\circ$$

or

$$\gamma_1 < \gamma_2 / 2 - 10^\circ$$

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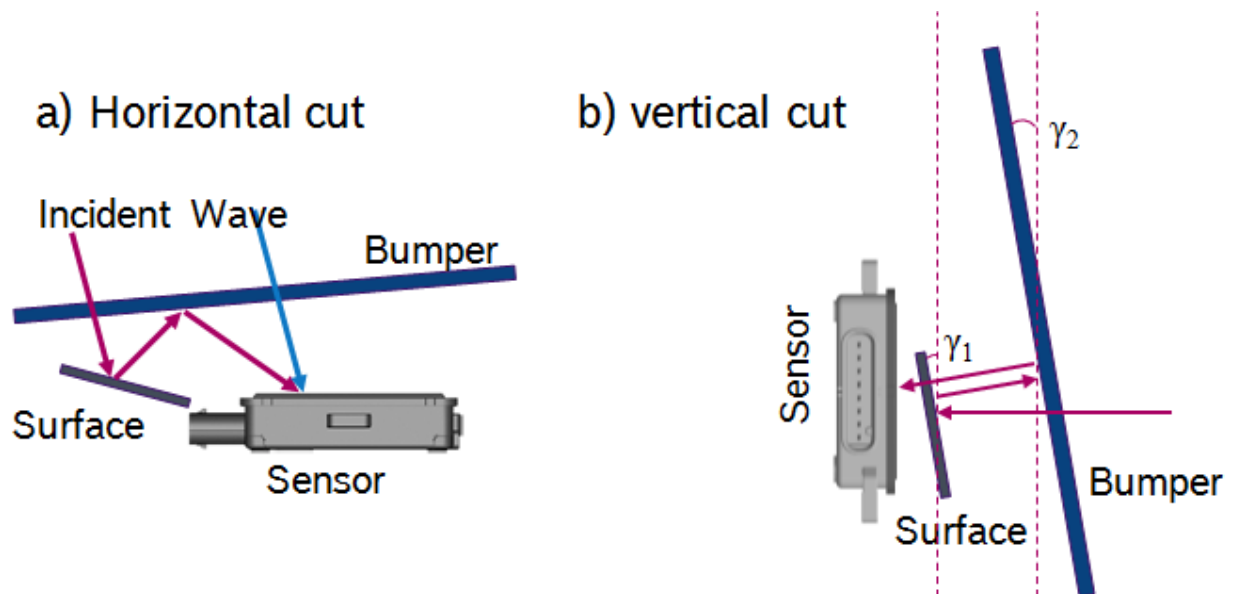


Figure: a) Requirements for parts outside radar cone to avoid multipath reflection

The same requirements are valid for a horizontal tilt of the fascia.

3. Technical data with measured variables and measuring conditions

3.1. Mechanical characteristics

Gravel bombardment:

According to ISO 20567-1 against back housing (covered installation)

Mechanical shock:

According to DIN EN 60068-2-27

500m/s² / 6ms duration

Mechanical vibration (broadband random vibration):

According to DIN EN 60068-2-64

Frequencyspectrum 5 Hz - 2000 Hz according to the following profile

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Frequency [Hz]	PSD [(m/s ²)/Hz]
5	0,884
10	20
55	6,5
180	0,25
300	0,25
360	0,14
1000	0,14
2000	0,14

$a_{\text{eff}} = 30.8 \text{ m/s}^2$

Protection class:

According to International Protection Marking, ISO 20653
IP6Kx, IPx6K, IPx7, IPx9K

Temperature range with restricted operation (communication interface working):

Top_max=+85°C ... Tmax=+95°C.

Temperature range of operation:

Top_min= -40°C ... Top_max=+85°C.

Duration see Reliability

Temperature range of operation:

Top_min= -40°C ... Top_max=+85°C.

Duration see Reliability

Corrosion resistance against salt spray and humidity

According to DIN EN 60068-2-11


Sensor may not be exposed to direct UV light for more than 48h

3.2. Electrical characteristics

The chapter electrical car integration describes the vehicle connector interface of the Radar SCU.

The detailed description of the following connection topics are adapted to the defined feature configuration:

- Connector Pinning

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- Connector Power Supply Interface
- Connector Communication Interface
- Connector Multi-Purpose I/O Interface

3.2.1. Electrical Vehicle Connector Pinning

This section describes the SCU vehicle connector pin properties and the connector pinning.

3.2.1.1. Pin Properties

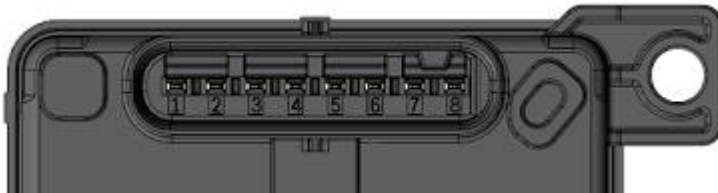
Every connector pin is robust against short circuits to the supply voltage, to GND and to the neighbour pins. The resistance of the short circuit may be as low as 0,1 Ohm.

An unwanted supply of the ECU by any other pins than the dedicated power supply pins is impossible.


The ECU is robust against 5 kOhm shunt between adjacent pins of the vehicle connector caused by dirt. No disturbance of the functionality.

3.2.1.2. Pin Assignment

Vehicle connector pin number assignment



Pin No.	Designation	Description
1	COM2-L	Ethernet (ETH_TRXN)
2	COM2-H	Ethernet (ETH_TRXP)
3	Spare	not used
4	Spare	not used
5	GND	Sensor ground: connected to terminal 31
6	COM1-L	Communication interface 1: Low signal
7	COM1-H	Communication interface 1: High signal
8	VBATT	Supply voltage for sensor (terminal 15/30)

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3.2.2. Vehicle Power Supply

3.2.2.1. Constraints and Definitions

The car battery supplies power to the Sensor (terminal 15/30)

All power supply parameters are measured at the ECU vehicle connector supply pins (VBATT to GND) unless different specified.

All power supply parameters are guaranteed and designed over ambient temperature $T_a = T_{a_min}$ to T_{a_max} unless different specified. (-40°C to 85°C, see Chapter "Operating Environment")

All power supply parameters are guaranteed and designed over lifetime unless different specified.

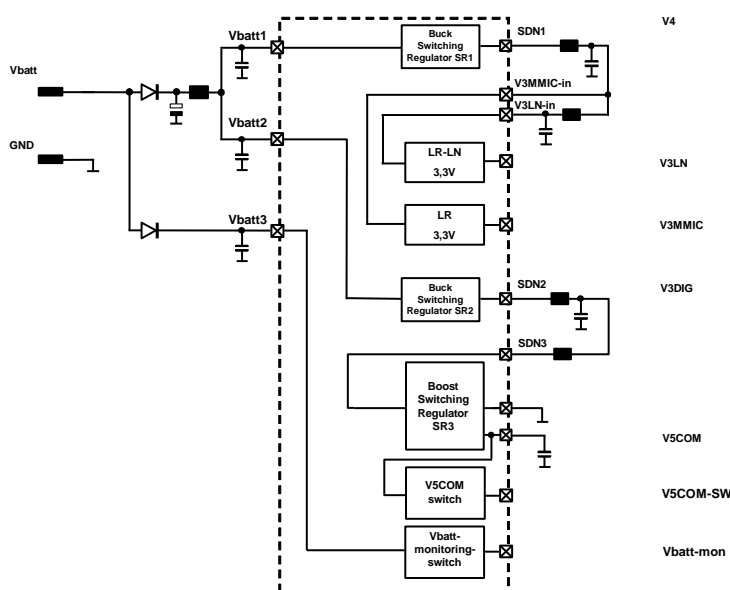
All power supply values are continuous values.


Definition **COM Interfaces ON:**

COM interfaces are working according to the respective communication standard.

3.2.2.2. Power Supply System 12V

The equivalent circuit diagram of the VBATT - Interface is as follows:



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Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
Umin	min. voltage without damaging the ECU	- reverse polarity - t <= 60s - Ri < 30mOhm	- 14,28	- 14,00		V

Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
Umax_res_up	max. reset voltage Power Up		-	-	6,0	V

Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
Umin_res_dn	min. reset voltage Power Down		4,5	-	-	V

Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
Umin_com	min. communication voltage	- COM Interfaces ON - Object list preservation - min value Power Down - max value Power Up	5,5	-	6	V

Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
Umin_op	min. operating voltage	- COM Interfaces ON - RF Module ON	-	-	7,0	V


Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
U_heating	radome heating operating voltage	Ta= - 25°C to 25°C	9	-	Umax_op	V

Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
Umax_op	max. operating voltage	- COM Interfaces ON - RF Module ON	16	-	-	V

Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
Umax_com	max. communication voltage	- COM Interfaces ON - Object list preservation	see Umax_op	see Umax_op	see Umax_op	V

Symbol	Parameter	Note or Test Condition	min	typ	max	Unit
Umax	max. voltage without damaging the ECU		-	-	35	V

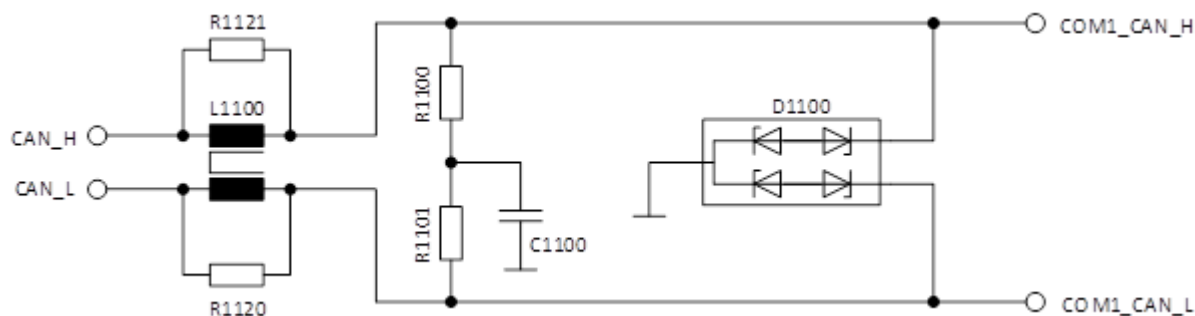
The inrush-current is below 30 A. It decays to 10 % of the maximum value within 150 µs.
Condition: V_Batt=14.0V, 5m wire harness length, 0.5mm²

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3.2.3. Electrical Communication Interface

3.2.3.1. CAN1 Interface

The equivalent circuit diagram of the CAN1 - Interface is as follows:




typical values:

Component	Typical Value	Package Size	Tolerance	Voltage Rating	Power Rating	Current Rating
R1100	61.9R	0805	1%	400V	400mW	-
R1101	61.9R	0805	1%	400V	400mW	-
C1100	4.7nF	0603	10%	100V	-	-
L1100	100μH	1210	+50/-30%	80V	-	150mA
R1120	not populated	0402	-	-	-	-
R1121	not populated	0402	-	-	-	-
D1100	not populated	SOT323-3L	-	-	-	-

The CAN1 communication interface is compliant to CAN-HS according to ISO 11898-2: 2015 and ISO 11898-5:2007

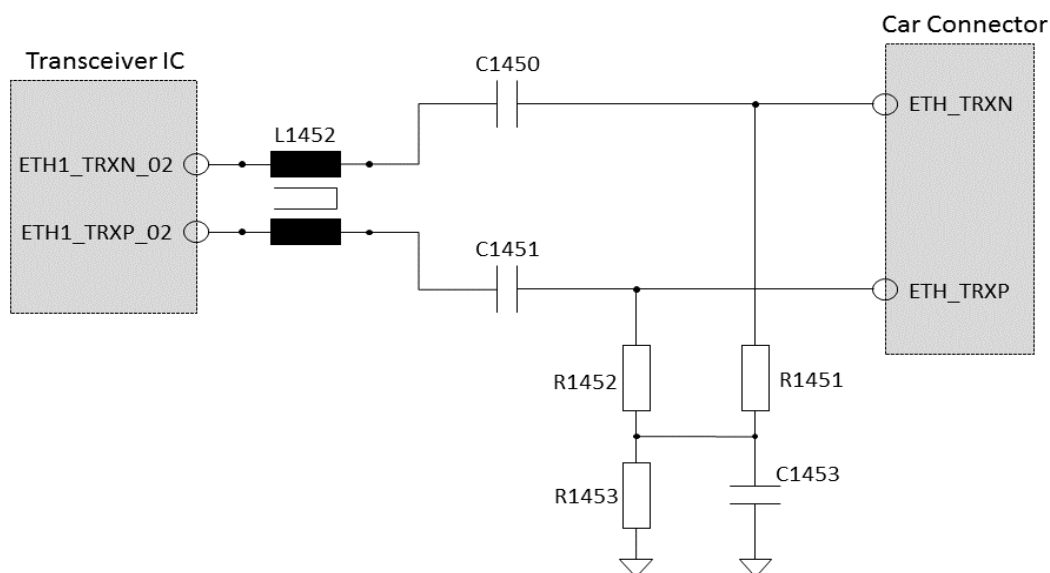
The CAN1 communication interface is compliant to CAN-FD according to ISO 11898-2: 2015 and ISO 11898-5:2007

ISO7637-2 Electrical disturbances from conduction and coupling

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3.2.3.2. Ethernet Interface

The equivalent circuit diagram of the Ethernet - Interface is as follows:



Component	Typical Value	Package Size	Tolerance	Voltage Rating	Power Rating	Current Rating
L1452	200uH	1210	-	-	-	50mA
R1451	1k	0805	1%	200V	0,4W	-
R1452	1k	0805	1%	200V	0,4W	-
R1453	100k	0603	1%	50V	0,1W	-
C1450	100nF	0603	10%	50V	-	-
C1451	100nF	0603	10%	50V	-	-
C1453	4,7nF	0603	10%	100V	-	-

The Ethernet communication interface is compliant to the IEEE100Base-T1

BOSCH 	Technical Customer Documentation	Document version: Refer to the Change history
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4. Change history of the template

Date	Template Version	Description	Author Name
15.11.2017	1.0	Initial version, created according to the requirements of the central directives CD-04504-000, 1.3 and CD-04504-001 Definition of contents, 1.3 and reviewed by Bernd Landes (CC-DA/QMM1) and Andre Reichmann (CC-DA/QMM1)	Mariana Georgieva-Grosse (CC-DA/EPV1)