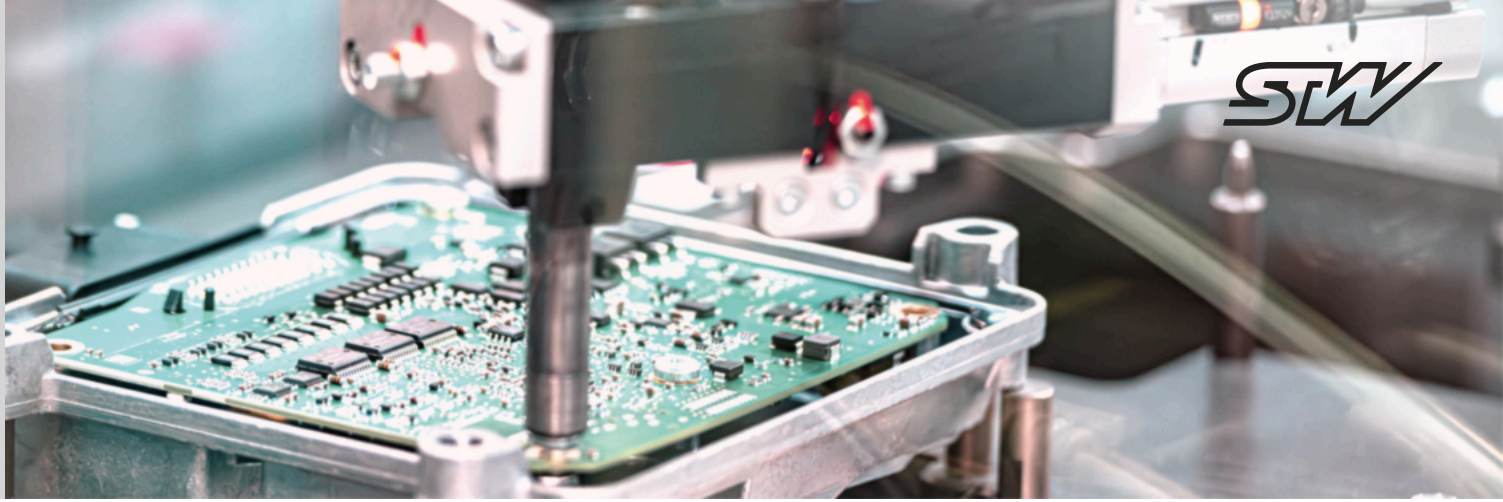


ESX.4cl

ESX control units

KEY FEATURES

- Control specially designed for use in harsh mobile applications
- Flexible programming in C, Matlab/Simulink or IEC61131-3 (logi.CAD 3)
- Suitable for safety-related applications up to SIL2 according to IEC 61508:2010, PL d according to EN ISO 13849-1:2015, and ASIL B according to ISO 26262:2018[SF)]

TECHNICAL DATA

- Aurix TC299 Multicore 32 bit, 300 MHz
- Internal: 2 MB RAM, 8 MB Flash
- External: optional data flash and F-RAM options
- 32 kB EEPROM
- 6 CAN interfaces (CAN FD), 1 RS232 or LIN, optional up to 6 Ethernet interfaces (3x 100BASE-Tx, 1x 1000BASE-T, 2x 100BASE-T1)
- 60 inputs
- 53 outputs
- 6 sensor supplies
- Coprocessor i.MX 6 with Linux (optional)

ACCESSORIES

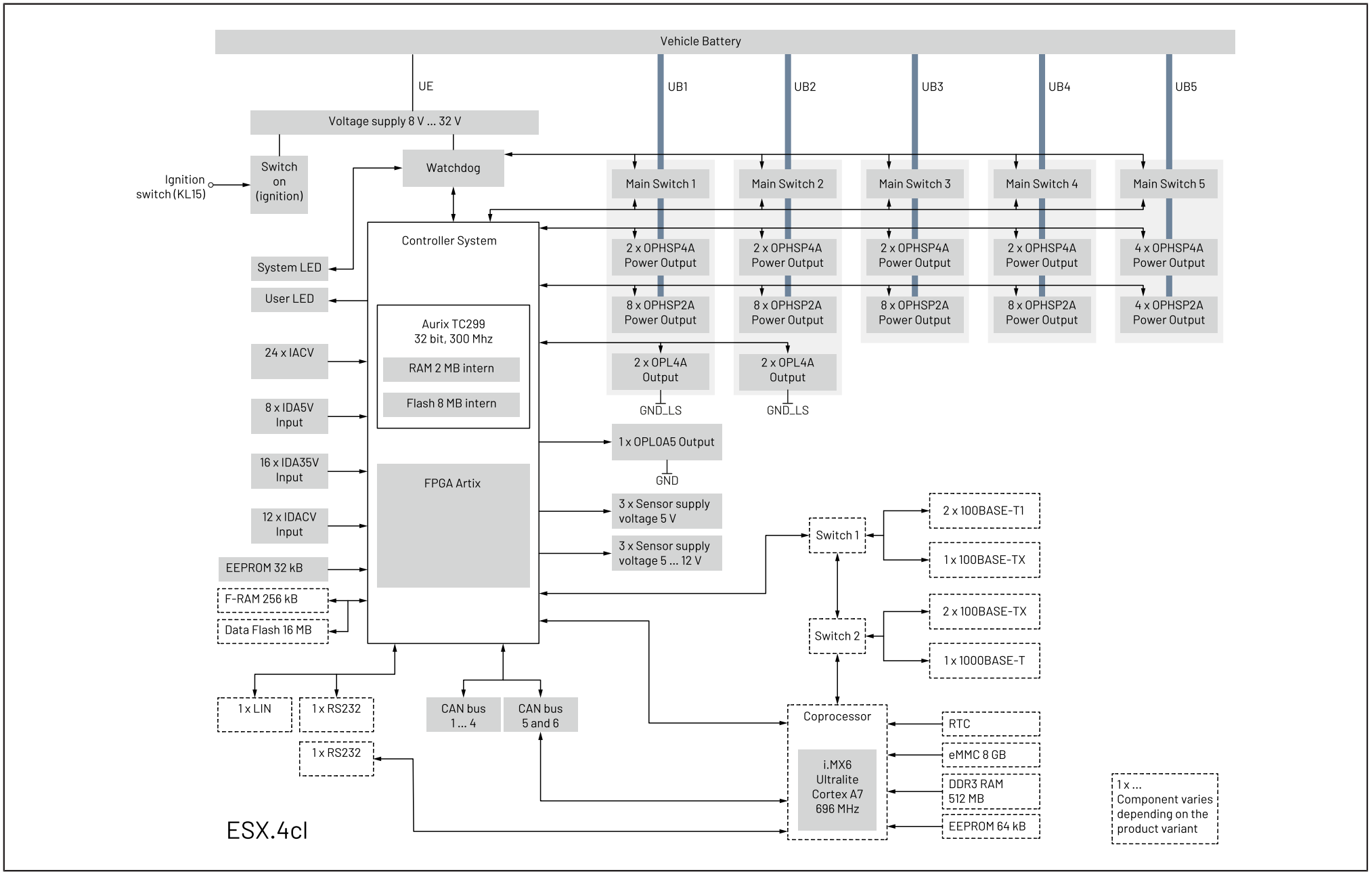
- Debug variants of the controller
- Debugger
- Compiler
- Starter kit
- Component deployment C, Matlab, and IEC61131-3 (logi.CAD 3)
- Mating plug
- Integrated into STW's openSYDE software platform

SF) Scheduled feature

Sensor-Technik Wiedemann GmbH

Am Bärenwald 6
87600 Kaufbeuren
Germany
+49 8341 9505-0
info.stw@wiedemann-group.com
www.stw-mm.com

BLOCK DIAGRAM



Variants

Variant features of the ESX.4cl

Feature		Variant 3	Variant 4
Processors and memory	32 bit Infineon Aurix TC299 multicore CPU, @ 300 MHz	✓	✓
	2 MB internal RAM	✓	✓
	8 MB internal Flash	✓	✓
	32 kB EEPROM	✓	✓
	i.MX6 UltraLite 32-bit MPU, ARM Cortex-A7 core, 700MHz (i.MX coprocessor)	-	✓
	512 MB DDR3 RAM	-	✓
	8 GB eMMC	-	✓
	64 kB EEPROM	-	✓
	Real Time Clock (RTC)	-	✓
Communication interfaces	CAN, from 100 kbit/s to 1 Mbit/s	6	6
	1 Gbit/s Ethernet (1000BASE-T)	1	1
	100 Mbit/s Ethernet (100BASE-TX)	3	3
	100 Mbit/s Single Pair Ethernet (100BASE-T1)	2	2
	RS232	1	1
	SENT	5	5
Inputs	Analog input IACV	24	24
	Multifunctional input IDA5V	8	8
	Multifunctional input IDA35V	16	16
	Multifunctional input IDACV	12	12

Variants

Variant features of the ESX.4cl

Feature		Variant 3	Variant 4
Outputs	Digital/PWM high side output OPHSP4A	12	12
	Digital/PWM high side output OPHSP2A	36	36
	Digital/PWM low side output OPL4A	4	4
	Digital/PWM low side output OPL0A5	1	1
	Sensor supply voltage 5 V	3	3
	Sensor supply voltage 5 ... 12 V	3	3

Available options of the ESX.4cl

Options	
Processor and memory	256 kB external F-RAM (other memory sizes are available on request)
	16 MB external data flash (other memory sizes are available on request)
Communication interface	LIN in accordance to LIN specification 2.2 A (with equipped i.MX6 the LIN option is not available)

TECHNICAL DATA

Processor and memory

Type	Properties	Features
Aurix TC299	32 bit, multicore processor, @ 300 MHz	• External system supervisor with programmable watchdog • 12 bit A/D converter for analog signal processing
Flash	8 MB	7.75 MB available for customer application
RAM	2 MB	On-chip RAM This memory mainly serves as system memory for BIOS stack and data, but also includes a heap for the customer application.
EEPROM	1 x 32 kB	Available for customer application. (temperature refers to the EEPROM specifications) Data Retention: • 50 years at 125 °C • 100 years at 25 °C Typical endurance according to manufacturer: • 4 million write cycles at 25 °C • 1.2 million write cycles at 85 °C
F-RAM (optional)	256 kB Other memory sizes are available on request	External High endurance 100 trillion read/write cycles
Data flash (optional)	16 MB Other memory sizes are available on request	External

TECHNICAL DATA

Processor and memory coprocessor

Type	Properties	Features
i.MX 6UltraLite	32 bit controller @ 696 MHz	Single ARM Cortex®-A7 core
RAM	512 MB DDR3	On-chip ECC
eMMC memory	8 GB	Write Endurance in Total Terabyte Written (TBW): 20TBW Data Retention (Fresh or Early Life Device): 15 years at 55 °C Data Retention (after 3K PE cycles): 20 month at 55 °C
EEPROM	1 x 64 kB	-
RTC	Accuracy: ±6 ppm at -40 °C to +85 °C	Buffering time for minimum 5 minutes
Temperature measurement	Accuracy: ±2 °C at -40 °C to 150 °C	Located close to coprocessor and RAM

Communication interfaces

Type	Maximum quantity	Configuration
CAN	6	CAN 2.0B, baud rate from 100 kbit/s to 1 Mbit/s CAN FD CAN 1 wake-up functionality (optional)
Ethernet	1	1000BASE-T (1 Gbit/s Ethernet)
	3	100BASE-TX (100 Mbit/s Ethernet)
	2	100BASE-T1 (100 Mbit/s Single Pair Ethernet)
RS232 (optional)	1	Baud rate up to 115 kBit/s
LIN (optional)	1	In accordance to LIN specification 2.2A

TECHNICAL DATA

Inputs

Type	Maximum quantity	Possible configuration	Measurement
Multifunctional input IDA35V	16	Analog voltage	0 ... 35 V
		Programmable pull-up resistor	1.1 kΩ to +8.5 V
		Programmable pull-down resistor	1 kΩ to GND
		NAMUR sensor	NAMUR sensor compatible
		Digital	Active-high/active-low
		Frequency	0.6 Hz ... 20 kHz
Analog input IACV	24	Analog voltage	0 ... 12 V
		Analog current	0 ... 24 mA
		Digital (voltage mode)	Active-high/active-low
Multifunctional input IDACV	12	Analog voltage programmable	0 ... 35 V 0 ... 12 V 0 ... 5 V
		Analog current	0 ... 24 mA
		Programmable pull-up resistor	1.1 kΩ to +8.5 V
		Programmable pull-down resistor	1 kΩ to GND
		NAMUR sensor	NAMUR sensor compatible
		Digital (voltage mode)	Active-high/active-low
		Frequency	0.6 Hz ... 20 kHz
		Incremental encoder interface	Change of position or angular change
Multifunctional input IDA5V	8	Analog voltage	0 ... 5 V
		Programmable pull-up resistor	6.8 kΩ to +5 V

TECHNICAL DATA

Inputs

Type	Maximum quantity	Possible configuration	Measurement
		Digital	Active-high/active-low
		Frequency	0.6 Hz ... 20 kHz
		Incremental encoder interface	Change of position or angular change
		SENT	SENT interface IDA5V is not fully compliant with SAE J2716:2016-04.

Outputs

Type	Maximum quantity	Possible configuration	Range	Characteristics	Feature
Digital/PWM high side output 0PHSP2A	36	PWM	0 ... 2.5 A	0 ... 100 % duty cycle resolution < 0.1 % PWM frequency 20 ... 1000 Hz	• high side switch • precise current measurement, accuracy is ±2.3 % ±70 mA • supports current control mode • digital feedback, open load detection in OFF state • automated shutdown on overcurrent > 4.6 A ±0.9 A • combine several outputs for parallel operation
		Digital	-	ON/OFF	
Digital/PWM high side output 0PHSP4A	12	PWM	0 ... 4 A	0 ... 100 % duty cycle resolution < 0.1 % PWM frequency 20 ... 500 Hz	• high side switch • precise current measurement, accuracy is ±2.3 % ±140 mA • supports current control mode • digital feedback, open load detection in OFF state • automated shutdown on overcurrent > 7.5 A ±1.5 A • combine several outputs for parallel operation
		Digital	-	ON/OFF	

TECHNICAL DATA

Outputs

Type	Maximum quantity	Possible configuration	Range	Characteristics	Feature
Digital/PWM low side output OPL4A	4	PWM	0 ... 4 A	0 ... 100 % duty cycle resolution < 0.1 % PWM frequency 20 ... 1000 Hz	• low side switch • precise current measurement, accuracy is ±2.3 % ±120 mA • supports current control mode • digital feedback, open load detection in OFF state • automated shutdown on overcurrent > 7.5 A ±0.9 A • output voltage feedback, accuracy is ±4.5 % ±200 mV
		Digital	-	ON/OFF	
Digital low side output OPL0A5	1	PWM	0 ... 0.5 A	0 ... 100 % duty cycle resolution < 0.1 % PWM frequency 20 ... 1000 Hz	• low side switch • output voltage feedback, accuracy is ±4 % ±200 mV
		Digital	-	ON/OFF	
Main Switch	5		8 ... 32 V DC	ON/OFF	• high-side switch • switches the output groups +UB1 to +UB5 • Current up to 12 A
Sensor supply voltage 5 V	3	-	5 V	ON/OFF Accuracy voltage output is +2 ... -2.5% Accuracy voltage readback is ±2.5% ±50 mV	Maximum output current 250 mA
Sensor supply voltage 5 ... 12 V	3	Voltage	5 ... 12 V	Accuracy voltage output is ±0.9% ±50 mV This is valid under the following conditions: • Capacitive load ≤470 µF • Settling time 100 ms Accuracy voltage readback: ±0.9% ±50 mV	Maximal output current I_{MAX} = 250 mA programmable output needs derating for output voltages U_{EXT} < 10 V: I_{MAX} = 0.875 / (13.5 - U_{EXT}) A

TECHNICAL DATA

Mechanical data

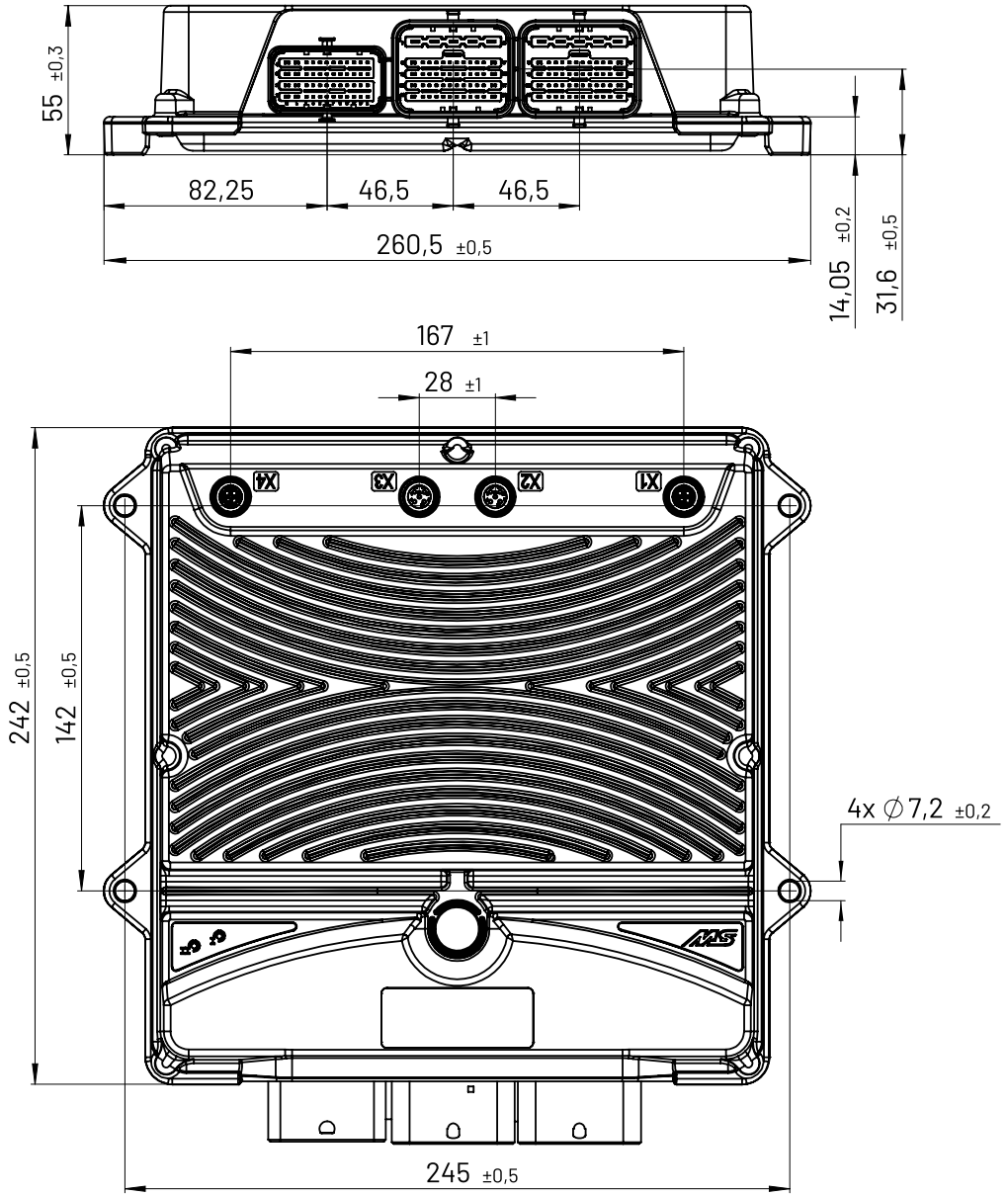
Component	Description	Value
Connectors	-	Automotive 154 pins, Molex CMC
		Ethernet, M12 connector: 100BASE-TX: 4 pins D-type 1000BASE-T: 8 pinx X-type,
Indicators	2 LED, dual color (red/green or mixed colors)	System LED and User LED
Housing	Die-cast aluminum	GORE-TEX™-breathing filter for pressure equalization
Weight	-	about 1.7 kg / about 3.7 lb
Degree of Protection	Variant without M12 Ethernet connector	IP6K6, IPX7, IPX9K
	Variant with M12 Ethernet connector	IP6K5, IPX7
Dimensions	-	264 mm x 260 mm x 55 mm
Operating temperature, housing temperature	-	-40 ... +85 °C (-40 ... +185 °F)
Operating altitude	-	-400 ... +4000 m

TECHNICAL DATA

Power supply

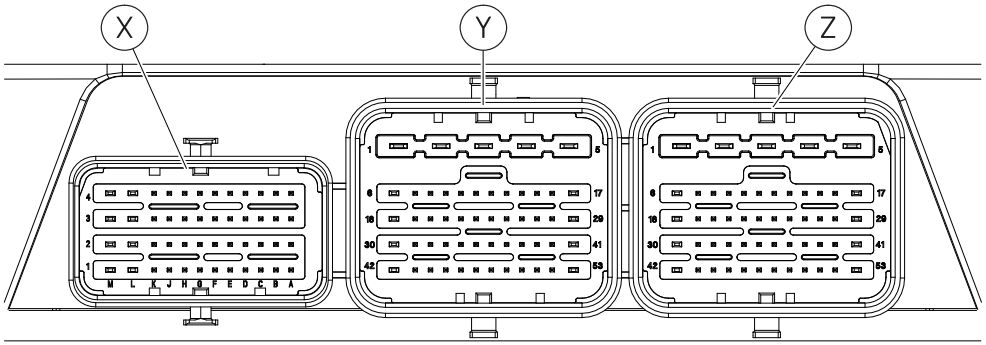
Component	Description	Range	
		Minimum Value	**Maximum Value**
DC voltage supply	Voltage at +UE ECU supply and +UB power supply	8 V DC	32 V DC
Current consumption	Power supply +UB1 fully loaded 12 A	-	60 A, short-term
	Power supply +UB2 fully loaded 12 A		
	Power supply +UB3 fully loaded 12 A		
	Power supply +UB4 fully loaded 12 A		
	Power supply +UB5 fully loaded 12 A		
	4 x low side output OPL4A	-	16 A, fully loaded
Standby	Sum of input currents at +UE and +UB (U_{KL15} = 0 V, ignition off) Without external load		< 1 mA (max. 28 V)
ECU active	+UE supply current (U_{KL15} > $U_{KL15HIGH}$, no external load) Only valid for Variant 4.		≈ 500mA at +UE = 12 V ≈ 300mA at +UE = 28 V
LIN voltage supply	12 V supply voltage for LIN. In a 24 V systems, one of the 5 ... 12 V sensor supplys can be connected to the LIN supply pin.	8 V	16 V

TECHNICAL DRAWING



PIN ASSIGNMENT

Pin Assigment Main Connector X1 (X, Y, Z)



Pin Assigment Main Connector X1 (X, Y, Z)

X		Y		Z	
Pin	**Signal name**	**Pin**	**Signal name**	**Pin**	**Signal name**
XA1	IDACV_8	Y1	OPHSP4A_7	Z1	UB2
XA2	IDACV_7	Y2	UB3	Z2	UB1
XA3	IDACV_6	Y3	UB4	Z3	GND
XA4	IDACV_5	Y4	UB5	Z4	GND_LS
XB1	IDA5V_8	Y5	OPHSP4A_8	Z5	UE
XB2	IDA5V_7	Y6	OPHSP4A_5	Z6	OPHSP4A_1
XB3	IDA5V_6	Y7	OPHSP2A_25	Z7	OPHSP2A_1
XB4	IDA5V_5	Y8	OPHSP2A_27	Z8	OPHSP2A_3
XC1	IDACV_4	Y9	OPHSP2A_29	Z9	OPHSP2A_5
XC2	IDACV_3	Y10	OPHSP2A_31	Z10	OPHSP2A_7
XC3	IDACV_2	Y11	IACV_21	Z11	IACV_1
XC4	IDACV_1	Y12	IDA35V_1	Z12	IACV_5
XD1	not connected	Y13	IDA35V_5	Z13	IACV_9
XD2	not connected	Y14	IDA35V_9	Z14	IACV_13
XD3	IDA5V_2	Y15	IDA35V_13	Z15	IACV_17
XD4	IDA5V_1	Y16	OPHSP2A_33	Z16	KL15
XE1	ETH1_P2_BRR+	Y17	OPHSP4A_9	Z17	OPL4A_1
XE2	CAN2_L	Y18	OPHSP4A_6	Z18	OPHSP4A_2
XE3	IDA5V_3	Y19	OPHSP2A_26	Z19	OPHSP2A_2

PIN ASSIGNMENT

Pin Assigment Main Connector X1 (X, Y, Z)

X		Y		Z	
Pin	**Signal name**	**Pin**	**Signal name**	**Pin**	**Signal name**
XE4	CAN1_L	Y20	OPHSP2A_28	Z20	OPHSP2A_4
XF1	ETH1_P2_BRR-	Y21	OPHSP2A_30	Z21	OPHSP2A_6
XF2	CAN2_H	Y22	IDACV_11	Z22	OPHSP2A_8
XF3	IDA5V_4	Y23	IACV_22	Z23	IACV_2
XF4	CAN1_H	Y24	IDA35V_2	Z24	IACV_6
XG1	not connected	Y25	IDA35V_6	Z25	IACV_10
XG2	not connected	Y26	IDA35V_10	Z26	IACV_14
XG3	CAN5_L	Y27	IDA35V_14	Z27	IACV_18
XG4	CAN4_L	Y28	OPHSP2A_34	Z28	IDACV_9
XH1	ETH1_P1_BRR+	Y29	OPHSP4A_10	Z29	OPL4A_2
XH2	CAN3_L	Y30	OPHSP2A_17	Z30	OPHSP4A_3
XH3	CAN5_H	Y31	OPHSP2A_19	Z31	OPHSP2A_9
XH4	CAN4_H	Y32	OPHSP2A_21	Z32	OPHSP2A_11
XJ1	ETH1_P1_BRR-	Y33	OPHSP2A_23	Z33	OPHSP2A_13
XJ2	CAN3_H	Y34	OPHSP2A_32	Z34	OPHSP2A_15
XJ3	CAN6_L	Y35	IACV_23	Z35	IACV_3
XJ4	RS232/LIN Rx[1)]	Y36	IDA35V_3	Z36	IACV_7
XK1	not connected	Y37	IDA35V_7	Z37	IACV_11
XK2	not connected	Y38	IDA35V_11	Z38	IACV_15

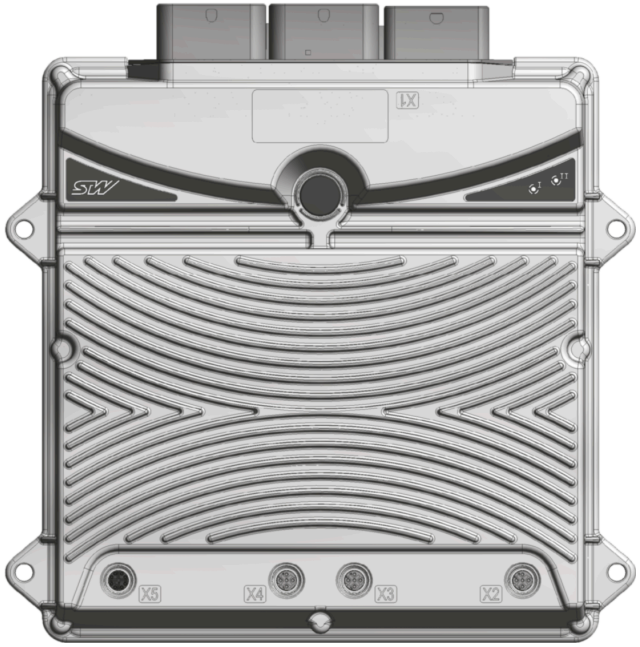
Pin Assigment Main Connector X1 (X, Y, Z)

X		Y		Z	
Pin	**Signal name**	**Pin**	**Signal name**	**Pin**	**Signal name**
XK3	CAN6_H	Y39	IDA35V_15	Z39	IACV_19
XK4	RS232 Tx/ LIN Sup[1)]	Y40	OPHSP2A_35	Z40	OPL0A5
XL1	AGND	Y41	OPHSP4A_11	Z41	OPL4A_3
XL2	UEXT5V_3	Y42	OPHSP2A_18	Z42	OPHSP4A_4
XL3	UEXT5V_2	Y43	OPHSP2A_20	Z43	OPHSP2A_10
XL4	UEXT5V_1	Y44	OPHSP2A_22	Z44	OPHSP2A_12
XM1	AGND	Y45	OPHSP2A_24	Z45	OPHSP2A_14
XM2	UEXT5-12V_3	Y46	IDACV_12	Z46	OPHSP2A_16
XM3	UEXT5-12V_2	Y47	IACV_24	Z47	IACV_4
XM4	UEXT5-12V_1	Y48	IDA35V_4	Z48	IACV_8
		Y49	IDA35V_8	Z49	IACV_12
		Y50	IDA35V_12	Z50	IACV_16
		Y51	IDA35V_16	Z51	IACV_20
		Y52	OPHSP2A_36	Z52	IDACV_10
		Y53	OPHSP4A_12	Z53	OPL4A_4

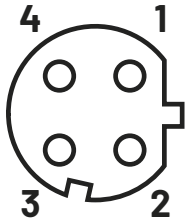
[1)] Scheduled feature

PIN ASSIGNMENT

Connectors X2 ... X5:

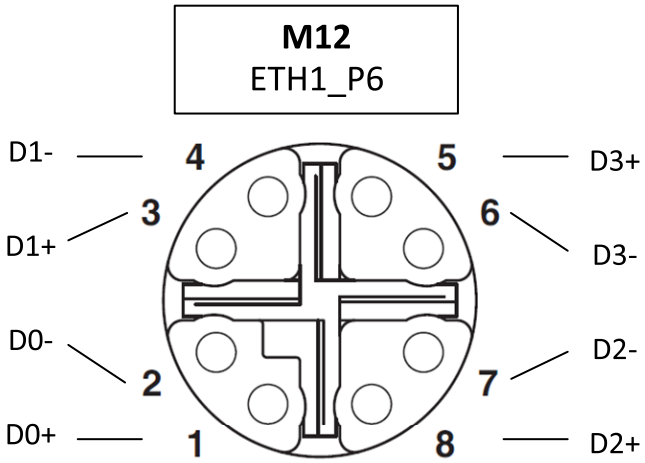


Pin Assignment M12 Connectors X2 ... X4:



Connector	Pin	Description
X2	1	ETH1_P3_TX+
X2	2	ETH1_P3_RX+
X2	3	ETH1_P3_TX-
X2	4	ETH1_P3_RX-
X3	1	ETH1_P4_TX+
X3	2	ETH1_P4_RX+
X3	3	ETH1_P4_TX-
X3	4	ETH1_P4_RX-
X4	1	ETH1_P5_TX+
X4	2	ETH1_P5_RX+
X4	3	ETH1_P5_TX-
X4	4	ETH1_P5_RX-

Pin Assignment M12 Connector X5:



Connector	Pin	Description
X5	1	ETH1_P6_D0+
X5	2	ETH1_P6_D0-
X5	3	ETH1_P6_D1+
X5	4	ETH1_P6_D1-
X5	5	ETH1_P6_D3+
X5	6	ETH1_P6_D3-
X5	7	ETH1_P6_D2-
X5	8	ETH1_P6_D2+

QUALIFICATION

Compliance Information

Standard	Description		Parameter
ISO/IEC 17050-1 REGULATION (EC) No 765/2008	CE	Conformity	See Declaration of Conformity
EN ISO 13849-1:2015	Safety of machinery		PL d / Cat. 2
IEC 61508:2010	Functional safety		SIL 2
ISO 26262:2018	Road vehicles - Functional safety		ASIL B[SF)]
KBA (Kraftfahrt-Bundesamt)	E1	Certification This approved device can be used on any vehicle type with the following restrictions: All vehicle types with a 12 V respectively 24 V - electrical wiring and battery(-) at the body	According UN ECE Regulation No. 10
2011/65/EU 2015/863/EU	RoHS	Restriction of Hazardous Substances	
2006/42/EC	Machinery directive		

SF) Scheduled feature

DETAILED QUALIFICATION

CE - EN IEC 61000-6-2:2019 (Test specifications are currently still being processed)

Standard	Test	Parameter
EN IEC 61000-6-2:2019	Immunity for industrial environments	-
	DIN EN 61000-4-2 Electrostatic discharge immunity test - direct discharges	330 Ω / 150 pF, Contact discharge ±4 kV Air discharge ±8 kV
	DIN EN 61000-4-2 Electrostatic discharge immunity test - indirect discharges (HCP, VCP)	330 Ω / 150 pF, Contact discharge ±4 kV
	DIN EN 61000-4-3 Radiated, radio-frequency, electromagnetic field immunity test	80 MHz to 1000 MHz ⟶ 10 V/m; 1.4 GHz to 6.0 GHz ⟶ 3 V/m; horizontal and vertical
	DIN EN 61000-4-4 Burst - supply lines (Electrical fast transient / burst immunity test)	±1 kV, 5/50 ns tr/th, repetition frequency 5 kHz or 100 kHz
	DIN EN 61000-4-4 Burst - data lines (Electrical fast transient / burst immunity test)	±1 kV, 5/50 ns tr/th, repetition frequency 5 kHz or 100 kHz
	DIN EN 61000-4-5 Surge - supply lines (immunity test)	asymmetrical: ±1 kV symmetrical: ±0,5 kV
	DIN EN 61000-4-5 Surge - data lines (immunity test)	asymmetrical: ±1 kV
	DIN EN 61000-4-6 Conducted immunity - supply lines (Immunity to conducted disturbances, induced by radio-frequency fields)	150 kHz to 80 MHz, 10 V
	DIN EN 61000-4-6 Conducted immunity - data lines	150 kHz to 80 MHz, 10 V

DETAILED QUALIFICATION

CE - EN IEC 61000-6-2:2019 (Test specifications are currently still being processed)

Standard	Test	Parameter
	(Immunity to conducted disturbances, induced by radio-frequency fields)	
	DIN EN 61000-4-8 magnetic field	50, 60 Hz, 30 A/m
EN 61000-6-4:2007 + A1:2011	Emission standard for industrial environments	Conducted (CE) 0.15 MHz ... 30 MHz Radiated (RE) 30 MHz ... 5000 MHz 10 m

DETAILED QUALIFICATION

Functional Safety - DIN EN 61326-3-1 (Test specifications are currently still being processed)

Standard	Test	Parameter
DIN EN 61326-3-1:2018	Tabelle 2 DIN EN 61000-4-2 - direct discharges Electrostatic discharge immunity test	330 Ω / 150 pF, Contact discharge ±6 kV Air discharge ±8 kV
	Tabelle 2 DIN EN 61000-4-2 - indirect discharges Electrostatic discharge immunity test	330 Ω / 150 pF, Contact discharge ±6 kV
	Tabelle 2 DIN EN 61000-4-3 Radiated, radio-frequency, electromagnetic field immunity test	80 MHz to 1000 MHz, 20 V/m; 1,4 GHz to 2 GHz, 10 V/m 2,0 GHz to 2,7 GHz ⟶ 3 V/m; horizontal, vertical
	Tabelle 2 DIN EN 61000-4-8 magnetic field	30 A/m (No higher test levels will be applied)
	Tabelle 4 DIN EN 61000-4-4 Burst - supply lines (Electrical fast transient / burst immunity test)	±3 kV, 5/50 ns tr/th, repetition frequency 5 kHz
	Tabelle 5 DIN EN 61000-4-4 Burst - data lines (Electrical fast transient / burst immunity test)	±2 kV, 5/50 ns tr/th, repetition frequency 5 kHz
	Tabelle 4 DIN EN 61000-4-5 Surge - supply lines (immunity test)	asymmetric: ±2 kV symmetric: ±1 kV
	Tabelle 5 DIN EN 61000-4-5 Surge - data lines (immunity test)	asymmetric: ±2 kV

DETAILED QUALIFICATION

Functional Safety - DIN EN 61326-3-1 (Test specifications are currently still being processed)

Standard	Test	Parameter
	Tabelle 4 DIN EN 61000-4-6 Conducted immunity - supply lines (Immunity to conducted disturbances, induced by radio-frequency fields)	150 kHz to 80 MHz, 10 V
	Tabelle 5 DIN EN 61000-4-6 Conducted immunity - data lines (Immunity to conducted disturbances, induced by radio-frequency fields)	150 kHz to 80 MHz, 10 V
	Tabelle 4 IEC 61000-4-16 Conducted common-mode voltages Supply lines	1 V to 10 V, 20 dB/Decade (1,5 kHz to 15 kHz) 10 V (15 kHz to 150 kHz) 10 V (constant with direct current, $16^2/_3$ Hz, 50 / 60 Hz and 150 / 180 Hz) 100 V short period (1 s, with direct current, $16^2/_3$ Hz and 50 / 60 Hz)
	Tabelle 5 IEC 61000-4-16 Conducted common-mode voltages signal lines	1 V to 10 V, 20 dB/Decade (1,5 kHz to 15 kHz) 10 V (15 kHz to 150 kHz) 10 V (constant with direct current, $16^2/_3$ Hz, 50 / 60 Hz and 150 / 180 Hz) 100 V short period (1 s, with direct current, $16^2/_3$ Hz and 50 / 60 Hz)
	Tabelle 4 IEC 61000-4-29 Votlage dips (Supply lines)	40 % U_T during 10 ms
	Tabelle 4 IEC 61000-4-29 Short interruptions (Supply lines)	0 % U_T during 20 ms

DETAILED QUALIFICATION

E1 - ECE R10(Test specifications are currently still being processed)

Standard	Test	Parameter
UN ECE R10 Add. 9, Rev. 6 Annex 7	Radiated broadband emissions from ESAs CISPR25:2004	30 MHz ... 1000 MHz
UN ECE R10 Add. 9, Rev. 6 Annex 8	Radiated narrowband emissions from ESAs CISPR25:2004	30 MHz ... 1000 MHz
UN ECE R10 Add. 9, Rev. 6 Annex 9	Immunity of ESAs to electromagnetic radiation General: ISO 11452-1:2005 ALSE: ISO 11452-2:2004 BCI: ISO 11452-4:2011 (Stripline and TEM alternative test methods)	General 20 MHz ... 2000 MHz 20 MHz ... 800 MHz: AM 800 MHz ... 2000 MHz: PM BCI: 20 MHz ... 400 MHz, 60 MA (substitution (150 Mm) or closed loop (900 Mm) method allowed) Antenne, ALS E (vert): 200 MHz ... 800 MHz, 30 V/m, AM 800 MHz ... 2000 MHz, 30 V/m, PM
UN ECE R10 Add. 9, Rev. 6 Annex 10	Conducted transient emission from ESAs on 12 V supply lines ISO 7637-2:2004	slow/fast: pos: +75 V neg: -100 V
	Conducted transient emission from ESAs on 24 V supply lines ISO 7637-2:2004	slow/fast: pos: +150 V neg: -450 V
	Electrical transient conduction along supply lines 12V System, Level 3 ISO 7637-2:2004	Pulse 1 - 75V, 5000 pulses t1 = 0,5 s to 5 s
		Pulse 2a 37V, 5000 pulses t1 = 0,2 s to 5 s

DETAILED QUALIFICATION

E1 - ECE R10(Test specifications are currently still being processed)

Standard	Test	Parameter
		Pulse 2b 10 V, 10 pulses td = 0,2 s to 2 s
		Pulse 3a -112 V, 1 hr
		Pulse 3b 75 V, 1 hr
		Pulse 4 Us = -6 V Ua = -2,5 V to -6V 1 pulse
	Electrical transient conduction along supply lines 24V System, Level 3 ISO 7637-2:2004	Pulse 1 -450 V, 5000 pulses t1 = 0,5 s to 5 s
		Pulse 2a 37 V, 5000 pulses t1 = 0,2 s to 2 s
		Pulse 2b 20 V, 10 pulses td = 0,2 s to 2 s
		Pulse 3a -150 V, 1 hr
		Pulse 3b +150 V, 1 hr
		Pulse 4 Us = -12 V Ua = -5 V to -12 V 1 pulse

DETAILED QUALIFICATION

Electrical Safety (Test specifications are currently still being processed)

Standard	Test	Parameter
ISO 16750-2:2012-11	Direct current supply voltage	Operation at Tmax with maximum and minimum voltage Operation at Tmin with maximum and minimum voltage
	Overvoltage - Systems with 12 V / 24 V nominal voltage - 12 V Systems	18 V for 60 min. at 20 °C below Tmax
		24 V for 60 s at room temperature
	Overvoltage - Systems with 12 V / 24 V nominal voltage - 24 V Systems	36 V for 60 min. at 20 °C below Tmax
	Superimposed alternating voltage - 12 V Systems	Usmax = 16 V (for U_N = 12 V) Sweep duration: 120 seconds Number of sweeps: 5 Severity 1, 2, 4
	Superimposed alternating voltage - 24 V Systems	Usmax = 32 V (for U_N = 24 V) Sweep duration: 120 seconds Number of sweeps: 5 Severity 1, 2, 3
	Slow decrease and increase of supply voltage	Decrease supply voltage from Usmin to 0 V and increase it from 0 V to Usmin. Applying a change rate of (0.5 ±0.1) V per minute
	Discontinuities in supply voltage - Momentary drop in supply voltage - 12 V Systems	Drop to 4.5 V for ≤ 100 ms ECU may perform a reset
	Discontinuities in supply voltage - Momentary drop in supply voltage - 24 V Systems	Drop to 9 V for ≤ 100 ms
	Discontinuities in supply voltage - Reset behavior voltage drop	Decrease supply voltage from Usmin in 5 % steps
	Discontinuities in supply voltage - Starting profile 12 V code C	Voltage cranking; Level 1
		Voltage cranking; Level 2

DETAILED QUALIFICATION

Electrical Safety (Test specifications are currently still being processed)

Standard	Test	Parameter
		Voltage cranking; Level 3
		Voltage cranking; Level 4
	Discontinuities in supply voltage - Starting profile 24 V code E	Voltage cranking; Level 1
		Voltage cranking; Level 2
		Voltage cranking; Level 3
	Discontinuities in supply voltage-Load Dump - Pulse B - 12 V System	with centralized load dump suppression 5 Pulses
	Discontinuities in supply voltage-Load Dump - Pulse B - 24 V System	with centralized load dump suppression 5 Pulses
	Reversed voltage - Case 1 - 12 V Systems	Unom. = 12 V → Case 1 - Test Voltage = -4 V reversed polarity Duration: 60 s
	Reversed voltage - Case 2 - 12 V Systems	Unom. = 12 V → Case 2 - Test Voltage = -14 V reversed polarity Duration: 60 s
	Reversed voltage - Case 2 - 24 V Systems	Unom. = 24 V → Case 2 - Test Voltage = 28 V reversed polarity Duration: 60 s
	Ground reference and supply offset - 12 V Systems	±1 V offset; only required if two or more power supplies exist; Low-Side-Sensor must be connected to ground point at ECU connector
	Ground reference and supply offset - 24 V Systems	±1 V offset; only required if two or more power supplies exist; Low-Side-Sensor must be connected to ground point at ECU connector
	Open circuit tests - Single line interruption - 12 V Systems	Interruption of each single Output for (10 ±1) s.
	Open circuit tests - Single line interruption - 24 V Systems	Interruption of each single Output for (10 ±1) s.
	Open circuit tests - Multiple line interruption - 12 V Systems	Disconnect the DUT for (10 ±1) s.

DETAILED QUALIFICATION

Electrical Safety (Test specifications are currently still being processed)

Standard	Test	Parameter
	Open circuit tests - Multiple line interruption - 24 V Systems	Disconnect the DUT for (10 ±1) s.
	Short circuit protection - signal circuits	Connect every In- and Output to maximum supply voltage (Usmax) and Ground for 1 minute various modes necessary
	Short circuit protection - load circuits (supply lines)	to load circuits

Electromagnetic Compatibility (E1) (Test specifications are currently still being processed)

Standard	Test	Parameter
ISO 7637-2: 2011	Conducted transient emission from ESAs on 12 V supply lines, Level 3 ISO 7637-2:2011	slow+: +37 V slow-: -75 V fast+: +75 V fast-: -112 V
	Conducted transient emission from ESAs on 24 V supply lines, Level 3 ISO 7637-2:2011	slow+: +37 V slow-: -150 V fast+: +150 V fast-: -150 V
	Electrical transient conduction along supply lines -24 V System, Level 4	Pulse 1 -600 V, 500 pulses t1 ≥ 0,5 s
		Pulse 2a +112 V, 500 pulses t1 = 0,2 s to 5 s
		Pulse 2b +20 V, 10 pulses td = 0,2 s to 2 s
		Pulse 3a -300 V, 1 h
		Pulse 3b +300 V, 1 h

DETAILED QUALIFICATION

Environmental Qualification

Standard	Test	Parameter
ISO 16750-3:2012	Resonance search	10Hz - 2000Hz, 1g, 0.5 oct/min
	Test VII - Commercial vehicle, sprung masses	Vibration noise with temperature superimposition in case of natural frequencies of DUT upper 30 Hz: random vibration acc IEC60068-2-64 from 10 Hz to 2000 Hz for 32 hrs each axis, Temperature cycle 8h from Tmin to Tmax
	Test VII - Commercial vehicle, sprung masses, Additional profile in the case of DUT natural frequencies < 30 Hz (Test VII)	Random vibration acc IEC60068-2-64 from 10 Hz to 45 Hz for 32 hrs each axis, Temperature cycle 8 h from Tmin to Tmax
	Mechanical Shock - Test for devices on rigid points on the body and on the frame	In acc. IEC 60068-2-27 half-sinusoidal Acceleration 500 m/s^2 Duration 6 ms room temperature 10 shocks per test direction
	Free fall (parts that may withstand falling without damages)	3 devices, 2 falls every device on the opposite side of the housing. Drop height: 1 m to concrete ground or steel plate
ISO 16750-4:2010	Tests at constant temperature: Low temperature - storage	- 40 °C for 24 hrs
	Tests at constant temperature: Low temperature - operation	Tmin for 24 hrs
	Tests at constant temperature: High temperature - storage	85 °C for 48 hrs
	Tests at constant temperature: High temperature - operation	Tmax for 96 hrs
	Temperature step test	20 °C to Tmin to Tmax, 5 °C steps; *Perform functional tests (OM 3.2) when DUT has reached the new temperature with Usmin and Usmax

DETAILED QUALIFICATION

Environmental Qualification

Standard	Test	Parameter
	Temperature cycling test	acc. to IEC 60068-2-14, Test Nb 30 cycles á 480 min , Tmin to Tmax Duration: 10 days *OM 3.2 for phases with electrical operation
	Temperature cycling test - Rapid change of Temperature	acc. to IEC 60068-2-14, Test Na Transfer time ≤ 30 sec.
	Ice water shock test - Splash water test	Heat the DUT at Tmax for the specified holding time t_h, then splash it with ice water (0 °C to +4 °C) for 3 sec.; (t_h = 1 hr or until temp. Stabilization is reached) 100 cycles each 66 Min.
	Salt spray test - Corrosion test	acc to IEC60068-2-52, Test Kb
	Salt spray test - Leakage and function	acc to IEC60068-2-11, Ka; 8h salt spray and 16h without spray, minimum 6 cycles á 24 hrs
	Humid heat cyclic - Test 2: Composite temperature / humidity cyclic test	acc to IEC60068-2-38, -Z/AD 10 cycles, upper temperature +65°C 93% r.H. 5 cycles with frost phase (-10°C); Duration: 11 days *OM 3.2 when the maximum cycle temperature is reached;
	Humid head cyclic - Test 3: Dewing test	In acc. To IEC 60068-2-38, Test Db Upper Temp.: 80°C, 5 cycles
	Damp heat, steady-state test	acc to IEC60068-2-78; +40°C and 85% r.H. OM: 2.1 for 20 days 23 hrs OM: 3.2 for the last hour Duration: 21 days
	Corrosion test with flow of mixed gas	acc to IEC60068-2-60, Test Ke, method 4; (SO2, H2S, NO2, CL2) 10 days (mounting passenger or luggage/load compartment) 21 days (other mounting locations)

DETAILED QUALIFICATION

Environmental Qualification

Standard	Test	Parameter
	Solar radiation	Confirmation of housing- and plug manufacturer about UV and OZON durability or test e.g. ISO 75220 or DIN EN 60068-2-5
	Dust Test	Acc. To ISO 20653 but different dust 50% limestone 50% fly ash (33% < 32 µm, 67% >32 µm but <250 µm) 20 cycles
	Protection against dust and water	ISO 20653
ISO 16750-5:2010	Chemical resistance	Exposure time 24 h, Exposure condition. 20 °C, 85% relative humidity, Gasoline, Methanol, Battery acid, Protective lacquer, Windshield washer fluid, Vehicle washing chemicals, Cold cleaning agent, Cleaning solvent, Denatured alcohol, Runway deicer, Aceton
		Exposure time 24 h Exposure. 125 °C, 85% rel. humidity Diesel fuel, Diesel fuel "Bio", Engine oil, Transmission fluid, Automatic transmission oil, Hydraulic oil, Greases, Silicone oil, Brake fluid, Antifreeze fluid, Urea, Protective lacquer remover, Contact spray
ISO 20653: 2013-02	IP Protection	IP6KX, IPX7, IPX9K IPX9K: This IP protection class only applies to variants that have a housing without M12 connector. IP6K7, during the IP protection class test, the following cables were used for Ethernet:

DETAILED QUALIFICATION

Environmental Qualification

Standard	Test	Parameter
		• Connector X2, X3, X4: Network cable - NBC-M12MSD/ 5,0-93B/M12MSD from Phoenix Contact • Connector X5: Network cable - NBC-M12MSX/ 5,0-94F/M12MSX from Phoenix Contact
ISO 4892-2:2013-06	Exposure from Xenon-arc lamps	Method A - Testing with filters for global radiation - Cycle no. 1, table 3)
DIN EN 50102:1997-09	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code).	IK7 Impact energy (joules): 2