

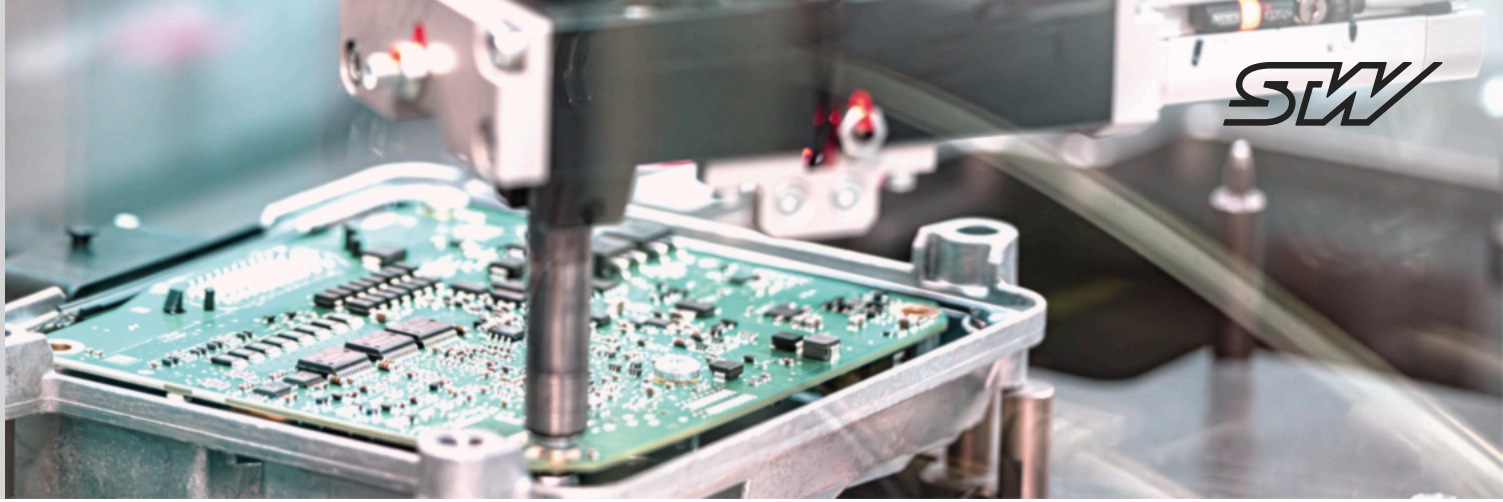

# ESX.4cl

ESX control units

## KEY FEATURES

- Control specially designed for use in harsh mobile applications
- Flexible programming in C, MATLAB Simulink or Neuron Power Engineer (IEC 61131-3, formerly 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 [SF)]), 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

- Integrated into STW's openSYDE software platform
- openSYDE CANopen handler
- Component deployment for C, MATLAB Simulink, and Neuron Power Engineer (IEC 61131-3, formerly logi.CAD 3)
- Mating plugs, development cables, and starter kit
- Debug device of the controller
- Debugger
- Compiler

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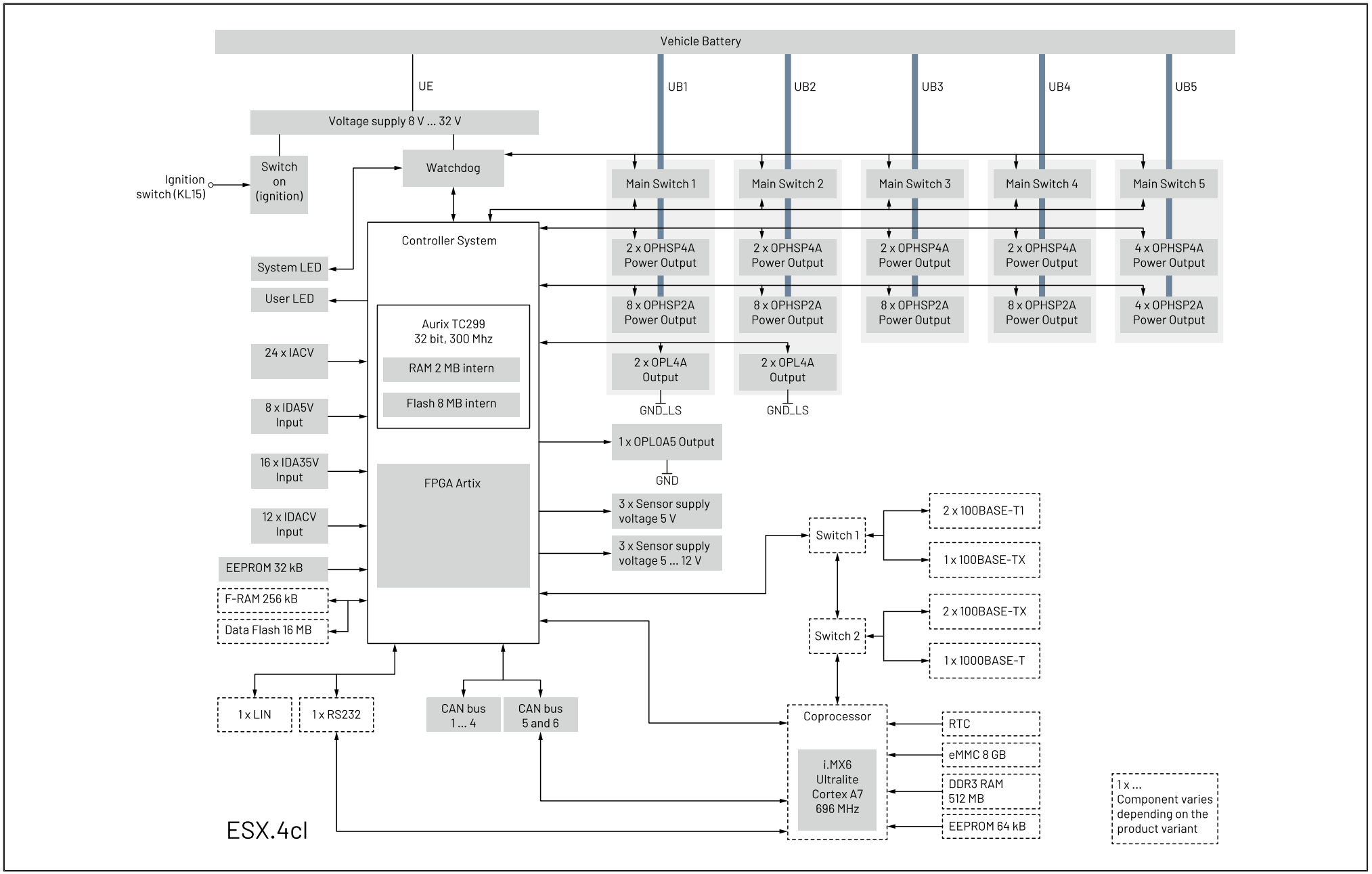
# BLOCK DIAGRAM



# Variants

**Variant features of the ESX.4cl**

| Feature | | Variant | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| Processors and memory | 32 bit Infineon Aurix TC299 multicore CPU, @ 300 MHz | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 2 MB internal RAM | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 8 MB internal Flash | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 32 kB EEPROM | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | 256 kB external F-RAM | - | - | - | - | - | - | - | ✓ |
| | 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 | 6 | 6 | 6 | 6 | 6 | 6 |
| | 1 Gbit/s Ethernet (1000BASE-T) | - | - | 1 | 1 | - | - | 1 | 1 |
| | 100 Mbit/s Ethernet (100BASE-TX) | - | 1 | 3 | 3 | - | 1 | 3 | 3 |
| | 100 Mbit/s Single Pair Ethernet (100BASE-T1) | - | 2 | 2 | 2 | - | 2 | 2 | 2 |
| | SENT | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | RS232 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - |
| | LIN | - | - | - | - | - | - | - | 1 |

# Variants

**Variant features of the ESX.4cl**

| Feature | | Variant | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| Inputs | Analog input IACV | 24 | 24 | 24 | 24 | 20 | 20 | 20 | 24 |
| | Multifunctional input IDA5V | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| | Multifunctional input IDA35V | 16 | 16 | 16 | 16 | - | - | - | 16 |
| | Multifunctional input IDACV | 12 | 12 | 12 | 12 | 10 | 10 | 10 | 12 |
| Outputs | Digital/PWM high side output OPHSP4A | 12 | 12 | 12 | 12 | 4 | 4 | 4 | 12 |
| | Digital/PWM high side output OPHSP2A | 36 | 36 | 36 | 36 | 16 | 16 | 16 | 36 |
| | Digital/PWM low side output OPL4A | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Digital/PWM low side output OPL0A5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Sensor supply voltage 5 V | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | Sensor supply voltage 5 ... 12 V | 3 | 3 | 3 | 3 | 3 | 3 | 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<br>• 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<br>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.<br>(temperature refers to the EEPROM specifications)<br>Data Retention:<br>• 50 years at 125 °C<br>• 100 years at 25 °C<br>Typical endurance according to manufacturer:<br>• 4 million write cycles at 25 °C<br>• 1.2 million write cycles at 85 °C |
| F-RAM (optional) | 256 kB<br>Other memory sizes are available on request | External<br>High endurance 100 trillion read/write cycles |
| Data flash (optional) | 16 MB<br>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):<br>20TBW<br>Data Retention (Fresh or Early Life Device):<br>15 years at 55 °C<br>Data Retention (after 3K PE cycles):<br>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 SF))<br>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 |

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# 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<br>0 ... 12 V<br>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 |

# TECHNICAL DATA

### Inputs

| Type | Maximum quantity | Possible configuration | Measurement |
|---|---|---|---|
| Multifunctional input IDA5V | 8 | Analog voltage | 0 ... 5 V |
| | | Programmable pull-up resistor | 6.8 kΩ to +5 V |
| | | Digital | Active-high/active-low |
| | | Frequency | 0.6 Hz ... 20 kHz |
| | | Incremental encoder interface | Change of position or angular change |
| | | SENT | SENT interface<br>IDA5V is not fully compliant with SAE J2716:2016-04. |

### Outputs

| Type | Maximum quantity | Possible configuration | Range | Characteristics | Feature |
|---|---|---|---|---|---|
| Digital/PWM high side output OPHSP2A | 36 | PWM | 0 ... 2.5 A | 0 ... 100 %<br>duty cycle resolution < 0.1 %<br>PWM frequency 20 ... 1000 Hz | • high side switch<br>• precise current measurement, accuracy is ±2.3 % ±70 mA<br>• supports current control mode<br>• digital feedback, open load detection in OFF state<br>• automated shutdown on overcurrent > 4.6 A ±0.9 A<br>• combine several outputs for parallel operation |
| | | Digital | - | ON/OFF | |

# TECHNICAL DATA

**Outputs**

| Type | Maximum quantity | Possible configuration | Range | Characteristics | Feature |
|---|---|---|---|---|---|
| Digital/PWM high side output OPHSP4A | 12 | PWM | 0 ... 4 A | 0 ... 100 %<br>duty cycle resolution < 0.1 %<br>PWM frequency 20 ... 500 Hz | • high side switch<br>• precise current measurement, accuracy is ±2.3 % ±140 mA<br>• supports current control mode<br>• digital feedback, open load detection in OFF state<br>• automated shutdown on overcurrent > 7.5 A ±1.5 A<br>• combine several outputs for parallel operation |
| | | Digital | - | ON/OFF | |
| Digital/PWM low side output OPL4A | 4 | PWM | 0 ... 4 A | 0 ... 100 %<br>duty cycle resolution < 0.1 %<br>PWM frequency 20 ... 1000 Hz | • low side switch<br>• precise current measurement, accuracy is ±2.3 % ±120 mA<br>• supports current control mode<br>• digital feedback, open load detection in OFF state<br>• automated shutdown on overcurrent > 7.5 A ±0.9 A<br>• 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 %<br>duty cycle resolution < 0.1 %<br>PWM frequency 20 ... 1000 Hz | • low side switch<br>• output voltage feedback, accuracy is ±4 % ±200 mV |
| | | Digital | - | ON/OFF | |
| Main Switch | 5 | | 8 ... 32 V DC | ON/OFF | • high-side switch<br>• switches the output groups +UB1 to +UB5<br>• Current up to 12 A |

# TECHNICAL DATA

**Outputs**

| Type | Maximum quantity | Possible configuration | Range | Characteristics | Feature |
|---|---|---|---|---|---|
| Sensor supply voltage 5 V | 3 | - | 5 V | ON/OFF<br>Accuracy voltage output is +2 ... -2.5%<br>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<br>This is valid under the following conditions:<br>• Capacitive load ≤470 µF<br>• Settling time 100 ms<br>Accuracy voltage readback: ±0.9% ±50 mV | Maximal output current<br>$I_{MAX}$ = 250 mA<br>programmable output needs derating for output voltages $U_{EXT}$ < 10 V:<br>$I_{MAX}$ = 0.875 / (13.5 - $U_{EXT}$) A |

# TECHNICAL DATA

## Mechanical data

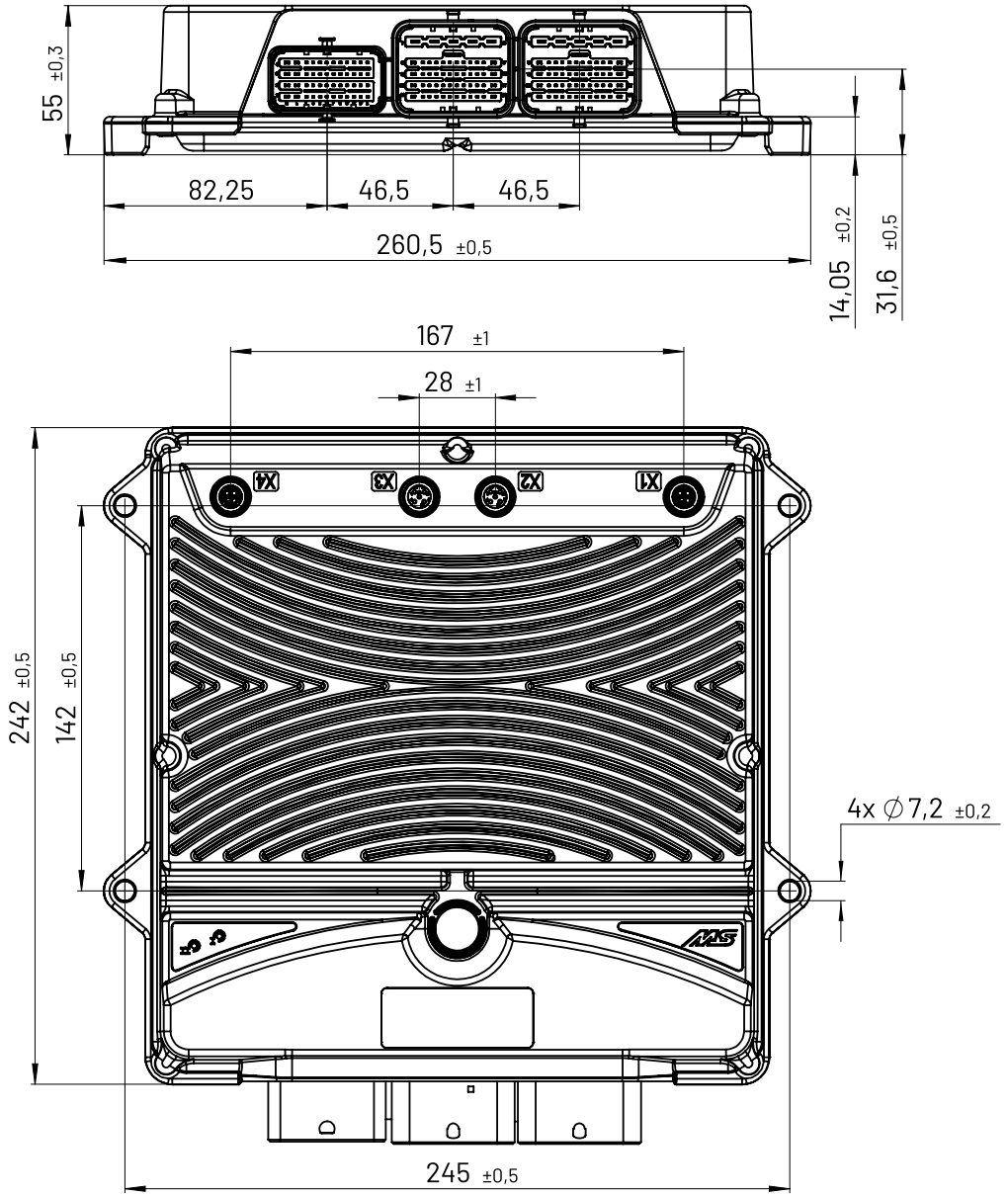
| Component | Description | Value |
|---|---|---|
| Connectors | - | Automotive 154 pins, Molex CMC |
| | | Ethernet, M12 connector:<br>100BASE-TX: 4 pins D-type<br>1000BASE-T: 8 pinx X-type, |
| Indicators | 2 LED, dual color (red/green or mixed colors) | System LED and User LED |
| Housing | Die-cast 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**

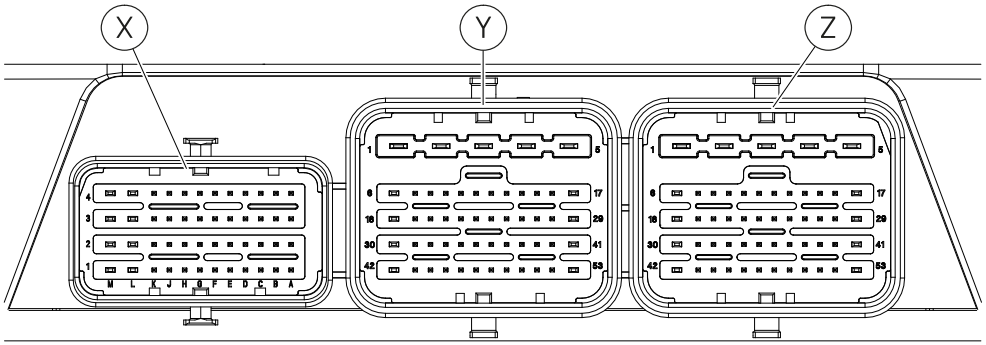
| Component | Description | Range | |
|---|---|---|---|
| | | Minimum Value | Maximum Value |
| DC voltage supply | Voltage at +UE ECU supply and +UB power supply | 8 V DC | 32 V DC |
| Current consumption | Power supply +UB1 fully loaded 12 A | - | 60 A, short-term |
| | Power supply +UB2 fully loaded 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)<br>Without external load | | < 1 mA (max. 28 V) |
| ECU active | +UE supply current ($U_{KL15}$ > $U_{KL15HIGH}$, no external load)<br>Only valid for Variant 4. | | ≈ 500mA at +UE = 12 V<br>≈ 300mA at +UE = 28 V |
| LIN voltage supply | 12 V supply voltage for LIN.<br>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)**

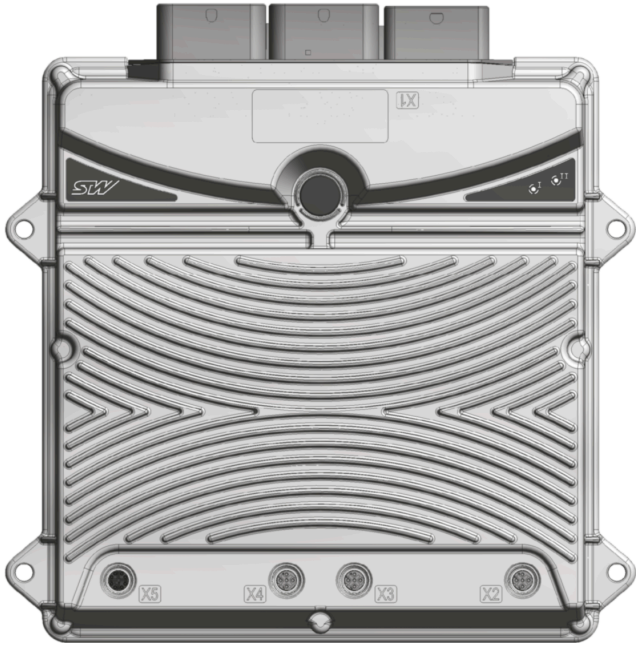
| X | | Y | | Z | |
|---|---|---|---|---|---|
| **Pin** | **Signal name** | **Pin** | **Signal name** | **Pin** | **Signal name** |
| XE4 | CAN1_L | Y20 | OPHSP2A_28 | Z20 | OPHSP2A_4 |
| XF1 | ETH1_P2_BRR- | Y21 | OPHSP2A_30 | Z21 | OPHSP2A_6 |
| XF2 | CAN2_H | Y22 | IDACV_11 | Z22 | OPHSP2A_8 |
| XF3 | 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 | 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)**

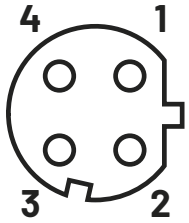
| X | | Y | | Z | |
|---|---|---|---|---|---|
| **Pin** | **Signal name** | **Pin** | **Signal name** | **Pin** | **Signal name** |
| XK3 | CAN6_H | Y39 | IDA35V_15 | Z39 | IACV_19 |
| XK4 | RS232 Tx/ LIN Sup | Y40 | OPHSP2A_35 | Z40 | OPL0A5 |
| XL1 | AGND | Y41 | OPHSP4A_11 | Z41 | OPL4A_3 |
| XL2 | 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 |

# PIN ASSIGNMENT

**Connectors X2 ... X5:**

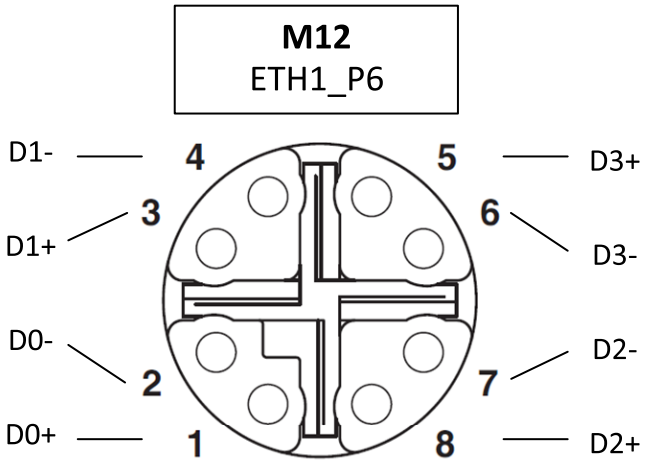



**Pin Assignment M12 Connectors X2 ... X4:**




| 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<br>REGULATION (EC) No 765/2008 | CE | Conformity | See Declaration of Conformity |
| EN ISO 13849-1:2023 | Safety of machinery | | PL d / Cat. 2 |
| IEC 61508:2010 | Functional safety | | SIL 2 |
| ISO 26262:2018 | Road vehicles - Functional safety | | ASIL B[SF)] |
| ISO 11783-2:2019 | CAN ISOBUS conformity | | AEF Conformance Test<br>Only hardware functionality tested. |
| KBA (Kraftfahrt-Bundesamt) | E1 | Certification<br>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 | | |

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# DETAILED QUALIFICATION

**Industrial EMC Tests**

| Standard | Test | Parameter |
|---|---|---|
| EN 61000-6-2:2019<br>EN 61000-6-2:2005 + AC:2005<br>Immunity for industrial environments | Electrostatic discharge immunity test - direct discharges<br>DIN EN 61000-4-2 | 330 Ω / 150 pF,<br>Contact discharge: ±4 kV<br>Air discharge: ±2 kV, ±4 kV, ±8 kV |
| | Electrostatic discharge immunity test - indirect discharges (HCP, VCP)<br>DIN EN 61000-4-2 | 330 Ω / 150 pF,<br>Contact discharge: ±4 kV |
| | Radiated, radio-frequency, electromagnetic field immunity test<br>DIN EN 61000-4-3 | 80 MHz to 1000 MHz -> 10V/m;<br>1.4 GHz to 6 GHz -> 3V/m;<br>horizontal and vertical |
| | Burst - supply lines<br>(Electrical fast transient / burst immunity test)<br>DIN EN 61000-4-4 | ±1 kV,<br>repetition frequency 100 kHz |
| | Burst - data lines<br>(Electrical fast transient / burst immunity test)<br>DIN EN 61000-4-4 | ±1 kV,<br>repetition frequency 100 kHz |
| | Surge - data lines<br>(immunity test)<br>DIN EN 61000-4-5 | Asymmetrical coupling: ±0.5 kV, ±1 kV<br>*Test on supply lines is not required as cable length does not exceed 30m. |
| | Conducted immunity - supply lines<br>(Immunity to conducted disturbances, induced by radio-frequency fields)<br>DIN EN 61000-4-6 | 150 kHz to 80 MHz, 10V |
| | Conducted immunity - data lines<br>(Immunity to conducted disturbances, induced by radio-frequency fields)<br>DIN EN 61000-4-6 | 150 kHz to 80 MHz, 10V |
| EN 61000-6-4:2019<br>EN 61000-6-4:2007 + A1:2011<br>Emission for industrial environments | Conducted Emission | 150 kHz to 30 MHz |
| | Radiated Emission | 30 MHz to 2000 MHz |

# DETAILED QUALIFICATION

**Automotive EMC Tests - ISO 13766-1, ISO 14982 and STW Company Standard (WN0054)**

| Standard | Test | Parameter |
|---|---|---|
| DIN EN ISO 13766-1:2018<br>Earth-moving and building construction machinery – Electromagnetic compatibility (EMC) of machines with internal electrical power supply | Radiated Emission - Broadband<br>CISPR25:2008 | 30 MHz to 1000 MHz |
| | Radiated Emission - Narrowband<br>CISPR25:2008 | 30 MHz to 1000 MHz |
| | Immunity of ESAs to electromagnetic radiation | BCI:<br>20 MHz to 400 MHz, 60 mA<br>(Substitution method - 150 mm, 450 mm and 750 mm)<br><br>Antenne, ALSE (hor/ver):<br>400 MHz to 2000 MHz, 30 V/m, CW<br>400 MHz to 1000 MHz, 30 V/m, AM<br>800 MHz to 2000 MHz, 30 V/m, PM |
| | Conducted transient emission from ESAs on 12 V supply lines, Level 3<br>ISO 7637-2:2011 | slow+: +37 V<br>slow-: -75V<br>fast+: +75V<br>fast-: -112V |
| | Conducted transient emission from ESAs on 24V supply lines, Level 3<br>ISO 7637-2:2011 | slow+: +37 V<br>slow-: -150V<br>fast+: +150V<br>fast-: -150V |
| | Electrical transient conduction along supply lines - 12V System, Level 3<br>ISO 7637-2:2011 | Pulse 1<br>-112V, 500 pulses |
| | | Pulse 2a<br>+55V, 500 pulses |
| | | Pulse 2b<br>+10V, 10 pulses |
| | | Pulse 3a<br>-165V, 1h |

# DETAILED QUALIFICATION

**Automotive EMC Tests - ISO 13766-1, ISO 14982 and STW Company Standard (WN0054)**

| Standard | Test | Parameter |
|---|---|---|
| | | Pulse 3b<br>+112V, 1h |
| | Electrical transient conduction along supply lines - 24V System, Level 3<br>ISO 7637-2:2011 | Pulse 1<br>-450V, 500 pulses |
| | | Pulse 2a<br>+55V, 500 pulses |
| | | Pulse 2b<br>+20V, 10 pulses |
| | | Pulse 3a<br>-220V, 1h |
| | | Pulse 3b<br>+220V, 1h |
| | Discontinuities in supply voltage - Starting profile - 12 V System Code B<br>ISO 16750-2:2012 | Voltage Cranking: Level 4 |
| | Discontinuities in supply voltage - Starting profile - 24 V System Code F<br>ISO 16750-2:2012 | Voltage Cranking: Level 2 |
| | Discontinuities in supply voltage - Load Dump (Pulse B) - 24 V System<br>ISO 16750-2:2012 | Test with centralized load dump suppression<br>10 Pulses<br>Us=202V, Us*=70V, Ri=80hm, td=350ms |
| | ESD - Component immunity test method (Powered-up test) - direct discharges<br>ISO 10605:2008 | 2000 Ω / 330 pF,<br>Contact discharge: ±4 kV, ±6 kV<br>Air discharge: ±4 kV, ±8 kV |
| | ESD - Component immunity test method (Powered-up test) - indirect discharges<br>ISO 10605:2008 | 2000 Ω / 330 pF,<br>Contact discharge: ±4 kV, ±6 kV |

# DETAILED QUALIFICATION

**Automotive EMC Tests - ISO 13766-1, ISO 14982 and STW Company Standard (WN0054)**

| Standard | Test | Parameter |
|---|---|---|
| DIN EN ISO 14982:2009<br>Agricultural and forestry machines – Electromagnetic compatibility<br>– Test methods and acceptance criteria | Radiated Emission - Broadband<br>CISPR16 / CISPR12 | 30 MHz to 1000 MHz |
| | Radiated Emission - Narrowband<br>CISPR16 / CISPR12 | 30 MHz to 1000 MHz |
| | Immunity of ESAs to electromagnetic radiation | BCI:<br>20 MHz to 400 MHz, 60 mA<br>(Substitution method - 150 mm, 450 mm and 750 mm)<br><br>Antenne, ALSE (hor/ver):<br>400 MHz to 2000 MHz, 30 V/m, CW<br>400 MHz to 1000 MHz, 30 V/m, AM<br>800 MHz to 2000 MHz, 30 V/m, PM |
| | Conducted transient emission from ESAs on 12 V supply lines<br>ISO 7637-2:2004 | slow/fast:<br>positive: +75V<br>negative: -100V |
| | Conducted transient emission from ESAs on 24V supply lines<br>ISO 7637-2:2004 | slow/fast:<br>positive: +150V<br>negative: -450V |
| | Electrical transient conduction along supply lines - 12V System<br>ISO 7637-2:2004 | Pulse 1<br>-25V, 5000 pulses |
| | | Pulse 2a<br>+25V, 5000 pulses |
| | | Pulse 3a<br>-25V, 1h |
| | | Pulse 3b<br>+25V, 1h |
| | | Pulse 4<br>Us = -4V, 1 pulse |

# DETAILED QUALIFICATION

**Automotive EMC Tests - ISO 13766-1, ISO 14982 and STW Company Standard (WN0054)**

| Standard | Test | Parameter |
|---|---|---|
| | | Pulse 5a<br>Us=101V, Us*=26.5V, Ri=4Ohm, td=400ms, 1 pulse |
| | Electrical transient conduction along supply lines - 24V System<br>ISO 7637-2:2004 | Pulse 1<br>-50V, 5000 pulses |
| | | Pulse 2a<br>+25V, 5000 pulses |
| | | Pulse 3a<br>-35V, 1h |
| | | Pulse 3b<br>+35V, 1h |
| | | Pulse 4<br>Us = -5V, 1 pulse |
| | | Pulse 5a<br>Us=202V, Us*=70V, Ri=8Ohm, td=350ms, 1 pulse |
| | ESD - Component immunity test method (Powered-up test) - direct discharges | 330 Ω / 330 pF,<br>330 Ω / 150 pF,<br>Contact discharge: ±2 kV, ±4 kV<br>Air discharge: ±2 kV, ±4 kV |
| | ESD - Component immunity test method (Powered-up test) - indirect discharges | 330 Ω / 330 pF,<br>330 Ω / 150 pF,<br>Contact discharge: ±2 kV, ±4 kV |
| STW Company Standard<br>(Art.Nr.: 26688) | Radiated emission<br>CISPR25:2016 | 150 kHz to 30 MHz - CISPR Class 2<br>30 MHz to 1 GHz - CISPR Class 1<br>1 GHz to 3 GHz - CISPR Class 2 |
| | Conducted emission<br>CISPR25:2016 | Power lines (Voltage method) - CISPR Class 3<br>Data lines (current probe method) - CISPR Class 1<br>150 kHz to 108 MHz |

# DETAILED QUALIFICATION

**Automotive EMC Tests - ISO 13766-1, ISO 14982 and STW Company Standard (WN0054)**

| Standard | Test | Parameter |
|---|---|---|
| | Immunity of ESAs to electromagnetic radiation<br>ALSE: ISO 11452-2:2019<br>BCI: ISO 11452-4:2020 | BCI:<br>1 MHz to 400 MHz, Level IV (200mA)<br>Substitution method (150mm, 450mm, 750mm)<br><br>Antenne, ALSE:<br>200 MHz to 800 MHz, Level V (200V/m), CW, AM<br>800 MHz to 3200 MHz, Level V (200V/m), CW, PM |
| | Conducted transient emission from ESAs on 12 V supply lines, Level 3<br>ISO 7637-2:2011 | slow+: +37 V<br>slow-: -75V<br>fast+: +75V<br>fast-: -112V |
| | Conducted transient emission from ESAs on 24V supply lines, Level 3<br>ISO 7637-2:2011 | slow+: +37 V<br>slow-: -150V<br>fast+: +150V<br>fast-: -150V |
| | Electrical transient conduction along supply lines - 12V System, Level 4<br>ISO 7637-2:2011 | Pulse 1<br>-150V, 500 pulses |
| | | Pulse 2a<br>+112V, 500 pulses |
| | | Pulse 2b<br>+10V, 10 pulses |
| | | Pulse 3a<br>-220V, 1h |
| | | Pulse 3b<br>+150V, 1h |

# DETAILED QUALIFICATION

**Automotive EMC Tests - ISO 13766-1, ISO 14982 and STW Company Standard (WN0054)**

| Standard | Test | Parameter |
|---|---|---|
| | Electrical transient conduction along supply lines - 24V System, Level 4<br>ISO 7637-2:2011 | Pulse 1<br>-600V, 500 pulses |
| | | Pulse 2a<br>+112V, 500 pulses |
| | | Pulse 2b<br>+20V, 10 pulses |
| | | Pulse 3a<br>-300V, 1h |
| | | Pulse 3b<br>+300V, 1h |
| | Faults on data lines; 12 V system, Level 4<br>ISO 7637-3:2016 | Slow +: ICC, +6V, 5 min<br>Slow -: ICC, -6V, 5 min<br>Pulse 3a: CCC, -110V, 10 min<br>Pulse 3b: CCC, +75V, 10 min |
| | Faults on data lines; 24 V system, Level 4<br>ISO 7637-3:2016 | Slow +: ICC, +10V, 5 min<br>Slow -: ICC, -10V, 5 min<br>Pulse 3a: CCC, -150V, 10 min<br>Pulse 3b: CCC, +150V, 10 min |
| | ESD - Component immunity test method (Powered-up test) - direct discharges<br>ISO 10605:2008 | 330 Ω / 330 pF,<br>330 Ω / 150 pF,<br>Contact discharge: ±2 kV, ±4 kV, ±8 kV<br>Air discharge: ±8 kV, ±15 kV, ±25 kV |
| | ESD - Component immunity test method (Powered-up test) - indirect discharges<br>ISO 10605:2008 | 330 Ω / 330 pF,<br>330 Ω / 150 pF,<br>Contact discharge: ±2 kV, ±4 kV, ±8 kV |
| | ESD - Packaging and handling (Unpowered test)<br>ISO 10605:2008 | 2000 Ohm / 150 pF<br>Contact discharge: ±2 kV, ±4 kV, ±8 kV<br>Air discharge: ±4 kV, ±8 kV, ±15 kV |

# DETAILED QUALIFICATION

**STW Company Standard (EMC Tests) - WN0054**

| Standard | Test | Parameter |
|---|---|---|
| STW Company Standard<br>(Art.Nr.: 26688) | Radiated emission<br>CISPR25:2016 | 150 kHz to 30 MHz - CISPR Class 2<br>30 MHz to 1 GHz - CISPR Class 1<br>1 GHz to 3 GHz - CISPR Class 2 |
| | Conducted emission<br>CISPR25:2016 | Power lines (Voltage method) - CISPR Class 3<br>Data lines (current probe method) - CISPR Class 1<br>150 kHz to 108 MHz |
| | Immunity of ESAs to electromagnetic radiation<br>ALSE: ISO 11452-2:2019<br>BCI: ISO 11452-4:2020 | BCI:<br>1 MHz to 400 MHz, Level IV (200mA)<br>Substitution method (150mm, 450mm, 750mm)<br><br>Antenne, ALSE:<br>200 MHz to 800 MHz, Level V (200V/m), CW, AM<br>800 MHz to 3200 MHz, Level V (200V/m), CW, PM |
| | Conducted transient emission from ESAs on 12 V supply lines, Level 3<br>ISO 7637-2:2011 | slow+: +37 V<br>slow-: -75V<br>fast+: +75V<br>fast-: -112V |
| | Conducted transient emission from ESAs on 24V supply lines, Level 3<br>ISO 7637-2:2011 | slow+: +37 V<br>slow-: -150V<br>fast+: +150V<br>fast-: -150V |
| | Electrical transient conduction along supply lines - 24V System, Level 4<br>ISO 7637-2:2011 | Pulse 1<br>-600V, 500 pulses |
| | | Pulse 2a<br>+112V, 500 pulses |
| | | Pulse 2b<br>+20V, 10 pulses |
| | | Pulse 3a<br>-300V, 1h |

# DETAILED QUALIFICATION

**STW Company Standard (EMC Tests) - WN0054**

| Standard | Test | Parameter |
|---|---|---|
| | | Pulse 3b<br>+300V, 1h |
| | Faults on data lines; 12 V system, Level 4<br>ISO 7637-3:2016 | Slow +: ICC, +6V, 5 min<br>Slow -: ICC, -6V, 5 min<br>Pulse 3a: CCC, -110V, 10 min<br>Pulse 3b: CCC, +75V, 10 min |
| | Faults on data lines; 24 V system, Level 4<br>ISO 7637-3:2016 | Slow +: ICC, +10V, 5 min<br>Slow -: ICC, -10V, 5 min<br>Pulse 3a: CCC, -150V, 10 min<br>Pulse 3b: CCC, +150V, 10 min |
| | ESD - Component immunity test method<br>(Powered-up test) - direct discharges<br>ISO 10605:2008 | 330 Ω / 330 pF,<br>330 Ω / 150 pF,<br>Contact discharge: ±2 kV, ±4 kV, ±8 kV<br>Air discharge: ±8 kV, ±15 kV, ±25 kV |
| | ESD - Component immunity test method<br>(Powered-up test) - indirect discharges<br>ISO 10605:2008 | 330 Ω / 330 pF,<br>330 Ω / 150 pF,<br>Contact discharge: ±2 kV, ±4 kV, ±8 kV |
| | ESD - Packaging and handling<br>(Unpowered test)<br>ISO 10605:2008 | 2000 Ohm / 150 pF<br>Contact discharge: ±2 kV, ±4 kV, ±8 kV<br>Air discharge: ±4 kV, ±8 kV, ±15 kV |

# DETAILED QUALIFICATION

### ISO 16750-2 (Electrical Loads)

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

# DETAILED QUALIFICATION

## ISO 16750-2 (Electrical Loads)

| Standard | Test | Parameter |
|---|---|---|
| | Discontinuities in supply voltage-Load Dump (Pulse B) - 12V System | Test with centralized load dump suppression<br>5 Pulses<br>Us=101V, Us*=35V, Ri=40hm, td=400ms |
| | Discontinuities in supply voltage-Load Dump (Pulse B) - 24V System | Test with centralized load dump suppression<br>5 Pulses<br>Us=202V, Us*=70V, Ri=80hm, td=350ms |
| | Reversed voltage - Case 2 - 12V System | Unom. = 12V -> Case 2 - Test Voltage = - 14V reversed polarity<br>Duration: 60 s |
| | Reversed voltage - Case 2 - 24V System | Unom. = 24V -> Case 2 - Test Voltage = 28V reversed polarity<br>Duration: 60 s |
| | Ground reference and supply offset - 12V System | ±1V offset; only required if two or more power supplies exist; Low-Side-Sensor must be connected to ground point at ECU connector<br>Case 1: offset between UB and UE, if no internal connection exists |
| | Ground reference and supply offset - 24V System | ±1V offset; only required if two or more power supplies exist; Low-Side-Sensor must be connected to ground point at ECU connector<br>Case 1: offset between UB and UE, if no internal connection exists |
| | Open circuit tests - Single line interruption - 12V System | Interruption of each single Output for (10 ± 1) s. |
| | Open circuit tests - Single line interruption - 24V System | Interruption of each single Output for (10 ± 1) s. |
| | Open circuit tests - Multiple line interruption - 12V System | Disconnect the DUT for (10 ± 1) s. |
| | Open circuit tests - Multiple line interruption - 24V System | Disconnect the DUT for (10 ± 1) s. |
| | Short circuit protection -<br>signal circuits | Connect every In- and Output to<br>maximum supply voltage (Usmax) and Ground for 1 minute<br>various modes necessary |
| | Withstand Voltage & Insulation Resistance Tests | Pre-Test requirement: Initially Perform a damp heat cyclic test in accordance with ISO 16750-4. The DUT shall remain at room temperature for 0.5 h after the damp heat cyclic test. |

# DETAILED QUALIFICATION

## ISO 16750-2 (Electrical Loads)

| Standard | Test | Parameter |
|---|---|---|
| | | Withstand Voltage:<br>Apply a sinusoidal test voltage of 500V AC (50 Hz to 60 Hz) to the DUT for 60 s, as follows, between terminals with galvanic isolation.<br><br>Insulation Resistance:<br>Apply a test voltage of 500V DC to the DUT for 60 s, as follows, between terminals with galvanic isolation.<br><br>Note: The test is carried out on the Ethernet connectors (4-pin M12 and 8-pin M12) against housing and all connector pins of DUT as, only they are galvanically isolated. |

1 (Test specifications are currently still being processed)

# DETAILED QUALIFICATION

**STW Company Standard (Electrical Loads) - WN0054**

| Standard | Test | Parameter |
|---|---|---|
| STW Company Standard<br>(Art.Nr.: 26688) | Overvoltage / Undervoltage / Switch-on hysteresis | 1st: Decrease supply voltage from Umin in steps of 0.1V until all outputs turned off. The determined voltage is called switch-off voltage. Increase supply voltage in steps of 0.1V. The voltage where the device is running again in normal operating mode is the determined switch-on voltage. The difference between switch-off voltage and switch-on voltage is the hysteresis. Operate the device below Umin. Duration: 5 minutes.<br><br>2nd: Overvoltage: Operate the device with maximum 3% above Umax (32.96V).<br>Duration: 5 minutes |
| | Short circuit strength of signal and communication lines | Case 2:<br>Short circuit test of PWM outputs and digital outputs to low resistance loads against GND for a duration of 1 minute.<br>Resitance loads: 0.1Ω (±0.05), 0.5Ω (±0.2), 1.0Ω (±0.2) and 1.5Ω (±0.2) |
| | Life-time (Operation) | Test Temperature: +95°C<br>Test Duration: 920 hrs.<br>O.M. 3.2 with Loaded Condition<br>Test temperature is set to 10°C more than maximum operational temperature (Tmax) to reduce the test duration. |
| | Slow decrease and increase of supply voltage | Decrease supply voltage from Usmax to 0V and increase it from 0V to Usmax. Applying a change rate of (0.5 ± 0.1)V per minute |

# DETAILED QUALIFICATION

**ISO 16750 (Environmental Qualification)**

| Standard | Test | Parameter |
|---|---|---|
| ISO 16750-3:2012 | Resonance search | 10 Hz to 2000 Hz, 1g, 0.5oct/min |
| | Test VII - Commercial vehicle, sprung masses | Vibration noise with temperature superimposition in case of natural frequencies of DUT upper 30 Hz:<br>random vibration according to IEC60068-2-64 from 10 Hz to 2000 Hz for 32 hrs each axis, Temperature cycle 8h from Tmin to Tmax. |
| | Mechanical Shock - Test for devices on rigid points on the body and on the frame | acc. to IEC 60068-2-27<br>half-sinusoidal<br>Acceleration 500 $m/s^2$<br>Duration 6 ms<br>room temperature<br>10 shocks per test direction |
| | Free fall<br>(parts that may withstand falling without damages) | 3 devices, 2 falls every device on the opposite side of the housing.<br>Drop height: 1 m to concrete ground or steel plate |
| ISO 16750-4:2010 | Tests at constant temperature:<br>Low temperature - storage | -40°C for 24 hrs |
| | Tests at constant temperature:<br>Low temperature - operation | Tmin for 24 hrs |
| | Tests at constant temperature:<br>High temperature - storage | +85°C for 48 hrs |
| | Tests at constant temperature:<br>High temperature - operation | Tmax for 96 hrs |
| | Temperature step test | 20°C to Tmin to Tmax, 5°C steps;<br>*Perform functional tests (OM 3.2) when DUT has reached the new temperature with Usmin and Usmax |
| | Temperature cycling test | acc. to IEC 60068-2-14, Test Nb<br>30 cycles á 480 min , Tmin to Tmax<br>Duration: 10 days<br>*OM 3.2 for phases with electrical operation |

# DETAILED QUALIFICATION

**ISO 16750 (Environmental Qualification)**

| Standard | Test | Parameter |
|---|---|---|
| | Temperature cycling test -<br>Rapid change of Temperature | acc. to IEC 60068-2-14, Test Na<br>Transfer time ≤ 30 sec.<br>100 cycles, Tmin to Tmax<br>Dwell time: 60 min. |
| | Ice water shock test - Splash water test | Heat the DUT at Tmax for the specified holding time th, then splash it with ice water (0 °C to +4 °C) for 3 sec.; (th = 1 hr or until temp. Stabilization is reached)<br>100 cycles each 66 Min. |
| | Salt spray test - Corrosion test | acc. to IEC 60068-2-52, Test Kb<br>Severity 4 |
| | Salt spray test - Leakage and function | acc. to IEC 60068-2-11, Test Ka<br>8h salt spray and 16h without spray,<br>minimum 6 cycles á 24 hrs |
| | Humid heat cyclic - Test 2:<br>Composite temperature / humidity cyclic test | acc. to IEC 60068-2-38, Test Z/AD<br>10 cycles, upper temperture +65°C<br>93% r.H. 5 cycles with frost phase (-10°C)<br>Duration: 11 days<br>*OM 3.2 when the maximum cycle temperature is reached |
| | Humid head cyclic - Test 3:<br>Dewing test | acc. to IEC 60068-2-38, Test Db<br>Upper Temperature: 80°C, 5 cycles |
| | Damp heat, steady-state test | acc. to IEC 60068-2-78;<br>+40°C and 85% r.H.<br>OM: 2.1 for 20 days and 23 hrs<br>OM: 3.2 for the last hour<br>Duration: 21 days |
| | Corrosion test with flow of mixed gas | acc. to IEC 60068-2-60, Test Ke<br>method 4; ($SO_2$, $H_2S$, $NO_2$, $CL_2$)<br>Test duration: 21 days |

# DETAILED QUALIFICATION

**ISO 16750 (Environmental Qualification)**

| Standard | Test | Parameter |
|---|---|---|
| | Solar radiation | acc. to ISO 4892-2 Method A - Testing with filters for global radiation - Cycle no. 1, Table 3 |
| | Dust Test | acc. to ISO 20653 but different dust<br>50% limestone<br>50% fly ash (33% < 32µm, 67% >32µm but <250µm)<br>20 cycles |
| ISO 16750-5:2010 | Chemical resistance | Exposure time: 24 h,<br>Exposure condition: 20 °C,<br>85% relative humidity,<br>Agents: Gasoline, Methanol, Battery acid, Protective lacquer, Windshield washer fluid, Vehicle washing chemicals, Cold cleaning agent, Cleaning solvent, Denatured alcohol, Runway deicer, Acetone |
| | | Exposure time: 24 h<br>Exposure condition: 125 °C,<br>85% relative humidity,<br>Agents: 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 16750-1:2018-11<br>Annex B | Life-time Test<br>Weibull Simulation | Test duration: 30 days<br>Min. temperature: -40 °C<br>Max. temperature: +125 °C<br>Holding time: 60 min.<br>Cycles: 352<br>Not in operation, 4 DUTs |
| ISO 20653:2013-02 | IP Protection | IP6KX, IPX7, IPX9K<br>IPX9K: This IP protection class only applies to variants that have a housing without M12<br>connector.<br>IP6K7, during the IP protection class test, the following cables were used for Ethernet:<br>- Connector X2, X3, X4: Network cable - NBCM12MSD/5,0-93B/M12MSD from Phoenix |

# DETAILED QUALIFICATION

**ISO 16750 (Environmental Qualification)**

| Standard | Test | Parameter |
|---|---|---|
| | | Contact<br>- Connector X5: Network cable - NBC-M12MSX/5,0-94F/M12MSX from Phoenix Contact |
| DIN EN 50102:1997-09 | Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code). | IK7<br>Impact energy (joules): 2<br>Provided that the installation has been carried out in accordance with the recommended mounting positions. |

**STW Company Standard (Environmental Qualification) - WN0054**

| Standard | Test | Parameter |
|---|---|---|
| STW Company Standard<br>(Art.Nr.: 26688) | Vibration (sinusoidal)<br>DIN EN 60068-2-6:2008 | 10 Hz to 2000 Hz, 5g<br>1 oct/min, 3 axis, 10 cycles, bidirectional |
| | Bump<br>DIN EN 60068-2-27:2010 | Acceleration: 30g<br>Time: 6ms<br>half-sine, 500 Shocks/direction |

# DETAILED QUALIFICATION

**Functional Safety - DIN EN 61326-3-1 & ISO 13766-2**

| Standard | Test | Parameter |
|---|---|---|
| DIN EN 61326-3-1:2018-04 | Table 2<br>Electrostatic discharge immunity test - direct discharges<br>DIN EN 61000-4-2 | 330 Ω / 150 pF,<br>Contact discharge: ±6 kV<br>Air discharge: ±8 kV |
| | Table 2<br>Electrostatic discharge immunity test - indirect discharges (HCP, VCP)<br>DIN EN 61000-4-2 | 330 Ω / 150 pF,<br>Contact discharge: ±6 kV |
| | Table 2<br>Radiated, radio-frequency, electromagnetic field immunity test<br>DIN EN 61000-4-3 | 80 MHz to 1000 MHz -> 20V/m;<br>1.4 GHz to 2 GHz -> 10V/m;<br>2 GHz to 2.7 GHz -> 3V/m;<br>horizontal and vertical |
| | Table 5<br>Burst - supply lines<br>(Electrical fast transient / burst immunity test)<br>DIN EN 61000-4-4 | ±2 kV,<br>5/50 ns tr/th,<br>repetition frequency 5 kHz<br>*As the DUT is not connected directly to a DC Voltage network, test on supply lines is performed as part of data lines. |
| | Table 5<br>Burst - data lines<br>(Electrical fast transient / burst immunity test)<br>DIN EN 61000-4-4 | ±2 kV,<br>5/50 ns tr/th,<br>repetition frequency 5 kHz |
| | Table 5<br>Surge - data lines<br>(immunity test)<br>DIN EN 61000-4-5 | Asymmetrical coupling: ±2 kV<br>*Test on supply lines is not required as cable length does not exceed 30m. |
| | Table 5<br>Conducted immunity - supply lines<br>(Immunity to conducted disturbances, induced by radio-frequency fields)<br>DIN EN 61000-4-6 | 150 kHz to 80 MHz, 10V<br>*As the DUT is not connected directly to a DC Voltage network, test on supply lines is performed as part of data lines. |
| | Table 5<br>Conducted immunity - data lines | 150 kHz to 80 MHz, 10V |

# DETAILED QUALIFICATION

**Functional Safety - DIN EN 61326-3-1 & ISO 13766-2**

| Standard | Test | Parameter |
|---|---|---|
| | (Immunity to conducted disturbances, induced by radio-frequency fields)<br>DIN EN 61000-4-6 | |
| | Table 5<br>Conducted common-mode voltages - data lines<br>(Immunity to radio-frequency conducted common-mode voltages)<br>DIN EN 61000-4-16 | 1 V to 10 V, 20 dB/Decade (1.5 kHz to 15 kHz)<br>10 V (15 kHz to 150 kHz)<br>10 V (constant with direct current, 16 2/3 Hz, 50 / 60 Hz and 150 / 180 Hz)<br>100 V short period (1 s, with direct current, 16 2/3 Hz and 50 / 60 Hz)<br>*Test on supply lines is not required as cable length does not exceed 30m. |
| DIN EN ISO 13766-2:2018-04 * | Immunity of ESAs to electromagnetic radiation<br>ALSE: ISO 11452-2<br>BCI: ISO 11452-4 | BCI:<br>1 MHz to 400 MHz, Level IV (100mA)<br>Substitution method (150mm, 450mm, 750mm)<br><br>Antenne, ALSE (hor/ver)<br>200 MHz to 800 MHz, 100V/m, AM<br>800 MHz to 1000 MHz, 100V/m, PM<br>2000 MHz to 2400 MHz, 10V/m, PM<br>2400 MHz to 2700 MHz, 5V/m, PM |
| | ESD - Component immunity test method<br>Powered-up test - direct discharges<br>ISO 10605 | 2000 Ω / 330 pF,<br>Contact discharge: ±2 kV, ±4 kV, ±8 kV<br>Air discharge: ±4 kV, ±8 kV, ±15 kV |
| | ESD - Component immunity test method<br>Powered-up test - indirect discharges<br>ISO 10605 | 2000 Ω / 330 pF,<br>Contact discharge: ±2 kV, ±4 kV, ±8 kV |
| | Electrical transient conduction along supply lines - 12V System, Level 3<br>ISO 7637-2 | Pulse 1<br>-112V, 500 pulses |
| | | Pulse 2a<br>+55V, 500 pulses |

# DETAILED QUALIFICATION

**Functional Safety - DIN EN 61326-3-1 & ISO 13766-2**

| Standard | Test | Parameter |
|---|---|---|
| | | Pulse 2b<br>+10V, 10 pulses |
| | | Pulse 3a<br>-165V, 1h |
| | | Pulse 3b<br>+112V, 1h |
| | Electrical transient conduction along supply lines - 24V System, Level 3<br>ISO 7637-2 | Pulse 1<br>-450V, 500 pulses |
| | | Pulse 2a<br>+55V, 500 pulses |
| | | Pulse 2b<br>+20V, 10 pulses |
| | | Pulse 3a<br>-220V, 1h |
| | | Pulse 3b<br>+220V, 1h |
| | Discontinuities in supply voltage - Starting profile 12V code B<br>ISO 16750-2 | Voltage Cranking: Level 4 |
| | Discontinuities in supply voltage - Starting profile 24V code F<br>ISO 16750-2 | Voltage Cranking: Level 2 |
| | Discontinuities in supply voltage - Load Dump (Pulse B) - 12V System<br>ISO 16750-2 | with centralized load dump suppression<br>5 Pulses<br>Us=101V, Us*=35V, Ri=4Ohm, td=400ms |
| | Discontinuities in supply voltage - Load Dump (Pulse B) - 24V System<br>ISO 16750-2 | with centralized load dump suppression<br>5 Pulses<br>Us=202V, Us*=58V, Ri=8Ohm, td=350ms |

# DETAILED QUALIFICATION

**Functional Safety - DIN EN 61326-3-1 & ISO 13766-2**

| Standard | Test | Parameter |
|---|---|---|
| | Faults on data lines; 12 V system, Level 4<br>ISO 7637-3 | Slow +: ICC, +6V, 5 min<br>Slow -: ICC, -6V, 5 min<br>Pulse 3a: CCC, -110V, 10 min<br>Pulse 3b: CCC, +75V, 10 min |
| | Faults on data lines; 24 V system, Level 4<br>ISO 7637-3 | Slow +: ICC, +10V, 5 min<br>Slow -: ICC, -10V, 5 min<br>Pulse 3a: CCC, -150V, 10 min<br>Pulse 3b: CCC, +150V, 10 min |

* This test was only performed for hardware revision X_SYS_HARDWARE_INFO_REVISION_SE4 and is therefore only valid for this revision.