

# ESX.3cm

## ESX Control Units

### KEY FEATURES

- Control specially designed for use in harsh mobile applications
- Flexible programming in C, CODESYS V3.5 IEC61131-3, logi.CAD 3 IEC61131-3 and Matlab\*
- Suitable for safety-related applications according to IEC 61508:2010 or according to EN ISO 13849-1:2015
  - C, logi.CAD 3\*: SIL 2 / PL d
  - CODESYS: SIL 1 / PL c
  - Matlab\*

\* Scheduled feature

### TECHNICAL DATA

- TriCore TC 1798 32 bit, 300 MHz
- 288 kB SRAM internal, 8 MB SDRAM external
- 4 MB Flash internal
- 32 kB EEPROM
- 4 CAN interfaces (CAN 1 with wake-up function), 1 RS232 interface, 1 Ethernet interface
- 28 inputs (SENT support)
- 28 outputs

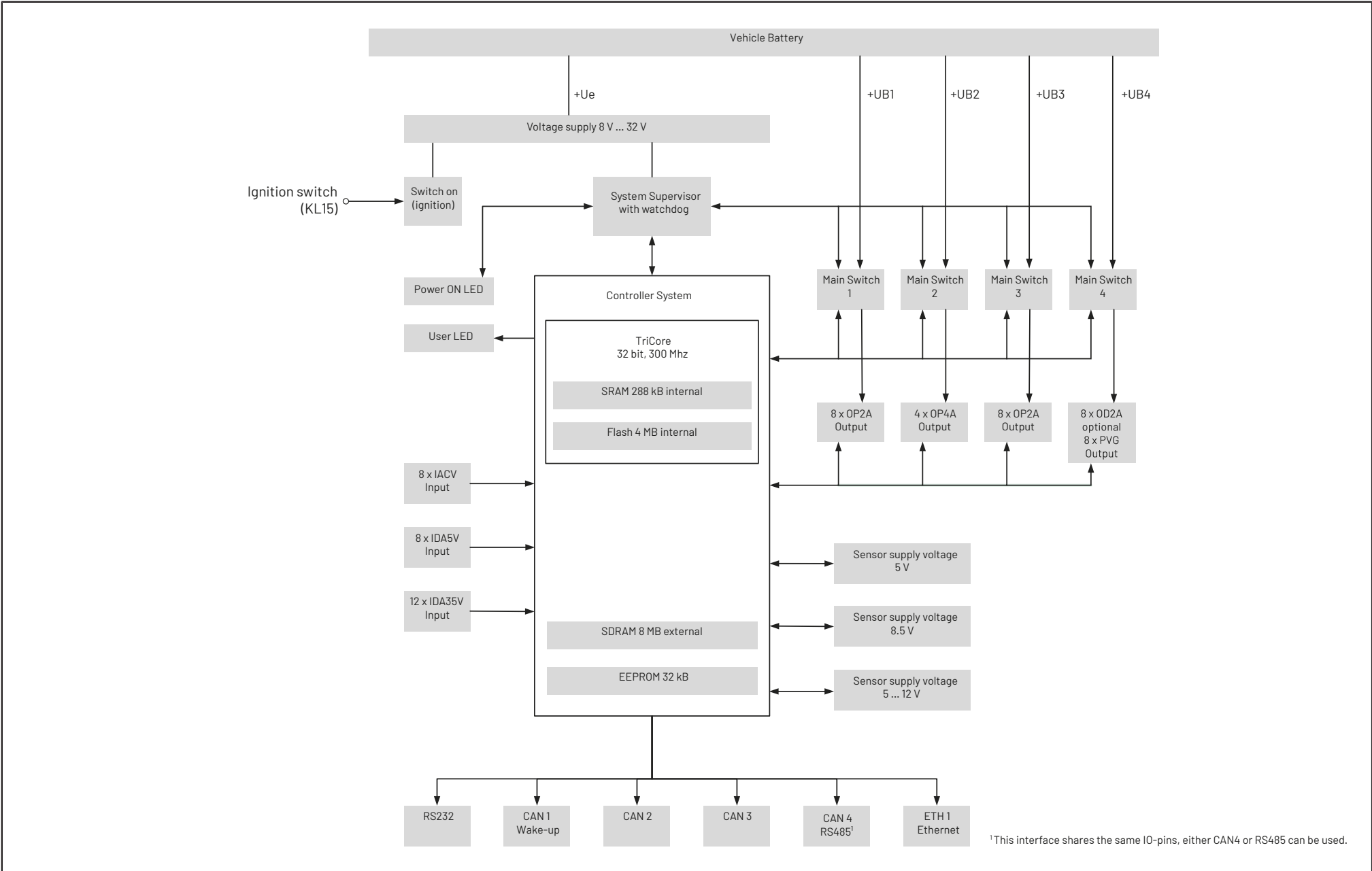
### ACCESSORIES

- Component Deployment C, CODESYS V3.5, logi.CAD and Matlab
- Compiler
- Mating Plug
- Integrated in STW Software Toolchain openSYDE
- Debug Adapter
- Debugger
- Starter kit
- ESX-Testbox Adapter

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# BLOCK DIAGRAM



## TECHNICAL DATA

### Processor and Memory

| Type           | Properties      | Description   |
|----------------|-----------------|---|
| TriCore TC1798 | 32 bit, 300 MHz | <ul style="list-style-type: none"> <li>External system supervisor with programmable watchdog</li> <li>12 bit A/D converter for analog signal processing</li> </ul>  |
| SRAM           | 128 kB internal | On-chip RAM of the TriCore. This memory is used for system and application data. The space available for the customer application depends on the configuration of the system.   |
| DSPRAM         | 128 kB internal | On-chip RAM of the TriCore without wait states. This memory mainly serves as system memory for BIOS stack and data, but also includes a heap for the customer application.  |
| SDRAM          | 8 MB external   | 7.8 MB available for customer application in C<br>3 MB available for customer application in CODESYS  |
| Flash          | 4 MB internal   | 3.75 MB available for customer application in C<br>2 MB available for customer application in CODESYS   |
| EEPROM         | 32 kB           | 24 kB available for customer application<br>typical endurance according to manufacturer: <ul style="list-style-type: none"> <li>1,000,000 erase/program cycles @ 25 °C</li> <li>300,000 erase/program cycles @ 85 °C</li> <li>data retention &gt; 20 years</li> </ul> |

### Communication Interfaces

| Type     | Max. Quantity | Configuration   |
|----------|---------------|---|
| CAN      | 4             | CAN 2.0 B, high-speed and low-speed, baud rate from 40 kbit/s to 1 Mbit/s<br><br>CAN bus 1 with ECU wake-up feature<br><br>CAN bus 4: Configurable as CAN- or RS485-interface |
| RS485    | 1             | CAN 4 configured as RS485 interface: Baud rate up to 115 kbit/s, half-duplex communication, in parallel to CAN bus 4, can be used as RS485 or CAN bus                         |
| RS232    | 1             | Baud rate up to 115 kbit/s  |
| Ethernet | 1             | 10/100 Mbit/s, hardware variant with additional connector   |

## TECHNICAL DATA

### Inputs

| Type                          | Max. Quantity | Possible Configuration                 | Measurement  |
|-------------------------------|---------------|--|--|
| Multi Functional Input IDA35V | 12            | Analog voltage                         | 0 ... 35 V   |
|                               |               | Programmable pull-up resistor to +8.5V | 1.1 kΩ   |
|                               |               | Programmable pull-down resistor to GND | 1 kΩ   |
|                               |               | NAMUR sensor compatible                |  |
|                               |               | Digital                                | Low active   |
|                               |               |  | High active  |
|                               |               | Event driven                           | Events, reacts on falling or rising edge of the signal |
|                               |               | Frequency                              | 0.6 Hz ... 20 kHz                                      |
|                               |               | Incremental encoder interface          | Change of position or angular change                   |
|                               |               | Analog Input IACV                      | 8  |
|                               |               | Analog current                         | 0 ... 25 mA  |
|                               |               | Digital (voltage mode)                 | Low active   |
|                               |               |  | High active  |
|                               |               | Event driven                           | Events, reacts on falling or rising edge of the signal |

### Inputs

| Type                         | Max. Quantity | Possible Configuration               | Measurement  |
|------------------------------|---------------|--------------------------------------|--|
| Multi Functional Input IDA5V | 8             | Analog voltage                       | 0 ... 5 V  |
|                              |               | Programmable pull-up resistor to +5V | 6.8 kΩ   |
|                              |               | Digital                              | Low active   |
|                              |               |                                      | High active  |
|                              |               | Event driven                         | Events, reacts on falling or rising edge of the signal |
|                              |               | Frequency                            | 0.6 Hz ... 20 kHz                                      |
|                              |               | SENT interface                       |  |

# TECHNICAL DATA

## Outputs (All Outputs are Short Circuit Protected)

| Type                    | Max. Quantity | Possible Configuration | Range     | Characteristics  | Feature  | Group   |
|-------------------------|---------------|------------------------|-----------|--|--|---|
| Digital/PWM Output OP4A | 4             | Digital<br>PWM         | 0 ... 4 A | ON/OFF<br>0 ... 100 %<br>Duty cycle resolution < 0.1 %<br>PWM frequency 20 ... 1000 Hz | <ul style="list-style-type: none"> <li>High-side switch</li> <li>Precise current measurement, accuracy is 2 %</li> <li>Supports current control mode</li> <li>Digital feedback, open load detection in OFF state</li> <li>Automated shutdown on overcurrent &gt; 7.5 A ±20 %</li> <li>Combine several outputs for parallel operation up to 15 A</li> </ul> | Power supply group 2<br>+UB2:<br>4 outputs<br>All outputs together can drive up to 15 A |

## Outputs (All Outputs are Short Circuit Protected)

| Type                    | Max. Quantity | Possible Configuration | Range       | Characteristics  | Feature  | Group   |
|-------------------------|---------------|------------------------|-------------|--|--|---|
| Digital/PWM Output OP2A | 16            | Digital<br>PWM         | 0 ... 2.5 A | ON/OFF<br>0 ... 100 %<br>Duty cycle resolution < 0.1 %<br>PWM frequency 20 ... 1000 Hz | <ul style="list-style-type: none"> <li>High-side switch</li> <li>Precise current measurement, accuracy is 2 %</li> <li>Supports current control mode</li> <li>Digital feedback, open load detection in OFF state</li> <li>Automated shutdown on overcurrent &gt; 4.6 A ±20 %</li> <li>Combine several outputs for parallel operation up to 15 A</li> </ul> | Power supply group 1<br>+UB1:<br>8 outputs<br>Power supply group 3<br>+UB3:<br>8 outputs<br>All outputs together can drive up to 15 A per group |

# TECHNICAL DATA

## Outputs (All Outputs are Short Circuit Protected)

| Type                       | Max. Quantity | Possible Configuration | Range       | Characteristics  | Feature  | Group   |
|----------------------------|---------------|------------------------|-------------|--|--|---|
| Digital Output OD2A        | 8             | Digital<br>PWM         | 0 ... 2.5 A | ON/OFF<br>0 ... 100 %<br>Duty cycle resolution < 0.1 %<br>PWM frequency 20 ... 1000 Hz | <ul style="list-style-type: none"> <li>High-side switch</li> <li>Optimized for digital operation mode (ON/OFF)</li> <li>Current feedback, measurement accuracy is <math>\pm 15.0\%</math> (gain) <math>\pm 100\text{mA}</math> (offset)</li> <li>Output voltage feedback, voltage measurement with <math>\pm 3\%</math></li> <li>Automated shutdown on overcurrent <math>&gt; 3.6\text{ A} \pm 20\%</math></li> <li>Combine several outputs for parallel operation up to 15 A</li> </ul> | Power supply group 4<br>+UB4:<br>8 outputs<br><br>All outputs together can drive up to 15 A |
| optional:<br>PVG<br>Output |               | PVG                    |             |  |  |   |

## Outputs (All Outputs are Short Circuit Protected)

| Type               | Max. Quantity | Possible Configuration | Range                     | Characteristics   | Feature   | Group                           |
|--------------------|---------------|------------------------|---------------------------|---|---|---------------------------------|
| Sensor supply Uext | 3             | programmable           | 5 ... 12 V<br>$\pm 2.5\%$ | Programmable output needs derating for output voltages $U_{EXT} < 10\text{ V}$ :<br>$I_{MAX} = 0.9 / (13.6 - U_{EXT})\text{ A}$ | <ul style="list-style-type: none"> <li>The Uext output voltage is stable also when the +UE input voltage is below the Uext output voltage. E.g. it is possible to use Uext = 12 V when +UE is at the min voltage <math>+UE_{MIN} = 8\text{ V}</math></li> </ul> | Supplied from ECU power pin +UE |
|                    |               | Fixed voltage          | 8.5 V $\pm 1.5\%$         | Maximal output current  |   |                                 |
|                    |               | Fixed voltage          | 5 V $\pm 1.0\%$           | $I_{MAX} = 250\text{ mA}$   |   |                                 |
| Main Switch        | 4             |                        |                           | ON/OFF  | <ul style="list-style-type: none"> <li>Switches the four output groups</li> <li>High-side switch</li> <li>Current up to 15 A</li> </ul>   |                                 |

## TECHNICAL DATA

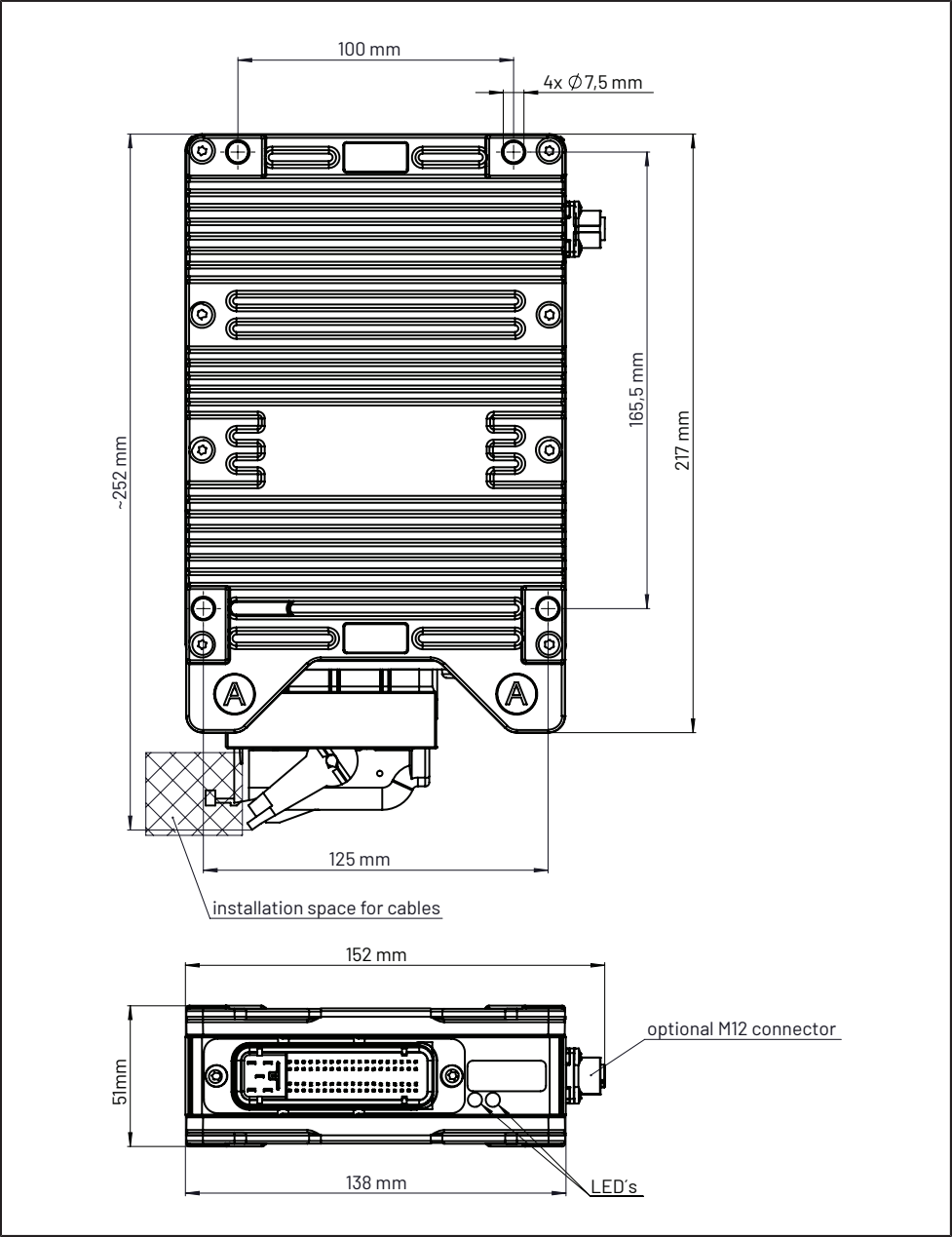
### Mechanical Data

| Component             | Description                                   | Value   |
|-----------------------|---|---|
| Connector             | KS1   | Automotive 81 pins, matching plug: Tyco 1473244-1 and 1473244-3 |
|                       | ETH1  | 4 pins M12 connector, D-coded                                   |
| Indicators            | 2 LED, dual color (red/green or mixed colors) | 1 for the state of the system, 1 freely programmable            |
| Housing               | Die-cast aluminum                             | GORE-TEX™-breathing filter for pressure equalization            |
| Weight                |   | About 1.3 kg (2 lb)   |
| Degree of Protection  | Variant without Ethernet connector            | IP6k7 and IP6k9k  |
|                       | Variant with Ethernet connector               | IP6k7   |
| Dimensions            | Variant without Ethernet connector            | 217 mm x 138 mm x 51 mm   |
|                       | Variant with Ethernet connector               | 217 mm x 152,5 mm x 51 mm                                       |
| Operating temperature | chassis temperature                           | -40 ... +85 °C (-40 ... +185 °F)                                |

### Power Supply

| Component           | Description  | Range         |  |
|---------------------|--|---------------|--|
|                     |  | Minimum Value | Maximum Value                                  |
| DC voltage supply   | Voltage at +UE ECU supply and +UB1..4 power supply                         | 8 V DC        | 32 V DC  |
| Current consumption | 4x 15 A power pins fully loaded, short-term                                |               | 60 A   |
| - Stand-by          | Sum of input currents at +UE and +UB1..4 ( $U_{KL15} = 0$ V, ignition off) |               | < 1 mA   |
| - ECU active        | +UE supply current ( $U_{KL15} > U_{KL15HIGH}$ , no external load)         |               | < 800 mA @ +UE = 12 V<br>< 400 mA @ +UE = 24 V |

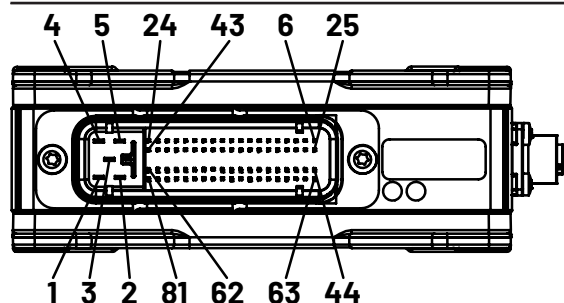
# TECHNICAL DRAWING





# PIN ASSIGNMENT

## Pin Assignment 81 Pin Connector:



Connectors (male) of KS1

| Pin | Functional Signal Name | BIOS Defines   | Description  |
|-----|------------------------|----------------|--|
| 1   | +UB4                   | X_SYS_RELAY_04 | Power supply for the digital outputs of type OD2A (High-Side Digital 2.5 A)                        |
| 2   | GND                    | -              | Ground of the ECU  |
| 3   | +UB2                   | X_SYS_RELAY_02 | Power supply of the PWM outputs of type OP4A (High-Side PWM 4 A)                                   |
| 4   | +UB3                   | X_SYS_RELAY_03 | Power supply of the PWM outputs of type OP2A (High-Side PWM 2.5 A)                                 |
| 5   | +UB1                   | X_SYS_RELAY_01 | Power supply of the PWM outputs of type OP2A (High-Side PWM 2.5 A)                                 |
| 6   | +UE                    | -              | Power supply of the ECU  |
| 7   | CAN1_H                 | X_CAN_BUS_01   | CAN bus 1(high)  |
| 8   | CAN3_H                 | X_CAN_BUS_03   | CAN bus 3(high)  |
| 9   | IACV_2                 | X_IN_14        | Analog input current 0 ... 25 mA / voltage 0 ... 12 V digital functionality with limited bandwidth |

## Pin Assignment 81 Pin Connector:

| Pin | Functional Signal Name | BIOS Defines | Description  |              |
|-----|------------------------|--------------|--|--------------|
| 10  | IDA35V_10              | X_IN_10      | Input digital, pull-up and pull-down, NAMUR, frequency, incremental input channel 4-A, analog input voltage 0 ... 35 V |              |
| 11  | IDA35V_6               | X_IN_06      | Input digital, pull-up and pull-down, NAMUR, frequency, analog input voltage 0 ... 35 V                                |              |
| 12  | IDA35V_2               | X_IN_02      | Input digital, pull-up and pull-down, NAMUR, frequency, incremental input channel 1-B, analog input voltage 0 ... 35 V |              |
| 13  | OP2A_5                 | X_OUT_05     | Output High-Side PWM/digital 2.5A  |              |
| 14  | OP2A_6                 | X_OUT_06     | Output High-Side PWM/digital 2.5A  |              |
| 15  | CAN1_H                 | X_CAN_BUS_01 | CAN bus 1(high)  |              |
| 16  | IACV_5                 | X_IN_17      | Analog input current 0 ... 25 mA / voltage 0 ... 12 V digital functionality with limited bandwidth                     |              |
| 17  | OP4A_2                 | X_OUT_10     | Output High-Side PWM/digital 4 A   |              |
| 18  | IDA5V_3                | X_IN_23      | Input digital, pull-up, SENT, frequency, analog input voltage 0 ... 5 V  |              |
| 19  | OP2A_15                | X_OUT_19     | Output High-Side PWM/digital 2.5 A   |              |
| 20  | OP2A_11                | X_OUT_15     | Output High-Side PWM/digital 2.5 A   |              |
| 21  | IDA5V_8                | X_IN_28      | Input digital, pull-up, SENT, frequency, analog input voltage 0 ... 5 V  |              |
| 22  | OD2A_8                 | X_OUT_28     | Output High-Side Digital/PWM 2.5 A   | Optional PVG |
| 23  | OD2A_4                 | X_OUT_24     | Output High-Side Digital/PWM 2.5 A   | Optional PVG |

## PIN ASSIGNMENT

### Pin Assignment 81 Pin Connector:

| Pin | Functional Signal Name | BIOS Defines            | Description  |
|-----|------------------------|-------------------------|--|
| 24  | 5Vext                  | X_SYS_SENSOR_SUP-PLY_03 | Sensor supply voltage 5 V  |
| 25  | KL15                   | -                       | Ignition (KL15)  |
| 26  | CAN1_L                 | X_CAN_BUS_01            | CAN bus 1 (low)  |
| 27  | CAN3_L                 | X_CAN_BUS_03            | CAN bus 3 (low)  |
| 28  | IACV_3                 | X_IN_15                 | Analog input current 0 ... 25 mA / voltage 0 ... 12 V digital functionality with limited bandwidth                     |
| 29  | IDA35V_11              | X_IN_11                 | Input digital, pull-up and pull-down, NAMUR, frequency, incremental input channel 4-B, analog input voltage 0 ... 35 V |
| 30  | IDA35V_7               | X_IN_07                 | Input digital, pull-up and pull-down, NAMUR, frequency, incremental input channel 3-A, analog input voltage 0 ... 35 V |
| 31  | IDA35V_3               | X_IN_03                 | Input digital, pull-up and pull-down, NAMUR, frequency, analog input voltage 0 ... 35 V                                |
| 32  | OP2A_1                 | X_OUT_01                | Output High-Side PWM/digital 2.5A  |
| 33  | OP2A_2                 | X_OUT_02                | Output High-Side PWM/digital 2.5A  |
| 34  | CAN1_L                 | X_CAN_BUS_01            | CAN bus 1 (low)  |
| 35  | IACV_6                 | X_IN_18                 | Analog input current 0 ... 25 mA / voltage 0 ... 12 V digital functionality with limited bandwidth                     |
| 36  | OP4A_3                 | X_OUT_11                | Output High-Side PWM/digital 4 A   |
| 37  | IDA5V_4                | X_IN_24                 | Input digital, pull-up, SENT, frequency, analog input voltage 0 ... 5 V  |
| 38  | OP2A_16                | X_OUT_20                | Output High-Side PWM/digital 2.5 A   |

### Pin Assignment 81 Pin Connector:

| Pin | Functional Signal Name | BIOS Defines             | Description  |              |
|-----|------------------------|--------------------------|--|--------------|
| 39  | OP2A_12                | X_OUT_16                 | Output High-Side PWM/digital 2.5 A   |              |
| 40  | AGND                   | X_SYS_SENSOR_SUP-PLY_03  | Analog GND of 5Vext (pin 24)   |              |
| 41  | IDA5V_5                | X_IN_25                  | Input digital, pull-up, SENT, frequency, analog input voltage 0 ... 5 V  |              |
| 42  | OD2A_5                 | X_OUT_25                 | Output High-Side Digital/PWM 2.5 A   | Optional PVG |
| 43  | OD2A_1                 | X_OUT_21                 | Output High-Side Digital/PWM 2.5 A   | Optional PVG |
| 44  | RS232_TxD              | X_SER_01                 | RS232 interface (TxD line)   |              |
| 45  | CAN2_H                 | X_CAN_BUS_02             | CAN bus 2 (high)   |              |
| 46  | CAN4_H or RS485_A      | X_CAN_BUS_04 or X_SER_02 | CAN bus 4 (high) or RS485 interface (A-line, positive line)  |              |
| 47  | AGND                   | X_SYS_SENSOR_SUP-PLY_01  | Analog GND of 5-12Vext (pin 66)  |              |
| 48  | IDA35V_12              | X_IN_12                  | Input digital, pull-up and pull-down, NAMUR, frequency, analog input voltage 0 ... 35 V                                |              |
| 49  | IDA35V_8               | X_IN_08                  | Input digital, pull-up and pull-down, NAMUR, frequency, incremental input channel 3-B, analog input voltage 0 ... 35 V |              |
| 50  | IDA35V_4               | X_IN_04                  | Input digital, pull-up and pull-down, NAMUR, frequency, incremental input channel 2-A, analog input voltage 0 ... 35 V |              |
| 51  | OP2A_3                 | X_OUT_03                 | Output High-Side PWM/digital 2.5 A   |              |
| 52  | OP2A_4                 | X_OUT_04                 | Output High-Side PWM/digital 2.5 A   |              |

## PIN ASSIGNMENT

### Pin Assignment 81 Pin Connector:

| Pin | Functional Signal Name | BIOS Defines             | Description  |              |
|-----|------------------------|--------------------------|--|--------------|
| 53  | 8V5ext                 | X_SYS_SENSOR_SUP-PLY_02  | Sensor supply voltage 8.5 V  |              |
| 54  | IACV_7                 | X_IN_19                  | Analog input current 0 ... 25 mA / voltage 0 ... 12 V digital functionality with limited bandwidth |              |
| 55  | OP4A_4                 | X_OUT_12                 | Output High-Side PWM/digital 4 A   |              |
| 56  | AGND                   | X_SYS_SENSOR_SUP-PLY_02  | Analog GND of 8V5ext (pin 53)  |              |
| 57  | IDA5V_1                | X_IN_21                  | Input digital, pull-up, SENT, frequency, analog input voltage 0 ... 5 V                            |              |
| 58  | OP2A_13                | X_OUT_17                 | Output High-Side PWM/digital 2.5 A   |              |
| 59  | OP2A_9                 | X_OUT_13                 | Output High-Side PWM/digital 2.5 A   |              |
| 60  | IDA5V_6                | X_IN_26                  | Input digital, pull-up, SENT, frequency, analog input voltage 0 ... 5 V                            |              |
| 61  | OD2A_6                 | X_OUT_26                 | Output High-Side Digital/PWM 2.5 A   | Optional PVG |
| 62  | OD2A_2                 | X_OUT_22                 | Output High-Side Digital/PWM 2.5 A   | Optional PVG |
| 63  | RS232_RxD              | X_SER_01                 | RS232 interface (Rx/D line)  |              |
| 64  | CAN2_L                 | X_CAN_BUS_02             | CAN bus 2 (low)  |              |
| 65  | CAN4_L or RS485_B      | X_CAN_BUS_04 or X_SER_02 | CAN bus 4 (low) or RS485 interface (B-line, negative line)   |              |
| 66  | 5-12Vext               | X_SYS_SENSOR_SUP-PLY_01  | Programmable sensor supply voltage 5 ... 12 V  |              |
| 67  | IACV_1                 | X_IN_13                  | Analog input current 0 ... 25 mA / voltage 0 ... 12 V digital functionality with limited bandwidth |              |

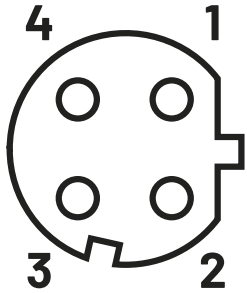
### Pin Assignment 81 Pin Connector:

| Pin | Functional Signal Name | BIOS Defines | Description  |              |
|-----|------------------------|--------------|--|--------------|
| 68  | IDA35V_9               | X_IN_09      | Input digital, pull-up and pull-down, NAMUR, frequency, analog input voltage 0 ... 35 V                                |              |
| 69  | IDA35V_5               | X_IN_05      | Input digital, pull-up and pull-down, NAMUR, frequency, incremental input channel 2-B, analog input voltage 0 ... 35 V |              |
| 70  | IDA35V_1               | X_IN_01      | Input digital, pull-up and pull-down, NAMUR, frequency, incremental input channel 1-A, analog input voltage 0 ... 35 V |              |
| 71  | OP2A_7                 | X_OUT_07     | Output High-Side PWM/digital 2.5 A   |              |
| 72  | OP2A_8                 | X_OUT_08     | Output High-Side PWM/digital 2.5 A   |              |
| 73  | IACV_8                 | X_IN_20      | Analog input current 0 ... 25 mA / voltage 0 ... 12 V digital functionality with limited bandwidth                     |              |
| 74  | IACV_4                 | X_IN_16      | Analog input current 0 ... 25 mA / voltage 0 ... 12 V digital functionality with limited bandwidth                     |              |
| 75  | OP4A_1                 | X_OUT_09     | Output High-Side PWM/digital 4 A   |              |
| 76  | IDA5V_2                | X_IN_22      | Input digital, pull-up, SENT, frequency, analog input voltage 0 ... 5 V  |              |
| 77  | OP2A_14                | X_OUT_18     | Output High-Side PWM/digital 2.5 A   |              |
| 78  | OP2A_10                | X_OUT_14     | Output High-Side PWM/digital 2.5 A   |              |
| 79  | IDA5V_7                | X_IN_27      | Input digital, pull-up, SENT, frequency, analog input voltage 0 ... 5 V  |              |
| 80  | OD2A_7                 | X_OUT_27     | Output High-Side Digital/PWM 2.5 A   | Optional PVG |
| 81  | OD2A_3                 | X_OUT_23     | Output High-Side Digital/PWM 2.5 A   | Optional PVG |

# PIN ASSIGNMENT

**Pin Assignment 4 Pin M12 Connector:**

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Pin assignment of the M12 connector of the Ethernet interface

| Pin | Description | Coding  |
|-----|-------------|---------|
| 1   | Tx+         |         |
| 2   | Rx+         | D-coded |
| 3   | Tx-         |         |
| 4   | Rx-         |         |

# QUALIFICATION

## Compliance Information

| Standard                    | Description  | Parameter                          |
|-----------------------------|--|------------------------------------|
| ISO/IEC 17050-1             | Conformity<br><br>Certification<br>This approved device can be used on any vehicle type with the following restrictions:<br>All vehicle types with a 12 V respectively 24 V - electrical wiring and battery(-) at the body | See Declaration of Conformity      |
| KBA (Kraft-fahrt-Bundesamt) | Restriction of Hazardous Substances<br><br>RoHS  | According UN ECE Regulation No. 10 |

# DETAILED QUALIFICATION

## Electrical Safety

| Standard             | Test Description                             | Test Parameter   |
|----------------------|--|--|
| ISO 16750-2: 2012-11 | Overvoltage                                  | 12 V: 60 min, Voltage supply = 18 V, T = 65 °C, 1 Cycle        |
| ISO 16750-2: 2012-11 | Overvoltage                                  | 24 V: 60 min, Voltage supply = 18 V, T = 65 °C, 1 Cycle        |
| ISO 16750-2: 2012-11 | Superimposed alternating voltage             | 12 V: Severity 4: Upp = 2 V, 10 min                            |
| ISO 16750-2: 2012-11 | Superimposed alternating voltage             | 24 V: Severity 2: Upp = 4 V, 10 min                            |
| ISO 16750-2: 2012-11 | Slow decrease and increase of supply voltage | Decrease and increase supply voltage with 0.5 V / min          |
| ISO 16750-2: 2012-11 | Momentary drop in supply voltage             | 12 V: Single voltage drop to 4.5 V                             |
| ISO 16750-2: 2012-11 | Momentary drop in supply voltage             | 24 V: Single voltage drop to 9 V                               |
| ISO 16750-2: 2012-11 | Reset behavior at voltage drop               | 12 V: Voltage drops in 5 % steps until 0 V, drop duration 10 s |
| ISO 16750-2: 2012-11 | Reset behavior at voltage drop               | 24 V: Voltage drops in 5 % steps until 0 V, drop duration 10 s |
| ISO 16750-2: 2012-11 | Starting profile switch-on hysteresis        | 12 V: Testlevel 4  |
| ISO 16750-2: 2012-11 | Starting profile switch-on hysteresis        | 24 V: Testlevel 3  |
| ISO 16750-2: 2012-11 | Load Dump                                    | 12 V Impulse a: Usmax = 70 V, 10 Pulses                        |
| ISO 16750-2: 2012-11 | Load Dump                                    | 12 V Impulse b: Usmax = 70 V, 5 Pulses                         |

## DETAILED QUALIFICATION

### Electrical Safety

| Standard             | Test Description                               | Test Parameter  |
|----------------------|--|---|
| ISO 16750-2: 2012-11 | Load Dump                                      | 24 V Impulse a: $U_{max} = 70 \text{ V}$ ,<br>10 Pulses     |
| ISO 16750-2: 2012-11 | Load Dump                                      | 24 V Impulse b: $U_{max} = 70 \text{ V}$ ,<br>5 Pulses      |
| ISO 16750-2: 2012-11 | Reversed voltage case 2                        | Duration: 1 min   |
| ISO 16750-2: 2012-11 | Ground reference and supply offset             | Max. offset ( $\pm 0.1$ ) V                                 |
| ISO 16750-2: 2012-11 | Open circuit test - Single line interruption   | Interruption 10 s $\pm$ 1 s                                 |
| ISO 16750-2: 2012-11 | Open circuit test - Multiple line interruption | Interruption 10 s $\pm$ 1 s                                 |
| ISO 16750-2: 2012-11 | Short circuits - signal lines                  | Connect every In- and Output to $U_{max}$ and GND for 1 min |
| ISO 16750-2: 2012-11 | Short circuits - load lines                    | To load circuits duration: 5 min                            |

### Electromagnetic Compatibility (CE)

| Standard                  | Test Description   | Test Parameter   |
|---------------------------|--|--|
| DIN EN 61000-6-3          | Emission   | Conducted Emission: 0.15 MHz to 30 MHz<br>Radiated Emission: 30 MHz to 5000 MHz  |
| DIN EN 61000-4-2: 2009-12 | Electrostatic Discharge (ESD) direct   | 330 Ohm / 150 pF<br>contact: $\pm 2 \text{ kV}$ / $\pm 4 \text{ kV}$ / $\pm 6 \text{ kV}$<br>air: $\pm 2 \text{ kV}$ / $\pm 4 \text{ kV}$ / $\pm 8 \text{ kV}$ / $\pm 15 \text{ kV}$ |
| DIN EN 61000-4-2: 2009-12 | Electrostatic Discharge (ESD) indirect HCP   | 330 Ohm / 150 pF<br>contact: $\pm 2 \text{ kV}$ / $\pm 4 \text{ kV}$ / $\pm 6 \text{ kV}$  |
| DIN EN 61000-4-2: 2009-12 | Electrostatic Discharge (ESD) indirect VCP   | 330 Ohm / 150 pF<br>contact: $\pm 2 \text{ kV}$ / $\pm 4 \text{ kV}$ / $\pm 6 \text{ kV}$  |
| DIN EN 61000-6-2: 2006-03 | Limits and methods of measurement of radio disturbance; characteristics for the protection of receivers used on board vehicles | 80 MHz to 2700 MHz, 10 V / m, 20 V / m   |
| DIN EN 61000-4-4: 2013-04 | Burst  | 1 kV & 3 kV (pos / neg)  |
| DIN EN 61000-4-5: 2007-06 | Surge  | Symmetric: 0.5 kV   1 kV<br>(Impedance: 2 Ohm + 18 $\mu$ F)<br>Dissymmetric 0.5 kV   1 kV   2 kV<br>(impedance 12 Ohm + 9 $\mu$ F)   |
| DIN EN 61000-4-6: 2014    | Voltage Dips   | 0.15 MHz to 80 MHz<br>AM: 80 % / sinusoidal: 1000 Hz   |

## DETAILED QUALIFICATION

### Electromagnetic Compatibility (E1)

| Standard                               | Test Description   | Test Parameter                                       |
|--|--|--|
| IEC/CISPR25: 2008/ECE R10              | Emission   | 0.15 MHz to 2500 MHz                                 |
| ISO 11452-2: 2004-11                   | Immunity   | 200 MHz bis 3000 MHz, 200 V / m                      |
| ISO 11452-4: 2011-12                   | Immunity   | 0.1 MHz bis 400 MHz, AM (1 kHz, 80 %)                |
| ISO 11452-5: 2002-04                   | Immunity   | 0.01 MHz bis 1000 MHz, 200 V / m                     |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Emission   | 12 V: (pos) + 100 V, (neg) - 150 V                   |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Emission   | 24 V: (pos) + 200 V, (neg) - 600 V                   |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 1 (12 V): - 100 V, 2 ms, 2 Ohm, 5000 pulses    |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 1 (24 V): - 600 V, 1 ms, 50 Ohm, 5000 pulses   |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 2a (12 V): + 50 V, 0.05 ms, 2 Ohm, 5000 pulses |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 2a (24 V): + 50 V, 0.05 ms, 2 Ohm, 5000 pulses |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 2b (12 V): + 10 V, 1 s, 10 pulses              |

### Electromagnetic Compatibility (E1)

| Standard                               | Test Description   | Test Parameter                                |
|--|--|---|
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 2b (24 V): + 20 V, 1 s, 10 pulses       |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 3a (12 V): - 150 V, 150 ns, 50 Ohm, 1 h |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 3a (24 V): - 200 V, 150 ns, 50 Ohm, 1 h |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 3b (12 V): + 100 V, 150 ns, 50 Ohm, 1 h |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 3b (24 V): + 200 V, 150 ns, 50 Ohm, 1 h |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 4 (12 V): - 7 V, 1 pulse                |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Pulse 4 (24 V): - 16 V, 1 pulse               |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Puls a (12 V): - 60 V, 10 min                 |
| ISO 7637-2: 2nd edition 2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Puls a (24 V): - 80 V, 10 min                 |

## DETAILED QUALIFICATION

### Electromagnetic Compatibility (E1)

| Standard                                  | Test Description   | Test Parameter  |
|---|--|---|
| ISO 7637-2: 2nd edition<br>2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Puls b (12 V): + 40 V, 10 min   |
| ISO 7637-2: 2nd edition<br>2004+AMD1:2008 | Road vehicles, electrical disturbance by conduction and coupling | Puls b (24 V): + 80 V, 10 min   |
| IEC/CISPR25: 2008                         | Emission   | 30 kHz to 108 MHz   |
| ISO 10605: 2008-07                        | Electrostatic Discharge (ESD)                                    | 330 Ohm / 330 pF,<br>contact: +/- 2 kV, +/- 4 kV,<br>+/- 6 kV, +/- 8 kV |
| ISO 10605: 2008-07                        | Electrostatic Discharge (ESD)                                    | 330 Ohm / 150 pF<br>+/- 6 kV, +/- 8 kV, +/- 15 kV,<br>+/- 25 kV         |

### Environmental Qualification

| Standard   | Test Description                                      | Test Parameter   |
|--|---|--|
| DIN EN 60068-2-64: 2009-04<br>ISO 16750-3: 2012-12 | Environmental testing:<br>Resonance search            | 5 Hz - 2000 Hz, 1 g, 1 oct / min   |
| DIN EN 60068-2-64: 2009-04<br>ISO 16750-3: 2012-12 | Environmental testing:<br>Resonance search            | 5 Hz - 2000 Hz, 1 g, 1 oct / min   |
| DIN EN 60068-2-27: 2010-02<br>ISO 16750-3: 2012-12 | Environmental testing:<br>Shock                       | 50 g / 6 ms,<br>halfsine wave,<br>10 shocks / axis   |
| DIN EN 60068-2-31: 2009-04<br>ISO 16750-3: 2012-12 | Environmental testing:<br>Free fall                   | Drop height: 1 m   |
| DIN EN 60068-2-6: 2008-10<br>ISO 16750-3: 2012-12  | Environmental testing -<br>Vibration (sinusoidal)     | Frequency range: 10 Hz - 2000 Hz<br>Acceleration: 5 g<br>Sweep rate: 1 oct / min   |
| DIN EN 60068-2-27: 2010-02<br>ISO 16750-3: 2012-12 | Environmental testing:<br>Shock                       | Pulse shape: half-sine<br>Control strategy: single channel<br>Acceleration: 50 g<br>Pulse duration: 11 ms<br>Number of tested axes: 3<br>Number of shocks: 3 positive, 3<br>negative per axis      |
| DIN EN 60068-2-27: 2010-02                         | Environmental testing:<br>Bump                        | Pulse shape: half-sine<br>Control strategy: single channel<br>Acceleration: 30 g<br>Pulse duration: 6 ms<br>Number of tested axes: 3<br>Number of shocks: 1000 positive,<br>1000 negative per axis |
| DIN EN 60068-2-1: 2008-01<br>ISO 16750-4: 2010-04  | Environmental testing:<br>Low temperature,<br>storage | Tmin: - 40 °C<br>Duration: 24 h  |



# DETAILED QUALIFICATION

## Environmental Qualification

| Standard   | Test Description  | Test Parameter  |
|--|---|---|
| DIN EN 60068-2-2: 2008-05<br>ISO 16750-4: 2010-04  | Environmental testing:<br>High temperature,<br>storage                    | Tmax.: + 105 °C<br>Duration: 48 h   |
| ISO 16750-4: 2010-04                               | Environmental testing:<br>Temperature step test                           | Tmax.: + 85 °C<br>Tmin: - 40 °C<br>Dwell time at each step:<br>1 hour (38 steps)<br>Duration: 2 days                  |
| DIN EN 60068-2-14: 2010-04<br>ISO 16750-4: 2010-04 | Environmental testing:<br>Rapid change of temper-<br>ature                | Tmin: - 40 °C<br>Tmax: + 85 °C<br>Dwell time at Tmin / Tmax: 60 min<br>Number of cycles: 100                          |
| DIN EN 60068-2-14: 2010-04<br>ISO 16750-4: 2010-04 | Environmental testing:<br>Temperature cycle with<br>specified change rate | Tmin: - 40 °C<br>Tmax: +85 °C<br>Duration: 30 cycles a 480 min  |
| DIN EN 60068-2-52: 1996-10<br>ISO 16750-4: 2010-04 | Environmental testing:<br>Salt spray corrosion test                       |   |
| DIN EN 60068-2-11: 2000-02<br>ISO 16750-4: 2010-04 | Environmental testing:<br>Salt spray, leakage and<br>function test        |   |
| DIN EN 60068-2-38: 2010-06                         | Environmental testing:<br>Damp heat, steady state                         | Tmax: + 65 °C<br>Tmin: - 10 °C<br>Duration: 240 h (10 cycles a 24 h)  |
| DIN EN 60068-2-78: 2014-02<br>ISO 16750-4: 2010-04 | Environmental testing:<br>Damp heat, steady state                         | Tmax: + 40 °C<br>Relative humidity: 85 % RH<br>Duration: 21 days  |
| DIN EN 60068-2-30: 2006-06<br>ISO 16750-4: 2010-04 | Environmental testing:<br>Dewing test                                     | Upper test temperature: + 80 °C<br>Lower test temperature: + 25 °C<br>Relative humidity:<br>98 % RH max / 55 % RH min |

## Environmental Qualification

| Standard   | Test Description                         | Test Parameter  |
|--|--|---|
|  |  | Number of test cycles:<br>5, 5.5 h per cycle<br>Total test duration: 27.5 h   |
| DIN EN 60068-2-60: 1996-09<br>ISO 16750-4: 2010-04 | Corrosion test with flow<br>of mixed gas | H2S - Concentration<br>NO2 - Concentration<br>Cl2 - Concentration<br>SO2 - Concentration  |
| ISO 20653: 2013-02                                 | IP Protection classes                    | IP6KX<br>IPX5   |
| ISO 16750-5: 2010-04                               | Chemical resistance                      | Diesel<br>Coffee Whitener<br>Biodiesel<br>Runway deicer<br>Kerosene<br>Coffeine / Sugar<br>Engine oil<br>Differential oil<br>Denatured alcohol<br>Methanol<br>Urea<br>Cosmetic products<br>Acetone<br>Hydraulic fluid |
| DIN EN 60068-2-14: 2010-04                         | Life test (Weibull)                      | - 40 °C to + 125 °C, dwell time: 1 h,<br>cycle time: 2 h, cycles: 290,<br>test time: 580 h (ca 24 days)   |