# AUTOMOTIVE CURRENT TRANSDUCER OPEN LOOP TECHNOLOGY
## DHAB S/06

## Introduction

The DHAB family is best suited for DC, AC, or pulsed currents measurement in high power and low voltage automotive applications. It features galvanic separation between the primary circuit (high power) and the secondary circuit (electronic circuit).

The DHAB family gives you a choice of having different current measuring ranges in the same housing (from ± 20 up to ± 600 A).

## Features

- Open Loop transducer using the Hall effect sensor
- Low voltage application
- Unipolar + 5 V DC power supply
- Primary current measuring range up to ± 20 A for channel 1 and ± 500 A for channel 2
- Maximum RMS primary admissible limited by the busbar, the magnetic core or the ASIC temperature T° < + 150 °C
- Operating temperature range: - 40 °C < T° < + 125 °C
- Output voltage: fully ratiometric (in sensitivity and offset) 2 measuring ranges to have a better accuracy.

## Advantages

- Excellent accuracy
- Very good linearity
- Very low thermal offset drift
- Very low thermal sensitivity drift
- Hermetic package.

## Automotive applications

- Battery Pack Monitoring
- Hybrid Vehicles
- EV and Utility Vehicles.

## Principle of DHAB Family

The open loop transducers uses a Hall effect integrated circuit. The magnetic flux density $B$, contributing to the rise of the Hall voltage, is generated by the primary current $I_P$ to be measured. The current to be measured $I_P$ is supplied by a current source i.e. battery or generator (Figure 1).

Within the linear region of the hysteresis cycle, $B$ is proportional to:

$$B (I_P) = \text{constant (a)} \times I_P$$

The Hall voltage is thus expressed by:

$$V_H = (R_H/d) \times I \times \text{constant (a)} \times I_P$$

Except for $I_P$, all terms of this equation are constant. Therefore:

$$V_H = \text{constant (b)} \times I_P$$

The measurement signal $V_H$ amplified to supply the user output voltage or current.
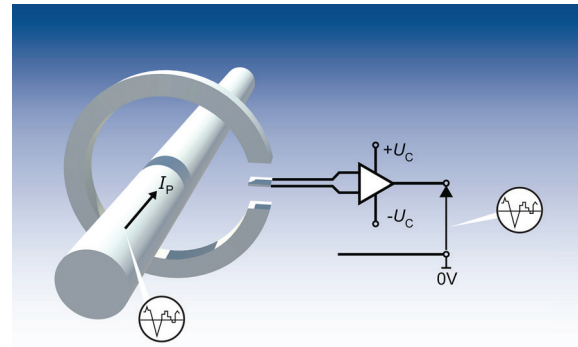


Fig. 1: Principle of the open loop transducer

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## Dimensions (in mm)



$I_P$ (positive primary current direction)

ELECTRICAL DIAGRAM

-PYYDDDHHMMSS = Date code
  -P: Production center
    1=GENEVA / 7 =BEIJING
  -YY: Year on 2 digits
  -DDD: Day of the year
  -HH: Hour
  -MM: Minute
  -SS: Second

-DHAB S/xx =sensor name / version.
- .. = Identification code for jig.

| Components list | |
|---|---|
| IC1 | Hall sensor ASIC |
| IC2 | Hall sensor ASIC |
| C1 | Decoupling capacitor |
| C2 | Decoupling capacitor |
| C3 | Decoupling capacitor |

| Pin out | |
|---|---|
| A | Channel 2 |
| B | $U_c$ |
| C | Gnd |
| D | Channel 1 |

-Logo LEM.
-CE marking.

1–Recommended max. torque for M3x0.5 screws = 1 N·m

>PA66-GF25<

## Mechanical characteristics

- Plastic case          >PA66-GF25<

- Magnetic core        Channel1:FeNi alloy
                       Channel 2: FeSi alloy

- Mass                 69.5 g

- Pins                 Brass tin plated

### Remarks

$$I_P = \left( \frac{5}{U_C} \cdot V_{out} - V_O \right) \cdot \frac{1}{G} \quad \text{with } G \text{ in (V/A)}$$

- $V_{out} > V_o$ when $I_P$ flows in the positive direction (see arrow on drawing).

## System Architecture



$R_L$ > 10 kΩ optional resistor for signal line diagnosis
$C_L$ < 100 nF EMC protection
$R_C$ Low pass filter EMC protection (optional)

# DHAB S/06

## Absolute ratings (not operating)

| Parameter | Symbol | Unit | Specification Min | Specification Typical | Specification Max | Conditions |
|---|---|---|---|---|---|---|
| Maximun supply voltage | $U_C$ | V | | | 8.5 | |
| Maximun over voltage | | V | | | 14 | 1 min |
| Maximun reverse voltage | | | - 14 | | | 1 min @ $T_A$ = 25 °C |
| Ambient storage temperature | $T_S$ | °C | - 40 | | 125 | |
| Continuous output current | $I_{out}$ | mA | - 10 | | 10 | |
| Maximum output voltage (Analog) | $V_{out}$ | V | | | 8.5 | |
| Maximum output over voltage (Analog) | | V | | | 14 | 1 min @ $T_A$ = 25 °C |
| Maximum Output short circuit duration | $t_c$ | min | | | 2 | |

## Operating characteristics in nominal range ($I_{PN}$)

| Parameter | Symbol | Unit | Specification Min | Specification Typical | Specification Max | Conditions |
|---|---|---|---|---|---|---|
| **Electrical Data** | | | | | | |
| Supply voltage | $U_C$ | V | 4.5 | 5 | 5.5 | |
| Ambient operating temperature | $T_A$ | °C | - 10 | | 65 | High accuracy |
| | | | - 40 | | 125 | Reduced accuracy |
| Output current | $I_{out}$ | mA | - 1 | | 1 | |
| Current consumption | $I_C$ | mA | | 15 | 20 | |
| Power up inrush current | | | | | 40 | @ $U_C$ < 3.5 V |
| Load resistance | $R_l$ | KΩ | 10 | | | |
| Capacitive loading | $C_l$ | nF | 1 | | 100 | |
| **Performance Data Channel 1** | | | | | | |
| Primary current | $I_{P\ channel\ 1}$ | A | - 20 | | 20 | |
| Calibration current | $I_{CAL}$ | | - 20 | | 20 | @ $T_A$ = 25 °C |
| Offset voltage [1] | $V_O$ | V | | 2.5 | | @ $U_C$ = 5 V |
| Sensitivity [1] | $G$ | mV/A | | 100 | | @ $U_C$ = 5 V |
| Resolution | | mV | | 2.5 | | @ $U_C$ = 5 V |
| Output clamping voltage min [1] | $V_{SZ}$ | V | 0.24 | 0.25 | 0.26 | @ $U_C$ = 5 V |
| Output clamping voltage max [1] | | V | 4.74 | 4.75 | 4.76 | @ $U_C$ = 5 V |
| Output internal resistance | $R_{OUT}$ | Ω | | 1 | 10 | |
| Frequency bandwidth | $BW$ | Hz | | 80 | | @ - 3 dB |
| Power up time | | ms | | 25 | 120 | |
| Setting time after over load | | ms | | | 25 | |
| **Performance Data Channel 2** | | | | | | |
| Primary current | $I_{P\ channel\ 2}$ | A | - 500 | | 500 | |
| Calibration current | $I_{CAL}$ | | - 500 | | 500 | @ $T_A$ = 25 °C |
| Offset voltage [1] | $V_O$ | V | | 2.5 | | @ $U_C$ = 5 V |
| Sensitivity [1] | $G$ | mV/A | | 4 | | @ $U_C$ = 5 V |
| Resolution | | mV | | 2.5 | | @ $U_C$ = 5 V |
| Output clamping voltage min [1] | $V_{SZ}$ | V | 0.24 | 0.25 | 0.26 | @ $U_C$ = 5 V |
| Output clamping voltage max [1] | | V | 4.74 | 4.75 | 4.76 | @ $U_C$ = 5 V |
| Output internal resistance | $R_{OUT}$ | Ω | | 1 | 10 | |
| Frequency bandwidth | $BW$ | Hz | | 80 | | @ - 3 dB |
| Power up time | | ms | | 25 | 120 | |
| Setting time after over load | | ms | | | 25 | |

Note: [1] The output voltage $V_{out}$ is fully ratiometric. The offset and sensitivity are dependent on the supply voltage $U_C$ relative to the following formula:

$$I_P = \left( \frac{5}{U_C} \cdot V_{out} - V_O \right) \cdot \frac{1}{G} \text{ with } G \text{ in (V/A)}$$

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## ACCURACY

### Channel 1

| Parameter | Symbol | Unit | Specification | | | Conditions |
|---|---|---|---|---|---|---|
| | | | **Min** | **Typical** | **Max** | |
| Electrical offset current | $I_{OE\ Channel\ 1}$ | mA | | ± 50 | | @ $T_A$ = 25 °C |
| Magnetic offset current | $I_{OM\ Channel\ 1}$ | mA | | ± 50 | | @ $T_A$ = 25 °C |
| Offset current | $I_{O\ Channel\ 1}$ | mA | - 250 | | 250 | @ $T_A$ = 25 °C |
| | | | - 410 | | 410 | @ - 10 °C < T° < 65 °C |
| | | | - 650 | | 650 | @ - 40 °C < T° < 125 °C |
| Sensitivity error | $\varepsilon_G$ | % | | ± 0.5 | | @ $T_A$ = 25 °C |
| | | | | ± 2 | | @ - 10 °C < T° < 65 °C |
| | | | | ± 3.5 | | @ - 40 °C < T° < 125 °C |
| Linearity error | $\varepsilon_L$ | % | | ± 0.5 | | off full range |

### Accuracy table

| Channel 1 | Global Absolute Error (A) | | | | | |
|---|---|---|---|---|---|---|
| **Temperature** | - 40 | - 20 | 0 | 25 | 65 | 125 |
| Overall accuracy @ 0 A | ± 0.51 | ± 0.43 | ± 0.35 | ± 0.25 | ± 0.41 | ± 0.65 |
| Overall accuracy @ ± 10 A | ± 0.81 | ± 0.67 | ± 0.53 | ± 0.35 | ± 0.63 | ± 1.05 |
| Overall accuracy @ ± 20 A | ± 1.10 | ± 0.90 | ± 0.70 | ± 0.45 | ± 0.85 | ± 1.45 |



DHAB S/06 Channel 1: Absolute overall accuracy $X_G$
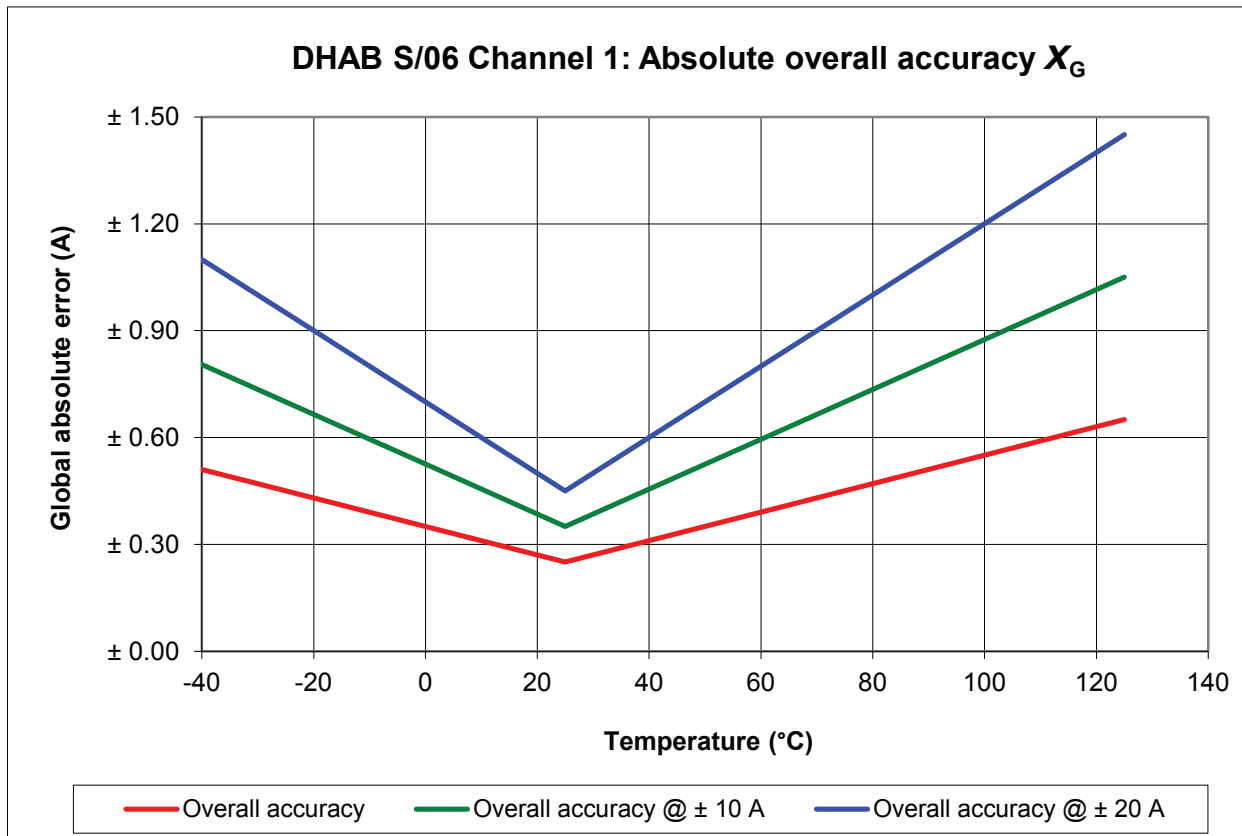
## ACCURACY

### Channel 2

| Parameter | Symbol | Unit | Specification | | | Conditions |
|---|---|---|---|---|---|---|
| | | | Min | Typical | Max | |
| Electrical offset current | $I_{OE\ Channel\ 2}$ | mA | | ± 0.8 | | @ $T_A$ = 25 °C |
| Magnetic offset current | $I_{OM\ Channel\ 1}$ | mA | | ± 2.8 | | @ $T_A$ = 25 °C |
| Offset current | $I_{O\ Channel\ 1}$ | mA | - 4 | | 4 | @ $T_A$ = 25 °C |
| | | | - 4.4 | | 4.4 | @ - 10 °C < T° < 65 °C |
| | | | - 5 | | 5 | @ - 40 °C < T° < 125 °C |
| Sensitivity error | $\varepsilon_G$ | % | | ± 0.5 | | @ $T_A$ = 25 °C |
| | | | | ± 2 | | @ - 10 °C < T° < 65 °C |
| | | | | ± 3.5 | | @ - 40 °C < T° < 125 °C |
| Linearity error | $\varepsilon_L$ | % | | ± 0.5 | | off full range |

### Accuracy table

| Channel 2 | Global Absolute Error (A) | | | | | |
|---|---|---|---|---|---|---|
| Temperature | - 40 | - 20 | 0 | 25 | 65 | 125 |
| Overall accuracy @ 0 A | ± 4.65 | ± 4.45 | ± 4.25 | ± 4.00 | ± 4.40 | ± 5.00 |
| Overall accuracy @ ± 200 A | ± 10.88 | ± 9.38 | ± 7.88 | ± 6.00 | ± 9.00 | ± 13.50 |
| Overall accuracy @ ± 500 A | ± 17.43 | ± 14.53 | ± 11.63 | ± 8.00 | ± 13.80 | ± 22.50 |



DHAB S/06 Channel 2: Absolute overall accuracy $X_G$

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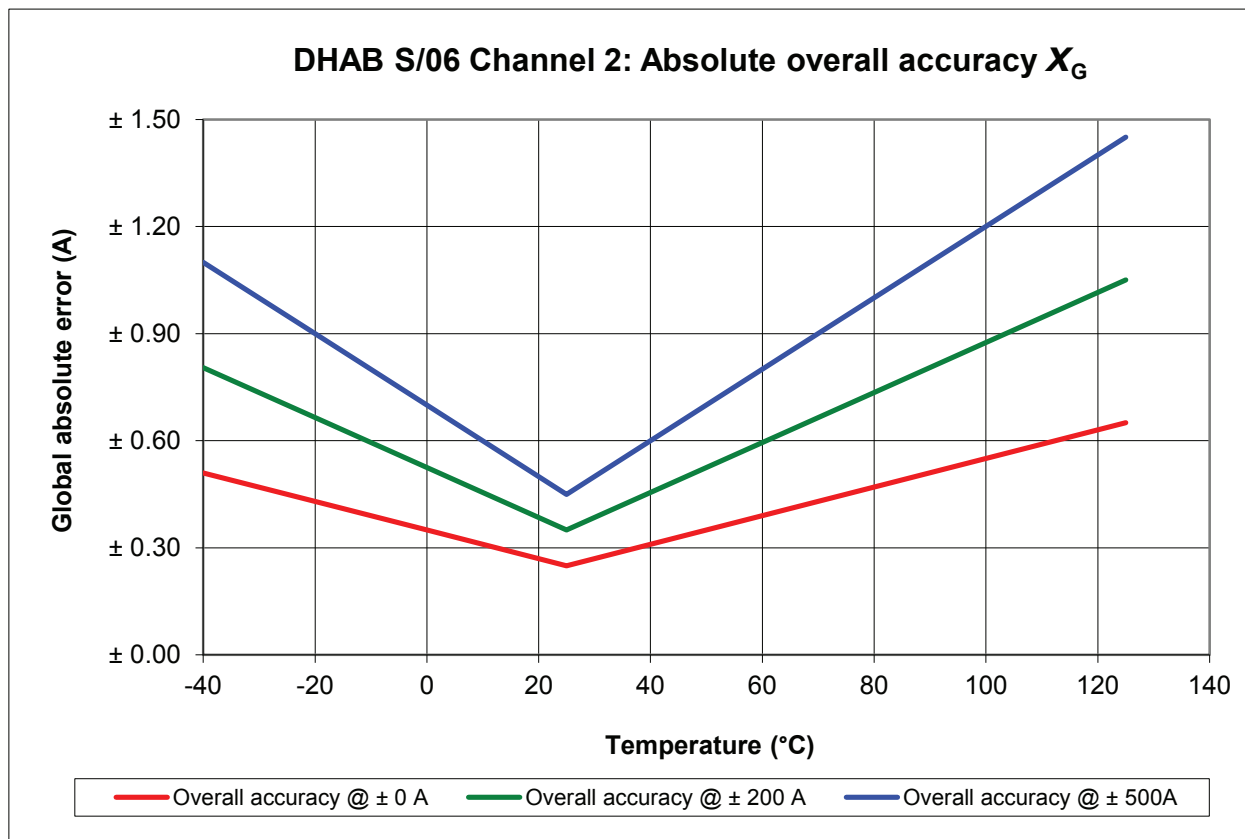
## PERFORMANCES PARAMETERS DEFINITIONS

### Primary current definition:



① Primary current nominal ($I_{PN}$)

② Primary current, measuring range ($I_{PM}$)
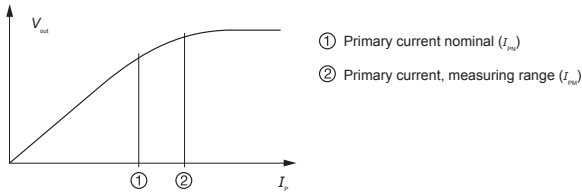
### Definition of typical, minimum and maximum values:

Minimum and maximum values for specified limiting and safety conditions have to be understood as such as values shown in "typical" graphs. On the other hand, measured values are part of a statistical distribution that can be specified by an interval with upper and lower limits and a probability for measured values to lie within this interval. Unless otherwise stated (e.g. "100 % tested"), the LEM definition for such intervals designated with "min" and "max" is that the probability for values of samples to lie in this interval is 99.73 %. For a normal (Gaussian) distribution, this corresponds to an interval between -3 sigma and +3 sigma. If "typical" values are not obviously mean or average values, those values are defined to delimit intervals with a probability of 68.27 %, corresponding to an interval between -sigma and +sigma for a normal distribution. Typical, maximal and minimal values are determined during the initial characterization of a product.

### Output noise voltage:

The output voltage noise is the result of the noise floor of the Hall elements and the linear amplifier.

### Magnetic offset:

The magnetic offset is the consequence of an over-current on the primary side. It's defined after an excursion of $I_{PN}$.

### Linearity:

The maximum positive or negative discrepancy with a reference straight line $V_{out} = f(I_P)$.
Unit: linearity (%) expressed with full scale of $I_{PN}$.

### Response time (delay time) $t_r$:

The time between the primary current signal ($I_{PN}$) and the output signal reach at 90 % of its final value.
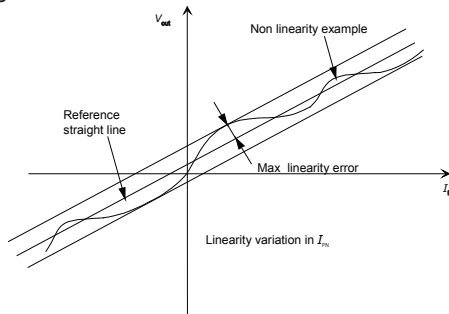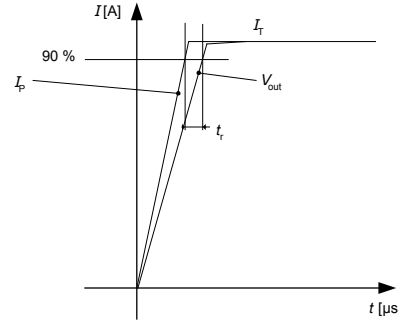


### Sensitivity:

The transducer's sensitivity $G$ is the slope of the straight line $V_{out} = f(I_P)$, it must establish the relation:

$$V_{out}(I_P) = U_C/5 \ (G \cdot I_P + V_o)$$

### Offset with temperature:



The error of the offset in the operating temperature is the variation of the offset in the temperature considered with the initial offset at 25 °C.
The offset variation $I_{OT}$ is a maximum variation the offset in the temperature range:

$$I_{OT} = I_{OE} \ max - I_{OE} \ min$$

The offset drift $TCI_{OEAV}$ is the $I_{OT}$ value divided by the temperature range.

### Sensitivity with temperature:

The error of the sensitivity in the operating temperature is the relative variation of sensitivity with the temperature considered with the initial offset at 25 °C.
The sensitivity variation $G_T$ is the maximum variation (in ppm or %) of the sensitivity in the temperature range:
$G_T$ = (Sensitivity max - Sensitivity min) / Sensitivity at 25 °C.
The sensitivity drift $TCG_{AV}$ is the $G_T$ value divided by the temperature range. Deeper and detailed info available is our LEM technical sales offices (www.lem.com).

### Offset voltage @ $I_P$ = 0 A:

The offset voltage is the output voltage when the primary current is zero. The ideal value of $V_O$ is $U_C/2$ at $U_C$ = 5 V. So, the difference of $V_O - U_C/2$ is called the total offset voltage error. This offset error can be attributed to the electrical offset (due to the resolution of the ASIC quiescent voltage trimming), the magnetic offset, the thermal drift and the thermal hysteresis. Deeper and detailed info available is our LEM technical sales offices (www.lem.com).

## Environmental test specifications:

| Name | Standard | Conditions |
|---|---|---|
| Low temperature storage test | ISO 16750-4<br>IEC 60068-2-1 | - 40 °C, 240 h; no power supply |
| Low temperature operation test | ISO 16750-4<br>IEC 60068-2-1 Ad | - 40 °C, 240 h; power ON |
| HTOE (high temperature operating endurance test) | ISO 16750-4<br>IEC 60068-2-2 Bd | 1000 h; power supply @ 125 °C |
| Powered thermal cycle endurance | IEC 60068-2-14 Nb | - 40 °C (20 min), + 125 °C (20 min), 600 cycles ; offset monitored |
| Thermal shock | IEC 60068-2-14 Na | - 40 °C (20 min soak) / 125 °C (20 min soak) , 1000 cycles, with connectors => 667 h (28 days) |
| High temperature and humidity endurance | JESD22-A101 | 1000 H; 85 °C / 85 % $HR$; power ON; Monitored once a day |
| Salt fog | IEC 60068-2-11 | 96 h @ 35 °C , 5 % of salt water solution, characterization before and after test only at 25 °C and $U_C$ nominal |
| **Mechanical tests** | | |
| Vibration in temperature | ISO 16750-3 § 4.1.2.4<br>mass suspended | Continuous monitoring: offset |
| Shocks | ISO 16750-3<br>§ 4.2 | Power ON. Profile 1 (500 m·s$^{-2}$; 11 ms) 10 shocks per axe Half sinusoidal pulse |
| Free Fall test | ISO 16750-3 | 3 axis, 2 directions by axis;1 sample per axis; 1 m. ; concrete floor |
| **EMC test** | | |
| B.C.I. (bulk current injection) | ISO 11452-4<br>Annex E.1.1, Table E.1 | From 1 to 400 MHz.<br>Level 1: 60 mA; Functional class: A<br>Level 2: 100 mA; Functional class: A<br>Level 4: 200 mA; Functional class: B |
| Radiated electromagnetic immunity | ISO 11452-2<br>GMW 3097 (04.2012)<br>table 12 p.21 (level 2) | Level: 100 V/m (rms); from 400 M to 1 GHz Functional class: A<br>Level: 70 V/m (rms) from 1 G to 2 GHz  Functional class: A |
| Emission | CISPR 25 | Table 9, Class 5 by default<br>Freq = 150 kHz to 2.5 GHz |
| E.S.D. not supplied | IEC 61000-4-2 +<br>ISO 10605<br>(07/2008) | Contact discharge: ± 4 kV & ± 8 kV<br>Air discharge: ± 15 kV<br>Functionnal class: A after reconnection<br>(150 pF, 330 Ω) |
| **Connector  tests** | | |
| Connector to connector engagement force | GMW 3191 § 4.11 | |
| Locked connector disengagement force | GMW 3191 § 4.13 | |
| Unlocked connector disengagement force | GMW 3191 § 4.14 | |

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