

Differential Current Sensor acc. to the standard UL2231 Ed.2.0



Date: 05.05.2023

K-No.: 26903

Customer: Standard type

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Description

- Fluxgate current sensor with toroidal core
- PCB mounting

Characteristics

- Excellent accuracy
- AEC-Q qualified components
- Switching open-collector outputs
- Compact design

Applications

- Mainly used for stationary and mobile applications:
- Charging systems acc. to UL2231

Patents: EP2571128 / US9397494 / CN103001175 // EP2813856

Electrical data – Ratings

| | | min. | typ. | max. | Unit |
|-----------------------------|--|------|--------|---------------------------------------|--------|
| I_P | Primary nominal RMS current (1phase / 3phase) | | 32 | 40 | A |
| $I_{\Delta N1}$ | Rated residual operating current 1 | | 5 | | mA rms |
| $I_{\Delta N2}$ | Rated residual operating current 2 | | 20 | | mA rms |
| $I_{\Delta N1, tolerance}$ | Trip tolerance 1 | 4 | 5 | 6 ⁽¹⁾ / 12 ⁽²⁾ | mA rms |
| $I_{\Delta N2, tolerance}$ | Trip tolerance 2 | 15 | | 20 ⁽¹⁾ / 50 ⁽²⁾ | mA rms |
| $S_{PWM-OUT}$ | Scaling factor of the rms component $I_{\Delta N1}$ (for monitoring purpose only!) | | 2 | | %/mA |
| $I_{\Delta R1,1/2}$ (Fig.1) | Recovery current level for $I_{\Delta N1}/I_{\Delta N2}$ (absolute value rms) | | 2 / 10 | | mA |

(1) f = DC to 1kHz (2) f = 1kHz to 2kHz

Accuracy – Dynamic performance data

| | | | | | |
|--------------------|--|------|---|------|-----|
| $I_{\Delta N,max}$ | Measuring range (peak) | -300 | | +300 | mA |
| X | Resolution (@ $I_{\Delta N}$, $\Theta_A = 25^\circ C$) | | < 0.2 | | mA |
| t_r (Fig.3) | Response time | | < $(20/I_{\Delta})^{1,43} - 10ms$ (According to UL2231-2 Ed. 2) | | |
| f_{BW} (Fig.4) | Frequency range | DC | | 2 | kHz |

General data

| | | | | | |
|-----------------------|--|-----|----------------|-----|--------|
| ϑ_A | Ambient operation temperature | -40 | | 85 | °C |
| $\vartheta_{Storage}$ | Ambient storage temperature ⁽³⁾ | -40 | | 85 | °C |
| m | Mass | | 32 | | g |
| V_{CC} | Supply voltage | 4.8 | 5 | 5.2 | V |
| I_{CC} | Supply current | 38 | | 45 | mA rms |
| $S_{clear, pp}$ | Clearance (primary to primary) | | 4.22 | | mm |
| $S_{creep, pp}$ | Creepage (primary to primary) | | 5.65 | | mm |
| $S_{clear, ps}$ | Clearance (primary to secondary) ⁽⁵⁾ | | 6.53 | | mm |
| $S_{creep, ps}$ | Creepage (primary to secondary) ⁽⁵⁾ | | 7.75 | | mm |
| FIT | EN/IEC 61709 / SN 29500 ⁽⁶⁾ (MIL-HDBK-217F) ⁽⁶⁾ | | 1529 (6349) | | fit |
| SW | Firmware | | D0462 V1.04 | | |

⁽³⁾ see M_sheet 3101; storage temperature inside cardboard packaging

⁽⁴⁾ Can only be achieved with the isolator; all values normative origin

⁽⁵⁾ The isolation coordination is according to: Reinforced insulation, Insulation material group 1, Pollution degree 3 and overvoltage category III. Values refer to nominal real clearance and creepage.

⁽⁶⁾ The results are valid under following conditions: 55°C mean component ambient temperature by continuous operation (8760h per year); Environment condition: ground mobile, no dust or harmful substances, according to IEC61709; Fit equals one failure per 10⁹ component hours.

General description of sensor function:

The Sensor is sensitive to AC and DC current and can be used for fault current detection in stationary applications. The Sensor detects AC fault currents according to UL2231-2 Ed.2. In the event of an AC fault current (5mA rms), PIN 3 will change it's state from a low level (GND) to high impedance state. In the event of an AC fault current (20mA rms), PINs 3 and 4 will change state from a low level (GND) to a high impedance state. Error conditions (e.g. an internal error) are signaled by PIN 1 (ERROR-OUT) which changes state to high impedance.

| Datum | Name | Index | Änderung |
|------------|------|-------|--|
| 05.05.2023 | SF | 84 | Sheet 4, table of final tests adjusted. Minor change |
| 11.10.2021 | ZB | 84 | Patents added on sheet 1. CN-21-290 |

| | | | |
|-----------------------|--------------|-----------|-----------------|
| Editor.: R&D-PD-NPI D | Designer: MB | MC-PM: BZ | Released by: SB |
|-----------------------|--------------|-----------|-----------------|

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Mechanical outline (mm): General tolerances DIN ISO 2768-c

○ Prüfmaß (test dimension)

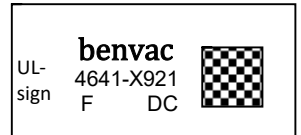
Beschriftung (marking)

DC = Date Code
F = Factory

Connections:

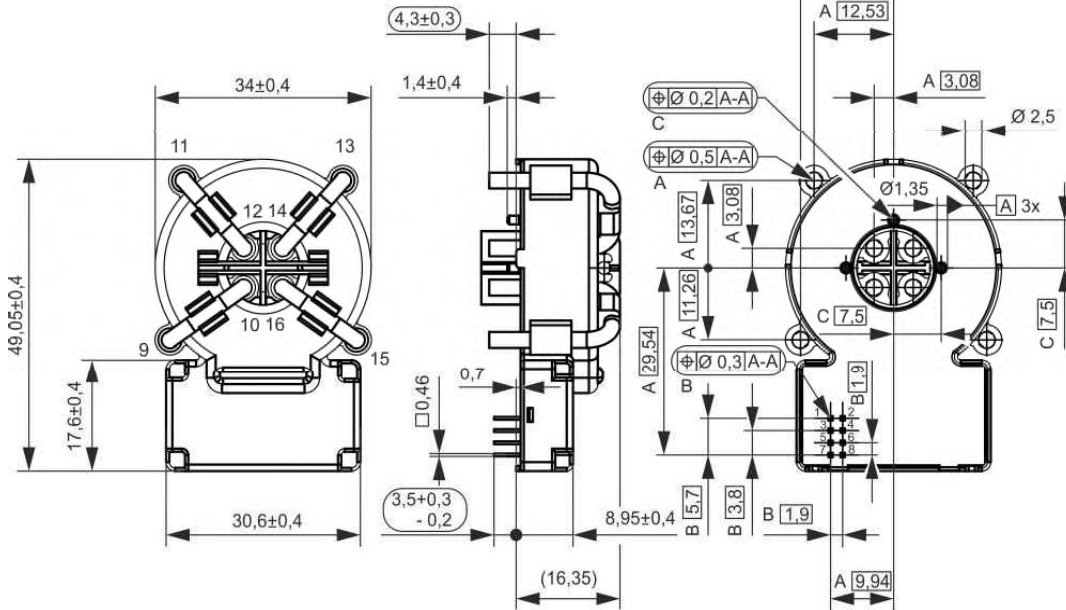
PIN no. 1-8: 0.46mm x 0.46mm
PIN no. 9-16: $\varnothing = 2.5\text{mm}$

Marking:



Content of Data-Matrix-Code is: benvac, 4641-X921, F, DC

Datecode Format: [YWW]
Example: J04: 2017, Week 4



PIN description:

| PIN no. | Description |
|---|---|
| PIN 1 → ERROR-OUT (open collector output) | If no system fault is detected, the output PIN 1 is a low level (GND). If a system fault is detected, PIN 1 is high impedance. In this case, PINs 3 and 4 will be set to a high impedance state (see tab. 1). |
| PIN 2 → TEST-IN (refer to Fig. 2) | A function test including an offset measurement (this value is stored in EEPROM for further calculation) is activated if this PIN is connected to GND for a period of 40ms to 1.2s. If the PIN is set to GND less than 40ms or more than 1.2s, no function test will be performed. Attention: During the functional test and offset measurement, no differential current may flow. To ensure high accuracy of the sensor this test should be activated at regular intervals (e.g. at startup, before measuring...). If a push-pull switch is used, the voltage range must be 0V...5V. |
| PIN 3 → X5-OUT (open collector output) | If the residual current is below 5mA rms and no system fault occurs the output on PIN 3 is a low level (GND). In any other case output PIN 3 is in a high impedance state. If PIN 4 is high impedance, PIN 3 will also be set to high impedance (see tab. 1). |
| PIN 4 → X20-OUT (open collector output) | If the residual current is below the 20mA rms and no system fault occurs the output on PIN 4 is a low level (GND). In any other case PINs 3 and 4 is in a high impedance state (see tab. 1). |
| PIN 5 → GND | Ground connection |
| PIN 6 → VCC | Positive supply voltage |
| PIN 7 → PWM-OUT | Acc. to the rms component of residual current a duty-cycle with $f=8\text{kHz}$ is generated. This is for monitoring purposes only and is not safety function! Refer to $S_{\text{PWM-OUT}} = 2\%/mA$ |
| PIN 8 → N.C. | Not connected |
| PIN 9 – 16 | For primary wires connection |

Editor.: R&D-PD-NPI D

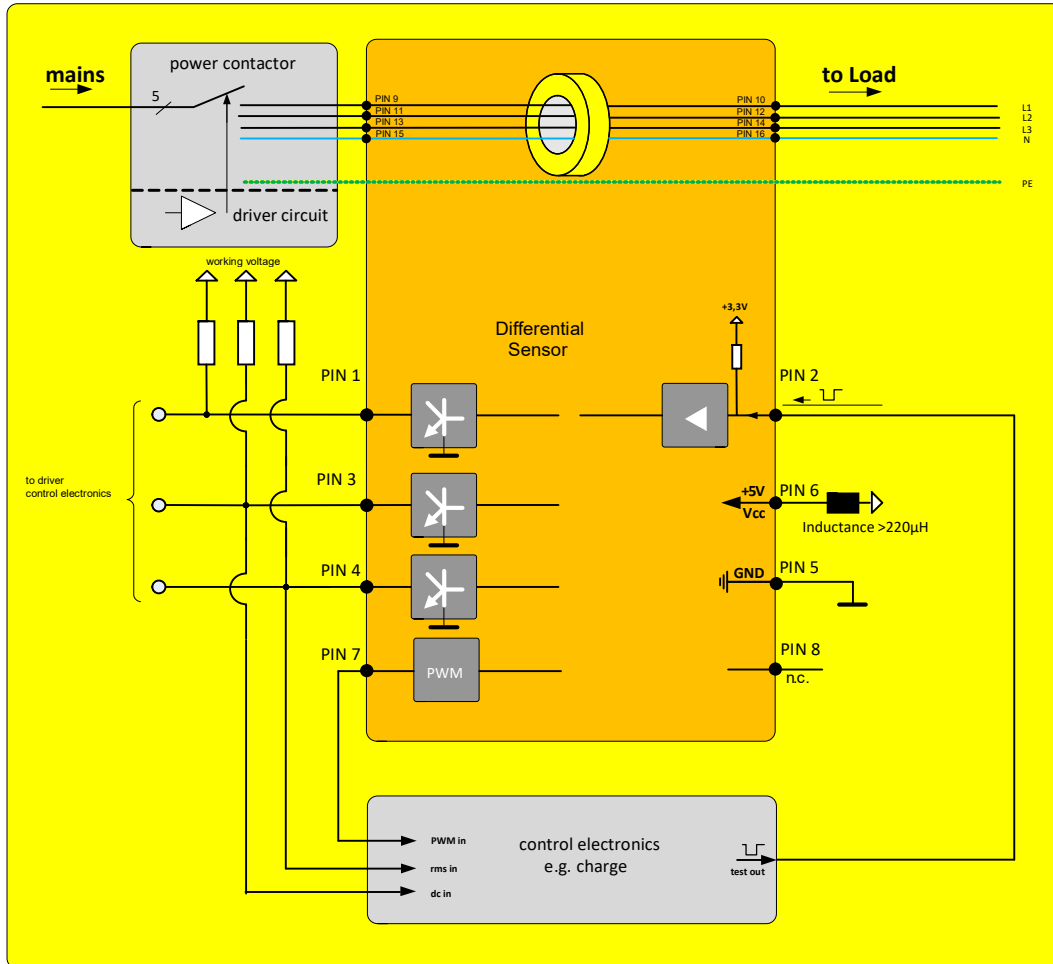
Designer: MB

MC-PM: BZ

Released by: SB



Typical application diagram:



Absolute maximum ratings⁽⁶⁾:

| | | | |
|---------------------|---|------|-----|
| V_{CE} | Collector-Emitter voltage (PINs 1, 3 and 4) | 40 | V |
| I_C | Collector current (PINs 1, 3 and 4) | 50 | mA |
| V_{CC} | Maximum supply voltage (without function) | -0.3 | 7 |
| U_{MAX} | Maximum rated voltage of primary conductors | 440 | V |
| $V_{TEST-IN, low}$ | TEST-IN Input Voltage, low level | 0 | 0.6 |
| $V_{TEST-IN, high}$ | TEST-IN Input Voltage, high level | 2.5 | 5 |

⁽⁶⁾Stresses above these ratings may cause permanent damage. Exposure to these conditions for extended periods may degrade device reliability. Functional operation of the device at these or any other conditions beyond those specified is not supported.

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Final Tests: (Measurements after temperature balance of the samples at room temperature, SC=significant characteristic)

| | | Min. | Max. | Unit |
|-----------------------|---|------|------|------|
| Vcc | Supply voltage | 4.9 | 5.1 | V |
| Icc | Supply current | 38.0 | 45.0 | mA |
| TEST-IN (SC) | TEST-IN voltage | 2.8 | 3.4 | V |
| X5-OUT (normal) | X5-OUT voltage | 0 | 0.6 | V |
| X20-OUT (normal) | X20-OUT voltage | 0 | 0.6 | V |
| ERROR-OUT (normal) | ERROR-OUT voltage | 0 | 0.6 | V |
| X5-OUT (activated) | X5-OUT voltage activated @5V, 1kΩ (pull-up)* | 4.9 | 5.1 | V |
| X20-OUT (activated) | X20-OUT voltage activated @5V, 1kΩ (pull-up)* | 4.9 | 5.1 | V |
| ERROR-OUT (activated) | ERROR-OUT voltage activated @5V, 1kΩ (pull-up)* | 4.9 | 5.1 | V |
| TC1 | Trip current 1 – X5 | 4.1 | 5.4 | mA |
| TC2 | Trip current 2 – X20 | 14 | 20 | mA |
| TC3 | Trip current 3 – X20 | 26 | 44 | mA |
| PWM-OUT (frequency) | PWM-OUT frequency | 7.8 | 8.2 | kHz |
| PWM-OUT (duty-cycle) | PWM-OUT duty-cycle @6mA DC | 11 | 13 | % |
| LV1 | Limit values of break time - X5-OUT@6mA, 60Hz | 0 | 700 | ms |
| LV2 | Limit values of break time – X5-OUT@6mA, 60Hz | 0 | 700 | ms |
| LV3 | Limit values of break time - X20-OUT@20mA, 60Hz | 0 | 1000 | ms |
| LV4 | Limit values of break time - X20-OUT@20mA, 60Hz | 0 | 100 | ms |

* the maximum values of collector-emitter voltage and current see “Absolute maximum ratings”

Product Tests:

| | | | |
|--------------|--|-----------------------------------|--------|
| | Acc. to VAC sheet M3238 Following tests differ from M3238: | passed | |
| | 4.5a: Damp heat, steady state. Duration: 1000 h | | |
| PD | IEC61000-4-1, EN60270,M3024 UPDE M3024, Partial discharge voltage (extinction) *acc. to table 24 | 1.5 | kV rms |
| ESD | Air- and contact discharge; U=±2000V, R=1500Ω, C=100pF Acc. to Human Body Model JESD22-A114 | ±2.0 | kV |
| | IEC61000-4-3 (Radiated, radio-frequency, electromagnetic field immunity) 20V/m 80MHz – 1GHz 80%AM 1kHz, recommend with the use of inductance of >220µH in series of Vcc input. | passed | |
| EMC | CISPR 14-1 (Immunity to conducted disturbances), recommend with the use of inductance of >220µH in series of Vcc input. | passed | |
| | IEC61000-6-4 (Emission standard for industrial environments, conducted disturbances) | Should be done in end application | |
| A , Φ | Amplitude and phase response over frequency 1% of I _{PN} or I _{Δn} | passed | |
| Impulse test | Monitoring of CS function during the current phase test 100A to 5kA | passed | |

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Regualification Tests: (replicated every year, Precondition acc. to M3238)

| | | | | |
|---------------------------------|-------|--|-----|--------|
| $\hat{U}_{W, \text{prim-sec}}$ | M3064 | Impulse test (1.2 μ s/50 μ s waveform) PIN 1-8 vs. PIN 9-16 5 pulse \rightarrow polarity +, 5 pulse \rightarrow polarity - | 5.5 | kV rms |
| $\hat{U}_{W, \text{prim-prim}}$ | M3064 | Impulse test (1.2 μ s/50 μ s waveform) PIN 9 vs. PIN 11, PIN 11 vs. PIN 13, PIN 13 vs. PIN 15, PIN 15 vs. PIN 9 5 pulse \rightarrow polarity +, 5 pulse \rightarrow polarity - | 4.0 | kV rms |
| U_d | M3014 | Test voltage, 60s PIN 1-8 vs. PIN 9-16 | 1.5 | kV rms |
| $U_{d, \text{prim-prim}}$ | M3014 | Test voltage between primary conductors, 5s PIN 9 vs. PIN 11, PIN 11 vs. PIN 13, PIN 13 vs. PIN 15, PIN 15 vs. PIN 9 | 1.5 | kV rms |
| U_{PDE} | M3024 | Partial discharge voltage (extinction) PIN 1-8 vs. PIN 9-16 *acc. to table 24 | 1.2 | kV rms |
| $U_{PD} \times 1.875$ | M3024 | Partial discharge voltage (extinction) PIN 1-8 vs. PIN 9-16 *acc. to table 24 | 1.5 | kV rms |

* IEC 61800-5-1:2007

Other instructions:

- Temperature of the primary conductor should not exceed 105°C.
- Housing and bobbin material UL-listed, flammability class 94V-0.
- Vcc during Test-In-Function must be at least 4.8V
- Fall- and rise-time of Vcc 2...50 μ s/V

Figures:

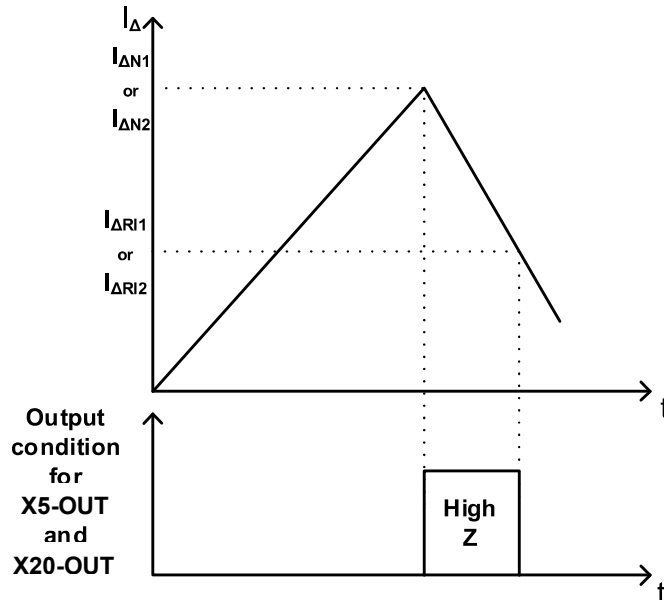
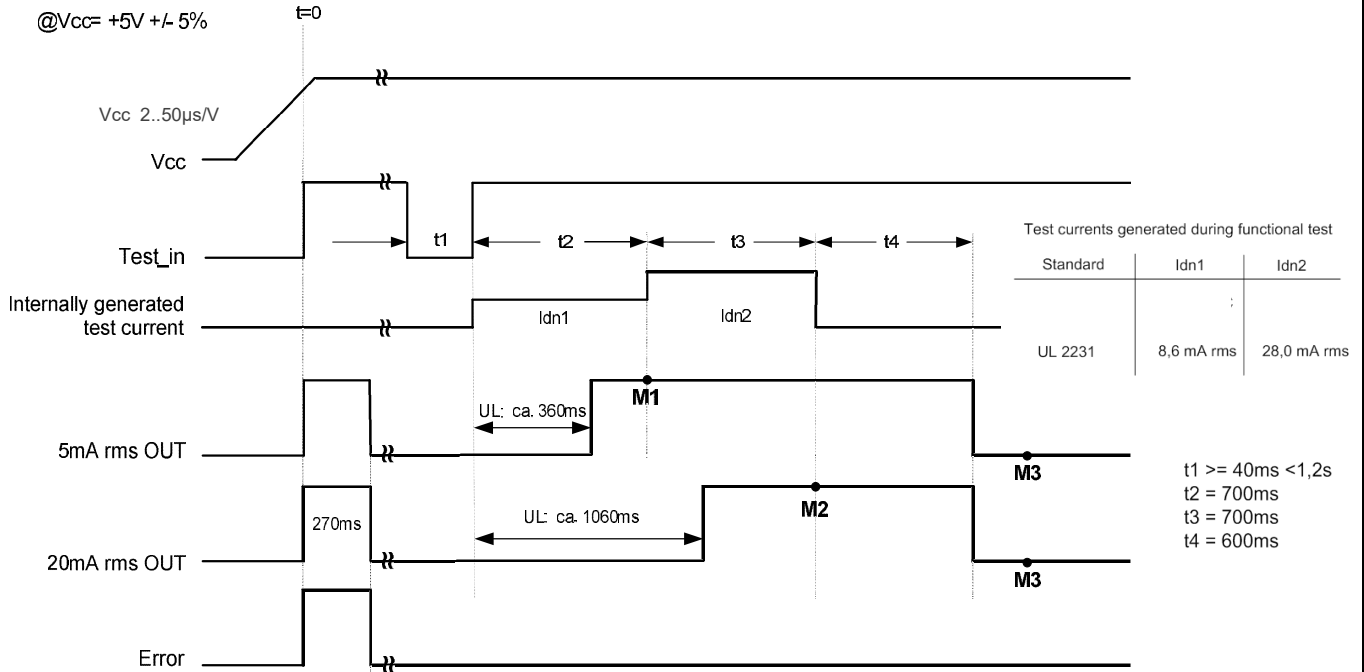


Fig. 1: Meaning of switching recovery level

If the trip-level $I_{\Delta N1}/I_{\Delta N2}$ is accomplished the outputs X5-OUT/X20-OUT will change their state from low-level (GND) to high impedance. Depending on the existence of the residual current I_{Δ} , the outputs X5-OUT/X20-OUT will remain in this state until I_{Δ} falls below the threshold $I_{\Delta R1}/I_{\Delta R2}$.



After activating the test sequence, the end product has to monitor the correct state of the switching outputs being used at the following points in time

- M1: check that 5mA rms OUT is disabled (latest time)
- M2: check that 20mA rms OUT is disabled
- M3: check that 20mA rms OUT resp. 5mA rms OUT is enabled

Fig. 2: Power-Up timing diagram

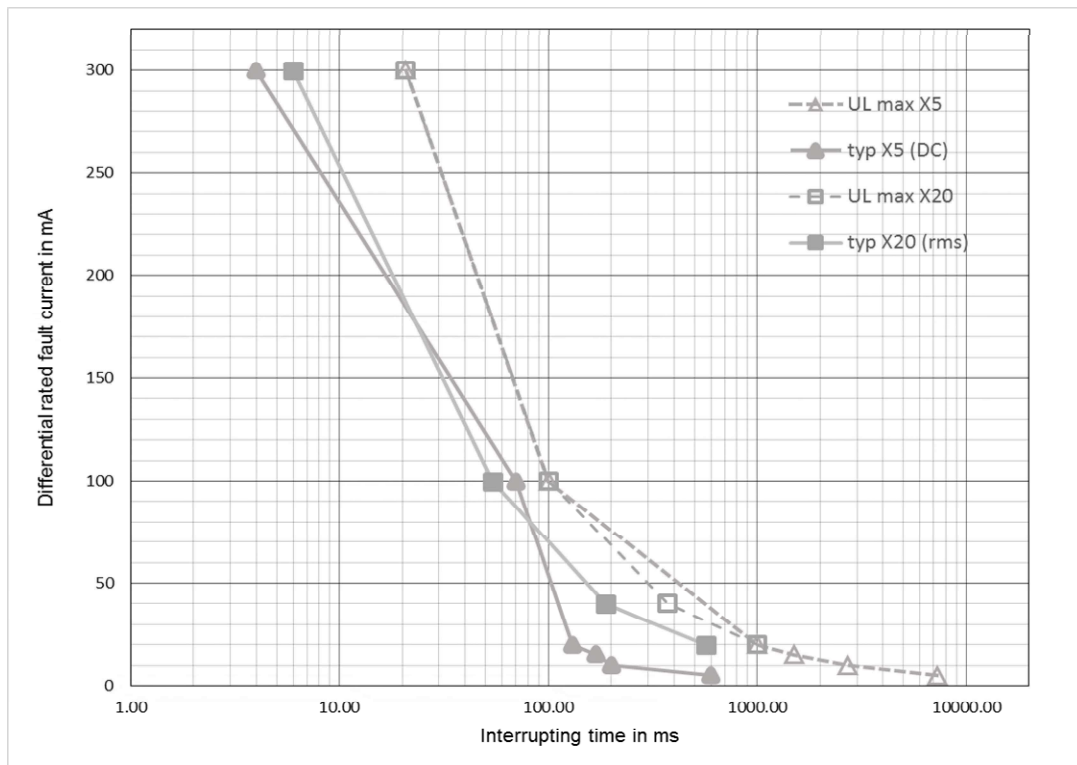


Fig. 3: Interrupting Time according to UL2231-2 Ed.2, page 30, fig. 6 and typical values of sensor

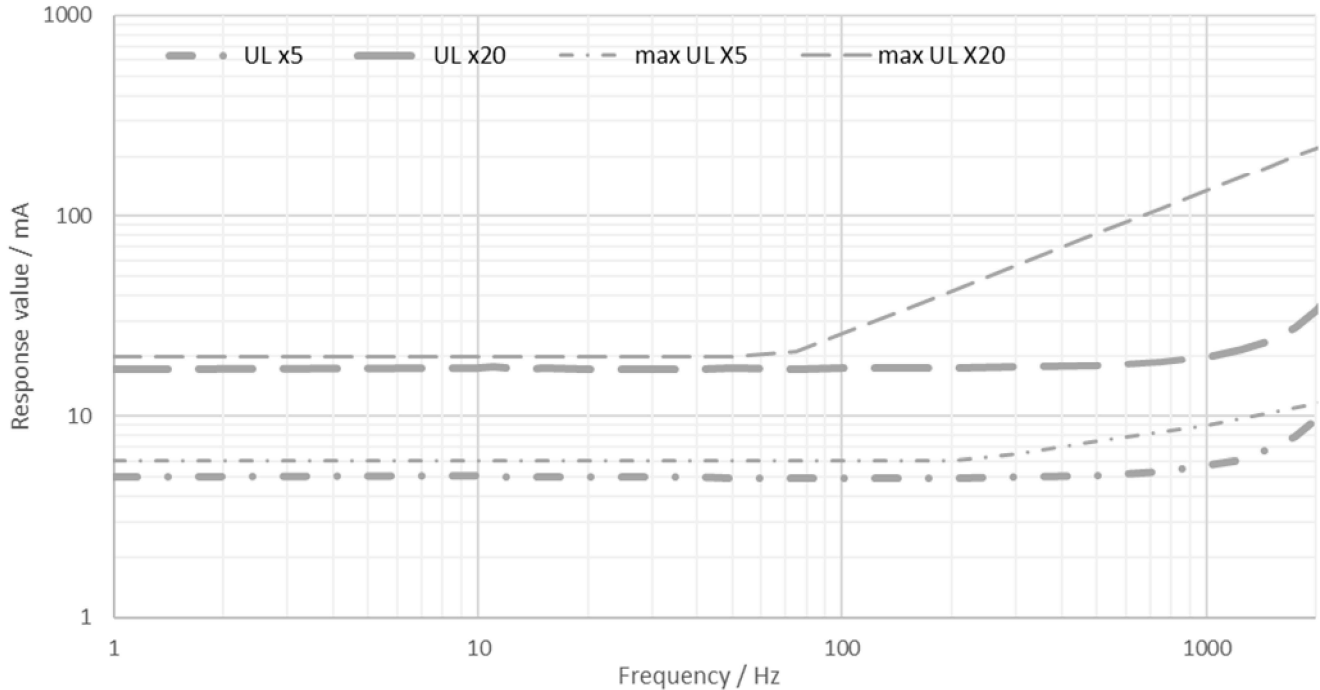


Fig. 4: Response value over frequency

| X5-OUT | X20-OUT | ERROR-OUT | State |
|---|----------------|----------------|---------------------------------|
| GND | GND | GND | Normal condition |
| High impedance | GND | GND | $I_{\Delta N1} \geq 5mA_{rms}$ |
| High impedance | High impedance | GND | $I_{\Delta N2} \geq 20mA_{rms}$ |
| High impedance | High impedance | High impedance | Error, system fault |
| All other conditions not mentioned in the table are not possible. If these conditions occur, the sensor is in unknown state and describes an Error. | | | |

Table 1: Possible output states