Differential Current Sensor for IC-CPD acc. to the standard UL2231

**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:
  - Personnel Protection Systems for EV acc. to UL2231

**Electrical data – Ratings**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>I_p</td>
<td>A</td>
</tr>
<tr>
<td>I_{ΔN1}</td>
<td>mA rms</td>
</tr>
<tr>
<td>I_{ΔN2}</td>
<td>mA rms</td>
</tr>
<tr>
<td>I_{ΔN1,tolerance}</td>
<td>mA rms</td>
</tr>
<tr>
<td>I_{ΔN2,tolerance}</td>
<td>mA rms</td>
</tr>
<tr>
<td>S_{PWM-OUT}</td>
<td>%/mA</td>
</tr>
<tr>
<td>I_{ΔN1,1/2} (Fig.1)</td>
<td>mA</td>
</tr>
<tr>
<td>I_{ΔR,l1/2} (Fig.1)</td>
<td>mA</td>
</tr>
</tbody>
</table>

**Accuracy – Dynamic performance data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>I_{ΔN,max}</td>
<td>mA</td>
</tr>
<tr>
<td>X</td>
<td>mA</td>
</tr>
<tr>
<td>l_{r} (Fig.3)</td>
<td>ms</td>
</tr>
<tr>
<td>f_{aw} (Fig. 4)</td>
<td>kHz</td>
</tr>
</tbody>
</table>

**General data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>S_A</td>
<td>°C</td>
</tr>
<tr>
<td>S_{Storage}</td>
<td>°C</td>
</tr>
<tr>
<td>m</td>
<td>g</td>
</tr>
<tr>
<td>V_{CC}</td>
<td>V</td>
</tr>
<tr>
<td>I_{CC}</td>
<td>mA</td>
</tr>
<tr>
<td>S_{clear}</td>
<td></td>
</tr>
<tr>
<td>S_{creep}</td>
<td></td>
</tr>
</tbody>
</table>

**General description of sensor function:**

The Sensor is sensitive to AC and DC current and can be used for fault current detection in IC-CPD applications. The Sensor detects fault currents according to UL2231-2 Ed.2. In the event of a 5mA rms fault current, PIN 3 will change its state from a low level (GND) to high impedance state. In the event of an 20mA rms fault current, 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.
### PIN description:

<table>
<thead>
<tr>
<th>PIN No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIN 1 → ERROR-OUT (open collector output)</td>
<td>If no system fault is detected, the output PIN 1 is at low level (GND). If a system fault is detected, PIN 1 is at high impedance state. In this case, PINs 3 and 4 will be set to a high impedance state too (see tab.1).</td>
</tr>
<tr>
<td>PIN 2 → TEST-IN (refer to Fig. 2)</td>
<td>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 shall flow. To ensure high accuracy of the sensor this test shall 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.</td>
</tr>
<tr>
<td>PIN 3 → X5-OUT (open collector output)</td>
<td>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 a high impedance state (see tab. 1).</td>
</tr>
<tr>
<td>PIN 4 → X20-OUT (open collector output)</td>
<td>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 are in a high impedance state (see tab. 1).</td>
</tr>
<tr>
<td>PIN 5 → GND</td>
<td>Ground connection</td>
</tr>
<tr>
<td>PIN 6 → VCC</td>
<td>Positive supply voltage</td>
</tr>
<tr>
<td>PIN 7 → PWM-OUT</td>
<td>Acc. to the DC component of residual current a duty-cycle with f=8kHz is generated. This is for monitoring purposes only and shall not be used to switch the power relay. Refer to SPWM-OUT = 2%/mA</td>
</tr>
<tr>
<td>PIN 8 → N.C.</td>
<td>Not connected</td>
</tr>
</tbody>
</table>
Typical application diagram:

Absolute maximum Ratings:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CE}$</td>
<td>40 V</td>
</tr>
<tr>
<td>$I_C$</td>
<td>50 mA</td>
</tr>
<tr>
<td>$V_{CC}$</td>
<td>-0.3 V</td>
</tr>
<tr>
<td>$U_{MAX}$</td>
<td>250 V</td>
</tr>
<tr>
<td>$V_{TEST-IN, low}$</td>
<td>0 V</td>
</tr>
<tr>
<td>$V_{TEST-IN, high}$</td>
<td>2.5 V</td>
</tr>
</tbody>
</table>

(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.
## Differential Current Sensor for IC-CPD

acc. to the standard UL2231

<table>
<thead>
<tr>
<th>K-No.: 26756</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer: Standard type</td>
</tr>
<tr>
<td>Customers Part no: RCMB 121-2</td>
</tr>
<tr>
<td>Page 4 of 7</td>
</tr>
</tbody>
</table>

### Specification

**Item no.:** T60404-N4641-X901

**Date:** 11.10.2021

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### Final Tests:

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

<table>
<thead>
<tr>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vcc</td>
<td>4.9</td>
<td>5.1</td>
</tr>
<tr>
<td>Icc</td>
<td>38.0</td>
<td>45.0</td>
</tr>
<tr>
<td>TEST-IN (SC)</td>
<td>TEST-IN voltage</td>
<td>2.8</td>
</tr>
<tr>
<td>X5-OUT (normal)</td>
<td>X5-OUT voltage</td>
<td>0</td>
</tr>
<tr>
<td>X20-OUT (normal)</td>
<td>X20-OUT voltage</td>
<td>0</td>
</tr>
<tr>
<td>ERROR-OUT (normal)</td>
<td>ERROR-OUT voltage</td>
<td>0</td>
</tr>
<tr>
<td>X5-OUT (activated)</td>
<td>X5-OUT voltage activated @5V, 1kΩ (pull-up)*</td>
<td>4.9</td>
</tr>
<tr>
<td>X20-OUT (activated)</td>
<td>X20-OUT voltage activated @5V, 1kΩ (pull-up)*</td>
<td>4.9</td>
</tr>
<tr>
<td>ERROR-OUT (activated)</td>
<td>ERROR-OUT voltage activated @5V, 1kΩ (pull-up)*</td>
<td>4.9</td>
</tr>
<tr>
<td>TC1</td>
<td>Trip current 1 – X5</td>
<td>4.1</td>
</tr>
<tr>
<td>TC2</td>
<td>Trip current 2 – X20</td>
<td>14</td>
</tr>
<tr>
<td>PWM-OUT (frequency)</td>
<td>PWM-OUT frequency</td>
<td>7.8</td>
</tr>
<tr>
<td>PWM-OUT (duty-cycle)</td>
<td>PWM-OUT duty-cycle @6mA DC</td>
<td>11</td>
</tr>
<tr>
<td>LV1</td>
<td>Limit values of break time - X5-OUT@6mA, 60Hz</td>
<td>0</td>
</tr>
<tr>
<td>LV2</td>
<td>Limit values of break time - X5-OUT@30mA, 60Hz</td>
<td>0</td>
</tr>
<tr>
<td>LV3</td>
<td>Limit values of break time - X20-OUT@20mA, 60Hz</td>
<td>0</td>
</tr>
<tr>
<td>LV4</td>
<td>Limit values of break time - X20-OUT@100mA, 60Hz</td>
<td>0</td>
</tr>
</tbody>
</table>

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

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### Product Tests:

- Acc. to customer specification  
  passed
- Following tests differ from M3238:
  - 3.4a: Rapid change of temperature for 300 cycles  
  - 4.5a: Damp heat, steady state. Duration: 1000 h  
  passed
- **PD**
  - IEC61000-4-1, EN60270,M3024
  - UPDE M3024, Partial discharge voltage (extinction) *acc. to table 24  
  passed
  - 1.5 kV rms
- **ESD**
  - Air- and contact discharge;
  - $U=\pm2000\text{V}, \ R=1500\Omega, \ C=100\text{pF}$
  - Acc. to Human Body Model JESD22-A114  
  passed
  - $\pm2.0$ kV
- **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)  
  passed
  - 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
Requalification Tests: (replicated every year, Precondition acc. to M3238)

<table>
<thead>
<tr>
<th>Test Description</th>
<th>K-No.</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impulse test (1.2µs/50µs waveform)</td>
<td>M3064</td>
<td>5.5 kV</td>
</tr>
<tr>
<td>PIN 1-8 vs. insulated primary wire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 pulse polarity +, 5 pulse polarity -</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test voltage, 60s</td>
<td>M3014</td>
<td>1.5 kV rms</td>
</tr>
<tr>
<td>PIN 1-8 vs. insulated primary wire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial discharge voltage (extinction)</td>
<td>M3024</td>
<td>1.2 kV rms</td>
</tr>
<tr>
<td>PIN 1-8 vs. insulated primary wire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*acc. to table 24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial discharge voltage (extinction)</td>
<td>M3024</td>
<td>1.5 kV rms</td>
</tr>
<tr>
<td>PIN 1-8 vs. insulated primary wire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*acc. to table 24</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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 test must be in rated range.
- Fall- and rise-time of Vcc: t > 10µs/V
- Further standards UL 2231 E-file No. 488116, category FFUQ2 / FFUQ8

Figures:

Fig. 1: Meaning of switching recovery level

If the trip-level $I_{AN1}/I_{AN2}$ is accomplished the corresponding output X5-OUT/X20-OUT will change its state from low-level (GND) to high impedance. Depending on the existence of the differential current $I_\Delta$, the outputs X5-OUT/X20-OUT will remain in their states until $I_\Delta$ is below the recovery threshold $I_{AR1}/I_{AR2}$. 
@Vcc= +5V +/- 5%

Test_in

Internally generated test current

9mA rms OUT

20mA rms OUT

Error

Test currents generated during functional test

<table>
<thead>
<tr>
<th>Standard</th>
<th>Idt1</th>
<th>Idt2</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL 2231</td>
<td>8.8 mA rms</td>
<td>28.0 mA rms</td>
</tr>
</tbody>
</table>

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

![Graph showing Interrupting Time according to UL2231-2 Ed.2](image)

Fig. 4: UL2231 response value over frequency

<table>
<thead>
<tr>
<th>X5-OUT</th>
<th>X20-OUT</th>
<th>ERROR-OUT</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>Normal condition</td>
</tr>
<tr>
<td>High impedance</td>
<td>GND</td>
<td>GND</td>
<td>$I_{AN1} \geq 5mA_{rms}$</td>
</tr>
<tr>
<td>High impedance</td>
<td>High impedance</td>
<td>GND</td>
<td>$I_{AN2} \geq 20mA_{rms}$</td>
</tr>
</tbody>
</table>

All other conditions not mentioned in the table are not possible. If these conditions occur, the sensor is an unknown state and describes an Error.

**Table 1: Possible output states**