



### Introduction

The CAB transducer family is specially designed for the DC current measurement of the battery packs in electric and hybrid vehicles. The CAB 1500 Family transducer is equipped with electronic mechanisms and software that guarantee a level of reliability that is required by the security concepts of battery management systems.

### Features

- Fluxgate transducer technology
- Busbar mounting or panel mounting
- Unipolar +12 V battery power supply
- Output signal: High speed CAN (500 kpbs).

|                  | CAN Resistor Termination | Casing Version | Other Comments |
|------------------|--------------------------|----------------|----------------|
| CAB-SF 1500-0014 | 120 Ω                    | Bus bar        |                |

### Automotive applications

The CAB 1500 Family is designed to run in a vehicle battery pack or in a battery disconnect unit and cannot be used in an environment exposed to water projections or gravel projections. The CAB-SF 1500 is compliant with Functional Safety standard ISO 26262.

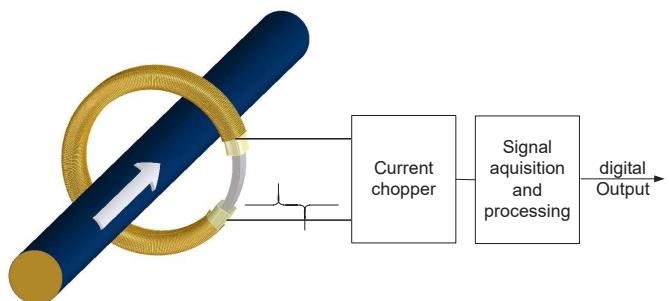
The test items used to validate the product are described at the end of the document.

### Principle of Fluxgate Transducers

A low-frequency fluxgate transducer is made of a wound core which saturates under low induction.

A current chopper switches the winding's current to saturate the magnetic core alternatively at  $\pm B_{max}$  with a fixed frequency. Fluxgate transducers use the change of the saturation's point symmetry to measure the primary current.

Due to the principle of switching the current, all offsets (electric and magnetic) are cancelled.



### Special features

- Connector type: Tyco AMP 1473672-1
- Configurable CAN speed
- Configurable CAN ID.

### Advantages

- Low offset
- Total error 0.5 % over temperature range:  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$
- Full galvanic separation
- Compatible with 800 V applications following IEC60664-1 standard.

## Safety



### Caution

If the device is used in a way that is not specified by the manufacturer, the protection provided by the device may be compromised. Always inspect the electronics unit and connecting cable before using this product and do not use it if damaged. Mounting assembly shall guarantee the maximum primary conductor temperature, fulfill clearance and creepage distance, minimize electric and magnetic coupling, and unless otherwise specified can be mounted in any orientation.



### Caution, risk of electrical shock

This transducer must be used in limited-energy secondary circuits SELV according to IEC 61010-1, in electric/electronic equipment with respect to applicable standards and safety requirements in accordance with the manufacturer's operating specifications.

Use caution during installation and use of this product; certain parts of the module can carry hazardous voltages and high currents (e.g. power supply, primary conductor).

Ignoring this warning can lead to injury and/or cause serious damage.

This transducer is a build-in device, whose hazardous live parts must be inaccessible after installation.

This transducer must be mounted in a suitable end-enclosure.

Besides make sure to have a distance of minimum 30 mm between the primary terminals of the transducer and other neighboring components.

This transducer is a built-in device, not intended to be cleaned with any product. Nevertheless if the user must implement cleaning or washing process, validation of the cleaning program has to be done by himself.



### ESD susceptibility

The product is susceptible to be damaged from an ESD event and the personnel should be grounded when handling it.

Do not dispose of this product as unsorted municipal waste. Contact a qualified recycler for disposal.

Although LEM applies utmost care to facilitate compliance of end products with applicable regulations during LEM product design, use of this part may need additional measures on the application side for compliance with regulations regarding EMC and protection against electric shock. Therefore LEM cannot be held liable for any potential hazards, damages, injuries or loss of life resulting from the use of this product.



Underwriters Laboratory Inc. recognized component

## UL 508: Ratings and assumptions of certification

File # E189713 Volume: 2 Section: 12

### Standards

CSA C22.2 NO. 14-10 INDUSTRIAL CONTROL EQUIPMENT - Edition 13  
 UL 508 STANDARD FOR INDUSTRIAL CONTROL EQUIPMENT - Edition 18

### Ratings

| Parameter                       | Symbol    | Unit    | Value  |
|---------------------------------|-----------|---------|--------|
| Primary involved potential      |           | V AC/DC | 600    |
| Max surrounding air temperature | $T_A$     | °C      | 85     |
| Primary current                 | $I_P$     | A       | 500    |
| Secondary supply voltage        | $U_c$     | V DC    | 18     |
| Output voltage                  | $U_{out}$ | V       | 0 to 5 |

### Conditions of acceptability

When installed in the end-use equipment, consideration shall be given to the following:

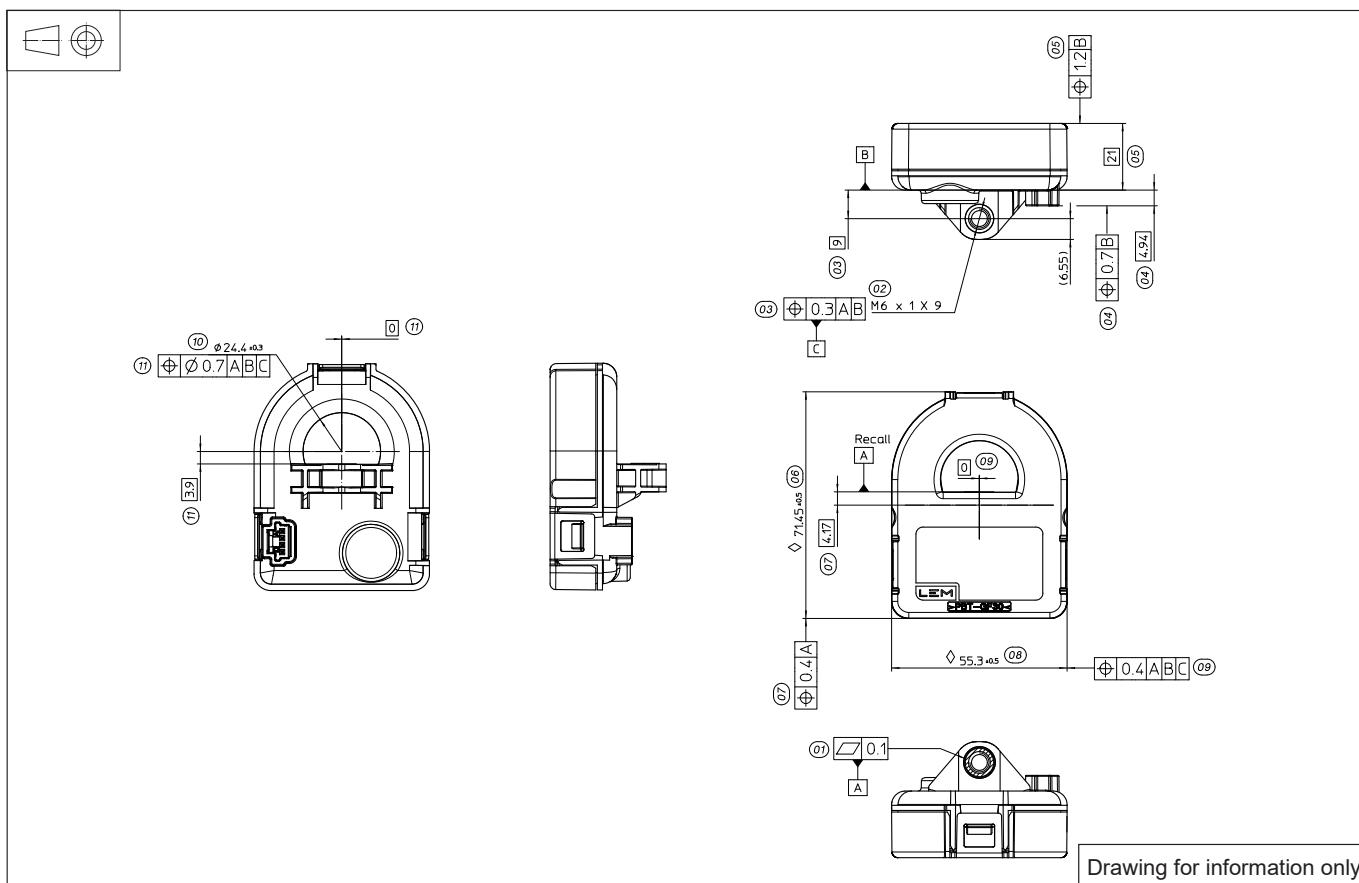
- 1 - *These products must be mounted in a suitable end-use enclosure.*
- 2 - *The secondary circuit pin terminals have not been evaluated for field wiring.*
- 3 - *Low voltage control circuit shall be supplied by an isolated source of supply.*
- 4 - *These products shall be used in a pollution degree 2 environments or better.*
- 5 - *Primary feeder of the devices shall be connected after an overvoltage device or system which has been evaluated by the Standard for Transient Voltage Surge Suppressors, UL 1449 with a maximum clamping voltage of 6 kV.*

### Marking

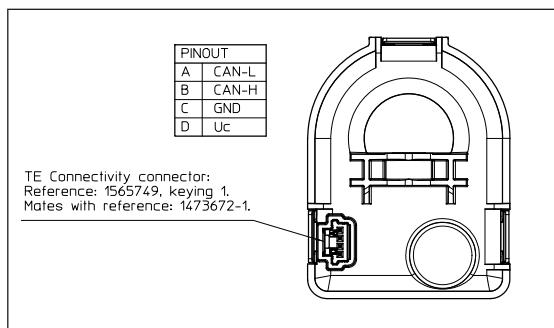
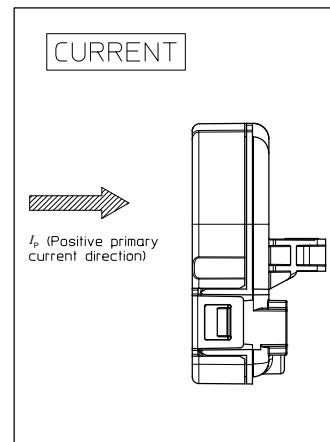
Only those products bearing the UR Mark should be considered to be Listed or Recognized and covered under UL's Follow-Up Service. Always look for the Mark on the product.

**Dimensions** (in mm. General geometrical tolerance  15; General linear tolerance  $\pm 0.5$ )

## Busbar version

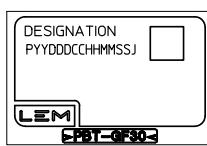


Drawing for information only

**Connector pin out**

**Primary current direction as below:**

**Weight and Recommended screwing torque instruction**
**Busbar Version**

- Weight: 94 g  $\pm 5$  %
- Recommended screwing torque instruction:
  - transducer shall be fixed with M6 fastener
  - tightening torque:
    - screw grade 6.8: 6.6 N·m
    - screw grade 8.8: 7.7 N·m

**Laser Marking**

| Designation     | Datacode  | 2D matrix content             | Text marking area   |
|-----------------|---|-------------------------------|---|
| CAB-SF 1500-014 | P = Production center ID<br>YY = Last two digit of the year<br>DDD = Day number of the year<br>CC = Machine ID<br>HH = Hour<br>MM = Minute<br>SS = Second<br>J = Machine jig ID | PYYDDDCCHHMMSSJ90.D9.65.014.0 |  |

**Absolute ratings (not operating)**

| Parameter                          | Symbol      | Unit | Specification | Conditions           |
|------------------------------------|-------------|------|---------------|----------------------|
| Over-voltage                       | $U_c$       | V    | 24            | 1 min                |
| Reverse polarity                   | $U_c$       | V    | -18           | 1 min                |
| Minimum supply voltage             | $U_{c\min}$ | V    | 6             | continuous           |
| Maximum supply voltage             | $U_{c\max}$ | V    | 18            | continuous           |
| Ambient storage temperature        | $T_{A,st}$  | °C   | -40 /+105     |                      |
| Creepage distance                  | $d_{Cp}$    | mm   | 12.5          |                      |
| Clearance                          | $d_{Cl}$    | mm   | 12.5          |                      |
| RMS voltage for AC insulation test | $U_d$       | kV   | 3.5           | 50 Hz, 1 min         |
| Insulation resistance              | $R_{INS}$   | MΩ   | 500           | 1000 V - ISO 16750-2 |
| IP Level                           |             |      | IP41          |                      |

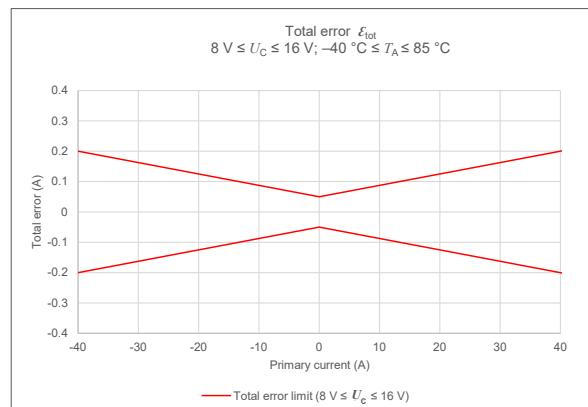
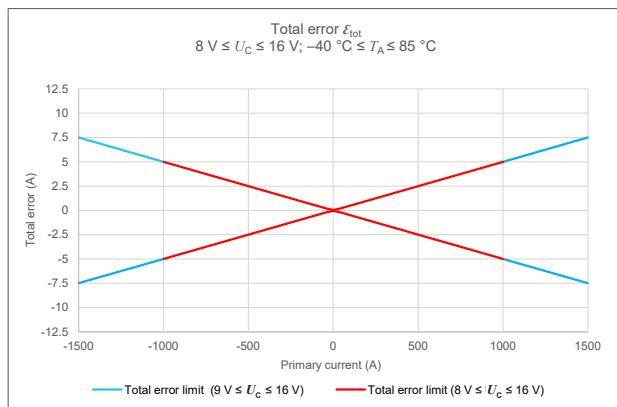
**Characteristics in nominal range**

| Parameter  | Symbol              | Unit | Specification |         |      | Conditions  |
|--|---------------------|------|---------------|---------|------|---|
|  |                     |      | Min           | Typical | Max  |   |
| <b>Electrical Data</b>                                     |                     |      |               |         |      |   |
| Supply voltage   | $U_c$               | V    | 9             | 13.5    | 16   | -1500 A $\leq I_p \leq$ 1500 A  |
|  |                     |      | 8             | 13.5    | 16   | -1000 A $\leq I_p \leq$ 1000 A  |
| RMS current consumption @ $I_p = 0$ A <sup>1)</sup>        | $I_c$               | mA   | 50            | 70      | 100  | 8 V $< U_c <$ 16 V, CAN acknowledge   |
| RMS current consumption @ $\pm I_p = 1000$ A <sup>1)</sup> | $I_c$               | mA   | 350           | 400     | 1000 | 8 V $< U_c <$ 16 V, CAN acknowledge   |
| RMS current consumption @ $\pm I_p = 1500$ A <sup>1)</sup> | $I_c$               | mA   | 430           | 500     | 1400 | 9 V $< U_c <$ 16 V, CAN acknowledge   |
| Ambient operating temperature                              | $T_A$               | °C   | -40           |         | +85  |   |
| <b>Performance Data</b>                                    |                     |      |               |         |      |   |
| Primary nominal DC current                                 | $I_{PN}$            | A    | -1500         |         | 1500 |   |
| CAN signal 'CSM_BAT_CURRENT' clamping value                |                     | A    | -1550         |         | 1550 | $1550 \text{ A} <  I_p  < \hat{I}_{P\max}$  |
| Primary withstand peak current (maximum)                   | $\hat{I}_{P\max}$   | A    |               | 1700    |      |   |
| Overload recovery time                                     | $t_s$               | ms   |               | 10      |      | When $I_p$ goes back under 1550 A   |
| Frequency bandwidth  | $BW$                | Hz   |               | 20      |      | With Periodic CAN message @ 10 ms   |
| Start-up time  | $t_{start}$         | ms   |               | 150     |      | Times after enabled timer/fluxgate, excluded 20 ms additional times for HW initialization/check   |
| <b>Analog measurement Channel</b>                          |                     |      |               |         |      |   |
| Linearity error  | $\varepsilon_L$     | %    |               | ±0.1    |      | At room temperature   |
| Total error:<br>[-1500 A, +1500 A]                         | $\varepsilon_{tot}$ | %    |               | ±0.5    |      | Over full temperature range<br>Performances are considered with average value over 20 CAN frames (200 ms);<br>Performances with average value over 10 CAN frames (100 ms), refer to Application Notes |
| Output noise   |                     | mA   |               | ±50     |      | With Periodic CAN message @ 10 ms. Peak to peak value. No averaging   |
| <b>Digital measurement channel</b>                         |                     |      |               |         |      |   |
| Total error  | $\varepsilon_{tot}$ | %    |               | ±7      |      | With a minimum of ±2 A<br>Typical value after ageing<br>Performances are considered with average value over 20 CAN frames (200 ms)  |

Note: <sup>1)</sup> Input current peak value refer to Application Notes .

## Total error

Analog Channel - Total error from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ :  
 Performances are considered with average value over 20 CAN frames (200 ms)



| $I_{\text{P}}$<br>(A) | Total error<br>( $9 \text{ V} \leq U_{\text{C}} \leq 16 \text{ V}; -40^{\circ}\text{C} \leq T_{\text{A}} \leq 85^{\circ}\text{C}$ ) |           |
|-----------------------|---|-----------|
|                       | (A)   | (%)       |
| -1500                 | $\pm 7.5$   | $\pm 0.5$ |
| -40                   | $\pm 0.2$   | $\pm 0.5$ |
| 0                     | $\pm 0.05$  | -         |
| 40                    | $\pm 0.2$   | $\pm 0.5$ |
| 1500                  | $\pm 7.5$   | $\pm 0.5$ |

| $I_{\text{P}}$<br>(A) | Total error<br>( $8 \text{ V} \leq U_{\text{C}} \leq 16 \text{ V}; -40^{\circ}\text{C} \leq T_{\text{A}} \leq 85^{\circ}\text{C}$ ) |           |
|-----------------------|---|-----------|
|                       | (A)   | (%)       |
| -1000                 | $\pm 5$   | $\pm 0.5$ |
| -40                   | $\pm 0.2$   | $\pm 0.5$ |
| 0                     | $\pm 0.05$  | -         |
| 40                    | $\pm 0.2$   | $\pm 0.5$ |
| 1000                  | $\pm 5$   | $\pm 0.5$ |

## External Magnetic Field Influences

The CAB 1500 Family delivers accurate current measurement. However, to ensure its proper functioning and to ensure the current measurement accuracy, it is necessary to comply with rules for setting up in the BMS environment. Thus, some conditions must be respected during the design of the environment of the transducer:

- Primary busbar centering
- Busbar shape
- Contactors position

LEM's recommendations can be found in the application notes available on request. Please contact LEM support team to ensure that your busbars design fits with LEM's design guideline.

## Current Ripple Influences

Current ripples on the high voltage DC lines could be induced during power conversion from devices like DC/DC, inverter, on-board charger, and so on.

Current ripples not only negatively impact on the health of li-ion batteries, but also could cause malfunctions of the CAB transducer. The failure mode can manifest itself as a disturbed current measurement due to aliasing effect, leading to internal error when the threshold is exceeded. The malfunctions can be automatically recovered when the ripple current disappears.

Normally the ripple current should be measured and minimized during vehicle system design and development. For proper function of the CAB transducer, the acceptable maximum value of the ripple current should be checked. Please contact LEM support team on the reference values, LEM's recommendations can be found in the application notes available on request.

## CAN output specification

- CAN protocol 2.0B
- Bit order: big endian (Motorola)
- CAN oscillator tolerance: 0.27 %
- No sleep mode capability
- CAB-SF 1500-014 integrates 120 Ohm termination resistor inside transducer
- Instruction for CAN modification can be found in the application notes available on request

## CAB-SF 1500 CAN message table

- CAB1500\_  $I_p$  message overview.  
Default frame ID: 0x3C2; transmit period: 10 ms.

| CAN Frame Content |                        |               |            |     |                        |     |                          |                         |
|-------------------|------------------------|---------------|------------|-----|------------------------|-----|--------------------------|-------------------------|
|                   | 7                      | 6             | 5          | 4   | 3                      | 2   | 1                        | 0                       |
| BYTE 0            | Sequence Counter $I_p$ |               |            |     | Status<br>Power Supply |     | Status<br>Internal Error | SafetyGoal<br>Violation |
|                   | MSB                    |               |            | LSB | MSB                    | LSB |                          |                         |
| BYTE 1            | Analog Current         |               |            |     |                        |     |                          |                         |
|                   | MSB                    |               |            |     |                        |     |                          |                         |
| BYTE 2            | Analog Current         |               |            |     |                        |     |                          |                         |
|                   |                        |               |            |     |                        |     |                          |                         |
| BYTE 3            | Analog Current         |               |            |     |                        |     |                          |                         |
|                   |                        |               |            |     |                        |     |                          | LSB                     |
| BYTE 4            | Digital Current        |               |            |     |                        |     |                          |                         |
|                   | MSB                    |               |            |     |                        |     |                          |                         |
| BYTE 5            | Digital Current        |               |            |     |                        |     |                          |                         |
|                   |                        |               |            |     |                        |     |                          | LSB                     |
| BYTE 6            | Reserved               | Aliasing Flag | Error Code |     |                        |     |                          |                         |
|                   | MSB                    |               |            |     |                        |     |                          | LSB                     |
| BYTE 7            | CRC_ $I_p$             |               |            |     |                        |     |                          |                         |
|                   | MSB                    |               |            |     |                        |     |                          | LSB                     |

- **‘Sequence Counter  $I_p$ ’ signal**

- Initialized with 0 and incremented by 1 for every subsequent send request
- When the counter reaches the value 15 (0xF), then restart with 1 for the next send request.

- **‘Status Power Supply’ signal**

| CAN Frame Content |                       |   |   |                   |     |                     |                     |   |
|-------------------|-----------------------|---|---|-------------------|-----|---------------------|---------------------|---|
|                   | 7                     | 6 | 5 | 4                 | 3   | 2                   | 1                   | 0 |
| BYTE 0            | SequenceCounter $I_p$ |   |   | StatusPowerSupply |     | StatusInternalError | SafetyGoalViolation |   |
|                   | MSB                   |   |   | LSB               | MSB | LSB                 |                     |   |

When Power Supply voltage measurement is not available, then ‘Status Power Supply’ = “1 1”

Notes:

- At transducer start-up, if supply voltage < 7.8 V or > 16.2 V, no CAN frame emission
- Status details can be found in the application notes available on request.

- **‘Status Internal Error’ signal**

This flag is set to 1 to inform the BMS about two scenarios:

- Internal hardware abnormal detected (reference voltage, DAC errors and impact from application ripple current, etc)
- Over current detected on the busbar - current above 1600 A. In this use case, the Status Internal Error flag is set to 1 (see details on the next page in ‘Analog Current’ signal section)

- **‘Safety Goal Violation’ signal [SG1: Current Sensing Error]**

In the current range of [ -1500 A; -220 A [ and ] +220 A; +1500 A ], if there is more than 20% of difference between analog current level and digital current level --> then Safety Goal Violation = 1

In the current range of [ -220 A; 220 A ], if there is a gap above 44 A between analog current level and digital current level --> then Safety Goal Violation = 1

Safe State: To provide Safety Goal Violation flag, keep providing current measurement  
 FTTI: 500 ms

- ‘Analog Current’ signal

Analog measurement of the primary current

$-1500 \leq I_p \leq +1500$ . ‘Analog Current’ signal =  $I_p$ . Error = 0.5 %

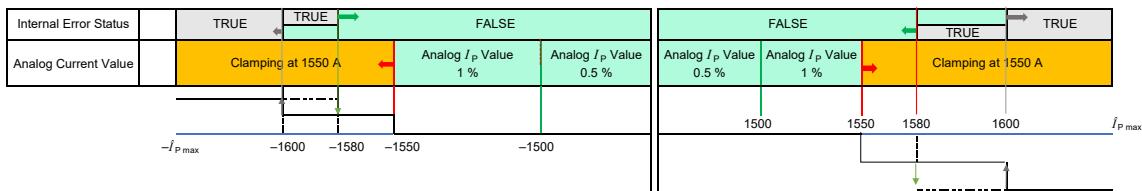
$1500 < |I_p| \leq 1550$ . ‘Analog Current’ signal =  $I_p$ . Error = 1 %

$-\hat{I}_{p \max} \leq I_p < -1550$ . ‘Analog Current’ signal is clamped at  $-1550$  A.

$+1550 < I_p \leq \hat{I}_{p \max}$ . ‘Analog Current’ signal is clamped at  $+1550$  A.

$|I_p| > \hat{I}_{p \max}$ . ‘Analog Current’ signal = 0xFFFFFFF.

Note:  $\hat{I}_{p \max} \approx 1700$  A

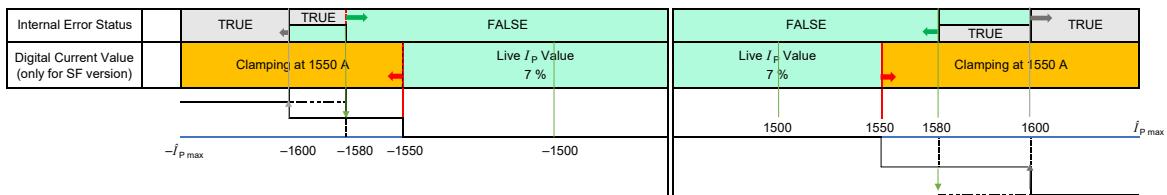


Here below the values for Byte 1, 2 and 3:

| $I_p$     | Hex value | MSB    |        | LSB    |
|-----------|-----------|--------|--------|--------|
|           |           | Byte 1 | Byte 2 | Byte 3 |
| 1550.000  | 97A6B0    | 97     | A6     | B0     |
| 1500.000  | 96E360    | 96     | E3     | 60     |
| 0.001     | 800001    | 80     | 00     | 01     |
| 0.000     | 800000    | 80     | 00     | 00     |
| -0.001    | 7FFFFF    | 7F     | FF     | FF     |
| -1500.000 | 691CA0    | 69     | 1C     | A0     |
| -1550.000 | 685950    | 68     | 59     | 50     |

- 'Digital Current' signal

$-\hat{I}_{P_{\max}} \leq I_P < -1550$  A. 'Digital Current' signal is clamped at  $-1550$  A. Error = NA  
 $+1550 < I_P \leq \hat{I}_{P_{\max}}$ . 'Digital Current' signal is clamped at  $+1550$  A. Error = NA



Digital measurement of the primary current, Byte 4 and 5:

| $I_P$ | Hex value | MSB    | LSB    |
|-------|-----------|--------|--------|
|       |           | Byte 4 | Byte 5 |
| 1550  | 860E      | 86     | 0E     |
| 1500  | 85DC      | 85     | DC     |
| 1     | 8001      | 80     | 01     |
| 0     | 8000      | 80     | 00     |
| -1    | 7FFF      | 7F     | FF     |
| -1500 | 7A24      | 7A     | 24     |
| -1550 | 79F2      | 79     | F2     |

- 'CRC\_  $I_P$ ' signal

8-bit SAE J1850 CRC calculation of the first seven bytes.

**• 'Aliasing Flag' signal**

In the current range of [ -1500 A; -220 A [ and ] +220 A; +1500 A ], if there is more than 10% of difference between analog current level and digital current level --> then aliasingFlag= 1

In the current range of [ -220 A; 220 A ], if there is a gap above 22 A between analog current level and digital current level --> then aliasingFlag = 1

**• 'Error Code' signal**

When the sensor detects an internal/external error, the corresponding ErrorCode is issued. Error codes can be found in the application note available on request.

**Applicable standards - Functional Safety - CAB-SF 1500**

| Safety                                  |                        |  |
|---|------------------------|--|
| Functional Safety<br>(ASIL C compliant) | ISO 26262<br>(11/2018) | <p style="text-align: right;">Safety Manual Table of Contents</p> <p>1 DOCUMENT</p> <p>1.1 Applicable documents</p> <p>1.2 Reference documents</p> <p>2 GLOSSARY</p> <p>3 Introduction</p> <p>4 Assumption</p> <p>5 Product overview</p> <p>5.1 Purpose</p> <p>5.2 Type of Current Transducer</p> <p>5.3 Safety Element out of Context (SEooC)</p> <p>5.4 Functional Block Diagram</p> <p>5.5 Mission Profile</p> <p>6 Safety Measures</p> <p>6.1 Safety Goal allocated to the transducer</p> <p>6.2 Safety Concept</p> <p>6.3 Description of the maintenance activities expected from the customer</p> <p>6.4 Description of the maintenance activities expected from the customer in the case of a failure indicated by the warning and degradation concept</p> <p>7 Hardware Requirements on System Level</p> <p>7.1 Datasheet Compliance</p> <p>8 Software Requirements on System Level</p> <p>8.1 DTC Monitoring</p> <p>9 Failure Rates and FMEDA</p> <p>9.1 FMEDA Reference Document</p> <p>9.2 FMEDA Applicable Standard</p> <p>9.3 Failure Mode Distribution</p> <p>9.4 FMEDA Results</p> <p>10 Provisions Against Dependent Failures</p> <p>10.1 External Parasitic Magnetic Fields</p> <p>10.2 Environmental constraints</p> <p>11 Measures to Prevent Systematic Failures</p> <p>11.1 Parasitic Magnetic Fields due to Bus Bar design</p> <p>11.2 Current Ripple Influences</p> <p>11.3 CAB-SF 1500-C Fastening</p> <p>12 Diagnostic</p> <p>12.1 Diagnostic Trouble Codes Monitoring</p> <p>12.2 Diagnostic Mode / Maintenance Operation</p> <p>13 Safety-related content of the instructions for operation, service and decommissioning</p> <p>14 Field Monitoring</p> |

\*Safety Manual availability after NDA and assurance of business signed.

**Applicable standards - PV tests performed - CAB-SF 1500**

| Test  | Standard                        | Procedure   |
|---|---------------------------------|---|
| CHARACTERIZATION AT 25 °C<br>(Initial and final)          | LEM CO.60.09.014.0              | Sensitivity; Total error; Offset; Linearity error; Current Consumption  |
| CHARACTERIZATION IN TEMPERATURE RANGE (Initial and final) | LEM CO.60.09.014.0              | Sensitivity; Total error; Offset; Linearity error; Current Consumption  |
| <b>Environmental test</b>                                 |                                 |   |
| Ageing 85 °C /85 % RH                                     | JESD 22-A101 (03/2009)          | $T^{\circ}\text{C} = 85^{\circ}\text{C}$ ; $RH = 85\%$ ; Duration = 1000 h<br>Transducer not supply<br>Check After stab. @ 25 °C (End test)<br>Performance after test, from -40 °C to 85 °C:<br>$I_o \leq 50 \text{ mA}$ , $\varepsilon_{\text{tot}} \leq 1\%$                                      |
| Low temperature storage                                   | ISO 16750-4 § 5.1.1.2 (04/2010) | $T^{\circ}\text{C} = -40^{\circ}\text{C}$<br>Duration = 24 h; Power off, no monitoring<br>Check After stab. @ 25 °C (End test)  |
| High temperature storage                                  | ISO 16750-4 § 5.1.2.2 (04/2010) | $T^{\circ}\text{C} = 85^{\circ}\text{C}$<br>Duration = 96 h; Power off, no monitoring<br>Check After stab. @ 25 °C (End test)   |
| Temperature cycle with specified change rate              | ISO 16750-4 § 5.3.1 (04/2010)   | $T^{\circ}\text{C} = -40^{\circ}\text{C} \& +85^{\circ}\text{C}$ , see Fig. 2 of ISO 16750-4<br>Duration = 30 cycles; 1 cycle = 8 h<br>Total duration = 10 days<br>$U_c = 13.5 \text{ V}$ ( $\equiv$ connected); $I_p = 0 \text{ A}$ ; no monitoring<br>Check After stab. @ 25 °C (End test)        |
| Thermal shock   | ISO 16750-4 § 5.3.2 (04/2010)   | $T^{\circ}\text{C} = "T^{\circ}\text{C Operating min \& max"}$ -40 to +85 °C<br>Duration = 300 cycles according to the climatic code (defined table 4);<br>Exposure time : 30 min.<br>$U_c =$ NO power supply ( $\equiv$ unconnected) and No wiring harness<br>Check After stab. @ 25 °C (End test) |
| Random Vibration  | ISO 16750-3 § 4.1.2.4 (12/2012) | Random;<br>-40 °C /+85 °C during 8 hours;<br>8 h for each axis and each DUT; RMS acceleration 27.1 m/s <sup>2</sup><br>Torque measurement before and after. Connected but not supply.<br>No monitoring  |
| Mechanical Shocks   | ISO 16750-3 § 4.2 (12/2012)     | Temperature: Ambient temperature.<br>Default § 4.2.2<br>Operating mode: 3.2<br>Pulse shape: half sine, 50 G, 6 ms<br>10 shocks per direction (total 60)<br>& Meas. torque Bef. and After<br>Offset before and after; Parts not connected<br>Check After stab. @ 25 °C (End test)                    |
| Free Fall   | ISO 16750-3 § 4.3 (12/2012)     | Number of devices: 3<br>Falls/DUT: 2<br>Height = 1 m on Concrete floor<br>3 axes; 2 directions by axis; 1 sample by axis<br>Operating mode: 1.1<br>Temperature: 25 °C if not specified<br>Check after test at 25 °C and visual inspection   |
| Cross section checking on PCBA                            | IPC-A-610G: 2017<br>Class 3     | IPC-TM-650 2.1.1F:2015  |
| Cross section checking on solderless connections          | GB/T 18290.5-2015               | IPC-TM-650 2.1.1F:2015  |
| Whisker checking on PCBA                                  | Refer to JESD201-A (04/2010)    | Refer to JESD22-A121A (04/2010)<br>Class 2  |

| Test   | Standard                          | Procedure  |
|--|-----------------------------------|--|
| <b>Electrical test</b>                       |                                   |  |
| Reversed voltage                             | ISO 16750-2 § 4.7<br>(12/2012)    | Test performed at room temperature<br>By default: case 2;<br>Duration : 60 s;<br>Level defined in table 7 according to the nominal system voltage  |
| Overvoltage (for 12 V nominal voltage)       | ISO 16750-2 § 4.3.1<br>(12/2012)  | $T^{\circ}\text{C} = T_{\text{max}} - 20^{\circ}\text{C}$ and room temperature;<br>At $T_{\text{max}}$ , apply 18 V for 60 min to all inputs;<br>At room temperature, apply 24 V for 60 s  |
| Superimposed alternating voltage             | ISO 16750-2 § 4.4<br>(12/2012)    | 12 V system<br>severity1: 1 V peak to peak according to Fig. 2<br>triangular, logarithmic<br>5 times sweep continuously  |
| Slow decrease and increase of supply voltage | ISO 16750-2 § 4.5<br>(12/2012)    | Test performed at room temperature<br>$U_{S_{\text{min}}} = 8.5 \text{ V}$<br>Decrease from $U_{S_{\text{min}}}$ to 0 V and increase from 0 V to $U_{S_{\text{min}}}$ ;<br>Change rate: 0.5 V/min<br>> 8.5 V<br>< 8.5 V  |
| Momentary drop in supply voltage             | ISO 16750-2 § 4.6.1<br>(12/2012)  | Test performed at room temperature<br>$U_{C_{\text{min}}} = 8.5 \text{ V}$<br>$U_{C_{\text{min}}} \text{ to } 4.5 \text{ V}$<br>See Fig. 4   |
| Reset behavior at voltage drop               | ISO 16750-2 § 4.6.2<br>(12/2012)  | Test performed at room temperature<br>See Fig. 6   |
| Load dump                                    | ISO 16750-2 § 4.6.4<br>(12/2012)  | Test performed at room temperature<br>Pulse B, Pulse described in table 6<br>'System with 12 V nominal voltage Class C'<br>$U_A = 14 \text{ V}$ , $U_S^* = 35 \text{ V}$ , $U_S = 80 \text{ V}$ , $R_i = 1 \text{ Ohm}$ $T_d = 400 \text{ ms}$ ,<br>5 pulses at 1 min intervals See Fig. 9 |
| Ground reference and supply offset           | ISO 16750-2 § 4.8<br>(12/2012)    | Test performed at room temperature and test method defined at § 4.8.2  |
| Open circuit test - single line interruption | ISO 16750-2 § 4.9.1<br>(12/2012)  | Operating the transducer and open the circuit line after line.<br>Opening duration for each line: 10 s   |
| Short circuit protection - signals circuits  | ISO 16750-2 § 4.10.2<br>(12/2012) | Connect all inputs and outputs to $U_{S_{\text{max}}} = 16 \text{ V}$ and to GND for a duration of 60 s  |
| Withstand voltage                            | ISO 16750-2 § 4.11<br>(12/2012)   | 3.5 KV AC 50 Hz 60 s   |
| Insulation resistance                        | ISO 16750-2 § 4.12<br>(12/2012)   | 1000 V DC for 60 s<br>Resistance criteria: > 1000 MΩ   |

| Test   | Standard              | Procedure  |
|--|-----------------------|--|
| <b>EMC test</b>  |                       |  |
| Resistance to electrostatic discharges (handling device)             | ISO 10605 (07/2008)   | Contact discharges: $\pm 8$ kV; Air discharges: $\pm 15$ kV.<br>$U_c$ = NO power supply ( $\equiv$ unconnected)  |
| Immunity to Radiated field- Anechoic chamber(ALSE with ground plane) | ISO 11452-2 (11/2019) | Test level II and Test level IV<br><ul style="list-style-type: none"> <li>· CW and AM in the [200 MHz – 800 MHz] frequency band.</li> <li>· CW, AM and PM1 in the [800 MHz – 1 GHz] frequency band.</li> <li>· CW and PM1 in the [1 GHz – 1.2 GHz] frequency band.</li> <li>· CW and PM2 in the [1.2 GHz – 1.4 GHz] frequency band.</li> <li>· CW and PM1 in the [1.4 GHz – 2.7 GHz] frequency band.</li> <li>· CW and PM2 in the [2.7 GHz – 3.2 GHz] frequency band.</li> </ul> |
| Transient Disturbances Conducted along Supply Lines                  | ISO 7637-2 (03/2011)  | test pulse :<br>$1 : -100 \text{ V } t_1 = 5 \text{ s}$ (0.2 to 5 s)<br>$2a : 50 \text{ V } t_1 = 0.2 \text{ to } 5 \text{ s}$<br>$2b : 10 \text{ V } t_d = 2 \text{ s}$<br>$3a : U -150 \text{ V}$<br>$3b : U 100 \text{ V}$  |
| Transient Disturbances Conducted along I/O or Transducer Lines       | ISO 7637-3 (07/2016)  | 12 V nominal supply voltage<br>Fast a : CCC –150 V 10 min<br>Fast b : CCC +100 V 10 min<br>slow pulse positive: ICC +20 V 20 min<br>slow pulse negative: ICC –20 V 20 min  |
| Immunity to Bulk Current Injection (BCI)                             | ISO 11452-4 (12/2011) | Table E.1<br>Test level I, 1 MHz to 3 MHz : $60 \text{ mA} * F(\text{MHz}) / 3$   3 to 400 MHz : 60 mA<br>Test level II, 1 MHz to 3 MHz : $100 \text{ mA} * F(\text{MHz}) / 3$   3 to 400 MHz : 100 mA<br>Test level IV, 1 MHz to 3 MHz : $200 \text{ mA} * F(\text{MHz}) / 3$   3 to 400 MHz : 200 mA   |
| Conducted emission - Voltage method                                  | CISPR 25 (2016) § 6.3 | Table 5, Class 3, BROADCAST and MOBILE SERVICES<br>$f = 0.15 \text{ MHz to } 108 \text{ MHz}$  |
| Radiated emission - ALSE   | CISPR 25 (2016) § 6.5 | Table 7, Class 3, BROADCAST and MOBILE SERVICES  |
| Immunity to magnetic fields  | ISO 11452-8 (2015)    | 12 V Nominal supply voltage<br>radiating loop method<br>Test requirement see Table A.1 (Internal field) Test level I<br>FPSC Status I  |

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