# AUTOMOTIVE CURRENT TRANSDUCER FLUXGATE TECHNOLOGY
# CAB-SF 500-C

## Introduction

The CAB-SF family is the best suited for battery monitoring application where functional safety is required by keeping a high accuracy and very low offset.
It offers galvanic insulation between the primary circuit (high voltage) and the secondary circuit (12 V system).

## Features

- Certified ASIL B acc. ISO 26262
- Transducer using Fluxgate technology
- Unlimited over-current capability
- Unipolar +12 V battery power supply
- Output signal: High speed CAN (500 kbps)
- Plug&Play with standard CAB family
- Mating connector type: Tyco AMP 1473672-1.

## Advantages

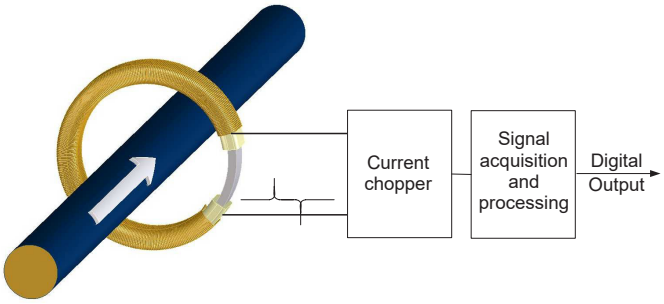
- Offset below 10 mA
- Total error [−40 °C to 85 °C]
  0.5 % typical total error at 1-sigma
  0.8 % total error at 3-sigma
- Full galvanic separation.

## Automotive applications

- Hybrid and electric vehicle battery pack
- Conventional lead-acid batteries
- Accurate current measurement for battery management applications (SOC, SOH, SOF, etc…).

## 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.





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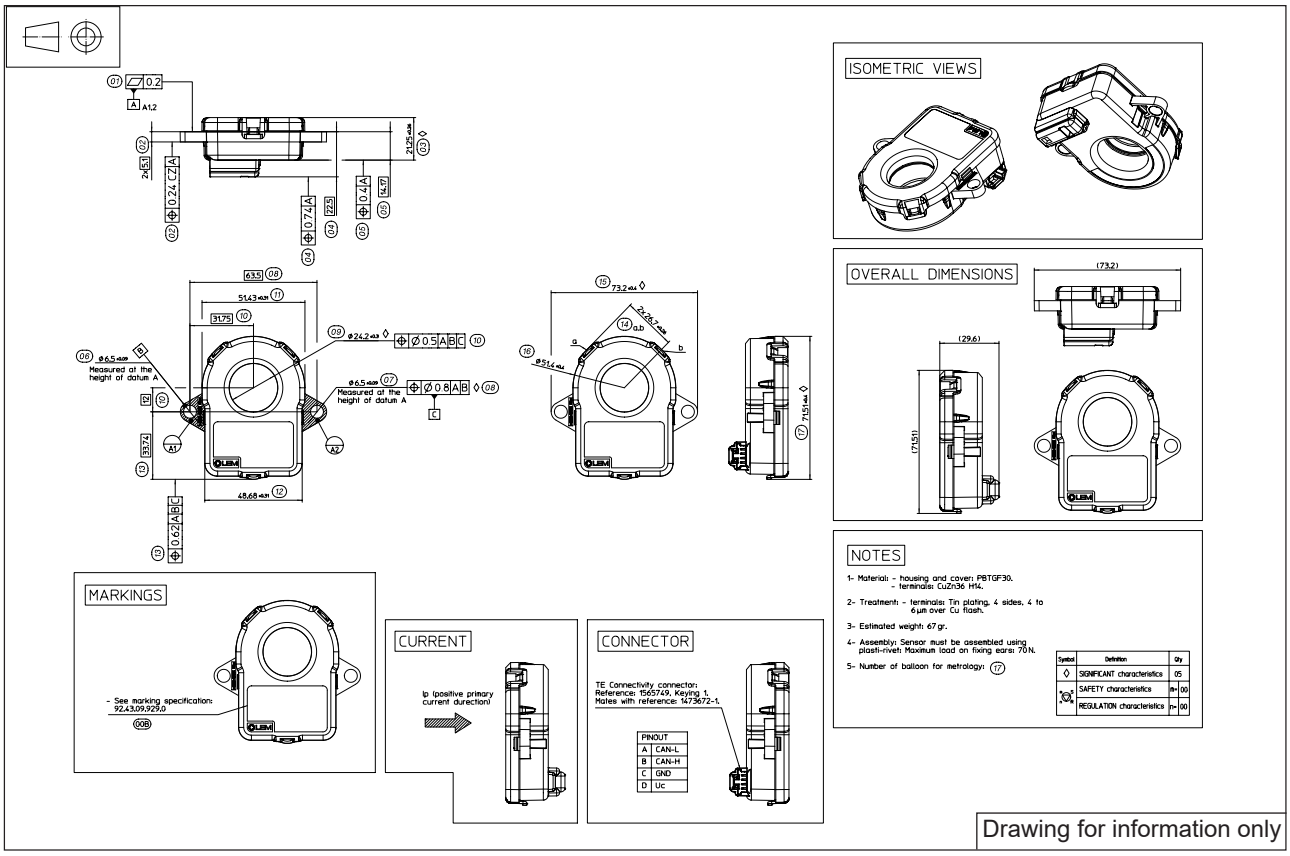
## Dimensions CAB-SF 500-C series (in mm)




## Mechanical characteristics

- Plastic case PBT GF 30
- Mass 67 g

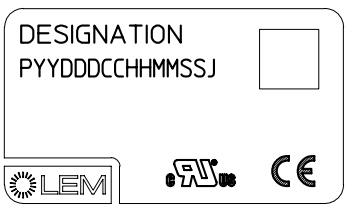
## Mounting recommendation

- Connector type Mating with Tyco-AMP P/N: 1 473672-1
- Assembly: Sensor must be assembled using plastic-rivet
- Maximum load on fixing ears: 70 N

## Marking

- DESIGNATION CAB-SF 500-C
- DATE CODE P = Production center ID
  YY = Last two digit of the year
  DDD = Day number of the year
  CC = Machine ID
  HH = Hour
  MM = Minute
  SS = Second
  J = Machine jig ID
- 2D MATRIX 90.D9.50.000.0PYYDDDCCHHMMSSJ.

- Example



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## Absolute ratings (not operating)

| Parameter | Symbol | Unit | Specification | Conditions |
|---|---|---|---|---|
| Over-voltage | $U_C$ | V | 24 | 1 minute |
| Reverse polarity | $U_C$ | V | −14 | 1 minute |
| Minimum supply voltage | $U_{C\,min}$ | V | 6 | continuous, not measuring |
| Maximum supply voltage | $U_{C\,max}$ | V | 18 | continuous, not measuring |
| Ambient storage temperature | $T_{A\,st}$ | °C | −40 / +105 | |
| Creepage distance | $d_{Cp}$ | mm | 7.2 | |
| Clearance | $d_{Cl}$ | mm | 6.95 | |
| RMS voltage for AC insulation test | $U_d$ | kV | 2.5 | 50 Hz,1 min |
| Insulation resistance | $R_{INS}$ | MΩ | 500 | 500 V -ISO 16750-2 |
| IP Level | | | IP42 | |

## Characteristics in nominal range

| Parameter | Symbol | Unit | Specification | | | Conditions |
|---|---|---|---|---|---|---|
| | | | Min | Typical | Max | |
| **Electrical Data** | | | | | | |
| Supply voltage | $U_C$ | V | 8.5 | 13.5 [1] | 16 | |
| Current consumption @ $I_P$ = 0 A | $I_C$ | mA | | 30 | 40 | @$U_C$ = 13.5 V, CAN acknowledge |
| Current consumption @ ±$I_P$ = 500 A | $I_C$ | mA | | 150 | 200 | @$U_C$ = 13.5 V, CAN acknowledge |
| Ambient operating temperature | $T_A$ | °C | −40 | | 85 | |
| **Performance Data** | | | | | | |
| Primary nominal DC or RMS current | $I_{P\,N}$ | A | −500 | | 500 | |
| Current clamping value | | A | −530 | | 530 | For $I_P$ between −530 A and minus over current value<br>For $I_P$ between +530 A and plus over current value |
| Output frequency of CAN signal [2] | | Hz | | 100 | | With Periodic CAN meassage @ 10 ms |
| Start-up time | $t_{start}$ | ms | | 150 | | |
| **Analog measurement Channel** | | | | | | |
| Linearity error | $\varepsilon_L$ | % | | ±0.1 | | At room temperature |
| Typical total error | $\varepsilon_{tot}$ | % | | ±0.5 | | See table next page |
| Output noise | | mA | | ±10 | | With Periodic CAN meassage @ 10 ms<br>Peak to peak value. No averaging. |
| **Digital measurement channel [3]** | | | | | | |
| Total error | $\varepsilon_{tot}$ | % | | ±5 | | |

Notes: 1) For the classical 12 V Lead-acid battery system, the mean value of battery voltage becomes to 13.5 V during charging
2) Output frequency depends on the emission period of the frame without digital filter
3) Digital measurement is only for internal safety function.







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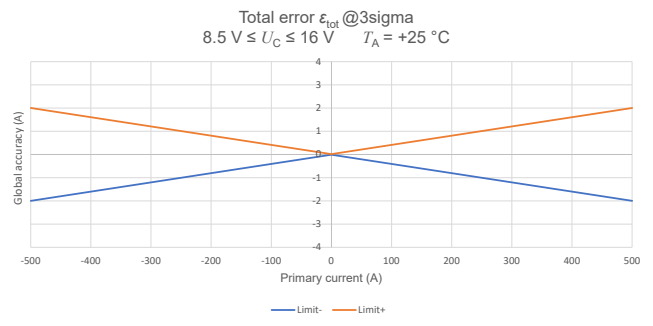
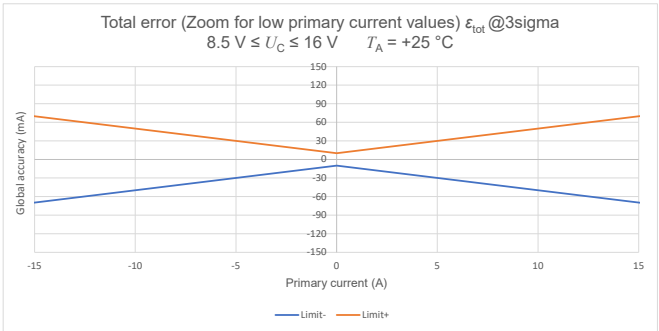
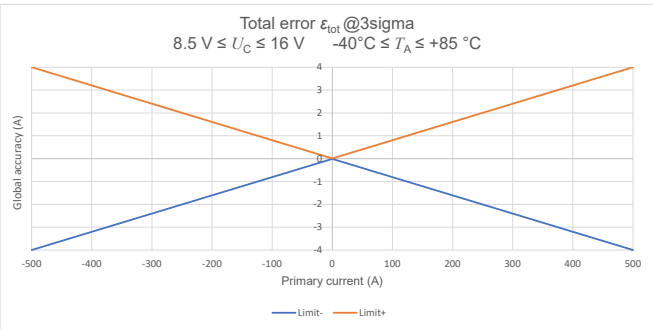
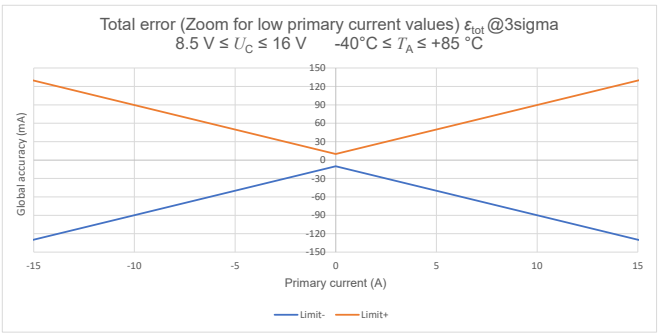
## Total Error Graph-Analog Measurement Channel

Performances are considered with average value over 10 CAN frames(100 ms)




| $I_P$ (A) | Total error @ 25 °C (A) | Total error @ −40 °C to 85 °C (A) |
|---|---|---|
| −500 | ±2 | ±4 |
| 0 | ±0.01 | ±0.01 |
| 500 | ±2 | ±4 |







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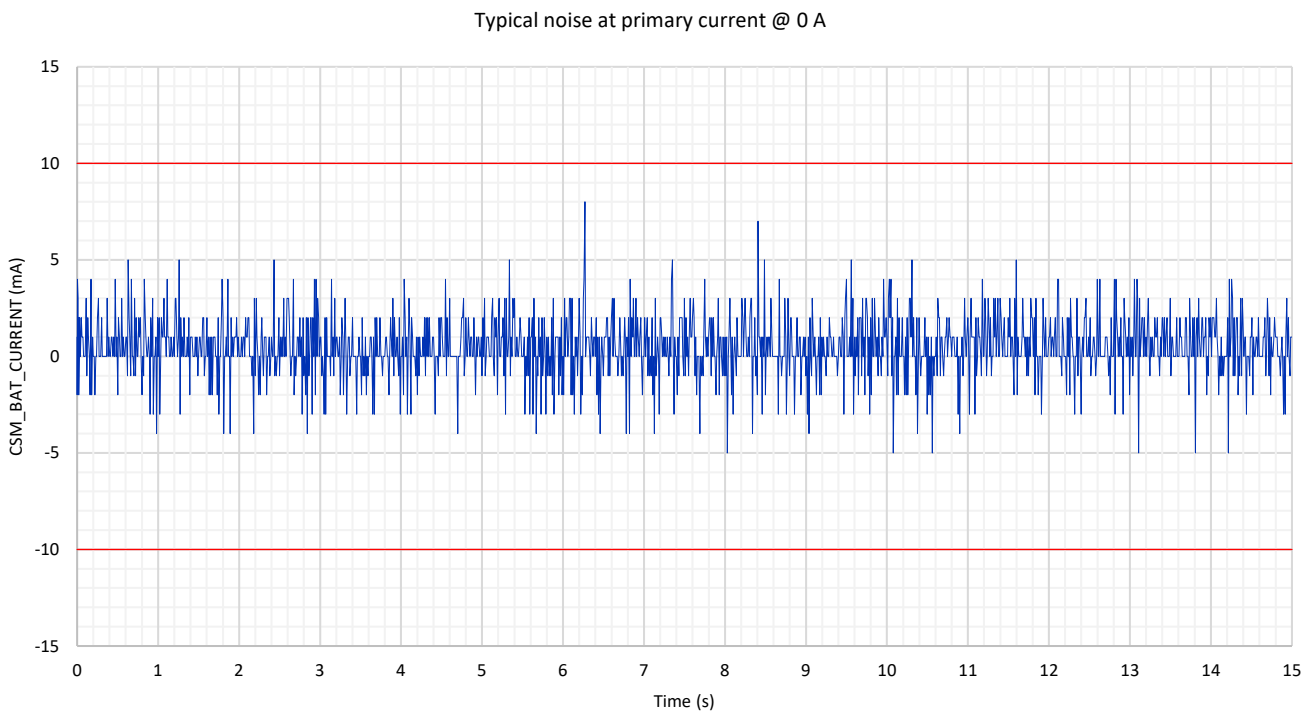
## Typical noise shape at primary current = 0 A







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## CAN output specification

- CAN protocol 2.0B
- Bit order: big endian (Motorola)
- CAN oscillator tolerance: 0.27 %
- No sleep mode capability
- 120 ohm termination resistor to be added externally, internal CAN impedance = 4.8 kohm.

| Message Description | CAN ID | Name | Data Length (Nb bytes) | Type of frame | Message launch type | Signal name | Start bit | Length |
|---|---|---|---|---|---|---|---|---|
| Return Current $I_P$ (mA) | 0x3C2 | CAB500_$I_P$ | 8 | Standard | Periodic frame Period : 10 ±1 ms | CSM_BAT_CURRENT 1) | 24 | 32 |
| | | | | | | ERROR_INDICATION 2) | 32 | 1 |
| | | | | | | CSM_FAIL 3) | 33 | 7 |
| | | | | | | ISO_WARNING 4) | 40 | 1 |
| | | | | | | SF_COUNTER 5) | 41 | 7 |
| | | | | | | SOFT_MAJOR_REV 6) | 48 | 8 |
| | | | | | | SOFT_MINOR_REV 7) | 56 | 8 |
| | 0x68D | UDS_CLIENT | 8 | Standard | | | | |
| | 0x68E | UDS_SERVER | 8 | Standard | | | | |

## Notes: CAB-SF 500-C $I_P$ message description

1) CSM_BAT_CURRENT
   - $I_P$ Value: 80000000H = 0 mA
     7FFFFFFFH = −1 mA
     80000001H = 1 mA
   - $0 \le I_P \le 530$ A $I_P$ Value follows the primary current value
   - $I_P$ over 530 A until overcurrent detected, $I_P$ value clamped to 530 A
   - Same behavior for negative current.

2) ERROR_INDICATION
   - 0 = Normal; 1 = Failure



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3) CSM_FAIL

| Piority | Failure Mode | Error Information | Filter (1) | Error Indication | $I_P$ value |
|---|---|---|---|---|---|
| 1 | Supply voltage (2) | 0x46 | 0.1/0.12 | 1 | 0xFFFFFFFF |
| 2 | Hardware defect: Reference voltage | 0x4B | 0.1/0.12 | 1 | 0xFFFFFFFF |
| 3 | Temperature (3) | 0x44 | 0.1/0.12 | 1 | 0xFFFFFFFF |
| 4 | Hardware defect: DAC Threshold | 0x4A | 0.1/0.12 | 1 | 0xFFFFFFFF |
| 5 | Hardware defect: ADC channel | 0x47 | 0.1/0.12 | 1 | 0xFFFFFFFF |
| 6 | Safety goal violation | 0x4C | 0.25/0.25 | 1 | $I_P$ Value |
| 7 | New Data not available | 0x49 | NO | 1 | 0xFFFFFFFF |
| 8 | Fluxgate under frequency | 0x42 | 0.25/0.3 | 1 | 0xFFFFFFFF |
| 9 | Overcurrent detection | 0x41 | 0.02/0.02 | 1 | 0xFFFFFFFF |

(1) x/y : Error should be active for 'x' seconds to set the 'ERROR_INDICATION' and 'CSM_FAIL' signal. 'y' seconds to clear the signal.

(2)

| Supply Voltage (V) | | 6.0 | | 7.2 | | 7.6 | | 17.1 | | 17.9 | | 20.0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Error Information | - | | 0x46 | | No Error | | | | | | 0x46 | | - |
| | | | 0x46 | | | | No Error | | 0x46 | | | | - |
| CAN Emission status | Disable | | Enable | | | | | | | | | | Disable |

(3) At sensor start-up, if supply voltage < 7.2 V or > 17.9 V, no CAN frame emission

| Temperature °C | | −50 | | 130 | |
|---|---|---|---|---|---|
| Error Information | 0x44 | | No Error | | 0x44 |

4) ISO_WARNING

- Indicate that the absolute difference between the analog and digital measurement is below/ higher than **Threshold**
- Filtering: Signal set to be '1' when the difference is above **Threshold** for at least 50ms. The signal reset to be '0' when the difference below **Threshold** for at least 60 ms.
- Threshold:
  5 % at [−530 A,−20 A] & [20 A, 530 A]
  2 A at ]−20 A, 20 A[

5) SF_COUNTER

- 'SF_COUNTER' shows the progression of the filtering on failure mode The 'Safety goal violation' error (CSM_FAIL = 0x4C)
- 'SF_COUNTER' increases if the absolute difference between the analog and digital measurement is higher than threshold; 'SF_ COUNTER' decrease if the absolute difference below threshold
- Error 'Safety goal violation' is set when 'SF_COUNTER' reaches 50. The error is reset when 'SF_COUNTER' goes below 25
- Threshold:
  20 % at [−530 A,−20 A] & [20 A, 530 A]
  5 A at ]−20 A, 20 A[

6) SOFT_MAJOR_REV

7) SOFT_MINOR_REV

- Information about the software release







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## SAFETY GOALS for CAB-SF 500-C

An hazard analysis was performed for the CAB-SF 500-C sensor. A list of hazard events have been identified and an ISO26262 rating has been made for each of them. The highest quotation for which the product meets is ASILB level.The electronic design followed the guidelines and development methods recommended by ISO26262. The constituent elements of the safety case can be consulted on request.



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## Applicable standards



| Test | Standard | Procedure |
|---|---|---|
| **Environmental test** | | |
| Low Temperature Operating Endurance | ISO 16750-4 (04/2010) | 120 hrs, −40 °C, power on |
| High Temperature Operating Endurance | ISO 16750-4 (04/2010) | 85 °C, 120 hrs, power on |
| Powered Thermal Cycle Endurance | ISO16750-4 (04/2010) | −40 °C (20 mins soak) / +85 °C (20 mins soak), slope 4 °C/min, 540 cycles (936 h, 39 days), power supply 13.5 V |
| Thermal Shock | ISO 16750-4 (04/2010) | −40 °C (20 mins soak) / +85 °C (20 mins soak), 1000 cycles (667 h, 28 days); no power supply |
| High Temperature and Humidity Endurance | JESD 22-A101 (03/2009) | 85 °C, 85 % humidity, 1000 hrs |
| Random Vibration | ISO 16750-3 (12/2012) | Test IV, −40 °C / +85 °C during 8 hours (Fig.1), RMS acceleration 27.1 $m/s^2$, 20 h / axis, 3 axis+, power on and output monitoring |
| Mechanical Shocks | ISO 16750-3 (12/2012) | 500 $m/s^2$, 10 each direction (60 total), Half sine pulse |
| Free Fall | ISO 16750-3 (12/2012) | 2 falls per DUT, 3 axis, total 6 falls, from 1 meter on concrete floor |
| Water Intrusion | DIN 40050-9 (1993-05) | IPx2, flow 3 (+0.5/0) mm/min, 10 mins, connector downward, parts inclined at 15° |
| Dust (and other solid intrusion) | DIN 40050-9 (1993-05) | IP4x, The rigid stem, 1 mm diameter, is pressed against the casing of the part with a 1N force<br>Vertical flow chamber, Portland cement, 2 kg/m^3, 6 s ON/15 min OFF for 20 cycles, parts inclined at 15° |
| Mixed Flowing Gas | IEC60068-2-60 (12/1996) | Mehod4 in Table1, H2S, NO2, Cl2, SO2, 25 ±1 °C, $RH$ 75 ±3 %, 21 days |
| Salt Fog | NISSAN M0158 (2009) / M0140 (2014) | NaCl 50 g/L, Cycle: salt spray 4 hrs, dry 2 hrs with 60 °C < 30 % $RH$, moistening 2 hrs with 50 °C 95 % $RH$, 110 cycles |
| **EMC test** | | |
| Conduted emission- Voltage method | CISPR 25 (03/2008) | 150 kHz-108 MHz<br>Class 4 (LW,VHF (68-87 MHz),FM);<br>Class 3 (MW,SW,CB);<br>Class 2 (VF (30-54 MHz)) |
| Conducted emission- Current method | CISPR 25 (03/2008) | 150 kHz -245 MHz<br>Class 4 ( only for LW, FM);<br>Class 3 (Rest frequency) |
| Radio frequency radiated Emission electric field | CISPR 25 (04/2016) | Class 5 (FM);<br>Class 4 (LW,VHF (68-87 MHz),GSM, EGSM/GSM 900);<br>Class 2 (VHF (30-54 MHz),VHF (142-175 MHz)) ;<br>Class 3 (Rest frequency) |
| IMMUNITY TO CURRENT INJECTION (BCI) | ISO 11452-4 (12/2011) | 1 MHz to 400 MHz<br>Level 1 100 mA: Class A;<br>Level 2 200 mA: Class C;<br>Level 3 300 mA: Class C |
| Immunity to Radiated field- Anechoic chamber (ALSE with ground plane) | ISO 11452-2 | 200 MHz-3.2 GHz; 150 V/m<br>Class A |
| RESISTANCE TO PULSES 1, 2A,2B (Transient Disturbance conducted along supply line) | ISO-7637-2 (03/2011) | pulse 1, pulse 2a 500 pulses;<br>pulse 2b 10 pulses<br>Class C |
| Resistance to pulses 3a & 3b (Transient Disturbance conducted along supply line) | ISO-7637-2 (03/2011) | pulse 3a, pulse 3b time duration = 1 hour<br>Class A |







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| | | |
|---|---|---|
| Resistance to pulses 4<br>(Starting profile) | ISO 16750-2 § 4.6.3<br>(11/2012) | pulse 4 10 pulses<br>Test level I: Class A;<br>Test level II: Class C;<br>Test level III: Class C |
| Load Dump | ISO 16750-2 § 4.6.4.2.3 | $U_A$ = 14 V, $U_S$* = 29 V, $R_i$ < 1 ohm $t_D$ = 400 ms<br>5 pulses<br>Class C |
| Transient disturbance conducted along i/o or sensor lines | ISO-7637-3<br>(07/2007) | Fast pulse a: CCC<br>Fast pulse b: CCC<br>Slow pulse +: DCC<br>Slow pulse -: DCC<br>level IV Class A |
| RESISTANCE TO ELECTROSTATIC DISCHARGES,<br>EQUIPMENT NOT CONNECTED(handling) | ISO 10605<br>IEC 61000-4-2 (2008) | $U_{N\text{-powered}}$ ±2 kV ±4 kV<br>air: ±8 kV ±15 kV |
| ESD Operating | ISO 10605<br>IEC 61000-4-2 (2008) | Powered<br>indirect contact discharge: ±4 kV air: ±8 kV |

## Electrical test

| | | |
|---|---|---|
| Direct current supply voltage | ISO 16750-2 § 4.2<br>(11/2012) | Code B |
| Overvoltage | ISO 16750-2 § 4.3.1<br>(11/2012) | 18 V, 1 h, @ 65 °C ; 24 V, 1 min, @ 25 °C |
| Superimposed Alternating Voltage | ISO 16750-2 § 4.4<br>(11/2012) | -severity 2: $U_{pp}$ = 4 V<br>-severity 4: $U_{pp}$ = 2 V |
| Resistance to slow decrease and increase of supply voltage | ISO 16750-2 § 4.5<br>(11/2012) | $U_{min}$ = 8 V, 0.5 V/min, Run DUT 10 mins |
| Momentary drop in supply voltage | ISO 16750-2 § 4.6.1<br>(11/2012) | Room temperature, $U_{S\ min}$ to 4.5 V |
| Re-initialization test<br>(Reset behaviour at voltage drop) | ISO 16750-2 § 4.6.2<br>(11/2012) | $U_{S\ min}$ = 8 V |
| Reverse voltage | ISO 16750-2 § 4.7<br>(11/2012) | Case 2 |
| Ground reference and supply voltage | ISO 16750-2 § 4.8<br>(11/2012) | Offset voltage = 1.0 ±0.1 V |
| Open Circuit | ISO 16750-2 § 4.9<br>(11/2012) | Single line / Multiple line interruption |
| Short circuit protection | ISO 16750-2 § 4.10.2 (11/2012) | Signal circuits, $U_{S\ max}$ = 16 V and GND, duration 60 s |
| RESISTANCE TO SHORT INTERRUPTION OF THE POWER SUPPLY | PSA B217110 E § 7.1.13<br>no reference | $U_S$ = 14 V, $t_D$ = 2 µs,1 ms, 5 ms |
| resistance to "volt control" voltage pulse | PSA B217110 E § 7.1.16<br>no reference | $U$ 1 = 15.2 V; $U$ 2 = 18.0 V; $t_r$ = 1 ms; $t_f$ = 300 ms<br>5 pulse with an interval of 1 min |
| resistance to supply voltage in the usual "volt control" range | PSA B217110 E § 7.1.2<br>no reference | $U_{min}$ = 10.5 V; $U_{max}$ = 16 V; $t_D$ = 5 s; $R_r$ = 10 V/s<br>5 pulse with an interval of 1 min |







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## Installation influence

### Overview

The CAB 500-C family uses a very accurate and sensitive technology and offers the customers the current measurement needed to the application.
In order to respect this accuracy, some conditions must be respected during the design of the environment of the sensor:

- Primary busbar centering
- Busbar shape
- Contactors

The busbar dimension for test:
20 mm (W) x 3 mm (H).
Environment: room temperature.

Due to the complexity of practical application, the examples cannot cover all the application conditions.

It can be reference during BDU design, but the performance validation of BDU is necessary.

The sensor has different performance on different angles. For details or any further questions, please contact LEM Technical Customer Support.

### Current ripple influence

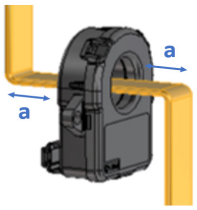
The CAB-SF 500-C might be disturbed by current ripples produced by inverters and electric machines. When the frequency of the current ripples gets close to the fluxgate coil's frquency, then the coil's frequency might get locked to the ripple current frequency.
The CAB-SF 500-C will detect it as ISO error flags.

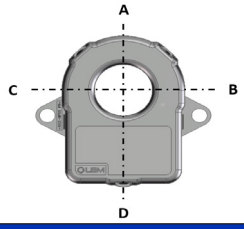
If such situation happens systematically during your testings linked to inverter/electric machines, please contact your LEM window for further technical support.

### Return busbar type definition

Explanation: Recommended / Case of accuracy close to the limit / Not recommended

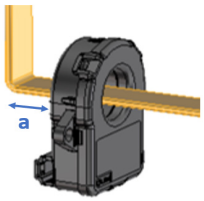
**S-shape busbar recommendation**

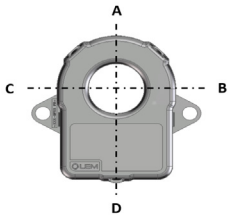


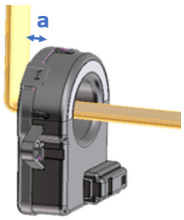

| a(mm) | | | | |
|---|---|---|---|---|
| 10 | A | B | C | D |
| >10 | A | B | C | D |

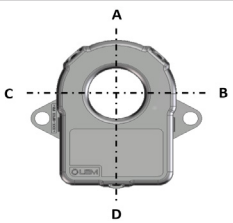
**L-shape busbar recommendation**




| a(mm) | | | | |
|---|---|---|---|---|
| 10 | A | B | C | D |
| >10 | A | B | C | D |




| a(mm) | | | | |
|---|---|---|---|---|
| 10 | A | B | C | D |
| >10 | A | B | C | D |



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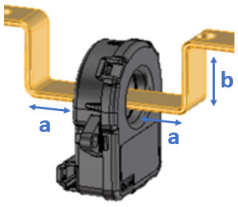
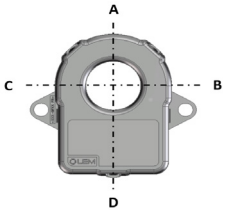
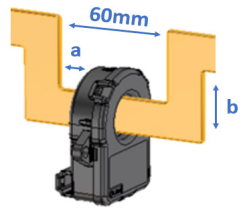
## U1-shape busbar recommendation

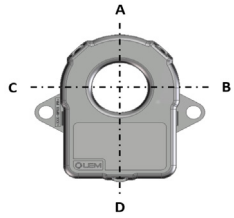


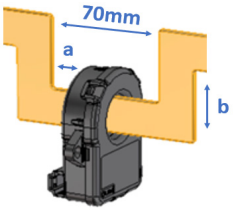

| b(mm) \ a(mm) | 10 | | 20 | | 30 | |
|---|---|---|---|---|---|---|
| 40 | A | B | A | B | A | B |
| | C | D | C | D | C | D |
| 50 | A | B | A | B | A | B |
| | C | D | C | D | C | D |
| 60 | A | B | A | B | A | B |
| | C | D | C | D | C | D |

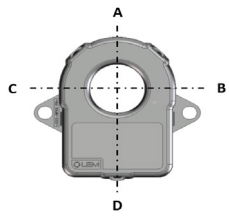
## U2-shape busbar recommendation



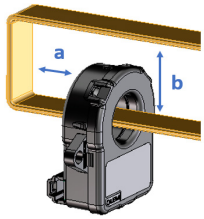

| b(mm) \ a(mm) | 10 | | 20 | | 30 | |
|---|---|---|---|---|---|---|
| 40 | A | B | A | B | A | B |
| | C | D | C | D | C | D |
| 50 | A | B | A | B | A | B |
| | C | D | C | D | C | D |

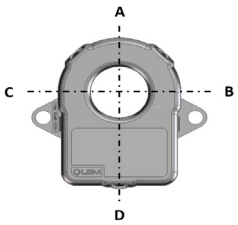


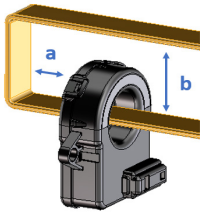

| b(mm) \ a(mm) | 10 | | 20 | | 30 | | 40 | |
|---|---|---|---|---|---|---|---|---|
| 50 | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D |

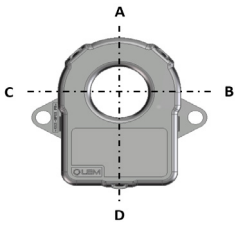
## U3-shape busbar recommendation



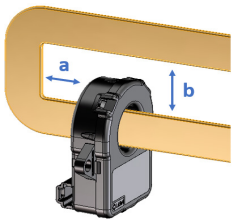

| b(mm) \ a(mm) | 20 | | 30 | | 40 | | 50 | | 60 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 70 | A | B | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D | C | D |
| 80 | A | B | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D | C | D |
| 90 | A | B | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D | C | D |
| 100 | A | B | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D | C | D |

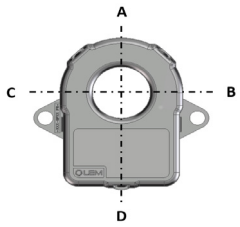


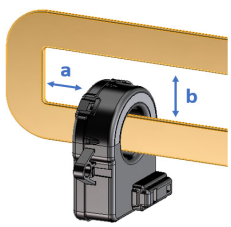

| b(mm) \ a(mm) | 20 | | 30 | | 40 | | 50 | | 60 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 70 | A | B | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D | C | D |
| 80 | A | B | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D | C | D |
| 90 | A | B | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D | C | D |
| 100 | A | B | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D | C | D |

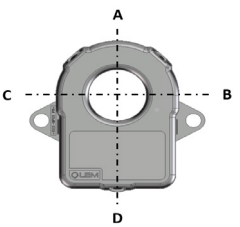
## U4-shape busbar recommendation




| b(mm) \ a(mm) | 20 | | 30 | | 40 | | 50 | |
|---|---|---|---|---|---|---|---|---|
| 70 | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D |
| 80 | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D |
| 90 | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D |
| 100 | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D |




| b(mm) \ a(mm) | 20 | | 30 | | 40 | | 50 | |
|---|---|---|---|---|---|---|---|---|
| 70 | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D |
| 80 | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D |
| 90 | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D |
| 100 | A | B | A | B | A | B | A | B |
| | C | D | C | D | C | D | C | D |



29September2021/Version 3



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