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

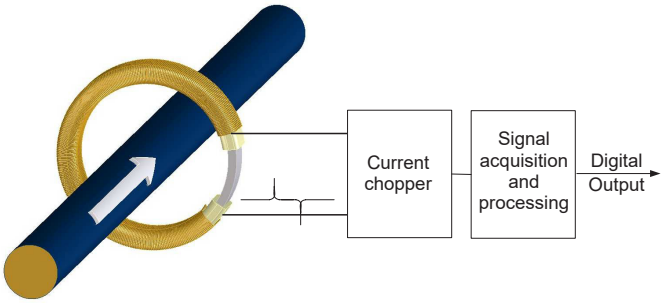
- Offset below 10 mA
- Total error [−40 °C to 85 °C]
  0.5 % typical total error at 1-sigma
  0.8 % total error at 3-sigma
- Full galvanic separation.

Automotive applications

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

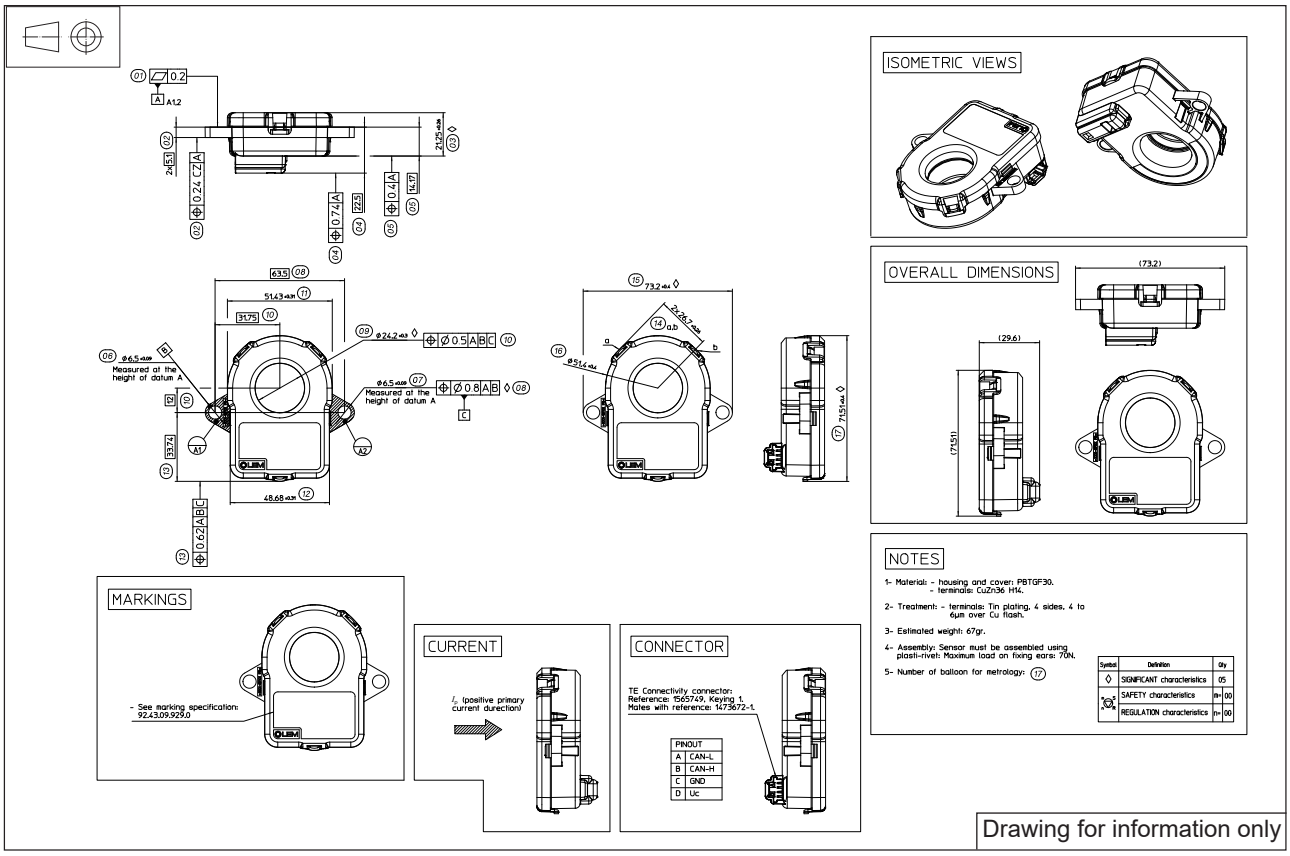
Principle of Fluxgate Transducers

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.



LEM reserves the right to carry out modifications on its transducers, in order to improve them.
LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

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



Mechanical characteristics

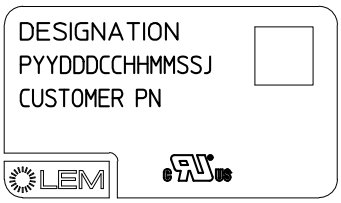
- Plastic case PBT GF 30
- Mass 67 g

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



LEM reserves the right to carry out modifications on its transducers, in order to improve them.

LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

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_{PN}	A	−500		500	
Current clamping value		A	−530		530	For I_P between −530 A and minus over current value For I_P between +530 A and plus over current value
Output frequency of CAN signal [2]		Hz		100		With Periodic CAN message @ 10 ms
Start-up time	t_{start}	ms		150		
Analog measurement Channel						
Linearity error	ε_L	%		±0.1		At room temperature
Typical total error	ε_{tot}	%		±0.5		See table next page
Output noise		mA		±10		With Periodic CAN message @ 10 ms Peak to peak value. No averaging.
Digital measurement channel [3]						
Total error	ε_{tot}	%		±5		

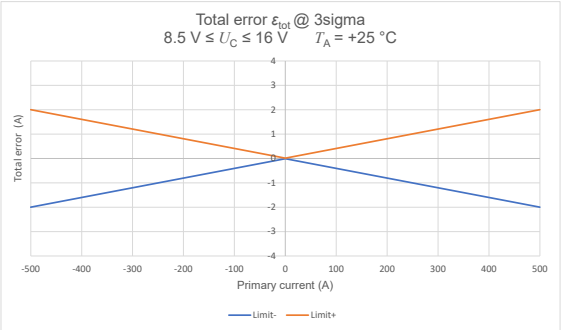
Notes: 1) For the classical 12 V Lead-acid battery system, the mean value of battery voltage becomes to 13.5 V during charging
2) Output frequency depends on the emission period of the frame without digital filter
3) Digital measurement is only for internal safety function.

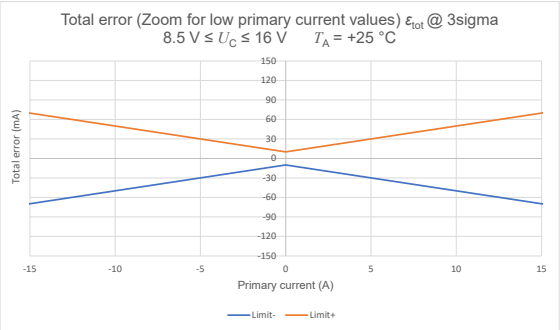
LEM reserves the right to carry out modifications on its transducers, in order to improve them.

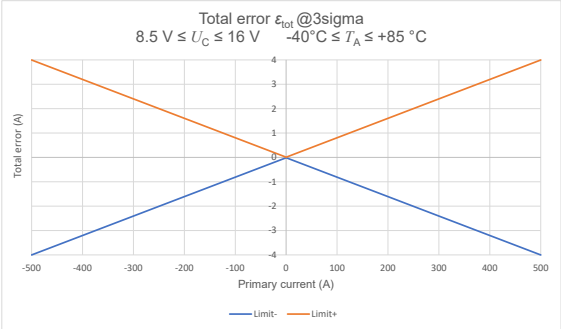
LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

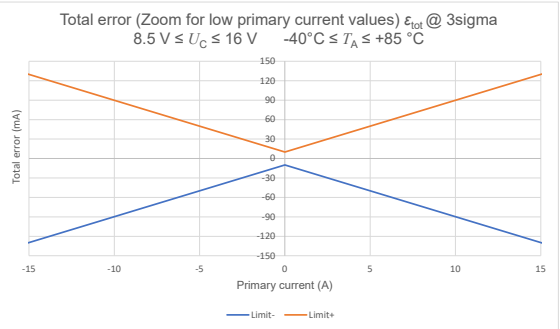
Total Error Graph-Analog Measurement Channel

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







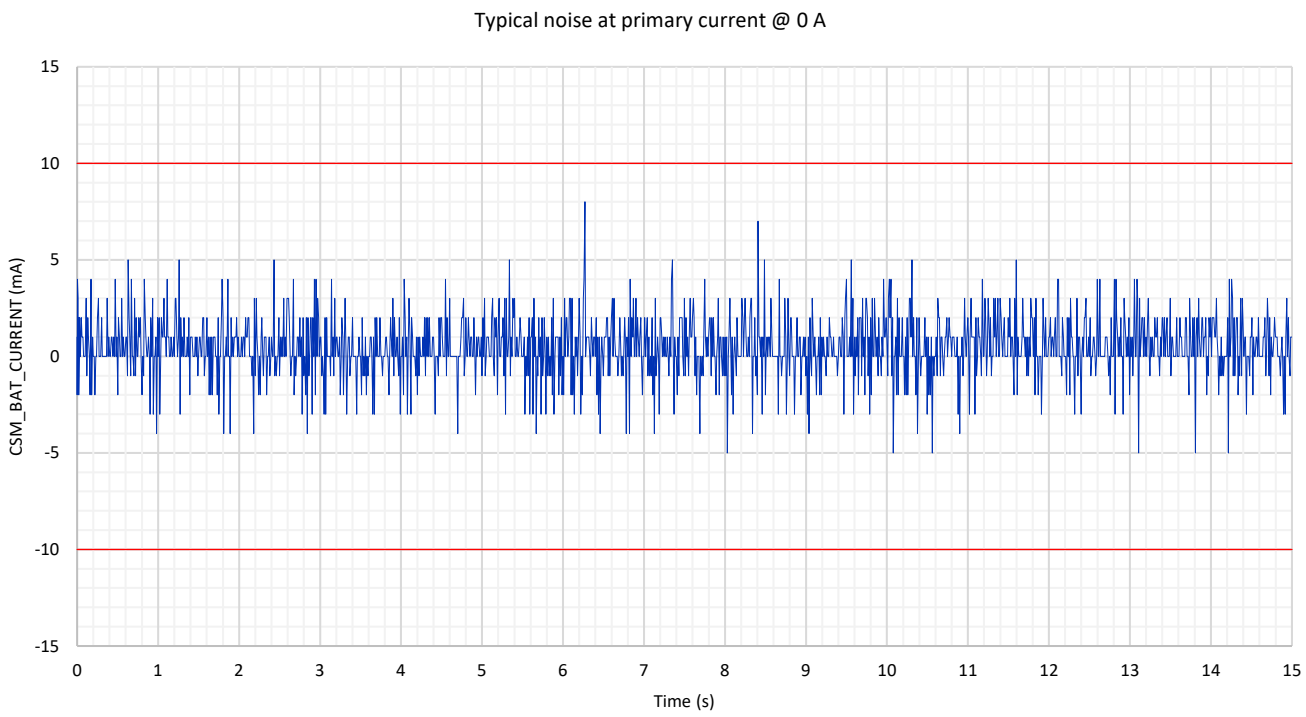


I_P (A)	Total error @ 25 °C (A)	Total error @ −40 °C to 85 °C (A)
−500	±2	±4
0	±0.01	±0.01
500	±2	±4

LEM reserves the right to carry out modifications on its transducers, in order to improve them.

LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

Typical noise shape at primary current = 0 A



LEM reserves the right to carry out modifications on its transducers, in order to improve them.

LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

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

LEM reserves the right to carry out modifications on its transducers, in order to improve them.

LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

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

LEM reserves the right to carry out modifications on its transducers, in order to improve them.

LEM International SA
Route du Nant-d’Avril, 152
1217 Meyrin
www.lem.com

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.

LEM reserves the right to carry out modifications on its transducers, in order to improve them.

LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

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 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 Class 4 (LW,VHF (68-87 MHz),FM); Class 3 (MW,SW,CB); Class 2 (VF (30-54 MHz))
Conducted emission- Current method	CISPR 25 (03/2008)	150 kHz -245 MHz Class 4 (only for LW, FM); Class 3 (Rest frequency)
Radio frequency radiated Emission electric field	CISPR 25 (04/2016)	Class 5 (FM); Class 4 (LW,VHF (68-87 MHz),GSM, EGSM/GSM 900); Class 2 (VHF (30-54 MHz),VHF (142-175 MHz)) ; Class 3 (Rest frequency)
IMMUNITY TO CURRENT INJECTION (BCI)	ISO 11452-4 (12/2011)	1 MHz to 400 MHz Level 1 100 mA: Class A; Level 2 200 mA: Class C; 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 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; pulse 2b 10 pulses 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 Class A

LEM reserves the right to carry out modifications on its transducers, in order to improve them.

LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

Resistance to pulses 4 (Starting profile)	ISO 16750-2 § 4.6.3 (11/2012)	pulse 4 10 pulses Test level I: Class A; Test level II: Class C; 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 5 pulses Class C
Transient disturbance conducted along i/o or sensor lines	ISO-7637-3 (07/2007)	Fast pulse a: CCC Fast pulse b: CCC Slow pulse +: DCC Slow pulse -: DCC level IV Class A
RESISTANCE TO ELECTROSTATIC DISCHARGES, EQUIPMENT NOT CONNECTED(handling)	ISO 10605 IEC 61000-4-2 (2008)	$U_{N\text{-powered}}$ ±2 kV ±4 kV air: ±8 kV ±15 kV
ESD Operating	ISO 10605 IEC 61000-4-2 (2008)	Powered indirect contact discharge: ±4 kV air: ±8 kV

Electrical test

Direct current supply voltage	ISO 16750-2 § 4.2 (11/2012)	Code B
Overvoltage	ISO 16750-2 § 4.3.1 (11/2012)	18 V, 1 h, @ 65 °C ; 24 V, 1 min, @ 25 °C
Superimposed Alternating Voltage	ISO 16750-2 § 4.4 (11/2012)	-severity 2: U_{pp} = 4 V -severity 4: U_{pp} = 2 V
Resistance to slow decrease and increase of supply voltage	ISO 16750-2 § 4.5 (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 (11/2012)	Room temperature, $U_{S\,min}$ to 4.5 V
Re-initialization test (Reset behaviour at voltage drop)	ISO 16750-2 § 4.6.2 (11/2012)	$U_{S\,min}$ = 8 V
Reverse voltage	ISO 16750-2 § 4.7 (11/2012)	Case 2
Ground reference and supply voltage	ISO 16750-2 § 4.8 (11/2012)	Offset voltage = 1.0 ±0.1 V
Open Circuit	ISO 16750-2 § 4.9 (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 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 no reference	U 1 = 15.2 V; U 2 = 18.0 V; t_r = 1 ms; t_f = 300 ms 5 pulse with an interval of 1 min
resistance to supply voltage in the usual "volt control" range	PSA B217110 E § 7.1.2 no reference	U_{min} = 10.5 V; U_{max} = 16 V; t_D = 5 s; R_r = 10 V/s 5 pulse with an interval of 1 min

LEM reserves the right to carry out modifications on its transducers, in order to improve them.

LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

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

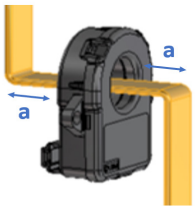
The CAB-SF 500-C might be disturbed by current ripples produced by inverters and electric machines. When the frequency of the current ripples gets close to the fluxgate coil's frquency, then the coil's frequency might get locked to the ripple current frequency.
The CAB-SF 500-C will detect it as ISO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

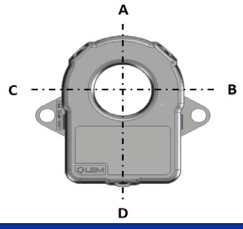
If such situation happens systematically during your testings linked to inverter/electric machines, please contact your LEM window for further technical support.

Return busbar type definition

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

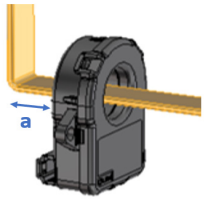
S-shape busbar recommendation

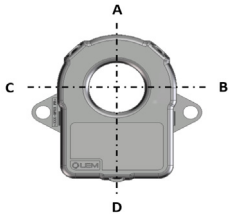




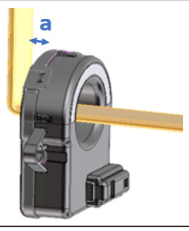
a(mm)				
10	A	B	C	D
>10	A	B	C	D

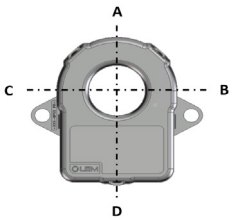
L-shape busbar recommendation





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





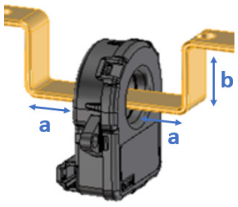
a(mm)				
10	A	B	C	D
>10	A	B	C	D

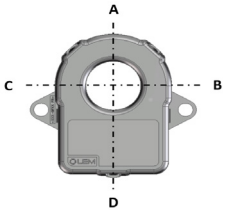
3April2023/Version 4

LEM reserves the right to carry out modifications on its transducers, in order to improve them.

LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com

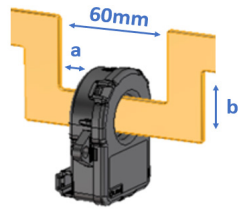
U1-shape busbar recommendation

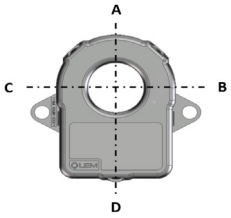




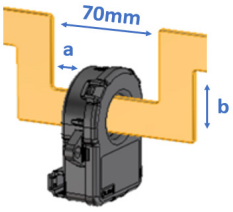
b(mm) \ a(mm)	10		20		30	
40	A	B	A	B	A	B
	C	D	C	D	C	D
50	A	B	A	B	A	B
	C	D	C	D	C	D
60	A	B	A	B	A	B
	C	D	C	D	C	D

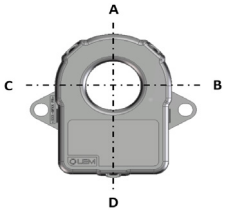
U2-shape busbar recommendation





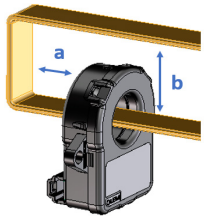
b(mm) \ a(mm)	10		20		30	
40	A	B	A	B	A	B
	C	D	C	D	C	D
50	A	B	A	B	A	B
	C	D	C	D	C	D

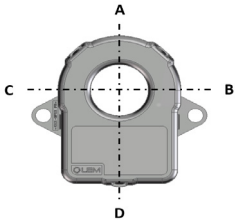




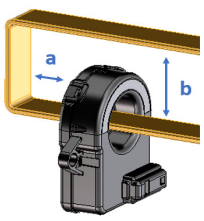
b(mm) \ a(mm)	10		20		30		40	
50	A	B	A	B	A	B	A	B
	C	D	C	D	C	D	C	D

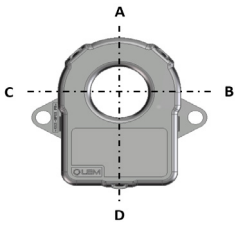
U3-shape busbar recommendation





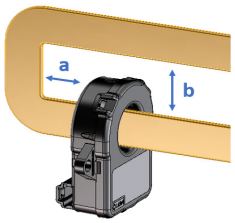
b(mm) \ a(mm)	20		30		40		50		60	
70	A	B	A	B	A	B	A	B	A	B
	C	D	C	D	C	D	C	D	C	D
80	A	B	A	B	A	B	A	B	A	B
	C	D	C	D	C	D	C	D	C	D
90	A	B	A	B	A	B	A	B	A	B
	C	D	C	D	C	D	C	D	C	D
100	A	B	A	B	A	B	A	B	A	B
	C	D	C	D	C	D	C	D	C	D

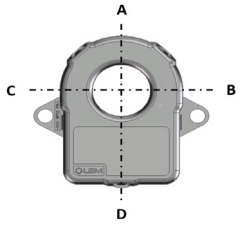




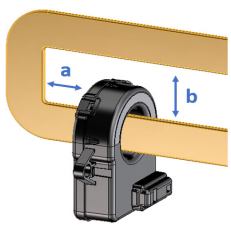
b(mm) \ a(mm)	20		30		40		50		60	
70	A	B	A	B	A	B	A	B	A	B
	C	D	C	D	C	D	C	D	C	D
80	A	B	A	B	A	B	A	B	A	B
	C	D	C	D	C	D	C	D	C	D
90	A	B	A	B	A	B	A	B	A	B
	C	D	C	D	C	D	C	D	C	D
100	A	B	A	B	A	B	A	B	A	B
	C	D	C	D	C	D	C	D	C	D

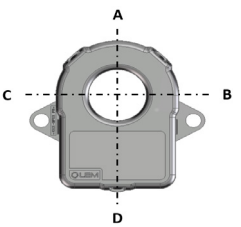
U4-shape busbar recommendation





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

3April2023/Version 4

LEM reserves the right to carry out modifications on its transducers, in order to improve them.

LEM International SA
Route du Nant-d'Avril, 152
1217 Meyrin
www.lem.com