

# CDT series: Automotive Residual Current Monitoring type B sensors

## CDT 0.3-S2, CDT-SF 0.3-S2, CDT 0.3-S4, CDT-SF 0.3-S4

### Product description:

The CDT series is the LEM RCM type B current sensor family designed to measure and protect from AC and DC fault current (leakage current), dedicated to automotive applications. Our proprietary fluxgate architecture allows the sensor to have best in class accuracy hence protection from potential fire hazards and electrical shocks. The package is configurable up to 4 conductors 48Arms capable, allowing 1 and 3 phases systems and offering an optimized leakage measurement of configurations by design.

The CDT series sensors provide a tripping fault current output and an SPI bus enabling fast response time and detailed fault information. For automotive applications, such as bidirectional On-Board Chargers, an ISO26262 ASIL B compliant version offers additional safety diagnostics.

### Measurement principle:

In a stable system the sum of current (phase and neutral) flowing in conductors is null, when a fault occurs, a difference is measured between phase and neutral conductors. This difference represents the leakage current typically caused by a loss of insulation from a conductor to the earth.

### Main Features & Advantages

- Automotive qualified (AEC-Q100 and 200 components)
- Up to 48 A RMS current per primary conductor
- Primary current measurement range:  $\pm 300$  mA DC
- External test via dedicated pin
- SPI and digital tripping outputs
- Compact design for PCB mounting
- Excellent accuracy
- Fast Tripping
- Reinforced galvanic insulation.

### Typical applications

Developed for, EV On Board Charger:

- Automotive OBC up to 22 kW (V2L, V2G, V2H)

Compatible with, Off board Charging:

- Mode 2: In Cord – Control and Protection Device (IC-CPD)
- Mode 3: Wall box chargers

### Functional safety (SF version only)

- ISO26262 ASIL B: refer to safety manual.

### EMC Compatible standards: \*

- IEC 61851-21: 2017

### Fault current tripping according to: \*

- IEC 62752: 2016 and UL 2231: 2012

\*Complete list of reference standards available in safety manual



Figure 1: CDT-SF 0.3-S2  
CDT 0.3-S2



Figure 2: CDT-SF 0.3-S4  
CDT 0.3-S4

## Sensor Selection Table

The following table summarizes the configuration of the product:

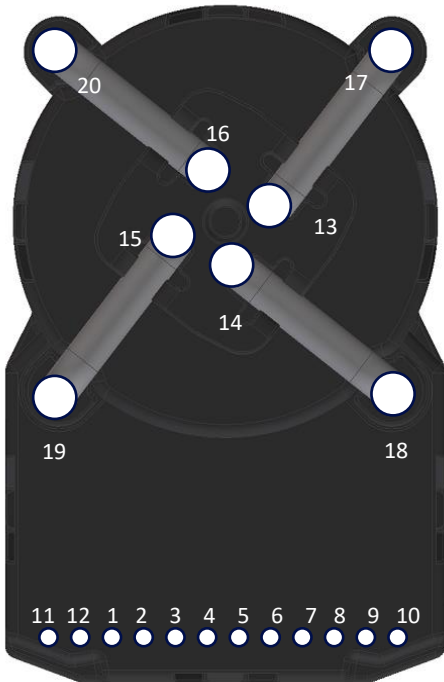
Reference	Item Number	HF Sensing 100 kHz (Y/N)	Safety Capable Sensor (Y/N) <sup>1</sup>	Number of Primary Conductors	Primary Conductor 1 Pin 13/17	Primary Conductor 2 Pin 14/18	Primary Conductor 3 Pin 15/19	Primary Conductor 4 Pin 16/20
CDT 0.3-S2	90.W3.A2.2xx.0*	N	N <sup>1</sup>	2	Mounted		Mounted	
CDT-SF 0.3-S2	90.W5.A2.2xx.0*	N	Y <sup>1</sup>	2	Mounted		Mounted	
CDT 0.3-S4	90.W3.A2.4xx.0*	N	N <sup>1</sup>	4	Mounted	Mounted	Mounted	Mounted
CDT-SF 0.3-S4	90.W5.A2.4xx.0*	N	Y <sup>1</sup>	4	Mounted	Mounted	Mounted	Mounted

1) The SPI Interface is not required, the fault current tripping signal is available via the dedicated tripping pin, see Sensor Pin Out. SPI is only required for ASIL B ISO26262 metrics compliance.

## Tripping configurations of the transducer:

Applicable Standard		Typ. Tripping threshold (mA @ 50 Hz or 60 Hz)	Typ. Recovery Level (mA @ 50 Hz or 60 Hz)	LEM tripping reference	xx item number
IEC62752 $I_{\Delta n} = 30$ mA AC RMS / 6 mA DC	AC	22.2	16.6	xCDT-IEC30m	00
	DC	4.4	3.3		
IEC62752 $I_{\Delta n} = 20$ mA RMS / 6 mA DC	AC	15	11.25	xCDT-IEC20m	01
	DC	4.4	3.3		
<b>Below tripping configuration available upon request and qualification.</b>					
IEC62752 $I_{\Delta n} = 6$ mA RMS / 6 mA DC	AC	4.5	3.37	xCDT-IEC6m	04
	DC	4.4	3.3		
UL2231 CCID20 ( $I_{\Delta n} = 20$ mA RMS)	AC	16.8	12.6	xCDT-UL20m	05
	DC	4.4	3.3		
UL2231 CCID5 ( $I_{\Delta n} = 5$ mA RMS)	AC	5	3.75	xCDT-UL5m	06
	DC	4.4	3.3		
<b>For customer system development support.</b> Single time tripping level selection via SPI from the following: xCDT-IEC30m, xCDT-IEC20m, xCDT-UL20m.					07

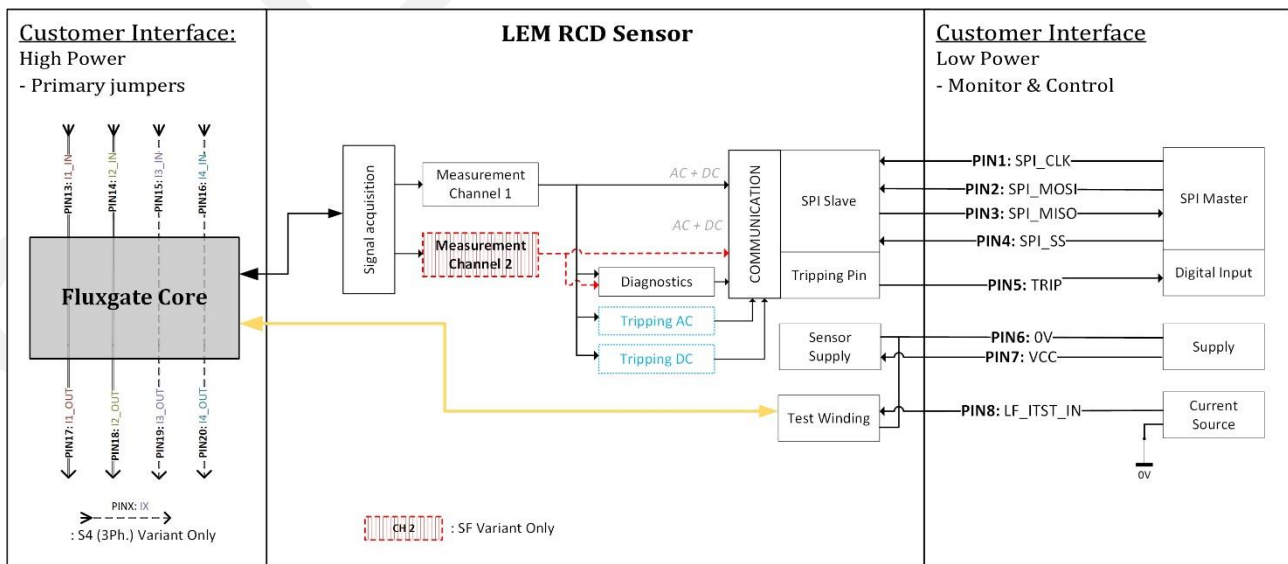
### Sensor Pin Out (TOP VIEW)



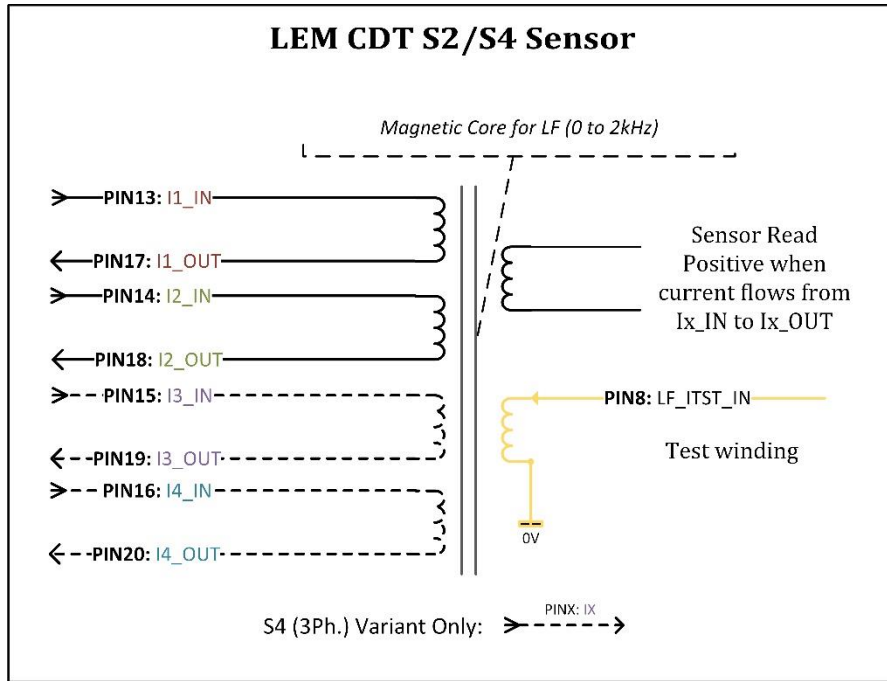
Pin n°	Signal Type	Type	Signal Name	Description
1	Digital (SPI) <sup>1)</sup>	Input	SCLK	SPI Clock
2	Digital (SPI) <sup>1)</sup>	Input	MOSI	SPI Master Output Slave Input
3	Digital (SPI) <sup>1)</sup>	Output	MISO	SPI Master Input Slave Output
4	Digital (SPI) <sup>1)</sup>	Input	SS	SPI Slave Select
5	Digital <sup>1)</sup>	Output	TRIP	Tripping Signal
6	Power supply (0V)		0 V	Negative power supply rail
7	Power supply (5V)		VCC	Positive power supply rail
8	Analog	Input	LF_ITST_IN	LF test winding current input
9				Not connected for CDT xx
10				Not connected for CDT xx
11				Not connected for CDT xx
12				Not connected for CDT xx
13	Phase 1 Input		I1_IN	Primary Conductor 1 input current
14	Phase 2 Input		I2_IN	Primary Conductor 2 input current*
15	Phase 3 Input		I3_IN	Primary Conductor 3 input current
16	Phase 4 Input		I4_IN	Primary Conductor 4 input current*
17	Phase 1 Output		I1_OUT	Primary Conductor 1 output current
18	Phase 2 Output		I2_OUT	Primary Conductor 2 output current*
19	Phase 3 Output		I3_OUT	Primary Conductor 3 output current
20	Phase 4 Output		I4_OUT	Primary Conductor 4 output current*

1): Please refer to chapter: **SPI and Tripping Pin characteristics (Digital)**

### Sensor Internal Architecture



## Sensor Magnetic Structure



### Absolute maximum ratings <sup>2) 3)</sup>

Parameter	Symbol	Unit	Value
Maximum primary conductor temperature	$T_B \text{ max}$	°C	150 °C (for short term period) <sup>1)</sup>
Primary peak current per primary conductor	$\hat{I}_P \text{ max}$	A	125
Electrostatic discharge voltage (HBM – Human Body Model)	$U_{\text{ESD HBM}}$	kV	2
Supply voltage	$U_C$	V	6

#### Notes:

- <sup>1)</sup> The design of customer PCB tracks (width & thickness) and the LEM transducer's primary jumpers can influence each other regarding thermal exchanges and self-heating. Customer remains responsible for thermal design.
- <sup>2)</sup> Absolute maximum ratings apply at 25 °C unless otherwise noted.
- <sup>3)</sup> Exposure to absolute maximum ratings for extended periods of time may affect reliability.

### General electrical ratings

Parameter	Symbol	Unit	Min	Typical	Max	Comment
Primary nominal AC RMS voltage (continuous)	$U_{P \text{ N AC}}$	V		400		
Primary current	$I_{P \text{ N AC}}$	A			40 <sup>1)</sup> 48 <sup>2)</sup>	Under qualification tests
Resistance of any primary conductor	$R_p$	uΩ		127		@ 25 °C
Base FIT of xCDT-SF 0.3-Sx		FIT		428 <sup>3)</sup>		

#### Notes:

- <sup>1)</sup> Tripping variants xCDT-IEC6m xCDT-UL5m
- <sup>2)</sup> Tripping variants xCDT-IEC30m xCDT-IEC20m xCDT-UL20m
- <sup>3)</sup> This value is calculated using IEC 62380 Standard and sensor ambient temperature profile of 73 °C. It is a FIT value with no safety mechanism applied. ISO 26262 PMHF is lower and compatible with ASIL-B metrics.

## Insulation coordination

Parameter	Symbol	Unit	Value	Comment
Primary/Primary RMS voltage for AC insulation test, 50 Hz, 1 min	$U_d$	kV	TBD	According to IEC60664-1
Primary/Secondary RMS voltage for AC insulation test, 50 Hz, 1 min	$U_d$	kV	TBD	According to IEC60664-1
Primary/Primary Impulse withstand voltage 1.2/50 $\mu$ s	$U_{Ni}$	kV	TBD	According to IEC60664-1
Primary/Secondary Impulse withstand voltage 1.2/50 $\mu$ s	$U_{Ni}$	kV	TBD	According to IEC60664-1
Primary/Primary Insulation Resistance	$R_{INS}$	M $\Omega$	TBD	According to IEC62752
Primary/Secondary Insulation Resistance	$R_{INS}$	M $\Omega$	TBD	According to IEC62752
Clearance (primary to primary) variant S2 & S4	$d_{Cl}$	mm	3.1	Shortest distance through air
Creepage distance (primary to primary) variant S4	$d_{CP}$	mm	3.1	Shortest path along device body
Creepage distance (primary to primary) variant S2	$d_{CP}$	mm	4	Shortest path along device body
Clearance (primary to secondary) variant S2 & S4	$d_{Cl}$	mm	9.6	Shortest distance through air
Creepage distance (primary to secondary) variant S2 & S4	$d_{CP}$	mm	9.6	Shortest path along device body
Case material	-	-	V0	According to UL 94
Comparative tracking index	$CTI$		600	

## Environmental and mechanical characteristics

Parameter	Symbol	Unit	Min	Typical	Max	Comment
Recommended ambient operating temperature (sensor external T°C)	$T_A$	°C	-40		105	Customer cooling related <sup>1)</sup>
Operating temperature (sensor internal PCBA T°C)	$T_A$	°C	-40		120	Software overtemperature protection flag at 120°C.
Ambient storage and transportation temperature	$T_{A,st}$	°C	-40		125	Sensor not connected. (no power supply)
Relative humidity	$RH$	%		50		

**Notes:** <sup>1)</sup> Sensor cooling is impacted by customer PCBA design. Adequate secondary routing (GND plane) may offer thermal improvement.

## General electrical ratings <sup>1)</sup>

Parameter	Symbol	Unit	Min	Typical	Max	Comment
DC primary residual current, measuring range	$I_{PRMDC}$	mA	-300		300	
AC RMS primary residual current, measuring range	$I_{PRMAC}$	mA	0		200	
Supply voltage	$U_C$	V	4.75	5	5.25	
Supply voltage rise rate	$SVCC$	V/ms	0.03			
Current consumption - Operating Mode	$I_C$	mA		70	100	<b>47 <math>\mu</math>F filtering capacitor required on sensor 5V supply.</b> Over full temperature and supply voltage range
Start-up time	$t_{start}$	ms		800		

1) Low voltage circuits are intended to be powered by a circuit derived from an isolating source (such as a transformer, optical isolator, limiting impedance or electro-mechanical relay) and having no direct connection back to the primary circuit (other than through the grounding means).

## Primary referred measurement performances of SPI outputs

Parameter	Symbol	Unit	Min	Typical	Max	Comment
Frequency bandwidth (-3 dB)	$BW$	kHz		2		
Total error CH1 referred to primary $I_{PR}$ : -8.6 mA < $I_{PRDC}$ < 8.6 mA	$\epsilon_{tot}$	mA	-1.3		1.3	Evaluated on 200 samples/400 ms
Total error CH1 referred to primary $I_{PR}$ : -300 mA < $I_{PRDC}$ < -8.6 mA and 8.6 mA < $I_{PRDC}$ < 300 mA	$\epsilon_{tot}$	mA		$\pm 15\% I_{PRDC}$		
Total error CH2 referred to primary $I_{PR}$ : -8.4 mA < $I_{PRDC}$ < 8.4 mA	$\epsilon_{tot}$	mA	-1.6		1.6	Evaluated on 200 samples/400 ms. xCDT-SF version only
Total error CH2 referred to primary $I_{PR}$ : -300 mA < $I_{PRDC}$ < -8.4 mA and 8.4 mA < $I_{PRDC}$ < 300 mA	$\epsilon_{tot}$	mA		$\pm 19\% I_{PRDC}$		xCDT-SF version only
50Hz mode rejection ratio	$RR$	dB	-200		-73	

## Test winding characteristics

Parameter	Symbol	Unit	Min	Typical	Max	Comment
Test winding peak voltage	$\hat{U}_T$	V	-10		10	@ $U_c$ Typical
DC test winding current range	$I_{TDC}$	mA	-18.75		18.75	
AC RMS test winding current range	$I_{TAC}$	mA	0		12.5	
Turn ratio	$N_p/N_s$			1:16		
Resistance of test winding (at 2 kHz)	$RT$	$\Omega$			3	

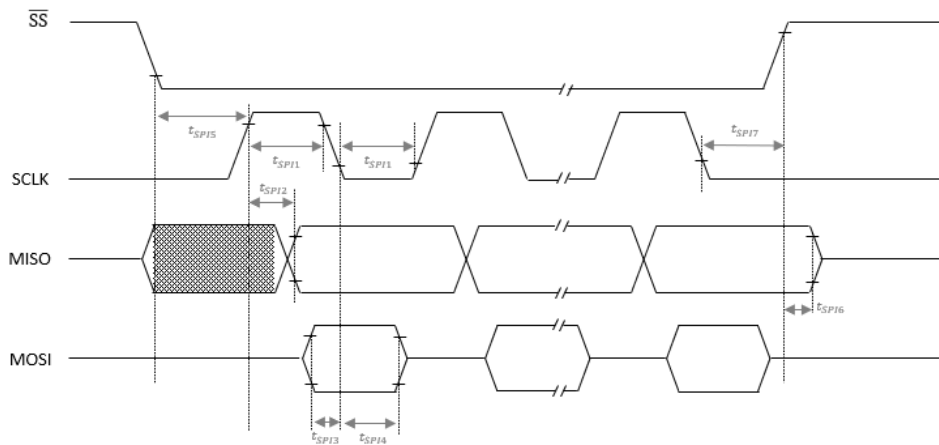
## SPI and Tripping Pin characteristics (Digital)

Parameter	Symbol	Unit	Min	Typical	Max	Comment
Output logic high		V	3.0/2.6	3.3	3.34	$I_{source}=3mA / I_{source}=9mA$ . It is recommended to set a line resistor on SPI MISO to limit current due to 3V3 imbalance. See application note.
Output logic low		V	0	0	0.3/0.7	$I_{sink}=3mA / I_{sink}=9mA$ .
Input logic high		V	2.7		3.43	It is recommended to set a line resistor on SPI SS, CLK and MOSI to limit current due to 3V3 imbalance. See application note.
Input logic low		V	0		0.6	
Sink / source output maximum current	$I_{out\ max}$	mA	-15		+15	
Input low injection current (in protection diod)	$I_{ICL}$	mA	0		-5	Input Voltage < 0V-0.3
Input high injection current (in protection diod)	$I_{ICH}$	mA	0		+5	Input Voltage > 3V3+0.3
Total Input Injection Current (sum of all I/O and control pins)	$\Sigma I_{LICT}$	mA	-20		+20	Absolute instantaneous sum of all $\pm$ input injection currents from all I/O pins.
Sensitivity of channel 1 and 2 (SPI)	$S_N$	LSB/mA		10		
Resolution of channel 1 and 2 (SPI)		mA/LSB		0.1		

## SPI and tripping switching characteristics <sup>1)</sup>

Parameter	Symbol	Unit	Min	Typical	Max	Comment
Clock input low or high time	$t_{SPI1}$	ns	15			
Data output valid after clock edge	$t_{SPI2}$	ns			20	
Setup time of input data to clock edge	$t_{SPI3}$	ns	10			
Hold time of input data to clock edge	$t_{SPI4}$	ns	15			
Slave Select falling edge to clock edge	$t_{SPI5}$	ns	4000			Value imposed by SW design choice.
Slave Select rising edge to Output high impedance	$t_{SPI6}$	ns	8		50	
Slave Select rising edge after clock edge	$t_{SPI7}$	ns	TBD			

**Notes:** <sup>1)</sup> Refer to SPI specification document for protocol details. SW implementation supports a SPI clock at 1 MHz +/- 10 KHz.



## Performance Parameters Definition

### Definition of typical, minimum and maximum values

Minimum and maximum values for specified limiting and safety conditions must be understood as such as well as values shown in "typical" graphs.

On the other hand, measured values are part of a statistical distribution that can be specified by an interval with upper and lower limits and a probability for measured values to lie within this interval.

Unless otherwise stated (e.g. "100 % tested"), the LEM definition for such intervals designated with "min" and "max" is that the probability for values of samples to lie in this interval is 99.73 %.

For a normal (Gaussian) distribution, this corresponds to an interval between -3 sigma and +3 sigma. If "typical" values are not obviously mean or average values, those values are defined to delimit intervals with a probability of 68.27 %, corresponding to an interval between -sigma and +sigma for a normal distribution.

Typical, maximal, and minimal values are determined during the initial characterization of the product.

## Sensor Application Notes

xCDT sensor Application note reference PDM number includes information that will ensure robust integration of the sensor in customer application (test set-up, magnetic environment...).

SPI Technical Specification reference PDM number detail the Serial Peripheral Interface protocol to be implemented by the customer to communicate with the sensor.

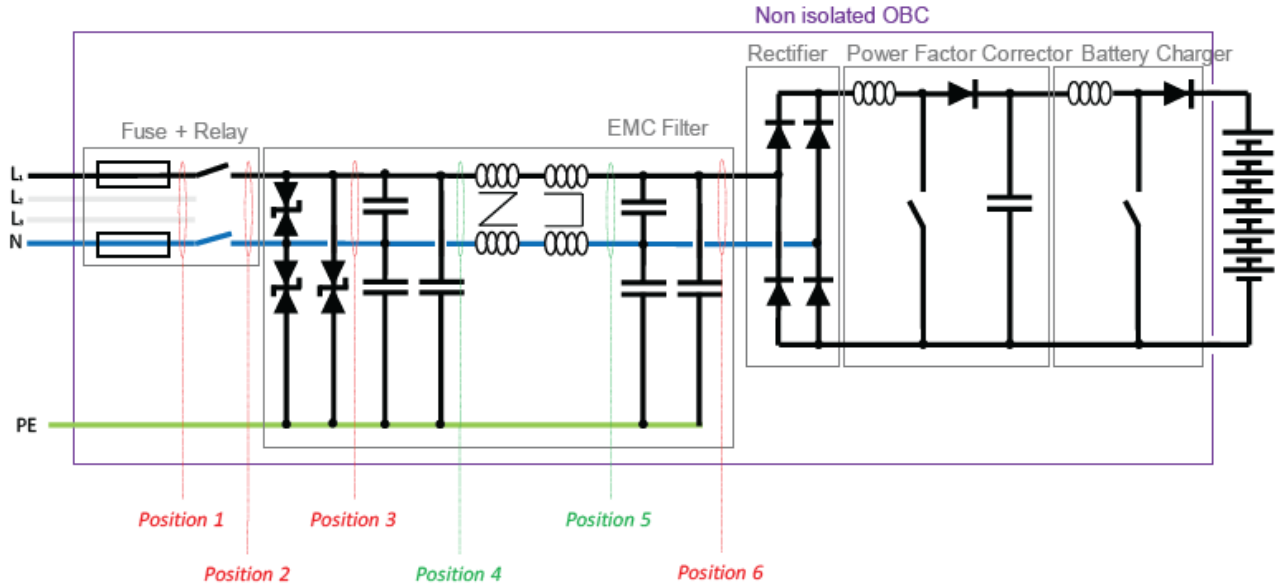
The latest version of these documents can be downloaded from LEM Website.

### Correct Sensor Integration inside Power Converters regarding EMC constraints

The differential transducer placement inside client application, typically in a car onboard charger, must be chosen to minimize EMC interferences. It shall be located after surge absorbers at position 4 to 5.

Other positioning may degrade the performance of the sensor.

The sensor is sensitive to aliasing phenomena on high frequency content (>10 kHz) which shall be minimized on the customer side.

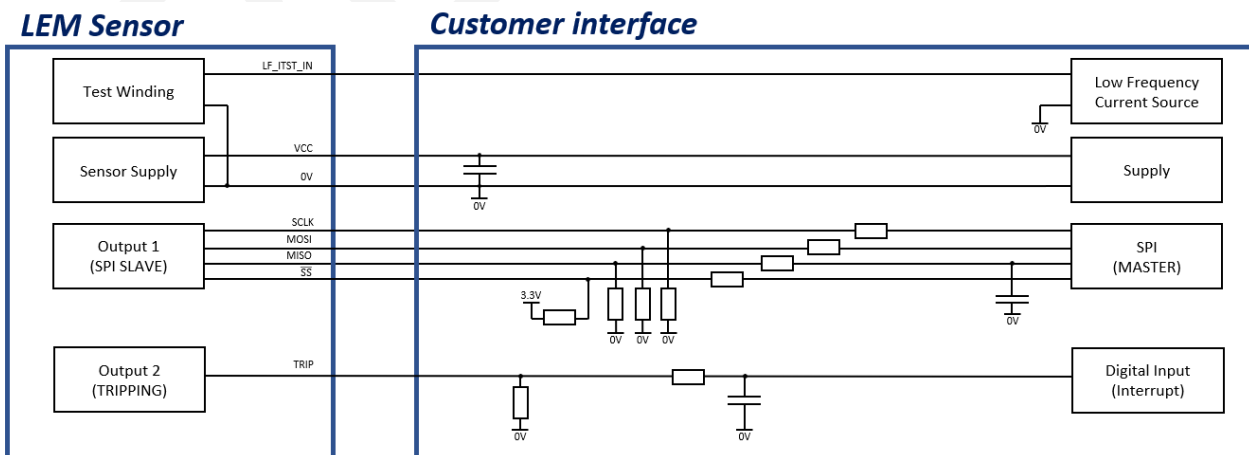


### Test Winding Low Frequency Sensing Element Design rules

Customer test winding driving circuit for low frequency sensor element must be designed carefully to avoid interactions with the sensor. It must behave as a perfect current source while injecting current and shall be floating while unused.

### Sensor typical interface

See Application Note for details on values of components.





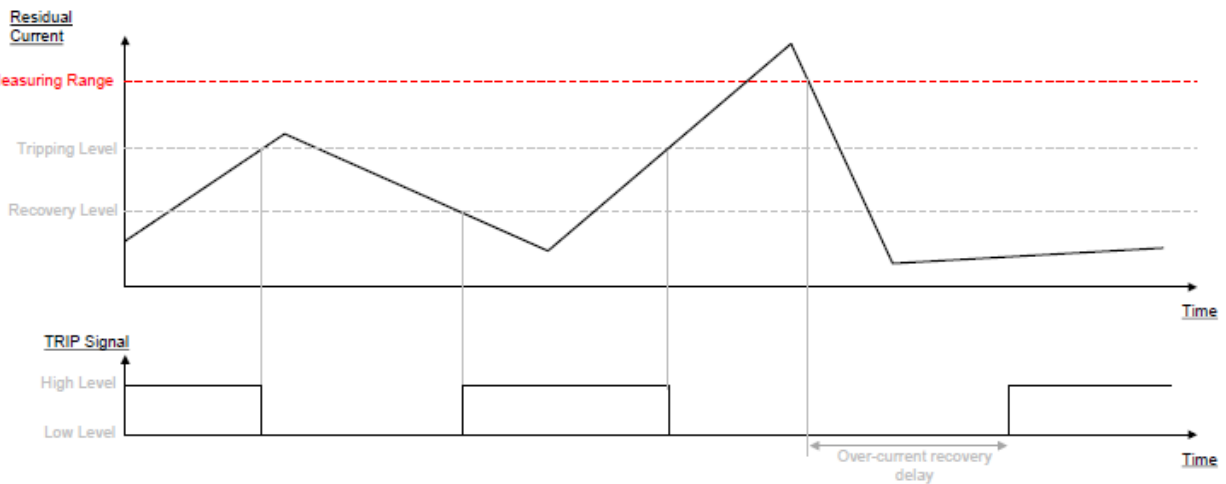
### Tripping Pin and SPI TRIP Signal

The tripping pin and SPI TRIP signal are used to indicate that a fault current has been detected. In such condition, the pin goes to LOW and the SPI signal goes to high whether AC or DC tripping occurred, or in a situation when the sensor is not operational. During startup, the TRIP pin is set-up in high impedance and requires a pull-down resistor for safe operation.

Please refer to the safety manual for detailed description of "safe state" according to ISO26262.

### Tripping timing diagram

The tripping signal will operate as follows:

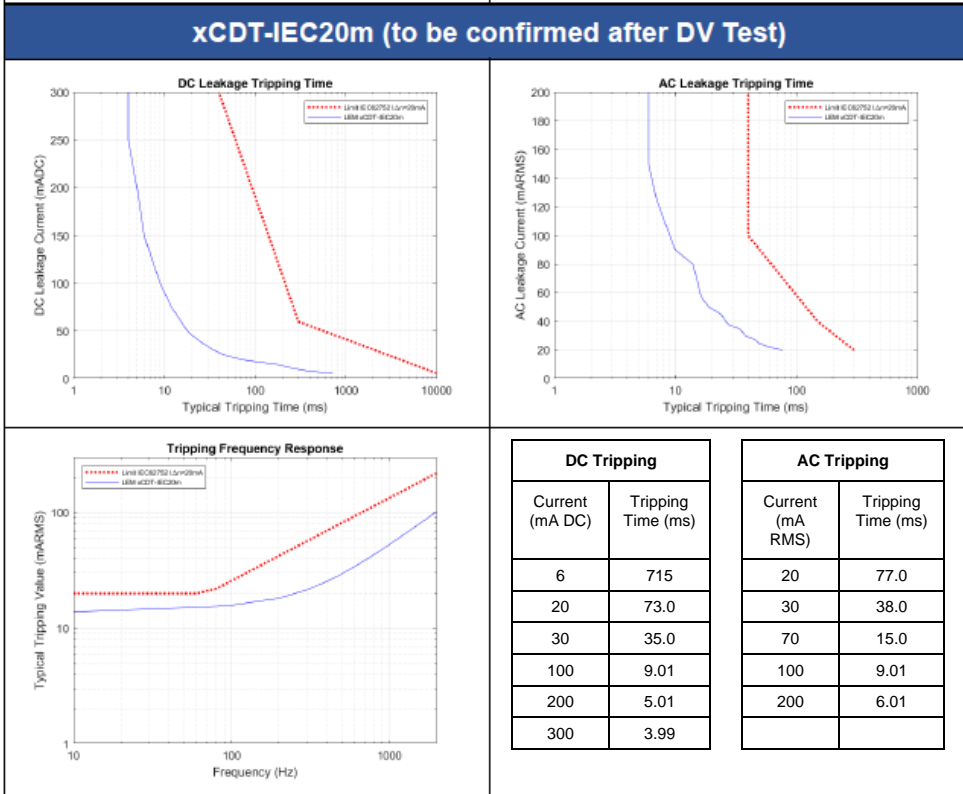
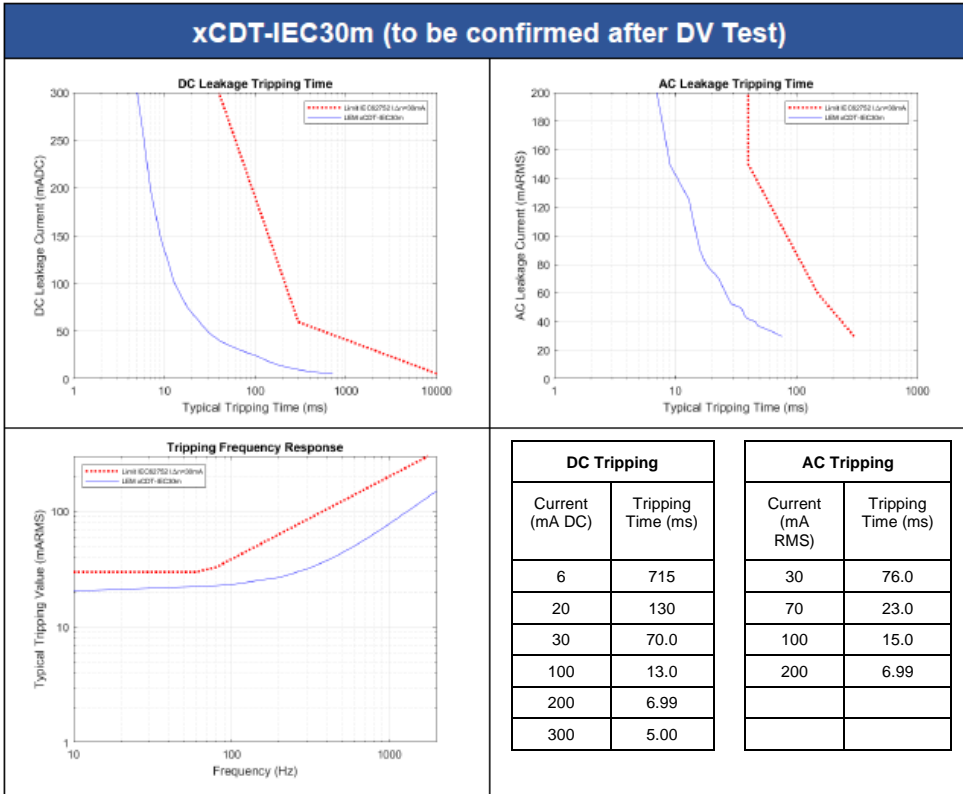


**Note:** The typical over-current recovery delay is 5ms.

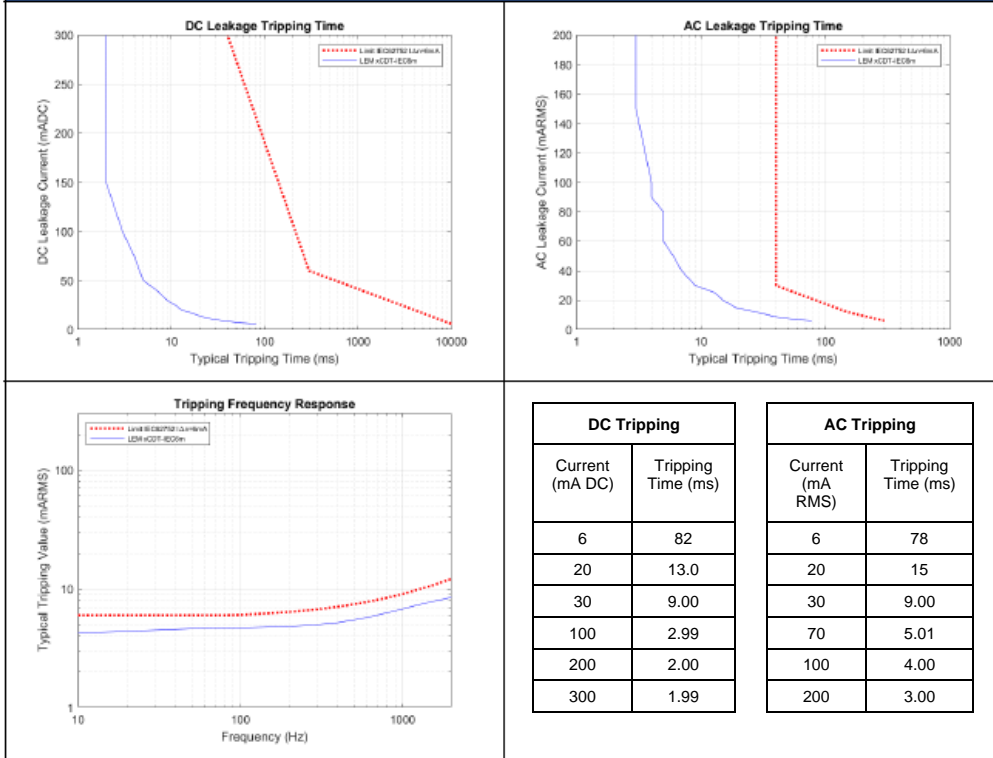
The Fault tripping time of LEM sensor only includes the delay related to the measurement of leakage current but does not comprise additional delay related to customer electronic circuit (control circuit of relay, relay opening time...).

On following graphs, the red dashed curve shows the tripping characteristic required by the norm and the blue curve gives you the theoretical tripping time programmed in the sensor software. To consider measurement tolerance, customer can include a maximum LEM actual tripping time variation of +/- 30 % compared to theoretical blue curve on short tripping time.

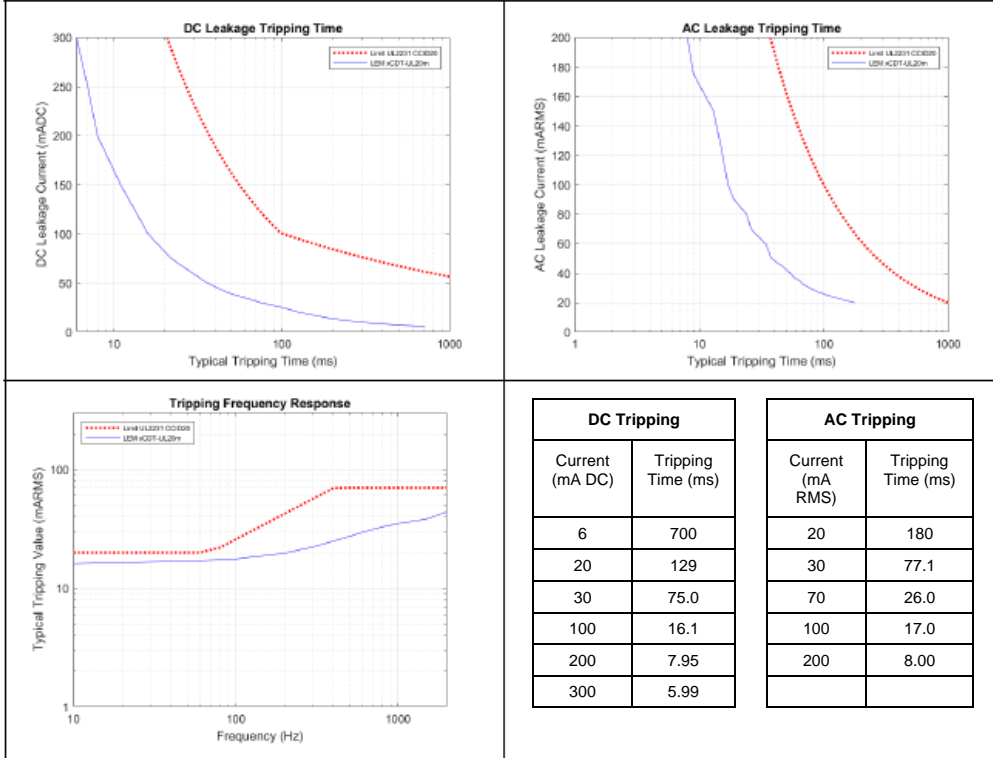
**Overcurrent specifications:** For a primary peak current ( $I_{PRM}$ ) above |300|mA the typical tripping time is 500us.

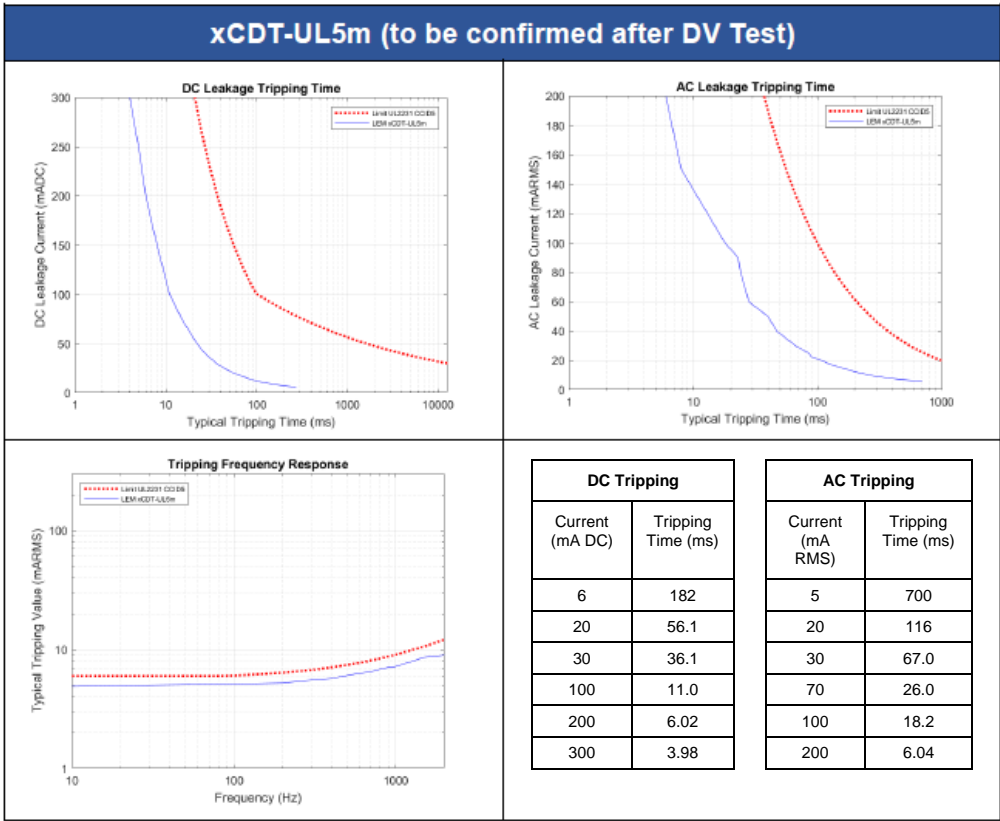


**xCDT-IEC6m (to be confirmed after DV Test)**

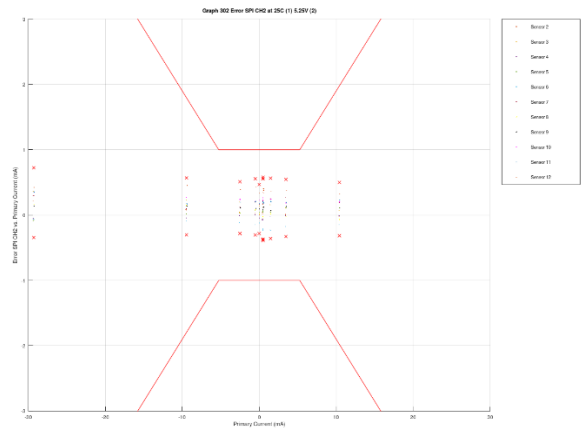
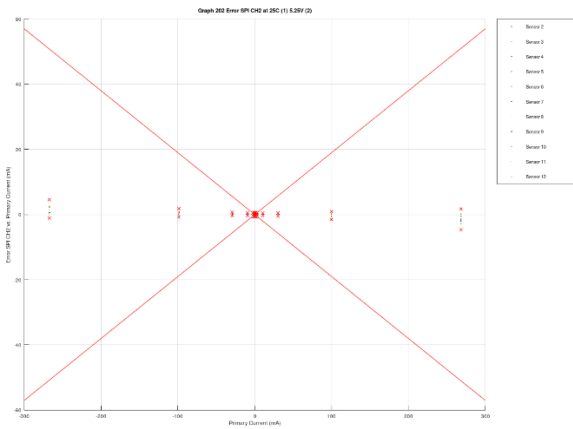
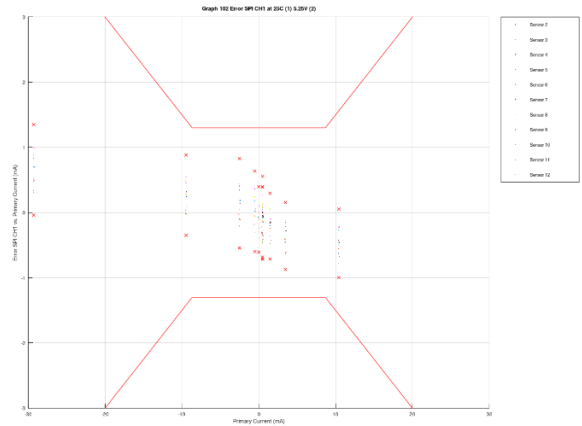
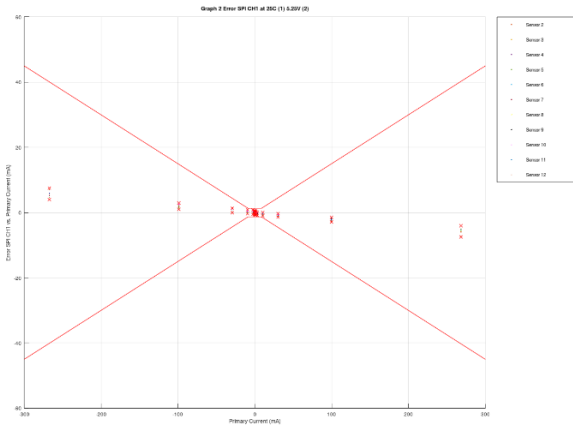


**xCDT-UL20m (to be confirmed after DV Test)**



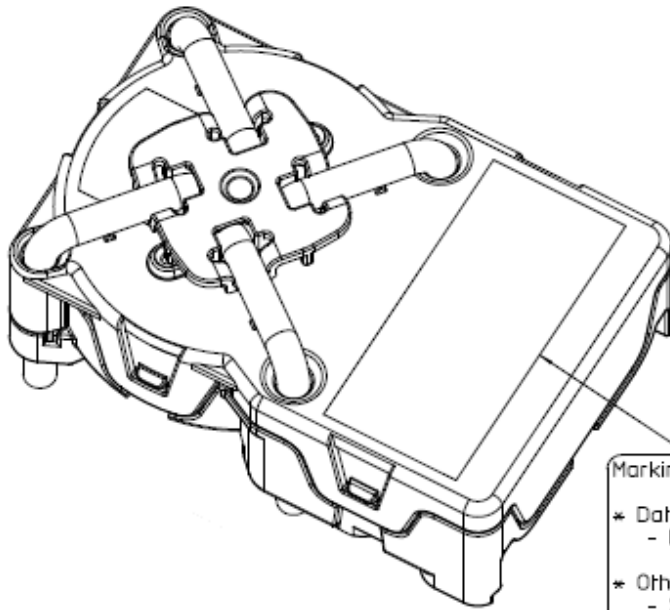


The absolute error of the sensor measurement channels versus voltage supply is given as follows (data extract DV test results 01/2023):



SPEC

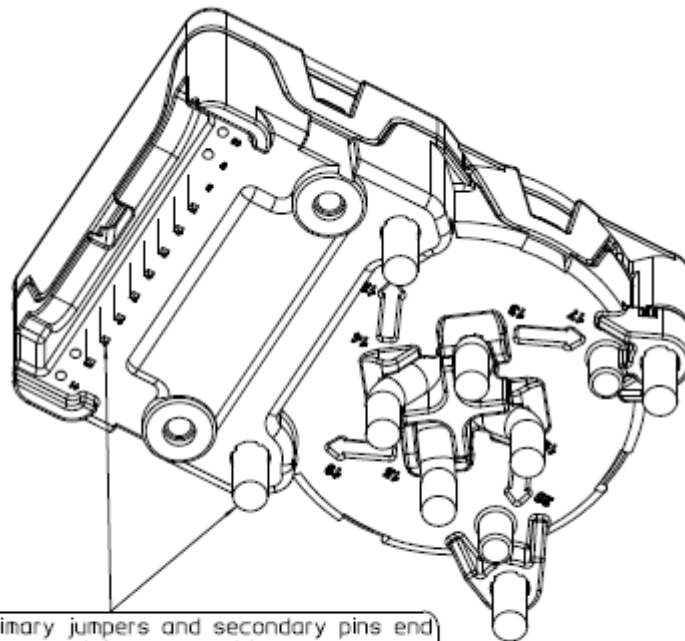
## Dimensions CDT 0.3-S2, CDT-SF 0.3-S2, CDT 0.3-S4, CDT-SF 0.3-S4 (in mm)



Marking area:

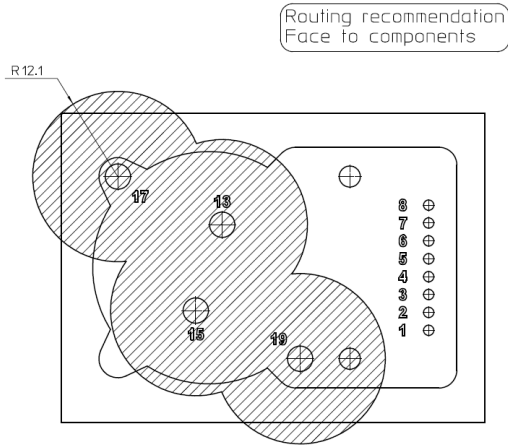
- \* Data matrix or QR code content
  - Date code + LEM or Customer P/N
- \* Other marking
  - Sensor designation
  - Date code: PYYDDDCCHMMSSJ

P - Production center  
 YY = Year  
 DDD - Day of the year  
 CC = Machine ID  
 HH = Hour  
 MM = Minute  
 SS = Second  
 J - Machine jig ID

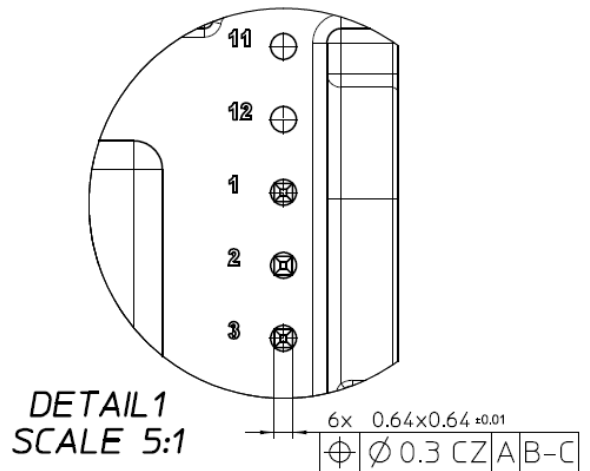
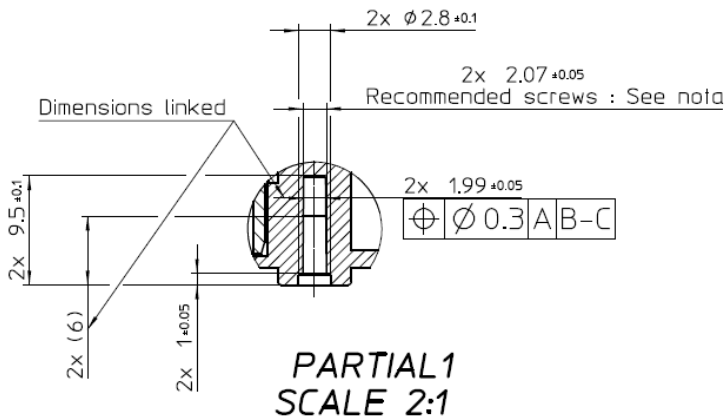
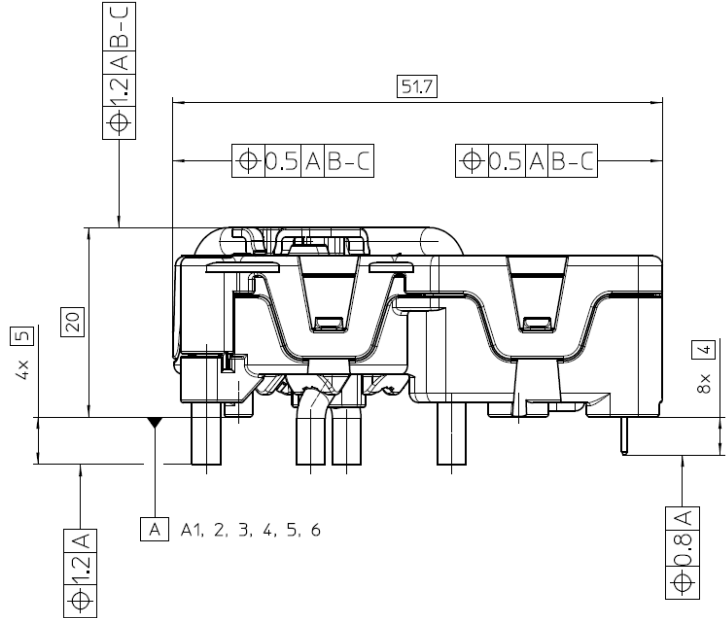
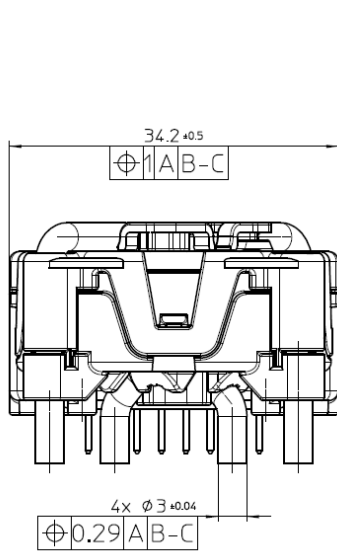
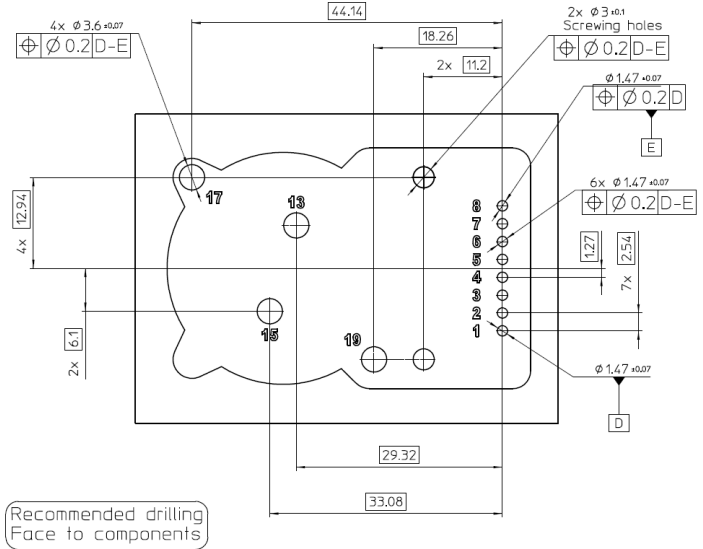


Primary jumpers and secondary pins end are tinned for wave soldering process (See details on notas)

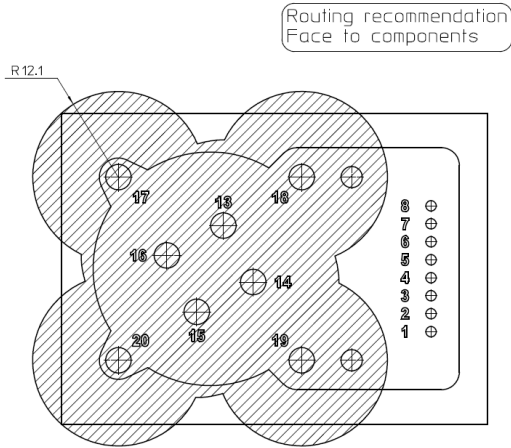
CDT-SF xxx-S2



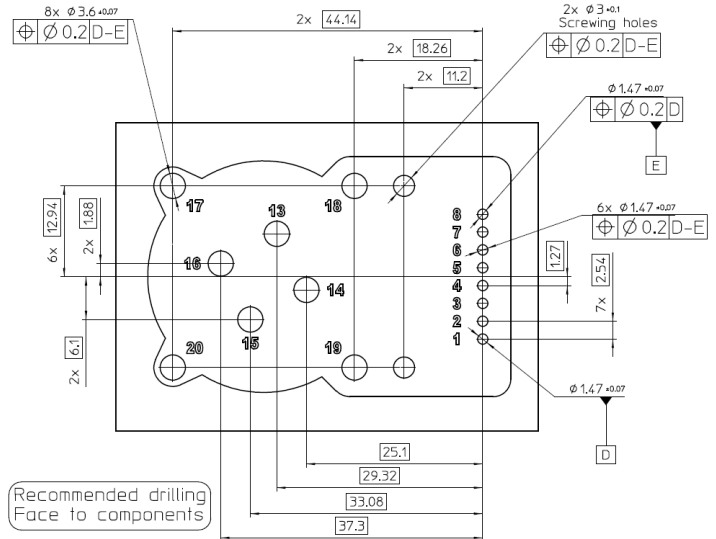
No secondary connection tracks in the hatched areas (for clearance and creepage insulation insurance)  
Areas are calculated considering  $\phi 5$  mm soldering pads around primary jumpers.



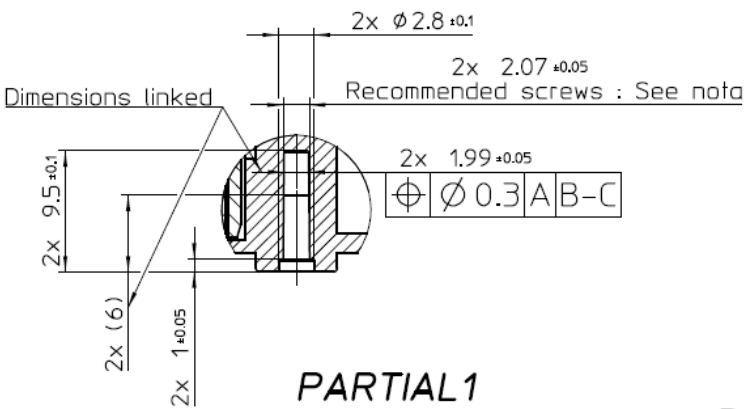
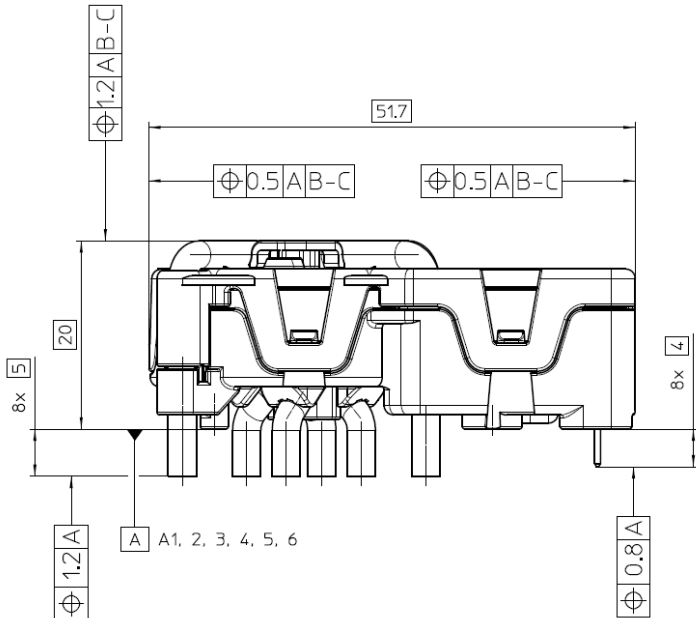
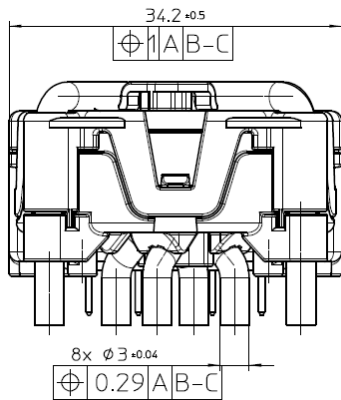
CDT-SF xxx-S4



No secondary connection tracks in the hatched areas (for clearance and creepage insulation insurance) Areas are calculated considering  $\varnothing 5$  mm soldering pads around primary jumpers.

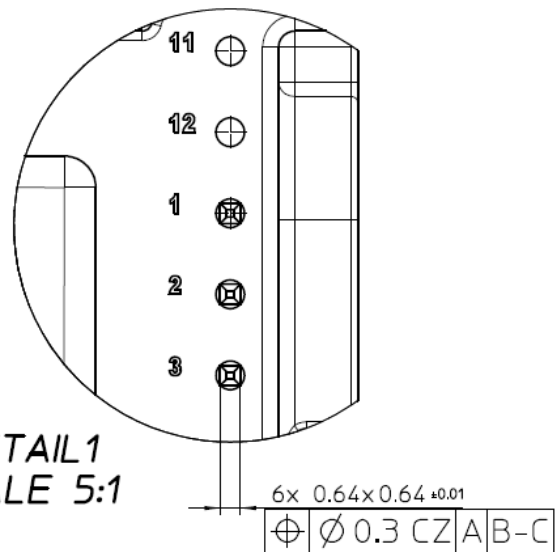


Recommended drilling Face to components



PARTIAL 1 SCALE 2:1

DETAIL 1 SCALE 5:1





## Mechanical characteristics

• Plastic case	PA66-GF25
• Mass	
- CDT-SF 0.3-S2	33 g
- CDT-SF 0.3-S4	41 g
• Primary conductor material	EN CW004A Cu-eti
• Electrical terminal coating	Nickel + Matte Tin Plating
• Degrees of protection provided by enclosure	IP40
• Connector type	Through Hole
• Soldering type	Wave or selective wave
• Soldering profile	Maximum TBD °C, 10 s
• Recommended PCB thickness	1.6 mm
Mandatory screws for the 2 fixing holes	DELTA PT Ø 2.5 x 8 mm INOX A2 or equivalent non-magnetic steel Fastening torque = 0.6 ±0.1 N·m.

## Assembly recommendations

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

The sensor shall be assembled in industrials ESD protected environment.

These devices are intended to be mounted on the printed wiring board of the end-use equipment.



## 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.

**If applicable:** De-energize all circuits and hazardous live parts before installing the product.

All installations, maintenance, servicing operations and use must be carried out by trained and qualified personnel practicing applicable safety precautions.

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 minimum 30 mm between the primary terminals of the transducer and other neighboring components.

**If applicable:** Main supply must be able to be disconnected.

**If applicable:** Always inspect the flexible probe for damage before using this product.

**If applicable:** Never connect or disconnect the external power supply while the primary circuit is connected to live parts.

**If applicable:** Never connect the output to any equipment with a common mode voltage to earth greater than 30 V.

**If applicable:** Always wear protective clothing and gloves if hazardous live parts are present in the installation where the measurement is carried out.

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.

**If applicable:** When defining soldering process, please use no cleaning process only.



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.

**If CE marking not applicable:** 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

## Version history

Date	Version	Comment
19/03/2024	1.19	Tripping timing diagrams updated. Architecture and Magnetic drawings. Dimension drawing updated. Various parameter fixes.
5/28/2024	2.19	Typos corrected. Accuracy range and SPI pin definition