AUTOMOTIVE CURRENT TRANSDUCER OPEN LOOP TECHNOLOGY
HBCT 250-V

Introduction

The HBCT family provides to an engine control unit (ECU) the actual value of current flowing in and out of the battery and the ambient temperature by a NTC thermistor. The current measurement is performed with a full galvanic separation between the primary circuit (high power) and the secondary circuit (electronic circuit).
The HBCT 250-V proposed a battery clamp mounting and the transducer is linked to the ECU with the wiring harness using a waterproof connector.

Features

- Open Loop transducer using the Hall effect
- Unipolar +5 V DC power supply
- Primary current measuring range up to −250 A / +100 A
- Maximum RMS primary admissible current: defined by battery pole to have T < +150 °C
- Operating temperature range: −30 °C < T < +90 °C
- Output voltage: full ratio-metric (in sensitivity and offset)
- Ferrite material magnetic core allowing high frequency primary current ripple with low self-heating.

Advantages

- Excellent accuracy
- Very good linearity
- Very low thermal offset drift
- Very low thermal sensitivity drift
- High frequency bandwidth
- Non insertion losses
- Very fast delay time.

Principle of HBCT family

The open loop transducers uses a Hall effect integrated circuit. The magnetic flux density B, contributing to the rise of the Hall voltage, is generated by the primary current I_P to be measured. The current to be measured I_P is supplied by a current source i.e. battery or generator (Figure 1).
Within the linear region of the hysteresis cycle, B is proportional to:

$$B\,(I_P) = a \times I_P$$

The Hall voltage is thus expressed by:

$$U_{Hall} = (c_{Hall} / d) \times I_{Hall} \times a \times I_P$$

Except for I_P, all terms of this equation are constant.
Therefore:

$$U_{Hall} = b \times I_P$$

a	constant
b	constant
c_{Hall}	Hall coefficient
d	thickness of the Hall plate
I_{Hall}	current across Hall plates

The measurement signal U_{Hall} is amplified to supply the user output voltage or current.

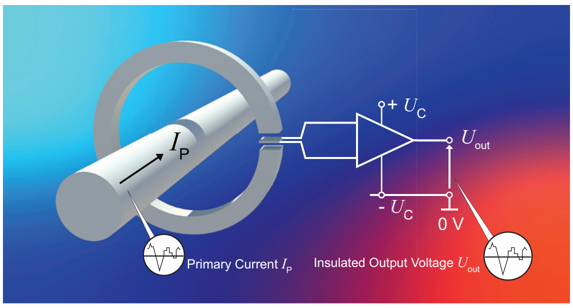
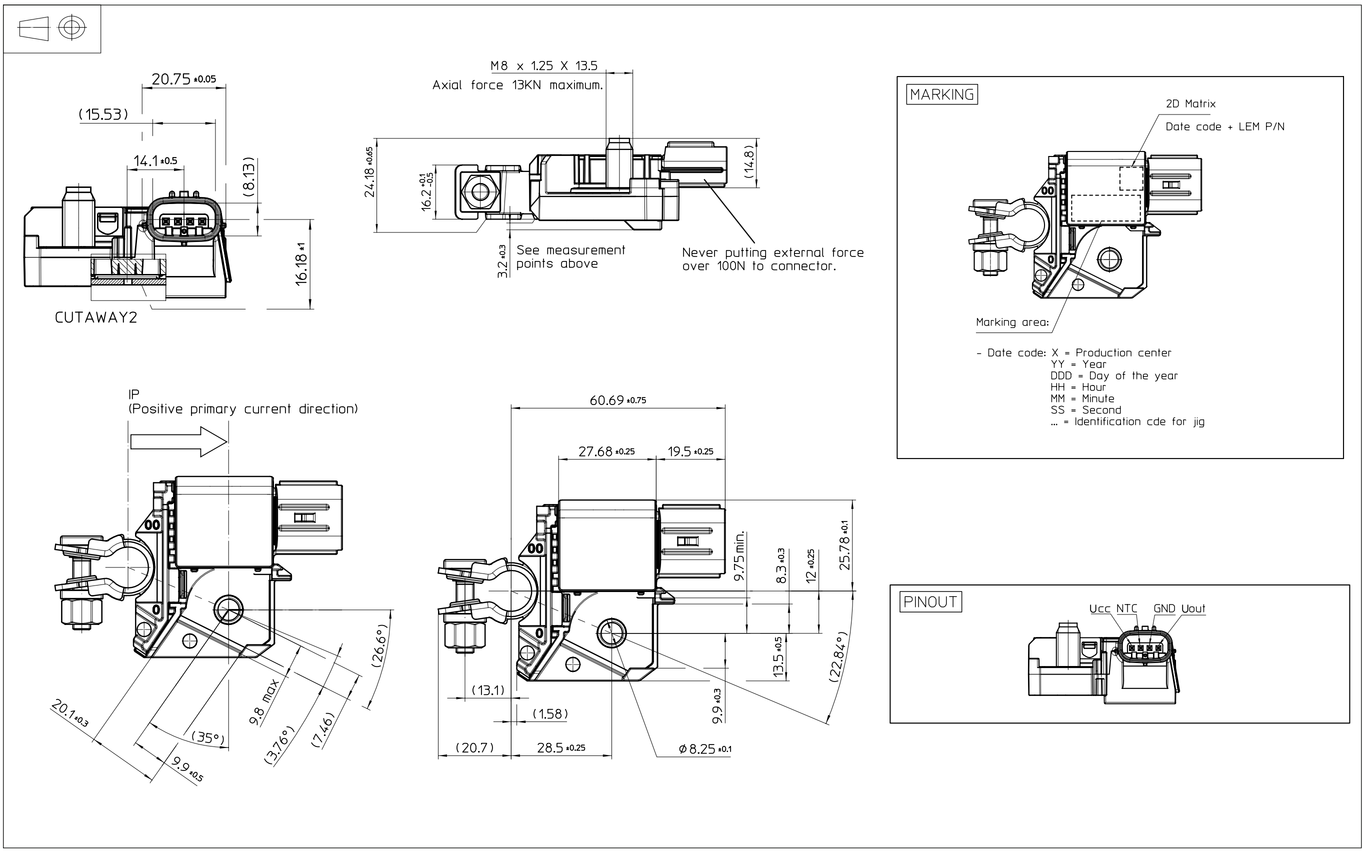


Fig. 1: Principle of the open loop transducer.

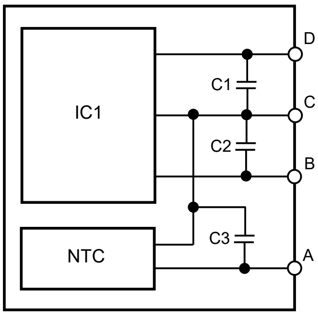
Dimensions HBCT 250-V (in mm)



Mechanical characteristics

- Plastic case — PBT GF 30 % (color black)
- Magnetic core — Ferrite
- Mass — see drawing
- Pins — see drawing
- IP level — IPx2

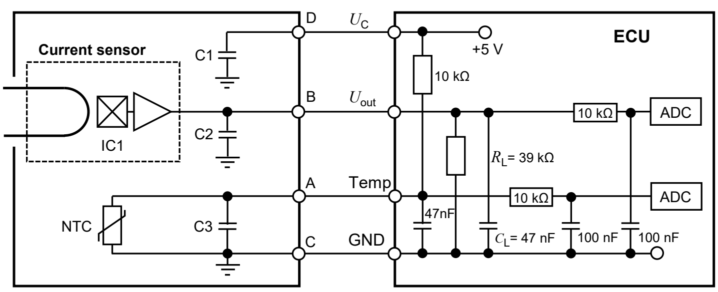
System architecture (example)



Components list	
IC1	Hall sensor ASIC
C1	Capacitor
C2, C3	Capacitors
NTC	Thermistor

Pin Out	
D	DC supply voltage (5 V)
C	Ground
B	Output signal
A	Temperature signal

System architecture (example)



Absolute ratings (not operating)

Parameter	Symbol	Unit	Specification			Conditions
			Min	Typical	Max	
Nominal supply voltage	U_C	V			14	1 min @ T = 25 °C
Ambient storage temperature	$T_{A\,st}$	°C	−40		125	
Electrostatic discharge voltage (HBM - Human Body Model)	$U_{ESD\,HBM}$	kV				±4 kV contact discharges (R = 330 Ω, C = 150 pF) ±8 kV air discharges (R = 330 Ω, C = 150 pF)
RMS voltage for AC insulation test	U_d	kV			2.5	50 Hz, 1 min
Creepage distance	d_{Cp}	mm		TBD		
Clearance	d_{Cl}	mm		TBD		
Comparative traking index	CTI			PLC3		

Operating characteristics in nominal range ($I_{P\,N}$)

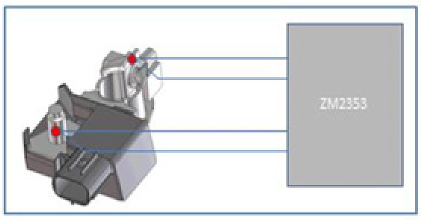
Parameter	Symbol	Unit	Specification			Conditions
			Min	Typical	Max	
Electrical Data						
Primary current, measuring range	$I_{P\,M}$	A	−250		100	
Primary nominal RMS current	$I_{P\,N}$	A	−250		100	
Supply voltage	U_C	V	4.5	5	5.5	
Ambient operating temperature	T_A	°C	−30		90	
Output voltage (Analog)	U_{out}	V		$U_{out} = (U_C/5) \times (U_O + S \times I_P)$		
Sensitivity	S	mV/A		11.43		@ T_A = 25 °C, @ U_C = 5 V
Offset voltage	U_O	V		3.357		
Current consumption	I_C	mA		8	10	
Output filter	R_{out}	Ω				see system architecture(example)
Performance Data						
Sensitivity error	ε_S	%		±0.6		@ T_A = 25 °C, @ U_C = 5 V
Electrical offset voltage	$U_{O\,E}$	mV		±3		@ T_A = 25 °C, @ U_C = 5 V
Magnetic offset voltage	$U_{O\,M}$	mV		±2.9		@ T_A = 25 °C, @ U_C = 5 V
Linearity error	ε_L	%	−1		1	% of full scale
Average temperature coefficient of $U_{O\,E}$	$TCU_{O\,E\,AV}$	mV/°C		±0.04		
Average temperature coefficient of S	TCS_{AV}	%/°C		±0.02		
Delay time to 90 % of the final output value for $I_{P\,N}$ step	$t_{D\,90}$	ms			1	
Frequency bandwidth	BW	Hz		257		
Peak-to-peak noise voltage	$U_{no\,pp}$	mV			14	DC to 1 MHz
Start-up time	t_{start}	µs			800	
NTC Resistance	R_{NTC}	kΩ	9.9	10	10.1	Accuracy of 1 % at 25 °C
B 25/85 constant			3399	3434	3468	
Temperature accuracy		°C	−2		2	−40 °C / 90 °C power off

Inductance

Freq [Hz]	20K	100K
Inductance [H]	270n	310n

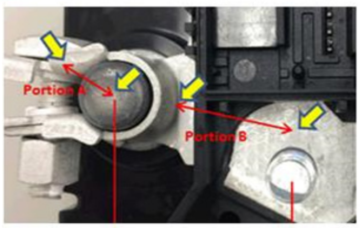
Equipment ZM2353 (Meker; NF Corporation)

Condition terminals connected to position A and stud (red points) via clip)

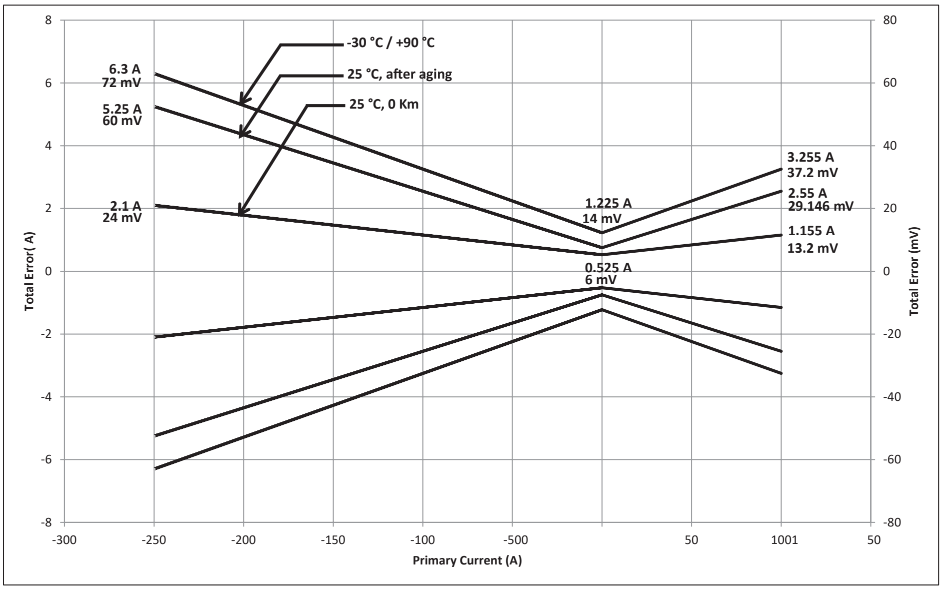


Voltage drop acceptance criteria

Portion	Initial value	After test
A+B	0.18 mV/A	0.19 mV/A



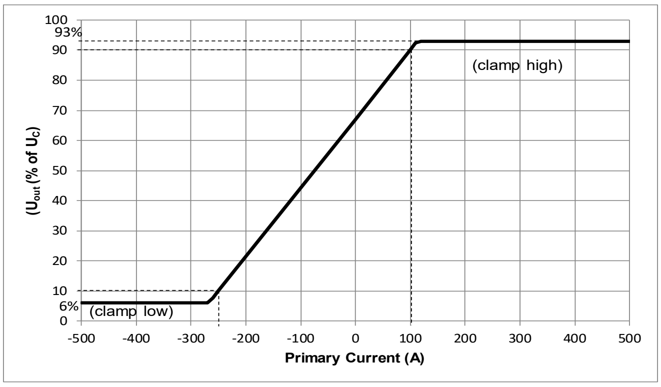
Total Error ε_{tot}



	At 0 Km			After Aging		
	0 A	−250 A	+100 A	0 A	−250 A	+100 A
T_A = 25 °C	±0.525 A	±2.1 A	±1.155 A	±0.75 A	±5.25 A	±2.55 A
	±6 mV	±24 mV	±13.2 mV	±8.57 mV	±60 mV	±29.146 mV
T_A = −30 °C / 90 °C	±1.225 A	±6.3 A	±3.255 A	±1.225 A	±6.3 A	±3.255 A
	±14 mV	±72 mV	±37.2 mV	±14 mV	±72 mV	±37.2 mV

Output and clamping

$$I_P = \left(\frac{5}{U_C}\times U_{out} - U_O\right)\times\frac{1}{S} \text{ with } S \text{ in (V/A)}$$

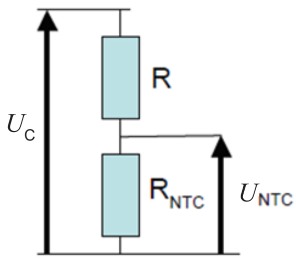


Temperature output

Complete formula:

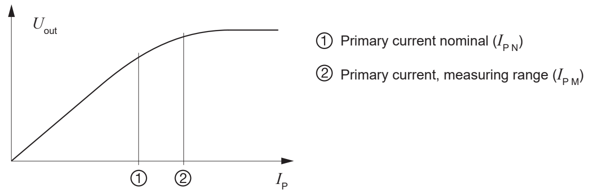
with $$T = \frac{1}{A + B * \ln(Rt) + C * (\ln(Rt))^3} - 273.15$$

A 0.000861133
B 0.000256414
C 1.68E-07



PERFORMANCES PARAMETERS DEFINITIONS

Primary current definition:



Definition of typical, minimum and maximum values:

Minimum and maximum values for specified limiting and safety conditions have to be understood as such 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, minimum and maximum values are determined during the initial characterization of a product.

Output noise voltage:

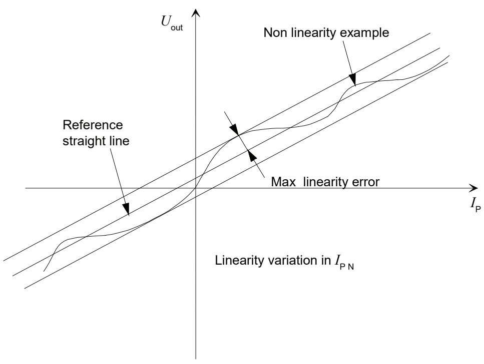
The output voltage noise is the result of the noise floor of the Hall elements and the linear amplifier.

Magnetic offset:

The magnetic offset is the consequence of an any current on the primary side. It's defined after a stated excursion of primary current.

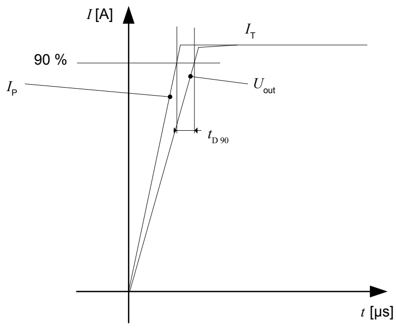
Linearity:

The maximum positive or negative discrepancy with a reference straight line $U_{out} = f(I_P)$.
Unit: linearity (%) expressed with full scale of I_{PN}.



Delay time t_{D90}:

The time between the primary current signal (I_{PN}) and the output signal reach at 90 % of its final value.



Sensitivity:

The transducer's sensitivity S is the slope of the straight line $U_{out} = f(I_P)$, it must establish the relation:

$$U_{out}(I_P) = U_C/5\ (S \times I_P + U_O)$$

Offset with temperature:

The error of the offset in the operating temperature is the variation of the offset in the temperature considered with the initial offset at 25 °C.

The offset variation I_{OT} is a maximum variation the offset in the temperature range:

$$I_{OT} = I_{OE}\ \text{max} - I_{OE}\ \text{min}$$

The offset drift $TCI_{OE\,AV}$ is the I_{OT} value divided by the temperature range.

Sensitivity with temperature:

The error of the sensitivity in the operating temperature is the relative variation of sensitivity with the temperature considered with the initial offset at 25 °C.

The average temperature coefficient of sensitivity TCS_{AV}, S_T is the maximum temperature variation of S (in ppm or %) of the sensitivity in the temperature range:

S_T = (Sensitivity max − Sensitivity min) / Sensitivity at 25 °C.
The average temperature coefficient of sensitivity TCS_{AV} is the S_T value divided by the temperature range.
Deeper and detailed info available is our LEM technical sales offices (www.lem.com).

Offset voltage @ I_P = 0 A:

The offset voltage is the output voltage when the primary current is zero. The ideal value of U_O is $U_C/2$. So, the difference of $U_O - U_C/2$ is called the total offset voltage error. This offset error can be attributed to the electrical offset (due to the resolution of the ASIC quiescent voltage trimming), the magnetic offset, the thermal drift and the thermal hysteresis. Deeper and detailed info available is our LEM technical sales offices (www.lem.com).

Environmental test specifications:

Refer to LEM GROUP test plan laboratory CO.11.11.515.0 with "Tracking_Test Plan_Auto" sheet.

TESTS	Procedure or Standard (generic)	Specific conditions
Resistance to electrostatic discharge		
ESD test	DTS0504G	Case: ±5 kV, ±10 kV, ±15 kV, ±20 kV, ±25 kV Terminals: ±5 kV, ±10 kV, ±15 kV Beta conditions Tests 6.1, 6.2, 6.4 with Model 2 --> 330 pF 2000 Ω Tests 6.3 with Model 1 --> 150 pF 330 Ω
Resistance to electromagnetic field		
Resistance to external magnetic field	None	25 °C, U_C = 5 V I_P = ±250 A (step 10 %) 3 axis, step angle 30°
Bench immunity test (TEM-CELL)	DTSC7006G	Class A. test level 2, 100 V/m
Environmental tests		
High-temperature operation test	DTSC7000G	90 °C (Max temperature) during 1000 hrs at U_C = 5.5 V Sensor supplied but no monitoring
Low temperature operation test	DTSC7000G	Approval drawing and DTSC7000G condition: Temperature: −30 °C ±3 °C Operation time: 192 h ±2 h Power supply: 5 V ±0.2 V Primary current step of 50 A
High temperature limit test (test for reference)	None	Temperature: 90 to 180 °C ±3 °C (10 °C by step) Power supply: No energization until the temperature is reached, once temperature is reached energize with the maximum voltage Current: 0 A Duration: 45 min at each temperature step
Low temperature limit test (test for reference)	None	Temperature: −40 °C to −60 °C ±3 °C (10 °C by step) Power supply: No energization until the temperature is reached, once temperature reached energize with the minimum voltage Current: 0 A Duration: 45 min at each temperature step
High-temperature storage test	DTSC7000G	Temperature: 100 °C ±3 °C Duration: 96 h±2 h Sensor not supplied
Low temperature storage test	DTSC7000G	Temperature: −40 °C ± 3 °C Duration: 96 h±2 h Sensor not supplied
High temperature High humidity test (Continuous operation durability test)	DTSC1904G	(TER) DTSC1904G: 85 °C ±5 °C, 90 % to 95 % *RH*, duration: 96 h Implemented with battery clamp attached to battery post (JIG) (SEN) 90 °C ,90 % *RH*,1000 h, 5 V
Thermal shock test	DTSC7000G DTSC1904G	Perform only one test conditions: −40 °C during 30 min and +90 °C during 30 min Repeat the cycle 1000 times (1000 h) Perform the cross section check of soldering: 1) intermediate: after 500 cycle, 3 pcs 2) after thermal shock; 2000 cycle, 3 pcs

Solder joint life test	DTSC0509G	Follow DTSC0509G Exact same conditions than Thermal shock Test duration 1000 h Perform the cross section check of soldering: after solder joint life test, 3 pcs
Dew condensation test	DTSC7000G	Reuse same conditions than HABT 2 h @ −5 °C and 10 min @ 85 % *RH* @ +35 °C No operational
Migration test (Power Application test under Dewing Conditions)	None	Test performed after thermal shock with following condition 1 cycle： −30 °C, No humidity control, no energization 1 h +25 °C, 90 % *RH*, energized 1 h, +25 °C, drying < 50% *RH*, no energization 1.5 h Power supply： 5 V Current： none Duration： 48 cycles
Combined environmental test (Vibration durability test)	DTSC1000G DTSC1904G	(TER) DTSC1904G: 1 cycle: 45 min energized, 15 min pause, 300 cycles by axes Acceleration: 44 m/s², 20 to 200 Hz, sweep time 3 min, 100 °C Battery clamp fix on vibration JIG Vibration Direction: top/bottom, front/back, left/right Sensor supply = 5 V Primary current = 150 A
Dust resistance test	DTSC1904G	Cycle: Spread uniformly 1.5 kg of Kanto loam powder by spraying compressed air for 10 s every 15 min (TER) DTSC1904G: 8 cycles remove the battery clamp from the post every 2 cycles (SEN) 24 cycles Disconnect/connect the connector every 12 cycles
Oil resistance test (Chemical resistance test)	DTSC1904G	(SEN) Follow DTSC0507G Temperature humidity cycle: 85 °C, 85 % *RH*, 200 h, 25 °C, 50 % *RH*, 24 h 5 cycles Temperature cycle: 0 °C, 30 min→60 °C, 30 min 1000 cycles 6 DUT for each test --> 12 DUT Remove 3 pcs after 500 h for each test
Whisker test	DTSC0507G	(SEN) Follow DTSC0507G Temperature humidity cycle: 85 °C, 85 % *RH*, 200 h, 25 °C, 50 % *RH*, 24 h 5 cycles Temperature cycle: 0 °C, 30 min→60 °C, 30 min 1000 cycles
Salt spray test	DTSC1000G DTSC1904G	Test performed with matting connector engaged state (CO) follow DTSC1000G: Step1 duration = 96 h →Salt spray, 35 °C ±5 °C, salt water concentration 5±1 mass %, specific gravity of 1.0268 to 1.0413, PH 6.5 to 7.2, 68.6 to 176.5 kPa, 14 V on pin (see fig6 DTSC1000G) Step2 duration = 96 h→80 °C ±5 °C, 90 to 95 % *RH* Step3 →drying at room temperature (TER) follow DTSC1904G: Step1 duration = 96 h →Salt spray, 35 °C ±5 °C, salt water concentration 5±1 mass %, specific gravity of 1.0268 to 1.0413, PH 6.5 to 7.2, 68.6 to 176.5 kPa Step2 duration = 96 h→80 °C ±5 °C, 90 to 95 % *RH* (SEN) Duration = 300 h,Temperature: 35 °C ±3 °C, salt water concentration 5±1 mass %

High-pressure washing test	DTSC1904G	(TER) DTSC1904G: Ejected water pressure 12 MPa 30 s Implemented with battery clamp attached to battery post (JIG)
Temperature humidity cycle test	DTSC1000G	(CO) DTSC1000G: Temperature humidity pattern (24 h) 10 cycles Performed with matting connector engaged state (SEN) Approval drawing condition: Temperature humidity pattern (24 h) 10 cycles
Temperature cycle test	DTSC7000G	(SEN) Approval drawing: 30 cycle (1 cycle, 8 h, −40 °C ±3 °C to 90 °C±3 °C) operational 5 H and non operational 3 H (240 h) (Only power supply ON/OFF)
Spray frost test	Same as HABT	(SEN) "Step1 : Dip devices under 300 mm of water during 60 minutes at a temperature of 25 °C ±10 °C Step 2: 1 h at atemperature of −20 °C ±3 °C Step 3: 1 h at a temperature of −30 °C ±3 °C
Dipping test	Same as HABT	(SEN) Storage temperature 80 ±3 °C Minimum storage time: 1 h Water temperature: 25 ±10 °C Dip depth: 100 mm Dipping time: 1 min No water immersion into inside of connector."
Mechanical tests		
Vibration test	DTSC1000G DTSC7000G	Interface circuit : Refer to separate sheet "IF_circuit" DTSC7000G table 14: Resonant point detection at 20-40 m/s² and 5 to 200 Hz and perform the sinus sweep test if no resonant frequency found Acceleration for both tests: 29.4 m/s² If sinus sweep: Frequency: 5 to 200 Hz, sweep time: 10 min Test duration: 4 h for Z axis 2 h by axis for XY axis If the resonance point 2 tests required: 1st test: frequency: resonant frequency, duration: 1 hour for Z (Vertical) , 0.5 h by axis for XY (lateral and longitudinal) 2nd test: frequency: 33 or 67 Hz (choose the closest to the resonance frequency), duration: 3 hours for Z (Vertical) , 1.5 h by axis for XY (lateral and longitudinal)
Impact test	DTSC7000G	Acceleration：490 m/s² Duration: 12 ms Waveform: half sine wave Number of impact: ±X, ±Y, ±Z (each 10 times) Note：Use the same DUT for + and − direction
Impact test (Drop test)	None	Approval Drawing Condition: Drop specimen from height of 1 m on concrete floor 3 times for each 5 faces and 15 times for connector face
Battery terminal Initial characteristics measurement	DTSC1904G	(TER) Follow DTSC1904G Implemented with battery clamp attached to battery post (JIG)

Overtorque assembly test	DTSC1904G	(TER) Follow DTSC1904G Fix the terminal 1 mm above the surface of the post with a tightening torque of 7.8 N·m Implemented with battery clamp attached to battery post (JIG)
Repetitive assembly test	DTSC1904G	(TER) Follow DTSC1904G 7.8 N·m × 50 Implemented with battery clamp attached to battery post (JIG)
Post tightening test	DTSC1904G	(TER) Follow DTSC1904G 1.9 N·m, 3.9 N·m, 4.9 N·m, 5.8 N·m, 6.8 N·m, 7.8 N·m, 8.8 N·m Implemented with battery clamp attached to battery post (JIG)
Terminal neck strength test	DTSC1904G	(TER) Follow DTSC1904G 500 N, 10 s Implemented with battery clamp attached to battery post (JIG)
Corrosive gas resistance test	DTSC1904G	(TER) Follow DTSC1904G 25 ppm, humidity 75 % RH, room temperature, leave in sulfurous gas for 96 hrs Implemented with battery clamp attached to battery post (JIG)
Tests for reference		
Current limit test	None	(SEN): Current: from 150 A to 1000 A by 100 A step Energization time： 1 min at each step supply: 5.0 V At each current the global error is measured
Operation limit test (test for reference)	None	Power supply is decreased by step of 0.5 V from minimum operating limit Electrical characteristics is measured at each voltage step
Voltage limit test (test for reference)	None	Power supply increased by step of 0.5 V from maxium operating limit to 30 V maximum Electrical characteristics is measured at each voltage step
High temperature limit test (test for reference)	None	Temperature: 90 to 180 °C ±3 °C (10 °C by step) Power supply: No energization until the temperature is reached, once temperature is reached energize with the maximum voltage Current: 0 A Duration: 45 min at each temperature step
Low temperature limit test (test for reference)	None	Temperature: −40 °C to −60 °C ±3 °C (10 °C by step) Power supply: No energization until the temperature is reached, once temperature reached energize with the minimum voltage Current: 0 A Duration: 45 min at each temperature step
Pressure cooker test (test for reference)	None	Temperature/Humidity: 120 ± 5 °C, 100 % RH Pressure: 0.9 MPa Power supply: No energization Current: None Time: 96 h
Electrical tests		
Engine starting voltage test	DTSC7001G	Voltage drop and fluctuation of power supply at the time of engine starting Acceptance criteria : During test CLASS C, After test CLASS A (5 V)
Voltage dips test	DTSC7001G	Short interruption of power supply voltage: 1 ms, 5 ms, 10 ms ,20 ms Acceptance criteria:During test CLASS C, After test CLASS A (5 V)
Reversed power connection test	DTSC7001G	Reversed power supply 13 V, 1 min Acceptance criteria:During test CLASS C, After test CLASS A (5 V)

Connector tests		
Appearance	DTSC1000G DTSC1225G	-
Insertion/Removal feeling	DTSC1000G DTSC1225G	-
Inserting force	DTSC1000G DTSC1225G	< 46.2 N (Connector)
Separating Force	DTSC1000G DTSC1225G	< 31.2 N (Connector)
Terminal holding Force	DTSC1000G DTSC1225G	> 100 N
Housing holding force	DTSC1000G DTSC1225G	> 100 N
Voltage drop	DTSC1000G DTSC1225G	Initial < 8 mV/A After endurance test < 10 mV/A
Low voltage current resistance	DTSC1000G DTSC1225G	Initial < 8 mΩ After endurance test < 10 mΩ
Insulation resistance	DTSC1000G DTSC1225G	> 100 MΩ
Withstand voltage	DTSC1000G DTSC1225G	no damage
Leak current	DTSC1000G DTSC1225G	< 50 mA
Sealing ability	DTSC1000G DTSC1225G	Initial > 50 kPa After endurance test > 30 kPa
Connector engaging sound	DTSC1000G DTSC1225G	-
Overcurrent passing test	DTSC1000G	(CO) DTSC1000G: Flow large current according to copper wire size (see table 22) The energization time differs for each specimen (0.5 s to 1 min see table 22) Performed with matting connector engaged state
Additional tests		
PCB Temperature measurement test	-	Measure the PCB temperature when rated current is applied with normal condition I_P= 250 A DC
Low pressure air test	DTSC0511G	(SEN) DTSC0511G (Transportation) 12 kPa 16 h, no power supply (Usage) 54 kPa 16 h Maximum voltage
Inductive noise test	DTSC0502G	(SEN) Refer to DTSC0502G for the test condition Perform test 1 (N/A for test 2)
High-pressure noise test	DTSC0502G	(SEN) Refer to DTSC0502G for the test condition perform both test condition 1 and test condition 2 Test level III fp condition as below (2 test conditions) - 5 kHZ(condition C) - 7.4 kHz
Silicone gas resistance test	DTSC0508G DTSC2901G	(SEN) Refer to DTSC0502G for the test condition