AUTOMOTIVE CURRENT TRANSDUCER OPEN LOOP TECHNOLOGY
SMU01

Introduction

The SMU family is a transducer for DC measurement in high power and low voltage automotive applications. It offers a galvanic separation between the primary circuit (high power) and the secondary circuit (electronic circuit).
The SMU family gives you a choice of having different current measuring ranges in the same housing (from ±400 A up to ±1500 A).

Features

- Open Loop transducer using the Hall effect sensor
- High insulation level
- Unipolar +5 V DC power supply
- Primary current measuring range up to ±1500 A
- Maximum RMS primary admissible current: defined by the busbar, the magnetic core or ASIC T < +125 °C
- Operating temperature range: −40 °C < T < +125 °C
- Output voltage: fully ratio-metric (in sensitivity and offset).

Advantages

- Excellent accuracy
- Very good linearity
- Very low thermal offset drift
- Very low thermal sensitivity drift
- High frequency bandwith
- No insertion losses.

Automotive applications

- Battery management
- EV, Hybrid and utility vehicles.

Principle of SMU 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 the Hall plates

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

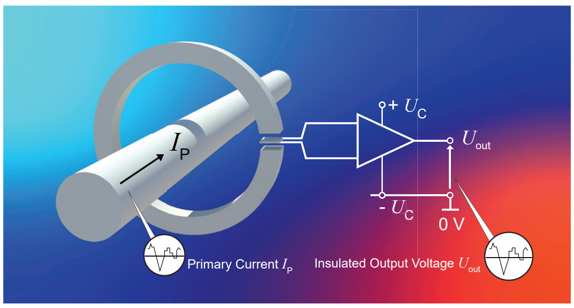

Fig. 1: Principle of the open loop transducer.

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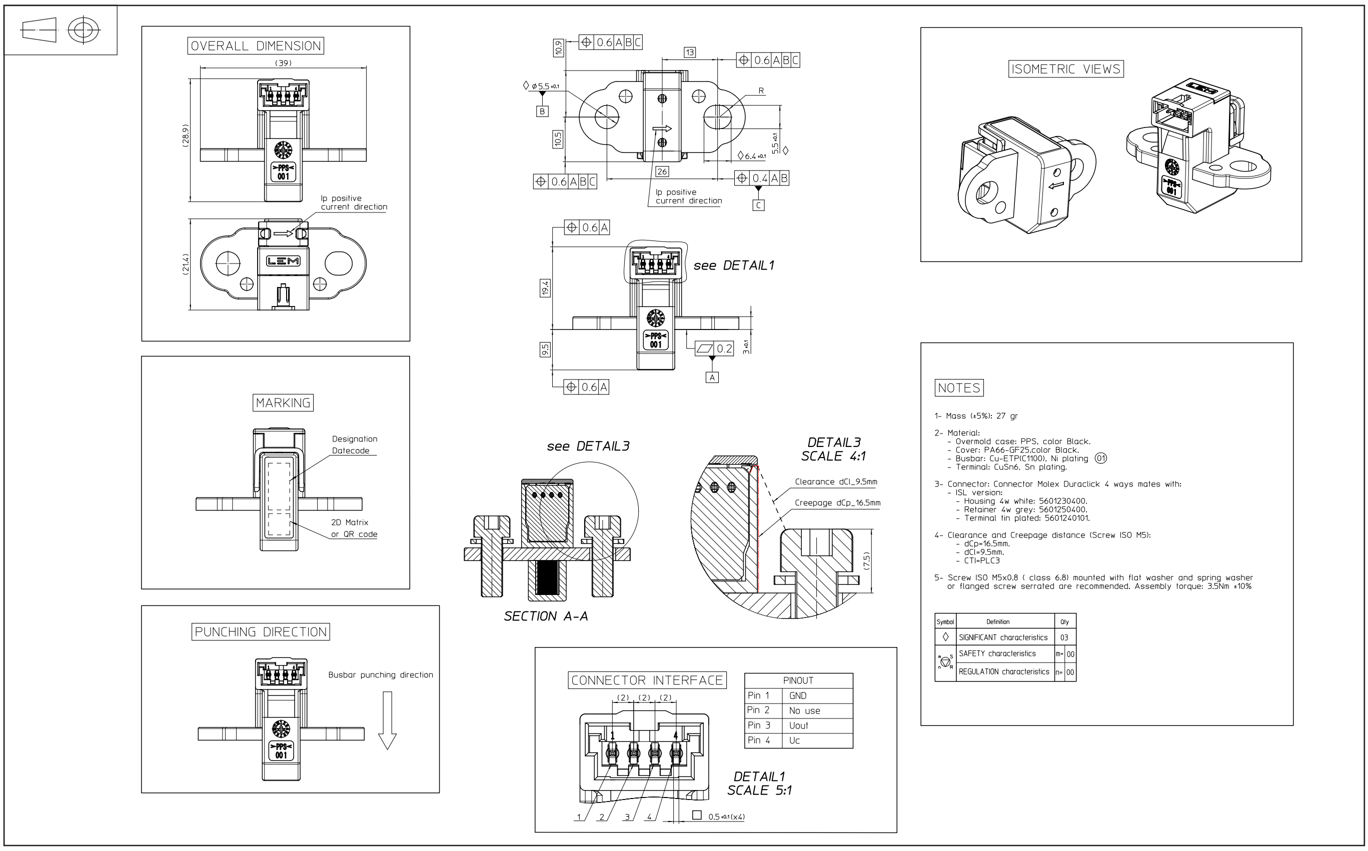
Dimensions (in mm)



Mechanical characteristics

- Refer to Outline Drawing.

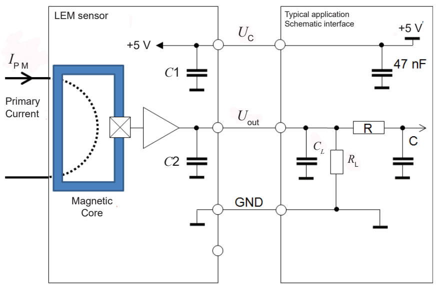
Mounting recommendation

- Assembly refer to Outline Drawing.

Remark

- U_{out} > U_O when I_P flows in the positive direction (see arrow on drawing).

System architecture (example)



C_L < 100 nF EMC protection (optional)
RC Low pass filter (optional)

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Absolute ratings (not operating)

Parameter	Symbol	Unit	Specification			Conditions
			Min	Typical	Max	
Maximum supply voltage	$U_{C\ max}$	V	−14		14	Continuous, not operating
Ambient storage temperature	$T_{A\ st}$	°C	−40		125	
Electrostatic discharge voltage (HBM - Human Body Model)	$U_{ESD\ HBM}$	kV			8	
RMS voltage for AC insulation test	U_d	kV			4.7	50 Hz, 1 min, IEC 60664 part1
Creepage distance	d_{Cp}	mm	16.5			
Clearance	d_{Cl}	mm	9.5			
Comparative tracking index	CTI	-	PLC3			
Maximum output current	$I_{out\ max}$	mA	−10		10	
Maximum output voltage	$U_{out\ max}$	V	−14		14	
Insulation resistance	R_{INS}	MΩ	500			1000 V DC

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

Parameter	Symbol	Unit	Specification			Conditions
			Min	Typical	Max	
Electrical Data						
Supply voltage	U_C	V	4.75	5	5.25	
Ambient operating temperature	T_A	°C	−40		125	
Output voltage (Analog) [1]	U_{out}	V	$U_{out} = (U_C/ 5) \times (U_O + S \times I_P)$			
Offset voltage	U_O	V		2.5		@ U_C = 5 V
Current consumption	I_C	mA		15		@ U_C = 5 V, @ T_A = 25 °C, @ I_P = 0 A
Load resistance	R_L	KΩ	10			
Output internal resistance	R_{out}	Ω		1	10	
Performance Data						
Ratiometricity error	ε_r	%		±0.3		@ T_A = 25 °C
Sensitivity error	ε_S	%		±1		@ 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		±1		@ T_A = 25 °C, @ U_C = 5 V
Average temperature coefficient of $U_{O\ E}$	$TCU_{O\ E\ AV}$	mV/°C		±0.04		@ −40 °C < T_A < 125 °C
Average temperature coefficient of S	TCS_{AV}	%/°C	−0.03	±0.01	0.03	@ −40 °C < T_A < 125 °C
Linearity error	ε_L			±1		@ U_C = 5 V, @ T_A = 25 °C
Frequency bandwidth [2]	BW	Hz		35		@ −3 dB
Peak-to-peak noise voltage	$U_{no\ pp}$	mV		10		@ DC to 1 MHz
Output RMS noise voltage	U_{no}	mV		1.5		@ DC to 1 MHz
Start-up time	t_{start}	ms			1	
Settling time after overloads	t_s	ms			10	

Notes: [1] The output voltage U_{out} is fully ratiometric. The offset and sensitivity are dependent on the supply voltage U_C relative to the following formula:

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

[2] Primary current frequencies must be limited in order to avoid excessive heating of the busbar, magnetic core and the ASIC (see feature paragraph in page 1/9).

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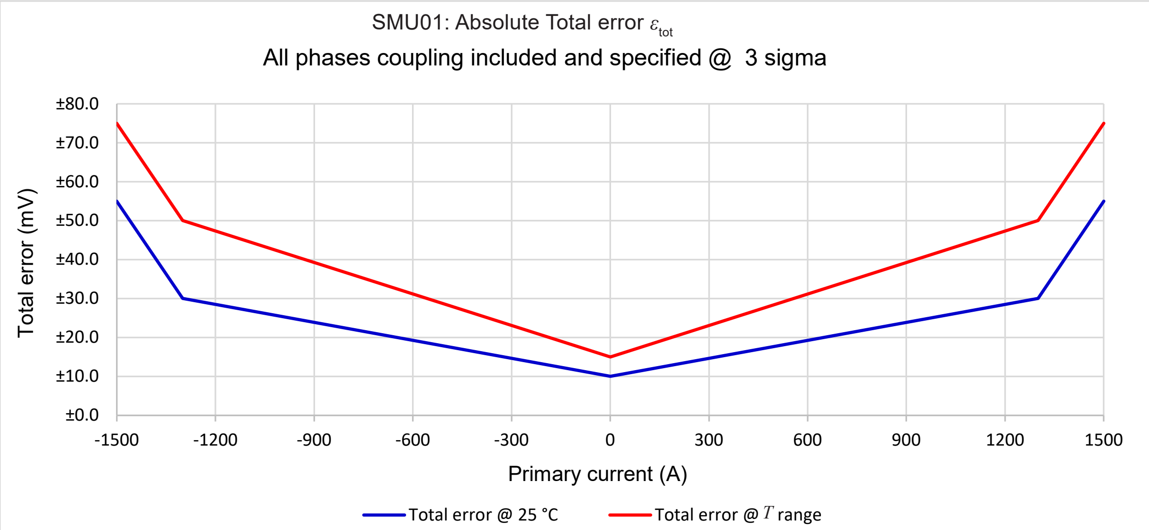
Parameter	Symbol	Unit	Specification			Conditions
			Min	Typical	Max	
Electrical Data						
Primary current, measuring range	I_{PM}	A	−1500		1500	
Sensitivity	S	mV/A		1.33		@ U_C = 5 V

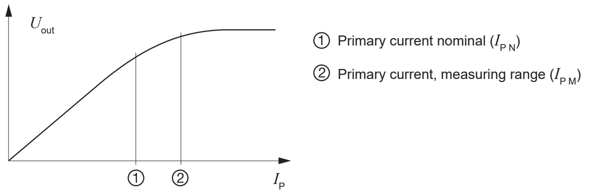
Total error



Primary current	Total error T = 25 °C, U_C = 5 V		Total error −40 °C ≤ T ≤ 125 °C, U_C = 5 V	
(A)	(mV)	(%)	(mV)	(%)
−1500	±55	2.75 %	±75	3.75 %
−1300	±30	1.50 %	±50	2.50 %
0	±10	0.50 %	±15	0.75 %
−1300	±30	1.50 %	±50	2.50 %
−1500	±55	2.75 %	±75	3.75 %

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:

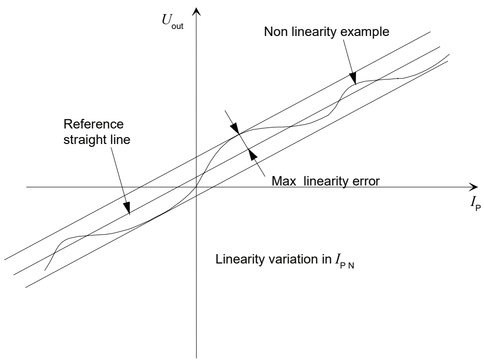
The output voltage noise is the result of the noise floor of the Hall elements and the linear amplifier.

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.

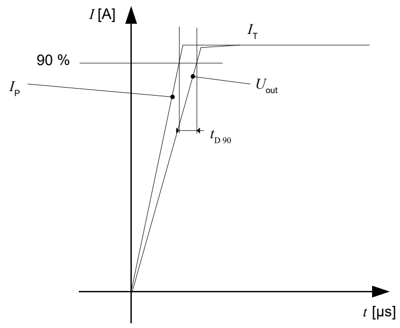
Linearity:

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



Response time (delay time) $t_{D\,90}$:

The time between the primary current signal ($I_{P\,N}$) 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 $I_{O\,T}$ is a maximum variation the offset in the temperature range:

$$I_{O\,T} = I_{O\,E}\,\text{max} - I_{O\,E}\,\text{min}$$

The offset drift $TCI_{O\,E\,AV}$ is the $I_{O\,T}$ 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 sensitivity variation S_T is the maximum variation (in ppm or %) of the sensitivity in the temperature range: S_T = (Sensitivity max − Sensitivity min) / Sensitivity at 25 °C.

The sensitivity drift 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.

Validation test specifications

Name	Standard	Condition
ENVIRONMENTAL TESTS		
Ageing 85 °C /85 % *RH*	JESD 22-A101 (03/2009)	85 °C/85 % *RH*; Duration = 1000 h; Power supply 5 V ; primary current 0 A; Monitoring output 1 time/hr
Low temperature operating endurance	ISO 16750-4 § 5.1.1.2 (04/2010)	−40 °C, 24 h; Power supply 5 V Monitoring: 2 times/hr
High temperature operating endurance	ISO 16750-4 § 5.1.2.2 (04/2010)	Temperature 125 °C; 96 h; power supply 5 V Monitoring 2 times/hr
Humidity heat, cyclic test: Test 2 Composite temperature/humidity cyclic test	ISO 16750-4 § 5.6.2.3 (04/2010)	Temperature range −10 °C/ +65 °C, 93 % *RH* Duration = 240 h (10 cycles)
Thermal shock	ISO 16750-4 § 5.3.2 (04/2010)	Temperature range −40 °C& 125 °C, 300 cycles; 40 min/40 min, no power supply
Random Vibration	ISO 16750-3 § 4.1.2.4	Monitoring U_C and U_{out} is mandatory, Temperature −40/125 °C, 10 to 1000 HZ, 27.1 m/s^2, 8 H/axis
Mechanical Shocks	ISO 16750-3 § 4.2.2	Operating mode: 3.2 Pulse shape: half sine, 500 m/s^2, 6 ms 10 shocks per direction (total 60)
Free Fall	ISO 16750-3 § 4.3	Height = 1 m 3 axes, 2 directions by axis, Operating mode: 1.1
Cross section checking on PCBA	IPC-A-610G: 2017 Class 3	IPC-TM-650 2.1.1F:2015
Whisker checking on PCBA	Refer to JESD201-A (04/2010)	Refer to JESD22-A121A (04/2010) Class 2
INSULATION TESTS		
Dielectric withstand voltage	ISO 16750-2 § 4.11 (11/2012)	4.7 kV test voltage, time = 60 s, No dielectric breakdown, no flash-over, functional after test
Insulation test	ISO 16750-2 § 4.12 (11/2012)	1000 V DC, time = 60 s, *R*isolation ≥ 500 MΩ Minimum
EMC TESTS		
Immunity to Electrostatic Discharges (Handling of devices)	ISO 10605 (07/2008)	Discharge module: 150 pF/330 Ω Contact discharges: ±4 kV, Air discharges: ±8 kV U_C = NO power supply, Criteria C
Immunity to Radiated disturbances (ALSE)	ISO 11452-2 (2019)	Power supply: 5 V f = 400 MHz to 1 GHz; Level = 100 V/m (CW, AM 80 %) f = 0.8 GHz to 1GHz; Level = 70 V/m (PM1) f = 1 GHz to 1.2 GHz; Level = 70 V/m (CW, PM1) f = 1.2 GHz to 1.4 GHz; Level = 70 V/m (CW, PM2) f = 1.4 GHz to 2 GHz; Level = 70 V/m (CW, PM1) Criteria: A Acceptance @ 2500 mV ±100 mV
Immunity to Conducted disturbances (BCI)	ISO 11452-4 (12/2011)	Level = see Annex E Fig. & Table E.1 (Test Level II) f = 1 MHz to 400 MHz Criteria: A Acceptance @ 2500 mV ±100 mV
Emission Radiated (ALSE)	CISPR 25 §6.5 (2016)	Table 7, Class 5 by default f = 150 kHz to 2.5 GHz Load simulator will be provided (R&D)

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