


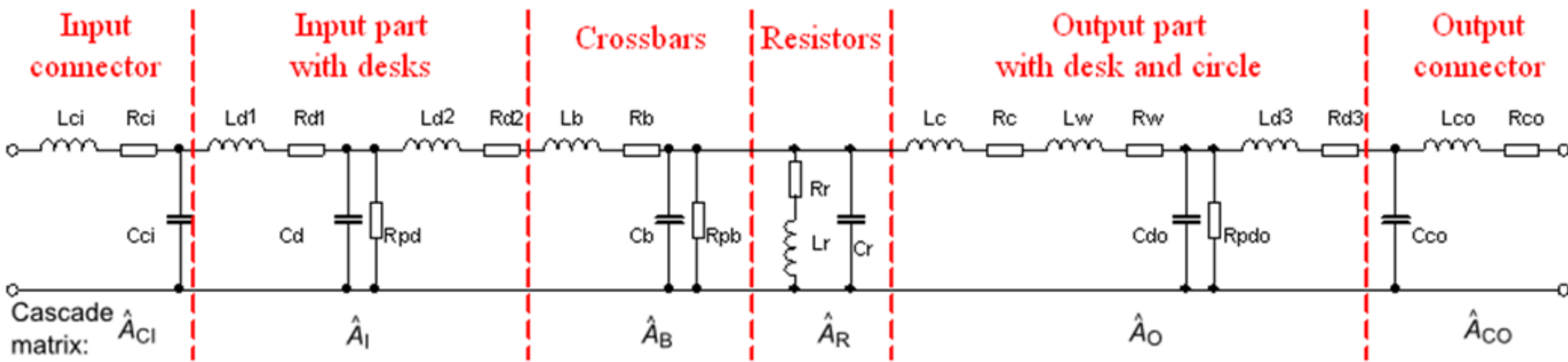
NEW GENERATION OF CURRENT SHUNTS

Original shunts




Designed for ac-dc transfer measurements
Range: 30 mA - 10 A
Voltage drop: 1 V (in paralell with PMJTC)

Lumped element model



Based on the cascade concatenation of two-ports assigned to each construction part.
All impedances calculated from geometric dimensions and material properties (except of resistors).
The transimpedance of the shunt derived from cascade matrix of the model (load considered).
Agreement of measured and caculated values of the original shunts: better than 6 ppm in ac-dc difference and better than 110 urad in phase angle error at 100 kHz.

New shunts



Designed for ac-dc transfer and power meas.
Range: 30 mA - 10 A (up to 100 A in development)
Voltage drop: 0.6 V (in paralell with PMJTC)
Improvements: hf PCB with reduced thicknes for low current shunts, only 3 crossbarrs in 30 mA shunt, reduced PCB thickness and smaller dimensions for 10 A shunt.

Parameters of the original shunts					Ac-dc difference sensitivity coefficients at 100 kHz						Parameters of the new shunts				
Nominal current	Resistance (Ω)	Number and value of resistors	Type of resistors	PCB type	Input quantity	30 mA shunt	100 mA shunt	1 A shunt	10 A shunt	Unit of sensitivity coefficient	Nominal current	Resistance (Ω)	Number and value of resistors	Type of resistors	PCB type
30 mA	50	3x 150 Ω	Z201	FR4	Capacitance of resistors	0.4	0.1	0.0	0.0	ppm/pF	30 mA	20	3x 60 Ω	Z201	RO4350B
100 mA	10	10x 100 Ω	3x S102C 7x S102K	FR4	Inductance of resistors	0.0	0.0	0.0	-0.1	ppm/nH	100 mA	6	10x 60 Ω	3x S102C 7x S102K	RO4350B
					PCB thickness	-44.3	-11.3	-2.9	3.2	ppm/mm	300 mA	2	30x 60 Ω	10x S102C 20x S102K	RO4350B
300 mA	3.3	30x 100 Ω	10x S102C 20x S102K	FR4	PCB permittivity	30.2	5.1	1.3	-3.2	ppm	1 A	0.6	50x 30 Ω	17x S102C 33x S102K	RO4350B
1 A	1	100x 100 Ω	33x S102C 67x S102K	FR4	PCB loss factor	57.8	12.9	4.0	1.1	ppm/10 ⁻²	10 A	0.06	100x 6 Ω	33x S102C 67x S102K	FR4
					With of crossbarrs	5.5	1.8	0.5	0.1	ppm/mm					
10 A	0.1	100x 10 Ω	33x S102C 67x S102K	FR4	Length of crossbarrs	2.8	0.4	0.1	0.0	ppm/mm					
					Size of disks	21.4	3.1	-0.3	-5.3	ppm/cm					

CPEM paper 2008:
Zachovalová, V.: "AC-DC current transfer difference in CMI," 2008 Digest of CPEM Conf., 2008, pp. 362-363.

IEEE TIM paper 2014:
Zachovalová, V. N.: "On the Current Shunts Modeling" IEEE TIM, vol.63, No.6, June 2014, pp. 1620-1627.

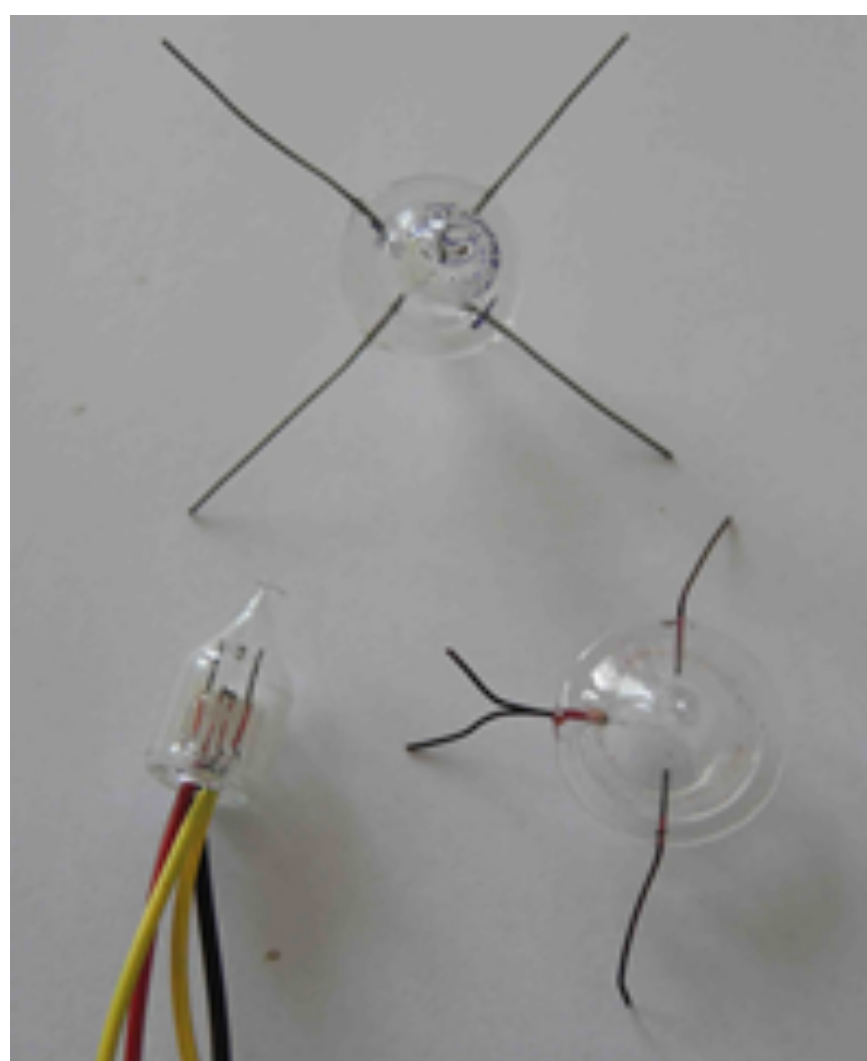
Acta IMEKO paper 2015:
Zachovalová, V. N., Šíra, M., Bednář, P., Mašláň, S.: "New generation of cage-type current shunts developed using model analysis" Acta IMEKO, accepted.

Comparison of the measured ac-dc difference values in ppm of the original and new shunts

Nominal current	Generation	Value	Frequency					
			500 Hz	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
30 mA	New	20 Ω	0	-1	2	3	5	7
	Original	50 Ω	-1	0	8	20	57	131
100 mA	New	6 Ω	-1	-2	1	3	4	6
	Original	10 Ω	1	-1	4	9	20	39
300 mA	New	2 Ω	1	1	1	2	4	6
	Original	3.3 Ω	0	0	4	7	13	22
1 A	New	0.6 Ω	-1	-1	-1	1	1	0
	Original	1 Ω	1	-3	-2	2	6	12
10 A	New	0.06 Ω	1	1	-2	-1	4	3
	Original	0.1 Ω	1	-1	-2	-3	-4	-23

ON THE MODELING OF SJTC's AC-DC CURRENT TRANFER DIFFERENCE

Available single-junction TCs



? made 5 mA

SSSR made 1 mA - 30 mA

UK made 5 mA - 10 mA

Frequency response modeling

Low frequencies: ac-dc difference measured by If method (on the basis of the paper Rydler, Tarasso: A Method to Determine the Low Frequency Behaviour of Thermal Converters, CPEM 2002).

Medium frequencies: ac-dc difference measurements by FRDC method (thanks to possibility to borrow a FRDC source from PTB).

High frequencies: ac-dc difference calculated using lumped element model (on the basis of the paper Budovsky, I.: Precision measurements of Alternating Current, 2005 NCSL International Workshop and Symposium).