VSL

7/19/2013

Ministerie van Economische Zaken

EURAMET
European Association of National Metrology Institutes

Comparison on electrical characterization of SSL and uncertainty analysis

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14:30-15:00, 24 April, NPL, UK

Dutch Metrology Institute

The need for electrical measurement

12.XX W

Significant discrepancy between results from different labs

Lab1

Lab2

Lab3

Less discrepancy

P

Vrms

S (Apparent Power)

Irms

PF(Power Factor)

THD (Total Harmonic distortion)

Significant discrepancy

Reactive power accurately measured? → Power operator

Reactive power is also important for Power operator

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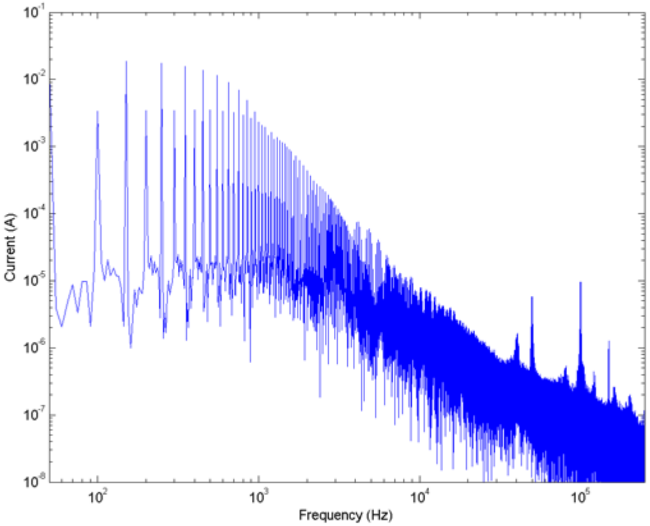
Intercomparison

Lamps used in comparison

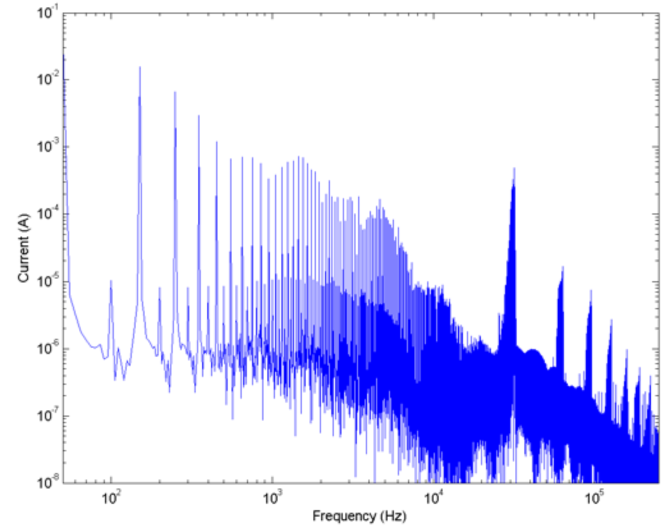
	Model
L1	Osram: PARATHOM PAR16 20
L2	Philips MASTER LED bulb MV
L3	Osram: Parathom A60
L4	Osram: Parathom A80
L5	Osram: Parathom A40FR

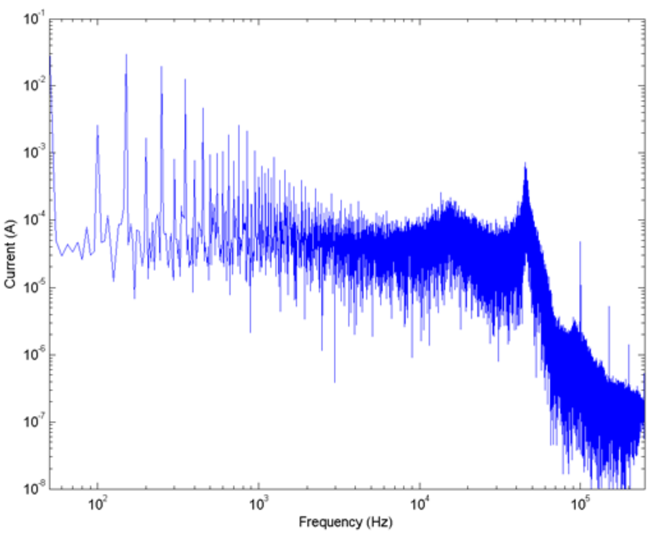
Rich current harmonics in SSL lamps



L1

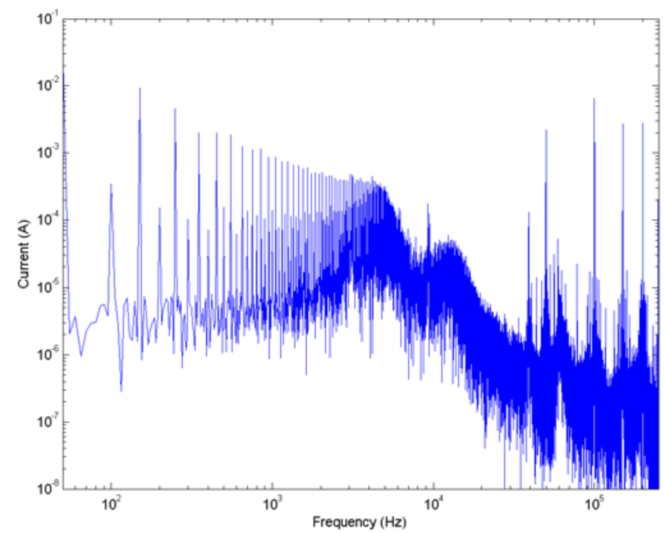
L3/ L4





L2

L5

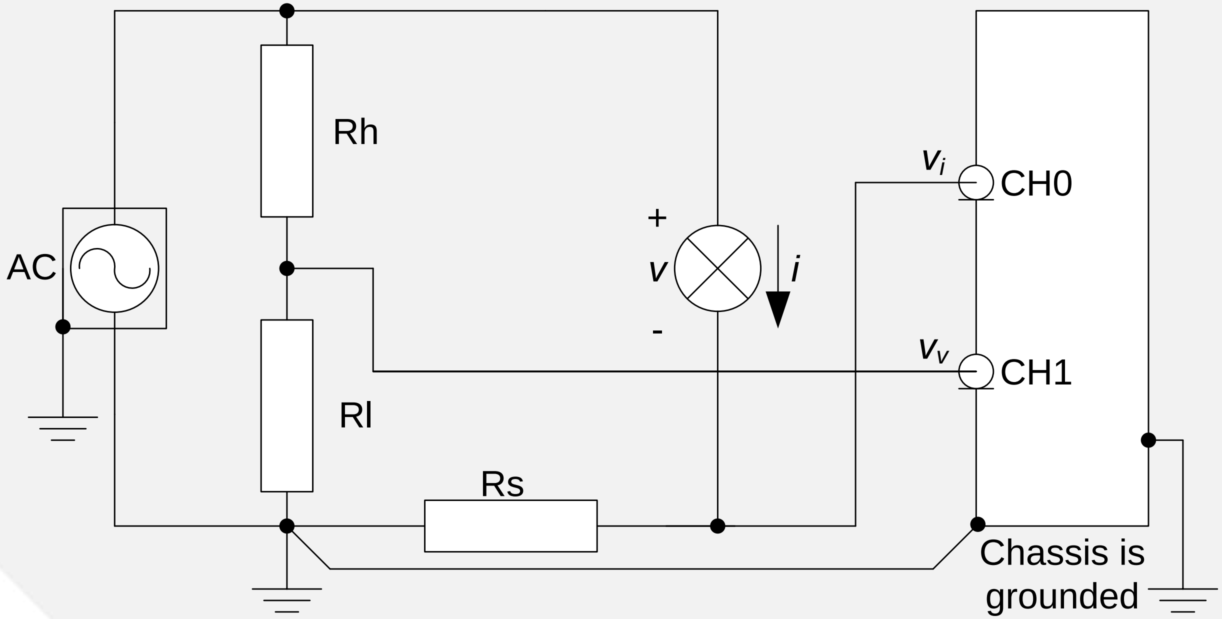


Measurement conditions

- More stringent than standard

- Ambinet condition: 23.0 ± 0.5 ○C (25.0 ± 1.0 ○C in standard)
- AC Power supply: THD<0.5% (3% in standard)
- Voltage regulated to within ± 0.1% under load (± 0.2% in standard)
- Stabilization: burn 72 hours after purchasing (>1000 hours)
- at least 3 readings of the electrical power over a period of 30 min, taken 15 minutes apart, is less than 0.2% (0.5% in standard)
- Operating orientation with lamp upward
- The connection between the power supply, transducer and lamps must be kept as short as possible
- 230V 50Hz

Measurement setup in three labs

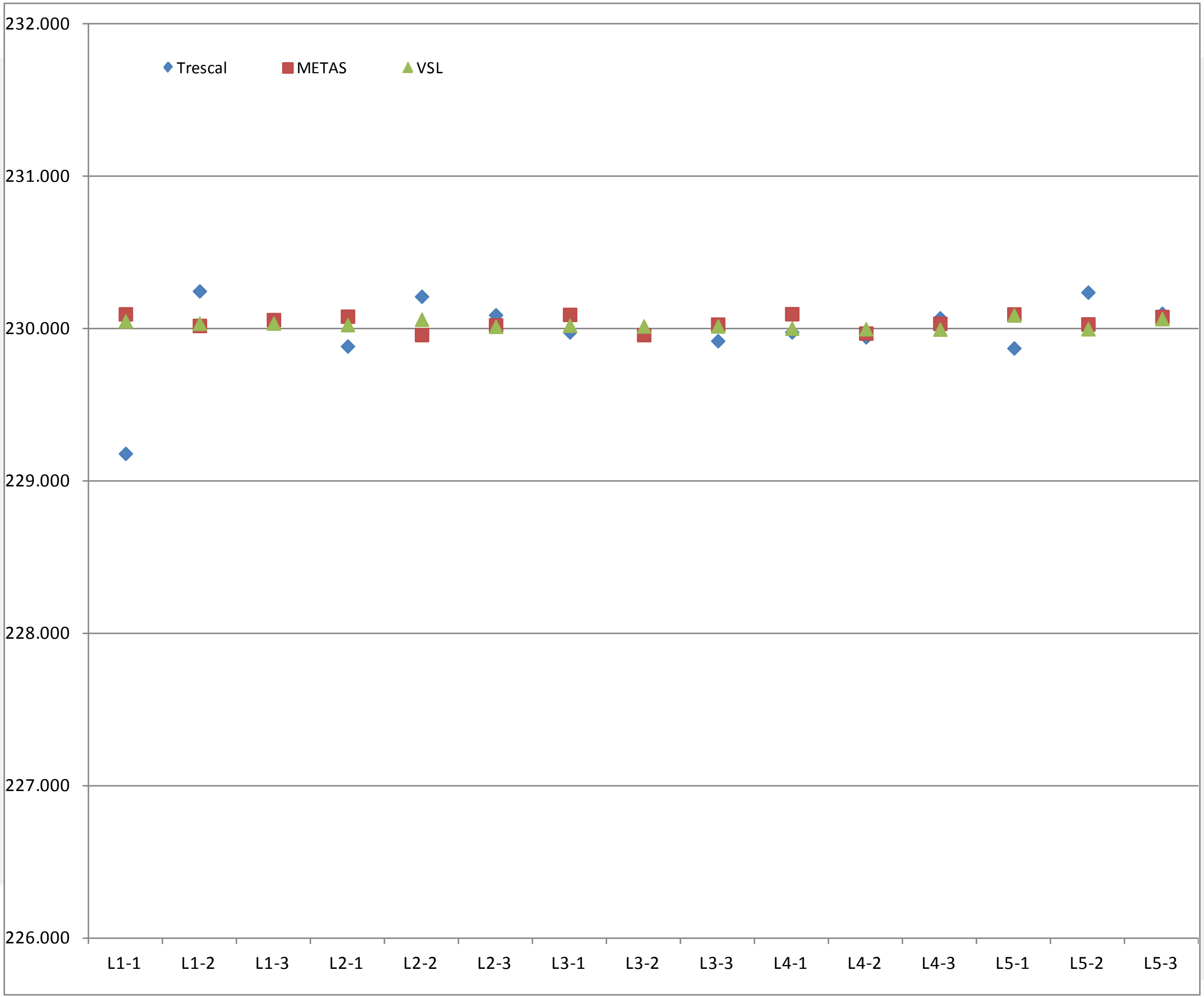


Setup 1

$$i = \frac{v_i}{R_s}$$

$$v = v_v \frac{R_h + R_l}{R_l} - v_i$$

Vrms measured



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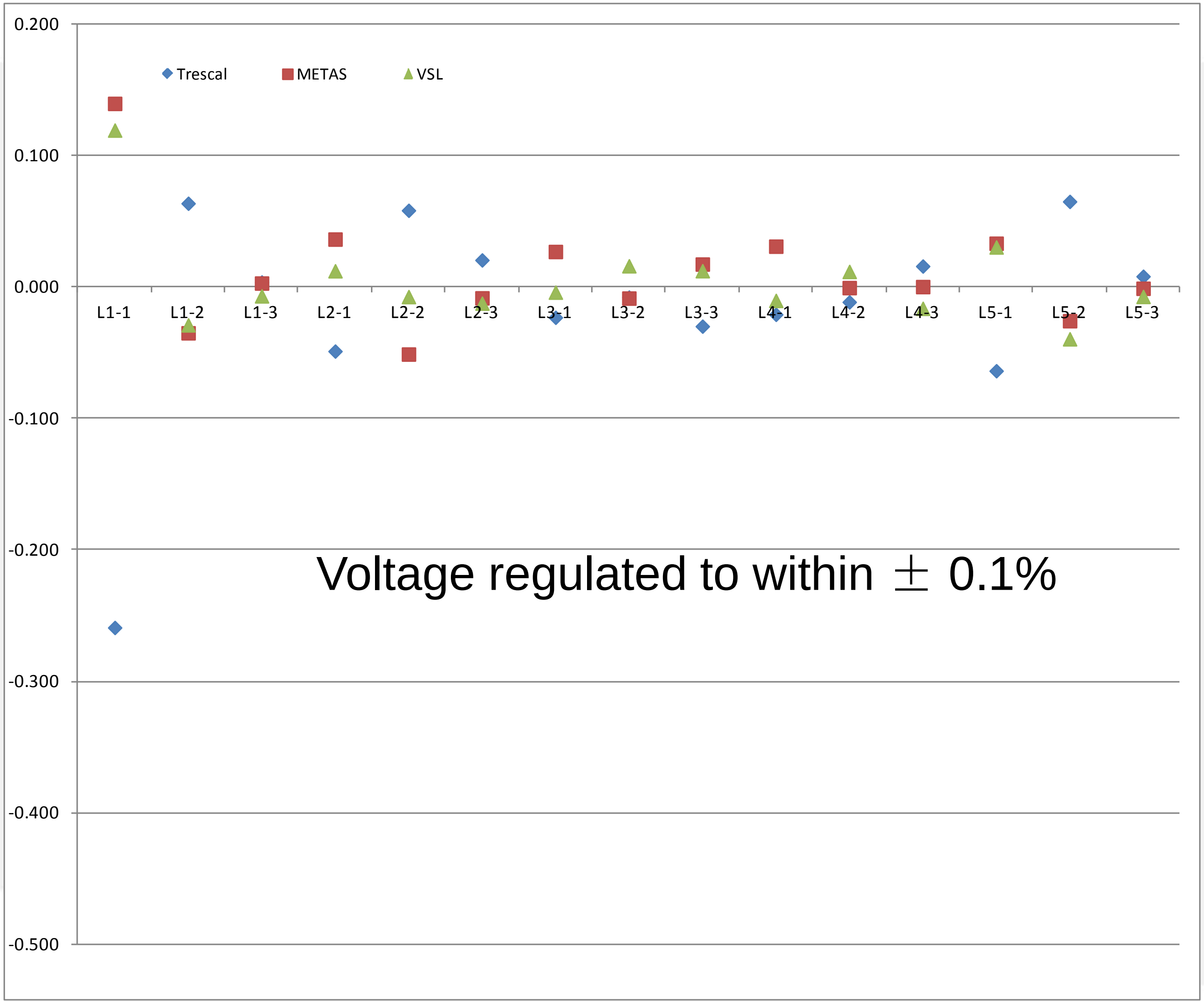
Vrms measured



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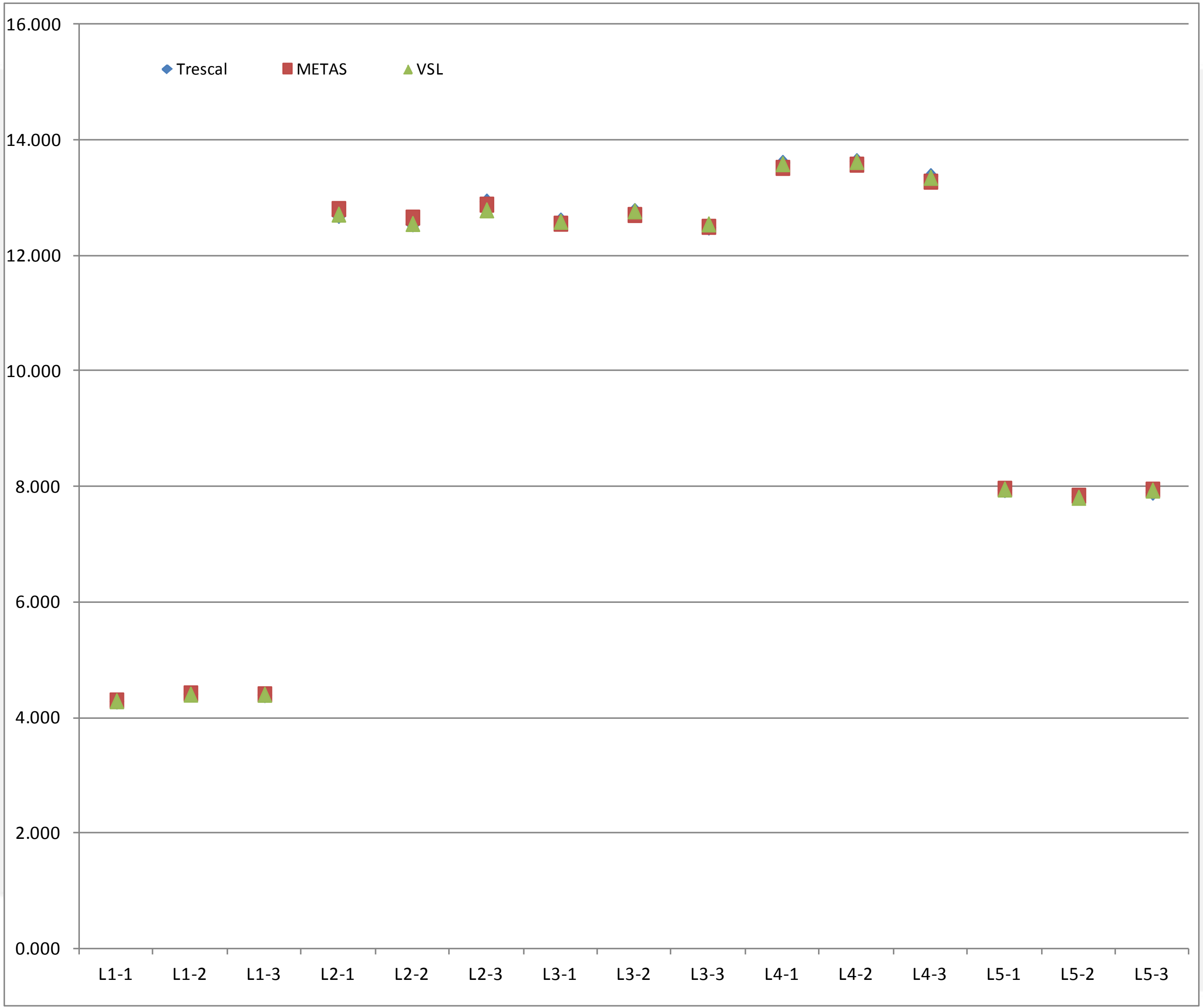
P measured



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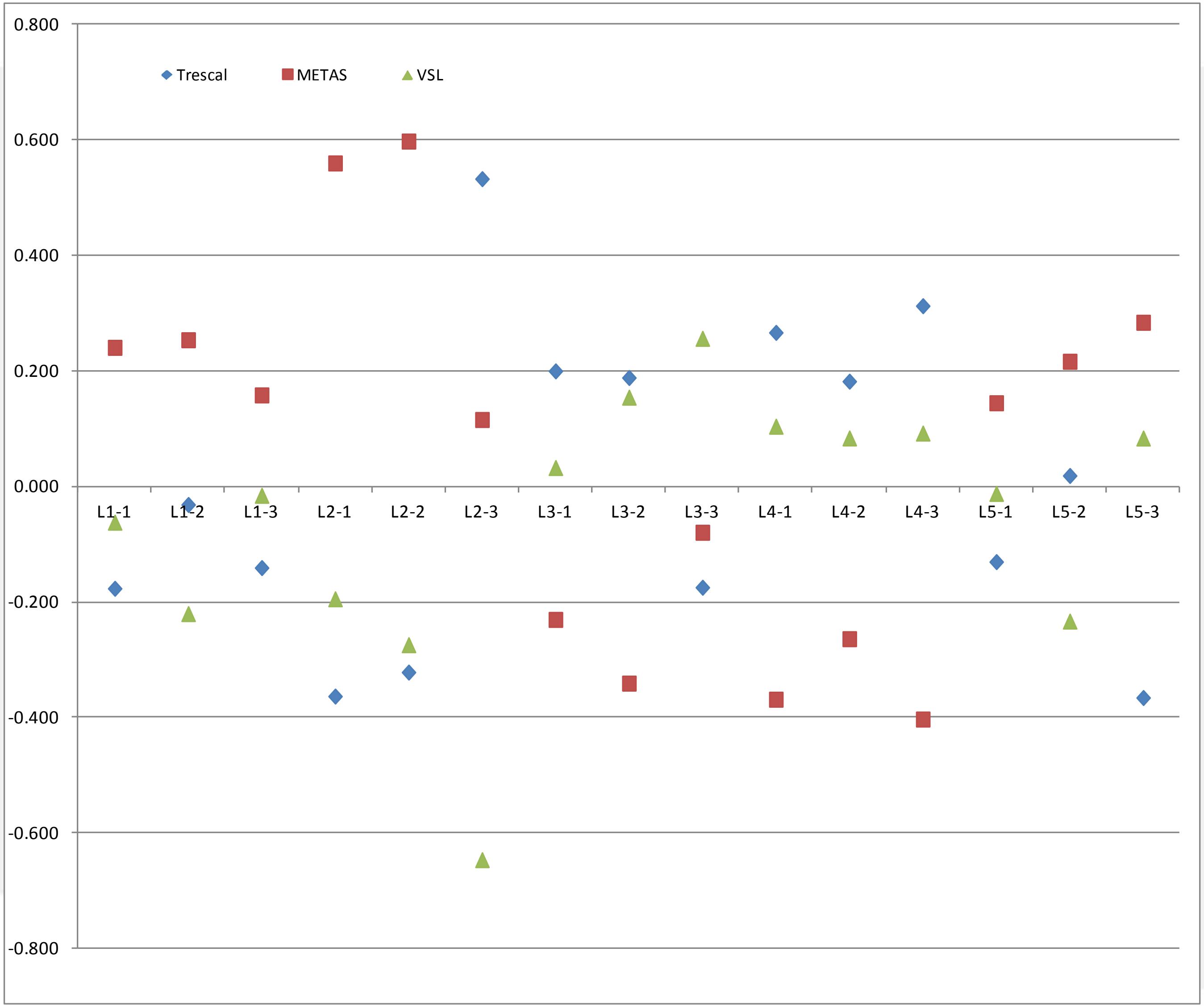
P measured



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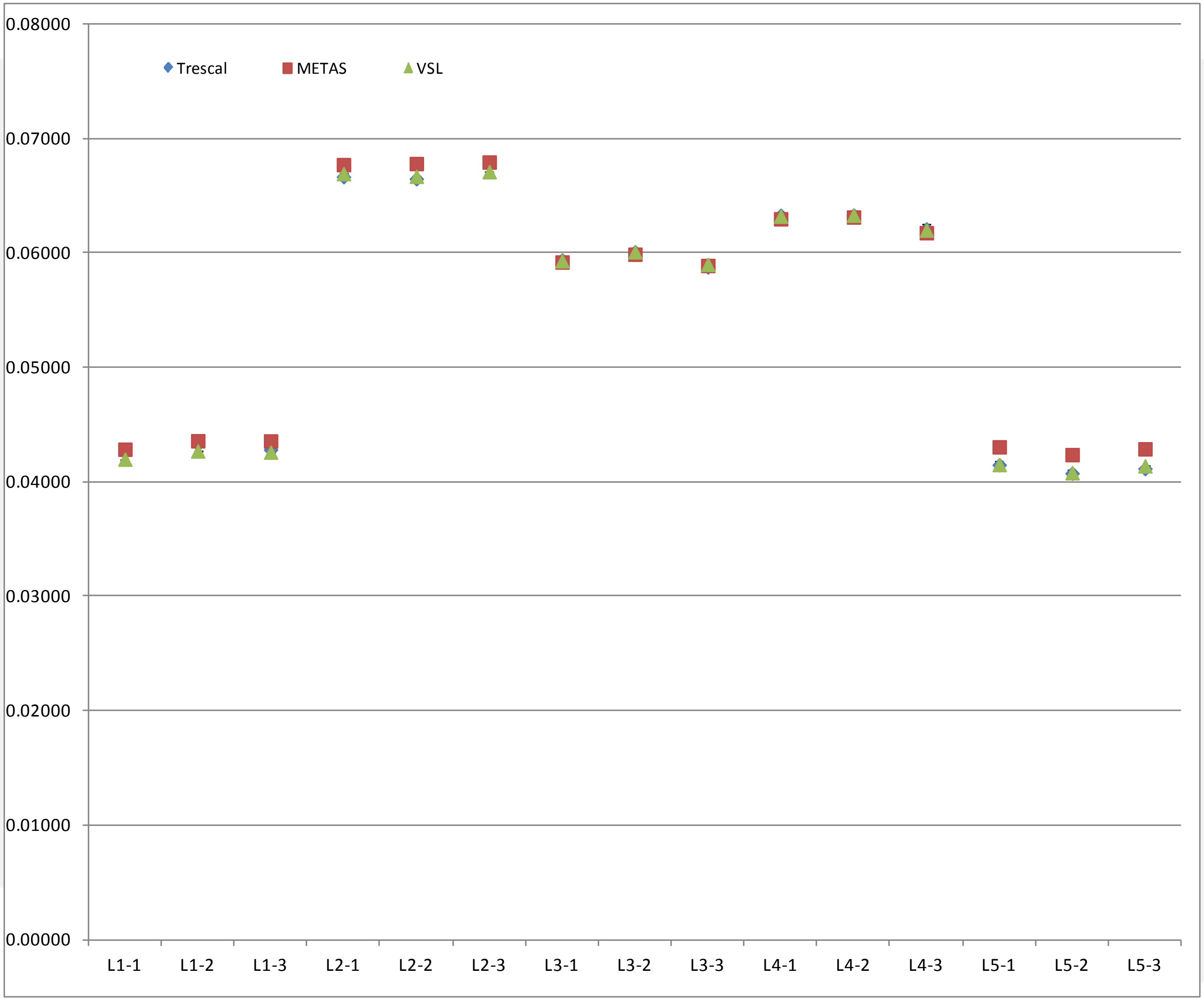
Irms measured



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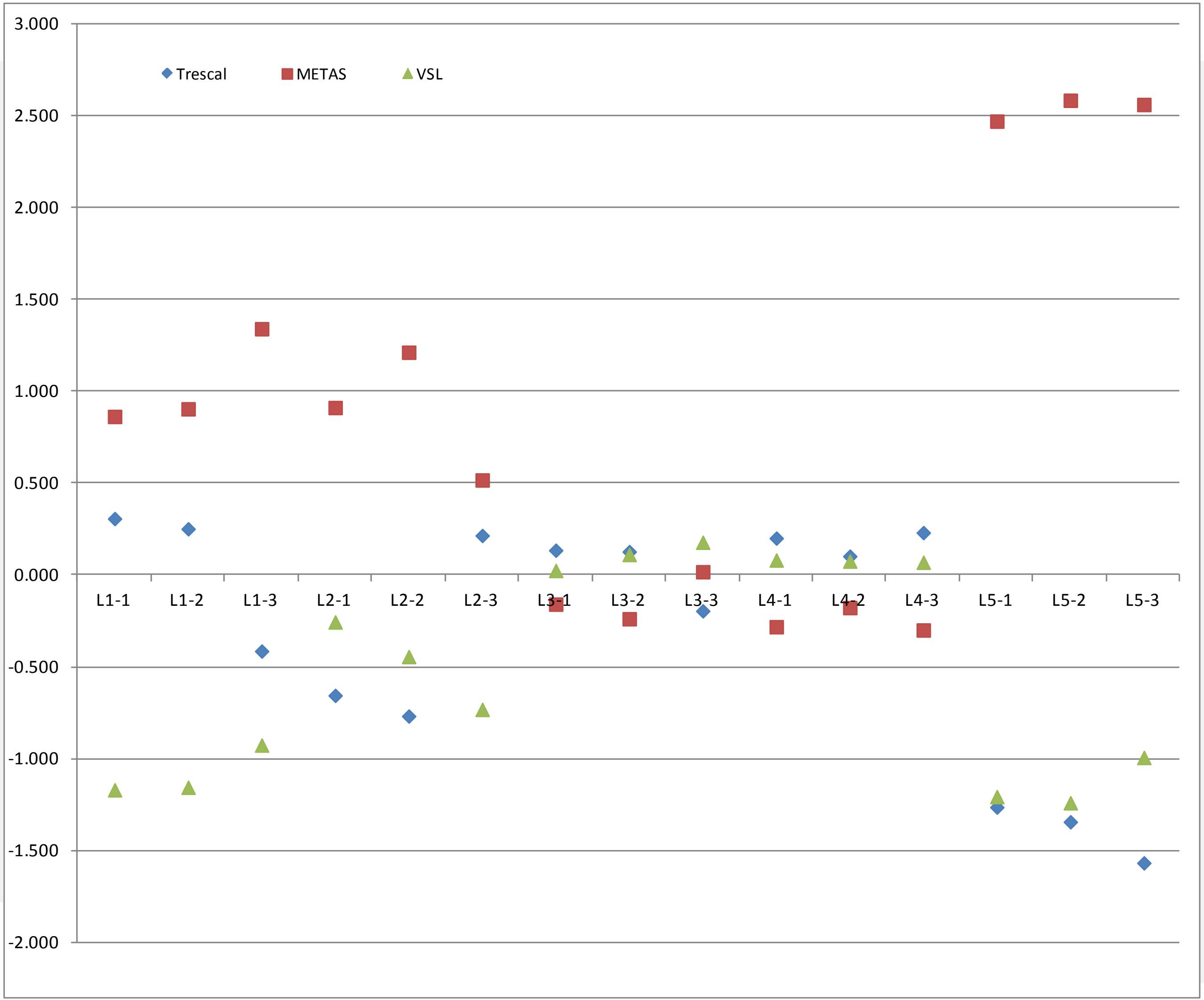
Irms measured



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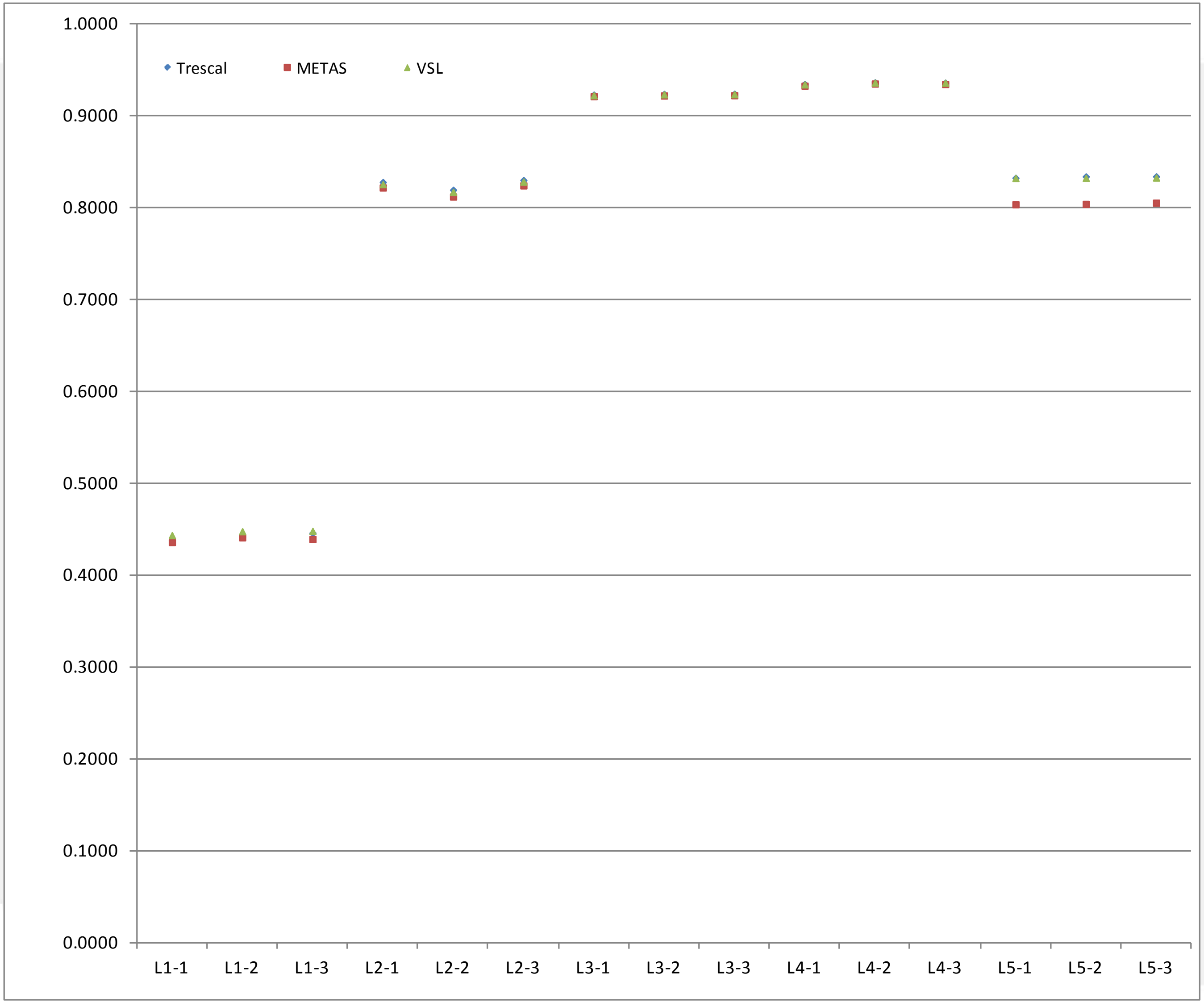
PF measured



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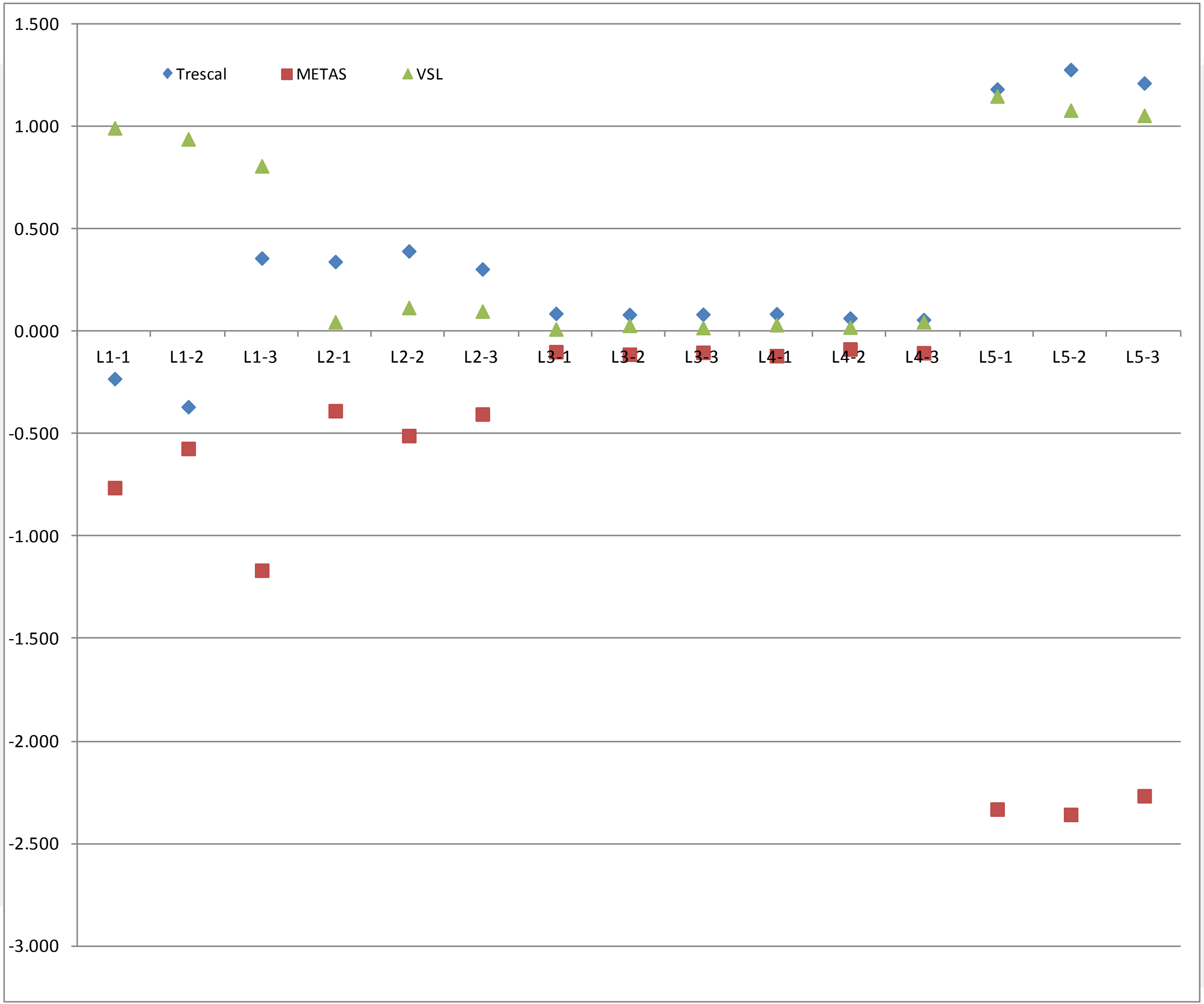
PF measured



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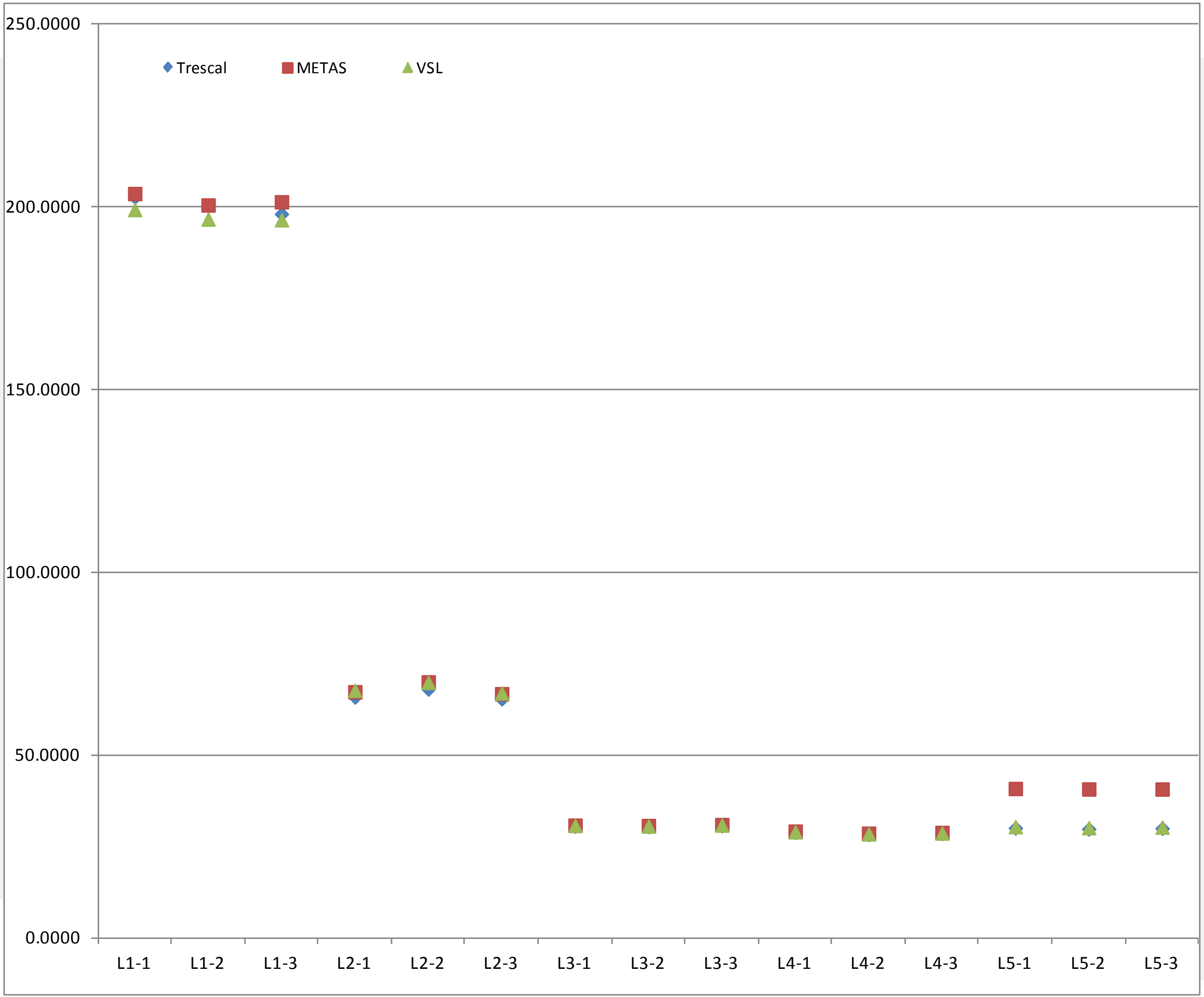
THD measured



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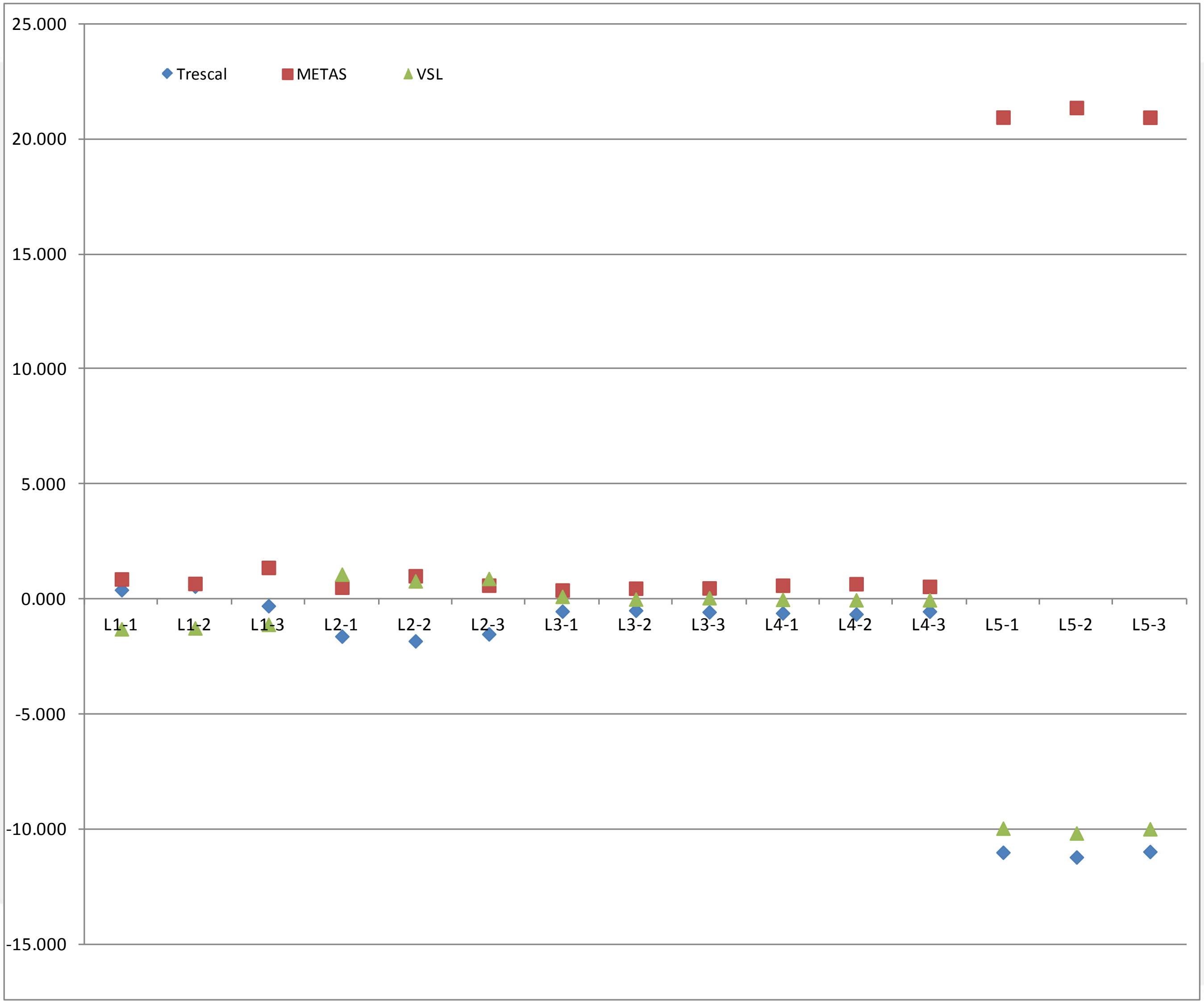
THD measured



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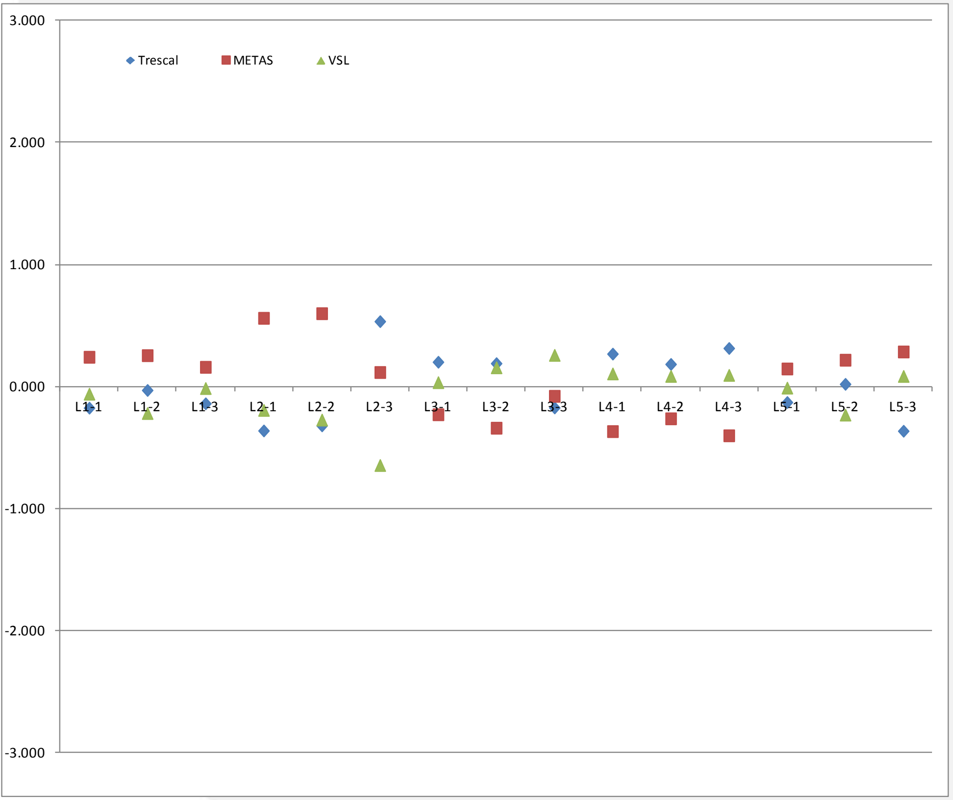
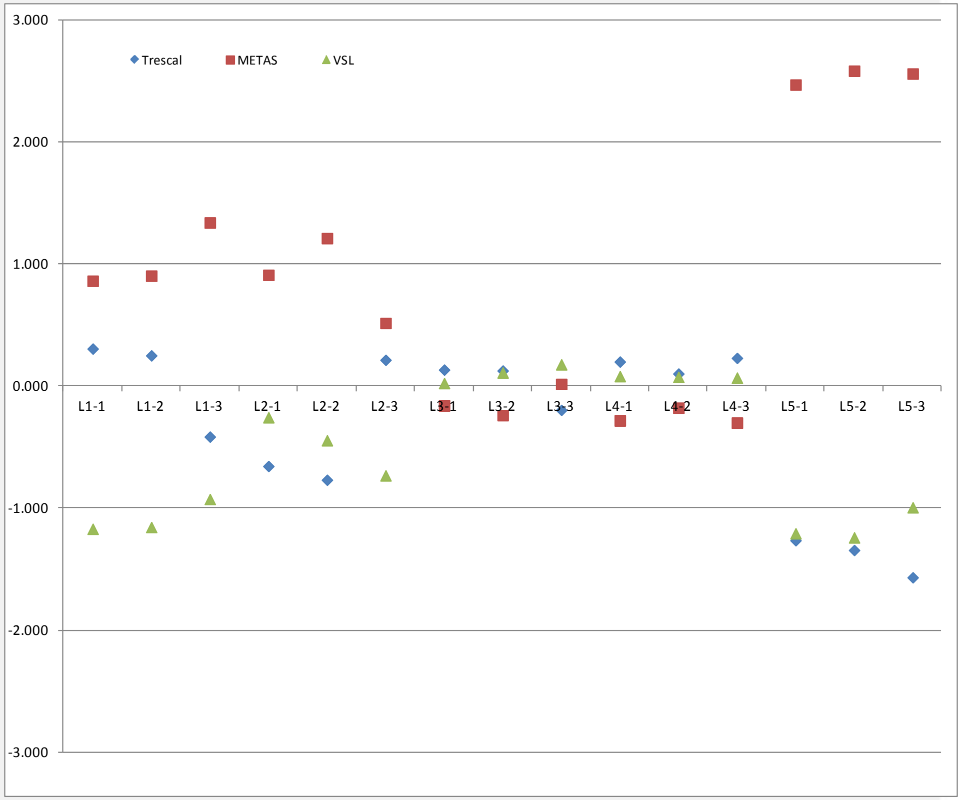
P


3.000
2.000
1.000
0.000
-1.000
-2.000
-3.000
Trescal
METAS
VSL
L1-1
L1-2
L1-3
L2-1
L2-2
L2-3
L3-1
L3-2
L3-3
L4-1
L4-2
L4-3
L5-1
L5-2
L5-3

Irms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L4-1
L4-2
L4-3
L5-1
L5-2
L5-3

Generally, the uncertainty of power measurement can be within 0.6% for EUT (Equipment under test) like SSL lamps. For I_{rms} measurement, the uncertainties are high for some special lamps, as high as 3%.

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The comparisons are done with the same lamps circulated around laboratories. The difference of the power measured using different samples of the same model can be as high as 2%. The difference of the I_{rms} measured using different samples of the same model can be as high as 3%.

The large uncertainty of I_{rms} measurement has three reasons

The first reason is that the measurement has larger uncertainty in higher frequency range. That is due to the characteristic of the digitizer and the transducers. If the EUT has rich harmonics in high frequency range, the total uncertainty increases.

The second reason is that the EUT includes not only the lamps in high frequency. The cable, the power supply, the connections are also parts of EUT which are variant in different setups. For some special EUTs, resonance occurs which becomes predominant source of uncertainty.

The third reason is that the transducers (mainly the current shunt) can change the current waveform of the EUT. This is a significant uncertainty source for some lamps with large peaks in current waveform, for instance, L1 in this comparison.

- Measurement capability of instruments
- Influence to the EUT
- The cable, the power supply, the connections are also parts of EUT in high frequency

Uncertainty Analysis

Calibration data in fundamental frequency

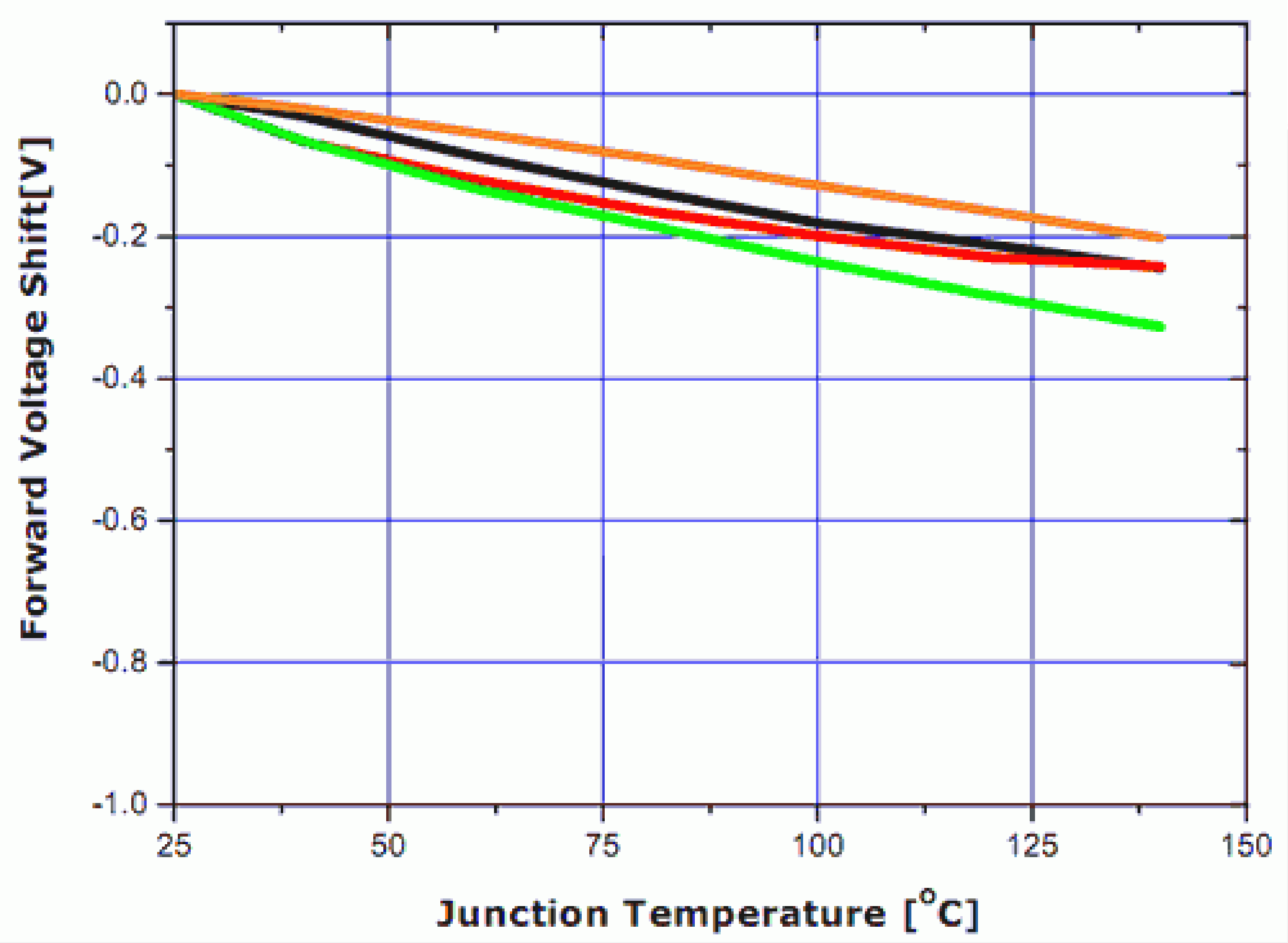
CERTIFICAAT

Nummer 3351314.01
Blad 1 van 2

Instellingen van de vermogensmeter		
Function	:	RMS
Lfilter	:	Off
Ffilter	:	Off
AVG	:	Off
Scale	:	Off
Sync	:	A
Reso	:	Hi
Urate	:	0,25
CF	:	3

Watt Function [W]		50 Hz						
Current	1 A	Current Range 2 A						
Range	Appl.	0 Deg	30 Deg	60 Deg	90 Deg	-30 Deg	-60 Deg	-90 Deg
15 V	15 V	15.011 ± 0.002	12.935 ± 0.001	7.364 ± 0.001	-0.0023 ± 0.001	12.941 ± 0.001	7.373 ± 0.001	0.003 ± 0.001
30 V	30 V	30.021 ± 0.003	25.884 ± 0.003	14.756 ± 0.002	-0.0051 ± 0.001	25.886 ± 0.002	14.764 ± 0.002	0.005 ± 0.001
60 V	60 V	60.033 ± 0.010	51.757 ± 0.001	29.509 ± 0.006	-0.0071 ± 0.006	51.747 ± 0.006	29.502 ± 0.010	0.008 ± 0.001
150 V	110 V	109.957 ± 0.009	95.372 ± 0.011	55.260 ± 0.010	-0.0201 ± 0.006	95.336 ± 0.006	55.240 ± 0.011	0.019 ± 0.011
150 V	150 V	149.945 ± 0.011	129.841 ± 0.019	74.907 ± 0.010	-0.0251 ± 0.009	129.799 ± 0.009	74.873 ± 0.012	0.026 ± 0.012
300 V	230 V	229.907 ± 0.012	199.295 ± 0.017	115.364 ± 0.015	-0.0446 ± 0.006	199.339 ± 0.017	115.430 ± 0.015	0.040 ± 0.018

Temperature inconsistence

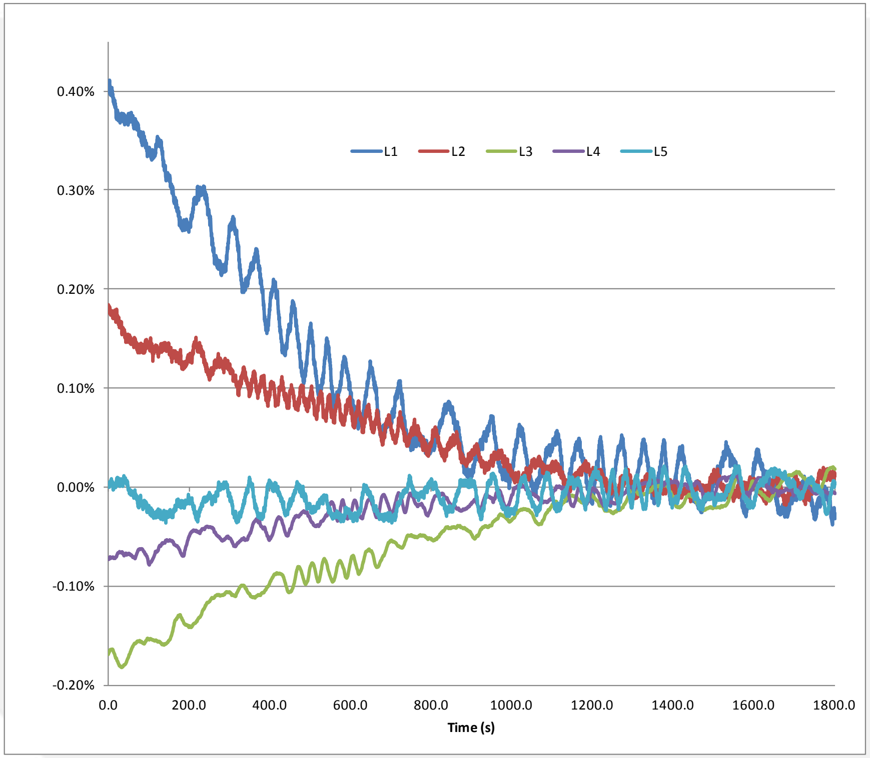


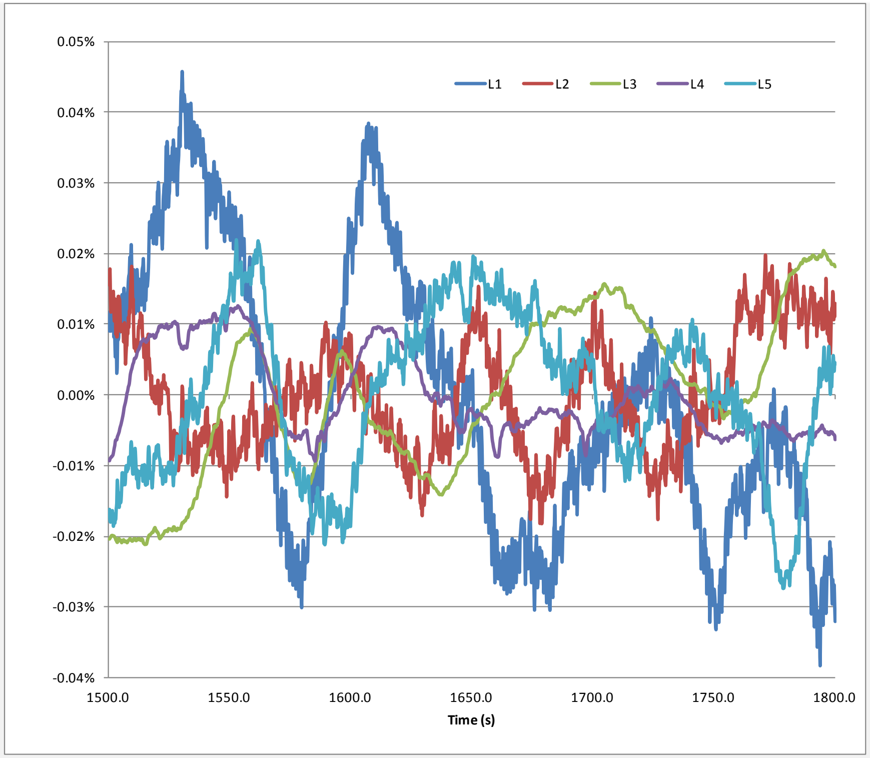
http://paralela.org/freeware_projects/bicycle_headlight_more_on_leds.html

DC offset

The DC offset of the input channel should be checked. The DC offset of the current measurement circuit can be checked when the load is disconnected from the measurement setup.

Instability of the SSL product





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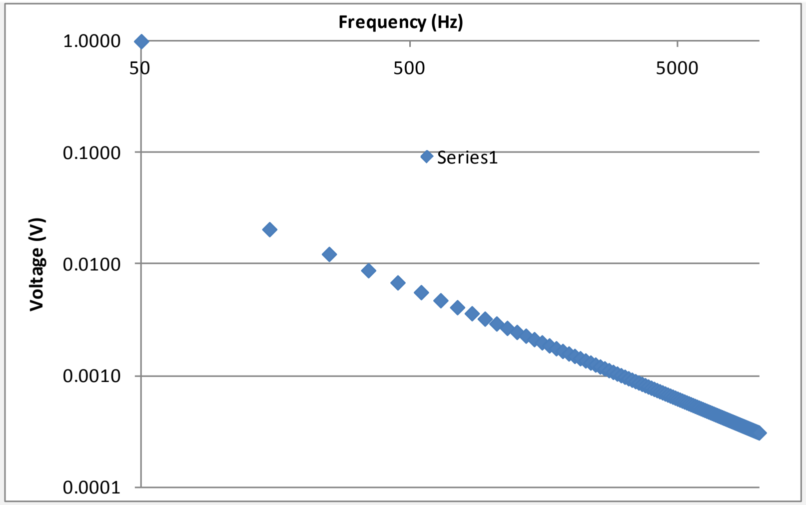
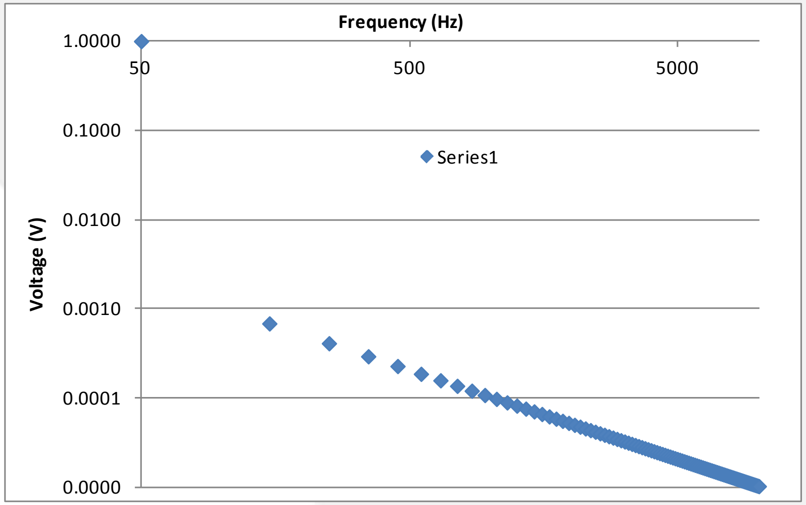
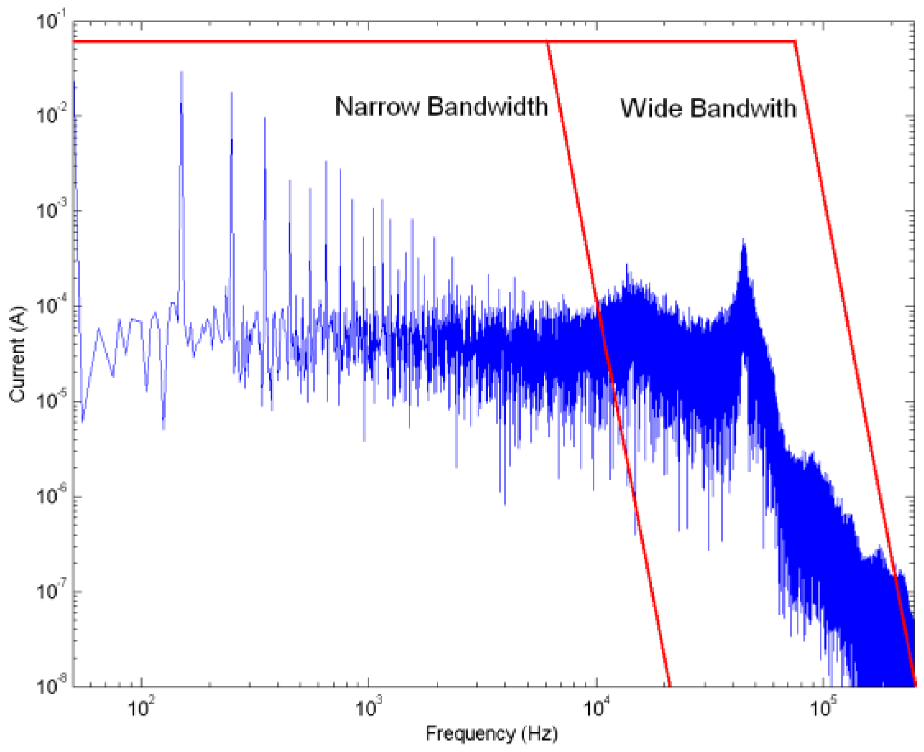
Influence of the distorted voltage signal of power supply





	L1	L2	L3	L4	L5
3.0%	5.77%	1.83%	0.61%	0.69%	0.81%
0.1%	0.18%	0.06%	0.02%	0.02%	0.03%

Bandwidth error



Bandwidth	Error
50000	0.21%

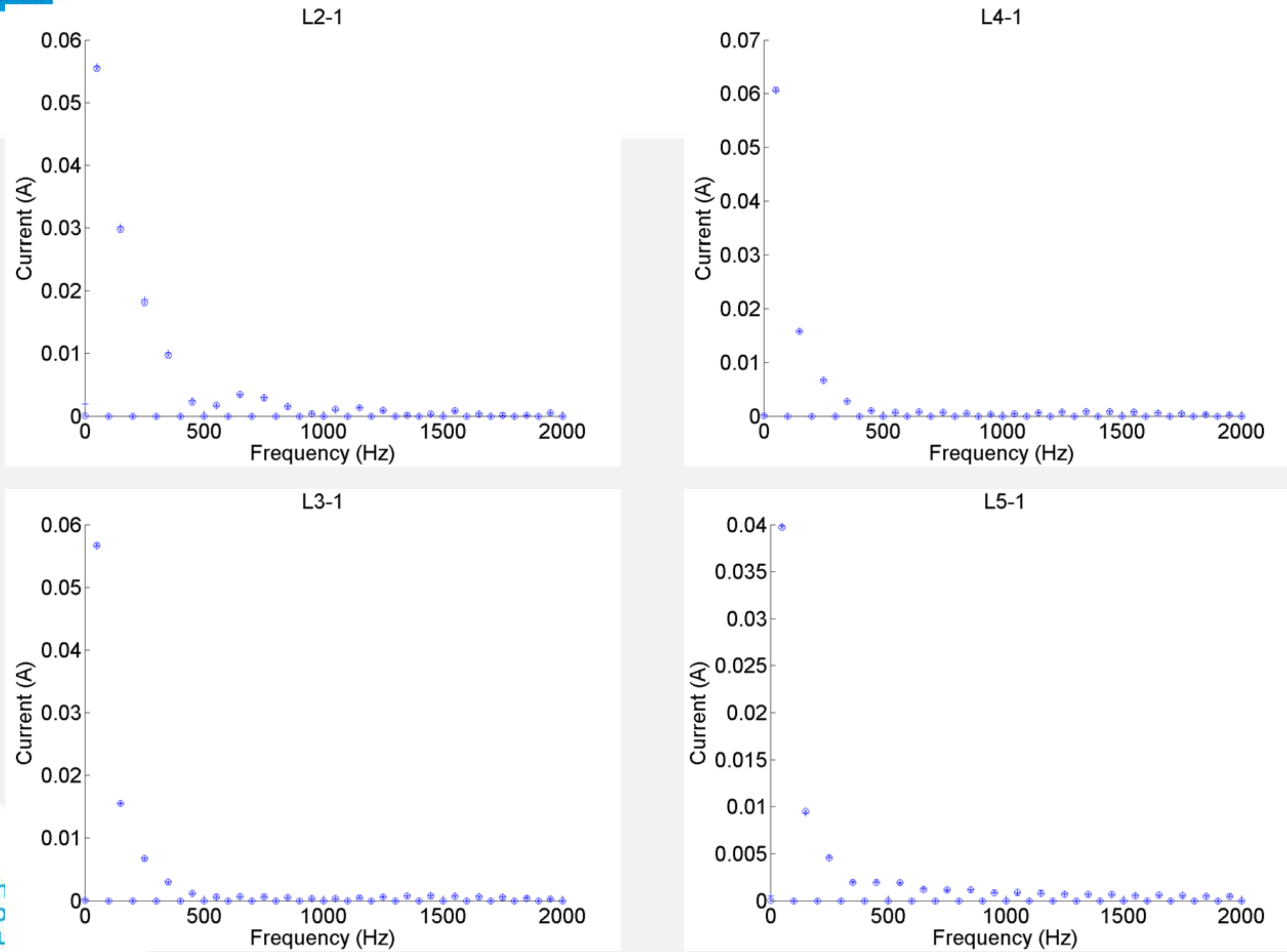
Ac frequency flatness error

K_Rdg	K_Rng	K_kHz	Error
0.0006	0.0003	0.0001	0.15%

Frequency	Accuracy ±(reading error + measurement range error)
DC	±(0.2% of reading + 0.1% of range)
0.1 Hz ≤ f < 10 Hz	±(0.2% of reading + 0.1% of range)
10 Hz ≤ f < 45 Hz	±(0.2% of reading + 0.05% of range)
45 Hz ≤ f ≤ 1 kHz	±(0.1% of reading + 0.05% of range)
1 kHz < f ≤ 10 kHz	±(0.1% of reading + 0.05% of range)
10 kHz < f ≤ 50 kHz	±(0.2% of reading + 0.1% of range)
50 kHz < f ≤ 100 kHz	±(0.6% of reading + 0.2% of range)
100 kHz < f ≤ 200 kHz	±(0.6% of reading + 0.2% of range)
200 kHz < f ≤ 400 kHz	±(1% of reading + 0.2% of range)
400 kHz < f ≤ 500 kHz	±((0.1 + 0.006 × f*)% of reading + 0.2% of range)
500 kHz < f ≤ 1 MHz	±((0.1 + 0.006 × f*)% of reading + 2% of range)
1 MHz < f ≤ 5 MHz	±((0.1 + 0.006 × f*)% of reading + 2% of range)

* The unit of f in the equation for the reading error is (kHz).

Influence of shunt resistor



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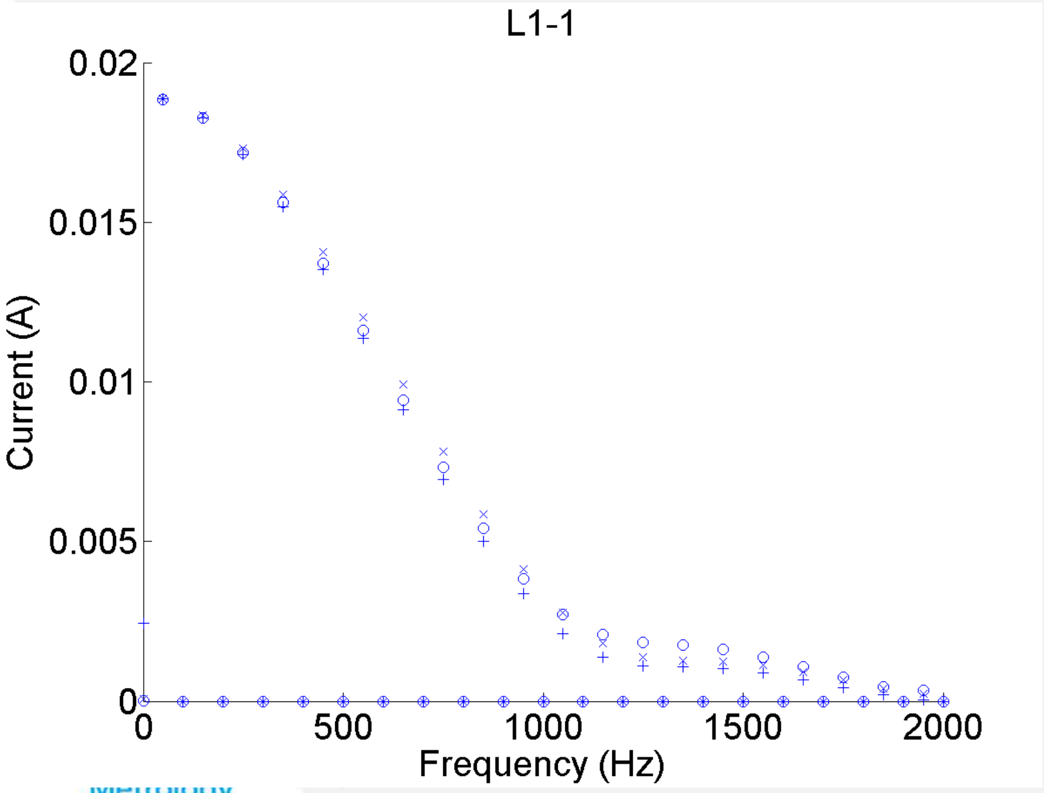
Influence of shunt resistor



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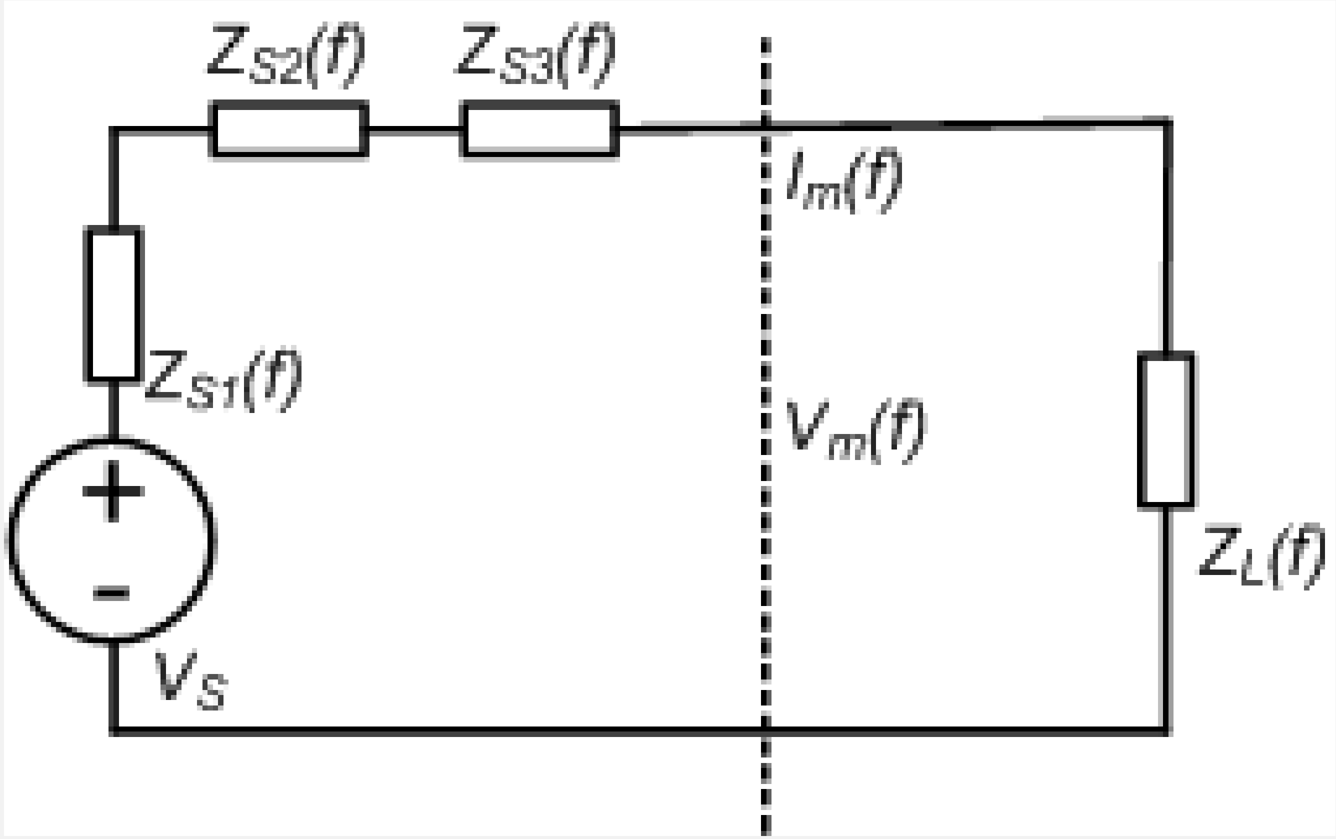
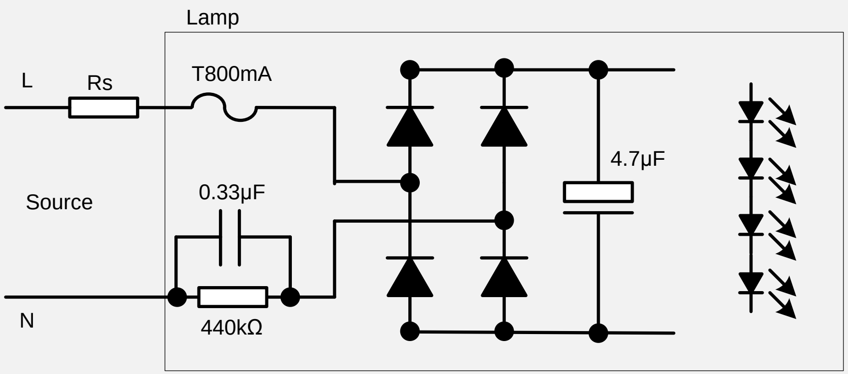
Model for low frequency harmonics

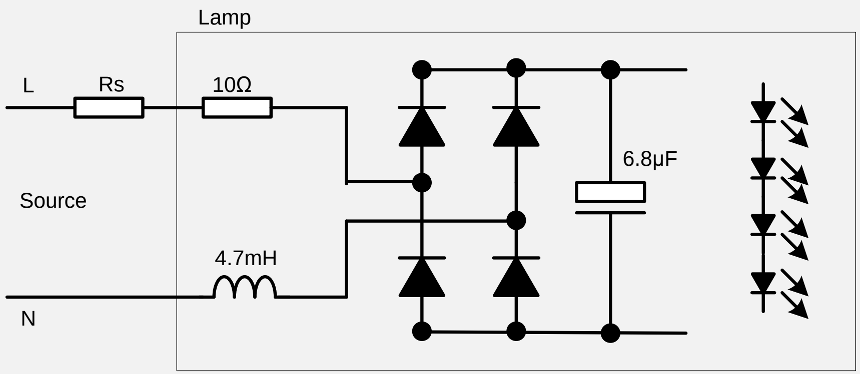


Influence of shunt resistor



L1	L2	L3	L4	L5
0.001%	0.000%	0.000%	0.000%	0.000%

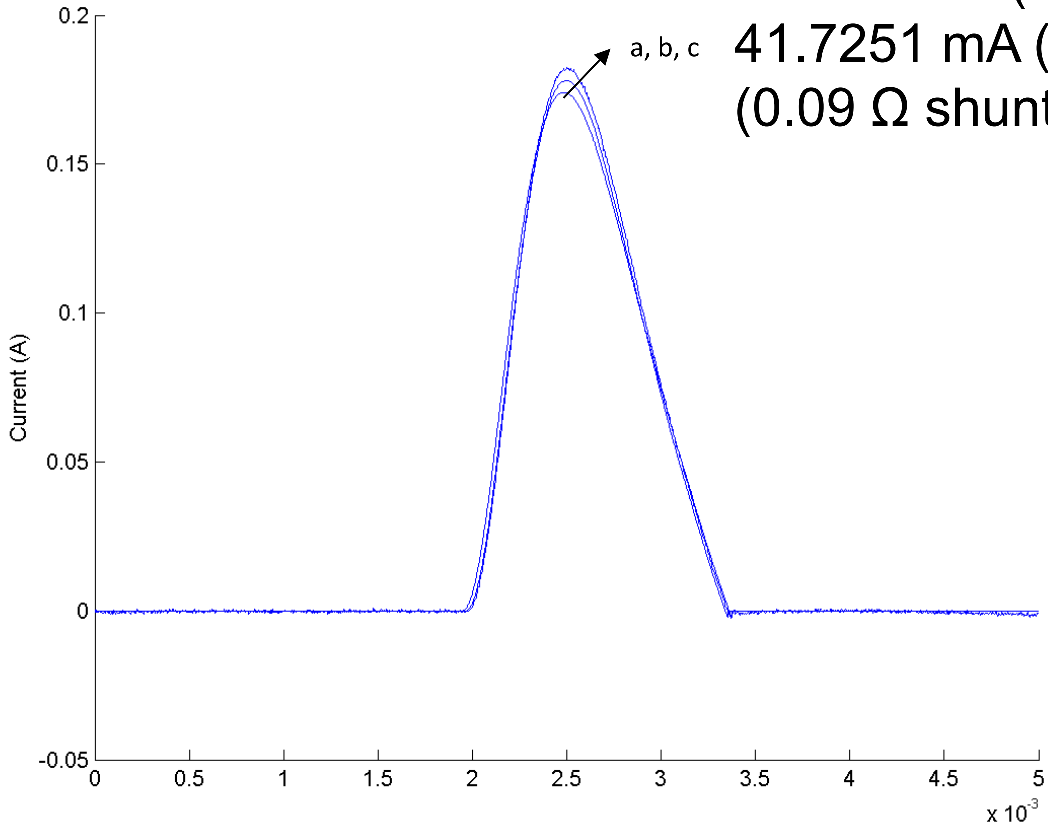
$$\text{Ratio} = \frac{3 + \frac{1}{j*2*\pi*f*0.33*10^{-6}}}{0.09 + \frac{1}{j*2*\pi*f*0.33*10^{-6}}}$$



L1	L2	L3	L4	L5
2.857%	0.204%	0.046%	0.044%	0.125%

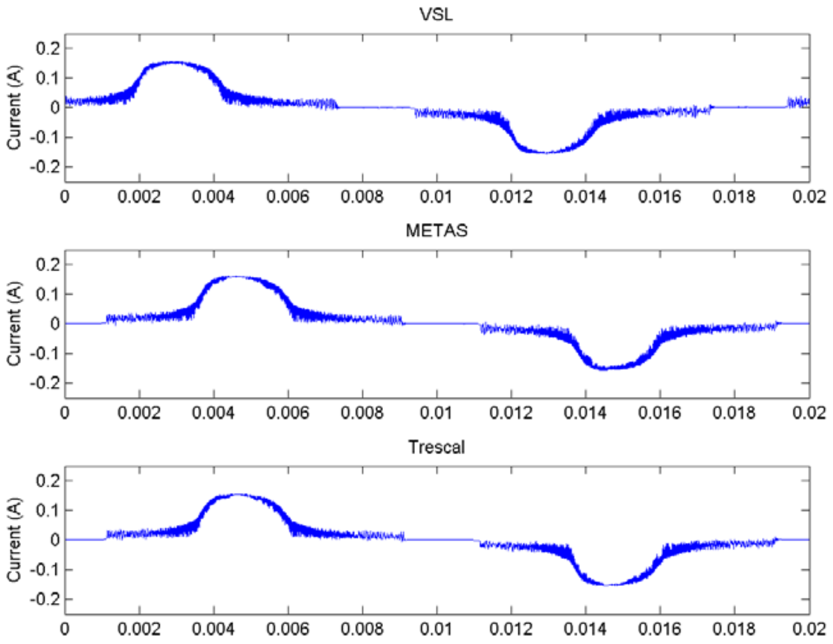
$$\text{Ratio} = \frac{3 + 10 + j*2*\pi*f*4.7*10^{-3} + \frac{1}{j*2*\pi*f*6.8*10^{-6}}}{0.09 + 10 + j*2*\pi*f*4.7*10^{-3} + \frac{1}{j*2*\pi*f*6.8*10^{-6}}}$$

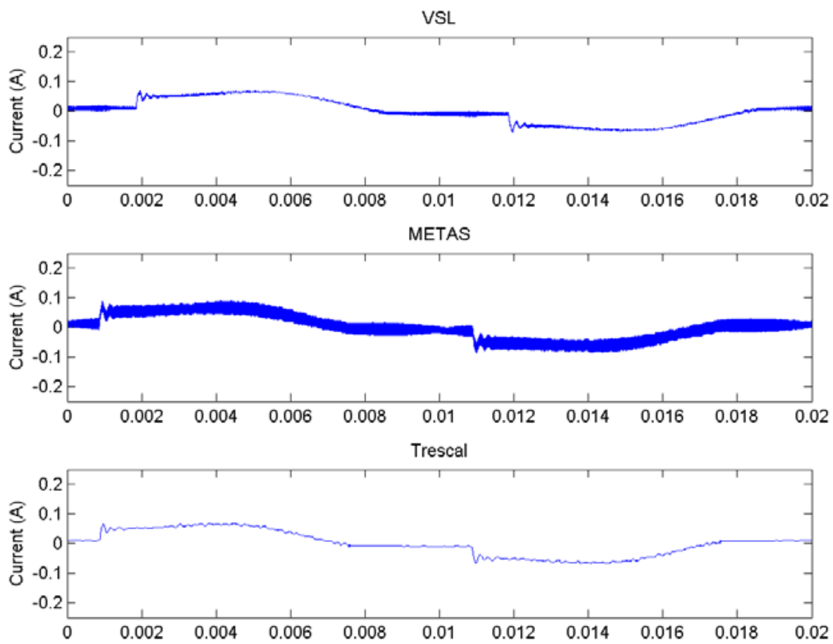
Influence of shunt resistor



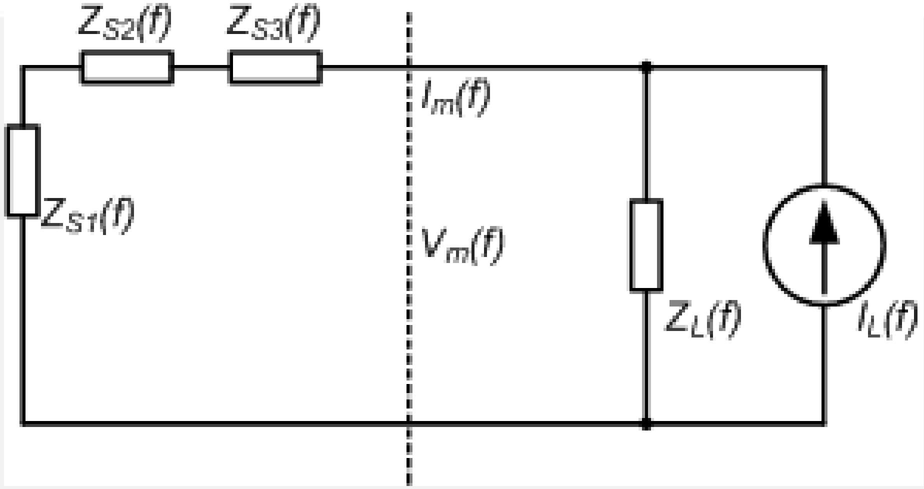
The current waveform measured using different current shunt resistors. Measured values are: (a) 41.6103 mA (3 Ω shunt) (b) 41.7251 mA (0.9 Ω shunt) (c) 42.6461 mA (0.09 Ω shunt)

Influence of power supply impedance





Model for high frequency harmonics



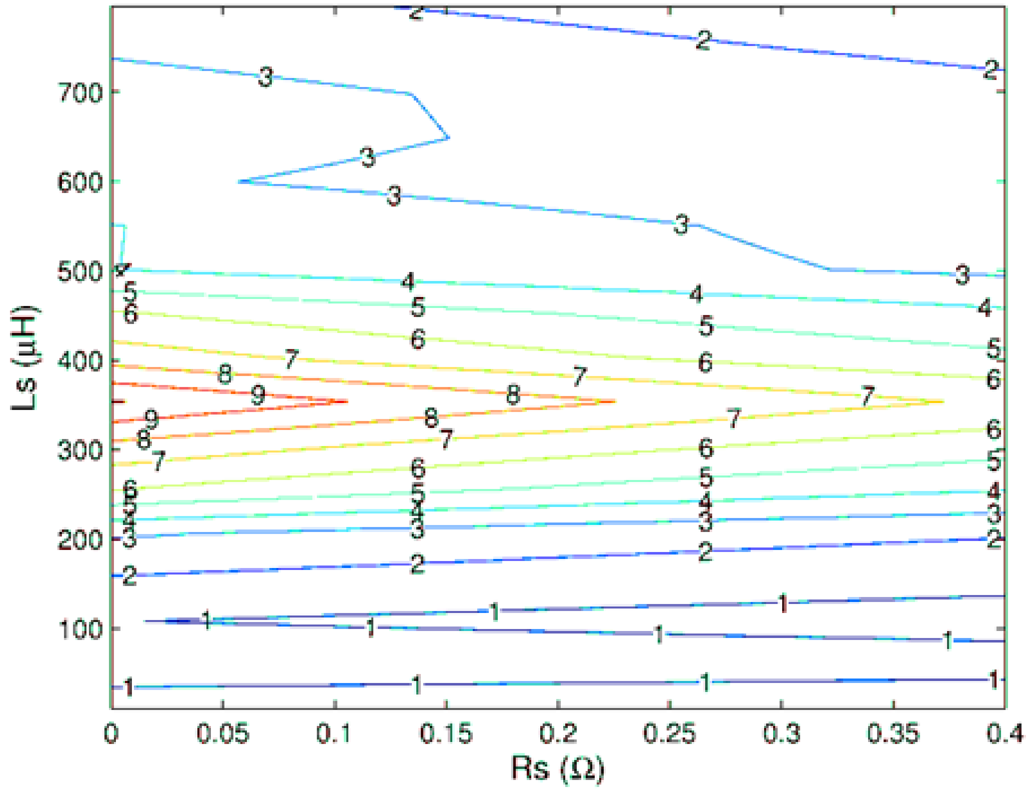
$$I_m(f_i) = I_L(f_i)\frac{Z_L(f_i)}{Z_S(f_i)+Z_L(f_i)}$$

$$V_m(f_i) = V_S - I_m(f_i)Z_S(f_i)$$

The source impedance level suggested by IEC-725(1981), Table-1, appears to be 0.4+0.25j at 50 Hz.

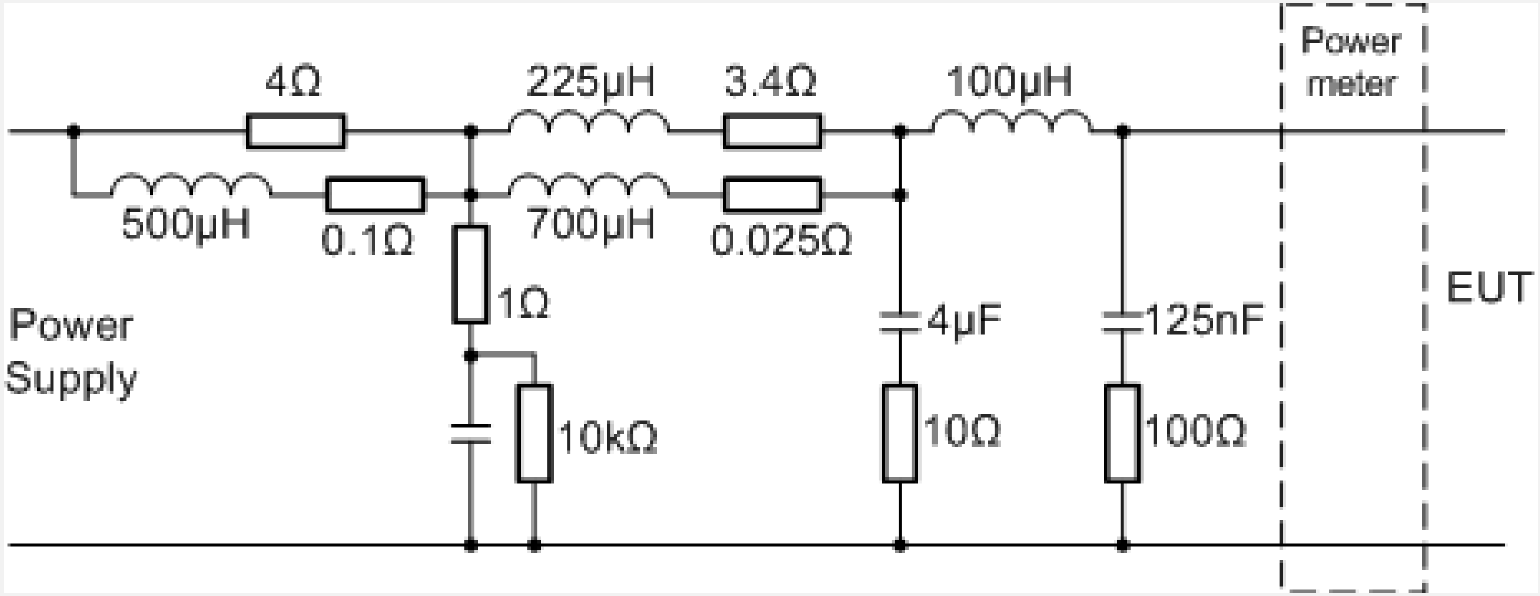
Influence of power supply impedance

Contour of the relative deviation (expressed as percentage) in RMS current value with variable source impedance



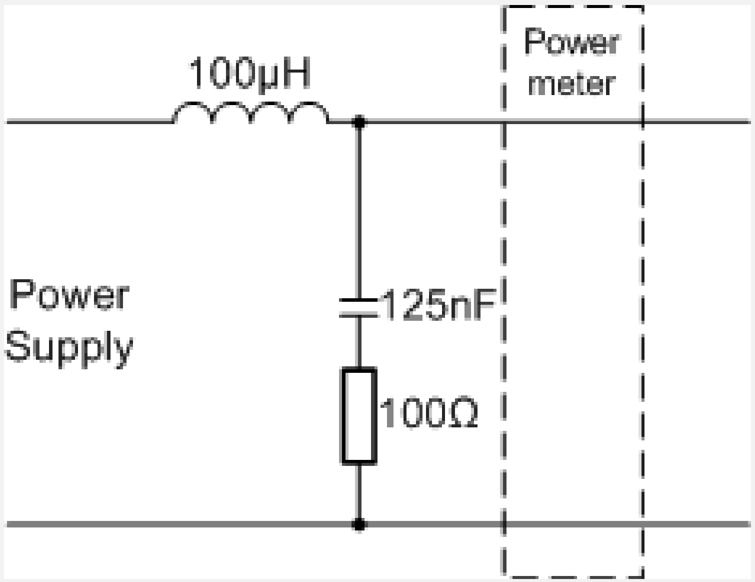
D. Zhao and G. Rietveld, "The Influence of Source Impedance in Electrical Characterization of Solid State Lighting Sources," Proceeding of 2012 Conference on Precision Electromagnetic Measurements, pp.300--301, Washington DC, US, 2012

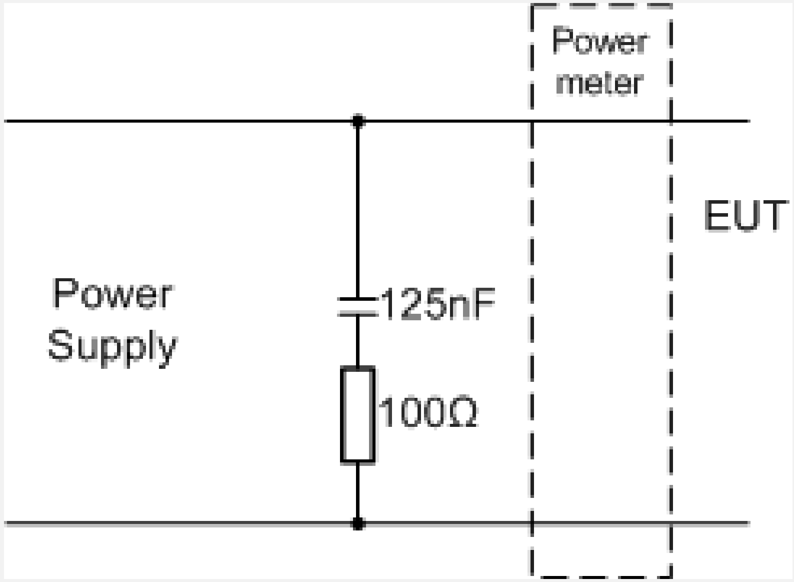
Proposed source impedance stabilization network



The RMS current deviation calculated becomes less than 0.02 %

Proposed simplified source impedance stabilization network





Example of uncertainty analysis

Uncertainty budget, Voltage	L1-x					
Source	**Type**	**Value (µV/V)**	**Distribution**	**k-factor**	**Sen.-Coef.**	**Std. Unc. (µV/V)**
Calibration voltage channel	B	435	Gaussian	1	1	434.8
Stability after varm-up	B	435	Uniform	1.732	1	251.0
Repeatability	A	210	Gaussian	1	1	210.0
				Combined uncertainty:		544

Uncertainty budget, Power	L1-x					
Source	**Type**	**Value (µW/VA)**	**Distribution**	**k-factor**	**Sen.-Coef.**	**Std. Unc. (µW/VA)**
Calibration current channel	B	100	normal	1	1	100.0
Calibration voltage channel	B	435	normal	1	1	434.8
Temperature dependence	B	800	Gaussian	1	1	800.0
Influence of power supply THD	B	1800	Uniform	1	1	1800.0
Wiring error	B	32	normal	1	1	32.0
Stablization of EUT	B	2000	normal	1	1	2000.0
Repeatability	A	100	normal	1	1	100.0
				Combined uncertainty:		2844

Example of uncertainty analysis

Uncertainty budget, Current	L1-x					
Source	**Type**	**Value (µA/A)**	**Distribution**	**k-factor**	**Sen.-Coef.**	**Std. Unc. (µA/A)**
Calibration current channel	B	100	normal	1	1	100.0
Bandwidth error	B	22	normal	1	1	22.0
Ac flatness of current channel	B	1500	normal	1	1	1500.0
Wiring error	B	32	normal	1	1	32.0
Influce of shunt resistor	B	8241	normal	1	1	8241.0
Stablization of EUT	B	2000	normal	1	1	2000.0
Repeatability	A	200	normal	1	1	200.0
				Combined uncertainty:		8615

Summary

- For SSL products, with rich high frequency harmonics, the uncertainty calculations of electrical parameters need completely new approaches. Uncertainty sources are identified and written into guideline.
- The uncertainty analysis for SSL electrical measurement is the firstly done in literature based on the solid understanding of the uncertainty sources.

Acknowledge

Discussions with colleagues of METAS and Trescal

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