



Trescal



Metrology  
for Solid State Lighting

# Electrical properties of SSL lamps.

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Teddington, April 2013

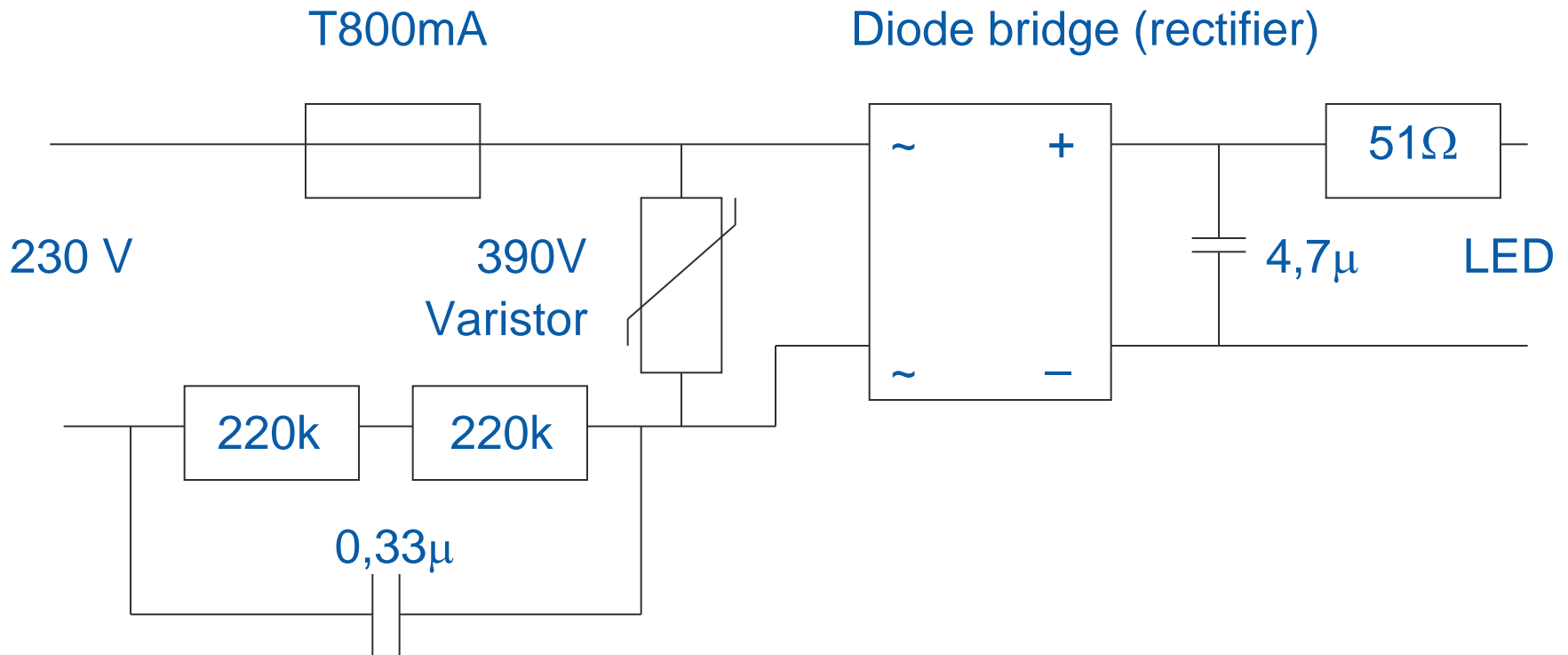
- Example of electronics
- Impedance issues - Impact
- Current THD
- Flicker

## PRO Light LED Standard 1,2 W

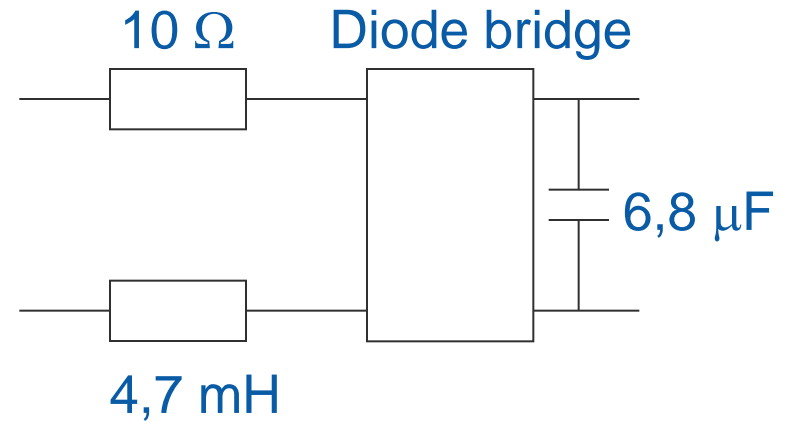
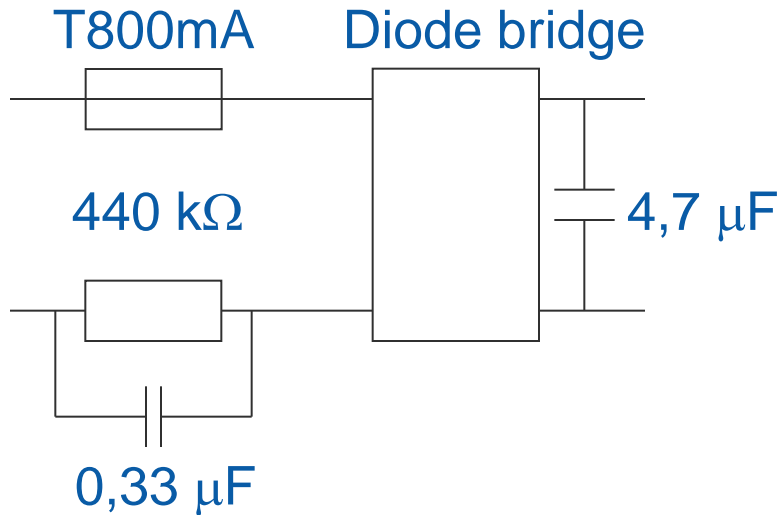


## PRO Light LED Standard 1,2 W

### Diagram



## Common SSL circuits



SSL lamps are non-linear loads  
High current distortion

## Impedance of some typical lamps

	Impedance	Resistance	Reactance
	Z (k $\Omega$ )	R (k $\Omega$ )	X (k $\Omega$ )
Pro Light 1,2 W	9,61	2,47	-9,19
Paulmann 3 W	9,88	6,03	-7,83
Philips 5 W	10,45	10,21	-2,25
Philips 12 W	4,06	4,05	-0,31
Osram 8 W	6,00	5,18	-3,02
Osram 4,5 W	11,67	11,56	-1,75
Osram 12 W	3,84	3,73	-0,88

## Consequences:

Current signal rich in harmonics, 30% - 200 % THD  
- affects current and power measurements

Power factor far below 1, down to 0,25

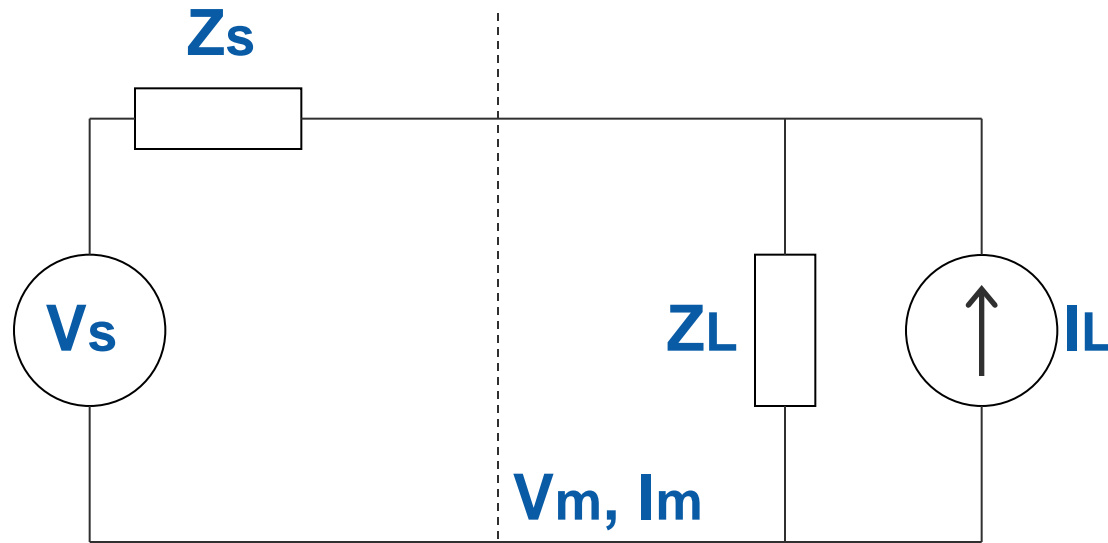
Highly frequency dependent impedance

- High impedance at low frequency
- Low impedance at high frequency

Frequency dependency, up to 2 %/Hz

## Basic Model

### Highly frequency dependent impedance



The source impedance standard value suggested by IEC-725(1981) is  $0.4 + j0.25 \Omega$  ( $\sim 800\mu\text{H}$ ) at 50 Hz.

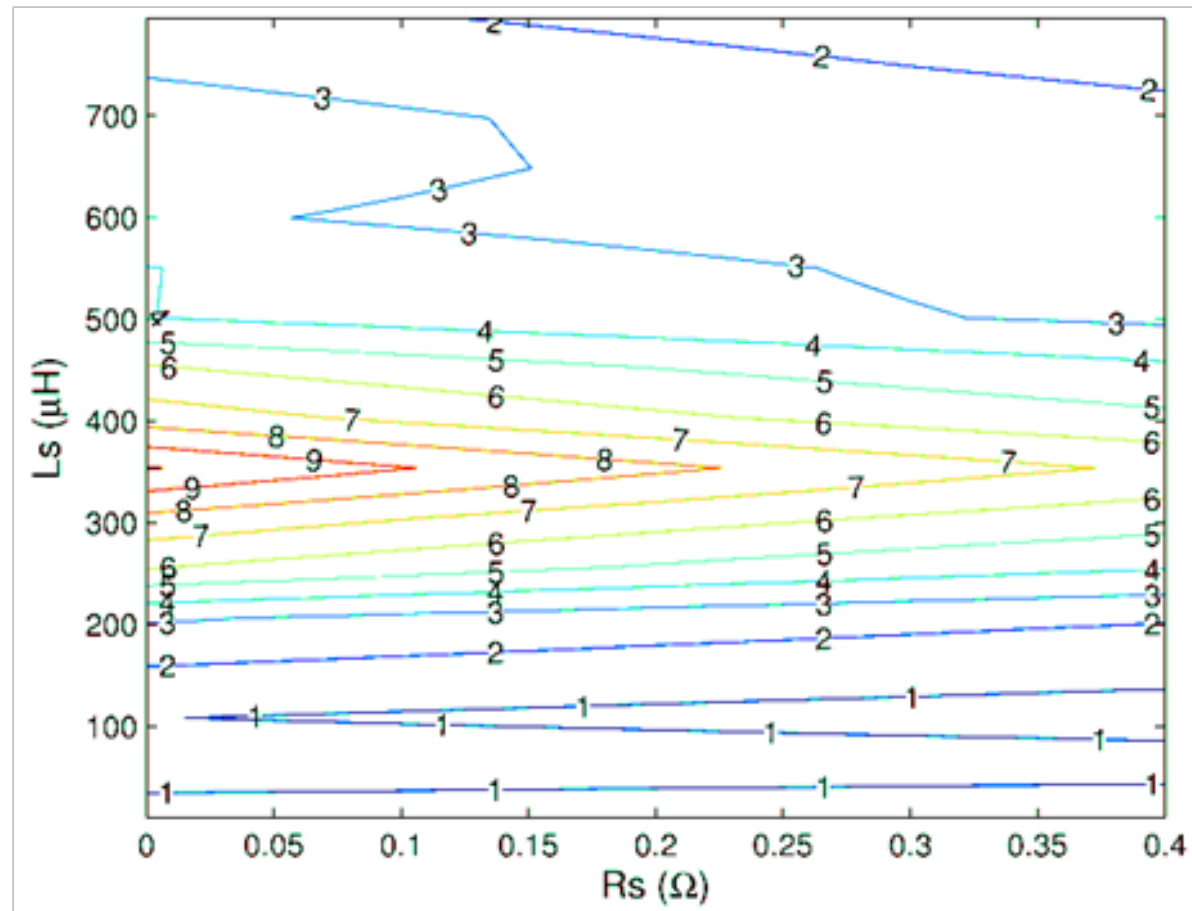


## Contour of the relative deviation (%) in RMS current value with variable source impedance



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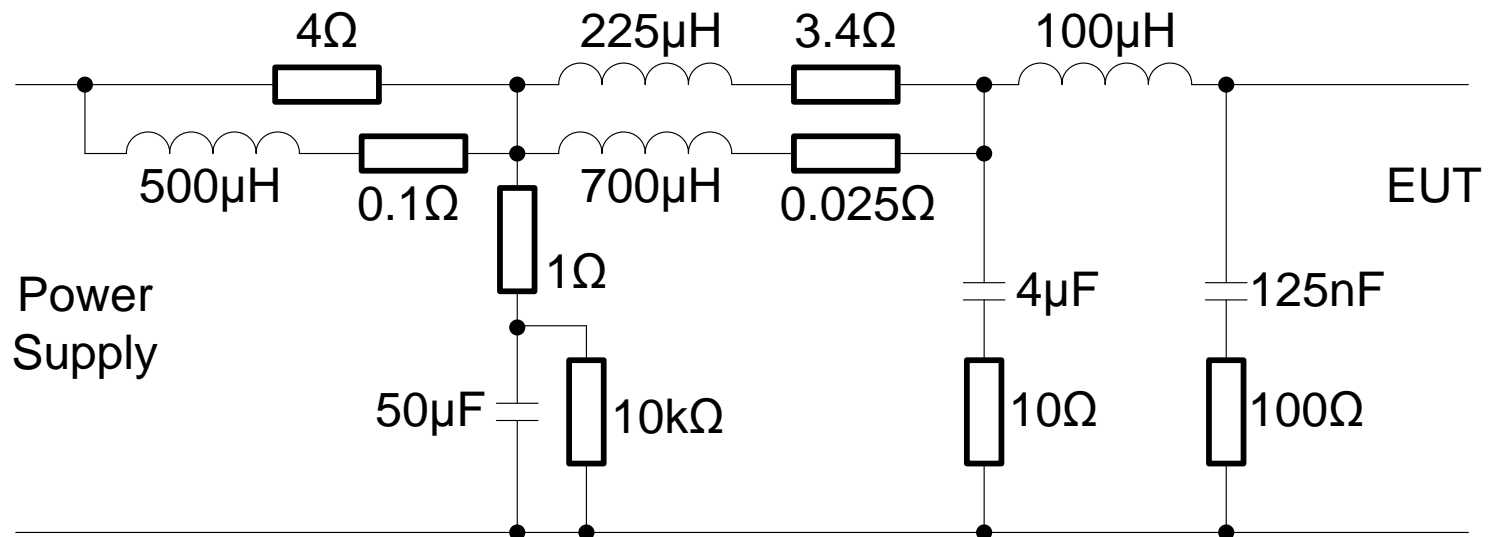


## Proposed source impedance stabilization network

The calculated current deviation becomes less than 0.02 % - major improvement



**D. Zhao**

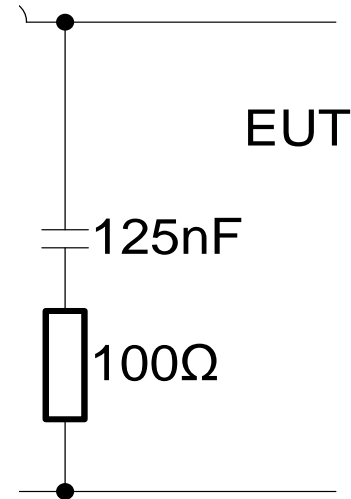


## Proposed simplified source impedance stabilization network



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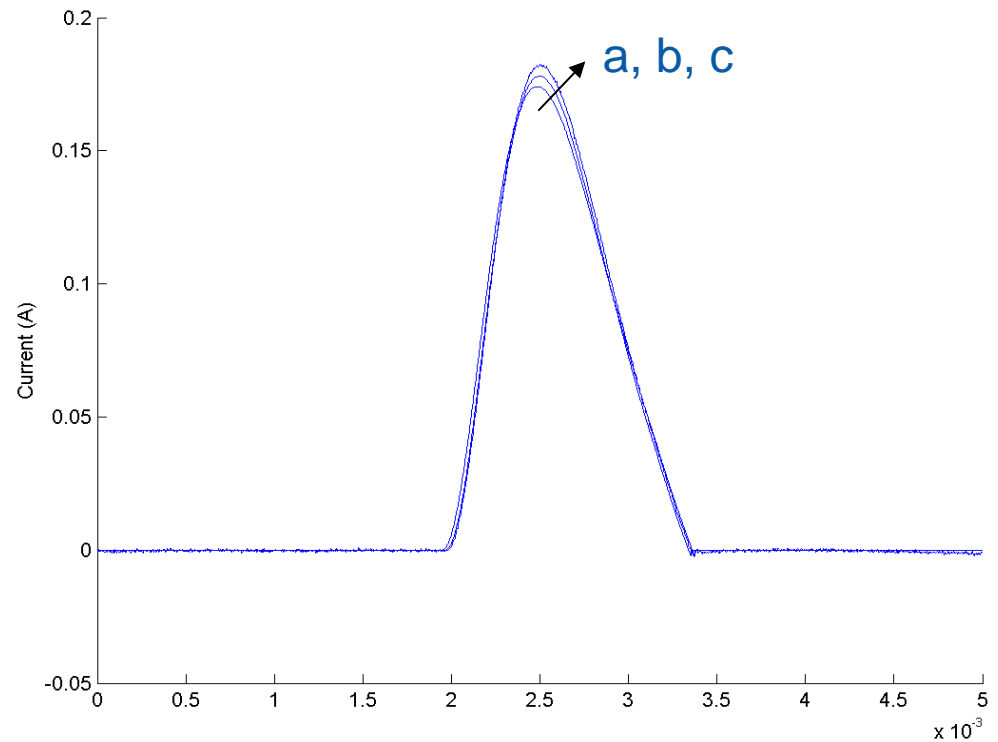
## Influence of current shunt resistance

a:  $3 \Omega$       41,61 mA

b:  $0,9 \Omega$       41,73 mA

c:  $0,09 \Omega$       42,65 mA

~ 2,5% difference



**BUT:** Extremely lamp dependent

# Impedance

## Influence of current shunt resistance

50 mA - 8  $\Omega$ , 100 mA - 4  $\Omega$ , 200 mA - 2  $\Omega$

Lamp	Shunt	I (mA)	P (W)	S (VA)	Q (Var)	PF
PRO Light 1,2 W	50 mA	24,90	1,417	5,727	5,549	0,247
	100 mA	0,34%	0,11%	0,33%	0,34%	-0,20%
	200 mA	0,20%	-0,20%	0,19%	0,22%	-0,36%
Osram 4,5 W	50 mA	40,91	4,308	9,408	8,364	0,458
	100 mA	2,59%	0,17%	2,62%	3,25%	-2,38%
	200 mA	3,27%	-0,47%	3,25%	4,22%	-3,60%

Main dependencies to be considered:

Lamps (electronics)

Power supply

Current shunt

Cables (length)

Observed differences for the same lamp model  
up to several %.

## Total Harmonic Distortion, Current

### Digitizer:

Entire spectrum in accordance with sample rate

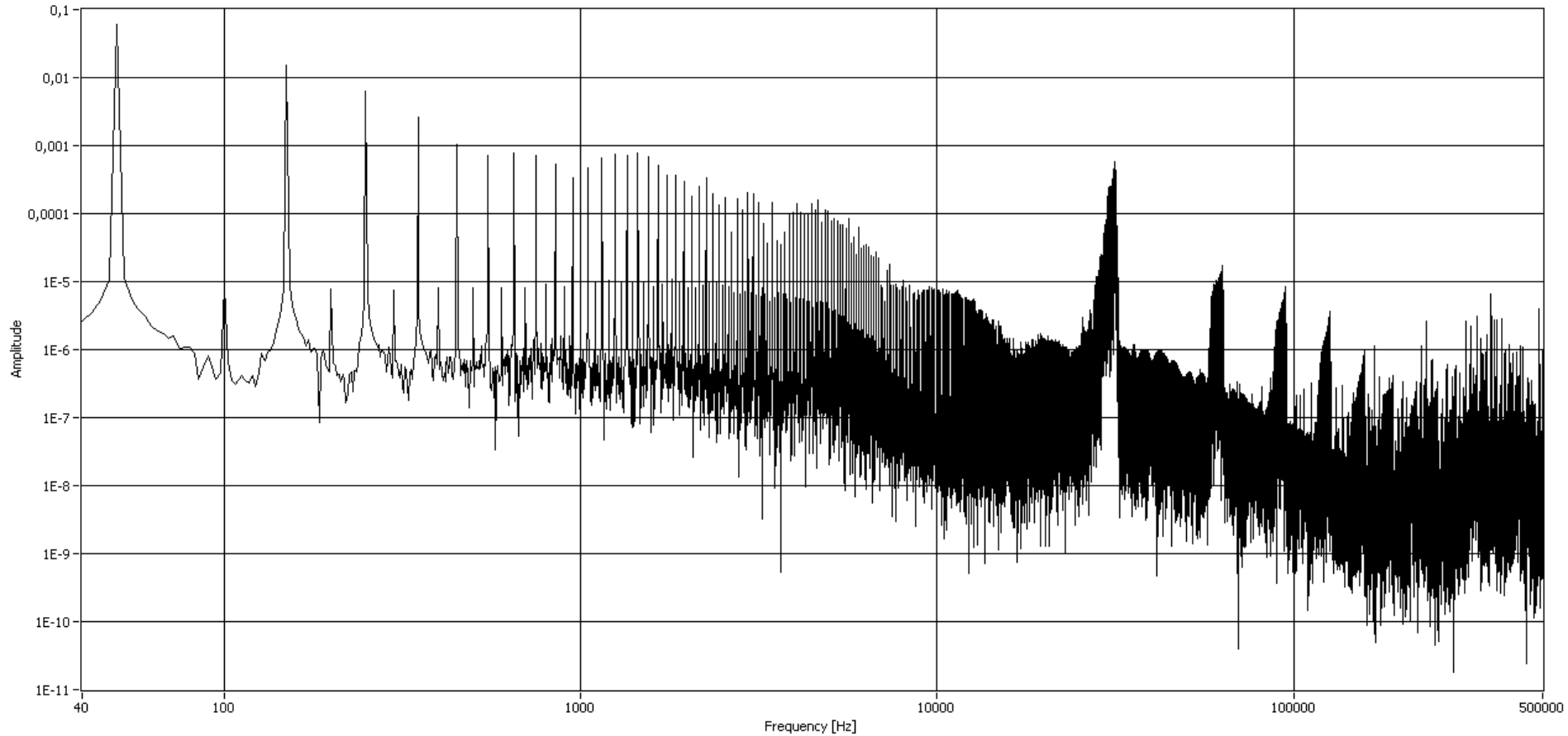
### Power Analyzer:

Limited no. of harmonics (harmonic analysis mode)

Key parameters may still be determined using the full bandwidth (V, I, P, PF, THD) – instrument dependent

## Typical Spectrum

OSRAM LED 12W





## Current, Total Harmonic Distortion

$$\text{THD} = \frac{1}{I_1} \sqrt{\sum_{m=2}^{m_{Max}} I_m^2}$$

or

$$\text{THD} = \frac{\sqrt{I_{rms}^2 - I_1^2}}{I_1}$$

## Some typical results, THD

L1	196 %
L2	68%
L3	31%
L4	29%
L5	30%
L1+L3+L5	36%

Variations among lamps of the same model can be several %

## THD - Voltage dependence

Lamp	L5 100 - 240 V	L6 230 V
100 V	24%	52%
150 V	18%	41%
200 V	25%	35%
230 V	30%	31%

## IEC 61000-4-15: Flickermeter

- 1 - 60 W, Incandescent
- 2 - 4.5 W (L1)
- 3 - 12 W (L3)
- 4 - 8 W (L5)

Sine wave: 230 V, 50 Hz

Square wave modulation: 8,8 Hz

Longe term flicker Plt:

$$Plt = \sqrt[3]{\frac{\sum_i^N P_{st}}{N}} = 0,87 \quad (N = 15)$$

## Measured PIt values:

Applied: 0,87

1 - 60 W Inc.: 0,81

2 - 4.5 W LED: 13,93

3 - 12 W LED: 0,26

4 - 8 W LED: 1,94



***The research leading to these results has received funding from the European Union on the basis of Decision No 912/2009/EC.***

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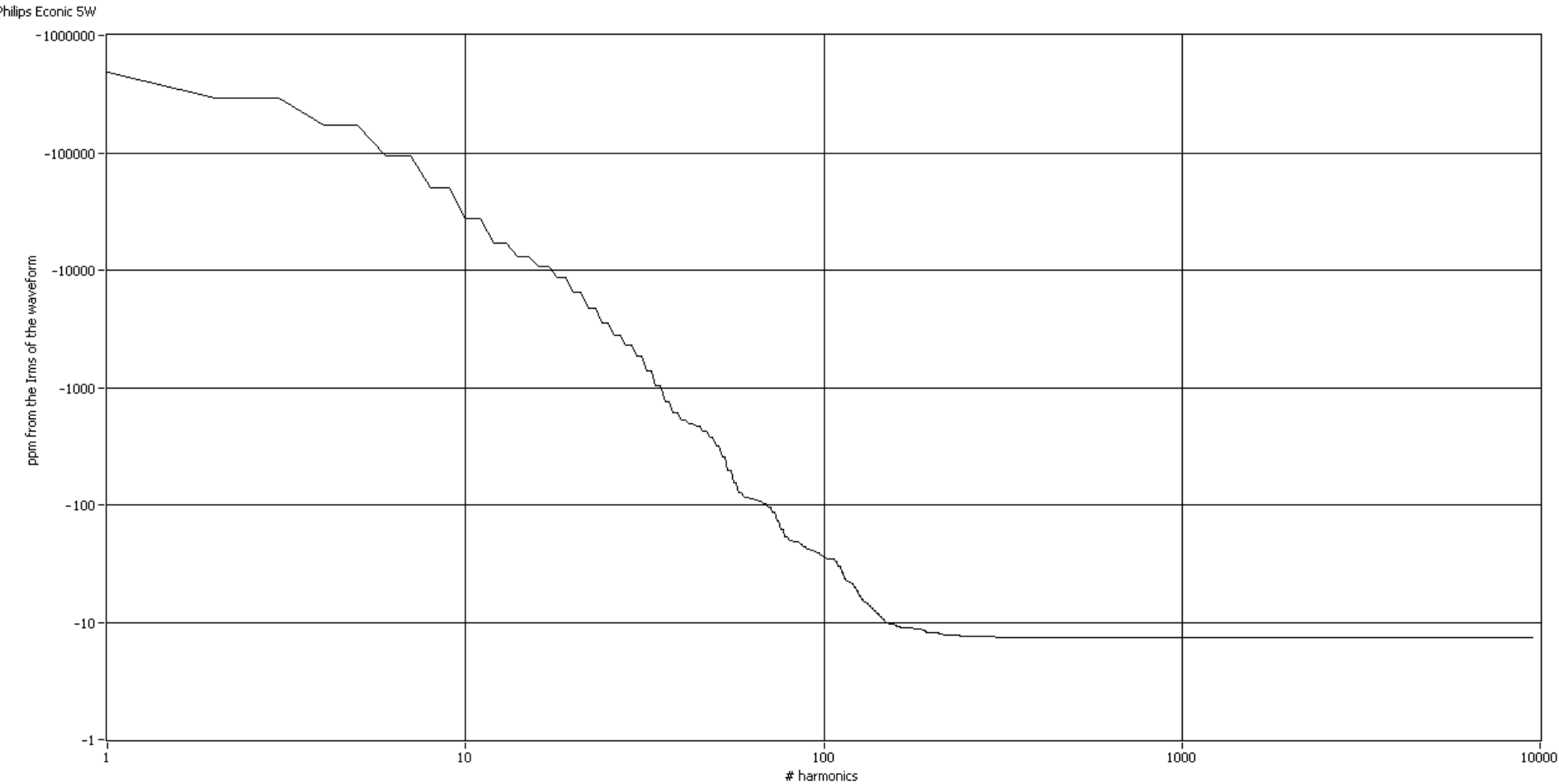


## Extras

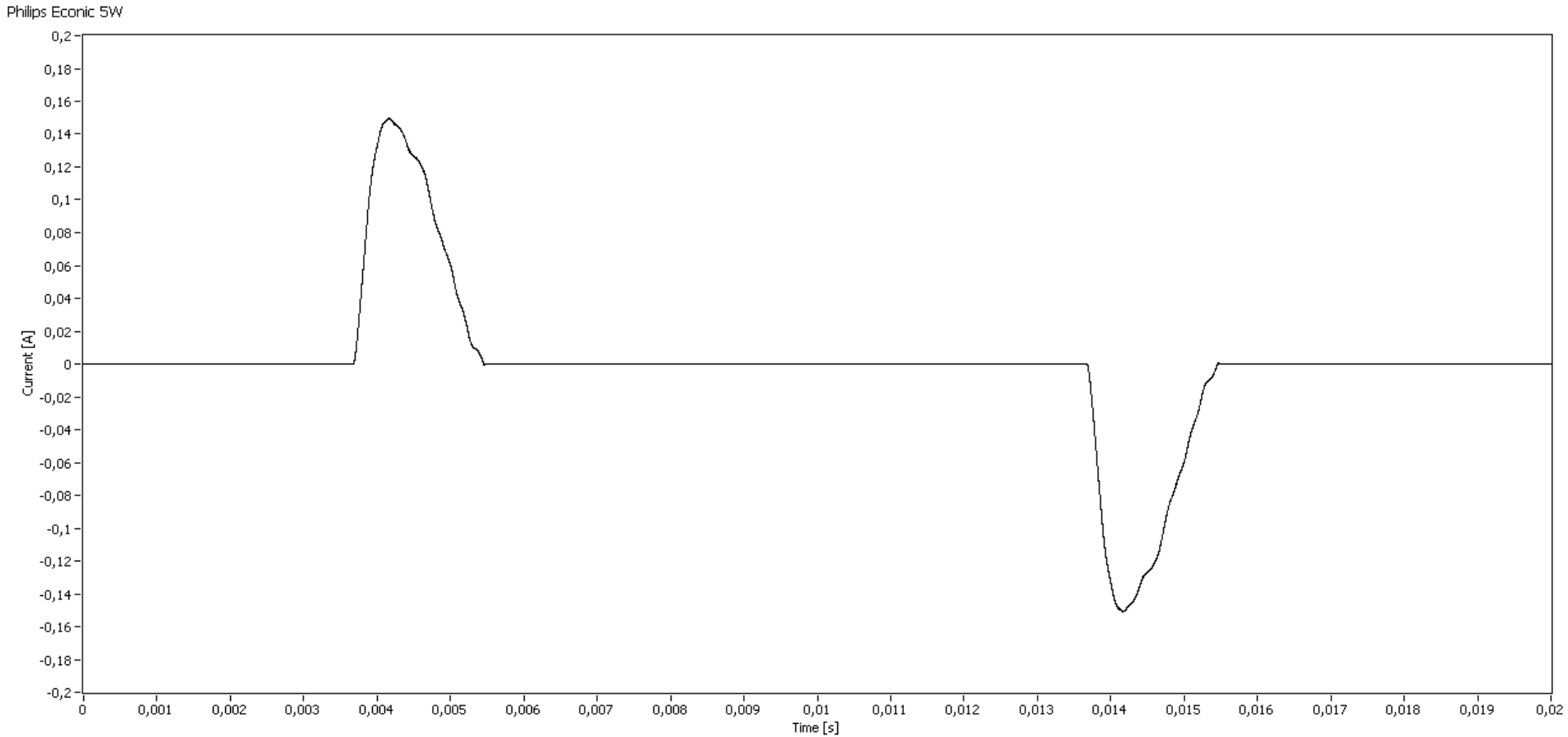


# SSL Power

Difference between Irms and the current calculated from the harmonics as a function of the number of harmonics used in the calculation.

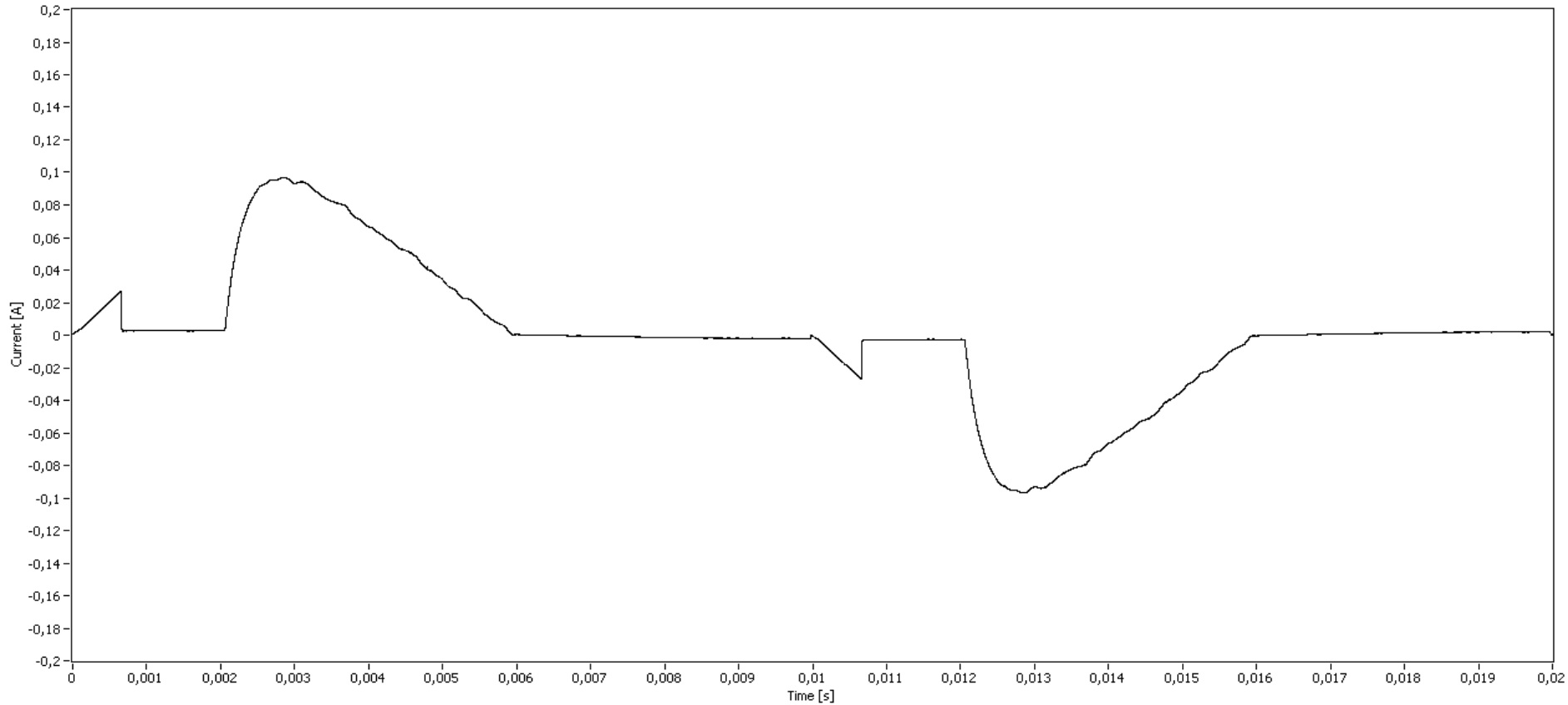


## Current waveform, Philips Econic, 5 W

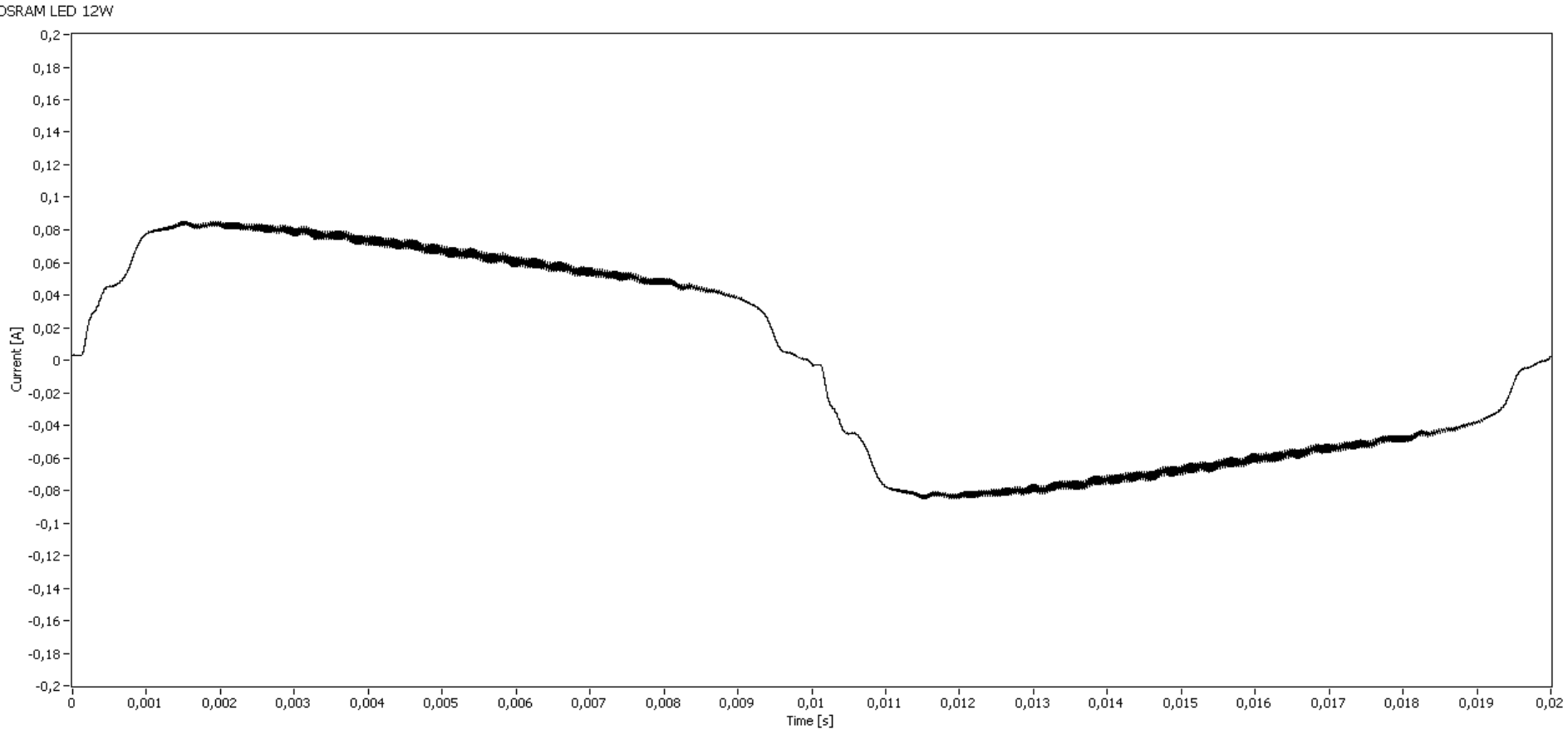


## Current waveform, Philips Econic with dimmer, 6 W

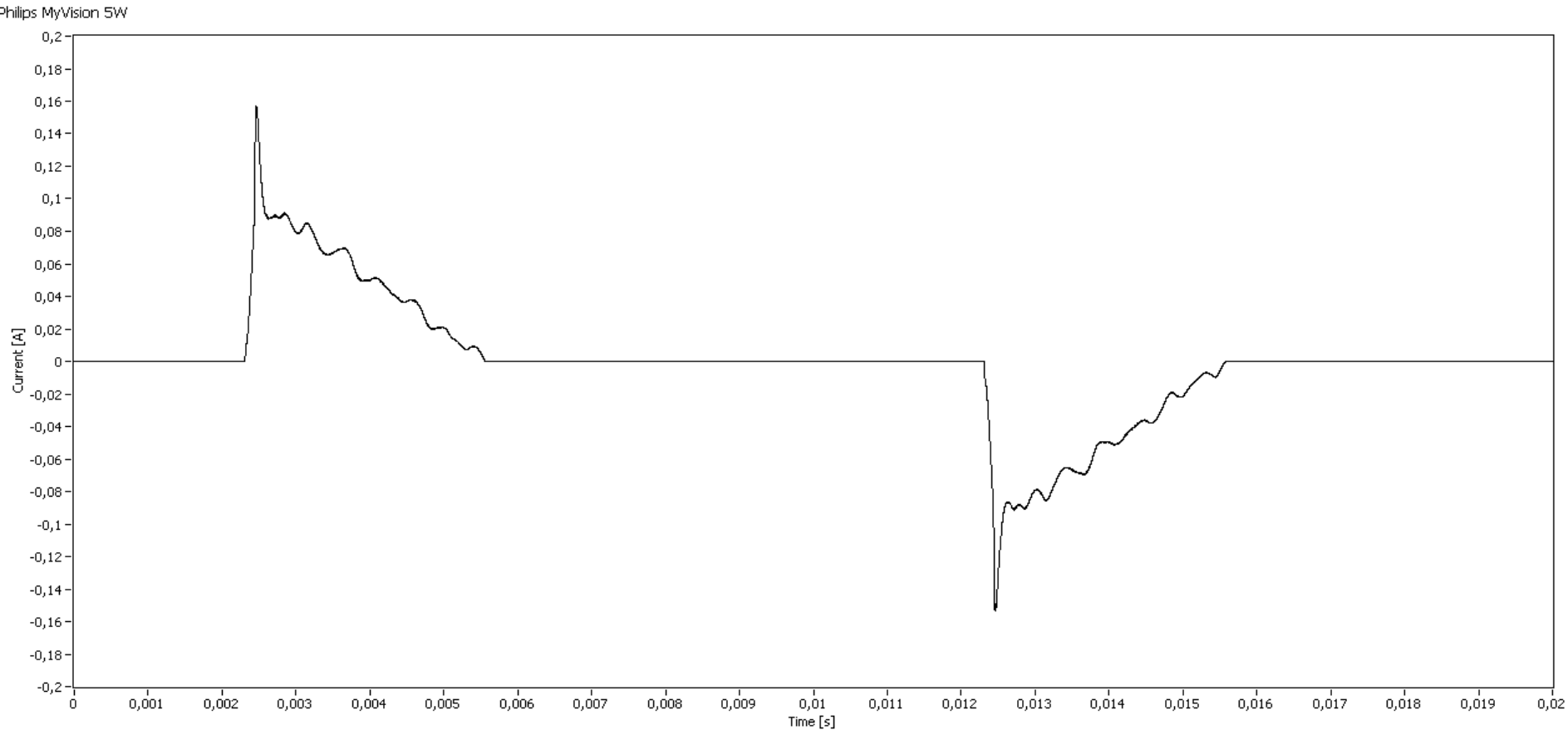
Philips Econic 6W with dimmer



## Current waveform, Osram, 12 W

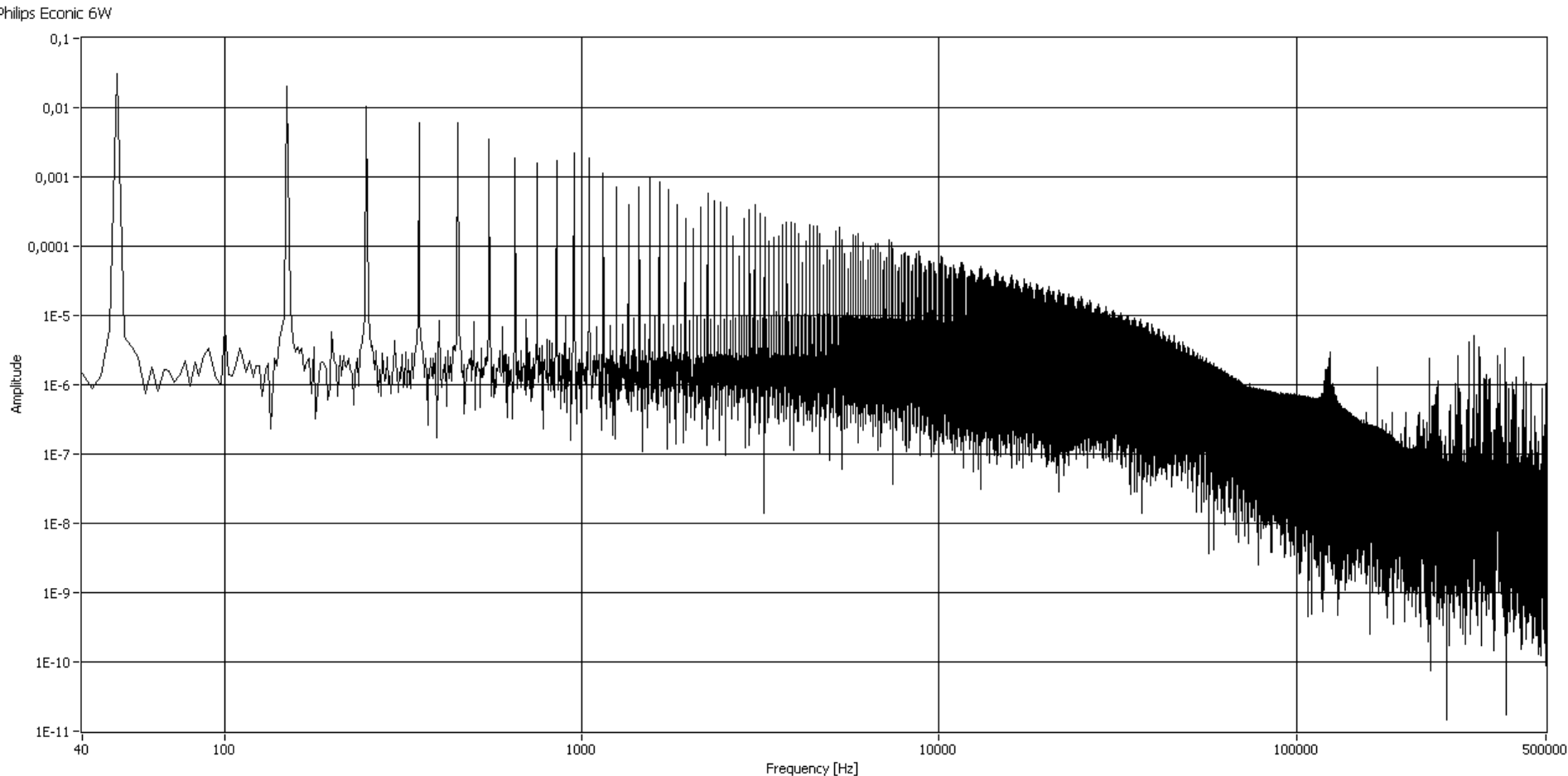


## Current waveform, Philips MyVision, 5 W

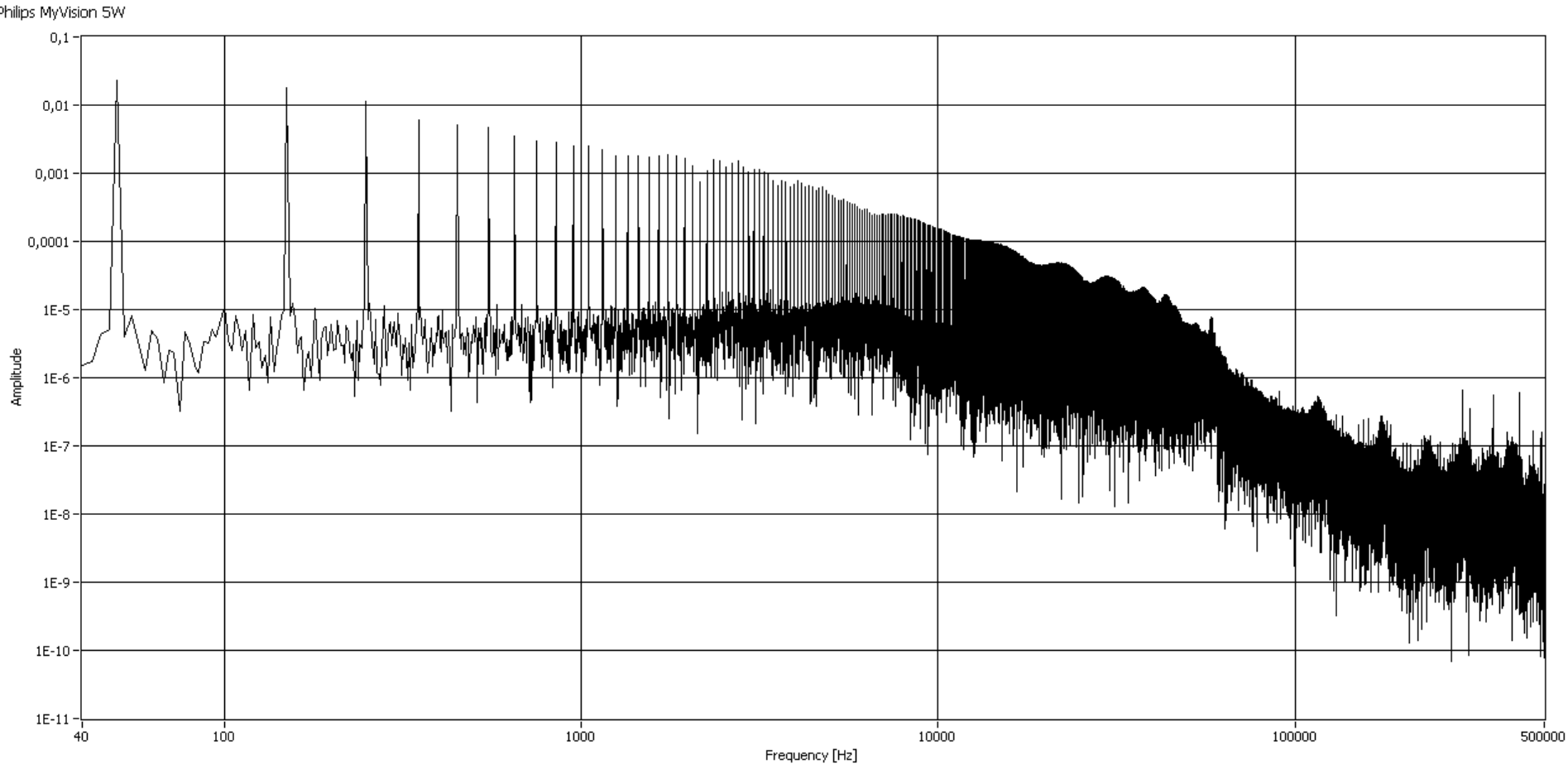


# SSL Power

## Frequency spectrum (500 kHz), Philips Econic, 6 W



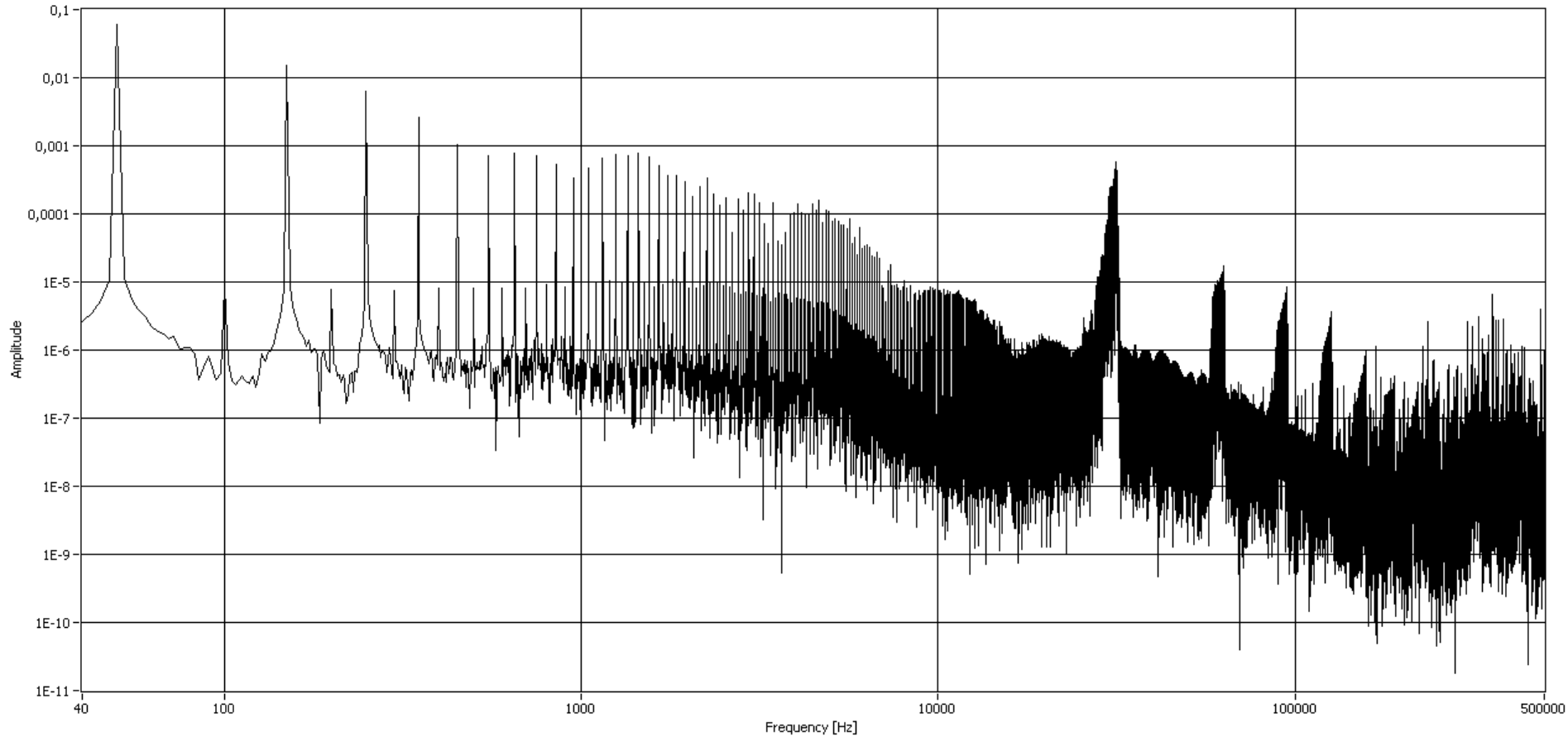
## Frequency spectrum (500 kHz), Philips MyVision, 5 W



# SSL Power

## Frequency spectrum (500 kHz), Osram, 12 W

OSRAM LED 12W





## Frequency spectrum (500 kHz), Philips Econic, 5 W

