



2010 Council for Optical Radiation Measurements Annual Meeting
Las Vegas, Nevada, May 9-11, 2010

Results, Findings, and Oddities from the Solid State Lighting Proficiency Testing for the NVLAP Energy Efficient Lighting Program

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Proficiency Testing – HB150-1 (2010 Draft)

- **3.4.2** Laboratories applying for initial accreditation for solid-state test methods shall participate satisfactorily in a bilateral proficiency testing with NIST before accreditation will be granted.
- **3.4.5** Laboratories renewing accreditation shall have satisfactorily participated in all required proficiency testing during their previous accreditation period.

Bilateral Test Items

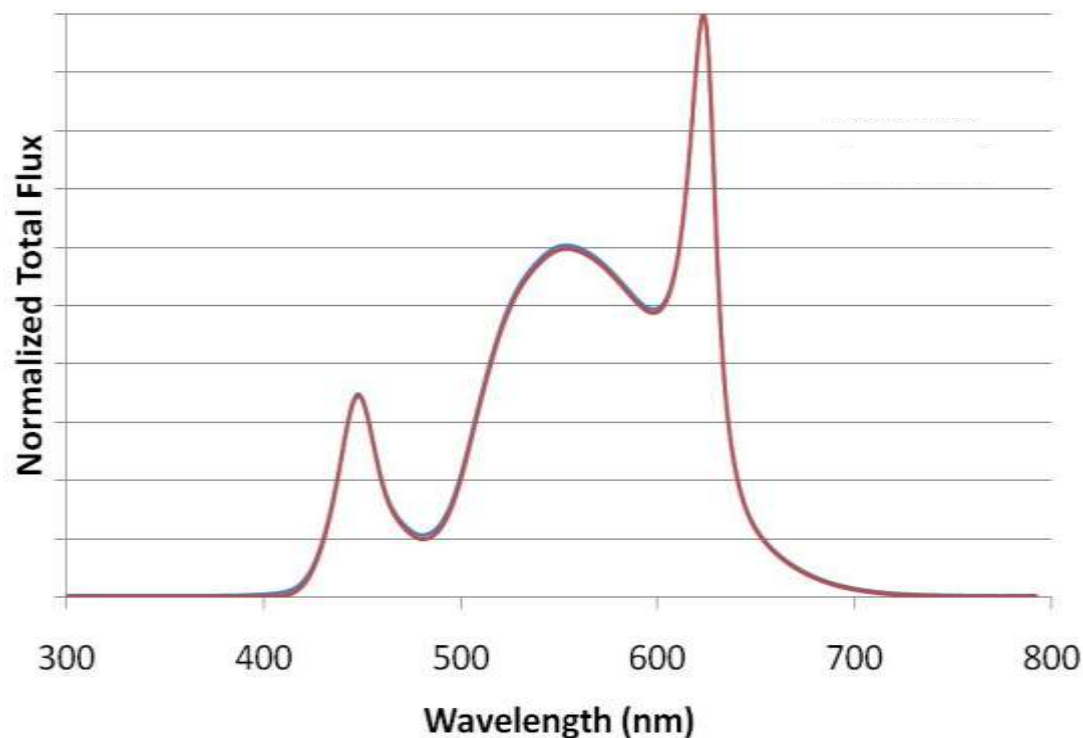
- Six items
 - Incandescent lamp (120 V AC)
 - Under cabinet SSL luminaire
 - (12 V DC, DC current controlled)
 - Four different white SSL luminaires (120 V AC)



Incandescent lamp and SSL-1

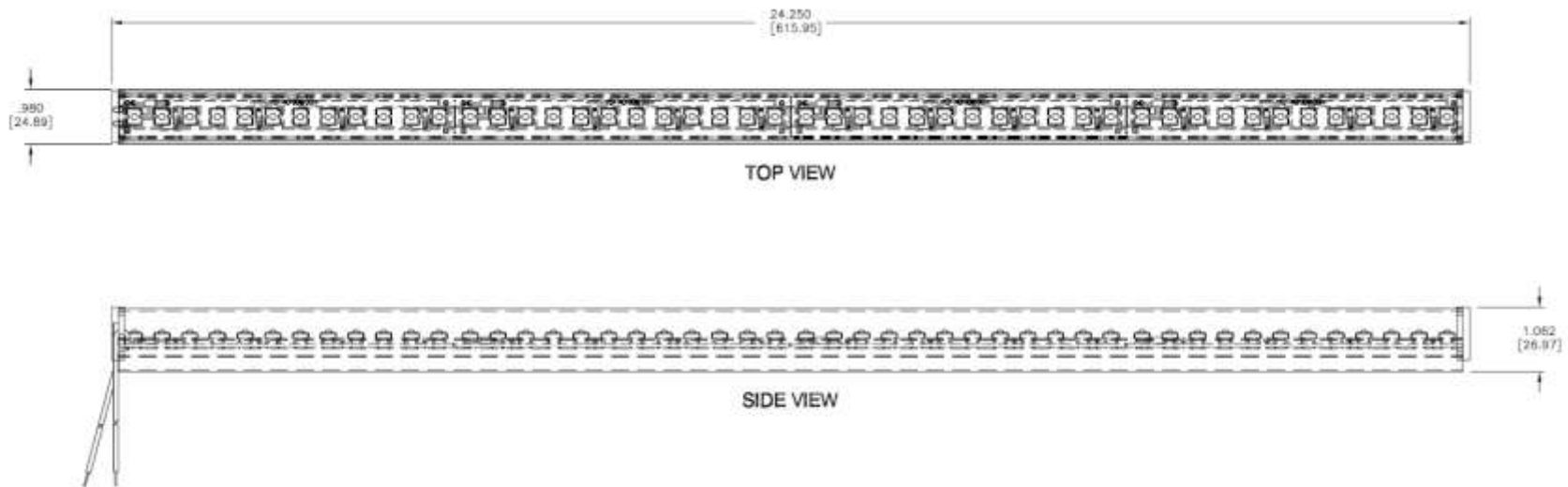
Primary purpose

- Check lumen scale
- Check stabilization time



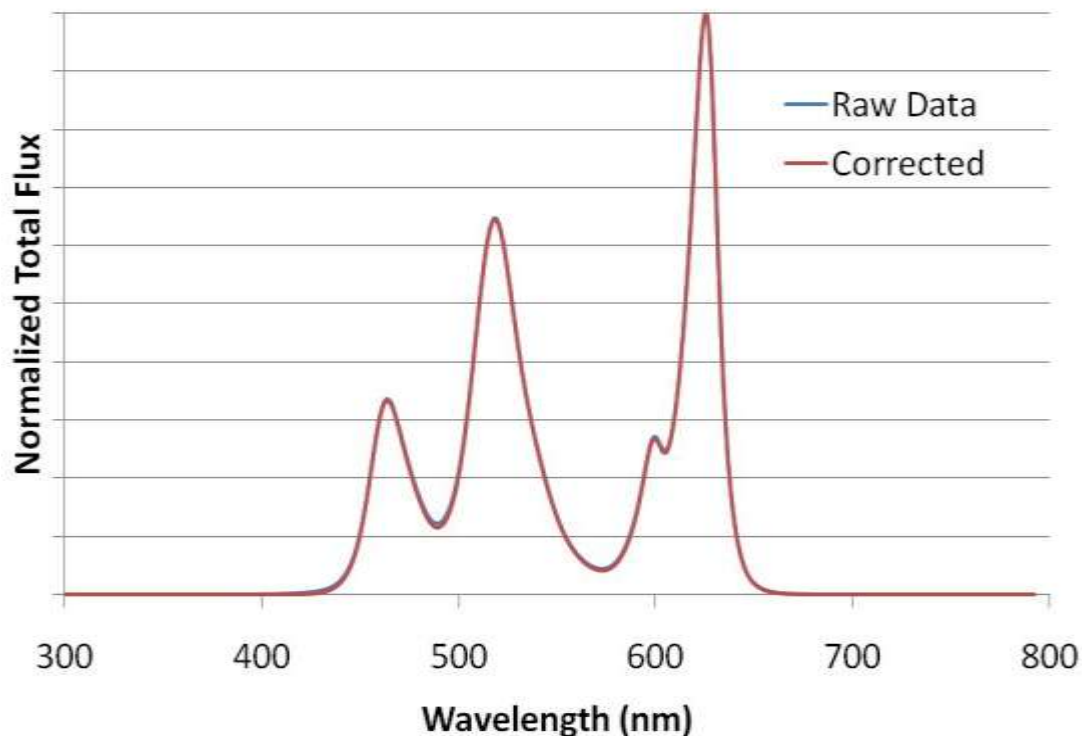
Under Cabinet SSL Luminaire

- Older technology
- Ambient temperature insensitive
- DC current controlled
- Spatial distribution is different
- Very high CCT

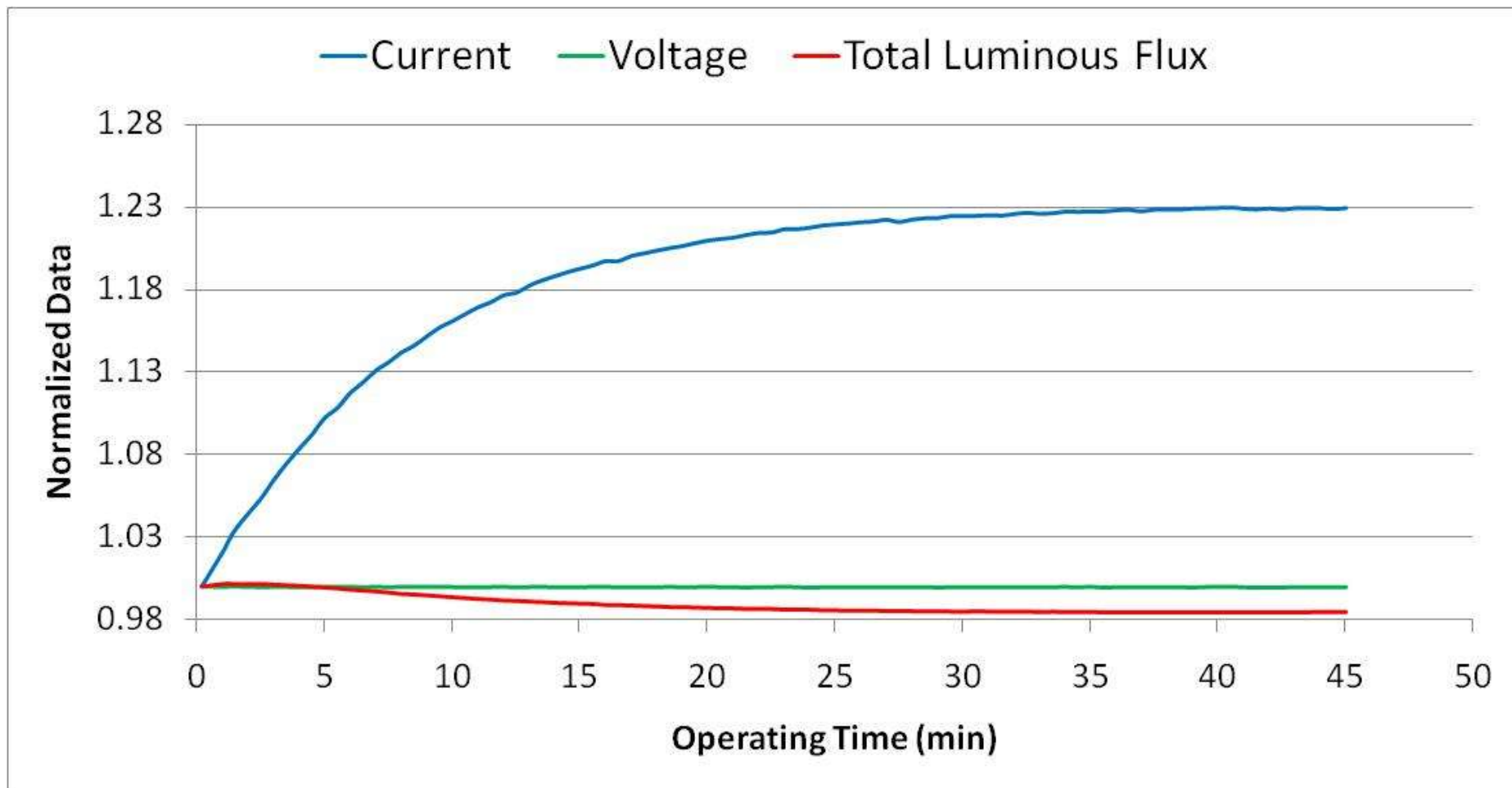


SSL-2, SSL-3, and SSL-4

- Various whites and spatial properties



Stabilization Time



NIST Characterization

| | Incandescent | SSL-1 | SSL-2 | SSL-3 | SSL-4 | Under Cabinet |
|----------|--------------|--------|--------|--------|--------|---------------|
| Voltage | 0.01 % | 0.00 % | 0.02 % | 0.01 % | 0.03 % | 0.00 % |
| Current | 0.01 % | 0.01 % | 0.19 % | 0.13 % | 0.14 % | 0.00 % |
| Power | 0.02 % | 0.00 % | 0.16 % | 0.05 % | 0.20 % | 0.00 % |
| Flux | 0.08 % | 0.02 % | 0.18 % | 0.05 % | 0.12 % | 0.21 % |
| Efficacy | 0.06 % | 0.02 % | 0.16 % | 0.10 % | 0.11 % | 0.21 % |
| CCT | 2 K | 1 K | 5 K | 3 K | 7 K | 7 K |
| CRI | 0.02 | 0.01 | 0.02 | 0.04 | 0.20 | 0.05 |

Total Flux Comparison

| | Lab 1 | Lab 2 | Lab 3 | Lab 4 | Lab 5 |
|---------------|-------|-------|-------|-------|-------|
| SSL 1 | 0.9% | 0.8% | -1.7% | -1.2% | -2.8% |
| SSL 2 | 10.5% | 36.9% | 7.1% | 12.7% | 9.1% |
| SSL 3 | 0.5% | 0.1% | -0.9% | -0.6% | 0.2% |
| SSL 4 | 9.6% | 28.1% | 5.8% | 10.9% | 6.2% |
| Under Cabinet | 0.5% | -0.3% | -5.4% | -0.8% | -2.3% |
| Incandescent | -0.6% | -1.5% | | 0.0% | -0.1% |

Luminous Efficacy

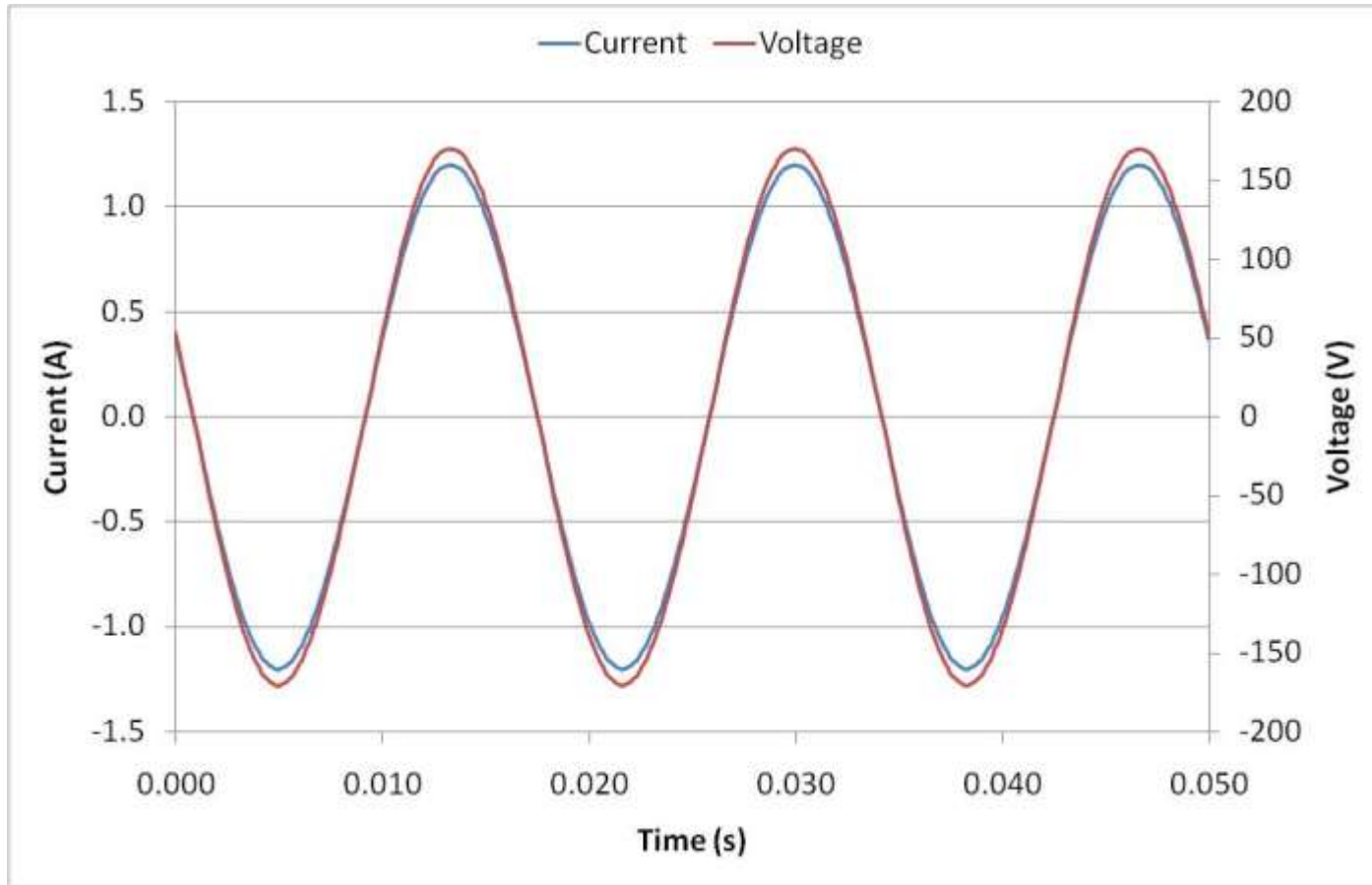
| | Lab 1 | Lab 2 | Lab 3 | Lab 4 | Lab 5 |
|---------------|-------|--------|--------|-------|-------|
| SSL 1 | 1.9% | 0.5% | 0.0% | 0.4% | -1.6% |
| SSL 2 | -3.5% | -17.1% | -5.6% | -2.7% | -7.6% |
| SSL 3 | 0.5% | 0.3% | -0.4% | 0.2% | 0.8% |
| SSL 4 | -3.2% | -20.0% | -16.4% | -4.2% | -7.9% |
| Under Cabinet | 0.9% | 0.4% | -4.3% | -0.8% | -2.3% |
| Incandescent | -0.9% | -1.9% | | -0.1% | -0.5% |

Power

| | Lab 1 | Lab 2 | Lab 3 | Lab 4 | Lab 5 |
|---------------|-------|-------|-------|-------|-------|
| SSL 1 | 0.5% | 0.4% | -1.7% | -1.6% | -1.2% |
| SSL 2 | 13.5% | 47.0% | 12.0% | 15.0% | 15.5% |
| SSL 3 | 0.0% | -0.2% | -0.5% | -0.8% | -0.6% |
| SSL 4 | 12.4% | 40.1% | 19.0% | 14.5% | 13.1% |
| Under Cabinet | 0.2% | 0.4% | -1.0% | 0.1% | 0.3% |
| Incandescent | 0.0% | -0.7% | | 0.1% | 0.1% |

Oscilloscope Measurements

Incandescent lamp – AC power supply



Power Meter
120.0 V rms
0.845 A rms
101.8 W true

Oscilloscope
120.0 V rms
0.845 A rms
101.4 W true

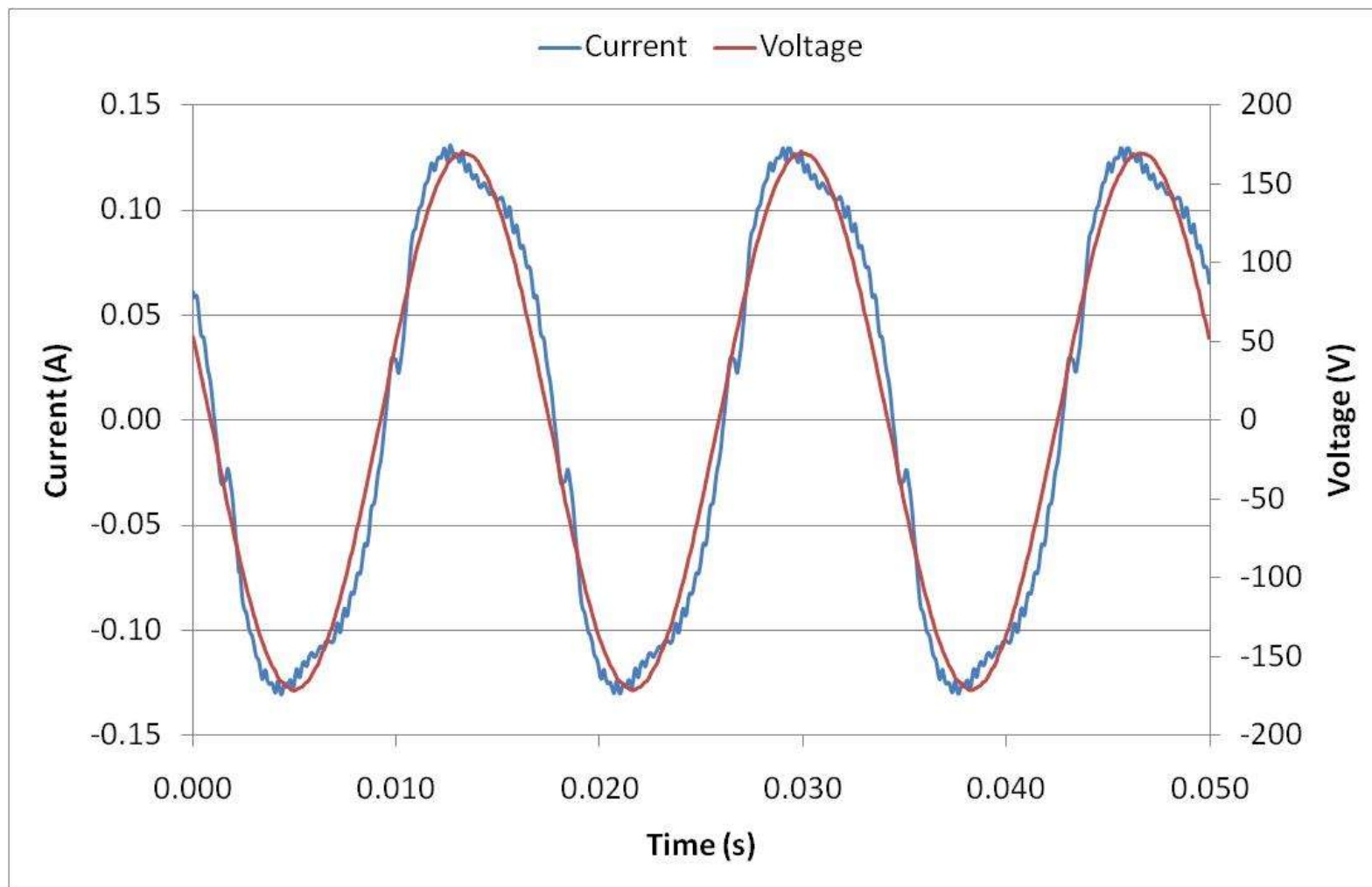
Crest Factor
1.417

Sine wave
1.414

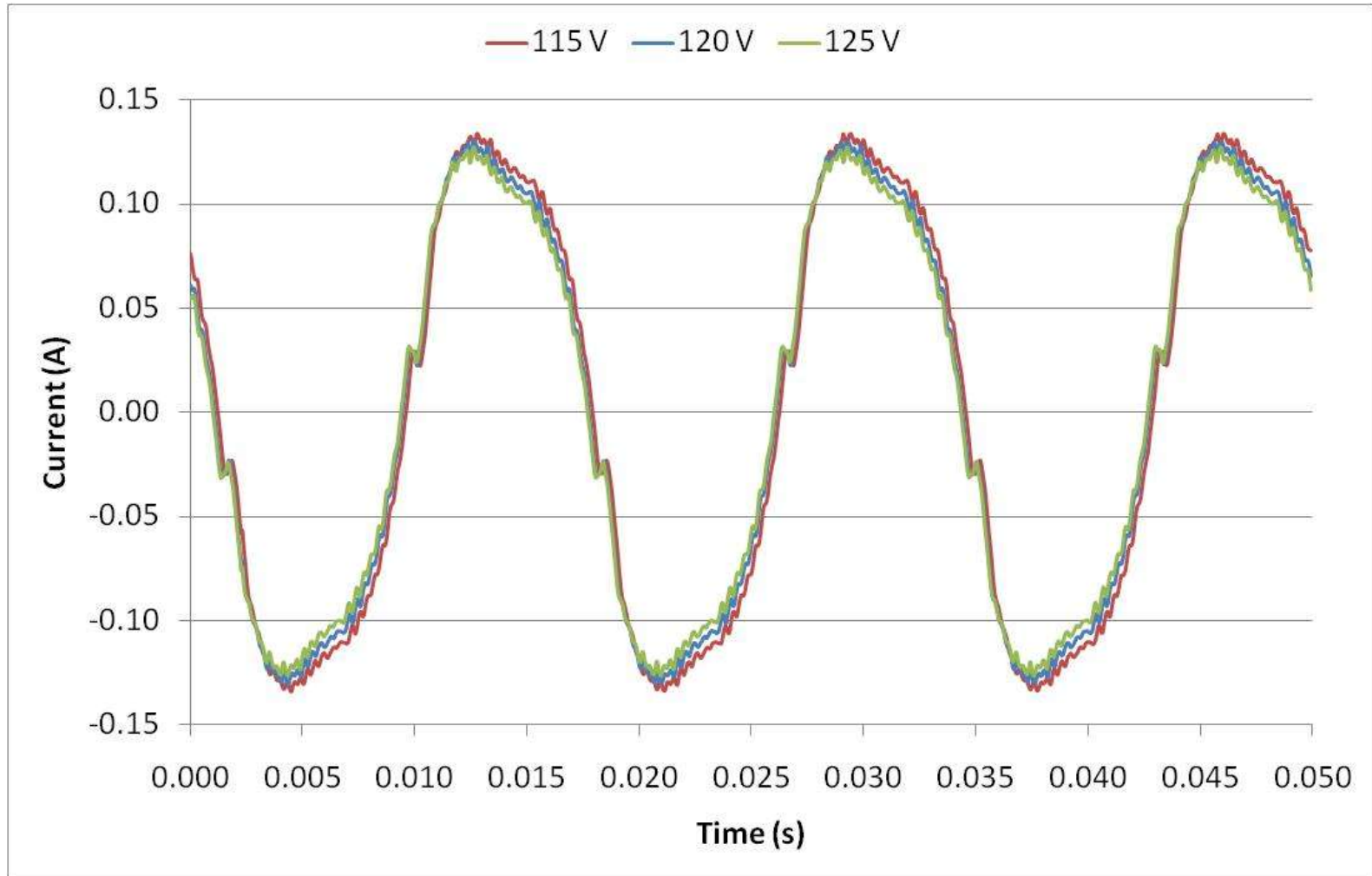
rms - root mean square

true – integration of $V \cdot A$

SSL-1 Measurements



SSL-1 Voltage Dependence

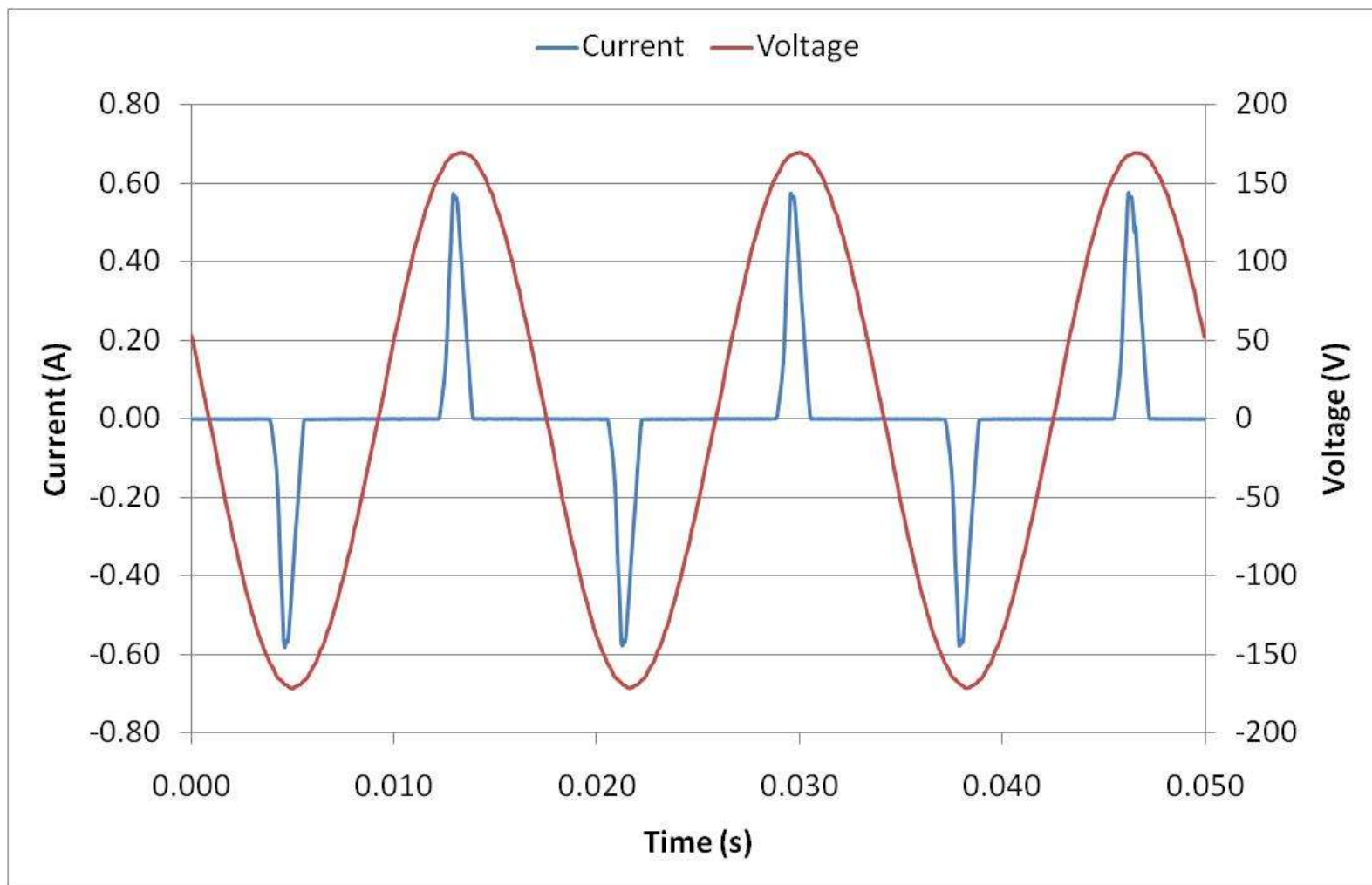


SSL-1 Electrical Time Dependence

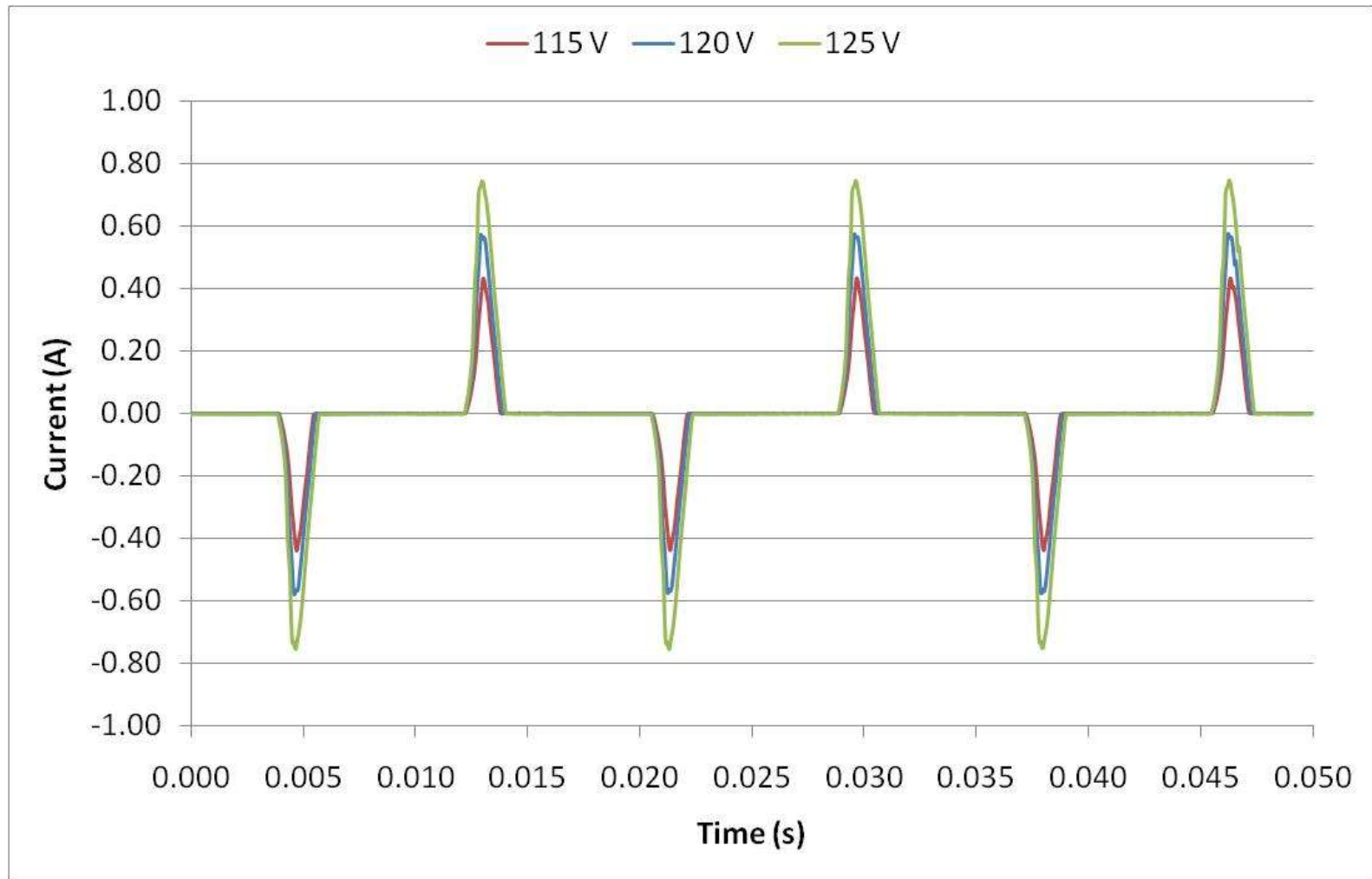
| Time | AC [Ω] | Real [Ω] | Imag. [Ω] | PF | THD i | THD v | Voltage | Current | Wattage |
|------|-----------|-------------|--------------|-------|-------|-------|---------|---------|---------|
| 0 | 1370 | 1320 | -378 | 0.961 | 12.0 | 0.08 | 120 | 0.0872 | 10.05 |
| 13 | 1340 | 1290 | -366 | 0.962 | 13.8 | 0.08 | 120 | 0.0895 | 10.33 |
| 25 | 1330 | 1280 | -363 | 0.962 | 14.2 | 0.09 | 120 | 0.0903 | 10.43 |
| 40 | 1325 | 1270 | -362 | 0.962 | 14.6 | 0.09 | 120 | 0.0906 | 10.47 |
| 55 | 1322 | 1270 | -361 | 0.962 | 14.8 | 0.09 | 120 | 0.0908 | 10.48 |
| 75 | 1320 | 1270 | -361 | 0.962 | 14.8 | 0.09 | 120 | 0.0909 | 10.50 |

| | AC [Ω] | Real [Ω] | Imag. [Ω] | PF | THD i | THD v | Voltage | Current | Wattage |
|--------|-----------|-------------|--------------|-------|-------|-------|---------|---------|---------|
| 1 ohm | 1320 | 1270 | -361 | 0.962 | 14.8 | 0.09 | 120 | 0.0909 | 10.50 |
| 10 ohm | 1320 | 1270 | -361 | 0.962 | 14.8 | 0.16 | 120 | 0.0909 | 10.50 |

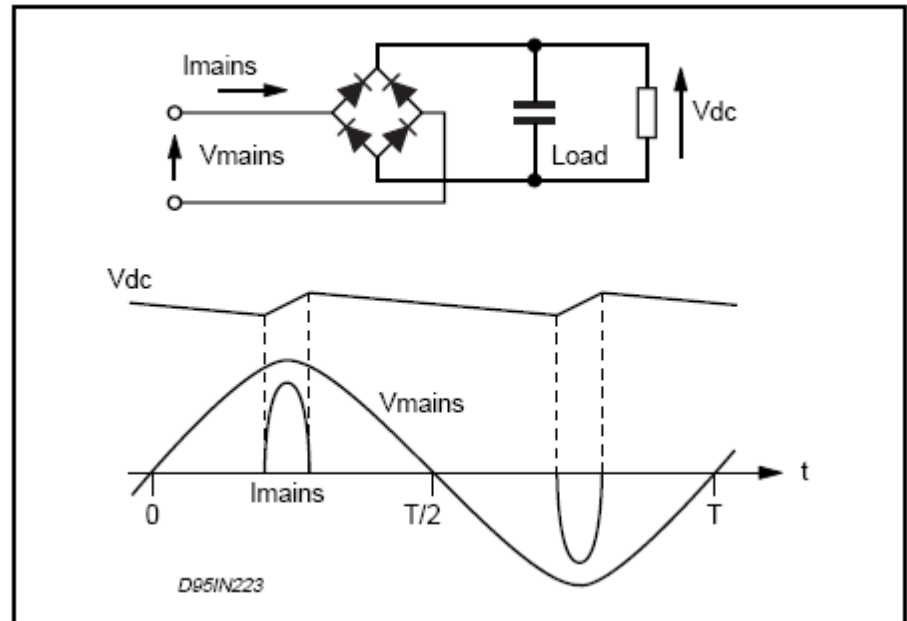
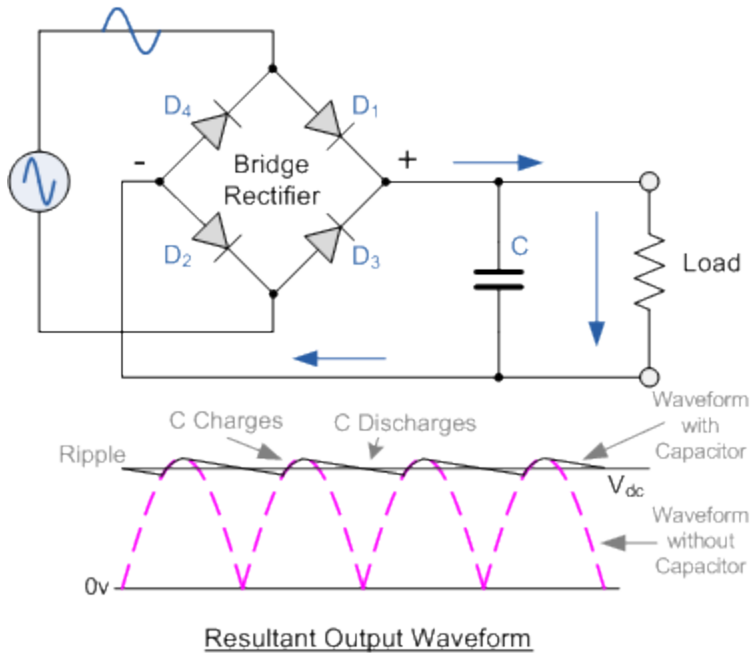
SSL-2 Oscilloscope Measurements



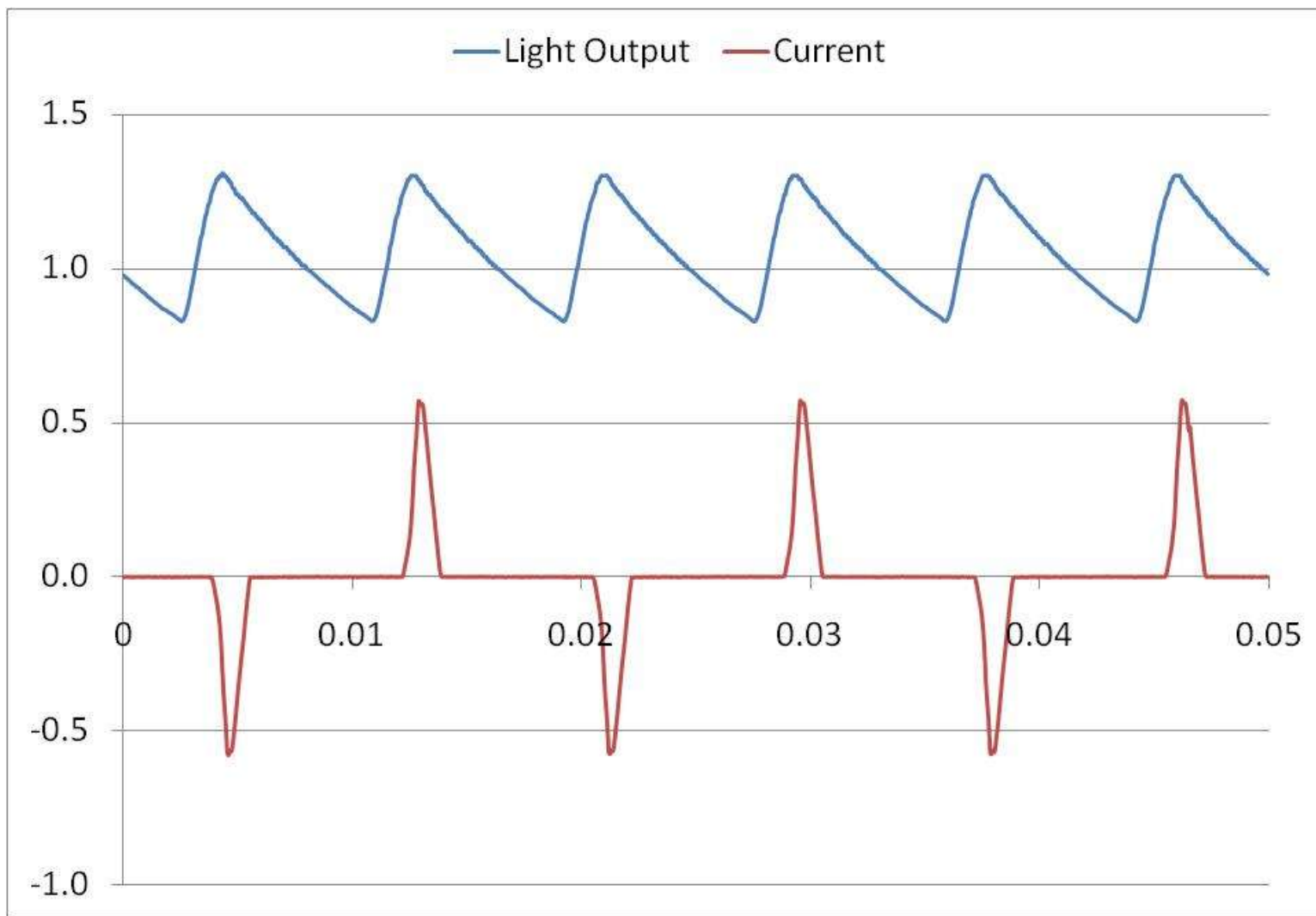
SSL-2 Voltage Dependence



Literature Search



SSL-2 Light Output



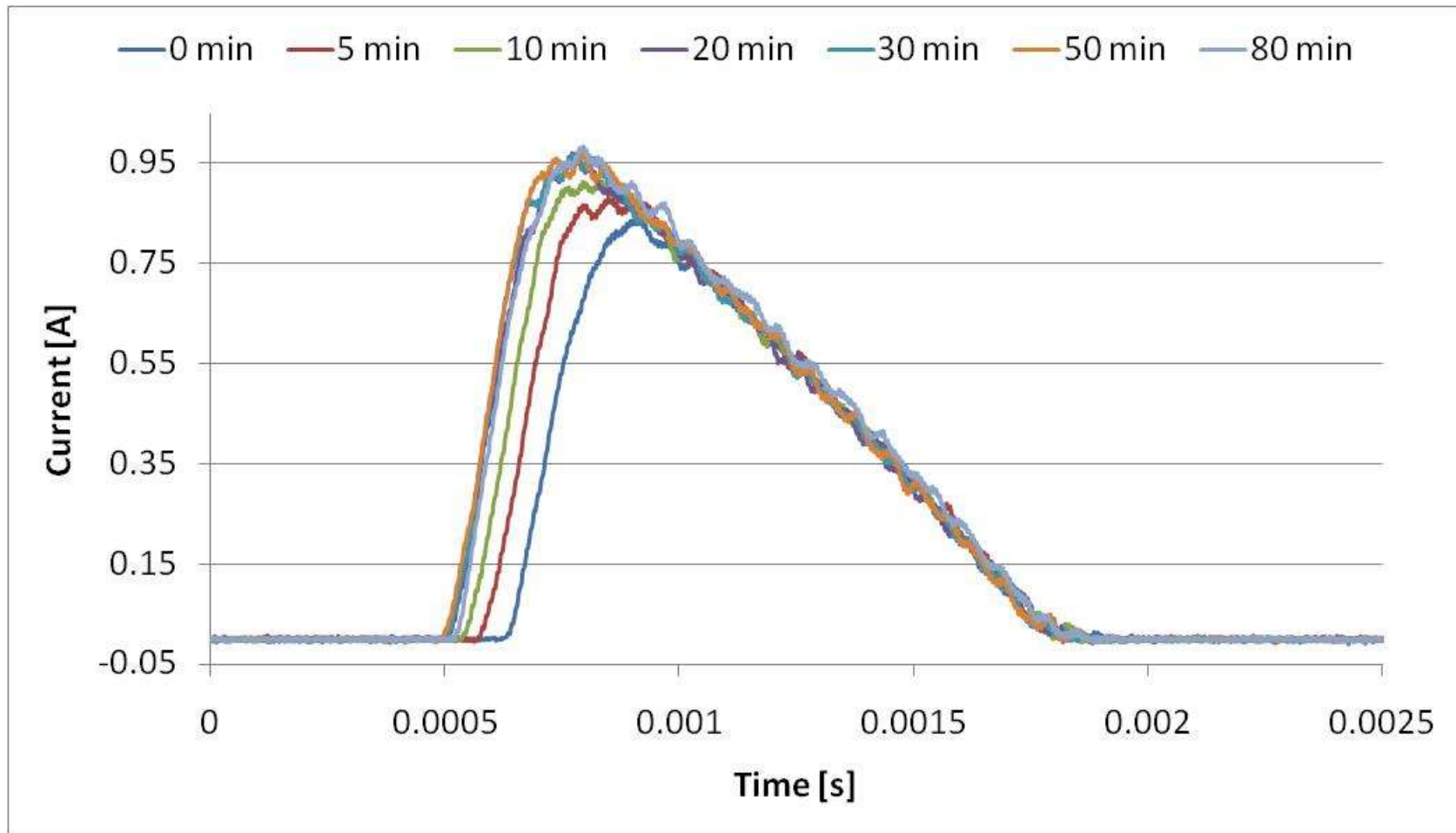
Time constant

Integration time

SSL-2 Electrical Time Dependence

| Time | AC [Ω] | Real [Ω] | Imag. [Ω] | PF | THD i | THD v | Voltage | Current | Wattage | Efficacy |
|------|--------------------|----------------------|-----------------------|-------|-------|-------|---------|---------|---------|----------|
| 0 | 600 | 273 | -536 | 0.456 | 190 | 0.30 | 120 | 0.198 | 10.86 | 30.5 |
| 5 | 556 | 258 | -493 | 0.463 | 185 | 0.32 | 120 | 0.214 | 11.93 | 28.4 |
| 10 | 527 | 247 | -465 | 0.468 | 183 | 0.38 | 120 | 0.226 | 12.76 | 26.8 |
| 20 | 510 | 240 | -452 | 0.471 | 181 | 0.42 | 120 | 0.235 | 13.29 | 25.8 |
| 30 | 503 | 237 | -444 | 0.472 | 180 | 0.40 | 120 | 0.237 | 13.52 | 25.4 |
| 50 | 499 | 236 | -439 | 0.473 | 180 | 0.34 | 120 | 0.239 | 13.65 | 25.2 |
| 80 | 498 | 236 | -438 | 0.473 | 179 | 0.34 | 120 | 0.241 | 13.70 | 25.1 |

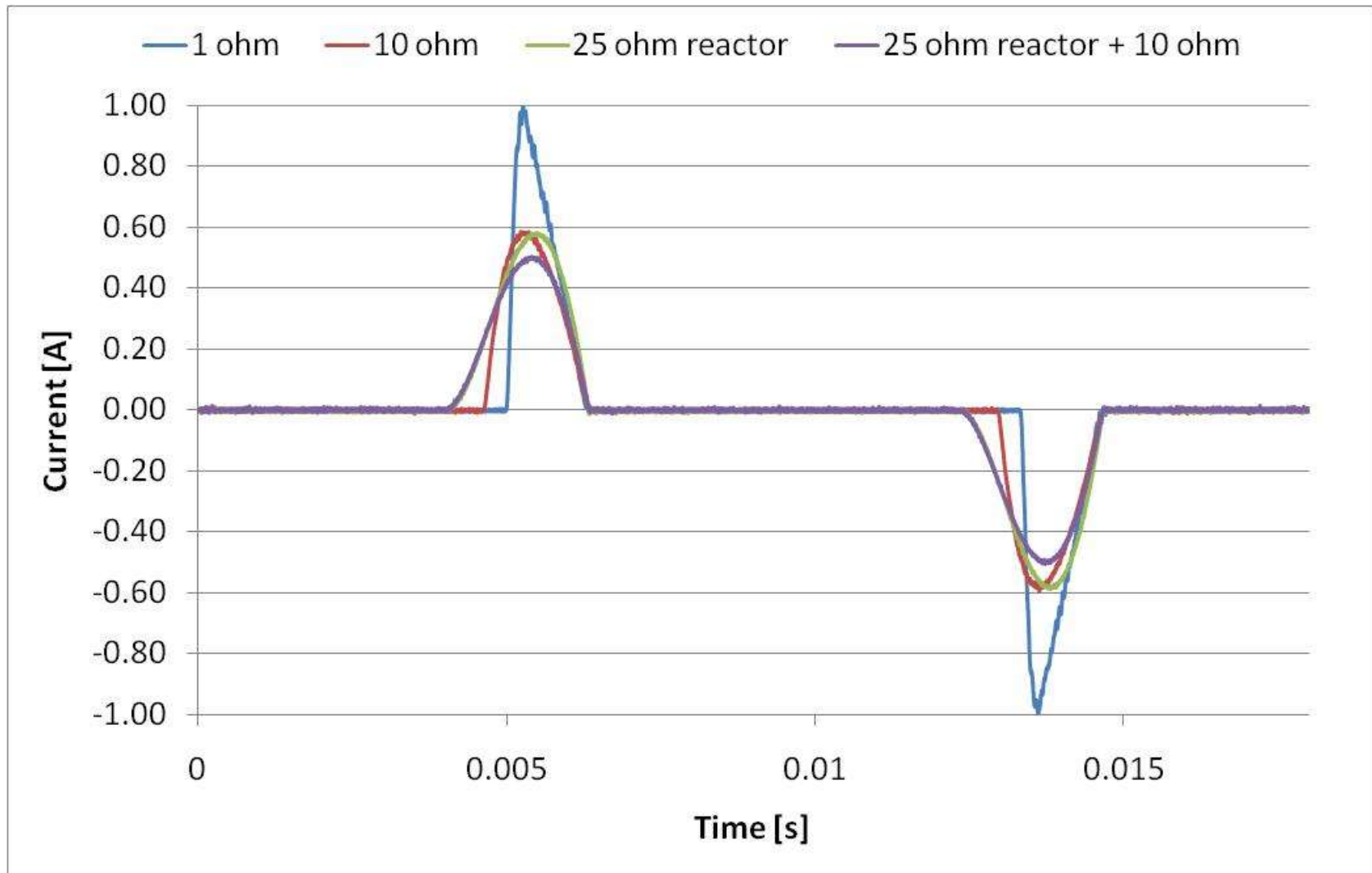
SSL-2 Current Waveshape



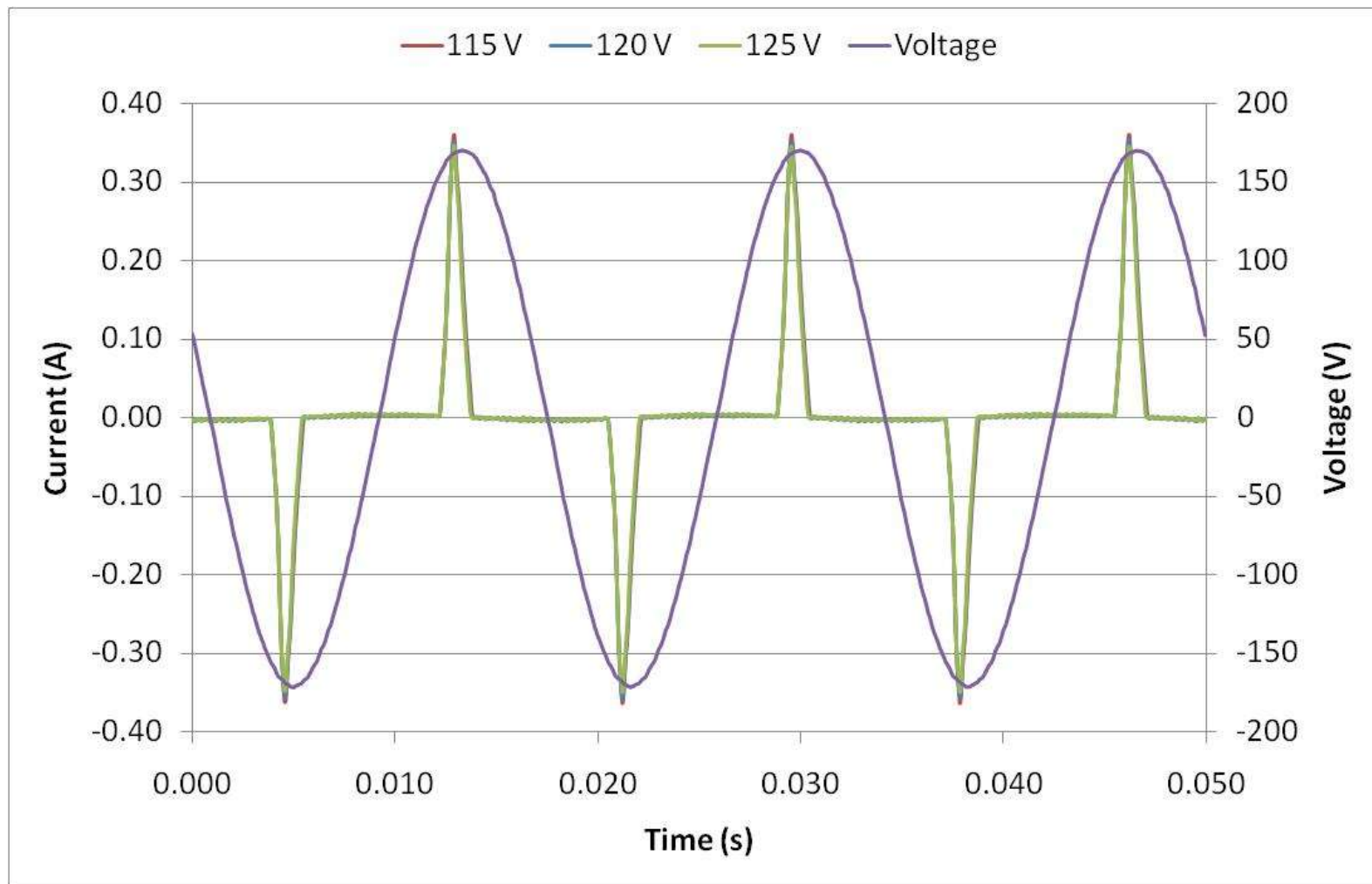
SSL-2 Supply Impedance Dependence

| | AC [Ω] | Real [Ω] | Imag. [Ω] | PF | THD i [%] | THD v [%] | Volt | Current | Wattage | Efficacy |
|---|--------------------|----------------------|-----------------------|-------|--------------|--------------|------|---------|---------|----------|
| No resistor | 477 | 218 | -424 | 0.458 | 186 | 0.18 | 120 | 0.252 | 13.86 | 25.0 |
| 1 Ω | 496 | 234 | -438 | 0.472 | 179 | 0.32 | 120 | 0.242 | 13.70 | 25.1 |
| 10 Ω | 641 | 355 | -534 | 0.554 | 144 | 1.5 | 120 | 0.187 | 12.45 | 26.1 |
| 25 Ω reactor | 594 | 369 | 465 | 0.621 | 124 | 3.9 | 120 | 0.202 | 15.00 | 24.1 |
| 25 Ω reactor + 10 Ω (27 Ω) | 678 | 423 | 530 | 0.623 | 121 | 3.6 | 120 | 0.177 | 13.30 | 25.4 |

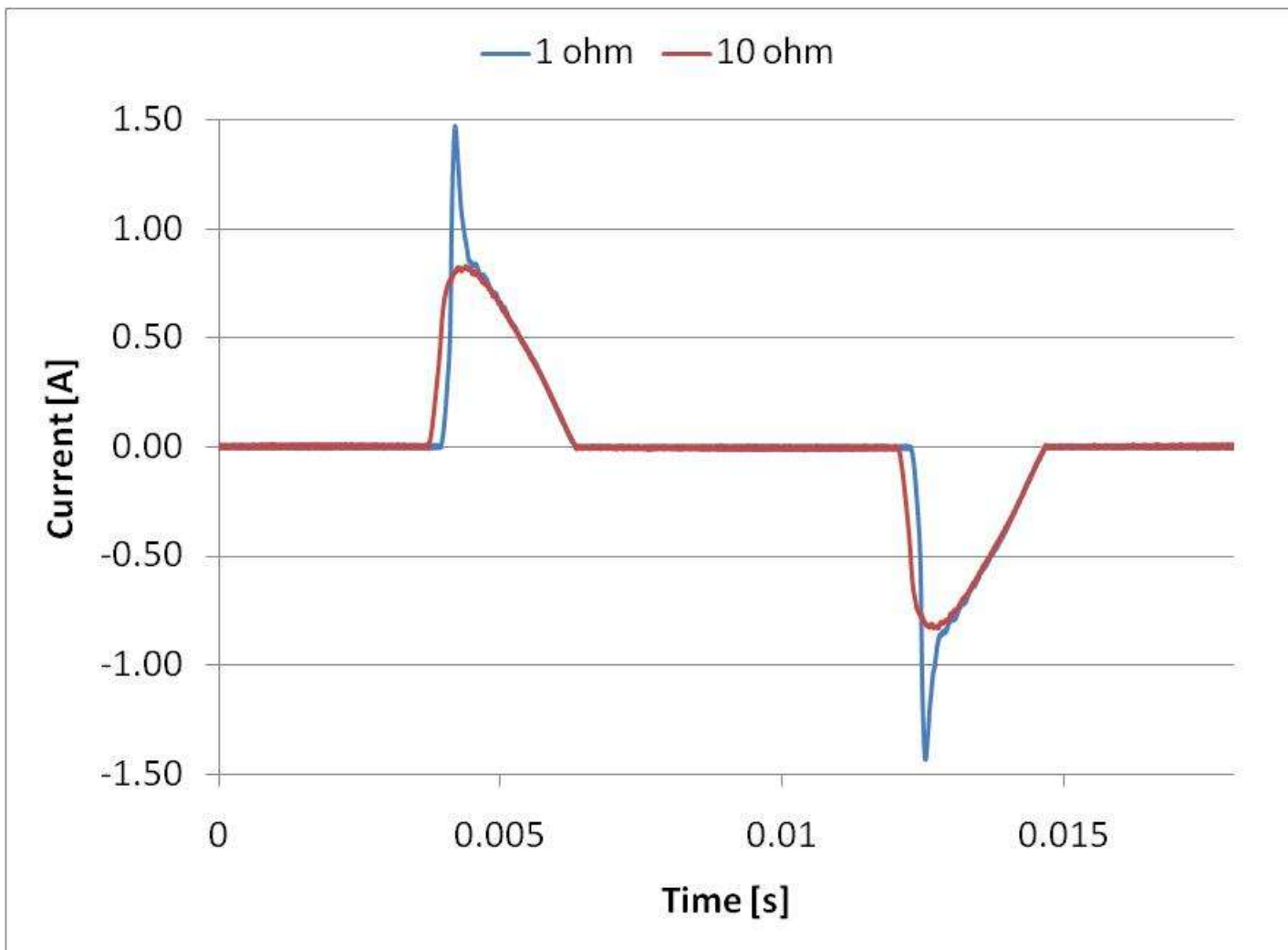
SSL-2 Impedance Waveshape Dependence



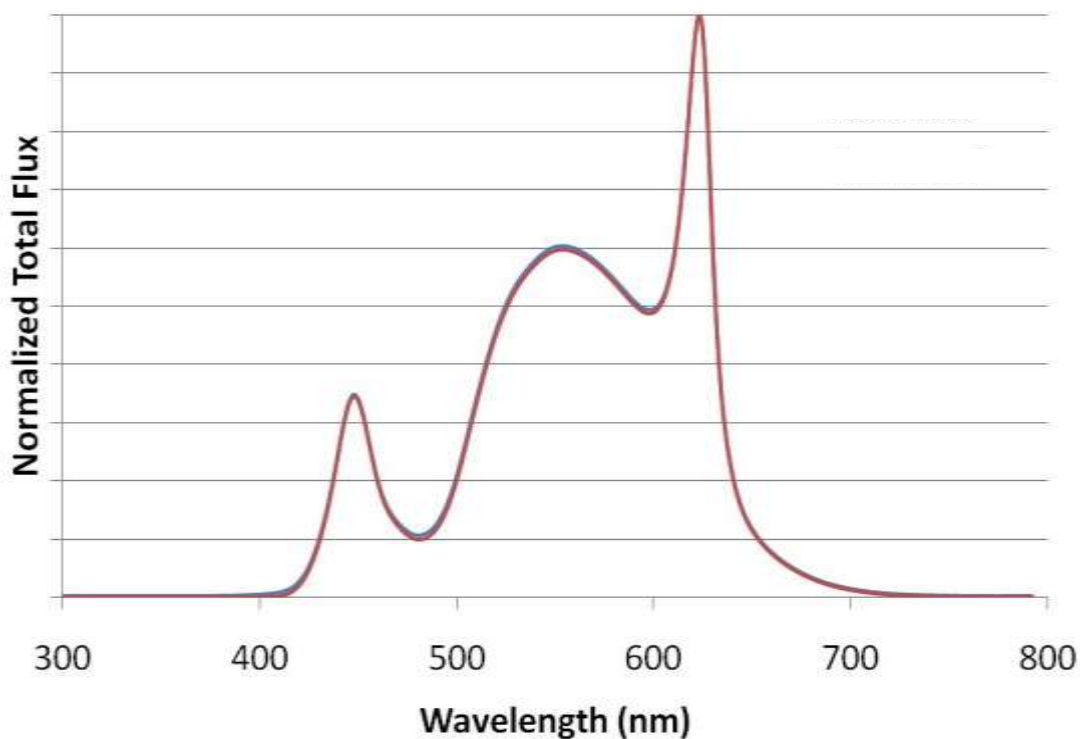
SSL-3 Voltage Dependence



Compact Fluorescent Lamp



Feedback Oddities



| | Voltage [volts] | Current [amps] | Power [watts] | Flux [lumens] | Efficacy [lpw] | Color [x] | Color [y] | CCT [K] | Color Rend [Ra] |
|---------|--------------------|-------------------|------------------|------------------|-------------------|-----------|-----------|---------|-----------------------|
| Aux on | 120 | 0.0974 | 11.33 | 680.6 | 60.06 | 0.4120 | 0.3924 | 3371 | 92.4 |
| Aux off | 120 | 0.0957 | 11.12 | 678.5 | 61.02 | 0.4058 | 0.3927 | 3505 | 90.8 |

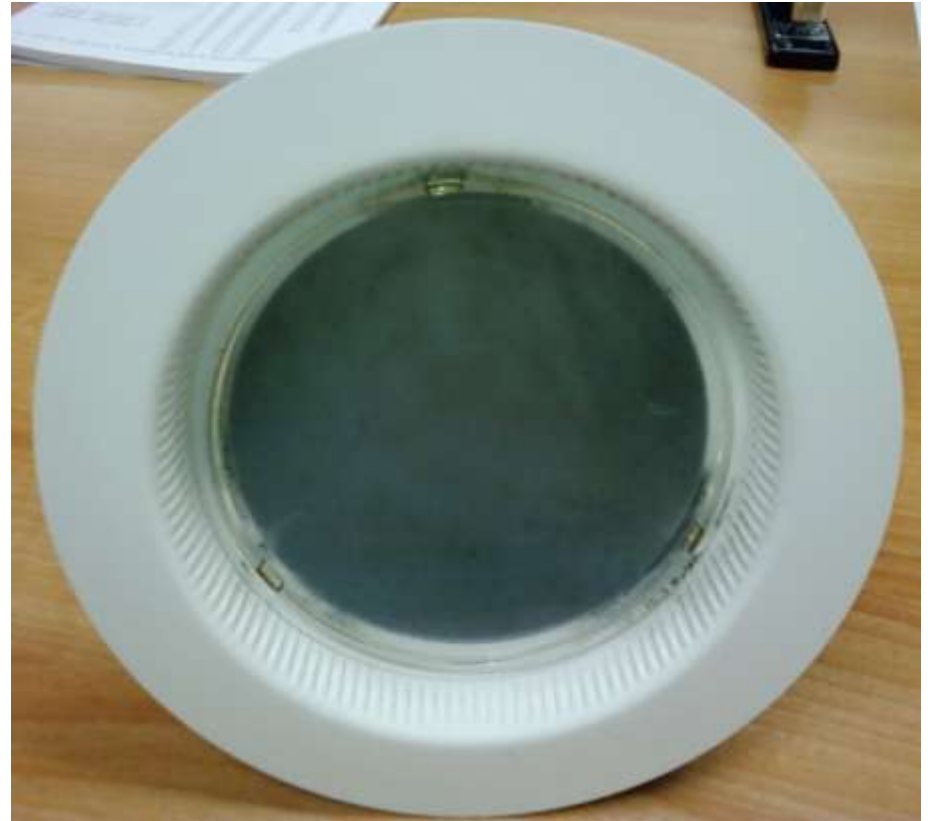
Inrush Oddities



17 A peak current draw

Zero phase power supply

More Oddities



Thank you for your time and questions