12.6.2 Output Load Regulation

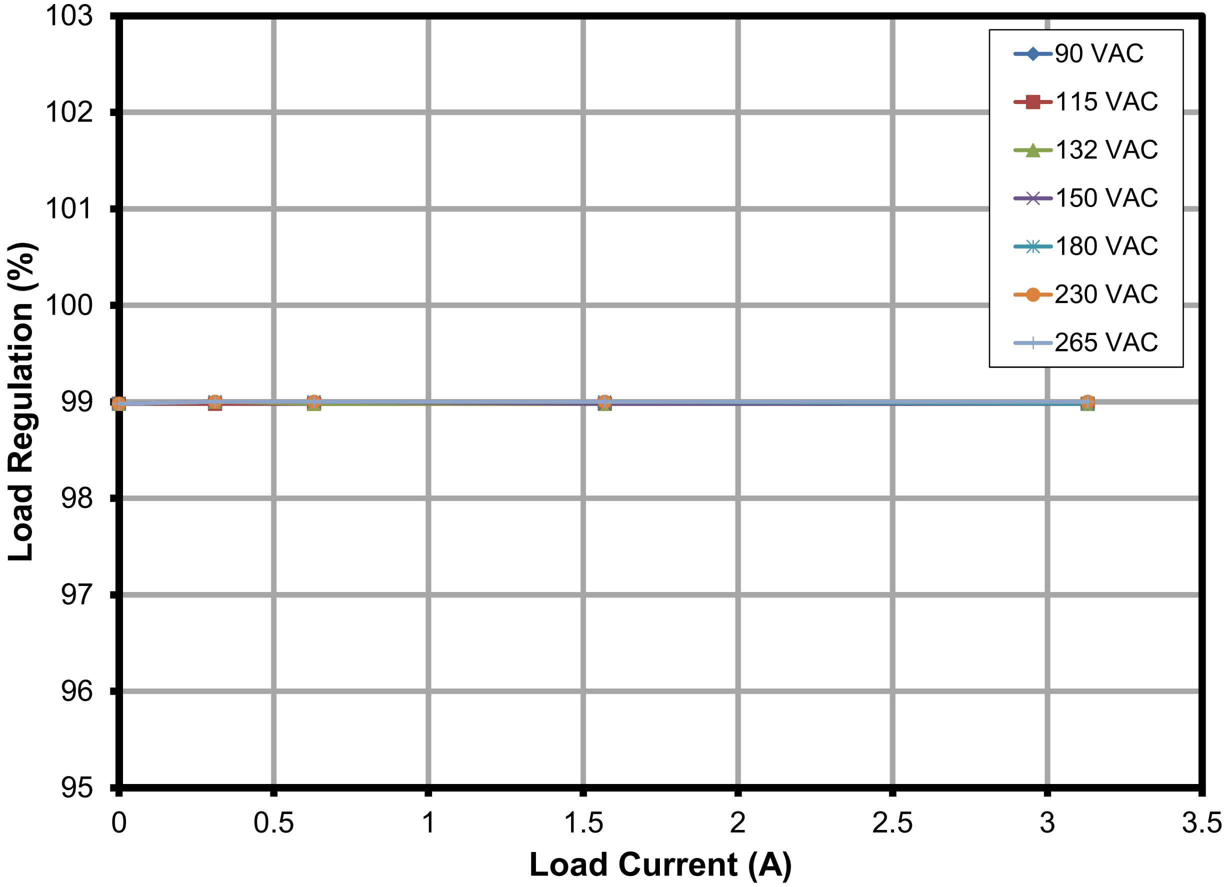

Figure 21 – Output Voltage vs. Output Load Current (Load Regulation).

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13 Input Current Harmonics vs. EN 61000-3-2 Class C Limits

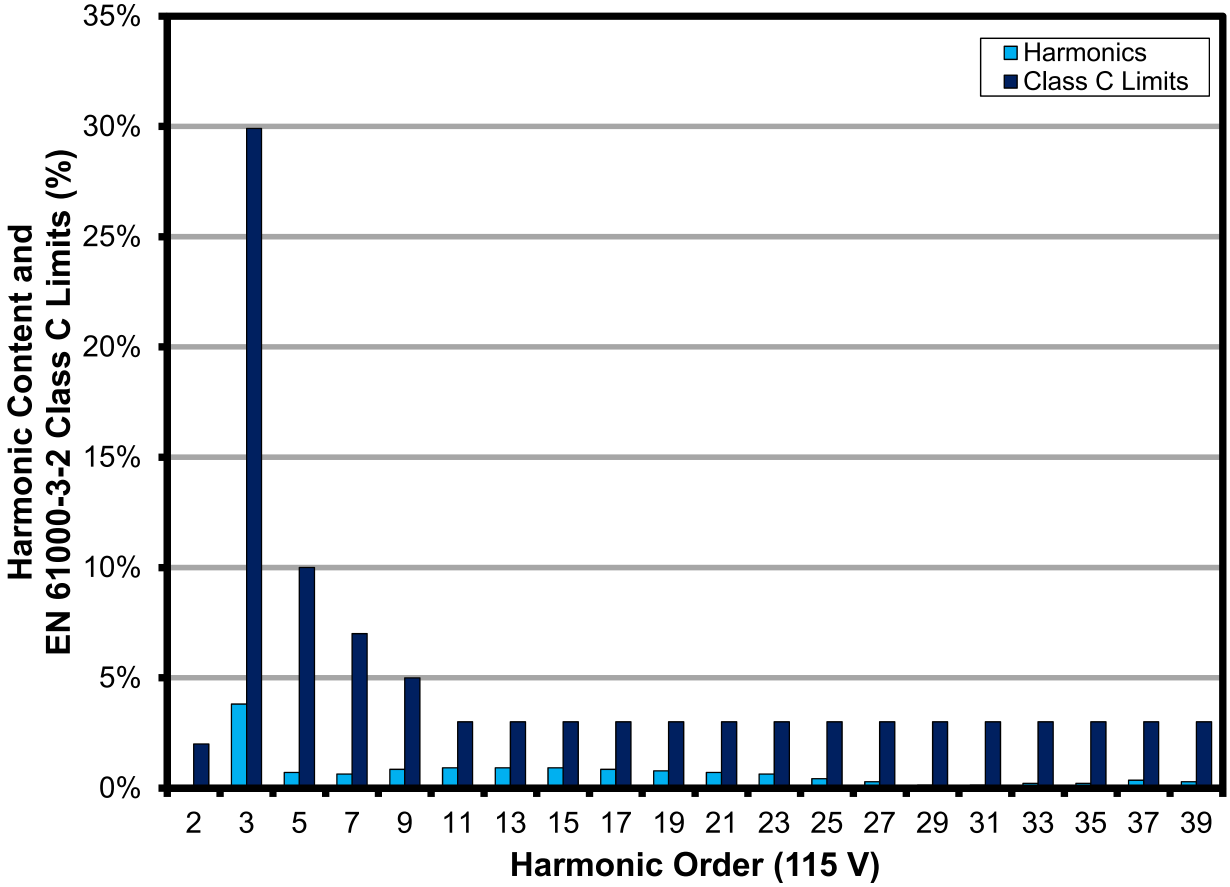

Figure 22 – AC Input Harmonics vs. EN 61000-3-2 Class C Limits, 115 VAC, 60 Hz, 100% Load.

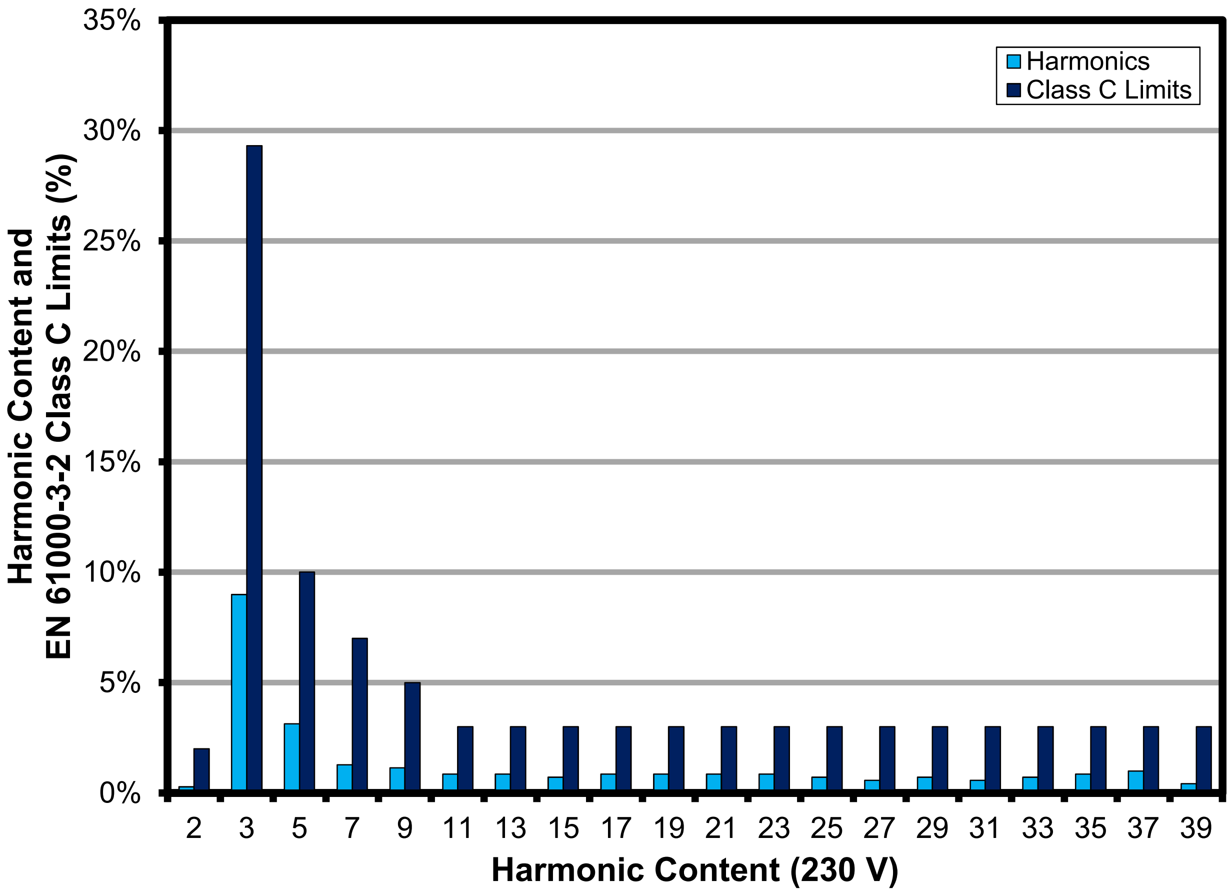

Figure 23 – AC Input Harmonics vs. EN 61000-3-2 Class C Limits, 230 VAC, 60 Hz, 100% Load.

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14 Waveforms

14.1 Input Voltage and Current

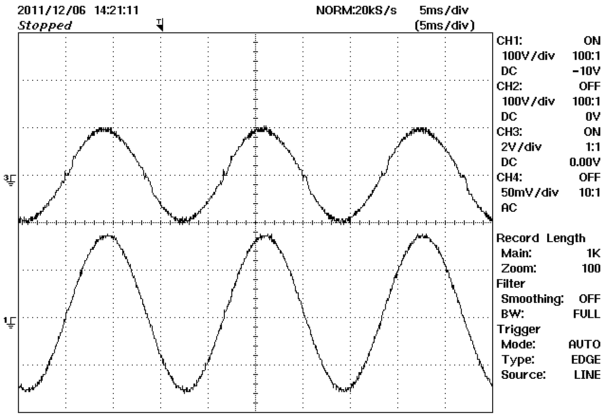

Figure 24 – 115 VAC, 150 W Load.
Upper: Input Current, 2 A / div.
Lower: Input Voltage, 100 V, 5 ms / div.

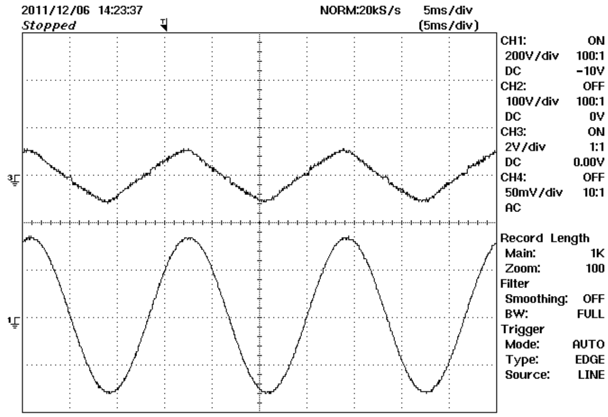

Figure 25 – 230 VAC, 150 W Load.
Upper: Input Current, 2 A / div.
Lower: Input Voltage, 200 V, 5 ms / div.

14.2 LLC Primary Voltage and Current

The LLC stage current was measured by adding a current sensing loop between C30 and B- that measures the LLC transformer (T3) primary current. The primary voltage waveform was measured at test point TP1.

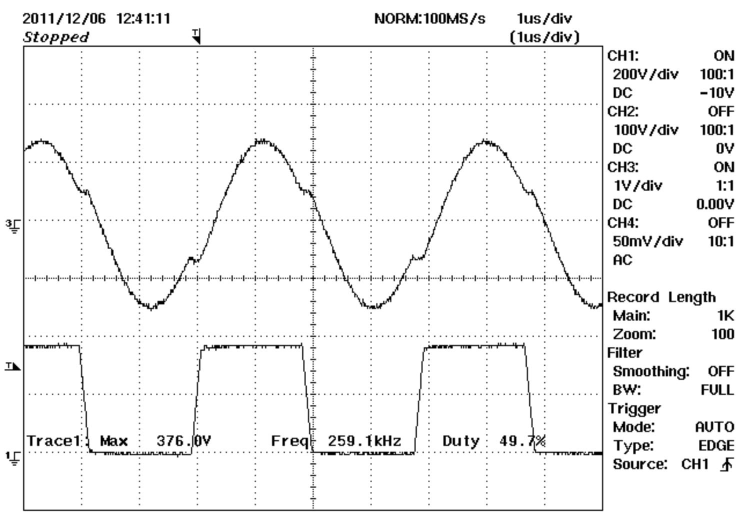

Figure 26 – LLC Stage Primary Voltage and Current.
Upper: Current, 1 A / div.
Lower: Voltage, 200 V, 1 μs / div.

14.3 PFC Switch Voltage and Current - Normal Operation

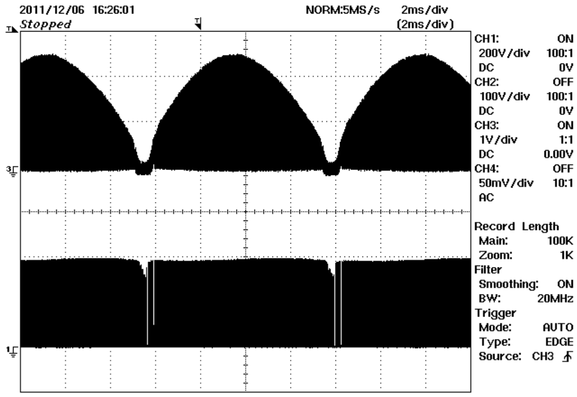

Figure 27 – PFC Stage Drain Voltage and Current, Full Load, 115 VAC
Upper: Drain Current, 1 A / div.
Lower: Drain Voltage, 200 V, 2 ms / div.

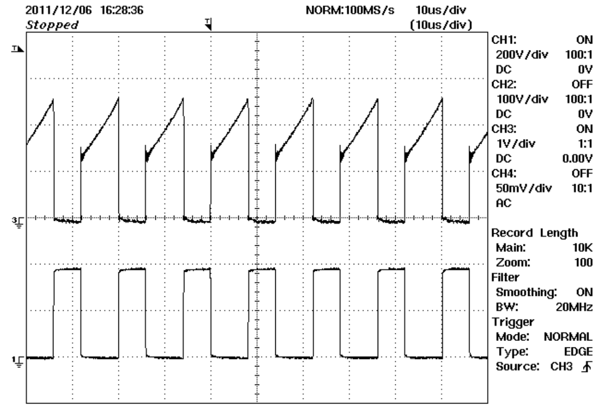

Figure 28 – PFC Stage Drain Voltage and Current, Full Load, 115 VAC.
Upper: Drain Current, 1 A / div.
Lower: Drain Voltage, 200 V, 10 μs / div.

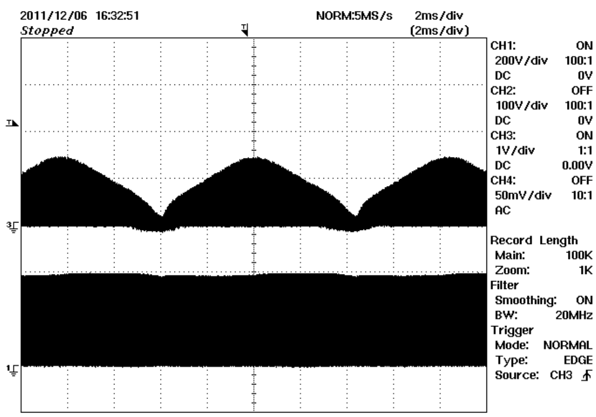

Figure 29 – PFC Stage Drain Voltage and Current, Full Load, 230 VAC.
Upper: Drain Current, 1 A / div.
Lower: Drain Voltage, 200 V, 2 ms / div.

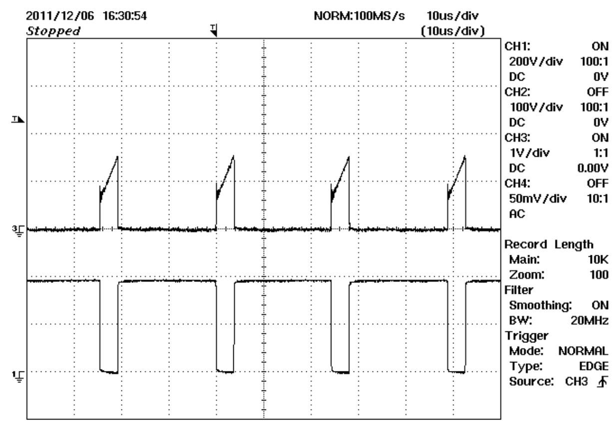

Figure 30 – PFC Stage Drain Voltage and Current, Full Load, 230 VAC.
Upper: Drain Current, 1 A / div.
Lower: Drain Voltage, 200 V, 10 μs / div.

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14.4 AC Input Current and PFC Output Voltage During Start-up

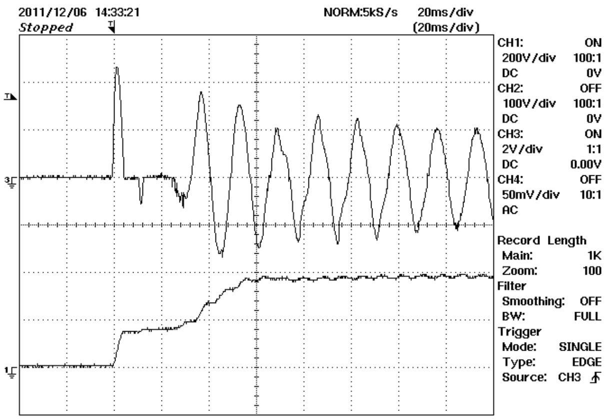

Figure 31 – AC Input Current vs. PFC Output Voltage at Start-up, Full Load, 115 VAC.
Upper: AC Input Current, 2 A / div.
Lower: PFC Voltage, 200 V, 20 ms / div

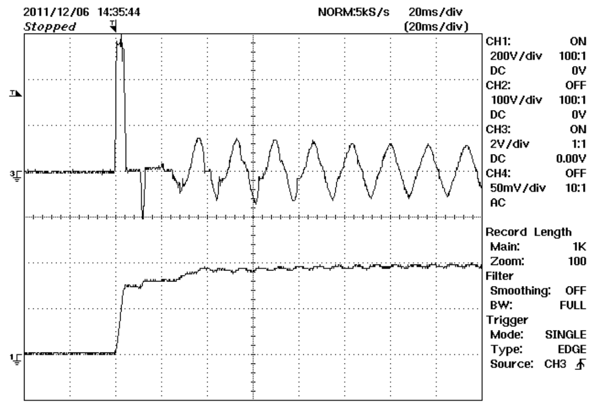

Figure 32 – AC Input Current vs. PFC Output Voltage at Start-up, Full Load, 230 VAC.
Upper: AC Input Current, 2 A / div.
Lower: PFC Voltage, 200 V, 20 ms / div.

14.5 Bias Supply Drain Waveforms

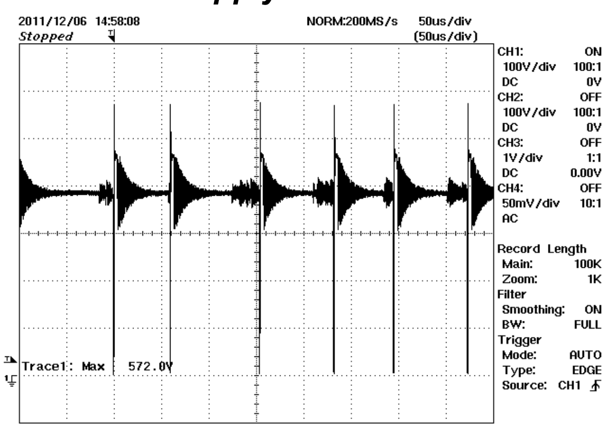

Figure 33 – Bias Supply LNK302 Drain Voltage, 100 V, 50 µs / div.

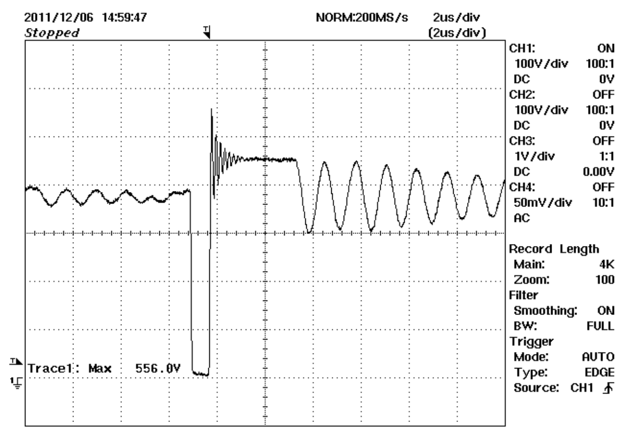

Figure 34 – Bias Supply LNK302 Drain Voltage, 100 V, 2 µs / div.

14.6 LLC Start-up

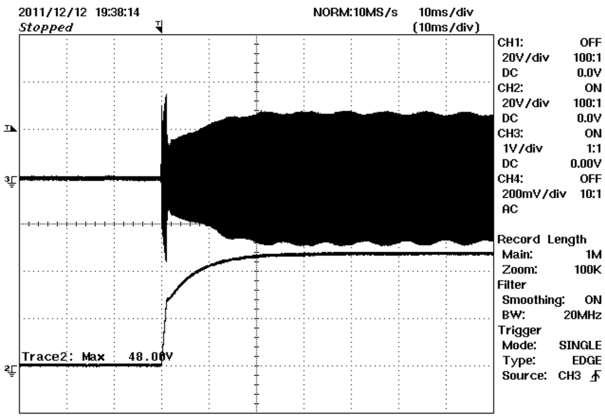

Figure 35 – LLC Start-up. 115 VAC, 100% Load.
Upper: LLC Primary Current, 1 A / div.
Lower: LLC Output Voltage, 20 V,
10 ms / div.

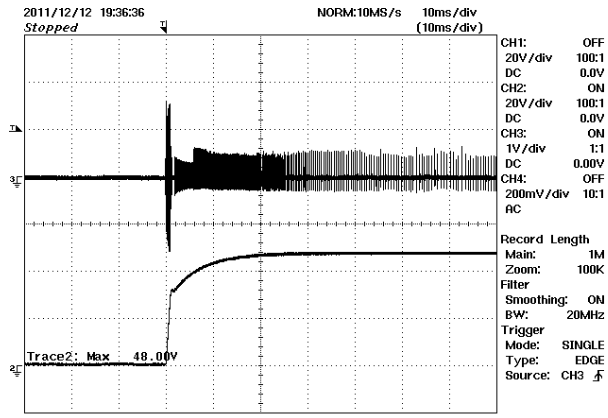

Figure 36 – LLC Start-up. 115 VAC, 0% Load.
Upper: LLC Primary Current, 1 A / div.
Lower: LLC Output Voltage, 20 V,
10 ms / div.

14.7 LLC Brown-Out

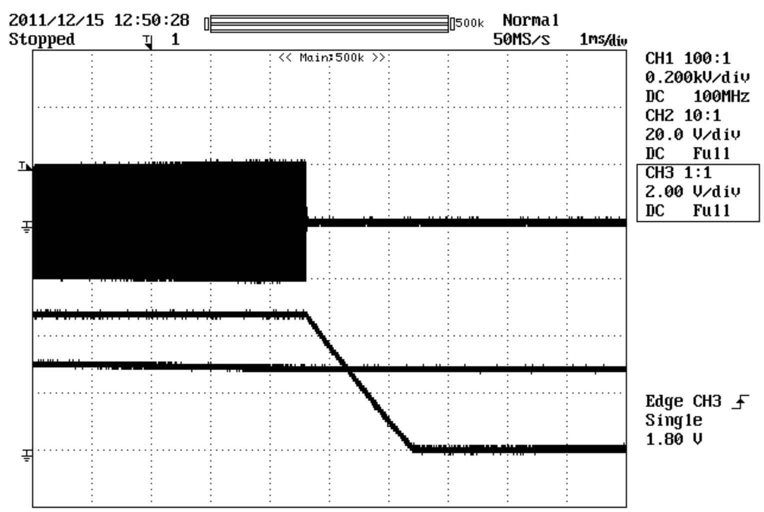

Figure 37 – LLC Brown-out.
Upper: Primary Current, 2 A / div.
Middle: Output Voltage, 20 V / div.
Lower: B+ Voltage, 200 V, 1 ms / div

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14.8 LLC Output Short-Circuit

The figure below shows the effect of an output short circuit on the LLC primary current. A mercury displacement relay was used to short the output to get a fast, bounce-free connection.

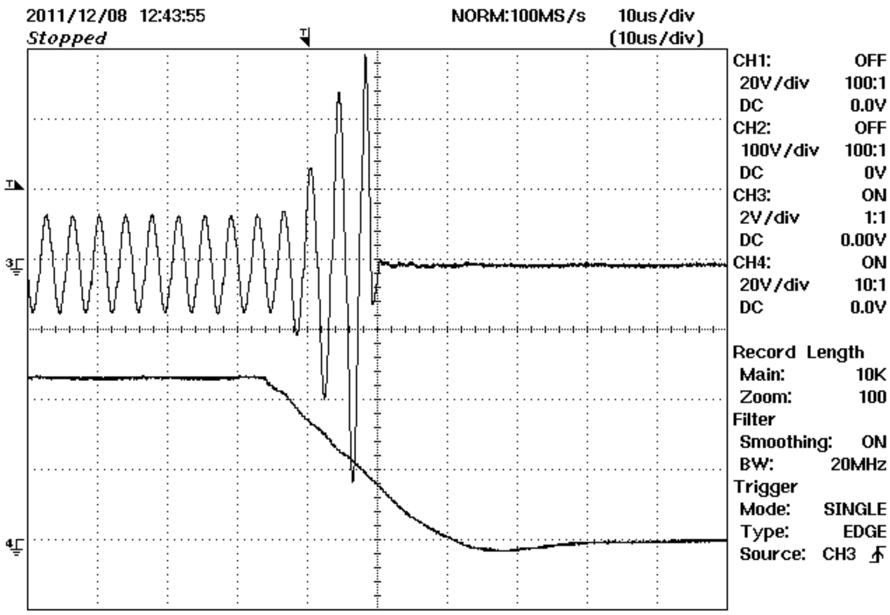

Figure 38 – Output Short Circuit Test.
Upper: LLC Primary Current, 2 A / div.
Lower: 48 V Output, 20 V, 10 μs / div.

14.9 Output Ripple Measurements

14.9.1 Ripple Measurement Technique

For DC output ripple measurements, use a modified oscilloscope test probe to reduce spurious signals. Details of the probe modification are provided in figures below.

Tie two capacitors in parallel across the probe tip of the 4987BA probe adapter. Use a 0.1 μF / 50 V ceramic capacitor and 1.0 μF / 100 V aluminum electrolytic capacitor. The aluminum-electrolytic capacitor is polarized, so always maintain proper polarity across DC outputs.

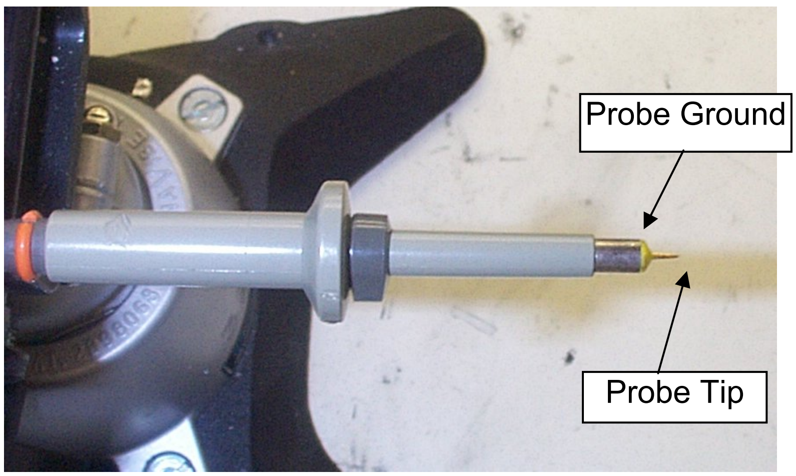

Figure 39 – Oscilloscope Probe Prepared for Ripple Measurement (End Cap and Ground Lead Removed).

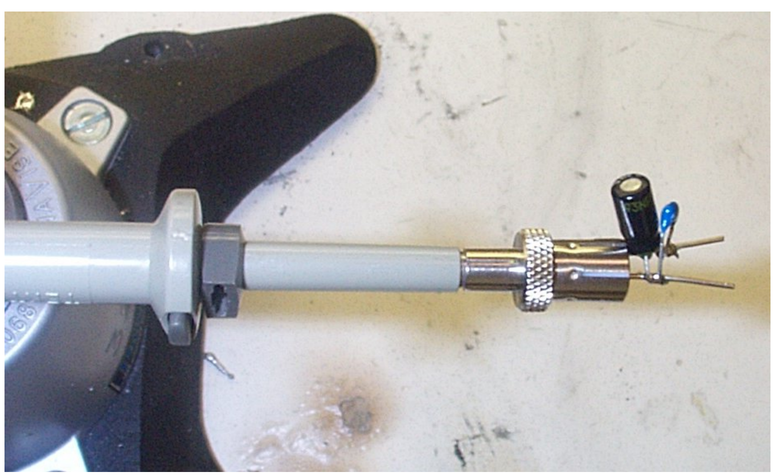

Figure 40 – Oscilloscope Probe with Probe Master 4987BA BNC Adapter (Modified with Wires for Probe Ground for Ripple measurement and Two Parallel Decoupling Capacitors Added).

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14.9.2 Full Load Output Ripple Results

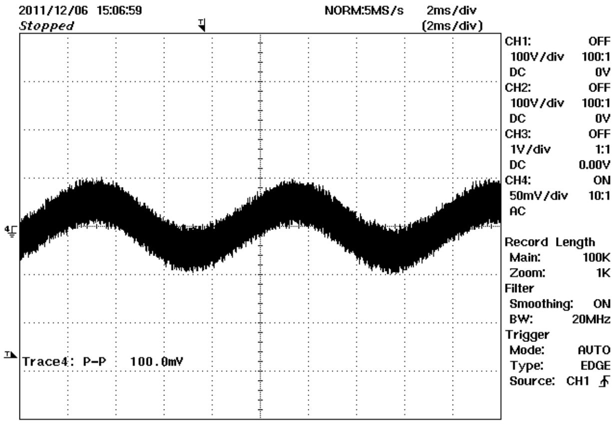

Figure 41 – 48 V Output Ripple, 100 mV, 2 ms / div.

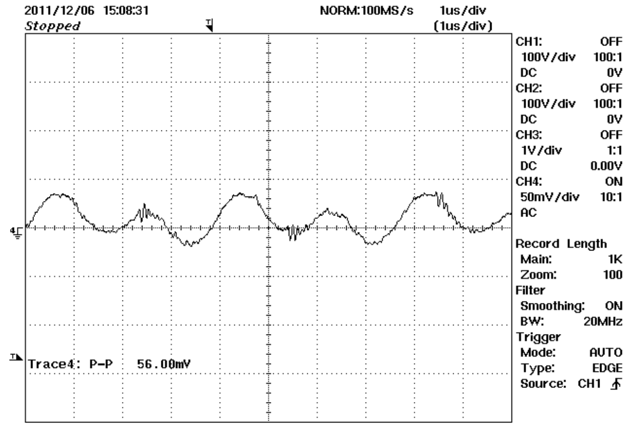

Figure 42 – 48 V Output Ripple, 100 mV, 1 μs / div.

14.9.3 No-Load Ripple Results

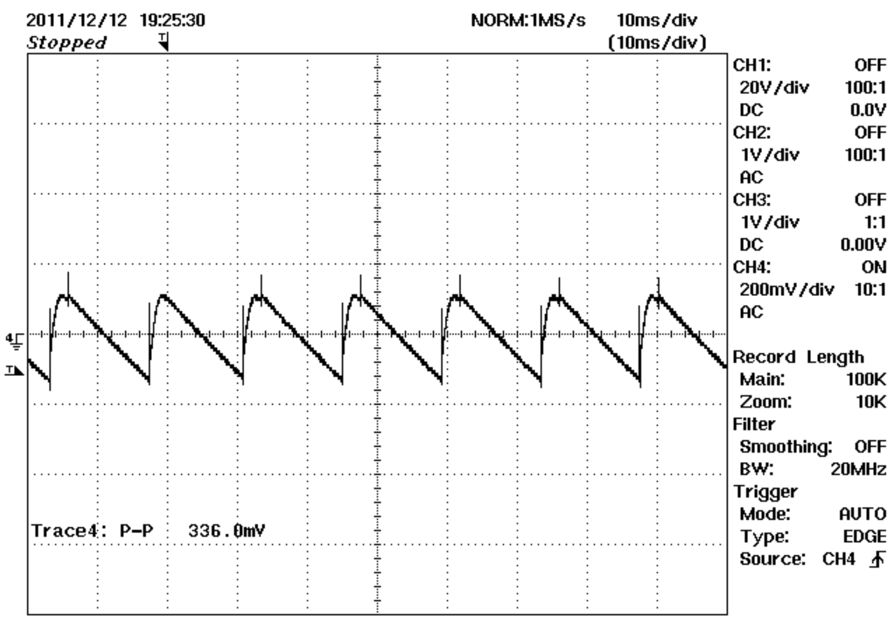

Figure 43 – 48 V No-Load Output Ripple, 200 mV, 10 ms / div.

14.10 Output Load Step Response

The figures below show transient response with a 75%-100%-75% load step for the 48 V output. The oscilloscope was triggered using the rising edge of the load step, and averaging was used to cancel out ripple components asynchronous to the load step in order to better ascertain the load step response.

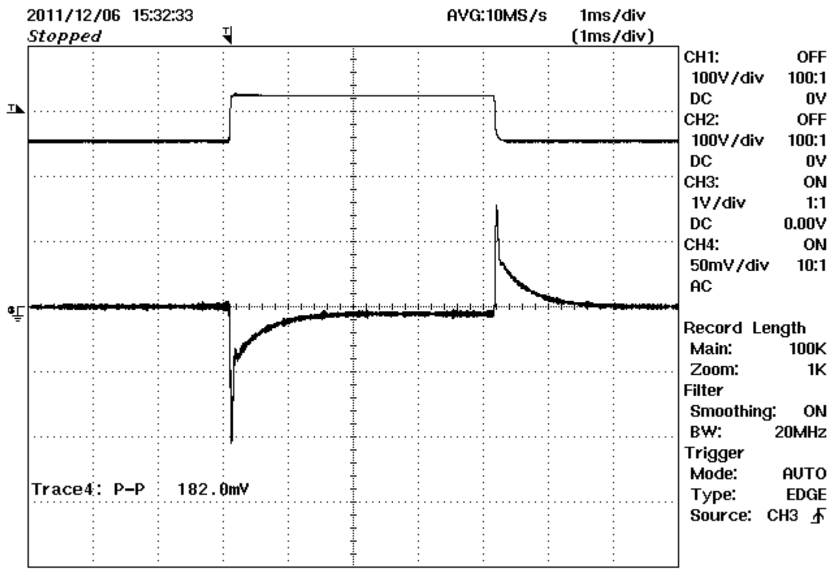

Figure 44 – Output Transient Response 3.13 A – 2.3 A – 3.13 A Load Step.
Upper: Output Load Step, 1 A / div.
Lower: 48 V Transient Response, 100 mV /,1 ms / div.

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14.10.1 100% to 0% Load Step

Figure 45 shows the response of the supply to a 100% to 0% load step. The LLC supply enters burst mode to maintain regulation.

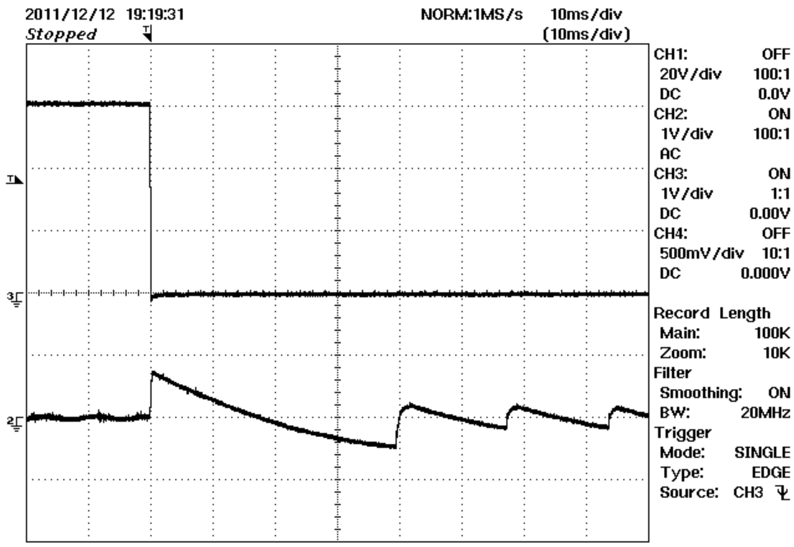

Figure 45 – Output Transient Response 3.13 A – 0 A Load Step.
500 mV, 10 ms / div.

14.10.2 0% to 100% Load Step

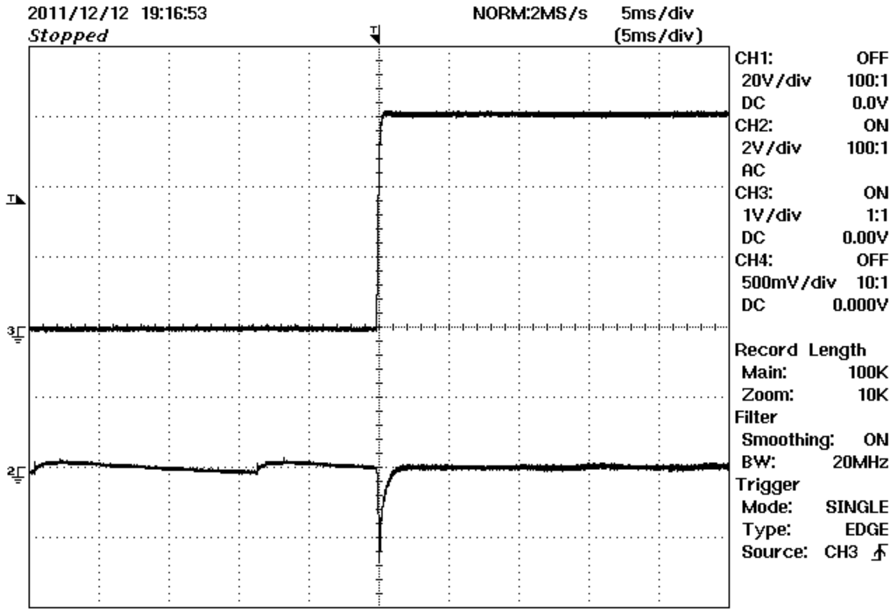

Figure 46 – Output Transient Response 0 A – 3.13 A Load Step.
1 V, 5 ms / div.

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14.10.3 Temperature Profiles

The board was operated at room temperature in a vertical orientation as shown below. For each test condition the unit was allowed to thermally stabilize (>1 hr) before measurements were made.

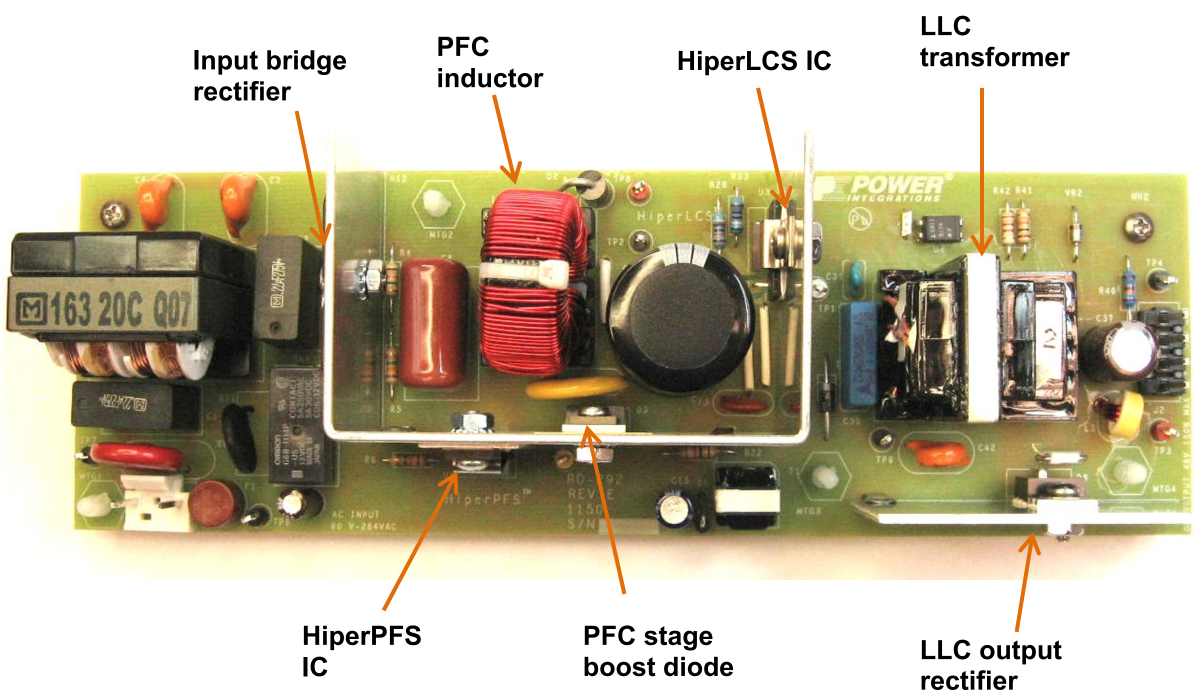

Figure 47 – Photograph of Board Used for Thermal Testing.

14.11 Thermal Results Summary

14.11.1 Testing Conditions

Thermal Measurement data is presented below. The unit was allowed to thermally stabilize (>1 hour in all cases) before gathering data.

14.11.2 90 VAC, 60 Hz, 150 W Output

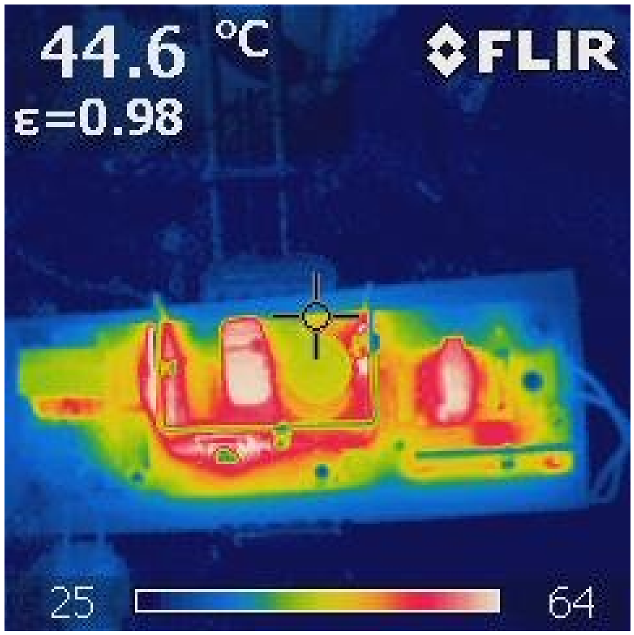

Figure 48 – Overall Thermal Profile, Room Temperature, 90 VAC, 60 Hz, 150 W Load (1 hr).

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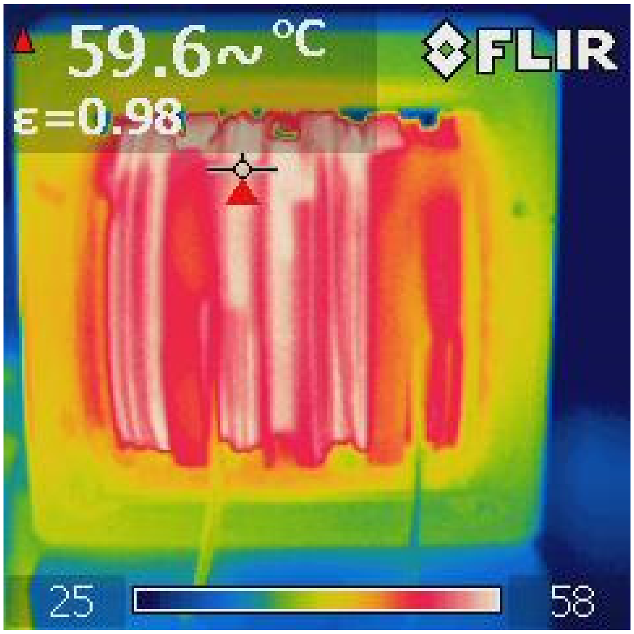

Figure 49 – Input Common Mode Choke Temperature, 90 VAC, Full load.

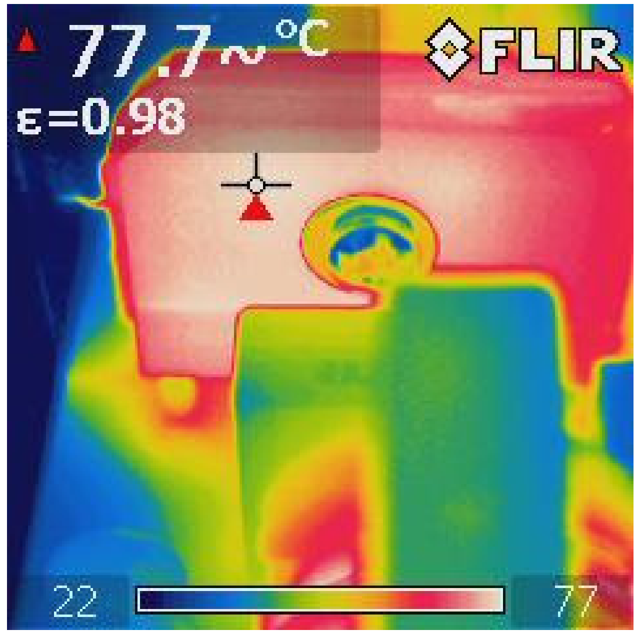

Figure 50 – Diode Bridge Case Temperature, 90 VAC, Full load.

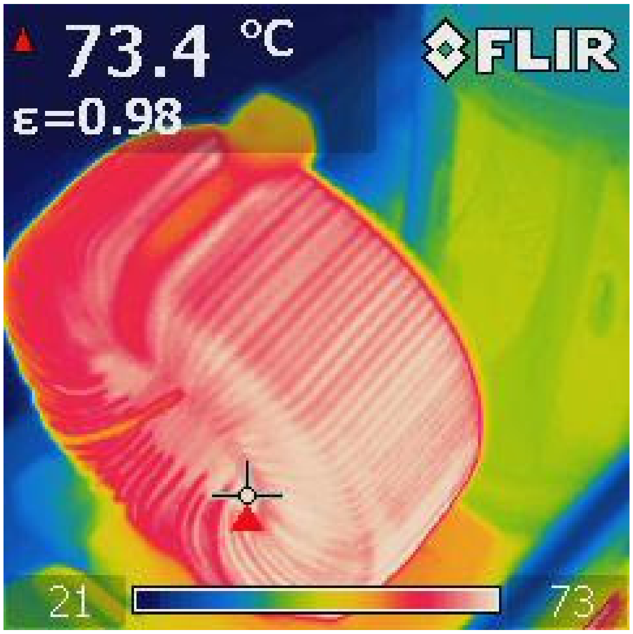

Figure 51 – PFC Choke Temperature, 90 VAC, Full Load.

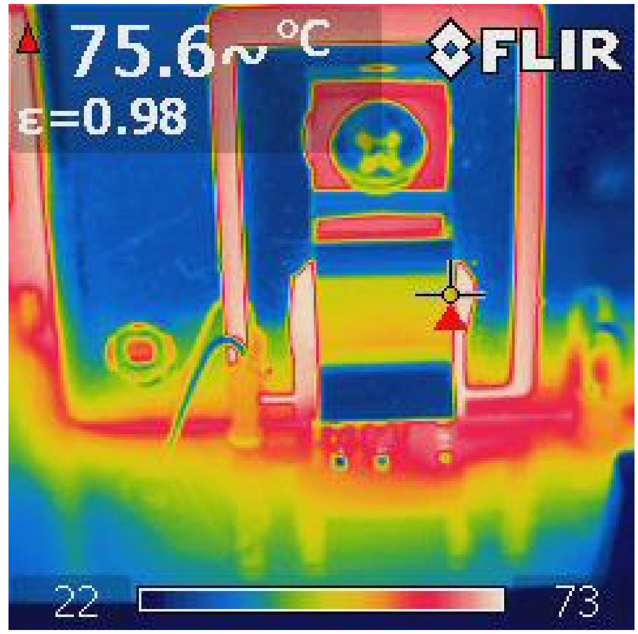

Figure 52 – PFS IC Case Temperature, 90 VAC, Full Load.

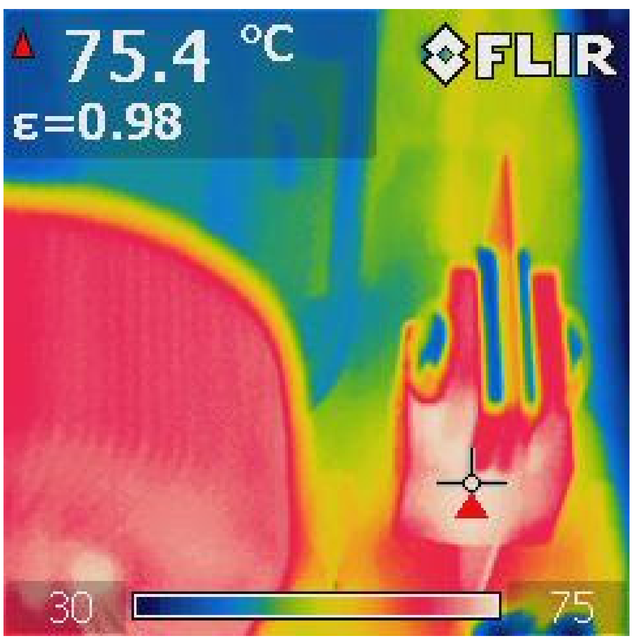

Figure 53 – PFC Output Rectifier Case Temperature, 115 VAC, Full Load.

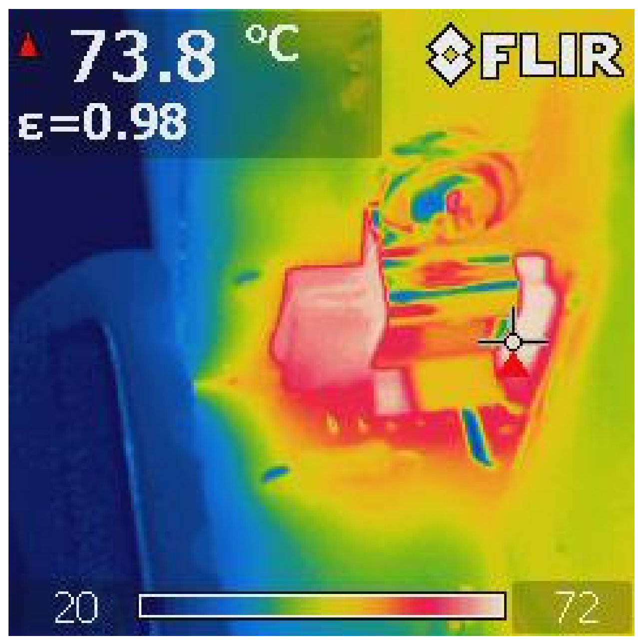

Figure 54 – LCS IC Case Temperature, 90 VAC, Full Load.

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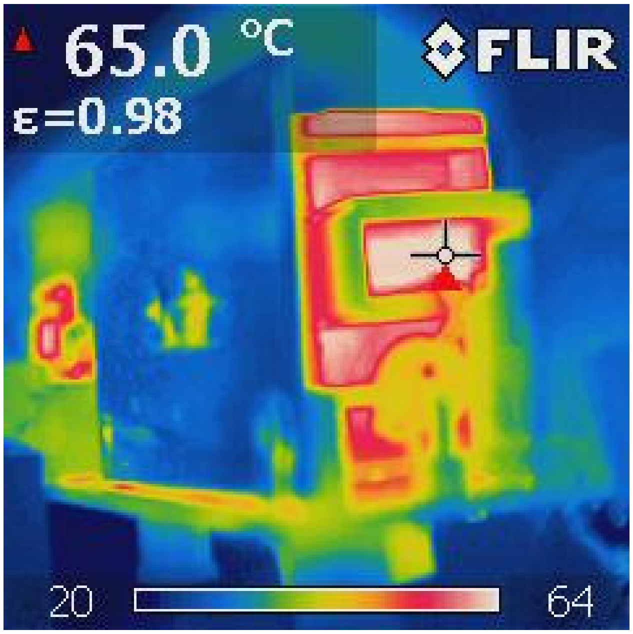

Figure 55 – LLC Transformer Hot Spot Temperature, 90 VAC, Full Load.

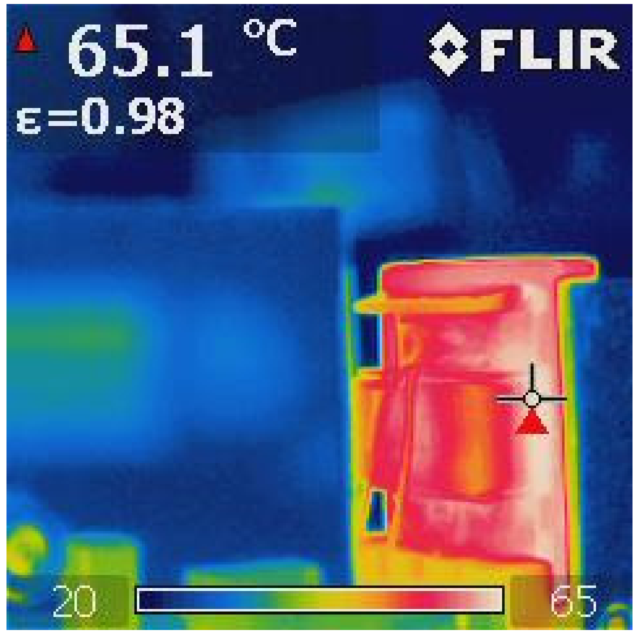

Figure 56 – LLC Transformer Hot Spot Temperature, 90 VAC, Full Load.

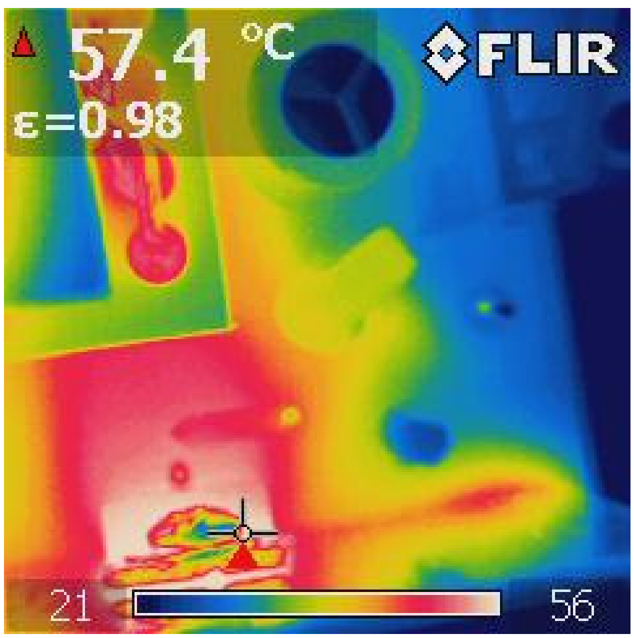

Figure 57 – LLC Output Diode CaseTemperature, 90 VAC, Full Load (Viewed from Above).

14.11.3 115 VAC, 60 Hz, 150 W Output

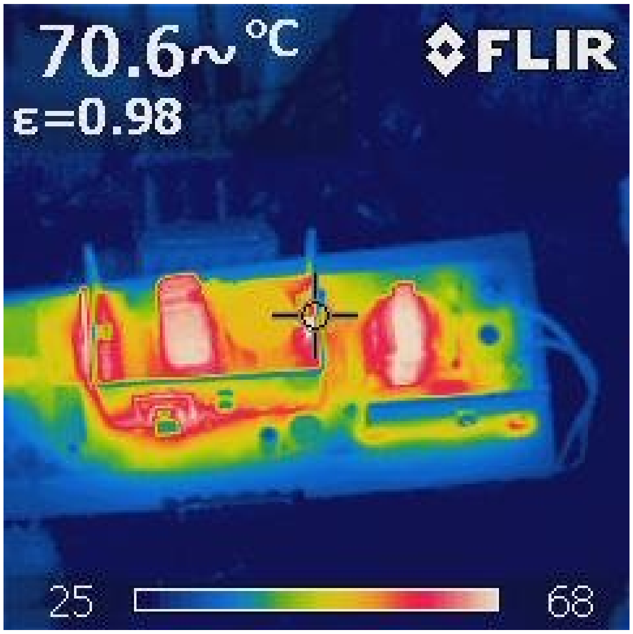

Figure 58 – Overall Thermal Profile. Room Temperature, 115 VAC, 60 Hz, 150 W Load (1 hr).

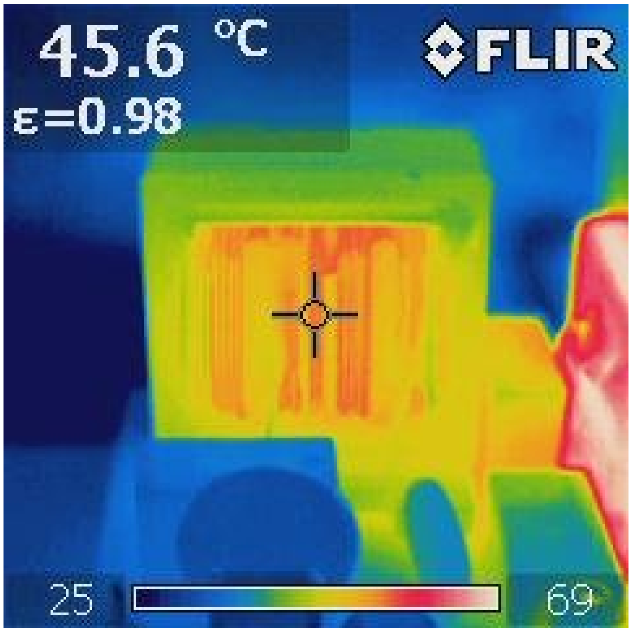

Figure 59 – Input Common Mode Choke Temperature, 115 VAC, Full Load.

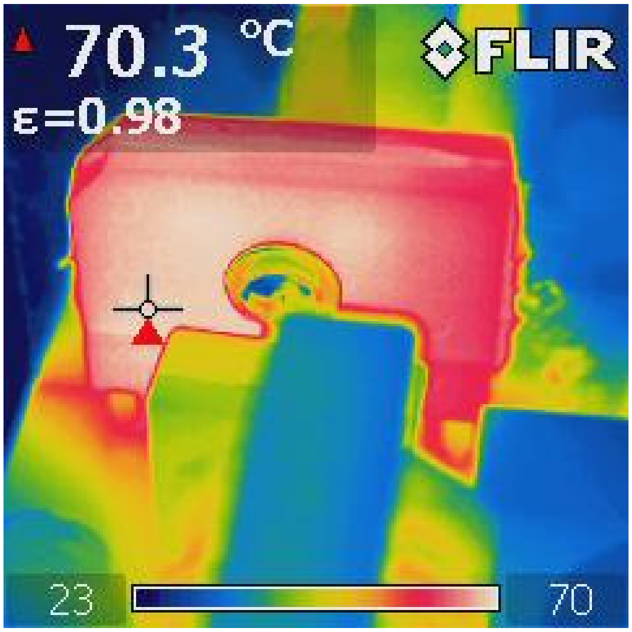

Figure 60 – Diode Bridge Case Temperature, 115 VAC, Full Load.

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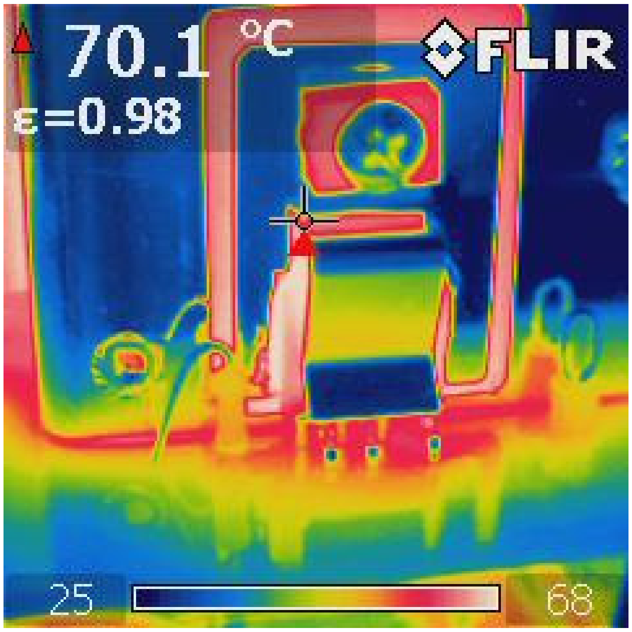

Figure 61 – PFS IC CaseTemperature, 115 VAC, Full Load.

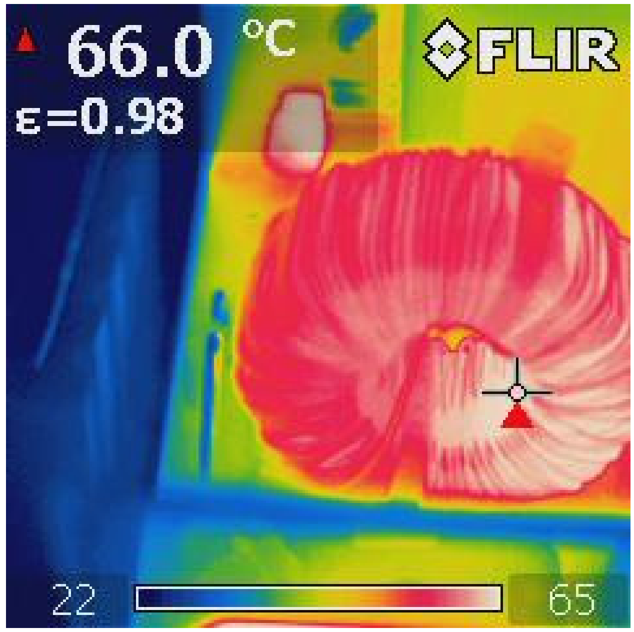

Figure 62 – PFC Choke Temperature, 115 VAC, Full Load.

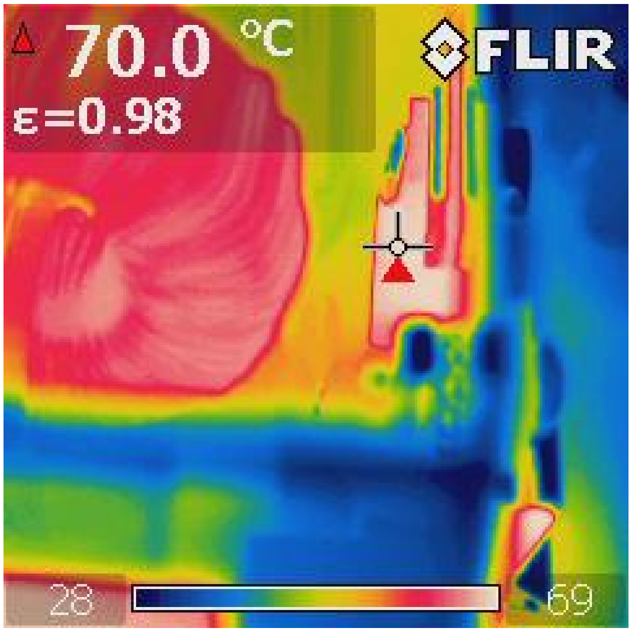

Figure 63 – PFC Output Rectifier Case Temperature, 115 VAC, Full Load.

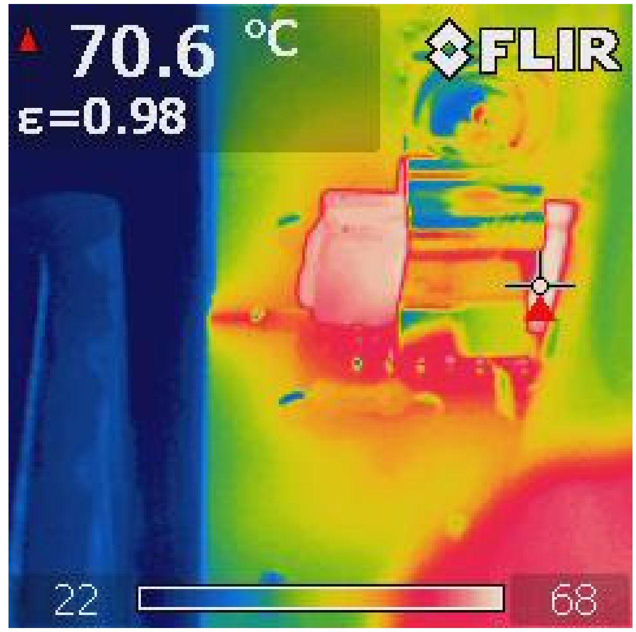

Figure 64 – LCS IC Case Temperature, 115 VAC, Full Load.

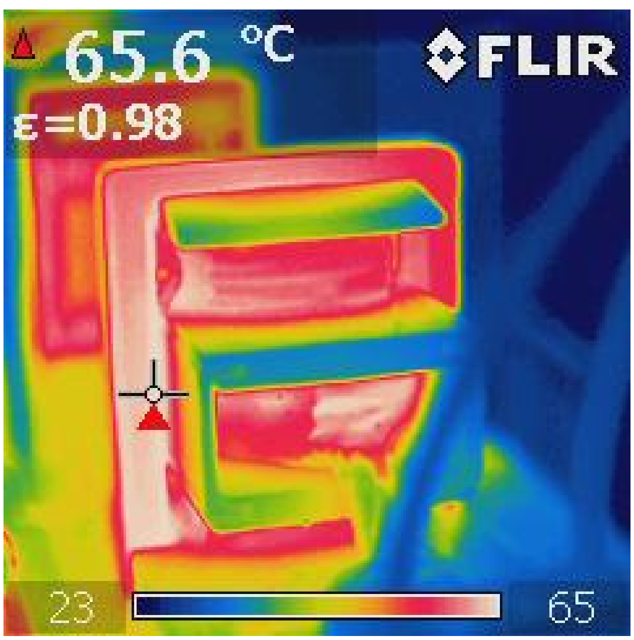

Figure 65 – LLC Transformer Secondary Side Hot Spot Temperature, 115 VAC, Full Load.

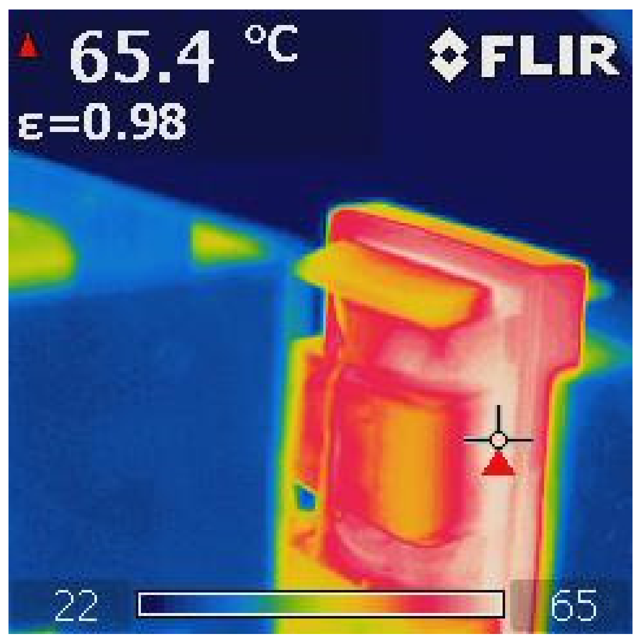

Figure 66 – LLC Transformer Primary Side Hot Spot Temperature, 115 VAC, Full Load.

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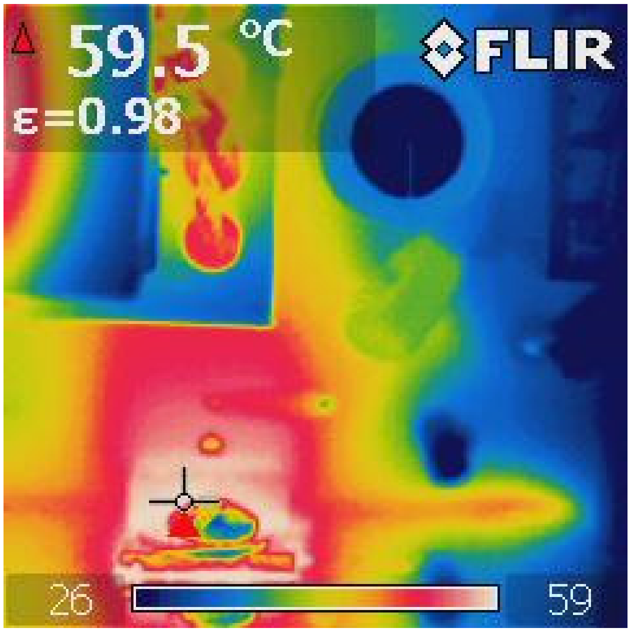

Figure 67 – LLC Output Rectifier Case Temperature, 115 VAC, Full Load (Viewed from Above).

14.11.4 230 VAC, 150 W, Room Temperature

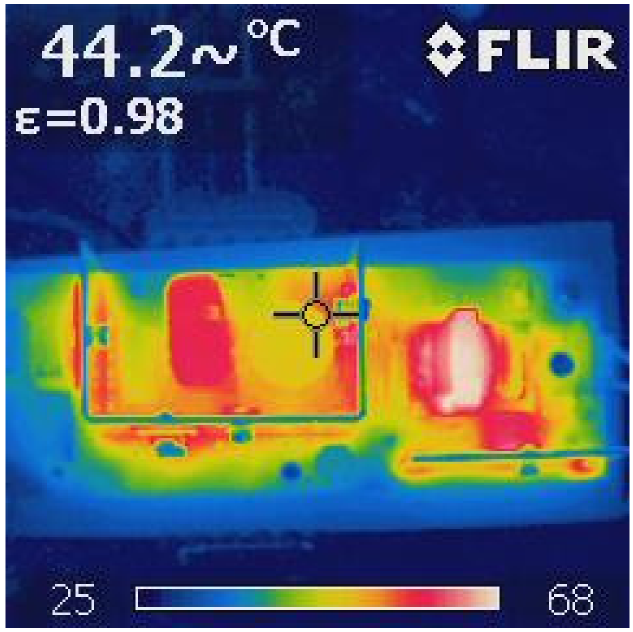

Figure 68 – Overall Temperature Profile, 230 VAC, Full Load.

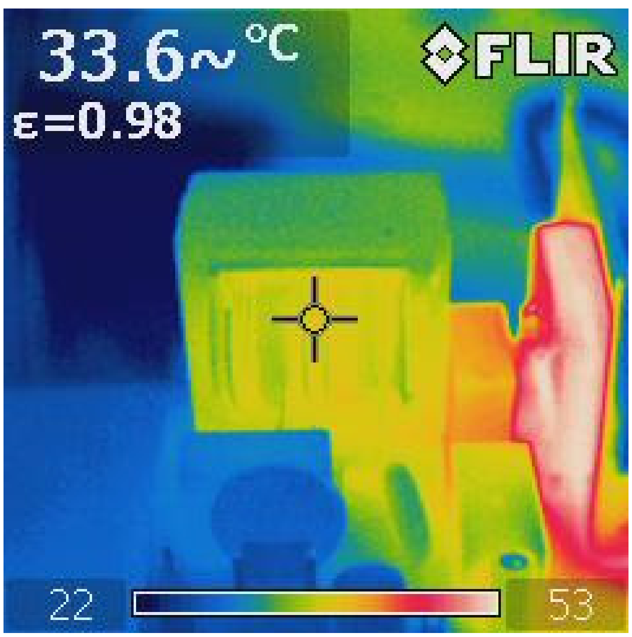

Figure 69 – Input Common Mode FilterTemperature, 230 VAC, Full Load.

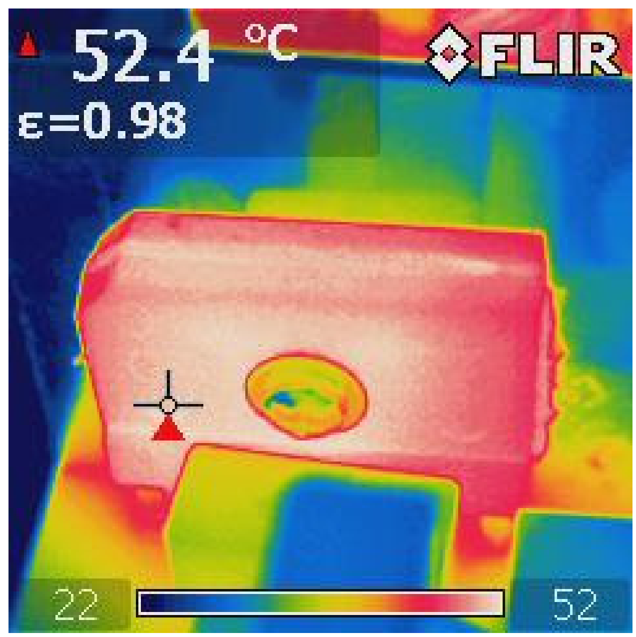

Figure 70 – Bridge Rectifier Case Temperature, 230 VAC, Full Load.

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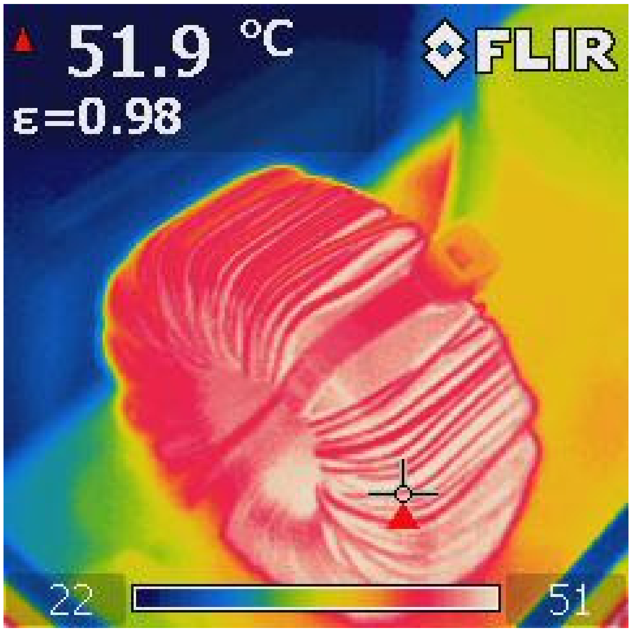

Figure 71 – PFC ChokeTemperature, 230 VAC, Full Load.

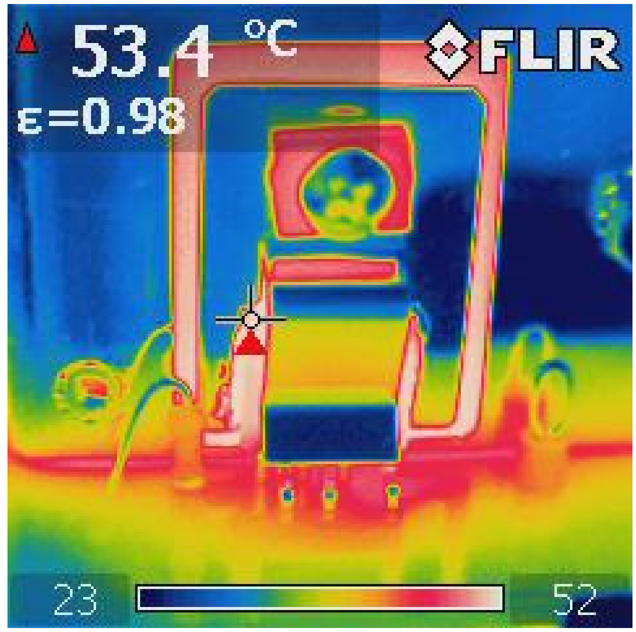

Figure 72 – PFS IC Case Temperature, 230 VAC, Full Load.

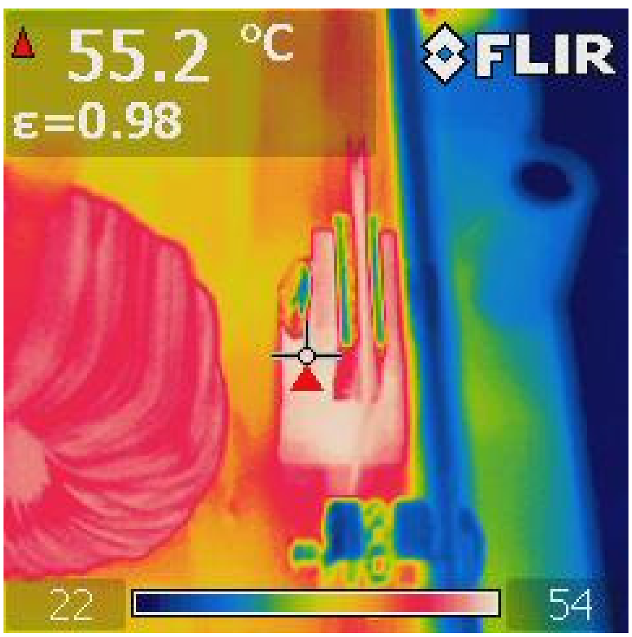

Figure 73 – PFC Output Rectifier Case Temperature, 115 VAC, Full Load.

Figure 74 – Hiper LCS CaseTemperature, 115 VAC, Full Load.

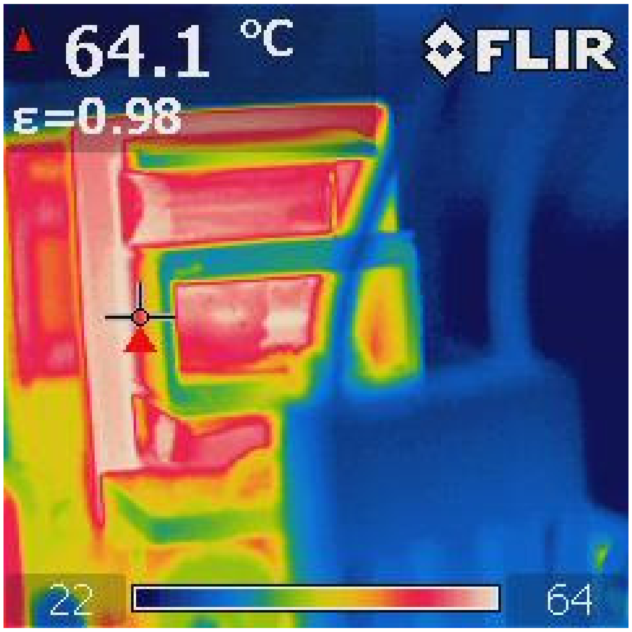

Figure 75 – LLC Output Transformer Secondary Side Hot Spot Temperature, 230 VAC, Full Load.

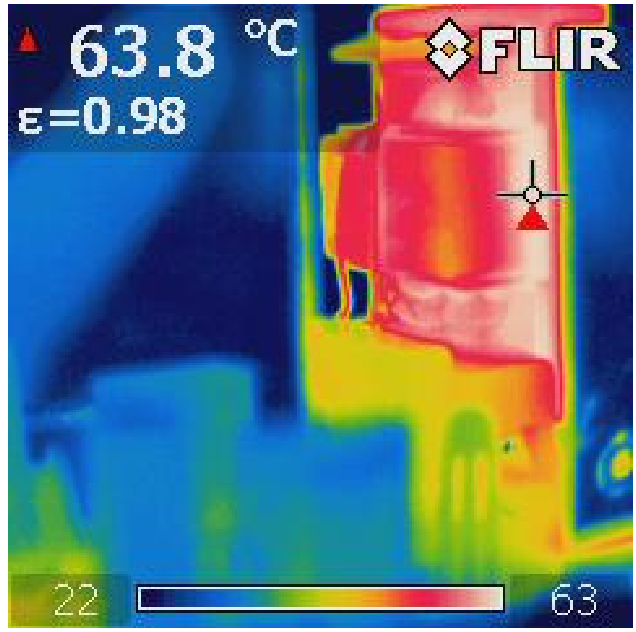

Figure 76 – LLC Output Transformer Primary Side Hot Spot Temperature, 230 VAC, Full Load.

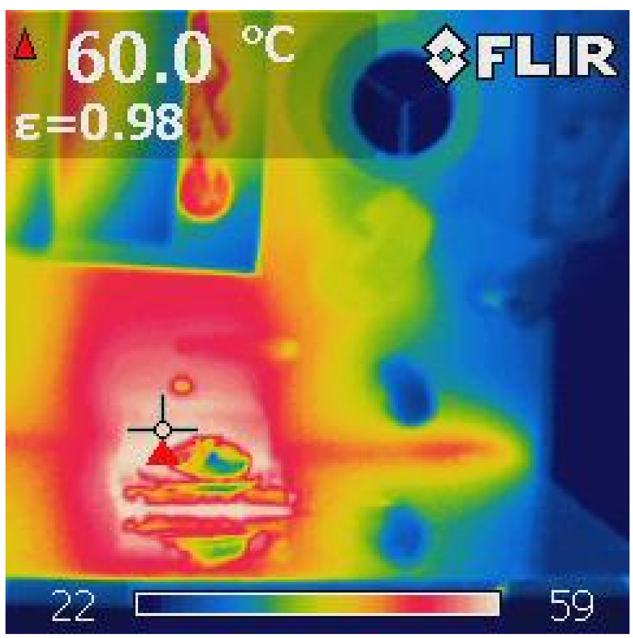

Figure 77 – LLC Output Rectifier Case Temperature, 230 VAC, Full Load (Viewed from Above).

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15 Conducted EMI

15.1 EMI Set-up

15.1.1 Power Supply Preparation for EMI Test

The picture below shows the power supply set-up for EMI and surge testing. The supply is attached to a ground plane approximately the size of the power supply A piece of single-sided copper clad printed circuit material was used in this case, but a piece of aluminum sheet would also work. The supply is attached to the ground plane in two places using ¼" 4-40 screws. Attachments points are the metal spacers marked as MH1 and MH2 on the top silk screen. An IEC AC connector was hard-wired to the power supply AC input, with the safety ground connected to the ground plane. A Fair-Rite 2643250302 ferrite bead was placed over the safety ground connection, and can be seen in the illustration below. This bead gives additional margin at ~20 MHz.

Figure 78 – RD-292 Set-up for EMI and Surge Testing.

15.1.2 EMI Test Set-up

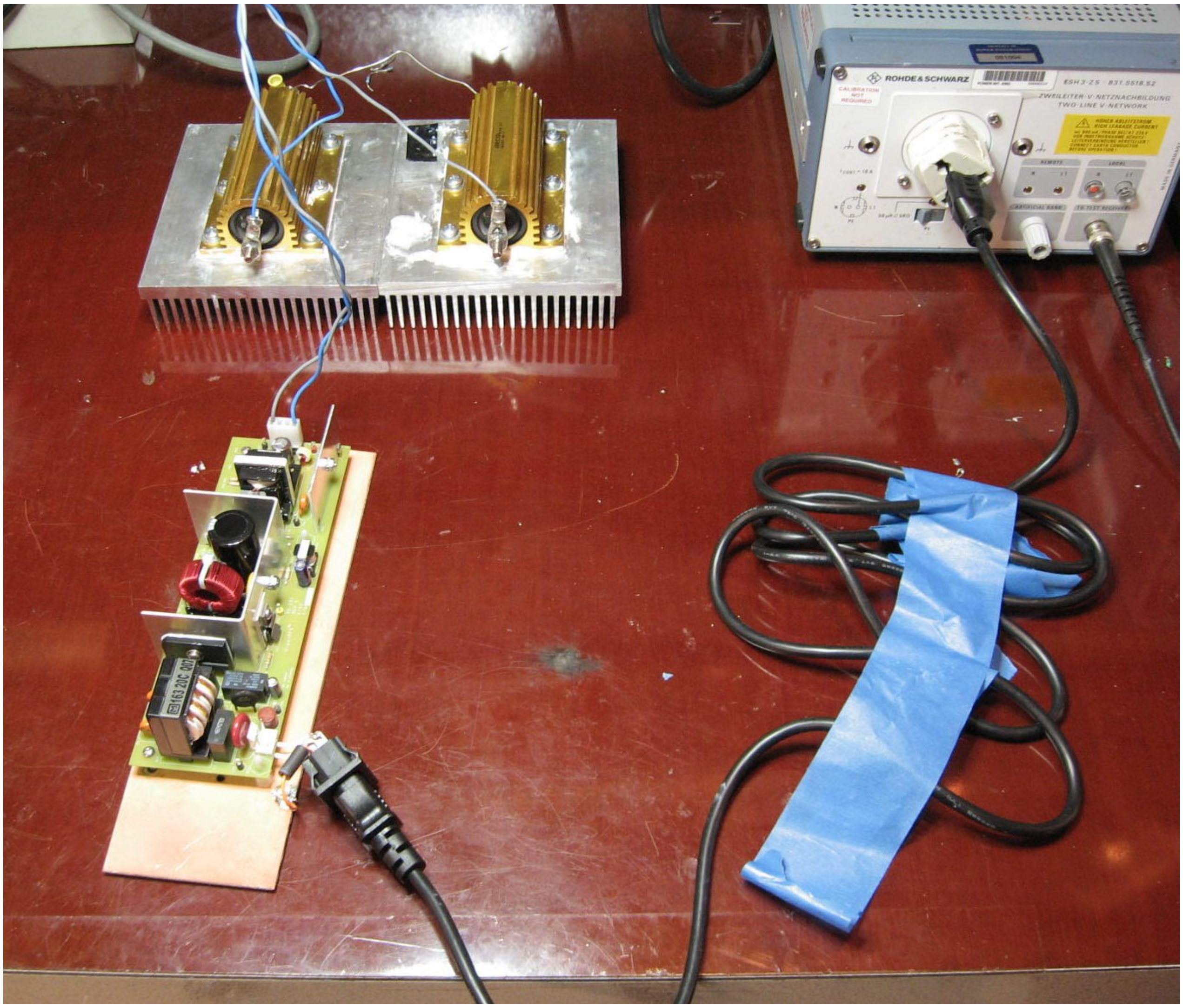

Figure 79 – EMI Room Set-up.

Conducted EMI tests were performed with a 16 Ω resistive load on the 48 V main output. The unit was attached to a metallic ground plane, which in turn was hard wired to the AC cord ground. The resistive load was left floating.

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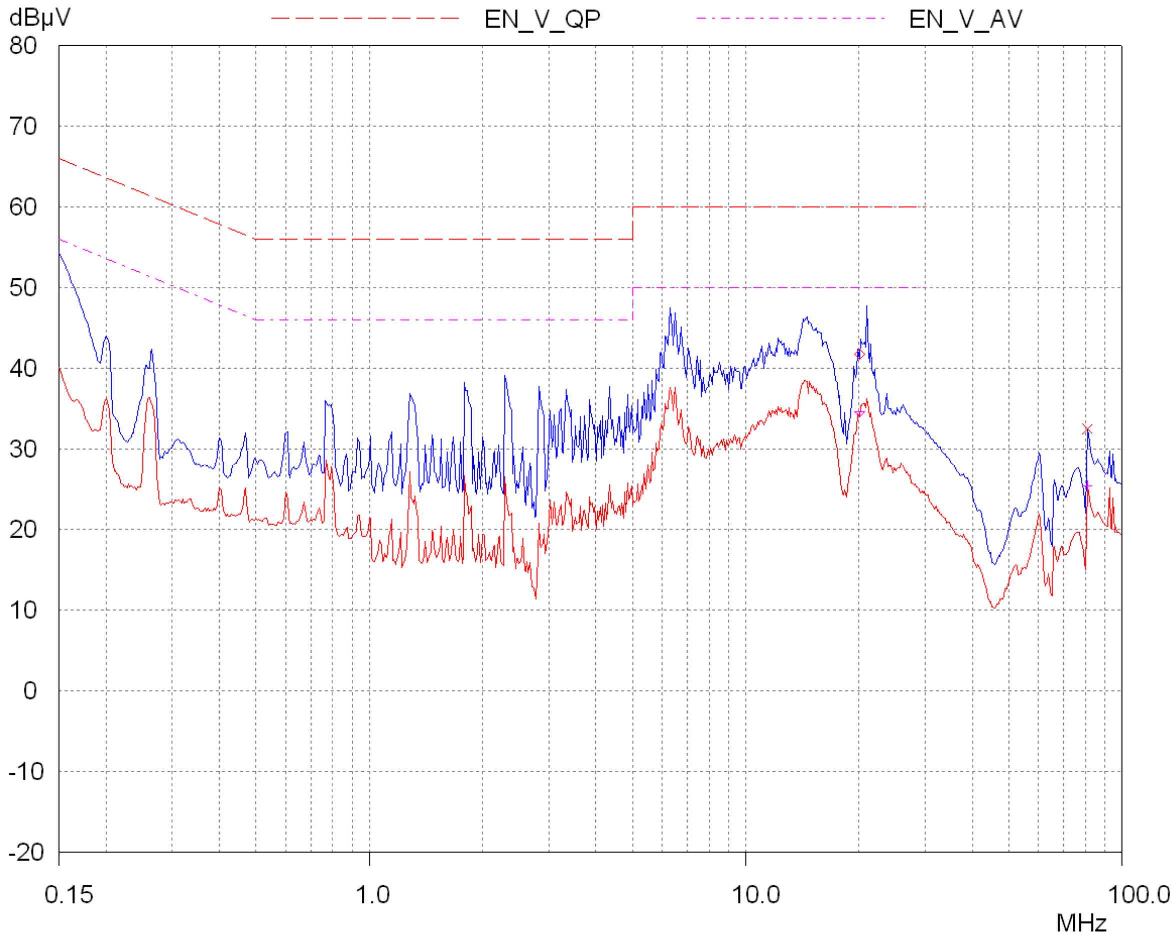

Figure 80 – Conducted EMI, 115 VAC.

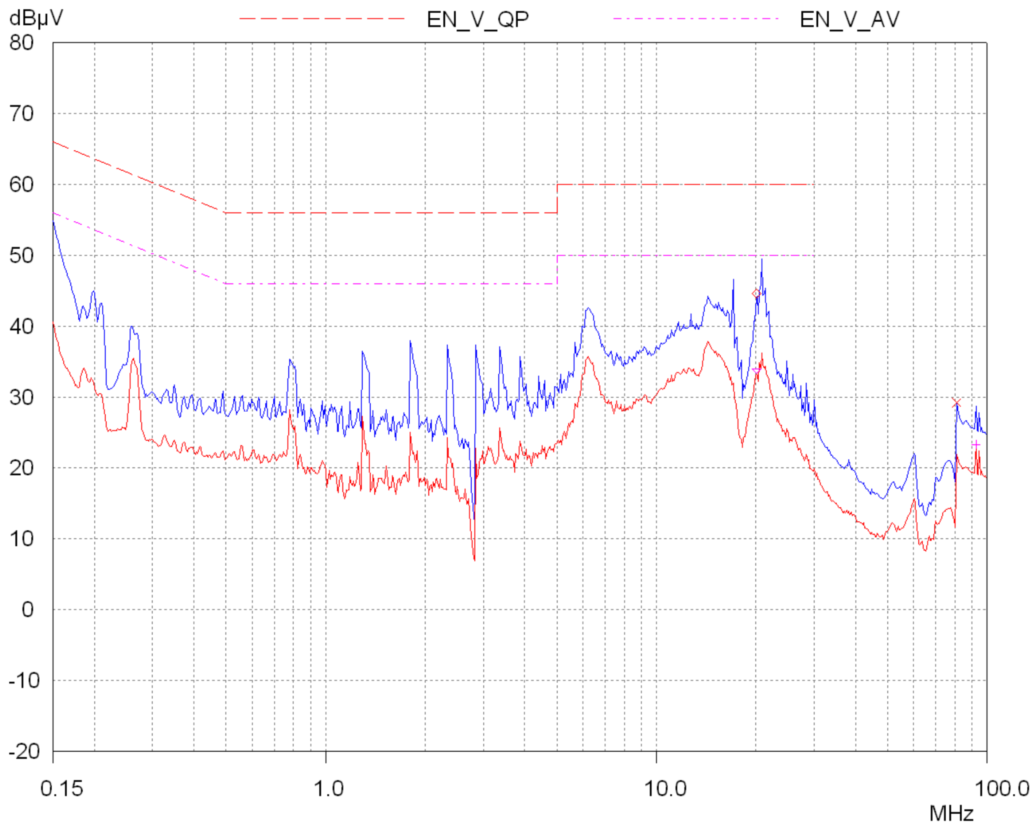

Figure 81 – Conducted EMI, 230 VAC.

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16 Gain-Phase Measurement

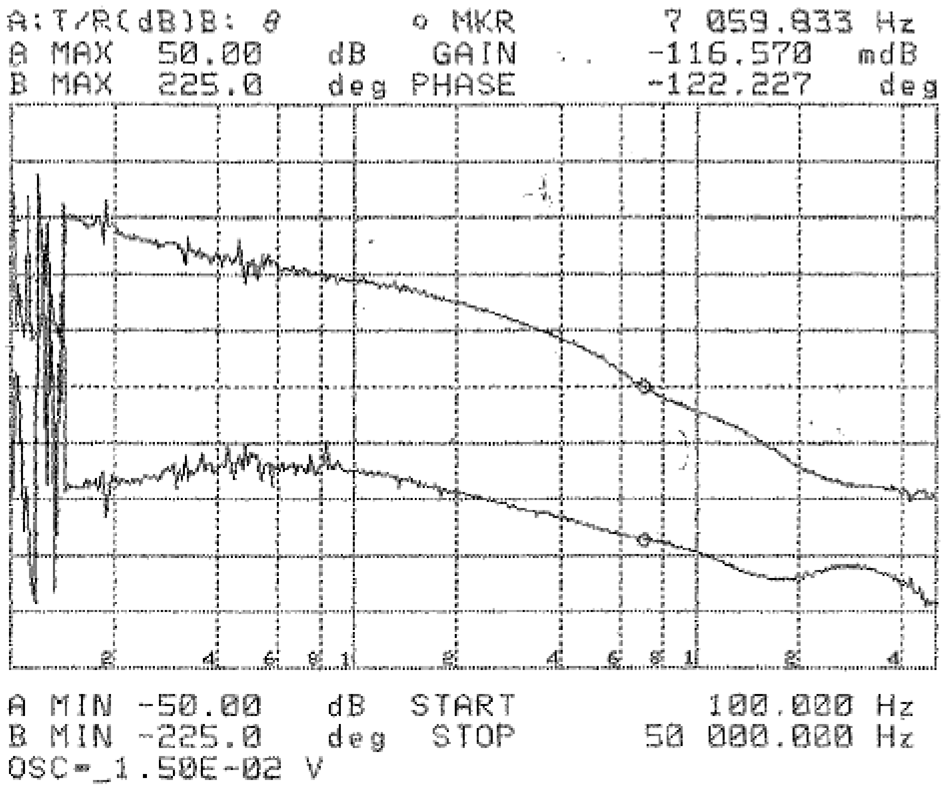

Figure 83 – RD-292 LLC Gain-Phase Measurement, Full Load Gain Crossover Frequency – 7.06 kHz, Phase Margin, 57.8º.

17 Input Surge Testing

17.1 Surge Test Set-up

The set-up for surge testing identical to that of EMI testing, with the UUT mounted on a ground plane as shown below, with a 16 Ω floating resistive load. An LED in series with a 680 Ω resistor and a 39 V, 1 W Zener diode was used to monitor the output, in order to detect dropouts/loss of function. The Zener diode provides extra sensitivity for dropout testing, as the LED will shut off in response to a partial loss of output voltage.

The UUT was tested using a Key Tek EMC Pro Plus surge tester. The power supply was configured on a ground plane as shown in Figure 84, with a floating 16 Ω resistive load. Results of common mode and differential mode surge testing are shown below. A test failure was defined as a non-recoverable output interruption requiring supply repair or recycling AC input voltage.

Figure 82 – RD-292 Set-up for Surge Testing.

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17.2 Differential Mode Surge, 1.2 / 50 μsec

AC Input Voltage (VAC)	Surge Voltage (kV)	Phase Angle (º)	Generator Impedance (Ω)	Number of Strikes	Test Result
115	+2	90	2	10	PASS
115	-2	90	2	10	PASS
115	+2	270	2	10	PASS
115	-2	270	2	10	PASS
115	+2	0	2	10	PASS
115	-2	0	2	10	PASS

AC Input Voltage (VAC)	Surge Voltage (kV)	Phase Angle (º)	Generator Impedance (Ω)	Number of Strikes	Test Result
230	+2	90	2	10	PASS
230	-2	90	2	10	PASS
230	+2	270	2	10	PASS
230	-2	270	2	10	PASS
230	+2	0	2	10	PASS
230	-2	0	2	10	PASS

17.3 Common Mode Surge, 1.2 / 50 μsec

AC Input Voltage (VAC)	Surge Voltage (kV)	Phase Angle (º)	Generator Impedance (Ω)	Number of Strikes	Test Result
115	+4	90	12	10	PASS
115	-4	90	12	10	PASS
115	+4	270	12	10	PASS
115	-4	270	12	10	PASS
115	+4	0	12	10	PASS
115	-4	0	12	10	PASS

AC Input Voltage (VAC)	Surge Voltage (kV)	Phase Angle (º)	Generator Impedance (Ω)	Number of Strikes	Test Result
230	+4	90	12	10	PASS
230	-4	90	12	10	PASS
230	+4	270	12	10	PASS
230	-4	270	12	10	PASS
230	+4	0	12	10	PASS
230	-4	0	12	10	PASS

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18 Revision History

Date	Author	Revision	Description and Changes	Reviewed
01-Mar-12	RH	6.0	Initial Release.	Apps & Mktg
19-Nov-13	KM	6.1	Updated Mfg Part Number for Q1 & Q3.	Apps & Mktg

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