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AND8185/D

300 W, Wide Mains, PFC Stage Driven by the NCP1653

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APPLICATION NOTE

Introduction

The NCP1653 is a Power Factor Controller to efficiently drive Continuous Conduction Mode (CCM) step−up pre−converters. As shown by the ON Semiconductor application note AND8184/D, that details the four key steps to design a NCP1653 driven PFC stage, this circuit represents a major leap towards compactness and ease of implementation.

Housed in a DIP8 or SO−8 package, the circuit minimizes the external components count without sacrificing performance and flexibility. In particular, the NCP1653 integrates all the key protections to build robust PFC stages like an effective input power runaway clamping circuitry.

When needed or wished, the NCP1653 also allows operation in Follower Boost mode(1) to drastically lower the pre−converter size and cost, in a straight−forward manner. For more information on this device, please refer to the ON Semiconductor data sheet NCP1653/D.

The board illustrates the circuit capability to effectively drive a high power, universal line application. More specifically, it is designed to meet the following specifications:

- Maximum output power: 300 W
- Input voltage range: from 90 Vrms to 265 Vrms
- Regulation output voltage: 385 V
- Switching frequency: 100 kHz

This application was tested using a resistive load. As in many applications, the PFC controller is fed by an output of the downstream converter, there is generally no need for an auto−supply circuitry. Hence, in our demo−board, the NCP1653 V_{CC} is to be supplied by a 15 V external power supply.

The external voltage source that is to be applied to the NCP1653 V_{CC}, should exceed 13.25 V typically, to allow the circuit startup. After startup, the V_{CC} operating range is from 9.5 to 18 V.

The voltage applied to the NCP1653 V_{CC} must NOT exceed 18 V.

The NCP1653 is a continuous conduction mode and fixed frequency controller (100 kHz). The coil (600 μH) is selected to limit the peak−to−peak current ripple in the range of 30% at the sinusoid top, in full load and low line conditions. Again, for details on how the application is designed, please refer to the ON Semiconductor application note AND8184/D.

As detailed in the document, the board yields very nice Power Factor ratios and effectively limits the Total Harmonic Distortion (THD).

(1)The “Follower Boost” mode makes the pre−converter output voltage stabilize at a level that varies linearly versus the AC line amplitude. This technique aims at reducing the difference between the output and input voltages to optimize the boost efficiency and minimize the cost of the PFC stage (refer to MC33260 and NCP1653 data sheet at *www.onsemi.com*).

Figure 1. The Board

Three coils from three different vendors have been validated on this board:

- C1062−B from CoilCraft
- MB09008 from microSpire
- SRW42EC−E02H001 from TDK.

For the sake of consistency, this application note reports the performance and results that were obtained using the CoilCraft coil. However, it has been checked that the two other coils yield high performance too.

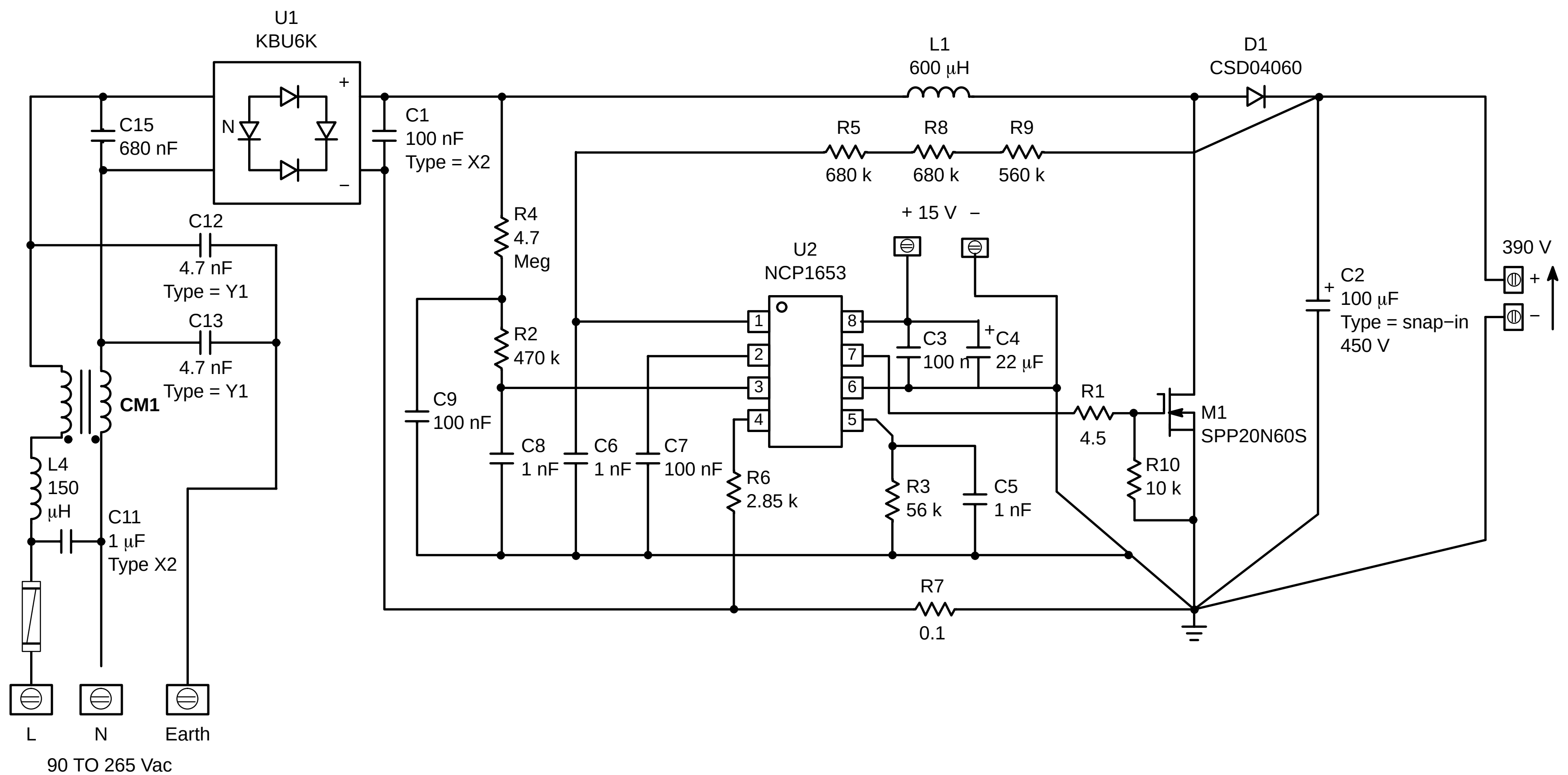

Figure 2. Application Schematic

PCB LAYOUT

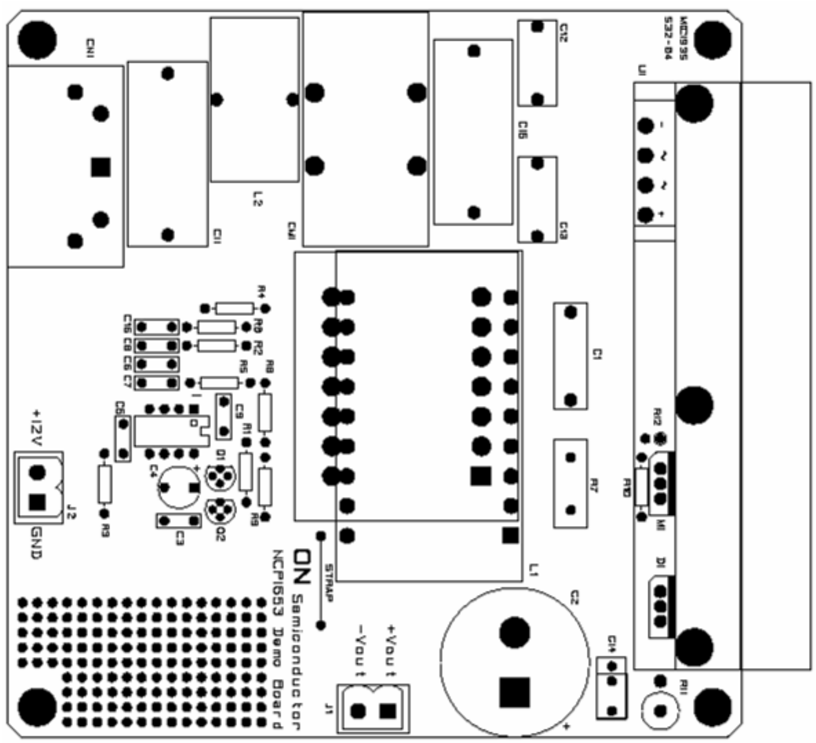

Figure 3. Component Placement

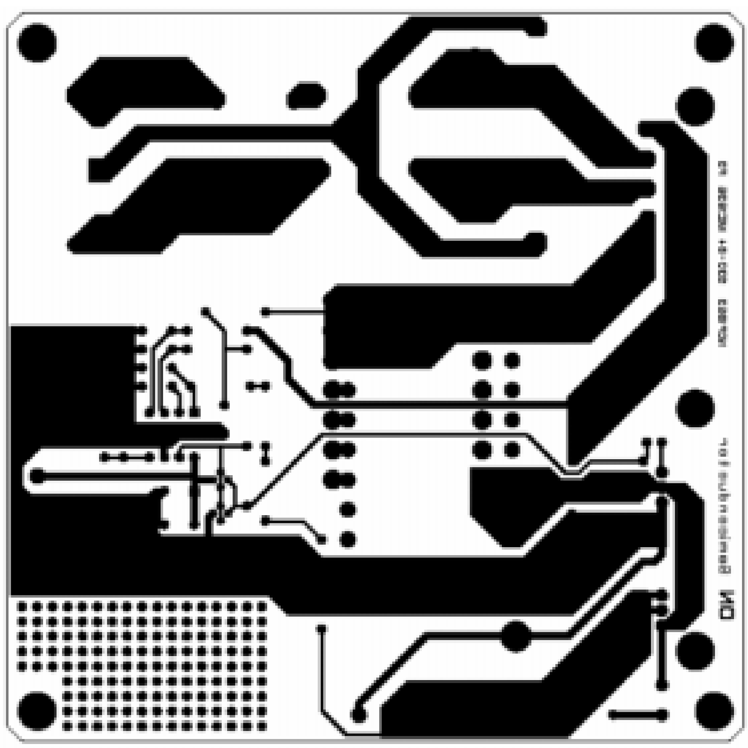

Figure 4. PCB Layout (Components' Side)

GENERAL BEHAVIOR − TYPICAL WAVEFORMS

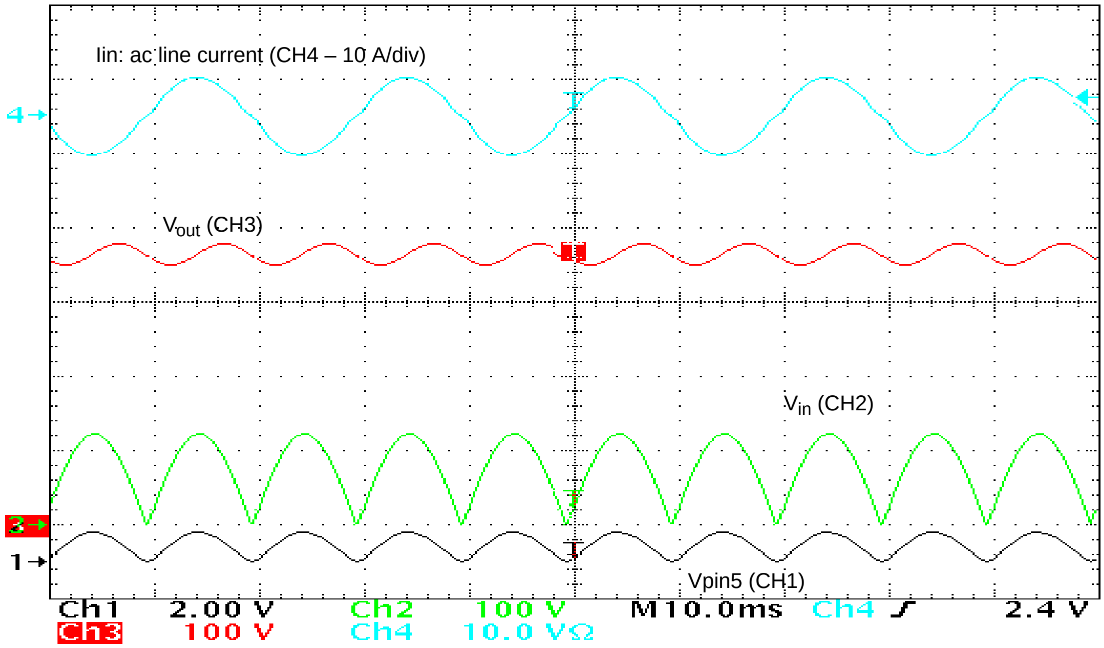

Figure 5.

V_{ac} = 90 V, P_{in} = 326.5 W, V_{out} = 365 V, I_{out} = 822 mA, PF = 0.999, THD = 4 %

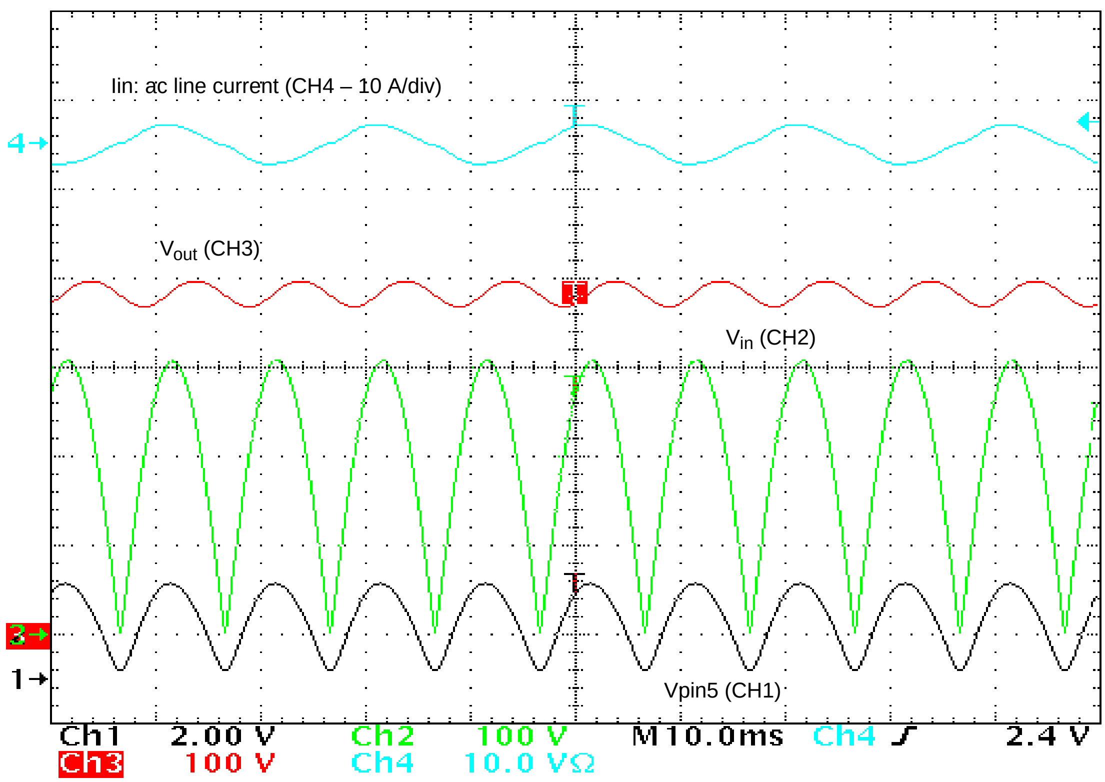

Figure 6.

V_{ac} = 220 V, P_{in} = 325 W, V_{out} = 384 V, I_{out} = 814 mA, PF = 0.989, THD = 8 %

THD and Efficiency at V_{ac} = 110 V

P_{in} (W)	V_{out} (V)	I_{out} (A)	PF (−)	THD (%)	eff (%)
331.3	370.0	0.83	0.998	4	93
296.7	373.4	0.74	0.998	4	93
157.3	381.8	0.38	0.995	7	92
109.8	383.5	0.26	0.993	9	91
80.7	384.4	0.19	0.990	10	91
67.4	385.0	0.16	0.988	10	91

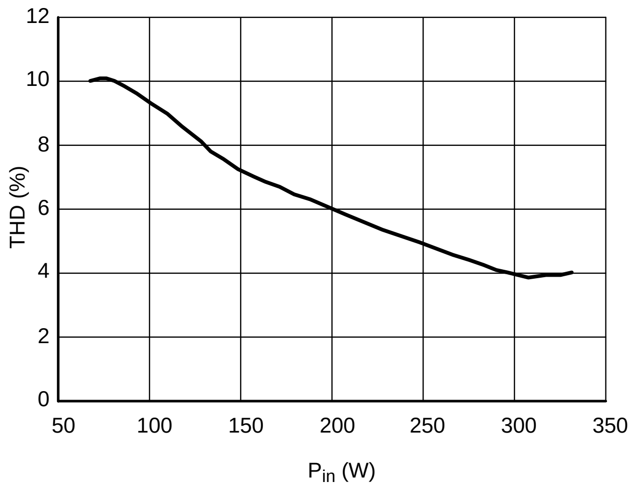

Figure 7. THD vs. P_{in}

The Total Harmonic Distortion keeps below 10% from Pmax (maximum power – 300 W) down to about Pmax/5.

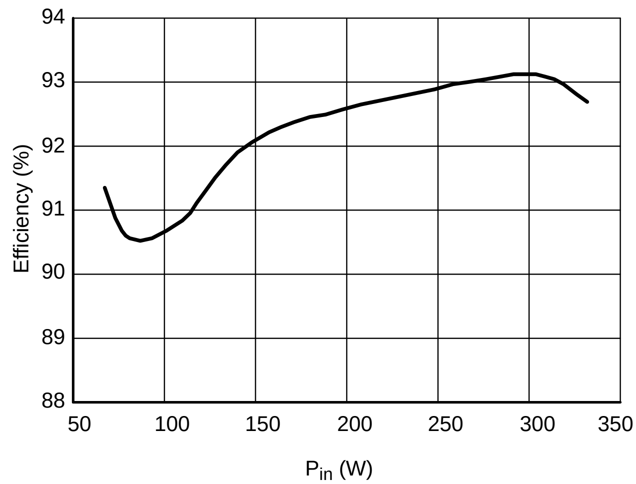

Figure 8. Efficiency vs. P_{in}

The efficiency remains higher than 90% for input powers ranging from 67 to 330 W.

In standby (no load conditions), the PFC stage enters a stable burst mode, where the circuit keeps regulating the output voltage and minimizes the power consumption (See Figure 11).

THD and Efficiency at V_{ac} = 220 V

P_{in} (W)	V_{out} (V)	I_{out} (A)	PF (−)	THD (%)	eff (%)
66.9	386.6	0.16	0.920	15	92
80.2	386.5	0.19	0.933	14	92
110.0	386.7	0.27	0.960	11	95
157.3	386.4	0.38	0.978	9	93
215.7	386.2	0.53	0.985	8	95
311.4	385.4	0.77	0.989	9	95

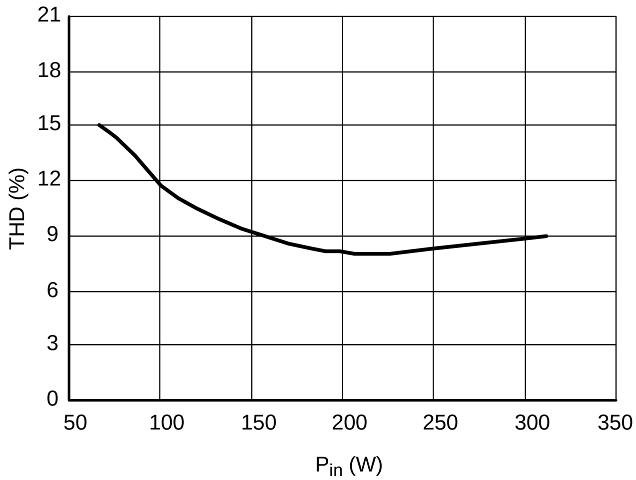

Figure 9. THD vs. P_{in}

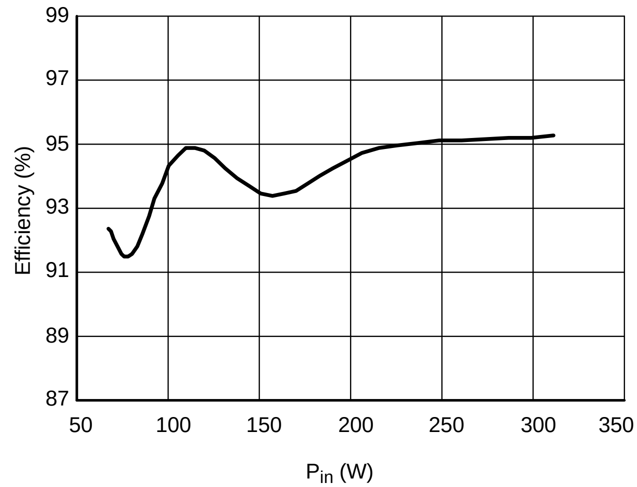

Figure 10. Efficiency vs. P_{in}

Similarly to the 110 Vac results, low THD values are obtained. The Total Harmonic Distortion keeps below 15% from Pmax (maximum power – 300 W) down to about Pmax/5.

Again the efficiency keeps high in a large power range. More specifically, it remains higher than 91% for input powers ranging from 67 to 330 W.

In standby (no load conditions), the PFC stage enters a stable burst mode, where the circuit keeps regulating the output voltage and minimizes the power consumption.

Thermal Measurements

The following results were obtained using a thermal camera, after a 1 h operation at 25°C ambient temperature. These data are indicative. They show that ***the demo−board may require additional heatsink capability*** if used in high ambient temperature applications.

Measurements Conditions:

- V_{ac} = 90 V
- P_{in} = 326 W
- V_{out} = 365 V
- I_{out} = 0.82 A
- PF = 0.999
- THD = 3 %

Power MOSFET	Heatsink	Bulk Capacitor	Output Diode	Coil (ferrite)	Coil (wires)	Input Bridge
100°C	80°C	50°C	75°C	100°C	130°C	85°C

No Load Operation

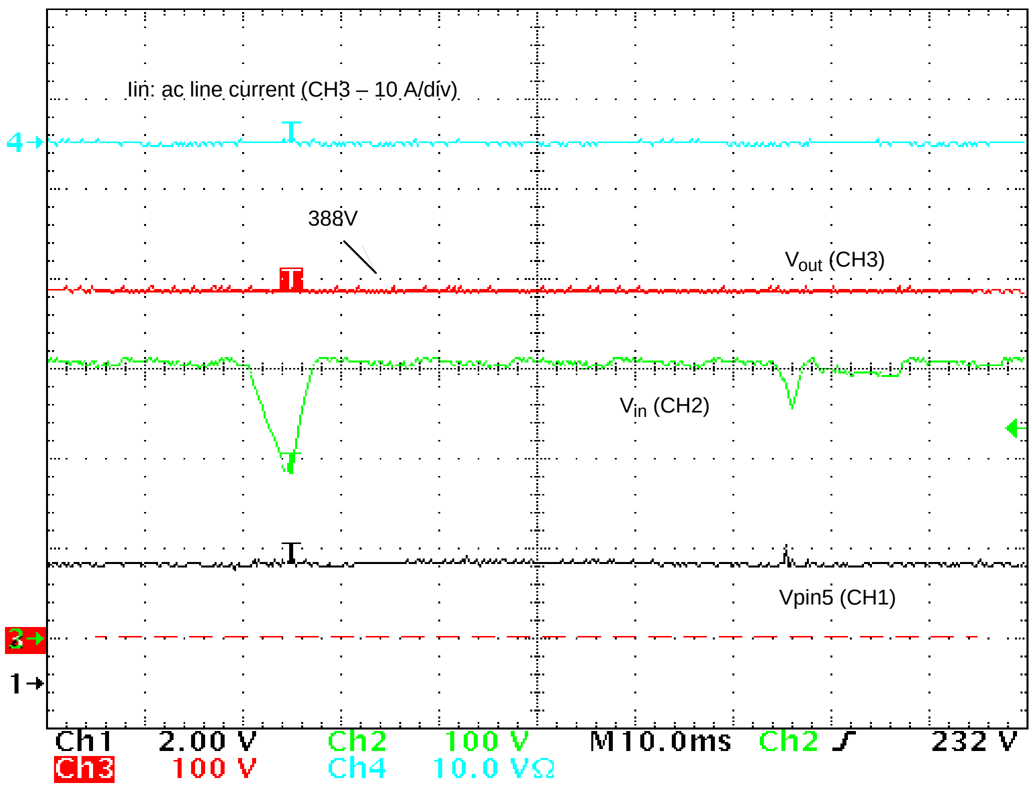

Figure 11.
P_{out} = 0 W, V_{ac} = 230 V

When in light load, the circuit enters a welcome burst mode that enables the circuit to keep regulating. Vpin5 oscillates around the pin5 internal reference voltage (2.5 V).

The power losses @ 220 V_{ac}, are nearly 130 mW. This result was obtained by using a W.h meter (measure duration: 1 h).

Soft−Start

The NCP1653 grounds the “$V_{control}$” capacitor when it is off, i.e., before each circuit active sequence (“$V_{control}$” being the regulation block output). Provided the low regulation bandwidth required by PFC stages, “$V_{control}$” increases slowly. As a result, **the power delivery rises gradually** and the PFC pre−regulator startup smoothly and noiselessly.

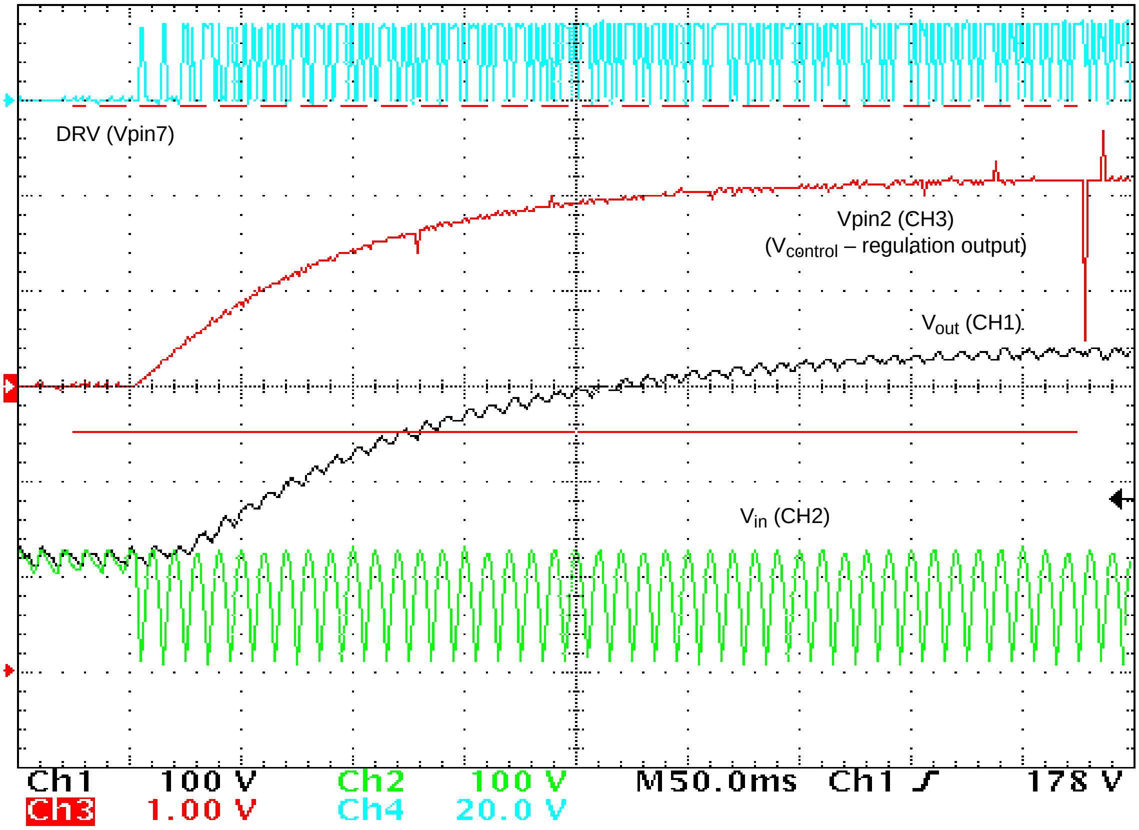

Figure 12.

Bill Of Materials

Ref Des	Description	Part Number	Manufacturer
C1	100 nF / 275 V type X2	PHE840MX6100M	RIFA
C2	100 μF / 450 V	2222 159 37101	BC Components
C3	100 nF / 50 V		various
C4	47 μF / 35 V		various
C5	1 nF / 50 V		various
C6	1 nF / 50 V		various
C7	100 nF / 50 V		various
C8	1 nF / 50 V		various
C9	100 nF / 50 V		various
C11	1 μF / 275 V type X2	PHE840MD7100M	RIFA
C12	4.7 nF / 250 V type Y	DE1E3KX472MA5B	muRata
C13	4.7 nF / 275 V type Y	DE1E3KX472MA5B	muRata
C15	680 nF / 275 V type X2	PHE840MD6680M	RIFA
R1	Resistor, Axial Lead, 4.5 Ω, 1/4 W, 1%		various
R2	Resistor, Axial Lead, 470 kΩ, 1/4 W, 1%		various
R3	Resistor, Axial Lead, 56 kΩ, 1/4 W, 1%		various
R4	Resistor, Axial Lead, 4.7 MΩ, 1/4 W, 1%		various
R5	Resistor, Axial Lead, 680 kΩ, 1/4 W, 1%		various
R6	Resistor, Axial Lead, 2.8 kΩ, 1/4 W, 1%		various
R7	Resistor, Axial Lead, 0.1 Ω, 3 W, 1%	RLP3 0R1 1%	VISHAY
R8	Resistor, Axial Lead, 680 kΩ, 1/4 W, 1%		various
R9	Resistor, Axial Lead, 560 kΩ, 1/4 W, 1%		various
R10	Resistor, Axial Lead, 10 kΩ, 1/4 W, 1%		various
L1	Coil 600 μH Coil 650 μH Coil 600 μH	C1062−B MB09008 SRW42EC−E03H001	CoilCraft microSpire TDK
L4	DM Choke	150 μH/5 A, WI−FI series	Wurth Elektronik
CM1	CM1 Filter (4 A, 2*6.8mH).	B82725−J2402−N20	EPCOS
U1	Diodes Bridge	KBU6K	General Semiconductor
D1	Output Diode	CSD04060	CREE
M1	MOSFET	SPP20N60S5	Infineon
	Heatsink (2.9°C/W)	437479	AAVID THERMALLOY
U2	Controller	NCP1653	ON Semiconductor

Vendors Contacts

Vendor	Contact	Product Information
CoilCraft		www.coilcraft.com
microSpire		www.microspire.com
TDK	Info@tdk.de	www.tdk.co.jp/tetop01/
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