NCP1605FORWGEVB

NCP1605 152 W Forward Evaluation Board User's Manual

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EVAL BOARD USER'S MANUAL

Introduction

When associated to forward or half−bridge converters taking advantage of a narrow input voltage range, the PFC stage should be designed to start first and to remain active as long as the power supply is plugged in. More specifically, the downstream converter turns on and operates while the output of the PFC stage is nominal. In other words, the PFC must be the master.

The NCP1605 is a Power Factor Controller especially designed to meet these requirements.

This driver features a "pfcOK" pin to enable the downstream converter when the PFC stage is ready for operation. Practically, it is in high state when the output voltage of the PFC stage is within regulation and low otherwise (fault or startup condition). In addition, the PFC stage having to remain active in light load conditions, the NCP1605 integrates the skip cycle capability to lower the standby losses to a minimum. For more information on this device, please refer to the datasheet at (http://www.onsemi.com/PowerSolutions/product.do?id=NCP1605).

Application Note AND8281 available at: (http://www.onsemi.com/pub/Collateral/AND8281−D.PDF) gives the main dimensioning criteria/equations for a NCP1605 driven application. For the sake of clarity, this process is illustrated in the following practical application:

- AC line range: 90 V up to 265 V
- Output Voltage: 19 V/8 A
- IEC61000−3−2 Class D compliant

The goal of this user's manual is to give more information on the practical implementation of this application and to present the performance of the solution.

The power supply consists of two stages:

- A PFC pre−converter that provides the main converter with a stable 390 Vdc input voltage
- The main conversion stage that is a 2−switch forward operating at 133 kHz

The 2−switch forward is driven by the NCP1217A.

Housed in a SOIC−7 or PDIP−7 package, the NCP1217A eases the design of modern ac−dc adapters and offers a true alternative to UC384X−based designs. This circuit is ideal for 2−switch forward converters. It limits the duty−cycle below 50% and its current mode control topology provides an excellent input audio susceptibility and inherent pulse−by−pulse control.

In addition, when the current set point falls below a given value; e.g., when the output power demand diminishes, the IC automatically enters the so−called skip cycle mode and provides high efficiency at light loads. Because this occurs at a user adjustable low peak current, no acoustic noise takes place. For more information, please refer to http://www.onsemi.com/PowerSolutions/product.do?id=NCP1217A.

Figure 1. The Board

October, 2012 − Rev. 1

Publication Order Number:
EVBUM2151/D

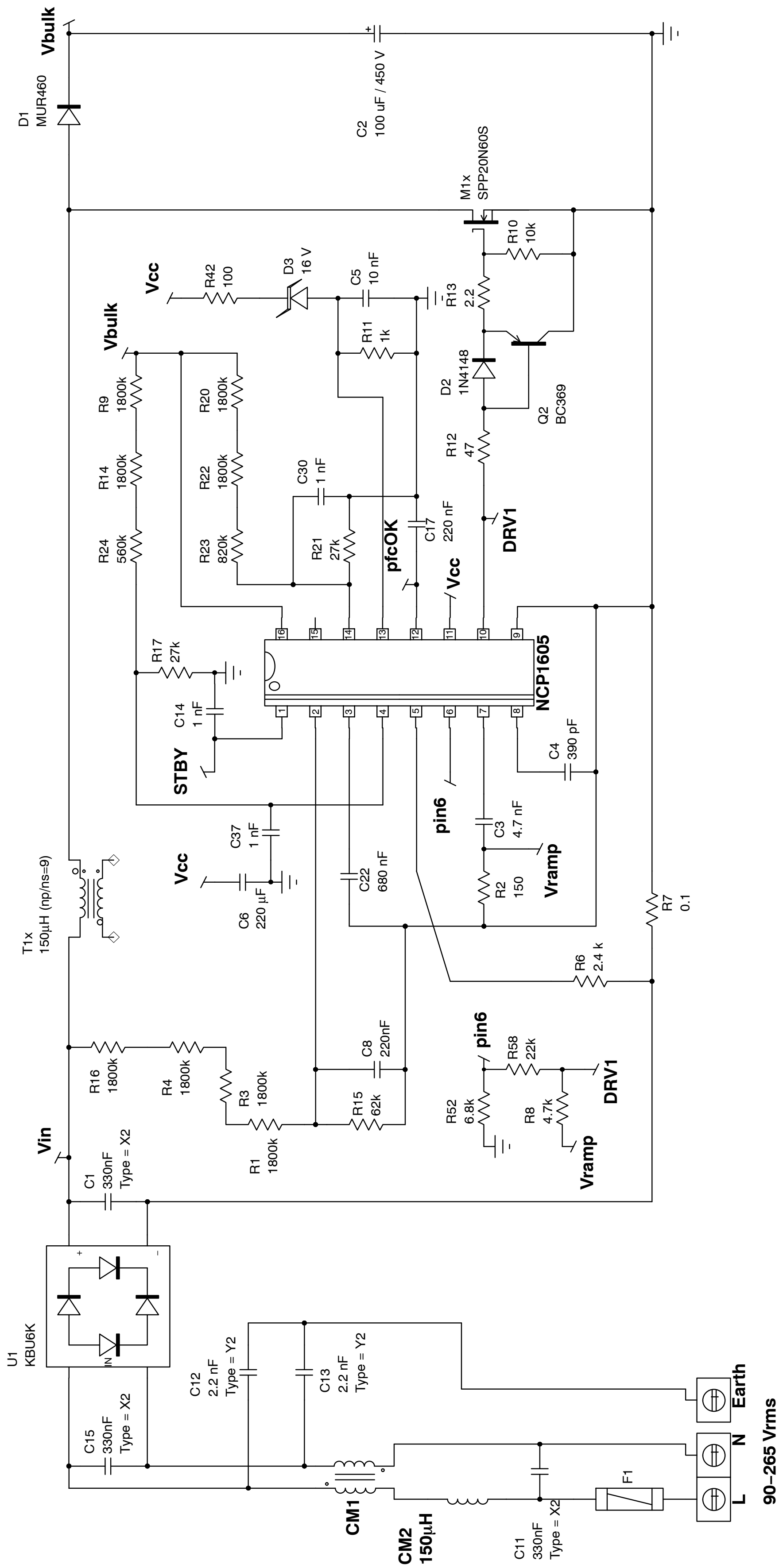
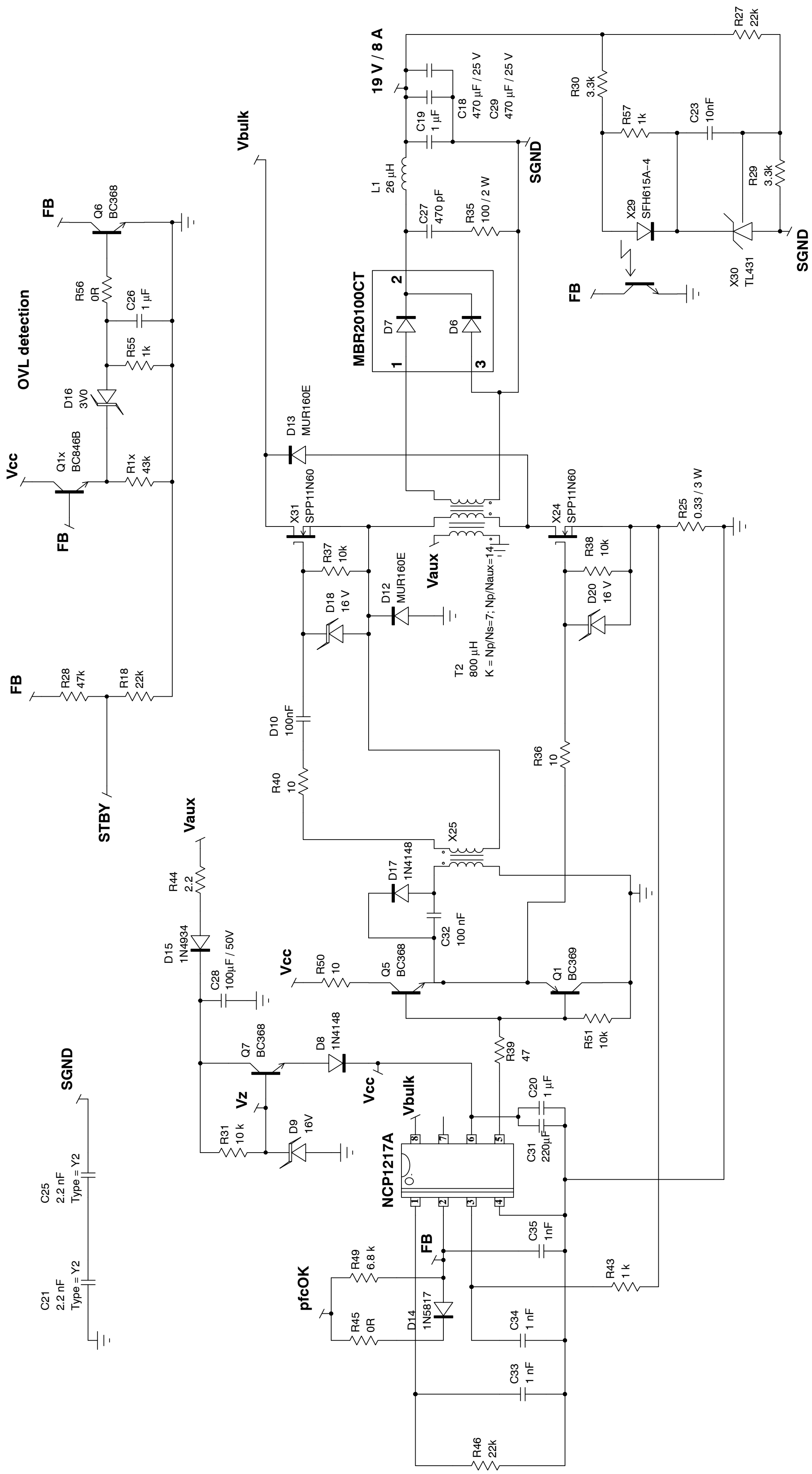


Figure 2. NCP1605 Forward Evaluation Board Schematic – PFC Stage



Note: the board is designed to also give the possibility to have the two MOSFETs of the 2-switch forward converter driven through a transformer. Some components (diodes D11, D19 and D21) that are necessary for this option, are useless in the presented version where only the high-side one is controlled through a transformer. They are short circuited in the board and, hence, they are not visible in this schematic.

Figure 3. Evaluation Board Schematic − 2 Switch Forward Converter

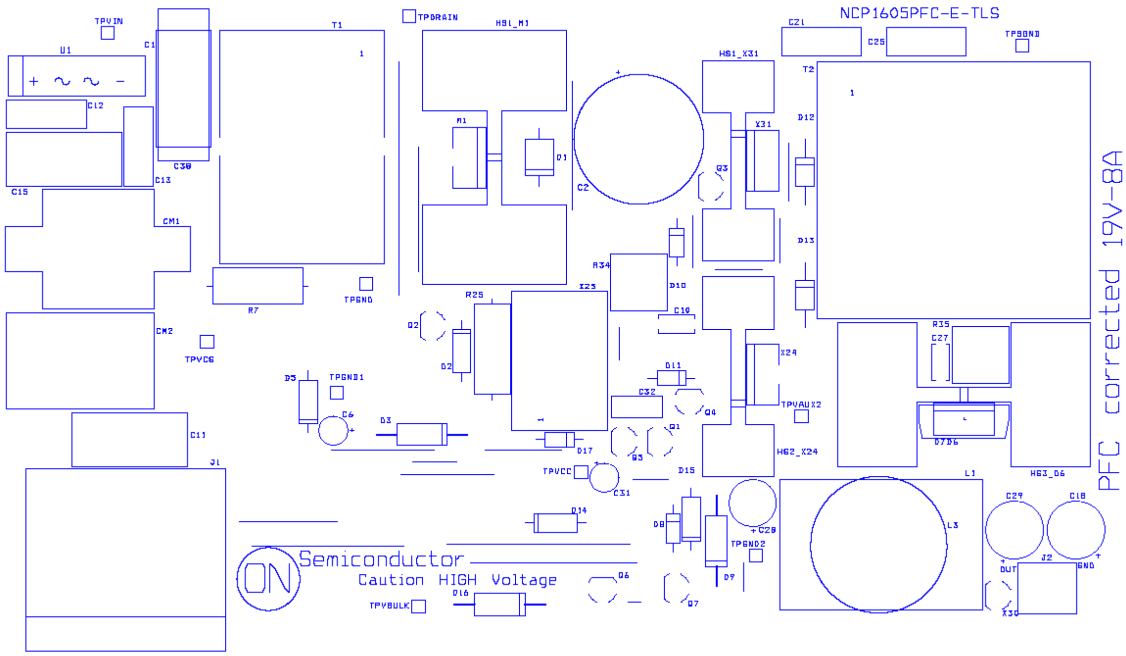


Figure 4. PCB Layout − Silkscreen Top

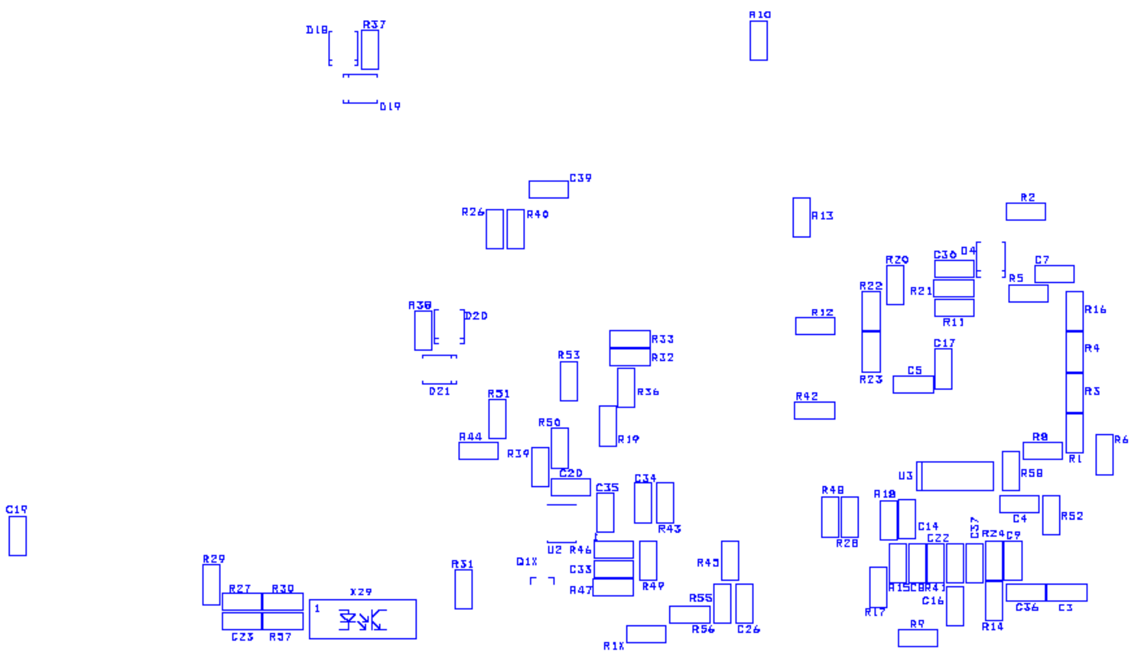


Figure 5. PCB Layout − Silkscreen Bottom

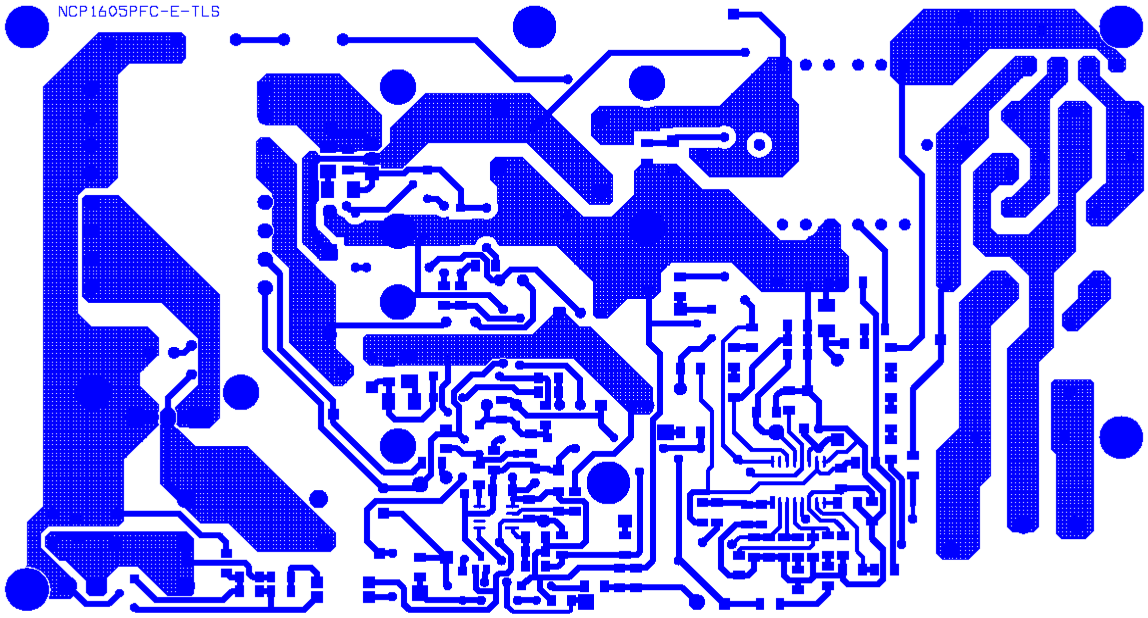
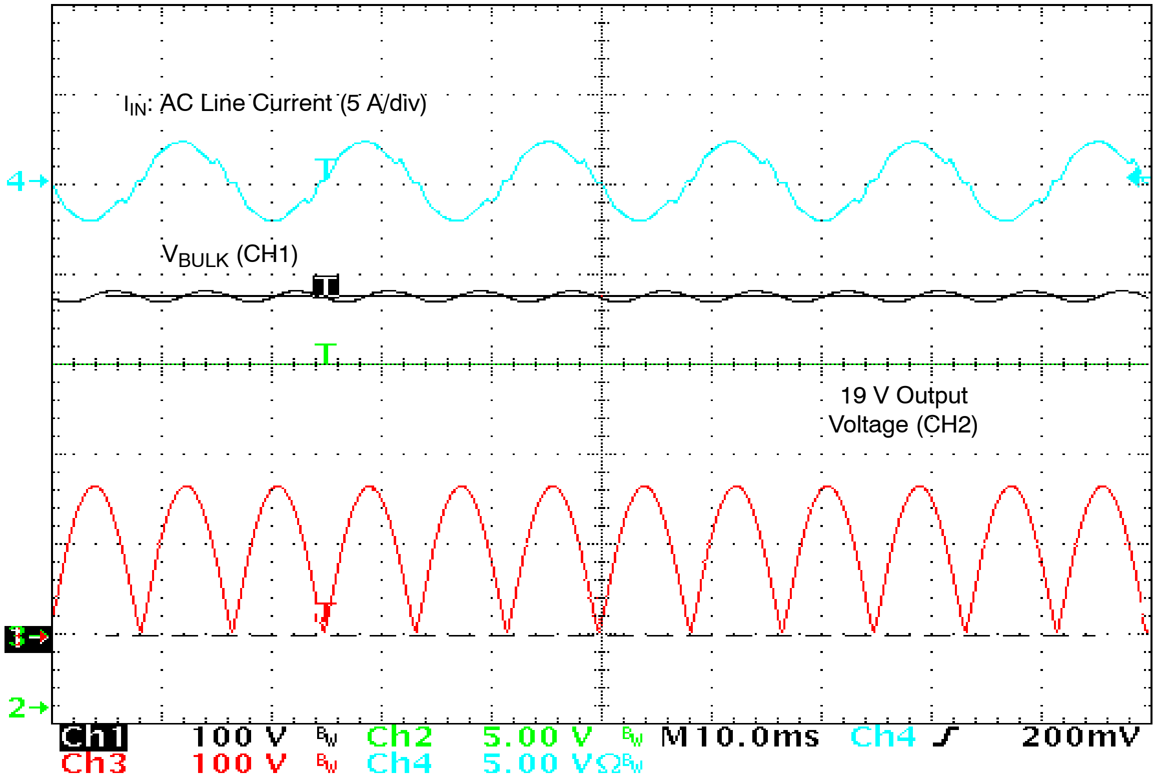
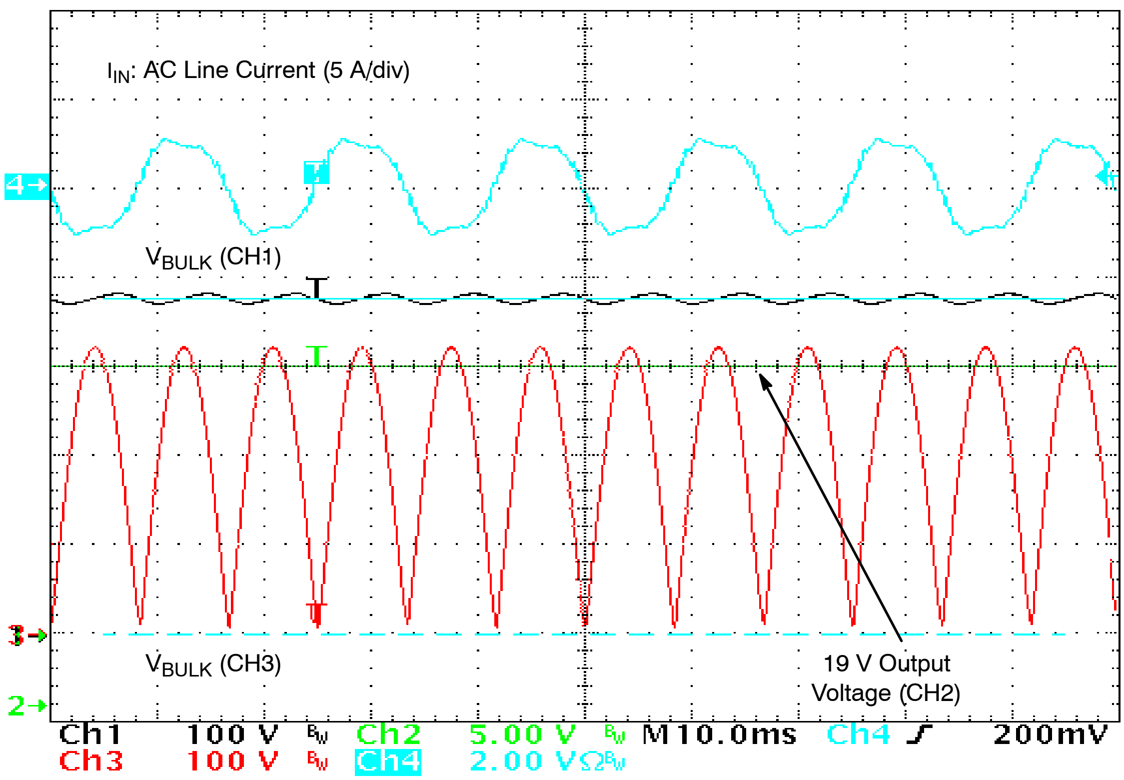


Figure 6. PCB Layout − Bottom Layer



$V_{IN,RMS}$ = 120 V, Pin = 183 W, I_{OUT} = 8 A, PF = 0.992, THD = 10%



$V_{IN,RMS}$ = 230 V, Pin = 177 W, I_{OUT} = 8 A, PF = 0.976, THD = 17%

Figure 7. General Behavior – Typical Waveforms

Table 1. POWER FACTOR AND EFFICIENCY

$V_{IN, RMS}$	$P_{IN, AVG}$	PF	THD	V_{BULK}	V_{OUT} (19 V)	V_{OUT} (19 V)	Efficiency
(V)	(W)	(–)	(%)	(V)	(V)	(A)	(%)
90	28.2	0.966	24	381	19.23	1.00	68.2
90	70.5	0.991	13	381	19.23	3.00	81.8
90	114.5	0.995	9	381	19.23	5.00	84.0
90	183.2	0.990	13	363	19.23	8.00	83.9
120	27.7	0.961	20	381	19.23	1.00	69.4
120	70.3	0.987	13	381	19.23	3.00	81.1
120	113.2	0.992	11	381	19.23	5.00	83.9
120	180.3	0.997	10	381	19.23	8.00	85.3
230	28.0	0.806	28	381	19.23	1.00	68.7
230	69.2	0.940	20	381	19.23	3.00	83.4
230	112.0	0.966	18	381	19.23	5.00	85.8
230	177.4	0.976	17	381	19.23	8.00	86.7
265	27.8	0.696	52	389	19.23	1.00	69.2
265	68.6	0.901	26	381	19.23	3.00	84.1
265	111.9	0.950	21	381	19.23	5.00	85.9
265	176.9	0.950	28	381	19.23	8.00	86.9

*At full load, the efficiency remains above 83.9%.

Startup Sequencing at 120 Vrms and I_{OUT} = 8 A

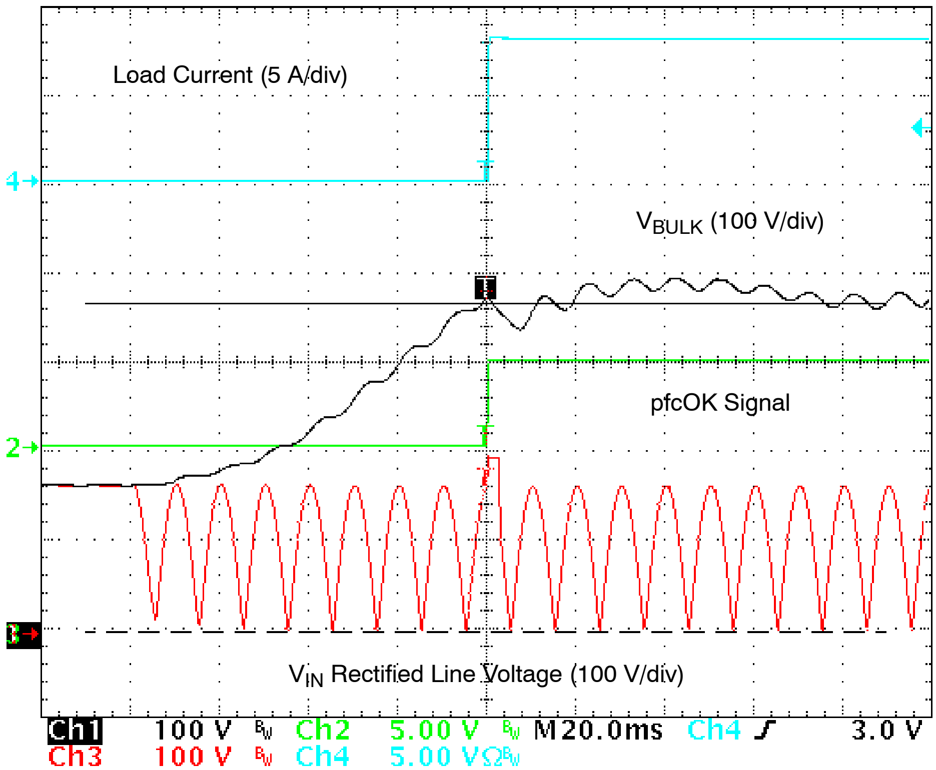


Figure 8. Startup Phase at 120 Vrms and I_{OUT} = 8 A

When the PFC output voltage (V_{BULK}) reaches its nominal voltage (about 382 V), the circuit detects the end of the startup phase. The «pfcOK» pin turns high allowing the downstream converter operation.

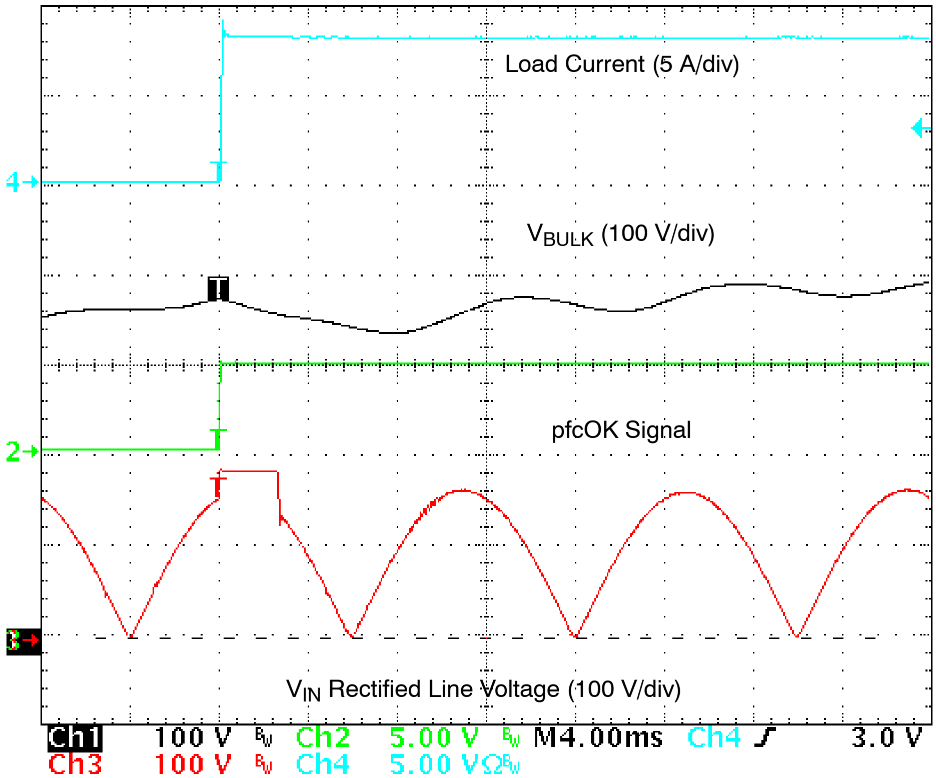


Figure 9. Zoom of the Precedent Plot

We can note some skipping sequence that takes place after «pfcOK» has turned high. This is because the NCP1605 standby management block is controlled by the feedback signal of the main converter. The PFC stage recovers activity as soon as V_{BULK} has dropped below 95.5% of its nominal level. This behavior avoids any overshoot during the startup sequence from occurring.

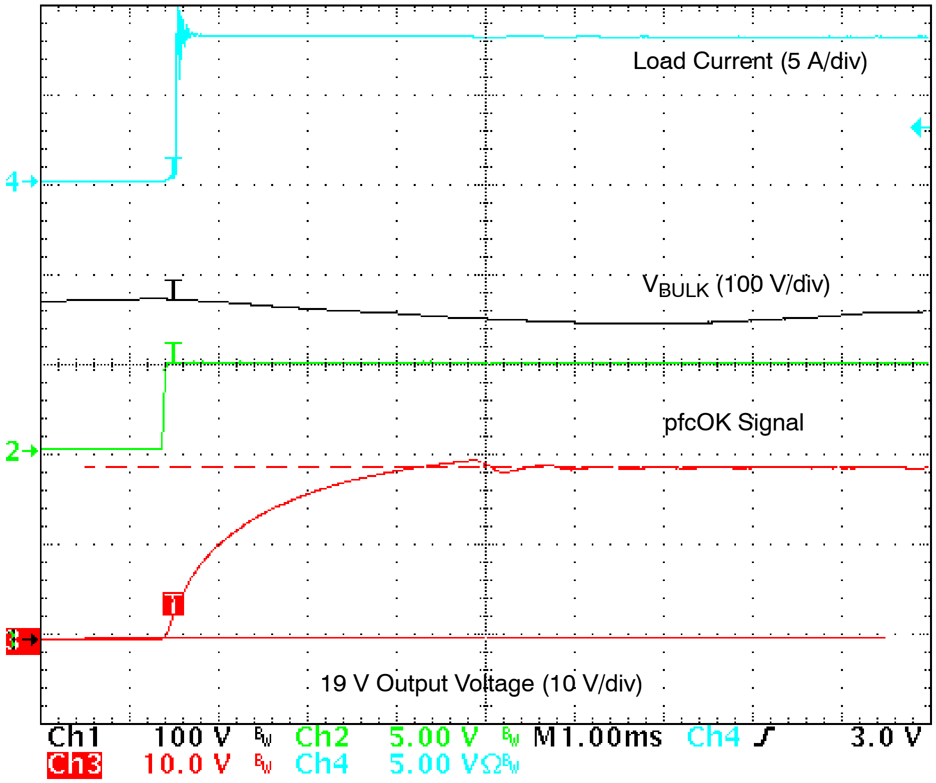


Figure 10. Startup Phase at 120 Vrms

Compared to the precedent one, Figure 10 further shows the 19 V output.

Overload / Short Circuit Protections

The application embeds a circuitry (see Figure 13) to detect overload conditions. A buffer (Q1x) builds a low impedance signal that is linearly dependent of the feedback pin of the forward controller. The OVL circuitry monitors this voltage and if it exceeds 3 V, the npn transistor Q3 turns on and disables the discrete regulator that powers the two controllers.

This circuitry protects the circuit in case of short circuit on the 19 V output. In this situation, the power supply enters a low duty−cycle, safe hiccup mode as shown by Figure 11. Figure 12 that zooms Figure 11 shows that the circuit operates over about 130 ms on a 3 s hiccup period (4% duty−cycle).

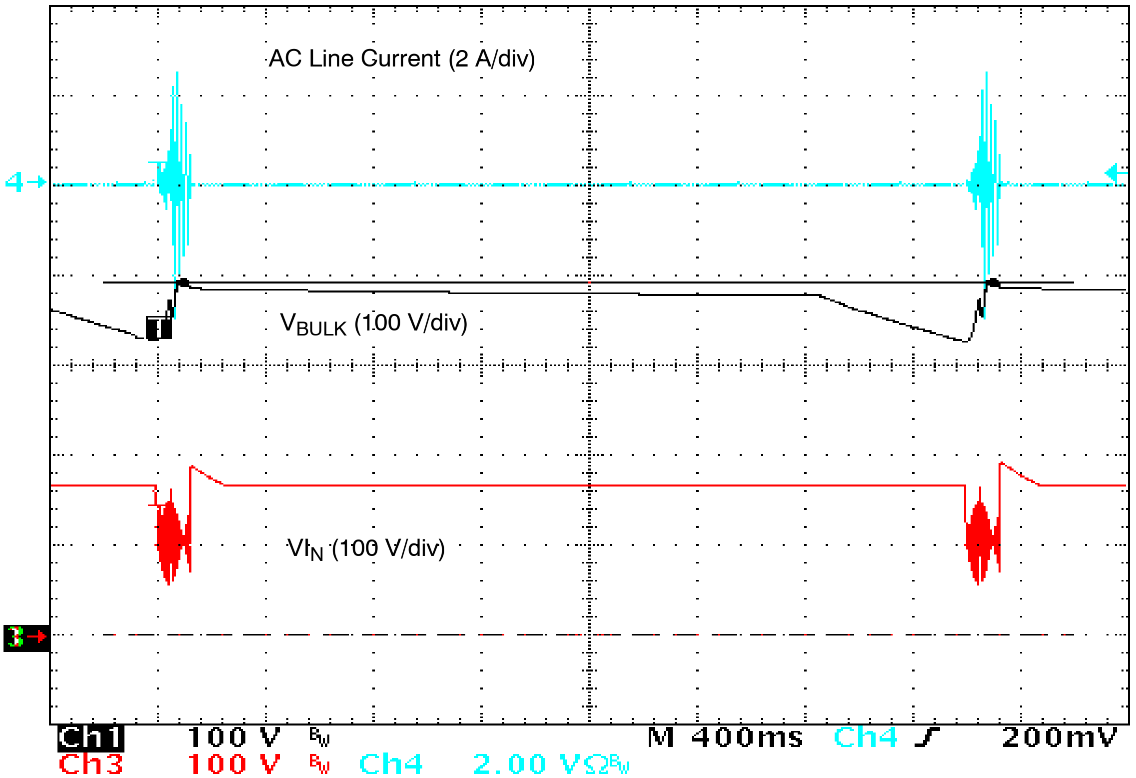


Figure 11. The Circuit Enters a Safe Low Duty−Cycle Hiccup Mode if the 19 V Output is Short Circuited (Test Made at 120 V_{RMS})

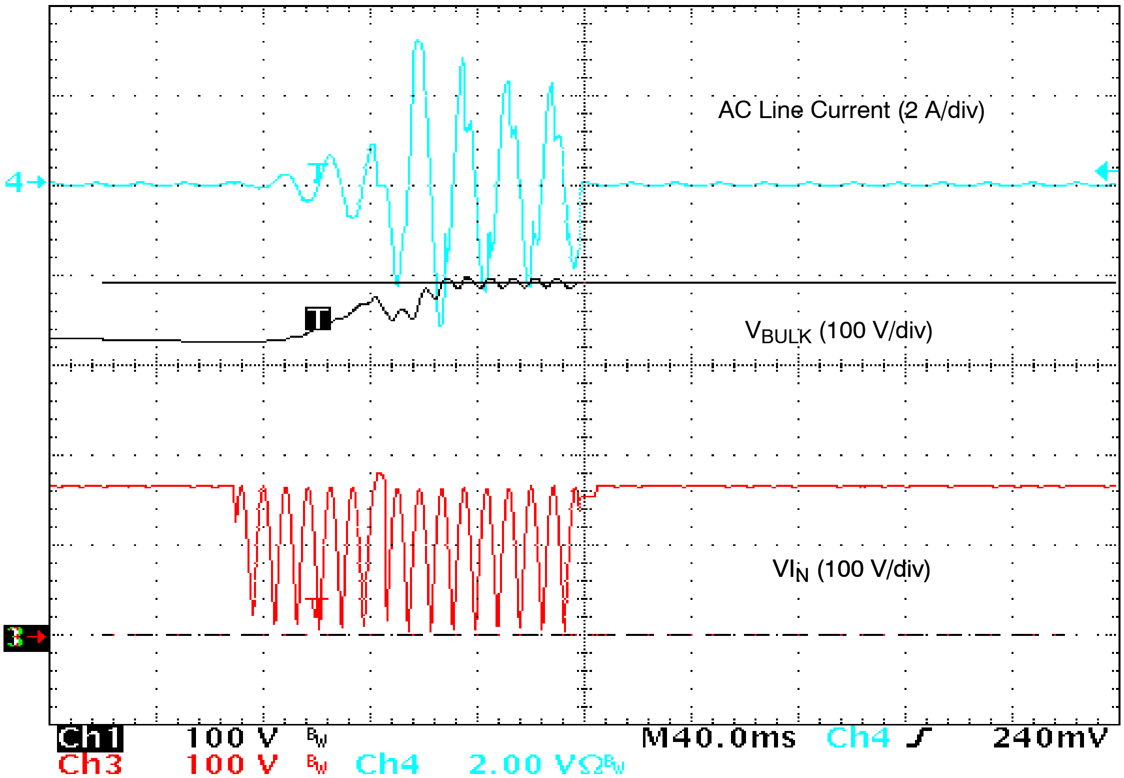


Figure 12. Zoom of the Precedent Plot

More generally, this protection triggers when the load current (I_{OUT}) is excessive. The following thresholds were measured:

Table 2.

$V_{IN, RMS}$	(V)	90	110	180	230	265
I_{OUT}	(A)	10.0	11.3	11.2	11.2	11.2

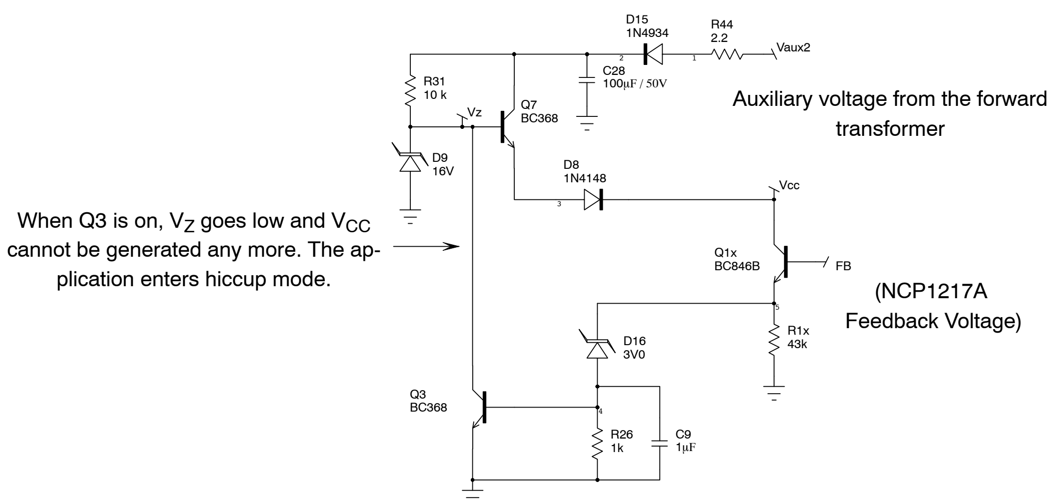


Figure 13. Circuit for Overload Protection

Protection of the PFC Stages

The NCP1605 protection features allow the design of very rugged PFC stages:

- The following brownout detection levels were measured (the 19 V output being loaded by a 5 A current):
  - Minimum line RMS voltage to start operation: 83 V.
  - RMS line voltage being which the system stops operation: 74 V.
- As shown by Figure 14, the line current is limited to 3.2 A. This corresponds to proper expected level with R_{OCP} = 2.4 kΩ:

$$\left(I_{LINE,MAX}\right) = \frac{R_{OCP} \cdot I_{REF}}{2 \cdot R_{SENSE}} = \frac{2.4\ k \cdot 250\ \mu A}{2 \cdot 0.1} = 3\ A$$

- Pin 14 monitors a portion of the output voltage and stops the circuit switching as long as the pin14 voltage exceeds 2.5 V. This overvoltage protection (OVP) guarantees that the bulk voltage cannot exceed the set OVP level (about 410 V here).
- The undervoltage that is also attached to pin 14, detects if the OVP pin is accidentally grounded or if one of the upper resistors is not correctly connected and prevents the circuit operation in case of such a fault. Ultimately, this protection avoids the power supply destruction if there is a failure in the OVP sensing network.
- Shut−down: if more than 2.5 V are applied to pin 13, the circuit latches off and cannot recover operation until the SMPS is unplugged (to enable the NCP1605 V_{CC} voltage to drop below its 4 V reset voltage). This latchoff capability is supposed to trigger in case of a major fault like any overheating of the SMPS. In this application, it is used to disable the power supply in case of a severe runaway of the V_{CC} voltage. This is simply made by applying the V_{CC} voltage through a 16 V zener diode (D3) so that if (V_{CC}−16 V) exceeds 2.5 V, the circuit latches off (see Figure 2). R11 adjusts the biasing current through D3 and together with R42 and C5, this resistor avoids that the protection falsely triggers due to some noise. R42 is chosen small compared to R11 not to modify the threshold since the actual voltage applied to pin 13 is:

$$\frac{R11}{R11 + R42} \cdot (V_{CC} - V_{D3}),$$

which is closed to

$$(V_{CC} - 16\ V)$$

if R42 is small compared to R11 and if D3 is properly biased.

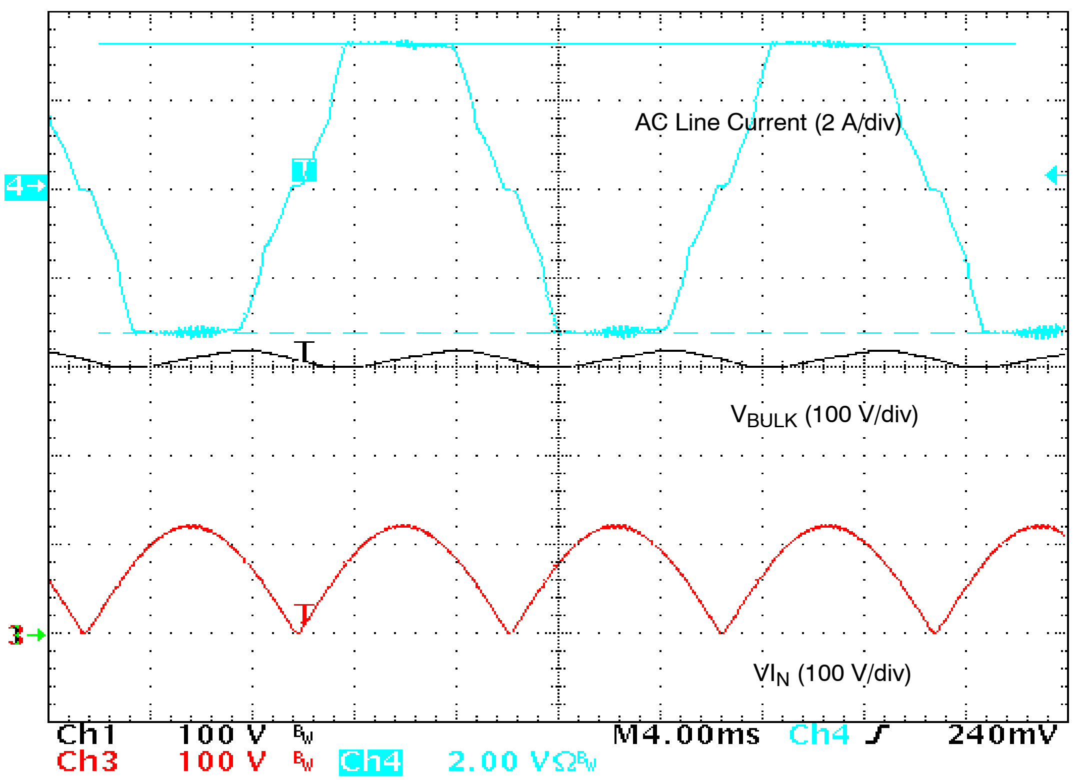


Figure 14. Action of the Overcurrent Limitation (This Test was Made by Creating an Overload Condition at 90 Vrms).

Dynamic Performance

The following plots were obtained by varying I_{OUT} from 2 A to 8 A (slope 2 A/µs) at 120 Vrms.

One can note that thanks to the NCP1605 dynamic response enhancer, the bulk voltage stays largely above 350 V while the load current suddenly increases from 25% to full load (see Figure 16).

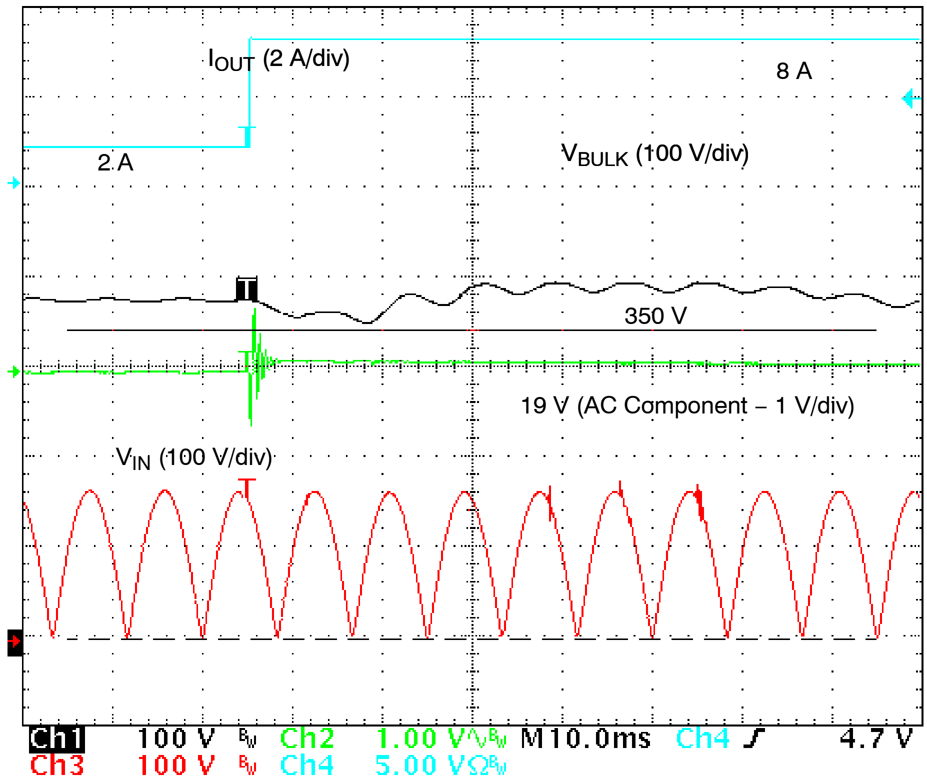


Figure 15. Abrupt Load Increase at 120 Vrms

Another interesting behavior is the absence of overshoot on V_{BULK} when the load current suddenly drops. The PFC stage takes benefit from the fast response of the 2−switch forward feedback voltage (FB). More specifically, an abrupt load decrease results in a rapid drop of the FB voltage. If this signal that controls the NCP1605 skip mode activity drops to a level that is low enough, the PFC stage skips cycles until the bulk voltage reaches 95.5% of its nominal value. This skipping period (see the V_{BULK} decay period from 381 V down to 360 V in Figure 11) avoids any overshoot and helps provide the 2−switch forward with a narrow input voltage.

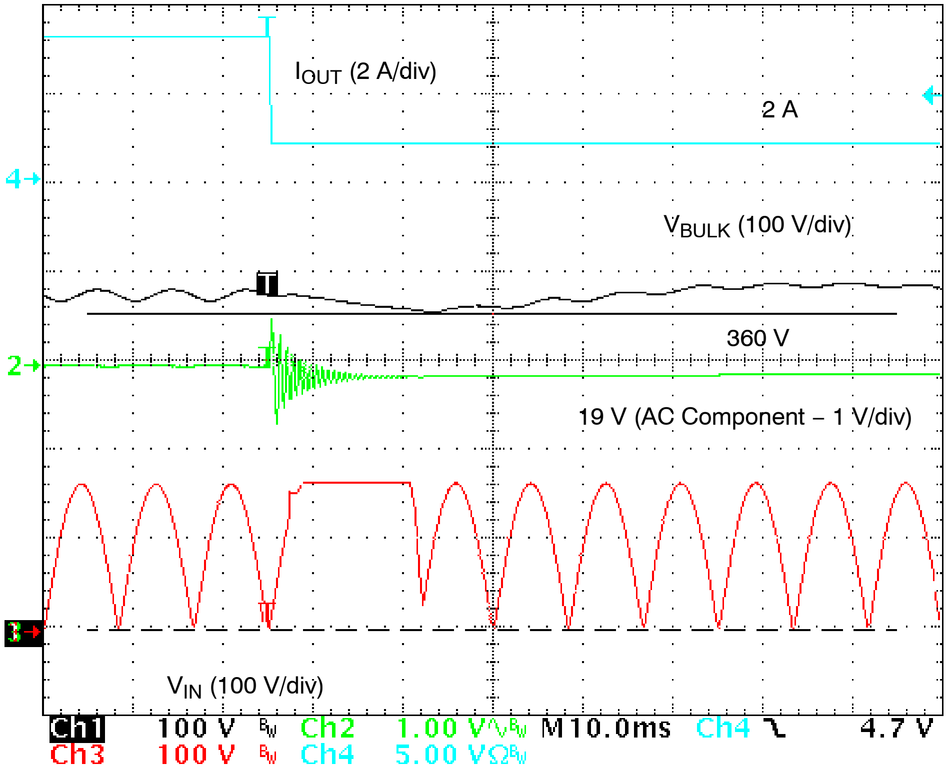


Figure 16. Abrupt Load Decrease at 120 Vrms

Standby Performance

In light load conditions, the circuit enters skip mode to reduce the losses (the PFC stage remaining on in stand−by to keep on providing the 2−switch forward with its nominal input voltage).

Table 3.

V_{ac}	(V)	90	110
$P_{IN, AVG}$ (No Load)	(mW)	425	450

*These values were obtained by measuring Wh during 2 mn with a power meter YOKOGAWA WT210 at I_{OUT} = 0.

One can note that among the measured losses, about 80 mW are due to the two V_{BULK} sensing networks (one for feedback, another one for OVP). We could then improve these results if only one sensing network was used and/or if the leakage current of these sensing networks was lowered by using higher impedance resistors dividers.

The PFC stage enters skip mode when the load current drops below 0.5 A.

The following figures show the V_{BULK} voltage in standby mode at low and high line. We can see that as explained in the data sheet, the NCP1605 skips operation until V_{BULK} reaches 95.5% of its nominal level and then recovers operation. Practically, V_{BULK} oscillates between about 380 and 360 V.

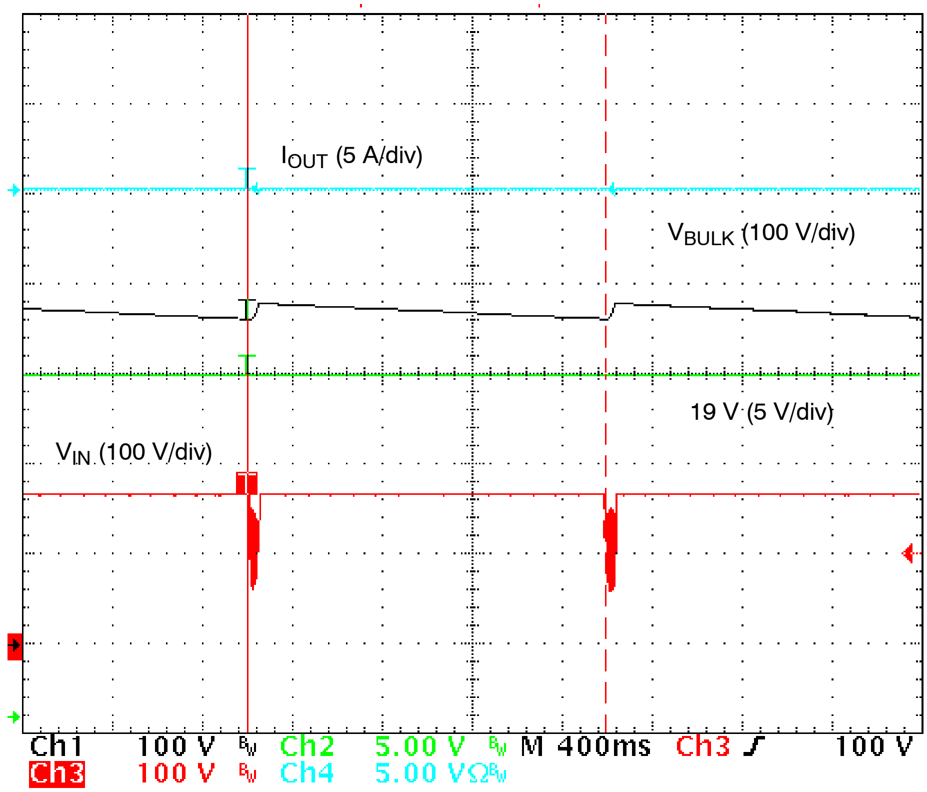


Figure 17. Skip Mode Operation of the PFC Stage at 120 Vrms, No Load. The Skip Mode Period is About 1.5 s.

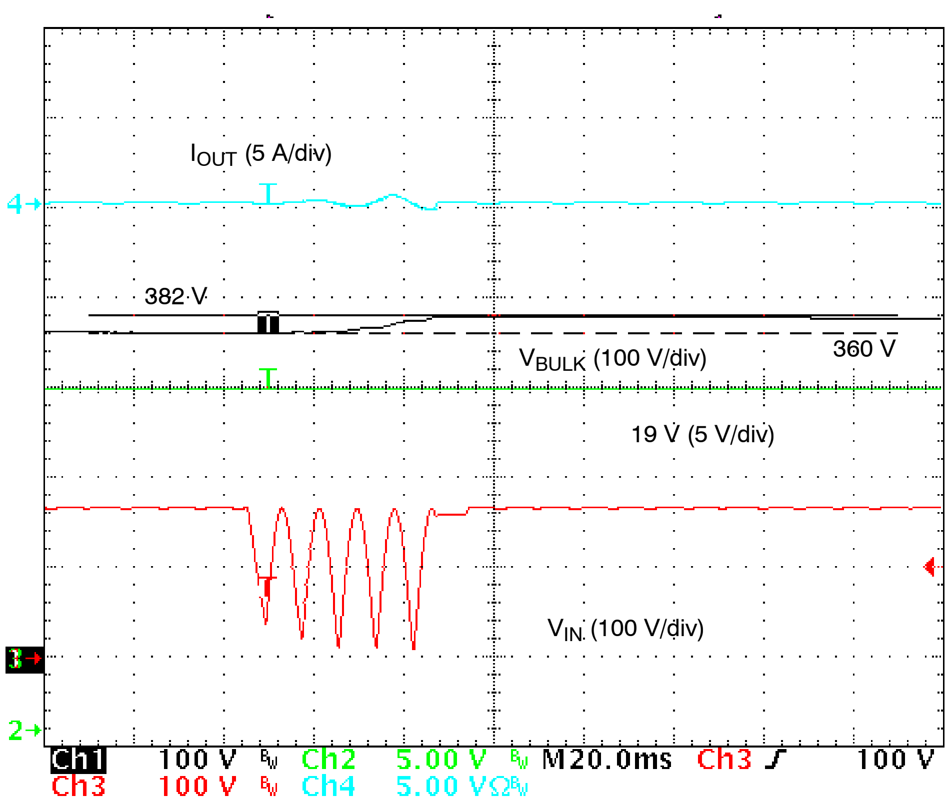


Figure 18. Zoom of the Precedent Plot

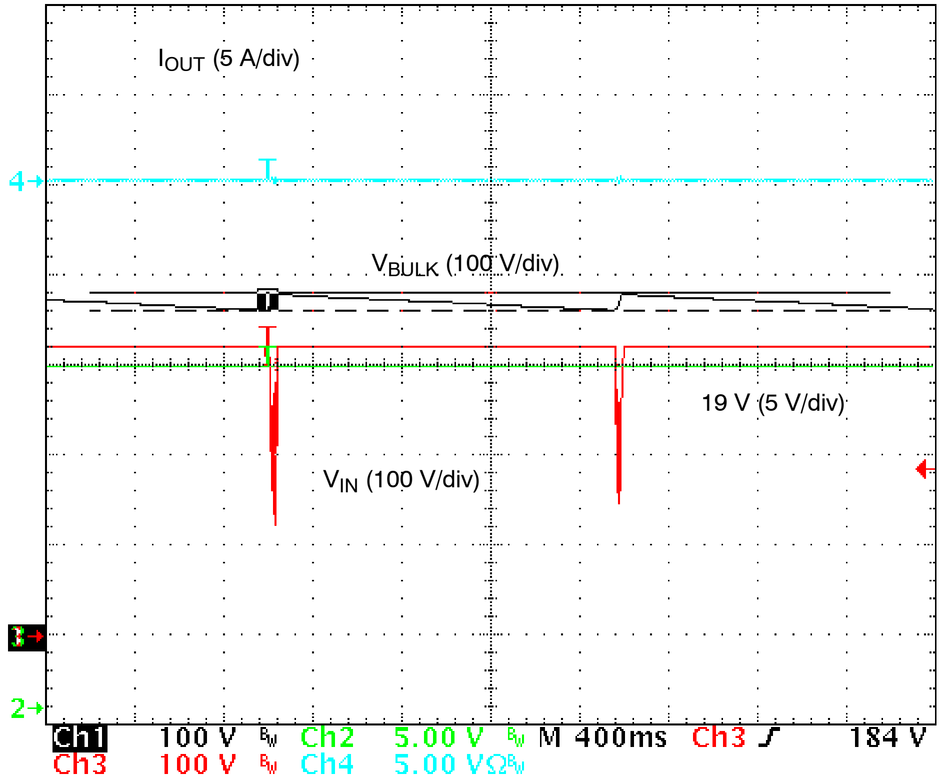


Figure 19. Skip Mode Operation of the PFC Stage at 230 Vrms, No Load

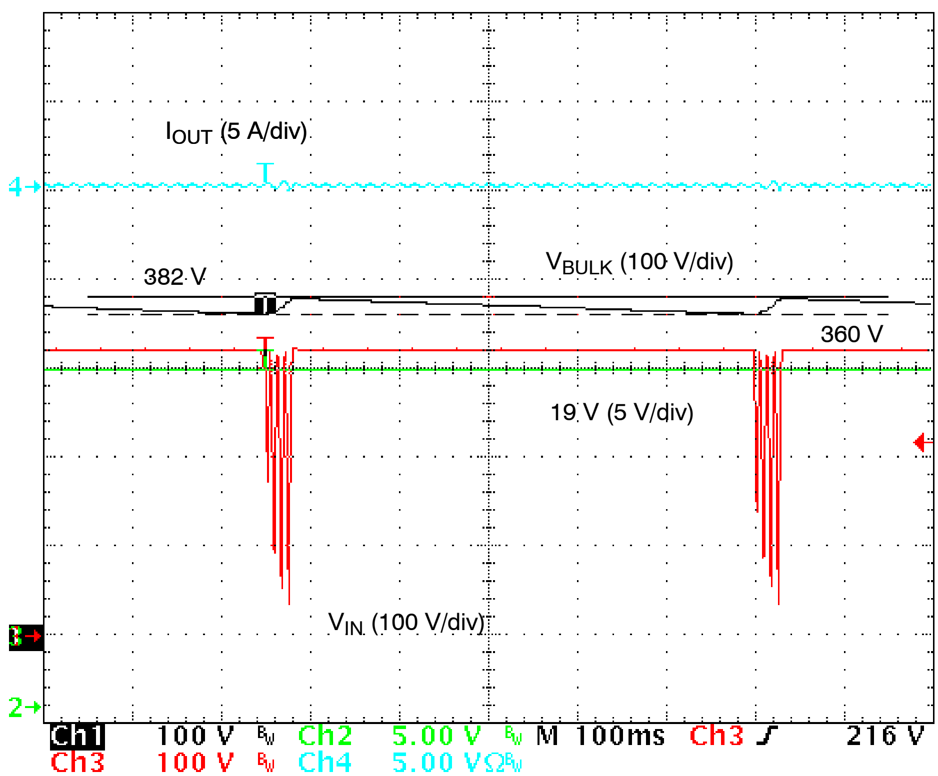


Figure 20. Zoom of the Precedent Plot

Thermal Measurements

The following results were obtained using a thermal camera, after a 2.5 h operation at 25°C ambient temperature. These data are indicative.

Table 4.

PFC Stage

Power MOSFET	Bulk Capacitor	Current Sense Resistor	Coil	Input Bridge
85°C	65°C	85°C	75°C	110°C

2−Switch Forward Stage

Power MOSFETs	Transformer	Output Capacitor	Output Coil	Output Diodes (MBR20100)
90°C (Low−Side) 85°C (High−Side)	75°C	55°C	100°C	110°C

*Measurement Conditions: Low line (90 Vrms), full load (I_{OUT} = 8 A).

Table 5. BILL OF MATERIALS FOR THE NCP1605FORWGEVB EVALUATION BOARD

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
CM1	1	Choke, Com Mode	2 x 6.8 mH / 3.2 A	50% / -30%	Through Hole	EPCOS	B82734-R2322-B30	No	Yes
CM2	1	DM Choke	WE-FI series - 150 μH / 5 A	±20%	Through Hole	Wurth Electronik	7447055	No	Yes
C1, C11, C15	3	X2 Capacitor	330 nF / X2	±20%	Through Hole	RIFA	PHE840MY6330M	Yes	Yes
C2	1	Bulk Capacitor	100 μF / 450 V / 105°C	±20%	Through Hole	Vishay	222215937101	Yes	Yes
C3	1	CMS Capacitor	4.7 nF	±5%	1206	Kemet	C1206C472J5GAC	Yes	Yes
C4	1	CMS Capacitor	390 pF	±10%	1206	Kemet	C1206C391K5GAC-TU	Yes	Yes
C8, C17	2	CMS Capacitor	220 nF	±10%	1206	Kemet	C1206F224K5RAC	Yes	Yes
C6, C31	2	Electrolytic Capacitor	220 μF / 25 V	±20%	Through Hole	Rubycon	25YXF220M8X11.5	Yes	Yes
C14, C33, C34, C35, C30, C37	6	CMS Capacitor	1 nF	±10%	1206	AVX	12065C102KAT2A	Yes	Yes
C27	1	Capacitor	470 pF / 100 V	±5%	Through Hole	AVX	SR211A471JTR	Yes	Yes
C21, C25, C12, C13	4	X1/Y2 Capacitor	4.7 nF / X1/Y2	±20%	Through Hole	muRata	DE2E3KH472MA3B	No	Yes
C18, C29	2	Electrolytic Capacitor	470 uF / 25 V	±20%	Through Hole	Nichicon	UPM1E471MPD	Yes	Yes
C19, C20, C26	3	CMS Capacitor	1 uF	±10%	1206	AVX	1206YC105KAT2A	Yes	Yes
C22	1	CMS Capacitor	680 nF	±10%	1206	Kemet	C1206C684K5RAC	Yes	Yes
C5, C23	2	CMS Capacitor	10 nF	±5%	1206	muRata	GRM3195C1H103JA01D	Yes	Yes
C28	1	Electrolytic Capacitor	100 μF / 50 V	±20%	Through Hole	Rubycon	50RX30100MEFG10X12.5	Yes	Yes
C32	1	Capacitor	100 nF	±10%	Through Hole	Epcos	B37987F1104K	Yes	Yes
C39	1	CMS Capacitor	100 nF	±10%	1206	Kemet	C1206F104K1RAC	Yes	Yes
D1	1	PFC Diode	MUR460RLG	-	Through Hole	ON Semiconductor	MUR460RLG	No	Yes
D2, D8, D17	3	DO-35 Diode	1N4148	-	DO-35	Philips	1N4148	Yes	Yes

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Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
D14	1	Schottky Diode	1N5817RLG	-	Axial Lead	ON Semiconductor	1N5817RLG	No	Yes
D3, D9	2	16 V Zener Diode	1N5930BRLG	-	Axial Lead	ON Semiconductor	1N5930BRLG	No	Yes
D18, D20	2	16 V Zener Diode	1SMA5930BT3G	-	SMA	ON Semiconductor	1SMA5930BT3G	No	Yes
D16	1	3V0 Zener Diode	BZX79-C3V0	-	DO-35	Philips	BZX79-C3V0	Yes	Yes
D6, D7	2	Dual Schottky Diode	MBR20100CTG	-	TO220	ON Semiconductor	MBR20100CTG	No	Yes
D12, D13	2	Demagnetization Diodes	MUR160RLG	-	Axial Lead	ON Semiconductor	MUR160RLG	No	Yes
D15	1	Rectifier	1N4934RLG	-	Axial Lead	ON Semiconductor	1N4934RLG	No	Yes
HS1_M1, HS3_D6	2	Heatsink	KL195/25.4SW	-	-	Fischer Elektronik	SK 104 25,4 STS TO 220	Yes	Yes
HS1_X31, HS2_X24	2	Heatsink	KL194/25.4SW	-	-	Fischer Elektronik	SK 129 25,4 STS TO 220	Yes	Yes
L1	1	DMT2-26-11L	26 μH power choke	-	Through Hole	CoilCraft	DMT2-26-11L	No	Yes
M1	1	PFC MOSFET	SPP20N60S5	-	TO220	Infineon	SPP20N60S5	Yes	Yes
Q1, Q2	2	PNP Transistor	BC369	-	TO92	ON Semiconductor	BC369ZL1G	No	Yes
Q1x	1	NPN Transistor	BC846B	-	SOT23	ON Semiconductor	BC846BDW1T1G	No	Yes
Q5, Q6, Q7	3	NPN Transistor	BC368	-	TO92	ON Semiconductor	BC368G	No	Yes
R1, R3, R4, R9, R14, R16, R20, R22	8	1%, 1/4 W Resistors	1.8 MΩ	±1%	1206	Phycomp	232272461805	Yes	Yes
R2	1	1%, 1/4 W Resistors	150 Ω	±1%	1206	Vishay	RCA1206150RFKEA	Yes	Yes
R12, R39	2	1%, 1/4 W Resistors	47 Ω	±1%	1206	Vishay	RCA120647R0FKEA	Yes	Yes
R6	1	1%, 1/4 W Resistors	2.4 kΩ	±1%	1206	Vishay	RCA12062K40FKEA	Yes	Yes
R7	1	3 W PFC CS Resistor	0R1 / 3W	±1%	Axial Lead	Vishay	LVR-3 .1 1% E70 E3	Yes	Yes
R8	1	1%, 1/4 W Resistors	4.7 kΩ	±1%	1206	Vishay	RCA12064K70FKEA	Yes	Yes
R10, R31, R37, R38, R51	5	1%, 1/4 W Resistors	10 kΩ	±1%	1206	Vishay	RCA120610K0FKEA	Yes	Yes
R13, R44	2	1%, 1/4 W Resistors	2.2 Ω	±1%	1206	Vishay	RCA12062K20FKEA	Yes	Yes
R15	1	1%, 1/4 W Resistors	62 kΩ	±1%	1206	Vishay	RCA120662K0FKEA	Yes	Yes
R17, R21	2	1%, 1/4 W Resistors	27 kΩ	±1%	1206	Vishay	RCA120627K0FKEA	Yes	Yes
R49	1	1%, 1/4 W Resistors	6.8 kΩ	±1%	1206	Vishay	RCA12066K80FKEA	Yes	Yes
R18, R27, R46, R58	4	1%, 1/4 W Resistors	22 kΩ	±1%	1206	Vishay	RCA120622K0FKEA	Yes	Yes
R23	1	1%, 1/4 W Resistors	820 kΩ	±1%	1206	Vishay	RCA1206820KFKEA	Yes	Yes

Table 5. BILL OF MATERIALS FOR THE NCP1605FORWGEVB EVALUATION BOARD

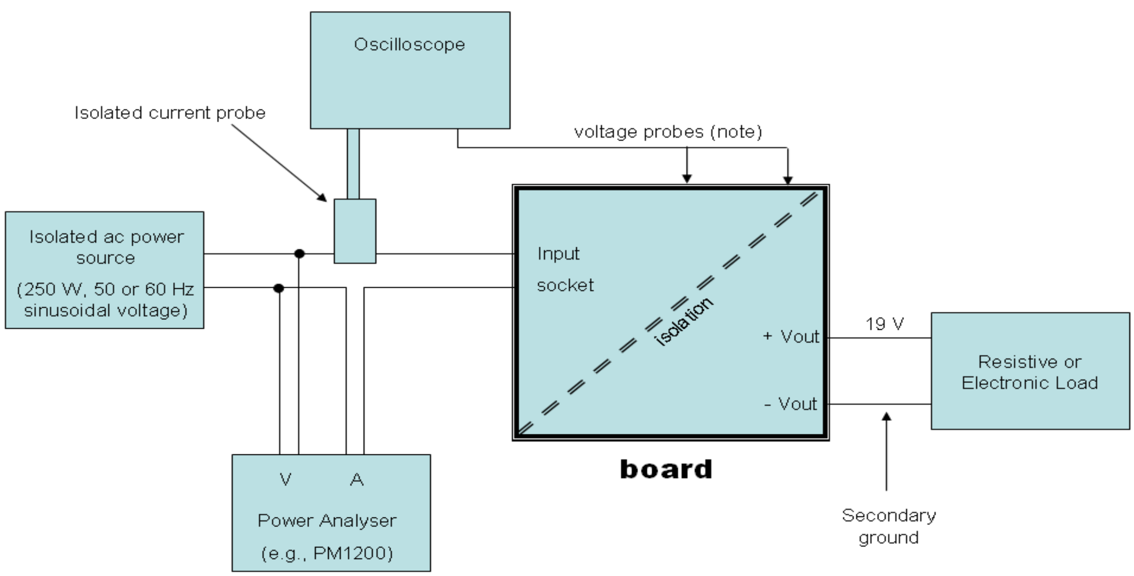
Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
R24	1	1%, 1/4 W Resistors	560 kΩ	±1%	1206	Vishay	RCA1206560KFKEA	Yes	Yes
R25	1	3 W 0.27 R Forward CS Resistor	0R27	±5%	Axial Lead	Welwyn	W31-R27 JI	Yes	Yes
R40, R50, R36	3	1%, 1/4 W Resistors	10 Ω	±1%	1206	Vishay	RCA120610K0FKEA	Yes	Yes
R28	1	1%, 1/4 W Resistors	47 kΩ	±1%	1206	Vishay	RCA120647K0FKEA	Yes	Yes
R29, R30	2	1%, 1/4 W Resistors	3.3 kΩ	±1%	1206	Vishay	RCA12063K30FKEA	Yes	Yes
R35	1	100 R / 4 W Resistor	100R / 4W	±5%	Axial Lead	Tyco Electronics	SBCHE4 100R	Yes	Yes
R11, R43, R55, R57	4	1%, 1/4 W Resistors	1 kΩ	±1%	1206	Vishay	RCA12061K00FKEA	Yes	Yes
R42	1	1%, 1/4 W Resistors	100 Ω	±1%	1206	Vishay	RCA1206100RFKEA	Yes	Yes
R52	1	1%, 1/4 W Resistors	6.8 kΩ	±1%	1206	Vishay	RCA12066K80FKEA	Yes	Yes
R1x	1	1%, 1/4 W Resistors	43 kΩ	±1%	1206	Vishay	RCA120643K0FKEA	Yes	Yes
R56, R45, R0, D19 (are replaced by straps)	4	1%, 1/4 W Resistors	0R	±1%	1206	Vishay	RCA12060R00FKEA	Yes	Yes
D21, D11 (are replaced by straps)	2	-	-	-	-	-	-	-	Yes
T1	1	PFC Coil	SICO 977	-	Through Hole	Sicoenergie	SICO 977	No	Yes
T2	1	Forward Transformer	SICO 978	-	Through Hole	Sicoenergie	SICO 978	No	Yes
U1	1	Diodes Bridge	KBU6K	-	Through Hole	General Semiconductor	KBU6K	Yes	Yes
U2	1	Forward Controller	NCP1217AD133R2G	-	SOIC-8	ON Semiconductor	NCP1217AD133R2G	No	Yes
U3	1	PFC Controller	NCP1605DR2G	-	SOIC-16	ON Semiconductor	NCP1605DR2G	No	Yes
X25	1	01:01 Pulse Transformer	Q3903-A	-	Through Hole	CoilCraft	Q3903-A	No	Yes
X29	1	Opto-Coupler	SFH6156-2	-	4-SIOC	Vishay	SFH6156-2	No	Yes
X30	1	Voltage Reference	TL431CLPG	-	TO92	ON Semiconductor	TL431CLPG	No	Yes
X24, X31	2	Forward MOSFET	SPP11N60S5	-	TO220	Infineon	SPP11N60S5	Yes	Yes
F1	1	4 A Fuse	4 A	-	5x20mm	Schurter	0001.1010	Yes	Yes
J1	1	Intlet, IEC Single Fused	Intlet Terminal Block	-	-	Schurter	GSF1.1002.41 / GSF1.1202.41	Yes	Yes
J2	1	Output Terminal Block	PM5.08/2/90	-	PM5.08/2	WeidMuller	PM5.08/2/90	Yes	Yes
Test Points	16	Test Points	Terminal, PCB Black PK100	-	1.02mm	Vero	20-2137	Yes	Yes
Insulating Kit	4	Bush, TO-220 PK10	TO-220; Voltage isolation 1 kV	-	-	Unbranded	MK3306	Yes	-

TEST PROCEDURE FOR THE NCP1605 FORWARD EVALUATION BOARD

Test Procedure

1. Apply a resistive or an active load across the output (between the “+V_{OUT}” and “-V_{OUT}” terminals of the board). This load must be able to draw 12 A from 19 V (use a 25 V or more voltage load for a safe headroom).
2. To evaluate the board performance, it is recommended to place a power analyzer able to measure:
   - The power delivered by the power source (“Pin”),
   - The power factor (“PF”) and the Total Harmonic Distortion (“THD”) of the current absorbed from the ac power source.

   As portrayed by Figure 21, this power-meter should be inserted between the power source and the board (the power source being defined in next point).
3. Plug the application to a 250 W or more, isolated ac power source. This source that is applied, is supposed to simulate the line utility. Hence, the power source voltage should be a 50 or 60 Hz sinusoid (without dc component). Its magnitude must remain below 265 Vrms.
4. You can then measure the board performance presented in ANDxxxx. Among them, we can list:
   - Apply 120 Vrms and load the output with 8 A
     1. The output voltage should be between 18.5 and 19.5 V.
     2. The power factor should be higher than 0.990
     3. The input power should be less than 190 W
   - Decrease the load current. When I_{OUT} is below 0.25 A, the PFC stage should have entered skip mode. You can check it by observing the line current that must be bursting.
   - Increase the load current until 19 V output voltage drops. The load current should be less than 12 A and the power supply should be hiccupping. Again, you can check this by observing the line current. This test must be very short to avoid any excessive heating of the board (designed for I_{OUT} = 8 A). Immediately stop the test if the power supply does not enter hiccup mode while I_{OUT} is 12 A.



Note: use as many voltage probes as needed to display the waveforms you want to observe. Please note that high-voltage ones may be necessary since the voltage across some parts of the board can be as high as 500 V (that across the power MOSFETs of both stages for instance).

Figure 21. Board Connection

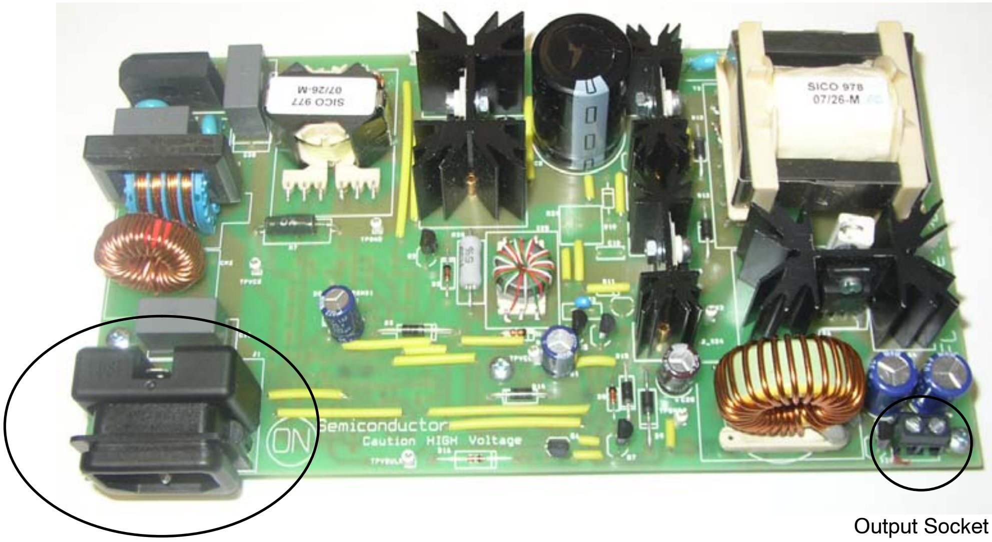


Figure 22. The Board

CAUTION:

The board contains high voltage, hot, live parts. Only persons skilled in the art of power electronics should manipulate or test it. Be very cautious when doing so. It is the responsibility of those who receive the board to take all the precautions to avoid that themselves or other people are injured by electric hazards or are victim of any other pains caused by the board.

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