TND316/D
Rev. 3, March-07

ON Semiconductor®

GreenPoint™
From ON Semiconductor

220 W LCD TV Power Supply Reference Design Featuring NCP1396 and NCP1605 Documentation

1 Overview

This reference document describes a built-and-tested, GreenPoint™ solution for an LCD TV power supply.

The reference design circuit consists of one single-sided 130 mm x 200 mm printed circuit board designed to fit into an LCD TV. Height is 25 mm.

An overview of the entire circuit is provided by Figure 1. As shown in that figure, ON Semiconductor devices are available for every block of the LCD TV power supply; and by judicious choice of design tradeoffs, optimum performance is achieved at minimum cost.

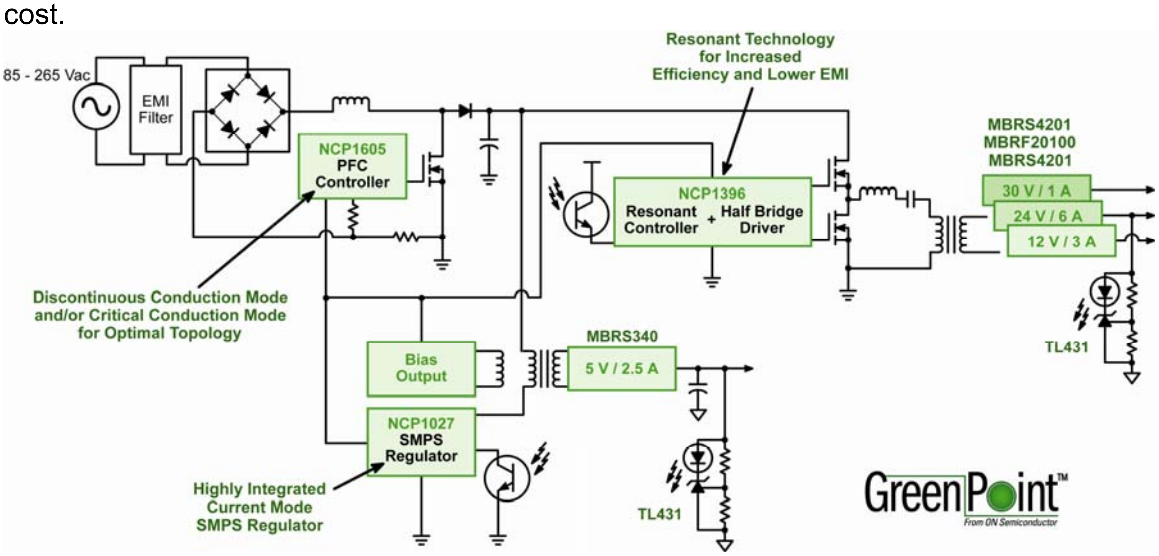


Figure 1

2 Introduction

From Tubes to Flat TVs

Since 1936 when the BBC begins the world's first public-television broadcast in London, the TV world made huge progress. A few examples:

- 1953: color broadcasting
- 1956: first VCR
- 1962: first television satellite (Telstar)
- 1981: NHK (Japan) demonstrates an HDTV system

But "the idea of sitting in front of a box in your living room is becoming obsolete. For the TV industry, technology is creating vast opportunities". – Newsweek, June 2005.

Obviously Flat Panel Display (FPD) is one of the technologies that will drive these opportunities:

- High Definition TV (HDTV).
- Digital TV: The analog TV signal will be shut down soon in Europe and in North America as it is replaced by Digital Terrestrial signal. Satellite and Cable Digital decoders are already very common.
- Bigger screen, smaller form factor: Now that we all have seen these fancy screens, who is willing to go back to the old big bulky box?

FPD includes both LCD (Liquid Crystal Display) and Plasma technologies.

3 LCD TV Power Supply Requirements

In large FPD (> 30"), the power supply is generally internal as it requires from 200 W to 600 W. A few voltages are needed to supply the different blocks such as backlighting, audio, video, demodulation, etc.

Because the input power is above 75 W, the application has to be compliant with the IEC1000-3-2 class D standard. Power Factor Correction is therefore needed. Because the main power supply has to be optimized for higher efficiency and slimmer form factor, an active PFC must be implemented to limit the variation of the input voltage in front of the main PSU.

Most of the LCD TV power supplies are designed to cope with universal mains: 85 Vac to 265 Vac, 47-63 Hz.

A 5 V auxiliary power supply is needed to supply the microcontroller that must remain alive in standby mode.

3.1 Standby mode

Having a low consumption in standby mode is a key requirement. Recent studies and in situ measurement campaigns have indicated that in the average EU household, between 5% and 10% of its total yearly electricity consumption is due to the standby mode of consumer electronics equipment and other apparatus. TV sets are obviously one of the biggest contributors.

In 1997, the European Commission concluded a negotiated agreement with individual consumer electronics manufacturers and the EU trade association EACEM, to reduce the stand-by losses of TVs and VCRs. In the year 2003 a new agreement for TVs and DVDs was concluded.

Many initiatives have been taken around the world. And even if these requirements are not yet standards, most of the manufacturers have already applied these rules in their designs.

Hereinafter the list of the most important initiatives:

Region / Country	Program name	Requirements for Televisions	Demoboard compliance
China	CSC	3 W	Yes
Korea	Energy Saving	3 W	Yes
European Union	EU Eco-Label	1 W 9 W with a STB	Yes
European Union	EU Code of Conduct	3 W with a STB	Yes
Europe	GEEA	1 W	Yes
US	1 Watt Executive Order	1 W	Yes

Energy Star

Product Category	Phase I Standby Mode (effective 7/1/02)	Phase II Standby Mode (effective 7/1/04)	Phase III Standby Mode (effective 7/1/05)
TV	< 3 Watts	Analog: < 1 Watt Digital: < 3 Watts	< 1 Watt
Television Monitor	Analog: < 1 Watt Digital: < 3 Watts		< 1 Watt
Component Television Unit	< 3 Watts		< 1 Watt
TV/VCR Combination Unit	< 6 Watts		< 1 Watt
TV/DVD, VCR/DVD, and TV/VCR/DVD Combinations	< 4 Watts		< 1 Watt

3.2 Active mode

According to the American Department of Energy's (DOE) Energy Information Administration (EIA), by 2015 electronics products may account for 18% of total household electricity demand – this will exceed lighting and appliances as a percent of total residential electricity consumption. This is linked to the fact that
TVs are 'on' more hours per day. According to Nielsen Media Research (NMR), for the September 2004 – September 2005 viewing season, the average U.S. household was tuned into television an average of 8 hours and 11 minutes per day. And this does not take into account additional hours that a TV is on due to peripheral devices such as game consoles, digital video recorders, and increased availability of cable/satellite programming.

Furthermore most of the flat panel televisions being purchased by consumers will consume double or more the active mode power of the smaller CRT televisions that they are replacing. Much of this differential in power consumption is simply attributable to the increased size of the products being sold now.

As a consequence of these market evolutions, Energy star / EPA intend to develop energy efficiency specifications for TVs that are performance-based and technology neutral. (See

4 Limitations of existing solutions

One of the key differentiating factors of a flat TV over a classical TV is the thickness of the cabinet - the thinner the better. But one must keep in mind:

- The amount of power to be delivered is relatively large: the number of watts per cm^3 is much larger compared to the one in a CRT TV.
- Because the TV will be used in the living room, audible noise can be a problem, and the use of fans is limited.
- Cost is key in the very competitive environment of the consumer electronics world.
- The panel, the power supply and the audio card are close to each other; therefore EMI and pollution could severely alter the picture and sound quality.

High efficiency and a low EMI signature at a reasonable cost are required, and classical topologies can hardly combine these needs:

- Flyback: transformer usage is far from being optimal
- Forward: the EMI signature is not reduced to its minimum

5 Overcoming limitations with NCP1605 / NCP1396 / NCP1027

5.1 Architecture Overview

First, the use of active power factor correction in the front-end allows system optimization because the PFC output voltage is well regulated. The implementation of the active PFC front end is done using the NCP1605.

The SMPS stage uses a Half Bridge Resonant LLC topology. This topology offers a number of advantages as demonstrated in the schematics and the results. It improves efficiency, reduces EMI signature and provides better magnetic utilization. The NCP1396 controller is used to implement the most effective control scheme of Half Bridge Resonant LLC converter.

For the standby output circuit, a higher integration level is made feasible by using the NCP1027, a PWM regulator that also incorporates an appropriate switch to provide all functionality in one package.

In summary, the architecture selected for this reference design allows design optimization so that the desired performance is achieved without increasing the component costs and circuit complexity too much. The performance results section demonstrates the performance.

5.2 Main power supply: NCP1396

5.2.1 Half Bridge Resonant LLC topology

The Half Bridge Resonant LLC topology, that is a member of the Series Resonant Converters (SRC), begins to be widely used in consumer applications such as LCD TVs or plasma display panels. In these particular applications, the output power level ranges from 200 W up to 600 W.

The Half Bridge Resonant LLC converter is an attractive alternative to the traditional Half Bridge (HB) topology for several reasons. Advantages include:

- **ZVS (Zero Voltage Switching) capability over the entire load range**: Switching takes place under conditions of zero drain voltage. Turn-on losses are thus nearly zero and EMI signature is improved compared to the HB, which operates under hard-switching conditions.
- **Low turnoff current:** Switches are turned off under low current conditions, and so the turn-off losses are also lowered compared to the HB topology.
- **Zero current turnoff of the secondary diodes:** When the converter operates under full load, the output rectifiers are turned off under zero-current conditions, reducing the EMI signature.
- **No increased component count:** The component count is virtually the same as the classical half bridge topology.

Figure 2 is the structure of this resonant converter. A 50 % duty-cycle half-bridge delivers high-voltage square waves swinging from 0 to the input voltage V_{IN} to a resonating circuit. By adjusting the frequency via a voltage-controlled oscillator (VCO), the feedback loop can adjust the output level depending on the power demand.

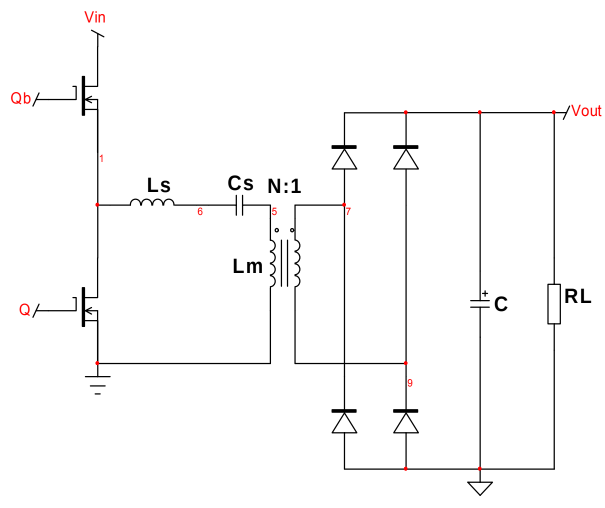


Figure 2

The resonating circuit is made of a capacitor, *Cs,* in series with two inductors, *Ls* and *Lm*. One of these inductors, *Lm*, represents the magnetizing inductor of the transformer and creates one resonating point together with *Ls* and *Cs*. The reflection of the load over this inductor will either make it disappear from the circuit (*Lm* is fully short-circuited by a reflected *RL* of low value at heavy load currents) or will make it stay in series with the series inductor *Ls* in light load conditions. As a result, depending on the loading conditions, the resonant frequency will move between a minimum and a maximum:

$$F_{max} = F_S = \frac{1}{2\pi\sqrt{L_S C_S}}$$

$$F_{min} = \frac{1}{2\pi\sqrt{(L_S + L_m)C_S}}$$

The frequency of operation depends on the power demand. For a low power demand, the operating frequency is rather high, away from the resonating point. To the contrary, at high power, the control loop reduces the switching frequency and approaches one of the resonant frequencies to deliver the necessary amount of current to the load.

This topology behaves like a frequency dependent divider.

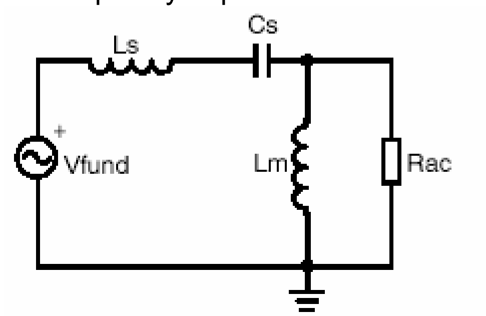


Figure 3: Substitutive schematic of the LLC resonant converter

$$R_{ac} = \frac{8 \cdot R_L}{\pi^2 \cdot n^2 \cdot \eta}$$

Where:
R_L is the real loading resistance
n is the transformer turns ratio
η is the expected efficiency

5.2.2 Protections

The NCP1396 differs from other resonant controllers thanks to its protection features. The device can react to various inputs like:

- **Fast events input:** Like an over-current condition, a need to shutdown (sleep mode) or a way to force a controlled burst mode (skip cycle at low output power).
- **Slow events input:** This input serves as a delayed shutdown, where an event like a transient overload does not immediately stop pulses but starts a timer. If the event duration lasts longer than what the timer imposes, then all pulses are disabled.

5.3 Standby Power Supply: NCP1027

A NCP1027 is used for the auxiliary flyback power supply. This power supply provides a stable Vcc to supply the NCP1653, the NCP1395 and the NCP5181 under all operating conditions, but it also supplies 5 V to the devices that must remain alive in standby mode.

5.3.1 NCP1027 characteristics:

- **Brown-out detection:** The controller will not allow operation in low mains conditions. You can adjust the level at which the circuit starts or stops operation.
- **Ramp compensation:** Designing in Continuous Conduction Mode helps to reduce conduction losses. However, at low input voltage (85 Vac), the duty-cycle might exceed 50% and the risk exists to enter a subharmonic mode. A simple resistor to ground injects the right compensation level.
- **Over power protection:** A resistive network to the bulk reduces the peak current capability and accordingly harnesses the maximum power at high line. As this is done independently from the auxiliary Vcc, the design gains in simplicity and execution speed.
- **Latch-off input:** Some PC manufacturers require a complete latch-off in the presence of an external event, e.g., over temperature. The controller offers this possibility via a dedicated input.
- **Frequency dithering:** The switching frequency (here 65 kHz) is modulated during operation. This naturally spreads the harmonic content and reduces the peak value when analyzing the signature.

5.4 Power Factor Correction: NCP1605

The NCP1605 is a PFC driver designed to operate in fixed frequency, discontinuous Conduction Mode (DCM). In the most stressful conditions, Critical Conduction Mode (CRM) can be achieved without power factor degradation and the circuit could be viewed as a CRM controller with a frequency clamp (given by the oscillator). Finally, the NCP1605 tends to give the best of both modes without their respective drawbacks. Furthermore, the circuit incorporates protection features for a rugged operation together with some special circuitry to lower the power consumed by the PFC stage in no load conditions.

6 Specifications

Input Voltage: Universal input 85 Vac to 265 Vac, 47-63 Hz

Main Power Supply Output voltages:

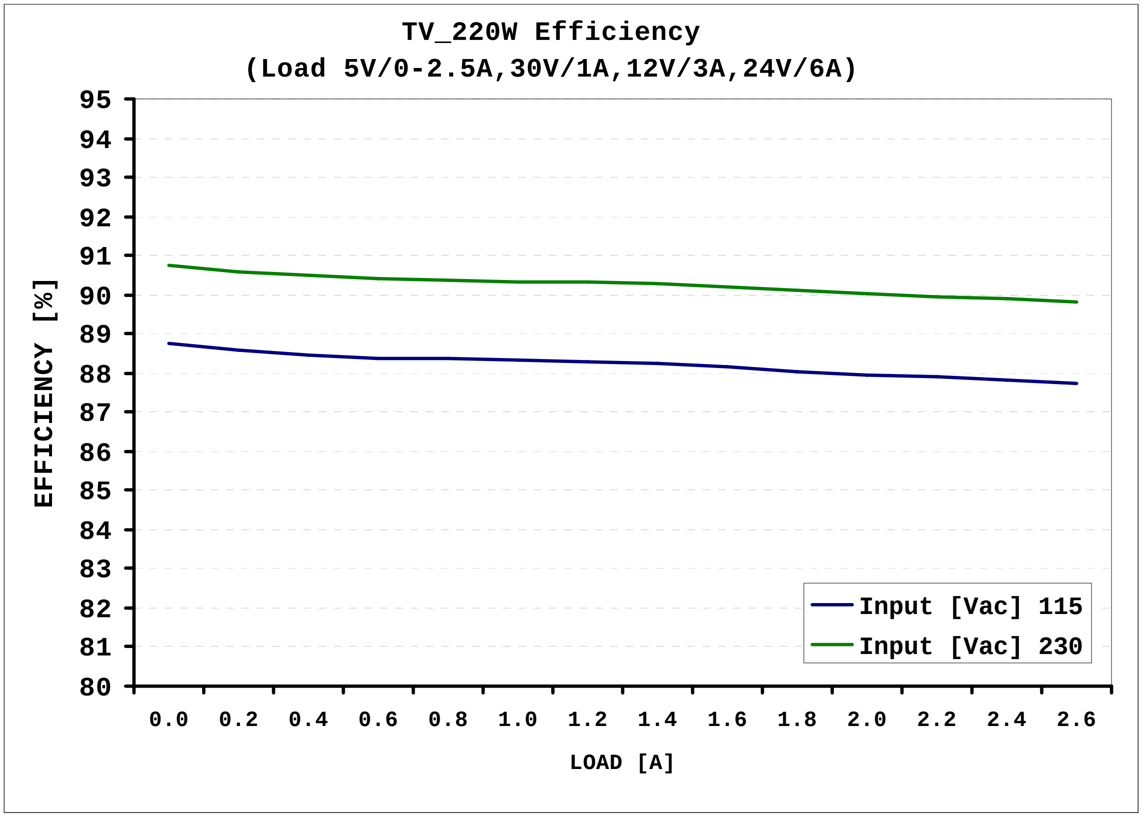
- 24 V / 6 A
- 12 V / 3 A
- 30 V / 1 A

Standby Power Supply:

- 5 V / 2.5 A
- Pin < 1 W when the consumption on the 5 V is 100 mA

7 Reference Design Performance Summary

7.1 *Efficiency*

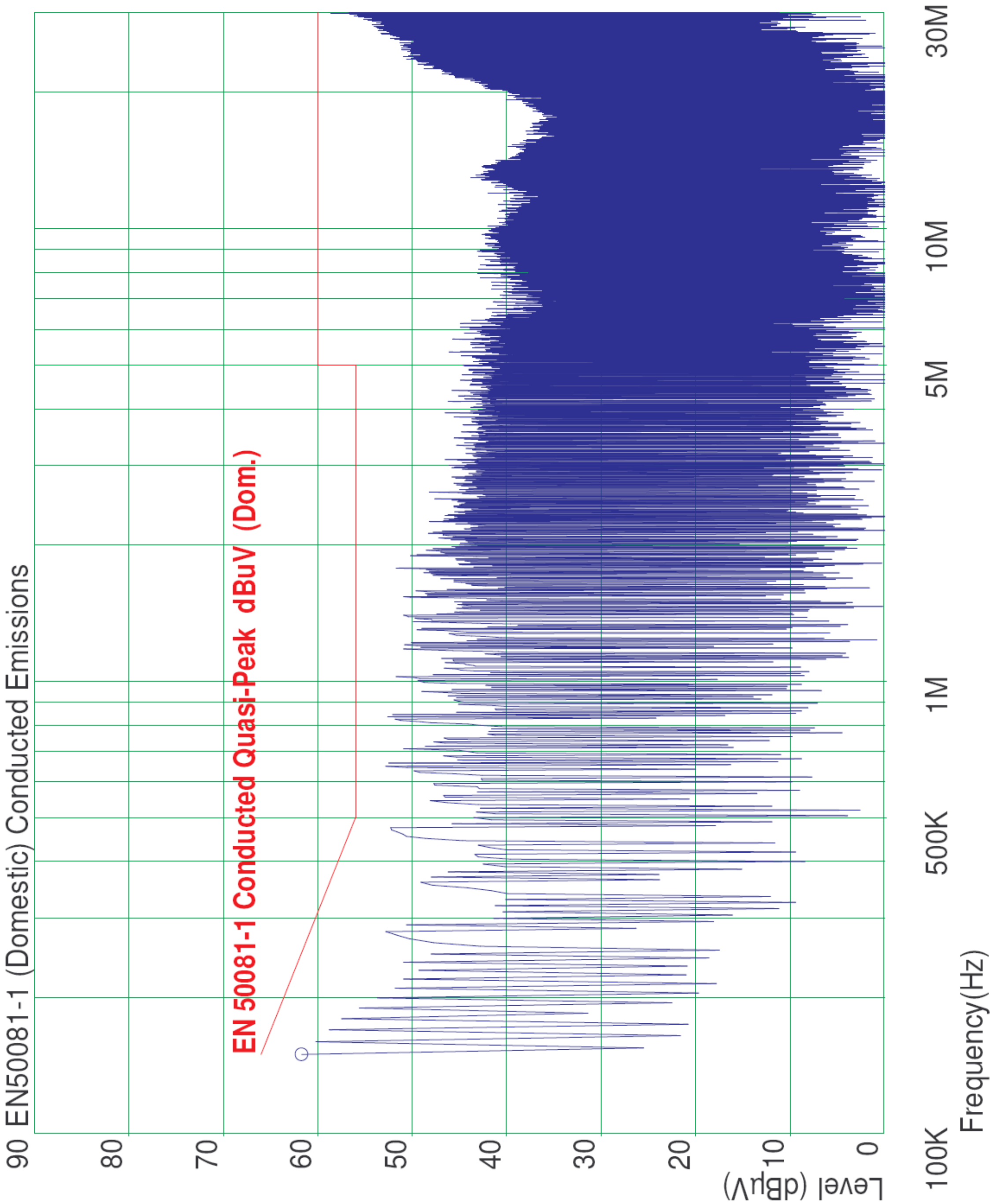


7.2 *Standby Power*

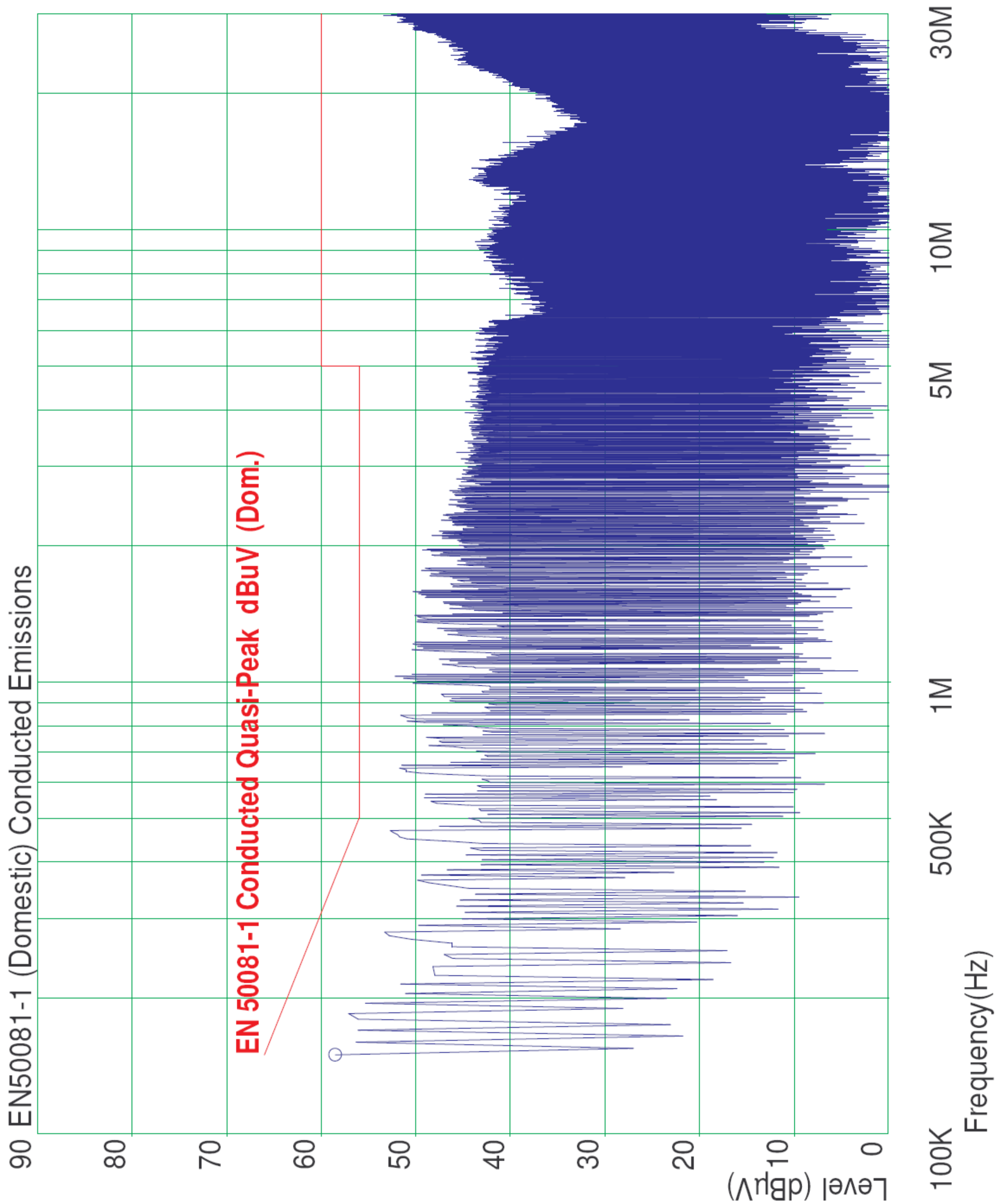
Input Voltage	Standby load	Power consumption
115 V	0.5 W	0.735 W
230 V	0.5 W	0.873 W

7.3 Standards and Regulations

Specification	Result
EN61000-3-2 – Limits for harmonic current emissions Class D	Pass



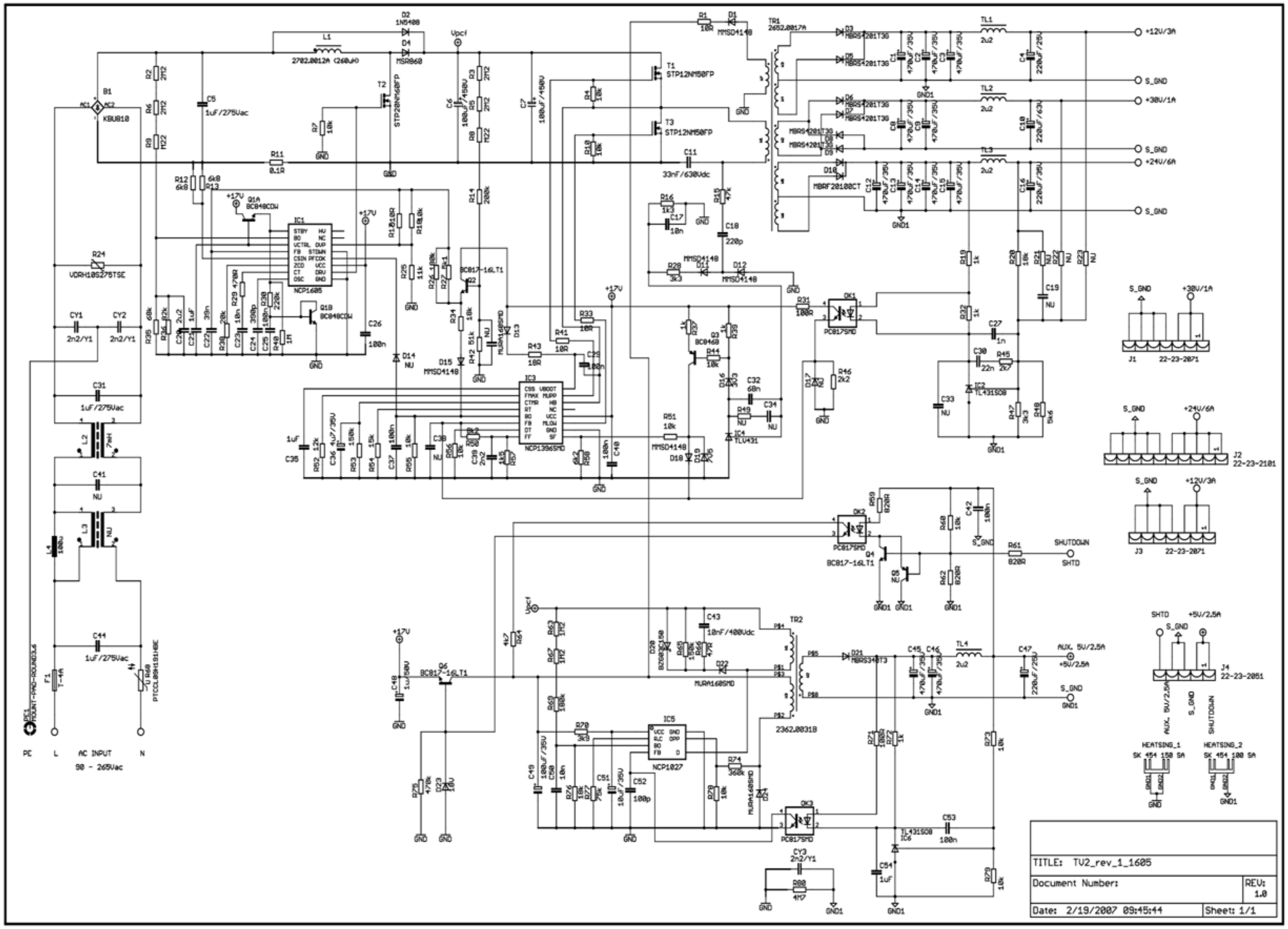
Conducted Emissions @ 230 Vac



Conducted Emissions @ 110 Vac

8 Board Picture

9 Schematic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Document Number:
REV: 1.0
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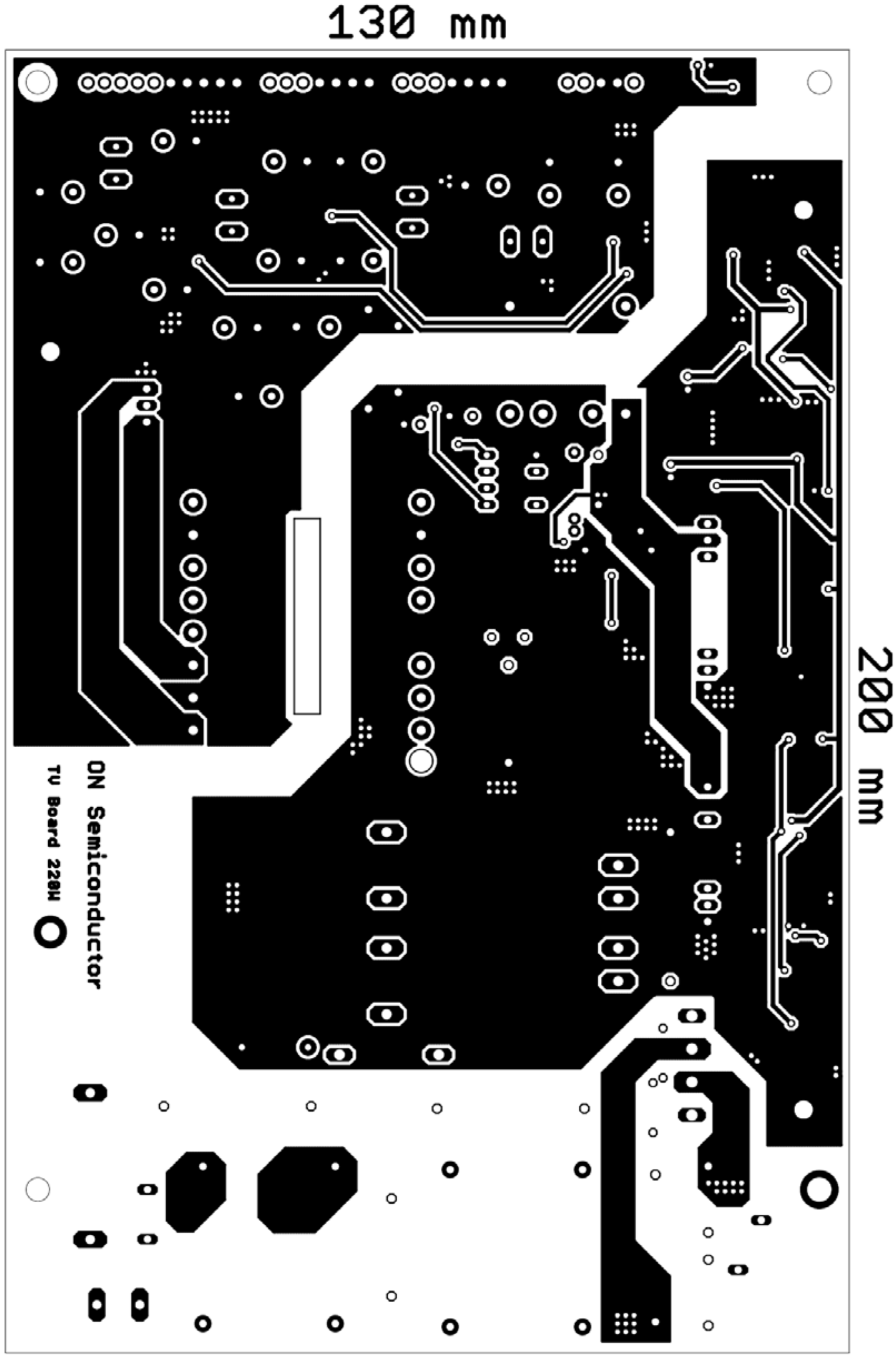
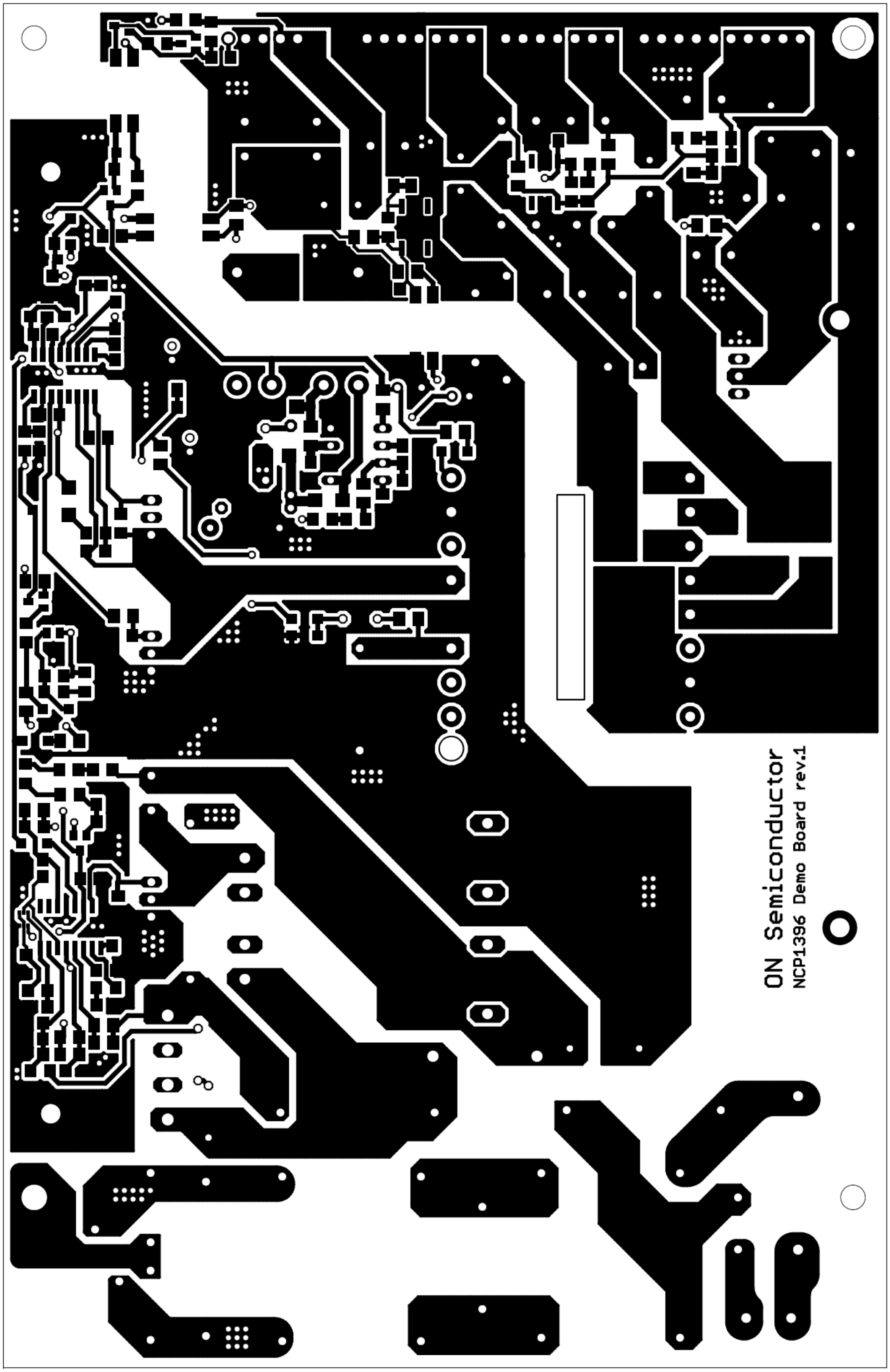
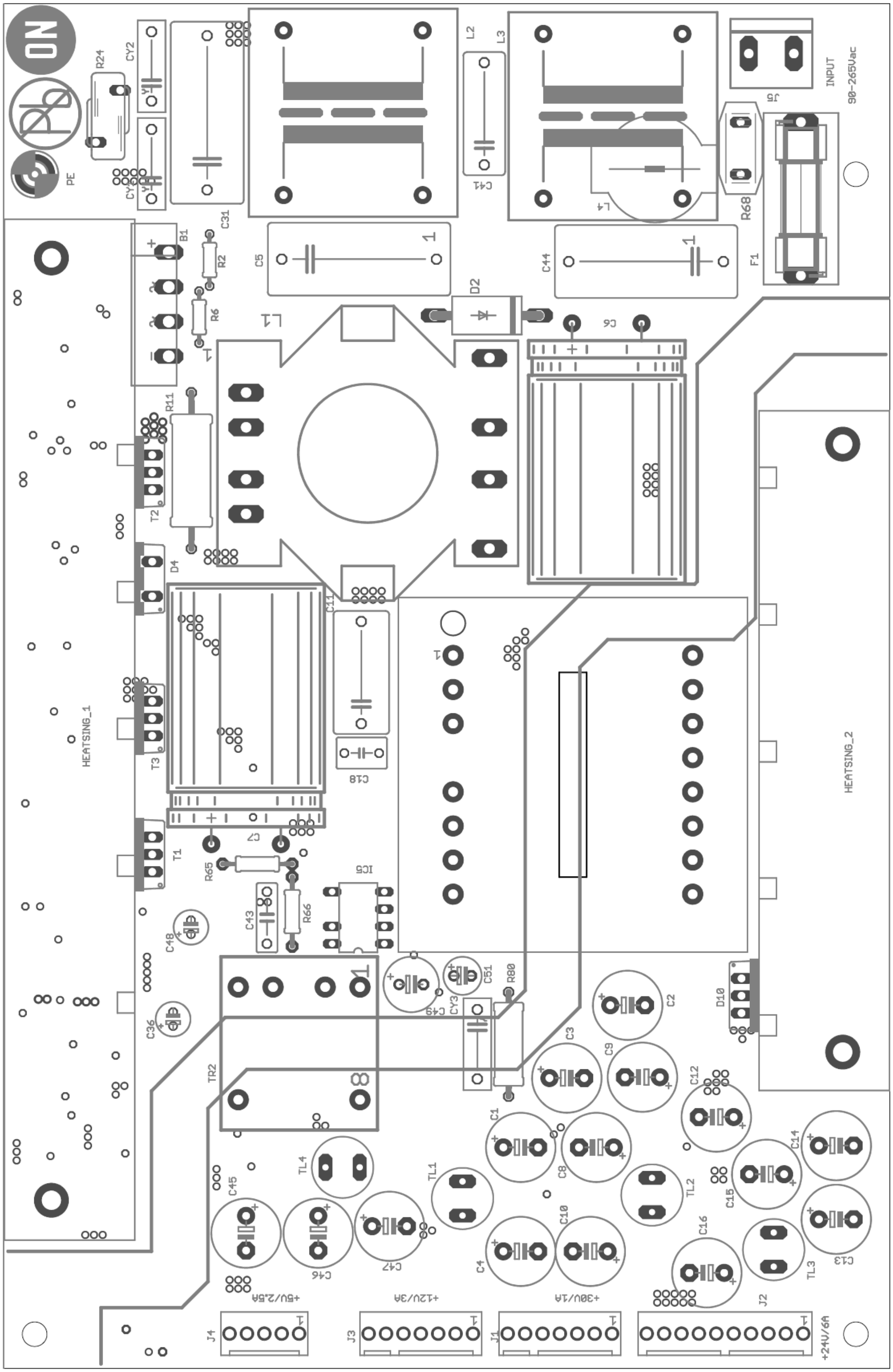
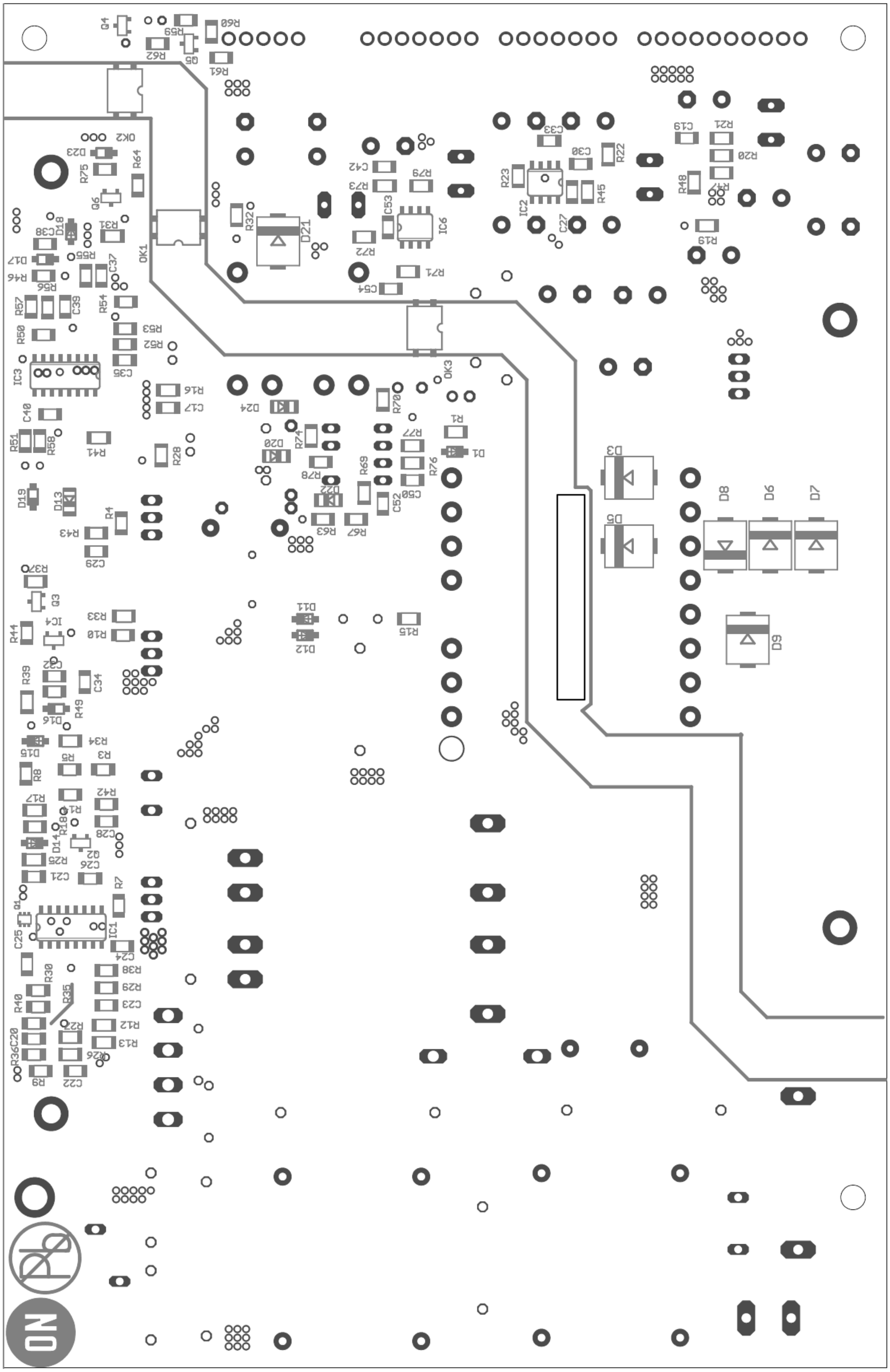
+12V/3A
S_GND
+30V/1A
+24V/6A
SHUTDOWN
SHTD
AUX. 5V/2.5A
+5V/2.5A
AC INPUT
90 - 265Vac
PE
L
N
NCP1605
NCP1396SMD
NCP1027
KBU810
STP20NM60FP
STP12NM50FP
TL431SOB
PC817SMD
J1 22-23-2071
J2 22-23-2101
J3 22-23-2071
J4 22-23-2051
HEATSING_1 SK 454 150 SA
HEATSING_2 SK 454 100 SA

10 Board Layout




ON Semiconductor
NCP1396 Demo Board rev.1


INPUT
90-265Vac
HEATSING_1
HEATSING_2
+5V/2.5A
+12V/3A
+30V/1A
+24V/6A



11 Bill Of Material

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part No.	Substitution Allowed	Lead Free	Comments
B1	1	Bridge rectifier	KBU8M		KBU	Fairchild	KBU8M	Yes	Yes	
C1, C2, C3, C8, C9, C12, C13, C14, C15, C45, C46	11	Electrolytic capacitor	470uF/35V	20%	CPOL-EUE5-10.5	Rubycon	35ZL470M10X20	Yes	Yes	
C10	1	Electrolytic capacitor	220uF/63V	10%	CPOL-EUE5-10.5	Rubycon	63 YXA220M 10×16	Yes	Yes	
C11	1	MKP Capacitor	33nF/630Vdc	20%	C-EU150-084X183	Arcotronics	R73-0.033uF 15 630V	Yes	Yes	
C16	1	Electrolytic capacitor	220uF/35V	20%	CPOL-EUE5-10.5	Rubycon	35 RX30220M 10×12.5	Yes	Yes	
C17, C23, C50	3	Ceramic capacitor SMD	10n	10%	C-EUC1206	Epcos	B37872A5103K060	Yes	Yes	
C18	1	Ceramic capacitor	220p	10%	C-EU050-045X075	Panasonic	ECKA3A221KBP	Yes	Yes	
C19, C28, C33, C34, C38	5		NU		C-EUC1206					
C20	1	Ceramic capacitor SMD	2u2	10%	C-EUC1206	Epcos	B37872K9225K062	Yes	Yes	
C21, C35, C54	3	Ceramic capacitor SMD	1uF	10%	C-EUC1206	Epcos	B37872K0105K062	Yes	Yes	
C22	1	Ceramic capacitor SMD	39n	10%	C-EUC1206	Epcos	B37872K5393K060	Yes	Yes	
C24	1	Ceramic capacitor SMD	390p	5%	C-EUC1206	Epcos	B37871K5391J060	Yes	Yes	
C25, C26, C29, C37, C40, C42, C53	7	Ceramic capacitor SMD	100n	10%	C-EUC1206	Epcos	B37872A5104K060	Yes	Yes	
C27	1	Ceramic capacitor SMD	1n	10%	C-EUC1206	Epcos	B37872A5102K060	Yes	Yes	
C30	1	Ceramic capacitor SMD	22n	10%	C-EUC1206	Epcos	B37872A5223K060	Yes	Yes	
C32	1	Ceramic capacitor SMD	68n	10%	C-EUC1206	Epcos	B37872A5683K060	Yes	Yes	
C36	1	Electrolytic capacitor	4u7/35V	20%	CPOL-EUE2-5	Rubycon	35 MH54.7M 4×5	Yes	Yes	
C39	1	Ceramic capacitor SMD	2n2	10%	C-EUC1206	Epcos	B37872A5222K060	Yes	Yes	
C4, C47	2	Electrolytic capacitor	220uF/25V	20%	CPOL-EUE5-10.5	Rubycon	25 NXA220M 10×12.5	Yes	Yes	
C41	1		NU		C-EU150-064X183					
C43	1	MKP Capacitor	10nF/400Vdc	20%	C-EU075-032X103	Epcos	B32520C6103M289	Yes	Yes	
C48	1	Electrolytic capacitor	1u	20%	CPOL-EUE2-5	Rubycon	50 MH51M 4×5	Yes	Yes	
C49	1	Electrolytic capacitor	100uF/35V	20%	CPOL-EUE5.5-8	Rubycon	50 PK100M 8×11.5	Yes	Yes	
C5, C31, C44	3	MKP Capacitor	1uF/275Vac	20%	C-EU225-108X268	Arcotronics	R46KM410000N1M	Yes	Yes	
C51	1	Electrolytic capacitor	10uF/35V	20%	CPOL-EUE2.5-6	Rubycon	50 MH710M 6.3×7	Yes	Yes	
C52	1	Ceramic capacitor SMD	100p	20%	C-EUC1206	Epcos	B37871K5101J060	Yes	Yes	
C6	1	Electrolytic capacitor	100uF/450V	20%	EC18L40'22L35'	Rubycon	450 VXG100M 22×30	Yes	Yes	
C7	1	Electrolytic capacitor	100uF/450V	20%	EC18L40'22L35_90'	Rubycon	450 VXG100M 22×30	Yes	Yes	
CY1, CY2, CY3	3	Ceramic capacitor	2n2/Y1	20%	CYYC10B4	Murata	DE1E3KX222MA5B	Yes	Yes	
D1, D11, D12, D15, D18	5	Diode	MMSD4148		SOD-123	ON semiconductor	MMSD4148T1G	No	Yes	
D10	1	Dual diode	MBRF20100CT		TO-220	ON semiconductor	MBRF20100CTG	No	Yes	
D13, D22, D24	3	Diode	MURA160SMD		SMA	ON semiconductor	MURA160T3G	No	Yes	

D14	1		NU		SOD-123					
D16	1	Zener diode	3V3	5%	SOD-123	ON semiconductor	MMSZ3V3T1G	No	Yes	
D17	1		NU		SOD-123					
D19	1	Zener diode	7V5	5%	SOD-123	ON semiconductor	MMSZ7V5T1G	No	Yes	
D2	1	Diode	1N5408		Axial Lead 9.50x5.30mm	ON semiconductor	1N5408G	No	Yes	
D20	1		NU		SMA					
D21	1	Diode	MBRS340T3		SMC	ON semiconductor	MBRS320T3G	No	Yes	
D23	1	Zener diode	18V	5%	SOD-123	ON semiconductor	MMSZ18T1G	No	Yes	
D3, D5, D6, D7, D8, D9	6	Diode	MBRS4201T3G		SMC	ON semiconductor	MBRS4201T3G	No	Yes	
D4	1	Diode	MSR860		TO-220	ON semiconductor	MSR860G	No	Yes	
F1	1	FUSEHOLDER, 20X5MM	SH22,5A		SH22,5A	Multicomp	MCHTC-15M	Yes	Yes	
	1	COVER, PCB FUSEHOLDER				Multicomp	MCHTC-150M	Yes	Yes	
	1	FUSE, MEDIUM DELAY 4A	4A			BUSSMANN	TDC 210-4A	Yes	Yes	
HEATSING_1	1	Heatsing	SK 454 150 SA		SK454/150_GND	Fischer Elektronik	SK 454 150 SA	Yes	Yes	
HEATSING_2	1	Heatsing	SK 454 100 SA		SK454/100_GND	Fischer Elektronik	SK 454 100 SA	Yes	Yes	
IC1	1	PFC controller	NCP1605		SOIC 16	ON semiconductor	NCP1605DR2G	No	Yes	
IC2, IC6	2	Programmable Precision Reference	TL431SO8		SOIC-8	ON semiconductor	NCV431AIDR2G	No	Yes	
IC3	1	Resonant controller	NCP1396A		SOIC 16	ON semiconductor	NCP1396ADR2G	No	Yes	
IC4	1	Programmable Precision Reference	TLV431A		SOT-23	ON semiconductor	TLV431ASN1T1G	No	Yes	
IC5	1	HV Switcher for Medium Power Offline SMPS	NCP1027		PDIP (8 Minus Pin 6)	ON semiconductor	NCP1027P065G	No	Yes	
J1, J3	2	Conector	22-23-2071		MOLEX-7PIN	Molex	22-23-2071	Yes	Yes	
J2	1	Conector	22-23-2101		MOLEX-10PIN	Molex	22-23-2101	Yes	Yes	
J4	1	Conector	22-23-2051		MOLEX-5PIN	Molex	22-23-2051	Yes	Yes	
J5	1	Conector	LP7.5/2/903.2 OR		Weidmueller	Weidmueller	LP7.5/2/903.2 OR	Yes	Yes	
L1	1	Inductor	2702.0012A (260uH)	10%	Pulse_2702	Pulse	2702.0012A	Yes	Yes	
L2	1	EMI filter	7mH	10%	TLBI	Pulse	6001.0069	Yes	Yes	
L3	1		NU		TLBI					
L4	1	Inductor	100u	20%	DO5040H_100	Coilcraft	DO5040H-104MLB	Yes	Yes	
OK1, OK2, OK3	3	Opto-coupler	PC817		PC817SMD	AVAGO TECHNOLOGIES	HCPL-817-300E	Yes	Yes	
Q1	1	NPN Dual General Purpose Transistor	BC848CDW		SOT−363 6 LEAD	ON semiconductor	BC848CDW1T1G	No	Yes	
Q2, Q4, Q6	3	NPN General Purpose Transistor	BC817-16LT1		SOT-23	ON semiconductor	BC817-16LT1G	No	Yes	
Q3	1	NPN General Purpose Transistor	BC846B		SOT-23	ON semiconductor	BC846BLT1G	No	Yes	

Q5	1		NU		SOT-23					
R1,R33, R41	3	Resistor SMD	10R	1%	R-EU_R1206	Vishay	RCA120610R0FKEA	Yes	Yes	
R11	1	Resistor trough hole	0.1R	1%	R-EU_0617/22	Vishay	PAC300001007FAC000	Yes	Yes	
R12, R13	2	Resistor SMD	6k8	1%	R-EU_R1206	Vishay	RCA12066K80FKEA	Yes	Yes	
R14	1	Resistor SMD	200k	1%	R-EU_R1206	Vishay	RCA120620K0FKEA	Yes	Yes	
R15	1	Resistor SMD	47k	1%	R-EU_R1206	Vishay	RCA120647K0FKEA	Yes	Yes	
R16	1	Resistor SMD	1k3	1%	R-EU_R1206	Vishay	RCA12061K30FKEA	Yes	Yes	
R17	1	Resistor SMD	910R	1%	R-EU_R1206	Vishay	RCA1206910RFKEA	Yes	Yes	
R19, R32, R37, R39, R72	5	Resistor SMD	1k	1%	R-EU_R1206	Vishay	RCA12061K00FKEA	Yes	Yes	
R2, R6	2	Resistor trough hole	2M2	1%	R-EU_0204/7	Vishay	MRS16000C2204FCT	Yes	Yes	
R20	1	Resistor SMD	18k	1%	R-EU_R1206	Vishay	RCA120618K0FKEA	Yes	Yes	
R21, R22, R23, R49	4		NU		R-EU_R1206					
R24	1	Varistor	VDRH10S275TSE		VARISTOR10K300	Vishay	2381 584 T271S	Yes	Yes	
R25	1	Resistor SMD	11k	1%	R-EU_R1206	Vishay	RCA120611K0FKEA	Yes	Yes	
R26, R69	2	Resistor SMD	180k	1%	R-EU_R1206	Vishay	RCA1206180KFKEA	Yes	Yes	
R27	1	Resistor SMD	5k1	1%	R-EU_R1206	Vishay	RCA12065K10FKEA	Yes	Yes	
R28	1	Resistor SMD	3k3	1%	R-EU_R1206	Vishay	RCA12063K30FKEA	Yes	Yes	
R29	1	Resistor SMD	470R	1%	R-EU_R1206	Vishay	RCA1206470RFKEA	Yes	Yes	
R3, R5	2	Resistor SMD	2M2	1%	R-EU_R1206	Vishay	RCA12062M20FKEA	Yes	Yes	
R30	1	Resistor SMD	220k	1%	R-EU_R1206	Vishay	RCA1206220KFKEA	Yes	Yes	
R31, R71	2	Resistor SMD	100R	1%	R-EU_R1206	Vishay	RCA1206100RFKEA	Yes	Yes	
R34, R76	2	Resistor SMD	18k	1%	R-EU_R1206	Vishay	RCA120618K0FKEA	Yes	Yes	
R35	1	Resistor SMD	68k	1%	R-EU_R1206	Vishay	RCA120668K0FKEA	Yes	Yes	
R36	1	Resistor SMD	82k	1%	R-EU_R1206	Vishay	RCA120682K0FKEA	Yes	Yes	
R38	1	Resistor SMD	20k	1%	R-EU_R1206	Vishay	RCA120620K0FKEA	Yes	Yes	
R4, R7, R10, R18, R44, R51, R55, R56, R60, R73, R78, R79	12	Resistor SMD	10k	1%	R-EU_R1206	Vishay	RCA120610K0FKEA	Yes	Yes	
R40	1	Resistor SMD	1M	1%	R-EU_R1206	Vishay	RCA12061M00FKEA	Yes	Yes	
R42	1	Resistor SMD	51k	1%	R-EU_R1206	Vishay	RCA120651K0FKEA	Yes	Yes	
R43	1	Resistor SMD	18R	1%	R-EU_R1206	Vishay	RCA120618R0FKEA	Yes	Yes	
R45	1	Resistor SMD	2k7	1%	R-EU_R1206	Vishay	RCA12062K70FKEA	Yes	Yes	
R46	1	Resistor SMD	2k2	1%	R-EU_R1206	Vishay	RCA12062K20FKEA	Yes	Yes	
R47	1	Resistor SMD	3k3	1%	R-EU_R1206	Vishay	RCA12063K30FKEA	Yes	Yes	

R48	1	Resistor SMD	5k6	1%	R-EU_R1206	Vishay	RCA12065K60FKEA	Yes	Yes	
R50	1	Resistor SMD	8k2	1%	R-EU_R1206	Vishay	RCA12068K20FKEA	Yes	Yes	
R52	1	Resistor SMD	12k	1%	R-EU_R1206	Vishay	RCA120612K0FKEA	Yes	Yes	
R53	1	Resistor SMD	150k	1%	R-EU_R1206	Vishay	RCA1206150KFKEA	Yes	Yes	
R54	1	Resistor SMD	15k	1%	R-EU_R1206	Vishay	RCA120615K0FKEA	Yes	Yes	
R57	1	Resistor SMD	1k5	1%	R-EU_R1206	Vishay	RCA12061K50FKEA	Yes	Yes	
R58	1	Resistor SMD	6k2	1%	R-EU_R1206	Vishay	RCA12066K20FKEA	Yes	Yes	
R59, R61, R62	3	Resistor SMD	820R	1%	R-EU_R1206	Vishay	RCA1206820RFKEA	Yes	Yes	
R63, R67	2	Resistor SMD	1M2	1%	R-EU_R1206	Vishay	RCA12061M20FKEA	Yes	Yes	
R64	1	Resistor SMD	4k7	1%	R-EU_R1206	Vishay	RCA12064K70FKEA	Yes	Yes	
R65	1	Resistor trough hole	150k	1%	R-EU_0207/10	Vishay	MRS25000C1503FCT	Yes	Yes	
R66	1	Resistor trough hole	47R	1%	R-EU_0207/10	Vishay	MRS25000C4709FCT	Yes	Yes	
R68	1	Thermistor PTCCL09H191HBE is type for 230V Thermistor PTCCL13H321HBE width range	PTCCL09H191HBE PTCCL13H321HBE		P594	Vishay	2381 661 51913 2381 662 53213	Yes	Yes	
R70	1	Resistor SMD	3k9	1%	R-EU_R1206	Vishay	RCA12063K90FKEA	Yes	Yes	
R74	1	Resistor SMD	360k	1%	R-EU_R1206	Vishay	RCA1206360KFKEA	Yes	Yes	
R75	1	Resistor SMD	470k	1%	R-EU_R1206	Vishay	RCA1206470KFKEA	Yes	Yes	
R77	1	Resistor SMD	75k	1%	R-EU_R1206	Vishay	RCA120675K0FKEA	Yes	Yes	
R8, R9	2	Resistor SMD	M22	1%	R-EU_R1206	Vishay	RCA1206220KFKEA	Yes	Yes	
R80	1	Resistor trough hole, high voltage	4M7	5%	R-EU_0414/15	Vishay	VR37000004704JA100	Yes	Yes	
T1, T3	2	MOSFET transistor	STP12NM50FP		TO-220	STMICROELECTRONICS	STP12NM50FP	Yes	Yes	
T2	1	MOSFET transistor	STP20NM60FP		TO-220	STMICROELECTRONICS	STP12NM50FP	Yes	Yes	
TL1, TL2, TL3, TL4	4	Inductor	2u2	20%	RFB0807	Coilcraft	RFB0807-2R2L	Yes	Yes	
TR1	1	Resonant transformer	2652.0017A	10%	2652	Pulse	2652.0017A	Yes	Yes	
TR2	1	Stand by transformer	2362.0031B	10%	2362	Pulse	2362.0031B	Yes	Yes	

12 Appendix

12.1 NCP1396

- Datasheet
- AND8255: A Simple DC SPICE Model for the LLC Converter
- Excel spreadsheet to help LLC circuit design

12.2 NCP1605

- Datasheet
- AND8281: Implementing the NCP1605 to Drive the PFC Stage of a 19 V / 8 A Power Supply
- NCP1605 PFC Boost Design Worksheet

12.3 NCP1027

- Datasheet
- AND8241: A 5 V/2 A Standby Power Supply for Intel Compliant ATX Applications
- NCP1027 Brownout Computing

12.4 References

Draft Commission Communication on Policy Instruments to Reduce Stand-by Losses of Consumer Electronic Equipment (19 February 1999)

- http://energyefficiency.jrc.cec.eu.int/pdf/consumer_electronics_communication.pdf

European Information & Communications Technology Industry Association

- http://www.eicta.org/
- http://standby.lbl.gov/ACEEE/StandbyPaper.pdf

CSC (China):

- http://www.cecp.org.cn/englishhtml/index.asp

Top Runner (Japan):

- http://www.eccj.or.jp/top_runner/index.html

EU Eco-label (Europe):

- http://europa.eu.int/comm/environment/ecolabel/product/pg_television_en.htm

EU Code of Conduct (Europe):

- http://energyefficiency.jrc.cec.eu.int/html/standby_initiative.htm

GEEA (Europe):

- http://www.efficient-appliances.org/
- http://www.efficient-appliances.org/Criteria.htm

Energy Star:

- http://www.energystar.gov/
- http://www.energystar.gov/index.cfm?c=product_specs.pt_product_specs
- http://www.energystar.gov/index.cfm?c=revisions.tv_vcr_spec

1 Watt Executive Order:

- http://oahu.lbl.gov/
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