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40 W Printer Power Supply Reference Design Documentation

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1 Overview

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

The reference design circuit consists of one single-sided 125 mm x 60 mm printed circuit board designed to fit into a printer adapter. Height is 30 mm.

An overview of the entire circuit is provided by Figure 1 **Error! Reference source not found.** As shown in that figure, ON Semiconductor devices are available for every block of the Printer power supply; and by judicious choice of design tradeoffs, optimum performance is achieved at minimum cost.

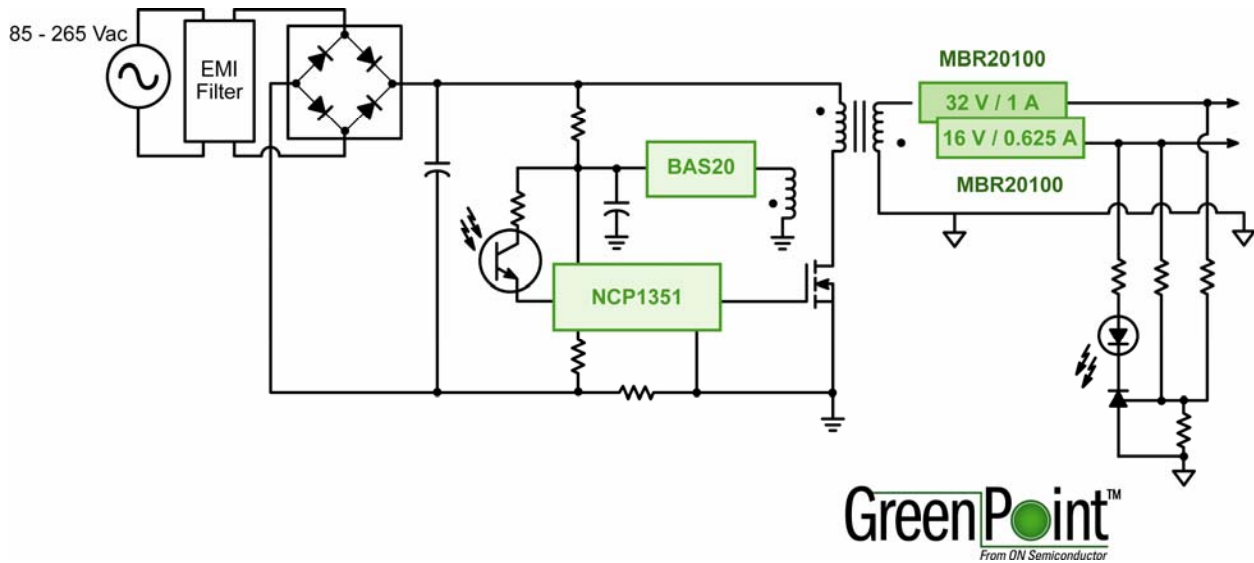


Figure 1

2 Introduction and definitions as per Energy Star

Imaging equipments are part of our every day life. They include Copiers, Digital Duplicators, Facsimile Machines, Mailing Machines, Multifunction Devices (MFD), Printers, and Scanners.

We use them everywhere for personal and professional purposes: from the big copier-printer-scanner in the office to the desktop printer we have at home and that we enjoy for giving us the possibility to quickly get the pictures of our last vacation or family event. But let's first define the topic of this 40 W power supply GreenPoint™ reference design: Desktop Printers.

2.1 Printer

A commercially-available imaging product that serves as a hard copy output device, and is capable of receiving information from single-user or networked computers, or other input devices (e.g., digital cameras). The unit must be capable of being powered from a wall outlet or from a data or network connection. This definition is intended to cover products that are marketed as printers, including printers that can be upgraded into Multifunction Devices in the field.

2.2 Multifunction Devices (MFD)

A commercially-available imaging product, which is a physically-integrated device or a combination of functionally-integrated components, that performs two or more of the core functions of copying, printing, scanning, or faxing. The copy functionality as addressed in this definition is considered to be distinct from single sheet convenience copying offered by fax machines. The unit must be capable of being powered from a wall outlet or from a data or network connection. This definition is intended to cover products that are marketed as MFDs or multifunction products (MFPs)

3 Printer Power Supply Requirements

Along with the global warming becoming a daily issue and the price of oil increasing sharply, the entire world became aware that the current usage rate of energy is not sustainable. A few initiatives have been taken around the world and in different domains (e.g.: external power supplies, home appliances, home electronics, etc..)

Naturally and because printers are widely used and consume a lot of power, they also became a field that governmental agencies wanted to address and make more energy efficient.

Even if these requirements are not yet standards, most of the manufacturers have already applied these rules in their designs.

3.1 Efficiency requirements

Region / Country	Program name	Requirements for Printers	Demoboard compliance
Japan	Eco Mark	15 W / 30 W / 45 W * "Off" mode 1 W	Yes
Korea	Energy Saving	10 W - 75 W*	Yes
Norway, Denmark, Iceland, Finland, Sweden	Nordic Swan	Laser Printer: 10 W - 85 W Ink Jet/Matrix: 6 W / "Off" 3 W	Yes

Germany	Blue Angel	15 W / 30 W / 45 W * "Off" mode 1 W	Yes
Europe	GEEA	3 W - 15 W* / "Off" mode 1 W	Yes
Europe	Energy Star Imaging equipment	Web site	Yes
US	1 Watt Executive Order	1 W	Yes
US	Energy Star Imaging equipment	Web site	Yes

Note: Refer to each program specifications to get the latest standby requirements.

- Depends on print rate.

3.1.1 Earning the ENERGY STAR

The very well know Energy Star organization has been very active and has been working on [Imaging Equipment Specifications](#)

“ENERGY STAR qualified printers automatically enter a low-power “sleep” mode after a period of inactivity. Separate specifications are available for stand-alone printer models depending on paper handling size and color capabilities.

Spending a large portion of time in low-power mode not only saves energy but helps printing equipment run cooler and last longer.

Many ENERGY STAR qualified machines can print double-sided pages, reducing paper costs by as much as \$30 a year.

Businesses that use ENERGY STAR enabled office equipment may realize additional savings on air conditioning and maintenance.

Over its lifetime, ENERGY STAR qualified equipment in a single home office (e.g., computer, monitor, printer, and fax) can save enough electricity to light an entire home for more than 4 years.

Remember, saving energy prevents pollution.

Printers are generally turned on 24 hours a day, so power management features are important for saving energy and are an easy way to reduce air pollution.” (Extract from [Energy Star WEB site](#))

3.1.2 Energy Star requirements

The Version 1.0 specification shall commence on April 1, 2007, with the exception of digital duplicators. All products, including models originally qualified under previous imaging equipment specifications, with a date of manufacture on or after the effective date, must meet the new Version 1.0 requirements in order to qualify for ENERGY STAR (including additional manufacturing runs of models originally qualified under previous specifications). The date of manufacture is specific to each unit and is the date (e.g., month and year) on which a unit is considered to be completely assembled.

- Tier I – Tier I shall commence on April 1, 2007. Tier I applies to all products described in Section 2 of the specification.
- Tier II – Tier II shall commence on April 1, 2009. Tier II will apply to the maximum **Typical Electricity Consumption (TEC)** levels for all TEC products, as well as to Standby levels for Large-format Operational Mode (OM) products and mailing machines. In addition, the definitions, products addressed, the manner in which they are addressed, and levels included for all products under this Version 1.0 specification may be reconsidered. EPA will inform stakeholders of plans to make

such changes at most six months following the effective date of Tier I. March 31, 2007.

- **Typical Electricity Consumption (TEC) Approach** – A method of testing and comparing the energy performance of imaging equipment products, which focuses on the typical electricity consumed by a product while in normal operation during a representative period of time. The key criteria of the TEC approach for imaging equipment is a value for typical weekly electricity consumption, measured in kilowatt-hours (kWh). Detailed information can be found in the [“ENERGY STAR Qualified Imaging Equipment Typical Electricity Consumption Test Procedure”](#)

TEC 1 Table

Product(s): Copiers, Digital Duplicators, Fax Machines, Printers		
Size Format(s): Standard-size		
Marking Technologies: DT, Mono DS, Mono EP, Mono Stencil, Mono TT		
	Tier I	Tier II
Product Speed (ipm)	Maximum TEC (kWh/week)	Maximum TEC (kWh/week)
≤ 12	1.5 kWh	TBD
12 < ipm ≤ 50	(0.20 kWh/ipm)x – 1 kWh	TBD
> 50 ipm	0.80 kWh/ipm)x – 31 kWh	TBD

TEC 2 Table

Product(s): Copiers, Digital Duplicators, Fax Machines, Printers		
Size Format(s): Standard-size		
Marking Technologies: Color DS, Color Stencil, Color TT, Color EP, SI		
	Tier I	Tier II
Product Speed (ipm)	Maximum TEC (kWh/week)	Maximum TEC (kWh/week)
≤ 50	(0.20 kWh/ipm)x – 2 kWh	TBD
> 50	0.80 kWh/ipm)x – 28 kWh	TBD

Product Type & Size Format	Standby (W) – Tier 1	Standby (W) – Tier 2
All Small Format and Standard-size OM Products without Fax Capability	1	Tier 1 levels remain unchanged
All Small Format and Standard-size OM Products with Fax Capability	2	Tier 1 levels remain unchanged
All Large Format OM Products and Mailing Machines	N/A	TBD

3.2 Safety requirements

3.2.1 Limited Power Source

A printer power supply must be compliant with the limited power source requirement as defined in section. 2.5 of IEC 60950-1 1st Edition and for each output independently.

A Limited Power Source must include an isolating transformer and must comply with one of the following:

- The output is inherently limited in compliance with Table 1 or

- An impedance limits the output in compliance with Table 1. If a PTC is used, it must pass the test specified in IEC 60730-1, clause 15, 17, J15 and J17 or
- An over current protective device is used and the output is limited in compliance with Table 2, or
- A regulation network limits the output in compliance with Table 1 both under normal and after single fault, or
- A regulation network limits the output in compliance with Table 1 and an over current protective device limits the output in compliance with Table 2 after single fault

Where an over current protective device is used, it must be a fuse, or a non adjustable, non auto-reset, electromechanical device.

Output voltage (Uoc)		Output current (Isc) A	Apparent power (S) VA
Va,c	Vd,c		
≤ 20	≤ 20	≤ 8	≤ 8 * Uoc
20 < Uoc ≤ 30	20 < Uoc ≤ 30	≤ 8	≤ 100
-	20 < Uoc ≤ 60	≤ 150 / Uoc	≤ 100

- Uoc : Output voltage measured with all load disconnected. Voltages are for substantially sinusoidal a.c. and ripple free sinusoidal a.c. and d.c with ripple greater than 10%. The peak voltage shall not exceed 42.4 V.
- Isc: Maximum output current with any non capacitive load, including a short circuit, measured 60 s after the application of the load
- Maximum output VA with any load, initial transients lasting less than 100 ms are permitted to exceed the limit

Table 1: limits for inherently Limited Power Sources

Output voltage (Uoc)		Output current (Isc) A	Apparent power (S) VA	Current rating of protective device (S) VA
Va,c	Vd,c			
≤ 20	≤ 20	≤ 1000 / Uoc	≤ 250	≤ 5
20 < Uoc ≤ 30	20 < Uoc ≤ 30			≤ 100 / Uoc
-	20 < Uoc ≤ 60			≤ 100 / Uoc

- Uoc : Output voltage measured with all load disconnected. Voltages are for substantially sinusoidal a.c. and ripple free sinusoidal a.c. and d.c with ripple greater than 10%. The peak voltage shall not exceed 42.4 V.
- Isc: Maximum output current with any non capacitive load, including a short circuit, measured 60 s after the application of the load. Current limiting impedance in the equipment remains in the circuit during the measurement but over current protective devices are bypassed
- Maximum output VA with any load. Current limiting impedance in the equipment remains in the circuit during the measurement but over current protective devices are bypassed. Initial transients lasting less than 100 ms are permitted to exceed the limit.
The reason for making the measurements with over current limiting devices bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the protective devices
- The current rating of over current protective devices are based on fuses and circuit breakers that break the circuit between 120 s with a current equal to 210% of the current rating specified in that table

Table 2: limits for Power Sources non-inherently limited (over current protective device required)

3.2.2 Safety standards

- Underwriters Laboratories Recognized Component power supply assembly for use in Information Technology Equipment per the following standard: UL1950, third edition dated March 1, 1998 without deviations.
- Canadian Standards Association Certified Component per the following standard: CAN/CSA C22.2 No. 950-1-03.
- NEMKO licensed to EN60950-1: 1st edition (Safety of Information Technology Equipment Including Electrical Business Equipment), plus EMKO-TSE (74-SEC) 203/94, (Nordic deviations).
- IEC 60950-1 1st Edition

4 Limitations of existing solutions

The existing adapters barely meet the current requirements for efficiency in light load conditions and standby power in no-load; whereas more stringent requirements are coming. In addition the total cost of the adapter must be extremely low, as this is a highly competitive market. Therefore meeting these requirements while ensuring reliability and reproducibility of the adapter performances is a challenge.

5 Overcoming limitations with NCP1351

This design using NCP1351C offers a perfect solution for printer adapter applications. Thanks to the fixed peak current / variable off time architecture, this adapter has high efficiency from nominal to light loads (including the various printer sleep modes); as well as a very low no-load consumption. It also features the ability to transiently deliver peak power while providing effective protection functions such as latched over-load, short-circuit and over-voltage protections. In addition the unique NCP1351C architecture allows reducing the high-voltage input capacitor by one third compared to the state-of-the-art printer adapters, thus saving cost and size for the same performances.

Implementing a fixed peak current mode control (also known as “quasi-fixed” ton), the NCP1351 modulates the off time duration according to the output power demand. In high power conditions, the switching frequency increases until a maximum is hit. This upper limit depends on an external capacitor selected by the designer. In light load conditions, the off time expands and the NCP1351 operates at a lower frequency. As the frequency reduces, the contribution of all frequency-dependent losses accordingly goes down (driver current, drain capacitive losses, switching losses), naturally improving the efficiency at various load levels.

- **Peak current compression at light loads:** reducing the frequency will certainly force the converter to operate into the audible region. To prevent the transformer mechanical resonance, the NCP1351 gradually reduces – compresses – the peak current setpoint as the load becomes lighter. When the current reaches 30% of the nominal value, the compression stops and the off duration keeps expanding towards low frequencies.
- **Low standby power:** the frequency reduction technique offers an excellent solution for designers looking for low standby power converters. Also, compared to the skip-cycle method, the smooth off time expansion does not bring additional ripple in no-load conditions: the output voltage remains quiet.
- **Natural frequency dithering:** the quasi-fixed ton mode of operation improves the EMI signature since the switching frequency varies with the natural bulk ripple voltage.

- **Extremely low start-up current:** built on a proprietary circuitry, the NCP1351 startup section does not consume more than 10 μ A during the startup sequence. The designer can thus easily combine startup time and standby consumption.
- **Overload protection based on Fault Timer:** every designer knows the pain of building converters where a precise over current limit must be obtained. When the fault detection relies on the auxiliary VCC, the pain even increases. Here, the NCP1351C observes the lack of feedback current to start a timer to countdown. At the end of its charge, the timer permanently latches the controller off. What is unique with the NCP1351C is that the Fault timer does not start when the controller delivers its maximum power (corresponding to the maximum switching frequency), but at 60% of this maximum: it means that when the timer is counting the power supply can transiently deliver a higher power. This is particularly suitable in printer adapter applications where the power supply must be able to deliver transient power peaks while meeting the Limited Power Source (LPS) requirements.
- **Latch Fault Input:** a dedicated input lets the designer externally trigger the latch to build additional protections such as overvoltage (OVP) or overtemperature (OTP).

6 Specifications

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

Power Supply Output voltages:

- 32 V / 1 A
- 16 V / 0.625 A

Peak Power:

- 80 W (32 V / 2.5 A and 16 V / 0 A) during 40 ms
- 62 W (32 V / 1.94 A and 16 V / 0 A) during 400 ms

Efficiency requirements:

- > 80 % at full load (40 W)
- > 70 % in sleep modes (2 W and 4 W)
- Pin < 0.3 W in no-load conditions

Protections:

- Latched overpower protection below 100 W (to meet LPS)
- Latched overvoltage protection (OVP)
- Latch recovery time < 3 s

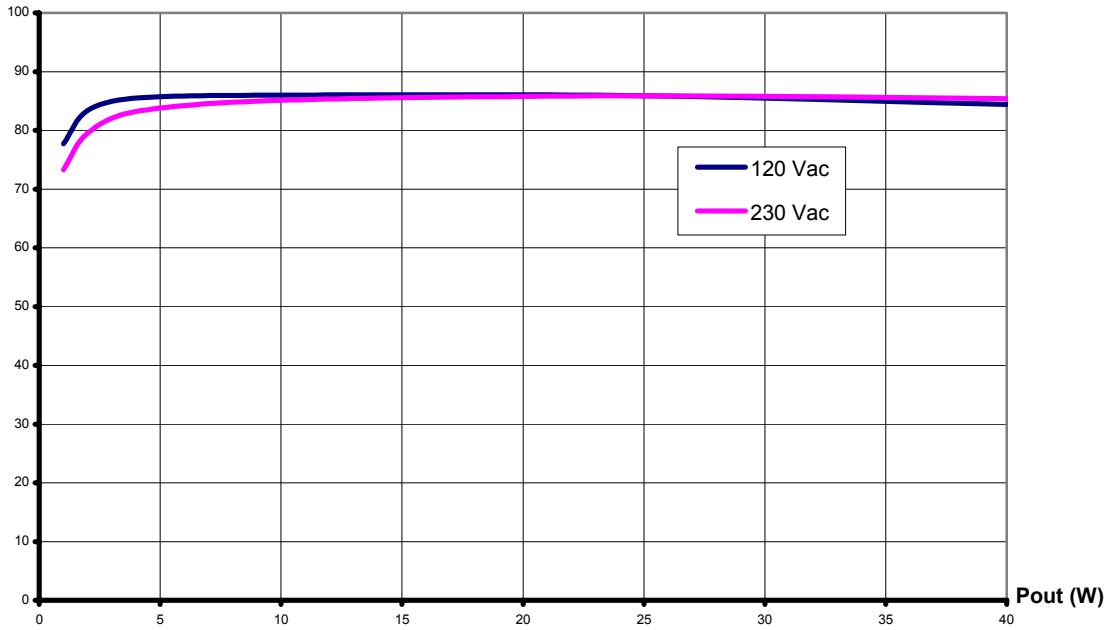
Others:

- Start-up time < 3 s
- No damage and no output voltage bouncing during brown-in and brown-out tests

7 Reference Design Performance Summary

7.1 Efficiency

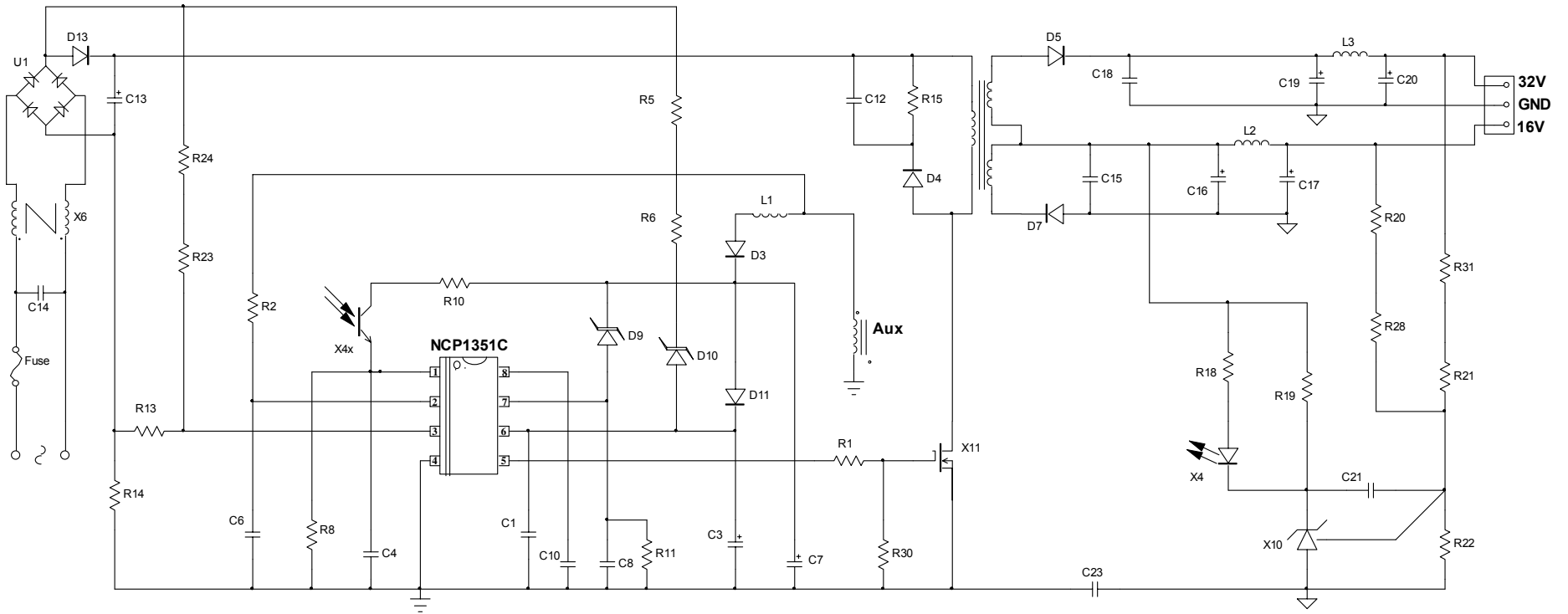
Efficiency (%)



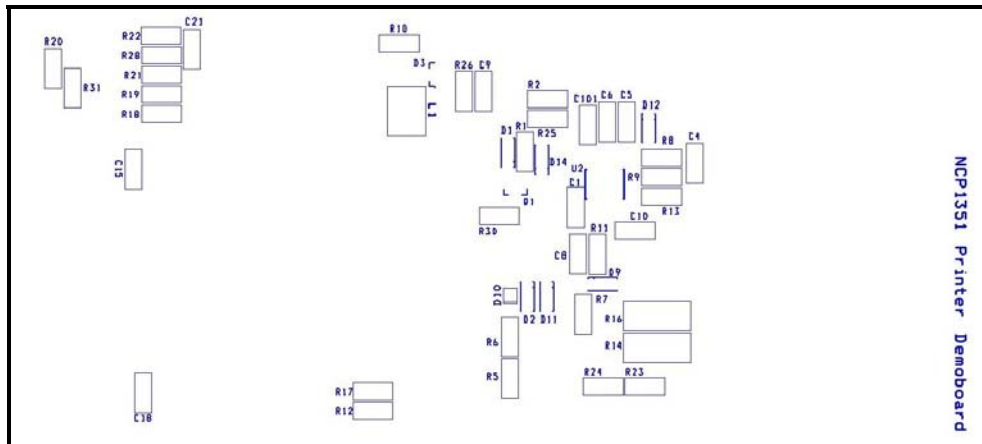
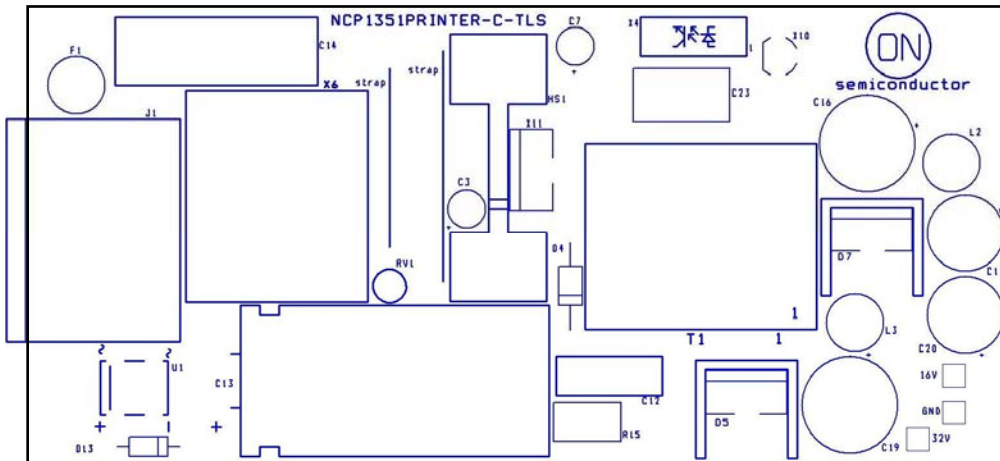
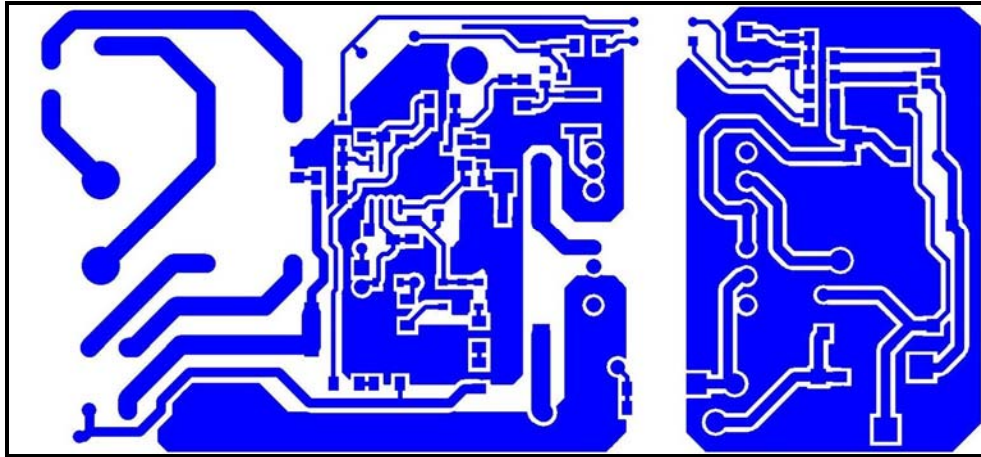
7.2 No-load Input Power

Ac Input Voltage	Input power consumption
120 V	73 mW
230 V	137 mW

8 Schematic



9 Board Layout



10 Bill of Material

Designator	Qty	Description	Value	Tol.	Footprint
C1, C4, C15, C18, C21	5	SMD capacitor	100 nF / 50 V	5 %	SMD 1206
C3	1	electrolytic capacitor	4.7 μ F / 50 V	20 %	radial
C5	0	SMD capacitor	-	5 %	SMD 1206
C6	1	SMD capacitor	180 pF / 50 V	5 %	SMD 1206
C7	1	electrolytic capacitor	47 μ F / 50 V	20 %	radial
C8	1	SMD capacitor	10 nF / 50 V	5 %	SMD 1206
C9	0	SMD capacitor	-	5 %	SMD 1206
C10	1	SMD capacitor	1.5 μ F		SMD 1206
C12	1	Film capacitor	10 nF / 630V	10 %	radial
C13	1	electrolytic capacitor	100 μ F / 400 V	20 %	radial
C14	1	x2 capacitor	330 nF / 250 Vac	20 %	radial
C16	1	electrolytic capacitor	1000 μ F / 50 V	20 %	radial
C17	1	electrolytic capacitor	100 μ F / 50 V	20 %	radial
C19	1	electrolytic capacitor	1000 μ F / 25 V	20 %	radial
C20	1	electrolytic capacitor	100 μ F / 25 V	20 %	radial
C23	1	y1 capacitor	2.2 nF / 250 Vac	20 %	radial
C101	0	SMD capacitor	-	5 %	SMD 1206
D1	1	SMD resistor	0 Ω / 0.25 W	5 %	SMD 1206
D2	0	Zener diode	-	5 %	SOD-123
D3	1	High-voltage switching diode BAS20	200 mA / 200 V	-	SOT-23
D4	1	Fast-recovery rectifier 1N4937	1 A / 600 V	-	axial
D5, D7	2	Schottky rectifier MBR20100CT	20 A / 100 V	-	TO-220
D9	1	Zener diode	17 V / 0.5 W	5 %	SOD-123
D10	1	Zener diode	60 V / 0.5 W	5 %	SOD-123
D11	1	Switching diode	200 mA / 75 V	-	SOD-123
D12	1	Zener diode	6.2 V / 0.5 W	5 %	SOD-123
D13	1	Standard rectifier	1 A / 1000 V	-	axial
D14	0	Switching diode	-	-	SOD-123
HS1	1	Heatsink	6.2 $^{\circ}$ C / W	-	radial
HS2, HS3	2	TO-220 heatsink	27 $^{\circ}$ C / W	-	-
U1	1	Rectifier bridge DB105	1A / 600 V	-	DIP-4
U2	1	CMOS IC NCP1351A	-	-	SOIC-8
X4	1	Optocoupler SFH615	-	-	DIP-4
X6	1	Common-mode choke	2 * 15 mH/ 1 A	-	radial

Panasonic ELF-25F108A					
X10	1	shunt regulator TL431	2.5 – 36 V	5 %	TO-92
X11	1	Power MOSFET N-Channel	3 A / 600 V	-	TO-220
Q1	0	PNP transistor	-	-	TO-92
T1	1	Transformer Coilcraft GA0007-AL	-	-	radial
J1	1	connector	230 Vac		radial
F1	1	Fuse	2 A / 250 Vac	T	radial
L1	1	SMD inductor Coilcraft	10 μ H		SMD DO1605T
L2, L3	1	inductor	4.7 μ H / 10 A	-	radial
R1	1	SMD resistor	15 Ω / 0.25 W	5%	SMD 1206
R2	1	resistor	4.7 M Ω / 0.33 W	5%	axial
R5, R6	2	SMD resistor	330 k Ω / 0.25 W	1%	SMD 1206
R7	1	SMD resistor	0 Ω / 0.25 W	5%	SMD 1206
R8, R19	2	SMD resistor	2.7 k Ω / 0.25 W	5%	SMD 1206
R9, R12	2	SMD resistor	0 Ω / 0.25 W	5%	SMD 1206
R10, R11, R18	3	SMD resistor	1 k Ω / 0.25 W	5%	SMD 1206
R13	1	SMD resistor	3.4k Ω / 0.25 W	1%	SMD 1206
R14	1	SMD resistor	0.33 W / 0.5 W	1 %	SMD 2010
R15	1	resistor	150 k Ω / 2 W	5%	axial
R16	0	SMD resistor	-	-	SMD 2010
R17	0	SMD resistor	-	-	SMD 1206
R20	1	SMD resistor	100 k Ω / 0.25 W	1%	SMD 1206
R21	1	SMD resistor	56 k Ω / 0.25 W	1%	SMD 1206
R22	1	SMD resistor	10 k Ω / 0.25 W	1%	SMD 1206
R23, R24	2	SMD resistor	3.3 M Ω / 0.25 W	5%	SMD 1206
R25	0	SMD resistor	-	1%	SMD 1206
R26	1	SMD resistor	0 Ω / 0.25 W	1%	SMD 1206
R28	1	SMD resistor	8.2 k Ω / 0.25 W	1%	SMD 1206
R30	1	SMD resistor	47 k Ω / 0.25 W	1%	SMD 1206
R31	1	SMD resistor	180 k Ω / 0.25 W	1%	SMD 1206
RV1	1	NTC	-	-	Radial

11 Appendix

11.1 NCP1351

- [Datasheet](#)
- [AND8263](#): Evaluation Board, 19 V - 3 A Adapter
- [AND8278](#): Evaluation Board, 16 V/ 32 V 40 W Printer Power Supply

11.2 References

CSC (China):

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

Eco Mark (japan)

- <http://www.ecomark.jp/english/>
- <http://www.ecomark.jp/english/nintei.html>

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=archives.img equip_spec&layout=print
- http://www.energystar.gov/index.cfm?fuseaction=find_a_product.ShowProductGroup&pgw_code=PR

1 Watt Executive Order:

- <http://oahu.lbl.gov/>
- http://oahu.lbl.gov/level_summary.html