AND8288/D

NCP1351 Evaluation Board, a 12 V / 2 A Full DCM Adapter

Prepared by Stéphanie Conseil

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This application note describes a 12 V / 2 A simple adapter operated by NCP1351, a fixed *on-* time / variable *off-time* controller.

This adapter features a very low standby power (below 90 mW at 230 VAC input voltage) and shows a good EMI signature.

The NCP1351 at a Glance

Fixed t_{on}, Variable t_{off} Current-mode Control: Implementing a fixed peak current mode control (hence the more appropriate term "quasi-fixed" t_{on}), 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 t_{on} mode of operation improves the EMI signature since the switching frequency varies with the natural bulk ripple voltage.

Extremely Low Startup Current: Built on a proprietary circuitry, the NCP1351 startup section does not consume more than 10 μA during the startup sequence. The designer can thus easily combine startup time and standby consumption requirement.

Overload Protection Based on Fault Timer: Every designer knows the difficulty of building converters where a precise over current limit must be obtained. When the fault detection relies on the auxiliary V_{CC}, the pain even increases. Here, the NCP1351 observes the lack of feedback current starts a timer to countdown. At the end of its charge, the timer either triggers an auto-recovery sequence (auto-restart, B version) or permanently latches-off (A).

Latch Fault Input: A dedicated input lets the designer externally trigger the latch to build additional protections such as overvoltage (OVP) or overtemperature (OTP).

Schematic

The design must fulfill the following specifications:

Input Voltage: 90 VAC – 265 VAC
Output Voltage: 12 V @ 2 A
Auto-recovery Short-circuit Protection
Standby Power: 90 mW or Lower
Startup Duration: Less than 3 s

The maximum switching frequency is selected to 65 kHz.

The converter operates in DCM only which allows a smaller transformer compared to CCM mode. Also, the converter behaves as a first order system and is easier to stabilize.

The transformer parameters have been calculated by using the design recommendations described in the NCP1351 datasheet:

L_P = 310 μH
I_P = 1.8 A
N_P:N_S = 1:0.18
N_P:N_{AUX} = 1:0.22

The core is a PQ20*20 made of a N87 material and has been manufactured by Delta Electronics (reference: 86H-7071). The leakage inductance is very low (around 1% of L_P) leading to a good efficiency and reduced losses in no load condition.

Half-wave connection for the startup resistors ensures less power loss in the startup resistor network compared to a classical bulk connection.

Voltage regulation at the secondary is achieved through a TLV431, which requires very low bias current (> 100 μA). Thus no additional bias resistor is needed.

NCP1351 features natural frequency dithering as the switching frequency varies with the bulk ripple. Additional frequency dithering can be provided to the controller by injecting some half-wave ripple in the CS pin through a 3.3 MΩ resistor connected to the input line. A jumper on the board allows to connect or to disconnect the dithering resistor.

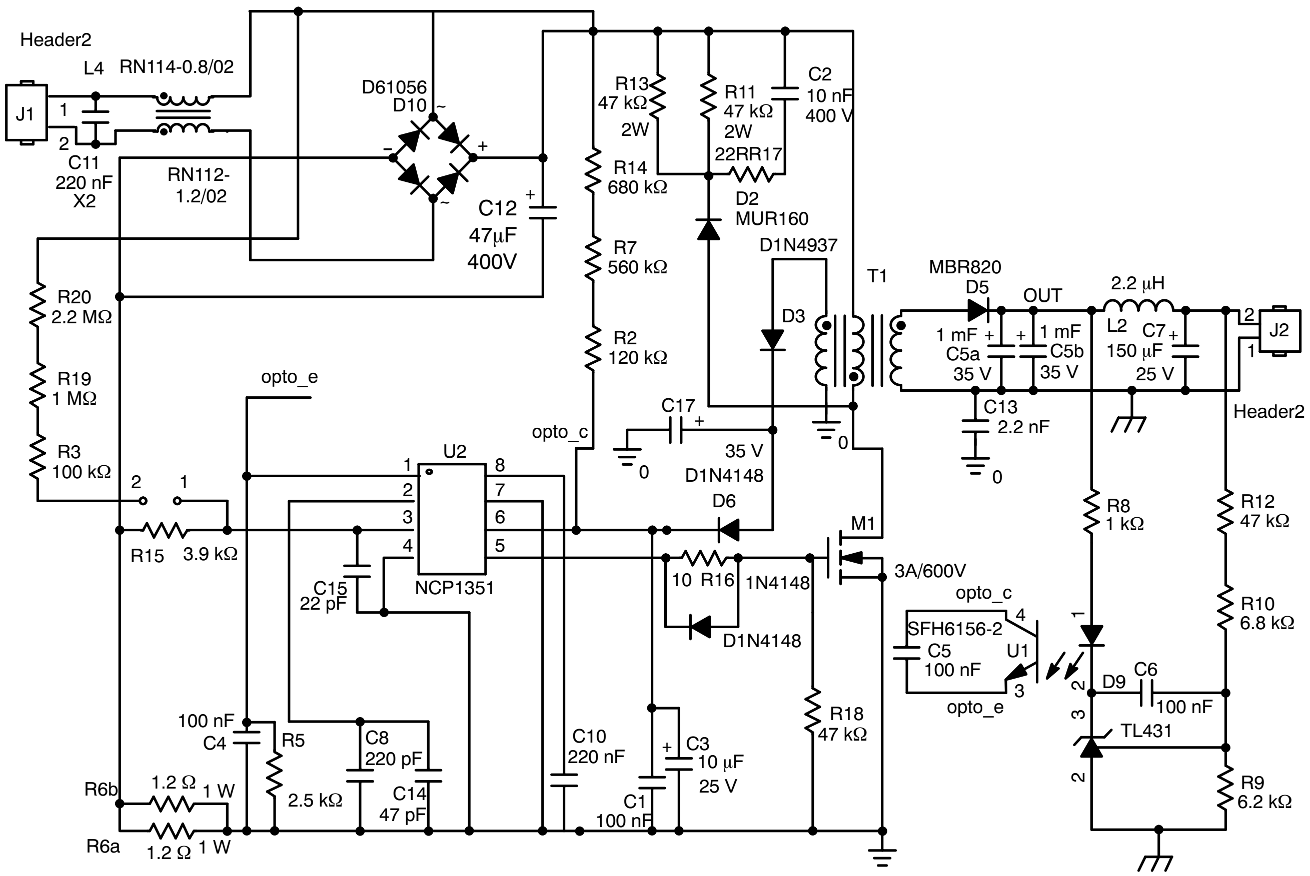

Figure 1. Board schematic

Measurements

We obtained maximum startup duration of 2.5 s with a startup resistor of 1.36 MΩ and half-wave connection for the resistor. (See Figures 2 and 7)

STARTUP

P_{OUT}	V_{IN} = 120 VDC	V_{IN} = 320 VDC
Startup Time @ I_{OUT} = 2 A	2.5 s	1 s

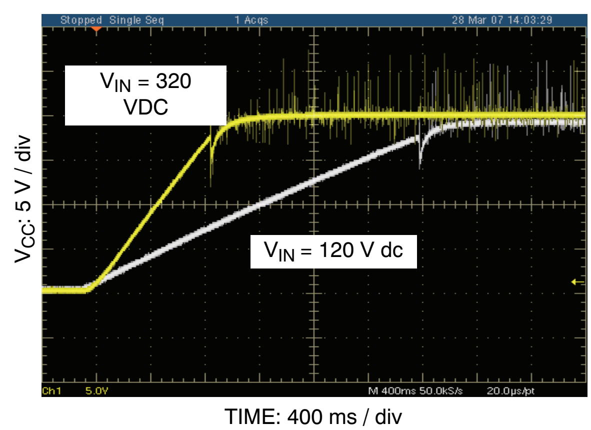

Figure 2. V_{CC} Startup at Low and High Input Voltage

The power measurements were performed with a WT210A from Yokogawa.

Before doing the measurements we operated the board for 15 minutes at full power to allow some warm-up time.

EFFICIENCY

P_{OUT}	V_{IN} = 90 VAC	V_{IN} = 230 VAC
24 W	83%	85%
12 W	82%	84%
6 W	77%	83%
1 W	69%	75%
0.5 W	63%	64%

STANDBY

P_{OUT}	V_{IN} = 90 VAC	V_{IN} = 230 VAC
No-load	78 mW	82 mW

In the above arrays, we can see that we achieve a good efficiency despite the load variation. Also, thanks to the expansion of the switching frequency at light loads, the efficiency does not decrease too much.

By optimizing power dissipation in startup resistor and feedback components, we achieve an outstanding standby power of 82 mW at 230 VAC input voltage.

After operating the board during 15 mn at full load in order to warm it up, conducted electromagnetic emission measurements were made in average mode using a Rohde & Schwarz EMI Test Receiver following the CISPR22 standard.

The measurement was made with and without frequency dithering option, and with two different inputs filter size: 2x15 mH and 2x27 mH. (See Figure 3, Figure 4, Figure 5 and Figure 6)

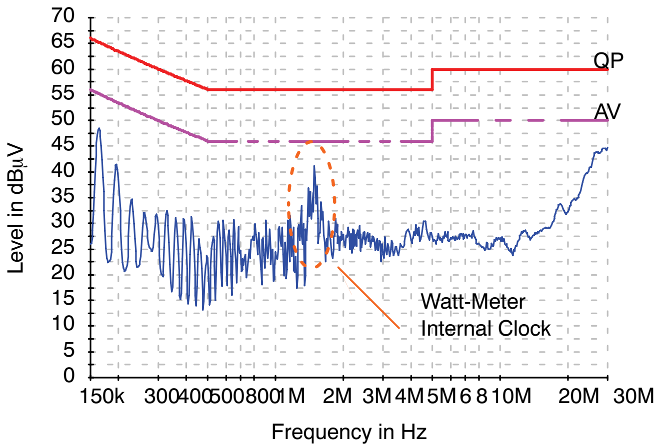

Figure 3. Board Conducted Emission at 110 VAC, 1.4 A Load, 2x27 mH Input Filter

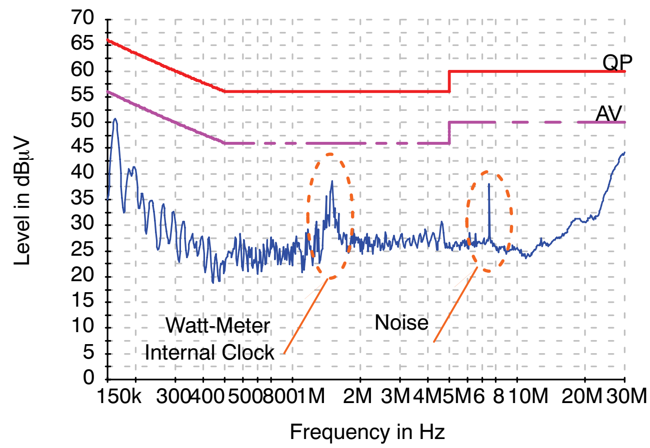

Figure 4. Board Conducted Emission at 110 VAC, 1.4 A Load, 2x15 mH Input Filter and Frequency Dithering

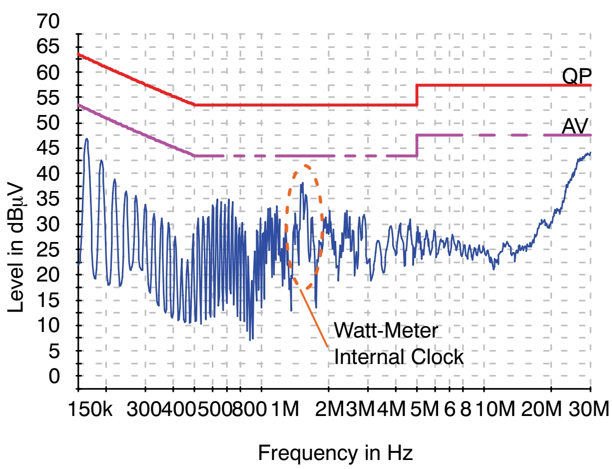

Figure 5. Board Conducted Emission at 220 VAC, 1.4 A Load, 2x27 mH Input Filter

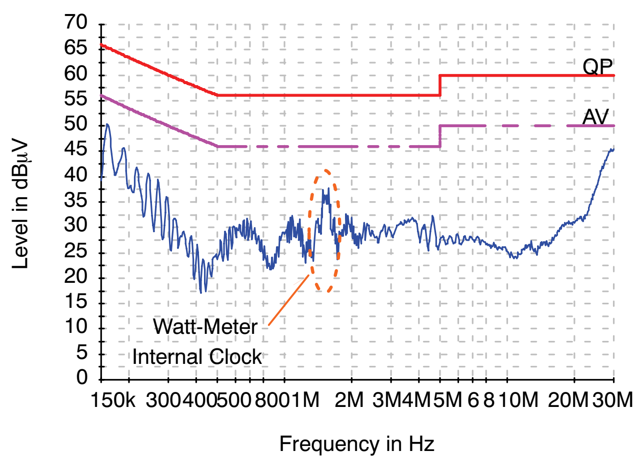

Figure 6. Board Conducted Emission at 220 VAC, 1.4 A Load, 2x15 mH Input Filter and Frequency Dithering

The peak seen at 1.5 MHz on the graphs is the watt-meter internal clock.

The graphs show that frequency dithering improves the EMI signature between 400 kHz and 25 MHz (emission level below 35 dBμV)

The drawback of implementing frequency dithering on CS pin is that it increases the output voltage ripple at light output loads.

The output voltage ripple is 50 mV at 16 W output power 10 mV at 1 W output power. (See Figure 8)

SCOPE SHOOTS

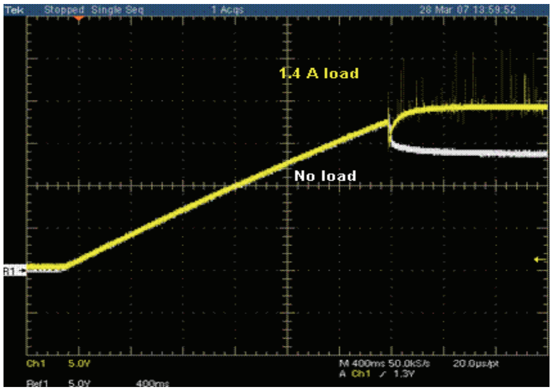

Figure 7. V_{CC} Startup at No Load and 1.4 A Load

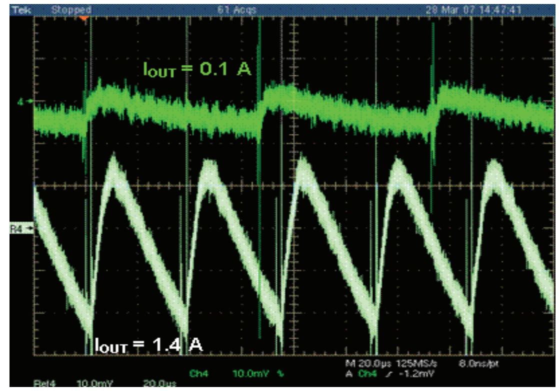

Figure 8. Output Voltage Ripple for Different Loads at V_{IN} = 320 VDC

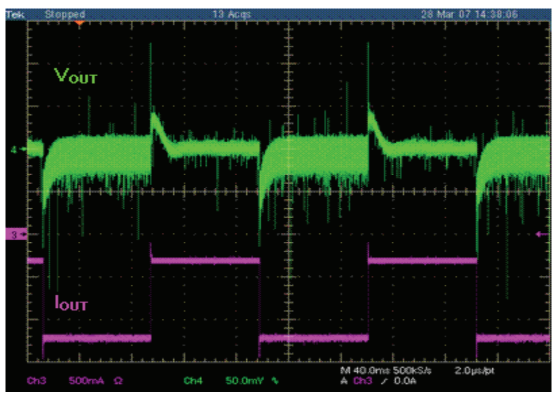

Figure 9. Load Step from 1.2 A to 0.1 A with a 0.1 A / μs Slew-Rate from a 230 VAC Source

Conclusion

The 24 W adapter built with NCP1351 shows excellent results on several parameters like the standby power (82 mW at V_{IN} = 230 VAC), the efficiency, the EMI signature.

The board features an option to inject frequency dithering in the design allowing to improve the EMI signature and to use a smaller input filter at the cost of the output ripple at light load.

Delta Electronics Transformer contact

Americas

Delta Products Corporation
4405 Cushing Parkway
Fremont, CA 94538
U.S.A.
Gordon Kuo
Phone: (1) 510-668-5166
email: GKuo@delta-corp.com

Asia

Delta Electronics, Inc.
252 Shangying Road, Guishan Industrial Zone
Taoyuan County 33341
Taiwan, R.O.C.
Jack Kuo
Phone: (886)-3-3591968 #2342
Fax: (886)-3-3591991
E-mail: jack.zc.kuo@delta.com.tw

Europe

Delta Electronics Europe
Wegalaan 16
2132JC Hoofddorp
The Netherlands
Coleman Liu
Phone: (31) 23 566 8950
Fax: (31) 23 566 8910
Email: cliu@euro.delta-corp.com

BILL OF MATERIAL

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Pb-Free
C1,C4, C5,C10	4	SMD Capacitor	100nF/50V	5%	SMD 1206	Phycomp	2238 581 15649	Yes	Yes
C2	1	Capacitor	10nF/630V	10%	Radial	Vishay	MKT1822310635	Yes	Yes
C3	1	Electrolytic Capacitor	10μF/50V	20%	Radial	Panasonic	ECA1HM100	Yes	Yes
C5b,C5a	2	Electrolytic Capacitor	1000μF/35V	20%	Radial	Panasonic	EEUFC1V102	no	Yes
C6	1	Capacitor	100nF/50V	10%	Radial	Murata	RPER71H104K2M 1A05U	Yes	Yes
C7	1	Electrolytic Capacitor	150μF/35V	20%	Radial	Panasonic	EEUFC1V151	Yes	Yes
C8	1	SMD Capacitor	220pF/50V	5%	SMD 1206	Phycomp	2238 863 15221	Yes	Yes
C11	1	x2 Capacitor	220nF/630V	20%	Radial	Evox Rifa	PHE840MD6220M	Yes	Yes
C12	1	Electrolytic Capacitor	47μF/400V	20%	Radial	Panasonic	ECA2GM470	Yes	Yes
C13	1	y1 Capacitor	2.2nF/250V	20%	Radial	Ceramite	440LD22	Yes	Yes
C14	1	SMD Capacitor	47pF/50V	5%	SMD 1206	Phycomp	2238 863 15479	Yes	Yes
C15	1	SMD Capacitor	22pF/50V	5%	SMD 1206	Phycomp	2238 863 15229	Yes	Yes
C17	1	Electrolytic Capacitor	100μF/35V	20%	Radial	Panasonic	ECA1VM101	Yes	Yes
D2	1	Ultrafast Rectifier	1A/600V	0%	Axial	ON Semiconductor	MUR160G	Yes	Yes
D3	1	Rectifier Diode	1A/600V	0%	Axial	ON Semiconductor	1N4937G	Yes	Yes
D5	1	Schottky Diode	8A/100V	0%	TO-22	ON Semiconductor	MUR820G	Yes	Yes
D6	1	High-speed Diode	0.2A/75V	0%	Axial	Philips Semiconductor	1N4148	Yes	Yes
D8	1	High-speed Diode	0.2A/100V	0%	SMD	ON Semiconductor	MMSD4148T1G	Yes	Yes
D9	1	Shunt Regulator	2.5-36V/1-100mA	2%	TO-92	ON Semiconductor	TLV431ILPG	Yes	Yes
D10	1	Diode Bridge	1A/600V	0%	Radial	TAIWAN Semiconductor	DB105G	Yes	Yes
HS2	1	Heatsink	6.2°C/W	0%	Radial	Seifert	KL194/25.4/SWI	Yes	Yes
J1	1	Connector	230VAC/	0%	Radial	Multicomp	JR-201S(PCB)	Yes	Yes
J2	1	Connector	2/"	0%	RAD5.08 mm	Weidmuller	PM5.08/2/90	Yes	Yes
L4	1	Inductor	2*27mH /0.8A	0%	Radial	Schaffner	RN114-0.8/02	Yes	Yes
M1	1	Power MOSFET N-Channel	3A/600V	0%	T0-220	Fairchild	FQP3N60	Yes	Yes
R2	1	Resistor	120kR /0.25W	5%	SMD 1206	Vishay	CRCW12061203F	Yes	Yes
R3	1	Resistor	100kR /0.25W	5%	SMD 1206	Vishay	CRCW12061003F	Yes	Yes
R5	1	SMD Resistor	2.4kR /0.25W	1%	SMD 1206	Welwyn	WCR 1206 2K4 2%	Yes	Yes
R6b,R6a	2	SMD Resistor	1.2R/1W	5%	SMD 1218	Phycomp	232273571208	Yes	Yes
R7	1	SMD Resistor	560kR /0.25W	1%	SMD 1206	Vishay	CRCW12065603F	Yes	Yes
R8	1	Resistor	1kR/0.33W	5%	Axial	Neohm	CFR25J1K0	Yes	Yes
R9	1	SMD Resistor	6.2kR /0.25W	1%	SMD 1206	Phycomp	232272466202	Yes	Yes

BILL OF MATERIAL

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Pb-Free
R10	1	SMD Resistor	6.8kR /0.25W	1%	SMD 1206	Vishay	CRCW12066801F	Yes	Yes
R11,R13	2	Resistor	47kR/2W	5%	Axial	Neohm	CFR200J47K	Yes	Yes
R12,R18	2	SMD Resistor	47kR /0.25W	1%	SMD 1206	Vishay	CRCW12064702F	Yes	Yes
R14	1	SMD Resistor	680kR /0.25W	1%	SMD 1206	Vishay	CRCW12066803F	Yes	Yes
R15	1	SMD Resistor	3.9kR/0.2W	1%	SMD 1206	Vishay	CRCW12063901F	Yes	Yes
R16	1	SMD Resistor	10R/0.25W	1%	SMD 1206	Vishay	CRCW120610R0F	Yes	Yes
R17	1	SMD Resistor	22R/0.25W	1%	SMD 1206	Vishay	CRCW120622R0F	Yes	Yes
R19	1	Resistor	1MR/0.25W	5%	SMD 1206	Vishay	CRCW12061004F	Yes	Yes
R20	1	SMD Resistor	2.2MR /0.25W	1%	SMD 1206	Phycomp	232272462205	Yes	Yes
T1	1	Transformer	86H-7071		Radial	Delta Electronics	86H-7071	No	Yes
U1	1	Optocoupler	SFH6156/	0%	SMD	Vishay	SFH6156-2T	No	Yes
U2	1	CMOS IC	NCP1351		SOIC-8H	ON Semiconductor	NCP1351B	No	Yes

PCB LAYOUT

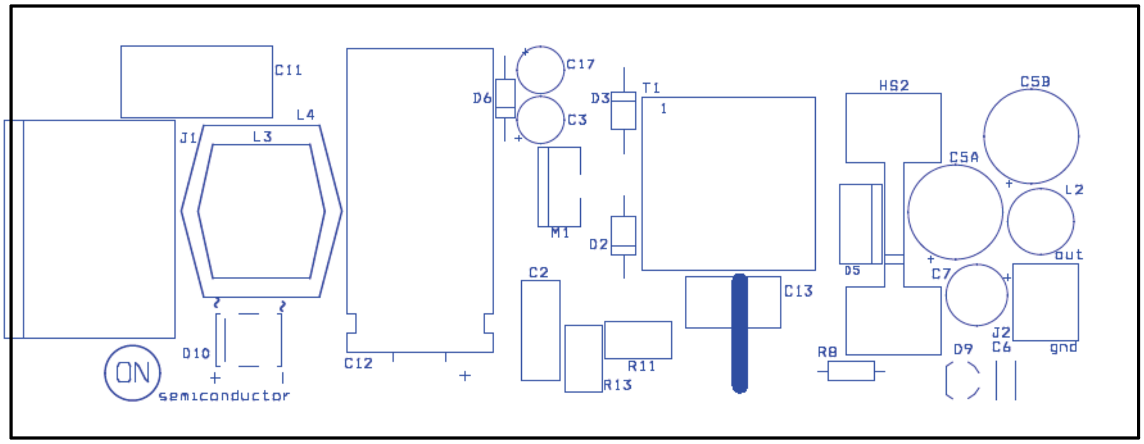

Figure 10. Top Side Components

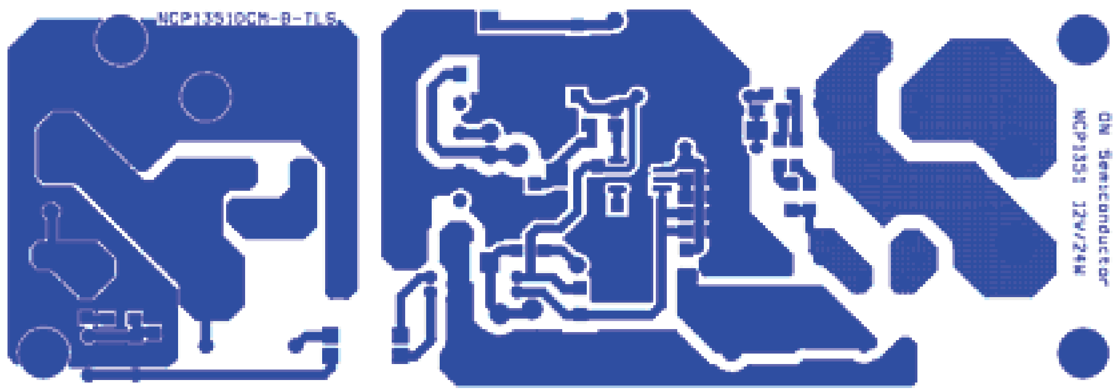

Figure 11. Copper Traces

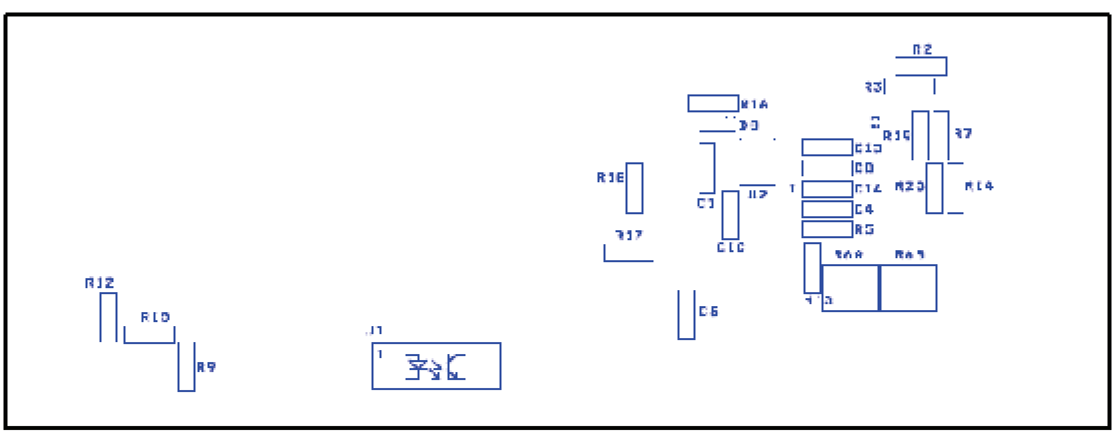

Figure 12. SMD Components

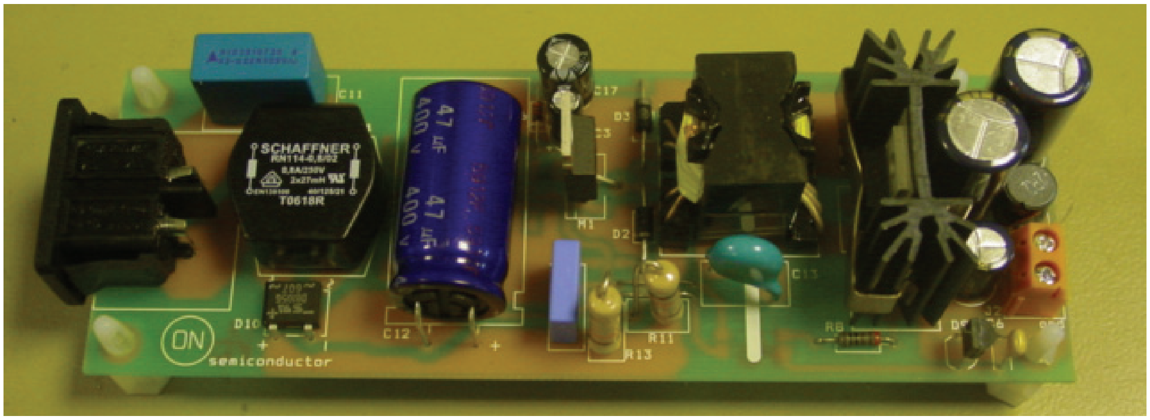

Figure 13. Adapter 12 V/24 W Picture (Top Side)

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