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A 12 V / 40 W AC-DC Demonstrator with NCP1250

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APPLICATION NOTE

Introduction

The NCP1250 is implemented in a 40-W ac-dc adapter delivering a dc voltage of 12 V. The converter takes advantage of the NCP1250 high integration level to offer a very good performance in standby power and Over Power Protection.

The Adapter Schematic

The adopted schematic appears in Figure 1. You can see the NCP1250B (auto-recovery short-circuit protection, 65 kHz) driving a power MOSFET in a flyback current-mode configuration. The mains is applied on the rectifying diodes bridge through an EMI filter made of a 10-mH common-mode choke. Its leakage inductance is used together with C_{11} to form a differential mode filter. To further save power in standby mode ($P_{out} = 0$ W), we have combined the need to discharge the 0.47 μ F X2 capacitor using resistors that will also be used to crank the controller at start-up. This is achieved by the set of four resistors (R_{15} , R_{27} , R_{17} and R_{20}) that ensure the discharge of the capacitor when the power cord is un-plugged. For a 0.47 μ F capacitor, a total of 2 M Ω is necessary to make the time constant less than 1 s, as recommended by the safety document IEC-950. As these resistors join at the NCP1250 V_{cc} pin where a 4.7 μ F capacitor is connected, it offers a cheap charging means for the capacitor connected there. Experiments show that this solution supplies enough current to start the converter in less than 3 s at an input voltage of 85 V rms. Over Power Protection, Over Temperature Protection and Over Voltage Protection are implemented around pin 3. Please refer to the available application notes for design details regarding these parts.

The controller drives a 4 A/600 V power MOSFET whose turn-off is accelerated by the addition of a small PNP transistor, Q_1 . A 100 pF capacitor smoothes the drain-source signal at the switch opening and helps to soften the EMI signature. The transformer is built in a RM10 ferrite shape made of 3C90 material. The primary inductance is 700 μ H and the turns ratio between the power secondary and the primary side is 1:0.15. This number is slightly increased to 1:0.17 on the auxiliary winding to maintain V_{cc} in no-load situations.

The secondary side implements a classical TL431 whose bias current is automatically disconnected in a no-load situation through C_5D_7 . This proprietary technique reduces the bias voltage applied to R_{19} left terminal when the converter enters standby mode. As this 1 mA burden disappears from the 19 V output in a no-load configuration, the input power greatly benefits from the situation. Furthermore, this architecture does not impact the transient response of the converter when transitioning from no-load to full-load.

The converter has been laid out in a compact style as shown in Figure 2. The board can deliver a continuous current up to 3.5 A when operated in a 50°C ambient temperature. The overpower protection trips for a maximum current of 4.2 A. This value slightly varies between the boards and the line level but stays typically within a short range thanks to the proprietary non-dissipative OPP implemented in the NCP1250. Please see below the board performance in terms of efficiency in various loading conditions.

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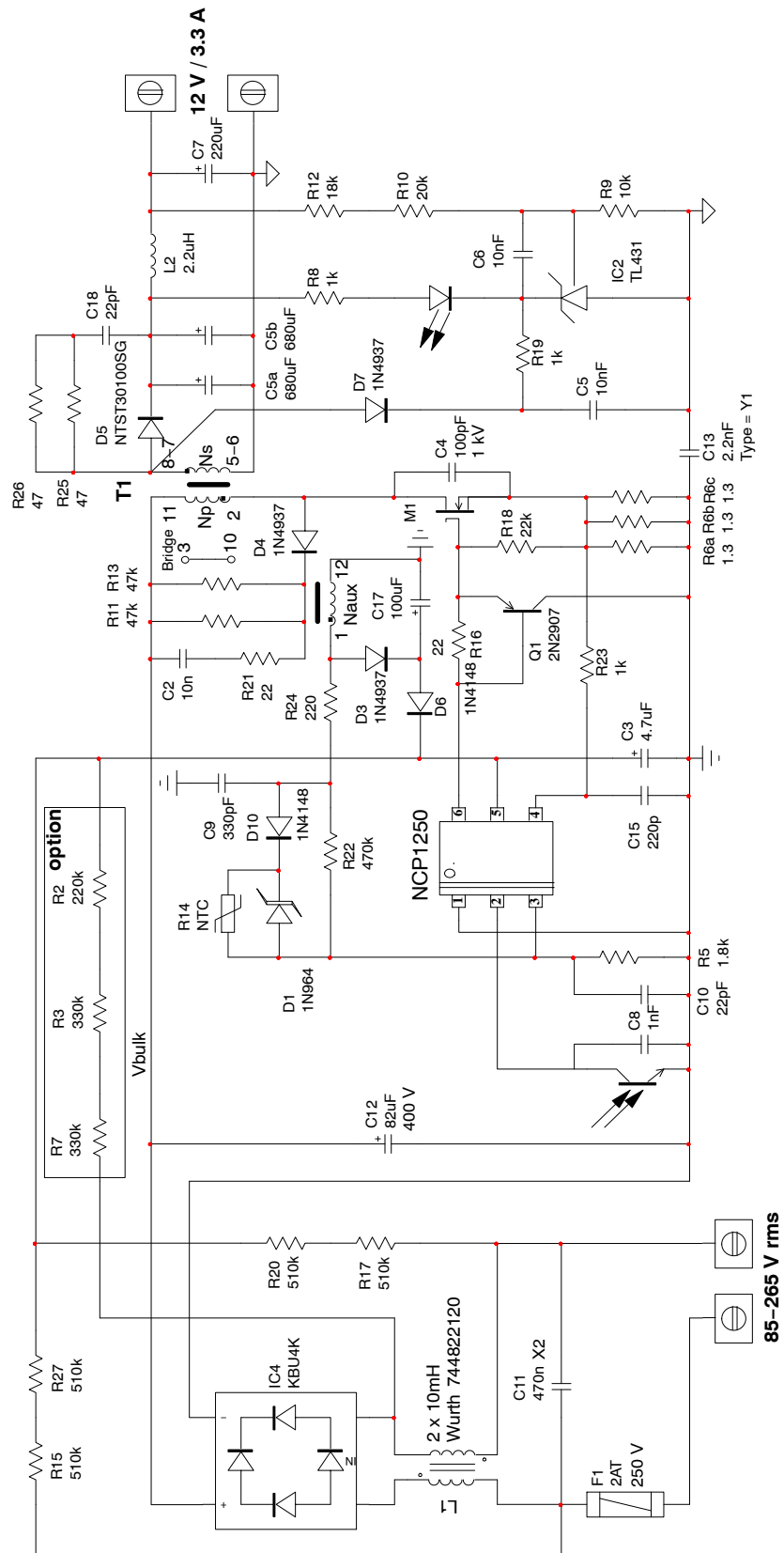


Figure 1. The adapter uses all the features brought by the NCP1250 to implement a high-performance 40-W converter.

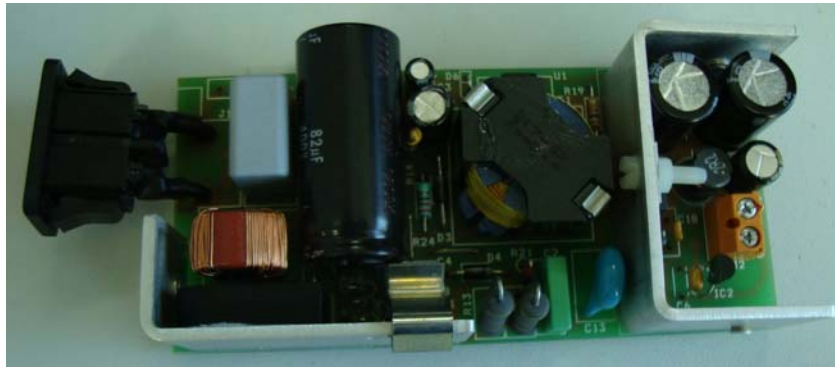


Figure 2. The PCB layout and component arrangement offers a compact size.

Efficiency Performance

The NCP1250 excels in terms of efficiency and standby power. We have made a series of tests on the proposed adapter, carried at both high and low lines. The load is applied directly at the board terminals. The results appear below.

Output Power	Efficiency - $V_{in} = 115\text{ V rms}$ (%)	Efficiency - $V_{in} = 230\text{ V rms}$ (%)
10.3 W - 25%	87.18	85.1
20.7 W - 50%	88.13	86.9
31.2 W - 75%	88.10	88.2
41.5 W - 100%	87.76	88.5
Average efficiency	87.8	87.2

No-load standby power:

Output Power	Input power - $V_{in} = 100\text{ V rms}$ (mW)	Input power - $V_{in} = 230\text{ V rms}$ (mW)
0	33	75

Light load efficiency:

Output Power	Input power - $V_{in} = 100\text{ V rms}$ (W)	Input power - $V_{in} = 230\text{ V rms}$ (W)
0.5 W	0.7	0.76
0.6 W	0.83	0.89

The performance is linked to the combined action of the frequency foldback and the skip cycle operation at constant peak current. Please note that the no-load standby power includes the 2 MΩ discharge resistors string placed across the X2 capacitor on the input filter. These numbers are excellent considering a low-voltage controller featuring a start-up network.

Conclusion

This application note describes how an ac-dc converter meeting all new efficiency challenges can be built with the new NCP1250. Despite a small TSOP-6 package and a limited amount of pins, the performance of the final board nicely competes against other more complex circuits by offering a similar set of options plus some unique features such as the non-dissipative OPP circuit. This makes the part the ideal candidate where space constraints, performance and cost sensitivity have to be combined.

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Designator	Quantity	Description	Value	Footprint	Manufacturer	Manufacturer Part Number
C2	1	high-voltage capacitor	10 nF/630 Vdc	through-hole	Vishay	MKT1822310635
C3	1	electrolytic capacitor	4.7 uF/35 V	through-hole	Panasonic	ECA1VAD4R7X
C4	1	ceramic capacitor	100 pF/1000 V	through-hole	Panasonic	ECKA3A101KBP
C5a, C5b	2	electrolytic capacitor	680 uF/35 V	through-hole	Rubycon	35ZL680MEFC12.5X20
C5	1	ceramic capacitor	10 nF	SMD1206	Multicomp	MC1206B103K500CT
C6	1	film capacitor	10 nF	through-hole	Multicomp	MCRR50103X7RK0050
C7	1	electrolytic capacitor	220 uF/25 V	through-hole	Rubycon	25ML220M8X9
C8	1	ceramic capacitor	1 nF	SMD1206	Multicomp	MC1206B102K500CT
C9	1	ceramic capacitor	330 pF	SMD1206	Multicomp	MC1206B220K500CT
C10	1	ceramic capacitor	22 pF	SMD1206	Multicomp	MC1206B331K500CT
C11	1	X2 capacitor	470 nF/275 Vac	through-hole	Epcos	B32922C3474M
C12	1	high-voltage electrolytic capacitor	82 uF/400 V	through-hole	Panasonic	EEUED2G820
C13	1	EMI Y1 capacitor	2.2 nF/ 250 Vac	through-hole	CERAMITE	440LD22
C15	1	ceramic capacitor	220 pF	SMD1206	Multicomp	MC1206B221K500CT
C17	1	electrolytic capacitor	100 uF/35 V	through-hole	Panasonic	ECA1VM101
C18	1	ceramic capacitor	22pF	through-hole	Murata	RPE5C2A220J2M1Z03A
D1	1	Zener diode	18 V/ 0.5 W	SOT23	ON Semiconductor	BZX84C18LT3G
D3, D4	2	fast diode	1N4937	through-hole	ON Semiconductor	1N4937G
D5	1	power diode	NTST30100SG	TO220	ON Semiconductor	NTST30100SG
D6	1	signal diode	1N4148	through-hole	NXP	1N4148
D7	1	fast diode	MURA160	SMA	ON Semiconductor	MURA160T3G
D10	1	signal diode	1N4148	SOD123	ON Semiconductor	MMSD4148T3G
F1	1	Fuse	250 V / 2 A T	through-hole	Multicomp	MST 2A 250V
HS1, HS2	2	heat sink				
IC2	1	shunt regulator	TL431	through-hole	ON Semiconductor	TL431CLPG
IC4	1	diode bridge	KBU4K	through-hole	Multicomp	KBU4K
J1	1	connector	-	through-hole	Multicomp	JR-201S
J2	1	connector	-	through-hole	WEIDMULLER	PM5.08/2/90
L1	1	common mode inductor	2*10 mH/2 A	through-hole	Würth Elektronik	744823210
L2	1	inductor	2.2 uH/6 A	through-hole	Würth Elektronik	744772022
M1	1	high-voltage MOSFET	4 A/600 V	TO220	ON Semiconductor	NDF04N60ZG
Q1	1	PNP transistor	BC857	SOT23	ON Semiconductor	BC857ALT1G
R5	1	resistor	1.8 k	SMD1206	Vishay	CRCW12061K80FKEA
R6a, R6b, R6c	3	resistor	1.3	through-hole	Multicomp	MF251R3
R8, R19	2	resistor	1 k / 0.25 W	through-hole	Multicomp	MF251K
R9	1	resistor	10 k	SMD1206	Vishay	CRCW120610K0FKEA
R10	1	resistor	20 k	SMD1206	Vishay	CRCW120620K0FKEA
R11, R13	2	power resistor	47 k / 3 W	through-hole	Vishay	PR03000204702JAC00
R12	1	resistor	18 k	SMD1206	Vishay	CRCW120618K0FKEA
R14	1	NTC thermal sensor	100k@25°C	through-hole	Vishay	NTCLE100E3104JB0
R15, R17, R20, R27	4	mains-connected resistor	510k	SMD1206	Vishay	CRCW1206510K00FKEA

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Designator	Quantity	Description	Value	Footprint	Manufacturer	Manufacturer Part Number
R16	1	resistor	10	SMD1206	Vishay	CRCW120610R0FKEA
R18	1	resistor	22 k	through-hole	Multicomp	MF2522K
R21	1	power resistor	22 /1 W	through-hole	Vishay	PR01000102209JR500
R22	1	resistor	470 k	SMD1206	Vishay	CRCW1206470KFKEA
R23	1	resistor	1 k	SMD1206	Vishay	CRCW12061K00FKEA
R24	1	resistor	220	through-hole	Multicomp	MF25220
R25, R26	2	resistor	47 / 1 W	through-hole	Vishay	PR01000104709JA500
T1	1	RM10 flyback transformer		through-hole	CME France	17452/02
U1	1	optocoupler	SFH615A-2		Vishay	SFH615A-2
U3	1	65 kHz controler	NCP1250B	TSOP6	ON Semiconductor	NCP1250A
V1	1	countersunk head screws + nut	M3x6mm			
V2	1	nylon screw + nut	M3x6mm			

The transformer has been designed and manufactured by the following French company:

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