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Design Note – DN05054/D

Universal AC Input, 5 Volt Output, 20 Watt Power Supply

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP1136 NCP431	Smart Meters, Electric Meters, White Goods	85 to 305 Vac	20 W Nominal 25 W Peak	CCM Flyback	Isolated (3 kV)

	Output Specification
Output Voltage	5 Vdc
Ripple	100 mV p/p @ full load
Nominal Current	4 Amps continuous
Max Current	5 A maximum (with R7/8 modification)
Min Current	zero

PFC (Yes/No)	No, (Pout < 25 watts)
Efficiency	Meet Energy Star 2.0
Input Protection	Fuse
Operating Temp. Range	0 to +50°C
Cooling Method	Convection
Standby Power	30 mW at 120 Vac 80 mW at 230 Vac

Circuit Description

This design note describes a simple 20 watt, universal AC input, constant voltage power supply intended for AC adapters, industrial equipment, or white goods where isolation from the AC mains is required, and low cost, high efficiency, low standby power are essential.

The featured power supply is a simple CCM flyback topology utilizing ON Semiconductor's new NCP1136 monolithic switcher with integral 4-ohm, vertical channel MOSFET in a DIP8 package (U1). This Design Note provides the complete circuit schematic details and BOM for 5 volt, 4 amp power supply with a surge rating to 5 amps. Other output voltages from 3.3 Vdc up to 28 Vdc are easy to implement by modifying the values (or ratings) of a few of the secondary side output components and the flyback transformer's secondary winding (T1 The NCP431 programmable zener is used as an error amplifier (U3), plus an optocoupler feedback scheme (U2) provides for excellent line and load regulation with high input-to-output safety isolation.

Performance characteristics for efficiency, output ripple, and internal MOSFET drain switching characteristics (Vds, Id) are shown in the figures and plots below for the 5V/4A version. Enhanced input transient protection (lightning, etc.) can be accomplished with the addition of an appropriate TVS device across the input of the diode bridge BD1.

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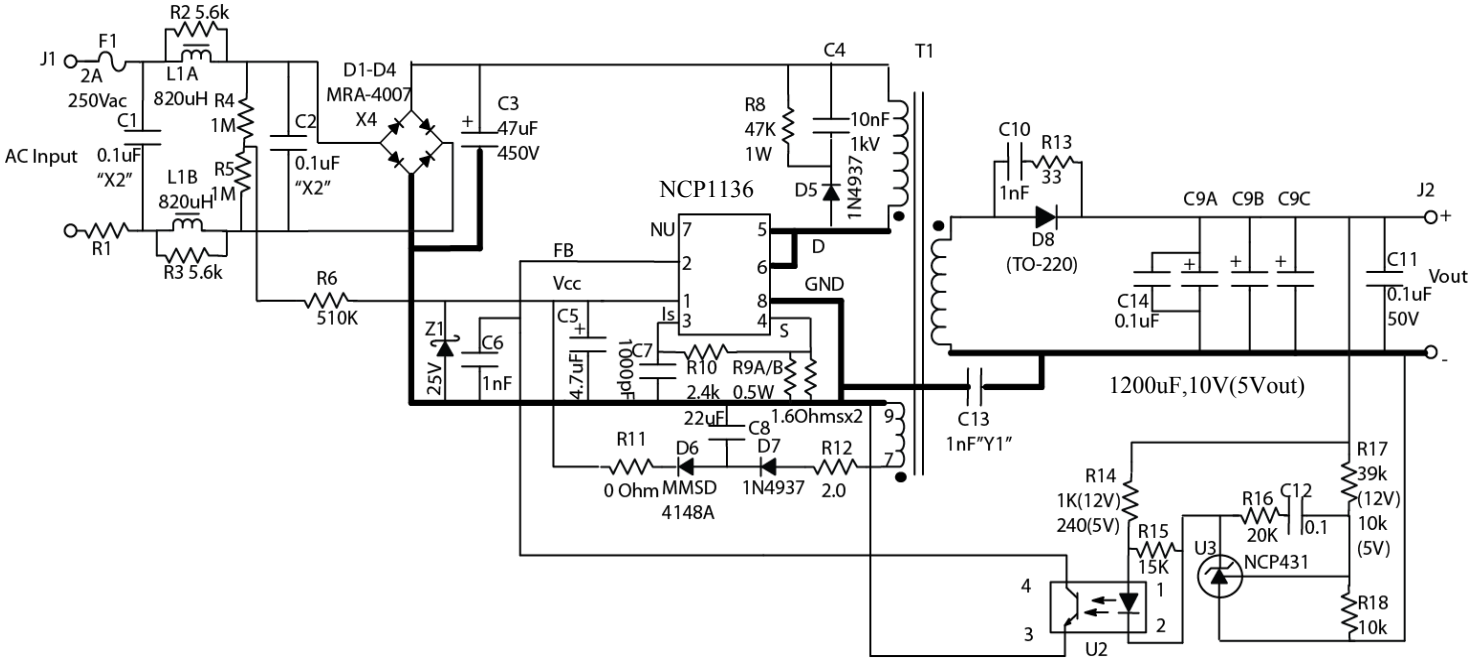
Key Features

- Universal AC input range (85 – 305 Vac).
- 800V Avalanche rated Internal MOSFET
- Very low standby (no load) power consumption.
- Frequency foldback under light load and/or overcurrent conditions.
- Inherent over-current, over-voltage and over temperature protection.

For optimum thermal characteristics, the printed circuit board should be laid out to include clad “pours” around pins 5 and 6 of the DIP8 package (MOSFET drain pins). Resistors 9A & B (paralleled) set the peak current limit point for the internal overcurrent protection circuit of U1 and can be adjusted for desired max output current (see NCP1136 data sheet). For output voltages other than 5 volts, typical circuit changes include the transformer turns ratio for both the secondary and the primary aux winding, the value of R17 in the output voltage sense divider, and selecting appropriate voltage ratings for output rectifier D8 and output capacitors C9A, B & C. Depending on the transformer aux winding characteristics, it may be necessary to change R11 to a higher value resistance value to adjust the nominal Vcc voltage. Z1 can be added as an option in the event that the compliance range of the Vcc over the output load range exceeds the OVP trip point on pin 1 of U1 (28 volts). Such a scenario would be the result of a transformer with high leakage inductance.

Circuit Schematic



NOTES:

1. Crossed lines on schematic are NOT connected.
2. U2 is NEC PS2561L-1 or equivalent optocoupler(CTR>50%).
3. R1 is optional for increased inrush limiting- use wire wound only.
4. L1A/L1B are Wurth #7447728215 inductors (820uH, 500mA).
5. Output caps(C9A/B/C) are radial lead, low impedance types(UCC LXV series or similar).
6. R11 is for Vcc trimming(<28Vmax), typically zero ohms.
7. R9A/B sets max output current.
8. Heavy schematic lines indicate recommended ground plane areas.

15/20 Watt NCP 1136 Power Supply
With Universal AC Input

Differences between NCP1126/9 (650 V MOSFET) and NCP1136 (800 V MOSFET) Eval Boards:

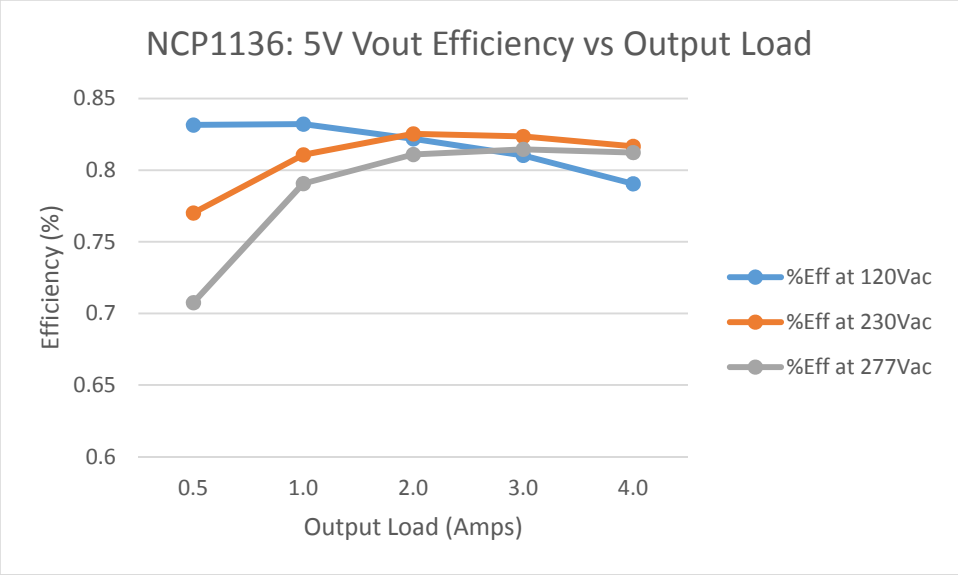
1. NCP1136 accepts wider input voltage range of 85 V ac to 305 V ac compared to 85 V ac to 265 V ac in NCP1126/9
2. Bulk capacitor (C3) voltage rating increased to 450 V to accommodate higher input voltage compared to NCP 1126/9
3. Current sense resistor (R9) is reduced to 1.6 Ω for better voltage regulation across the wider input voltage.

T1 Transformer Designs (Available from ICE Components Inc. and Wurth Electronics)

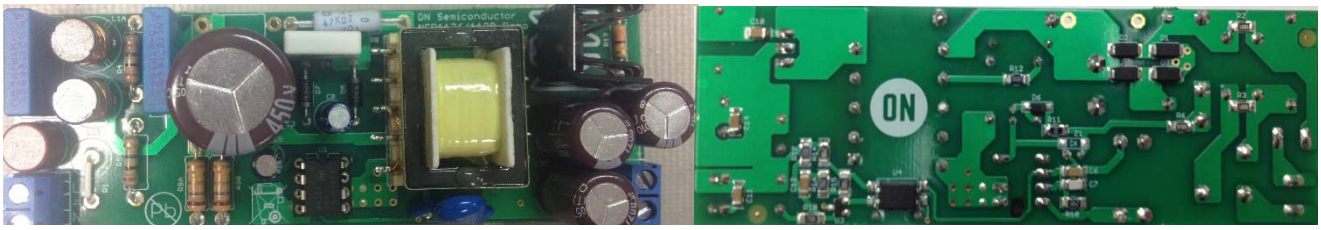
5V/4A, 65 kHz Version (ICE # TO0915-1, Wurth Electronics #750313860 Rev 01)

Core: E25/10/6 (812E250)
Primary A: 55 turns of 0.25mm mag wire
5V Secondary: 11 turns bifilar of 0.6mm Triple Insulated Wire (2 layers)
Aux/Vcc: 25 turns of 0.15mm mag wire spiral wound over 1 layer
Primary B: 55 turns of 0.25mm mag wire
Primary Inductance (Pri A and B in series): 2 mH +/- 10% (gap in center leg)
Leakage Inductance (5Vsec & Aux shorted): 40 uH max

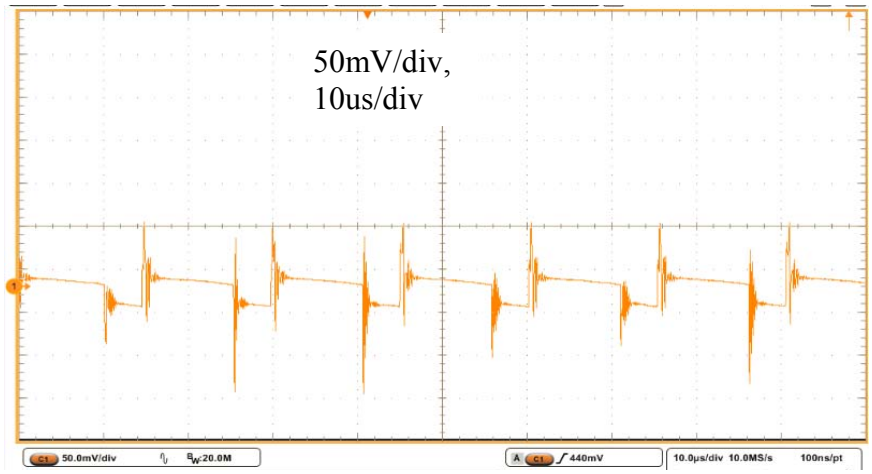
5 Volt Efficiency vs Output Load Curves



Board Picture

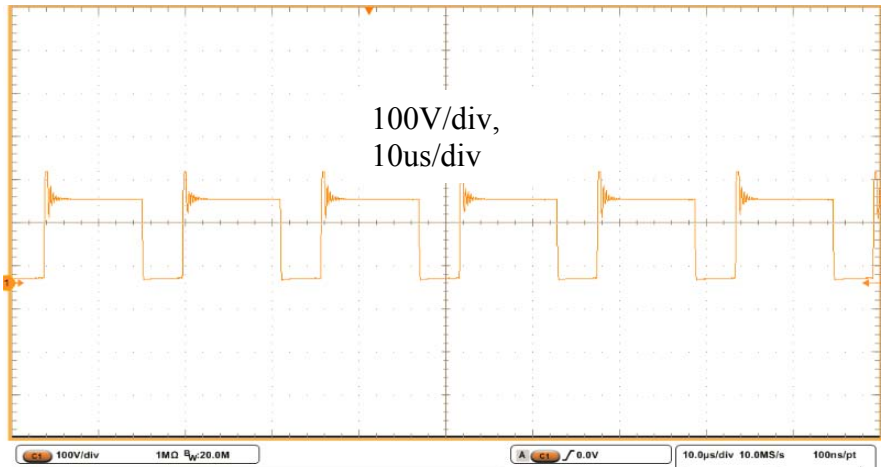


Full Load Output Voltage Ripple @ 120 Vac Input

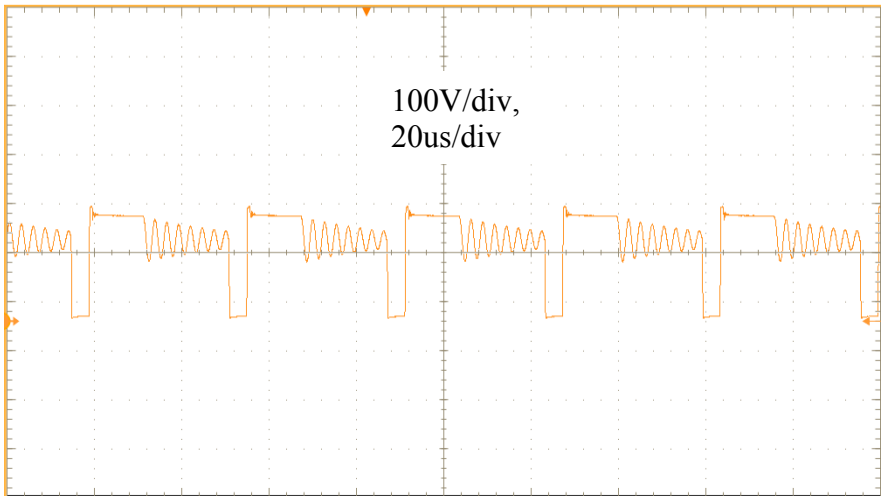


MOSFET Drain Voltage (120 Vac Input)

Full Load

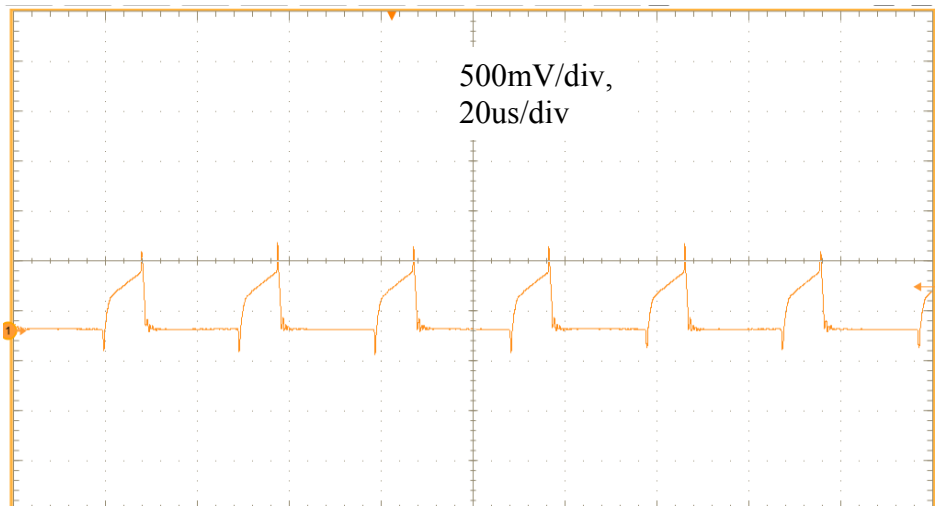


0.5 Amp Load

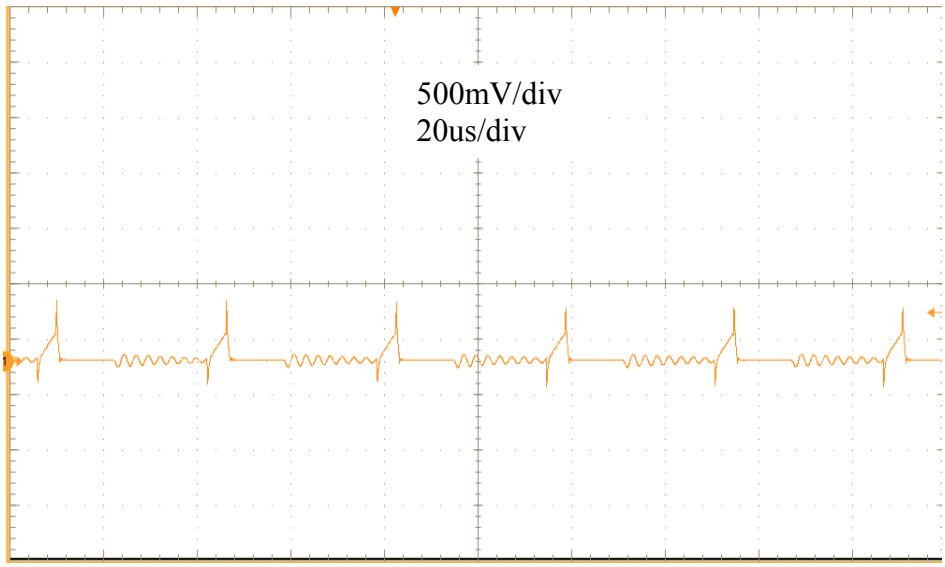


Mosfet Drain Current (120 Vac Input)

Full Load



0.5 Amp Load



Bill Of Materials

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed
D8 (5Vout)	1	Schottky diode	20A,100V		TO-220	ON Semi	NTST20100CTG	No
D1, 2, 3, 4	4	Diode - 60 Hz,	1A, 800V		SMA	ON Semi	MRA4007	No
D5, D7	2	Diode - fast recov	1A, 600V		axial lead	ON Semi	1N4937	No
D6	1	Signal diode	100mA, 100V		SOD-123	ON Semi	MMSD4148A	No
Z1	1	Zener diode	27V		SOD-123	ON Semi	MMSZ5254B	
U3	1	Programmable zener	2.5V		SOT23	ON Semi	NCP431A	No
U2	1	Optocoupler	CTR >/= 0.5		4-pin	Vishay or NEC	SFH6156A-4 or PS2561L-1	Yes
U1	1	Controller - NCP1126/1129	65 kHz		DIP8	ON Semi	NCP1126/1129BP65G	No
C1, C2	2	"X" cap, box type	100nF, X2		LS = 15 mm	Rifa, Wima	TBD	Yes
C13	1	"Y1" cap, disc type	1nF, Y1		LS = 7.5 mm	Rifa, Wima	TBD	Yes
C4	1	Ceramic cap, box	10 nF, 1kV	10%	13x4 mm, LS=10 mm	Vishay	MKT1822310635	Yes
C6	1	Ceramic cap, monolythic	1 nF, 50V	10%	1206	AVX, Murata	TBD	Yes
C11, 12, 13	3	Ceramic cap, monolythic	100nF, 50V	10%	1206	AVX, Murata	TBD	Yes
C7	1	Ceramic cap, monolythic	100pF, 50V	10%	1206	AVX, Murata	TBD	Yes
C10	1	Ceramic cap, monolythic	1 nF, 200V	10%	1206	AVX, Murata	TBD	Yes
C3	1	Electrolytic cap	47uF, 450V	10%	LS=7.5mm, D=18mm	UCC	EKXG401ELL470MM20S	Yes
C5	1	Electrolytic cap	4.7uF, 50Vdc	10%	LS=2.5mm, D=5mm	UCC, Panasonic	TBD	Yes
C8	1	Electrolytic cap	22uF, 50Vdc	10%	LS=2.5mm, D=6.3mm	Panasonic - ECG	ECA-1HM220	Yes
C9A,B,C (5V)	3	Electrolytic cap	1,200uF, 10V	10%	10x20mm, LS=5mm	UCC	EKZE100ELL122MJ20S	Yes
R1	1	#22 bare wire jumper	(wire jumper)		LS=7.5mm, D=7mm			Yes
R8	1	Resistor, 2W, metal film	47K, 1W	10%	Axial lead; LS=18mm	Panasonic - ECG	ERG-2SJ473A	Yes
R4, R5	2	Resistor, 1/2W metal film	1 Meg, 1/2W	10%	Axial lead; LS=12.5mm	Ohmite, Dale	TBD	Yes
R9A, B	2	Resistor, 1/2W metal film	1.6 ohm, 1/2W	5%	Axial lead; LS=12.5mm	AVX, Vishay, Dale	TBD	
R13	1	Resistor, 1/4W metal film	33 ohms, 1/4W	10%	Axial lead; LS=10mm	AVX, Vishay, Dale	TBD	
R2, R3	2	Resistor, 1/4W SMD	5.6K	5%	SMD 1206	AVX, Vishay, Dale	TBD	
R6	1	Resistor, 1/4W SMD	510K	5%	SMD 1206	AVX, Vishay, Dale	TBD	Yes
R10	1	Resistor, 1/4W SMD	2.4K	5%	SMD 1206	AVX, Vishay, Dale	TBD	Yes
R11	1	Resistor, 1/4W SMD	TBD (0 ohms)	5%	SMD 1206	AVX, Vishay, Dale	TBD	
R12	1	Resistor, 1/4W SMD	2.0 ohms	5%	SMD 1206	AVX, Vishay, Dale	TBD	
R15	1	Resistor, 1/4W SMD	15K	5%	SMD 1206	AVX, Vishay, Dale	TBD	
R16	1	Resistor, 1/4W SMD	20K	5%	SMD 1206	AVX, Vishay, Dale	TBD	
R18	1	Resistor, 1/4W SMD	10K	5%	SMD 1206	AVX, Vishay, Dale	TBD	
R14 (5Vout)	1	Resistor, 1/4W SMD	240 ohms	5%	SMD 1206	AVX, Vishay, Dale	TBD	Yes
R17 (5Vout)	1	Resistor, 1/4W SMD	10K	5%	SMD 1206	AVX, Vishay, Dale	TBD	Yes
F1	1	Fuse, TR-5 style	2A		TR-5, LS=5mm	Minifuse	TBD	Yes
L1A/B	1	Inductor (EMI choke)	820 uH, 500 mA		See Wurth Drawing	Wurth Magnetics	7447728215	Yes
T1 (5Vout)	1	Transformer	E20/10/6 core		See Mag Drawing	ICE Magetics	TO09151-1	Yes
J1, J2	2	Screw Terminal			LS = 0.2"	DigiKey	# 281-1435-ND	Yes
D8 Heatsink	1	Clip-on Heatsink	(TO-220)		0.52" x 0.52" x 0.75"H	Mouser (Aavid)	532-576802B00 or equiv.	

References

ON Semiconductor data sheet for NCP1136 monolithic switcher.

ON Semiconductor Design Notes DN05012, DN05017, DN05018, DN05028, DN05029, DN05043/D

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