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AND8142/D

A 6.0 W/12 W Universal Mains Adapter with the NCP101X

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APPLICATION NOTE

The present report depicts a demonstration board built around the NCP1013P06, a new monolithic high−voltage switcher. Delivering 6.0 W from 90 VAC to 250 VAC, the board complies with EMI testing CISPR0022 and offers the ability to either use the Dynamic Self−Supply or an auxiliary winding. With this latter, the converter passes less than 100 mW in a no−load situation at 230 VAC.

Schematic Description

Figure 1 portrays the board application schematic whose heart is powered by the NCP1013 operating at 65 kHz. This frequency is selected for a) passing the CISPR0022 EMI specification (that starts at 150 kHz) more easily b) reducing the switching losses.

As one can see from Figure 1, a jumper exists and offers the ability to disconnect the Dynamic Self−Supply (DSS): when left open, the DSS powers the controller and introduces frequency jittering thanks to the V_{CC} ripple injected inside the circuit. It also offers a precise short−circuit trip point since the decision is taken independently of any loosely coupled auxiliary winding. The input power consumption is directly the current needed to power the controller multiplied by the rectified bulk voltage. If we assume an average controller current of 1.0 mA and a bulk level of 330 VDC, the input power will be around 330 mW in a no−load situation. If the jumper is now put in place, the DSS disconnects itself and the standby power reduces below 100 mW. Precise numbers are given in a summary table at the end of this document.

An RCD network safely clamps the maximum drain excursion below 700 V at the highest mains conditions, e.g. Vbulk = 370 V. A small 1.0 nF capacitor decouples the FB to ground and prevents any noise from coupling inside the controller. The resistor in series with the auxiliary winding limits the current in the active V_{CC} clamp, in case the auxiliary winding is connected. Please note that this option enables the optocoupler fail−safe protection: if the loop gets accidentally opened, the V_{CC} grows−up and imposes an abnormal current into the V_{CC} pin. The internal circuitry detects it and the controller is fully latched−off. The user must unplug the converter from the mains until V_{CC} collapses below 4.0 V to reset all internal logic blocks.

Practical Measurements

Some typical measurements are detailed below and highlight the impact between the DSS or the auxiliary winding implementation. All measurements were carried in a 25°C operating temperature.

Standby Power

When the load is removed, it becomes possible to measure the power absorbed by the demoboard in both operating modes, DSS or auxiliary winding. It is required to let the converter warm up for 15 minutes before recording the numbers:

DSS: Vin = 120 VDC, Iout = 0, Pin = 130 mW
Vin = 330 VDC, Iout = 0, Pin = 320 mW

Aux.: Vin = 120 VDC, Iout = 0, Pin = 69 mW
Vin = 330 VDC, Iout = 0, Pin = 66 mW

The slight difference in the low/high numbers with the auxiliary winding is due to the startup leakage current (35 μA), although very low, this number decreases as the junction heats up (the internal controller consumption too). With 330 VDC, the die temperature is slightly higher than with 120 VDC and it explains the minor difference.

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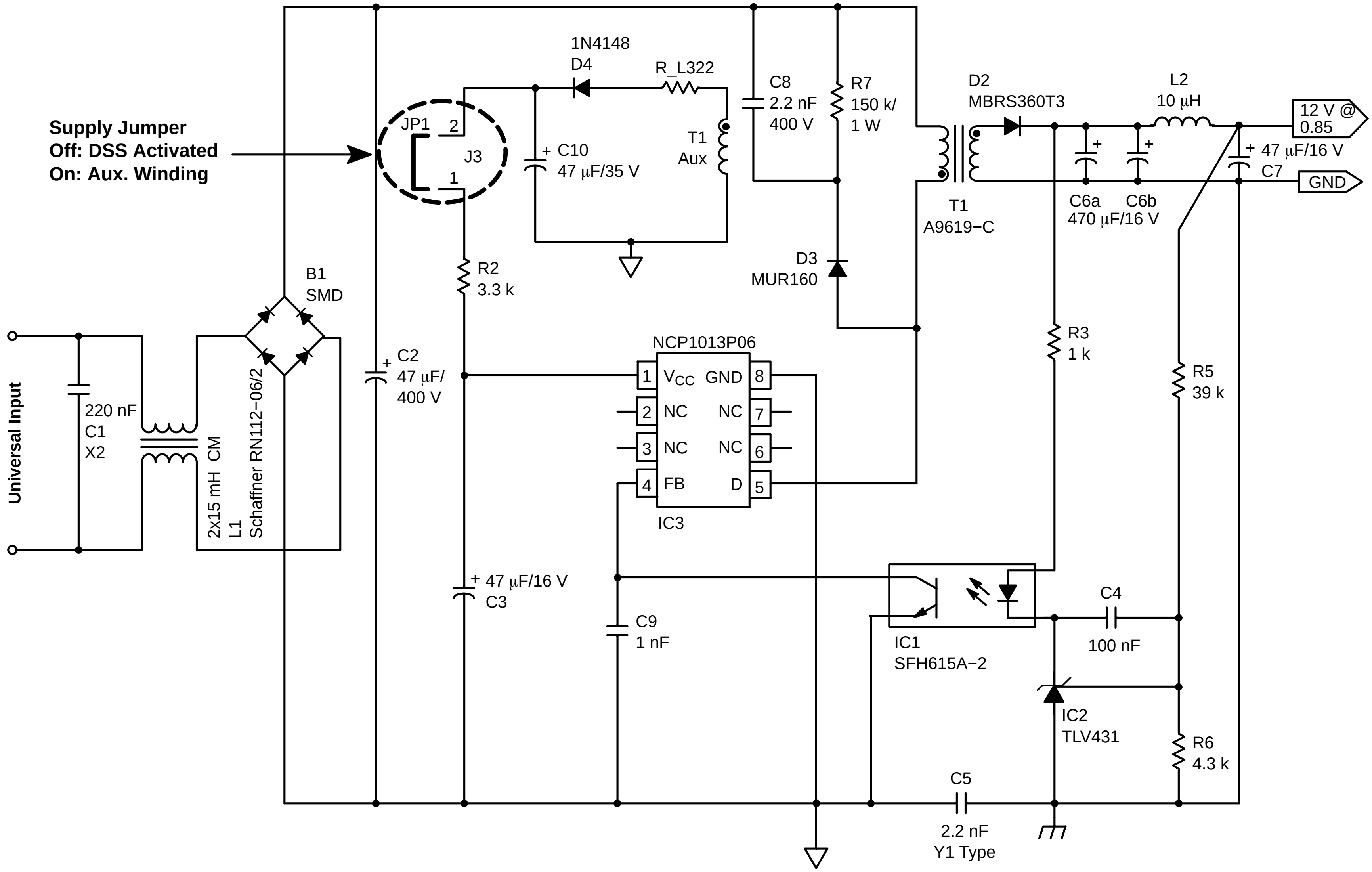

Figure 1. The Electrical Schematic of the 6.0 W Power Supply

Efficiency

As the DSS is directly drawing current from the rectified rail via the drain pin, the average consumption permanently present (though lowered when skip is activated) slightly degrades the efficiency at light loads and low output power. Nevertheless, efficiency is still above 50% at 730 mW output power. Figures 2 and 3 portray the efficiency evolution at both input voltages with either DSS or auxiliary winding.

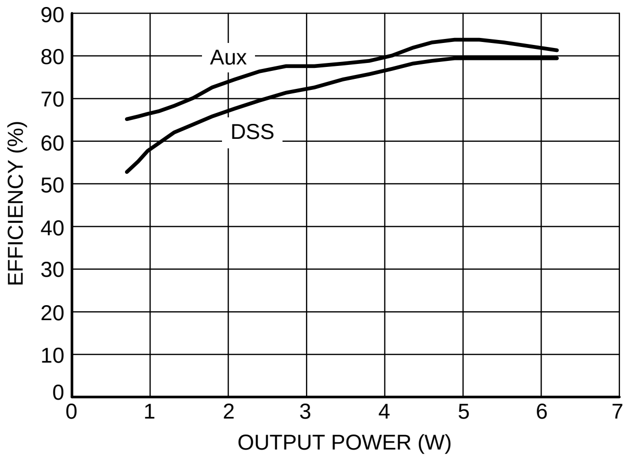

Figure 2. Efficiency vs Power, Vin = 330 Vdc
Efficiency at High Input Line

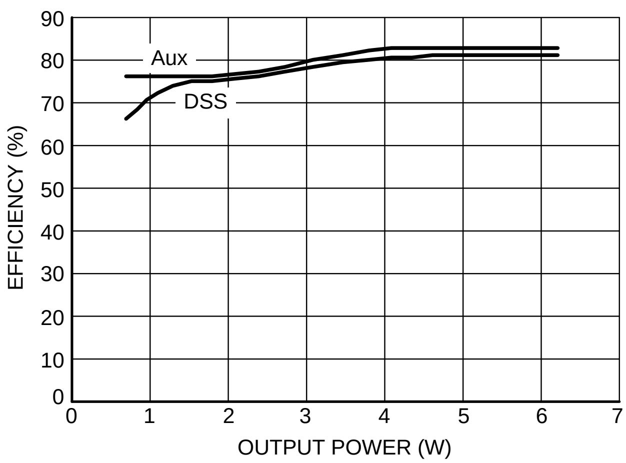

Figure 3. Efficiency vs Power, Vin = 120 Vdc
Efficiency at Low Input Line

Output Voltage Versus Output Current

Using the DSS or an auxiliary winding makes a big difference in the ability to let the power supply detect an over current condition. Both versions will be protected against real short−circuits (Rload = 0), but the DSS will naturally offer an improved performance when a precision trip point is needed. This is mainly due to the poor coupling between the auxiliary winding and the power winding which prevents proper collapsing when Vout goes low. Also, the built−in OVP forces us to grow the auxiliary voltage, which does not play in our favor either.

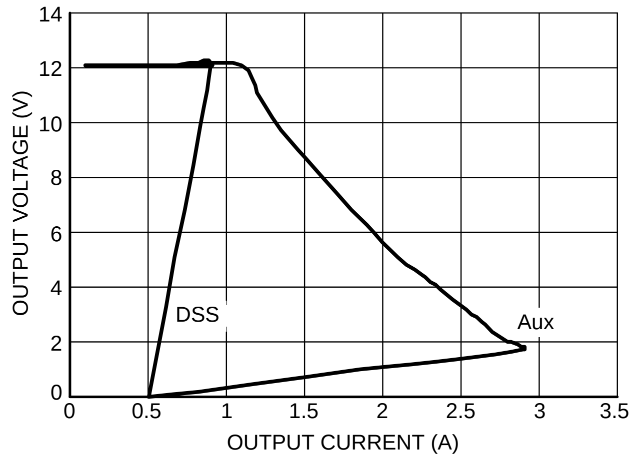

Figure 4. Vout vs Iout (330 Vdc)
The DSS Offers a Better Performance to Detect an Overcurrent Condition

Operating Curves

It is important to check that critical parameters are well within control before releasing the board to production. Following are some curves captured on the demonstration board with their individual comments.

Drain−Source Waveform

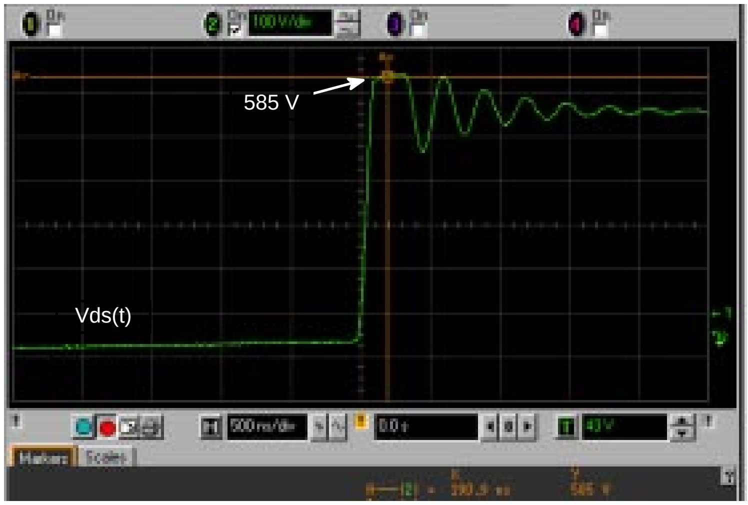

Figure 5. Drain−Source Voltage Captured at V_{in} = 370 VDC with Maximum Output Power

This shot has been taken just before the maximum current trip point is reached. It corresponds to the highest peak power and the largest reflected voltage on the drain. This event also occurs during the start−up sequence, just before the loop is closed (e.g. Vout reaches its target). The displayed level of 585 V gives sufficient room when compared to the internal MOSFET BVdss of 700 V.

Feedback Loop Closure

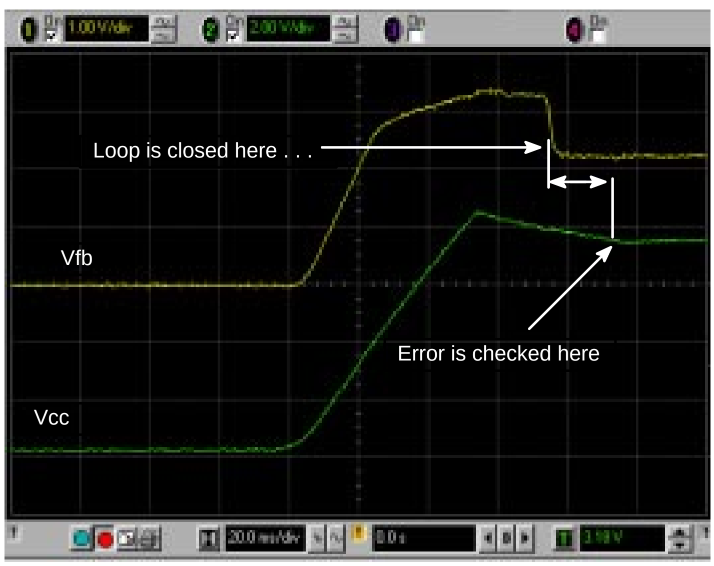

Figure 6. It is Important to Check for a Safe Start−Up Sequence

At power−on, the controller delivers the maximum peak current. During this time, an error flag is internally raised, signalling that the power supply has reached the maximum peak limit. The fault management circuitry consists in checking the presence of this flag every time the ripple on the V_{CC} pin comes down to 7.5 V. If the error flag is activated at this time, the controller considers the presence of a fault and it triggers the protective burst mode. As a result, since the V_{CC} capacitor must be sized to give enough room to let Vout reach the target before the V_{CC} ripple touches the 7.5 V setpoint. Worse case corresponds to 120 VDC and maximum output power, e.g. 6.0 W in our case.

Short−Circuit Protection

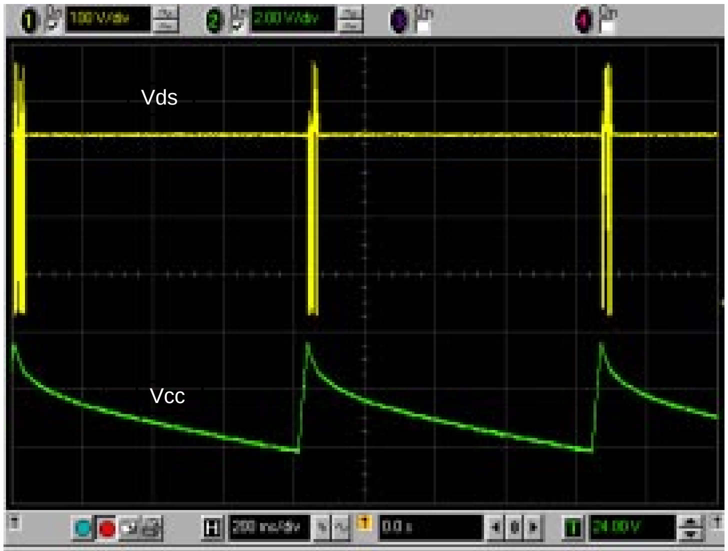

Figure 7. A Short−Circuit has Occurred, the Controller Enters Burst−Mode

As we explained above, when the 7.5 V internal check reveals that the error flag is raised, the controller stops pulsing and reduces its consumption. V_{CC} thus falls down until another lower level is reached ($V_{CClatch}$) where the start−up source is re−activated and a new start−up attempt is made. This is an auto−recovery system: if the fault fades away, the power supply resumes its operation.

Optocoupler Fail−Safe Protection

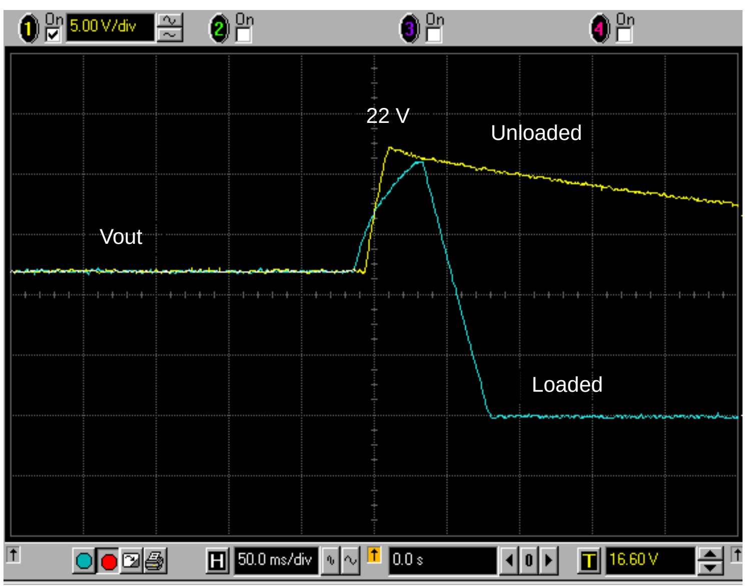

Figure 8. Fail−Safe Optocoupler Protection Triggered by a Short on the Secondary LED

When the feedback loop is broken, the auxiliary and output voltages run away. When the V_{CC} pin is supplied by the auxiliary winding (jumper is on), an internal circuitry clamps to 8.7 V typical (a kind of active zener diode). When the auxiliary level runs away, it pushes more current into the active zener. If this current exceeds a given level, the circuit fully latches off and all activity is stopped. The DSS keeps going up and down, but the power supply is permanently stopped. The user needs to reset the controller by unplugging the converter to have V_{CC} falling down below 4.0 V where the latch is reset.

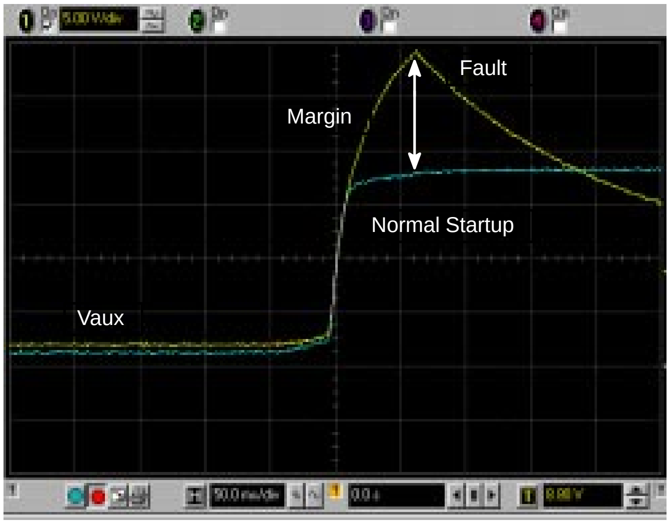

Figure 9. It’s also important that start−up overshoots do not have the bad luck to trigger the fail−safe circuitry.

A 100 nF capacitor connected over the TL431 offers a pure integral compensation. Despite its simplicity, this kind of capacitive network can engender start−up overshoots. If the overshoot is low, as on this board, there is no problem. However, it is important to check that, again, a sufficient margin exists between a normal start−up and a real fault detection. If this margin is too small, there are risks that the supply gets latched at start−up. Figure 9 confirms the adequate margin with the demo. Playing on R2 will offer a reduction of the overvoltage level, but can affect the margin as well as the standby consumption (e.g. if the active zener is turned on in standby, it is more difficult to go below 100 mW).

Conducted EMI Sweeps

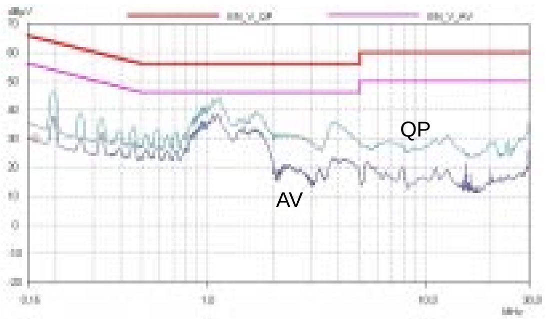

Figure 10. When the DSS is on, EMI Jittering is Active

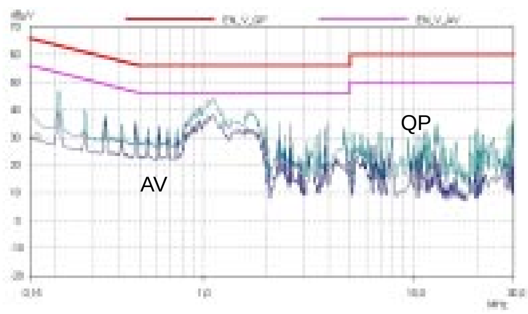

Figure 11. The Aux Winding Deactivates the Jittering

Figures 10 and 11 portray the conducted EMI sweeps captured at V_{in} = 100 VAC. One can see the nice spreading effect of the frequency sweep on Figure 10 where the high−frequency noise is artificially reduced: it naturally offers more margin to pass the limit. When the auxiliary winding is put in place, it disconnects the frequency sweep. Nevertheless, the power supply still passes the limit.

Figures 12 and 13 show the same plots but when the converter is powered from a 230 VAC input source. EMI effects are also visible on Figure 12.

Conducted EMI Sweeps

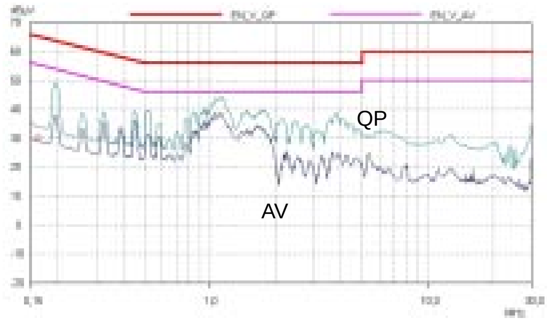

Figure 12. When the DSS is on, the Frequency Jitters

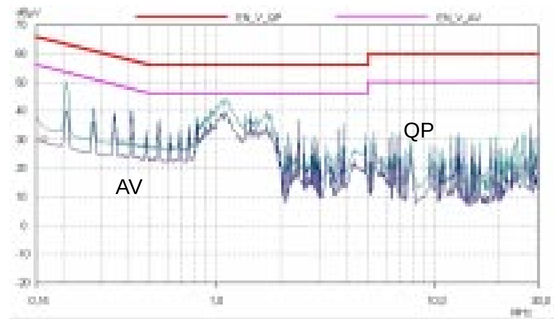

Figure 13. The Aux Winding Stops the Jittering

Stability Check

By pulsing the converter output, it becomes possible to detect any oscillations in the way the converter reacts. Figure 14 shows stable results at low and high line, for a 10% to 100% current excursion.

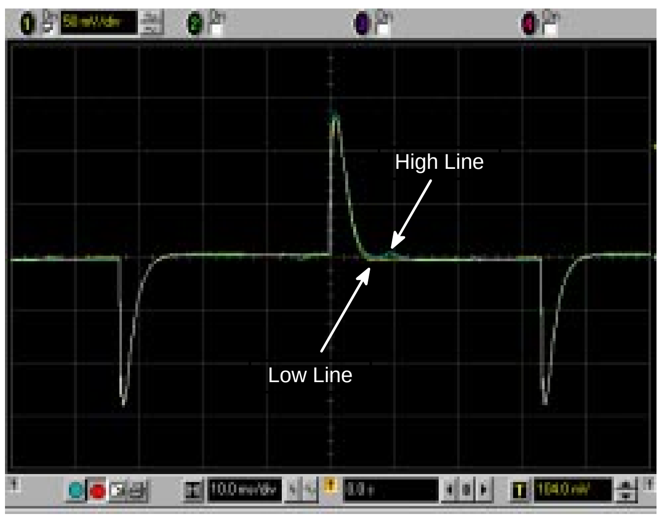

Figure 14. Pulsing the Output Current Confirms the Stability at Both High and Low Line Conditions

Increasing the Output Power

The current demonstration board is supplied with a Coilcraft A9619−C transformer featuring a primary inductance of 3.0 mH. This device allows an output power of 6.0 W continuous on a 70°C ambient temperature. However, with the same board, it is possible to raise the output power up to 12 W on a 230 VAC ± 15% application.

1. Plug another transformer, the Coilcraft B0570−B that features a 3.4 mH primary inductor but whose turn ratio is higher. The pinout is compatible with the PCB, it is thus easy to wire it.
2. Replace the NCP1013P06 by an NCP1013P10, the 100 kHz version.
3. Replace the 150 kΩ RCD resistor (R7) by a 100 kΩ/2.0 W value.

The rest is kept unchanged. Please note that the board is now able to deliver up to 12 W output power. Experiments have shown that if the NCP1013P10 layout is improved (more copper area), the new board can experimentally deliver up to 19 W of continuous power in a 60°C ambient temperature.

Conclusion

This board shows how to build, and test for reliability, a power supply made around the new NCP101X device. Despite a DIP8 package, the converter can be used in a variety of applications ranging from auxiliary power supplies up to a few watts converters. Once the chip specification is understood, it becomes a child's play to make it work!

6.0 W − Universal Mains NCP101X Demonstration Board Part List

Reference	Value	Part Number	Manufacturer	Comment
R2	3.3 kΩ	−	Any	1/4 W Thru Holes
R3	1.0 kΩ	−	Any	1206 SMD
R4	−	−	−	Not Wired
R5	39 kΩ	−	Any	1/4 W Thru Holes
R6	4.3 kΩ	−	Any	1206 SMD
R7	150 kΩ	2322 194 13154	BC Comp.	PRO1 Thru Holes
R_L3	22 Ω	−	Any	1/4 W Thru Holes Replaces L3
L1	2 x 15 mH	RN112−0.6/02	Schaffner	CM Mode
L2	10 μH	744 772 100	Wurth Elect.	LC Filter
L3	−	−	−	Not Wired
B1	800 V/1.0 A	DF08M	General Semiconductor	DIP8
D2	MBRS360T3	−	ON Semiconductor	SMD Type
D3	MUR160	−	ON Semiconductor	Axial
D4	1N4148	−	Any	Axial
C1	220 nF/X2	2222 335 5224	BC Comp.	X2 Type
C2	47 μF/400 V	ECA2GM470	Panasonic	Radial
C3	47 μF/16 V	ECA1CM470	Panasonic	−
C4	100 nF/25 V	−	Any	1206 SMD
C5	2.2 nF	WKP222MCMBFOK	Vishay	Y1
C6b	470 μF/16 V	ECA1CM471	Panasonic	Radial
C6a	470 μF/16 V	ECA1CM471	Panasonic	Radial
C7	47 μF/16 V	ECA1CM470	Panasonic	Radial
C8	2.2 nF/400 V	R82MC1220DQ02J	Arcotronics	−
C9	1.0 nF/10 V	−	Any	1206 SMD
C10	47 μF/35 V	ECA1VM470	Panasonic	Radial
C11	−	−	−	Not Wired
IC1	SFH615A−2	−	Siemens	SMD
IC2	TLV431ALP	−	ON Semiconductor	TO92
IC3	NCP1013P06	−	ON Semiconductor	DIP8
T1	A9619−C	−	Coilcraft	−
J1	Connector	PX0786/PC	Bulgin	Mains Inlet
J2	Connector	L145202010002	LMI	12 V Output
J3	Connector	4710334140400	Kontek	−
JP1	Jumper Shunts	−	Any	−
Feet	Board Feet	LCBS−TF−M4−6−01	Richco	9.5 mm Height

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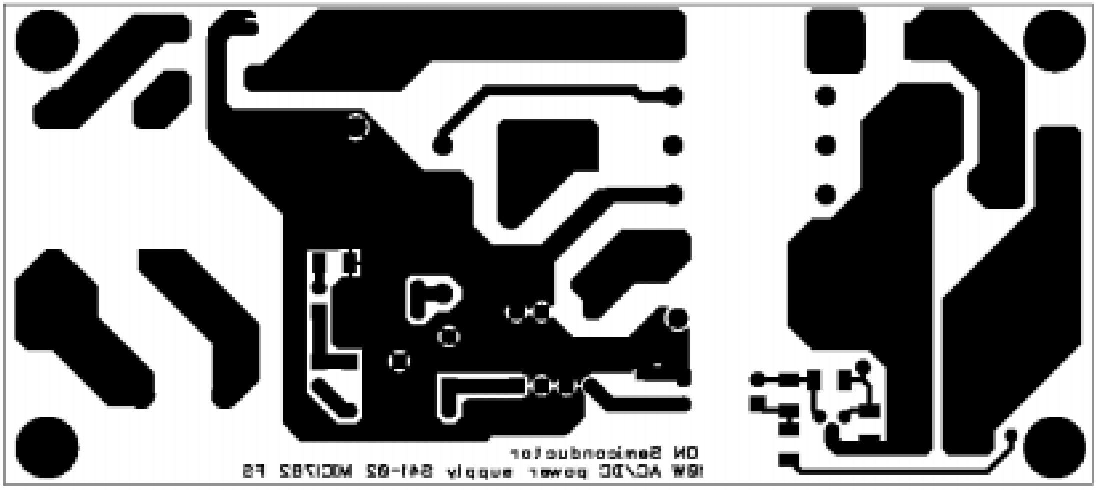

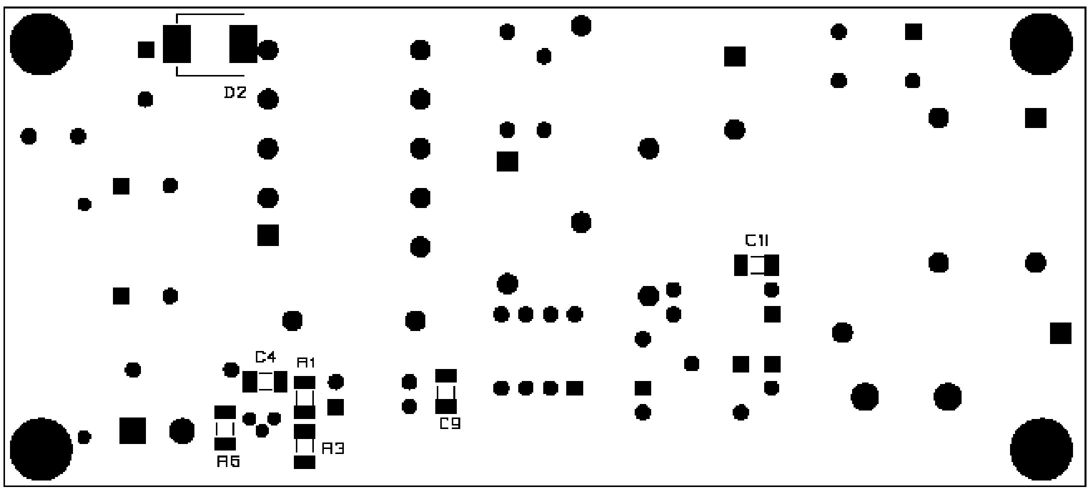

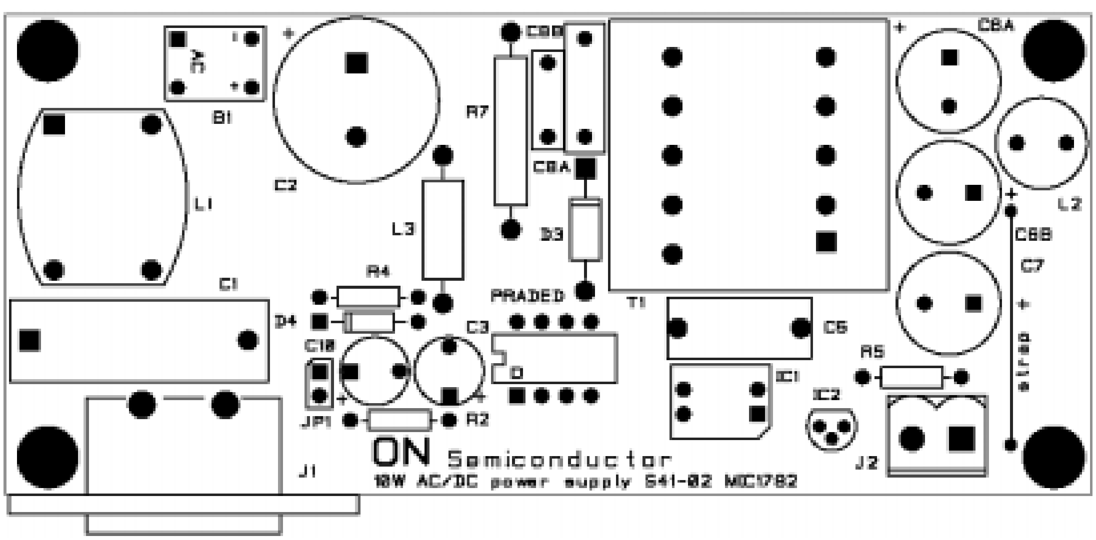

Figure 15. PCB Layout and Component Views

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