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NCP1380EVB/D

Performances of a Quasi-Resonant Adapter Driven by the NCP1380

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Quasi−square wave resonant converters also known as quasi−resonant (QR) converter are widely used in the adaptor market. They allow designing flyback Switched−Mode Power Supply (SMPS) with reduced Electro−Magnetic Interference (EMI) signature and improved efficiency. However, as the switching frequency of QR converter increases as the load decreases, the frequency must be limited.

In traditional QR converter, the frequency is limited by a frequency clamp. But, when the switching frequency of the system reaches the frequency clamp limit, valley jumping occurs: the controller hesitates between two valleys resulting in an unstable operation and noise in the transformer at medium and light output loads.

In order to overcome this problem, the NCP1380 features a "valley lockout" circuit: the switching frequency is decreased step by step by changing valley as the load decreases. Once the controller selects a valley, it stays locked in this valley until the output power changes significantly. This technique extends the QR operation of the system towards lighter loads without degrading the efficiency.

This application note focuses on the experimental results of an adapter driven by the NCP1380.

Specifications of the Adapter

The adapter is designed to meet the following specifications:

Table 1. SPECIFICATIONS OF THE 19 V, 60 W ADAPTER

Parameter	Symbol	Value
Minimum input voltage	$V_{in,min}$	85 Vrms
Maximum input voltage	$V_{in,max}$	265 Vrms
Output voltage	V_{out}	19 V
Nominal output power	$P_{out(nom)}$	60 W
Switching frequency at $V_{in,min}$, $P_{out(nom)}$	F_{sw}	45 kHz

Description of the Board

The 60 W adapter has been designed using the method described in the application note AND8431/D [1].

The B version of NCP1380 has been chosen to drive the adaptor.

BOARD SCHEMATIC

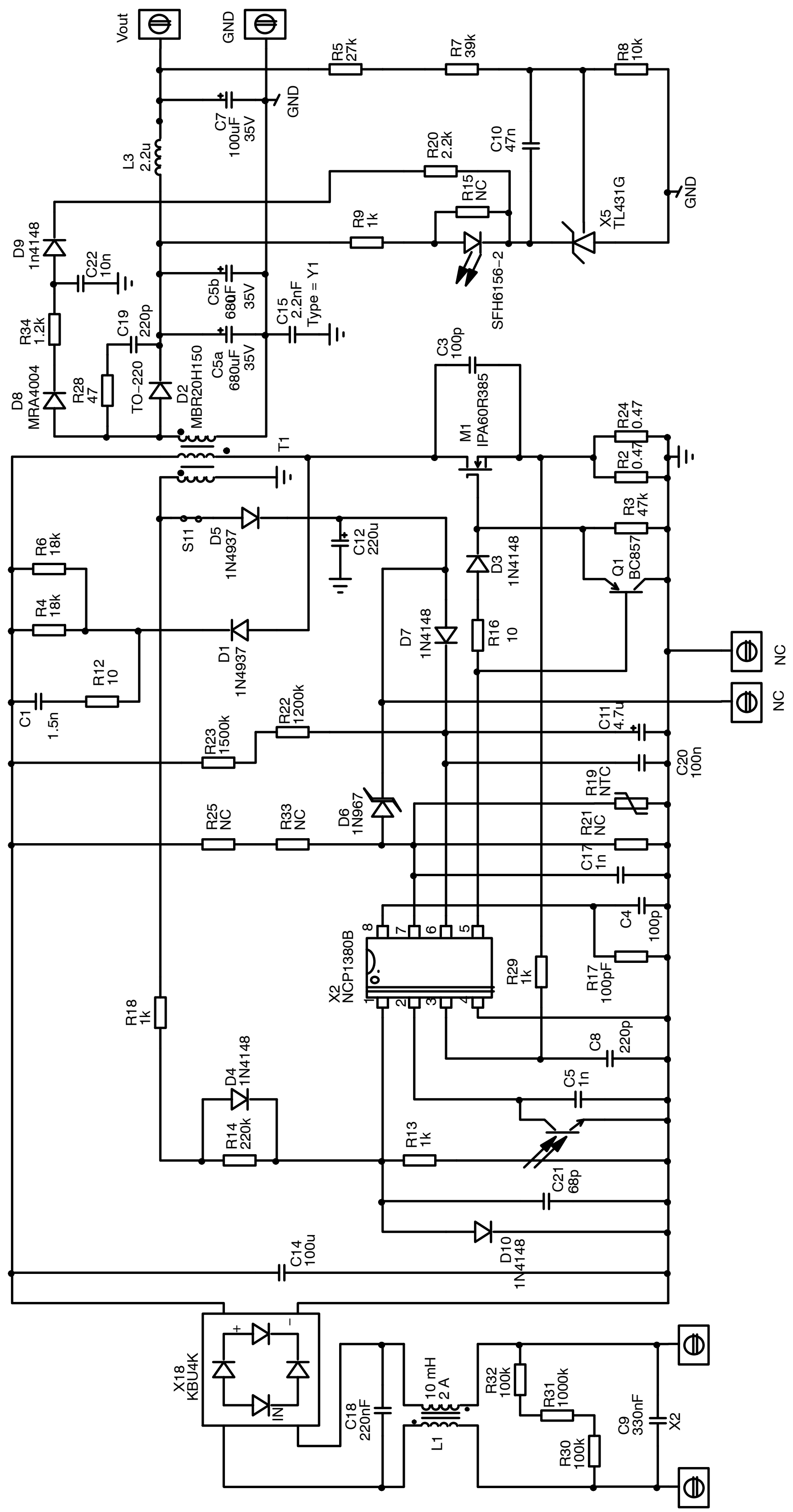

Figure 1. Schematic of the 60 W Adapter

Figure 2. Photograph of the Top Side of the Board

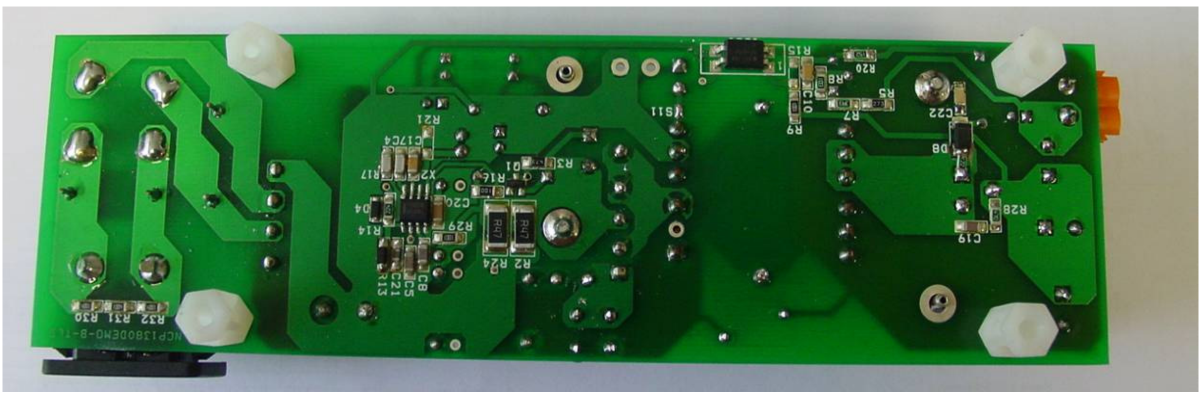

Figure 3. Photograph of the Bottom Side of the Board

Efficiency

The measurements were made after the board was operated during 10 mn at full load, low line, with an open frame and at ambient temperature.

The input power was measured with the power meter WT210A from Yokogawa.

The output current and the output voltage were measured using the digital multimeter 34401A from HP.

Output Power		Efficiency (%)	
P_{out} (W)	P_{out} (%)	V_{in} = 115 Vrms	V_{in} = 230 Vrms
60.6	100	88.3	89.1
45.5	75	88.7	88.4
30.3	50	88.2	87.3
15.2	25	86.4	86.1

At V_{in} = 115 Vrms, the average efficiency is **87.9**%. At V_{in} = 230 Vrms, the average efficiency is **87.7**% which is above the 87% limit defined by the ENERGY STAR® norm EPA 2.0.

Efficiency at Light Output Load

The efficiency at light load was first measured with the TL431 normally biased by a 1 kΩ resistor inserted in parallel of the optocoupler LED (Figure 4)

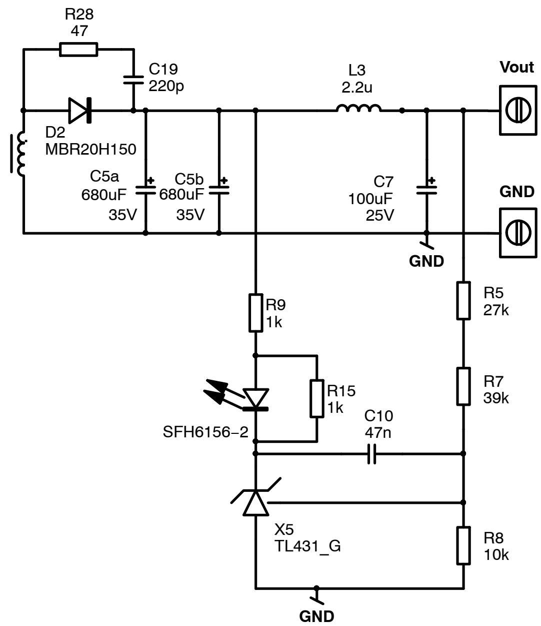

Figure 4. TL431 Biased by a 1 kΩ Resistor

The following results were obtained:

Table 2. LIGHT LOAD EFFICIENCY WITH THE TL431 BIASED BY A 1 kΩ

P_{out} (W)	115 Vrms		230 Vrms	
	P_{in} (W)	Efficiency (%)	P_{in} (W)	Efficiency (%)
1.0	1.312	76.1	1.364	73.2
0.7	0.945	73.9	0.993	70.4
0.5	0.701	71.6	0.750	66.9

In order to increase the efficiency at light load and to decrease the power consumption at no load, the TL431 bias is removed at light load using a special circuit patented by ON Semiconductor, shown in Figure 5.

The efficiency at light load is very good. Also, for an output power of 0.7 W the input power consumption is less than 1 W at low line and high line.

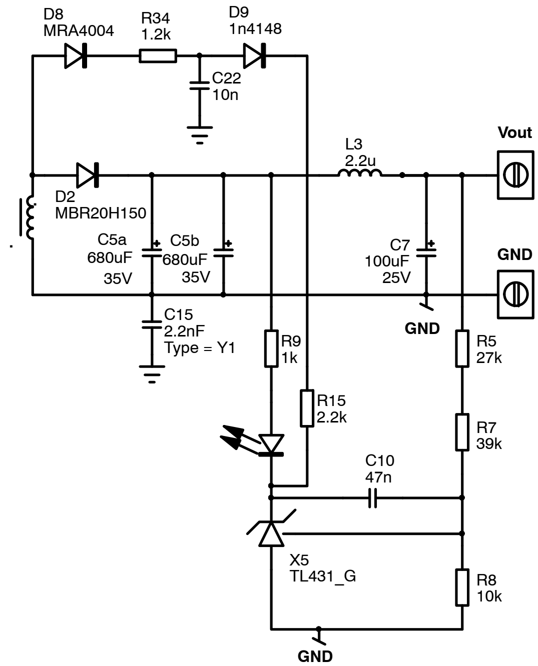

Figure 5. TL431 Bias Removal Circuit

The results obtained with the TL431 bias removed are summarized inside Table 3.

Table 3. LIGHT LOAD EFFICIENCY WITHOUT THE TL431 BIAS

P_{out} (W)	115 Vrms		230 Vrms	
	P_{in} (W)	Efficiency (%)	P_{in} (W)	Efficiency (%)
1.0	1.290	77.6	1.340	74.6
0.7	0.923	75.9	0.965	72.2
0.5	0.678	73.8	0.720	69.6

By removing the TL431 bias at light load, we increase the efficiency at 0.5 W by **3%** at 230 Vrms and by **2%** at 115 Vrms. We also gain 1% efficiency at 1 W with the TL431 bias removed.

No Load Power Consumption

The no load power consumption is the power drawn on the mains by the adaptor when no output load is connected to the board.

Table 4 shows the power consumption with the TL431 biased by a 1 kΩ resistor.

Table 5 shows the power consumption with the TL431 bias removed using the special circuit patented by ON Semiconductor.

Table 4. NO LOAD CONSUMPTION WITH THE TL431 BIAS

P_{out} (W)	115 Vrms	230 Vrms
	P_{in} (mW)	P_{in} (mW)
0	82	122

Table 5. NO LOAD CONSUMPTION WITHOUT THE TL431 BIAS

P_{out} (W)	115 Vrms	230 Vrms
	P_{in} (mW)	P_{in} (mW)
0	64	98

By removing the TL431 bias, we managed to decrease the power consumption below 100 mW at no load. The power consumption is only **98 mW** for a 230 Vrms input voltage.

Thus, removing the TL431 bias has allowed saving 24 mW at high line.

It is possible to decrease further the power consumption at no load by connecting the start−up resistor to the half−wave instead of the bulk rail as shown by Figure 6.

For the same startup time, we only need to divide the value of the startup resistors from the schematic (R23 + R22 = 3.2 MΩ) by π. We obtain a half−wave startup resistor of 1.1 MΩ. The reference [1] shows in details how to calculate the half−wave startup resistor.

With the half wave startup resistor of 1.1 MΩ, we measure a startup time of 2.6 s instead of the 3 s startup duration that was obtained with the 3.2 MΩ resistor connected to the bulk rail. While observing the half−wave voltage, we noticed that there is a slight distortion of the waveform, leading to a higher mean value of the half−wave voltage. The half−wave mean value being higher than expected (at 230 Vrms, the half−wave voltage mean value is 148 V instead of 103 V), the startup current is higher and charges the V_{CC} capacitor faster than expected.

For the sake of comparison, the half−wave resistor is increased to have a startup time equal to the startup time obtained with the startup resistor connected to the bulk rail. Finally, the half−wave startup resistor value is 1.3 MΩ.

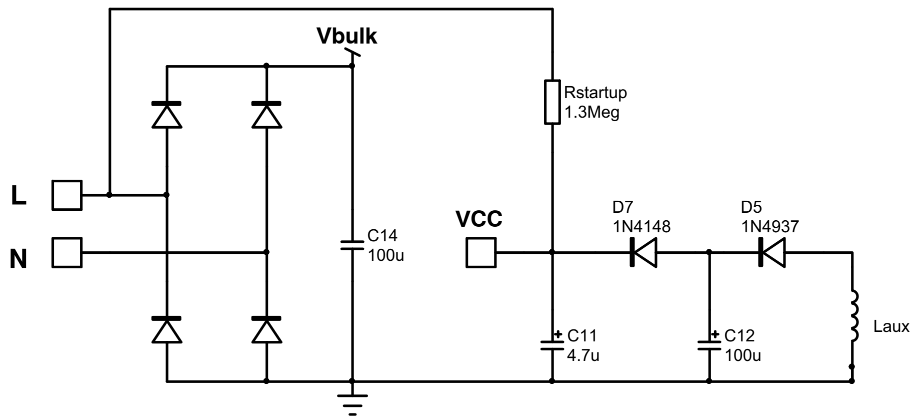

Figure 6. The Startup Resistor is Connected to the Half−Wave

Table 6 highlights the no load consumption obtained with the startup resistor connected to the half−wave. The power consumption is decreased to 85 mW at high line!

Table 6. NO LOAD CONSUMPTION WITH THE STARTUP RESISTOR CONNECTED TO THE HALF−WAVE AND WITHOUT THE TL431 BIAS

	115 Vrms	230 Vrms
P_{out} (W)	P_{in} (mW)	P_{in} (mW)
0	59	85

Waveforms

Valley Lockout

Thanks to the valley lockout, the controller changes valley (from the 1st to the 4th valley) as the load decreases without any valley jumping. This allows extending the quasi−resonance operation range.

The following scope shoots show the operating valley as the load decreases for an input voltage of 230 Vrms.

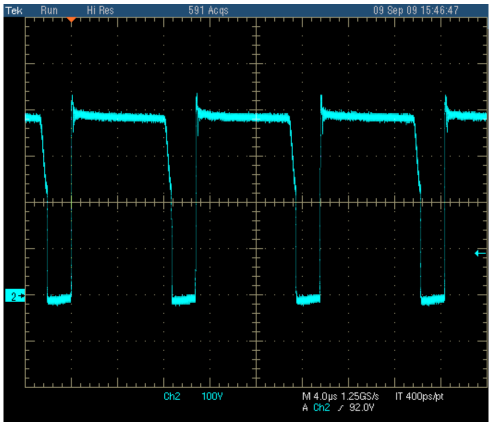

Figure 7. 1st Valley Operation at 60 W, 230 Vrms

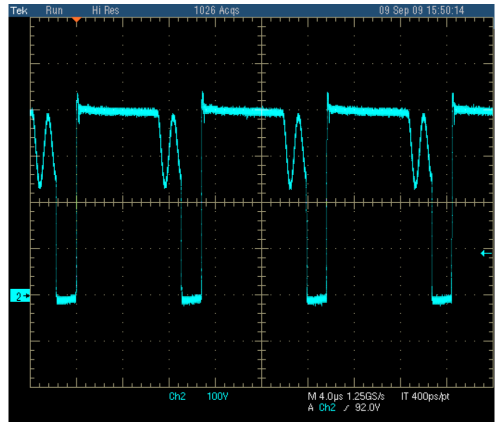

Figure 8. 2nd Valley Operation at 45 W, 230 Vrms

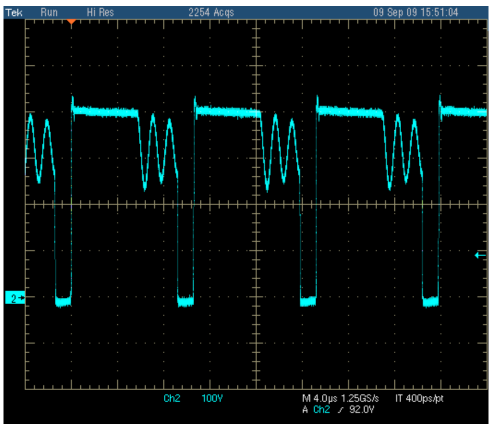

Figure 9. 3rd Valley Operation at 30 W, 230 Vrms

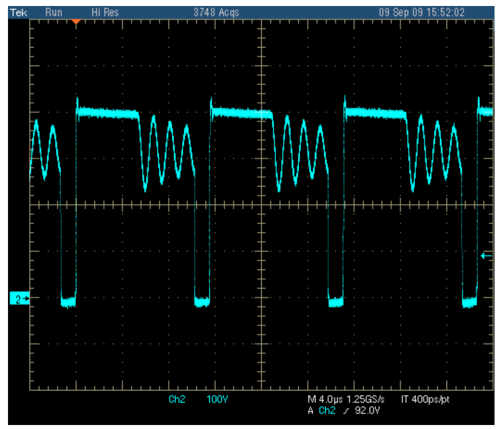

Figure 10. 4th Valley Operation at 24 W, 230 Vrms

The following graph shows the switching frequency evolution as the output load varies.

The **pink** curve portrays the switching frequency variation when the output load is **decreased** from 60 W to 0 W.

The **blue** curve represents the switching frequency evolution when the output load is **increased** from 0 to 60 W.

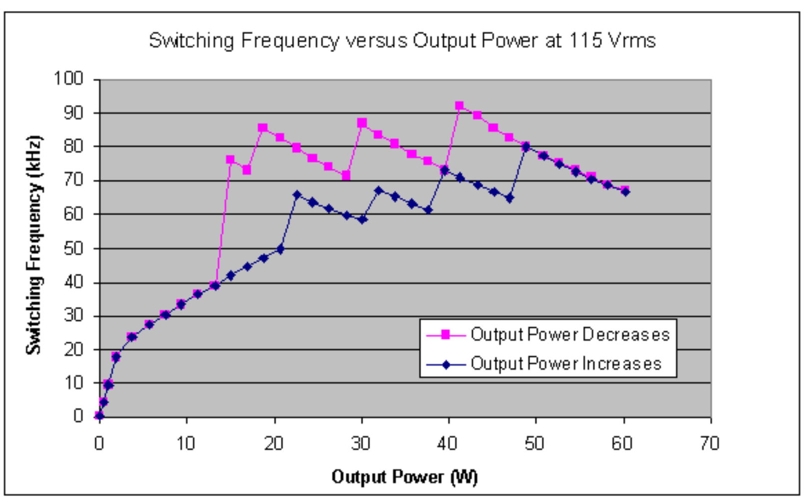

Figure 11. Switching Frequency Evolution versus Output Power at V_{in} = 115 Vrms

VCO Mode

At light output load, the controller will operate in VCO mode. In this mode, the peak current is fixed to 17.5% of its maximum values when $V_{FB} < 0.56$ V. The switching frequency is variable and decreases as the output load decreases thus minimizing the switching losses.

In the 60 W adapter, the switching frequency is around 31 kHz at P_{out} = 10 W and drops to 6 kHz for an output power of 1 W.

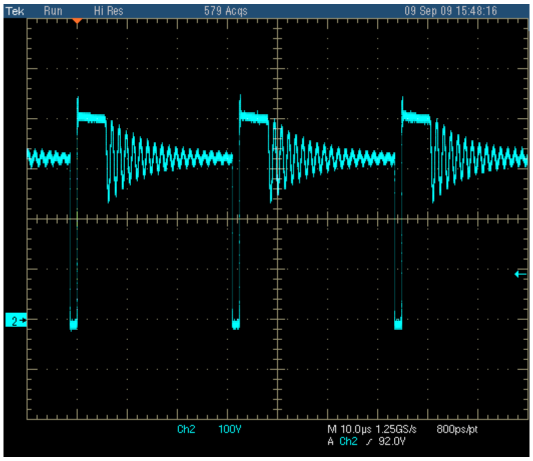

Figure 12. VCO Mode at 10 W, 230 Vrms

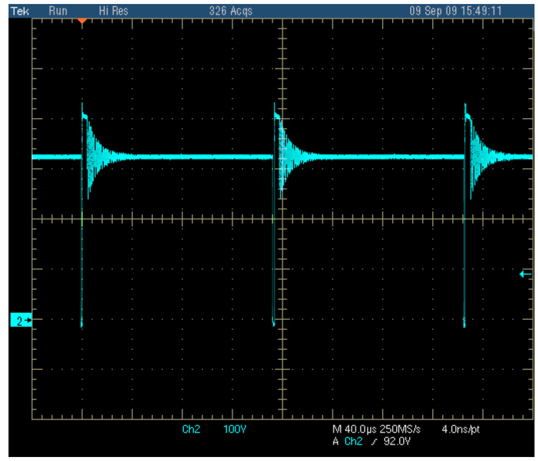

Figure 13. VCO Mode at 1 W, 230 Vrms

Startup

The NCP1380 consume a very low current during startup (20 μA maximum). Thus, the power supply designer can choose startup resistors values in the range of MΩ and this allows decreasing the power consumption in standby.

The following scope shoots show the startup time at the lowest input voltage for a 3.2 MΩ resistor connected to the bulk rail and for a 1.3 MΩ resistor connected to the half−wave.

In each case, the startup time is around 3 s.

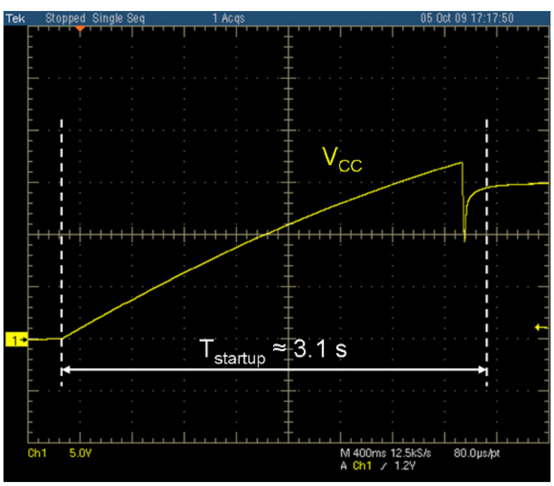

Figure 14. Startup Duration with a 3.2 MΩ Resistor Connected to the Bulk Rail, V_{in} = 85 Vrms

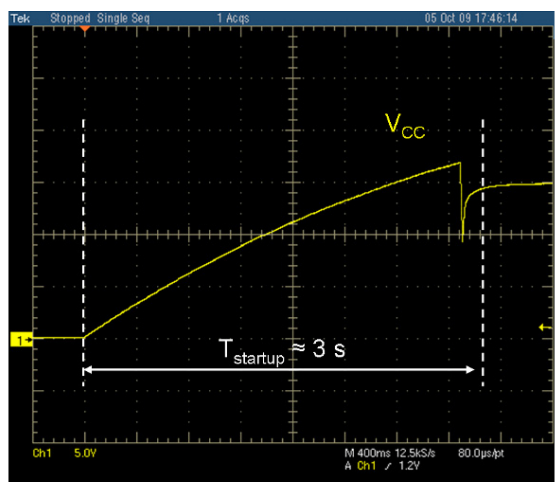

Figure 15. Startup Duration with a 1.3 MΩ Resistor Connected to the Half−Wave, V_{in} = 85 Vrms

Output Load Step

In order to verify the stability of the adapter, a variable load is applied to its output. The output current varies between 3.2 A and 0.1 A (100% to 3% of the maximum output power) with a slew rate of 1 A / μs and at a frequency of 20 Hz.

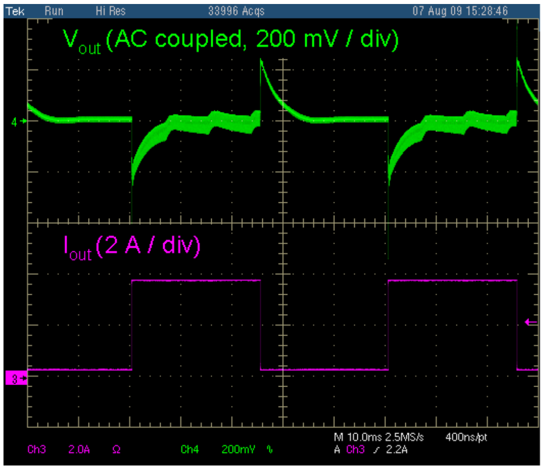

Figure 16. Transient Load Step Response at V_{in} = 115 Vrms

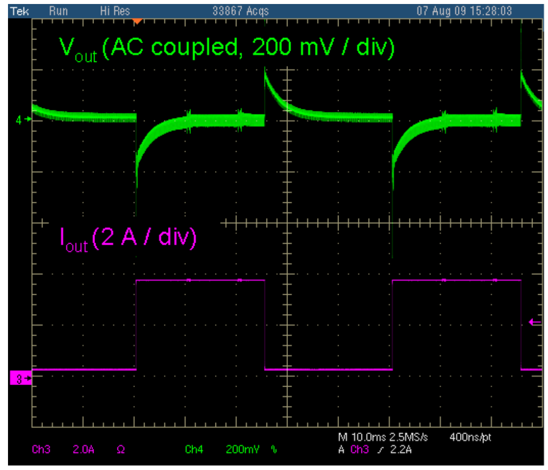

Figure 17. Transient Load Step Response at V_{in} = 230 Vrms

The output voltage waveform (Figures 16 and 17) shows that the loop is stable and indicates a phase margin above 60°.

Conclusion

Due to the valley lockout, the NCP1380 allows building QR adapter without valley jumping.

Building adapter with average efficiency greater than 87% is easily achievable with the NCP1380.

The controller offers every protection needed to build safe power supply. Also, by combining functions on single pins, the NCP1380 allows saving space on the board and decreasing the bill of material cost.

Very low standby power consumption can be obtained with the NCP1380. For an input voltage of 230 Vrms, we measured a power consumption of only **85 mW**!

References

1. Stéphanie Conseil, “Designing a Quasi−Resonant Adaptor Driven by the NCP1380”, Application Note AND8431/D.

Table 7. BILL OF MATERIAL

Reference	Qty	Value	Description	Manufacturer	Part Number
C1	1	1.5n	Ceramic Capacitor, Axial, 1000 V	Standard	Standard
C3	1	100 pF	Ceramic Capacitor, Axial, 1000 V	Standard	Standard
C4	1	100 pF	Ceramic capacitor, SMD, 50 V	Standard	Standard
C5b,C5a	2	680 uF	Electrolytic capacitor, 35 V	RUBYCON	35ZL680M12.5X20
C5,C17,C22	3	1 nF	Ceramic capacitor, SMD, 50 V	Standard	Standard
C7	1	100 uF	Electrolytic capacitor, 35 V	Standard	Standard
C12	1	220 uF	Electrolytic capacitor, 25 V	Standard	Standard
C8,C19	2	220 pF	Ceramic capacitor, SMD, 50 V	Standard	Standard
C9	1	330 nF	X2 capacitor, 305 V	EPCOS	B32922D3334M784
C10	1	47 nF	Ceramic capacitor, SMD, 50 V	Standard	Standard
C11	1	4.7u	Electrolytic capacitor, 25 V	Standard	Standard
C14	1	100 uF	Electrolytic capacitor, 400 V	NICHICON	UCY2G101MHD
C15	1	2.2 nF	Y1 capacitor, 250 V	CERAMITE	440LD22
C18	1	220 nF	X2 capacitor, 305 V	EPCOS	B32922C3224M784
R17	1	100 pF	Ceramic Capacitor, SMD, 50 V	Standard	Standard
C20	1	100 nF	Ceramic capacitor, SMD, 50 V	Standard	Standard
C21	1	68 pF	Ceramic capacitor, SMD, 50 V	Standard	Standard
D1,D5	2	D1N4937	Fast Recovery Diode, Axial, 1 A, 600 V	ON Semiconductor	1N4937G

Table 7. BILL OF MATERIAL

Reference	Qty	Value	Description	Manufacturer	Part Number
D2	1	MBR20H150	Schottky Diode, TO−220, 20 A, 150 V	ON Semiconductor	MBRF20H150CTG
D3,D7,D9	3	D1N4148	Diode, Axial, 100 V	NXP	1N4148
D4, D10	2	D1N4148	Diode, SMD, 100 V	VISHAY	1N4148W
D6	1	Zener	18 V Zener Diode, Axial	Standard	Standard
D8	1	MRA4004	Diode, SMD, 1 A, 400 V	ON Semiconductor	MRA4004T3G
HS1	1		Heatsink, 14°C/W	SEIFERT	KL194/25.4SW
HS2	1		Heatsink, 8.2°C/W	SEIFERT	KL196/25.4SW
ISO1	1	SFH6156−2	Optocoupler SFH6156−2, SMD	VISHAY	SFH6156−2T
J1	1		Input Connector, 2.5 A, 260 V	MULTCOMP	JR−201S(PCB)
J2	1		Output Connector	WEIDMULLER	PM5.08/2/90
J3	1		Connector for external V_{CC}	WEIDMULLER	PM5.08/2/91
L1	1	10 mH	Common Mode Choke, 2*10 mH, 2 A	WURTH	744823210
L3	1	2.2 uH	Radial Coil, 2.2 uH, 6 A, 20%	WURTH	744772022
M1	1	IPP60R385	MOSFET, 600 V, 7 A	INFINEON	IPP60R385CP
Q1	1	BC857	PNP transistor, SMD	ON Semiconductor	BC857ALT1G
R2,R24	2	0.47 Ω	Ceramic Resistor, SMD, 1W, 1%, 50 V	Standard	Standard
R3, R21	2	47 kΩ	Ceramic Resistor, SMD, 0.25 W, 1%, 50 V	Standard	Standard
R4,R6	2	18 kΩ	Resistor, Axial, 3 W, 5%	Standard	Standard
R5	1	27 kΩ	Ceramic Resistor, SMD, 0.25W, 50 V	Standard	Standard
R7	1	39 kΩ	Ceramic Resistor, SMD, 0.25W, 50 V	Standard	Standard
R8	1	10 kΩ	Ceramic Resistor, SMD, 0.25W, 50 V	Standard	Standard
R9,R13,R15, R29,R30, R31,R32	7	1 kΩ	Ceramic Resistor, SMD, 0.25W, 50 V	Standard	Standard
R12	1	10 Ω	Resistor, Axial, 1 W, 1%	Standard	Standard
R14	1	220 kΩ	Ceramic Resistor, SMD, 0.25 W, 50 V	Standard	Standard
R16	1	10 Ω	Ceramic Resistor, SMD, 0.25 W, 50 V	Standard	Standard
R18	1	1 kΩ	Resistor, Axial, 0.25 W, 1%	Standard	Standard
R19	1		NTC, 100 kΩ at 25°C, Beta = 4190	VISHAY	NTCLE100E3104JB0
R20	1	2.2 kΩ	Ceramic Resistor, SMD, 0.25 W, 50 V	Standard	Standard
R22	1	1200 kΩ	Resistor, Axial, 0.25 W, 1%	Standard	Standard
R23	1	1500 kΩ	Resistor, Axial, 0.25 W, 1%	Standard	Standard
R25,R33	2	3000 kΩ	Resistor, Axial, 0.25 W, 1%	Standard	Standard
R28	1	47 Ω	Ceramic Resistor, SMD, 0.25 W, 50 V	Standard	Standard
R34	1	1.2 kΩ	Ceramic Resistor, SMD, 0.25 W, 50 V	Standard	Standard
U1	1		QR Transformer	CME	17212
X2	1	NCP1380B	QR controller	ON Semiconductor	NCP1380B
X5	1	TL431	Shunt Regulator, 2.5 − 36 V, 1 − 100 mA	ON Semiconductor	TL431CLPG
X18	1	KBU4K	Diode Bridge, 4 A, 800 V	MULTICOMP	KBU4K

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