**ON Semiconductor** 

Is Now

# Onsemi

To learn more about onsemi<sup>™</sup>, please visit our website at <u>www.onsemi.com</u>

onsemi and ONSEMI. and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "onsemi" or its affiliates and/or subsidiaries in the United States and/or other countries. onsemi owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of onsemi product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. onsemi reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and onsemi makes no warranty, representation or guarantee regarding the accuracy of the information, product factures, availability, functionality, or suitability of its products for any particular purpose, nor does onsemi assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using onsemi products, including compliance with all laws, regulations and asfety requirements or standards, regardless of any support or applications information provided by onsemi. "Typical" parameters which may be provided in onsemi data sheets and/or by customer's technical experts. onsemi products and actal performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. onsemi products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use onsemi products for any such unintended or unauthorized application, Buyer shall indemnify and hold onsemi and its officers, employees, subsidiari

# A 12 W Adaptor with NCP1362 Quasi Resonant Controller

The NCP1362 offers a new Primary Side Regulation (PSR) solution targeting output power levels up to 12 W continuously in a universal-mains flyback application.

Thanks to a Novel Method, this new controller saves the secondary feedback circuitry for Constant Voltage and Constant Current regulation, achieving excellent line and load regulation without traditional opto coupler and TL431 voltage reference.

The NCP1362 operates in valley lockout quasi-resonant peak current mode control mode at high load to provide high efficiency. When the power on the secondary side starts to diminish, the controller automatically adjusts the duty-cycle then at lower load the controller enters in pulse frequency modulation at fixed peak current with a valley switching detection. This technique allows keeping the output regulation with tiny dummy load. Valley lockout at



# **ON Semiconductor®**

#### www.onsemi.com

# **APPLICATION NOTE**

the first 4 valleys prevent valley jumping operation and then a valley switching at lower load provides high efficiency.

This application note focuses on the experimental results of a 12–W adaptor driven by the NCP1362 and on the general behavior of this controller.

#### Table 1. EVALUATION BOARD SPECIFICATION

Parameter	Value			
Minimum input voltage	85 V rms			
Maximum input voltage	265 V rms			
Output voltage	12 V			
Nominal output power	12 W			



Figure 1. EVB Picture (Top View)



Figure 2. EVB Picture (Bottom View)

## **BOARD SCHEMATIC**



## **TYPICAL WAVEFORMS**

#### Start-up

The start-up sequence is performed with resistors connected to the bulk capacitor or directly to the mains input voltage to reduce the power dissipation. To further reduce the standby power, the start-up current of the controller is extremely low, below 6.3  $\mu$ A maximum. The start-up time is directly linked to the V<sub>cc</sub> capacitor value. Also, this capacitor has to be large enough to maintain the V<sub>cc</sub> voltage above V<sub>cc(off)</sub> level in no load condition. Indeed, in light load

or no load condition, the controller operates at the minimum frequency clamp and the dead time between two cycles will be 1 ms. The  $V_{cc}$  voltage has to be kept above  $V_{cc(off)}$ . Finally, the last constraints regarding the  $V_{cc}$  capacitor is the start–up time. Generally, the power supply has to start in less than 3 s regardless the input voltage. Taking in account these parameters, in our application board, we have successfully tested (Figure 4) a 2.2– $\mu$ F value for C<sub>6</sub>.



Figure 4. The Start-up Sequence is below 2 s at 85 V rms - Room Temperature

#### Valley Lockout

The valley lockout technique makes controller changes valley (from the 1<sup>st</sup> to the 4<sup>th</sup> valley) as the load decreases without any valley jumping. This allows extending the quasi–resonance (QR) operation range.

The following scope shoots show the operating valley as the load decreases for an input voltage of 115 V rms.



Figure 5. QR (1st valley) Operation @ 1 A / 115 V rms



Figure 6. 2<sup>nd</sup> Valley Operation @ 0.9 A / 115 V rms



Figure 7. 3<sup>rd</sup> Valley Operation @ 0.6 A / 115 V rms



Figure 8. 4<sup>th</sup> Valley Operation @ 0.4 A / 115 V rms

#### **Frequency Foldback Mode**

If while operating at valley 4, the load further decreases, the NCP1362 will operate in Frequency Foldback (FF) mode. Practically, the circuit enters in FF mode when comp voltage drops below 2.1 V. The current is frozen to  $V_{CS(VCO)}$ and regulation is made by varying the switching frequency (f<sub>SW</sub> reduces if the power demand diminishes). The system reduces the switching frequency by adding some dead–time after the 4<sup>th</sup> valley is detected. Moreover, in order to keep the high efficiency benefit inherent to the QR operation, the controller turns on again with the next valley after the dead time has ended. As a result, the controller will still run in valley switching mode even when the FF is enabled.

In this 12–W evaluation boards, at 115 V rms, the switching frequency is around 73 kHz @ 0.37 A at the beginning of the frequency foldback mode. The primary peak current is frozen to V<sub>CS(VCO)</sub>.



Figure 9. FF Mode &  $V_{CS(VCO)}$  @ 0.37 W / 115 V rms

#### 1-kHz Minimum Frequency Clamp

Due to the primary side regulation, the only way to have an information of the output voltage is to generate a new cycle and read the voltage on the auxiliary winding. This voltage is an image of the output voltage affected by the transformer turns ratio. For this reason, the system has to impose a minimum switching frequency to refresh the sampling on the primary side and have a good transient response. The default minimum frequency clamp is set to 1 kHz.

So the frequency clamp impose to transfer energy from primary to secondary side each ms. Because there is no load on the output, the 12–V voltage cannot be maintained to the nominal level and will increase until the OVP protection is trigged. To avoid this fault, a dummy load is generally connected on the output to dissipate this energy in no load condition but the stand–by performance will be affected. For this reason, a second frozen peak current called  $V_{CS(STB)}$  is implemented in this controller to reduce to the minimum the energy transfer each cycle and so limit the power dissipated in the dummy load.



Figure 10. 1 kHz Minimum Frequency Clamp & V<sub>CS(STB)</sub> @ No Load / 115 V rms

#### Transient Load

Figure 11 and Figure 12 show an output transient load step from 0% to 50% of the maximum output power at low line and high line.

The step load response is 950 mV or 7.9% of the output voltage in the worth case.



Figure 11. Step Load Response between 0% to 50% @ 115 V rms



Figure 12. Step Load Response between 0% to 50% @ 230 V rms

Figure 13 and Figure 14 show an output transient load step from 50% to 100% of the maximum output power at low line and high line. The slew rate is 1 A/ $\mu$ s and the frequency is 25 Hz.

The step load response is  $\pm 75$  mV.



Figure 13. Step Load Response between 50% to 100% @ 115 V rms



Figure 14. Step Load Response between 50% to 100% @ 230 V rms

#### Efficiency Results and Stand-by Performance

All measurements have been done after a 30 min warm-up phase at full load and an additional 5 min at the load under consideration.

The output voltage and output current were measured using digital multimeter embedded on dc electronic load 63103 from Chroma.

The input power was measured with the power meter 66202 from Chroma.

Table 2. EFFICIENCY	′@	115	V	RMS	AND	230	۷	RMS
---------------------	----	-----	---	-----	-----	-----	---	-----

Input voltage	Pout (%)	Pout (W)	Pin (W)	Efficiency (%)
115 V rms	100	11.99	13.98	85.74
	75	9.09	10.55	86.16
	50	5.99	6.96	86.07
	25	2.43	2.82	86.20
	Average*	-	-	86.04
	10	1.15	1.37	83.69
	No load	-	24 m	-
230 V rms	100	12.00	13.73	87.40
	75	9.08	10.45	86.89
	50	6.01	6.99	86.02
	25	2.41	2.87	83.80
	Average*	-	-	86.03
	10	1.15	1.41	81.56
	No load	-	44 m	-

\*The average efficiency was calculated from the efficiency measurements at 25%, 50%, 75% and 100% of the nominal output power.

The stand-by consumption is a key parameter for this kind of application. Thanks to the double frozen peak current, both light load and no load condition are optimized. The standby consumption is below 60 mW regardless the input voltage (55 mW at 265 V rms) like shown in the Table 2.

Please note that, if the BO pin voltage is grounded to disable this function, the power dissipation in the BO

resistances will be saved. In this configuration, the no load consumption drops below 40 mW at 265 V rms. Also, by using capacitive startup, 17 mW at 265 V rms could be saved (or 13 mV @ 230 Vrms) so the standby power consumption is dropping below 30 mW.



Figure 15. Efficiency (%) vs Output Current at 115 V rms and 230 V rms

If we expand our view on the light-load power consumption, in the range of 1–W output power, we can see

that we can deliver more than 0.77 W in the output and keep the input consumption below 1 W.



Figure 16. Low Power Consumption

#### **Constant Voltage and Constant Current Regulation**

Thanks to the NCP1362, both voltage and current are regulated to insure safe operation. When the load is below the nominal level (i.e. 1.1 A for this application), the output voltage is regulated to 12 V. Then, if the load increased, the current loop takes the control to limit the output current regardless the output voltage information. Finally, the BO/LFF pin improves the constant current regulation by sensing the input voltage and compensates the propagation delay effect at high line. These all functions put together allow us to extract the CC/CV curve depicted in the Figure 17.



Figure 17. Constant Current (CC) / Constant Voltage (CV) Curve

Designator	Quantity	Description	Value	Tolerance	Manufacturer Part Number	
C2	1	Ceramic capacitor, 1206, 200 V	470 pF	10%, 200 V	Standard	
C3	1	X2 capacitor, 305 V	100 nF	305 V	B32921C3104	
C4, C5	2	Electrolytic capacitor, 400 V	10 μF	400 V	UVC2G100MPD	
C6	1	Ceramic capacitor, 0805, 35 V	2.2 μF	10%, 35 V	Standard	
C7	1	Y1 capacitor, 440 V	100 pF	440 V	CD70-B2GA101KYNKA	
C9, C16	2	Ceramic capacitor, 0805, 50 V	22 pF	10%, 50 V	Standard	
C10	1	Ceramic capacitor, 0805, 50 V	100 pF	10%, 50 V	Standard	
C11	1	Ceramic capacitor, 0805, 50 V	4.7 μF	10%, 35 V	Standard	
C12	1	Ceramic capacitor, 0805, 50 V	4.7 nF	10%, 50 V	Standard	
C14	1	Ceramic capacitor, 0805, 50 V	1 nF	10%, 50 V	Standard	
C15	1	Ceramic capacitor, 0805, 50 V	100 nF	10%, 50 V	Standard	
CM1	1	Common mode choke	2.2 mH	0.5 A	50225C	
COUT1, COUT2	2	Polymer capacitor, 16 V	470 μF	20%, 16 V	PLF1C471MDO1	
COUT3	1	Electrolytic capacitor, 16 V	47 μF	20%, 16 V	ECA1CAK470X	
D1	1	Schottky Diode, SMB, 5 A, 100 V	NRVTSS5100	5 A, 100 V, SMB	NRVTSS5100ET3G	
D2	1	Fast Recovery Diode, Axial, 1 A, 600 V	CSFMT108	1 A, 600 V, SOD123H	CSFMT108-HF	
D3	1	Diode, Axial, 200 mA, 250 V	BAS21	200 mA, 250 V, SOD323	BAS21AHT1G	
D4	1	Diode, SMD, 100 V	D1N4148	100 V	MMSD4148	
D5	1	18 V Zener Diode	Zener	18 V, SOD123	Standard	
DB1	1	Diode bridge, SMD, 0.8 A, 600V	HD06		Standard	
IC1	1	PSR controller	NCV1362	SOIC8	NCV1362AADR2G	
J1, J2	2	Output Connector	PM5.08/2/90	10 A, 300 V	PM5.08/2/90	
L1	1	Radial Coil, 220 μH, 0.5 A, 10%	220 μF	10%, 0.5 A	7447462221	
L2	1	Radial Coil, 1 μH, 3 A, 30%	1 μH	30%, 3 A	SRN4026-1R0Y	
M2	1	MOSFET, 650 V, 6 A	FCU600N65	IPAK	FCU600N65S3R0	
Q1	1	PNP transistor, SMD	BC857	SOT-23	BC857ALT1G	
R4, R9	2	Ceramic Resistor, 1206, 0.25W, 200 V	68 kΩ	5%	Standard	
R6	1	Ceramic Resistor, 1206, 0.25W	150 Ω	5%	Standard	
R8	1	Through hole resistor, 1 W, 1%	5 Ω	1%	CMF605R0000FKBF	
R10, R13, R19	3	Ceramic Resistor, 0805, 0.25 W	0 Ω	5%	Standard	
R11	1	Ceramic Resistor, 0805, 0.25 W	16 kΩ	5%	Standard	
R15, R17	2	Ceramic Resistor, 0805, 0.25 W	1 MΩ	5%	Standard	
R16	1	Ceramic Resistor, 0805, 0.25 W	<b>10</b> Ω	5%	Standard	
R18	1	Ceramic Resistor, 0805, 0.25 W	47 kΩ	5%	Standard	
R22	1	Ceramic Resistor, 0805, 0.25 W	10 k $\Omega$ // 300 k $\Omega$	5%	Standard	
R24	1	Ceramic Resistor, 0805, 0.25 W	4.3 kΩ	5%	Standard	
R25	1	Ceramic Resistor, 0805, 0.25 W	10 MΩ	5%	Standard	
R28	1	Ceramic Resistor, 0805, 0.25 W	75 kΩ	5%	Standard	
R29	1	Ceramic Resistor, 0805, 0.25 W	240 kΩ	5%	Standard	
R30	1	Ceramic Resistor, 0805, 0.25 W	1.2 kΩ	5%	Standard	
R31	1	NTC, 100 k $\Omega$ at 25°C, Beta = 4190	100k @ 25°C	0.05	NTCLE100E3104JB0	
ROUT1	1	Ceramic Resistor, 2512, 1 W	0R	5%	Standard	
RS1	1	Ceramic Resistor, 0805, 0.25 W	1.3 Ω	1%	Standard	
RS2	1	Ceramic Resistor, 0805, 0.25 W	3.0 Ω	1%	Standard	
T1	1	Transformer, Wurth			7508111333r03	

#### Table 3. BILL OF MATERIAL (BOM)

#### Conclusion

This application note has described the results obtained for a 12–W primary side regulation topology driven by the NCP1362 controller. Thanks to the dual frozen peak current in light and no load condition, the consumption have been improved. Also, the LineFeed Forward brings a better constant current regulation compared to previous PSR generation. The controller offers all necessary protections needed to safe power supply.

The author wishes to thank Wurth Elektronik for kindly providing samples for the transformer.

#### References

- [1] NCP1362 Datasheet NCP1362/D
- [2] "Designing a PSR Quasi–Resonant adaptor driven by the NCP1362" by Yann Vaquette, AND90024/D.
- [3] NCV1362WGEVB Evaluation board

ON Semiconductor and are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at <u>www.onsemi.com/site/pdf/Patent-Marking.pdf</u>. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for implantation in the human body. Should Buyer purchase or use ON Semiconductor hy such unithended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated wi

#### PUBLICATION ORDERING INFORMATION

#### LITERATURE FULFILLMENT:

## TECHNICAL SUPPORT

ON Semiconductor Website: www.onsemi.com

Email Requests to: orderlit@onsemi.com

North American Technical Support: Voice Mail: 1 800–282–9855 Toll Free USA/Canada Phone: 011 421 33 790 2910 Europe, Middle East and Africa Technical Support: Phone: 00421 33 790 2910 For additional information, please contact your local Sales Representative