NCP1076FLBKGEVB

NCP1076B Flyback Converter Evaluation Board User's Manual

Universal AC Mains, Up to 18 Watt Isolated Power Supply

ON Semiconductor®

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EVAL BOARD USER'S MANUAL

Introduction

This evaluation board manual describes 18 W High voltage switching, universal AC mains Flyback converter.

The converter provides constant voltage output. The supply can be used for powering utility electric meters, white goods or similar industrial equipment where isolation from the AC mains is required. The main benefits of provided solution are high efficiency, cost effectiveness and low no−load power consumption. The converter is utilizing monolithic ON Semiconductor switcher NCP1076B with integrated 4.7 Ω MOSFET in a PDIP7 package. The design note provides complete circuit diagram and bill of materials. The current capability of provided converter is user adjustable.

Circuit Description

The varistor R6 together with resistor R2 form simple protection that enhances application robustness against line over−voltage and voltage spikes. Resistor R2 also limits the inrush current when the power supply is connected to mains. The EMC filter is implemented to reduce conducted electromagnetic emissions to the mains.

The Flyback converter itself is formed by the high voltage switching regulator IC1, transformer TR1, freewheeling diode D3. Capacitors C4, C5, C12 and C13 are used as the output filtering and energy storage bank. Resistor R9 and capacitor C14 for filter, C9, R1 and D8 are forming voltage clamp for the switcher drain. Optocouple OK1 and IC3 − NCP431 is used in feedback network. Resistors R13 and R14 form resistive divider and sets output voltage.

Diode D2 and resistor R7 provide supply voltage VCC for IC1 from auxiliary winding. The capacitor C18 is the energy storage element that keeps IC1 powered during light load conditions, when the switching frequency drops and energy from auxiliary winding refills VCC capacitors less often.

Pin BO/AC_OVP is connected through resistor divider formed by R5, R15, R16 and R17 to bulk voltage and sets Brown−out function, AC line over−voltage protection and over−power protection.

The frequency compensation of the feedback loop system is ensured by external capacitor C10 that is connected to the IC OTA output.

Key Features

- Universal AC Input Range (85 – 265 Vac)
- Input Filter for Conducted EMI Attenuation
- Very Low Standby and No−load Power Consumption
- Frequency Fold−back for Improved Efficiency at Light Load
- Inherent Over−current, Over−voltage and Over−temperature Protections
- Frequency Jittering for Better EMI Signature
- Adjustable Peak Current to Set the Required Level of Over−current Protection
- Adjustable Brown−out Function

Table 1.

Description	Output Specification
Output Voltage	12 Vdc
Output Ripple	< 100 mV @ Full Load
Nominal Output Current	1.2 A
Max Output Current	1.5 A
Min Output Current	0 A
Efficiency	See Efficiency Charts
Inrush Limiting	Inrush Resistor R2
Operating Temperature Range	0°C to 50°C
Cooling Method	Passive Cooling
No−load Power Consumption	< 60 mW @ 85 − 265 Vac

Table 2.

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP1076B	White Goods, E−Meters	85 to 265 Vac	18 W	Flyback	Yes

CIRCUIT DIAGRAM

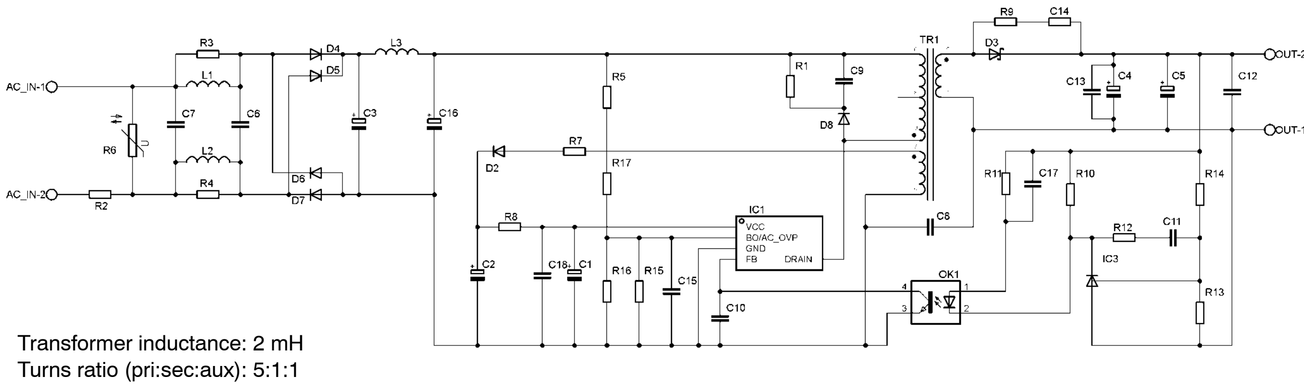

Figure 1. Circuit Diagram

CIRCUIT LAYOUT AND COMPONENTS

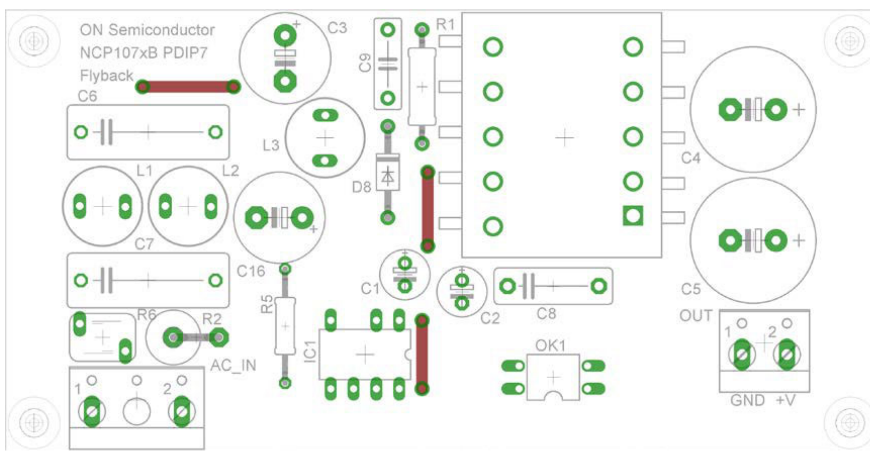

Figure 2. Circuit Layout− Top Side

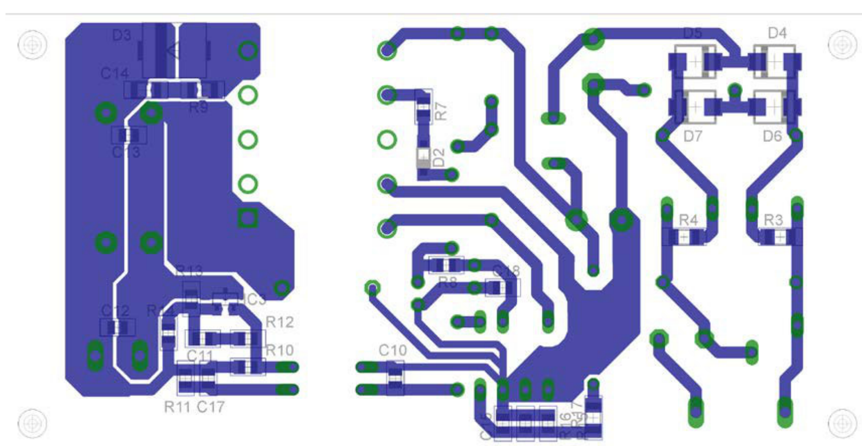

Figure 3. Circuit Layout − Bottom Side

EVALUATION BOARD

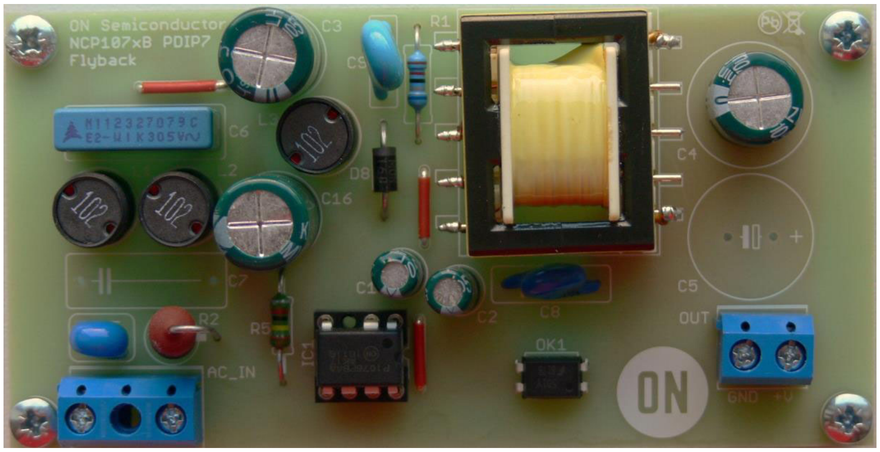

Figure 4. Evaluation Board − Top Side

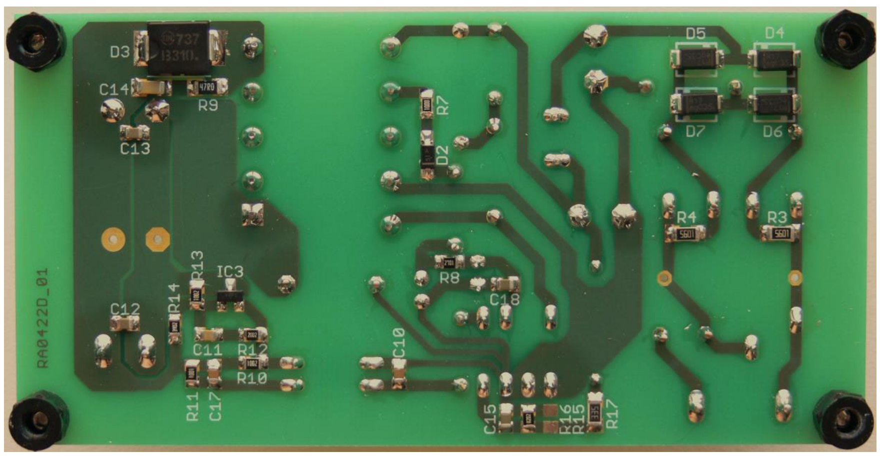

Figure 5. Evaluation Board − Bottom Side

THERMAL MEASUREMENT

Figure 6. Thermal Measurement – Top Side

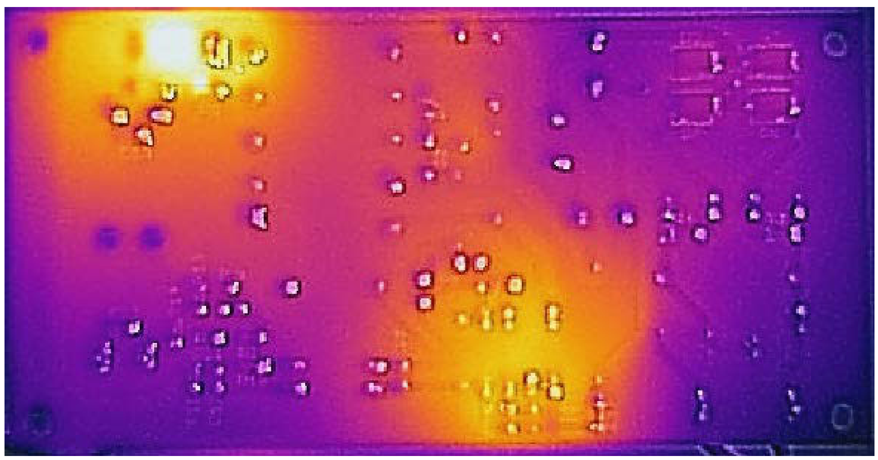

Figure 7. Thermal Measurement – Bottom Side

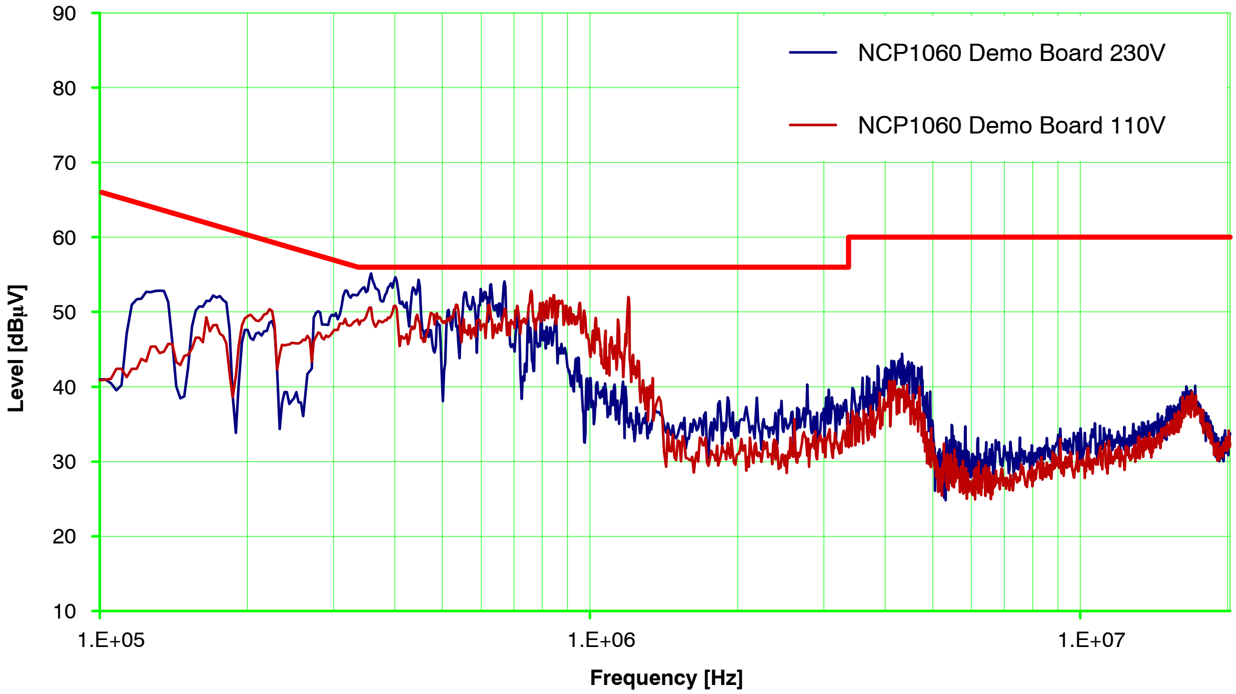

Figure 8. Conducted Emission Quasi−peak dBμV (Domestic)

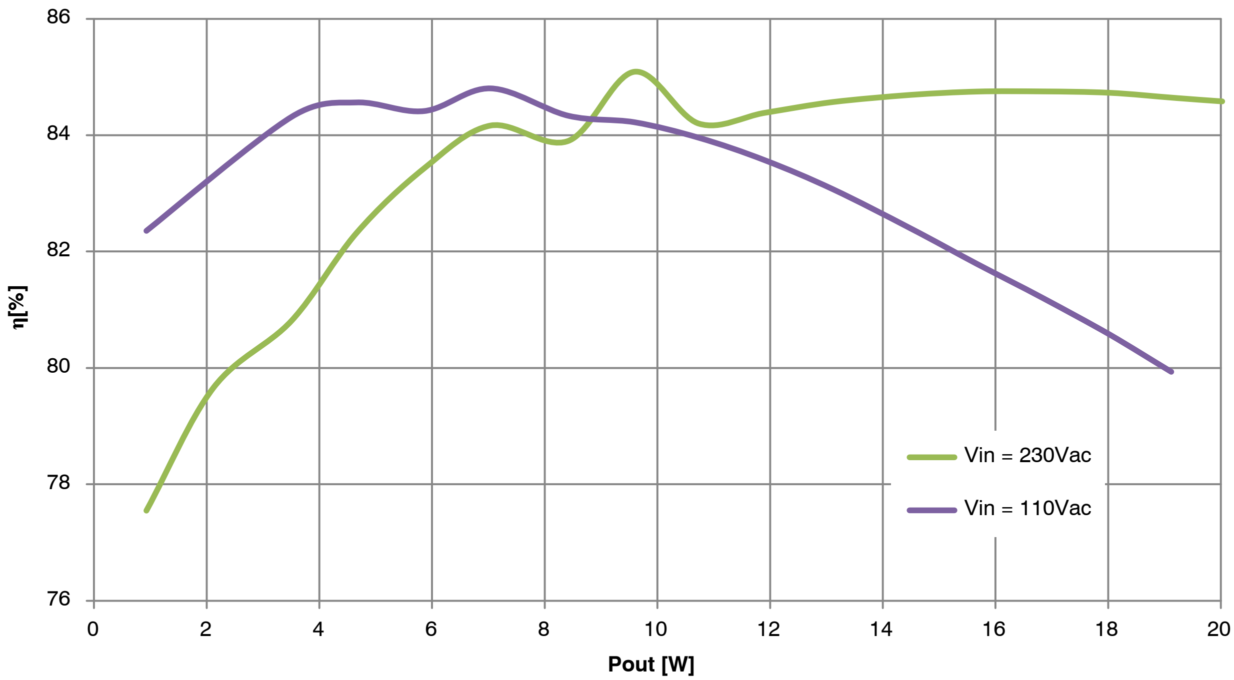

Figure 9. Efficiency vs. Output Load Curves

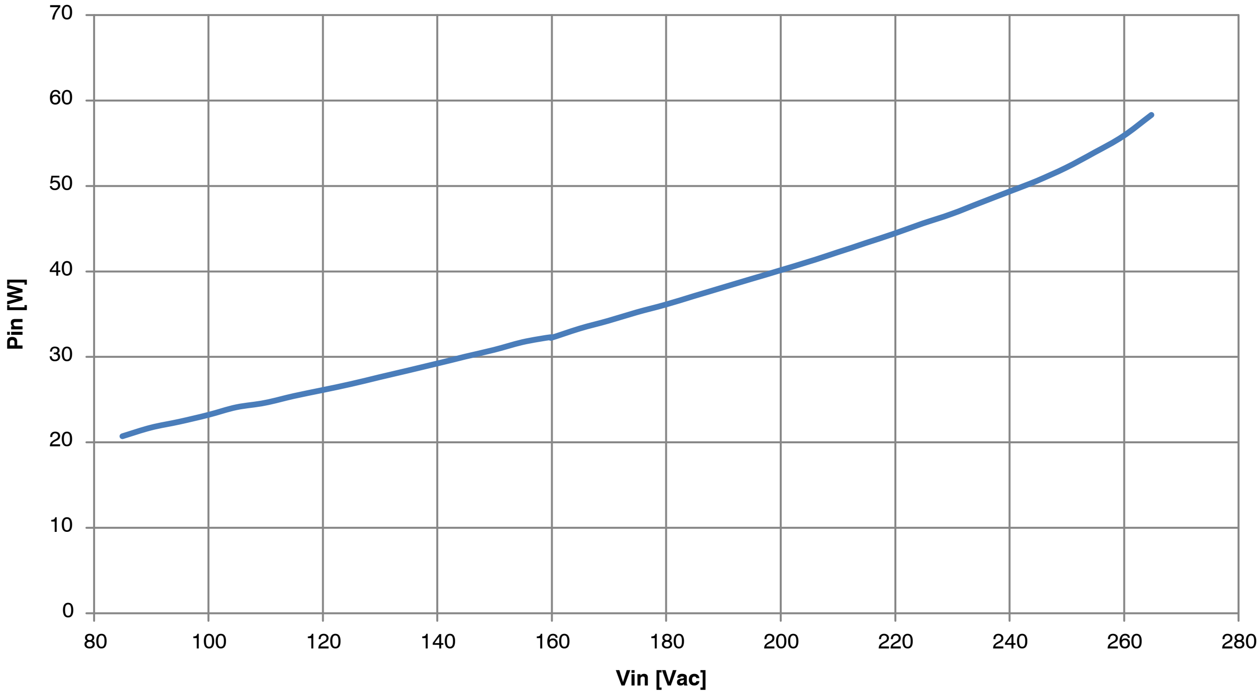

Figure 10. No−load Power Consumption vs. Line Input Curves

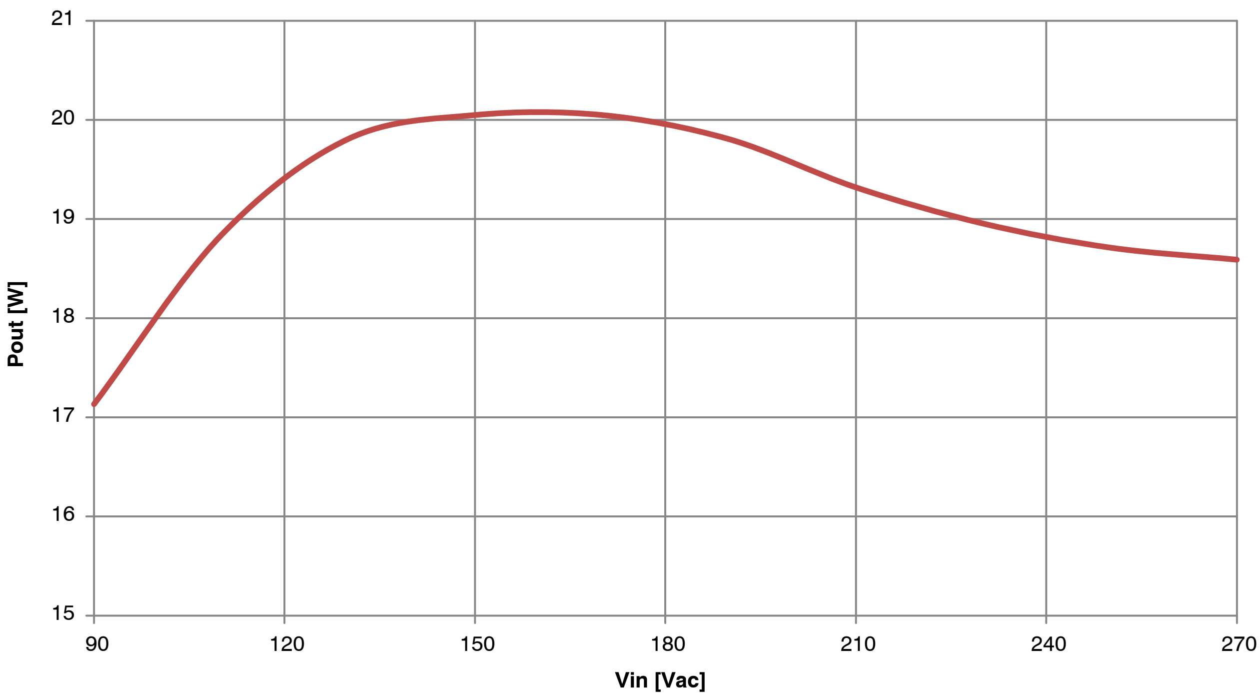

Figure 11. Maximal Output Power vs. Line Input Curves

Brown−out Protection

Brown−out protection prevents SMPS operating from a low input voltage when conduction losses could damage the MOSFET.

When BO/AC_OVP pin is grounded (voltage on this pin is below $V_{BO(EN)}$), then an internal comparator monitors the drain voltage. If the drain voltage is lower than the internal threshold $V_{HV(EN)}$ (91 V dc typically), the internal power switch is inhibited. If BO/AC_OVP pin is connected to bulk voltage via resistive divider then function Line detection is inhibited and the IC starts switching when on BO/AC_OVP pin reach $V_{BO(ON)}$.

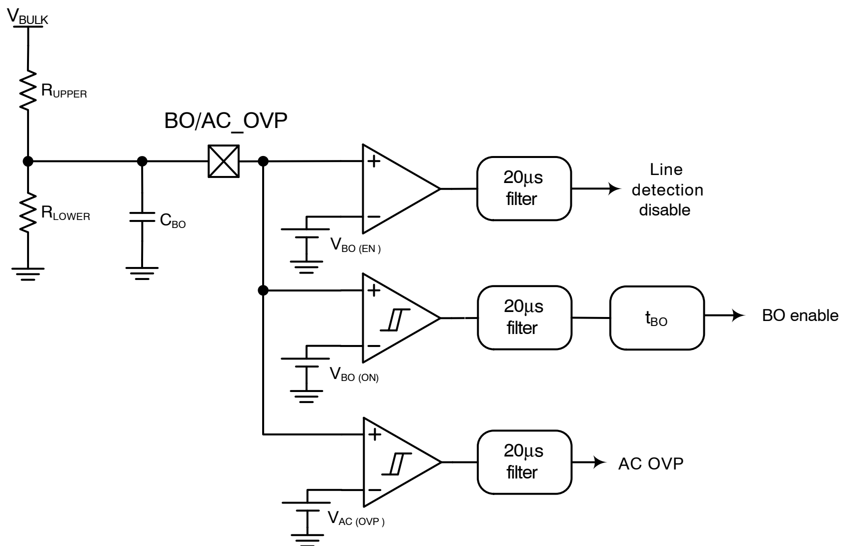

Figure 12. A Resistive Divider Made of R_{UPPER} and R_{LOWER}, brings a Portion of the HV Rail on BO/AC_OVP Pin

In this application R_{UPPER} is serial combination of R5 and R17, R_{LOWER} is R16.

Calculation of the resistive divider:

$$\frac{R_{LOWER}}{R_{UPPER}} = \frac{V_{BO(ON)}}{V_{BULK} - V_{BO(ON)}}$$

If we decide to start pulsing at $V_{BULK(ON)}$ = 113 V dc (80 V rms at ac mains):

$$\frac{R_{LOWER}}{R_{UPPER}} = \frac{V_{BO(ON)}}{V_{BULK} - V_{BO(ON)}} = \frac{0.8}{113 - 0.8} \approx 7.1\ \text{m}$$

We choose R_{LOWER} = R16 = 82 kΩ

$$R_{UPPER} = R5 + R17 = \frac{82 \cdot 10^{3}}{7.1 \cdot 10^{-3}} = 11.5\ \text{M}\Omega =$$

$$= 8.2\ \text{M}\Omega + 3.3\ \text{M}\Omega$$

It is better to connect capacitor with lower value on BO/AC_OVP pin because on capacitor with higher value there is lower ripple but average voltage value. It means the IC could start switching at 80 Vac but it stops switching at 75 Vac not at 70 Vac – lower hysteresis. If there is lower capacitor then ripple is higher but if voltage peak reach $V_{BO(OFF)}$ value each t_{BO} = 50 ms minimal then the IC doesn't stop switching.

AC Line OVP

AC line overvoltage protection is a mean to prevent SMPS operating at high input voltage. This protection is set the same resistive divider as Brown−out protection.

If the voltage on BO/AC_OVP pin exceed $V_{ACOVP(ON)}$, the switcher immediately stops pulsing until the voltage on BO/AC_OVP pin drops under $V_{ACOVP(OFF)}$. For $V_{BULK(ON)}$ = 113 V dc will be over−voltage protection (voltage when the switcher stops pulsing):

$$V_{BULK(OVP)} = V_{ACOVP(ON)} \cdot \frac{R_{LOWER} + R_{UPPER}}{R_{LOWER}} =$$

$$= V_{ACOVP(ON)} \cdot \frac{V_{BULK(ON)}}{V_{BO(ON)}} = 2.9 \cdot \frac{113}{0.8} = 409\ \text{Vdc}$$

It corresponds to 290 V rms. SMPS starts switching again when bulk voltage drops down to:

$$V_{ACOVP(OFF)} \cdot \frac{V_{BULK(ON)}}{V_{BO(ON)}} = 2.6 \cdot \frac{113}{0.8} = 367\ \text{Vdc} = 260\text{Vrms}$$

Then power losses on resistive divider for worst case (V_{BULK} = 409 V dc)

$$P = U \cdot I = \frac{U^{2}}{R} = \frac{U^{2}}{R_{UPPER} + R_{LOWER}} =$$

$$= \frac{409^{2}}{11.5 \cdot 10^{6} + 82 \cdot 10^{3}} \approx 15\ \text{mW}$$

Over−power Protection

Over−power protection is internal function using the bulk voltage to program the maximum current reduction for a given input voltage. Internal OPP is active when BO/AC_OVP pin is connected via resistive divider to the bulk voltage. At 0.8 V on BO/AC_OVP pin the peak current is not reduced, if the same voltage rises to 2.65 V then the peak current is reduced by 20%, in this application it corresponds to 375 V dc bulk voltage. On the Maximal Output Power vs. Line Input Curves graph you can see dependence of output power on line input curves.

2nd LEB − Peak Current Protection

There is a second level of current protection with 100 ns propagation delay to prevent IC against high peak current. It could prevent destruction when forward diode on secondary side or transformer is shorted. If peak current is 150% max peak current limit, then the controller stops switching after three pulses and waits for an auto−recovery period ($t_{recovery}$) before attempting to re−start.

Startup and 2nd LEB

In Flyback topology there are pulses with higher value before soft−start. If the pulse value reaches 150% I_{PK} then the IC stops switching and it couldn't start to normal operation. The maximal value could be affected by output capacitor value, transistor inductance or turns ratio or secondary side diode forward voltage.

OUTPUT RIPPLE VOLTAGE

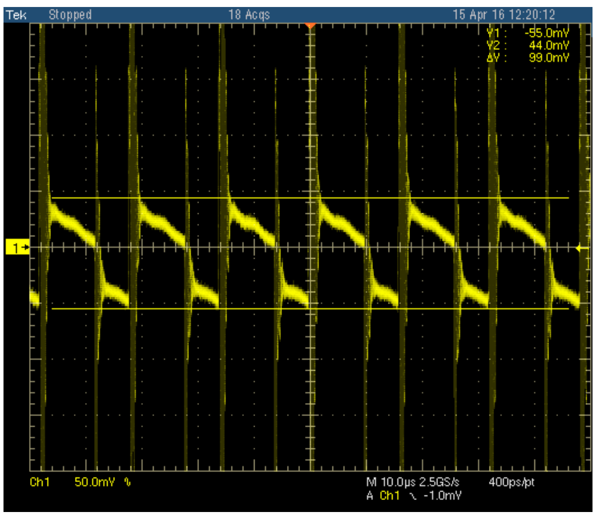

Figure 13. Input Voltage 90 Vac and 1.2 A Load

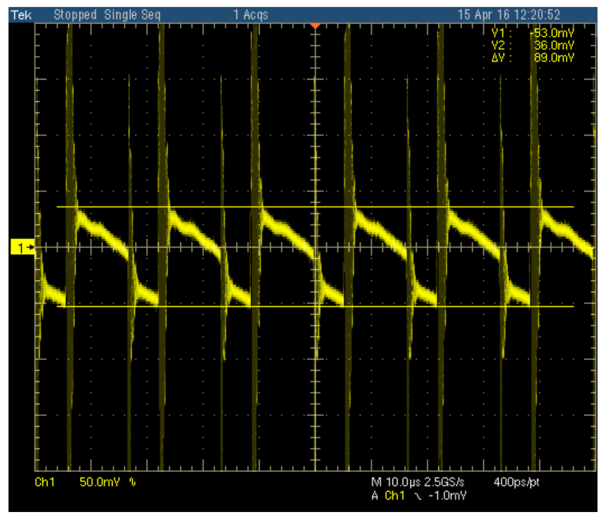

Figure 14. Input Voltage 110 Vac and 1.2 A Load

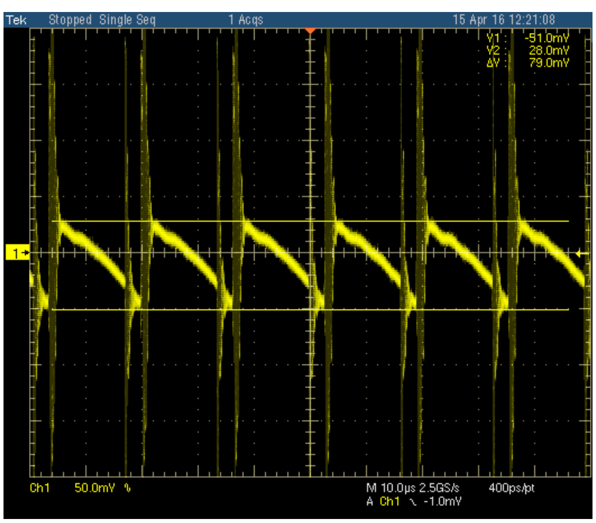

Figure 15. Input Voltage 230 Vac and 1.2 A Load

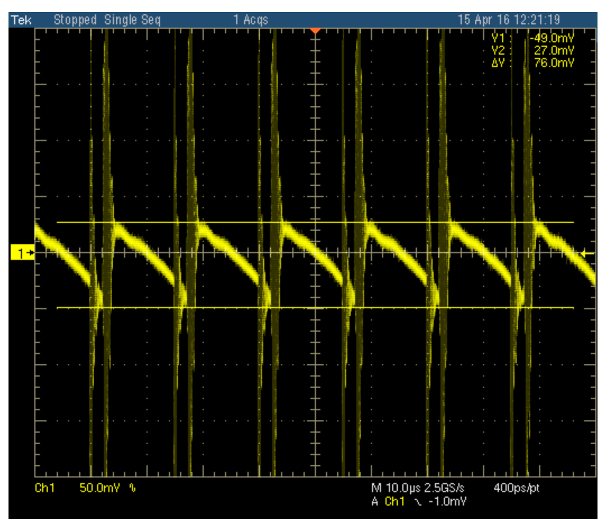

Figure 16. Input Voltage 265 Vac and 1.2 A Load

TRANSIENT RESPONSE

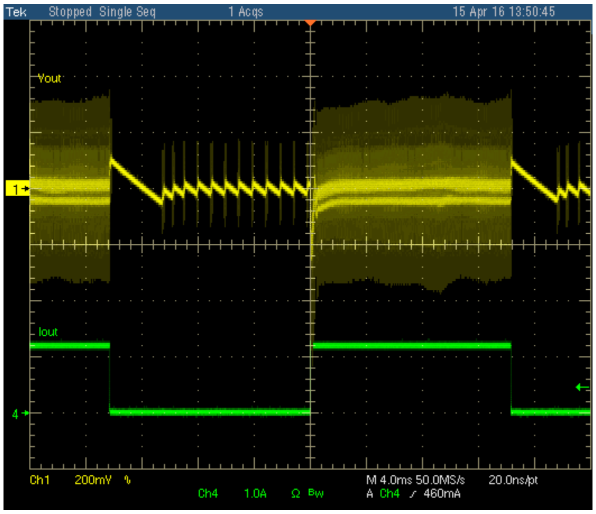

Figure 17. Test Condition: 30−1200 mA, 28 ms Cycle, 110 Vac

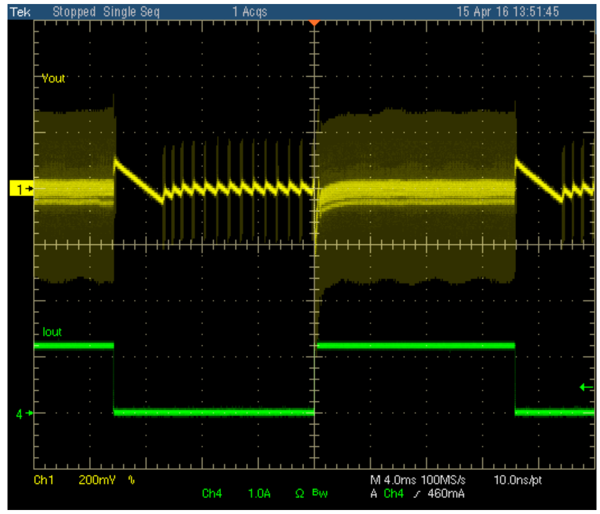

Figure 18. Test Condition: 30−1200 mA, 28 ms Cycle, 230 Vac

STARTUP TIME

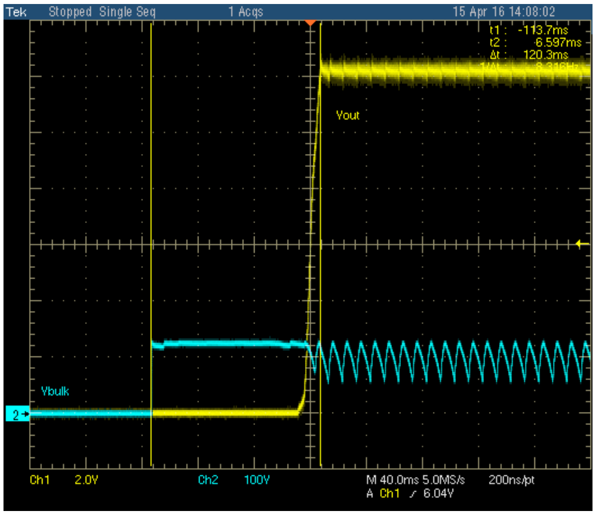

Figure 19. Input Voltage 90 Vac and 1.2 A Load

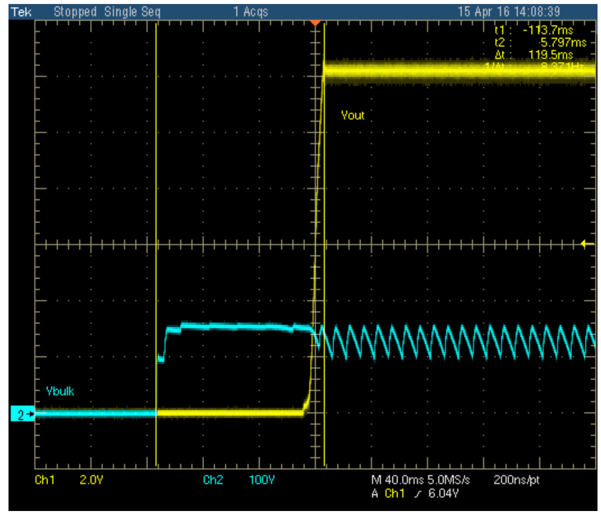

Figure 20. Input Voltage 110 Vac and 1.2 A Load

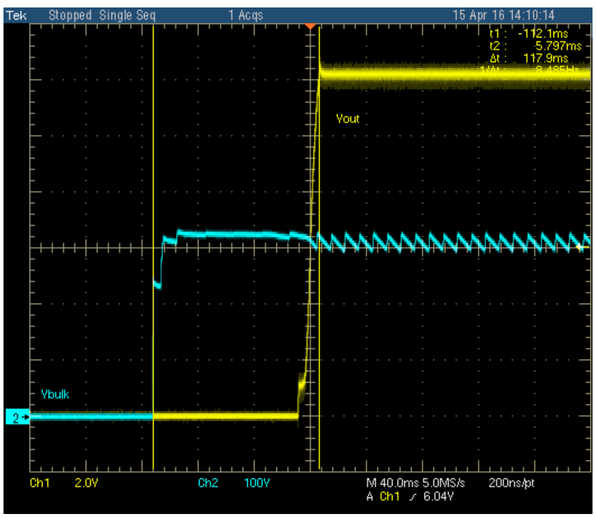

Figure 21. Input Voltage 230 Vac and 1.2 A Load

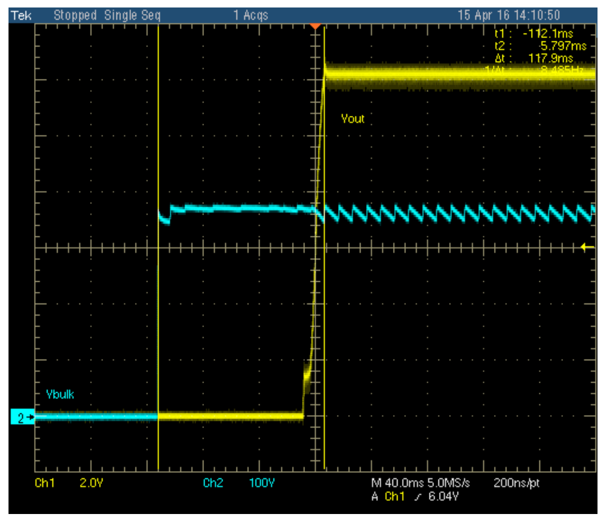

Figure 22. Input Voltage 265 Vac and 1.2 A Load

STARTUP AND 2nd LEB PROTECTION

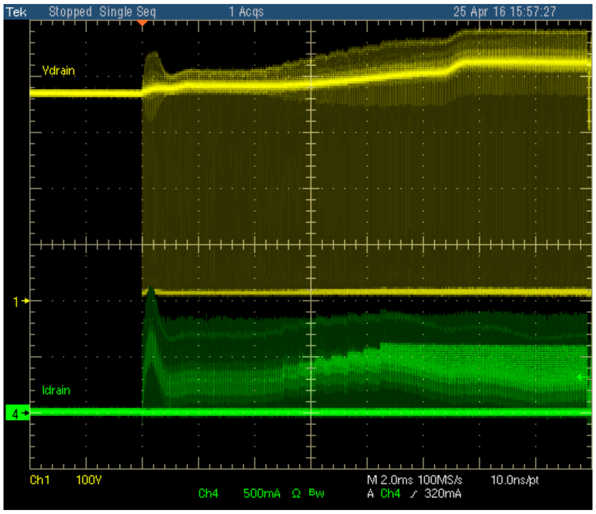

Figure 23. 265 Vac 1.2 A Load

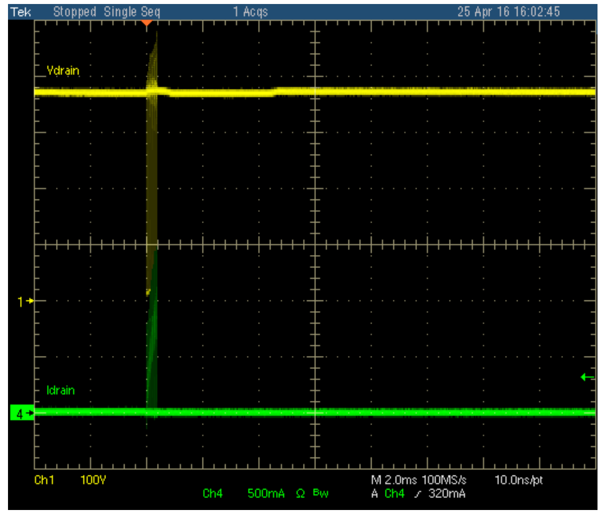

Figure 24. 265 Vac Short−circuit

OVER−CURRENT PROTECTION

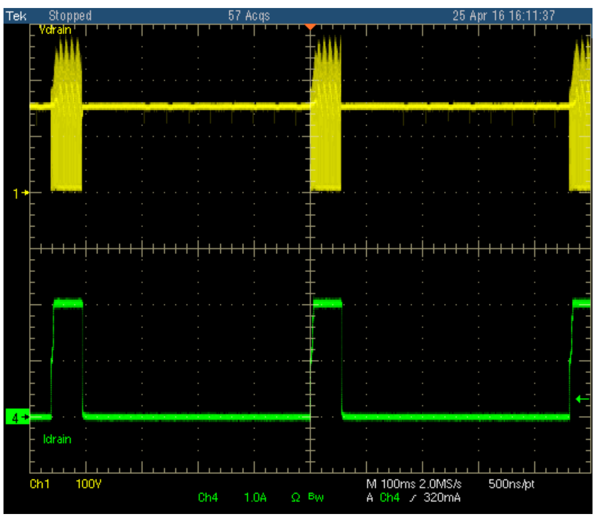

Figure 25. 110 Vac 2 A Load

Figure 26. 110 Vac 3.5 A Load

POWER OFF

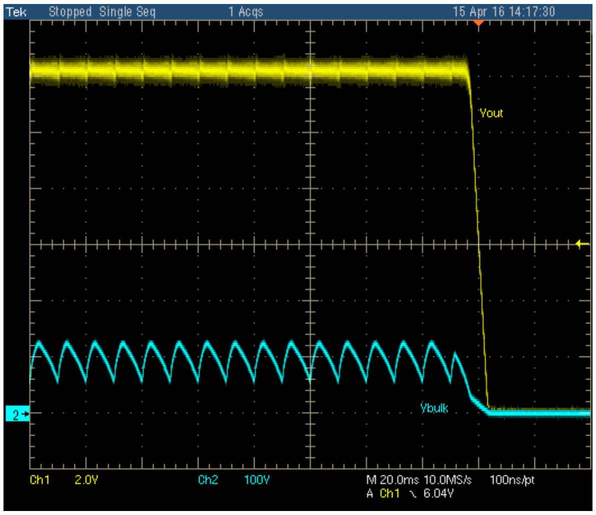

Figure 27. Input Voltage 90 Vac and 1.2 A Load

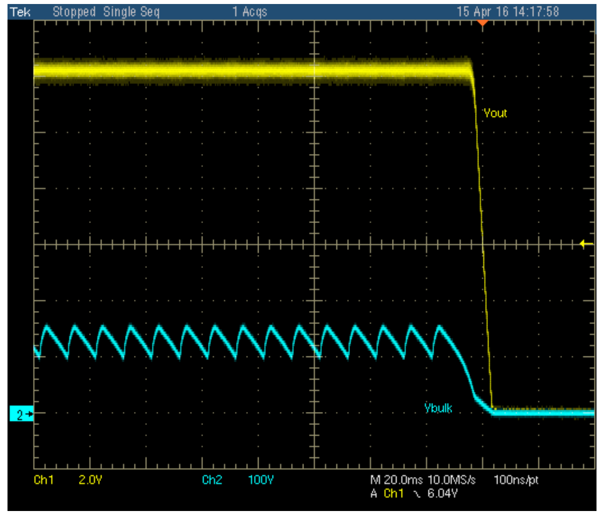

Figure 28. Input Voltage 110 Vac and 1.2 A Load

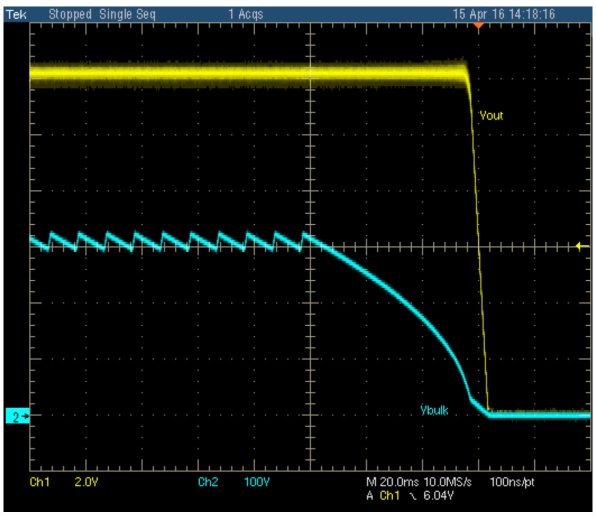

Figure 29. Input Voltage 230 Vac and 1.2 A Load

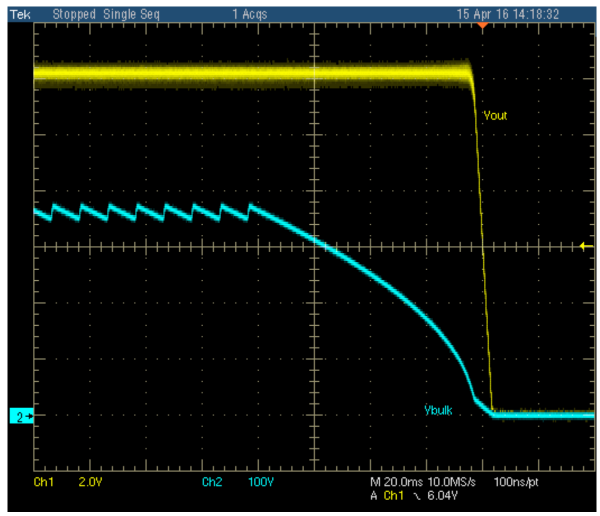

Figure 30. Input Voltage 265 Vac and 1.2 A Load

BROWN−OUT

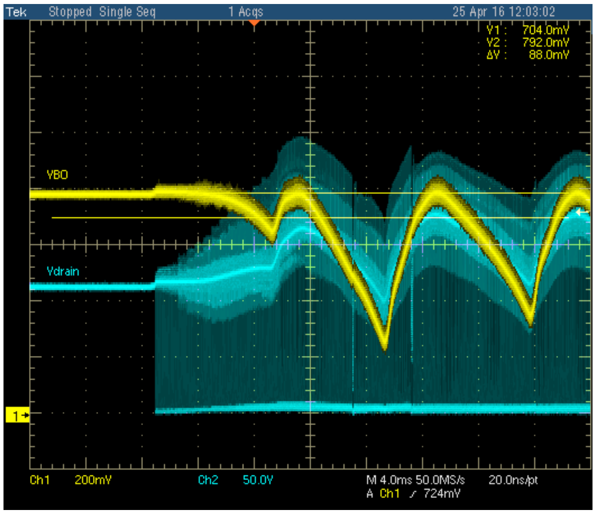

Figure 31. 82 Vac 1 A Load

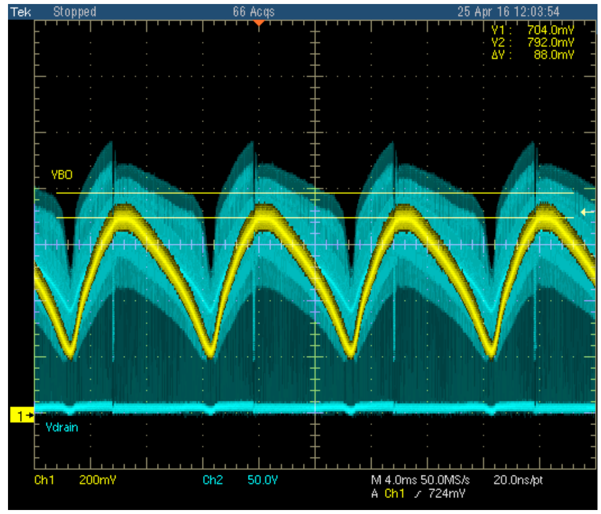

Figure 32. 73 Vac 1 A Load

Table 3. BILL OF MATERIALS

Designator	Qty	Description	Value	Toler-ance	Footprint	Manufacturer	Manufacturer Part Number	Substi-tution Allowed
C1, C12, C13	3	CAPACITOR	100 nF	10%	0805	Kemet	C0805C104K5RACTU	Yes
C2	1	ELECTROLYTIC CAPACITOR	4.7 μF / 50 V	20%	THROUGH HOLE	Würth Elektronik	860020672008	Yes
C3, C16	2	ELECTROLYTIC CAPACITOR	10 μF / 400 V	20%	THROUGH HOLE	Würth Elektronik	8.60021E+11	Yes
C4	1	ELECTROLYTIC CAPACITOR	470 μF / 16 V	20%	THROUGH HOLE	Würth Elektronik	860010374012	Yes
C5	1	ELECTROLYTIC CAPACITOR	NU	–	THROUGH HOLE	–	–	–
C6	1	CAPACITOR X2	100 nF	10%	THROUGH HOLE	Kemet	R463I310050M1K	Yes
C7	1	CAPACITOR X2	NU	–	THROUGH HOLE	–	–	–
C8, C9, C10, C17, C15	5	CAPACITOR	1 nF	10%	0805	Kemet	C0805X104K1RACTU	Yes
C11	1	CAPACITOR	10 nF	10%	0805	Kemet	C0805C103K5RACAUTO	Yes
C14	1	CAPACITOR	1 nF	10%	1206	Kemet	C1206C104K5RACTU	Yes
C18	1	CAPACITOR	22 μF / 25 V	20%	THROUGH HOLE	Würth Elektronik	860010472003	Yes
D2	1	DIODE	MMSD4148	–	SOD–123	ON Semiconductor	MMSD4148	No
D3	1	DIODE	MBRS3100T3	–	SMC	ON Semiconductor	MBRS3100T3	No
D4, D5, D6, D7	4	DIODE	MRA4007	–	SMA	ON Semiconductor	MRA4007T3G	No
D8	1	DIODE	MUR160	–	THROUGH HOLE	ON Semiconductor	MURA160T3G	No
IC1	1	SWITCHER	NCP1076B	–	PDIP7	ON Semiconductor	NCP1076B	No
IC3	1	VOLTAGE REGULATOR	NCP431	1%	SOD–23–3	Würth Elektronik	NCP431	No
L1	1	INDUCTOR	1 mH	–	THROUGH HOLE	Würth Elektronik	744772102	No
L2	1	INDUCTOR	1 mH	–	THROUGH HOLE	Würth Elektronik	744772102	No
L3	1	INDUCTOR	1 mH	–	THROUGH HOLE	Würth Elektronik	744772102	No
OK1	1	OPTOCOUPLER	PC817	–	DIP–4	Rohm Semiconductor	PC817B	No
R1	1	RESISTOR	68 kΩ	1%	THROUGH HOLE			Yes
R2	1	RESISTOR	20 Ω	5%	THROUGH HOLE			Yes
R3, R4	2	RESISTOR	5.6 kΩ	1%	1206	Vishay	CRCW12065K60FKEAHP	Yes
R5	1	RESISTOR	8.2 MΩ	5%	THROUGH HOLE			Yes
R6	1	VARISTOR	SO5K275	–	THROUGH HOLE			No
R7	1	RESISTOR	10 Ω	1%	0805	Vishay	CRCW080510R0FKEA.	Yes
R8	1	RESISTOR	5.1 kΩ	5%	0805	Vishay	CRCW08055K10JNEA	Yes
R9	1	RESISTOR	47 Ω	1%	1206	Vishay	CRCW120647R0FKEA	Yes
R10, R13	2	RESISTOR	10 kΩ	1%	0805	Vishay	CRCW080510K0FKEAHP	Yes
R11	1	RESISTOR	1 kΩ	1%	0805	Vishay	CRCW08051K00FKTA	Yes

Table 3. BILL OF MATERIALS

Designator	Qty	Description	Value	Toler-ance	Footprint	Manufacturer	Manufacturer Part Number	Substi-tution Allowed
R12	1	RESISTOR	20 kΩ	1%	0805	Vishay	CRCW080520K0FKEA	Yes
R14	1	RESISTOR	39 kΩ	1%	0805	Vishay	CRCW080539K0JNEA	Yes
R15	1	RESISTOR	NU	1%	0805	–	–	–
R16	1	RESISTOR	82 kΩ	1%	0805	Vishay	CRCW080582K0JNEA	Yes
R17	1	RESISTOR	3.3 MΩ	1%	1206	Vishay	CRCW12063M30FKEA	Yes
TR1	1	TRANSFORMER	750313861	–	THROUGH HOLE	Würth Elektronik	750313861	No
X1 (AC_IN)	1	WAGO SCREW CLAMP	691213710003	–	THROUGH HOLE	Würth Elektronik	691213710003	No
X2 (OUT)	1	WAGO SCREW CLAMP	691211720002	–	THROUGH HOLE	Würth Elektronik	691211720002	No

NOTE All components are lead free.

REFERENCES

[1] ON Semiconductor datasheet for NCP1076B monolithic switcher
[2] ON Semiconductor design notes DN05012, DN05017, DN05018, DN05028, DN05029
[3] Würth Electronic http://www.we−online.com/

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