

NCP1076FLBKGEVB



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NCP1076B Flyback Converter Evaluation Board User's Manual

Universal AC Mains, Up to 18 Watt Isolated Power Supply

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.

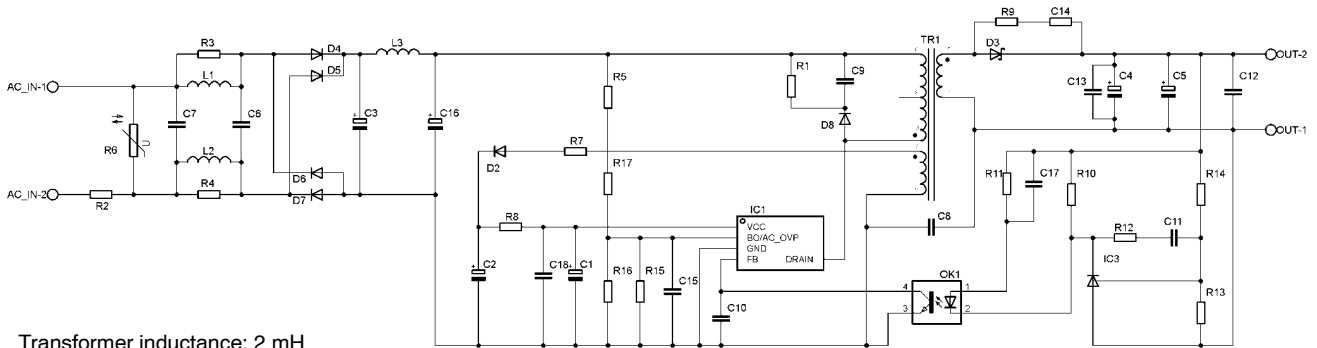
| Description | Output Specification |
|-----------------------------|------------------------|
| Output Voltage | 12 Vdc |
| Output Ripple | < 100 mV @ Full Load |
| Nominal Output Current | 1.2 A |
| Max Output Current | 1.5 A |
| Min Output Current | 0 A |
| Efficiency | See Efficiency Charts |
| 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 |

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CIRCUIT DIAGRAM



Transformer inductance: 2 mH
Turns ratio (pri:sec:aux): 5:1:1

Figure 1. Circuit Diagram

CIRCUIT LAYOUT AND COMPONENTS

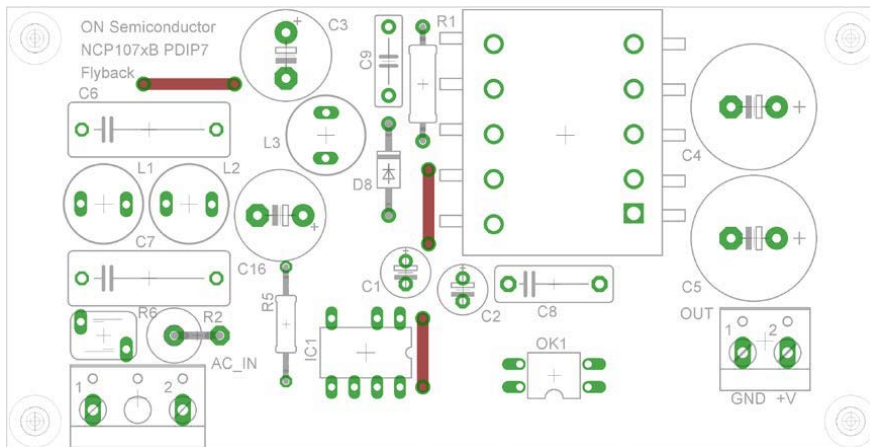


Figure 2. Circuit Layout- Top Side

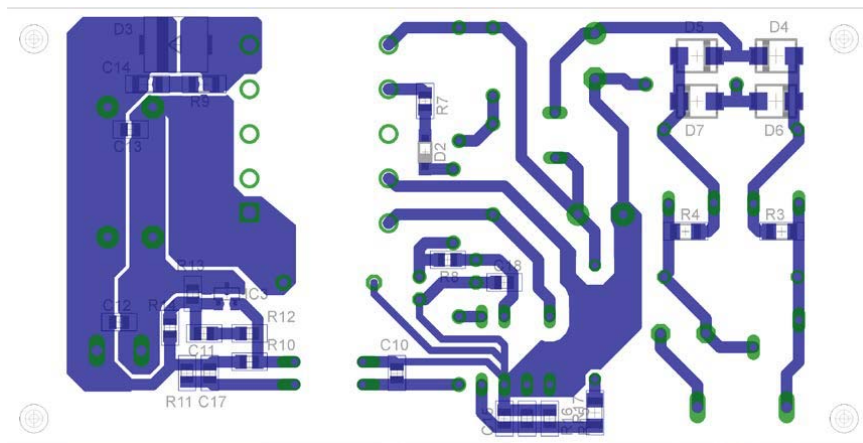


Figure 3. Circuit Layout - Bottom Side

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EVALUATION BOARD

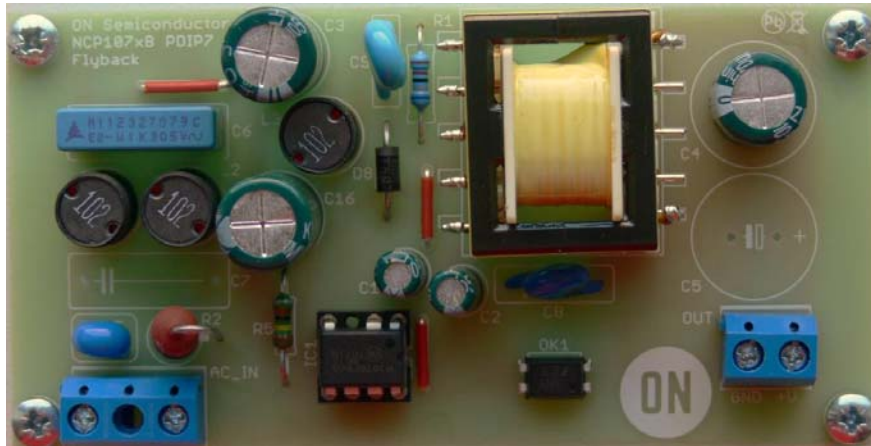


Figure 4. Evaluation Board – Top Side

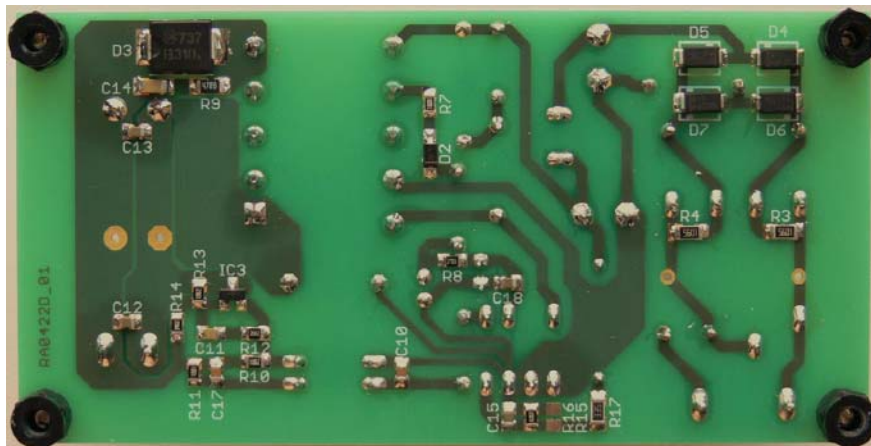


Figure 5. Evaluation Board – Bottom Side

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THERMAL MEASUREMENT

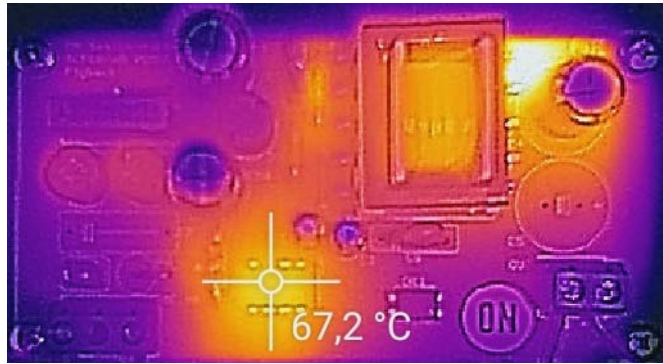


Figure 6. Thermal Measurement – Top Side

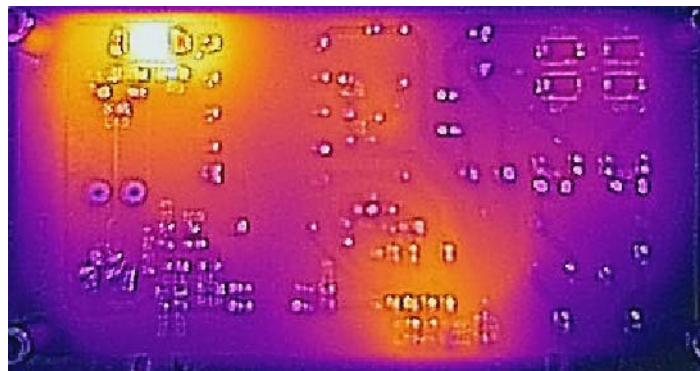


Figure 7. Thermal Measurement – Bottom Side

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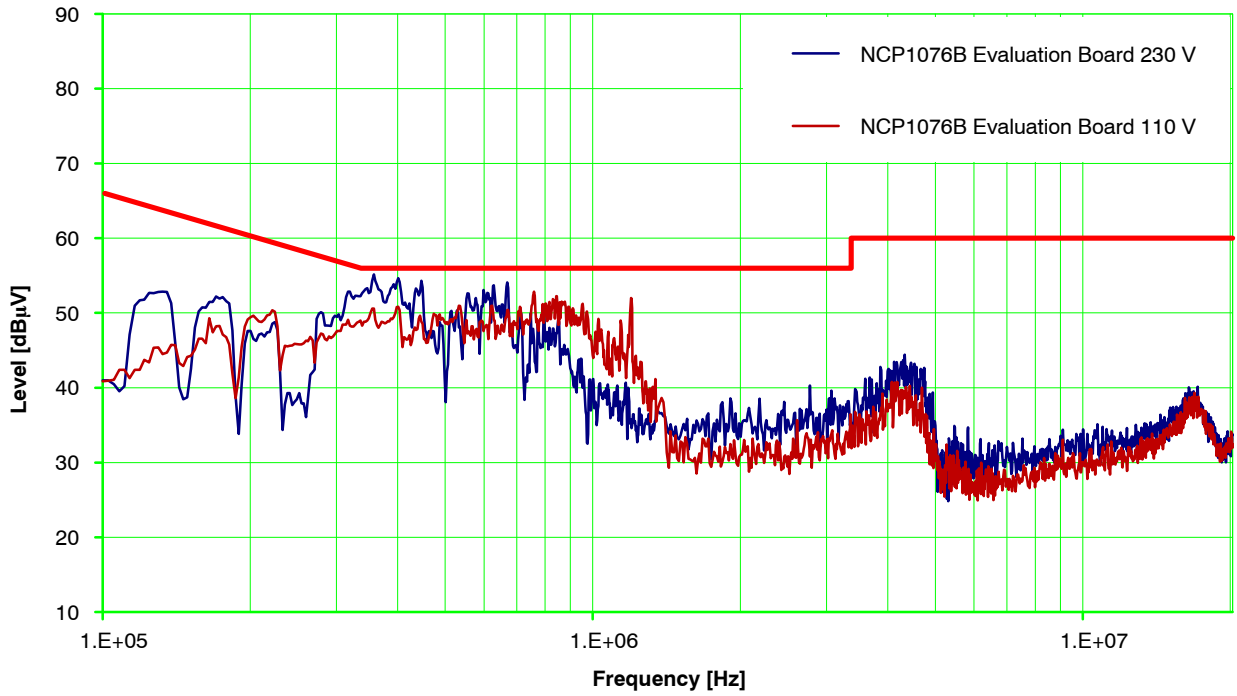


Figure 8. Conducted Emission Quasi-peak dBµV (Domestic)

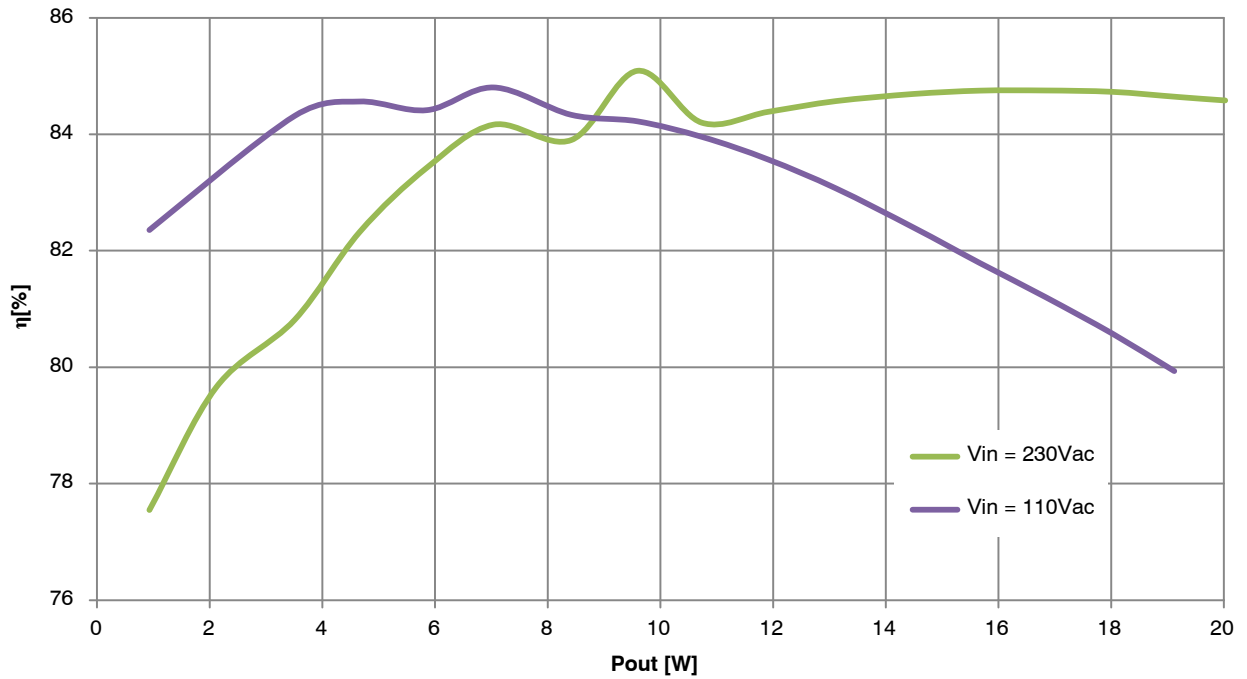


Figure 9. Efficiency vs. Output Load Curves

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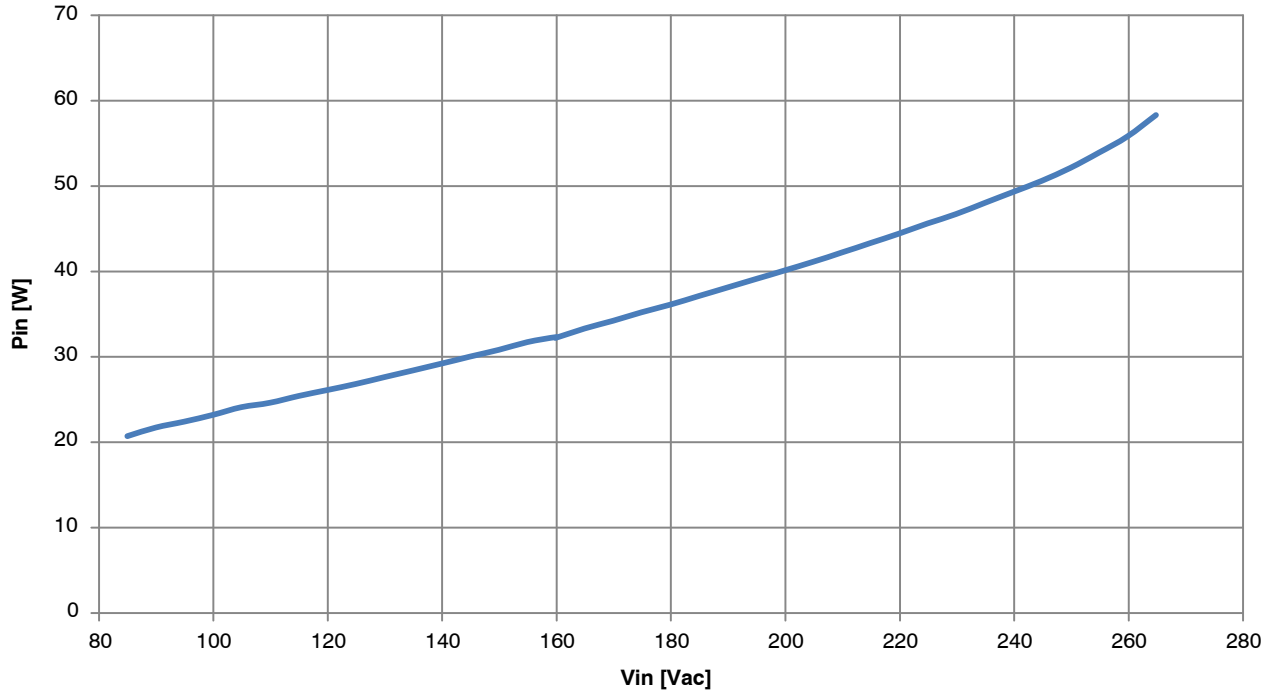


Figure 10. No-load Power Consumption vs. Line Input Curves

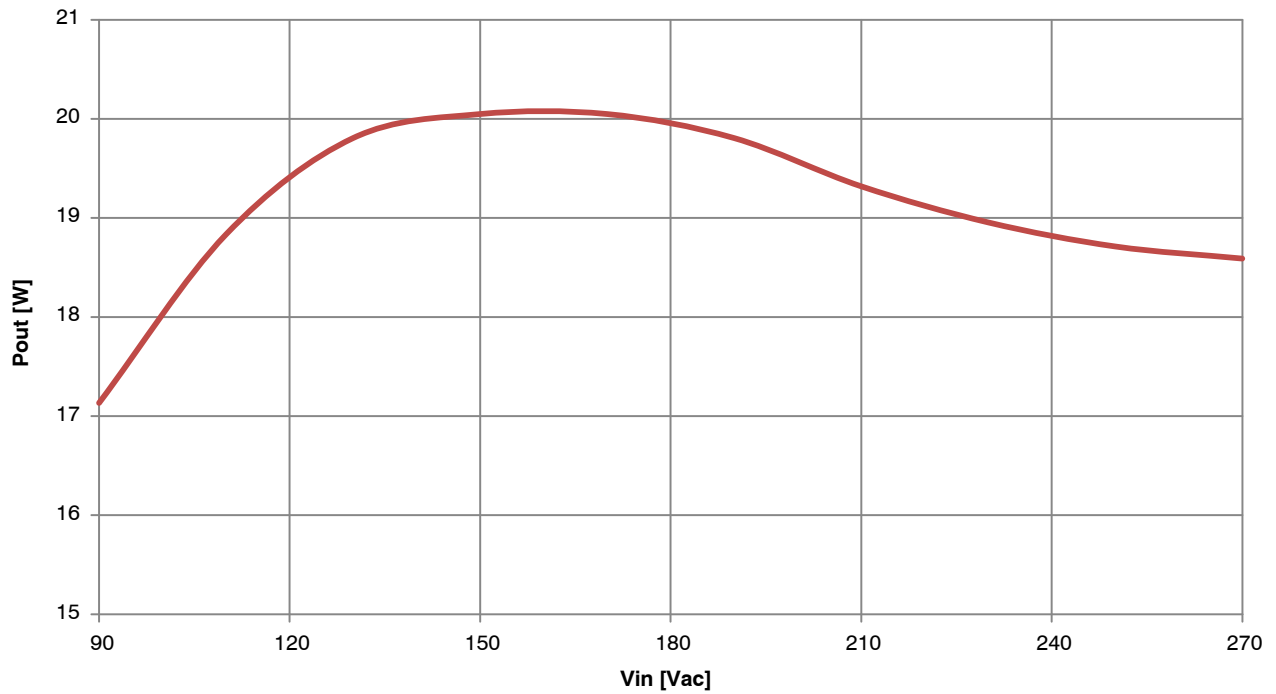


Figure 11. Maximal Output Power vs. Line Input Curves

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 $V_{BO(ON)}$.

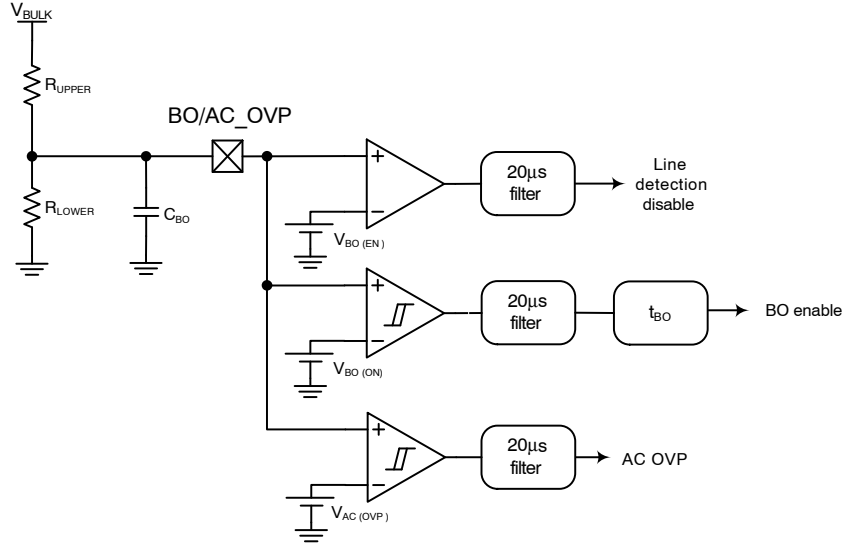


Figure 12. A Resistive Divider Made of R_{UPPER} and R_{LOWER} , brings a Portion of the HV Rail on BO/AC_OVP Pin

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 $R_{LOWER} = R16 = 82 \text{ k}\Omega$

$$R_{UPPER} = R5 + R17 = \frac{82 \cdot 10^3}{7.1 \cdot 10^{-3}} = 11.5 \text{ M}\Omega = 8.2 \text{ M}\Omega + 3.3 \text{ M}\Omega$$

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

$$V_{BULK(OVP)} = V_{AC(OVP)} \cdot \frac{R_{LOWER} + R_{UPPER}}{R_{LOWER}} = V_{AC(OVP)} \cdot \frac{V_{BULK(ON)}}{V_{BO(ON)}} = 2.9 \cdot \frac{113}{0.8} = 409 \text{ Vdc}$$

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

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

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

$$P = U \cdot I = \frac{U^2}{R} = \frac{U^2}{R_{UPPER} + R_{LOWER}} = \frac{409^2}{11.5 \cdot 10^6 + 82 \cdot 10^3} \approx 15 \text{ mW}$$

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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

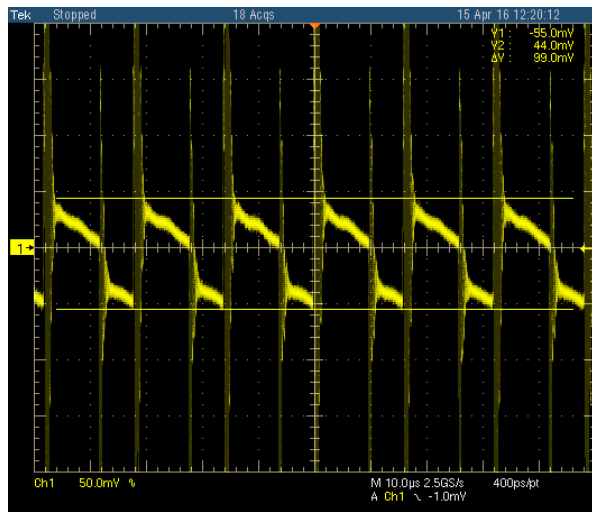


Figure 13. Input Voltage 90 Vac and 1.2 A Load

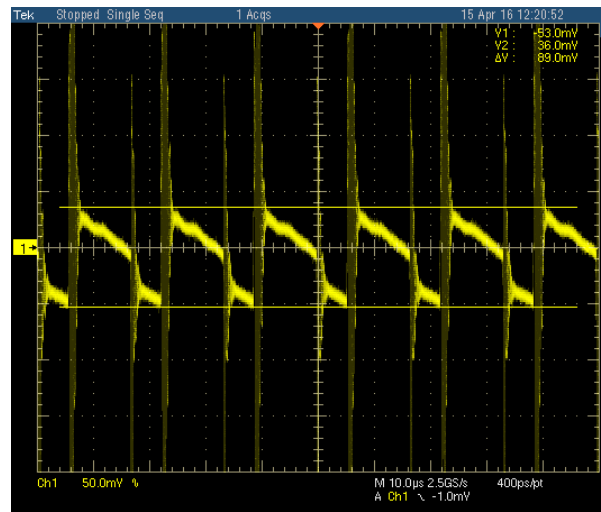


Figure 14. Input Voltage 110 Vac and 1.2 A Load

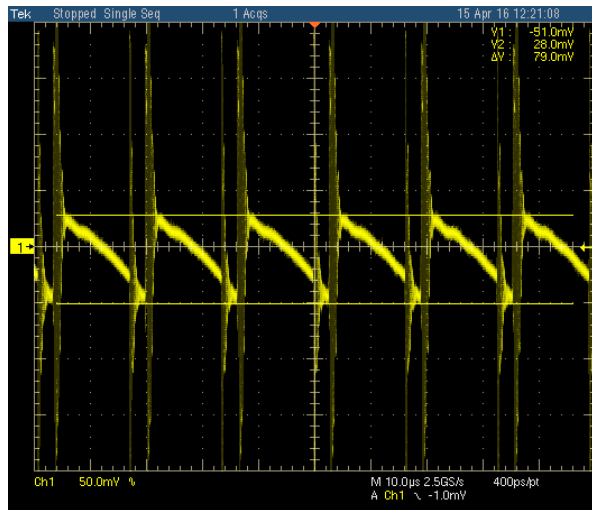


Figure 15. Input Voltage 230 Vac and 1.2 A Load

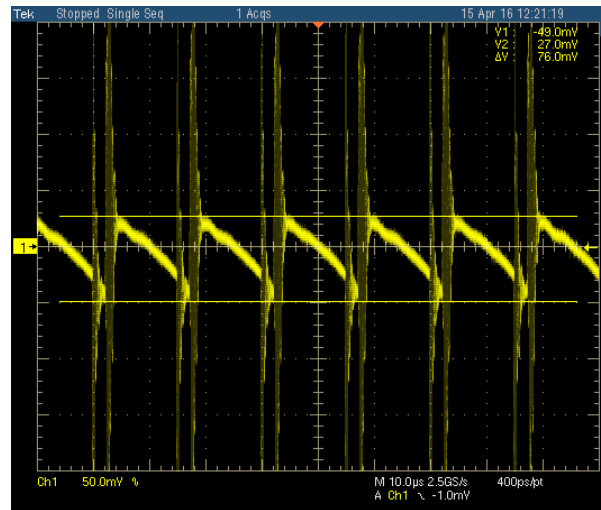


Figure 16. Input Voltage 265 Vac and 1.2 A Load

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TRANSIENT RESPONSE

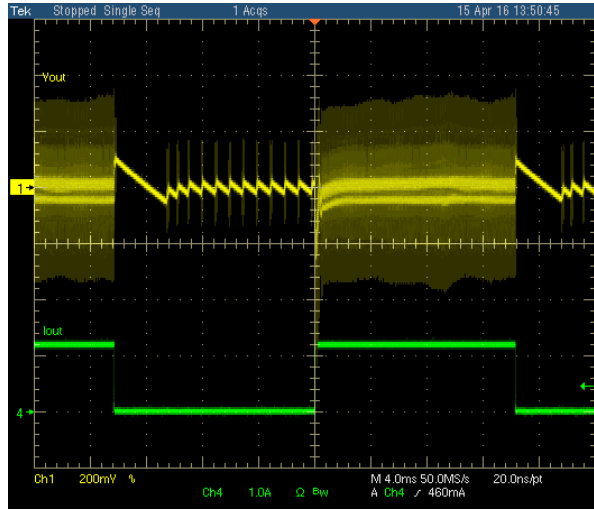


Figure 17. Test Condition: 30–1200 mA, 28 ms Cycle, 110 Vac

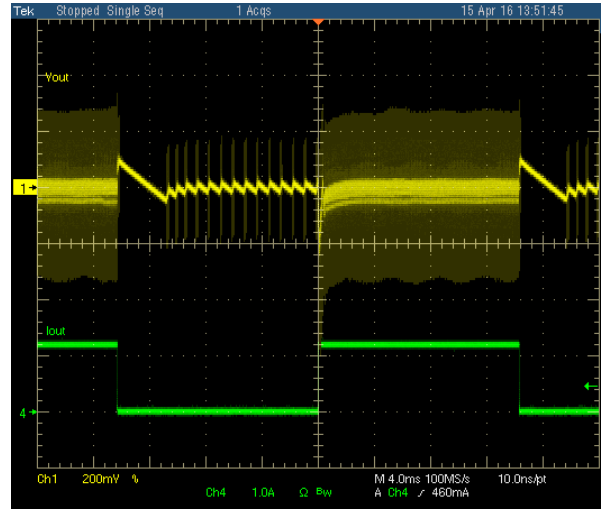


Figure 18. Test Condition: 30–1200 mA, 28 ms Cycle, 230 Vac

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STARTUP TIME

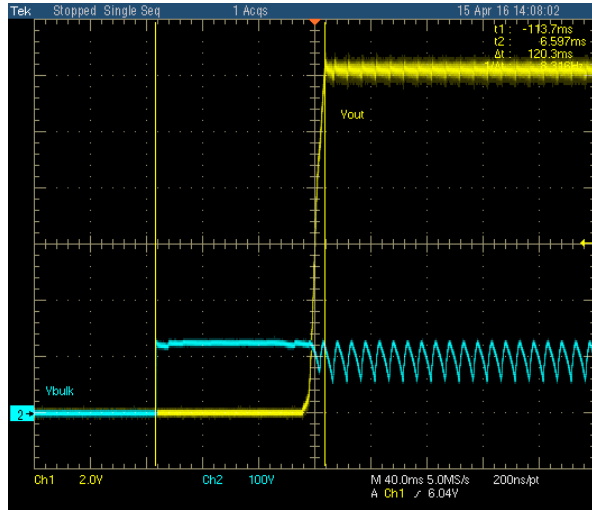


Figure 19. Input Voltage 90 Vac and 1.2 A Load

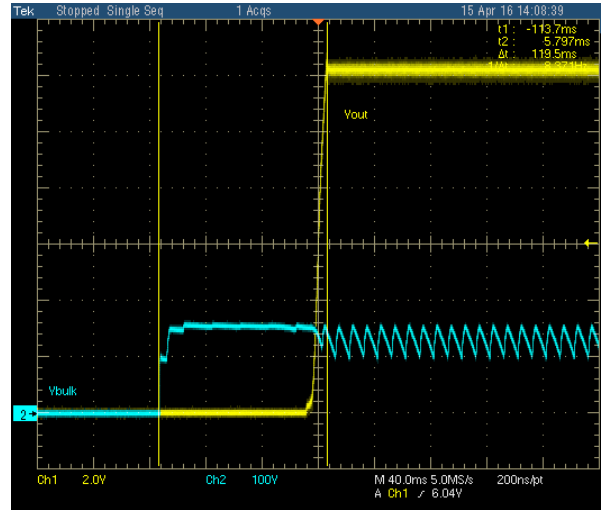


Figure 20. Input Voltage 110 Vac and 1.2 A Load

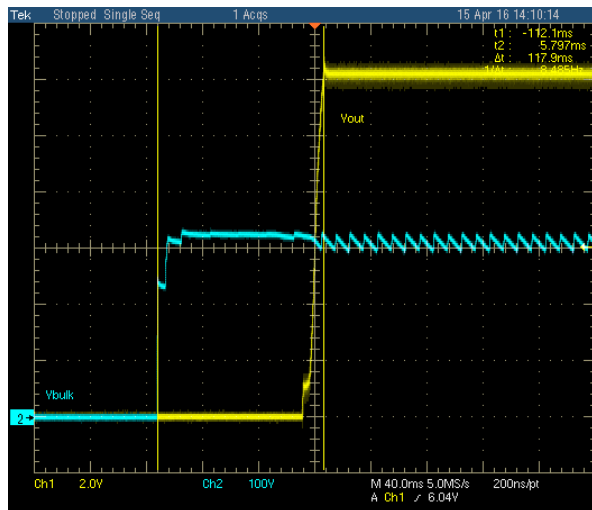


Figure 21. Input Voltage 230 Vac and 1.2 A Load

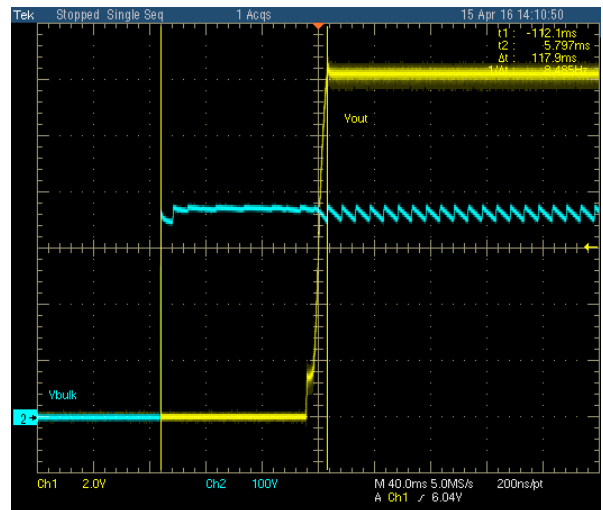


Figure 22. Input Voltage 265 Vac and 1.2 A Load

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STARTUP AND 2nd LEB PROTECTION

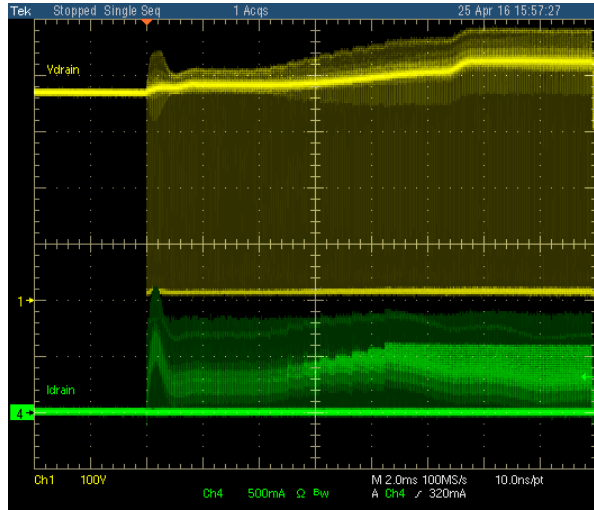


Figure 23. 265 Vac 1.2 A Load

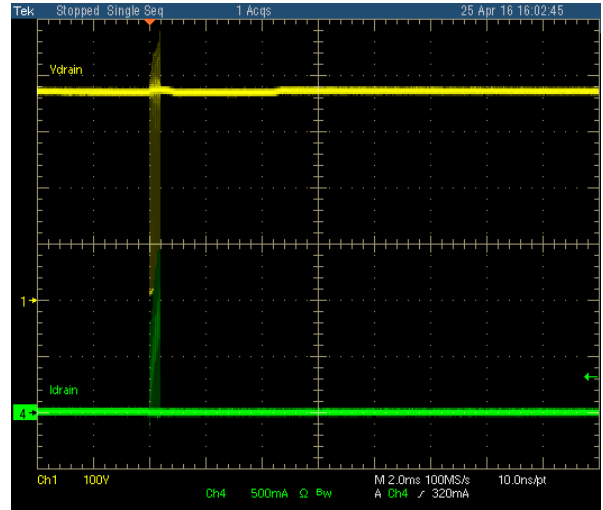


Figure 24. 265 Vac Short-circuit

OVER-CURRENT PROTECTION

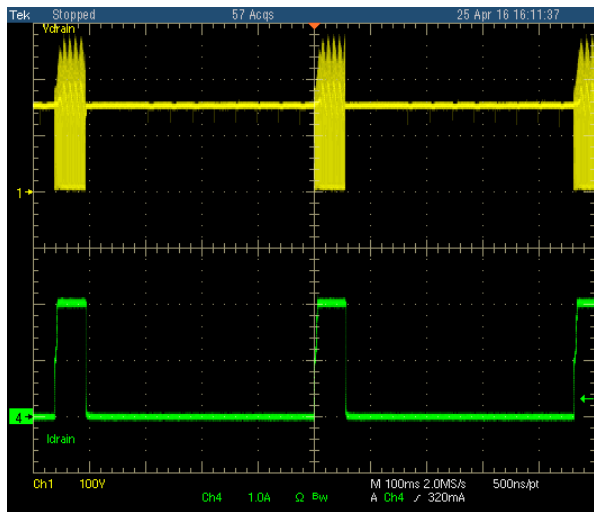


Figure 25. 110 Vac 2 A Load

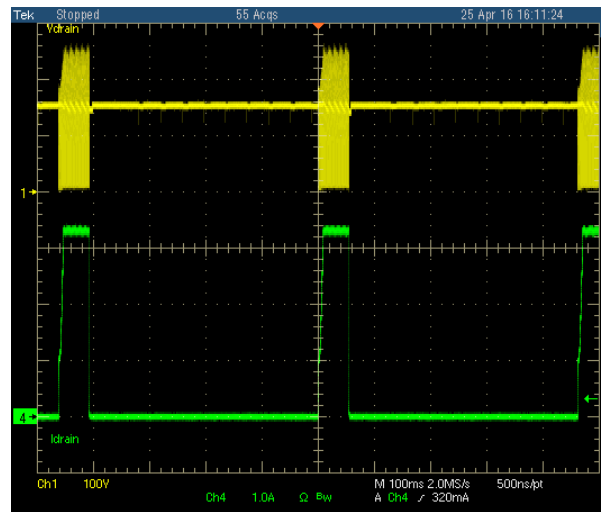


Figure 26. 110 Vac 3.5 A Load

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POWER OFF

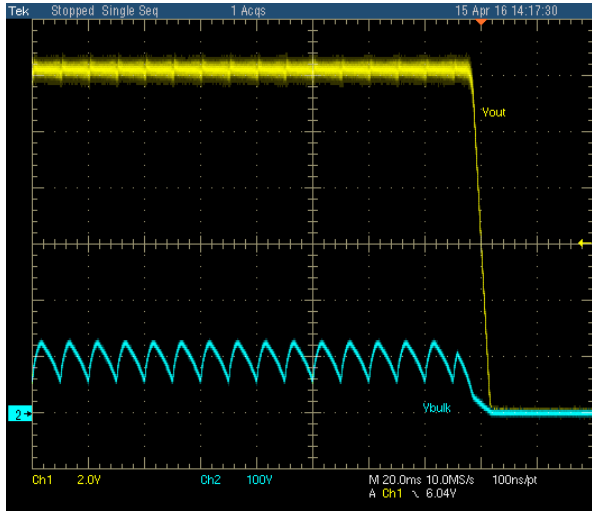


Figure 27. Input Voltage 90 Vac and 1.2 A Load

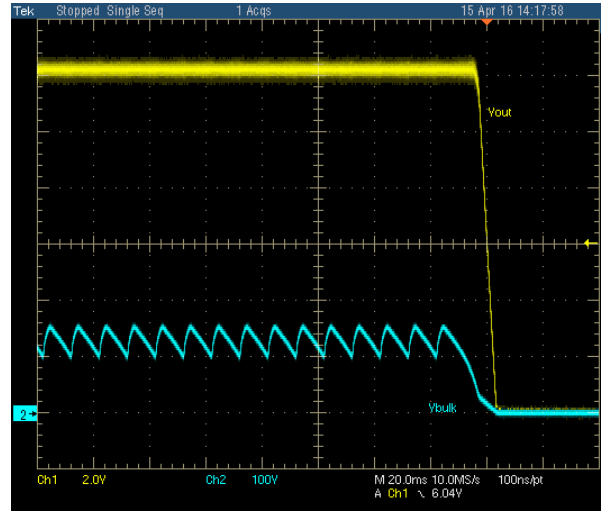


Figure 28. Input Voltage 110 Vac and 1.2 A Load

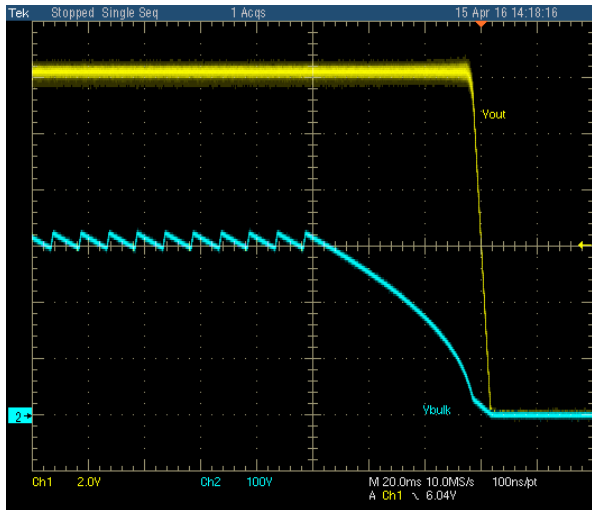


Figure 29. Input Voltage 230 Vac and 1.2 A Load

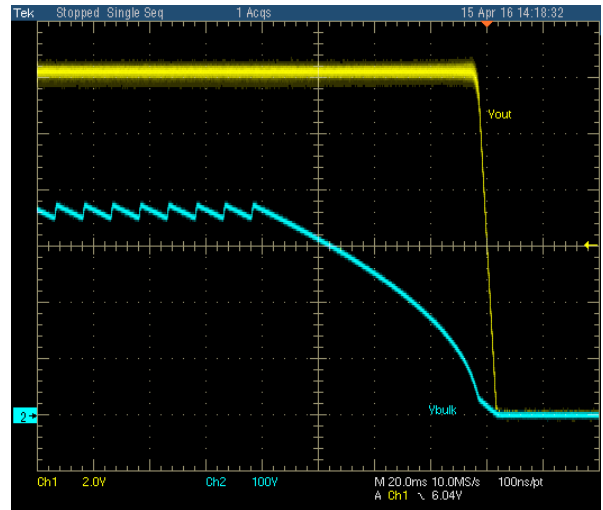


Figure 30. Input Voltage 265 Vac and 1.2 A Load

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BROWN-OUT

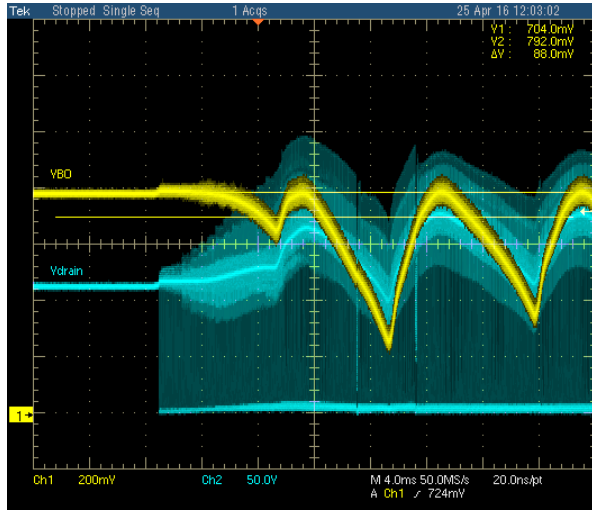


Figure 31. 82 Vac 1 A Load

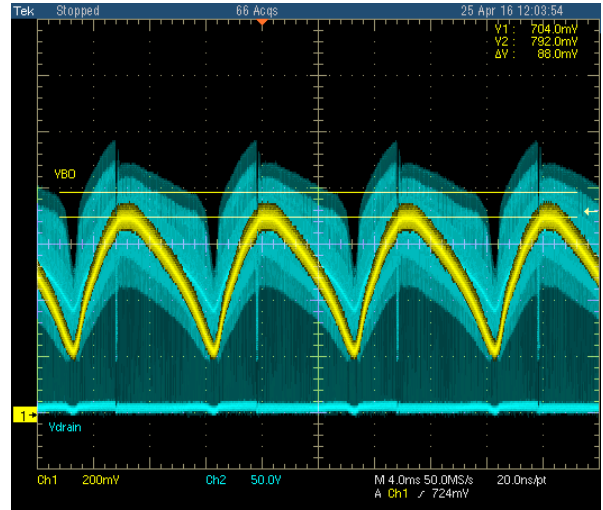


Figure 32. 73 Vac 1 A Load

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Table 3. BILL OF MATERIALS

| Designator | Qty | Description | Value | Tolerance | Footprint | Manufacturer | Manufacturer Part Number | Substitution Allowed |
|-----------------------|-----|------------------------|--------------------|-----------|--------------|--------------------|--------------------------|----------------------|
| C1, C12, C13 | 3 | CAPACITOR | 100 nF | 10% | 0805 | Kemet | C0805C104K5RACTU | Yes |
| C2 | 1 | ELECTROLYTIC CAPACITOR | 4.7 μ F / 50 V | 20% | THROUGH HOLE | Würth Elektronik | 860020672008 | Yes |
| C3, C16 | 2 | ELECTROLYTIC CAPACITOR | 10 μ F / 400 V | 20% | THROUGH HOLE | Würth Elektronik | 8.60021E+11 | Yes |
| C4 | 1 | ELECTROLYTIC CAPACITOR | 470 μ F / 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 μ F / 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 k Ω | 1% | THROUGH HOLE | | | Yes |
| R2 | 1 | RESISTOR | 20 Ω | 5% | THROUGH HOLE | | | Yes |
| R3, R4 | 2 | RESISTOR | 5.6 k Ω | 1% | 1206 | Vishay | CRCW12065K60FKEAHP | Yes |
| R5 | 1 | RESISTOR | 8.2 M Ω | 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 k Ω | 5% | 0805 | Vishay | CRCW08055K10JNEA | Yes |
| R9 | 1 | RESISTOR | 47 Ω | 1% | 1206 | Vishay | CRCW120647R0FKEA | Yes |
| R10, R13 | 2 | RESISTOR | 10 k Ω | 1% | 0805 | Vishay | CRCW080510K0FKEAHP | Yes |
| R11 | 1 | RESISTOR | 1 k Ω | 1% | 0805 | Vishay | CRCW08051K00FKTA | Yes |

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Table 3. BILL OF MATERIALS

| Designator | Qty | Description | Value | Tolerance | Footprint | Manufacturer | Manufacturer Part Number | Substitution 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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