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Design Note – DN05094/D

Power Supply with Ultra High Voltage Linear Regulator

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP785A	Consumer	85 Vac – 265 Vac	33 mW	Linear regulator	No

Other Specification

	Output 1	Output 2	Output 3	Output 4
Output Voltage	3.3 V	N/A	N/A	N/A
Ripple	N/A	N/A	N/A	N/A
Nominal Current	6.5 mA	N/A	N/A	N/A
Max Current	10 mA	N/A	N/A	N/A
Min Current	0	N/A	N/A	N/A

PFC (Yes/No)	No
Minimum Efficiency	N/A
Inrush Limiting / Fuse	No
Operating Temp. Range	-40 °C - 85°C
Cooling Method / Supply Orientation	N/A
Signal Level Control	N/A

Others	

Circuit Description

The NCP785A is a high−performance linear regulator, offering a very wide operating input voltage range of up to 450 V DC, with an output current of up to 10 mA. Ideal for high input voltage applications such as industrial and home metering, home appliances. The NCP785A family offers ±5% initial accuracy, extremely high−power supply rejection ratio and ultra−low quiescent current. The NCP785A is optimized for high−voltage line and load transients, making this part ideal for harsh environment applications.

The NCP785A is offered in fixed output voltage options 3.3 V, 5.0 V, 12 V and 15 V. SOT−89 package offers good thermal performance and help to minimize the solution size

This circuit is designed to operate as a non-isolated off-line power supply with minimum external parts producing a fixed voltage 3.3 V output from a standard wide range input voltage from 85 Vac up to 265 Vac. It provides a maximum output current of 10 mA. The output ripple is significantly reduced by a linear regulator topology which has very high PSRR (70dB typ.) over the frequency range of 50 Hz to 120 Hz. This low ripple output voltage is suitable for supplying various smart metering systems sensitive to power line pollution. The NCP785A is optimized for high-voltage line and load transients, making it ideal for harsh environment applications.

Schematic

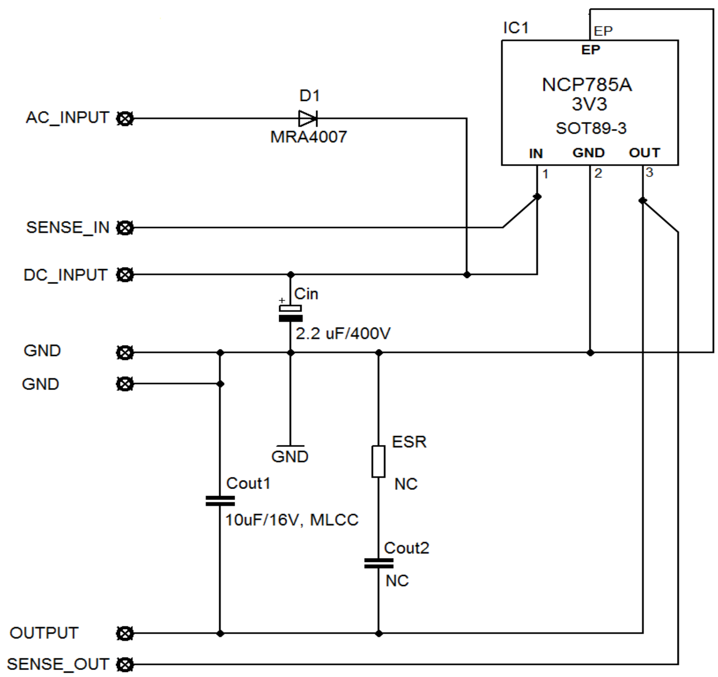
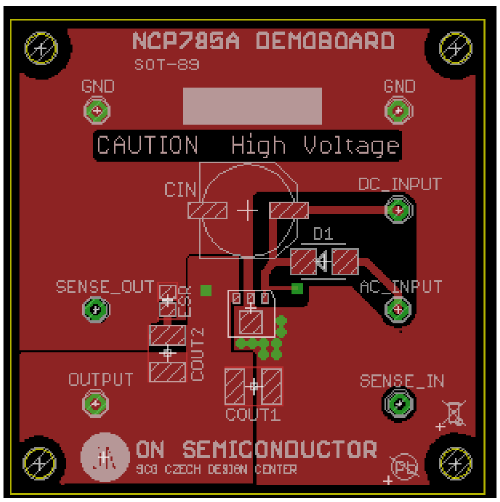


Figure 1. Schematic

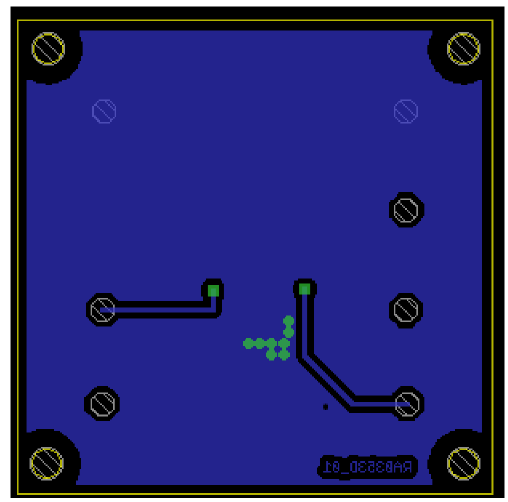
Figure 2. Demoboard

PCB Details

Double layer PCB 50 x 50 mm, 16 um Copper plated, FR4.



PCB Top Side
1891 mm^2 total Cu area, 1439 mm^2 GND Cu area



PCB Bottom Side
2063 mm^2 total Cu area, 2009 mm^2 GND Cu area

Figure 3. PCB layout and dimensions

Note:
All charts mentioned below are related to this PCB unless otherwise noted.

Performance Information

The following Figures show typical measured performance of the NCP785A in this evaluation board.

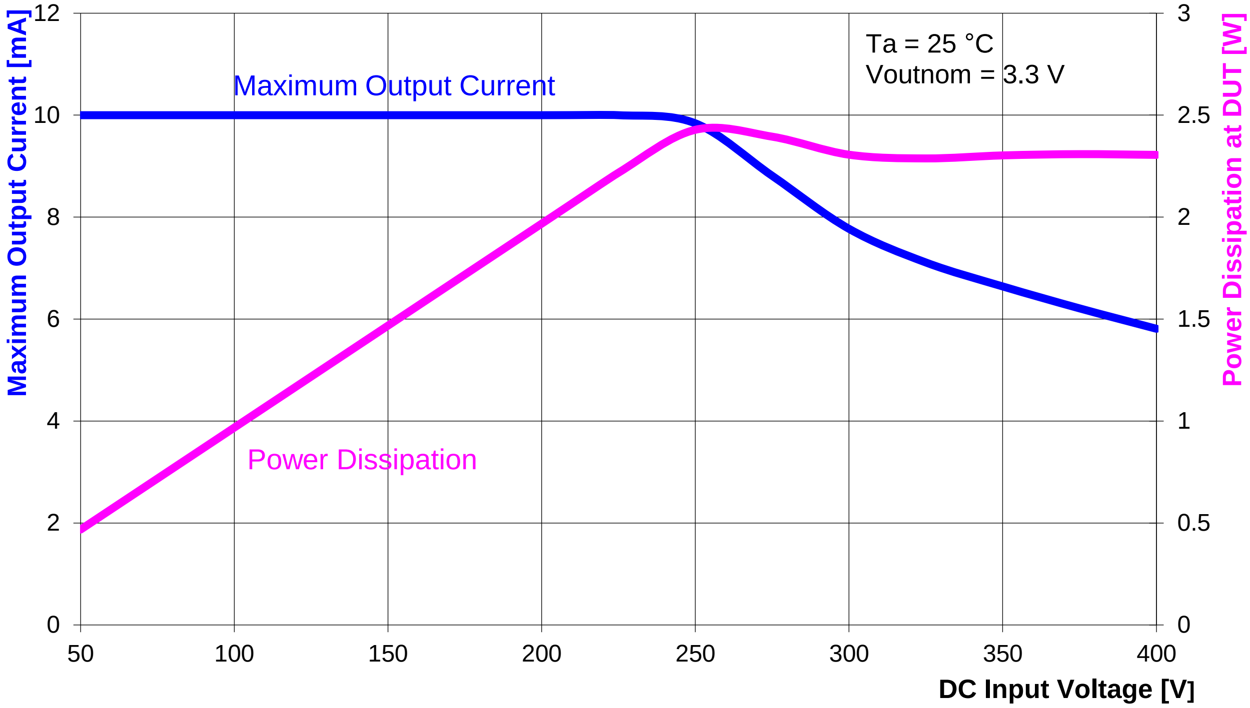


Figure 4. Maximum Output Current & Power Dissipation vs. Input Voltage

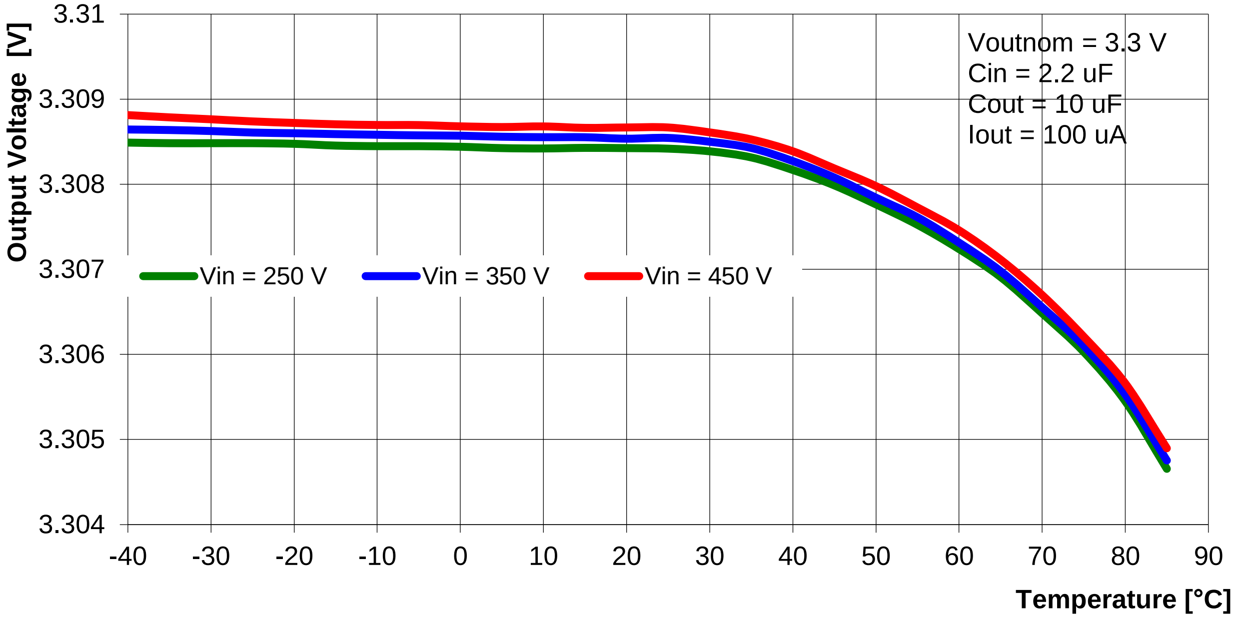


Figure 5. Output Voltage vs. Temperature

The chart in Figure 4. shows the maximum allowable output current at different input voltages for 3% output voltage falling. The power dissipation of 2.35 W limits the maximum output current of the reference design board. Figure 5 shows the thermal characteristics of the board where the output voltage decreases with increasing junction temperature. The oscillogram in Figure 6. shows typical output voltage behavior a few seconds after starting from room temperature with overloading. The overheating invokes the repetitive activation thermal shutdown protection and the output voltage is quickly switched on and off and the behavior looks like oscillation. Figure 7. shows the temperature map of the reference PCB. You can see how the top side copper helps spread the thermal load across the board and reduce the junction temperature of the part.

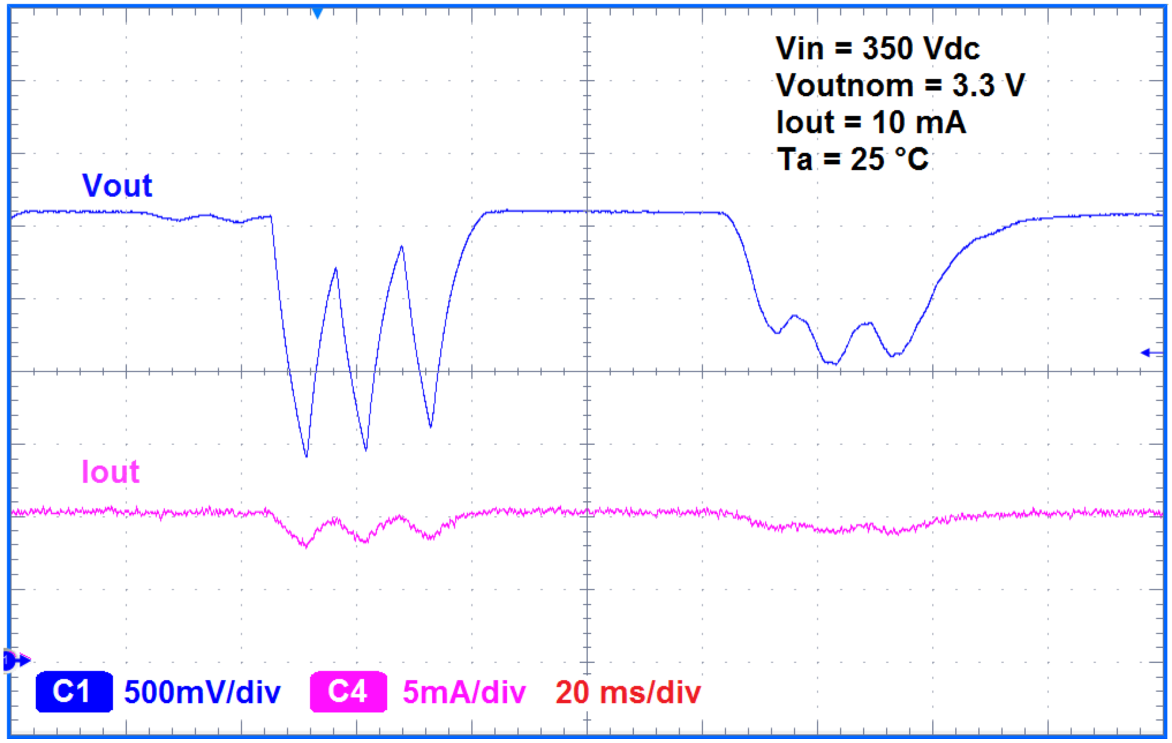


Figure 6. Thermal Shutdown Protection behavior

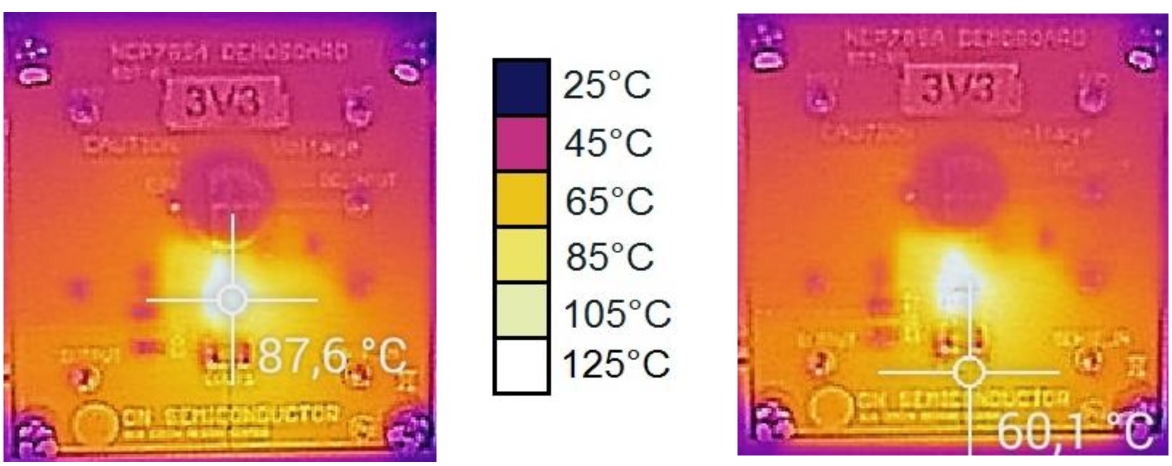


Figure 7. Thermal relief at PCB

Application Recommendations

Maximum allowed output current is strongly limited by power dissipation and proper cooling conditions. The Figure 8. shows the SOT89-3 package maximum power dissipation and Theta$_{JA}$ dependence on the cooper area for single side board, based on the basic thermal equation (eq.1).

$$P_{D(MAX)} = [T_{J(MAX)} - T_A] \,/\, \Theta_{JA} \qquad \text{(eq. 1)}$$

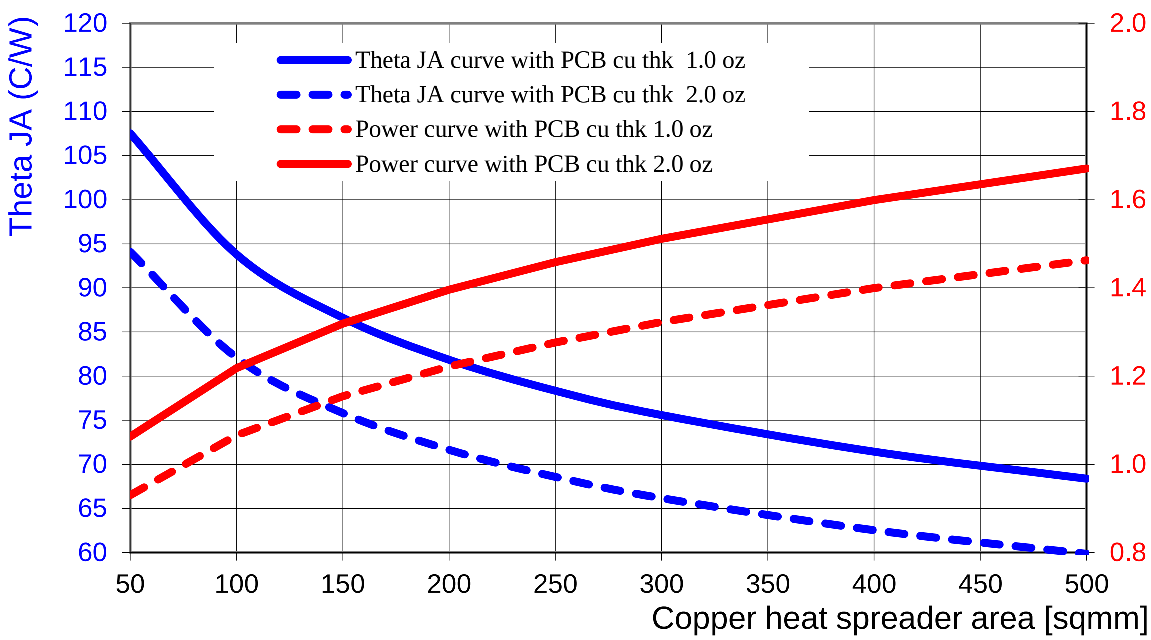


Figure 8. Maximum Power Dissipation & Theta$_{JA}$ vs. Copper Area

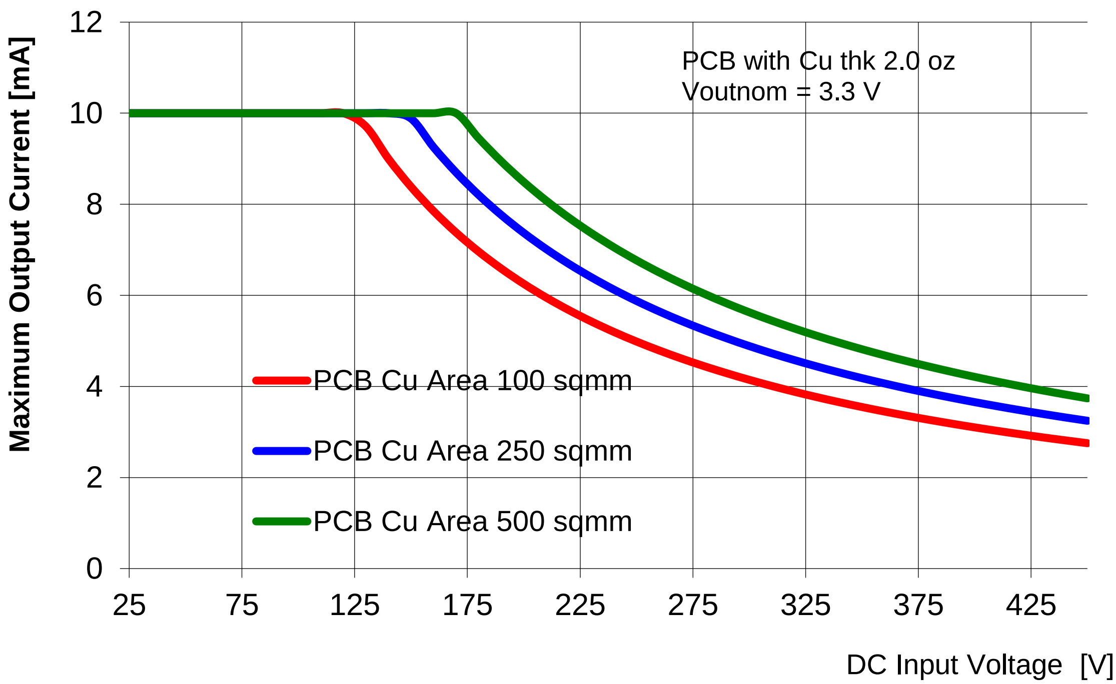


Figure 9. Maximum Power Dissipation vs. DC Input Voltage

In the real application it is very useful to check the maximum temperature on the case of the device by a thermal imaging camera. Figure 9. Shows calculated maximum output current dependence on the input voltage for three different Copper areas.

The power supply based on NCP785A linear regulator is ideal for microcontroller applications with very low consumption in stand-by or sleep mode for more than 90% of working time and for short time the device is able to deliver high current up to maximum capability limited by power dissipation for data transfer or another operations. The typical application example shown here is a wireless Bluetooth thermometer. Figure 10. shows the typical timing and consumption characteristics of this application. The average current is 249.7 uA and the total power consumption from 235 Vac main is below 83 mW. The average current is 249.7 uA and the total power consumption from 235Vac main is below 83 mW. The consumption of SMPS in this application is usually 2 – 5 times higher and 2 – 5 times more expensive. The 66 uA consumption at sleep time is given by sum of 10 uA quiescent current and 56 uA microcontroller consumption in sleep mode. In case the average current exceed 500 uA the efficiency of the power supply based on NCP785A device rapidly fall. The current peak 3.7 mA during radio communication could be increased up to 10 mA but there is necessary to keep the duration of this current as short as possible.

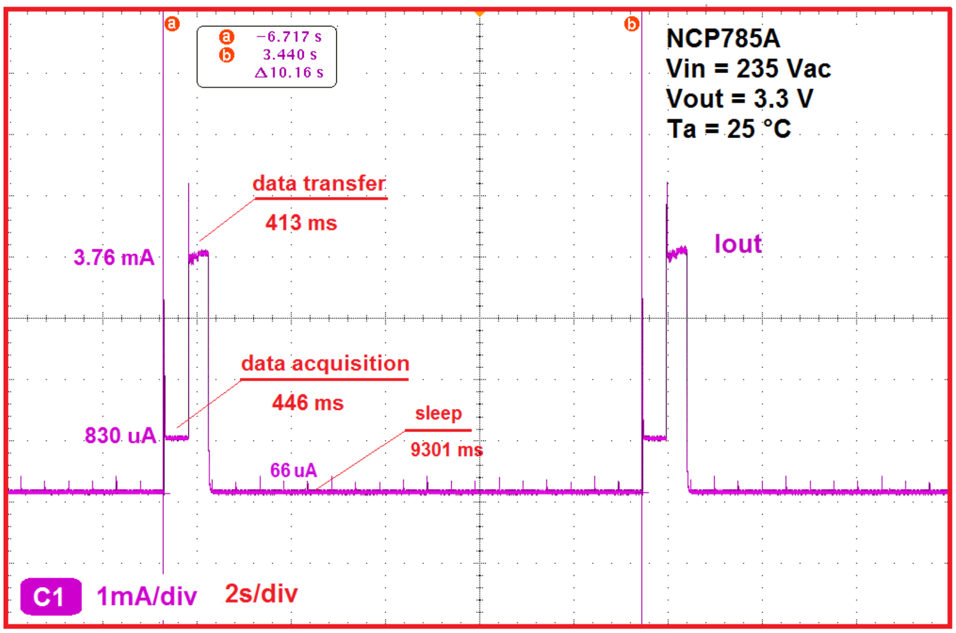


Figure 10. Timing and consumption characteristic

Input Capacitor Selection

The input capacitor Cin must maintain the regulator minimum input voltage 25 V at full load for AC voltage as low as 85 Vac.

For half wave rectification the recommended value is Cin=2.2uF, the rectifier waveforms are shown in Fig. 11. Lower capacitor values would limit the maximum output current; only 6.5 mA can be achieved with Cin=1uF. If the application can be floating, it is possible to use full wave rectifier which assures the minimum input voltage at NCP785A with input capacitor 1uF up to 10 mA load. The waveforms for this case are shown in the Figure 12.

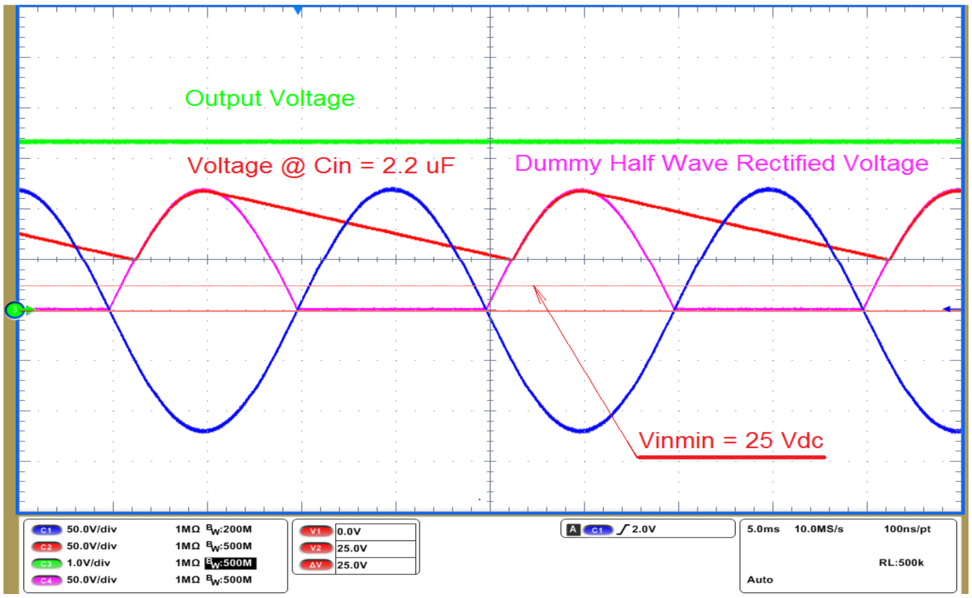


Figure 11. Output Voltage at Vin = 85 Vac, half-wave rectifier, Cin = 2.2 uF, Iload = 6.5 mA

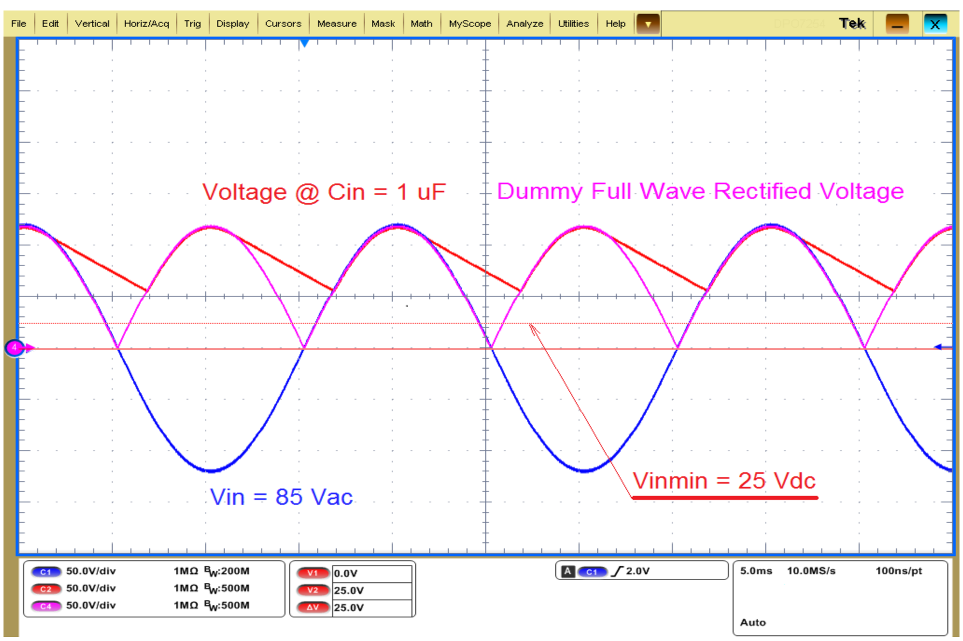


Figure 12. Output Voltage at Vin = 85 Vac, full-wave rectifier, Cin = 1 uF, Iload = 10 mA

Conclusion

The NCP785A linear regulator allows you to create a simple and cost effective non-isolated power supply.

This approach is a more efficient solution for low output power applications compared to a complex switching convertor or capacitive dropper.
Maximum output current is limited by power dissipation given by PCB layout and Input Voltage.

Bill of Materials

MM/DD/YYYY

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
CIN	1	Capacitor	2.2 uF	20%	SMD	Nichicon	ULH2W2R2MNL1GS	Yes	Yes
D1	1	Diode	MBR4007	N/A	SMD	ON Semiconductor	MBR4007T3G	Yes	Yes
COUT	1	Capacitor	10 uF	10%	1206	TDK	C3225X7R1C106M250AC	Yes	Yes
REG1	1	UHV Regulator	3.3 V	5%	SOT89-3	ON Semiconductor	NCP875AH330T1G	No	Yes

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