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Design Note – DN05113/D

Power Supply with NCP786A Ultra High Voltage Linear Regulator

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP786A	Consumer	85 V_{AC} – 265 V_{AC}	12.7 - 150 mW	Linear regulator	No

Other Specification

	Output 1	Output 2
Output Voltage	Adjustable (1.27 – 15) V	N/A
Ripple	N/A	N/A
Nominal Current	1.5 mA	N/A
Max Current	10 mA	N/A
Min Current	0	N/A

Others	

Circuit Description

The NCP786A is a high−performance linear regulator, offering a very wide operating input voltage range from 55V_{DC} 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 and IoT applications. The NCP786A family offers ±3% initial accuracy, extremely high−power supply rejection ratio and ultra−low quiescent current. The NCP786A is optimized for high−voltage line and load transients, making this part ideal for harsh environment applications.

The NCP786A has adjustable output voltage in range from 1.27 V up to 15V. The new DFN6 5x6 Pb-free package offers good thermal performance and helps to minimize the solution size. The package Clearance of 2.8 mm allows creating proper PCB with sufficient Creepage Distance.

This circuit is designed to operate as a non-isolated off-line power supply with minimum external parts producing an adjustable voltage from 1.27 V up to 15 V. The desired output voltage can be set by trimer R_{SET} or it is also possible to use additional R_{1B} and R_{2B} resistors for resistor divider.

The output ripple is significantly reduced by linear regulator topology with two regulators in series. The first one for high voltage conversion with high Power Dissipation creates an internal voltage line with a voltage about 23 V for supplying the second fine output regulator. The device has very high PSRR (90dB typ.) up to 100 kHz frequency due to this topology. This ripple-less output voltage is suitable for supplying applications with various sensors directly from AC plug in wide range from 85 V_{AC} up to 265 V_{AC}.

The ADJ pin typical consumption about 7.5 nA allows leaving out the impact of this current on output voltage at the current through resistor divider higher than 1 uA. In this case the output voltage is given by simplified equation 1:

$$Vout = V_{TH} \times \left(1 + \frac{R_2}{R_1}\right) \qquad \text{(eq.1)}$$

The ADJ pin Current does not almost depend on the Input Voltage as shows the Figure 1. And the dependence on the temperature is depicted in the Figure 2.

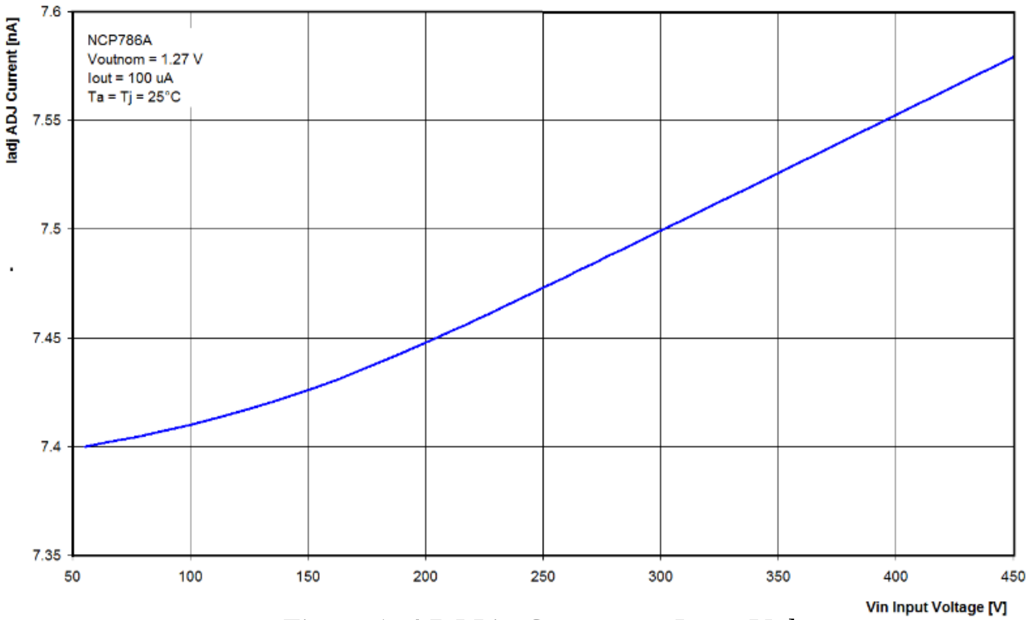


Figure 1. ADJ Pin Current vs. Input Voltage

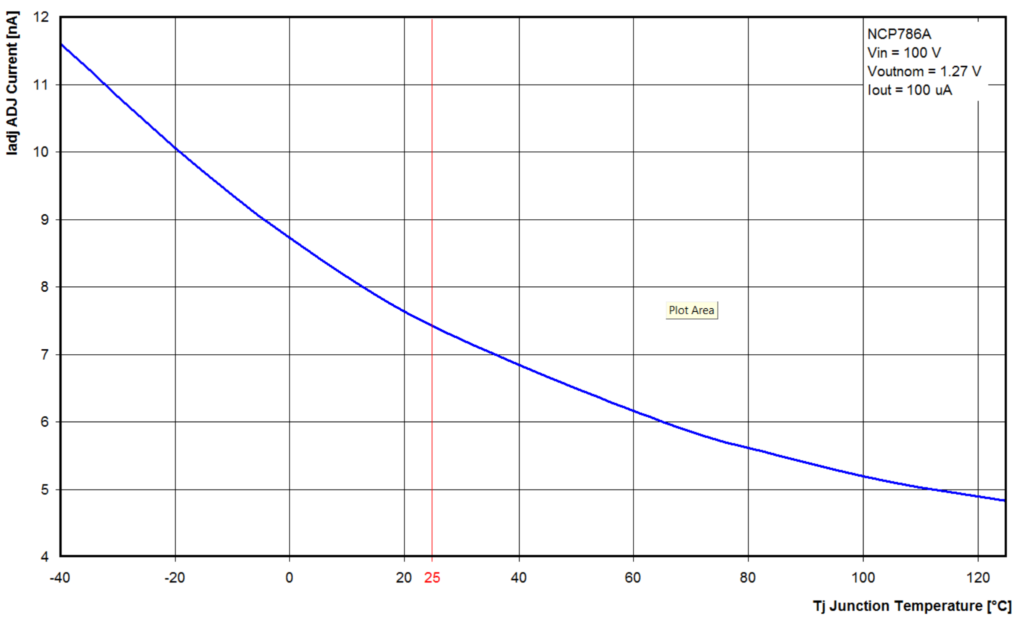


Figure 2. ADJ Pin Current vs. Temperature

Schematic

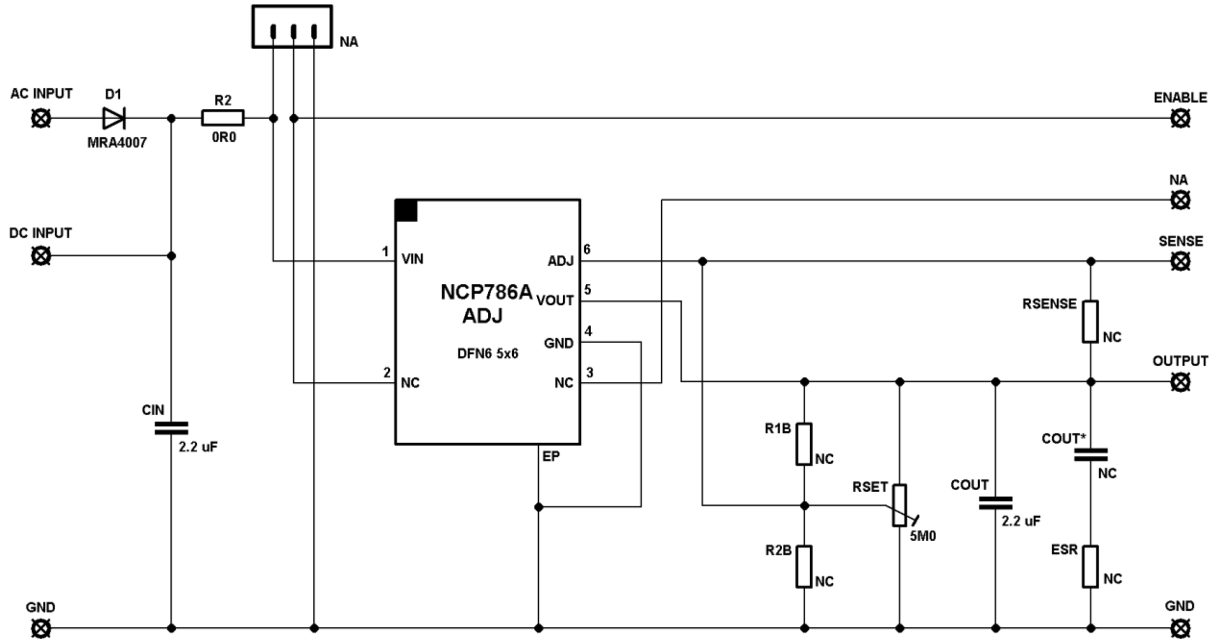


Figure 3. Schematic

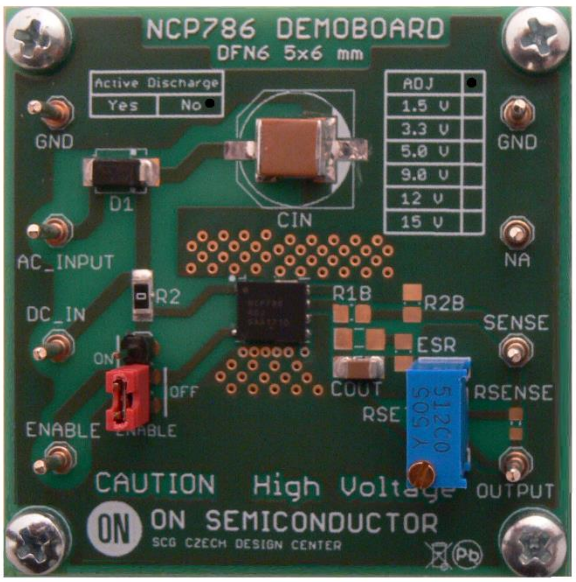
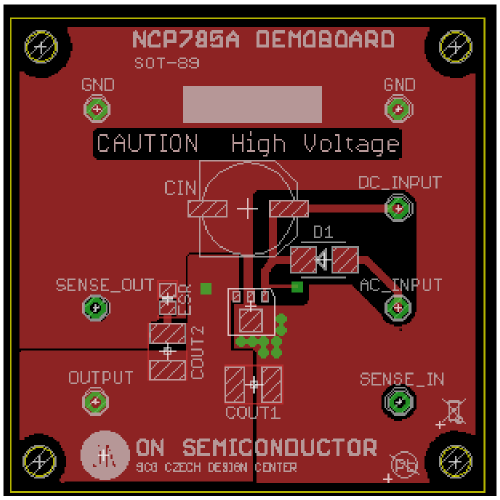


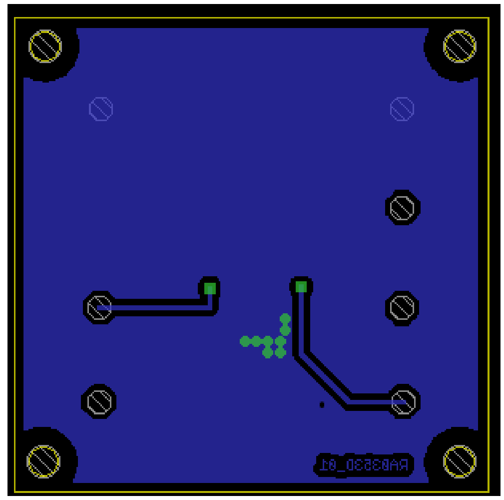
Figure 4. Demoboard

PCB Details

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



PCB Top Side
1891 mm² total Cu area, 1439 mm² GND Cu area



PCB Bottom Side
2063 mm² total Cu area, 2009 mm² GND Cu area

Figure 5. 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 NCP786A in this evaluation board.

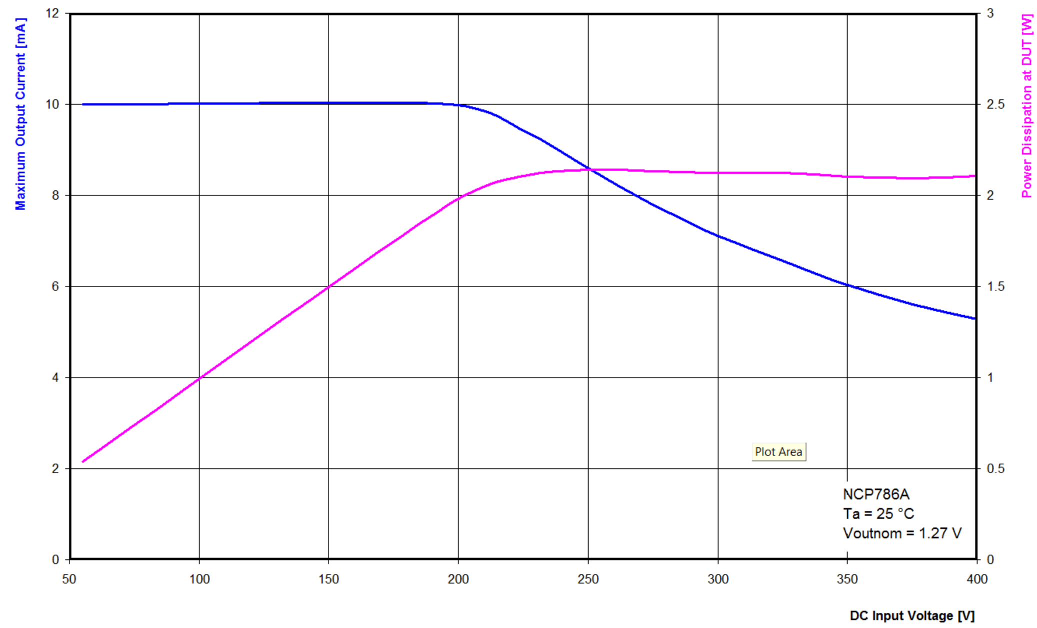


Figure 6. Maximum Output Current & Power Dissipation vs. Input Voltage

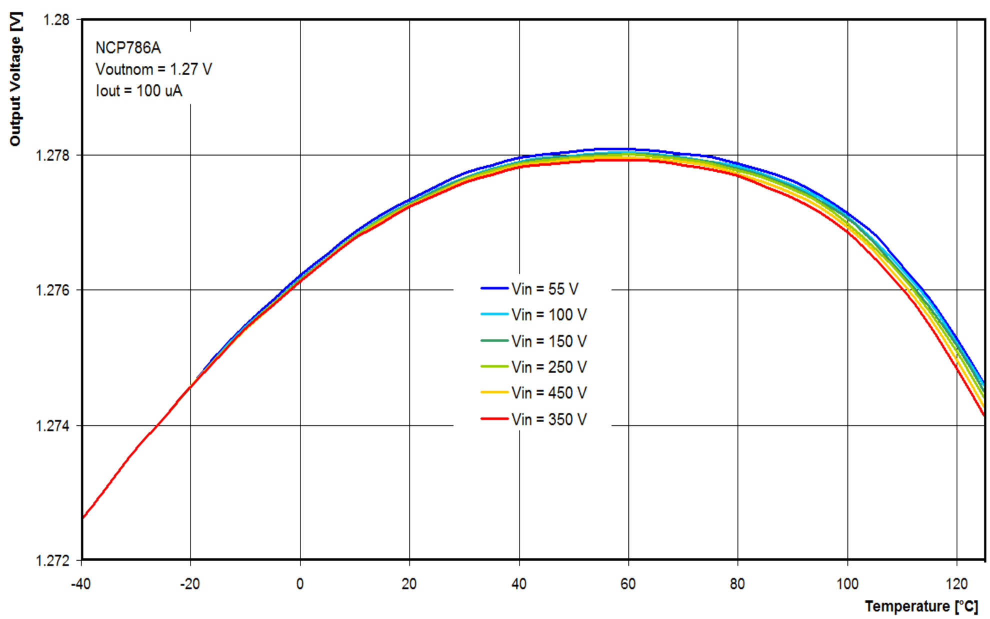


Figure 7. Output Voltage vs. Temperature

The chart in Figure 6. shows the maximum allowable output current at different input voltages for 3% output voltage falling. The power dissipation of 2.15 W limits the maximum output current of the reference design board. Figure 7. shows the thermal characteristics of the output voltage with increasing ambient temperature at low load 100 uA. Figure 8. shows the temperature map of the reference double side PCB for three different power dissipations at the device. You can see how the top side copper helps spread the thermal load across the board and reduce the junction temperature of the device.

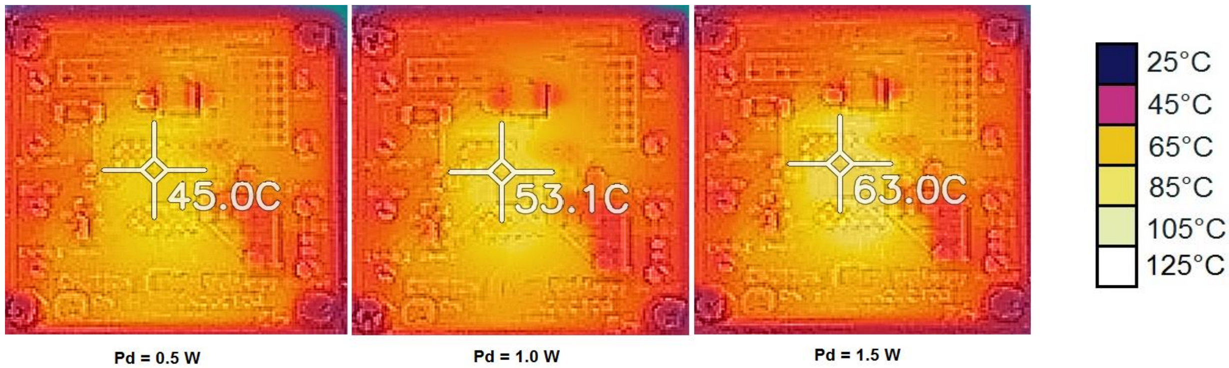


Figure 8. Thermal relief at PCB

Application Recommendations

Maximum allowed output current is strongly limited by power dissipation and proper cooling conditions. The Figure 9. shows the DFN6 5x6 package Maximum Power Dissipation and Theta$_{JA}$ dependence on the cooper area for single side board in accordance with JEDEC 51.3 standard and double side board in accordance with JEDEC 51.7 standard, based on the basic thermal equation (eq.2).

$$P_{D(MAX)} = \left[T_{J(MAX)} - T_A\right] / \Theta_{JA} \qquad \text{(eq. 2)}$$

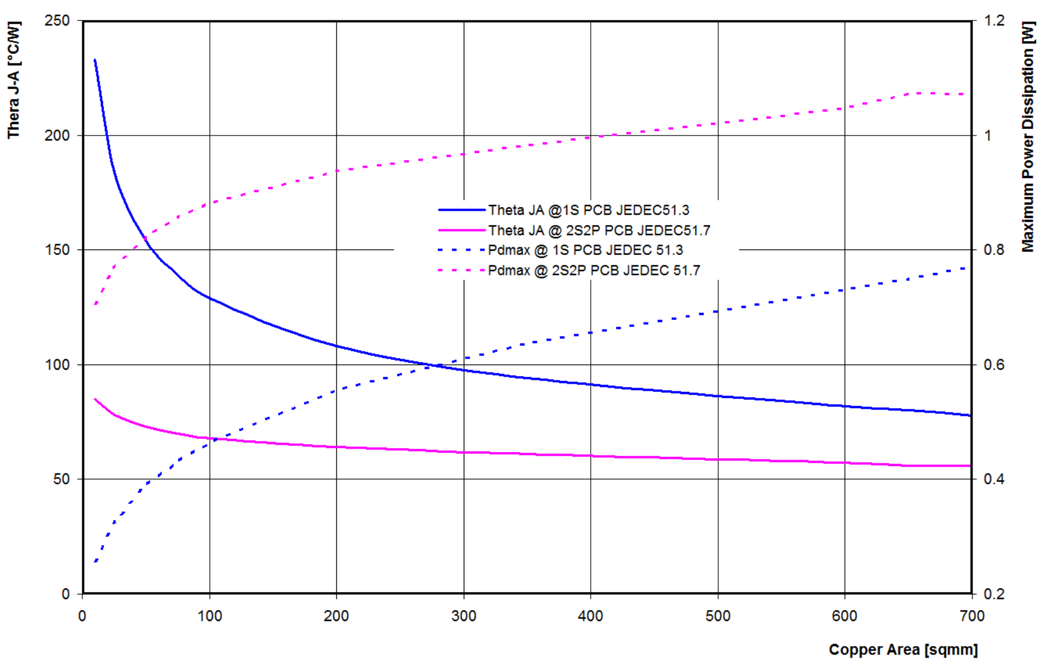


Figure 9. Maximum Power Dissipation and Theta$_{JA}$ vs. Copper Area

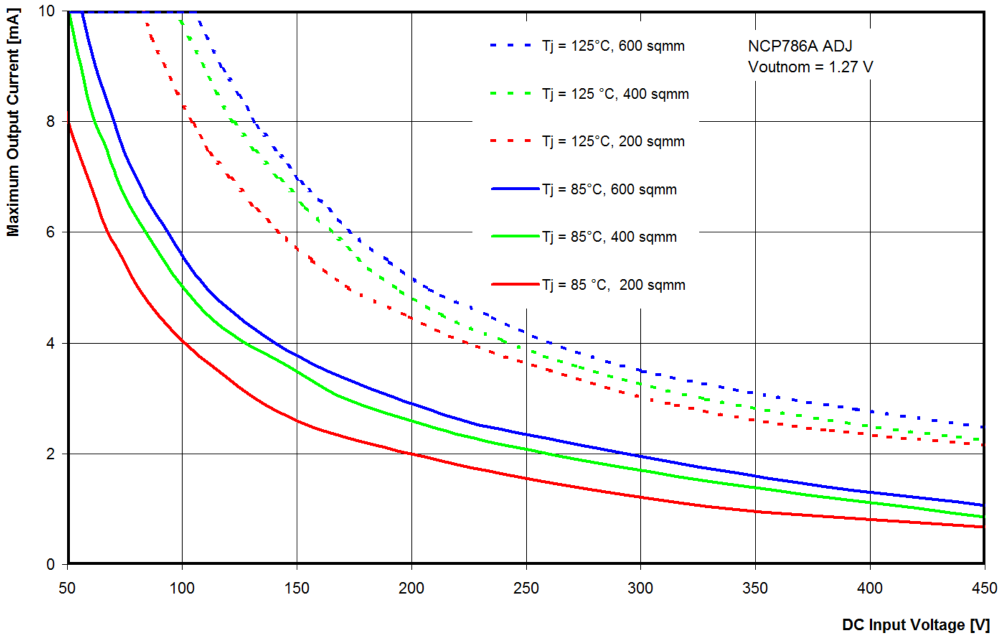


Figure 10. Maximum Power Dissipation vs. DC Input Voltage

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 10. shows the maximum output current dependence on the input voltage for three different Copper areas of single side board in steady state for junction temperatures 85°C and 125 °C.

The power supply based on NCP785A linear regulator is ideal for the 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 operation like sensors ripple less supplying.

Input Capacitor Selection

The input capacitor C_{IN} must maintain the regulator minimum DC input voltage 55 V at full load for AC voltage as low as 85 V_{AC}.

For half wave rectification the minimum recommended value is C_{IN} = 2.2 uF. Lower capacitor values would limit the maximum output current. If the application is floating, it is possible to use full wave rectifier which assures the required minimum DC input voltage at NCP786A with input capacitor as low as 1 uF up to 10 mA load.

Conclusion

The NCP786A 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 complex switching convertor or capacitive dropper. The wide range of Output voltage can fulfill most customer's applications.

Maximum output current is limited by power dissipation given by PCB layout and Input Voltage

Bill of Materials

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
CIN	1	Capacitor	2.2 uF	20%	SMD	TDK	C5750X6S2W2 25M250KA	Yes	Yes
D1	1	Diode	MBR 4007	N/A	SMD	ON Semiconductor	MBR4007T3G	Yes	Yes
COUT	1	Capacitor	2.2 uF	10%	1206	TDK	C3225X7R1C2 25M250AC	Yes	Yes
R2	1	Resistor	0R0	N/A	1206	MULTICOMP	MCMR12X000 PTL	Yes	Yes
RSET	1	Trimming Potentiometer	5M0	1%	Through hole	Bourns	3296Y-1-505LF	Yes	Yes
REG1	1	UHV Regulator	ADJ	3%	DFN 6 5x6	ON Semiconductor	NCP786AST ADJTBG	No	Yes

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