ON Semiconductor

Design Note – DN05103/D

Power Supply with High Voltage Linear Regulator

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP781	Industrial	15 Vdc – 150 Vdc	500 mW	Linear regulator	No

Other Specification

	Output 1	Output 2	Output 3	Output 4
Output Voltage	5 V	N/A	N/A	N/A
Ripple	N/A	N/A	N/A	N/A
Nominal Current	Limited by SOA	N/A	N/A	N/A
Max Current	100 mA	N/A	N/A	N/A
Min Current	0	N/A	N/A	N/A

Minimum Efficiency	N/A
Inrush Limiting / Fuse	No
Operating Temp. Range	-40 °C - 125°C
Cooling Method / Supply Orientation	N/A
Signal Level Control	N/A

Circuit Description

The NCP781 is a high−performance linear regulator, offering a very wide operating input voltage range of up to 150 V DC, with an output current of up to 100 mA. Ideal for high input voltage applications such as industrial measure equipment and sensors, telecommunication and home appliances. The NCP781 family offers 2.5% initial accuracy, extremely high−power supply rejection ratio and low quiescent current. The NCP781 is optimized for high−voltage line and load transients, making this part ideal for harsh environment applications sensitive to power line pollution.

The NCP781 is offered in fixed output voltage options 3.3 V, 5.0 V, 12 V and 15 V and also adjustable in range from 1.23 V up to 15 V. The DFN6 3.3 x 3.3, 0.65P package offers good thermal performance and help to minimize the solution size. Even though the dimensions of this package are reasonable small the power dissipation and especially the clearance of higher than 1.1 mm allows one to create an applications in many branches. The mentioned clearance fulfills requirements for safe PCB design in accordance with IPC 2221 standard.

This device placed on below mentioned PCB is designed to operate as a high voltage DC regulator with minimum external parts producing a fixed voltage 5.0 V output from a DC input voltage from 15 V up to 150 V. It provides a maximum output current of 100 mA respect to SOA. The output ripple is significantly reduced by a linear regulator topology with two regulators in series. The first one for high voltage conversion with high power dissipation creates an internal voltage line for the second fine output regulator. The Figure 2. shows a simplified block diagram of the regulator. The device has very high PSRR (84dB typ.) up to the frequency 100 kHz due to this topology. The Enable feature allows putting the device into standby state with consumption below 1uA. The Enable pin could be connected directly to Input voltage line.

Schematic

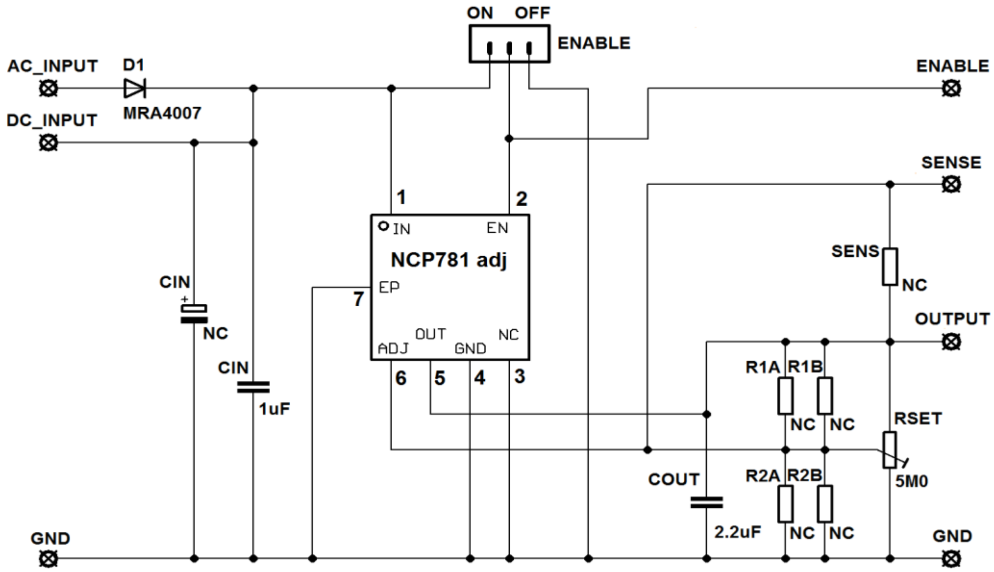


Figure 1. Schematic

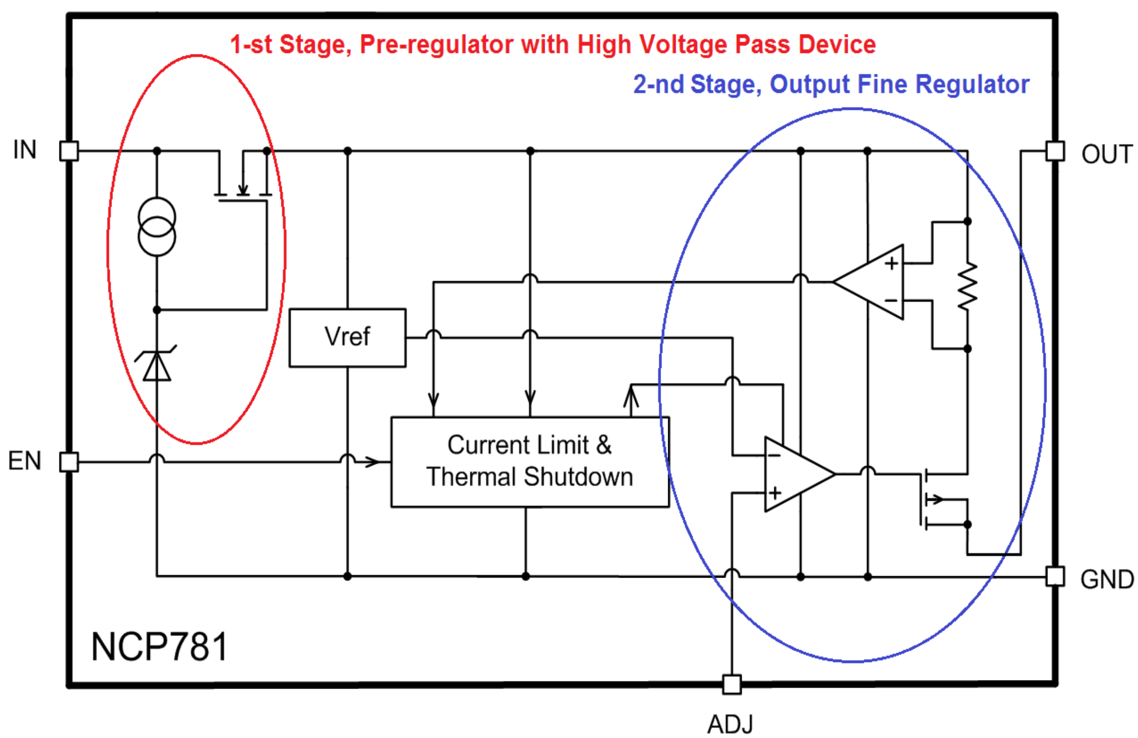


Figure 2. Simplified block diagram

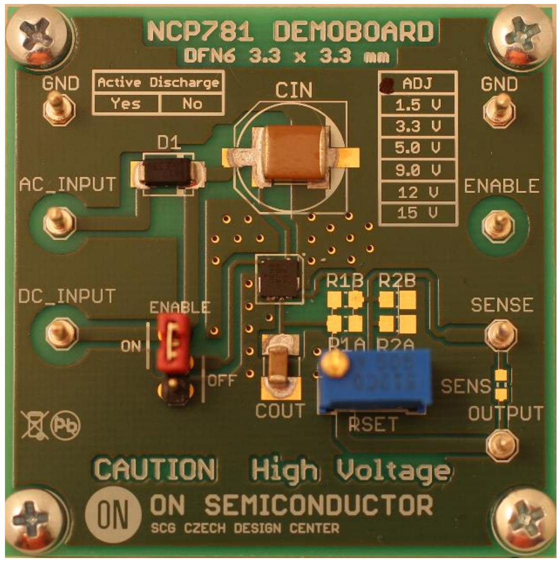
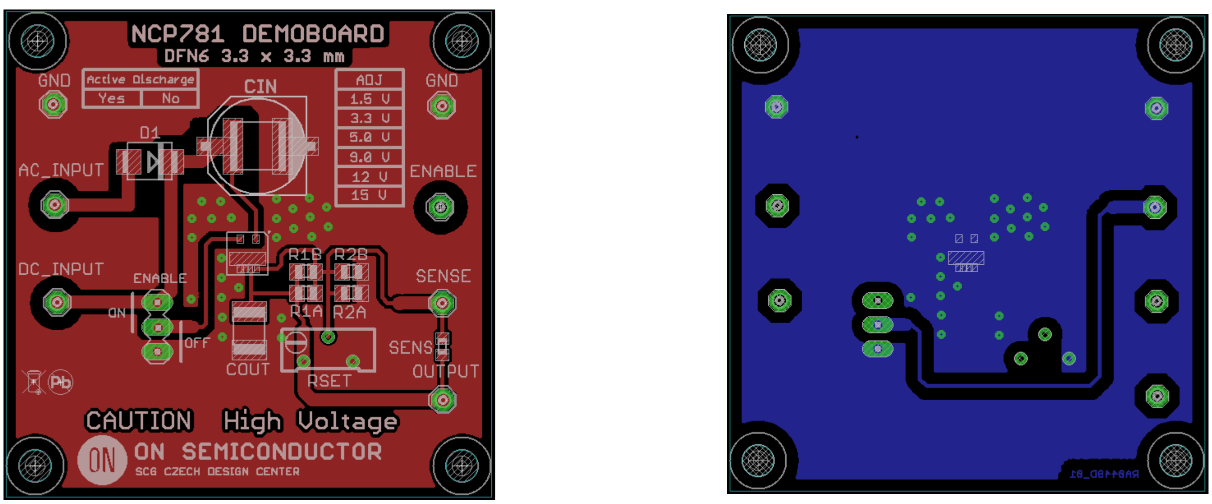


Figure 3. Demoboard

PCB Details

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



PCB Top Side
1771 mm² total Cu area, 1552 mm² GND Cu area

PCB Bottom Side
1874 mm² total Cu area, 1815 mm² GND Cu area

Figure 4. 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 NCP781 in the evaluation board mentioned above.

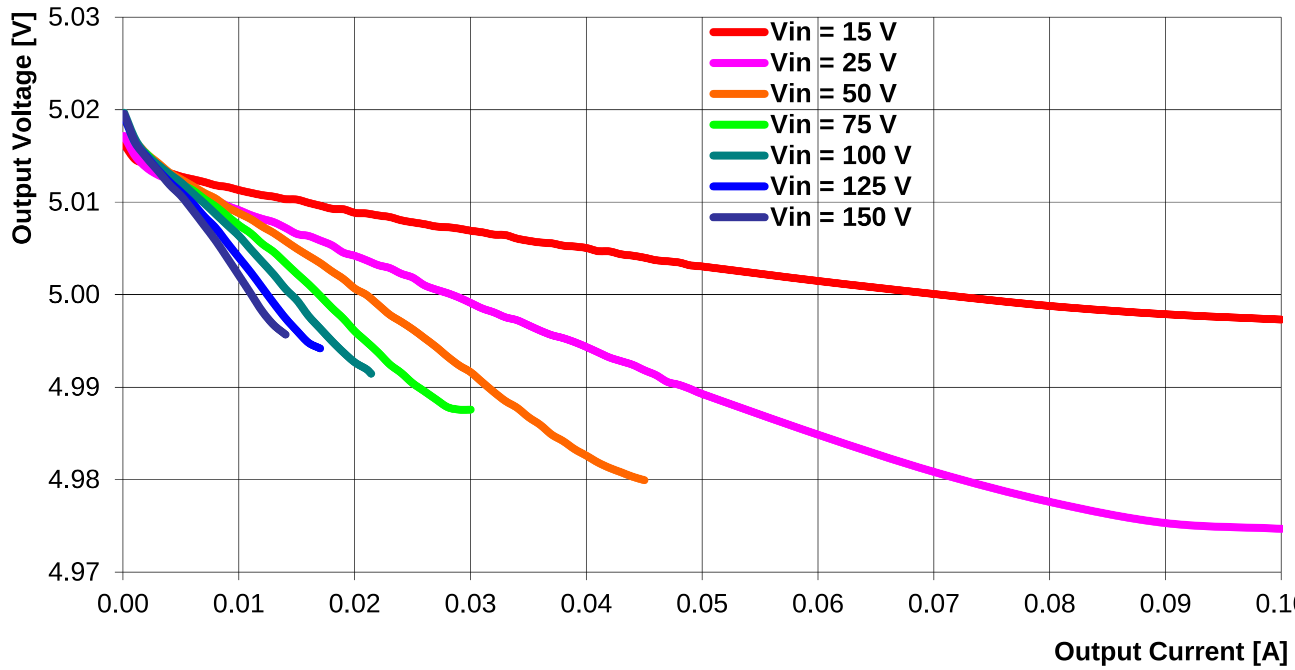


Figure 5. Output Voltage vs. Output Current

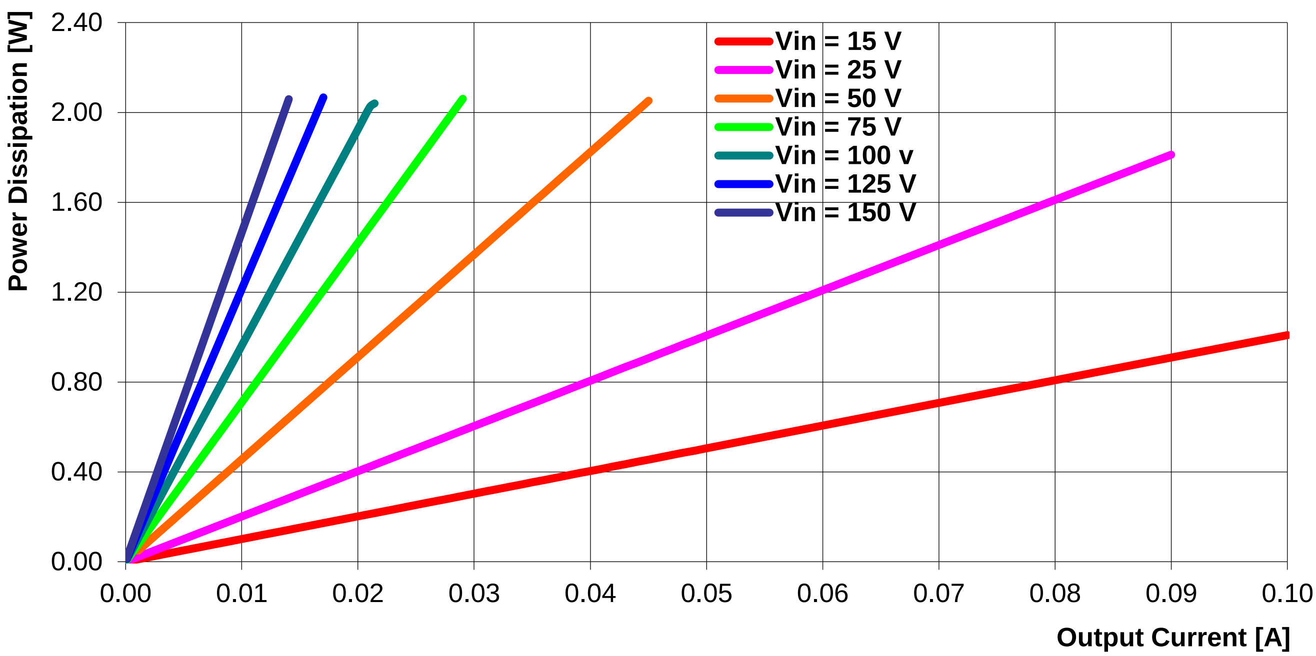


Figure 6. Power Dissipation vs. Output Current

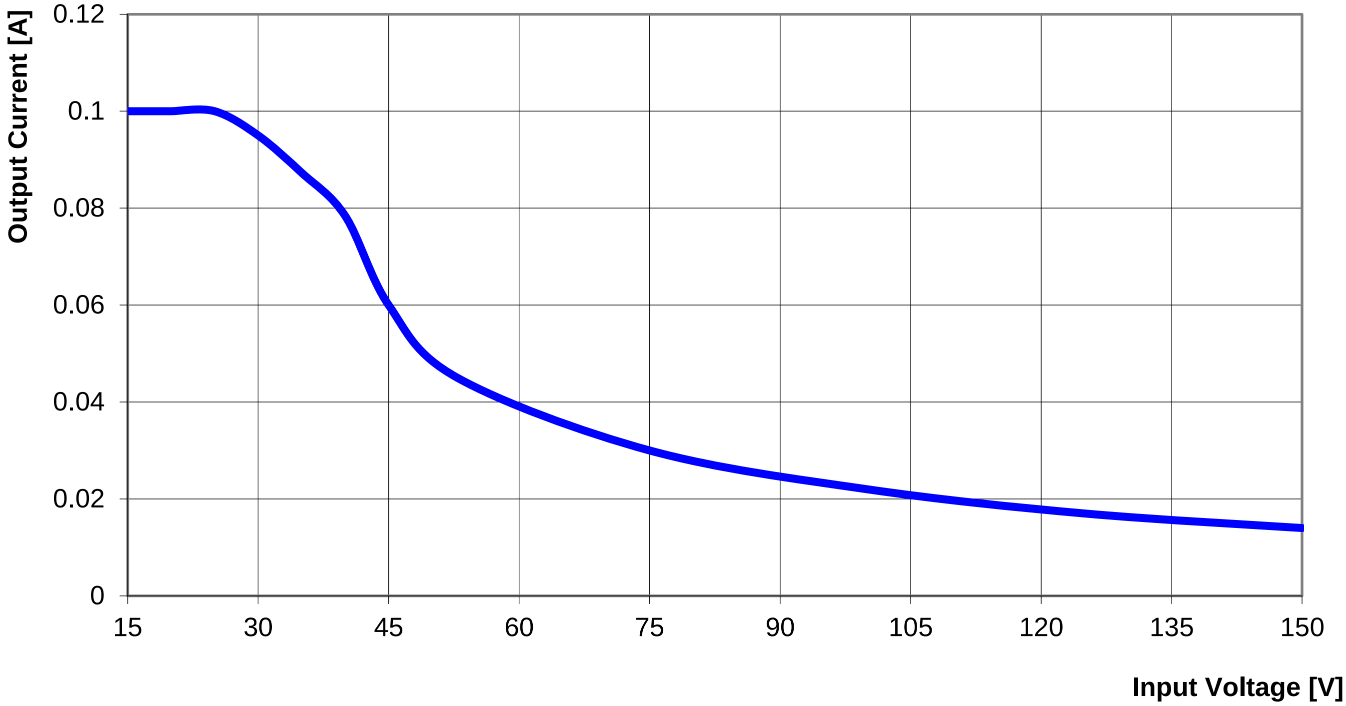


Figure 7. Safe Operating Area

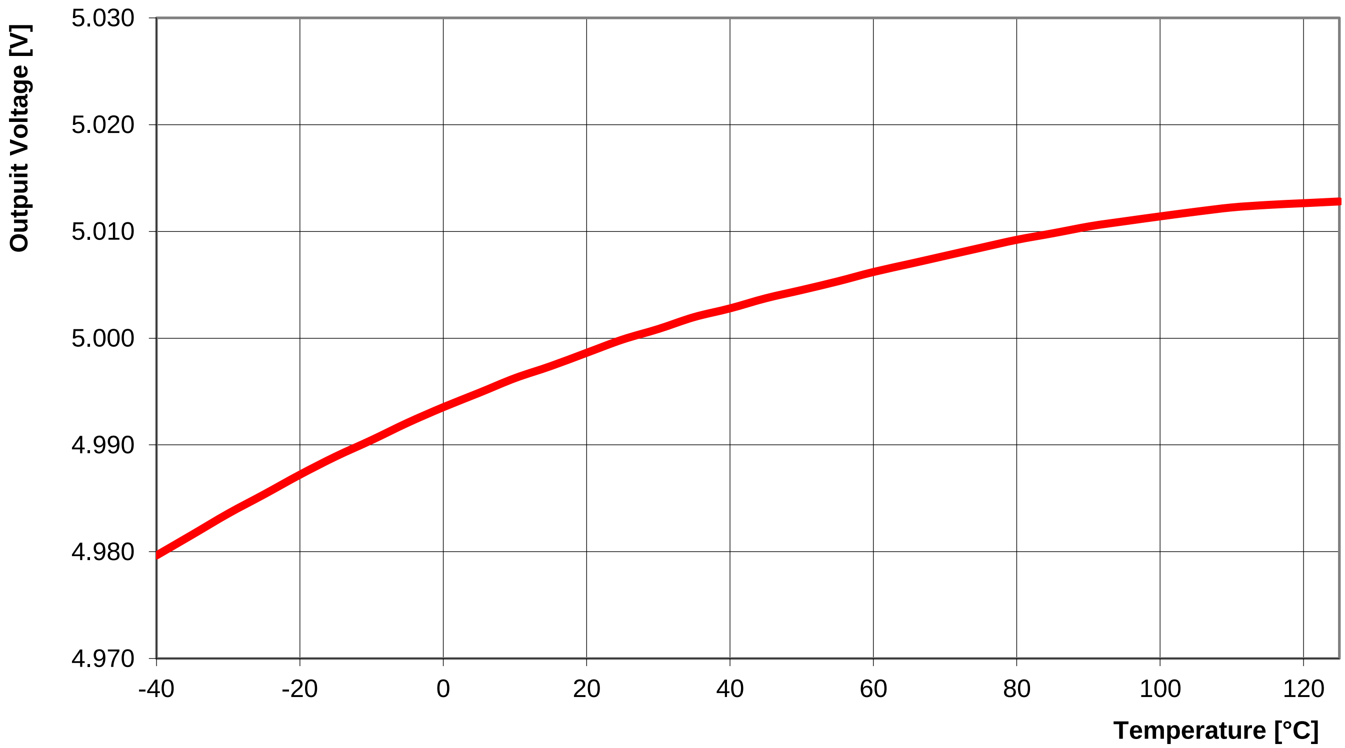
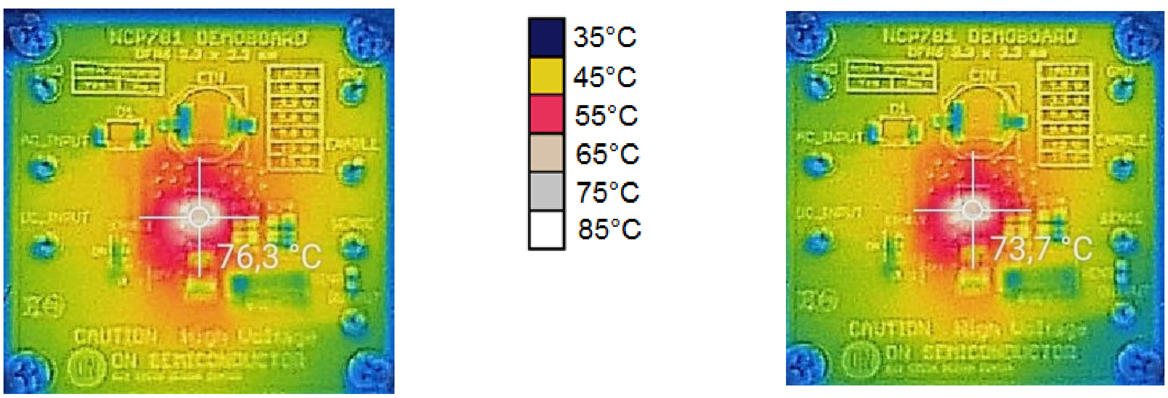


Figure 8. Output Voltage vs. Temperature @ Vin = (15 – 150) V, Iout = 100 uA

The chart in Figure 5. shows the maximum allowable output current at different input voltages for 3% output voltage falling. The power dissipation below 2.1 W limits the maximum output current of the reference design board with minimum impact of temperature. The Figure 6. shows the Power Dissipation characteristics for the measurements described in the Figure 4. The SOA curve depicted in the Figure 7. describes the internal current limitation at higher voltages. In this case the output current was limited by junction temperature Tj =125 °C in steady state conditions. The output current above 100 mA at the low input voltages was not applied. The curve in Figure 8. shows typical thermal characteristics for Output Voltage at small 100 uA load in full Input Voltage range from 15V up to 150 V. The Figure 9. 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. In the picture on the left side the heat is generated mostly by low voltage stage with small occulated die area and the picture on the right side shows the thermal relief for the same Power dissipation but the heat is produced at the high voltage stage with significantly higher die area. The internal thermal sensor acts for both stages and fully protect the device at all operating conditions by thermal shutdown. In the real application it is very useful to check the maximum temperature on the case of the device by a thermal imaging camera.



Vin = 25 V, Pd = 1 W,

Vin = 150 V Pd = 1W .

Figure 9. Thermal relief at PCB

Application Recommendations:

Maximum allowed output current is strongly limited by power dissipation and proper cooling conditions. The

Figure 10. shows the DFN6 3.3 x 3.3 package maximum Power Dissipation and Theta$_{JA}$ dependence on the cooper area for single and double side board, based on the basic thermal equation (eq.1).

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

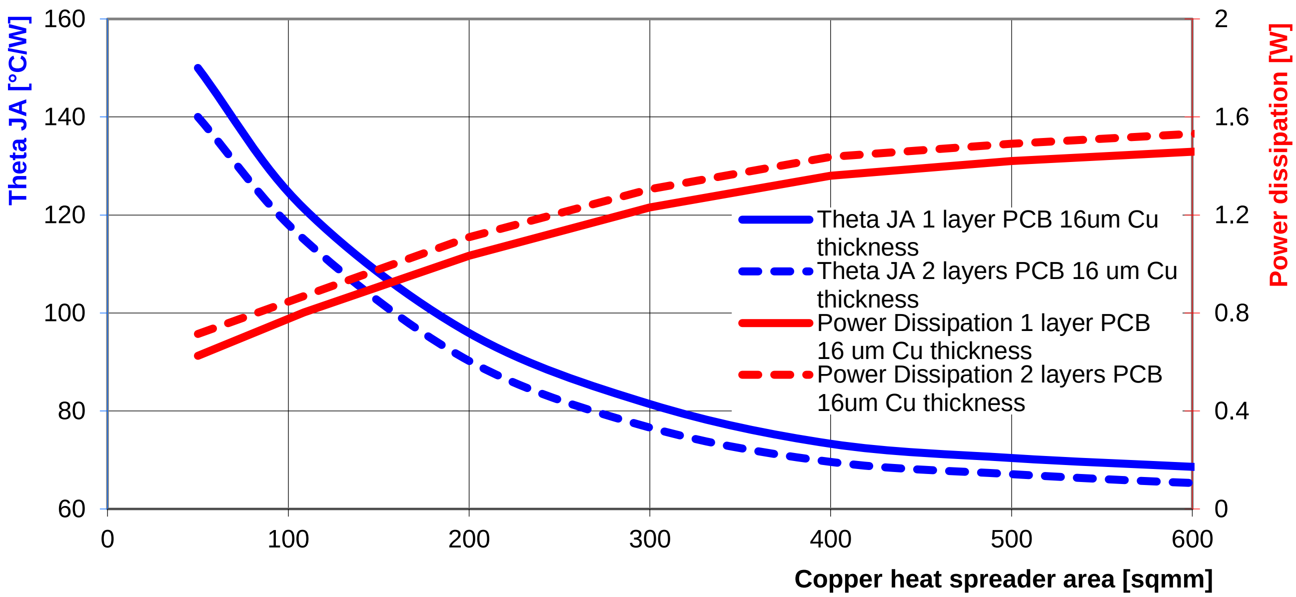


Figure 10. Maximum Power Dissipation & Theta$_{JA}$ vs. Copper Area

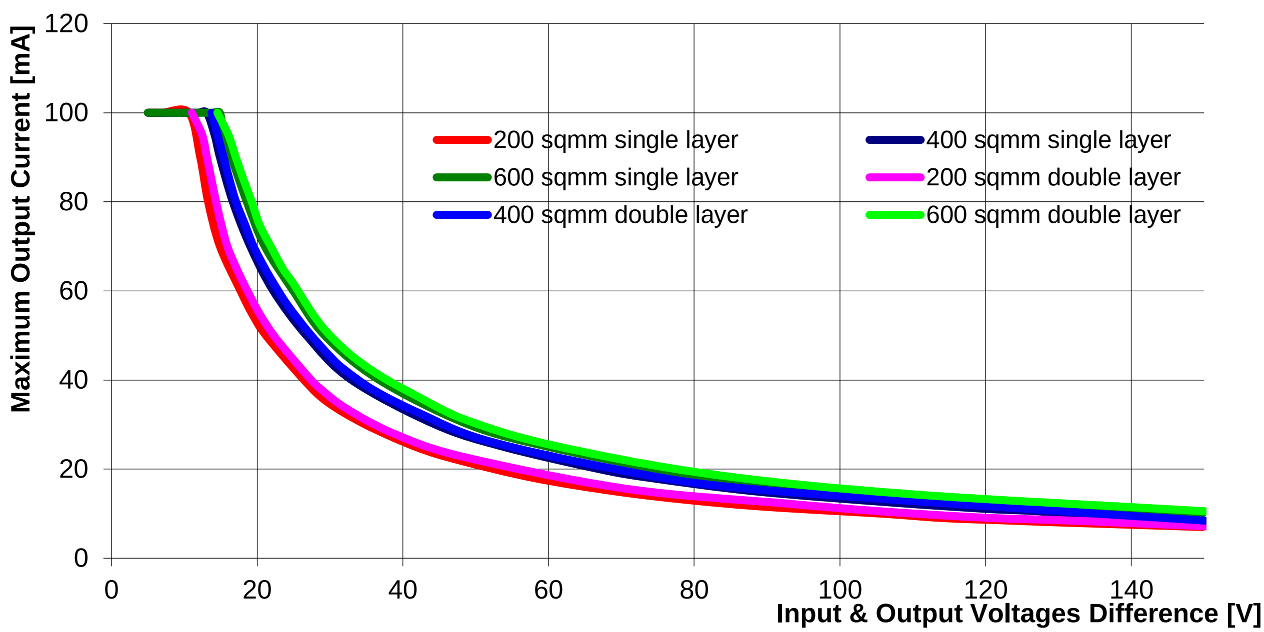


Figure 11. Maximum Output Current vs. Input and Output Voltages difference

The last chart in the Figure 11. shows the maximum Output Current versus Input and Output Voltages difference at 200 sqmm, 400 sqmm and 600 sqmm single and double layer PCBs for free air cooling with natural air flow at the ambient temperature Ta = 25°C and Junction temperature Tj = 125°C. This is steady state behavior description. The measurements were taken on FR4 single and double layer PCBs with copper thicknes 16 um.

Conclusion

The NCP781 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. 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	1 uF	20%	SMD	Murata	GRM55DR72D105KW1L	Yes	Yes
D1	1	Diode	MBR4007	N/A	SMD	ON Semiconductor	MBR4007T3G	Yes	Yes
COUT	1	Capacitor	2.2 uF	10%	1206	Kemet	C1206C225K5RACTU	Yes	Yes
RSET	1	Adjustable Resistor	5M0	10%	Through Hole	Bourns	3296Y-1-505LF	Yes	Yes
REG1	1	UHV Regulator	Adj.	2.5%	DFN6	ON Semiconductor	NCP781BMNADJTAG	No	Yes

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