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How to Prevent Thermal Issues with High Output Current DC to DC Converters in Portable Applications

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APPLICATION NOTE

Introduction

As power demand in portable designs is more and more important, designers must optimize full system efficiency in order to save battery life and reduce power dissipation. Energy losses study allows knowing thermal stakes. Due to integration and miniaturization, junction temperature can increase significantly which could lead to bad application behaviors or in worst case to reduce components reliability.

Stand alones DC to DC converters are commonly used in order to increase system efficiency. This document will focus high output current switching regulators to demonstrate that basic thermal skills are sufficient to avoid any thermal issue. Tips and tricks to improve thermal dissipation will be tackled in this document.

Power Dissipation Evaluation

Efficiency measurements directly lead to electrical power dissipation results. It can be easily calculated on switching converters using Equation 1.

$$P_{DIP} = V_{OUT} \times I_{OUT}\left(\frac{1}{Eff} - 1\right) \qquad \text{(eq. 1)}$$

Worst environment cases allow designers to determine the maximum power dissipation point. Following table could help to determine worst cases of each parameter to get the worst efficiency point.

Table 1. WORST ENVIRONMENT CASES FOR DC-DC EFFICIENCY

	Switching Converters
Ambient Temperature	High
Input Voltage	Minimum
Output Current	Maximum

NCP1529 – 1 A DC to DC converter – will be used to illustrate following application example which consists to drive a core at 1.2 V; power demand will not exceed 900 mA.

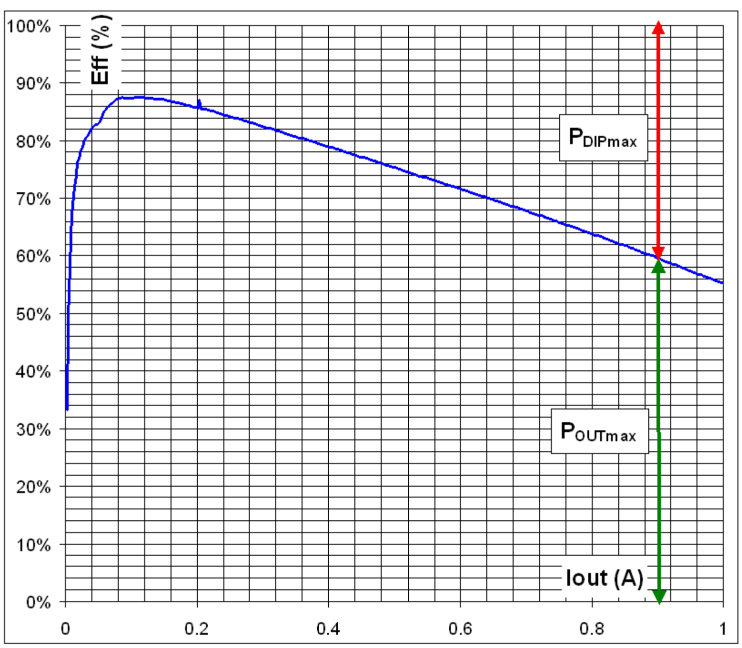

Figure 1. NCP1529 Efficiency at V_{IN} = 2.7 V, V_{OUT} = 1.2 V, Temp = 85°C

The worst case power dissipation point – according to Table 1, Figure 1 and using Equation 1 – gives:

$$P_{DIPmax} = V_{OUT} \times I_{OUT}\left(\frac{1}{Eff} - 1\right) = 1.2 \times 0.9 \times \left(\frac{1}{60\%} - 1\right) = 720\ mW \quad \text{(eq. 2)}$$

Next section will describe how designers can optimize their application using NCP1529 to dissipate 720 mW.

Convert Power to Thermal

The capacity of transferring a large amount of heat from silicon junction to air is defined as thermal resistor. This parameter − shown in maximum rating section of specification – is highly dependant of application board layout. $R_{\theta JA}$ allows conversion from power in Watt to temperature in Celsius Degrees; this resistor given in °C/W is symbolized by:

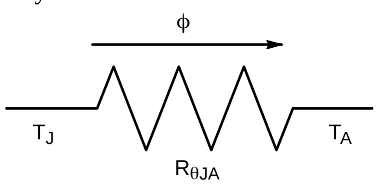

Figure 2.

The lower the thermal resistor is; the better the ability of the device to transfer a large amount of heat is. This thermal resistor is proportional to the difference in temperatures between the junction (T_J) and its surroundings, or ambient (T_A), Equation 3 gives:

$$T_J - T_A = R_{\theta JA} \times \phi \quad \text{(eq. 3)}$$

Where the thermal flow ϕ in Watt is the thermal energy transfer in Joules which cross an isotherm area per time unit:

$$\phi = \frac{dQ}{dt} \quad \text{(eq. 4)}$$

The pass from thermal to electrical engineering links the thermal flow to the power dissipation:

$$P_{DIP} = \phi \quad \text{(eq. 5)}$$

At the end, thermal silicon junction to air resistor allows to calculate maximum ambient temperature application can reach without thermal issue.

$$T_{Amax} = T_{Jmax} - (R_{\theta JA} \times P_{DIPmax}) \quad \text{(eq. 6)}$$

Where T_{Jmax} is maximum junction temperature allowed, T_{Jmax} = 150°C for NCP1529.

The thermal dissipation process can be decomposed into four areas: silicon junction, leadframe, package, board or PCB and ambient. Each section is symbolized by a thermal resistor except the ambient symbolized by the electrical ground:

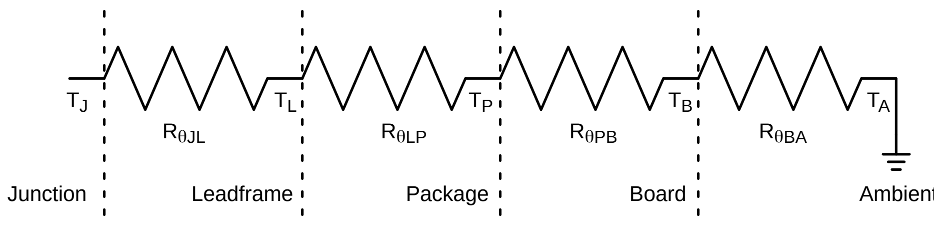

Figure 3.

This model reveals that board layout acts in the heat flow process. Figure 4 pictures whole thermal resistor performance from junction to ambient versus three board configurations (depending on dissipation area and thermal vias). These measures were extract from NCP1529 characterization mounted on a 2S2P board (2-Signal, 2-power/ground Planes) where the power/ground planes were assumed 100% coverage.

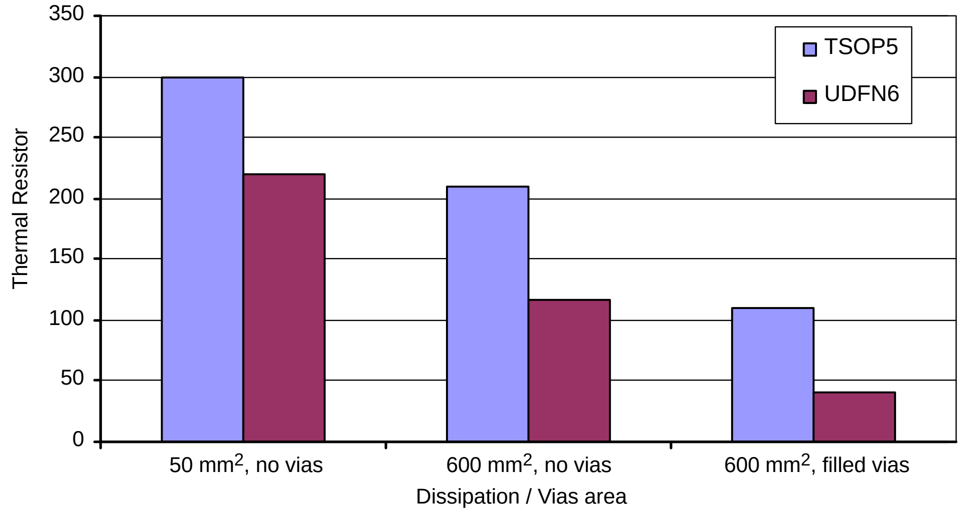

Figure 4. UDFN6/TSOP5 Thermal Resistor Performance vs. Board Layout

Recommended application board – NCP1529 mounted on a 600 mm^2 board with filled vias – optimizes power dissipation performance up to five time.

Package selection is also a main concern to meet ambient temperature requirement in final application: NCP1529 device is available in TSOP−5 (3 x 3 mm) and UDFN−6 (2 x 2 mm) package. Previous application example must be able to dissipate 720 mW, Equation 6 leads to following results:

Table 2. EXAMPLE OF POWER TO THERMAL CONVERSION

Package	TSOP−5	UDFN−6
P_{DIPmax}	720 mW	720 mW
$R_{\theta JA}$	110°C/W	40°C/W
T_{Amax}	70.8°C	121.2°C

Package selection is a main concern to meet ambient temperature requirement in final application.

Package Selection

Identify the best package is also possible using power derating which specifies maximum ambient temperature threshold versus power dissipation.

Below 70°C, both TSOP−5 and UDFN−6 packages are able to dissipate 720 mW required in previous application example. However UDFN−6 package dissipation capabilities lead to higher operating temperature than TSOP−5 package. The main performance difference between UDFN−6 and TSOP−5 packages comes from package structure which maximizes thermal connections from silicon to application board.

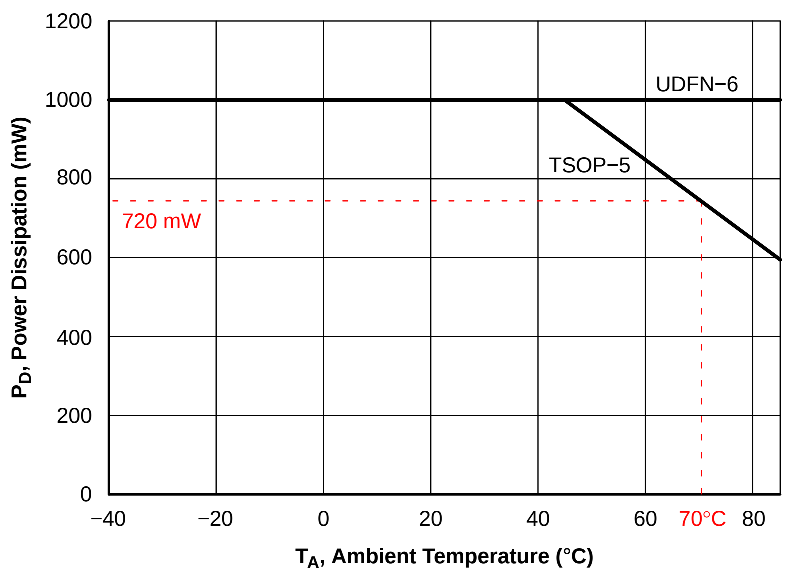

Figure 5. Circuit's Power Derating

Board Layout Optimization

Exposed pad of UDFN−6 package can considerably improve thermal dissipation if it is correctly connected. Following rules could reduce thermal junction-to-air resistor up to five times:

- Prefer use of four layers PCB or more with ground and power plane. This will also improve electrical performances.
- Enlarge high current path such as V_{IN} & SW traces.
- Connect ground top plane to exposed pad and ground pins.
- Add thermal dissipation vias from top to ground plane and bottom to ground plane, as closed as possible or under exposed pad if it is allowed by soldering process. These free vias will increase equivalent dissipator size.

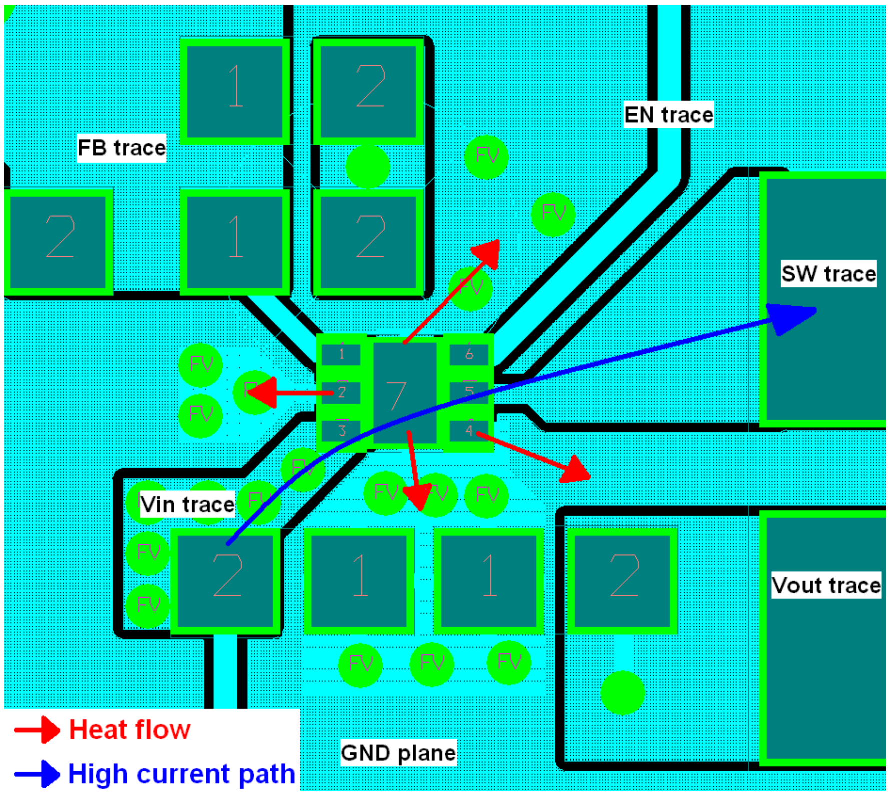

Figure 6. NCP1529 UDFN−6 Recommended Board Layout

To maintain high performance DC to DC converters in small and tiny area, electrical designers must take care of power dissipation. To prevent integrated circuits from thermal issues, NCP1529 switching regulators include short circuit and thermal shutdown protections.

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