

ON Semiconductor

Is Now

onsemi™

To learn more about onsemi™, please visit our website at
www.onsemi.com

onsemi and **onsemi** and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi** product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.



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

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.

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

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.

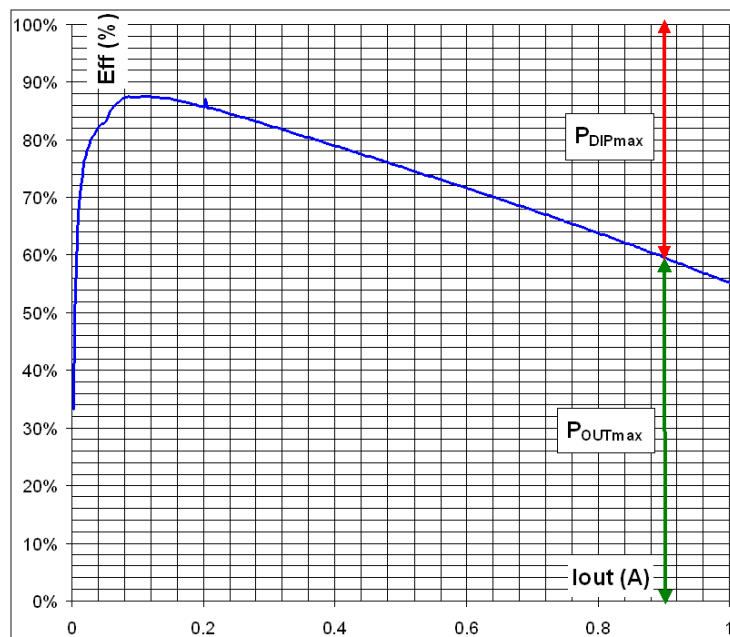


Figure 1. NCP1529 Efficiency at $V_{IN} = 2.7\text{ V}$, $V_{OUT} = 1.2\text{ V}$, $Temp = 85^{\circ}\text{C}$

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

$$P_{DIPmax} = V_{OUT} \times I_{OUT} \left(\frac{1}{E_{ff}} - 1 \right) \quad (eq. 2)$$

$$= 1.2 \times 0.9 \times \left(\frac{1}{60\%} - 1 \right) = 720 \text{ mW}$$

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:

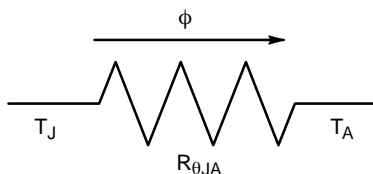


Figure 2.

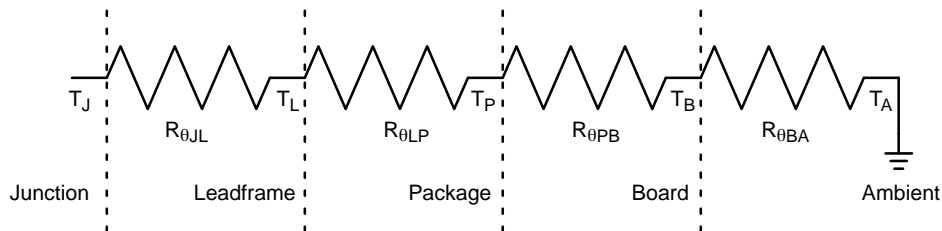


Figure 3.

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

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:

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

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

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

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

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

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

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

Where T_{Jmax} is maximum junction temperature allowed, $T_{Jmax} = 150^\circ\text{C}$ 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:

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.

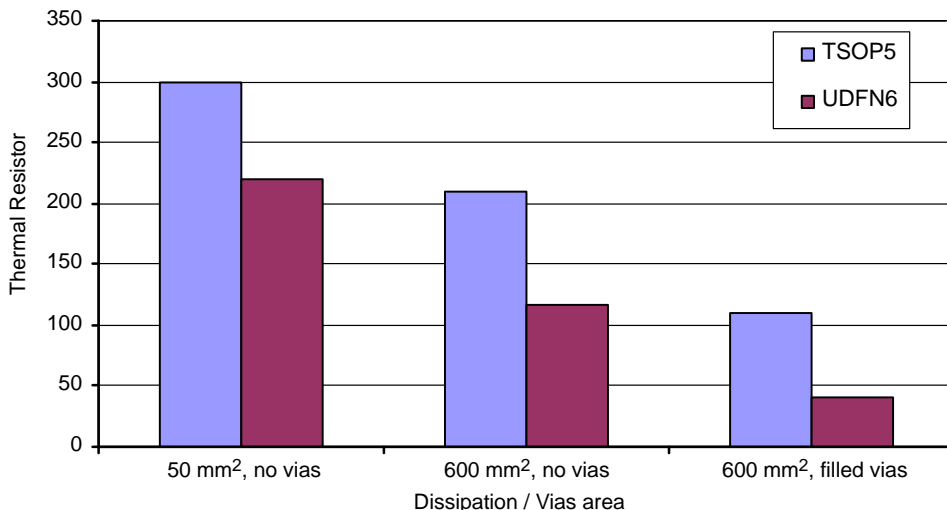


Figure 4. UDFN6/TSOP5 Thermal Resistor Performance vs. Board Layout

Recommended application board – NCP1529 mounted on a 600 mm² 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.

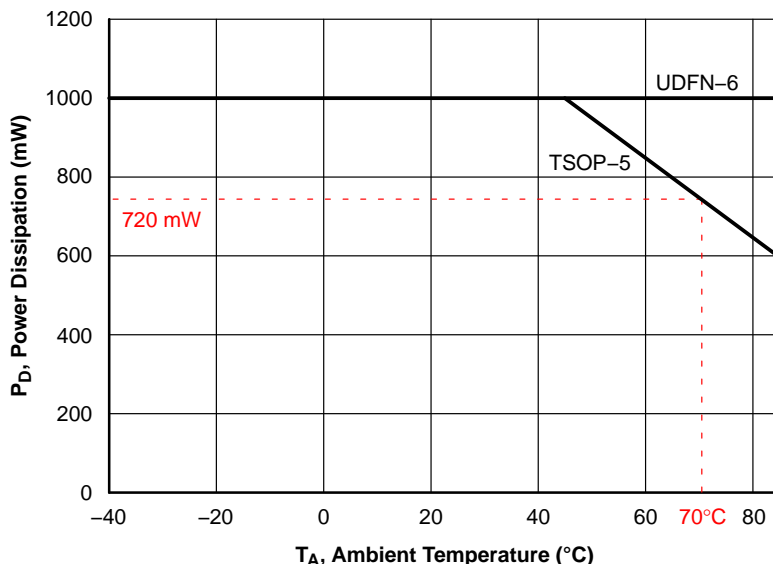


Figure 5. Circuit's Power Derating

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.

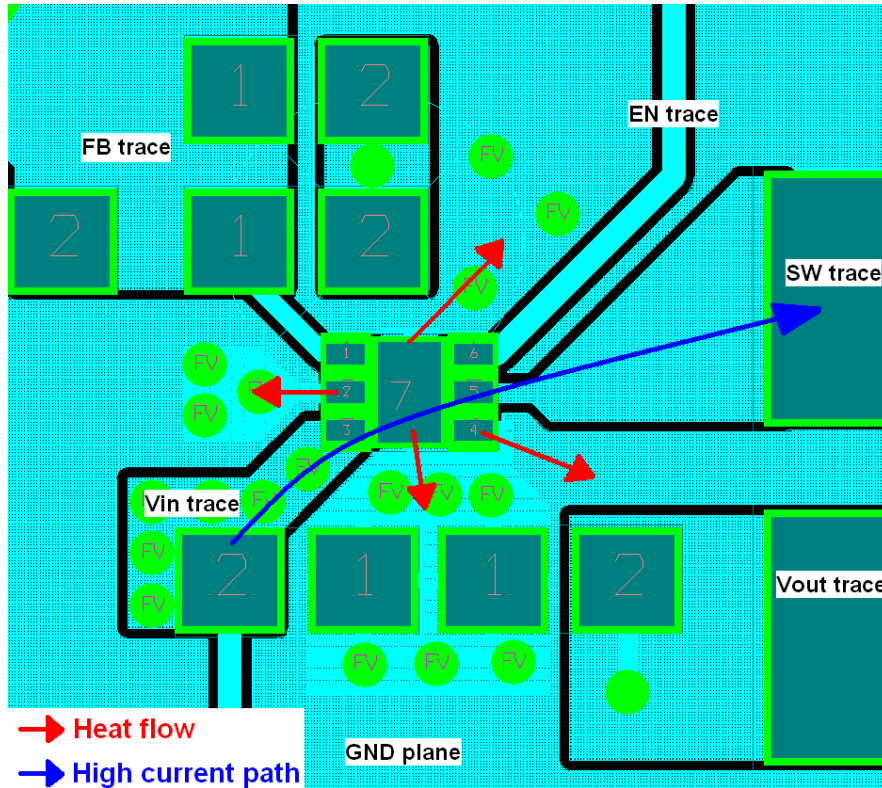


Figure 6. NCP1529 UDFN-6 Recommended Board Layout

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.

ON Semiconductor and are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
 Literature Distribution Center for ON Semiconductor
 19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303-675-2175 or 800-344-3860 Toll Free USA/Canada
Fax: 303-675-2176 or 800-344-3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800-282-9855 Toll Free
 USA/Canada
Europe, Middle East and Africa Technical Support:
 Phone: 421 33 790 2910
Japan Customer Focus Center
 Phone: 81-3-5817-1050

ON Semiconductor Website: www.onsemi.com
Order Literature: <http://www.onsemi.com/orderlit>
 For additional information, please contact your local Sales Representative