Application Report

SNVA719–September 2014

Thermal Design made Simple with LM43603 and LM46002

Marc Davis-Marsh

ABSTRACT

This Application Report will walk through the thermal design of power supplies using the LM43603 and LM46002. In the process we will cover common tips and approximations to speed up your design.

Contents

List of Figures

1 Board Layout for Good Thermal Design

Thermal design doesn't need to be arduous. Let's walk through a quick thermal design for the LM43603 or LM46002 using WEBENCH® and some rules of thumb. Then we will look at measurement results and see the type of accuracy we can expect.

CAUTION

Use of these tips will speed up your board layout for good thermal performance, but you should still take due diligence to ensure that your design is working to your specifications.

First off, in any thermal design, you need to calculate how much power is being dissipated by your device. You can do this one of two ways. You can calculate it by hand or you can use the online design tool WEBENCH®

Secondly you need to determine the thermal environment to which the part is going to be subjected. If you have an enclosure with access to open air and the device is allowed to run hot this would correspond to an ambient temperature (T_A) of your open air and a maximum junction temperature (T_J) for the device of 125°C. This would allow you to calculate a thermal impedance from the junction to ambient air (θ_{JA}).

$$\theta_{JA} \le \frac{Tj_{max} - Tamb}{Pd(IC)} \tag{1}$$

And finally, you need to lay out the board with enough copper or external heat-sinking to achieve the thermal impedance calculated above. The rest of this application note will walk you through the process.

2 Power Dissipation Hand Calculation

The most common method to calculate the power dissipation is to look in the datasheet curves and find the efficiency for your operating condition. With the efficiency information you can back calculate the system power dissipation. You would then subtract out the inductor power loss or external diode power losses to find the IC power loss. Here is an example: Your input voltage is 24 V. Your output Voltage is 5 V. Your peak load current is 3 A. You decide to run at 500 kHz to trade off physical component size and efficiency. You look up the datasheet in the product folder at the TI website.Http://www.ti.com/product/LM43603

Then you find the efficiency curve in which you are interested.

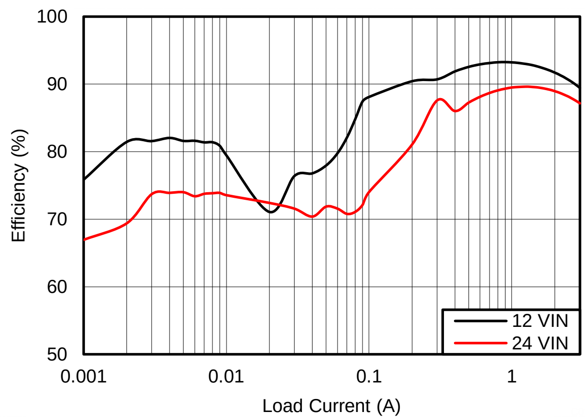


Figure 1. Efficiency Curve

The efficiency from the graph is ≈86%.

The DCR of the inductor (33 mΩ) can be found in the Bill of Materials on page 10 of the LM43603EVM User's Guide. The power dissipation P_D can then be estimated by

P_D (IC) ~ PD (System) – PD (Inductor)

P_D (IC) ~ (Vout x Iout) x [(1/Efficiency)-1] – ((1.1 x Iout)^2 x DCR)

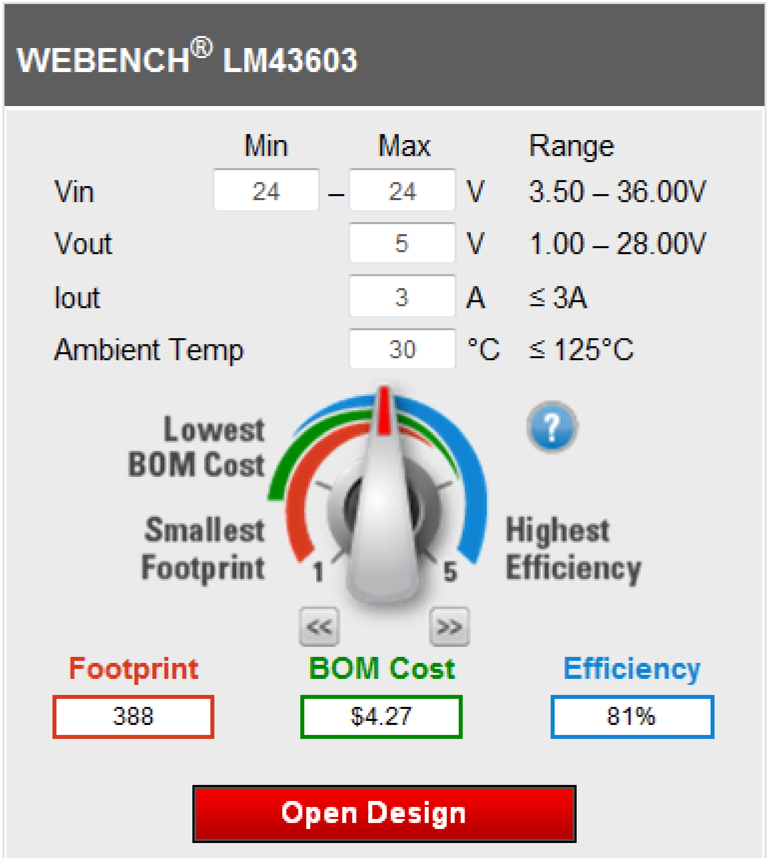
P_D (IC) ~ (5V x 3A) x [(1/0.86)-1] – (1.1 x (3A)^2 x 0.033 Ω)

P_D ~ 2.08W

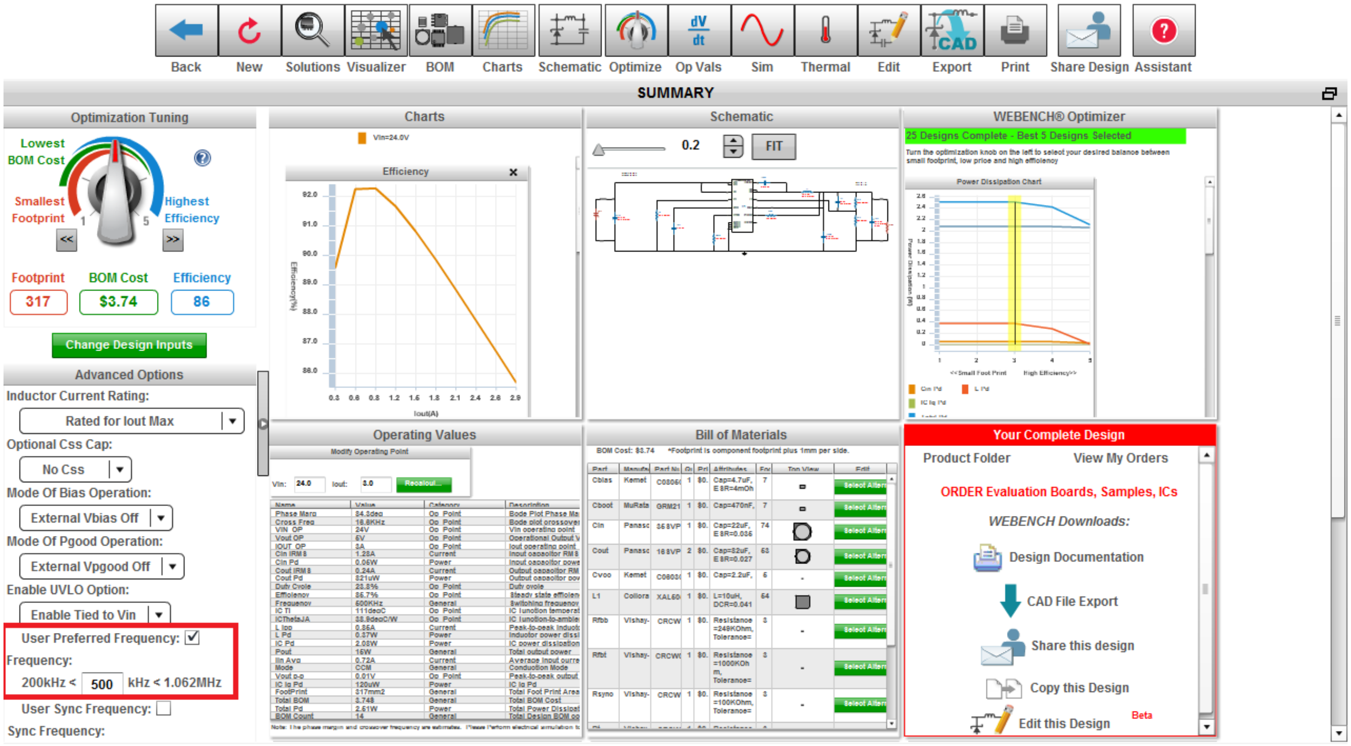
3 Power Dissipation on WEBENCH®

The easiest method to calculate the power dissipation is to run the design in WEBENCH® and read the IC power dissipation from the table. Here is an example: Your parameters are the same as before: Vin = 24 V, Vout = 5 V, Iout = 3 A, f_{SW} = 500 kHz. Go to WEBENCH® either on the TI.COM main page or the product folder at the TI website. Http://www.ti.com/product/LM43603

On the right hand side enter the parameters into the WEBENCH® interface. Enter an ambient temperature of 27°C. Click "Open Design".



Once into the WEBENCH® interface the design, several versions of the design will have been created and WEBENCH® will show the version it feels has been optimized for size and efficiency. To force WEBENCH® to use the frequency we want, the lower left corner has a check box for user preferred frequency. Check this box, enter your preferred frequency and update the design.



If you look at the operating values at the bottom left, or click on the Op Vals tab for a close up, you will see a variety of values that WEBENCH® has computed to complete the design. The Value IC PD is the power dissipation of the IC. According to WEBENCH® the power dissipation is 1.96W.

What other information can we glean from WEBENCH®

If you look further into the Operating values you can see that WEBENCH® has calculated and estimated the IC temperature based upon the θ_{JA} simulated on a JEDEC board. The IC θ_{JA} WEBENCH® used was 38.9°C/W and the calculated IC temperature calculated was IC T_J = 102°C.

If the IC temperature is low enough for your design, then try to mimic a JEDEC layout. A JEDEC layout has an unbroken 3 by 3 inch (76.2 x 76.2 mm) ground plane on the 2nd layer that connects to the exposed pad of the IC with thermal vias. The number of thermal vias should be appropriate to the size of the exposed pad. Typically the thermal vias are 8 mils (200 um) to avoid solder wicking and spaced near a 1 mm grid. With the LM43603, with an exposed, pad of 2.4 x 3.2mm, you can easily fit nine thermal vias.

If the JEDEC thermal impedance is too high for your application, remember that the JEDEC design uses no additional copper heat-sinking on the top or bottom layers to spread the heat away from the exposed pad. While this is very realistic for a high density design, the board design is not always so constrained. There is often room on either the top or bottom layer for additional copper to spread the heat away from the part.

In the datasheet for the LM43603 there is a curve that shows the area of copper used for heat-sinking versus the thermal impedance. Remember when using this curve that it is assuming that either 2 layers or 4 layers all contain the copper heat sinking area shown on the x-axis of the curve.

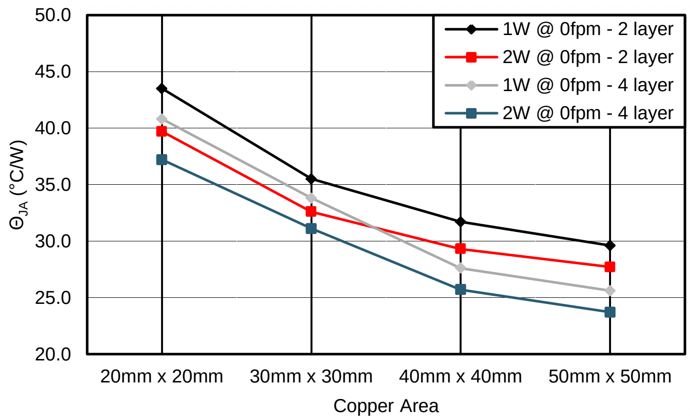


Figure 2. θ_{JA} vs Copper Area; 2oz Copper on Outer Layers and 1oz Copper on Inner Layers

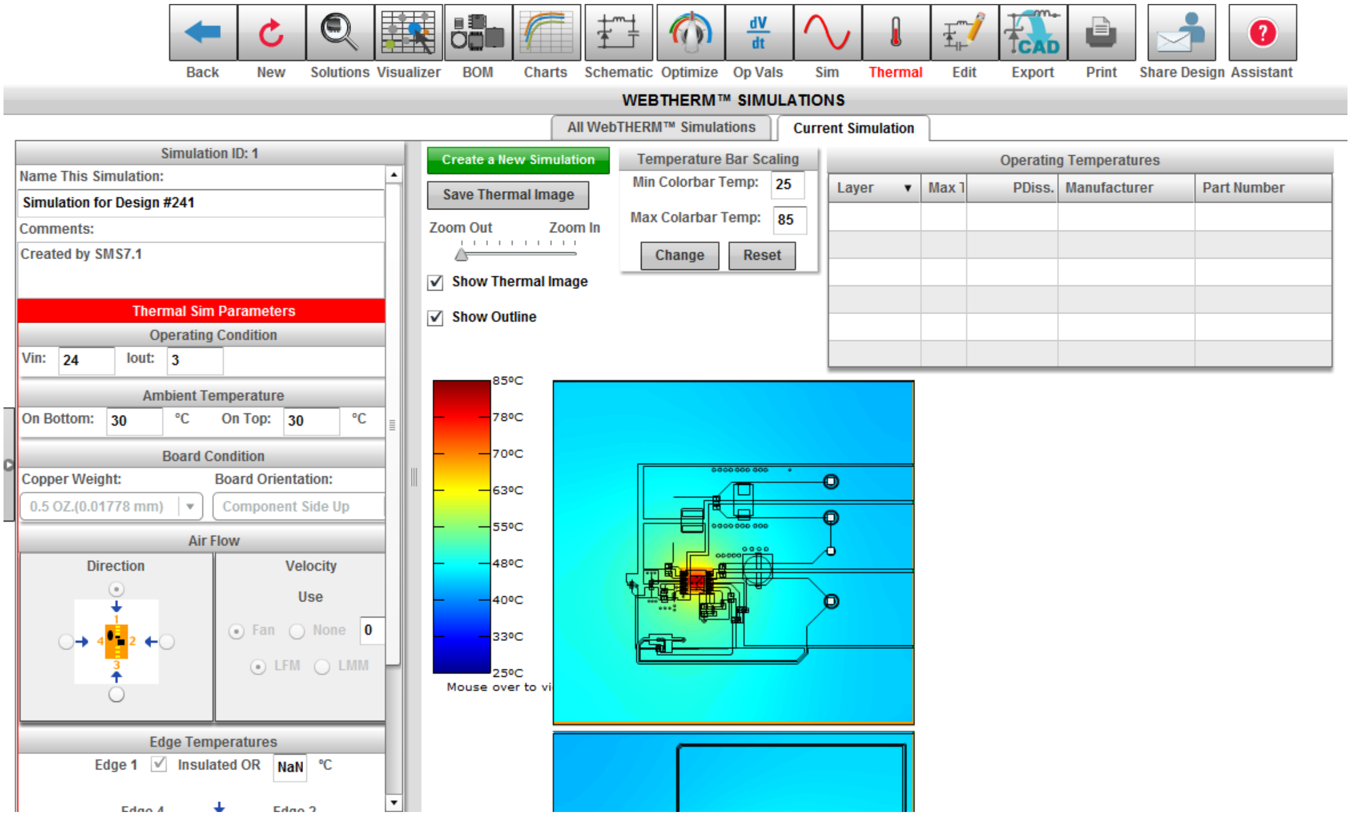
You can see from the graph that the thermal impedance can be reduced from the JEDEC value of 38.9C/W to around 24°C/W if we pay attention to the thermal design. A general rule of thumb is that the amount of copper needed on the top and bottom of a two layer design is

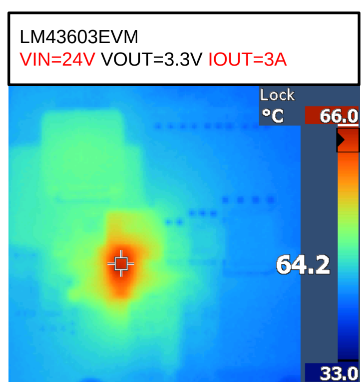
$$\text{Board Area (cm}^2\text{)} \geq 15.29 \frac{\text{cm}^2}{\text{W}} \times P_D$$

For the 2.09W in our design this leads to a recommended minimum copper for heat-sinking of 56 x 56mm. If we look at our curve this corresponds to θ_{JA} ≈ 27°C/W, and an IC temperature of 86°C.

4 Comparison to Thermal Camera Images and WEBENCH®

Now the test. Can I use WEBENCH ® or the datasheet to predict the temperature of a running board? If we go back to the WEBENCH®interface and click on the thermal tab, we can start a thermal simulation of the Evaluation board for the LM43603. The simulation parameters are on the left hand side. Enter an input voltage of 24 V, and output current of 3 amps. The temperature of my lab is 27°C. And the copper weight is 2 oz. Click the “Create a New Simulation” button. This will start a pop-up window with a list of simulations. When yours is finished click on the results and you will see a simulation similar to the one below. The simulation predicted the IC temperature to be 67°C using the evaluation board. Now what if we use the θ_{JA} from the curve. The Evaluation board size is 90 x 70 mm. The area is roughly equivalent to 79 x 79 square mm. If we extrapolate from the curves in Figure 2 this leads to a θ_{JA} of roughly 20°C/W. This leads to an estimated IC temperature of 20 * 2.08 + 27 = 68.6°C. With an Evaluation board under a thermal imaging camera you can see that the case temperature was measured to be 64.2°C. The die temperature of the part would be a few degrees hotter than the case. Using ψ_{JT} of 0.7W/C from the datasheet, we can calculate that the die temperature was 0.7C/W * 2.08 + 64.2 = 65.6°C. So with this data we can see that both methods were very accutate, With these tools, and parts with great thermal layouts, a thermal design for the LM43603 or LM46002 can be extremely simple. For more information on thermal layouts, please see SNVA419 Thermal Design by Insight, Not Hindsight.


Back
New
Solutions
Visualizer
BOM
Charts
Schematic
Optimize
Op Vals
Sim
Thermal
Edit
Export
Print
Share Design
Assistant
WEBTHERM™ SIMULATIONS
All WebTHERM™ Simulations
Current Simulation
Simulation ID: 1
Name This Simulation:
Simulation for Design #241
Comments:
Created by SMS7.1
Thermal Sim Parameters
Operating Condition
Vin: 24
Iout: 3
Ambient Temperature
On Bottom: 30 °C
On Top: 30 °C
Board Condition
Copper Weight:
Board Orientation:
0.5 OZ.(0.01778 mm)
Component Side Up
Air Flow
Direction
Velocity
Use
Fan
None
0
LFM
LMM
Edge Temperatures
Edge 1
Insulated OR
NaN
°C
Create a New Simulation
Save Thermal Image
Zoom Out
Zoom In
Show Thermal Image
Show Outline
Temperature Bar Scaling
Min Colorbar Temp: 25
Max Colarbar Temp: 85
Change
Reset
Operating Temperatures
Layer
PDiss.
Manufacturer
Part Number
85ºC
78ºC
70ºC
63ºC
55ºC
48ºC
40ºC
33ºC
25ºC


LM43603EVM
VIN=24V VOUT=3.3V IOUT=3A
Lock
°C
66.0
64.2
33.0

5 Figures

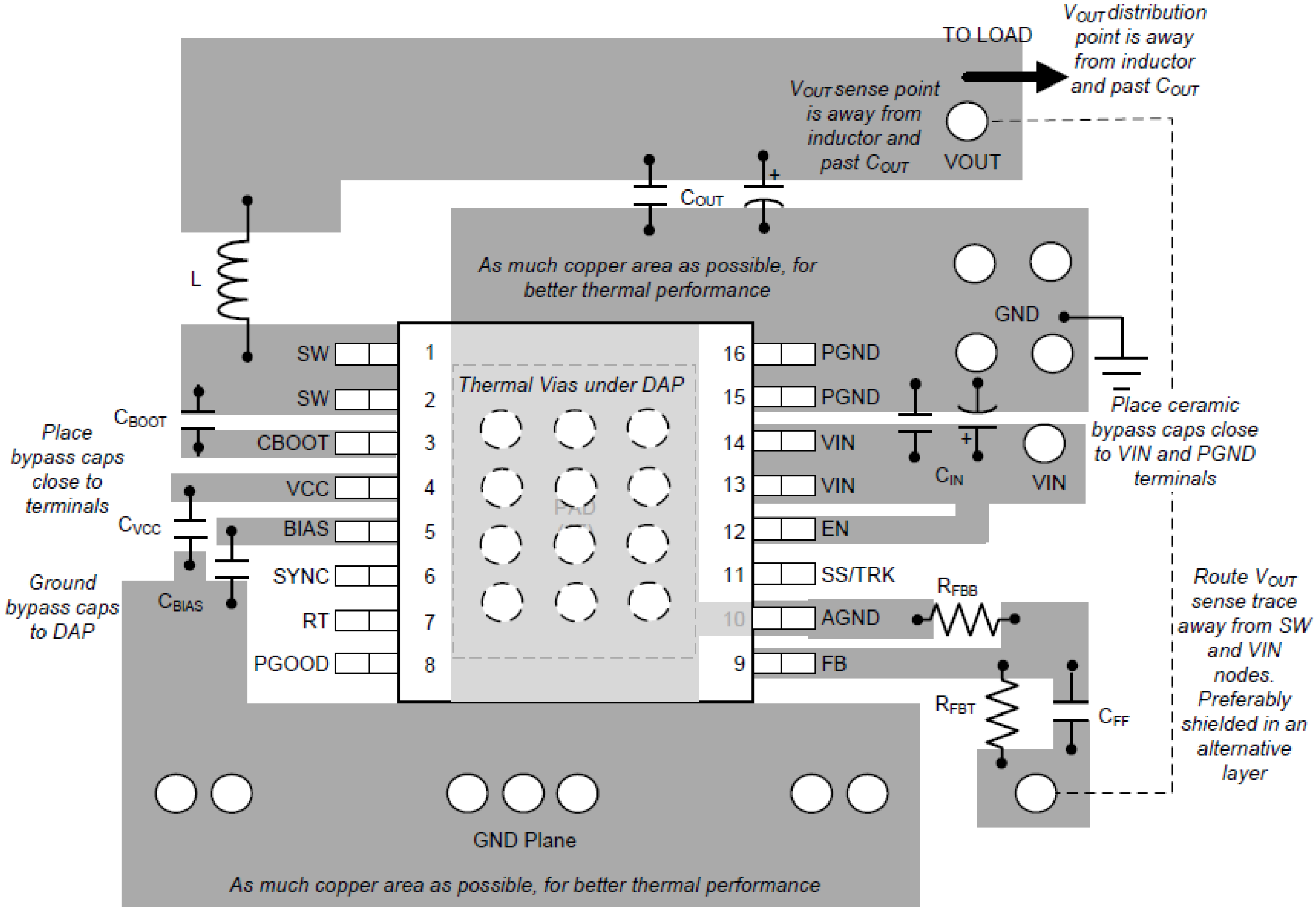


Figure 3. Layout Recommendations

6 References

1. AN-2020 Thermal Design By Insight, Not Hindsight (SNVA419)

2. LM43603 SIMPLE SWITCHER® 3.5 V to 36 V 3-A Synchronous Step-Down Voltage Converter (SNVSA09)