

TRM Case Study No.1

Simulated and Experimental Component Temperature on the Intersil™ ISL8240 Evaluation Board

J. Adam, ADAM-Research, Leimen, Germany

M. Jouppi, Thermal Management LLC, Centennial CO, USA

INTRODUCTION

There is not that much material public available comprising a consistent set of fabrication data and experimental results from which thermal board models can be built and compared. In a recent article Intersil's J. Johnston [3] described the thermal behavior of a QFN package on a 4-layer evaluation board based on the vertical thermal resistance of the layer stack and the copper cladding in vias. Although we do not agree with his assumptions and conclusions a subsequent search for more data led us to a fine set of files and reports. Using them we created a thermal board model with TRM software and the results seem to fit quite nicely.

The board under consideration is called ISL8240MEVAL4Z and can be found on Intersil's home page at www.intersil.com. There is also a sister board with name ISL8240MEVAL3Z.

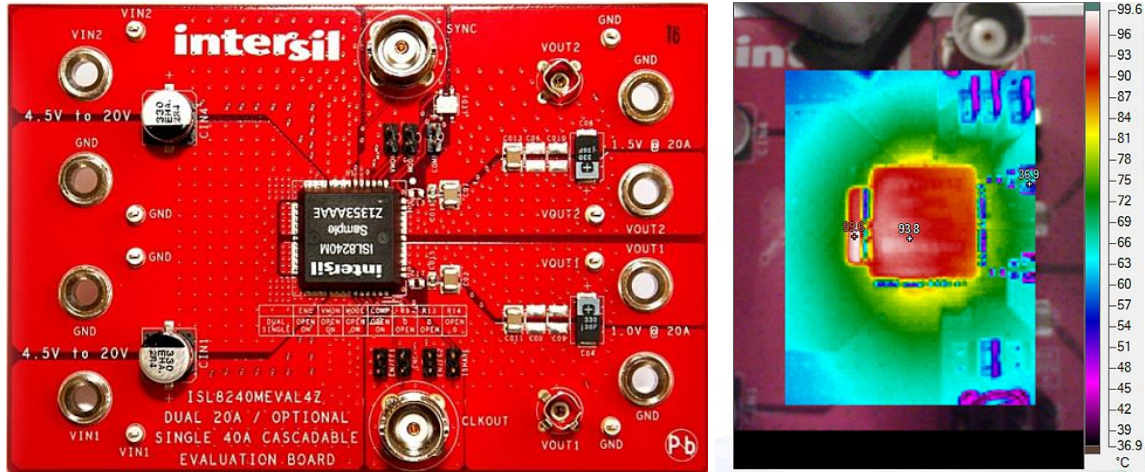


Figure 1: The board under consideration. Size is 4" by 3" (Taranovich, 2015).

THE MATERIAL

The website [2] <http://www.intersil.com/en/tools/reference-designs/isl8240mevalxz.html> contains lots of documents and resources. Important for us are production data in “Design Files”

Home > Tools > Reference Designs and Evaluation Platforms > ISL8240MEVALxZ

ISL8240MEVAL3Z, ISL8240MEVAL4Z

Dual 20A/Single 40A Step-Down Power Module

OVERVIEW	DOCUMENTS	DESIGN RESOURCES
APPLICATION NOTES		
Title		
ISL8240MEVAL4Z User Guide		
ISL8240MEVAL3Z User Guide		
DATASHEETS		
Title		
ISL8240M Datasheet		
DESIGN FILES		
Title		
ISL8240MEVAL4Z Design Files		
ISL8240MEVAL3Z Design Files		

Figure 2: Download items.

The artwork Gerber files around the component look like this

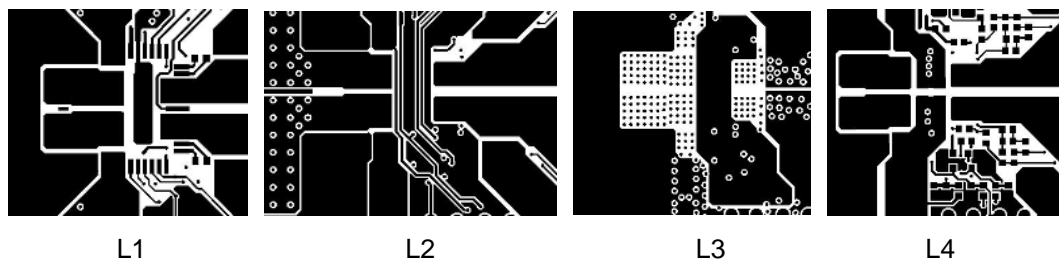


Figure 3: Thumbnails of the artwork.

Search in the internet for ISL8240MEVAL4Z is leading to a report by Taranovich [4] where power considerations and (uncoated) infrared images of the board can be found.

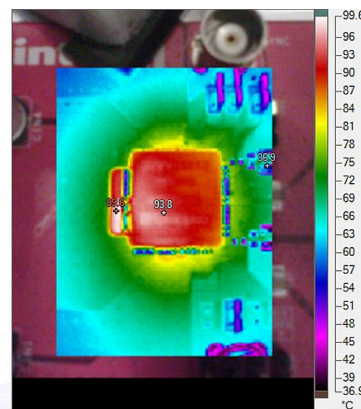

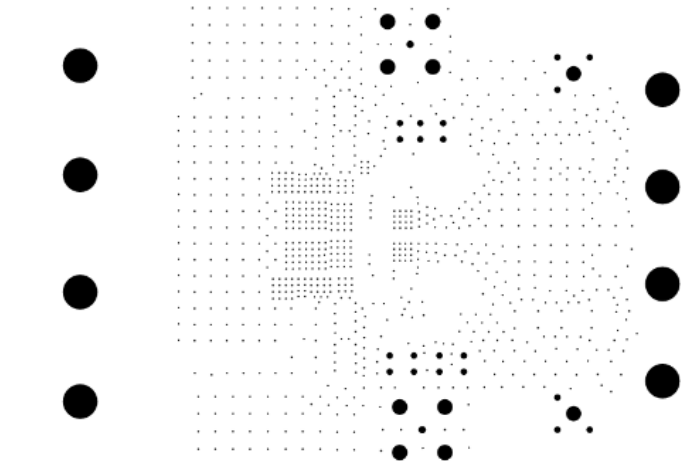


Figure 4: Infrared image of ISL8240MEVAL4Z which we try to simulate (Taranovich (2015)).

BOARD MODELING

We just paste some TRM input panes or output frames. Most of the input will be obvious.

<p>Film size</p> <p>Length x: <input type="text" value="114.3"/> mm</p> <p>Width y: <input type="text" value="76.2"/> mm</p> <p>Width y</p>  <p>Length x</p> <p>Resolution</p> <p>Thermal pixel: <input type="text" value="0.1"/> mm</p>	<p>Default Materials</p> <p>Conductor:</p> <ul style="list-style-type: none"> FR4\$TRM Cu\$TRM Comp_diel_loc\$TRM Comp_diel_hic\$TRM Comp_diel_vhc\$TRM perfectE\$TRM Ignore\$TRM Al\$TRM <p>Dielectric:</p> <ul style="list-style-type: none"> FR4\$TRM Cu\$TRM Comp_diel_loc\$TRM Comp_diel_hic\$TRM Comp_diel_vhc\$TRM perfectE\$TRM Ignore\$TRM Al\$TRM <p>Frame size in film</p> <p>x0: <input type="text" value="0"/> y0: <input type="text" value="0"/></p> <p>x1: <input type="text" value="114.3"/> y1: <input type="text" value="76.2"/></p>	<p>Board size is 4" by 3".</p> <p>The finest structures in the layout are around 0.1 mm. This is the lateral resolution which we demand for the results.</p> <p>No special materials are used.</p>																																																																									
<table border="1"> <thead> <tr> <th>Level ▲</th> <th>Name</th> <th>Type</th> <th>File</th> <th>View</th> <th>FR4 white?</th> <th>Thick (mu)</th> <th>Conductor</th> <th>Dielectric</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>L1</td> <td>ger</td> <td>layer1.art</td> <td>View</td> <td><input checked="" type="checkbox"/></td> <td>70</td> <td>Cu\$TRM</td> <td>FR4\$TRM</td> </tr> <tr> <td>2</td> <td>pre1</td> <td>pre</td> <td></td> <td>View</td> <td><input checked="" type="checkbox"/></td> <td>210</td> <td></td> <td>FR4\$TRM</td> </tr> <tr> <td>3</td> <td>L2</td> <td>ger</td> <td>layer2.art</td> <td>View</td> <td><input checked="" type="checkbox"/></td> <td>35</td> <td>Cu\$TRM</td> <td>FR4\$TRM</td> </tr> <tr> <td>4</td> <td>pre2</td> <td>pre</td> <td></td> <td>View</td> <td><input checked="" type="checkbox"/></td> <td>850</td> <td></td> <td>FR4\$TRM</td> </tr> <tr> <td>5</td> <td>L3</td> <td>ger</td> <td>layer3.art</td> <td>View</td> <td><input checked="" type="checkbox"/></td> <td>35</td> <td>Cu\$TRM</td> <td>FR4\$TRM</td> </tr> <tr> <td>6</td> <td>pre3</td> <td>pre</td> <td></td> <td>View</td> <td><input checked="" type="checkbox"/></td> <td>210</td> <td></td> <td>FR4\$TRM</td> </tr> <tr> <td>7</td> <td>L4</td> <td>ger</td> <td>layer4.art</td> <td>View</td> <td><input checked="" type="checkbox"/></td> <td>70</td> <td>Cu\$TRM</td> <td>FR4\$TRM</td> </tr> </tbody> </table>			Level ▲	Name	Type	File	View	FR4 white?	Thick (mu)	Conductor	Dielectric	1	L1	ger	layer1.art	View	<input checked="" type="checkbox"/>	70	Cu\$TRM	FR4\$TRM	2	pre1	pre		View	<input checked="" type="checkbox"/>	210		FR4\$TRM	3	L2	ger	layer2.art	View	<input checked="" type="checkbox"/>	35	Cu\$TRM	FR4\$TRM	4	pre2	pre		View	<input checked="" type="checkbox"/>	850		FR4\$TRM	5	L3	ger	layer3.art	View	<input checked="" type="checkbox"/>	35	Cu\$TRM	FR4\$TRM	6	pre3	pre		View	<input checked="" type="checkbox"/>	210		FR4\$TRM	7	L4	ger	layer4.art	View	<input checked="" type="checkbox"/>	70	Cu\$TRM	FR4\$TRM	<p>Taranovich is claiming 2 oz outer layers and 1 oz inner layers.</p> <p>The user guide claims 2 oz in all layers.</p> <p>Gerber files come from Cadence Allegro.</p>
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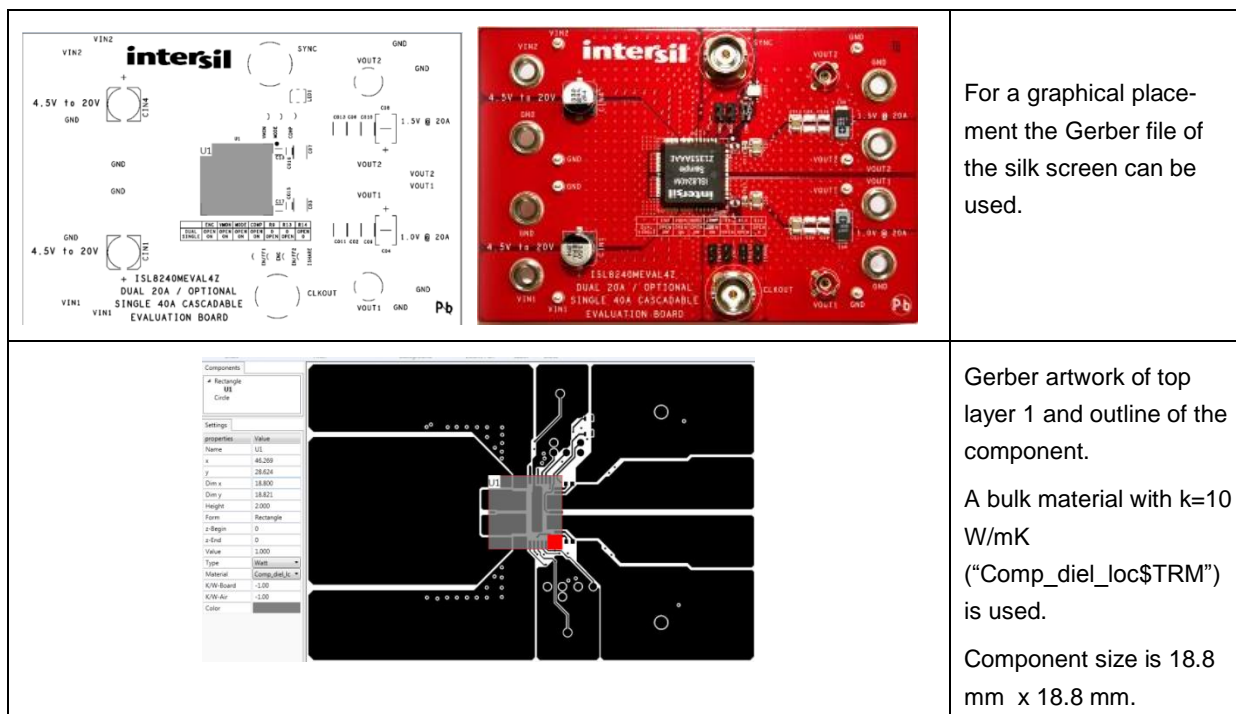


Figure 5: Summary of the model-build in TRM.

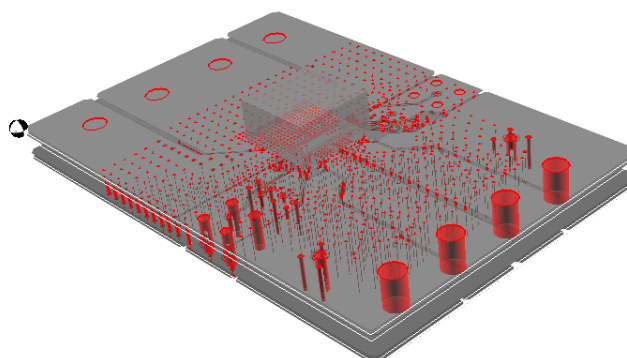


Figure 6: Transparent 3D view of our board model. Watch the drills underneath the package.

COMPONENT MODELLING

The focus of TRM is to calculate the thermal behavior of the printed board. Components are treated as simple as possible, also because no information about the complex inner structure is available. Common practice is to create a rectangular volume and to assign a bulk conductivity together with a thermal power value. As a material definition for this type of QFN package we chose the entry “comp_diel_loc\$TRM” from the TRM material database. The power dissipation for the experiment in Fig. 4 can be estimated from the data sheet and the text for Fig. 1 in Taranovich [4]:

“The first test was as follows: $V_{in}=12V$, $V_{out}=1V$, $F_{sw}=500kHz$, $I_{out}=40A$ with the board configured in a two-phase parallel single output mode (Mode 5A). Thermal imaging test results showed a maximum temperature of 99.6 C. See Figure 1.”

When we look into the Data Sheet [1] we find on p. 27 the graph shown in Fig. 7. Unfortunately the combination $V_{out}=1V$, $F_{sw}=500kHz$ cannot be found. From other graphs in the Data Sheet [1] we infer that the efficiency at 500 kHz must be close to that at 300 kHz.

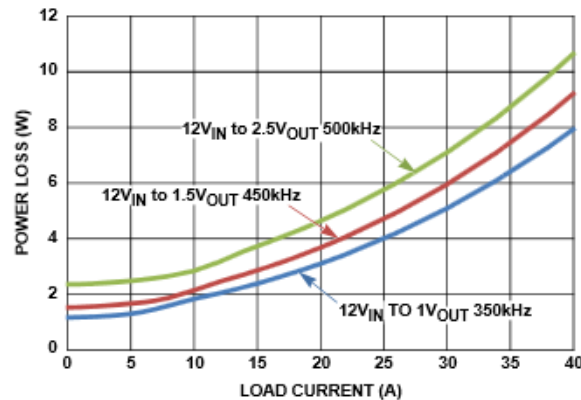


FIGURE 37. POWER LOSS CURVES OF 12V_{IN}

Figure 7: Graph for power dissipation from Data Sheet of ISL8240 [1]

We decide to use a power loss of 8 Watts on the blue line at 40 A.

ENVIRONMENT CONDITIONS

Any thermal calculation needs as a reference temperature the external air temperature plus the cooling conditions. The Taranovich report [4] says:

"Tests were performed using the evaluation board at room temperature with zero air flow."

Unfortunately he does not tell the mounting situation precisely: was the board placed vertically or horizontally and held within free air flow or did it lie on the table, etc. nor he gave the value of the room temperature (we wouldn't believe that is was 39.6 C Fig.1). In our thermal calculation we just assume an air room temperature of 20 C plus a heat transfer coefficient $h=13 \text{ W/m}^2\text{K}$. To get this value is quite complicated. There are two fundamentals: first, semi-empirical formulae that describe the heat transfer by free convection air flow over the surface of a plate and, second, the Stefan-Boltzmann law of radiation. Both laws together lead to an equilibrium temperature of a homogeneously heated plate and from this the effective total heat exchange coefficient can be deduced. The procedure is coded in the TRM Heat Transfer Assistant module.

BASIC RESULT

Fig. 8 shows the simulation result for a 2,1,1,2 oz board with an 8 Watt component at 20 C air temperature in free convection in steady-state.

The maximum value in the calculated temperature field is around 99 C in a spot somewhere in the center of the component model. More or less this temperature can be interpreted as the surface temperature because of the choice of the bulk conductivity, with some uncertainties.

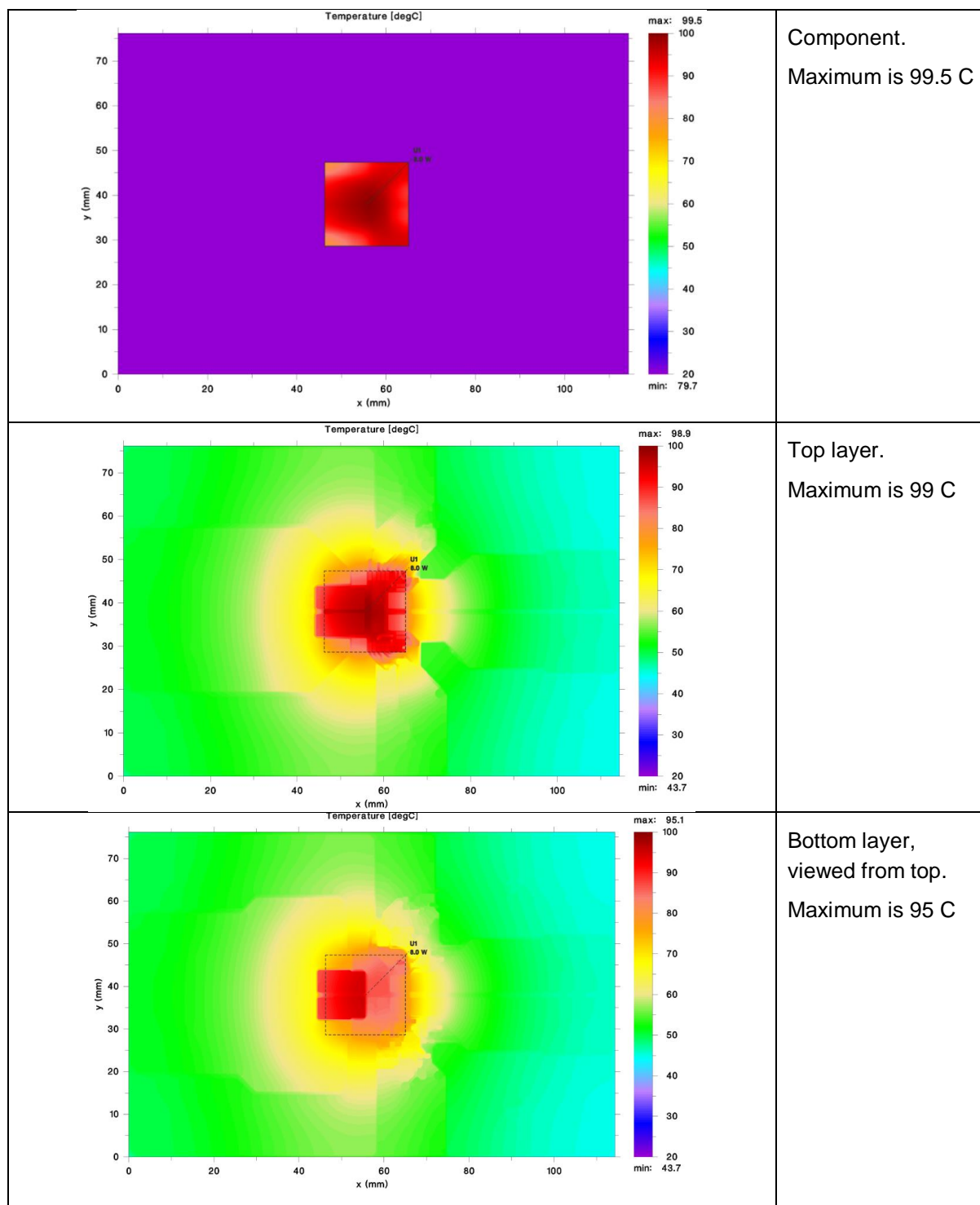


Figure 8: Simulated temperature of ISL8240MEVAL4Z with our basic parameters.

Apart from the maximum temperature also features in shape and look of the infrared image are nicely reproduced. Edges and corners are caused by the artwork of the layers, which is the same in simulation and experiment. However, the infrared image in Fig 9 is that of an uncoated board i.e. metallic surfaces have low emission and appear blue. TRM assumes coated board (emissivity 0.9) and component surfaces in order to be able to compare simulation with infrared imaging. This makes a strict quantitative comparison difficult. However, we can adapt the same color bar as was used in the thermograph.

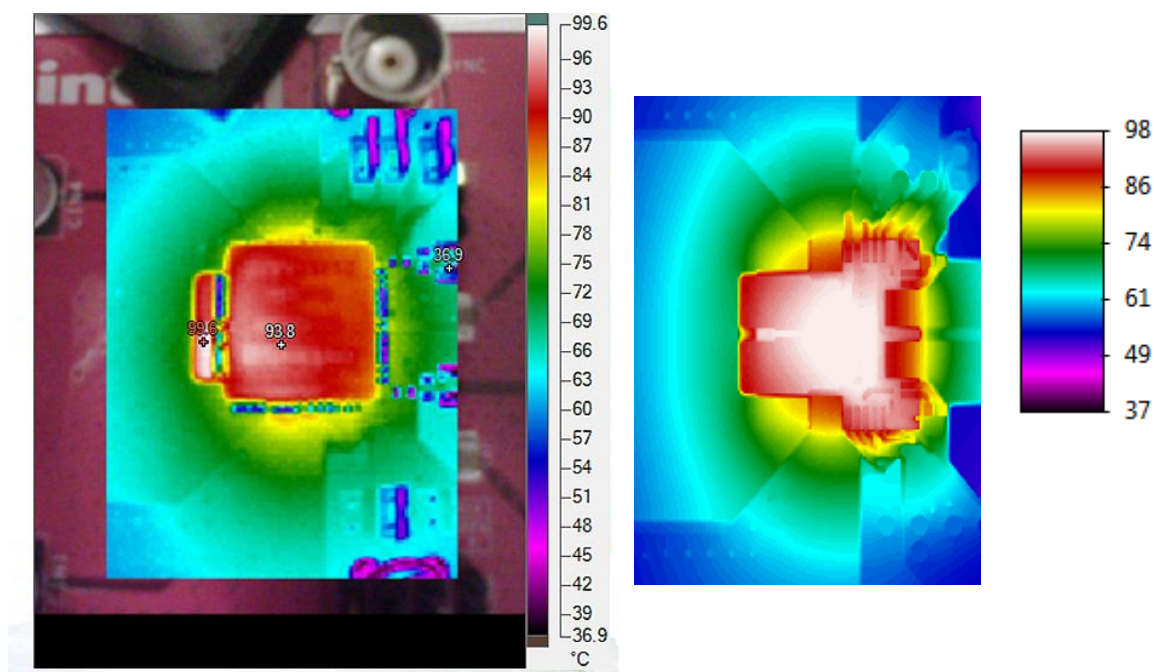


Figure 9: Details in experiment [4] (left) and simulation (right, layer 1) agree.

In TRM we can show the layout as a background picture. This was done in Fig. 9 (right) using the top layer. We may wonder why the yellow isotherms end abruptly at coordinate $x=30$ mm (s. Fig. 8). This is caused by the insulation in the inner layer L2 (Fig.10).

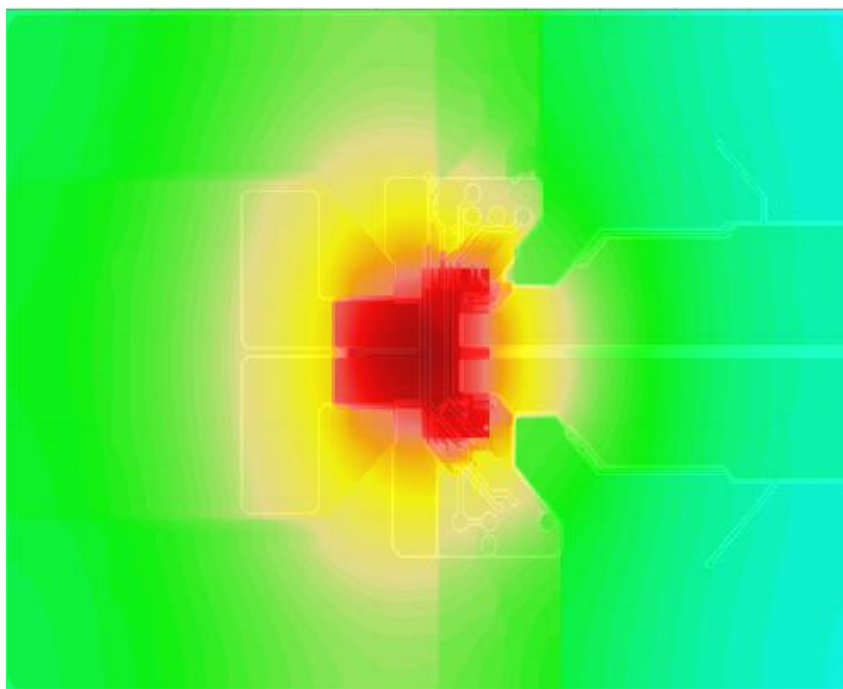


Figure 10: Superposition of calculated top face temperature and the layout of L2.

VARIATIONS

There are some major uncertainties in the data:

- The unknown room temperature and heat transfer
- The ambiguous thickness of the inner layers (1 oz or 2 oz?)
- The unknown power dissipation of the component
- The unknown case-to-board thermal resistance of the component
- The unknown and non-uniform emissivity of the infrared image.

How does the temperature change if we change parameter values? Table 1 gives values for the maximum temperature relative to the ambient air temperature.

Table 1: Parametric study. Temperature above ambient in K.

Parameter 1 Parameter 2	2,1,1,2 oz 6 oz	2,2,2,2 oz 8 oz = 6+30%	15 W/m ² K 6 oz
8 W	80 K (Fig. 8)	72 K	-
10.5 W (8+30%)	105 K	94 K	-
6 W (8-30%)	62 K	57 K	-
8 W	80 K (Fig. 8)	-	74

- The maximum temperature relative to ambient is proportional to dissipated power. This implies that the thermal resistance to ambient does not change much with power.
- Increasing the total thickness of layers by 30% leads to a decrease of relative temperature of -10% only. This is not predictable in a back-of-the-envelope calculation and a genuine 3D simulation result.
- As in the theory of point like heat sources the maximum temperature relative to ambient is proportional to the square root of the heat exchange coefficient.

ACKNOWLEDGEMENT

We thank Intersil Corp. for permission to use the information and files found on their website for this article and on our websites.

REFERENCES

- [1] Data Sheet: <http://www.intersil.com/content/dam/Intersil/documents/isl8/isl8240m.pdf>
- [2] Intersil Corp. <http://www.intersil.com/en/tools/reference-designs/isl8240mevalxz.html>
- [3] Johnston, J.: "Carrying the Heat Away from Power Module PCB Designs" in <http://www.powerelectronicstips.com/carrying-the-heat-away-from-power-module-pcb-designs/> (2015) and similar material in <http://www.intersil.com/content/dam/Intersil/whitepapers/power-module/carry-heat-away-from-power-module.pdf>
- [4] Taranovich, S.: "Unique Intersil thermal design removes heat from encapsulated, compact 50A power modules" in <http://www.edn.com/electronics-products/electronic-product-reviews/other/4439182/Unique-Intersil-thermal-design-removes-heat-from-encapsulated--compact-50A-power-modules> (2015)
- [5] User Guide: <http://www.intersil.com/content/dam/Intersil/documents/an19/an1922.pdf>