電源IC之熱仿真與實證

CPSDAE
Finn Liu
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RICHTEK
your power partner.

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Influence of Thermal Effect on IC

Significance of Thermal Simulation:

- ✓ Package Enhancement
- ✓ IC Layout Improvement

} IC's thermal resistor↓➔Competiveness↑↑↑

- ✓ PCB Layout Optima Arrangement
- ✓ Thermal Dissipation Prediction
- ✓ Component Selection

} Product performance↑↑↑

Tendency of package

Flip-chip package:

Die ↓

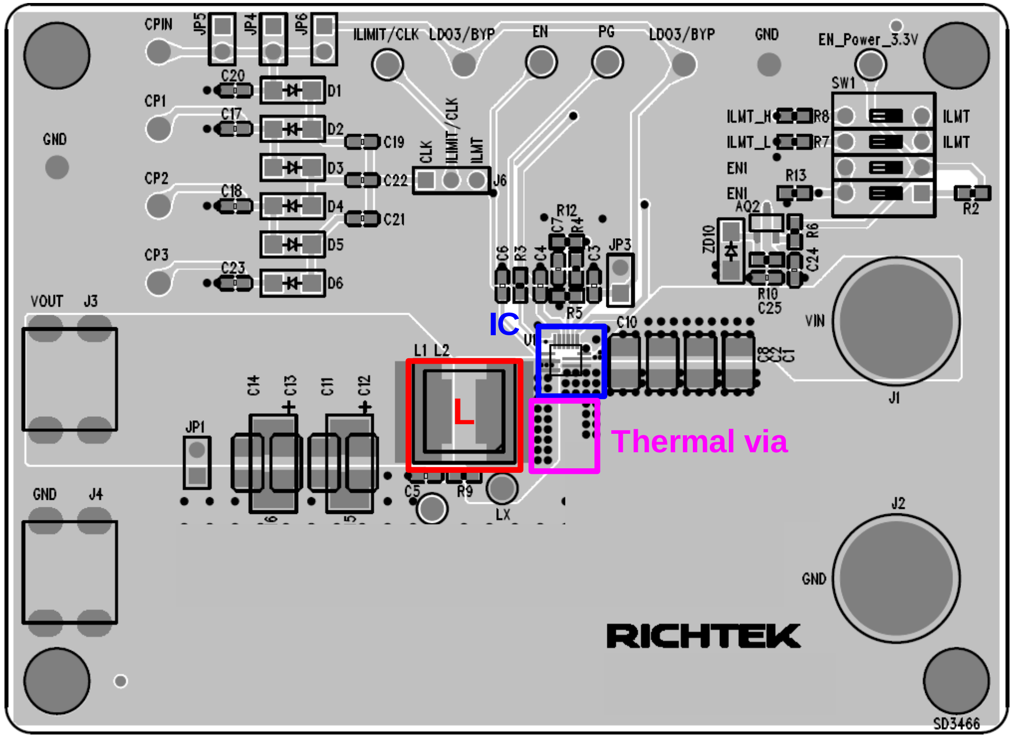
Heat dissipation ↑

Hard to evaluate thermal characteristic

Contents

Thermal Flow Prediction by FloTHERM

- **Real board**



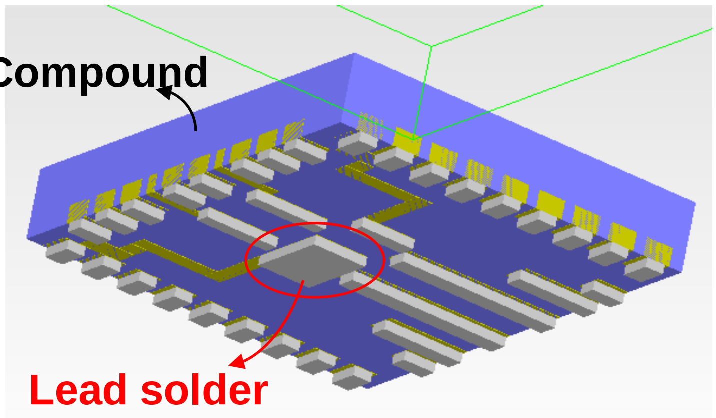
Critical factors on thermal flow:

- ➢ **IC**
- ➢ **PCB layout**
- ➢ **Thermal via**
- ➢ **Inductor**

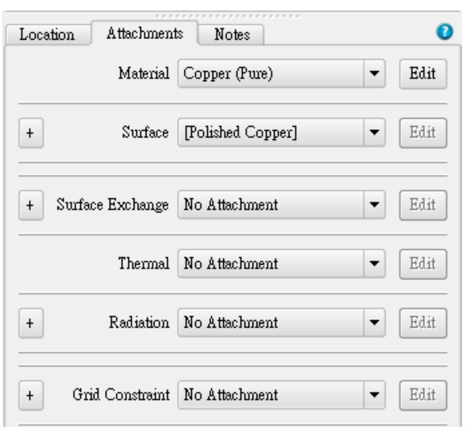
IC Thermal Model on FloTHERM

Referring to IC layout and material characteristic

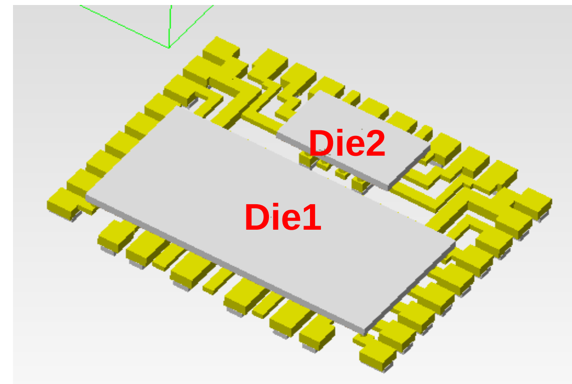
- **Appearance of IC**



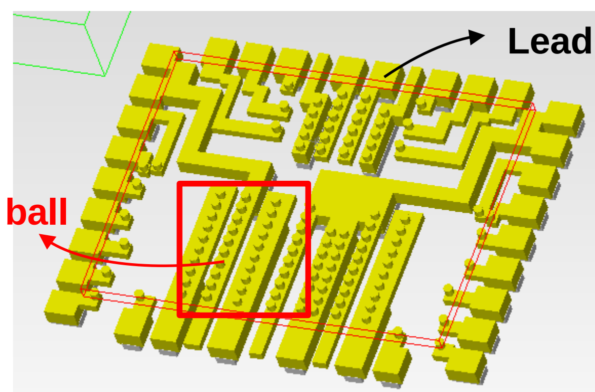
- **Material coefficient**



- **Inner of compound**



- **Inner of compound**



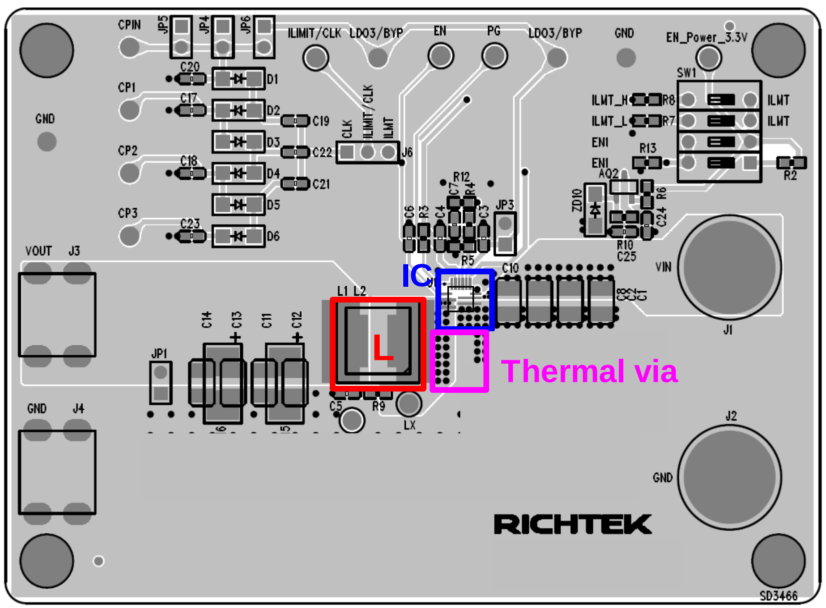
PCB Thermal Model on FloTHERM

Following real layout guide and criteria

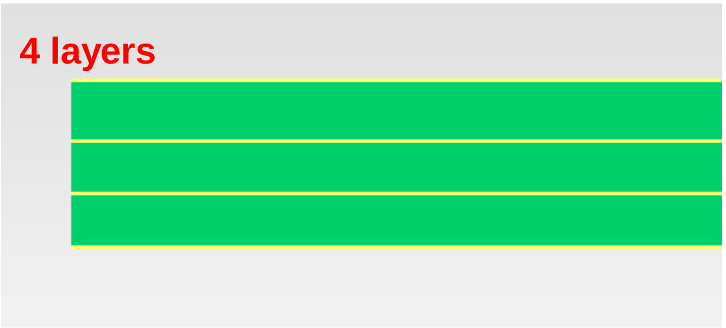
- PCB Dimension: 100mm x 72mm
- Copper Thickness: 1oz

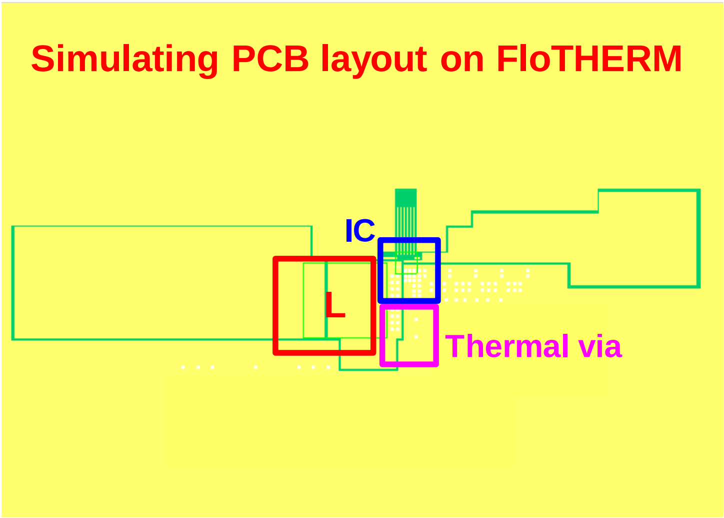
4 layers:

– Top: Control loop, power path, and GNG
– Others: GND



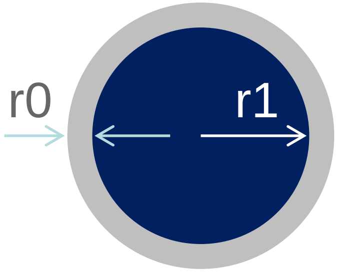
- **FloTHERM**

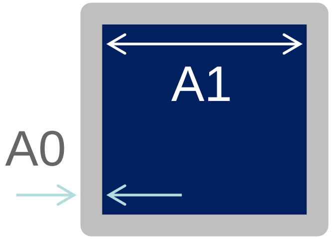




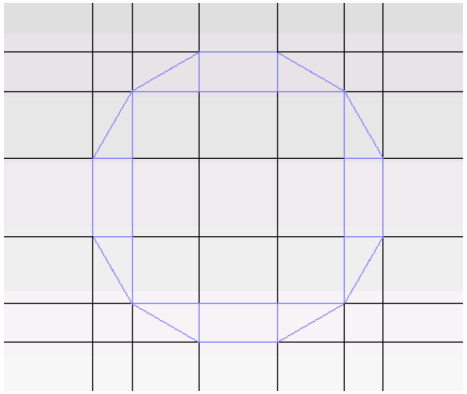
Influence on Different Shape of Via@FloTHERM

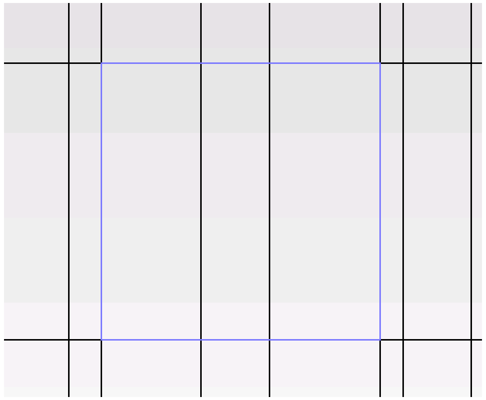
Prerequisite condition: All the comparison results are **under the same area of via**





Wireframe@FloTHERM



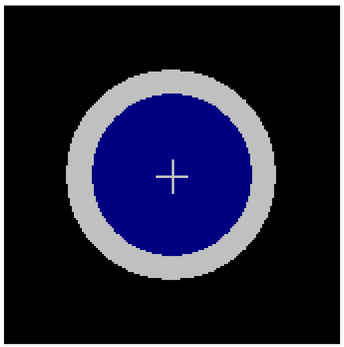


- Circle via is totally with real via on PCB➔ **More accuracy**
- Circle via needs more gird for convergence➔ **More time consuming**

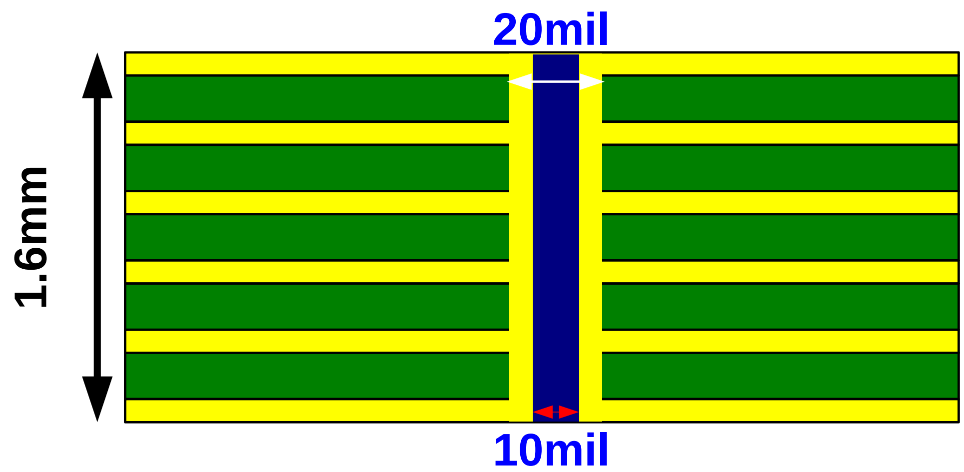
Material of Via’s Filler

Top view

Via size: 20D10



Side view



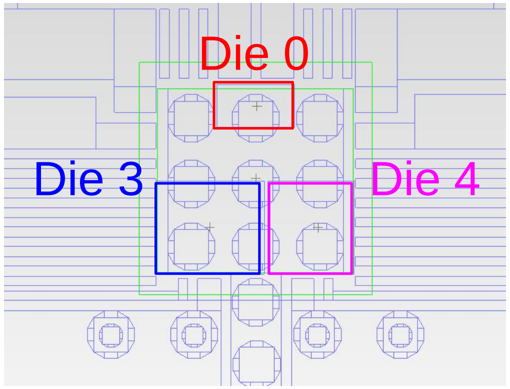
Materials of filler:

• Copper paste AE303	(7.8W/mK)
• Resin PHP-900 IR-6P	(0.54W/mK)
• Solder 63/67	(59W/mK)
• Air	(0.0257W/mK)

Comparison Results

- Circle via

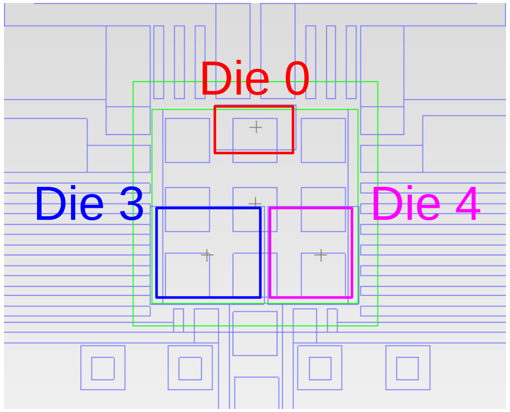
Circle via area: 20 mil*20 mil*π= 1256 mil²



	compound (degC)	Die:0 (degC)	Die:3 (degC)	Die:4 (degC)
32767	105.846	150.167	104.257	111.813
32766	105.846	150.167	104.257	111.813
32765	105.846	150.167	104.257	111.813
32764	105.846	150.167	104.257	111.813
32763	105.846	150.167	104.257	111.813

- Square via

Square via area: 35.449 mil* 35.449 mil =1256 mil²



	compound (degC)	Die:0 (degC)	Die:3 (degC)	Die:4 (degC)
32767	105.472	149.005	103.981	111.329
32766	105.472	149.005	103.981	111.329
32765	105.472	149.005	103.981	111.329
32764	105.472	149.005	103.981	111.329
32763	105.472	149.005	103.981	111.329

In FloTHERM simulation results, there is no difference between circle via and square via, if the area is the same.

Contents

Stand Alone Analysis for IC

- **Purposes of stand alone analysis on IC**

  Understand IC's thermal capability

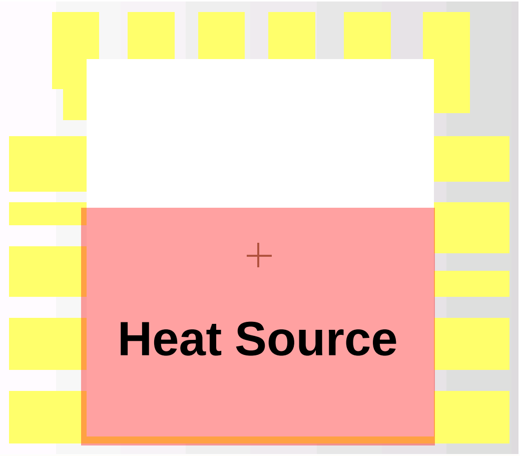
  ➢ **Find out what affects IC's thermal performance**

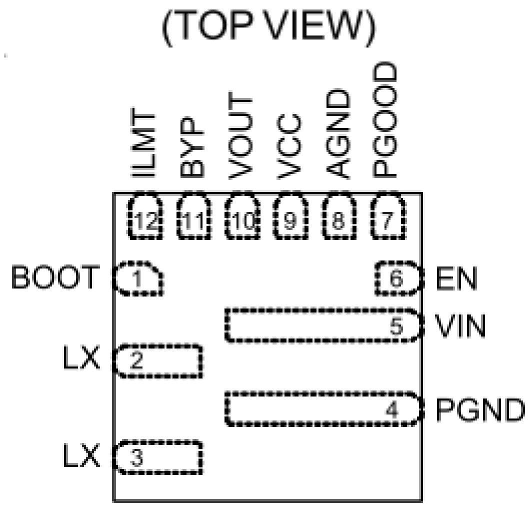
  ➢ **IC's layout optima**

- **8A Converter IC**

  Package Type : UQFN-12HL 3x3 -56B(FC)

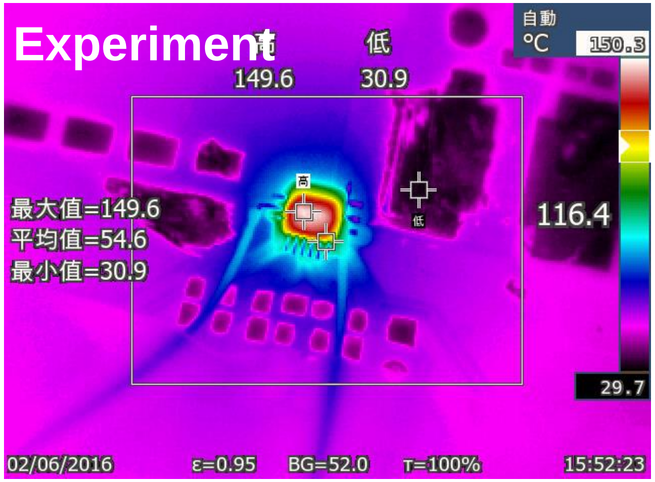
➢ **8A Converter IC FloTHERM Model**

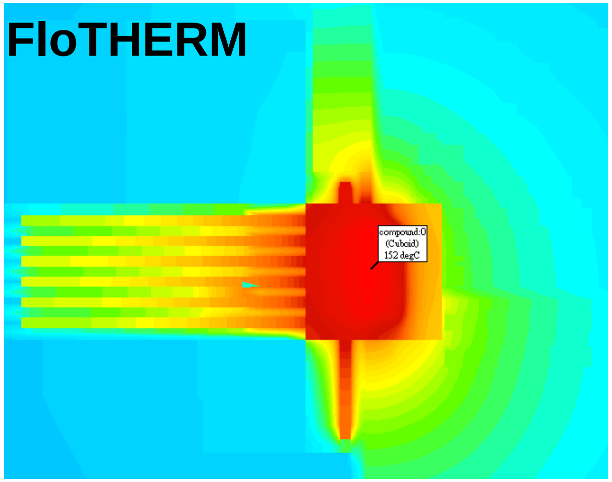




Stand Alone Analysis for IC

Product	$V_{SW\text{-}VIN}$(V)	$I_{SW\text{-}VIN}$(A)	P_{D_IC} IC Power loss(W)	TA(℃)	TC(℃)	TC_sim(℃)	q_{CA}
8A Converter IC	0.706401	1.998	**1.41139**	25.8	**81.6**	**81.9**	39.5
8A Converter IC	0.67094	3.997	**2.681748**	26.4	**136**	**133**	40.8





Easy predicting IC's thermal resistor

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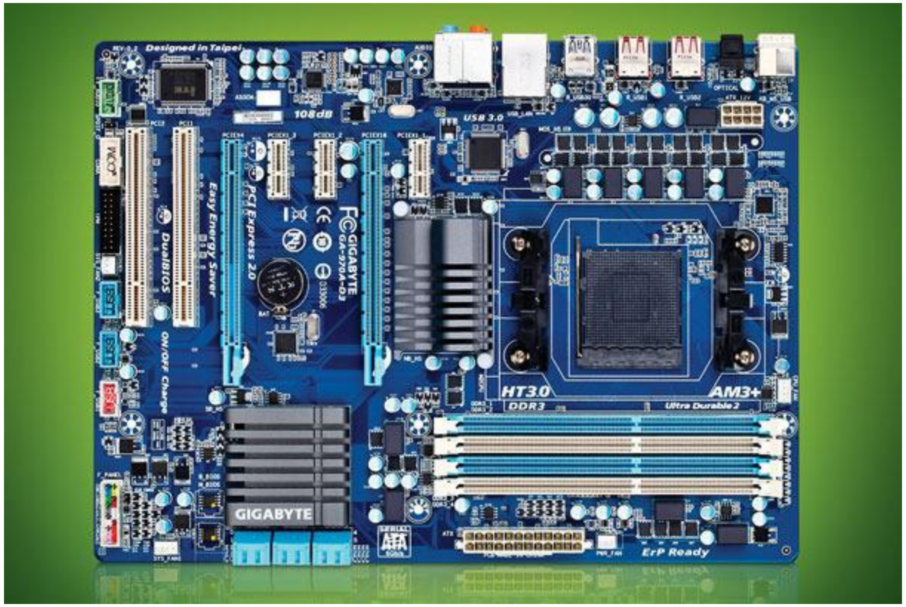
Thermal Effect on IC with Whole System

In the system board, there are so many factors and components affecting IC's thermal performance.

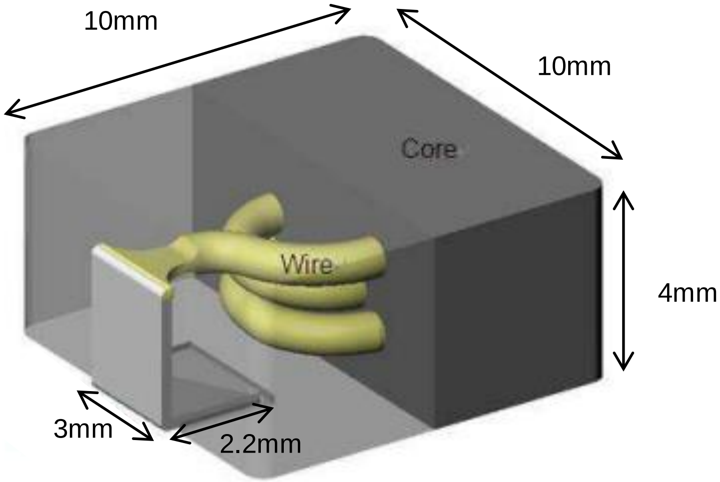


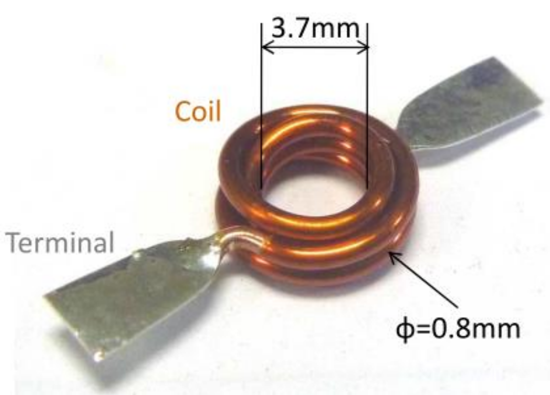
- EMI components
- Inductor
- Transformer
- Heatsink
- PCB Layout

Through thermal simulation, each component's thermal effect can be understood.

- ✓ Components selection
- ✓ PCB layout evaluation

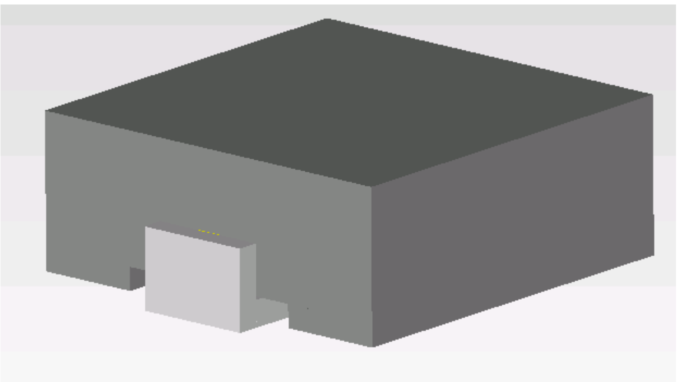
Inductor Thermal Model on FloTHERM

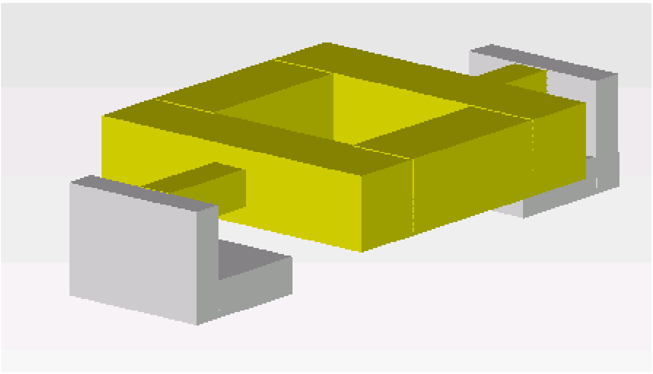




漆包線直徑：0.8mm
繞線內徑：3.7mm
圈數：內圈2圈、外圈2圈

Building Thermal Model

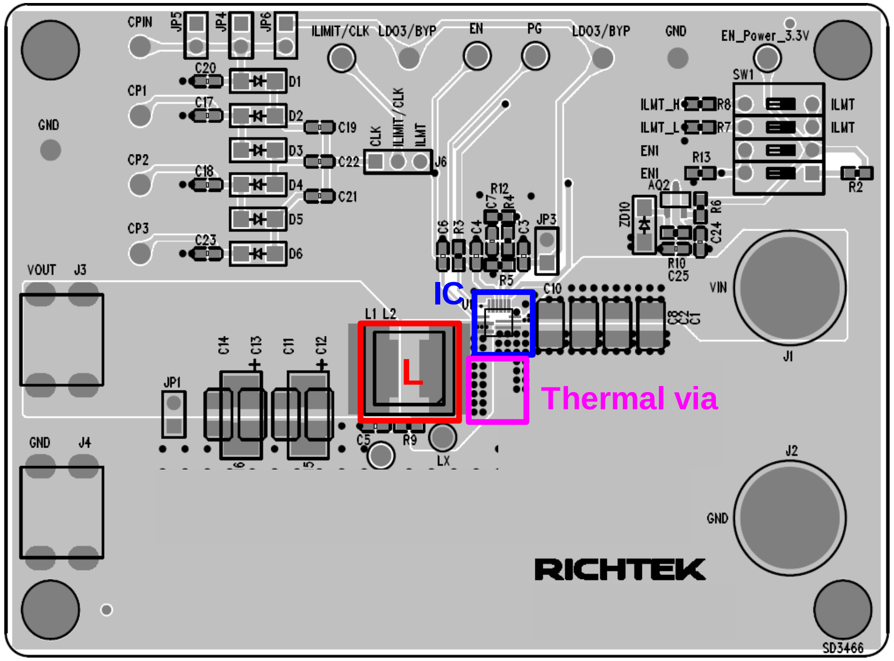




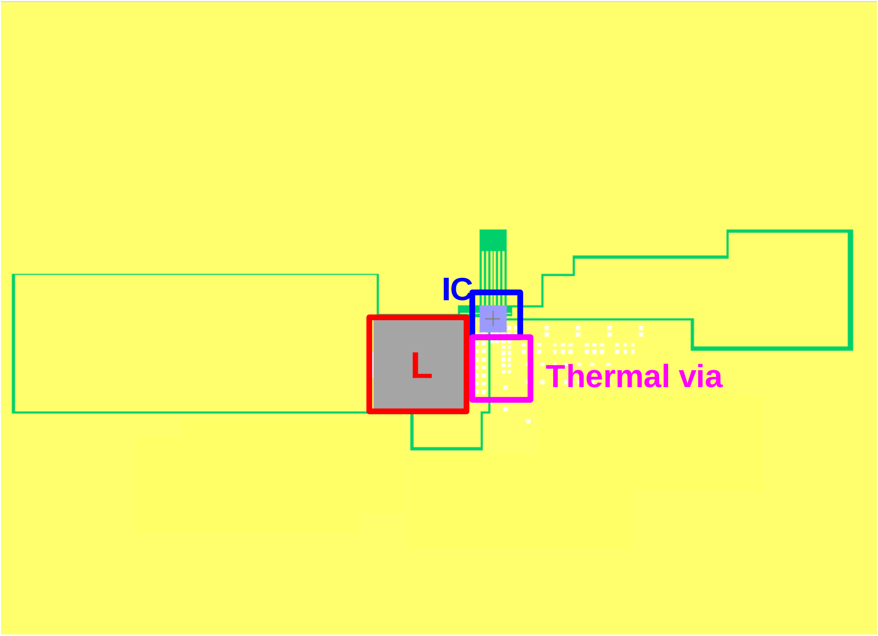
Material	Conductivity
Powder	4.353 (W/mK)
Terminal	385 (W/mK)
Copper wire	385(W/mK)
Solder 63/67	59(W/mK)

Thermal Simulation on FloTHERM

- **Real Board**



- **Constructed FloTHERM Model**



How to define correct power dissipation on each components under a specific condition? P_{IC}=?, P_L=? & P_{PCB}=?

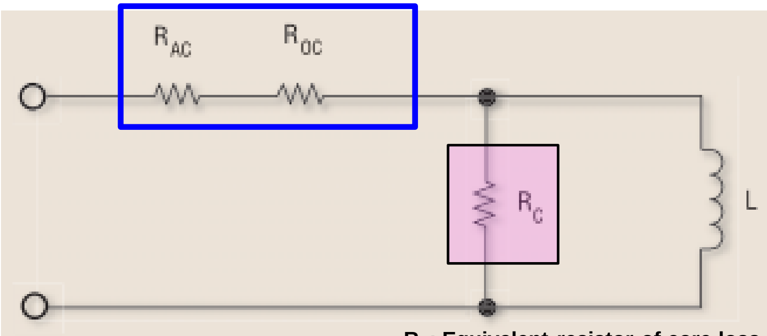
Elements of Inductor Losses

Copper loss

$P_{AC} = I_{ac,rms}^2 \times R_{AC}$

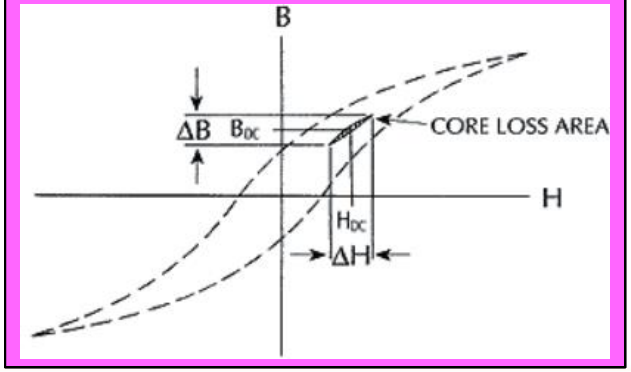
$P_{DC} = I_{dc}^2 \times R_{DC}$

Equivalent circuit of inductor



R_C: Equivalent resistor of core loss

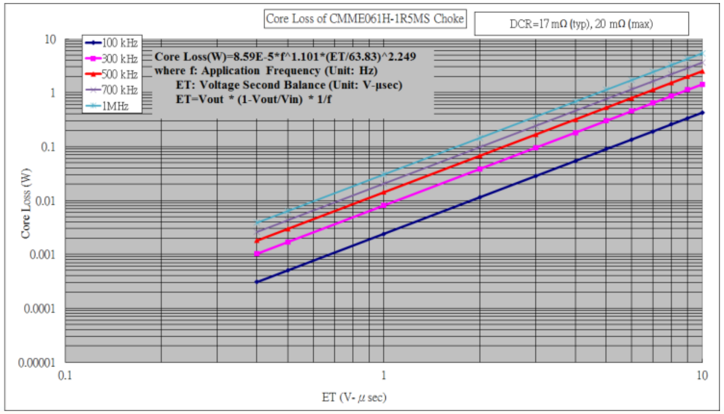
Core loss



Power Dissipation Estimation_Inductor

What does **INDUCTOR LOSSES** be made up?

- DCR: Wire loss caused by dc resistor is constant
  - ➢ **Easy prediction and calculation by current injection method**
- ACR: Wire loss caused by AC resistor is varied with frequency
  - ➢ **Easy prediction and calculation by LCR meter**
- **Core Loss: Material loss caused by EΔt (Ripple current)**
  - ➢ **It is hard to measure and calculate directly.**
  - ➢ **Vender provides core loss curve or coefficients of core loss formula**



$$P_{core}\,(mW) = K_1 f^x B^y \times V_e$$

Where:

K_1 = Constant for core material

f = Frequency in kHz

B = Peak Flux Density in kGauss

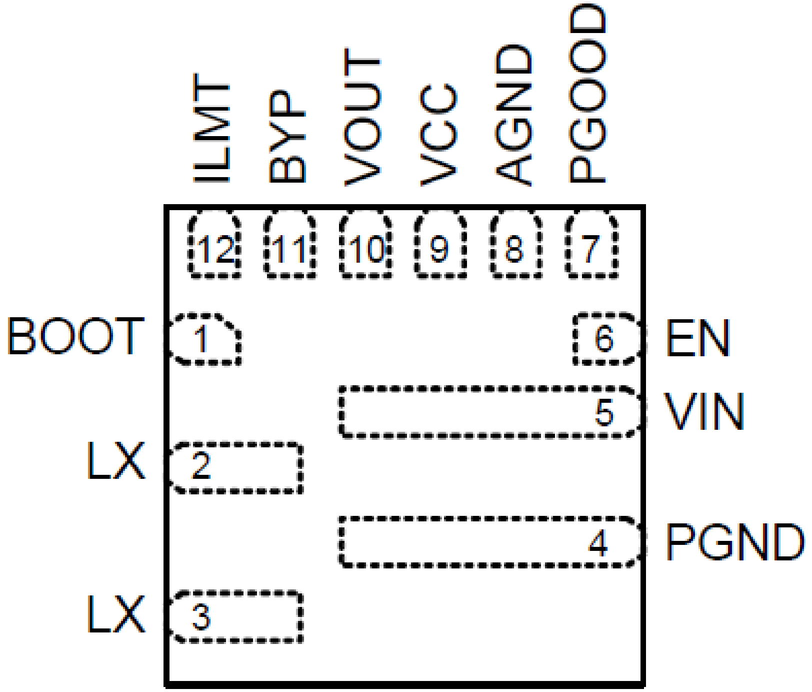
x = Frequency exponent

y = Flux Density exponent

V_e = Effective core volume (cm^3)

Power Dissipation Estimation_IC

- **Converter IC(MOSFET integrated)**



Power Losses Component:

High-side MOSFET:

- Conduction Loss= $I_{rms}^2 \cdot R_{DS(on)}$
- Switching Loss= $I_{DSW} \cdot V_{DS}$

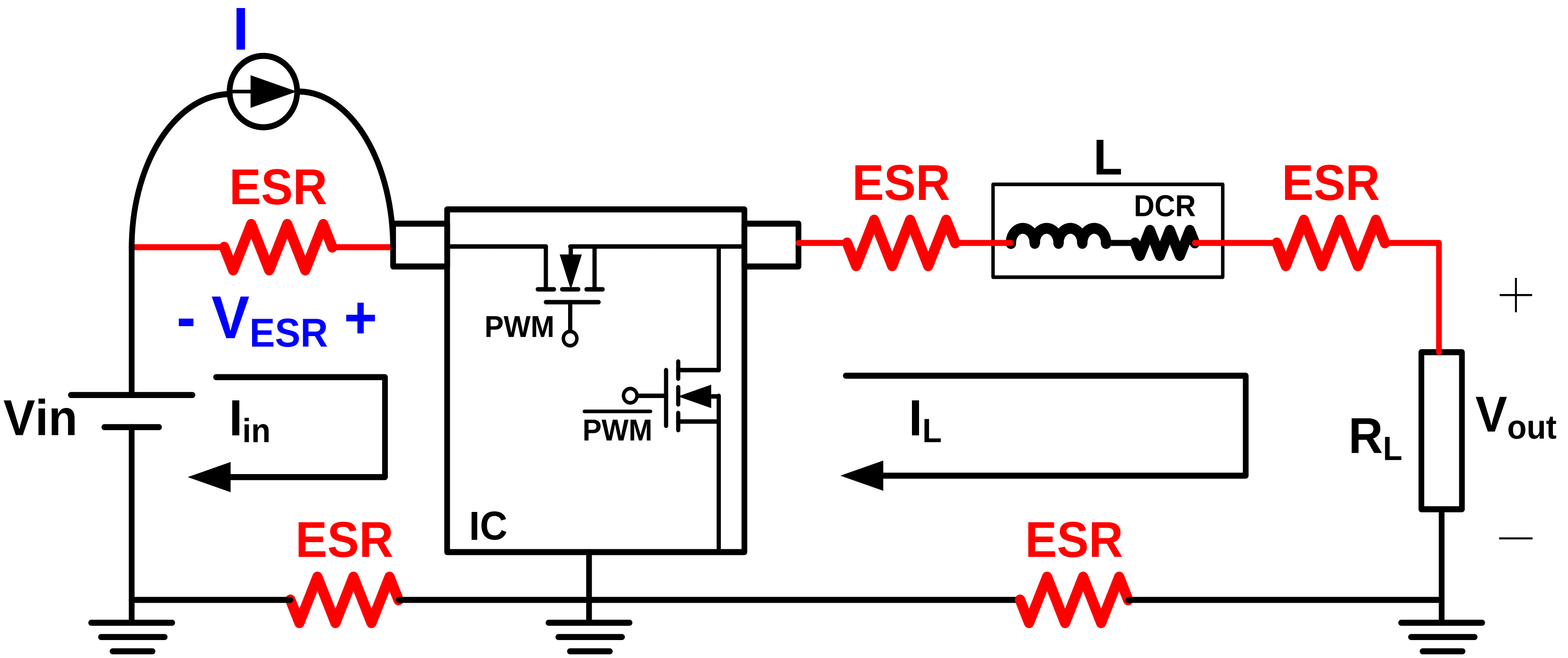
Low-side MOSFET:

- Conduction Loss= $I_{rms}^2 \cdot R_{DS(on)}$
- Switching Loss= $I_D \cdot V_{DS}$

VCC internal regulator:

- Power consumption= $V_{CC} \cdot I_{CC}$

Power Dissipation Estimation_Trace Loss



$$ESR = \frac{V_{ESR}}{I}$$

where,

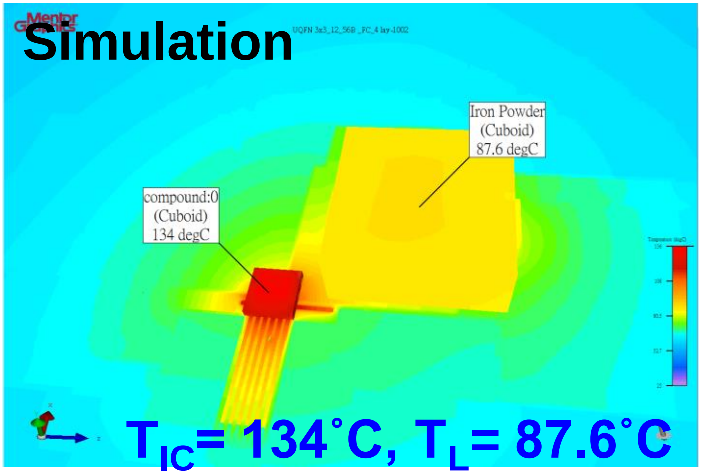
I: Injecting current

V_{ESR}: Measured voltage of ESR

Experiment and Simulation Verification

- **Case Study 1:**

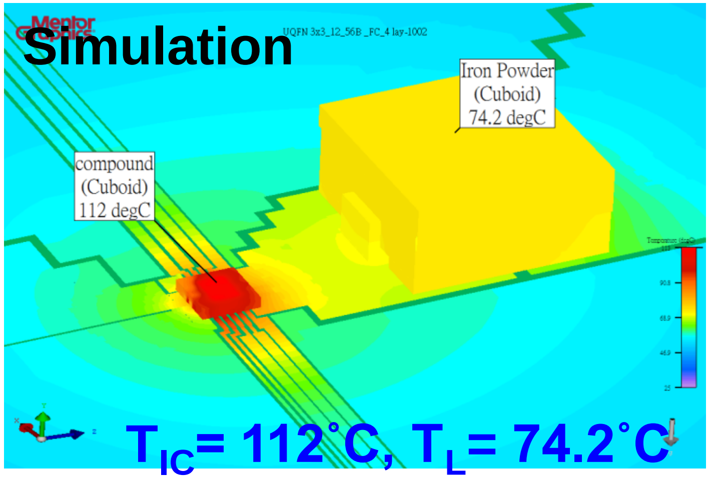
Thermal Model		
Chip	8A Converter IC	
Inductor	1uH/10*10*4mm^3	
Test Condition		
V_{in}(V)	V_{out}(V)	I_{out}(A)
19	3.3	8
Power Dissipation		
P_{d_IC}(W)	P_{d_L}(W)	P_{d_trace}(W)
2.194	1.041	0.214

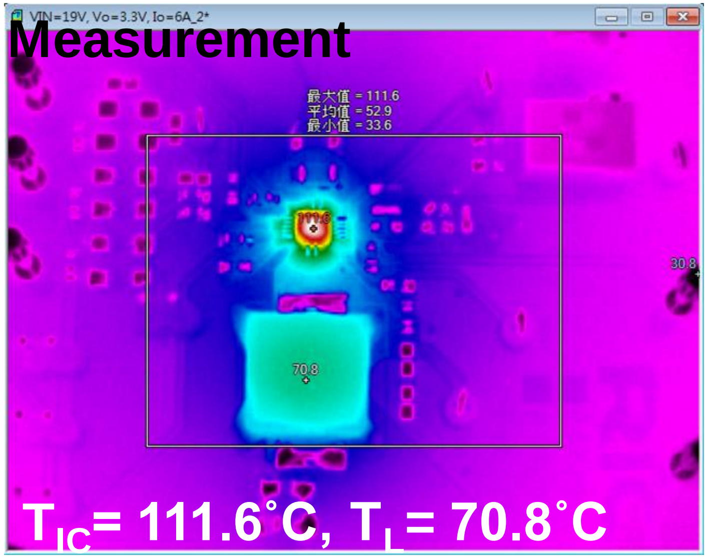


Experiment and Simulation Verification

- **Case Study 2:**

Thermal Model		
Chip	6A Converter IC	
Inductor	1uH/10*10*4mm^3	
Test Condition		
V_{in}(V)	V_{out}(V)	I_{out}(A)
19	3.3	6
Power Dissipation		
P_{d_IC}(W)	P_{d_L}(W)	P_{d_trace}(W)
1.729	0.927	0.3

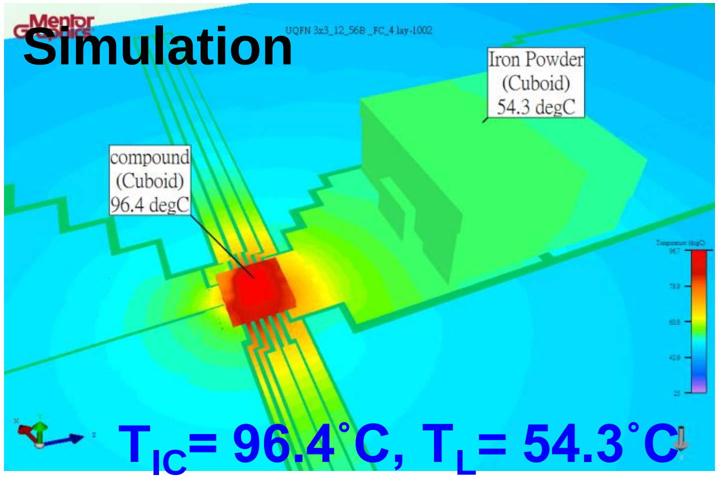


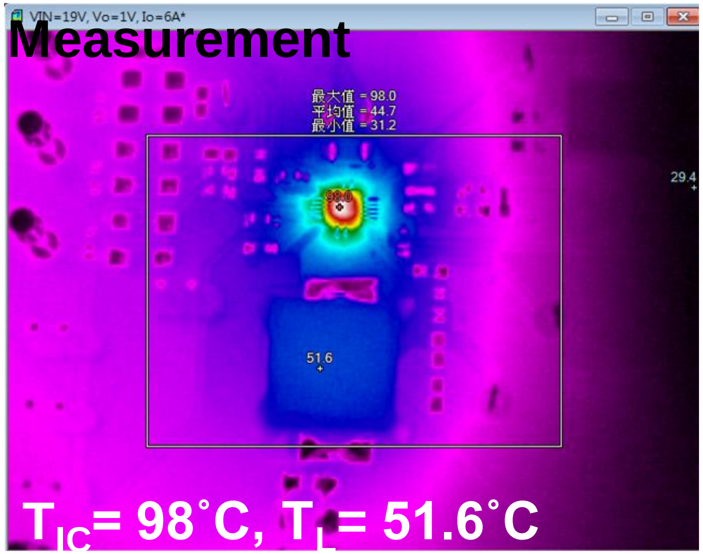


Experiment and Simulation Verification

- **Case Study 3:**

Thermal Model		
Chip	6A Converter IC	
Inductor	1uH/10*10*4mm^3	
Test Condition		
V_{in}(V)	V_{out}(V)	I_{out}(A)
19	1	6
Power Dissipation		
P_{d_IC}(W)	P_{d_L}(W)	P_{d_trace}(W)
1.53	0.286	0.3

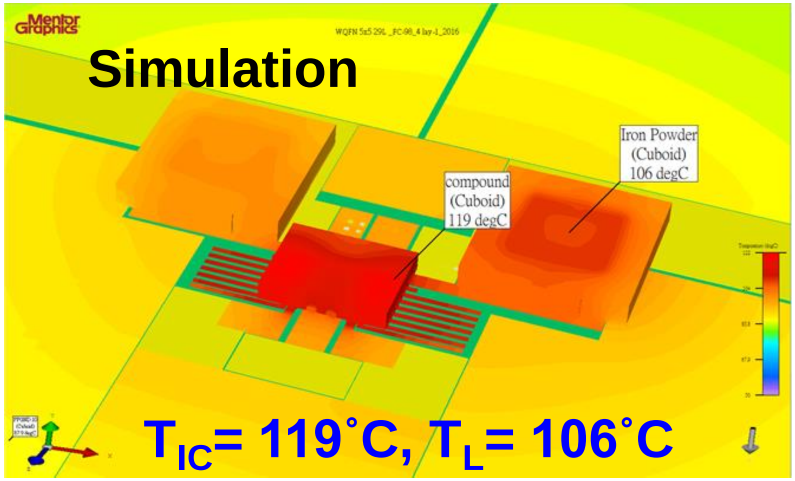


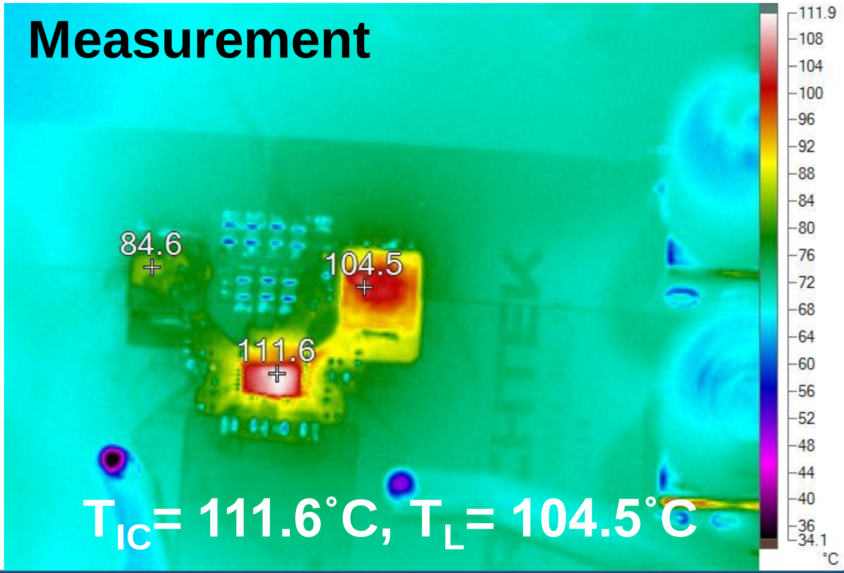


Experiment and Simulation Verification

• Case Study 4: Multi-Die IC

Thermal Model			
Chip	MCM IC		
Inductor	1.5uH/7.4*6.8*1.8mm^3		
Test Condition			Ta=50ºC
V_{in}(V)	V_{out}(V)		I_{out}(A)
Converter			
19	3.3		2
	5.1		2
LDO			
19	3.3		50m
	5.1		20m
Load Switch			
3.3	3.3		1
5.1	5.1		3
Power Dissipation			
P_{d_IC}(W)	P_{d_L}(W)		P_{d_trace}(W)
2.106	0.35(3.3V)	0.78(5.1V)	0.101





Summary

1. IC's thermal capability can be simply realized
   - **Package improvement**
   - **Process enhancement**
   - **IC layout optima design**
2. Understanding every components' thermal effect in system board
   - **Component selection**
   - **Layout arrangement estimation**
   - **Thermal dissipation prediction**

Q&A