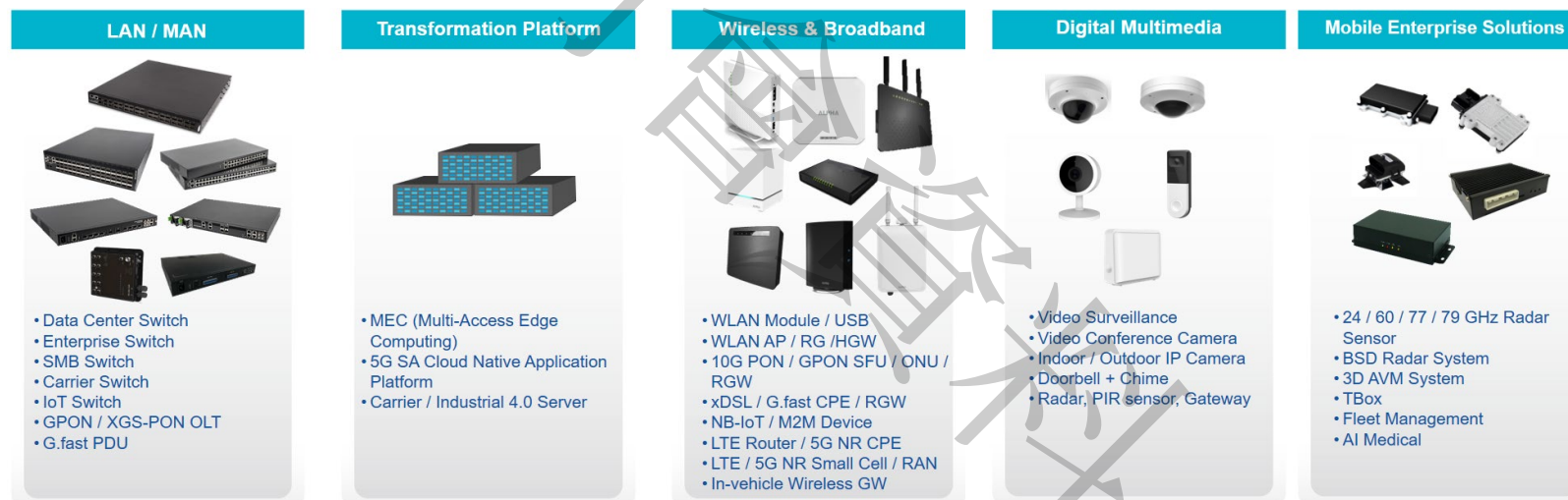


5G基地台最佳化散熱鰭片

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前言

隨著5G的出現，許多智慧應用與數位服務已經有了廣泛的市場應用，高通近期財報中預估2025年全球5G的連網數將有30億，並且5G網路基礎建設市場將超過80億美元[1]。為了因應網通設備在高速網路條件下的市場需求，許多散熱部門致力研發於使用不同散熱技術增加廢熱的排除，其中不乏應用於5G基地台與5G相關設備的設計。

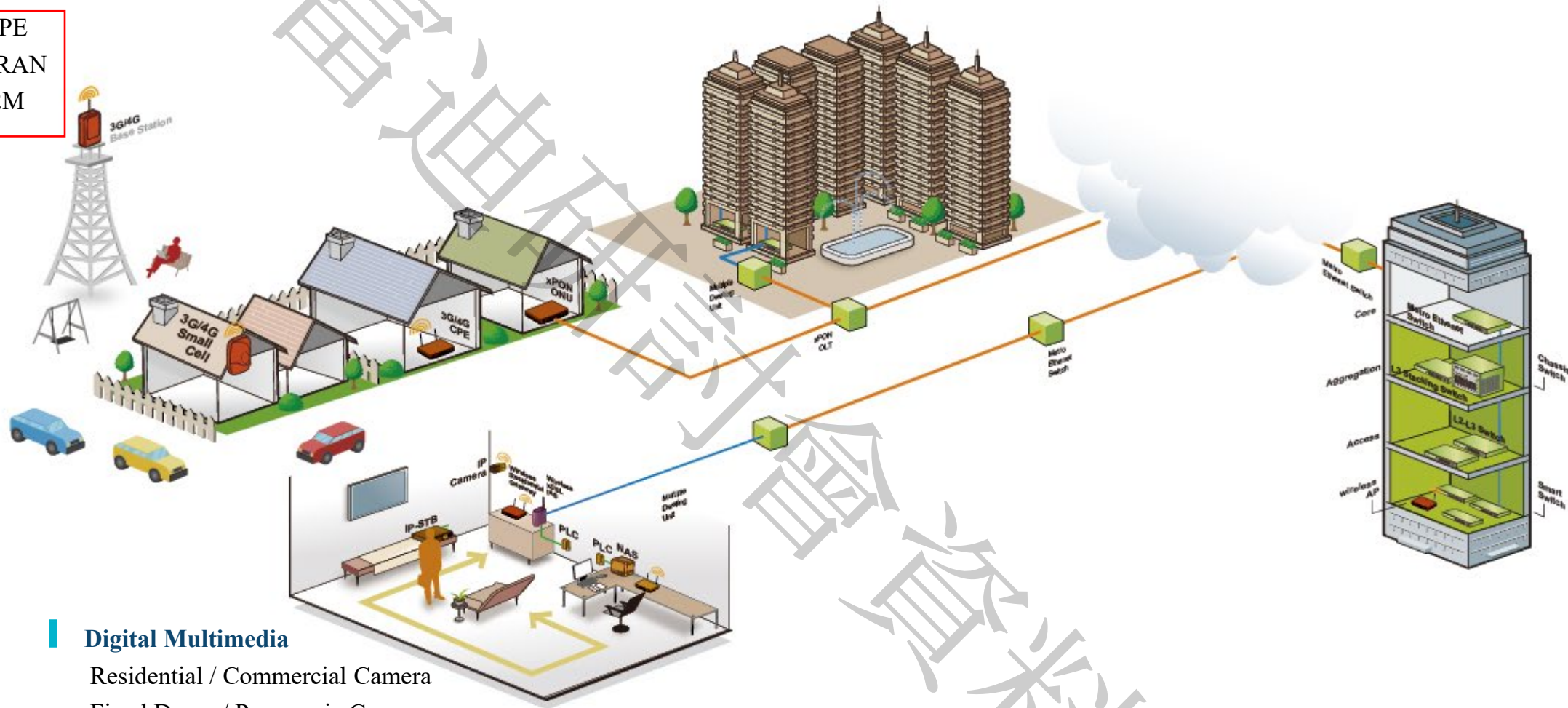


5G Networks

• Network Product Portfolio

• Mobile Broadband

- 5G & LTE CPE
- LTE-A / 5G RAN
- NB-IoT / M2M



Digital Multimedia

Residential / Commercial Camera
Fixed Dome / Panoramic Camera
Battery / Doorbell / Fisheye Camera
Full HD, 4K, Edge AI

散熱鰭片簡介與回顧

- 鰭片的幾何外形可以改變流體的流動性質，指出平板鰭片幾何性質流動較單一，因此側流效應是最少的。
- 此外散熱面積與鰭片之密距相關，鰭片密距定義為鰭片內部空氣體積除以總空氣體積，可視為鰭片內部的阻力，隨著密距越密，鰭片流阻將會變大。
- 循環流受到鰭片幾何影響分割成數個對流細胞，鰭片間距太小時，將會使循環對流阻力增加而使流動強度減弱，流體將無力形成對流細胞的現象。

5G RU Model

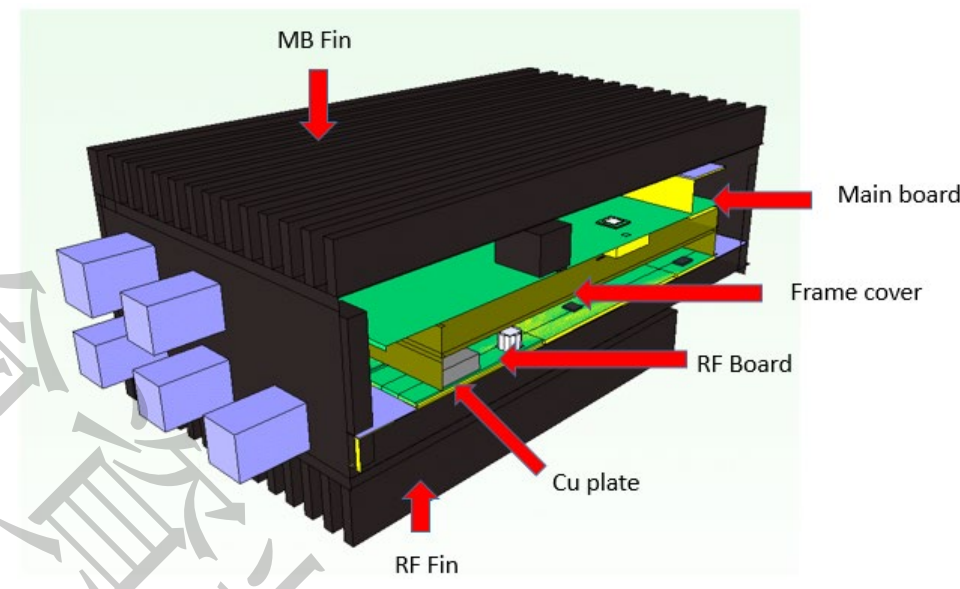


模擬架構與方法

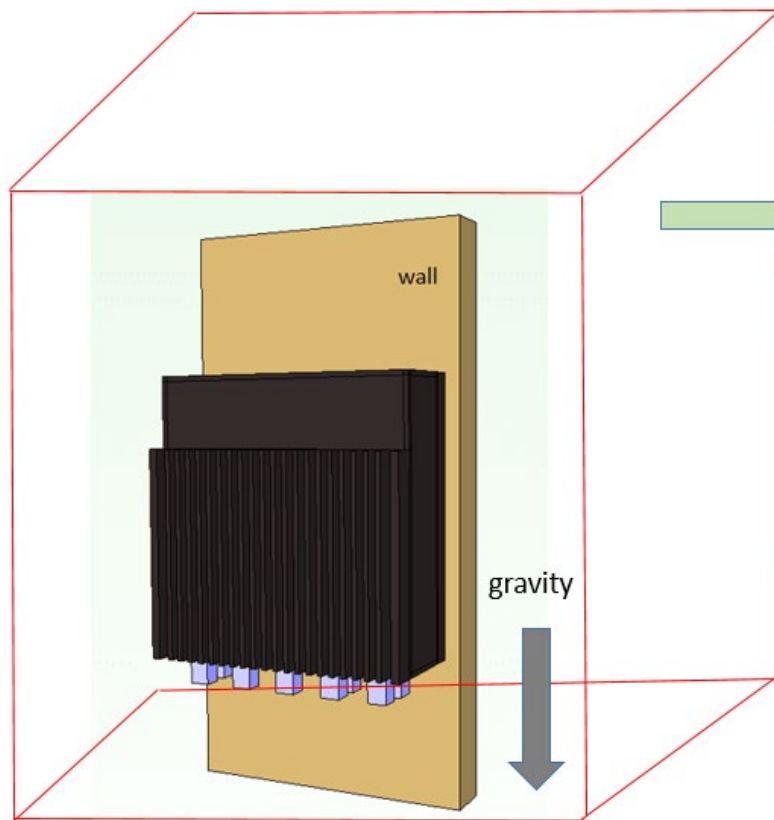
數值模擬架構為圖中所示，模擬使用Flotherm，機構3D零件由MCAD轉進模擬，進行最佳化則以Command Center功能進行輔助。

模擬模型假設條件為

- 空氣流體為均勻、穩態、層流以及自然對流
- 考慮熱輻射效應
- 固體材料依照不同熱物性為常數
- 環境溫度為定值50 °C



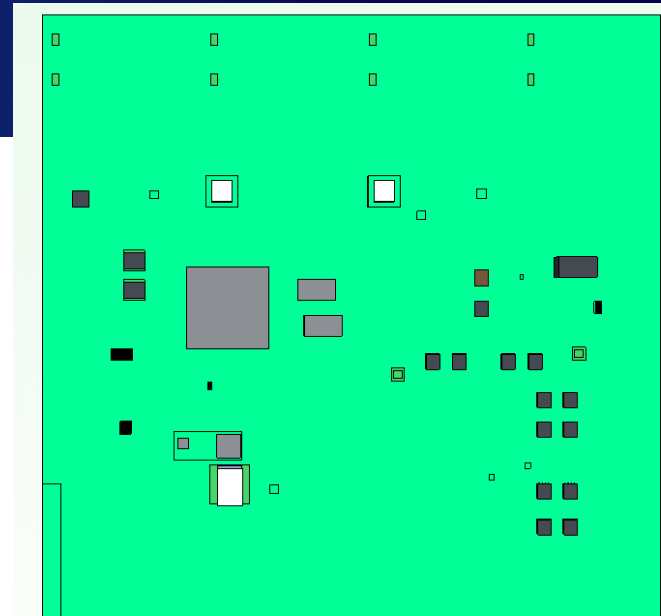
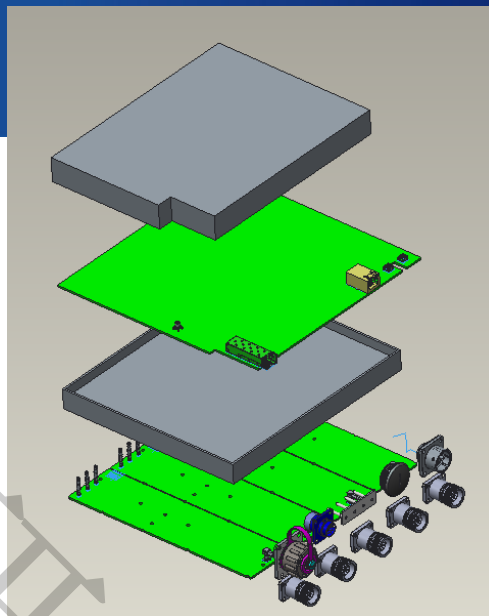
5G RU模型與架構



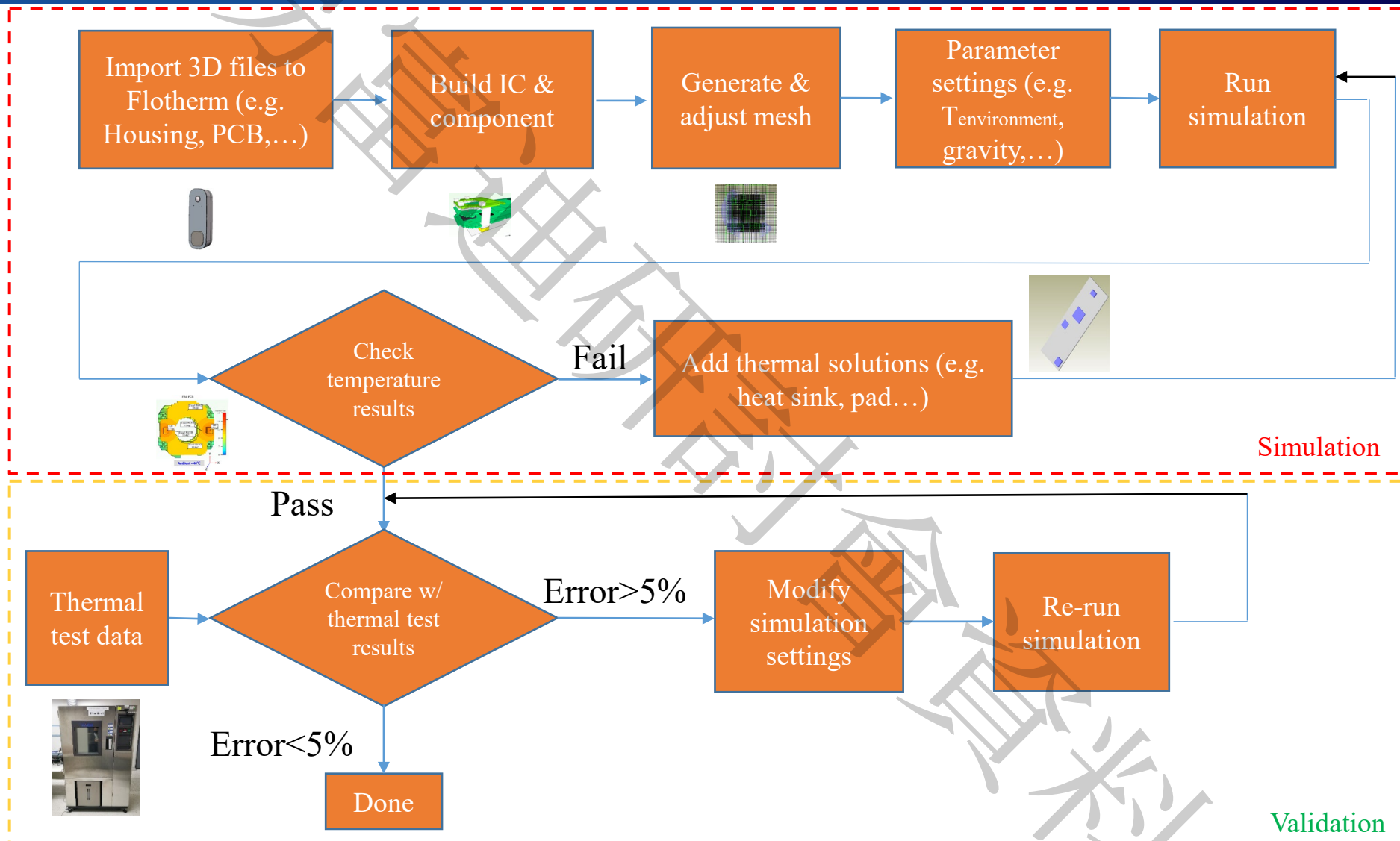
Boundary open,
50 °C

環溫:50度C
自然對流條件
層流型態
考慮熱輻射
穩態

整機防水故無開對外開孔



模擬流程



內部散熱結構

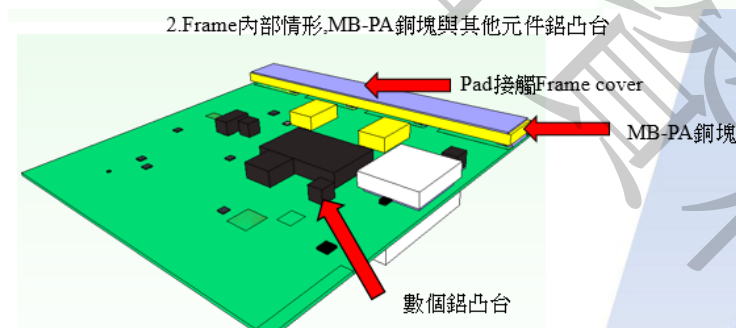
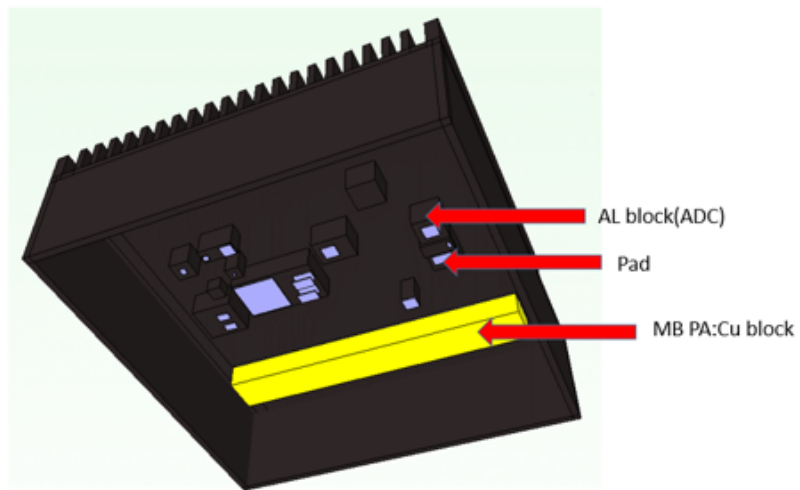
由於散熱鰭片採外露方式，本案的散熱鰭片為散熱途徑的末端，途徑前端則是IC到Housing殼體的傳熱途徑，因此內部如何將廢熱導至外殼，減少殼體不均熱的情況，充分利用外露散熱鰭片的效能，才能達到整體的散熱最佳化。本案內部結構的考量如下：

➤外殼壓鑄件內部長凸台接觸IC的pad

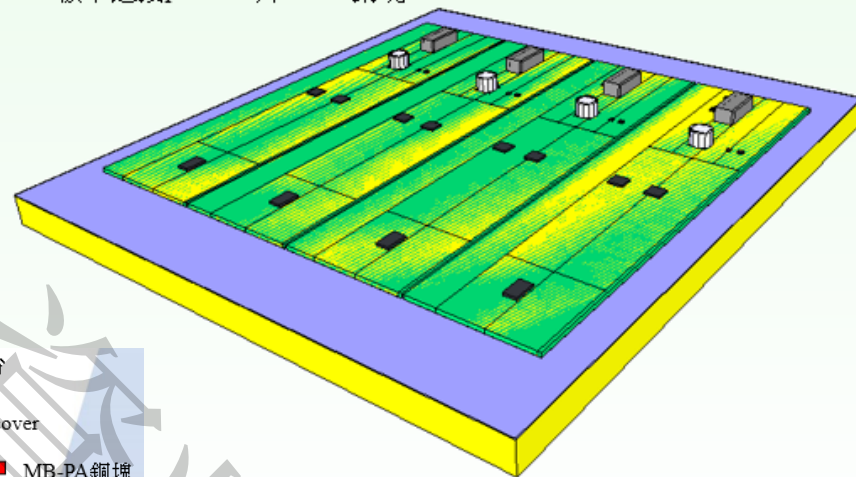
➤PCB版上的鋪銅&Via

➤PCB往外殼靠,減少到殼的傳熱距離

- 1.上蓋(MB側)採用數個凸台,由鋁壓鑄殼延伸長出
- 2.MB PA元件採用板背部加銅塊接觸Frame

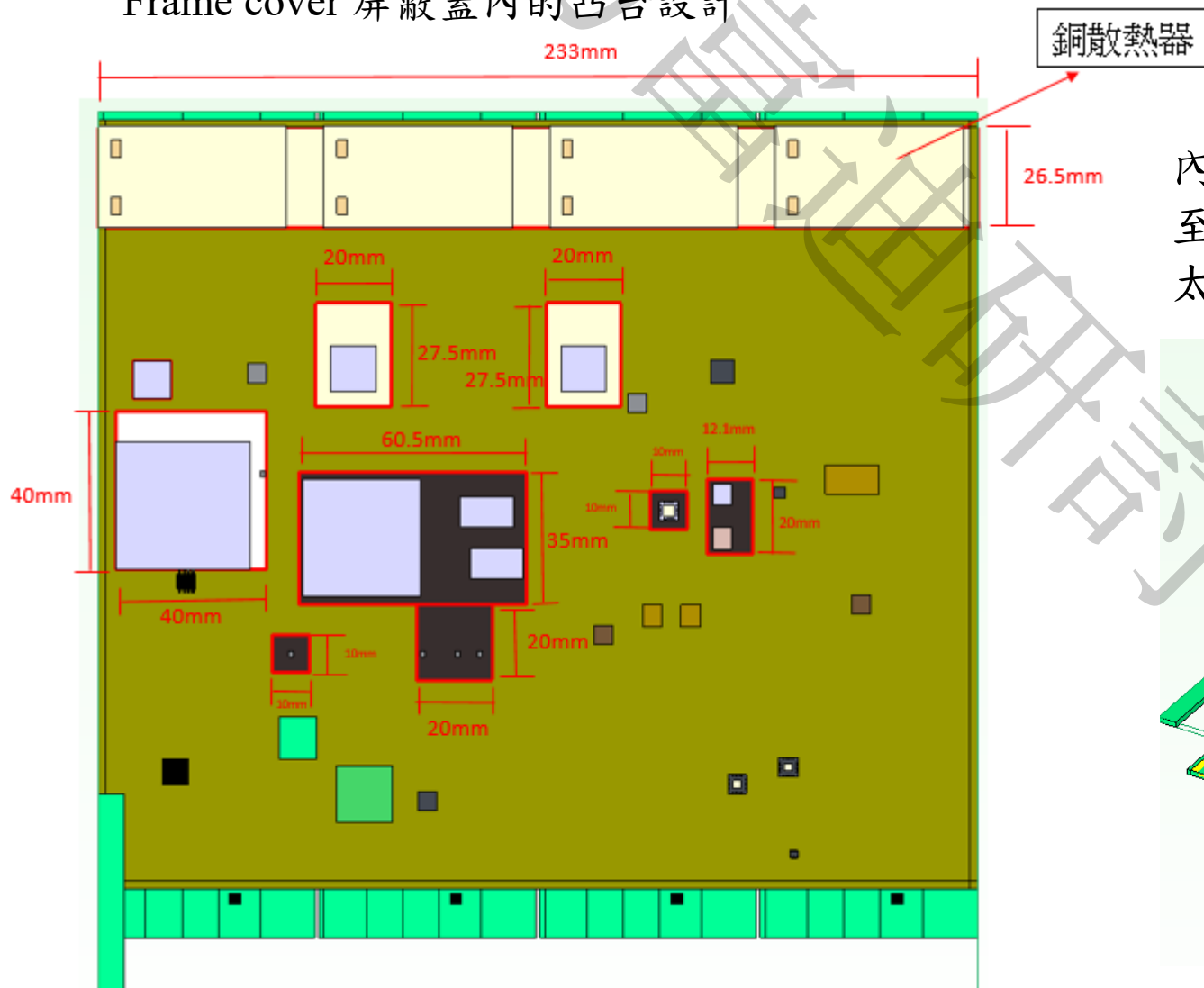


RF板上 具有Ground & via,
RF板下連接pad&一片14mm銅塊

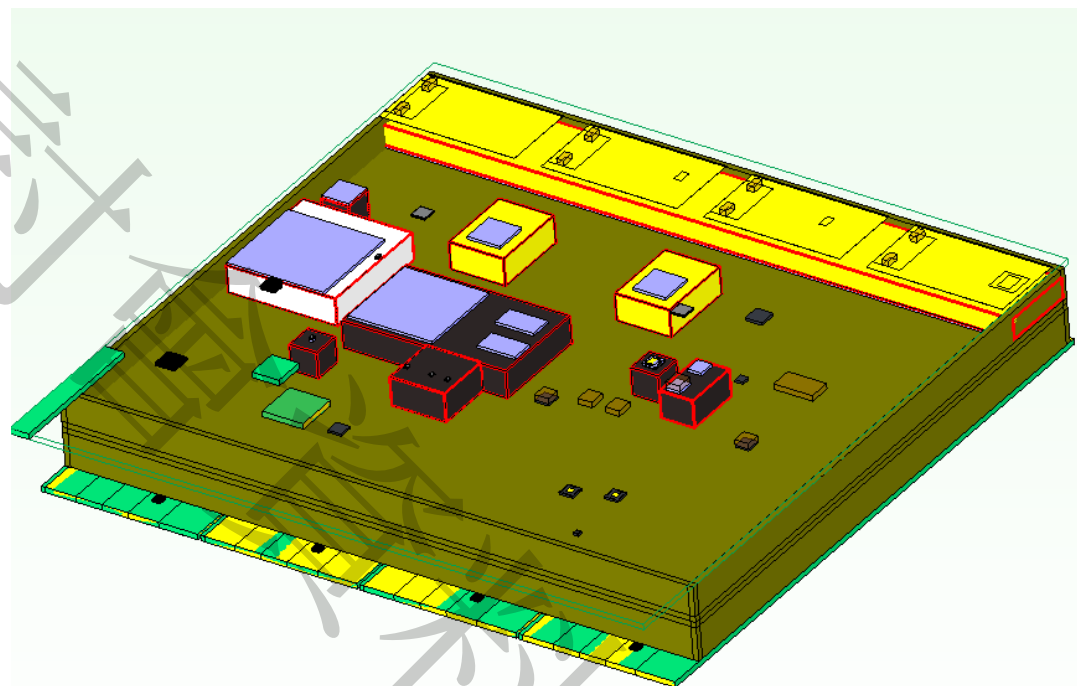


內部散熱結構

Frame cover 屏蔽蓋內的凸台設計



內部的凸台與pad需配合公差，才能有效將熱傳至殼體，並且需注意金屬殼若有推滑動組裝，太薄的pad可能會破損



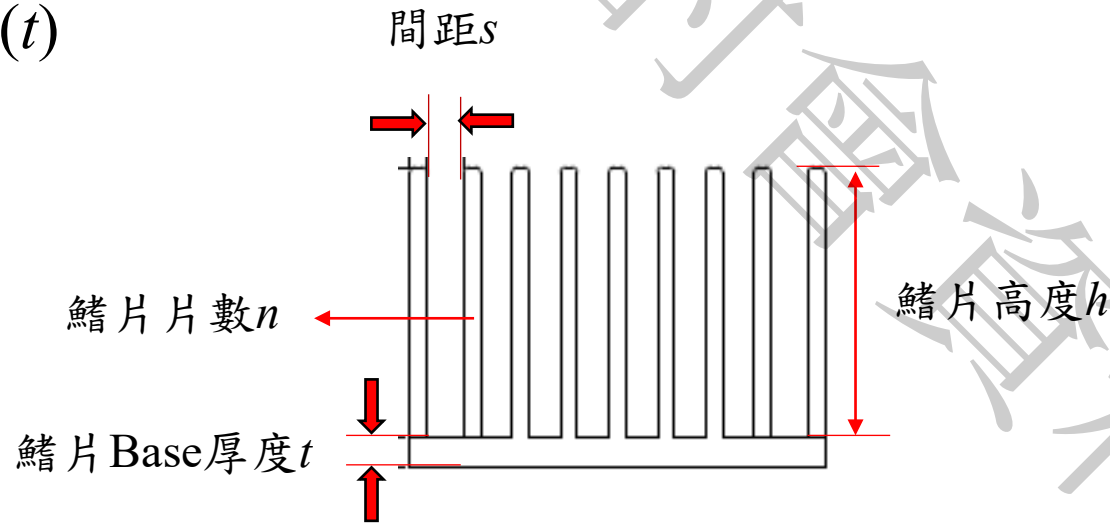
外部散熱結構

本案量產採用壓鑄鋁殼具有一體成型的外露鰭片，影響散熱鰭片效能的因素諸多，但考量實際量產時製程上的可行性，與成本上是否over design，藉由模擬前端設計與實測驗證經驗，本案針對下述鰭片參數進行優化

➤ 鰭片片數(n)與間距(s)

➤ 鰭片Base厚度(t)

➤ 鰭片高度(h)



Thermal simulation



Heatsink Optimization

Parameter

1 →
2 →

	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Heat Sink : Number of Internal Fins	10	9	17	18
Heat Sink : Number of Internal Fins	10	9	17	18
Solution Status	All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...
Store Results?	History Only	History Only	History Only	History Only
Initialize From	Base Project	Base Project	Base Project	Base Project
U1-1-QPD0405* : Temperature (°C)	131.2134	131.8541	131.6437	131.5544
U1-1-QPD0405* : Temperature (°C)	131.2636	131.8115	131.5459	131.6275
U62-XCZU9CG-2FFVC900 : Temperature (°C)	92.32994	92.93474	92.55379	92.51733
U61-MT41K512M16HA-125IT : Temperature (°C)	87.04222	87.59713	87.21899	87.22739
U66-MT41K512M16HA-125IT : Temperature (°C)	87.09529	87.64122	87.29564	87.31564

worst

Use simulation function “command center” to optimize :

- **Total Fin numbers** = internal fins +2 (due to fix first and last fin).

best

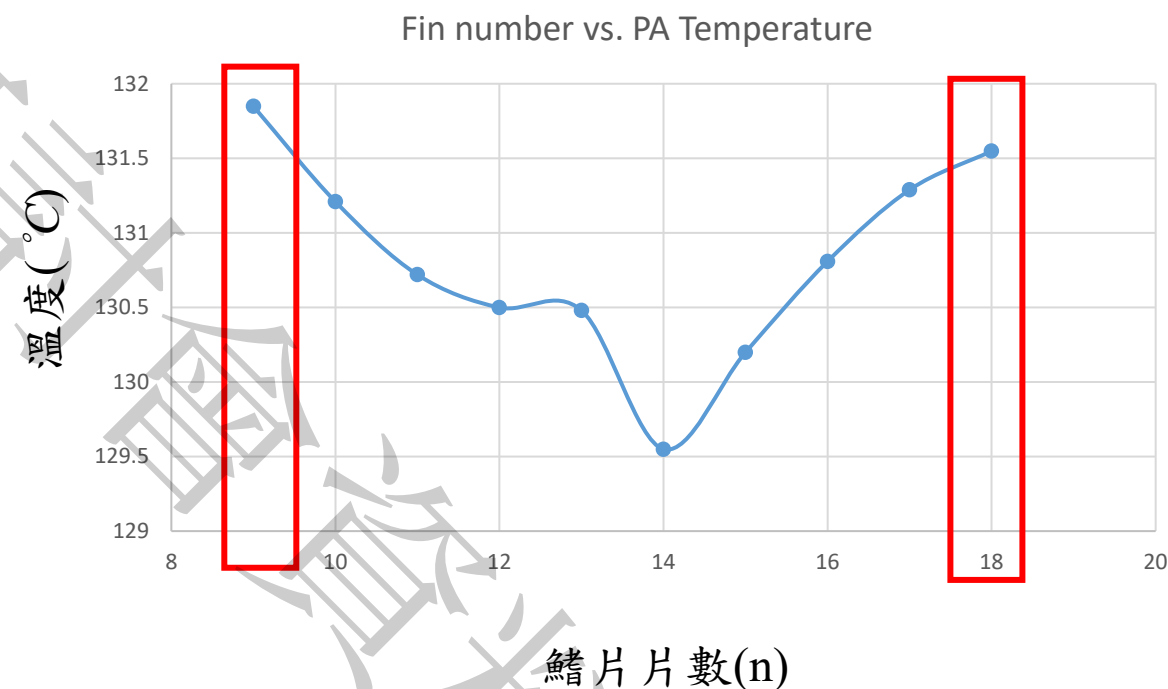
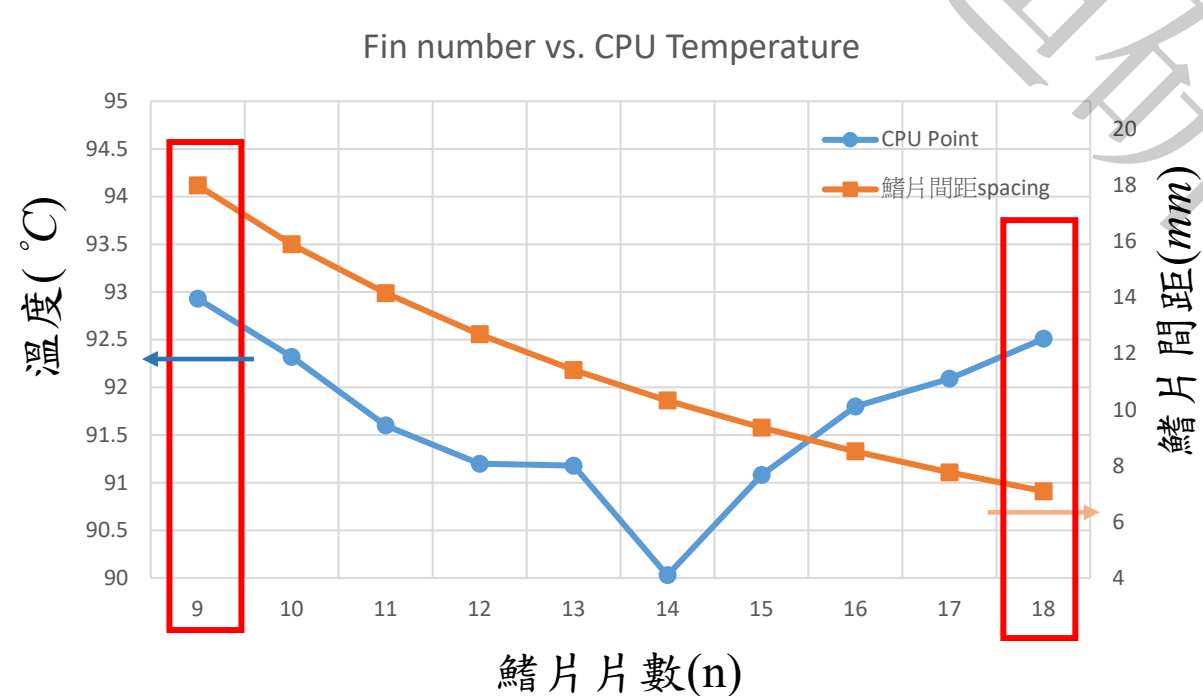
9 fins vs. 14fins 散熱面積增加45%
9 fins vs. 18fins 散熱面積增加1倍
but

Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
15	14	13	12	11
15	14	13	12	11
All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...
History Only	History Only	History Only	History Only	History Only
Base Project	Base Project	Base Project	Base Project	Base Project
130.202	130.1885	130.4831	130.5002	130.7289
130.3032	130.102	130.5063	130.5339	130.8258
91.08107	90.86771	91.18659	91.20535	91.6068
85.68021	85.49567	85.81374	85.76545	86.21706
85.76416	85.57366	85.88187	85.83392	86.27602

- **Best optimized result :**
Heatsink with 14fins
CPU ↓ 2.07 °C
PA ↓ 1.6 °C

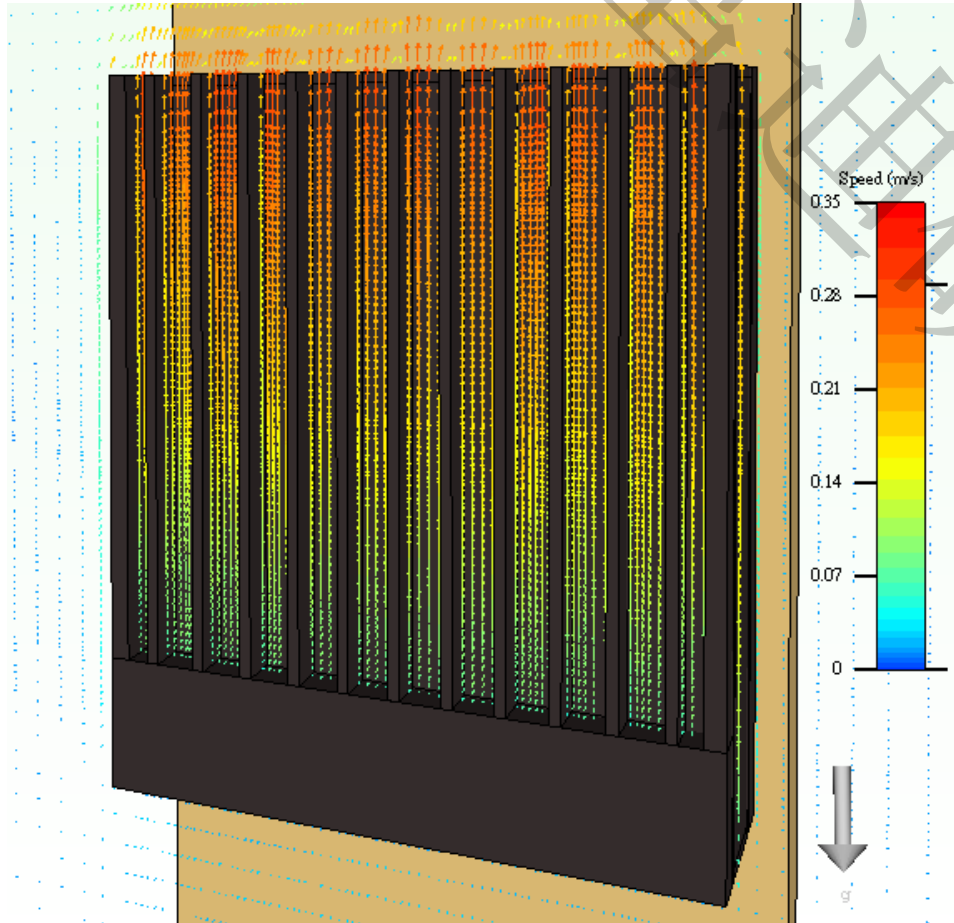
間距&片數探討

最佳化模擬的鰭片片數由9至18片，最佳片數為14片(鰭片間距為10.3mm)，CPU溫度為90.86度C，PA溫度為129.55度C。在測試範圍中，最差的片數為9片(鰭片間距為18mm)。

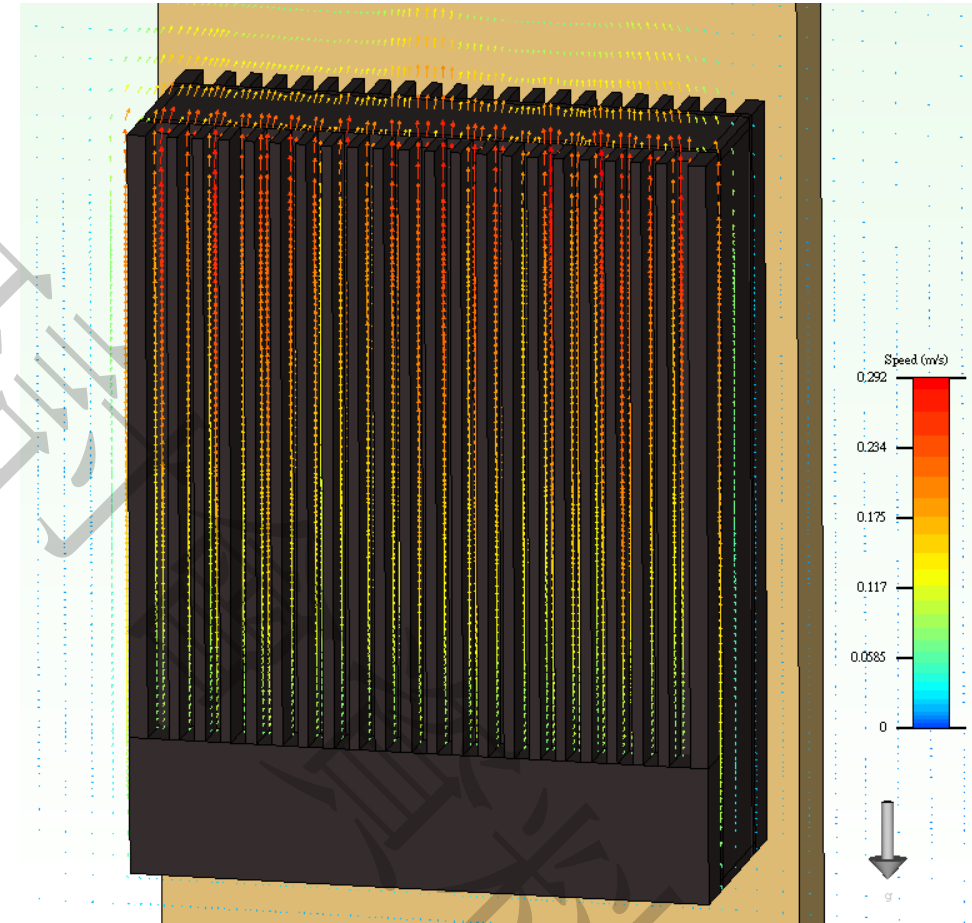


Thermal result : Fin number 9 vs. 18

9 fins vs. 18 fins 內部的空氣流動差異, 9 fins 間距18mm , 18 fins 間距7.1mm



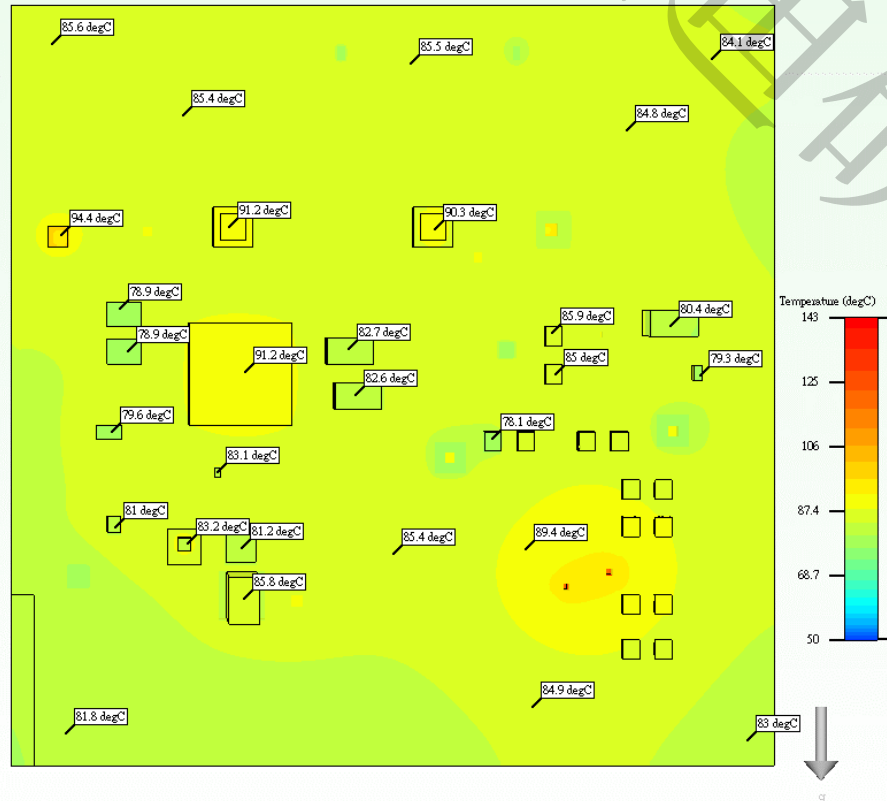
9 fins 空氣流速箭頭圖(m/s)



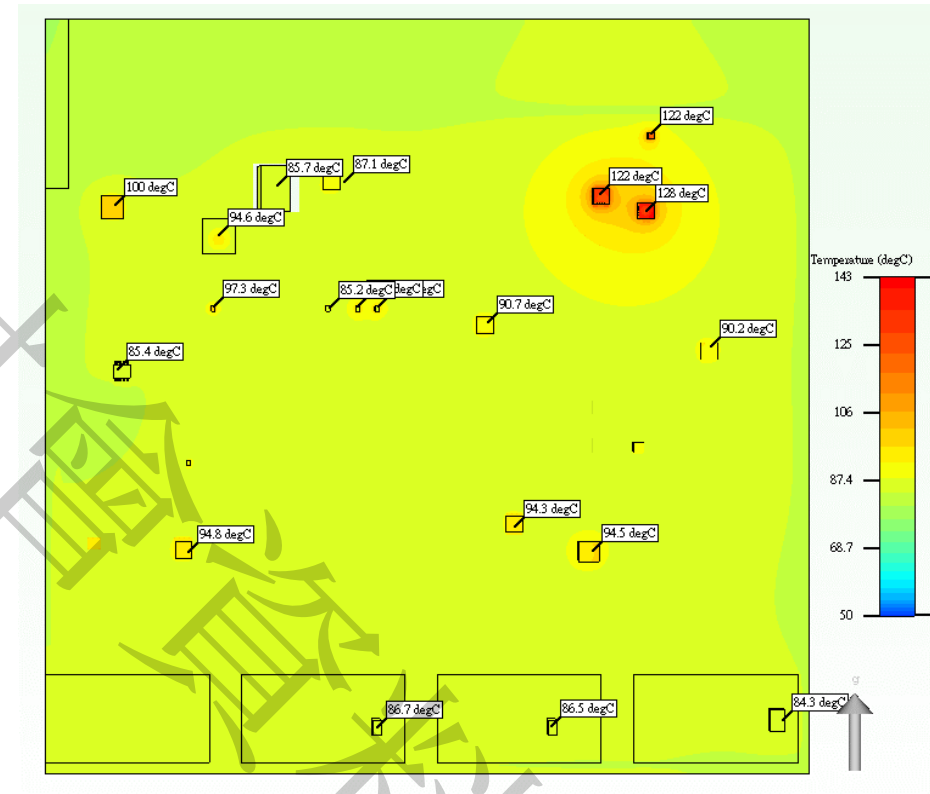
18 fins 空氣流速箭頭圖(m/s)

Thermal result

藉由熱模擬，可預估PCB板溫與元件的溫度分布



PCB正面溫度分佈

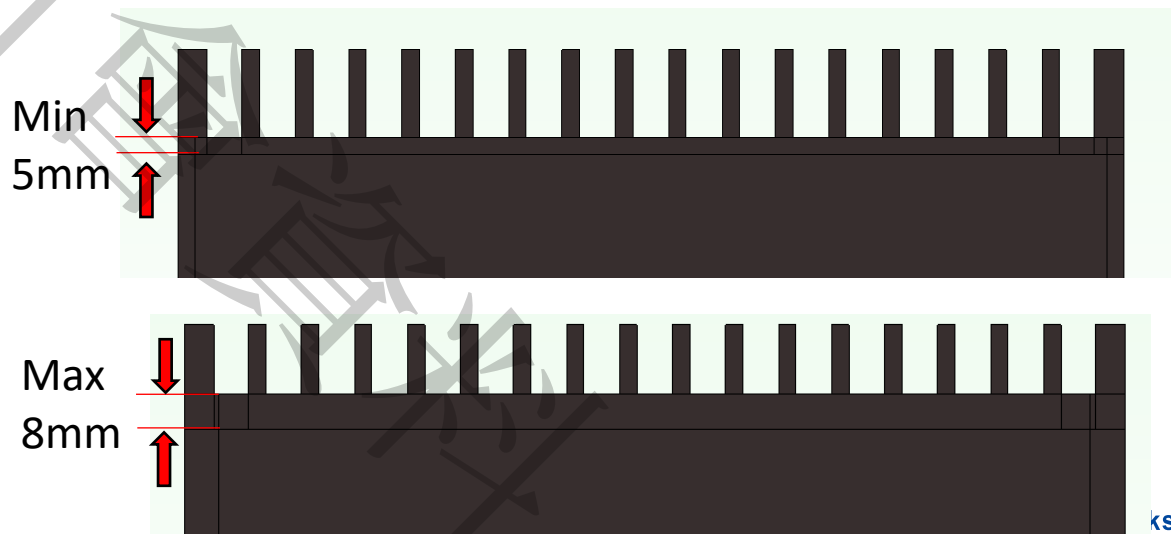
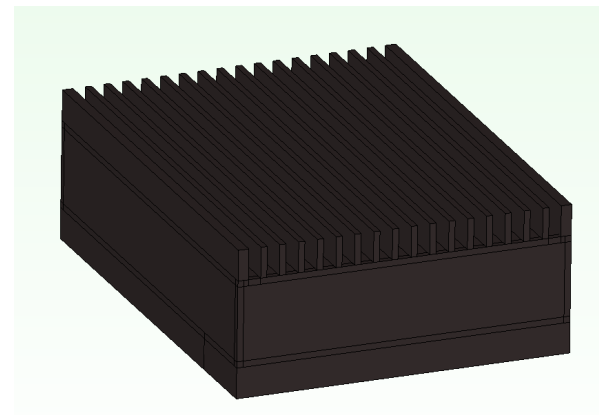
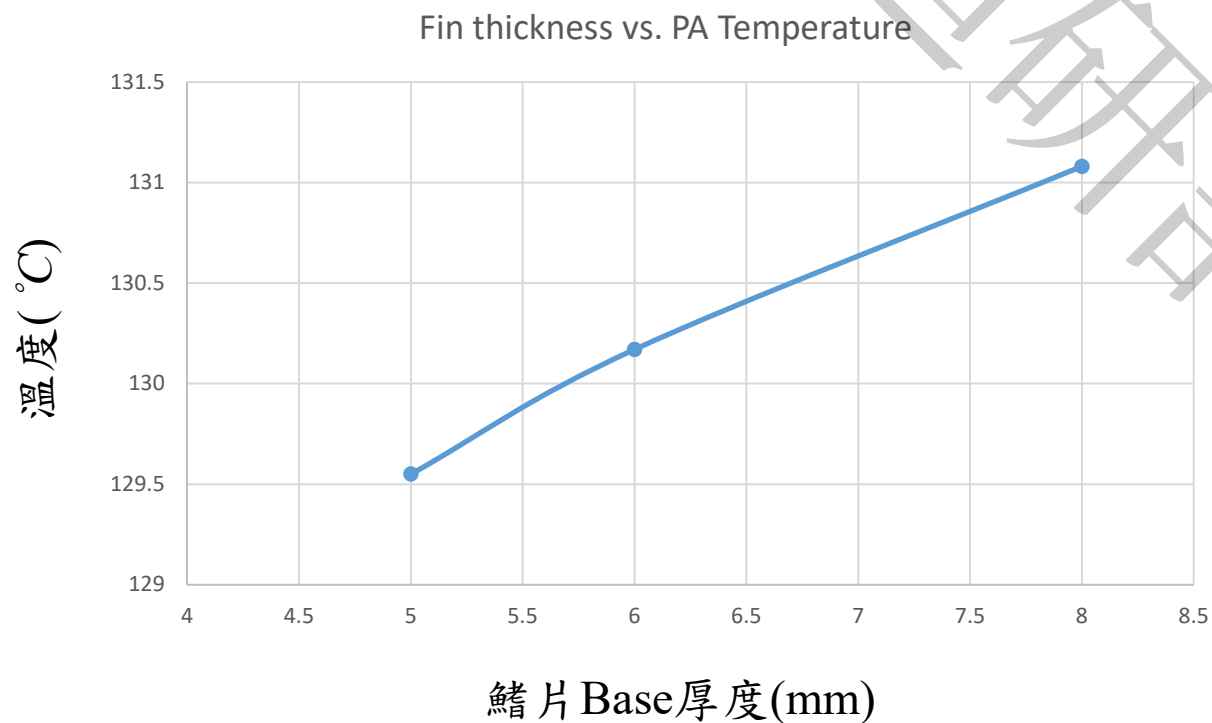


PCB背面溫度分佈

Base厚度探討

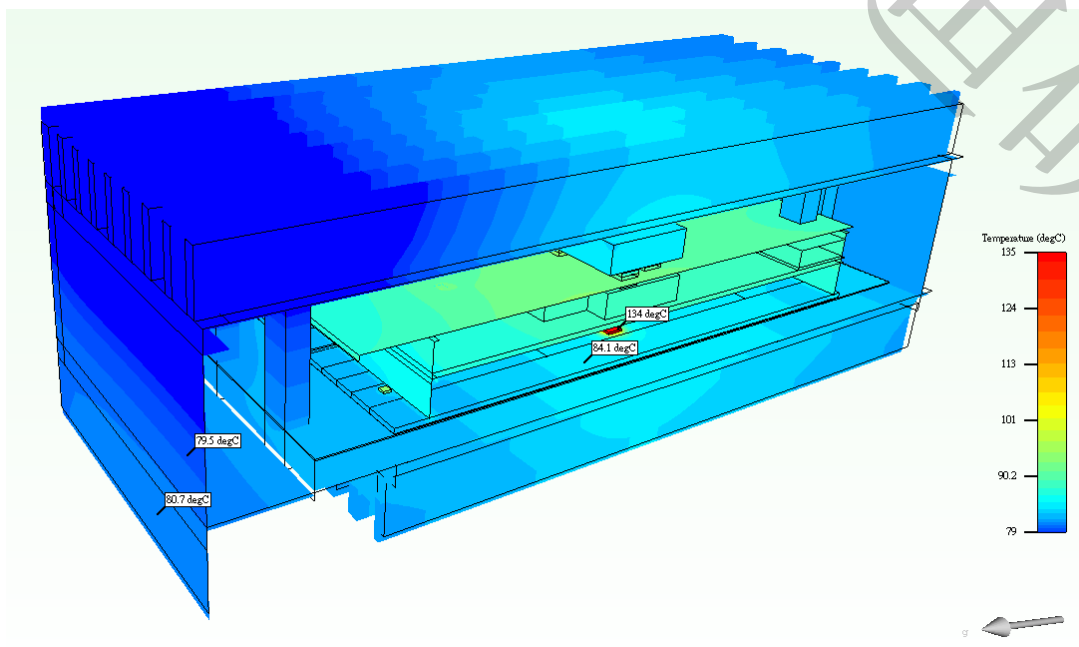
鰭片底座的厚度與熱擴散有相關, 太薄的Base底座, 可能造成底座溫度不均, 量產困難;

太厚的Base底座, 可能造成傳熱至延伸表面的距離增加, 成本上升

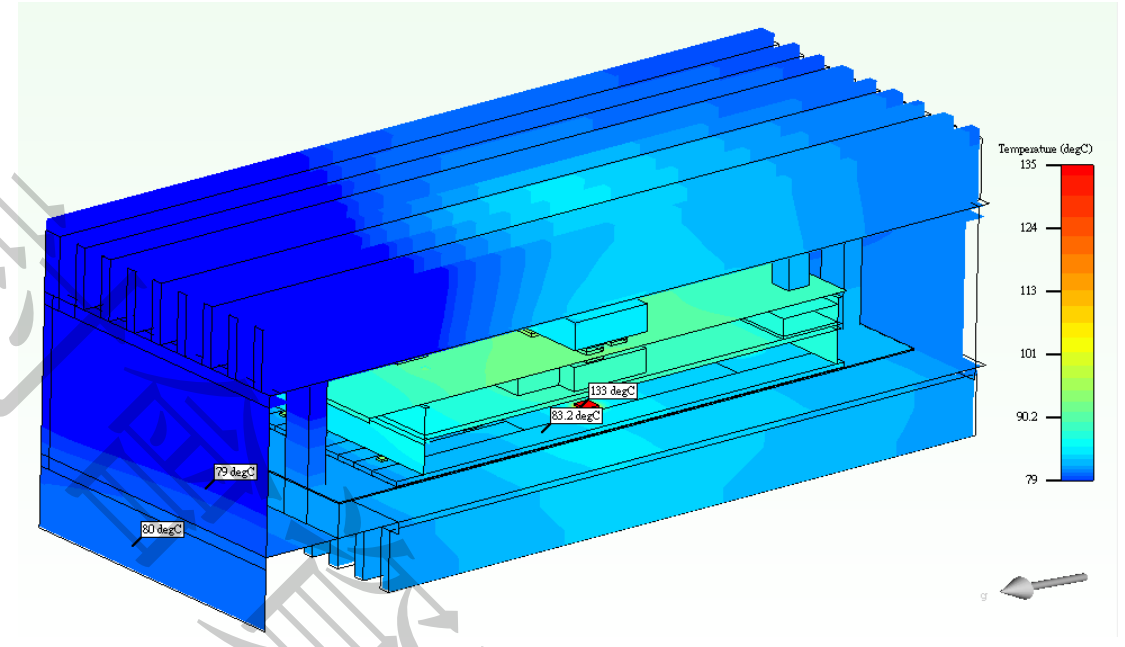


Thermal result : Heatsink Base thickness mm vs. 8mm

PA傳熱至外殼表面的距離變長, 元件與板溫蓄熱, 溫度皆為上升



底座厚度8mm溫度分佈圖



底座厚度5mm溫度分佈圖

結果與討論

- 影響散熱鰭片效率的因素包含鰭片片數&密距、鰭片高度、翅片厚度、鰭片base厚度。
- 模擬結果顯示密距太密的鰭片使得空氣難以通過，造成散熱不良。
- 最佳化結果得知須兼顧散熱面積與空氣流經鰭片的流速作為考量。
- 實際組裝時，PAD需配合公差避免不良的接觸。

Outdoor外在條件探討

考量產品置於戶外環境中，產品的適應性會有氣候因素的考量，如冬季高緯度地區，是否需要加熱系統使IC達開機溫度；夏季的太陽輻射，日照量是否會使產品於較差的條件下超出規範。以下為我們以前的案例探討

- 實際案例A：Outdoor camera採暫態模擬，環境溫度-35度C，電池與IC工作溫度約-25至-20度C以上，以市售加熱片做為瓦數與尺寸參考，需要加熱幾秒後使其開機。
- 實際案例B：Outdoor doorbell於北緯34度中，產品朝西，近夏至日照量與日照面積worst的時刻(PM15:00)，不同於廢熱設計的考量。

Solar setting

Solar Configuration

☒ Solar Radiation

Model Orientation From North

Angle Measured From: X Axis

Angle: 0 deg

Solar Position

Latitude: 25 deg

七月, 2021

週日	週一	週二	週三	週四	週五	週六
27	28	29	30	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
1	2	3	4	5	6	7

Date: 31

Solar Time (HH:MM:SS): 11:00:00

Solar Calculation Type: Solar Intensity

Solar Intensity: 902.2757 W/m²

Calculated Values

Calculated Solar Intensity: 902.2757 W/m²

Azimuth Angle: 111.8318 deg

Solar Altitude: 74.67495 deg

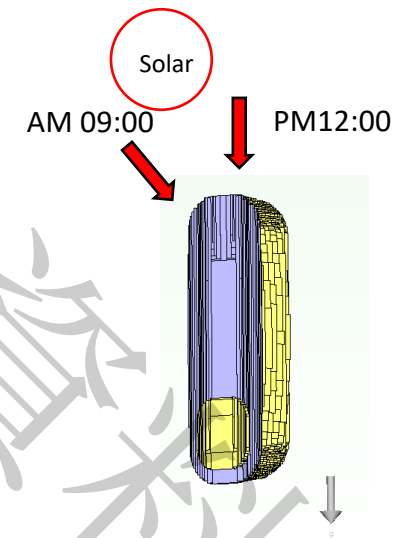
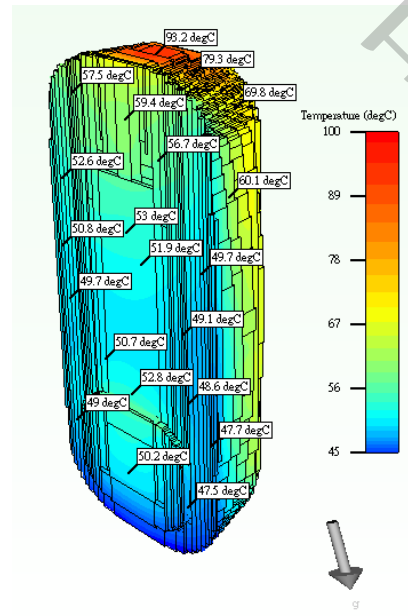
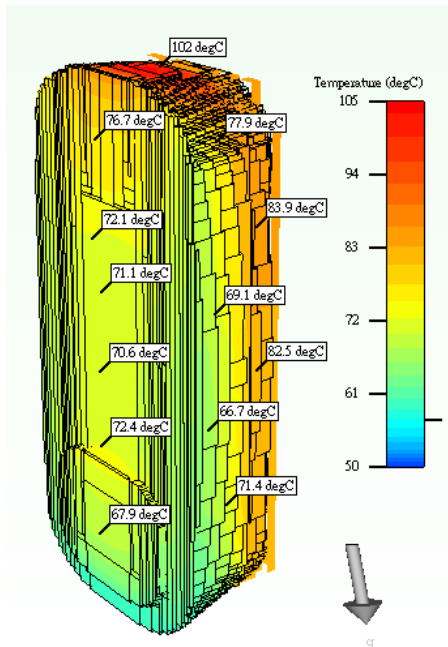
OK Cancel

Radiation setting

1. Latitude : N 25°
2. Date : 7/31
3. Time : AM9:00 / AM10:00 / AM 11:00 / PM 12:00
Worst case : Doorbell face to sun before noon
4. Solar intensity : Flotherm database

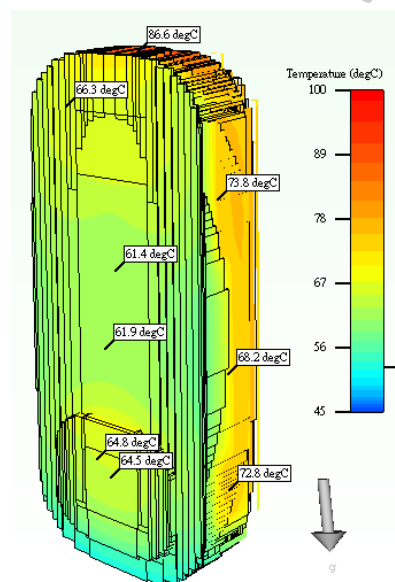
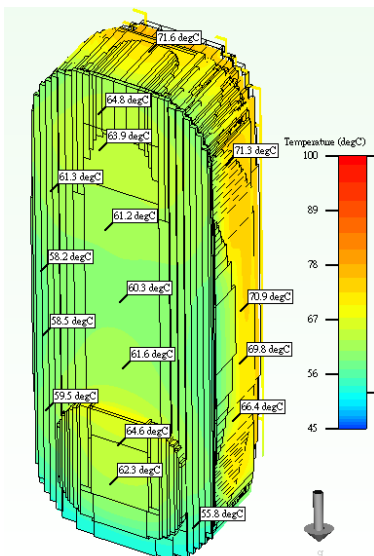
日照時間與日照量的溫度影響

	Power consumption (W)	Rear cover	IR Board	Heatsink	Weather	Ambient	Latitude & Time	Solar intensity	Simulation (Housing)
Case4(day mode)	3.8	PC With metal plate	MCPCB	AL plate & copper boss	Sunny day No cloud	40 °C	N 25° PM12:00	908.7 W/m ²	93.4 °C
Case4(day mode)	3.8	PC With metal plate	MCPCB	AL plate & copper boss	Sunny day No cloud	40 °C	N 25° AM11:00	902.2 W/m ²	96.2 °C
Case4(day mode)	3.8	PC With metal metal plate	MCPCB	AL plate & copper boss	Sunny day No cloud	40 °C	N 25° AM10:00	881.4 W/m ²	96.0 °C
Case4(day mode)	3.8	PC With metal plate	MCPCB	AL plate & copper boss	Sunny day No cloud	40 °C	N 25° AM09:00	841.1 W/m ²	94.2 °C



顏色對於日照的影響

	Glass (Color print)	Glass properties	Rear & Front cover	Button	Power consumption (W)	Ambient	Solar intensity	Max Button Temp.	Max. Temp. (Plastic Housin g)	Temp. (Image sensor)	Temp. (CPU)
Case16 B	White	$\varepsilon = 0.84$ $\rho = 0.07$ $r = 0.8$	White	Black	3.8	45 °C	900 W/m^2	64.6 °C	70.68 ° C	81.76 ° C	79.81
Case16 C	White	$\varepsilon = 0.84$ $\rho = 0.07$ $r = 0.8$	Black	Black	3.8	45 °C	900 W/m^2	64.8 °C	89.1 °C	84.60 ° C	82.45



Heatsink Optimization

Ecobee1025-newcase19-AM15-goodTP - Command Center - Simcenter Flotherm 2019.1

Project Scenario Edit View Create Scenarios Chart Window Viewer Macro Profiles Calibration Help

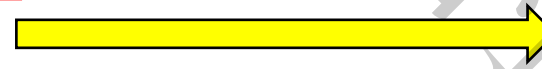
Before

Workplane Normal Y Position

Parameter	Base Project	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Heat Sink : Internal Fin Uniform Width (mm)	1.5	2	1.5	2	2.5	1.5	2
Heat Sink : Number of Internal Fins	11	11	9	9	9	7	7
Solution Status	All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...
Store Results?	Full	History Only	History Only	History Only	History Only	History Only	History Only
Initialize From	No Project	Base Project	Base Project	Base Project	Base Project	Base Project	Base Project
U5003-CPU-CV28M : Temperature (°C)	83.71127	83.87795	83.61348	83.72205	83.8214	83.33303	83.53233
U5020-OS05A20 : Temperature (°C)	83.84669	83.91003	83.7079	83.78442	83.84849	83.51974	83.66262

Use simulation function “command center” to optimize :

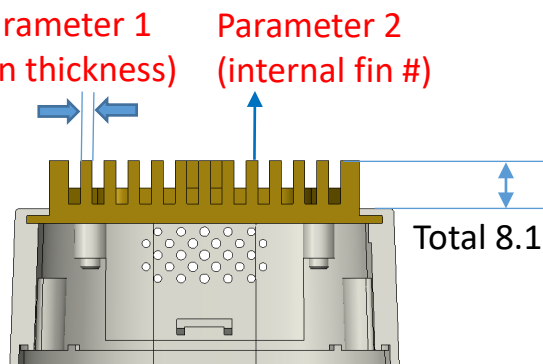
- Total Fin numbers** = internal fins +2 (due to fix first and last fin).



Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12	Scenario 13
2.5	1.5	2	2.5	1.5	2	2.5
7	5	5	5	3	3	3
All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...	All Monitor Po...
History Only	History Only	History Only	History Only	History Only	History Only	History Only
Base Project	Base Project	Base Project	Base Project	Base Project	Base Project	Base Project
83.70367	82.82643	83.1177	83.30724	82.23349	82.36327	82.66697
83.78091	83.15097	83.35388	83.48772	82.70688	82.80423	83.01248

Best optimized result :
Heatsink with 5 fins.
Fin thickness 1.5 mm.

CPU ↓ 1.5 °C
Sensor ↓ 1.1 °C



Simplified model