AirPrime EM919X-EM7690 Thermal Application Note

2174257-Rev 3.0

Author:	**Sierra Wireless**	**Date:**	**September 25, 2020**

APN Content Level	**BASIC**		**INTERMEDIATE**	✓	**ADVANCED**		**Confidentiality**	**Public**	✓	**Private**	

Hardware Compatibility	**Product Line**	**AirPrime**	**Series**	**EM919X**	
				EM7690	

Software Compatibility	**ALL**	**Document Type**	**Application Note**	✓	**Technical Note**	

1 Version

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2 Introduction

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3 Glossary

Term/Initials	Definition
CTM	Compact Thermal Model
TA	The temperature of the ambient environment
TC	The temperature of case on top of module, the center of shield case's outer surface
TB	The temperature of board on bottom of module, the center of PCB's bottom surface
TJ	The temperature of junction, internal temperature of SDX55 chip
PC	The thermal power dissipated through case-shield case
PB	The thermal power dissipated through board-module PCB
PD	The thermal power of device, PD = PC + PB

4 The Scope of Thermal Application Note

This application note intends to provide AirPrime EM919X and EM7690 thermal characteristics and detailed information in a wide variety of system-level thermal design, simulation, and validation.

5 Thermal Model

The EM919X and EM7690 product is a module with multiple inner heat sources, and it can dissipate internal thermal power through its top shield case and bottom PCB surface; both of them would be dissipated to ambient environment directly or through contacted parts which are mounted on shield case or bottom PCB surface like application board, housing, and heatsink.

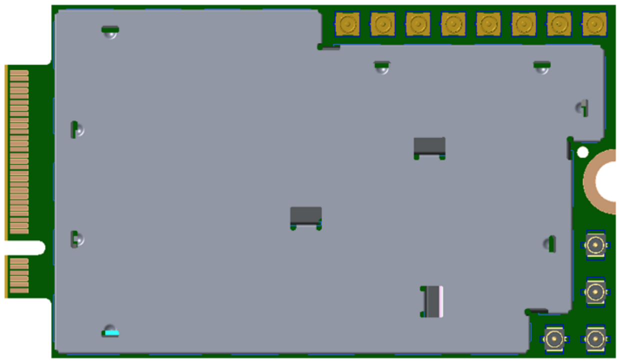


Figure 5-1 Top Shield Case Surface

Figure 5-2 Bottom PCB Surface

A CTM represents a simplified model which satisfies the technical requirements of accuracy and software compatibility in thermal design and simulation. This CTM model is defined based on below assumptions:

- Module is mounted horizontally, and shield case faces up
- Module is exposed in 25°C still air
- Bare module, no host connection

The EM9190 CTM thermal model is defined as below:

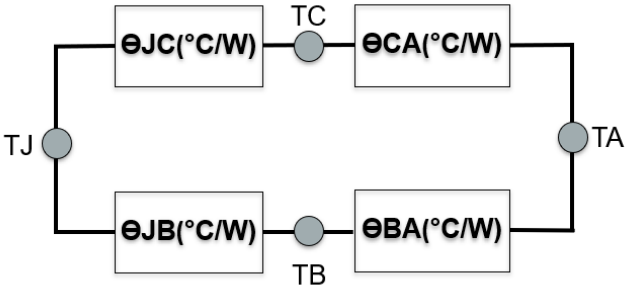


Figure 5-3 Thermal Model Diagram

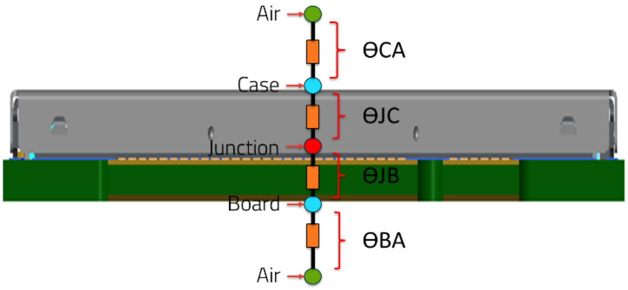


Figure 5-4 Thermal Model Physical Definition

Table 5-1 Thermal Model

Thermal Resistance	EM9190 mmWave (°C/W)	EM9190 Sub-6/LTE (°C/W)	EM9191 Sub-6/LTE (°C/W)	EM7690 LTE (°C/W)
ϴJC (Junction-to-Case thermal resistance)	2.8	3.3	3.3	2.6
ϴCA (Case-to-Ambient thermal resistance)	49.1	58.6	61.8	66.8
ϴJB (Junction-to-Board thermal resistance)	2.1	2.2	2.2	2.0

Thermal Resistance	EM9190 mmWave (°C/W)	EM9190 Sub-6/LTE (°C/W)	EM9191 Sub-6/LTE (°C/W)	EM7690 LTE (°C/W)
ϴBA (Board-to-Ambient thermal resistance)	22.9	28.7	30.1	33.7
ϴJA (Junction-to-Ambient thermal resistance)	16.9	20.6	21.6	23.6

Note: *ϴJA is calculated by formula:*

$$\Theta_{JA} = \frac{(\Theta_{JC} + \Theta_{CA}) * (\Theta_{JB} + \Theta_{BA})}{\Theta_{JC} + \Theta_{CA} + \Theta_{JB} + \Theta_{BA}}$$

The thermal model is thermal attributes of the module, no external contact part included, ϴCA and ϴBA will also differ if the mounting orientation is different.

There are some differences between different use cases, it is because different heat source locations in the module, likewise, there could be also slight difference with different operating bands. Nevertheless, the thermal resistances provided in the table should be good reference for any application's evaluation.

6 Thermal Power

The EM919X and EM7690 module has challenged use cases of thermal power dissipation. The thermal projection in below table is summarized from Qualcomm suggested worst-case with maximum thermal power working at extreme conditions. They could be used for system thermal design and solution evaluation in your device. However, the realistic worst-case thermal power may differ from these values. Sierra Wireless recommends that you identify realistic worst-case condition and perform appropriate thermal evaluation. For example, different combinations of data throughput rate and Tx output power in certain length of time.

Table 6-1 Thermal Power Worst Case

Product	Condition	Thermal Power (PD)
EM9190 mmWave	• DL 4.1 Gbps/UL 0.55 Gbps • mmWave:100 MHz BW/CC, DL/UL duty cycle: ~60/40 • Slot configuration: 2 DL slot, 1 Special slot (mostly DL symbols), 2 UL slots n260 • mmWave Rx = -50 dBm, 64 QAM, 2 ×2 MIMO • mmWave Tx = 28.5 dBm (TRP), SISO, QPSK • LTE: FDD B3, Tx = 23 dBm, Intra-band ULCA, QPSK • @TJ = 90°C	13.53W
EM9190 Sub-6	• Sub-6 1CC + LTE 20 layers, 4*4 MIMO • Total RF power = 23 dBm (2 uplinks, 20 dBm LTE + 20 dBm Sub-6) • @TJ = 100°C	8.51W
EM9191 Sub-6	• Sub-6 1CC + LTE 12 layers, 4*4 MIMO • Total RF power = 23 dBm (2 uplinks, 20 dBm LTE + 20 dBm Sub-6) • @TJ = 100°C	7.49W

Product	Condition	Thermal Power (PD)
EM7690	• LTE 20 layers • Total RF power = 23 dBm • @TJ = 90°C	5.65W

Note: *According to the thermal power document released by Qualcomm (80-PK564-12A), the thermal power values of EM9190 mmWave are evaluated based on TJ 90°C, the other thermal powers are evaluated based on real measurement and compensate some margins for deviations. the thermal power values would vary a bit with different TJs on customer's device.*

7 Operating Temperature Specification

Three types of temperatures are defined to help the thermal evaluation with EM919X and EM7690 module, they are module junction temperature (TJ), module surface temperature on both top and bottom (TC and TB), and ambient temperature around the module (TA). Details are provided in the following sections.

Note: *The specification of TJ should be strictly followed, TC and TB specifications should be used as reference only when TJ is not available, and TA is just a general operating temperature range that can be stated with proper thermal designs.*

7.1 TJ

TJ, the inner die temperature of semiconductor chip, is important to performance and reliability of chips. There are multiple heat sources inside EM919X and EM7690 module such as SDX55, PAs (power amplifier), and PMX55 (power management IC), transceiver, etc. EM919X and EM7690 use TJ of SDX55 (can be reported by AT commands **AT!PCTEMP?**) as the base reference to represent overall module's temperature as it contributes the most to the temperature rise of the whole module, but it may not have the hottest junction among all inner chips in all use cases. The range of EM919X and EM7690's operating TJ is specified as below:

Table 7-1 TJ's Operating Temperature Range

Parameter	Operating Class	Temperature Range
TJ	Class A	-30°C<TJ<100°C
	Class B	-40°C<TJ<115°C

Note: *Class A is defined as the operating temperature range that the device:*
1) Shall exhibit normal function during and after environmental exposure.
2) Shall meet the minimum requirements of 3GPP or appropriate wireless standards.

Class B is defined as the operating temperature range that the device:
1) Shall remain fully functional during and after environmental exposure
2) Shall exhibit the ability to establish a voice, SMS or DATA call (emergency call) at all times even when one or more environmental constraint exceeds the specified tolerance.
3) Unless otherwise stated, full performance should return to normal after the excessive constraint(s) have been removed.

TJ can be used as the top priority to evaluate system-level thermal design and solution for the EM919X and EM7690 module integrated applications, and enough margin should be kept for system thermal design to make sure that TJ would not exceed its maximum temperature limit.

The TJ ranges have been qualified in Sierra Wireless lab within 1 hour's test duration (refer to Thermal Power for the test conditions). Sierra Wireless does not recommend that the module works at high TJ for a long period although there are some thermal management designs in firmware. For more details of EM919X and EM7690 thermal mitigation firmware management, refer to the document *[4] AirPrime EM919x Thermal Mitigation*.

TJ can also be evaluated by calculation as below:

$$TJ = \Theta_{JA} * PD + TA$$

where ΘJA = thermal resistance from junction to ambient (°C/W)

TA = ambient temperature (°C)

PD = power dissipation of EM919X or EM7690 module (W)

7.2 TC and TB

TC and TB are recommended to be used for evaluating EM919X and EM7690 thermal risk only when TJ is not available. The measurement locations are specified as Figure 7-1 and Figure 7-2. They are easy to be measured by attaching a thermocouple to the center of bottom PCB surface or top shield case surface. Their operating range is as below:

Table 7-2 TC and TB Operating Temperature Range

Parameter	Operating Class	Temperature Range
TC	Class A	-30°C<TC<83°C
	Class B	-40°C<TC<98°C
TB	Class A	-30°C<TB<85°C
	Class B	-40°C<TB<100°C

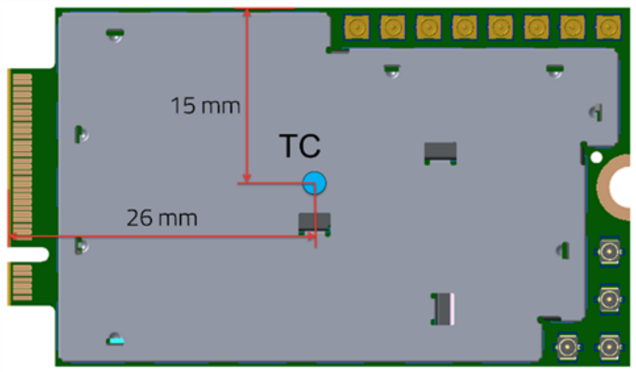


Figure 7-1 The Location of TC

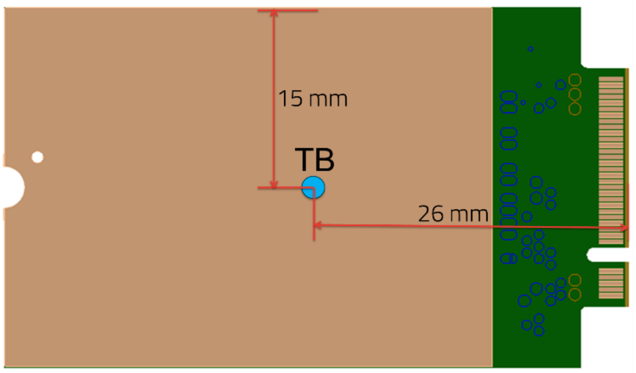


Figure 7-2 The Location of TB

7.3 TA

TA is defined as 25 mm from module's bottom according to JESD51 standard.

Table 7-3 TA Operating Temperature Range

Parameter	Operating Class	Temperature Range
TA	Class A	-30°C<TA<70°C
	Class B	-40°C<TA<85°C

Note: It is not the standard to justify whether the module could work normally or not, but is useful for first-level thermal measurement or design evaluation, as system-level thermal dissipation design like heatsink and flowing air would have significant impact on the module's TJ even though TA is the same.

The EM919X and EM7690 modules marked operating temperature range Class B at TA from -40°C to 85°C and Class A from -30°C to 70°C when solid system-level thermal design is taken to ensure TJ does not exceed its specification, otherwise EM919X and EM7690 may not work normally in defined TA range.

8 Operating Temperature Evaluation

8.1 Operating Temperature Evaluation by Thermal Model

In development stage, EM919X and EM7690 operating temperature could be evaluated by released thermal model. However, the thermal resistance ϴCA and ϴBA may differ in actual customer's application, as ϴCA and ϴBA are affected by contact parts on shield case or bottom PCB board, temperature and air flow of ambient air, the orientation of module mounting, etc., you should evaluate ϴCA and ϴBA with your own application. Following are some typical thermal design solutions for reference.

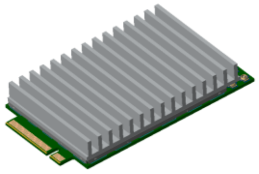
8.1.1 Heatsink on Shield Case

When using a heatsink on shield case, ϴCA is replaced by the thermal resistance of heatsink to air (ϴHS), for example: the thermal resistance of heatsink to air is 5°C/W and the module works on maximum thermal power 8.51W EM9190 Sub-6/LTE use case, the TA is 25°C still air, we can evaluate the module's TJ as below calculation:

$$\theta_{JA} = \frac{(\theta_{JC}+\theta_{HS})*(\theta_{JB}+\theta_{BA})}{\theta_{JC}+\theta_{HS}+\theta_{JB}+\theta_{BA}} = \frac{(3.3+5)*(2.2+28.7)}{3.3+5+2.2+28.7} = 6.54℃/W$$

$$TJ = PD*\theta_{JA}+TA = 8.51*6.54+25 = 80.7℃$$

Table 8-1 Thermal Model with Heatsink on Top

Heatsink on Top	Thermal Resistance	EM9190 Sub-6/LTE Case (°C/W)
	ϴJC (Junction-to-Case thermal resistance)	3.3
	ϴHS (Heat-sink thermal resistance)	5
	ϴJB (Junction-to-Board thermal resistance)	2.2
	ϴBA (Board-to-Ambient thermal resistance)	28.7
	ϴJA (Junction-to-Ambient thermal resistance)	6.54

Note: *ϴBA would not be the value of 28.7°C/W if the module is not mounted horizontally or the ambient is flowing air.*

PD may not be 8.51W in your use case.

Top heatsink is a generalized definition here, in realistic application, the thermal resistance of heatsink may be a combined effect of physical heatsink, housing, plate and other mechanical parts designed in system.

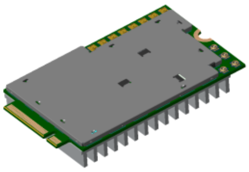
8.1.2 Heatsink on Bottom PCB Surface

When using a heatsink on bottom PCB surface, ϴBA is replaced by the thermal resistance of heatsink to air (ϴHS), for example: the thermal resistance of heatsink to air is 5°C/W and the module works on maximum thermal power 8.51W EM9190 Sub-6/LTE use case, the TA is 25°C still air, we can evaluate the module's TJ as below calculation:

$$\theta_{JA} = \frac{(\theta_{JC}+\theta_{CA})*(\theta_{JB}+\theta_{HS})}{\theta_{JC}+\theta_{CA}+\theta_{JB}+\theta_{HS}} = \frac{(3.3+58.6)*(2.2+5)}{3.3+58.6+2.2+5} = 6.45℃/W$$

$$TJ = PD*\theta_{JA}+TA = 8.51*6.45+25 = 79.9℃$$

Table 8-2 Thermal Model with Heatsink on Bottom

Heatsink on Bottom	Thermal Resistance	EM9190 Sub-6/LTE Case (°C/W)
	ϴJC (Junction-to-Case thermal resistance)	3.3
	ϴCA (Case-to-Ambient thermal resistance)	58.6
	ϴJB (Junction-to-Board thermal resistance)	2.2
	ϴHS (Heat-sink thermal resistance)	5
	ϴJA (Junction-to-Ambient thermal resistance)	6.45

Note: *ϴCA would not be the value of 58.6°C/W if the module is not mounted horizontally or the ambient is flowing air.*

PD may not be 8.51W in your use case.

Bottom heatsink is a generalized definition here, in realistic application, the thermal resistance of heatsink may be a combined effect of physical heatsink, application board, host connector, housing, chassis and other mechanical parts designed in system.

8.2 Operating Temperature Evaluation by Simulation

In development stage, EM919X and EM7690 operating temperature could also be evaluated by thermal simulation, using CAE tools like FloTHERM, ICEPAK, etc.

You can create the compact 3D mode and set the thermal resistance of ϴJC and ϴJB according to table in Thermal Model, the thermal resistance ϴCA and ϴBA will be ignored as they will be simulated in CAE tool automatically.

Sierra Wireless can provide FloTHERM XT simulation model package of .sldasm format for your simulation.

8.3 Operating Temperature Evaluation by Measurement

When EM919X and EM7690 module has been integrated into your device, you can use AT commands to obtain the TJ of SDX55 under any operating mode or measure TC and TB by thermocouples to evaluate system-level thermal risk.

To perform thermal measurement of the module:

- Attach thermocouples at the TC and TB locations specified in Figure 7-1 and Figure 7-2, if heatsink is mounted on PCB bottom surface or shield case surface, the thermocouples should be attached at the point on the heatsink closest to TC or TB point, in this case, their temperatures are close to TC or TB. Note that this may need a blind hole or concave geometry added on heatsink for thermocouples attachment.
- Mount the module at its designed location on the platform, set the same ambient airflow as realistic environment in your application.
- Set up a call with the worst-case thermal power use case in your platform (throughput, output power, duty cycle, etc.).
- Monitor the TJ by AT commands, TC and TB by thermal recorder machine, record the temperature values when they reach thermal stabilization.
- Increase the environment ambient temperature and check the safe margin to operating temperature specification of TJ, TC, TB defined in Operating Temperature Specification.

9 Appendix

9.1 Design Guide of Thermal Dissipation

The thermal design should focus on how to improve dissipation from device to environment, there are some design guides for your reference:

- High thermal conductivity heatsink is mounted on shield case or bottom PCB surface. For example, copper heatsink is better than aluminum heatsink.
- Heatsink should be exposed in environment directly and not be isolated by still air in a small enclosure space.
- The bottom PCB surface could contact to application mother board by metal heatsink or contact to metal housing by thermal pad to improve heat dissipation from bottom.
- Flowing air is very important to carry heat to environment, forced convection airflow is recommended to be designed over/around the module when it is mounted in enclosure space. For example: cooling fan.
- Heat pipe could be used to conduct heat from module to other mechanical parts which are easy to dissipate heat to environment when heatsink could not be mounted on top or bottom due to space limitation. For example, heat pipe is connected to heatsink which is close to fan or metal housing exposed to environment.
- Locate the module away from other heat sources.

9.1.1 Thermal Design of Laptop Use Case

When EM919X and EM7690 module is used in laptop configuration, the internal air should be flowing as there is typical fan design inside the enclosure, Figure 9-1 to Figure 9-16 are thermal simulation results of laptop use case on different thermal design configurations.

From the simulation results:

- Placing a large size heatsink between application board and module PCB is a recommended solution.
- The speed of flowing air is critical to reduce TJ, high speed flowing air should be considered in thermal design.

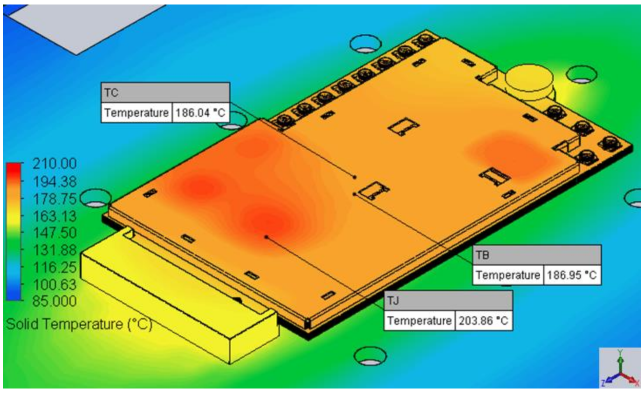


Figure 9-1

Configuration:

- **No thermal pad between module and application board**
- **No heatsink**
- **85°C still air**
- **Thermal power: mmWave 13.53W**

Result:

There is 89°C's gap to meet maximum TJ (115°C) of class B requirement.

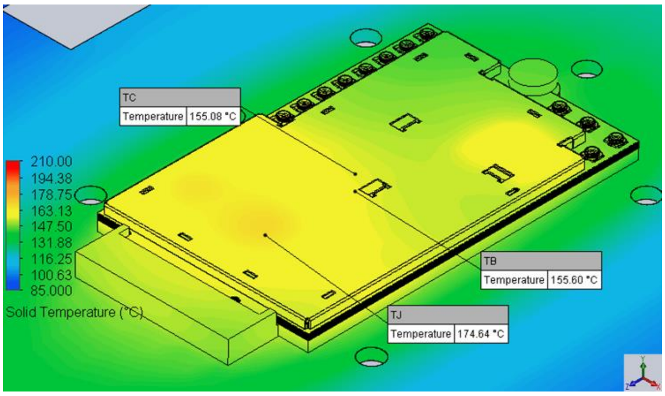


Figure 9-2

Configuration:

- **Thermal pad between module and application board**
- **No heatsink**
- **85°C still air**
- **Thermal power: mmWave 13.53W**

Result:

There is 60°C's gap to meet maximum TJ (115°C) of class B requirement.

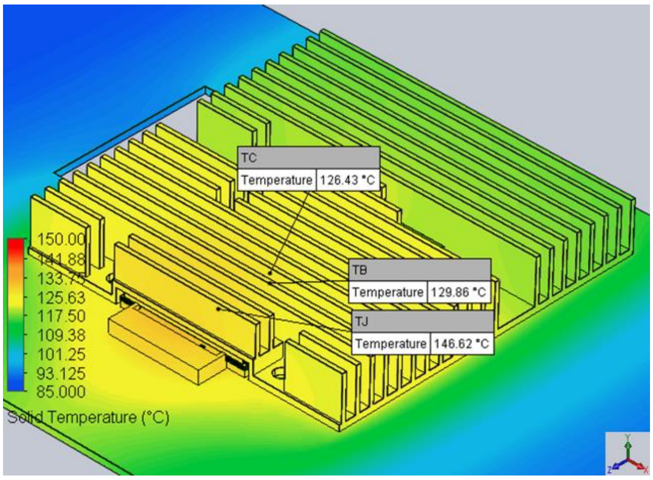


Figure 9-3

Configuration:

- **Thermal pad between module and application board**
- **Top aluminum heatsink 75X75X12 mm, area 39026 mm^2**
- **85°C still air**
- **Thermal power: mmWave 13.53W**

Result:

There is 32°C's gap to meet maximum TJ (115°C) of class B requirement.

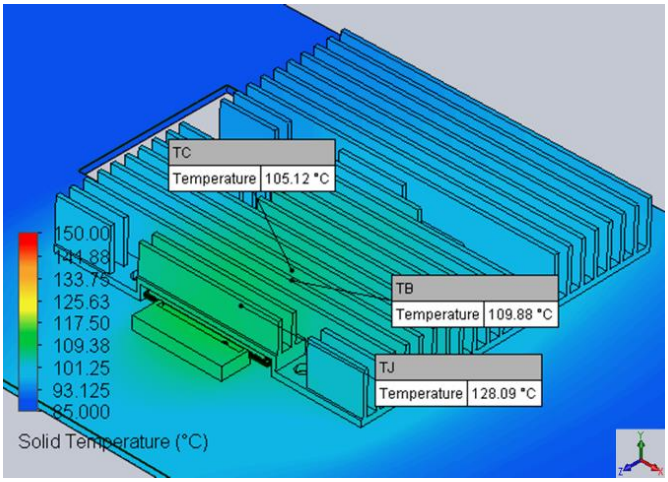


Figure 9-4

Configuration:

- **Thermal pad between module and application board**
- **Top aluminum heatsink 75X75X12 mm, area 39026 mm^2**
- **85°C 2.5 m/s speed flowing air at X direction**
- **Thermal power: mmWave 13.53W**

Result:

There is 13°C's gap to meet maximum TJ (115°C) of class B requirement.

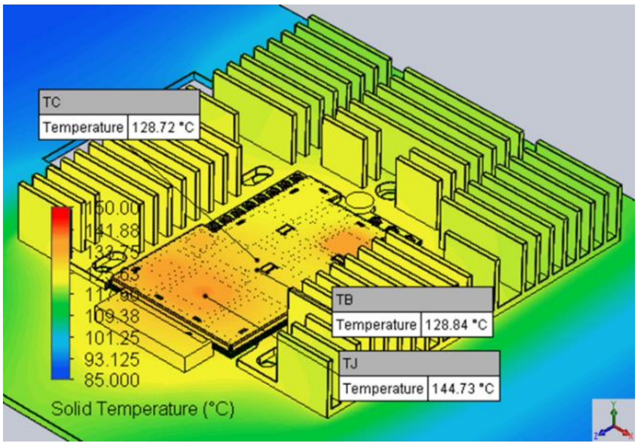


Figure 9-5

Configuration:

- **Bottom aluminum heatsink 75X74.5X12 mm, area 31005 mm^2**
- **85°C still air**
- **Thermal power: mmWave 13.53W**

Result:

There is 30°C's gap to meet maximum TJ (115°C) of class B requirement.

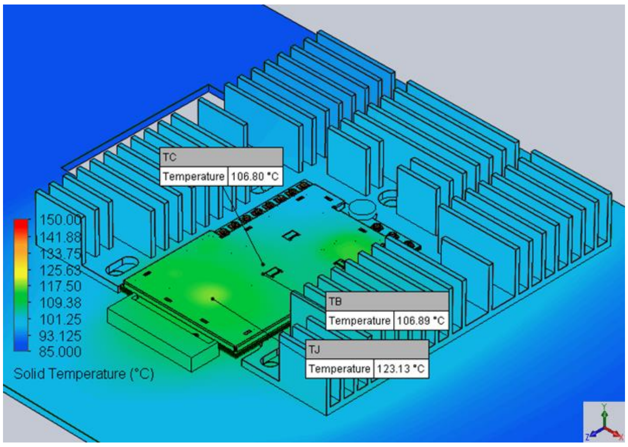


Figure 9-6

Configuration:

- **Bottom aluminum heatsink 75X74.5X12 mm, area 31005 mm^2**
- **85°C 2.5 m/s speed flowing air at X direction**
- **Thermal power: mmWave 13.53W**

Result:

There is 8°C's gap to meet maximum TJ (115°C) of class B requirement.

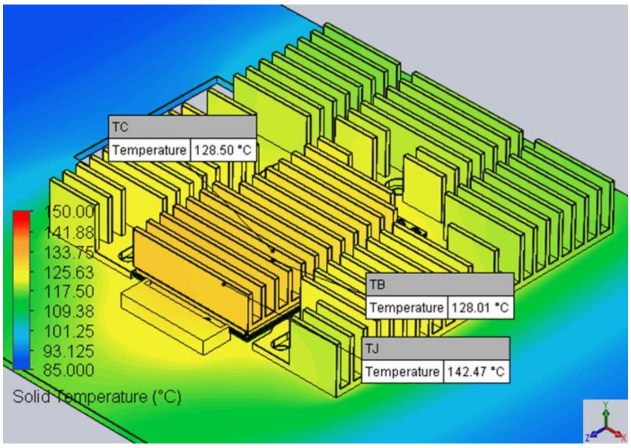


Figure 9-7

Configuration:

- Bottom aluminum heatsink 75X74.5X12 mm, area 31005 mm^2
- Top aluminum heatsink 47X30X8.38 mm^2, area 8267 mm^2
- 85°C still air
- Thermal power: mmWave 13.53W

Result:

There is 27°C's gap to meet the maximum TJ (115°C) of class B requirement.

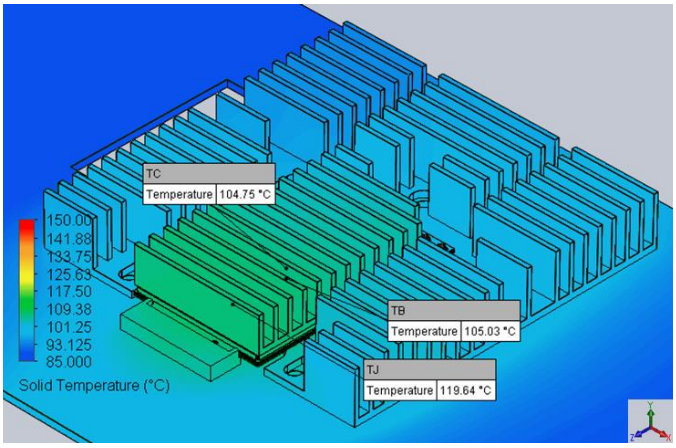


Figure 9-8

Configuration:

- Bottom aluminum heatsink 75X74.5X12 mm, area 31005 mm^2
- Top aluminum heatsink 47X30X8.38 mm^2, area 8267 mm^2
- 85°C 2.5 m/s speed flowing air at X direction
- Thermal power: mmWave 13.53W

Result:

There is 5°C's gap to meet the maximum TJ (115°C) of class B requirement.

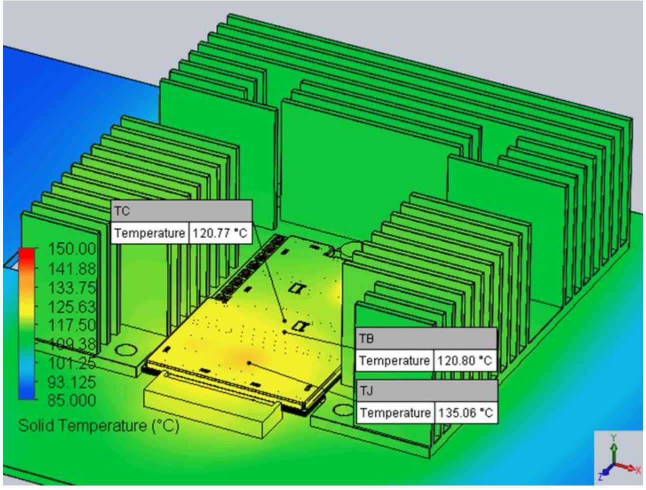


Figure 9-9

Configuration:

- Bottom aluminum heatsink 75X75X25 mm, area 56949 mm^2
- 85°C still air
- Thermal power: mmWave 13.53W

Result:

There is 20°C's gap to meet maximum TJ (115°C) of class B requirement.

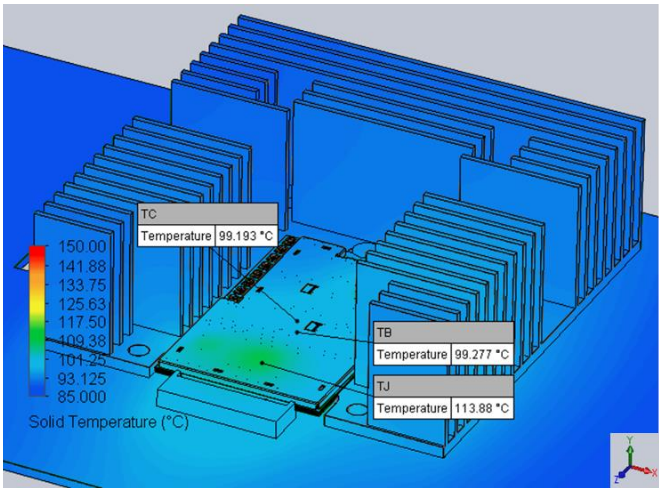


Figure 9-10

Configuration:

- Bottom aluminum heatsink 75X75X25 mm, area 56949 mm^2
- 85°C 2.5 m/s speed flowing air at X direction
- Thermal power: mmWave 13.53W

Result:

Meet maximum TJ (115°C) of class B requirement.

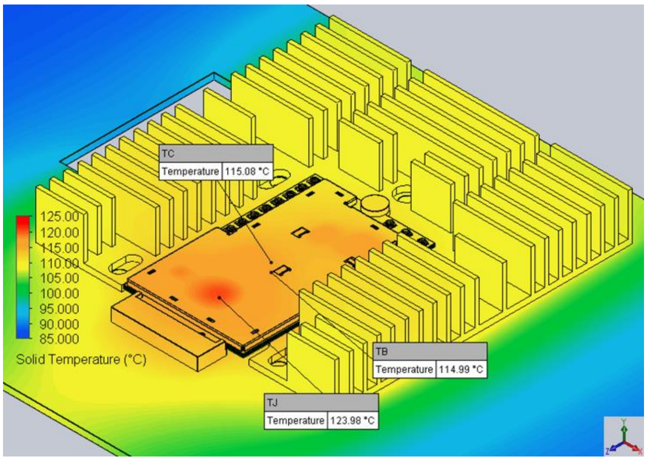


Figure 9-11

Configuration:

- **Bottom aluminum heatsink 75X74.5X12 mm, area 31005 mm^2**
- **85°C still air**
- **Thermal power: Sub-6 8.51W**

Result:

There is 9°C's gap to meet maximum TJ (115°C) of class B requirement.

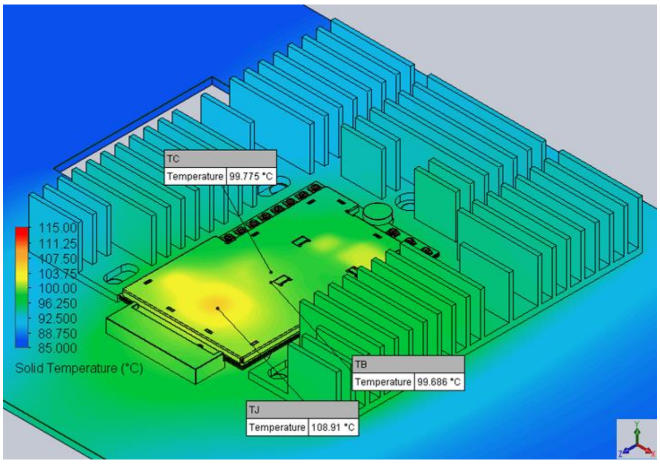


Figure 9-12

Configuration:

- **Bottom aluminum heatsink 75X74.5X12 mm, area 31005 mm^2**
- **85°C 2.5 m/s speed flowing air at X direction**
- **Thermal power: Sub-6 8.51W**

Result:

TJ 109°C meet maximum TJ (115°C) of class B requirement, but has 9°C's gap to meet class A requirement (maximum TJ 100°C).

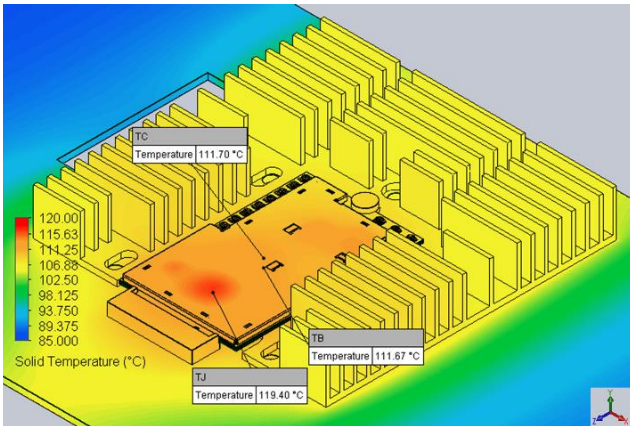


Figure 9-13

Configuration:

- **Bottom aluminum heatsink 75X74.5X12 mm, area 31005 mm^2**
- **85°C still air**
- **Thermal power: Sub-6 7.49W**

Result:

There is 4°C's gap to meet maximum TJ (115°C) of class B requirement.

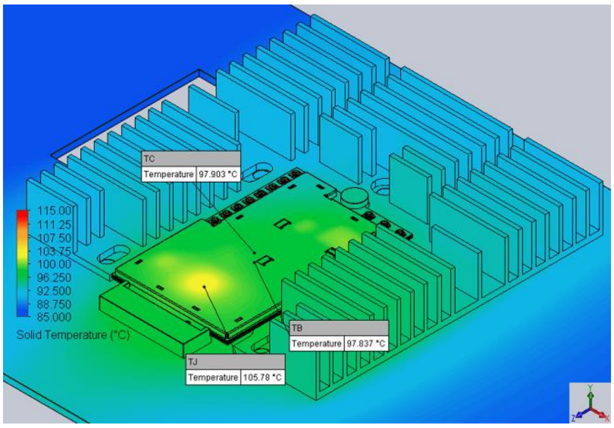


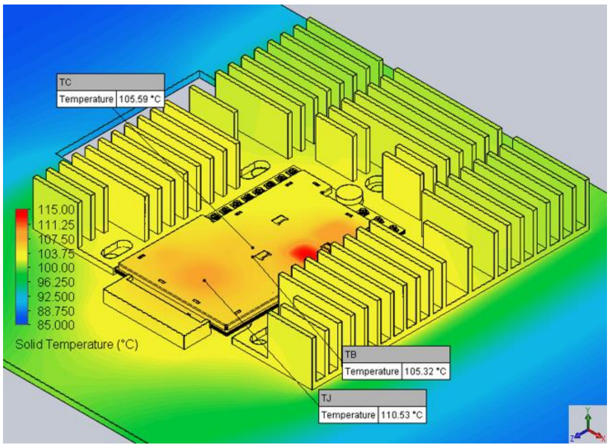
Figure 9-14

Configuration:

- **Bottom aluminum heatsink 75X74.5X12 mm, area 31005 mm^2**
- **85°C 2.5 m/s speed flowing air at X direction**
- **Thermal power: Sub-6 7.49W**

Result:

Meet maximum TJ (115°C) of class B requirement.

<table>
<tr>
<td>


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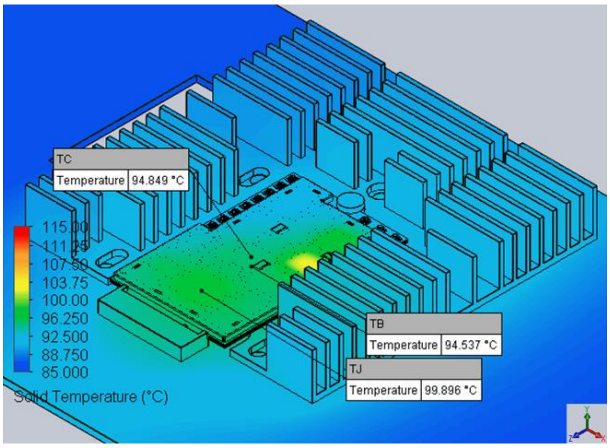

</td>
</tr>
<tr>
<td>
Figure 9-15
Configuration:
• **Bottom aluminum heatsink 75X74.5X12 mm, area 31005 mm^2**
• **85°C still air**
• **Thermal power: LTE 5.65W**
Result:
TJ 111°C meet maximum TJ (115°C) of class B requirement, but has 11°C's gap to meet class A requirement (maximum TJ 100°C).
</td>
<td>
Figure 9-16
Configuration:
• **Bottom aluminum heatsink 75X74.5X12 mm, area 31005 mm^2**
• **85°C 2.5 m/s speed flowing air at X direction**
• **Thermal power: LTE 5.65W**
Result:
TJ 100°C meets maximum TJ (115°C) of class B requirement and maximun TJ (100°C) of class A.
</td>
</tr>
</table>

The thermal conductivity of mechanical parts used in simulations of laptop use case are listed in below table:

Table 9-1 Thermal Conductivity of Mechanical Parts Used in Laptop Application

Part Name	Material	Thermal Conductivity [W/(Mk)]	Size
Shield Case	Nickel silver	33	46.83X29.3X1.19 mm
Shield Frame	Nickel silver	33	46.53X29X1.19 mm
Gap Fillers	GEL30	3.5	Case surfaces of hot components
Module PCB	Hi_Tg FR4&Copper	251 at axial and 251 in plane	52X30X1.6 mm
Application Board	FR4&Copper	7 at axial and 35 in plane	190X120X1.6 mm
Host Connector	Cool Polymers (E2) LCP	20	21.7X7.15X3.2 mm
Dev-kit Standoff	Copper	380	ϕ5.5X1.5 mm (inner hole: ϕ2 mm)
Thermal Pad	PMP-P-300K	6	48X30X1.5 mm
Heatsink	Aluminum	140	Refer to simulation cases

The configurations of thermal design on laptop use cases are as below:

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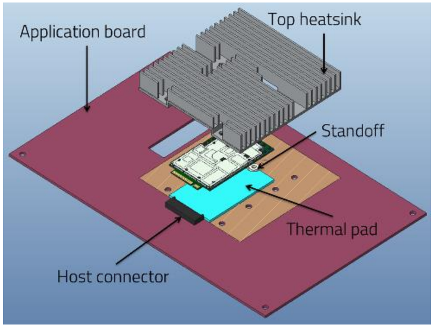
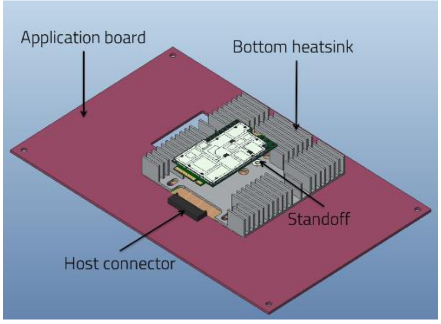
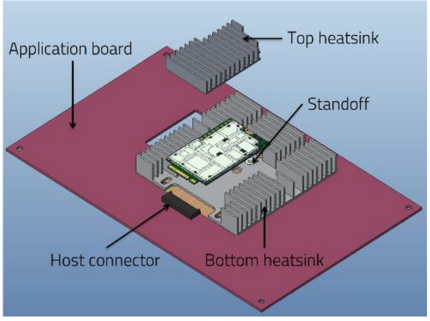
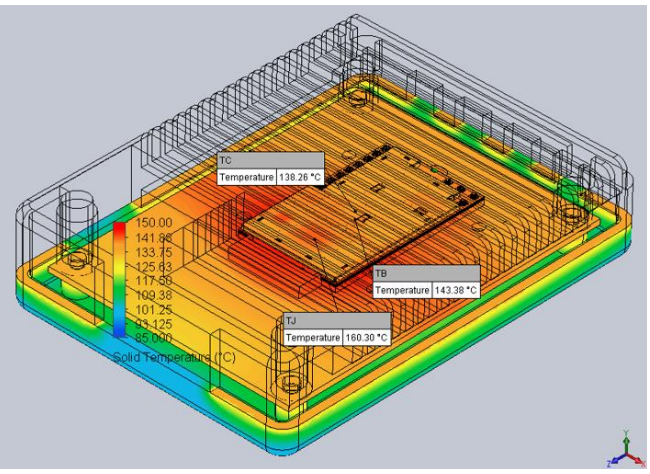
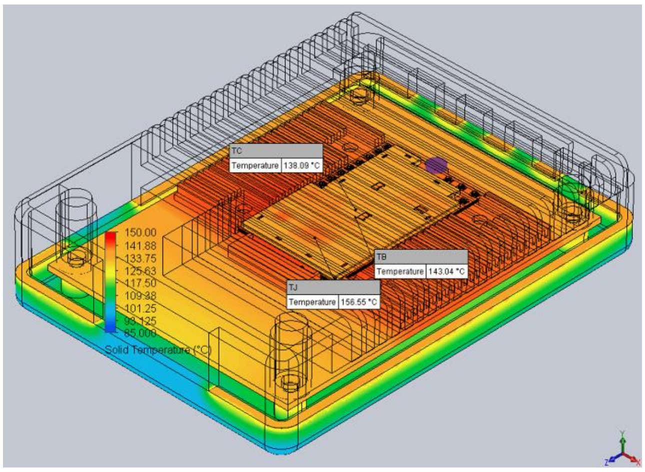
<td> </td>
<td> </td>
<td> </td>
</tr>
<tr>
<td>Figure 9-17 Heatsink mounted on top (Simulation: Figure 9-3, Figure 9-4)</td>
<td>Figure 9-18 Heatsink mounted on bottom (Simulation: Figure 9-5, Figure 9-6, Figure 9-9, Figure 9-10, Figure 9-11, Figure 9-12, Figure 9-13, Figure 9-14, Figure 9-15, Figure 9-16)</td>
<td>Figure 9-19 Heatsink mounted on both top and bottom (Simulation: Figure 9-7, Figure 9-8)</td>
</tr>
</table>

9.1.2 Thermal Design of Router Use Case

When EM919X and EM7690 are used in router configuration, the module will be mounted in housing enclosures and no fan is designed inside typically. In this use case, module's heat could be dissipated through housings to air ambient environment. Sierra Wireless recommends metal housings for better heat dissipating. On the other hand, you may need to identify the maximum TA for your real applications to meet TJ specification, for example, operating temperature TA can be defined within 70° C for routers of indoor usage. Figure 9-20 to Figure 9-33 are thermal simulation results of router use case on different thermal design configurations for your reference.

From the simulation results:

- Thermal design should consider balanced dissipations from top and bottom housing.
- Heatsink placed between module and application board can reduce TJ significantly.

<table>
<tr>
<td> </td>
<td> </td>
</tr>
<tr>
<td>Figure 9-20
Configuration:
• Aluminum top housing 115X85X18.5 mm
• Plastic bottom housing 115X85X8.6 mm
• Thermal pad between PCB and application board
• 85°C still air
• Thermal power: mmWave 13.53W
Result:
There is 45°C's gap to meet maximum TJ (115°C) of class B requirement.</td>
<td>Figure 9-21
Configuration:
• Aluminum top housing 115X85X18.5 mm
• Plastic bottom housing 115X85X8.6 mm
• Aluminum heatsink between PCB and application board
• 85°C still air
• Thermal power: mmWave 13.53W
Result:
There is 42°C's gap to meet maximum TJ (115°C) of class B requirement.</td>
</tr>
</table>

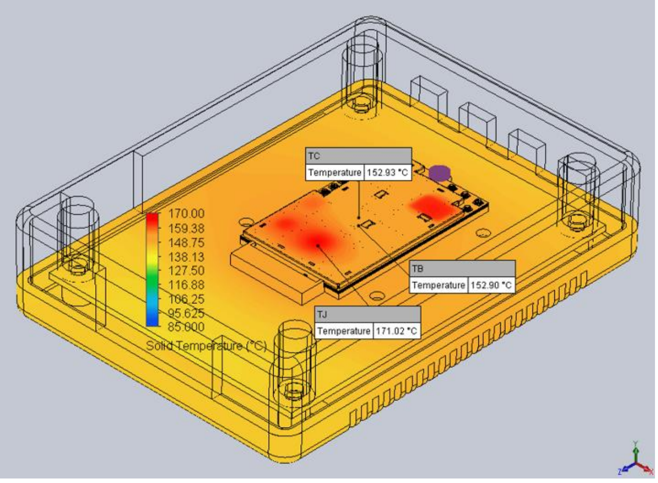


Figure 9-22

Configuration:

- **Plastic top housing 115X85X18.5 mm**
- **Aluminum bottom housing 115X85X8.6 mm**
- **Thermal pad between PCB and application board**
- **85°C still air**
- **Thermal power: mmWave 13.53W**

Result:

There is 56°C's gap to meet maximum TJ (115°C) of class B requirement.

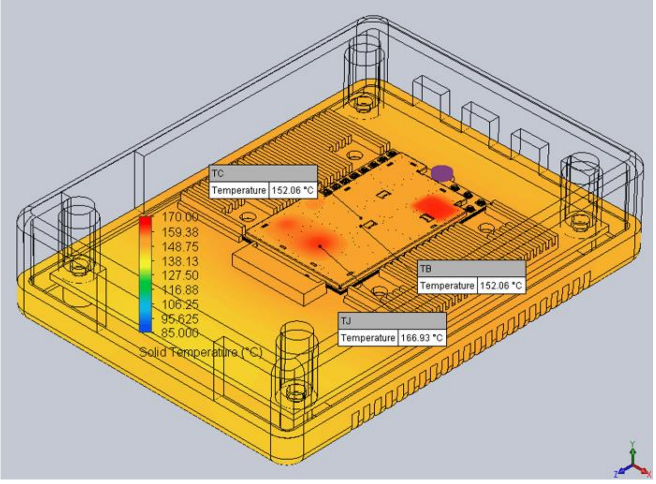


Figure 9-23

Configuration:

- **Plastic top housing 115X85X18.5 mm**
- **Aluminum bottom housing 115X85X8.6 mm**
- **Aluminum heatsink between PCB and application board**
- **85°C still air**
- **Thermal power: mmWave 13.53W**

Result:

There is 52°C's gap to meet maximum TJ (115°C) of class B requirement.

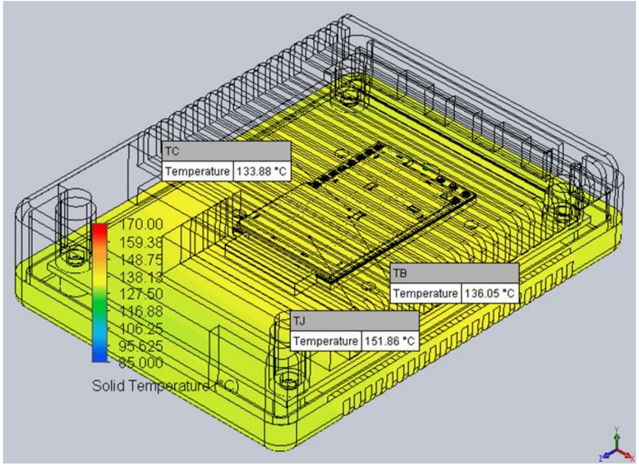


Figure 9-24

Configuration:

- **Aluminum top housing 115X85X18.5 mm**
- **Aluminum bottom housing 115X85X8.6 mm**
- **Thermal pad between PCB and application board**
- **85°C still air**
- **Thermal power: mmWave 13.53W**

Result:

There is 37°C's gap to meet maximum TJ (115°C) of class B requirement.

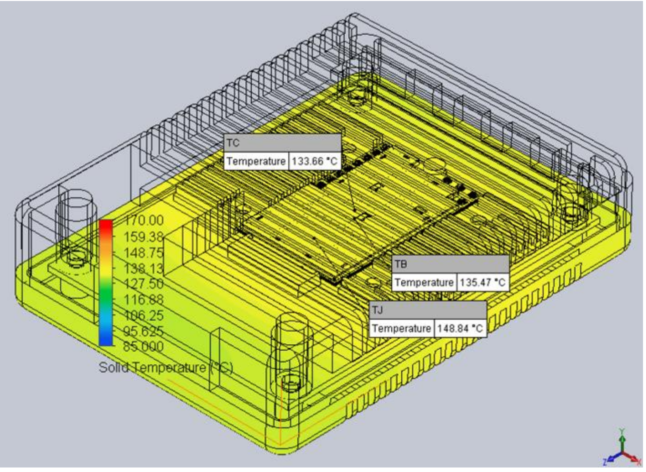


Figure 9-25

Configuration:

- **Aluminum top housing 115X85X18.5 mm**
- **Aluminum bottom housing 115X85X8.6 mm**
- **Aluminum heatsink between PCB and application board**
- **85°C still air**
- **Thermal power: mmWave 13.53W**

Result:

There is 34°C's gap to meet maximum TJ (115°C) of class B requirement.

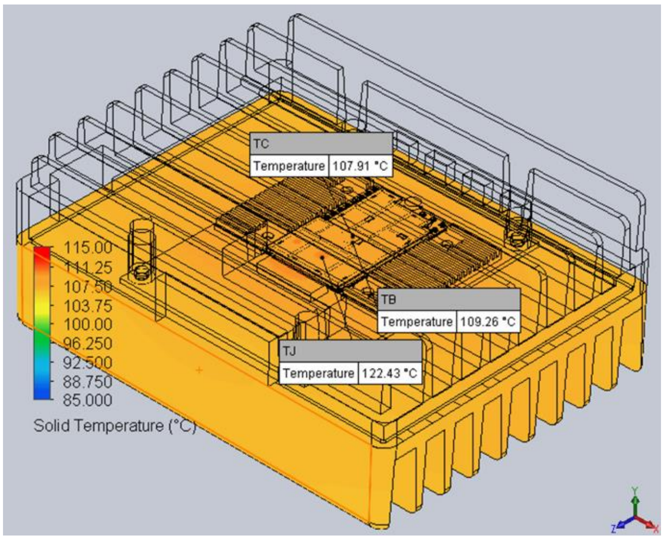


Figure 9-26

Configuration:

- **Aluminum top housing 150X115X30 mm**
- **Aluminum bottom housing 150X115X30 mm**
- **Aluminum heatsink between PCB and application board**
- **85°C still air**
- **Thermal power: mmWave 13.53W**

Result:

There is 7°C's gap to meet maximum TJ (115°C) of class B requirement.

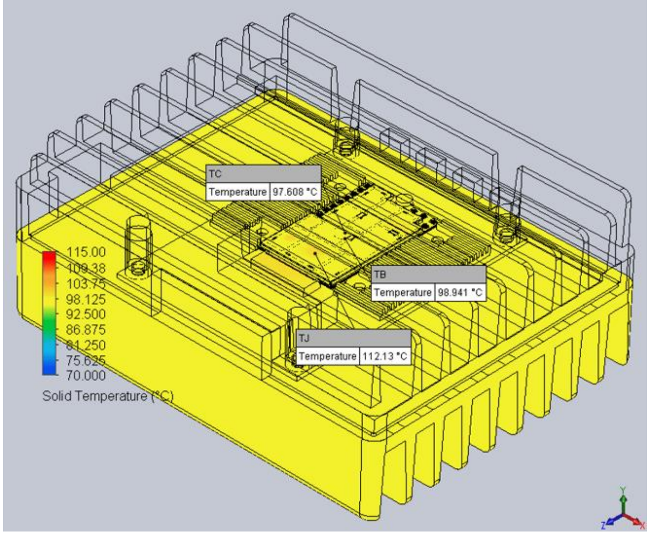


Figure 9-27

Configuration:

- **Aluminum top housing 150X115X30 mm**
- **Aluminum bottom housing 150X115X30 mm**
- **Aluminum heatsink between PCB and application board**
- **70°C still air**
- **Thermal power: mmWave 13.53W**

Result:

TJ 112°C meet maximum TJ (115°C) of class B requirement, but has 12°C's gap to meet class A requirement (maximum TJ 100°C).

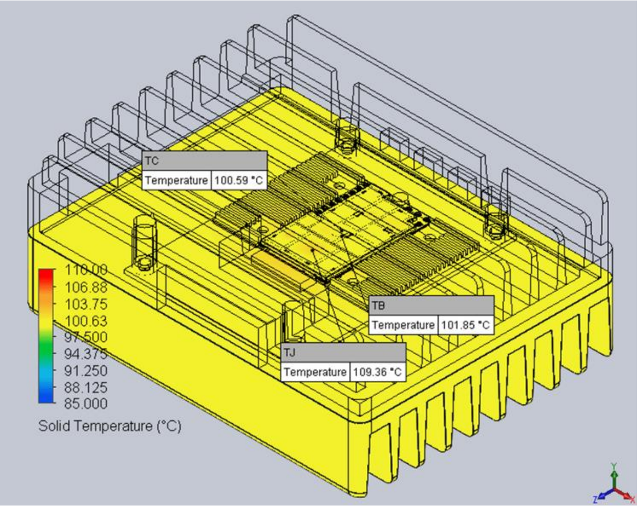


Figure 9-28

Configuration:

- **Aluminum top housing 150X115X30 mm**
- **Aluminum bottom housing 150X115X30 mm**
- **Aluminum heatsink between PCB and application board**
- **85°C still air**
- **Thermal power: Sub-6 8.51W**

Result:

TJ 109°C meets maximum TJ (115°C) of class B requirement, but has 9°C's gap to meet class A requirement (maximum TJ 100°C).

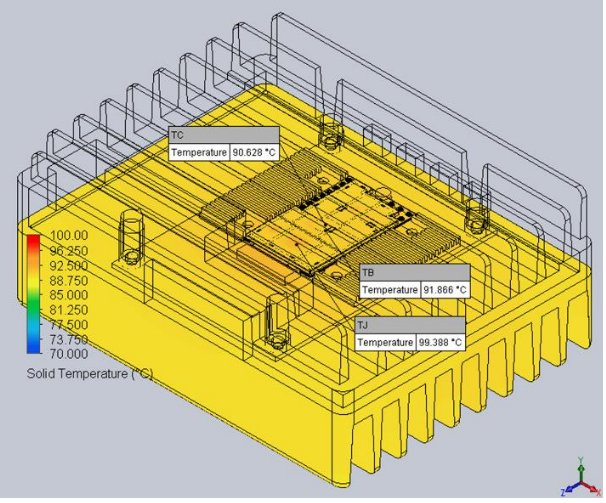


Figure 9-29

Configuration:

- **Aluminum top housing 150X115X30 mm**
- **Aluminum bottom housing 150X115X30 mm**
- **Aluminum heatsink between PCB and application board**
- **70°C still air**
- **Thermal power: Sub-6 8.51W**

Result:

TJ 99°C meets maximum TJ (115°C) of class B requirement and maximun TJ (100°C) of class A

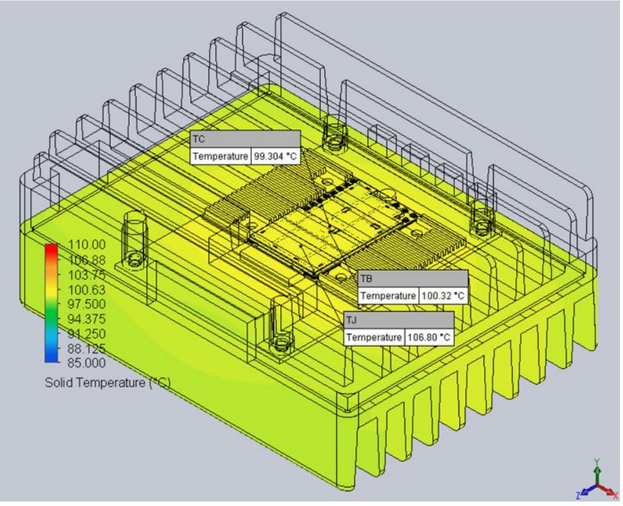


Figure 9-30

Configuration:

- **Aluminum top housing 150X115X30 mm**
- **Aluminum bottom housing 150X115X30 mm**
- **Aluminum heatsink between PCB and application board**
- **85°C still air**
- **Thermal power: Sub-6 7.49W**

Result:

TJ 107°C meets maximum TJ (115°C) of class B requirement, but has 7°C's gap to meet class A requirement (maximum TJ 100°C).

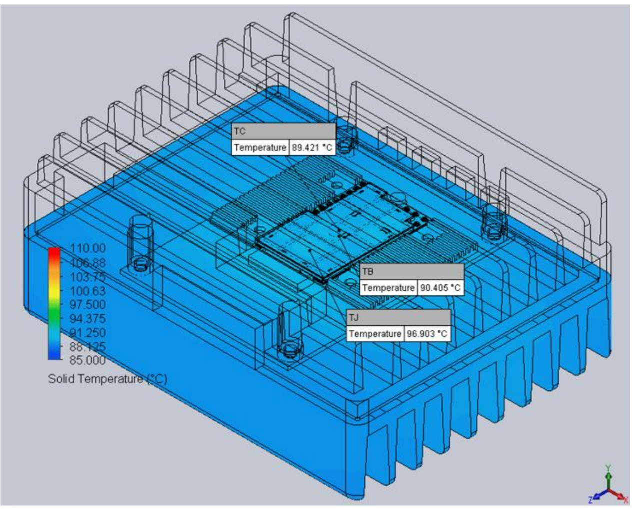


Figure 9-31

Configuration:

- **Aluminum top housing 150X115X30 mm**
- **Aluminum bottom housing 150X115X30 mm**
- **Aluminum heatsink between PCB and application board**
- **70°C still air**
- **Thermal power: Sub-6 7.49W**

Result:

TJ 97°C meets maximum TJ (115°C) of class B requirement and maximun TJ (100°C) of class A

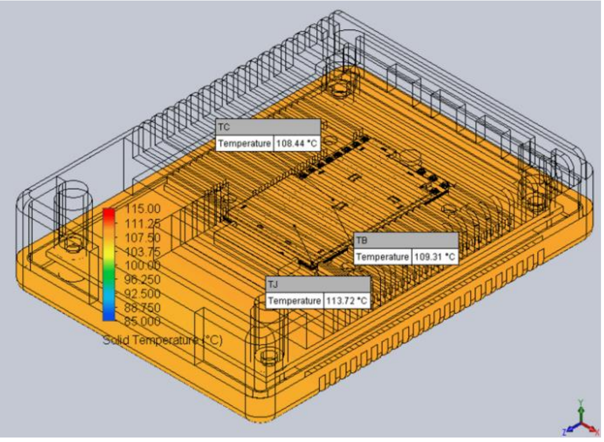


Figure 9-32

Configuration:

- **Aluminum top housing 115X85X18.5 mm**
- **Aluminum bottom housing 115X85X8.6 mm**
- **Aluminum heatsink between PCB and application board**
- **85°C still air**
- **Thermal power: LTE 5.65W**

Result:

TJ 114°C meets maximum TJ (115°C) of class B requirement, but has 14°C's gap to meet class A requirement (maximum TJ 100°C).

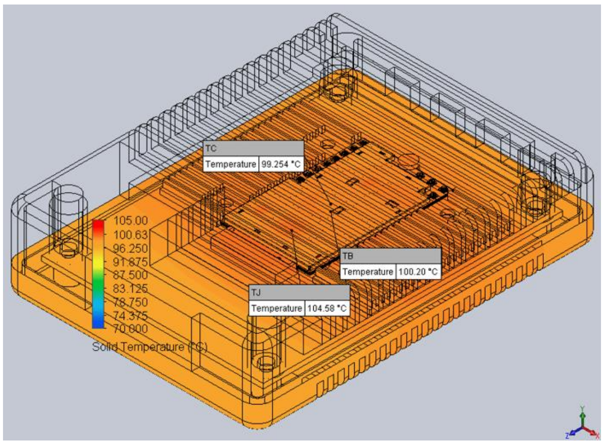


Figure 9-33

Configuration:

- **Aluminum top housing 115X85X18.5 mm**
- **Aluminum bottom housing 115X85X8.6 mm**
- **Aluminum heatsink between PCB and application board**
- **70°C still air**
- **Thermal power: LTE 5.65W**

Result:

TJ 105°C meets maximum TJ (115°C) of class B requirement, but has 5°C's gap to meet class A requirement (maximum TJ 100°C).

The thermal conductivity of mechanical parts used in simulations of router use case is listed in below table:

Table 9-2 Thermal Conductivity of Mechanical Parts Used in Router Application

Part Name	Material	Thermal Conductivity [W/(Mk)]	Size
Shield Case	Nickel Silver	33	46.83X29.3X1.19 mm
Shield Frame	Nickel Silver	33	46.53X29X1.19 mm
Gap Fillers	GEL30	3.5	Case surfaces of hot components
Module PCB	Hi_Tg FR4&Copper	251 at axial and 251 in plane	52X30X1.6 mm
Application Board	FR4&Copper	10 at axial and 38.5 in plane	100X74X1.6 mm
Host Connector	Cool Polymers (E2) LCP	20	21.7X7.15X3.2 mm
Dev-kit Standoff	Copper	380	ϕ5.5X1.5 mm (inner hole: ϕ2 mm)
Thermal Pad_PCB	PMP-P-300K	6	48X30X1.5 mm
Thermal Pad_top hsg	PMP-P-300K	6	47X30X0.38 mm
Thermal Pad_bot hsg	PMP-P-300K	6	60X48X0.5 mm
Heatsink	Aluminum	140	60X48X3.6mm
Top Housing	Plastic or Aluminum	0.15 or 140	Refer to simulation cases
Bottom Housing	Plastic or Aluminum	0.15 or 140	Refer to simulation cases

The configurations of thermal design on router use case are as below:

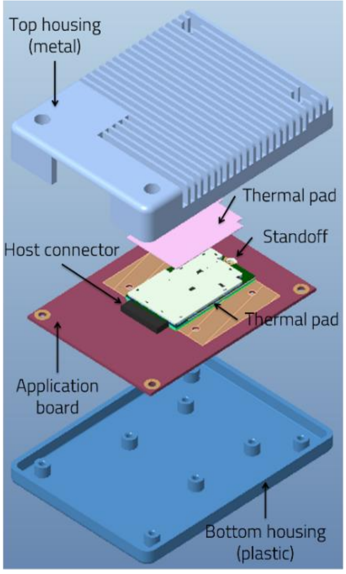


Figure 9-36 Metal housing on top and plastic housing on bottom, thermal pad between PCB and application board (Simulation Figure 9-20)

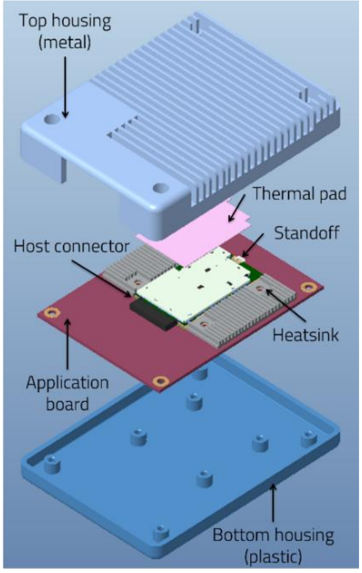


Figure 9-37 Metal housing on both top and plastic housing on bottom, heatsink between PCB and application board (Simulation Figure 9-21)

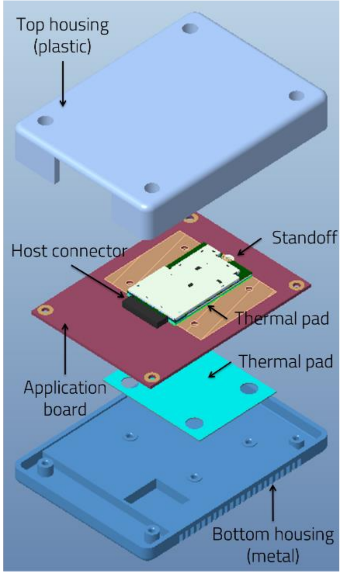


Figure 9-38 Plastic housing on top and metal housing on bottom, thermal pad between PCB and application board (Simulation Figure 9-22)

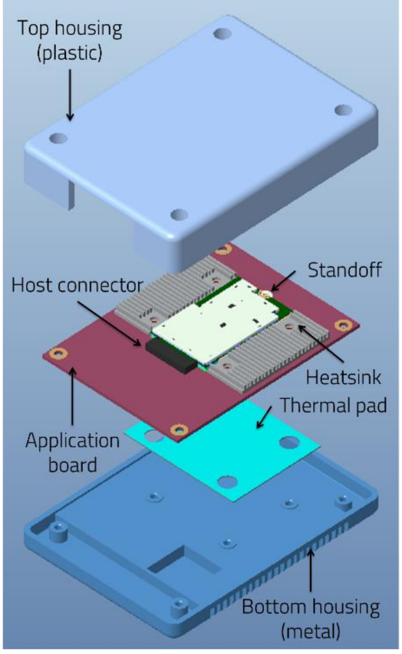


Figure 9-39 Plastic housing on top and metal housing on bottom, heatsink between PCB and application board (Simulation Figure 9-23)

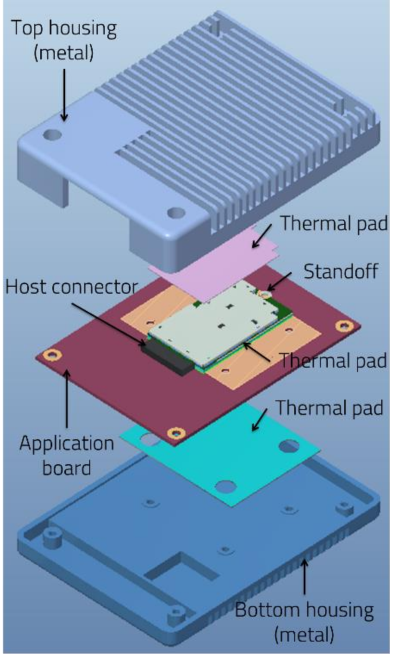


Figure 9-40 Metal housing on both top and bottom, thermal pad between PCB and application board (Simulation Figure 9-24)

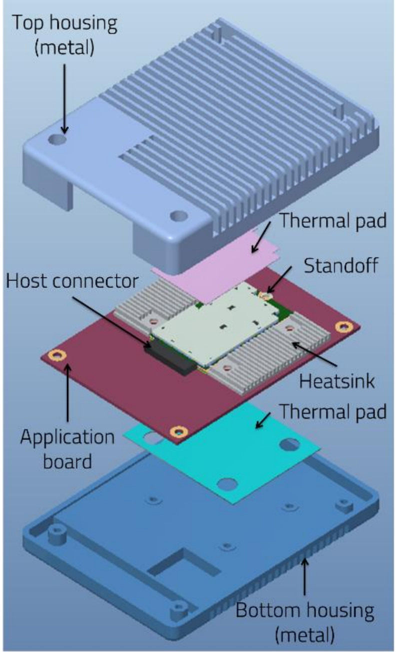


Figure 9-41 Metal housing on both top and bottom, heatsink between PCB and application board (Simulation Figure 9-25, Figure 9-26, Figure 9-27, Figure 9-28, Figure 9-29, Figure 9-30, Figure 9-31, Figure 9-32, Figure 9-33)

10 References

No.	Reference	Title
[1]	JESD51	Methodology for the Thermal Measurement of Component Packages (Single Semiconductor Device), Dec. 1995.
[2]	JESD15	Thermal Modeling Overview, Oct. 2008
[3]	80-PK564-12A	80_PK564_12A_B_SDX55___QTM527_CHIPSET_THERMAL_POWER (Qualcomm document)
[4]	2174267	AirPrime EM919x Thermal Mitigation

11 Support

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12 Document History

Version	Date	History
1.0	November 1, 2019	Creation
2.0	June 3, 2020	Updated for production hardware
3.0	September 25, 2020	Updated EM9190 thermal model and thermal power, added EM9191 and EM7690 thermal model and thermal power

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