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							EM7595			
Software Compatibility	ALL				Document Type		App Note	✓	Tech Note	

1 Version

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2 Introduction

This document is provided to Sierra Wireless distributors and clients to aid more rapid development of embedded applications using the Sierra Wireless portfolio of cellular solutions. To request a new application/technical note, contact your regional Sierra Wireless Product Marketing Manager.

Note: In this document:

- *EM759X refers to EM7590 and EM7595.*

3 Glossary

Term	Definition
CFD	Computational Fluid Dynamics
CTM	Compact Thermal Model
IC	Integrated Circuit
PA	Power Amplifier
PCB	Printed Circuit Board
ΔP	Delta Power

4 Thermal Model

The EM759X module has multiple inner heat sources. Thermal power (heat) from these sources is dissipated through the module's top shield case and bottom PCB surface:

- Directly into the ambient environment, or
- Through parts in contact with these surfaces, such as the host platform application board, housing, and heatsink

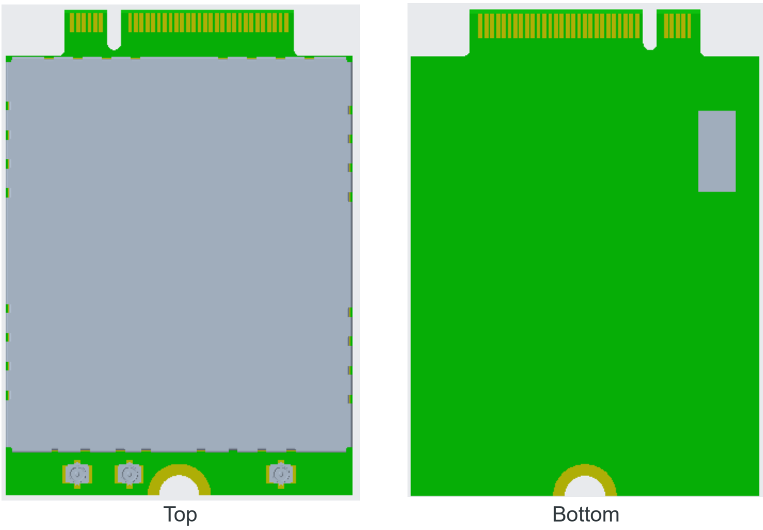


Figure 1: EM759X Top (Shield) and Bottom (PCB) Surfaces

A compact thermal model (CTM) is a simplified model that satisfies the technical requirements of accuracy and software compatibility in thermal design and simulation. The EM759X CTM model described below in Figure 2 and Table 1 is defined based on the following assumptions:

- The module is mounted horizontally with the shield case facing upward
- The module is exposed in 25°C still air (i.e., ambient temperature = 25°C)
- The module is bare and unmounted (i.e., no host connection)
- Thermal resistance values in Table 1 are for the module only. The values do not include any external parts in contact with the module.

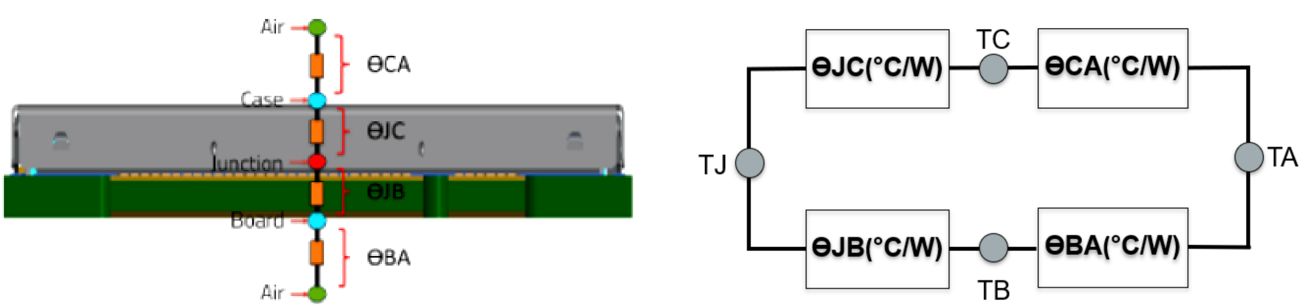


Figure 2: EM759X CTM Description

Table 1: EM759X CTM

Path	Thermal Resistance (°C/W)
θ_{JC} (Junction-to-Case thermal resistance)	6.5
θ_{CA} (Case-to-Ambient thermal resistance)	14.2
θ_{JB} (Junction-to-Board thermal resistance)	2.4
θ_{BA} (Board-to-Ambient thermal resistance)	31.3
θ_{JA} (Junction-to-Ambient thermal resistance) $\theta_{JA} = \frac{(\theta_{JC} + \theta_{CA}) \times (\theta_{JB} + \theta_{BA})}{\theta_{JC} + \theta_{CA} + \theta_{JB} + \theta_{BA}}$	13.7

Note that with respect to the thermal resistance values in Table 1:

- θ_{CA} and θ_{BA} will be affected by the module's mounting orientation
- Values may vary between use cases:
  - The use case's effect on the module's various internal heat sources may cause slight differences.
  - Different operating bands may cause slight differences.

Nevertheless, the thermal resistances provided in Table 1 should be a good reference for any application's evaluation.

5 Thermal Power Use Cases

The EM759X module has challenging use cases for thermal power dissipation.

Table 2 describes the theoretical worst-case scenario with maximum thermal power under extreme conditions, which can be used for system thermal design and solution evaluation in your device. However, the realistic worst-case use case for your device may differ from this value.

Sierra Wireless recommends that you identify the realistic worst-case condition for your device and perform appropriate thermal evaluation. (For example, your use case could consider different combinations of data throughput rate, Tx output power, and test duration.)

Table 2: Thermal Power—Theoretical Worst Case

Module	Condition	Thermal Power @ TJ=65°C (W)	Notes
EM7590	• Cat13, 2CA, 2 x 20 MHz • DL 383 Mbps, UL 147 Mbps • Tx power max 23 dBm (DL 256QAM, UL 64QAM)	4.7	Thermal power (4.7 W) is based on TJ=65°C (per Qualcomm thermal power document 80-12402-12 Rev.AB). Actual thermal power measured will vary depending on the actual TJ value on the customer’s device.
EM7595	• Cat12, 3CA, 3 x 20 MHz • DL 598 Mbps, UL 149 Mbps • Tx power max 23 dBm (DL 256QAM, UL 64QAM)		

6 Operating Temperature Specification

The EM759X module's thermal (operating temperature) evaluation is based, in part, on the following temperature parameters:

- TJ—Module junction temperature. This specification must be strictly followed.
- TC, TB—Module surface temperatures. (TC—Top, TB—Bottom). These are reference specifications that should be used only when TJ is not available.
- TA—Ambient temperature around the module. This is a general operating temperature range that can be stated with proper thermal designs.

6.1 TJ—Module Junction Temperature

There are multiple heat sources inside the EM759X module, such as the SDX12 baseband semiconductor chip, PAs (power amplifiers), PMD9655 (power management IC), transceiver, etc.

For the EM759X thermal evaluation, TJ represents the overall module's temperature and is based on the SDX12 die temperature, since the SDX12 contributes the most to the module's temperature rise. However, the SDX12 may not have the hottest junction temperature of all the chips in all use cases.

The operating range for TJ is shown in Table 3.

Table 3: Operating Temperature Range—TJ

Parameter	Operating Class	Temperature Range
TJ	Class A	-30°C < TJ < 70°C
	Class B	-40°C < TJ < -30°C 70°C < TJ < 105°C

Note:

- Class A is defined as the operating temperature range that the device:
  - **i.** Shall exhibit normal function during and after environmental exposure.
  - **ii.** Shall meet the minimum requirements of 3GPP or appropriate wireless standards.
- Class B is defined as the operating temperature range that the device:
  - **i.** Shall remain fully functional during and after environmental exposure.
  - **ii.** 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.
  - **iii.** 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 solutions for applications with integrated EM759X modules, and enough margin should be kept for system thermal design to make sure that TJ will not exceed its maximum temperature limit.

Sierra Wireless does not recommend operating the module at high TJ for a long period. If the module's operational temperature rises too high, the module automatically attempts to reduce the temperature—for details, refer to *[3] EM759X Series Thermal Mitigation Guide*.

TJ can be evaluated using the following equation:

$$TJ = \theta_{JA} \times \Delta P + TA$$

where:

- θ_{JA} = Thermal resistance from junction to ambient (°C/W)
- TA = Ambient temperature (°C)
- ΔP = Power dissipation of EM759X module (W)

6.2 TC and TB—Module Surface Temperatures

TC and TB are recommended to be used for evaluating EM759X thermal risk only when TJ is not available. Measurement locations for TC and TB are shown in Figure 3.

To measure these values, attach a thermocouple to the center of the surface being measured (i.e., the bottom PCB surface or top shield case surface).

The operating ranges of TC and TB are shown in Table 4.

Table 4: Operating Temperature Range—TC, TB

Parameter	Operating Class	Temperature Range
TC	Class A	-30°C < TC < 64°C
	Class B	-40°C < TC < -30°C 64°C < TC < 99°C
TB	Class A	-30°C < TB < 68°C
	Class B	-40°C < TB < -30°C 68°C < TB < 103°C

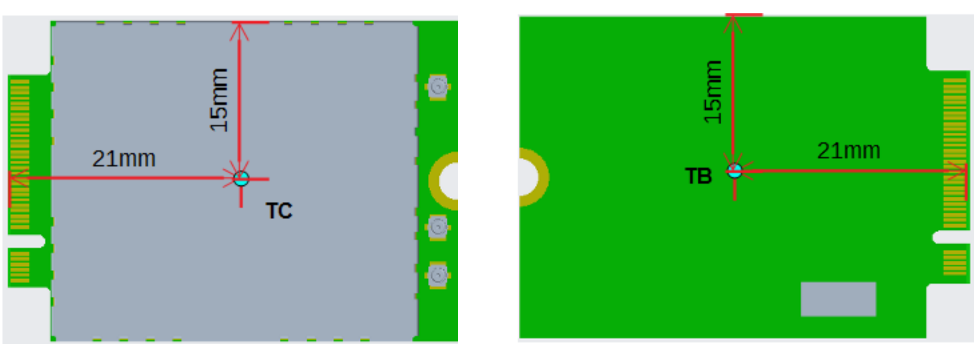


Figure 3: TC/TB Measurement Locations

6.3 TA—Ambient Temperature

TA (the ambient temperature) is measured at 25 mm from the module's bottom surface, per the JESD51 standard.

The operating range of TA is shown in Table 5.

Table 5: Operating Temperature Range—TA

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

TA is a useful value to use for first-level (initial) thermal measurement or design evaluation. It should not be used to indicate whether the module will function properly under real operating conditions, since system-level thermal dissipation design methods such as heatsinks and flowing air could have significant impacts on the module's TJ while TA remains unchanged.

The EM759X module's operating temperature range is Class B at TA from -40°C to 85°C and Class A from -30°C to 70°C. Integrators must ensure thermal design such that TJ does not exceed its specification, otherwise the EM759X may not work normally in the defined TA range.

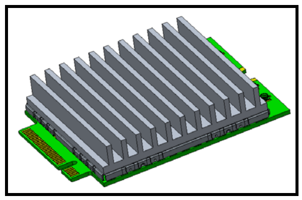
7 Operating Temperature Evaluation

7.1 Operating Temperature Evaluation by Thermal Model

During the customer's application development stage, the EM759X operating temperature can be evaluated using the thermal model described in Table 1 on page 3. However, because thermal resistances θ_{CA} and θ_{BA} may differ in the application (due to parts contacting the shield case or the bottom of the module's PCB, ambient temperature and air flow, module mounting orientation, etc.), the application's actual θ_{CA} and θ_{BA} should be evaluated.

This section describes some typical thermal design solutions, for reference.

7.1.1 Heatsink on Shield Case



When a heatsink is used on the shield case, θ_{HS} (thermal resistance of heatsink-to-air) replaces θ_{CA} (from the EM759X CTM in Table 1) in the θ_{JA} calculation.

For example, Table 6 describes the thermal model for the EM759X with a heatsink on the shield case, using θ_{HS} instead of θ_{CA}.

Using this thermal model with TA=25°C in still air and ΔP=4.7 (theoretical worst-case thermal power use case from Table 2), the module's TJ value is evaluated as 65.4°C:

$$TJ = \theta_{JA} \times \Delta P + TA$$

$$TJ = 8.6°\text{C/W} \times 4.7\text{W} + 25°\text{C}$$

$$TJ = 65.4°\text{C}$$

Table 6: Thermal Model[a]—EM759X with Heatsink on Shield Case

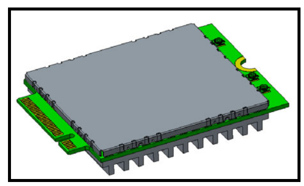
Thermal Resistance	EM759X LTE Use Case (°C/W)	Notes
θ_{JC} (Junction-to-Case thermal resistance	6.5	
θ_{HS} (Heatsink-to-Air thermal resistance	5	θ_{HS} replaces θ_{CA} from the EM759X CTM (Table 1)
θ_{JB} (Junction-to-Board thermal resistance	2.4	
θ_{BA} (Board-to-Ambient thermal resistance	31.3	
θ_{JA} (Junction-to-Ambient thermal resistance $\theta_{JA} = \frac{(\theta_{JC}+\theta_{HS})\times(\theta_{JB}+\theta_{BA})}{\theta_{JC}+\theta_{HS}+\theta_{JB}+\theta_{BA}}$	8.6	

a. Based on Table 1, EM759X CTM, on page 3, including assumptions described in Thermal Model on page 2.

Note—In a realistic application, other values in Table 6 would also likely be changed. For example:

- θ_{BA} will vary depending on the mounting orientation (e.g., not mounted horizontally) or if TA is measured in flowing air instead of still air.
- ΔP will vary if the module is not operated at maximum (worst-case) thermal power.
- θ_{HS} will be based on a realistic top heatsink. (e.g., θ_{HS} will be affected by the actual heatsink type, housing, plate, and other mechanical parts designed in the system)
  The value used in Table 6 is a generalized (theoretical) definition.

7.1.2 Heatsink on Bottom PCB Surface



When a heatsink is used on the bottom PCB surface, θ_{HS} (thermal resistance of heatsink-to-air) replaces θ_{BA} (from the EM759X CTM in Table 1) in the θ_{JA} calculation.

For example,Table 7 describes the thermal model for the EM759X with a heatsink on the bottom of the PCB, using θ_{HS} instead of θ_{BA}.

Using this thermal model with TA=25°C in still air and ΔP=4.7 W (theoretical worst-case thermal power use case from Table 2), the module's TJ value is evaluated as 50.9°C:

$$TJ = \theta_{JA} \times \Delta P + TA$$
$$TJ = 5.5°\mathrm{C/W} \times 4.7\mathrm{W} + 25°\mathrm{C}$$
$$TJ = 50.9°\mathrm{C}$$

Table 7: Thermal Model[a]—EM759X with Heatsink on Bottom

Thermal Resistance	EM759X LTE Use Case (°C/W)	Notes
θ_{JC} (Junction-to-Case thermal resistance	6.5	
θ_{CA} (Case-to-Ambient thermal resistance	14.2	
θ_{JB} (Junction-to-Board thermal resistance	2.4	

Table 7: Thermal Model[a]—EM759X with Heatsink on Bottom (Continued)

Thermal Resistance	EM759X LTE Use Case (°C/W)	Notes
θ_{HS} (Heatsink-to-Air thermal resistance	5	θ_{HS} replaces θ_{BA} from the EM759X CTM (Table 1)
θ_{JA} (Junction-to-Ambient thermal resistance $\theta_{JA} = \frac{(\theta_{JC}+\theta_{CA})\times(\theta_{JB}+\theta_{HS})}{\theta_{JC}+\theta_{CA}+\theta_{JB}+\theta_{HS}}$	5.5	

a. Based on Table 1, EM759X CTM, on page 3, including assumptions described in Thermal Model on page 2.

Note—In a realistic application, other values in Table 7 would also likely be changed. For example:

- θ_{CA} will vary depending on the mounting orientation (e.g., not mounted horizontally) or if TA is measured in flowing air instead of still air.
- ΔP will vary if the module is not operated at maximum (worst-case) thermal power.
- θ_{HS} will be based on a realistic bottom heatsink. (e.g., θ_{HS} will be affected by the actual heatsink type, housing, plate, and other mechanical parts designed in the system)
  The value used in Table 7 is a generalized (theoretical) definition.

7.2 Operating Temperature Evaluation by Simulation

During the customer's application development stage, the EM759X module's operating temperature can also be evaluated by thermal simulation:

- Use FloTHERM to create the compact 3D model with appropriate thermal resistance values:
  - θ_{JC} and θ_{JB}—Use the values in Table 1, EM759X CTM, on page 3.
  - θ_{CA} and θ_{BA}—These values are simulated automatically in the CFD tool.
- Upon request, Sierra Wireless can provide a FloTHERM simulation model package (.pdml format) for your simulation.

7.3 Operating Temperature Evaluation by Measurement

When the EM759X module has been integrated into your device, you can evaluate system-level thermal risk by comparing measured TJ, TC and TB values to their operating temperature ranges. (The SDX12 TJ is obtained using AT commands to under any operating mode, and TC/TB are obtained using thermocouples.)

To perform thermal measurement of the module:

1. Attach thermocouples at the TC and TB locations specified in Figure 3.

   If a heatsink is mounted on the PCB bottom surface or the shield case surface, attach the thermocouples at the points on the heatsink closest to the TC and TB locations.
2. Mount the module at the designated location on the platform. Set the ambient airflow to match the application's typical realistic usage environment.
3. Set up a call with the worst-case thermal power use case for your platform (throughput, output power, duty cycle, etc.).
4. Monitor the TJ via AT commands (see *[2] EM759X Series AT Commands Reference*), and TC and TB via a thermal monitor. Record the temperature values when they reach thermal stabilization.
5. Increase the environment's ambient temperature, then:

   a. Measure TJ, TC and TB.

   b. Confirm the values meet the applicable specifications/limits—Table 3 (TJ) and Table 4 (TC and TB).

8 Reference Documents

The following documents are available at source.sierrawireless.com:

Document	Document #	Description
[1] EM759X Series Product Technical Specification	41114425	Product details (RF, Power, Interfaces, Mechanical, etc.)
[2] EM759X Series AT Commands Reference	41114426	Supported standard and proprietary AT commands.
[3] EM759X Series Thermal Mitigation Guide	2174324	Thermal mitigation techniques employed by the module to reduce operational temperature.

9 Support

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10 Document History

Revision	Release Date	Changes
1	April 08, 2022	Creation
2	June 16, 2023	Populated Table 2, Thermal Power—Theoretical Worst Case (replaced TBD) Updated Table 3, Operating Temperature Range—TJ (updated ranges) Updated Table 4, Operating Temperature Range—TC, TB (updated ranges) Updated Figure 3 (combined Figure 3 TC Measurement Location and Figure 4 TB Measurement Location) Updated Table 5, Operating Temperature Range—TA (updated ranges) Updated Table 7, Operating Temperature Evaluation (general update including updated subsection descriptions, table values,procedure descriptions, etc.) Updated to use only FloTHERM tool
3	August 29, 2023	Added EM7595, replaced EM7590 with EM759X where applicable Replaced equation variable PD with ΔP Updated Table 1, EM759X CTM (thermal resistance values) Updated Table 2, Thermal Power—Theoretical Worst Case (added EM7595 case) Updated Table 6, Thermal Model—EM759X with Heatsink on Shield Case (Use case values) Updated Table 7, Thermal Model—EM759X with Heatsink on Bottom (Use case values)

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