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Content Level	BASIC		INTERMEDIATE		ADVANCED	✓	Confidentiality	Public	✓	Private	

Hardware Compatibility	Product Line	IoT Modules	Series	RC7110	
				RC7120	

Software Compatibility	ALL	Document Type	App Note	✓	Tech Note	

1 Version

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2 Introduction

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Note: In this document, RC71xx refers to RC7110 and RC7120.

3 Glossary

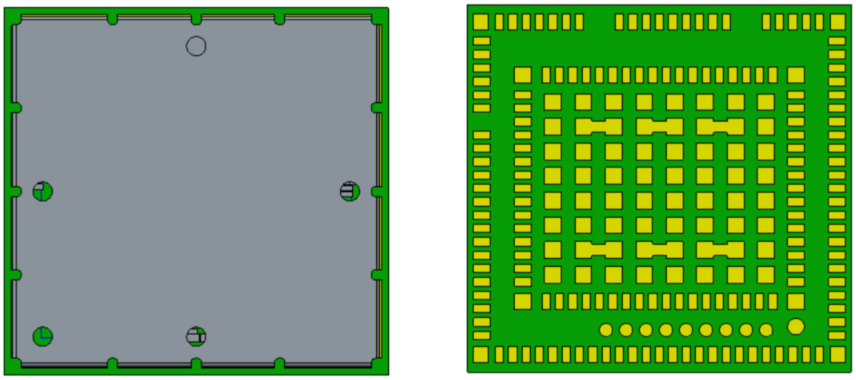
Term	Definition
CFD	Computational Fluid Dynamics
CTM	Compact Thermal Model
IC	Integrated Circuit
PA	Power Amplifier
PCB	Printed Circuit Board
ΔP	Delta Power

4 Thermal Model

The RC71xx module has multiple inner heat sources. Thermal power (heat) from these sources is dissipated through the module's top shielding 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.



Top Bottom

Figure 1: RC71xx Top (Shield Case) 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 RC71xx 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 (i.e., in the opposite direction of gravity)
- The module is exposed in 25°C still air (i.e., ambient temperature = 25°C)
- The module is bare (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.

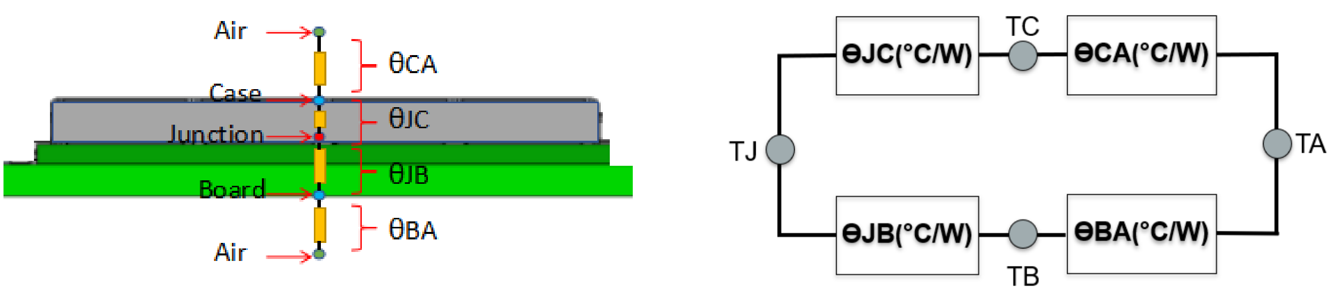


Figure 2: RC71xx CTM Description

Table 1: RC71xx CTM

Path	Thermal Resistance (°C/W)
θ_{JC} (Junction-to-Case thermal resistance)	6.5
θ_{CA} (Case-to-Ambient thermal resistance)	6.7
θ_{JB} (Junction-to-Board thermal resistance)	9.8

Table 1: RC71xx CTM (Continued)

Path	Thermal Resistance (°C/W)
θ_{BA} (Board-to-Ambient thermal resistance)	3.4
θ_{JA} (Junction-to-Ambient thermal resistance) $$\theta_{JA} = \frac{(\theta_{JC}+\theta_{CA})\times(\theta_{JB}+\theta_{BA})}{\theta_{JC}+\theta_{CA}+\theta_{JB}+\theta_{BA}}$$	13.2

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 source locations 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 RC71xx 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 thermal power for your device may differ from this value.

Semtech 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
RC7110	▪ Cat1bis, B7, 20 MHz ▪ DL 10.296 Mbps, UL 632 Kbps ▪ Tx power max 23 dBm	2.793	Actual thermal power measured will vary depending on the actual TJ value on the customer's device.
RC7120	▪ Cat1bis, B2, 20 MHz ▪ DL 10.296 Mbps, UL 632 Kbps ▪ Tx power max 23 dBm	2.608	

6 Operating Temperature Specification

The RC71xx module's thermal (operating temperature) evaluation is based, in part, on the following temperature parameters:

- TJ — Module junction temperature.

  Important: 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 RC71xx module, such as the QCX216 baseband semiconductor chip and QPA8675 PA (power amplifier).

For the RC71xx thermal evaluation, TJ represents the overall module's temperature and is based on the QCX216 die temperature, since the QCX216 contributes the most to the module's temperature rise. However, the QCX216 may not have the hottest junction temperature in all use cases (e.g., the QPA8675 PA may be hotter in some use cases).

Note: TJ (i.e., the QCX216 die temperature) can be reported using the AT command ***AT!MADC=1***

The operating temperature range for TJ is specified in Table 3.

Table 3: Operating Temperature Range — TJ

Parameter	Operating Class	Temperature Range
TJ	Class A	-30°C < TJ < 92°C
	Class B	-40°C < TJ < -30°C 92°C < TJ < 93°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 any of the device's supported call modes (SMS, Data) even when one or more environmental constraints exceed the specified tolerance.
  - **iii.** Unless otherwise stated, full performance should return to normal after the excessive constraint(s) have been removed.

Important: *TJ can be used as the top priority to evaluate system-level thermal design and solutions for applications with integrated RC71xx modules, and enough margin should be kept for system thermal design to make sure that TJ will not exceed 92°C (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] RC71xx Series Thermal Mitigation Guide (Doc# 2174356)*.

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 RC71xx module (W)

6.2 TC and TB — Module Surface Temperatures

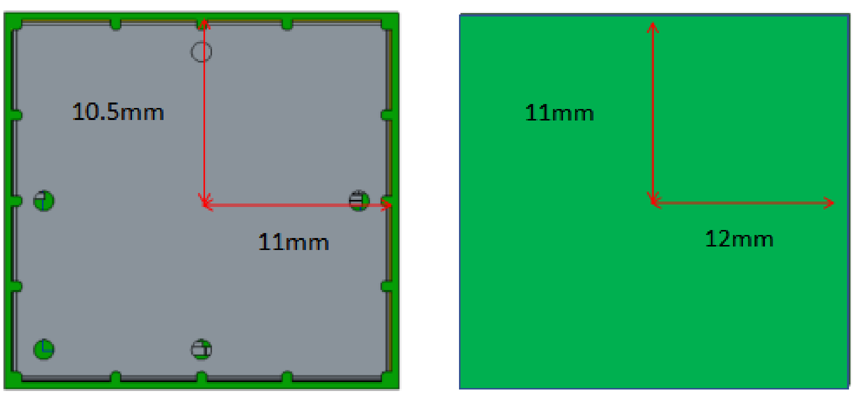
TC and TB are recommended to be used for evaluating RC71xx thermal risk only when TJ is not available. Measurement locations for TC and TB are shown in Figure 3.

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 < 75°C
	Class B	-40°C < TC < -30°C 75°C < TC < 80°C
TB	Class A	-30°C < TB < 75°C
	Class B	-40°C < TB < -30°C 75°C < TB < 80°C



TC location TB location

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 temperature 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.

Integrators must implement a solid system-level thermal design to ensure TJ does not exceed its specification (Table 5), otherwise the RC71xx 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 RC71xx operating temperature can be evaluated using the thermal model described in Table 1 on page 2. 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.

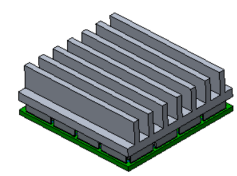
This section describes some typical thermal design solutions, for reference.

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 RC71xx CTM in Table 1) in the θ_{JA} calculation.

For example,Table 6 describes the thermal model for the RC71xx 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=2.793 W (theoretical worst-case thermal power use case from Table 2), the module's TJ value is evaluated as 59.1°C:



Heatsink on Shield

$$TJ = \theta_{JA} \times \Delta P + TA$$
$$TJ = 12.2°\mathrm{C/W} \times 2.793\,\mathrm{W} + 25°\mathrm{C}$$
$$TJ = 59.1°\mathrm{C}$$

Table 6: Thermal Model[a] — RC71xx with Heatsink on Shield Case

Thermal Resistance	RC71xx LTE Use Case (°C/W)	Notes
θ_{JC} (Junction-to-Case thermal resistance	3.0	
θ_{HS} (Heatsink-to-Air thermal resistance	9.2	θ_{HS} replaces θ_{CA} from the RC71xx CTM (Table 1)

Table 6: Thermal Model[a] — RC71xx with Heatsink on Shield Case (Continued)

Thermal Resistance	RC71xx LTE Use Case (°C/W)	Notes
θ_{JB} (Junction-to-Board thermal resistance	6.6	
θ_{BA} (Board-to-Ambient thermal resistance	5.5	
θ_{JA} (Junction-to-Ambient thermal resistance $\theta_{JA} = \frac{(\theta_{JC}+\theta_{HS})\times(\theta_{JB}+\theta_{BA})}{\theta_{JC}+\theta_{HS}+\theta_{JB}+\theta_{BA}}$	12.2	

a. Based on Table 1, RC71xx CTM, on page 2, including assumptions described in 4 Thermal Model.

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.

8 Operating Temperature Evaluation by Simulation

During the customer's application development stage, the RC71xx 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, RC71xx CTM, on page 2.
  - 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.

8.1 Operating Temperature Evaluation by Measurement

When the RC71xx 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 QCX216 TJ is obtained using AT commands 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 to obtain values that are close to TC and TB.

   Note: This may require adding a blind hole or concave geometry on the heatsink for thermocouple attachment.
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] RC71xx AT Command Reference (Doc# 41114675)*, and TC and TB via a thermal recorder machine. 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). %%[add any safe margin wording?]

9 References

Sierra Wireless

[1] RC71xx Product Technical Specification (Doc# 41114675)
[2] RC71xx AT Command Reference (Doc# 41114675)
[3] RC71xx Series Thermal Mitigation Guide (Doc# 2174356)

10 Support

For direct clients: contact your Semtech FAE

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11 Document History

Revision number	Release date	Changes
1	May 2024	Creation

12 Legal Notice

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