RG520N&RG525F&RG5x0F&RM5x0N Series Software Thermal Management Guide

5G Module Series

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About the Document

Revision History

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-	2022-04-02	Aydan DING	Creation of the document
1.0	2023-03-28	Aydan DING	First official release

Contents

Table Index

1 Introduction

This document describes the software thermal management mechanism and related AT commands for Quectel 5G RG520N series, RG525F-NA, RG5x0F family, and RM5x0N family. When the temperature reaches a specific threshold, any one of the thermal management mechanisms will be adopted to achieve thermal management.

1.1. Applicable Modules

Table 1: Applicable Modules

Module Family	Module
-	RG520N Series
-	RG525F-NA
RG5x0F	RG520F Series
	RG530F Series
RM5x0N	RM520N Series
	RM530N-GL

2 AT Command Description

2.1. AT Command Introduction

2.1.1. Definitions

- **<CR>**   Carriage return character.
- **<LF>**   Line feed character.
- **<...>**   Parameter name. Angle brackets do not appear on the command line.
- **[...]**   Optional parameter of a command or an optional part of TA information response. Square brackets do not appear on the command line. When an optional parameter is not given in a command, the new value equals to its previous value or the default settings, unless otherwise specified.
- **Underline**   Default setting of a parameter.

2.1.2. AT Command Syntax

All command lines must start with **AT** or **at** and end with **<CR>**. Information responses and result codes always start and end with a carriage return character and a line feed character: **<CR><LF><response><CR><LF>**. In tables presenting commands and responses throughout this document, only the commands and responses are presented, and **<CR>** and **<LF>** are deliberately omitted.

Table 2: Types of AT Commands

Command Type	Syntax	Description
Test Command	**AT+<cmd>=?**	Test the existence of the corresponding command and return information about the type, value, or range of its parameter.
Read Command	**AT+<cmd>?**	Check the current parameter value of the corresponding command.
Write Command	**AT+<cmd>=<p1>[,<p2>[,<p3>[...]]]**	Set user-definable parameter value.
Execution Command	**AT+<cmd>**	Return a specific information parameter or perform a specific action.

2.2. Declaration of AT Command Examples

The AT command examples in this document are provided to help you learn about the use of the AT commands introduced herein. The examples, however, should not be taken as Quectel's recommendations or suggestions about how to design a program flow or what status to set the module into. Sometimes multiple examples may be provided for one AT command. However, this does not mean that there is a correlation among these examples, or that they should be executed in a given sequence.

2.3. AT+QTEMP   Query Module Temperature

This command queries the module's temperature.

AT+QTEMP Query Module Temperature	
Test Command **AT+QTEMP=?**	Response **OK**
Execution Command **AT+QTEMP**	Response **+QTEMP:<sensor>,<temp>** **…** **OK**
Maximum Response Time	300 ms
Characteristics	/

Parameter

<sensor>	String type. Sensor type.
	"modem-lte-sub6-pa1" External PA #1
	"modem-sdr0-pa0" 3G/4G/5G low band PA module
	"modem-sdr0-pa1" 4G/5G mid/high band ET PA module
	"modem-sdr0-pa2" 5G SUB6 n77/n79 LPAF ET PA module
	"modem-sdr1-pa0" 3G/4G/5G low band PA module
	"modem-sdr1-pa1" 4G/5G mid/high band ET PA module
	"modem-sdr1-pa2", 5G SUB6 n77/n79 LPAF ET PA module
	"modem-mmw0" mmWave thermal sensor
	"aoss-0-usr" Always-on subsystem unit
	"cpuss-0-usr" CPUSS.0
	"mdmq6-0-usr" DSP processor
	"mdmss-0-usr" MDMSS.0
	"mdmss-1-usr" MDMSS.1

	"mdmss-2-usr"	MDMSS.2
	"mdmss-3-usr"	MDMSS.3
	"modem-lte-sub6-pa2"	External PA #2
	"modem-ambient-usr"	Ambient temperature detection
\<temp\>	Integer type. The temperature. Unit: ºC.	

Example

```
AT+QTEMP                              //Query the module's temperature.
+QTEMP:"modem-lte-sub6-pa1","28"
+QTEMP:"modem-sdr0-pa0","0"
+QTEMP:"modem-sdr0-pa1","0"
+QTEMP:"modem-sdr0-pa2","0"
+QTEMP:"modem-sdr1-pa0","0"
+QTEMP:"modem-sdr1-pa1","0"
+QTEMP:"modem-sdr1-pa2","0"
+QTEMP:"modem-mmw0","0"
+QTEMP:"aoss-0-usr","29"
+QTEMP:"cpuss-0-usr","28"
+QTEMP:"mdmq6-0-usr","28"
+QTEMP:"mdmss-0-usr","28"
+QTEMP:"mdmss-1-usr","28"
+QTEMP:"mdmss-2-usr","28"
+QTEMP:"mdmss-3-usr","28"
+QTEMP:"modem-lte-sub6-pa2","27"
+QTEMP:"modem-ambient-usr","28"

OK
```

NOTE

If the queried temperature is 0 ºC or -273 ºC, the corresponding sensor is inactive, and these queried values are invalid.

2.4. AT+QTHERMAL   Extended Commands of Thermal Management Mechanism

These extended commands configure the thermal management mechanism.

AT+QTHERMAL Extended Commands of Thermal Management Mechanism	
Test Command **AT+QTHERMAL=?**	Response **+QTHERMAL: "thermal_sensor",\<sensor>** **+QTHERMAL: "thermal_level"** **+QTHERMAL: "urc_enable",**(list of supported **\<enable>**s**)** **+QTHERMAL: "pa_trigger",\<level>,\<trig>,\<clr>** **OK**
Maximum Response Time	300 ms
Characteristics	/

2.4.1. AT+QTHERMAL="thermal_sensor"   Query Temperature of a Specific Sensor

This command queries all the thermal sensors supported by the module and the temperature of a specific thermal sensor.

AT+QTHERMAL="thermal_sensor" Query Temperature of a Specific Sensor	
Write Command **AT+QTHERMAL="thermal_senso r"[,\<sensor>]**	Response If the optional parameter is omitted, query all the thermal sensors supported by the module: **+QTHERMAL: "thermal_sensor",\<sensor1>,…,\<sensorN>** **OK** If the optional parameter is specified, query the temperature of a specific thermal sensor: **+QTHERMAL: "thermal_sensor",\<sensor>,\<temp>** **OK** If there is an error: **ERROR**
Maximum Response Time	300 ms
Characteristics	/

Parameter

\<sensorN>	String type. Sensor type. Commonly used sensor types are as follows:
	"pa" PA
	"mdm" MDM

<temp>	Integer type. The temperature. Unit: ºC.

Example

<pre>
AT+QTHERMAL="thermal_sensor"   //Query the thermal sensors supported by the module.
+QTHERMAL: "thermal_sensor","pa","mdm"

OK
AT+QTHERMAL="thermal_sensor","pa"   //Query the temperature of PA.
+QTHERMAL: "thermal_sensor","pa",32

OK
</pre>

2.4.2. AT+QTHERMAL="thermal_level" Query Thermal Management Level

This command queries all the current thermal management levels of the module.

AT+QTHERMAL="thermal_level" Query Thermal Management Level	
Write Command **AT+QTHERMAL="thermal_level"**	Response **+QTHERMAL: "thermal_level",<thermal_mitigation>,<level>** **+QTHERMAL: "thermal_level",<thermal_mitigation>,<level>** … **OK** If there is an error: **ERROR**
Maximum Response Time	300 ms
Characteristics	/

Parameter

<thermal_mitigation>	String type. Thermal management mechanisms supported by the module.	
	"modem_lte_dsc"	LTE MDM thermal management mechanism
	"modem_nr_dsc"	NR_MCG MDM thermal management mechanism
	"modem_nr_scg_dsc"	NR_SCG MDM thermal management mechanism
	"pa_lte_sdr0_dsc"	LTE PA thermal management mechanism
	"pa_nr_sdr0_dsc"	NR_MCG PA thermal management mechanism
	"pa_nr_sdr0_scg_dsc"	NR_SCG PA thermal management mechanism
<level>	Integer type. Thermal management level. Range: 0–255.	

Example

AT+QTHERMAL="thermal_level"   //Query current thermal management level.
+QTHERMAL: "thermal_level","modem_lte_dsc",0
+QTHERMAL: "thermal_level","modem_nr_dsc",0
+QTHERMAL: "thermal_level","modem_nr_scg_dsc",0
+QTHERMAL: "thermal_level","pa_lte_sdr0_dsc",0
+QTHERMAL: "thermal_level","pa_nr_sdr0_dsc",0
+QTHERMAL: "thermal_level","pa_nr_sdr0_scg_dsc",0

OK

NOTE

1. "modem_lte_dsc", "modem_nr_dsc", and "modem_nr_scg_dsc" are related to MDM thermal management mechanism, while "pa_lte_sdr0_dsc", "pa_nr_sdr0_dsc", and "pa_nr_sdr0_scg_dsc" are related to PA thermal management mechanism.
2. The higher the temperature of the module, the greater the thermal management level triggered.

2.4.3. AT+QTHERMAL="urc_enable" Control Thermal Management Level URC

This command enables or disables the URC **+THERMAL: <thermal_mitigation>,<level>** for reporting the changes of the thermal management level.

AT+QTHERMAL="urc_enable" Control Thermal Management Level URC	
Write Command **AT+QTHERMAL="urc_enable"[, <enable>]**	Response If the optional parameter is omitted, query the current setting: **+QTHERMAL: "urc_enable",<enable>** **OK** If the optional parameter is specified, enables or disables the thermal management level URC : **OK** If there is an error: **ERROR**
Maximum Response Time	300 ms
Characteristics	The command takes effect immediately. The configuration is saved automatically.

Parameter

<enable>	Integer type. Whether to enable the thermal management level URC.
	<u>0</u> Disable
	1 Enable (The URC is reported once it is enabled. The URC format is: **+THERMAL: <thermal_mitigation>,<level>**)
<thermal_mitigation>	String type. Thermal management mechanism supported by the module.
	"modem_lte_dsc" LTE MDM thermal management mechanism
	"modem_nr_dsc" NR_MCG MDM thermal management mechanism
	"modem_nr_scg_dsc" NR_SCG MDM thermal management mechanism
	"pa_lte_sdr0_dsc" LTE PA thermal management mechanism
	"pa_nr_sdr0_dsc" NR_MCG PA thermal management mechanism
	"pa_nr_sdr0_scg_dsc" NR_SCG PA thermal management mechanism
<level>	Integer type. Thermal management level. Range: 0–255.

Example

AT+QTHERMAL="urc_enable"	//Query whether the thermal management level URC is enabled.
+QTHERMAL: "urc_enable",0	
OK	
AT+QTHERMAL="urc_enable",1	//Enable the thermal management level URC.
OK	
AT+QTHERMAL="urc_enable"	//Query whether the thermal management level URC is enabled.
+QTHERMAL: "urc_enable",1	
OK	
+THERMAL: "pa_lte_sdr0_dsc",10	//The URC is reported when the thermal management level changes.

2.4.4. AT+QTHERMAL="pa_trigger"   Set PA Thermal Management Mechanism

This command sets and queries the PA thermal management mechanism.

AT+QTHERMAL="pa_trigger" Set PA Thermal Management Mechanism	
Write Command **AT+QTHERMAL="pa_trigger"[,<level>,<trig>,<clr>]**	Response If the optional parameters are omitted, query the current setting: **+QTHERMAL: "pa_trigger",1,<trig>,<clr>** **+QTHERMAL: "pa_trigger",2,<trig>,<clr>** **+QTHERMAL: "pa_trigger",3,<trig>,<clr>**

	OK
	If the optional parameters are specified, set the thermal management mechanism of the PA: **OK**
	If there is an error: **ERROR**
Maximum Response Time	300 ms
Characteristics	The command takes effect after the module is rebooted. The configurations are saved automatically.

Parameter

\<level\>	Integer type. Thermal management level of the PA. Each level corresponds to a set of **\<trig\>** and **\<clr\>**. 1 Level 1, limiting the UL data rate (*see Chapter 3.1.1*) 2 Level 2, restricting the PA power based on Level 1 (*see Chapter 3.1.2*) 3 Level 3, entering Limited-Service Mode (*see Chapter 3.1.3*).
\<trig\>	Integer type. Triggering temperature threshold. When the temperature reaches **\<trig\>**, the corresponding thermal management level (**\<level\>**) is triggered. Range: 0–120. Unit: ºC. When **\<level\>**=1, **\<trig\>** is the temperature threshold to trigger the UL data rate limit. Default: 95. When **\<level\>**=2, **\<trig\>** is the temperature threshold to trigger the PA power restriction. Default: 100. When **\<level\>**=3, **\<trig\>** is the temperature threshold to enter Limited-Service Mode. Default: 105.
\<clr\>	Integer type. Terminating temperature threshold. When the temperature drops to **\<clr\>**, the corresponding thermal management level (**\<level\>**) is terminated. Range: 0–120. Unit: ºC. When **\<level\>**=1, **\<clr\>** is the temperature threshold to terminate the UL data rate limit. Default: 90. When **\<level\>**=2, **\<clr\>** is the temperature threshold to terminate the PA power restriction. Default: 95. When **\<level\>**=3, **\<clr\>** is the temperature threshold to exit the Limited-Service Mode. Default: 100.

Example

AT+QTHERMAL="pa_trigger",1,95,90	//Level 1 lowers the temperature by limiting the UL data rate. When the temperature reaches 95 ºC, it limits the UL data rate; when the temperature drops to 90 ºC, it stops limiting

the UL data rate.

OK

AT+QTHERMAL="pa_trigger"   //Query the current settings of the PA thermal management mechanism.

+QTHERMAL: "pa_trigger",1,95,90
+QTHERMAL: "pa_trigger",2,100, 95
+QTHERMAL: "pa_trigger",3,105,100

OK

3 Thermal Management Mechanism

3.1. PA Thermal Management Mechanism

3.1.1. Limit UL Data Rate

The PA temperature is lowered by limiting PUSCH transmission duty cycle, reducing the PA turn-on time, and reducing the power consumption.

The module limits the UL data rate at different target rates based on the configured temperature thresholds within a certain period after you executes **AT+QTHERMAL="pa_trigger",1,<trig>,<clr>**.

Taking **AT+QTHERMAL="pa_trigger",1,95,90** (the triggering threshold is 95 °C and the terminating threshold is 90 °C) as an example, the thermal management mechanism is implemented as below:

1. The temperature obtained by the sensor "pa" reaches 95 °C (the triggering threshold).
2. The module enters Level 1 and limits the UL data rate.
3. If the temperature keeps higher than 90 °C (the terminating threshold), the limited UL data rate will be reduced gradually until it reaches the lowest value of 20 Mbps under 5G NR network or 1 Mbps under LTE network. The PA will be turned off when there is no data transmission.
4. The module exits Level 1 when the temperature drops to 90 °C.

NOTE

The principle of the UL data rate limit is that the UE sends a false BSR to the base station, and the base station controls the UL channel throughput rate of the UE.

3.1.2. Restrict PA Power

The PA's workload can be reduced by restricting the PA TX power.

The module restricts the PA power based on the configured temperature thresholds after you executes **AT+QTHERMAL="pa_trigger",2,<trig>,<clr>**.

Taking **AT+QTHERMAL="pa_trigger",2,100,95** (the triggering threshold is 100 °C and the terminating threshold is 95 °C) as an example, the thermal management mechanism is implemented as below:

1. The temperature obtained by the sensor "pa" reaches 100 ºC (the triggering threshold).
2. The module enters Level 2 and restricts the PA power.
3. If the temperature keeps higher than 95 °C (the terminating threshold), the power backoff value will be increased gradually. Under 5G NR network, the lowest restricted PA power is 15 dBm, and under LTE network, the backoff value will eventually increase to a maximum of 6 dBm.
4. The module exits Level 2 when the temperature drops to 95 °C.

NOTE

When the software thermal management mechanism enters Level 2, Level 1 remains effective. That is, the UL data rate limit and PA power restriction will be implemented simultaneously.

3.1.3. Enter Limited-Service Mode

If the UL data rate limit and PA power restriction mechanisms can hardly achieve the thermal management, the module enters Limited-Service Mode and stops all services to protect the hardware from damage due to overheating. Under this circumstance, only the emergency voice call is available.

After you executes **AT+QTHERMAL="pa_trigger",3,<trig>,<clr>**, the module enters Limited-Service Mode based on the configured temperature threshold and lower the temperature by limiting the services.

Taking **AT+QTHERMAL="pa_trigger",3,105,100** (the triggering threshold is 105 ºC and the terminating threshold is 100 ºC) as an example, the module enters Level 3 when the temperature obtained by the sensor "pa" reaches 105 ºC. After entering Level 3, the module allows emergency voice calls only.

NOTE

After the module enters Level 3, its operation will recover only when the temperature drops to the terminating threshold of Level 1 (that is, the temperature obtained by the sensor "pa" drops to the terminating threshold of the UL data rate limit).

3.2. MDM Thermal Management Mechanism

This section introduces four MDM thermal management mechanisms based on the temperature obtained by the sensor "mdm", and describes in detail the triggering and terminating threshold under different networks.

These mechanisms and related temperature are unconfigurable.

3.2.1. MDM Thermal Management Mechanism Introduction

3.2.1.1. Drop SCells

The module reports CQI-0 (indicating dropping SCells) in LTE network and CQI-0 and Rank 1 in 5G NR network to reduce SCC and power consumption.

3.2.1.2. Fall Back from 4RX to 2RX

The module falls back from 4RX to 2RX to reduce the power on the RF transceiver and the modem baseband.

> **NOTE**
>
> This mechanism is not triggered when the module supports 2RX only.

3.2.1.3. Limit DL Data Rate

The module reports different CQIs and ranks to the network to reduce the DL data rate and reduce the load and power consumption of the MDM processor.

3.2.1.4. Enter Limited-Service Mode

The module enters Limited-Service Mode and stops all services to protect the hardware from damage due to overheating. Under this circumstance, only the emergency voice call is available.

3.2.2.   MDM Thermal Management Mechanism Under Different Networks

3.2.2.1. 5G NSA

Under 5G NSA, the MCG is in LTE and the SCG is in FR1.

Table 3: MDM Thermal Management Mechanism Under 5G NSA

Scenario	Triggering Threshold	Terminating Threshold	Thermal Management Mechanism
The number of the activated FR1 CCs on the SCG is greater than or equal to 2	95 ºC	92 ºC	• Reduce the number of FR1 CCs to 2 • Reduce the number of CCs that support 4RX to 1
	98 ºC	95 ºC	• Reduce the number of FR1 CCs to 2 • Reduce the number of CCs that support 4RX to 1
	100 ºC	97 ºC	Drop PSCell (5G)
	105 ºC	92 ºC	Enter Limited-Service Mode
The number of the activated FR1 CCs on the SCG is 1	95 ºC	92 ºC	Fall back from 4RX to 2RX
	100 ºC	97 ºC	Drop PSCell (5G)
	105 ºC	92 ºC	Enter Limited-Service Mode

3.2.2.2. 5G SA

Under 5G SA, the MCG is in FR1.

Table 4: MDM Thermal Management Mechanism Under 5G SA

Scenario	Triggering Threshold	Terminating Threshold	Thermal Management Mechanism
The number of the activated FR1 CCs on the MCG is greater than or equal to 2	95 ºC	92 ºC	• Reduce the number of FR1 CCs to 2 • Reduce the number of CCs that support 4RX to 1
	98 ºC	95 ºC	• Drop SCells • Reduce the number of CCs that support 4RX to 1

100 ºC	97 ºC	● Reduce the number of FR1 CCs to 1 ● Fall back from 4RX to 2RX
105 ºC	92 ºC	Enter Limited-Service Mode

Scenario			
The number of the activated FR1 CCs on the MCG is 1	95 ºC	92 ºC	Fall back from 4RX to 2RX
	98 ºC	95 ºC	● Fall back from 4RX to 2RX ● Limit DL data rate: report rank 2 at most and the reduced CQI
	100 ºC	97 ºC	● Fall back from 4RX to 2RX ● Limit DL data rate: report rank 1 at most and the reduced CQI
	105 ºC	92 ºC	Enter Limited-Service Mode

3.2.2.3. LTE

Table 5: MDM Thermal Management Mechanism Under LTE

Scenario	Triggering Threshold	Terminating Threshold	Thermal Management Mechanism
The number of the activated LTE CCs is 3	95 ºC	92 ºC	Reduce the number of CCs that support 4RX to 1
	100 ºC	97 ºC	● Reduce the number of LTE CCs to 2 ● Reduce the number of CCs that support 4RX to 1
	102 ºC	99 ºC	● Drop SCells ● Reduce the number of CCs that support 4RX to 1
	105 ºC	92 ºC	Enter Limited-Service Mode
The number of the activated LTE CCs is 2	95 ºC	92 ºC	Reduce the number of CCs that support 4RX to 1
	100 ºC	97 ºC	● Drop SCells ● Reduce the number of CCs that support 4RX to 1
	105 ºC	92 ºC	Enter Limited-Service Mode

4 Appendix Terms and Abbreviations

Table 6: Terms and Abbreviations

Abbreviation	Description
BSR	Buffer Status Request
CC	Component Carrier
CPU	Central Processing Unit
CQI	Channel Quality Indicator
DSP	Digital Signal Processor
ET	Envelope Tracking
FR	Frequency Band
LPAF	Low-Noise Amplifier PA Filter
LTE	Long-Term Evolution
MCG	Master Cell Group
MDM	Modem
MTPL	Maximum Transmission Power Level
NR5G	5 Generation New Radio
NSA	Non-Standalone
PA	Power Amplifier
PSCell	Primary SCG Cell
PUSCH	Physical Uplink Shared Channel
RX	Receive
SA	Standalone

SCG	Secondary Cell Group
TA	Terminal Adapter
TX	Transmit
URC	Unsolicited Result Code

SCG   Secondary Cell Group