

RG50xQ&RM5xxQ Series Software

Thermal Management Guide

5G Module Series

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About the Document

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1 Introduction

This document describes the use and AT commands related to the software thermal mitigation mechanism on Quectel 5G RG50xQ series and RM5xxQ series modules. When the temperature reaches the specific threshold, any thermal mitigation strategy can be adopted to cool down the module.

1.1. Applicable Modules

Table 1: Applicable Modules

Module Series	Model
RG50xQ	RG500Q Series
	RG501Q Series
	RG502Q Series
RM5xxQ	RM500Q Series
	RM502Q Series
	RM510Q-GL
	RM505Q-AE

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 corresponding Write Command and return information about the type, value, or range of its parameter.
Read Command	AT+<cmd>?	Check the current parameter value of a corresponding Write 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 how to use the AT commands introduced herein. The examples, however, should not be taken as Quectel's recommendation or suggestions about how you should design a program flow or what status you should set the module into. Sometimes multiple examples may be provided for one AT command. However, this does not mean that there exists 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 module's specific 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.
"qfe_wtr_pa0"	QPM5621 – 4G/5G low band ET PA module
"qfe_wtr_pa1"	QPM5670 – 4G/5G mid/high band ET PA module
"qfe_wtr_pa2"	QPM5677 – 5G LB/MB GHz ET PA module
"qfe_wtr_pa3"	QPM6585 – 5G n41 PA module
"aoss0-usr"	Always-on subsystem unit
"mdm-q6-usr"	DSP processor
"ipa-usr"	IP accelerator unit
"cpu0-a7-usr"	ARM processor
"mdm-5g-usr"	Modem processor core1
"mdm-vpe-usr"	Modem processor core3
"mdm-core-usr"	Modem processor core3
"xo-therm-usr"	Crystal oscillator

	"sdx-case-therm-usr"	BB chipset
	"ambient-therm-usr"	Ambient temperature detection
<temp>	Integer type. Unit: °C.	

Example

```

AT+QTEMP //Query the module's specific temperature.
+QTEMP:"qfe_wtr_pa0","35"
+QTEMP:"qfe_wtr_pa1","32"
+QTEMP:"qfe_wtr_pa2","30"
+QTEMP:"qfe_wtr_pa3","29"
+QTEMP:"aoss0-usr","31"
+QTEMP:"mdm-q6-usr","30"
+QTEMP:"ipa-usr","30"
+QTEMP:"cpu0-a7-usr","31"
+QTEMP:"mdm-5g-usr","30"
+QTEMP:"mdm-vpe-usr","30"
+QTEMP:"mdm-core-usr","30"
+QTEMP:"xo-therm-usr","29"
+QTEMP:"sdx-case-therm-usr","29"
+QTEMP:"ambient-therm-usr","29"

OK
    
```

NOTE

When the queried temperature is 0 °C or -273 °C, it means that the current sensor is inactive, and the corresponding parameter for temperature query is invalid.

2.4. AT+QCFG="thermal5g/modem" Set PA Thermal Mitigation Level

This command sets the PA thermal mitigation level. When the module temperature reaches the <trig> value, the corresponding level of thermal mitigation (<level>) is triggered. If the temperature drops to the <clr> value, the entered level of thermal mitigation will be cancelled; and UE will enter normal mode of operation. The <clr> value must be lower than the <trig> value.

AT+QCFG="thermal5g/modem" Set PA Thermal Mitigation Level	
Write Command	Response
AT+QCFG="thermal5g/modem" [,<level>,<trig>,<clr>]	If the optional parameters are omitted, return the current configuration: +QCFG: "thermal5g/modem",1,<trig>,<clr>

	<p>+QCFG: "thermal5g/modem",2,<trig>,<clr> +QCFG: "thermal5g/modem",3,<trig>,<clr></p> <p>OK</p> <p>If the optional parameters are specified, set the thermal mitigation level of PA:</p> <p>OK Or ERROR</p>
Maximum Response Time	300 ms
Characteristics	The command takes effect after rebooting. The configurations will be saved automatically.

Parameter

- <level>** Integer type. Thermal mitigation level.
 - 1 Level 1, limits uplink data throughput rate (See **Chapter 3.1.1**)
 - 2 Level 2, restricts PA power and limits UL data throughput rate simultaneously (See **Chapter 3.1.2**)
 - 3 Level 3, enters Limited Service Mode. In Limited Service Mode, data calls are not allowed, and the UE only allows emergency voice calls. (See **Chapter 3.1.3**)
- <trig>** Integer type. Temperature threshold for triggering thermal mitigation. Range: 0–120. Unit: °C.

When **<level>**=1, **<trig>** is the temperature threshold for limiting UL data throughput rate. Default value: 105.

When **<level>**=2, **<trig>** is the temperature threshold for restricting transmission power (PA output power) and limiting UL data throughput rate simultaneously. Default value: 110.

When **<level>**=3, **<trig>** is the temperature threshold for entering Limited Service Mode. Default value: 115.
- <clr>** Integer type. Temperature threshold for cancelling thermal mitigation. Range: 0–120. Unit: °C.

When **<level>**=1, **<clr>** is the temperature threshold to stop limiting UL data throughput rate. Default value: 100.

When **<level>**=2, **<clr>** is the temperature threshold for restricting the PA power and limiting UL data throughput rate simultaneously. Default value: 105.

When **<level>**=3, **<clr>** is the temperature threshold for exiting the Limited Service Mode. Default value: 110.

Example

```
AT+QCFG="thermal5g/modem",1,105,100 //Cool down the device by limiting UL data throughput rate at Level 1. If the temperature reaches 105 °C, it limits the UL data throughput rate; if the temperature drops below 100 °C, it stops limiting UL data throughput
```

```

rate and exits from Level 1.
OK
AT+QCFG="thermal5g/modem" //Query the current thermal mitigation strategy level.
+QCFG: "thermal5g/modem",1,105,100
+QCFG: "thermal5g/modem",2,110,105
+QCFG: "thermal5g/modem",3,115,110
OK
    
```

2.5. AT+QCFG="thermal5g/mdm" Set MDM Thermal Mitigation Level

This command sets the MDM thermal mitigation level. When the module temperature reaches **<trig>** value, the corresponding level of thermal mitigation (**<level>**) is triggered. If the temperature drops to the **<clr>** value, the entered level of thermal mitigation will be cancelled; and UE will enter normal mode of operation. The **<clr>** value must be lower than the **<trig>** value.

AT+QCFG="thermal5g/mdm" Set Thermal Mitigation Level of MDM	
Write Command AT+QCFG="thermal5g/mdm" [,<level>,<trig>,<clr>]	Response If the optional parameters are omitted, return the current configuration: +QCFG: "thermal5g/mdm",1,<trig>,<clr> +QCFG: "thermal5g/mdm",2,<trig>,<clr> +QCFG: "thermal5g/mdm",3,<trig>,<clr> OK If the optional parameters are specified, set the thermal mitigation level of MDM: OK Or ERROR
Maximum Response Time	300 ms
Characteristics	The command takes effect after rebooting. The configurations will be saved automatically.

Parameter

<level>	Integer type. Thermal mitigation level. 1 Level 1 (Currently not supported) 2 Level 2, performs LTE fallback (see Chapter 3.2.1) 3 Level 3, enters Limited Service Mode. In Limited Service Mode, data calls are not
----------------------	---

allowed. The UE only allows emergency voice calls. (See **Chapter 3.2.2**)

- <trig>** Integer type. Temperature threshold for triggering thermal mitigation. Range: 0–120. Unit: °C.
 When **<level>=1**, **<trig>** is the temperature threshold of Level 1. Default value: 100. (Currently not supported)
 When **<level>=2**, **<trig>** is the temperature threshold of LTE fallback. Default value: 105.
 When **<level>=3**, **<trig>** is the temperature threshold for entering Limited Service Mode. Default value: 110.
- <clr>** Integer type. Temperature threshold for cancelling thermal mitigation. Range: 0–120. Unit: °C.
 When **<level>=1**, **<clr>** is the temperature threshold of Level 1. Default value: 97. (Currently not supported)
 When **<level>=2**, **<clr>** is the temperature threshold for cancelling LTE fallback. Default value: 98.
 When **<level>=3**, **<clr>** is the temperature threshold for exiting Limited Service Mode. Default value: 103.

Example

```

AT+QCFG="thermal5g/mdm",2,105,98 //Cool down the device by limiting UL data throughput rate
                                  at Level 1. If the temperature reaches 105 °C, it limits the UL
                                  data throughput rate; if the temperature drops below 100 °C,
                                  it stops limiting UL data throughput rate and exits from
                                  Level 1.

OK
AT+QCFG="thermal5g/mdm" //Query the current thermal mitigation strategy level of
                          MDM.

+QCFG: "thermal5g/mdm",1,100,97
+QCFG: "thermal5g/mdm",2,105,98
+QCFG: "thermal5g/mdm",3,110,103

OK
    
```

3 Thermal Mitigation Strategy

Table 3: Thermal Mitigation Strategy

Strategy	Level			
	Sensor	Level 1	Level 2	Level 3
5G NR Sub-6GHz PA	qfe_wtr_pax	UL throttling	Restrict PA power (MTPL)	Limited service
5G NR Sub-6GHz MDM	sdx-case-therm-usr	-	Back off to LTE	Limited service
LTE PA	qfe_wtr_pax	UL throttling	Restrict PA power (MTPL)	Limited service

3.1. 5G NR Sub-6 GHz PA

3.1.1. Limit UL Data Throughput Rate

PUSCH transmission duty cycle is limited and the PA ON time is reduced by limiting the uplink throughput rate so that PA temperature is lowered.

By executing `AT+QCFG="thermal5g/modem",1,<trig>,<clr>`, the module limits the UL throughput rate at different target rates based on the configured temperature thresholds within a certain period.

Taking `AT+QCFG="thermal5g/modem",1,105,100` as an example, the thermal mitigation strategy is as follows:

When the temperature obtained by any sensor from "qfe_wtr_pax0" to "qfe_wtr_pax3" reaches 105 °C, the module will automatically limit the UL throughput rate; PA will be turned off when there is no data transmission. After entering Level 1 (temperature mitigation level), the initial target rate is reduced to 100 Mbps by default. In addition, the target UL throughput rate will be reduced by 20 Mbps every 15 s until it is down to 20 Mbps/s or the module exits Level 1. After entering Level 1, the uplink data are transmitted in cycles of 130 ms transmission periods and 130 ms stop periods. During the stop period, the PA is temporarily powered off to reduce PA output power.

NOTE

The principle of limiting the uplink data throughput rate and intermittently transmitting data is that the UE reports 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

Restricting the PA power is a good way to lighten PA workload.

By executing `AT+QCFG="thermal5g/modem",2,<trig>,<clr>`, the module restricts the PA power with specified power backoff values based on the configured temperature thresholds within a certain period.

Taking `AT+QCFG="thermal5g/modem",2,110,105` as an example, when the module temperature rises to 110 °C, the module enters Level 2 and automatically starts backing off the PA power.

After the module enters Level 2, its PA power drops by 3 dBm immediately, and continues dropping by 3 dBm every 15 s until the PA reaches 15 dBm or the module exits Level 2.

The power backoff is in duty cycle mode, in which 60 ms is half a cycle, and the duty cycle is 50%. For example, if the initial transmission power is 21 dBm, after entering Level 2, it drops to 18 dBm for 30 ms, and is restored to 21 dBm for 30 ms, and then drops to 18 dBm for 30 ms, and it is restored to 21 dBm for 30 ms and so on. After 15 s, it drops to 15 dBm for 30 ms, and returns to 21 dBm for 30 ms, and so on until the module exits Level 2.

Table 4: PA Power Back-off Information

Parameter Type	Parameter Name	Value	Remark
Reference power back-off	<i>P_backoff</i>	3 dBm	
Maximum power back-off	<i>Max_backoff</i>	15 dBm	The power back-off sequence (e.g. initial transmission power is 21 dBm): 21 dBm, 18 dBm, 15 dBm, 15 dBm, 15 dBm...
Duration of normal power	<i>T_on</i>	30 ms	
Duration of power back-off	<i>T_off</i>	30 ms	
Detection cycle	<i>Step_timer</i>	15 s	

NOTE

When the module enters Level 2, the thermal mitigation mechanism of Level 1 takes effect at the same time, that is, executing reducing the uplink data transmission rate and the PA power at the same time.

3.1.3. Enter Limited Service Mode

If the temperature mitigation cannot provide cooling down of the module by limiting the uplink data throughput rate and restricting PA power, the module will stop all services to protect the hardware from damage due to overheating.

According to the temperature threshold set with **AT+QCFG="thermal5g/modem",3,<trig>,<clr>**, the module can enter Limited Service Mode to lower the temperature.

Taking **AT+QCFG="thermal5g/modem",3,115,110** as an example, when the temperature obtained by any sensor from "qfe_wtr_pax0" to "qfe_wtr_pax3" reaches 115 °C, the module enters Level 3. After entering Level 3, the module allows only emergency voice calls.

NOTE

After executing thermal mitigation in Level 3, the module can work normally again only when the temperature of the module is lower than the temperature threshold for exiting Level 1, that is, the highest temperature value obtained by any sensor ("qfe_wtr_pax0" to "qfe_wtr_pax3") falls below the temperature threshold for terminating the lowering of the uplink rate.

3.2. 5G NR Sub-6 GHz MDM

3.2.1. Back off to LTE

When the module is in 5G NSA, falling back to LTE backoff is performed to reduce MDM CPU workload and PA power consumption to cool down the module after executing **AT+QCFG="thermal5g/mdm",2,<trig>,<clr>**.

Taking **AT+QCFG="thermal5g/mdm",3,105,98** as an example, when the temperature obtained by "sdx-case-therm-usr" reaches 105 °C, the module enters Level 2 and falls back to LTE. When the temperature drops to 98 °C, the module exits Level 2 and stops LTE fallback.

NOTE

The network falls back to LTE only under 5G NSA and no operation is performed under 5G SA.

3.2.2. Enter Limited Service Mode

When the temperature rises to 110 °C, the module enters Level 3 and stops all services to protect the hardware from damage due to overheating.

AT+QCFG="thermal5g/mdm",3,<trig>,<clr> command sets the temperature thresholds that define when module operates in the Limited Service Mode to lower the temperature.

Taking **AT+QCFG="thermal5g/mdm",3,110,103** as an example, when the temperature obtained by "sdx-case-therm-usr" reaches 110 °C, the module enters Level 3. After entering Level 3, the module only allows emergency voice calls.

NOTE

After executing thermal mitigation in Level 3, the module can only work again only when the temperature of the module is lower than the temperature threshold of exiting Level 1.

3.3. LTE PA

The PA thermal mitigation strategy under LTE is the same as that of 5G NR Sub-6GHz PA, see **Chapter 3.1** for more information.

4 Appendix Reference

Table 5: Terms and Abbreviations

Abbreviation	Description
5G NR	5 Generation New Radio
BB	Baseband
BSR	Buffer Status Request
CPU	Central Processing Unit
LTE	Long-Term Evolution
ET	Envelope Tracking
MDM	Modem
MT	Mobile Termination
MTPL	Maximum Transmission Power Level
NSA	Non-Standalone
PA	Power Amplifier
PUSCH	Physical Uplink Shared Channel
SA	Standalone
TA	Terminal Adapter
UE	User Equipment
UL	Uplink
XO	Crystal Oscillator