

# **EC2x&EG2x&EG9x&EM05 Series**

## **Software Thermal Management Guide**

**LTE Standard Module Series**

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At Quectel, our aim is to provide timely and comprehensive services to our customers. If you require any assistance, please contact our headquarters:

**Quectel Wireless Solutions Co., Ltd.**

Building 5, Shanghai Business Park Phase III (Area B), No.1016 Tianlin Road, Minhang District, Shanghai 200233, China

Tel: +86 21 5108 6236

Email: [info@quectel.com](mailto:info@quectel.com)

**Or our local offices. For more information, please visit:**

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# About the Document

## Revision History

Version	Date	Author	Description
1.0	2020-06-30	Max TANG/ Wayne WEI	Initial
2.0	2022-11-22	Colin CUI	<ol style="list-style-type: none"><li>1. Changed the name of the document from Thermal Mitigation User Guide to Thermal Management Guide.</li><li>2. Added applicable module EG25-GL.</li><li>3. Added AT+QTEMP.</li><li>4. Adjusted document structure.</li><li>5. Deleted AT+QNVFW.</li><li>6. Added maximum response time and characteristics of the AT commands.</li></ol>

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# 1 Introduction

This document describes the AT commands related to the software thermal mitigation policy on Quectel LTE Standard EC2x, EG9x, EG2x and EM05 family modules. When the temperature reaches a specific threshold, the thermal mitigation policy is implemented to cool down the module.

## 1.1. Applicable Modules

Table 1: Applicable Modules

Module Family	Module
EC2x	EC25 series
	EC21 series
	EC20-CE
EG9x	EG95 series
	EG91 series
EG2x	EG25-G
	EG25-GL
	EG21-G
	EG21-GL
EM05	EM05 series

# 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 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 Command

Command Type	Syntax	Description
Test Command	<b>AT+&lt;cmd&gt;=?</b>	Test the existence of the corresponding command and return information about the type, value, or range of its parameter.
Read Command	<b>AT+&lt;cmd&gt;?</b>	Check the current parameter value of the corresponding command.
Write Command	<b>AT+&lt;cmd&gt;=&lt;p1&gt;[,&lt;p2&gt;[,&lt;p3&gt;[...]]]</b>	Set user-definable parameter value.
Execution Command	<b>AT+&lt;cmd&gt;</b>	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 module temperature.

AT+QTEMP Query Module Temperature	
Test Command <b>AT+QTEMP=?</b>	Response <b>OK</b>
Execution Command <b>AT+QTEMP</b>	Response <b>+QTEMP: &lt;bb_temp&gt;,&lt;XO_temp&gt;,&lt;PA_temp&gt;</b>  <b>OK</b> Or <b>ERROR</b>
Maximum Response Time	300 ms
Characteristics	/

### Parameter

<b>&lt;bb_temp&gt;</b>	Integer type. Baseband temperature. Unit: Degree Celsius.
<b>&lt;XO_temp&gt;</b>	Integer type. XO temperature. Unit: Degree Celsius.
<b>&lt;PA_temp&gt;</b>	Integer type. PA temperature. Unit: Degree Celsius.

### Example

```

AT+QTEMP //Query module temperature.
+QTEMP: 30,28,27

OK
```

## 2.4. AT+QCFG="thermal/modem" Set Thermal Mitigation Policy

This command sets the thermal mitigation policy. The configured policy will be triggered by the highest temperature value queried by **AT+QTEMP**.

AT+QCFG="thermal/modem" Set Thermal Mitigation Policy	
Write Command <b>AT+QCFG="thermal/modem" [, &lt;level&gt;, &lt;trig&gt;, &lt;clr&gt;]</b>	Response If the optional parameters are omitted, query the current setting: <b>+QCFG: "thermal/modem",1,&lt;trig&gt;,&lt;clr&gt;</b> <b>+QCFG: "thermal/modem",2,&lt;trig&gt;,&lt;clr&gt;</b> <b>+QCFG: "thermal/modem",3,&lt;trig&gt;,&lt;clr&gt;</b>  <b>OK</b>  If the optional parameters are specified, set the thermal mitigation level: <b>OK</b> Or <b>ERROR</b>
Maximum Response Time	300 ms
Characteristics	The command takes effect after the module is rebooted. The configurations will be saved automatically.

### Parameter

<b>&lt;level&gt;</b>	Integer type. Thermal mitigation level. Each level corresponds to a set of <b>&lt;trig&gt;</b> and <b>&lt;clr&gt;</b> . 1 Level 1 - uplink data rate is limited (See <b>Chapter 3.1.1</b> ) 2 Level 2 - downlink data rate is limited based on level 1(See <b>Chapter 3.1.2</b> ) 3 Level 3 - module enters Limited-Service Mode. In Limited-Service Mode, data calls are not allowed. UE only allows emergency voice calls. (See <b>Chapter 3.3</b> )
<b>&lt;trig&gt;</b>	Integer type. Temperature threshold of triggering. When the module temperature reaches the <b>&lt;trig&gt;</b> threshold, thermal mitigation policy of the corresponding level ( <b>&lt;level&gt;</b> ) will be triggered. Unit: 0.001 °C. If <b>&lt;level&gt;</b> =1, <b>&lt;trig&gt;</b> is the temperature threshold for reducing uplink data rate. Default value: 100000. If <b>&lt;level&gt;</b> =2, <b>&lt;trig&gt;</b> is the temperature threshold for reducing downlink data rate. Default value: 105000. If <b>&lt;level&gt;</b> =3, <b>&lt;trig&gt;</b> is the temperature threshold for entering Limited-Service Mode. Default value: 115000.
<b>&lt;clr&gt;</b>	Integer type. Terminating threshold. When the temperature is lower than the <b>&lt;clr&gt;</b> threshold, thermal mitigation policy of the corresponding level ( <b>&lt;level&gt;</b> ) will be cancelled. Unit: 0.001 °C.

If **<level>=1**, **<clr>** is the temperature threshold for cancelling uplink data rate reduction. Default value: 95000.

If **<level>=2**, **<clr>** is the temperature threshold for cancelling downlink data rate reduction. Default value: 100000.

If **<level>=3**, **<clr>** is the temperature threshold for exiting Limited-Service Mode. Default value: 105000.

### Example

```

AT+QCFG="thermal/modem",1,100000,95000 //Cool down the device by limiting uplink data rate
                                         at Level 1. If the temperature reaches 100 °C, the
                                         device starts limiting the uplink data rate; if the
                                         temperature drops below 95 °C, it stops limiting
                                         uplink data rate and exits Level 1.

OK
AT+QCFG="thermal/modem" //Query thermal mitigation level.
+QCFG: "thermal/modem",1,100000,95000
+QCFG: "thermal/modem",2,105000,100000
+QCFG: "thermal/modem",3,115000,105000

OK

```

## 2.5. AT+QCFG="thermal/txpwrImt" Control Transmit Power

This command controls the thermal mitigation policy.

AT+QCFG="thermal/txpwrImt" Control Transmit Power	
Write Command <b>AT+QCFG="thermal/txpwrImt"[, &lt;enable&gt;,&lt;sensor&gt;,&lt;temp_thre shold&gt;,&lt;duration&gt;,&lt;trig_cnt&gt;,&lt; clr_cnt&gt;]</b>	Response If the optional parameters are omitted, query the current setting: <b>+QCFG: "thermal/txpwrImt",&lt;enable&gt;,&lt;sensor&gt;,&lt;temp_thresh old&gt;,&lt;duration&gt;,&lt;trig_cnt&gt;,&lt;clr_cnt&gt;</b>  <b>OK</b>  If the optional parameters are specified, control transmit power: <b>OK</b> Or <b>ERROR</b>
Maximum Response Time	300 ms
Characteristics	The command takes effect after the module is rebooted. The configurations will be saved automatically.

## Parameter

<b>&lt;enable&gt;</b>	Integer type. Enable/disable transmit power control. 0 Disable 1 Enable
<b>&lt;sensor&gt;</b>	Integer type. Temperature sensor ID. It corresponds to the temperature value detected by the sensor that is returned by <b>AT+QTEMP</b> . 2 Baseband temperature sensor (Default value. It is recommended not to modify it.) 5 PA temperature sensor 7 XO temperature sensor
<b>&lt;temp_threshold&gt;</b>	Integer type. Temperature thresholds that restrict the transmit power. Range: -150–150. Default value: 105. Unit: °C.
<b>&lt;duration&gt;</b>	Integer type. Length of temperature detection cycle. Range: 1000–360000. Default value: 1000 (It is recommended not to modify it.). Unit: ms.
<b>&lt;trig_cnt&gt;</b>	Integer type. Number of times transmit power detection thresholds have been triggered. Range: 1–10000. Default value: 3 (It is recommended not to modify it.).
<b>&lt;clr_cnt&gt;</b>	Integer type. Number of times power recovery detection thresholds have been triggered. Range: 1–10000. Default value: 10 (It is recommended not to modify it.).

## Example

```

AT+QCFG="thermal/txpwrlimt",1,2,105,1000,3,10 //Enable transmit power control.
OK
AT+QCFG="thermal/txpwrlimt" //Query the transmit power setting.
+QCFG: "thermal/txpwrlimt",1,2,105,1000,3,10
OK

```

## 2.6. AT+QCFG="thermal/limit\_rates" Enable/Disable Thermal Mitigation

This command enables/disables the thermal mitigation policy.

### AT+QCFG="thermal/limit\_rates" Enable/Disable Thermal Mitigation

Write Command

**AT+QCFG="thermal/limit\_rates  
"[,<enable>]**

Response

If the optional parameter is omitted, query the current setting:  
**+QCFG: "thermal/limit\_rates",<enable>**

**OK**

If the optional parameter is specified, enable or disable thermal

	mitigation: <b>OK</b> Or <b>ERROR</b>
Maximum Response Time	300 ms
Characteristics	The command takes effect after the module is rebooted. The configurations will be saved automatically.

## Parameter

<b>&lt;enable&gt;</b>	Integer type. Enable/disable thermal mitigation policy.
0	Disable
1	Auto-configure temperature thresholds. Auto-configure the software thermal mitigation policy based on the default values of <b>AT+QCFG="thermal/modem"</b> and <b>AT+QCFG="thermal/txpwr1mt"</b>

## Example

```

AT+QCFG="thermal/limit_rates"           //Query thermal mitigation policy state.
+QCFG: "thermal/limit_rates",0

OK
AT+QCFG="thermal/limit_rates",1         //Enable thermal mitigation policy.
OK

```

### NOTE

To ensure module reliability and stability, it is recommended not to disable software thermal management during normal operation of the module.

# 3 Thermal Mitigation Policy

## 3.1. Limit Data Rate

The workload of components such as CPU and PA can be reduced by limiting data rate. However, the thermal mitigation is not effective in case of no data or low data rate.

If **AT+QCFG="thermal/modem",1,<trig>,<clr>** is executed, the module limits the uplink data rate to lowering temperature; and if **AT+QCFG="thermal/modem",2,<trig>,<clr>** is executed, the module limits the downlink data rate once a certain temperature threshold is exceeded.

### 3.1.1. Limit Uplink Data Rate

When the temperature reaches Level 1, it will set the maximum transmit rate to 40 Mbit/s (target\_rate[1]). The detection cycle of the temperature sensor is 3 seconds by default. If the temperature is still at Level 1 (or the temperature rises, the module reaches Level 2) after 3 seconds, the transmit rate will drop to 20 Mbit/s (target\_rate[2]). The temperature is detected every 3 seconds. If the temperature is still higher than the terminating threshold, the transmit rate level will increase until the transmit rate drops to 4 Mbit/s (target\_rate[9]). After the temperature of the module drops below the terminating threshold, the transmit rate will return to 50 Mbit/s (target\_rate[0]) step by step.

**Table 3: Uplink Rate Threshold Levels**

Parameter Category	Parameter ID	Value (In Decimal)
Number of uplink rate threshold levels	num_states	10
Initial uplink rate threshold level for entering Level 1	default_state	target_rate[1]
Uplink rate threshold levels	target_rate[0]	50 Mbit/s
	target_rate[1]	40 Mbit/s
	target_rate[2]	20 Mbit/s
	target_rate[3]	10 Mbit/s

target_rate[4]	8 Mbit/s
target_rate[5]	7 Mbit/s
target_rate[6]	6 Mbit/s
target_rate[7]	6 Mbit/s
target_rate[8]	4 Mbit/s
target_rate[9]	4 Mbit/s

#### NOTE

1. The uplink rate threshold levels in the above table are the default values automatically configured by the module to enable the software thermal management policy. In the test procedure, they are different for different modules, and are affected by the module's own state, heat dissipation, and surrounding environment.
2. When performing the test on CMW500, the software thermal management policy can be triggered only if a non-00101 blank SIM card is used.

### 3.1.2. Limit Downlink Data Rate

PUCCH is an uplink physical channel that carries UCI (Uplink Control Information). The PUCCH cycle is 200 ms (Time On + Off). ACK/NACK is sent in PUCCH when the cycle is on and ACK/NACK is not sent in PUCCH when the cycle is off. Once the module enters Level 2, State 3 (On: 100 ms; Off: 100 ms) is the default downlink rate reduction cycle. If the temperature is at Level 2 for 10 seconds, the reduction cycle will be limited to State 2 (On: 80 ms; Off: 120 ms); The temperature is detected every 10 seconds. If the temperature is still higher than the terminating threshold, the state level will gradually decrease until it falls to State 0 (On: 30 ms; Off: 170 ms). After the temperature of the module drops below the terminating threshold, the state level will recover step by step until the downlink rate returns to normal. See the table below for details.

**Table 4: PUCCH cycle of Downlink Rate Reduction**

Parameter	Value
PUCCH cycle	200 ms
Number of classes	6
Default state for thermal mitigation	3

Default state for CPU-based flow control	3
State 0 (timer [0])	On: 30 ms; Off: 170 ms
State 1 (timer [1])	On: 60 ms; Off: 140 ms
State 2 (timer [2])	On: 80 ms; Off: 120 ms
State 3 (timer [3])	On: 100 ms; Off: 100 ms
State 4 (timer [4])	On: 120 ms; Off: 80 ms
State 5 (timer [5])	On: 140 ms; Off: 60 ms
Step timer for each state	10000 ms
Default state for each CPU-based flow control	400

**NOTE**

1. The module cannot directly control the downlink rate but tries to force the network to limit the downlink rate by not returning the network ACK at the wireless protocol stack level. This requires the support of the protocol between the module and the network, but the rate threshold is uncontrollable.
2. When the module enters Level 2, the thermal mitigation policy of both Level 2 and Level 1 takes effect at the same time, i.e., the module limits the uplink and downlink data rate simultaneously.

## 3.2. Limit PA Power

Restricting the PA power is a good way to lighten PA workload. However, the transmit power in field test is configured by the network. If the network signal is relatively good, the transmit power is generally not high, and thus the thermal mitigation is not effective by limiting the transmit power.

When the transmit power is restricted and lower than that of the configured network, the network may not be able to receive the signal sent by the module or decode the signals, resulting in a decrease in the data transmission performance.

The transmit power affects the power consumption and heat of the PA, and theoretically module temperature can be reduced by limiting the transmit power. The transmit power is divided into eight levels Level 0–Level 7, which respectively correspond to different maximum transmit power levels 22–15 dBm.

For example, if transmit power control is enabled with **AT+QCFG="thermal/txpwrlimt",1,2,105,1000,3,10**, the module will detect the current temperature every second (1000 milliseconds), and transmit power detection thresholds can be triggered 3 times, by default. If the temperature is higher than 105 °C for 3



seconds, the highest transmit power of the module will be reduced by 1 dBm, until the lowest transmit power drops to 15 dBm. If the current module temperature is below 105 °C for 10 consecutive detection cycles (10 seconds), the maximum transmit power will be increased by 1 dBm until it reaches 22 dBm.

### 3.3. Enter Limited-Service Mode

If the module cannot be cooled down by limiting the uplink data 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="thermal/modem",3,<trig>,<clr>**, the module enters Limited-Service Mode to lower the temperature.

For example, if the thermal mitigation levels are set by **AT+QCFG="thermal/modem",3,115000,105000**, when the module temperature reaches 115 °C, the module enters Level 3 and allows only emergency voice calls.

#### **NOTE**

After executing Level 3 thermal mitigation, the module can restore all functionalities only after its temperature drops below the temperature threshold for exiting Level 1 thermal mitigation.

### 3.4. Reboot the Module

When the temperature of the module reaches about 120 °C, it will automatically reboot to protect the hardware. Please note that you can manually configure neither the policy nor the temperature threshold.

## 4 Appendix Reference

Table 5: Terms and Abbreviations

Abbreviation	Description
ACK	Acknowledgement
CPU	Central Processing Unit
LTE	Long-Term Evolution
NACK	Negative Acknowledgement
PA	Power Amplifier
PUCCH	Physical Uplink Control Channel
SIM	Subscriber Identity Module
TA	Terminal Adapter
XO	Crystal Oscillators