EC2x&EG9x Power Management Application Note

LTE Module Series

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About the Document

History

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1 Introduction

When Quectel LTE modules are embedded into a host system, it will increase the whole power consumption of the system. Therefore, we provide several power management solutions on Quectel LTE modules, thus allowing the host to reduce the overall power consumption through managing the LTE module's power consumption.

Quectel LTE module power management solutions mainly include the following aspects:

- Sleep and wakeup mechanism of the host system (e.g. USB driver suspend and remote wakeup).
- Physical connection between the module and the host.
- Sleep and wakeup software mechanism of Quectel LTE modules.

The following chapters will illustrate Quectel LTE modules' hardware interfaces and URC events relating to sleep and host-wakeup modes, power save solutions for some typical application scenarios, and the modules' sleep and host-wakeup software mechanism.

This document is applicable to the following Quectel LTE modules:

- EC2x (EC21, EC25, EC20 R2.0, EC20 R2.1)
- EG9x (EG91, EG95)

2 Hardware Interfaces

The communication between Quectel EC2x/EG9x module and the host is mainly realized through USB and UART ports. Also, there are some other functional pins provided for the host to manage the module's power consumption.

2.1. EC2x/EG9x Pin Assignment

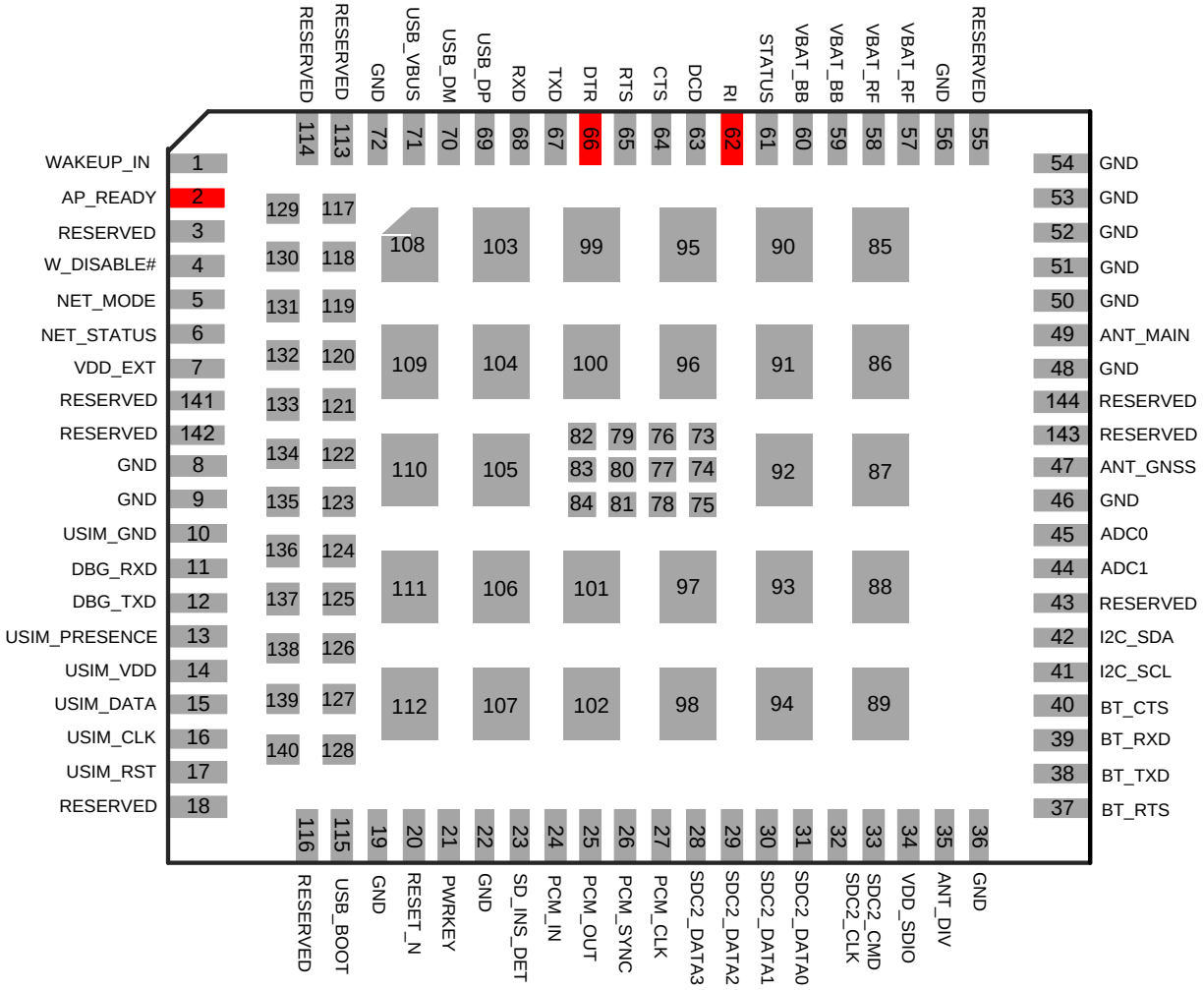

Figure 1: EC2x Pin Assignment (Top View)

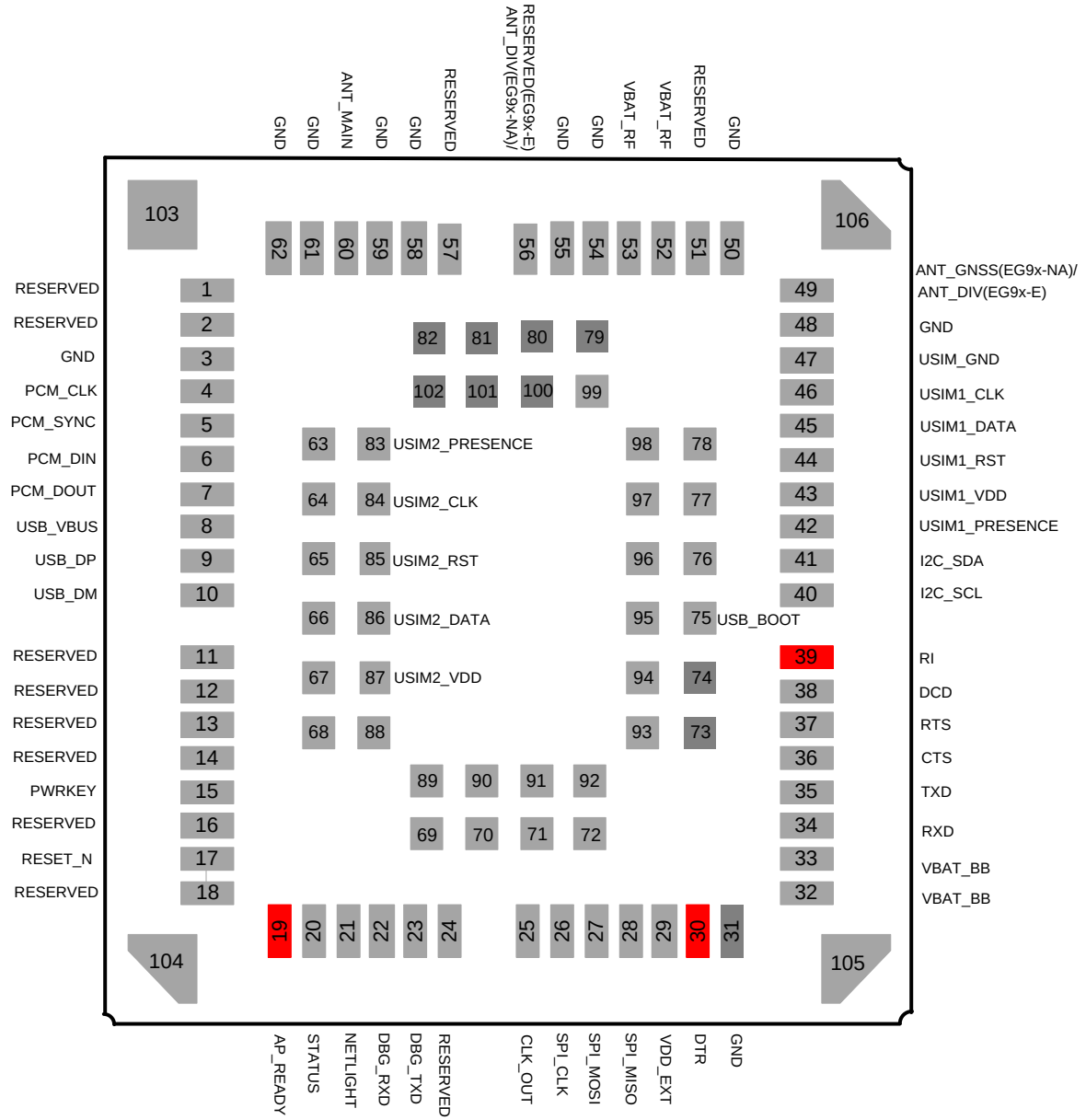

Figure 2: EG9x Pin Assignment (Top View)

2.2. EC2x/EG9x Power Management Pins

Table 1: EC2x/EG9x Power Management Pin

Pin Name	I/O	Description
DTR	DI	● For the host to wake up EC2x/EG9x and allow EC2x/EG9x to enter into the sleep mode.

		● DTR has been pulled up internally by default. ● When it is in high level, EC2x/EG9x is allowed to enter into sleep mode. ● When the module is in sleep mode, it can be woken up by pulling down DTR.
RI	DO	● For EC2x/EG9x to inform the host there is a URC to report. ● When the module has no URC to report, RI will keep in high level. ● When there is a URC to report, RI will output a low pulse. In such case, if the host is in sleep mode, it will be woken up and process the reported URC.
AP_READY	DI	● Used to inform the module whether the host is in sleep state. ● AP_READY can be configured by **AT+QCFG="apready"**, and it supports high level or low level detection.

NOTE

For more details about the AT commands mentioned in this document, please refer to ***document [1]***, ***[2]***, ***[3]*** or ***[4]*.**

2.2.1. DTR

Pulling up DTR indicates the module is allowed to enter into sleep mode. For the methods to make the module enter into sleep mode, please refer to ***Chapter 4***.

If DTR is pulled down, the module will not be able to enter into sleep mode.

If the module has entered into sleep mode, it can be woken up by pulling down DTR.

2.2.2. RI

When a host-wakeup event is arrived at the module, the RI pin of module will generate a low pulse (last for 120ms by default, and the time can be configured by **AT+QCFG="urc/ri/ring"** command) to inform the host.

When the host is in sleep mode, it will be woken up when detecting the low pulse. After the host is woken up, AP_READY can be used to inform the module that the host is in wakeup mode currently.

2.2.3. AP_READY

Most host systems contain several sleep modes, for instance, suspend to memory or suspend to hard disk in Linux system.

In different sleep modes, the degree of sleep is different.

- When the host is in light sleep, it can be woken up quickly, and host application can quickly recover the communication between the module, and read/write data normally from USB or UART port.
- When the host is in deep sleep, it is slower to wake it up, and it needs more time to recover the communication between the module before it begins to read and write date form USB or UART port. This means when the host and the module are in sleep mode at the same time, if the module has URC to report, then during the whole procedure of sleep→wakeup→URC processing, the host cannot provide reliable guarantee for the integrity of data receiving, thus the data reported by module may not be processed effectively.

In order to enable the host to control the procedure of sleep→wakeup→URC processing, EC2x/EG9x provides the AP_READY functional pin for host sleep state indication and also provides **AT+QCFG="apready"** command for the host to configure the pin behavior. After the host has enabled AP_READY pin, the module will report the URC to host according to the configured parameters, thus to ensure that the host can receive the URC correctly and process it in any mode.

2.2.3.1. Function Description

When there is a URC for the module to be reported, the module will detect whether the AP_READY pin is in active level first.

- When the host is in wakeup mode (AP_READY in active level), the module will output the URC to the host directly.
- When the host is in sleep mode, the module will cache the URC first, and detect AP_READY pin level according to the configured detection intervals. And it will not output the URC until AP_READY pin is detected to be active, i.e. the host has been woken up.

NOTE

The module will cache maximally 15 URCs following FIFO principle.

2.2.3.2. Example

```
…….

//System software initialization
…….

AT+QCFG="apready",1,0,200
OK                          //The host enables AP_READY pin, and AP_READY pin is
                            active low, which means when the pin is in low level, the host is
```

in wakeup mode. If the module has URC to report, then it will output the data to host directly. When AP_READY pin is in high level, it indicates the host is in sleep mode, and if the module has URC to report, it will detect the pin level at an interval of 200ms. When the AP_READY pin is detected in low level, it will output URC to the host.

//Both the host and the module enter into sleep mode.

……

When a host-wakeup event is arrived at the module, the module's RI pin will generate a low pulse to inform the host. The module will detect whether or not the host is woken up from the sleep mode by AP_READY pin. If the host is in wakeup mode, the module will output URC to the host directly, otherwise, it will detect AP_READY pin level at an interval of 200ms until the system is in wakeup mode. As for host, after it has detected the low pulse on the module's RI pin, it will be woken up. After been woken up completely, the host will pull up AP_READY pin to inform the module to output URC. The host will process URC normally after receiving it.

3 Introduction on URC

In normal data interaction process, the module not only responds the request from the host, but also takes the initiative to report external events to the host, such as incoming calls and short messages. In general, the unsolicited information reported by the module is called URC (Unsolicited Result Code).

The processing of URC is embodied in two aspects: report event information to host actively and generate low pulse on RI pin. In Quectel LTE module power management, the RI pin can inform the incoming URC to host in the form of pulse after the host enters into sleep mode. For the module supporting several types of URC, frequent URC report will repeatedly wake up the host from the sleep mode, which will reduce the power management efficiency of the whole system. In order to avoid this, the host should select corresponding URCs based on its own needs.

3.1. Set URC Port

Generally, the module and the host communicate with each other by UART or USB port, and the module only reports URC through one of the two ports.

The URC report port can be configured by **AT+QURCCFG** command.

3.2. URC Event

EC2x/EG9x module contains various URCs. For example, network status URC is used to report the current network status to host, short message URC is used to report the new incoming short messages and phone call URC is used to report the call state.

For most URCs, customers can configure whether to report them or not by AT command. So the host can enable or disable URC report in different system status according to its own needs. For instance,

- When system starting, the host can be set to actively report the URC relevant to network, short messages and phone calls.
- Before entering into sleep mode, it can be set not to report the URC related to network, but only report the URC related to short messages and phone calls.
- After the host has entered into sleep mode, it will only be woken up by URC related to short messages and phone calls.

In this way, the basic requirements of the host are met, and the power management efficiency of whole system is improved as well.

3.3. Example of URC Configuration

```
//The following example shows how to configure the relevant URCs:
AT+CREG=1 or AT+CREG=2          //Enable to actively report the CS network registration status (Disabled by default)
OK
AT+CREG=0                       //Disable to actively report the CS network registration status
OK

AT+CGREG=1 or AT+CGREG=2        //Enable to actively report the PS network registration status (Disabled by default)
OK
AT+CGREG=0                      //Disable to actively report the PS network registration status
OK
AT+QINDCFG="csq",1              //Enable to actively report the value of CSQ signals (Disabled by default)
OK
AT+QINDCFG="csq",0              //Disable to actively report the value of CSQ signals
OK

AT+QINDCFG="ring",1             //Enable to actively report the RING of incoming call (Enabled by default)
OK
AT+QINDCFG="ring",0             //Disable to actively report the RING of incoming call
OK

AT+QINDCFG="smsincoming",1      //Enable to actively report the incoming of new short messages (Enabled by default)
OK
AT+QINDCFG="smsincoming",0      //Disable to actively report the incoming of new short messages
OK
```

4 Power Save Solutions

This chapter mainly introduces the recommended power save solutions for some typical application scenarios.

4.1. Power on/off

When the module is powered on, the host should remain at least 25 seconds before power off the module.

It is recommended to use AT command or PWRKEY to power off the module before switching off the VBAT power supply.

4.2. Power Save Solutions Based on UART Port

4.2.1. Requirement Description

When the device is implementing power saving solutions, it is required that:

- Both the host and the module are able to enter into power save mode.
- The host communicates with the module by UART port, rather than USB port.

The following will illustrate the detailed implementation method based on these requirements.

4.2.2. Hardware Connection Configuration

1. The host is connected to the module by UART port.
2. The host's I/O pin is connected to the module's RI pin, and the I/O pin must support host wakeup function.
3. The host's I/O pin is connected to the module's DTR pin.
4. The host's I/O pin is connected to the module's AP_READY pin (AP_READY can be configured).

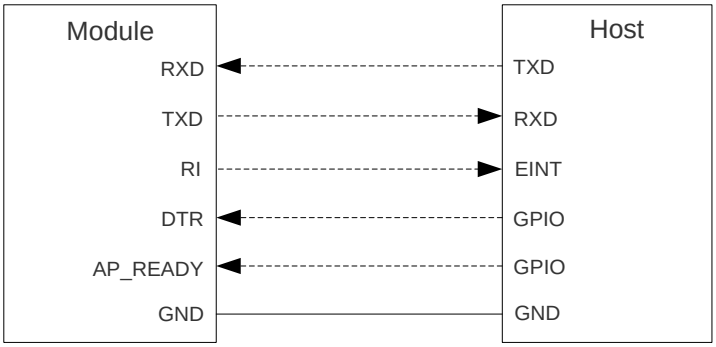

Figure 3: Connection Diagram Based on UART

The UART port is an important channel for communication between the module and the host. Through the DTR pin, the host can manage the module's power consumption easily.

- When DTR is in high level, the module is allowed to enter into sleep mode.
- When DTR is in low level, if the module is in wakeup mode, it will not enter into sleep mode.
- If the module is in sleep mode, driving DTR to low level will wake the module up.

NOTE

In the above diagram and the following diagrams in this chapter, the connection in dotted line indicates special attention should be paid to the level match between the two systems, and the connection in solid line means that they can be connected directly.

4.2.3. Software Initialization Configuration

1. Enable the module to enter into sleep mode by **AT+QSCLK=1**.
2. Specify UART port to report URC from the module by **AT+QURCCFG="urcport","uart1"**.
3. Enable the module's AP_READY function by the following command:
   AT+QCFG="apready",<enable>[,<level>,[<interval>]].
4. Configure URCs needed for the module to report by **AT+QINDCFG**.
5. Configure RI pin by **AT+QCFG="risignaltype","physical"** to make sure the RI always behaves on UART1 when any URC reports.

NOTE

The DTR is pulled up by default. When **AT+QSCLK=1** command is configured, UART1 will be disabled and will not respond any AT command. It is recommended to drive the DTR to low level before the module goes to sleep to avoid disabling of UART1.

4.2.4. Implementation Method

1. When host enters into sleep mode

When the host enters into power save mode, it should pull up DTR to enable the module entering into sleep mode, and set AP_READY as inactive to indicate that the host is in sleep mode.

2. When host is woken up from sleep mode

- Host wakes up module

The host pulls down DTR pin, and sets AP_READY pin as active to indicate the host is in wakeup mode.

- Module wakes up host

When the module has URC to report, its RI pin will generate a low pulse (120ms duration by default, and it can be configured by AT command) to inform the host that URC is coming. When the host is in sleep mode, it is required to ensure that the change of RI pin level can wake up the host itself. After the host is woken up, AP_READY pin should be set as active to indicate the host is in wakeup mode.

4.3. Power Save Solutions Based on USB Remote Wakeup

4.3.1. Requirement Description

When the device is implementing power save solution, it is required that:

- Both the host and the module are able to enter into power save mode.
- The host supports USB suspend/resume and remote wakeup functionality.

The following will illustrate the detailed implementation method based on these requirements.

4.3.2. Hardware Connection Configuration

1. Connect the host to the module via USB.
2. The host's I/O pin is connected to the module's AP_READY pin (AP_READY can be configured)..

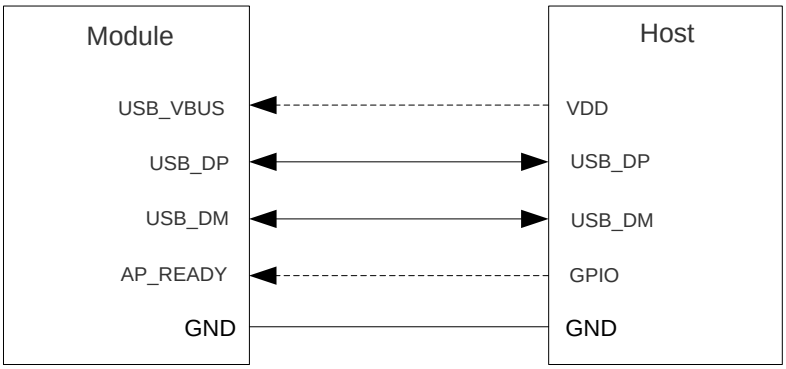

Figure 4: Connection Diagram Based on USB Remote Wakeup

4.3.3. Software Initialization Configuration

1. Enable the module to enter into sleep mode by **AT+QSCLK=1**.
2. Specify USB AT port to report URC by **AT+QURCCFG="urcport","usbat"**.
3. Enable the module's AP_READY function by the following command: **AT+QCFG="apready",<enable>[,<level>,[<interval>]]**.
4. Configure URCs needed for the module to report by **AT+QINDCFG**.
5. Configure the corresponding system and driver settings in host system. (For details, please contact Quectel technical support team.)

4.3.4. Implementation Method

1. When host enters into sleep mode

The host sets AP_READY as inactive, and suspends USB (the module supports selective suspend and global suspend).

2. When host is woken up from sleep mode

- Host wakes up module actively

When the host sends data to the module actively, it will resume USB and set AP_READY as active.

- Module wakes up host actively

When the module has URC to report, its USB will send remote wakeup signals first. The host USB must be able to wake up the host itself through these signals, and then set AP_READY as active.

4.4. Power Save Solutions Based on USB_VBUS Disconnection

4.4.1. Requirement Description

When the device is implementing power save solution, it is required that:

- Both the host and the module are able to enter into power save mode.
- The host does not support USB suspend/resume and remote wakeup functionality. So the host should disconnect the USB_VBUS when the device enters into power save mode.

The following will illustrate the detailed implementation method based on these requirements.

4.4.2. Hardware Connection Configuration

1. Connect the host to the module via USB.
2. The host's I/O pin is connected to the module's AP_READY pin (AP_READY can be configured).
3. The host's I/O pin is connected to the module's RI pin, and the I/O pin must support host wakeup function.

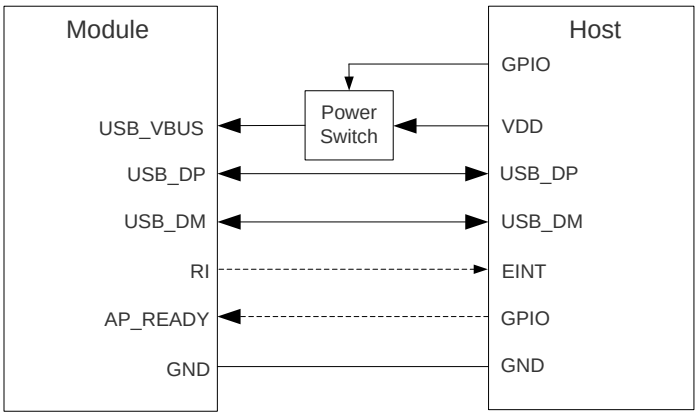

Figure 5: Connection Diagram Based on USB Disconnection

4.4.3. Software Initialization Configuration

1. Enable the module to enter into sleep mode by **AT+QSCLK=1**.
2. Specify USB AT port to report URC by **AT+QURCCFG="urcport","usbat"**.
3. Enable the module's AP_READY function by the following command: **AT+QCFG="apready",<enable>[,<level>,[<interval>]]**.
4. Configure URCs needed for the module to report by **AT+QINDCFG**.
5. Configure RI pin by **AT+QCFG="risignaltype","physical"** to make sure the RI always behaves on UART1 when any URC reports.

4.4.4. Implementation Method

1. When host enters into sleep mode

The host disconnects the module's USB_VBUS, and sets AP_READY as inactive.

NOTE

When USB_VUBS is disconnected, the USB port on host system will disappear. Due to this, host application should stop the data connection or AT commands on USB port and close the port before disconnecting.

2. When host is woken up from sleep mode

- Host wakes up module actively

The host connects to the module's USB_VBUS and sets AP_READY as active, and then the host sends data to the module.

- Module wakes up host actively

When the module has URC to report, its RI pin will generate a low pulse (120ms duration by default, and it can be configured by AT command), and the host must be able to be woken up by RI pin. After the host has been woken up, it pulls up the module's USB_VBUS, and set AP_READY as active to indicate that the host is woken up and the module can output the URC to the host now.

4.5. Power Save Solutions Based on USB Suspend/Resume and RI Pin

4.5.1. Requirement Description

When the device is implementing power save solution, it is required that:

- Both the host and the module are able to enter into power save mode.
- The host can support USB suspend/resume, but does not support USB remote wakeup functionality.
- The module's RI pin is the external wakeup source of the host.
- The host should disconnect the USB when the device enters into power save mode.

The following will illustrate the detailed implementation method based on these requirements.

4.5.2. Hardware Connection Configuration

1. Connect the host to the module via USB.
2. The host's I/O pin is connected to the module's AP_READY pin (AP_READY can be configured).

3. The host's I/O pin is connected to the module's RI pin, and the I/O pin must support host wakeup function.

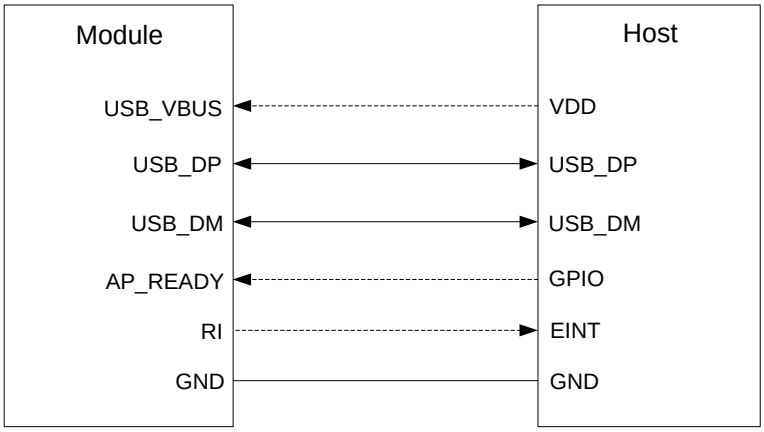

Figure 6: Connection Diagram Based on USB Suspend/Resume and RI Pin

4.5.3. Software Initialization Configuration

1. Enable the module to enter into sleep mode by **AT+QSCLK=1**.
2. Specify USB AT port to report URC by **AT+QURCCFG="urcport","usbat"**.
3. Enable the module's AP_READY function by the following command: **AT+QCFG="apready",<enable>[,<level>,[<interval>]]**.
4. Configure URCs needed for the module to report by **AT+QINDCFG**.
5. Configure RI pin by **AT+QCFG="risignaltype","physical"** to make sure the RI always behaves on UART1 when any URC reports.

4.5.4. Implementation Method

1. When host enters into sleep mode

The host sets AP_READY pin as inactive, and suspends USB.

2. When host is woken up from sleep mode

- Host wakes up module actively

The host resumes USB, and sets AP_READY pin as active.

- Module wakes up host actively

When the module has URC to report, its RI pin will generate a low pulse (120ms duration by default, and it can be configured by AT command), and the host must be able to be woken up by RI pin. After the host has been woken up, the host sets AP_READY as active to indicate that the host is woken up and the

module can output the URC to the host now.

4.6. Power Save Solutions in Non-Sleep Modes

When the module is working, the host can lower the power level by steps below:

1. Using UART1 or USB only. For example, if the host is using USB, then the host can pull up the DTR and send **AT+QSCLK=1** to disable the UART1 port. In this way, UART1 port will not work and thus the current consumption is reduced.

2. Control the speed rate of data transmitting. The slower data transmitting, the lower current will happen.

5 Software Mechanisms

5.1. Sleep Mechanism

There is a lower-priority sleep mission within EC2x/EG9x module, which is used to detect whether the module can enter into sleep mode or not. Other service missions (such as RF/USB/UART and so on) and sleep control variables have rights to vote on the sleep mission to decide whether or not the module can enter into sleep mode. When other service missions and sleep control variables both agree the module to enter into sleep mode, sleep mission will be executed and the module will enter into sleep mode. It should be noted that when the module enters into sleep mode, the module will work in DRX mode.

5.2. Sleep Process

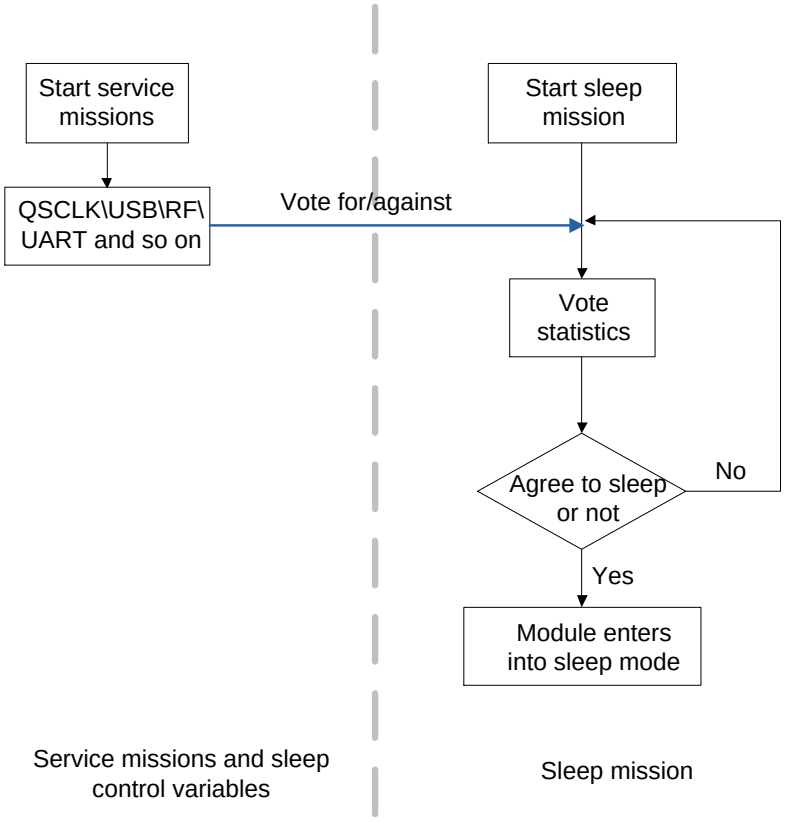

Figure 7: Sleep Process

5.3. USB Sleep Mechanism

When USB is working normally, root hub in hub or HCD will send SOF package periodically (full speed USB sends one package at an interval of 1ms, high speed USB sends one package at an interval of 125μs). At this time, USB on the module will vote against the module to enter into sleep mode.

According to the description of suspend in USB standard protocol, when the host system sets the port attached with USB device in hub or root hub as suspend, hub or root hub will stop sending SOF package and USB bus will enter into suspend mode. Then USB on the module will enter into suspend mode, and vote for the module to enter into sleep mode.

NOTES

1. Quectel EC2x/EG9x module provides USB suspend solutions for different host systems. Customers can control the module to enter into suspend mode on host system by these solutions.
2. If customers use the USB driver developed by their own, the driver should support both global suspend and selective suspend functions.

5.4. Wakes up Host

5.4.1. Host Wakeup Event

Host wakeup event is the event that the module takes the initiative to report information to the host and wake up the host when the host is in sleep mode. Host wakeup event is also called URC.

5.4.2. USB Remote Wakeup

When the host enters into sleep mode, and host USB bus is in suspend mode, if the module has URC to report, it will send remote wakeup signals (duration time>3ms) to inform the host to resume USB.

The key points of module's remote wakeup function are listed as follows:

- Host USB controller must support remote wakeup, and it can wake up the host. If USB controller does not support remote wakeup, it will not process remote wakeup signals received from the module. Similarly, if USB controller cannot wake up the host, then the host will not be woken up from sleep mode by USB remote wakeup.

- As for the host, the module's remote wakeup function can be set by USB standard request. The host can enable remote wakeup function by "SET_FEATURE" and disable it by "CLEAR_FEATURE". Before the host enters into sleep mode, the module's remote wakeup function must be enabled.

- When the module sends remote wakeup signals to the host, the host must resume signals for at least 20ms. After that, USB bus will enter into idle state. And before USB bus enters into idle state, USB controller must retrieve to send SOF package on USB bus within 3s. Otherwise the module would enter into suspend mode again.

5.4.3. Configure Host Wakeup Event

The host can configure URC report port by **AT+QURCCFG**, for example, UART port or USB AT port. In specific application scenarios, the host can specify URC port according to the actual hardware connection ways. The default port is USB AT port.

In order to avoid host being woken up frequently by URC, the host can choose reporting only necessary URC events by **AT+QINDCFG** based on its own needs to optimize power consumption of the whole system.

6 Appendix A References

Table 2: Related Documents

SN	Document Name	Remark
[1]	Quectel_EC25&EC21_AT_Commands_Manual	EC25 & EC21 AT Commands Manual
[2]	Quectel_EC20_R2.1_AT_Commands_Manual	EC20 R2.1 AT Commands Manual
[3]	Quectel_EC20_R2.0_AT_Commands_Manual	EC20 R2.0 AT Commands Manual
[4]	Quectel_EG9x_AT_Commands_Manual	EG91 & EG95 AT Commands Manual

Table 3: Terms and Abbreviations

Abbreviation	Description
AP	Application
DRX	Discontinuous Reception
FIFO	First-in, First-out
I/O	Input/Output
SOF	Start of Frame
URC	Unsolicited Result Code
USB	Universal Serial Bus