EC2x&EG9x&EG25-G Series
QuecOpen Low Power Mode Application Note

LTE Standard Module Series

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About the Document

Revision History

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-	2020-10-05	Gale GAO/ Young XU	Creation of the document
1.0.0	2020-11-05	Gale GAO/ Young XU	Preliminary

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1 Introduction

Quectel LTE Standard EC2x series, EG9x series and EG25-G modules support QuecOpen® solution. This document introduces the QuecOpen® low power mode (LPM) based on Linux autosleep and wakelock features. The autosleep and wakelock features are contradictory communities, which respectively implement the sleep and wake-up functions of the module.

- Autosleep: After enabling the autosleep, the module always has the tendency to freeze the process, suspend peripheral devices and force the CPU to sleep.
- Wakelock: If the kernel or any application holds one or more wakelocks, it inhibits the module from going to sleep.

1.1. Applicable Modules

Table 1: Applicable Modules

Module Series	Module
EC2x series	EC25 series
	EC21 series
	EC20 R2.1
EG9x series	EG95 series
	EG91 series
EG25-G	EG25-G

2 Low Power Mode

2.1. Low Power Mode Status Diagram

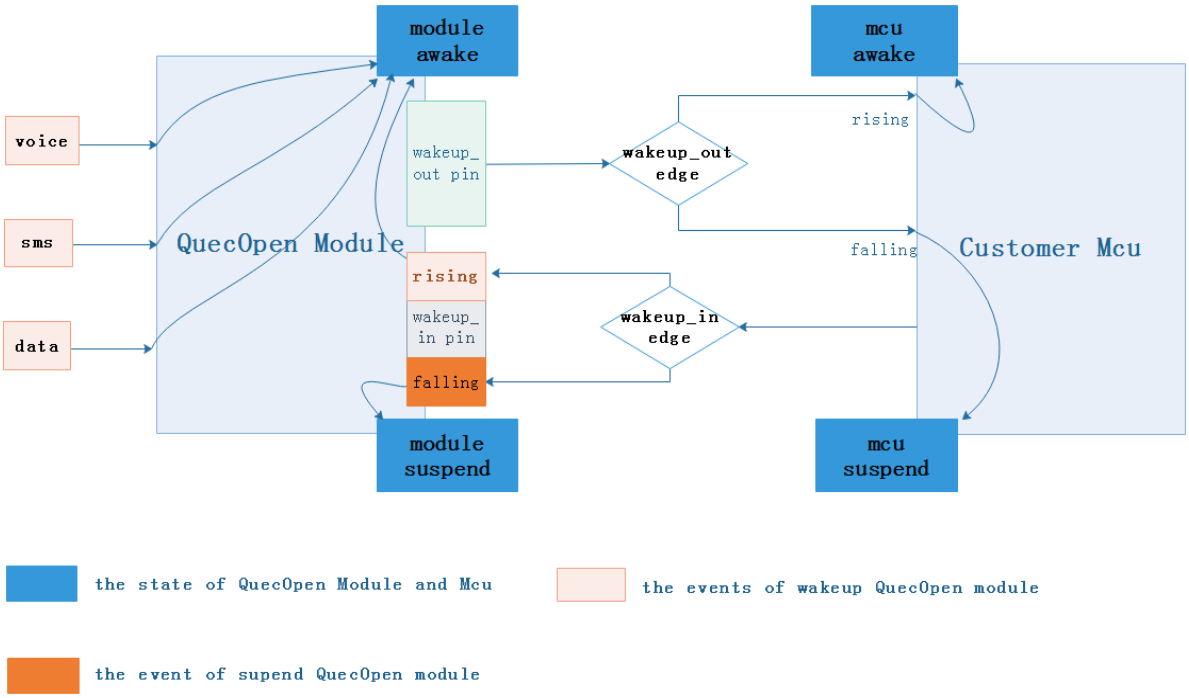

Figure 1: Low Power Mode Status

2.2. Solution to Wake up from Sleep

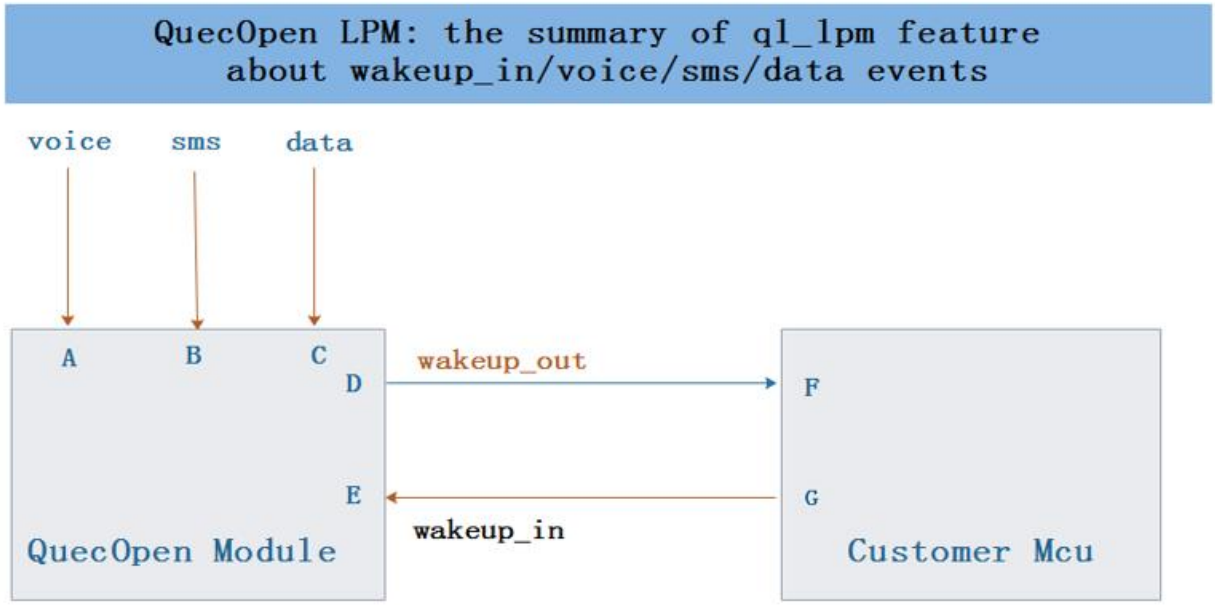

Figure 2: Solution to Wake up from Sleep

Table 1: Events in the Solution to Wake up from Sleep

State	Event	Description
Initial state	D	The wakeup_out pin outputs high level, so that the initial state of the "F" pin of the MCU is in high level
	G	The MCU pin outputs high level, so that wakeup_in pin is in high level
QuecOpen Module suspend	E	When the wakeup_in pin receives a falling edge, the application will release the wakelock. When the module enters low power mode, the wakeup_out pin automatically outputs low and feedback to the MCU
QuecOpen Module awake	A/B/C/E	When the module is waken up by these wake-up events, the application needs to lock the wakelock
	D	When A, B, C, E events occur, D controls the wakeup_out pin to output high level, wake up/feedback to MCU

NOTE

1. For examples of D event, please refer to:
   ql-ol-extsdk/example/low_power_consume_app/example_lpm.c

2. For examples of A, B, C and E events, please refer to:
   ql-ol-extsdk/example/low_power_consume_app/example_lpm_all.c

3 LPM Related APIs

3.1. Header File

The API header file *ql_lpm.h* is located in the *ql-sdk/ql-ol-extsdk/example/wakelock/main.c* directory. Unless otherwise stated, the header files mentioned in this document are in the *ql-sdk/ql-ol-extsdk/example/wakelock/main.c* directory.

3.2. API Description

3.2.1. QL_Lpm_Init

This function initializes the low power mode. The module automatically loads the ql_lpm driver, and at the same time monitor the wakeup_in pin state changes to notify *ql_lpm_handler*.

- **Prototype**

```
int QL_Lpm_Init(QL_Lpm_Handler_T ql_lpm_handler, QL_Lpm_Cfg_T *ql_lpm_cfg)
```

- **Parameter**

ql_lpm_handler:
[In] User callback. This callback function is called once there is any change in wakeup_in pin level.

ql_lpm_cfg:
[In] User parameter data structure. It supports to configure pins and trigger mode; it is recommended to input NULL (by using the default pin and trigger mode).

- **Return Value**

0 Indicates the function is executed successfully
-1 Indicates the function fails to be executed

3.2.1.1.QL_Lpm_Handler_T

If this function is registered through *QL_Lpm_Init*, it is triggered when the wakeup_in pin level changes.

- **Prototype**

```
typedef void (*QL_Lpm_Handler_T) ( ql_lpm_edge_t lpm_edge)
```

- **Parameter**

lpm_edge:
[In] Edge change of wakeup_in pin level reported by the lower layer
E_QL_LPM_FALLING Falling edge
E_QL_LPM_RISING Rising Edge

- **Return Value**

None.

3.2.2. QL_Lpm_Deinit

This function deinitializes the low power mode, uninstalls the ql_lpm kernel module, and deinitializes the handler.

- **Prototype**

```
int QL_Lpm_Deinit()
```

- **Parameter**

NA

- **Return Value**

0 Indicates the function is executed successfully
-1 Indicates the function fails to be executed

3.2.3. Ql_Autosleep_Enable

This function enables the autosleep feature. After the autosleep feature is enabled, the system automatically goes to sleep after meeting certain conditions

- **Prototype**

```
int Ql_Autosleep_Enable(char enable)
```

- **Parameter**

enable:
[In] Enable the autosleep feature or not
1 Enable autosleep
i Cancel autosleep（Normally it is not used. If the module needs to be awake, please call *Ql_SLP_WakeLock_Lock* to lock the wakelock after waking up the system to keep the system awake.）

- **Return Value**

0 Indicates the function is executed successfully
-1 Indicates the function fails to be executed

NOTE

After autosleep is enabled by *Ql_Autosleep_Enable,* it is generally recommended to call *Ql_SLP_WakeLock_Lock* to keep the system awake instead of *Ql_Autosleep_Enable(0)*. *Ql_SLP_WakeLock_Unlock* can release the wakelock to give up the sleep lock. See ***Chapter 3.2.5*** and ***Chapter 3.2.6*** for details. All process is frozen after the system goes into sleep and continues operating once the system wakes up from sleep mode.

3.2.4. Ql_SLP_WakeLock_Create

This function creates the wakelocks. The owner of the wakelocks created by this interface is the current process. It supports to create maximum 512 wakelocks.

- **Prototype**

```
int Ql_SLP_WakeLock_Create(const char *name, size_t len)
```

- **Parameter**

name:
[In] Wakelock name which is reflected in */sys/kernel/debug/wakeup_sources*.

len:
[In] The length of the wakelock name. The maximum length is 28 characters.

- **Return Value**

Wakelock descriptor	Indicates the function is executed successfully. Please check the error codes through errno.
-1	Indicates the function fails to be executed

3.2.5. Ql_SLP_WakeLock_Lock

This function locks the created wakelocks. After locking the wakelocks, Linux cannot enter low power mode.

- **Prototype**

```
int Ql_SLP_WakeLock_Lock(int fd)
```

- **Parameter**

fd:
[In] Wakelock descriptor

- **Return Value**

0	Indicates the function is executed successfully
-1	Indicates the function fails to be executed

3.2.6. Ql_SLP_WakeLock_Unlock

This function unlocks the specified wakelocks. If there is no other wakelock in the system, and the application has enabled the autosleep feature, Linux enters low power mode.

- **Prototype**

```
int Ql_SLP_WakeLock_Unlock(int fd)
```

- **Parameter**

fd:
[In] Wakelock descriptor

- **Return Value**

0	Indicates the function is executed successfully
-1	Indicates the function fails to be executed

3.2.7. Ql_SLP_WakeLock_Destroy

This function destroys the wakelocks.

- **Prototype**

```
int Ql_SLP_WakeLock_Destroy(int fd)
```

- **Parameter**

fd:
[In] Wakelock descriptor

- **Return Value**

0 Indicates the function is executed successfully
-1 Indicates the function fails to be executed

4 Current Consumption

The current consumption of LTE Standard QuecOpen modules under different networks is shown in the table below:

Table 2: Power Consumption under Different Networks (3.3V VBAT Powered)

Parameter	Mode	Condition	Typical value	Unit
I_{VBAT}	Power-off	The module is powered off	12	uA
	LPM	**AT+CFUN=0**(Disconnect the USB)	1.11	mA
		EGSM @DRX=2(Disconnect the USB)	2.21	mA
		EGSM @DRX=5(Disconnect the USB)	1.67	mA
		EGSM @DRX=5(Suspend the USB)	1.91	mA
		EGSM @DRX=9(Disconnect the USB)	1.51	mA
		DCS @DRX=2(Disconnect the USB)	2.02	mA
		DCS @DRX=5(Disconnect the USB)	1.45	mA
		DCS @DRX=5(Suspend the USB)	1.64	mA
		DCS @DRX=9(Disconnect the USB)	1.32	mA
		TD-SCDMA Band A @PF=64 (disconnect the USB)	2.03	mA
		TD-SCDMA Band A @PF=128 (disconnect the USB)	1.67	mA
		TD-SCDMA Band A @PF=256 (disconnect the USB)	1.56	mA
		TD-SCDMA Band A @PF=512 (disconnect the USB)	1.42	mA
		BC0 @SCI=1(Disconnect the USB)	3.45	mA
		BC0 @SCI=1(Suspend the USB)	3.74	mA

		WCDMA @PF=64(Disconnect the USB)	2.02	mA
		WCDMA @PF=64(Suspend the USB)	2.17	mA
		WCDMA @PF=128(Disconnect the USB)	1.71	mA
		WCDMA @PF=256(Disconnect the USB)	1.42	mA
		WCDMA @ PF=512(Disconnect the USB)	1.33	mA
		LTE-FDD @PF=32(Disconnect the USB)	3.37	mA
		LTE-FDD @PF=64(Disconnect the USB)	2.27	mA
		LTE-FDD @PF=64(Suspend the USB)	2.53	mA
		LTE-FDD @PF=128(Disconnect the USB)	1.86	mA
		LTE-FDD @PF=256(Disconnect the USB)	1.52	mA
		LTE-TDD @PF=32(Disconnect the USB)	3.41	mA
		LTE-TDD @PF=64(Disconnect the USB)	2.27	mA
		LTE-TDD @PF=64(Suspend the USB)	2.51	mA
		LTE-TDD @PF=128(Disconnect the USB)	1.71	mA
		LTE-TDD @PF=256(Disconnect the USB)	1.42	mA
	Idle	EGSM @DRX=5(Disconnect the USB)	17.54	mA
		EGSM @DRX=5(Connect by USB）	27.67	mA
		BC0 @SCI=1(Disconnect the USB)	18.92	mA
		BC0 @SCI=1(Connect by USB）	29.08	mA
		TD-SCDMA Band A @PF=64 (Disconnect the USB)	17.61	mA
		TD-SCDMA Band A @PF=64 (Connect by USB）	27.60	mA
		WCDMA @PF=64(Disconnect the USB)	17.92	mA
		WCDMA @PF=64(Connect by USB）	28.00	mA
		LTE-FDD @PF=64(Disconnect the USB)	17.84	mA
		LTE-FDD @PF=64(Connect by USB）	27.94	mA

		LTE-TDD @ PF=64(Disconnect the USB)	18.11	mA
		LTE-TDD @ PF=64(Connect by USB）	28.08	mA
	GPRS data transmission (GNSS is disabled)	GSM900 4DL/1UL @32.62 dBm	246.8	mA
		GSM900 3DL/2UL @32.45 dBm	418.3	mA
		GSM900 2DL/3UL @30.73 dBm	513.2	mA
		GSM900 1DL/4UL @29.75 dBm	594.3	mA
		DCS1800 4DL/1UL @29.57 dBm	170.8	mA
		DCS1800 3DL/2UL @29.45 dBm	274.9	mA
		DCS1800 2DL/3UL @29.28 dBm	374.8	mA
		DCS1800 1DL/4UL @29.11 dBm	475.5	mA
	EDGE data transmission (GNSS is disabled)	GSM900 4DL/1UL @27.24 dBm	157.3	mA
		GSM900 3DL/2UL @27.14 dBm	258.8	mA
		GSM900 2DL/3UL @27.01 dBm	358.3	mA
		GSM900 1DL/4UL @26.91 dBm	461.0	mA
		DCS1800 4DL/1UL @25.85 dBm	143.4	mA
		DCS1800 3DL/2UL @25.57 dBm	235.2	mA
		DCS1800 2DL/3UL @25.55 dBm	323.7	mA
		DCS1800 1DL/4UL @25.22 dBm	415.7	mA
	CDMA/TD-SCDMA data transmission (GNSS is disabled)	BC0 @23.98 dBm	600.7	mA
		TD-SCDMA Band A @23.42 dBm	130.6	mA
		TD-SCDMA Band F @23.32 dBm	131.9	mA
	WCDMA data transmission (GNSS is disabled)	WCDMA B1 HSDPA @21.06 dBm	503.8	mA
		WCDMA B1 HSUPA @20.56 dBm	500.6	mA
		WCDMA B8 HSDPA @21.16 dBm	469.5	mA
		WCDMA B8 HSUPA @20.83 dBm	527.2	mA

	LTE data transmission (GNSS is disabled)	LTE-FDD B1 @22.04 dBm	709.7	mA
		LTE-FDD B3 @22.87 dBm	717.1	mA
		LTE-FDD B5 @22.11 dBm	609.6	mA
		LTE-FDD B8 @22.40 dBm	609.4	mA
		LTE-TDD B38 @22.75 dBm	434.4	mA
		LTE-TDD B39 @22.90 dBm	336.5	mA
		LTE-TDD B40 @23.04 dBm	360.5	mA
		LTE-TDD B41 @22.95 dBm	403.8	mA
	GSM voice call	GSM900PCL=5 @32.71 dBm	244.4	mA
		GSM900PCL=12 @19.53 dBm	111.7	mA
		GSM900PCL=19 @5.69 dBm	81.2	mA
		DCS1800 PCL=0 @29.64 dBm	165.6	mA
		DCS1800 PCL=7 @16.66 dBm	126.4	mA
		DCS1800 PCL=15 @0.41 dBm	105.0	mA
	CDMA voice call	BC0 @24.09 dBm	686.3	mA
		BC0 @-60.12 dBm	114.3	mA
	WCDMA voice call	WCDMA B1 @23.01 dBm	607.9	mA
		WCDMA B8 @22.57 dBm	542.3	mA

5 Precautions

5.1. Unable to Enter LPM

If the wakelocks are released in the application, but the module still cannot enter LPM, you can use the following command to view the wakelocks held by the current system:

```
awk '$6 != 0 {print $1"    "$6}' /sys/kernel/debug/wakeup_sources
```

Case 1: If **msm_otg** is output, it means that the usb_vbus pin is in high level and needs to be pulled low to enter LPM.

```
~ # awk '$6 != 0 {print $1"  "$6}' /sys/kernel/debug/wakeup_sources
name  active_since
msm_otg  77464
~ #
```

Case 2: If **DATA1** is output, it means that the GPS data is restricting the module from going to sleep. Call *QL_LOC_Stop_Navigation ()* to disable the GPS feature. After that, the module enters LPM.

```
~ # awk '$6 != 0 {print $1"  "$6}' /sys/kernel/debug/wakeup_sources
name  active_since
DATA1  448
msm_otg  1105442
~ #
```

Case 3: If **bam_dmux_wakelock** is output, it means that there is data transmission on rmnet_data internet access, and the data transmission needs to be stopped to enter LPM.

```
~ # awk '$6 != 0 {print $1"  "$6}' /sys/kernel/debug/wakeup_sources
name  active_since
bam_dmux_wakelock  1714
msm_otg  226735
~ #
```

Case 4: If the Wi-Fi function is enabled, call *ql_wifi_disable()* to enter LPM by disabling the Wi-Fi function.

Case 5: If the Ethernet is enabled, call *ql_sgmii_disable()* to enter LPM by disabling Ethernet.

5.2. Wake up from Sleep Unexpectedly

To check whether the module wakes up from LPM unexpectedly, KEYSIGHT power source is one of the method to capture the current consumption; the other one is using Debug UART port of the module to capture the logs. The logs can be analyzed to find out the reasons to confirm whether it is an unexpected wake-up.

First, execute the following commands:

```
~ # echo 1 > /sys/module/printk/parameters/perf_mode_console
~ # echo 1 > /sys/module/msm_show_resume_irq/parameters/debug_mask
~ # echo 0x2 > /sys/module/ipc_router_core/parameters/debug_mask
```

Then, call the relevant APIs to put the module into LPM and observe the logs. If the following logs are printed, it indicates that the module may have been unexpectedly waken up:

```
[   113.386694] gic_show_resume_irq: 57 triggered qcom,smd-modem
[   113.386694] gic_show_resume_irq: 200 triggered qcom,smd-rpm
[   113.386694] resume cycles:          2542257600
[   113.388512] [IPCRTR]  CLI RX Len:0xd T:0x1 CF:0x0 SVC:<0x3:0x1> SRC:<0x3:0x11> DST:<0x1:0x43> DATA: 51000b04 13000600
[   113.388520] PM: noirq resume of devices complete after 0.975 msecs
[   113.389994] PM: early resume of devices complete after 1.088 msecs
```

If the above logs are printed, it means that one of the following situations may occur:

Case 1: Print **gic_show_resume_irq: 57 triggered qcom,smd-modem**

- **57** indicates that the modem sends a QMI message to the AP through SMD;
- If it is **58**, it means that there are IP packets sent to AP.

Case 2: Print **[IPCRTR] CLI RX Len:0xd T:0x1 CF:0x0 SVC:<0x3:0x1> SRC:<0x3:0x11> DST:<0x1:0x43> DATA: 51000b04 13000600**

- **CLI RX** indicates that the QMI client received a message, which may be a response or an indication. In this case, it needs to be distinguished by the **DATA** field.
- **SVC: <0x3:0x1>**: **0x3** represents QMI MSG ID: NAS
- **DATA: 51000b04 13000600**: This field is 13000600 51000b04 in reverse order, where 04 field represents an indication, and 51 field represents MI_NAS_SIG_INFO_IND, which is the QMI MSG reporting the status change due to the change in signal strength.

Table 3: Common NAS Wakeup Messages

NAS Wakeup Messages	Field	Description
QMI_NAS_ERR_RATE_IND	0x0053	Provide specific RAT error rate information
QMI_NAS_SIG_INFO_IND	0x0051	Provide information on changes in signal strength status
QMI_NAS_RF_BAND_INFO_IND	0x0066	Report current RF band information
QMI_NAS_SYS_INFO_IND	0x004E	Indicates changes in system information
QMI_NAS_SERVING_SYSTEN_IND	0x0024 indication	Indicates the current service system registration status and/or changes in radio technology (not recommended)

5.3. High Current Consumption in LPM

If the average current consumption is still high after the module enters LPM, there may be three types of reasons: unexpected wakeup, bottom current, and RF (network, frequency band, etc.). The troubleshooting steps are as follows:

Step 1: Use the module's Debug UART to capture the logs. First confirm whether the module wakes up unexpectedly. Please refer to ***Chapter 5.2*** for details.

Step 2: If no unexpected wakeup is found in ***Step 1***, check whether the bottom current is too high. Execute **AT+CFUN=0** to turn off the radio frequency interference, and observe whether the bottom current is still too high (normally below 1.5 mA); if the bottom current is still high, check whether the pin forms a leakage circuit with the external circuit and causes the bottom current to be high.

Step 3: If current consumption in LPM is still high after excluding ***Step 1*** and ***Step 2***, use KEYSIGHT Power Supply to capture the accurate current consumption diagram to view the reasons, as shown in the following figure:

Figure 3: KEYSIGHT Current Consumption Diagram

6 Appendix A References

Table 4: Abbreviations

Abbreviation	Description
AP	Access Point
API	Application Program Interface
APN	Access Point Name
CPU	Central Processing Unit
DRX	Discontinuous Reception
GNSS	Global Navigation Satellite System
GPIO	General-purpose input/output
GSM	Global System for Mobile Communication
LPM	Low Power Mode
LTE	Long Term Evolution
MCU	Microcontroller Unit
NAS	Network Access Serve
QMI	QUALCOMM Message Interface
RF	Radio Frequency
SMS	Short Messaging Service
UART	Universal Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
WCDMA	Wideband Code Division Multiple Access