



## **GR5xx FreeRTOS Example Application**

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# Preface

## Purpose

This document introduces how to use and modify a FreeRTOS example in the Bluetooth Low Energy (Bluetooth LE) GR5xx Software Development Kit (SDK), to help users quickly get started with secondary development.

## Audience

This document is intended for:

- Device user
- Developer
- Test engineer
- Hobbyist developer
- Technical writer

## Release Notes

This document is the third release of *GR5xx FreeRTOS Example Application*, corresponding to Bluetooth LE GR5xx System-on-Chip (SoC) series.

## Revision History

Version	Date	Description
1.0	2023-01-10	Initial release
3.0	2023-03-30	Updated descriptions about GR5xx SoCs.
3.1	2023-11-06	Updated the approaches for obtaining GProgrammer, GRToolbox, and GRUart.

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# 1 Introduction

FreeRTOS is an excellent embedded real-time operating system for microcontrollers. Being light-weighted, distributed freely under MIT open-source License, and built with an emphasis on portability, tailorability, and flexible scheduling policy, it requires low RAM/ROM consumption and supports management of task, time, semaphore, message queue, and memory.

This document introduces the FreeRTOS porting example in the GR5xx Software Development Kit (SDK), including usage of the example and descriptions of major source code.

Before getting started, you can refer to the following documents.

Table 1-1 Reference documents

Name	Description
Developer guide of the specific GR5xx SoC	Introduces GR5xx SDK and how to develop and debug applications based on the SDK.
Keil User Guide	Offers detailed Keil operational instructions. Available at <a href="https://www.keil.com/support/man/docs/uv4/">https://www.keil.com/support/man/docs/uv4/</a> .
FreeRTOS Documentation	Provides guidance on using FreeRTOS. Available at <a href="https://www.freertos.org/Documentation/RTOS_book.html">https://www.freertos.org/Documentation/RTOS_book.html</a> .

## 2 Introduction to FreeRTOS Source Directory

FreeRTOS source code is in `SDK_Folder\external\freertos`, which contains the include folder, the portable folder, and the .c source files.

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**Note:**

SDK\_Folder is the root directory of the GR5xx SDK in use.

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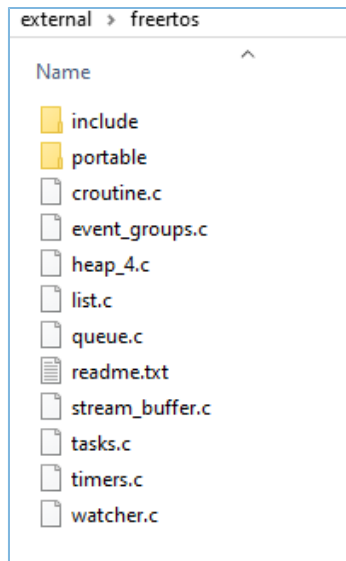


Figure 2-1 The freertos folder in GR5xx SDK

- The include folder: It contains all FreeRTOS APIs, related structures, and macro definitions.
- The portable folder: It contains FreeRTOS code to be ported to GR5xx System-on-Chips (SoCs) with modifications.
- The .c source files: Implement core service code of FreeRTOS.

For more information about FreeRTOS, visit the FreeRTOS official website: <https://www.freertos.org/>.

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**Note:**

The files used for transporting FreeRTOS in `armcc/gcc/iar` are different. Corresponding files shall be selected according to compilation requirements. Specific files are in the portable folder.

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## 3 Initial Operation

This chapter introduces how to rapidly verify the FreeRTOS example in the GR5xx SDK.

### 3.1 Preparation

Perform the following tasks before verifying a FreeRTOS example.

- **Hardware preparation**

Table 3-1 Hardware preparation

Name	Description
Development board	Starter Kit Board (SK Board) of the corresponding SoC
Connection cable	USB Type C cable (Micro USB 2.0 cable for GR551x SoCs)
Android phone	A mobile phone running on Android 5.0 (KitKat) or later
iOS device	Any iOS device supporting Bluetooth LE 4.0 and later, such as iPhone 4S and iPad 3

- **Software preparation**

Table 3-2 Software preparation

Name	Description
Windows	Windows 7/Windows 10
Keil MDK5	An integrated development environment (IDE). MDK-ARM Version 5.20 or later is required. Available at <a href="https://www.keil.com/download/product/">https://www.keil.com/download/product/</a> .
GRToolbox (iOS)	A Bluetooth Low Energy (Bluetooth LE) debugging tool. Available at App Store.
GRToolbox (Android)	A Bluetooth LE debugging tool. Available at <a href="https://www.goodix.com/en/software_tool/grtoolbox">https://www.goodix.com/en/software_tool/grtoolbox</a> .
GRUart (Windows)	A serial port debugging tool. Available at <a href="https://www.goodix.com/en/download?objectId=43&amp;objectType=software">https://www.goodix.com/en/download?objectId=43&amp;objectType=software</a> .
GProgrammer (Windows)	A programming tool. Available at <a href="https://www.goodix.com/en/software_tool/gprogrammer_ble">https://www.goodix.com/en/software_tool/gprogrammer_ble</a> .

### 3.2 Firmware Programming

You can download *ble\_app\_template\_freertos.bin* to the SK Board through GProgrammer. For details, see *GProgrammer User Manual*.

 **Note:**

*ble\_app\_template\_freertos.bin* is in SDK\_Folder\projects\ble\ble\_peripheral\ble\_app\_template\_freertos\build\.

### 3.3 Test and Verification

After the SK Board and the required software get ready, start the test and verification of the FreeRTOS example. The test includes the following two aspects:

- FreeRTOS features
- Bluetooth function

1. Verify FreeRTOS features.

Start GRUART; open the configured serial port, and check the trace results. If GRUART prints log information like **AAP\_I: TickCount: tick count, Time: month/day hour:minute:second.millisecond** every other second in the **Receive Data** pane, the FreeRTOS system runs successfully.

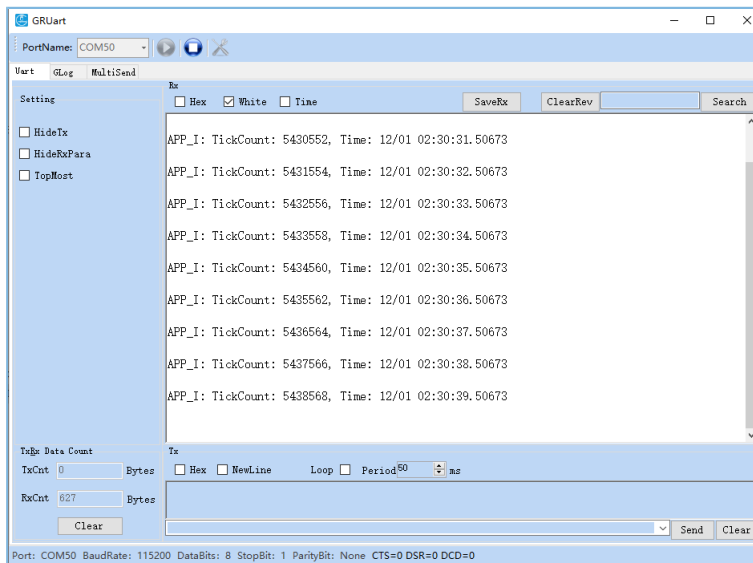


Figure 3-1 Operating results

2. Verify the Bluetooth function.

Run GRToolbox and scan Bluetooth devices nearby. If **Goodix\_Tem\_OS** is in the device list, the FreeRTOS application runs normally.



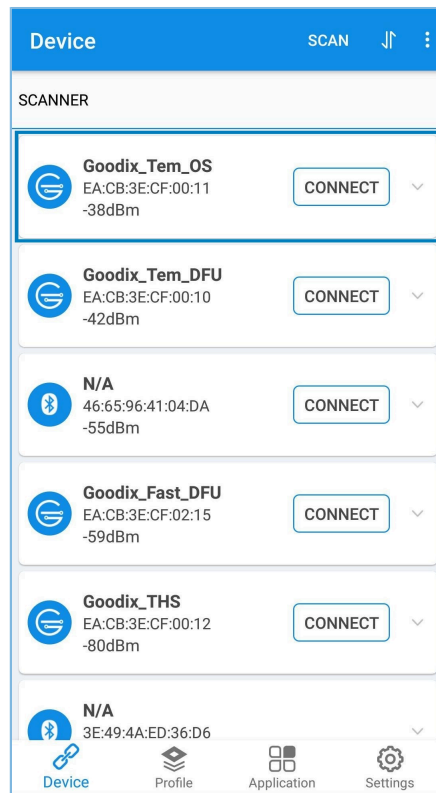


Figure 3-2 Discovering **Goodix\_Tem\_OS**

**Note:**

Screenshots of GRToolbox in this document are for reference only, to help users better understand the software operation. In the case of interface differences due to version changes, the interface of GRToolbox in practice shall prevail.

## 4 Application Details

Users can customize the FreeRTOS application by modifying configurations of the `ble_app_template_freertos` example. For example:

- Modify the FreeRTOS configurations.
- Modify the example program configurations.

This chapter introduces configurations and major code of the `ble_app_template_freertos` example.

### 4.1 Configuration

Users can customize the FreeRTOS memory management policy and the FreeRTOS kernel based on product requirements.

#### 4.1.1 Memory Management Policy Configuration

The project adopts `heap_4.c` as the memory management policy. Users can replace the `heap_4.c` with other ones on demand.

FreeRTOS supports five memory management policies, which are implemented through `heap_1.c`, `heap_2.c`, `heap_3.c`, `heap_4.c`, and `heap_5.c` respectively. Information about each file is provided as follows:

Table 4-1 FreeRTOS memory management policy

Source File	Characteristics
<code>heap_1.c</code>	<ul style="list-style-type: none"> <li>• It is easy to be implemented with less code.</li> <li>• It supports memory application only, and does not permit memory to be released once the memory has been allocated.</li> </ul>
<code>heap_2.c</code>	<ul style="list-style-type: none"> <li>• Apply the optimum matching algorithm.</li> <li>• Allow releasing allocated memory blocks.</li> <li>• Do not merge adjacent free blocks, which may cause memory fragmentation.</li> <li>• Repeated applications and releases of memory cause memory fragmentation.</li> </ul>
<code>heap_3.c</code>	<ul style="list-style-type: none"> <li>• Wrap <code>malloc()</code> and <code>free()</code> functions for thread safety.</li> <li>• Need to configure the heap size in the startup assembling file <code>startup_gr55xx.s</code>.</li> <li>• It requires selecting the <b>Use MicroLIB</b> in the <b>Options for Target</b> pane of Keil; otherwise, this policy cannot work.</li> </ul>
<code>heap_4.c</code>	<ul style="list-style-type: none"> <li>• Apply the optimum matching algorithm.</li> <li>• Allow releasing allocated memory blocks.</li> <li>• Merge adjacent free memory blocks.</li> <li>• Repeated applications and releases of memory cause memory fragmentation.</li> </ul>
<code>heap_5.c</code>	<ul style="list-style-type: none"> <li>• Apply the optimum matching algorithm.</li> <li>• Allow releasing allocated memory blocks.</li> <li>• Merge adjacent free memory blocks.</li> </ul>

Source File	Characteristics
	<ul style="list-style-type: none"> <li>• Allow spanning memory heaps across multiple non-adjacent memory blocks.</li> <li>• Need to initialize memory heaps successively.</li> </ul>

 **Note:**

The source files are in SDK\_Folder\external\freertos\portable\MemMang.

## 4.1.2 Kernel Configuration

FreeRTOS kernel is configured by the macro definitions in the *FreeRTOSConfig.h*, including configuration of the main clock frequency and the highest priority level of a task. Users can modify these macro definitions to customize a new kernel. Common macro definitions of FreeRTOS are shown in the table below:

Table 4-2 FreeRTOS common macro definitions

Macro Definition	Configuration
configUSE_IDLE_HOOK	1: Enable the HOOK function of idle tasks. 0: Disable the HOOK function of idle tasks.
configUSE_TICK_HOOK	1: Enable the Hook function of the TICK interrupt. 0: Disable the Hook function of the TICK interrupt.
configCPU_CLOCK_HZ	Define the main frequency of CPU (unit: Hz); the default value of the current platform is 64000000.
configTICK_RATE_HZ	Define the clock tick count of the system (unit: Hz); the default value of the current platform is 1000.
configMAX_PRIORITIES	Define the maximum priorities for users. If the maximum number is defined to 5, the priority levels available for users are 0, 1, 2, 3 and 4, excluding 5.
configMINIMAL_STACK_SIZE	Define the default minimum stack size for system tasks (unit: word); the default value of the current platform is 512 words (2,048 bytes in total).
configTOTAL_HEAP_SIZE	Refer to the memory pool capacity for memory management (unit: KB); the default value of the current platform is 32 KB. If dynamic APIs are used, the FreeRTOS kernel requests memory from the memory pool. The total memory shall be allocated on demand to avoid abnormal system operation.
configPRIO_BITS	Refer to bits occupied by the priority level set for the current platform (default value: 4).
configLIBRARY_LOWEST_INTERRUPT_PRIORITY	Refer to the lowest priority level supported by the current platform (default value: 15).

Macro Definition	Configuration
configLIBRARY_MAX_SYSCALL_INTERRUPT_PRIORITY	<p>Define the highest priority level of interrupts under the FreeRTOS management.</p> <p>A smaller number indicates a higher priority level.</p> <p>If the number is set to 5, tasks at a priority level below 5 are beyond the control of FreeRTOS. In interrupt masking, interrupts at priority levels below 5 are not masked.</p>

#### Note:

- *FreeRTOSConfig.h* is in SDK\_Folder\app\projects\ble\ble\_peripheral\ble\_app\_template\_freertos\Src\user.
- For more information about macro configurations, visit <https://www.freertos.org/a00110.html>.

## 4.2 Major Code

This section describes how to use code to create tasks and to implement Bluetooth LE scheduling.

### 4.2.1 Task Creation

- Create a task.

In this example project, `print_test_task` is created. This task is responsible for printing information.

**Path:** ble\_app\_template\_freertos\Src\user\main.c

**Function:** vStartTasks();

```
static void vStartTasks(void *arg)
{
    app_calendar_init();
    xTaskCreate(print_test_task, "print_task", APP_TASK_STACK_SIZE,
                NULL, configMAX_PRIORITIES - 1, NULL);
    xTaskCreate(dfu_schedule_task, "dfu_schedule_task", DFU_TASK_STACK_SIZE,
                NULL, configMAX_PRIORITIES - 2, NULL);
    #if APP_LOG_STORE_ENABLE
        xTaskCreate(log_store_dump_task, "log_store_dump_task",
                    LOG_STORE_DUMP_TASK_STACK_SIZE, NULL, configMAX_PRIORITIES - 3, NULL);
    #endif
    vTaskDelete(NULL);
}
```

**Path:** ble\_app\_template\_freertos\Src\user\main.c

**Function:** print\_test\_task();

This function implements cyclic printing at a 1-second latency. The `vTaskDelay` function is in units of millisecond.

```
static void print_test_task(void *arg)
{
    while (1)
    {
        app_rtc_get_time(&g_calendar_time);
        APP_LOG_INFO("TickCount: %d, Time: %02d/%02d %02d:%02d:%03d\r\n",
```

```
        xTaskGetTickCount(),
        g_calendar_time.mon, g_calendar_time.date,
        g_calendar_time.hour, g_calendar_time.min, g_calendar_time.sec,
        g_calendar_time.ms);
    app_log_flush();
    vTaskDelay(1000);
}
}
```

## 4.2.2 Bluetooth LE Scheduling

This section introduces how Bluetooth LE Protocol Stack and Bluetooth LE applications schedule tasks in FreeRTOS.

After entering the main() function, complete the following steps before performing FreeRTOS task scheduling:

1. Initialize hardware peripherals.
2. Apply for the memory block (heaps\_table) required to run the Bluetooth LE Protocol Stack.
3. Initialize Bluetooth LE Protocol Stack.

After initialization, Bluetooth LE Protocol Stack enables two interrupts: BLE\_IRQ and BLE\_SDK\_IRQ.

- Notify the Bluetooth LE Event of Bluetooth LE Protocol Stack to Bluetooth LE applications.

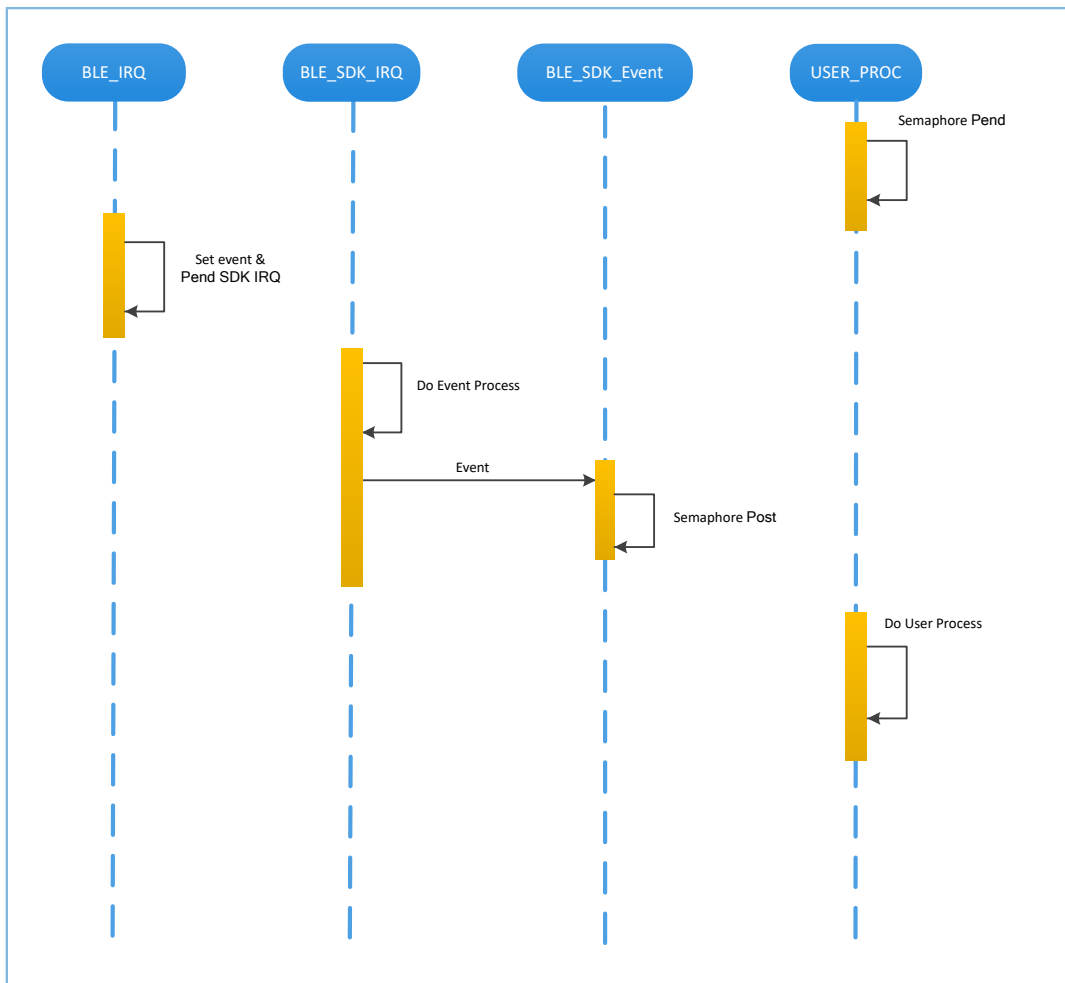


Figure 4-1 Bluetooth LE Protocol Stack notifying Bluetooth LE applications of a Bluetooth LE Event

As shown in the figure above, when Bluetooth LE Baseband receives a data package, it triggers BLE\_IRQ interrupt. BLE\_IRQ\_Handler generates a Bluetooth LE Event and sets the BLE\_SDK\_IRQ interrupt to Pending state. During BLE\_SDK\_IRQ\_Handler execution, the Bluetooth LE Event is processed and Bluetooth LE applications are notified of part of the Bluetooth LE Event through the BLE\_SDK\_Event function.

Recommendations for implementing BLE\_SDK\_Event function:

1. The BLE\_SDK\_Event function is called in the interrupt handling function (BLE\_SDK\_IRQ\_Handler). Thus it is recommended not to perform long-running operation in the event function; otherwise, implementation of user tasks may be delayed.
2. If any data or state information in the event function requires timely processing by Bluetooth LE applications, it is recommended to use the semaphore mechanism to complete service logic processing in user tasks. This means you should wait for the semaphore (Pend) in user tasks, and release the semaphore (Post) in the event function.
3. If the event function contains a large amount of data, and requires long-time processing or ordered processing, developers are recommended to use the message queue to cache data and then transfer the data to other tasks for processing.

4. In the BLE\_SDK\_Event function, call FreeRTOS APIs that end in "FromISR" if required, and forbid waiting for semaphore in the BLE\_SDK\_Event function.
- Send requests from Bluetooth LE application layer to Bluetooth LE Protocol Stack.

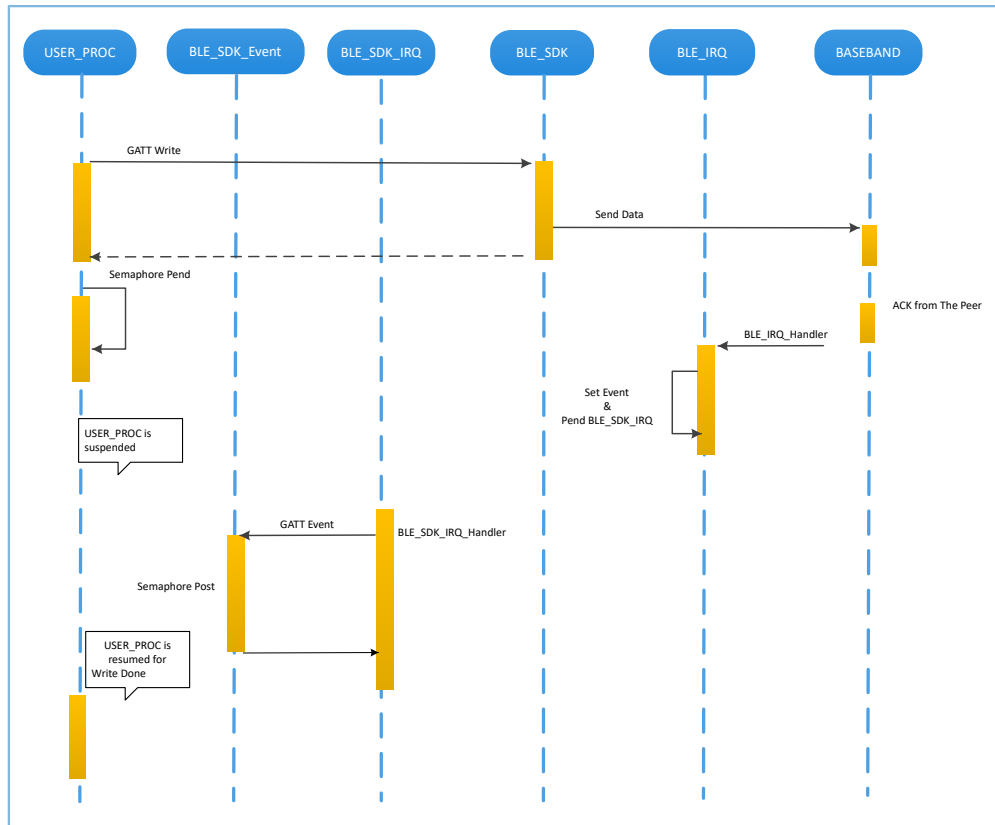


Figure 4-2 Processing of requests from Bluetooth LE applications to Bluetooth LE Protocol Stack

As shown in the figure above, Bluetooth LE applications uses GATT APIs to write data to the peer device. This action requires interactions with the peer device, and the operating results cannot be obtained immediately. Bluetooth LE applications need to wait for the processing results from Bluetooth LE Protocol Stack. Developers can use semaphore to convert an asynchronous function call to a synchronous function call according to service logic demands from Bluetooth LE applications:

1. Suspend the task by using the semaphore (Semaphore Pend) interface after GATT APIs are called by user tasks.
2. Bluetooth LE Protocol Stack waits for ACK from the peer device after sending the data from Bluetooth LE applications.
3. Bluetooth LE Baseband triggers the BLE\_IRQ interrupt after receiving ACK from the peer device.
4. BLE\_IRQ\_Handler generates a Bluetooth LE Event and sets the BLE\_SDK\_IRQ interrupt to Pending state.
5. The Bluetooth LE Event is processed, and the BLE\_SDK\_Event function is called during BLE\_SDK\_IRQ\_Handler execution.
6. Implement the semaphore (Post) interface in the BLE\_SDK\_Event function to release the blocked semaphore.

By then, implementation of user tasks resumes and data writes are done.

Generally, developers only need to focus on functions at the application layer, and how to implement event functions to enable interaction with users. Bluetooth LE Protocol Stack is transparent to developers. For GR5xx SDK programming model, refer to the developer guide of the specific GR5xx SoC.



## 5 FAQ

This chapter describes possible problems, reasons, and solutions during verification and application of the FreeRTOS example.

### 5.1 Why Is There No Output Information from GRUart?

- **Description**  
There is no output information from GRUart when the on-board program is running.
- **Analysis**  
Serial ports are set incorrectly. For example, if the baud rate is wrong, the serial port tool cannot correctly display the data received.
- **Solution**  
Check whether the serial cable is connected correctly, whether the COM port number is correct, and whether the baud rate is set correctly. It is recommended to first use the SDK default firmware to detect the development environment.

### 5.2 Why Does the Mobile Phone Discover No Bluetooth Advertising?

- **Description**  
A mobile phone cannot discover advertising when the on-board program is running.
- **Analysis**  
The firmware cannot run normally, resulting in no Bluetooth advertising.
- **Solution**  
Try to reset or re-download the default firmware, and check the antennas.