AN13792

如何使能异步中断并唤醒系统

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应用笔记

文档信息

信息	内容
关键词	AN13792, RT1180, 唤醒, 异步中断, 低功耗
摘要	本应用笔记将会介绍如何使能异步中断并将进入低功耗状态的芯片唤醒。

1 介绍

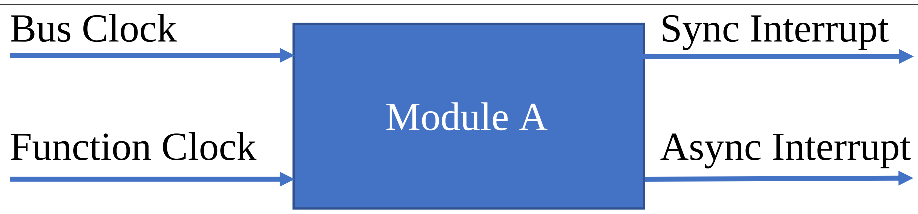
i.MX RT1180 跨界 MCU 系列包括千兆时间敏感网络（TSN）交换机，支持实时丰富的网络集成，可处理时间敏感和工业实时通信。i.MX RT1180 支持多种协议，桥接实时以太网和 Industry 4.0 系统之间的通信。该系列集成先进的 EdgeLock 安全区域，基于 800 MHz Cortex-M7 和 240 MHz Cortex-M33 双核架构，可实现设计灵活性。

低功耗设计同样是 RT1180 的关键功能，本应用笔记将会介绍如何使能异步中断并将进入低功耗状态的芯片唤醒。

2 同步中断和异步中断

本应用笔记中将同步中断和异步中断定义为：

- 同步中断：当 bus clock 使能时产生的中断，后续将会使用 Sync interrupt 作为同步中断的缩写。
- 异步中断：当 bus clock 关闭时产生的中断，后续将会使用 Async interrupt 作为异步中断的缩写。



Bus Clock	Function Clock	Sync Interrupt	Async Interrupt
Enabled	Enabled	Y	—
Disabled	Enabled	N	Y

图 1. 时钟与中断

图 1是时钟与中断关系的示意图。当进入一些低功耗状态时，系统的 bus clock 将会停止工作以更加节省功耗。此时，因为 bus clock 停止工作，同步中断无法产生，进而无法作为唤醒源唤醒系统。与此同时，需要注意的是当系统进入低功耗状态时产生中断的模块（例如各种外设，Timer, GPT, GPIO, LPSPI 等）的供电需要保持。

很多外设都支持产生异步中断，用户可以参考用户手册中的中断章节获取具体哪些外设支持异步中断功能。

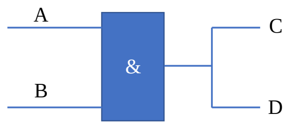
表 1. 部分支持异步中断的外设

19	LPUART1	OR	TX interrupt
19		OR	Async TX interrupt
19		OR	RX interrupt
19		OR	Async RX interrupt
57	GPIO2	OR	Interrupt 0
57		OR	Async interrupt 0

3 使能异步中断

当bus clock 始终关闭时异步中断不会自动被使能，用户需要通过配置寄存器的方法使能异步中断。通常在进入一个低功耗状态前需要使用握手功能（handshake），handshake 的目的是保证在CPU发出低功耗指令WFI之前，所有外设完成所有传输，不再接收新的传输，从而安全进入低功耗。 当握手完成后，异步中断功能自动使能。

在RT1180或者RT1170这样的多核系统中，如果一个外设没有被分配到一个域里，那么需要2个寄存器来完成握手。stop_req需要从CM33域内的GPR_SHARED8 和GPR_SHARED9以及 CM7域内的GPR_SHARED12 和GPR_SHARED13中发送出来，这时停止接收信号（stop_ack）才能被确认。



A	B	C	D
0	0	0	0
0	1	0	0
1	0	0	0
1	1	1	1

A: CAN1_STOP_REQ from GPR_SHARED8

B: CAN1_STOP_REQ from GPR_SHARED12

C: CAN1_STOP_ACK from GPR_SHARED_STATUS1

D: CAN1_STOP_ACK from GPR_SHARED_STATUS5

NOTE: Assuming the peripheral completed transmissions

图 **2. Handshake**

以 CAN1作为示例，`CAN1_STOP_REQ` 需要分别从 `GPR_SHARED8 bit[24]` 和 `GPR_SHARED12 bit[24]`发送：

```
CCM->GPR_SHARED_CTRL[8].GPR_SHARED |= 1<<24;
CCM->GPR_SHARED_CTRL[12].GPR_SHARED |= 1<<24;
```

接着检查传输是否完成，通过检查 `GPR_SHARED_STATUS1 bit[3]` 和 `GPR_SHARED_STATUS5 bit[3]` 即可获知状态：

```
while((CCM->GPR_SHARED_STATUS[1] & 0x8) == 0); //Check bit3
while((CCM->GPR_SHARED_STATUS[5] & 0x8) == 0); //Check bit3
```

如果一个外设被指定到一个域，那么只需要发送一个`stop_request`。 同样以CAN1为例，假定它被分派到CM33域， `CAN1_STOP_REQ` 只需要从 `GPR_SHARED8 bit[24]`发送即可：

```
CCM->GPR_SHARED_CTRL[8].GPR_SHARED |= 1<<24;
```

接着通过检查 `GPR_SHARED_STATUS1 bit[3]` 来检查传输是否结束：

```
while((CCM->GPR_SHARED_STATUS[1] & 0x8) == 0); //Check bit3
```

在进入低功耗模式之前，请确保所有的外设都完成了传输。除此之外，对于握手的序列需要注意的是，DMA/ENET（Bus Master）需要首先完成握手，然后才是 Flash/内存（Bus Slave）。

4 例子: 使能 GPIO 的异步中断

下面将会使用 RT1180 中的 RGPIO4 演示如何使能一个 GPIO 的异步中断功能。当 RT1180 进入系统睡眠状态（system sleep）时，bus clock 被关闭系统所有的 bus 总线会停止工作。此时异步中断将被作为可用的系统唤醒源将芯片从系统睡眠状态唤醒。在配置好 GPIO 的中断功能后（与普通的中断一样），用户需要参考下面的代码以使能异步中断。但是请注意，当握手步骤完成后，GPIO 的寄存器不能被 CPU 读写。正是基于这点，通常建议将握手的步骤放置在 WFI 指令之前完成。

```
void gpio_async_config()
{
 CCM->GPR_SHARED_CTRL[8].GPR_SHARED |= 1<<19;
 CCM->GPR_SHARED_CTRL[12].GPR_SHARED |= 1<<19;
 while((CCM->GPR_SHARED_STATUS[0] & (1<<19)) == 0); //Check bit19
 while((CCM->GPR_SHARED_STATUS[4] & (1<<19)) == 0); //Check bit19
}
```

当系统被 GPIO 唤醒后，用户需要清除 GPIO 中断的标志位，正如前文所述，当握手完成后，CPU 不能读写 GPIO 的寄存器。因此，在清除 GPIO 中断标志位前，用户需要取消握手，让 GPIO 的状态从 stop 状态恢复到 run 状态。可以参考以下代码。

```
void GPIO4_0_IRQHandler()
{
 CCM->GPR_SHARED_CTRL[8].GPR_SHARED &= ~(1<<19);//Cancel handshake first
 CCM->GPR_SHARED_CTRL[12].GPR_SHARED &= ~(1<<19); //Cancel handshake first
 RGPIO_ClearPinsInterruptFlags(RGPIO4, 0, 1 <<16); //Clean the interrupt flag
 SDK_ISR_EXIT_BARRIER;
}
```

5 Note about the source code in the document

Example code shown in this document has the following copyright and BSD-3-Clause license:

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6 修订记录

表 2 汇总了自初始版以来对本文档所做的更改。

表 **2.** 修订记录

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