AN14266

使用i.MX RT500的I2C监控模式

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文档信息

信息	内容
关键词	AN14266、I2C、监控模式、i.MX RT500
摘要	本应用笔记介绍了如何启用I2C的监控模式，从而在应用程序开发过程中调试I2C。

1 介绍

i.MX RT500是面向嵌入式应用的双核微控制器系列。它结合了Arm Cortex-M33 CPU和Cadence Xtensa Fusion F1音频数字信号处理器CPU。Cortex-M33包含两个硬件协处理器，能够为一系列复杂算法提供卓越的性能。该系列提供了丰富的外设和低功耗特性。

此器件包含以下部分：

- 5MB SRAM
- 2个FlexSPI（八线/四线SPI接口），每个接口配备32kB缓存，其中一个具备动态解密功能、高速USB设备/主机 + PHY和12位1MS/s ADC
- 模拟比较器
- 音频子系统，支持多达八个DMIC通道
- 带MIPI DSI PHY的2.5 D矢量GPU和LCD控制器
- 2个SDIO/eMMC
- FlexIO
- AES/SHA/Crypto M33协处理器
- PUF密钥生成

i.MX RT500还提供了UART、SPI、I2C和I2S等多种连接接口。本应用笔记介绍了如何启用I2C的监控模式，并提供了I2C总线上的事件信息，从而在应用程序开发过程中调试I2C。

为了实现I2C的监控功能，请执行以下步骤：

- 在CFG寄存器中启用监控模式
- 使能I2C状态标志位，让I2C事件发生时产生中断
- 读INTSTAT/STAT寄存器来识别触发中断事件及其相关信息

2 I2C监控模式

监控模式可提供I2C总线事件的信息，包括数据移动、数据确认、启动/停止事件等。

超时功能可提供I2C超时事件的信息，如下所示：

- SCL超时：表示SCL保持低电平的时间超出了TIMEOUT寄存器所设定的阈值。
- 事件超时：表示事件之间的时间间隔超过了TIMEOUT寄存器所设定的阈值。

监控模式和超时功能是互补的，可以分别独立启用。

当启用这些功能时，用户必须指定生成中断的状态标志位。一旦设定后，每当相应事件发生时，就会生成一个中断，并可以通过读取INTSTAT寄存器，在相应的中断处理程序中进行处理。

2.1 寄存器的修改

本节介绍如何对寄存器进行编程，以启用监控模式所需的I2C功能，具体步骤如下：

- 要启用所需的功能，必须使能相应的位，以此来修改I2C模块的CFG寄存器。

表1. 偏移量

寄存器	偏移量
CFG	800h

表2. 框图

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	Reserved															
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	Reserved										HSCAPAB...	MONCLKS...	TIMEOUT...	MONEN	SLVEN	MSTEN
Reset	u	u	u	u	u	u	u	u	u	u	0	0	0	0	0	0

- 因此，要启用监控和超时功能，请使能第2位和第3位。

表3. 字段

字段	功能
3 TIMEOUTEN	I2C总线超时启用 0b – 禁用。表示超时功能被禁用。禁用时，超时功能会在内部复位。 1b – 启用。表示超时功能已启用。如果启用这些标志位，则会生成两种类型的超时标志位，并引发中断。通常情况下，系统仅使用一种超时标志位。
2 MONEN	监控启用 0b -禁用。表示I2C监控功能被禁用。禁用时，不会更改监控功能配置的设置，但监控功能会在内部复位。 1b - 启用。表示I2C监控功能已启用。

- 要使能某个状态标志位来生成中断，可修改I2C模块的INTENSET寄存器，向相应的位写“1”。
- 用户可以重写`FLEXCOMMx_IRQHandler`函数，每当有中断发生时，以此对事件进行处理。
- I2C模块的INTSTAT寄存器会提供有关活动标志位的信息，即中断源和STAT寄存器的状态信息。例如，如果INSTAT“与”0x10000 = 1，则MONRDY生成了中断。

表4. 偏移量

寄存器	偏移量
INTSTAT	818h

表5. 框图

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	Reserved						SCLTIME...	EVENTTI...	Reserved				MONIDLE	Reserved	MONOV	MONRDY
W																
Reset	u	u	u	u	u	u	0	0	u	u	u	u	0	u	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	SLVDESEL	Reserved			SLVNOTS...	Reserved		SLVPEND...	Reserved	MSTSTST...	Reserved	MSTARBL...	Reserved			MSTPEND...
W																
Reset	0	u	u	u	1	u	u	0	u	0	u	0	u	u	u	1

表6. 偏移量

寄存器	偏移量
STAT	804h

表7. 框图

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	Reserved						SCLTIME...	EVENTTI...	Reserved				MONIDLE	MONACTI...	MONOV	MONRDY
W																
Reset	u	u	u	u	u	u	0	0	u	u	u	u	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	SLVDESEL	SLVSEL	SLVIDX		SLVNOTS...	SLVSTATE		SLVPEND...	Reserved	MSTSTST...	Reserved	MSTARBL...	MSTSTATE			MSTPEND...
W																
Reset	0	0	0	0	1	0	0	0	u	0	u	0	0	0	0	1

- 要得到MONRDY的更多信息，可读取STAT寄存器中的相应位（位置16）。由此可知，由于MONRXDAT寄存器中有数据正在等待读取，监控模式生成了中断。

表8. 字段

字段	功能
16 MONRDY	监控就绪 当MONRXDAT寄存器被读时，MONRDY标志位会被清除。 0b – 无数据。表示监控功能当前没有可用数据。 1b – 数据等待。表示监控功能有数据在等待读取。

表9. 偏移量

寄存器	偏移量
MONRXDAT	880h

表10. 框图

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	Reserved															
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
Bits	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
R	Reserved					MONNACK	MONREST...	MONSTART	MONRXDAT							
W																
Reset	u	u	u	u	u	0	0	0	0	0	0	0	0	0	0	0

表11. 字段

字段	功能
31-11 —	保留 读取值未定义；仅需写入0。
10 MONNACK	监控器接收NACK 0b – 已确认。表示至少有一个主机或从机的接收器确认了监控功能当前提供的数据。 1b – 未确认。表示没有接收器确认监控功能当前提供的数据。
9 MONRESTART	监控器接收重启 0b – 未检测到重启。监控功能没有在I2C总线上检测到重启事件。 1b – 检测到重启。监控功能在I2C总线上检测到重启事件。
8 MONSTART	监控器接收启动 0b – 未检测到启动。监控功能没有在I2C总线上检测到启动事件。 1b – 检测到启动。监控功能在I2C总线上检测到启动事件。
7-0 MONRXDAT	监控功能接收器数据 它反映了I2C引脚上传输的每个数据字节。

- 用户可以轻松地识别等待读取的数据类型。如果MONRXDAT“与”0x200 = 1，则表示在I2C总线上检测到了重复启动事件。
- 必须在处理后清除生成中断的标志位。在MONRDY中断的情况下，通过读取MONRXDAT寄存器可以自动清除该标志位。对于其他情况，向STAT寄存器中的相应位写入“1”可以清除该标志位。例如，写入0x1000000会清除第24位的标志位，即EVENTTIMEOUT。

如需了解更多信息，请参阅《i.MX RT500低功耗跨界MCU参考手册》（文档IMXRT500RM）。

3 软件示例

本示例基于i.MX RT500 SDK演示`evkmimxrt595_i2c_accel_event_trigger`，使用SDK 2.13.1和MCUXpresso IDE 11.7。

在不影响标准演示行为的前提下，对该工程进行了修改，已启用带超时功能的监控模式。因此，本应用笔记仅突出显示了相关的修改。此外，本软件示例还介绍了如何启用和应用不同的I2C功能。

这个标准演示展示了如何通过加速度传感器触发事件来唤醒处于低功耗模式下的主设备。即使主设备处于低功耗模式（或深度睡眠模式），加速度传感器也可以继续运行。并且只有捕捉到配置的事件时，加速度传感器才会触发中断来唤醒主设备。本示例使用I2C配置加速度传感器，使其在低噪声模式下以800Hz数据速率工作。当轻敲事件被触发时，主设备被唤醒，并捕获触发事件前后的32个采样点。

3.1 代码的修改

在本示例中，FLEXCOMM4被配置为I2C接口与板载加速度传感器进行通信。

如第2.1节“寄存器的修改”所述，通过修改I2C模块的CFG寄存器来启用监控和超时功能。本示例使用的是I2C4 (0x40122000)。

```
void APP_MonitorInit(I2C_Type *base)
{
/* set Monitor enable */
base->CFG = (base->CFG & (uint32_t)I2C_CFG_MASK) | I2C_CFG_MONEN_MASK;
}
void APP_EnableTimeOut(I2C_Type *base)
{
/* set Timeout enable */
base->CFG = (base->CFG & (uint32_t)I2C_CFG_MASK) | I2C_CFG_TIMEOUTEN_MASK;
}
```

可以设置不同的标志位来生成中断。以下标志位的设置与I2C主设备、监控和超时功能相关：

- 与主设备相关的标志位：启用主设备仲裁丢失（MSTARBLOSSEN）和启用主设备启动/停止错误中断（MSTSTSTPERREN）。
- 监控相关标志位：启用监控器数据就绪中断（MONRDYEN）。
- 超时相关标志位：启用事件超时中断（EVENTTIMEOUTEN）和SCL超时中断（SCLTIMEOUTEN）。

注：*根据应用程序的具体情况，可以设置/取消其他标志位。*

为了捕获和处理中断，必须启用与FLEXCOMM4相关的中断服务函数：

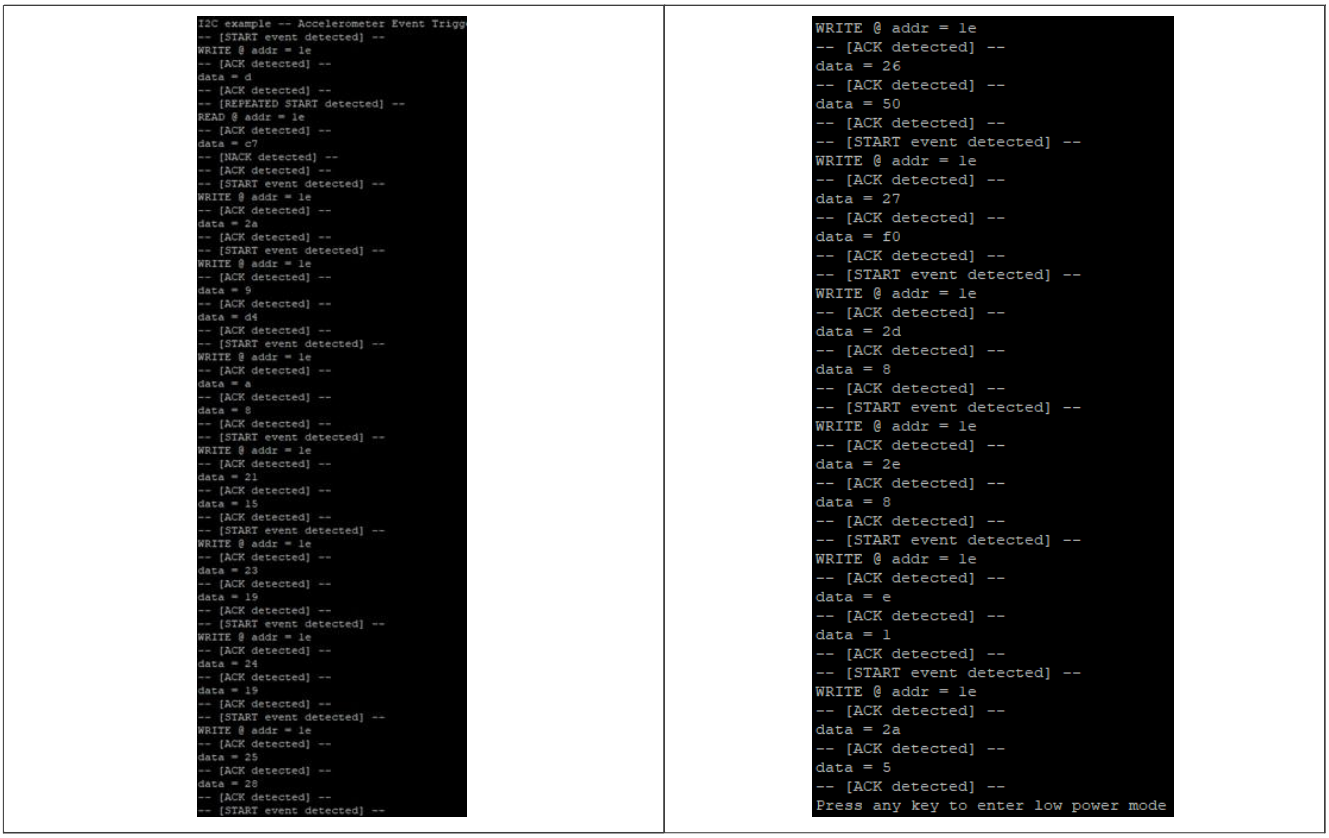
```
void APP_EnableInterrupts(I2C_Type *base)
{
uint32_t all_interrupts;
all_interrupts |= I2C_INTENSET_MONRDYEN_MASK;
all_interrupts |= I2C_INTENSET_MSTARBLOSSEN_MASK |I2C_INTENSET_MSTSTSTPERREN_MASK;
all_interrupts |= I2C_INTENSET_EVENTTIMEOUTEN_MASK | I2C_INTENSET_SCLTIMEOUTEN_MASK;
I2C_EnableInterrupts(base, all_interrupts);
DisableIRQ(FLEXCOMM4_IRQn);
IRQ_ClearPendingIRQ(FLEXCOMM4_IRQn);
EnableIRQ(FLEXCOMM4_IRQn);
}
```

FLEXCOMM4 IRQ处理程序已被修改，可以打印生成中断的标志以及有关数据内容的任何可用信息。

3.2 结果

表12所示为加速度传感器初始化期间的调试控制台。图中显示了中断处理程序捕获的事件与第3.1节“代码的修改”中提到的代码中的I2C序列之间的相关性。

表12. 调试控制台



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5 修订历史

表13总结了本文档的修订情况。

表13. 修订历史

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