

1 介绍

大多数 Layerscape 产品系列都采用带 16 位计数功能的 FlexTimer (FTM)。如果需要更长的计数，可以将多个 FTM 串接/级联，以进行 32 位或更多位的计数。有多少 FTM 可以被串接到更长的计数中以及可以采用哪些组合具体取决于 SoC 系列，如下表所示。

表 1. FlexTimer 串接选项

Layerscape SoC 系列	FlexTimer	级联选项 (最低有效位优先)	串接控制寄存器
LS1021A	8	5+1, 6+2, 7+3, 8+4	SCFG_FTM_CHAIN_CONFIG
LS1043A			
LS1046A			
LS1028A	8	1-8 和子范围	FTMCR
LS1088A	4	1-4 和子范围	FTMCR
LS2088A			
LX2160A	2	1-2	FTMCR

2 文档不一致之处

在我们描述如何正确级联 FTM 之前，应该注意有些参考手册的版本在串接 FTM 方面有些内容不一致，这可能会令人感到困惑。恩智浦正努力纠正这一问题，但您可能会在当前提供的文档中发现以下问题：

- FTMCR 文档可能错误地显示比器件上 FTM 更多的位。
- FTMCR 或 SCFG_FTM_CHAIN_CONFIG 文档可能没有提到，较低有效位的 FTM 的 CH7 为串接的具有更多有效位的 FTM 提供 PHA，正如 FlexTimer 章节前面仅针对基于 SCFG_FTM_CHAIN_CONFIG 的器件所做的那样。
- FTM 存储器映射中偏移量 0x80 处的 QDCTRL 寄存器可能未被记录，被称为 QUADEN 的位 0 或被称为 QUADMODE 的位 3 也未被记录。例如，当前的 LS1046Arm 中就缺少描述。
- 如果 FlexTimer 章节显示了正交解码支持，则可能没有明确表示它具体指的是外部引脚访问。在内部，所有可以添加到串接链中的 FTM 都具有这种支持，即使它当时只能用于串接。
- SCFG_FTM_RESET[FTMCHN_x] 位可能被错误地记录为串接位，而本应该引用的是 SCFG_FTM_CHAIN_CONFIG[FTM_CHN_x]。

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- SCFG_FTM_CHAIN_CONFIG[FTM_CHNx] 文档未说明编号较高的 FTM 是串接的 32 位计数器的最低有效部分、编号较低的 FTM 是串接的 32 位计数器的最高有效部分。

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3 串接控制寄存器能为您做些什么？

每当 FTM 溢出时，溢出必须作为适当的计数器信号传播到 FTM 串接链的下一级。控制寄存器使能从外部连接 FTM 的 SoC 逻辑。FTM<x> 通道 7 的输出连接到 FTM<y> 的正交解码器逻辑。然后，正交解码器对该 FTM 的预分频器进行计时。集成 FTMCR 作为控制寄存器的 SoC 通常允许在串接 FTM 时具有更大的灵活性。

因此，要使该串接链工作，我们不仅必须设置控制寄存器，还必须对 FTM 的输出和输入进行相应的编程。

4 配置 FlexTimer 的输出

在串接链中，除最后一个 FTM 外，每个 FTM 都需要一个特殊的输出配置。要为串接链配置 FTM 的通道 7，我们可能认为每当计时器溢出时都需要切换。然而问题是，下一个计时器只能以预期频率的一半计数，因为它只在适当的边缘来计数每秒钟切换。我们想要的是生成一个脉冲，以便下级计时器在当前计时器溢出时计数。

其中一个选项是设置 C7SC[MSB] 和 C7SC[ELSB]，它们组合选择“边缘对齐 PWM”模式和“高精度脉冲（匹配时清晰输出）”配置。为了完成设置，我们还需要将 C7V 设置为 0xffff，以便在合适的时间生成脉冲。

5 配置串接的 FlexTimer 的输入

在串接链中，除第一个 FTM 外，每个 FTM 都需要一个特殊的输入配置。在应该通过正交解码器计数的 FTM<y> 上，除了可以通过 QDCTRL[QUADEN] 启用之外，我们还希望通过设置 QDCTRL[QUADMODE] 将其设置为解码计数和正确的方向。这允许我们计算 FTM<x> 产生的脉冲，该脉冲通过 PHA 正交解码器输入反馈给我们。

6 读取串接的计数器

由于不能精准地读取多个 16b CNT 寄存器，读的值很容易变化，导致当前值的读取不一致。解决这一问题的常用程序如下：

- 读取串接的 CNT 寄存器的所有 16b 值，从最高有效计数器开始，到最低有效计数器结束，将它们存储到第一组变量中。
- 以相同顺序将所有 16b 值再次读入第二组变量，不包括最低有效 CNT 寄存器。
- 将第一组与第二组进行比较。如果不同，请从头开始。
- 使用第一组变量作为串接计数器的一致值。

此序列利用了这样一个事实，即读取比最低有效计数器溢出的速度快得多。因此，在读取序列期间遇到溢出的可能性很低。如果发生溢出可以检测到，下一次尝试将成功读取串接链中的所有值，而不会出现任何溢出。无条件地对任何差异重试都是必要的，例如中断可能会影响计时并增加意外延迟。

7 使用 SCFG_FTM_CHAIN_CONFIG 串接的示例

下文描述了将 LS1046A 上的 FTM 2 和 6 串接到 32 位计数器的简单示例，作为使用 SCFG_FTM_CHAIN_CONFIG 构建的 SoC 的示例。在此示例中，FTM6 使用减计数的 RTC 时钟进行计数，以使计数易于观察，然后溢出将对 FTM2 进行计时，以形成一个 32 位计时器。该示例也可用于 LS1043A 或 LS1021A 系列，前提是为硬件选择了适当的时钟。

该示例仅显示了串接计时器和启用基础计数器所需的步骤。其它所需的初始化步骤及应用需求被省略，必须按照 SoC 参考手册中的描述应用。

为了方便地再现示例，使用了简单的 U-Boot 命令直接写入寄存器。请注意，本例中的寄存器访问是 Big Endian，以与存储器映射匹配，也就是说，写入的 32 位字进行了字节交换。

表 2. 将 LS1046A 上的 FTM2 和 6 串接起来

U-Boot 命令	描述
=> mw.l 29e0054 05000000	在 FTM2 上启用 FTM 模式 (msb 计数器)
=> mw.l 2a20054 05000000	在 FTM6 上启用 FTM 模式 (lsb 计数器)
=> mw.l 29e0008 ffff0000	将自由运行计数器的 Modulo 设置为 max
=> mw.l 2a20008 ffff0000	将自由运行计数器的 Modulo 设置为 max
=> mw.l 1570154 00400000	使用 SCFG_FTM_CHAIN_CONFIG 串接 FTM2 和 FTM6
=> mw.l 2a20044 28000000	设置 FTM6 C7SC[MSB ELSB]以生成一个脉冲
=> mw.l 2a20048 ffff0000	将 FTM6 C7V 设置为 0xffff，在一个时间节点生成一个脉冲
=> mw.l 29e0080 09000000	设置 FTM2 QDCTRL[QUADMODE QUADEN]
=> mw.l 2a20000 12000000	启用 FTM2 的 RTC 时钟/4，作为示例参考时钟

参考时钟的选择是任意的。选择了一个慢时钟，以便在转储 CNT 寄存器时更容易观察计时器串接的操作。

8 使用 FTMCR 串接的示例

下文描述了将 LS1028A 上的 FTM 5 至 7 串接到 48 位计数器的示例，作为使用 FTMCR 构建的 SoC 的示例。为了方便再现，使用了简单的 U-Boot 命令直接写入寄存器。

该示例仅显示了串接计时器和启用基础计数器所需的步骤。其他所需的初始化步骤及应用需求被省略，必须按照 SoC 参考手册中的描述应用。

表 3. 将 LS1028A 上的 FTM 5 至 7 串接起来

U-Boot 命令	描述
=> mw.l 2860054 00000005	在 FTM7 上启用 FTM 模式 (msb 计数器)
=> mw.l 2850054 00000005	在 FTM6 上启用 FTM 模式
=> mw.l 2840054 00000005	在 FTM5 上启用 FTM 模式 (lsb 计数器)
=> mw.l 2860008 0000ffff	将自由运行计数器的 Modulo 设置为 max
=> mw.l 2850008 0000ffff	将自由运行计数器的 Modulo 设置为 max
=> mw.l 2840008 0000ffff	将自由运行计数器的 Modulo 设置为 max
=> mw.l 1e00960 00000030	使用 FTMCR 串接 FTM5-7
=> mw.l 2840044 00000028	设置 FTM5 C7SC[MSB ELSB]以生成一个脉冲
=> mw.l 2840048 0000ffff	将 FTM5 C7V 设置为 0xffff，在一个时间节点生成一个脉冲
=> mw.l 2850080 00000009	设置 FTM6 QDCTRL[QUADMODE QUADEN]
=> mw.l 2850044 00000028	设置 FTM6 C7SC[MSB ELSB]以生成一个脉冲

表格在下一页继续.....

表 3. 将 LS1028A 上的 FTM 5 至 7 串接起来 (续)

U-Boot 命令	描述
=> mw.l 2850048 0000ffff => mw.l 2860080 00000009	将 FTM6 C7V 设置为 0xffff，在一个时间节点生成一个脉冲 设置 FTM7 QDCTRL[QUADMODE QUADEN]
=> mw.l 2840000 0000000f	为 FTM5 启用系统时钟/128，作为示例参考时钟

参考时钟的选择是任意的。选择了一个稍慢的时钟，以便在转储 CNT 寄存器时更容易观察计时器串接的操作。

此处可以清楚地看到串接多个 FTM 的一般方法。由于具有 FTMCR 的其他器件（如 LS1088A、LS2088A 或 LX2160A）具有的计时器较少，因此需要适当调整此示例，以写入正确的计时器寄存器，并仅串接可用计时器的最大数量。

运行 LX2160A 示例需要进行一些更改，例如仅写 0x2800000 偏移地址的 FTM1 寄存器，和 0x2810000 偏移地址的 FTM2 寄存器，而不是写入 FTM5 和 FTM7 的寄存器，并将 FTMCR 设置为 0x01，以仅连接这两个 FTM。对 LS1088A 或 LS2088A 进行相同的修改。

表 4. 将 LX2160A 上的 FTM 1 至 2 串接起来

U-Boot 命令	描述
=> mw.l 2810054 00000005 => mw.l 2800054 00000005 => mw.l 2810008 0000ffff => mw.l 2800008 0000ffff	在 FTM2 上启用 FTM 模式（msb 计数器） 在 FTM1 上启用 FTM 模式（lsb 计数器） 将自由运行计数器的 Modulo 设置为 max 将自由运行计数器的 Modulo 设置为 max
=> mw.l 1e00960 00000001 => mw.l 2800044 00000028 => mw.l 2800048 0000ffff => mw.l 2810080 00000009	使用 FTMCR 串接 FTM1-2 设置 FTM1 C7SC[MSB ELSB]以生成一个脉冲 将 FTM1 C7V 设置为 0xffff，在一个时间节点生成一个脉冲 设置 FTM2 QDCTRL[QUADMODE QUADEN]
=> mw.l 2800000 0000000f	为 FTM1 启用系统时钟/128，作为示例参考时钟

9 修订历史

表 5. 修订历史

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