

1 介绍

LPC55(S)1x 产品系列具有一个全速 USB2.0 主从接口，通过软件的手段我们可以实现全速 USB 设备模式下无需外部晶振，这样做的好处是可以降低产品的成本。

为了实现无需外部晶振的全速 USB 设备操作，NXP 提供了基于软件的解决方案，该方案利用全速 USB 每 1 ms 发送的开始帧 (SOF) 来同步内部 FRO 时钟，提高 FRO 的时钟精度，从而使 FRO 达到全速 USB 设备操作的时钟精度要求 (全速 USB 数据传输需要的时钟精度为 $\pm 0.25\%$)。

本技术笔记将讲解如何通过修改用户的应用软件实现无晶振的全速 USB 设备操作所需的步骤。在此技术说明之外，在 MCUXpresso、Keil 和 IAR IDE 中还提供了一个 SDK 软件示例 (usb_device_composite_hid_audio_unified)。

2 描述

本节描述了 LPC55S1x/LPC551x 系列如何实现无外部晶振的 USB 全速设备操作的步骤。

2.1 MCU 内部时钟 FRO 的校准库

包括 FRO 校准库，可以校准 FRO 提高 FRO 的精度来满足全速 USB 通信对时钟精度的要求。

MCUXpresso、Keil、IAR 的 SDK 中预编译的库为：

- Keil IDE: keil_lib_fro_calib_CM33.lib
- IAR IDE: iar_lib_fro_calib_CM33.a
- MCUXpresso IDE: libfro_calib_hardabi.a, libfro_calib_softabi.a

2.2 头文件

基于 SDK 开发的全速 USB 设备的工程项目中的.c 文件，需要包括头文件：fsl_fro_calib.h。

2.3 源代码的修改

无论您创建项目所使用的 IDE 是什么，都需要在编译器中添加一个用于预处理的宏定义声明

“USB_DEVICE_FRO_CAL_LIBRARY_ENABLE=1”。用户在工程的代码中全局搜索这个关键字就可以找到所有需要修改的地方。

向源代码添加以下更改。

1. 调用 fro_calib_Get_Lib_Ver (void)函数。这个函数读取校准库的版本并返回 0x00010000。
2. 用户应用程序代码必须选择 FRO 96MHz 时钟作为时钟源(值 0x3 在 USB0CLKSEL 寄存器)，因为外部晶振不再需要。在本例中，I2S MCLK, 24.576MHz 使用 PLL0 时钟输出，然后将 PLL0 的输入时钟从原来的外部晶体切换到 FRO 12MHz。更多细节请参见与时钟配置相关的 LPC55S1x/LPC551x User Manua (文档 [UM11295](#))。
3. 校准库必须使用一个 32 位计时器来测量 USB 的 SOF 帧间隔时间并计算 FRO 的校准值。

目录

1	介绍.....	1
2	描述.....	1
2.1	MCU 内部时钟 FRO 的校准库.....	1
2.2	头文件.....	1
2.3	源代码的修改.....	1
2.4	LPC55S16 EVK 开发板.....	2



注

使用 AHBCLKCTRL1 寄存器将时钟启用到 CTimer 0、CTimer1 或 CTimer2。使用 AHBCLKCTRL2 寄存器启用时钟到 CTimer3 或 CTimer4。

- a. 使用 CTIMERCLKSEL0/1/2/3/4 寄存器，选择 96MHz 时钟作为 CTimer0/1/2/3/4 时钟源。
 - b. 通过定时器外设(CTIMER0, CTIMER1, CTIMER2, CTIMER3 或 CTIMER4)和系统时钟在 KHz 的库调用 SDK, void Chip_Timer_Instance_Freq (CTIMER_Type *base, unsigned int ctimerFreq);
 - c. 将定时器外设(CTIMER0 或 CTIMER1 或 CTIMER2 或 CTIMER3 或 CTIMER4)和系统时钟(KHz)的值传递给 SDK 库调用, void Chip_Timer_Instance_Freq (CTIMER_Type *base, unsigned int ctimerFreq);
4. 用户应用程序代码必须在 usb_device_lpcip3511.c 文件中启用 INTEN 寄存器的 FRAME_INT_EN :

```
/* enable interrupts */
lpc3511IpState->registerBase->INTEN = USB_LPC3511IP_INTSTAT_DEV_INT_MASK |
    USB_LPC3511IP_MAX_PHY_ENDPOINT_MASK
#if (defined(USB_DEVICE_SOF_EVENT_ENABLE) && (USB_DEVICE_SOF_EVENT_ENABLE > 0U))
| USB_LPC3511IP_INTSTAT_FRAME_INT_MASK
#endif
```

用户必须要在 usb_device_lpcip3511.c 文件中注意 FRAME_INT 的处理。

```
#if (defined(USB_DEVICE_SOF_EVENT_ENABLE) && (USB_DEVICE_SOF_EVENT_ENABLE > 0U))
    if (interruptStatus & USB_LPC3511IP_INTSTAT_FRAME_INT_MASK)
    {
        USB_DeviceLpc3511IpSofEvent(lpc3511IpState);
    }
#endif
```

5. 当 FRAME_INT 出现时，用户的应用程序代码必须调用 USB_SOF_Event()，不断地通过 USB 主机发来的 SOF 帧来校准 FRO。

2.4 LPC55S16 EVK 开发板

因为不再需要外部晶振，LPC55S16-EVK 开发板上的 16 MHz 晶体 (PCB 上器件标识符 Y2)，用户也可以移除 16 MHz 晶体的匹配电容可以删除电容器 (PCB 上器件标识 C463, C462)，查看 LPC55S16-EVK 开发板用户手册和原理图以获取更多的细节。

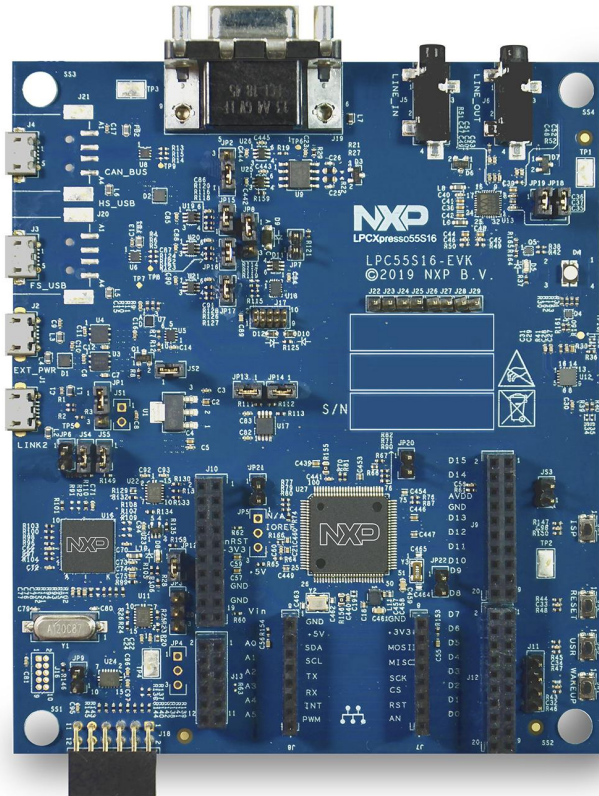


图 1. LPC55S16-EVK 开发板

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