AN14195

MCXN947上的USB远程唤醒功能

第1版—2024年1月24日 应用笔记

文档信息

信息	内容
关键词	AN14195、MCXN947、OTG
摘要	MCXN947包含两个USB 2.0接口。USB0是一个全速接口，由一个支持OTG协议的On-The-Go双角色子系统构成。

1 MCXN9上的USB简介

MCXN947包含两个USB 2.0接口。USB0是全速接口，包含支持OTG协议的OTG双角色子系统。这个USB0控制器中的OTG的实现提供了一种设备方案，可以针对全速的兼容外设，以及用于实现USB 2.0全速/低速兼容的嵌入式主机的有限主机的功能。图1所示为USB FS/LS子系统。

USB1是高速接口。它支持OTG功能，遵循通用串行总线USB修订版2.0规范以及OTG和嵌入式主机的相关补充规范。图2和图3所示分别为USB1 HS和USB 2.0 PHY的框图。USB1 HS控制器通过UTMI+接口与USB HS PHY连接。

此外，无论是作为主机还是设备的角色，这两个接口都可以支持远程唤醒功能。本文介绍了如何使用远程唤醒功能。

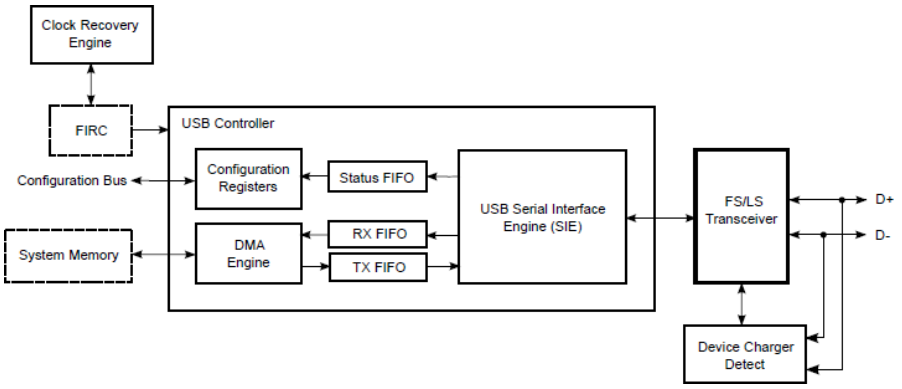

图1. USB0 FS/LS子系统的框图

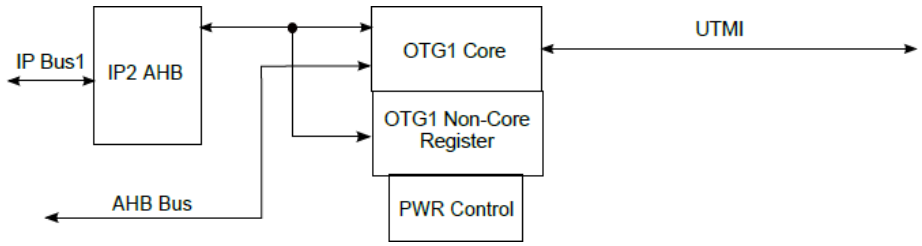

图2. USB1 HS的框图

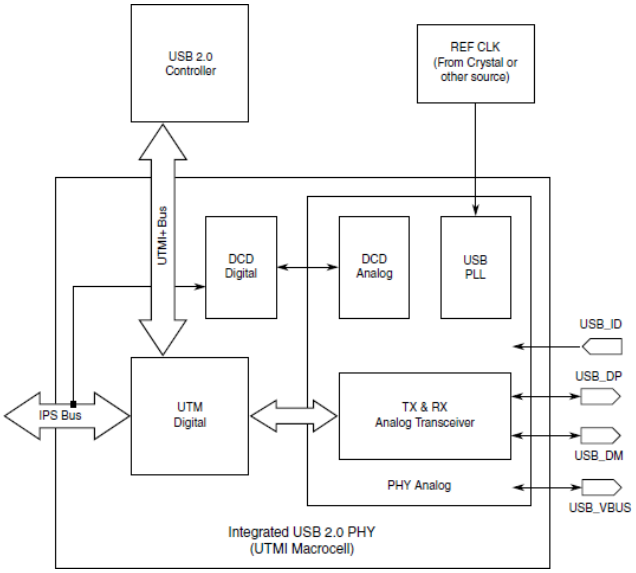

图3. USB2.0 PHY的框图

2 USB远程唤醒功能介绍

为了节省功耗，USB主机和设备可以在低功耗模式下运行。当主机处于睡眠模式时，会停止所有的总线流量。如果设备检测到总线上无流量超过3毫秒，则设备将进入挂起状态。当处于挂起模式时，USB设备可以保持其内部状态，例如设备的地址和配置。图4所示为设备的状态图。

MCXN947 MCU中的USB控制器支持睡眠模式、深度睡眠模式和掉电模式，以节省功耗。当USB子系统检测到USB总线上没有活动超过3毫秒时，会将ISTAT[SLEEP]位置1。该位可以触发一个中断，而软件将决定相应的操作。

此外，还可以设置USBTRC0[USBRESMEN]位来启用唤醒功能。启用此功能后，USB子系统会在上电时被唤醒，这是由USB总线上的活动所触发的一个异步中断来发生的。

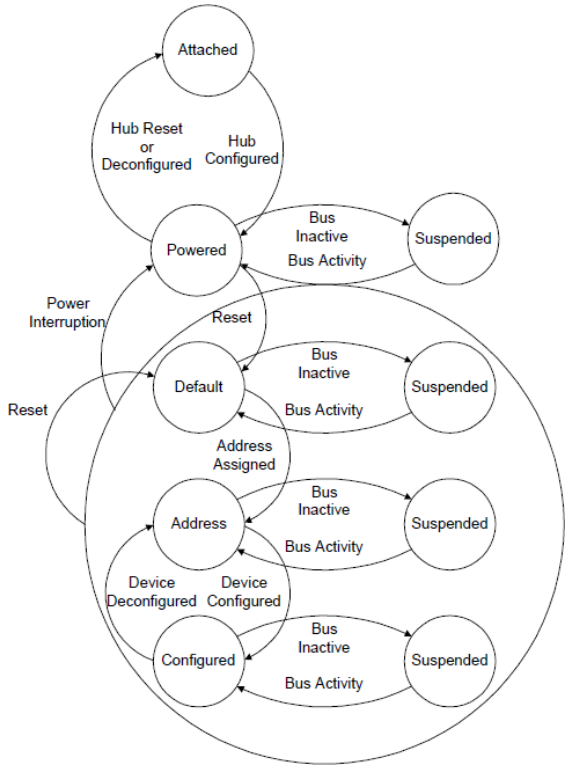

图4. 设备状态图

2.1 USB主机远程唤醒设备

主机可随时发出恢复信号。它必须发送至少20毫秒的恢复信号，然后用两种方式中的一种来结束恢复信号，具体取决于其端口在挂起时的运行速度。如果端口在挂起时处于低速/全速状态，则恢复信号应以标准的低速EOP结束（即两个低速位宽的SE0，后接一个J状态）。如果端口在挂起时处于高速运行状态，恢复信号必须用过渡到高速空闲状态来结束。图5所示为USB的恢复时序。

这20毫秒的恢复信号可确保网络中所有可接收恢复信号的设备都能被唤醒。由恢复信号建立的连接会在恢复结束时断开，从而为集线器的正常运行做好准备。在总线恢复后，主机必须在空闲状态开始后的3毫秒内发送总线流量（至少是SOF标志），以防止系统返回到挂起状态。图6所示为低速EOP的时序。

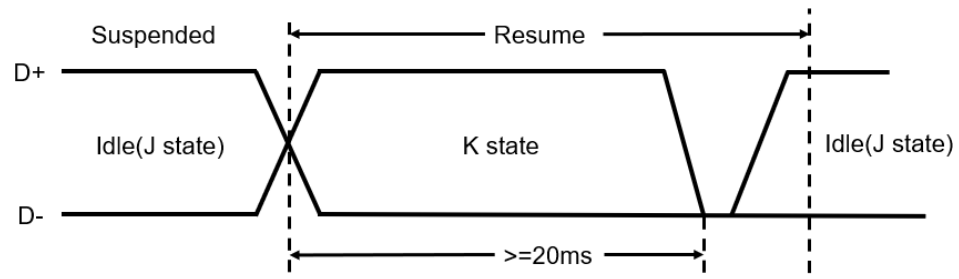

图5. USB恢复时序

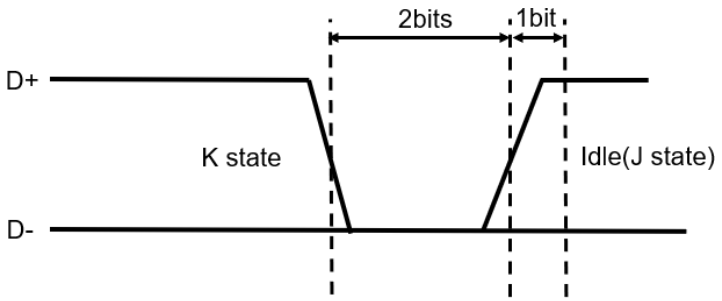

图6. USB LS的EOP时序

2.2 USB设备远程唤醒主机

USB设备的远程唤醒功能支持一个处于挂起状态的设备向同样挂起的主机发出信号。这会通知主机，它应从挂起模式恢复，如有必要，还为触发挂起的USB设备以向主机发出信号的外部事件提供服务。USB设备会在一个配置描述符中声明其支持远程唤醒的能力。如果设备支持远程唤醒，它还必须允许使用标准USB请求来启用和禁用该功能。

当设备处于挂起状态且其上游端口收到任何的非空闲信号时，设备将恢复正常运行。此外，如果USB系统软件启用了远程唤醒功能，此设备还可以向系统发出信号，以恢复运行。

一个具有远程唤醒功能的设备可能不会生成恢复信号，除非总线已连续5毫秒处于空闲状态（TWTRSM）。这允许集线器进入挂起状态，并准备传播恢复信号。远程唤醒设备必须保持恢复信号至少1毫秒，但不能超过15毫秒（TDRSMUP）。在这段时间结束时，设备会停止驱动总线，将其驱动器置于高阻抗状态，而不会将总线驱动至J状态。

2.3 USB集线器的远程唤醒功能

根据USB 2.0规范，USB集线器必须支持挂起和恢复功能，并负责在设备和主机之间传输挂起和恢复信号。集线器既支持全局挂起/恢复，也支持选择性挂起/恢复。全局挂起/恢复是指在不影响任何集线器的下游端口状态的情况下挂起或恢复整个总线。选择性挂起/恢复指的是在不影响集线器状态的情况下，挂起或恢复集线器的某个下游端口。全局挂起/恢复是通过主机的根端口实现的。选择性挂起/恢复是通过向集线器发出请求来实现的。

如果集线器的上游端口处于全速或高速模式，则所需的行为与上游端口处于全速或高速模式的功能相同。图7所示为FS/LS设备和集线器的远程唤醒-恢复时序。

当以高速模式运行的下游端口进入挂起状态时，它将切换到全速终端，但仍会保持高速端口状态。为了响应远程唤醒或选择性恢复，该端口会在整个恢复状态下驱动全速“K”状态。其要求和时序与下述的全速端口相同。在此信号结束后，总线将返回到高速空闲状态（使用SendEOR状态）。之后，端口返回到启用状态。在整个挂起-恢复周期中，端口的高速状态始终保持不变。图8所示为高速设备的远程唤醒恢复。

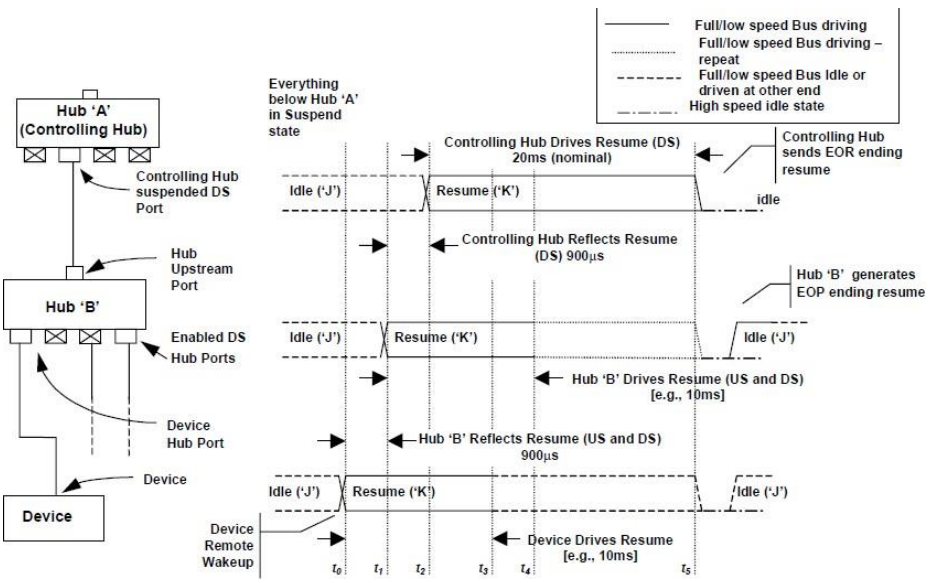

图7. 全速/低速设备的远程唤醒恢复信号

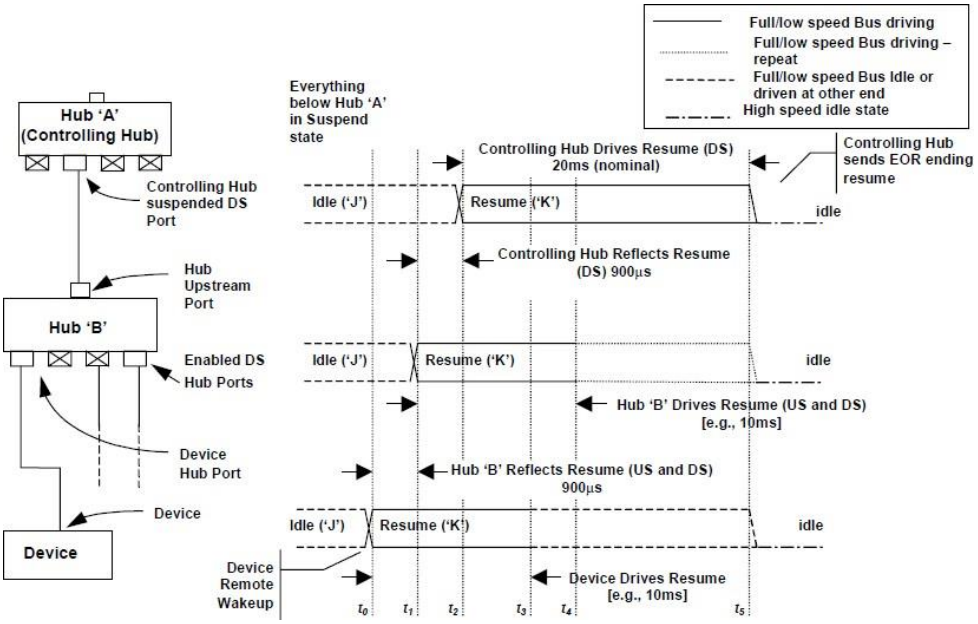

图8. 高速设备的远程唤醒恢复信号

3 USB的远程唤醒测试

本节介绍了USB的远程唤醒测试。

3.1 测试平台

本部分介绍了测试的平台。

3.1.1 硬件

此演示是在MCX-N9XX-EVK板上开发的。图9所示为MCX-N9XX-EVK板。

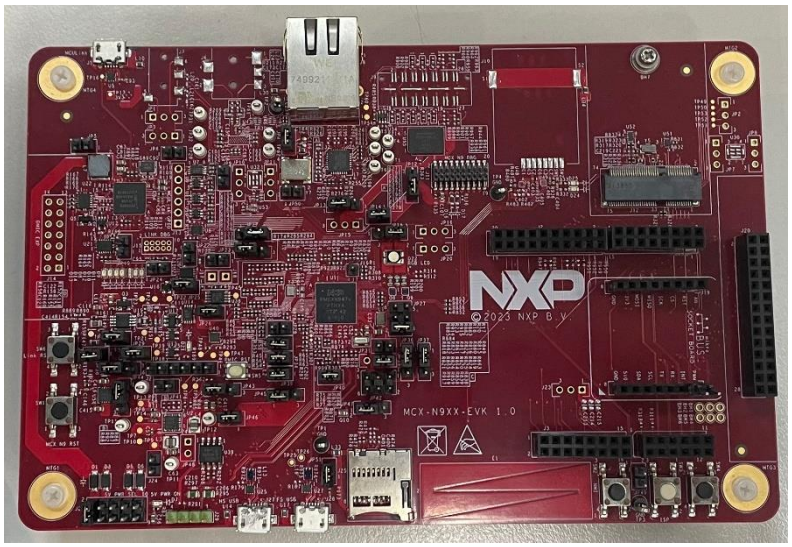

图9. MCX-N9XX-EVK板

3.1.2 软件

所使用的软件如下：

- SDK_2_14_0_MCX-N9XX-EVK
- IDE：MCUXpresso IDE v11.8.0

3.2 USB主机远程唤醒设备

在测试USB主机远程唤醒设备时，我们需要两块MCX-N9xx-EVK板，一块作为主机，另一块作为设备。USB主机测试代码位于SDK安装包中，路径为：

- <MCUXpresso_SDK_Install>/boards/<board>/usb_examples/usb_suspend_resume_host_hid_mouse

USB设备测试代码位于SDK安装包中，路径为：

- <MCUXpresso_SDK_Install>/boards/<board>/usb_examples/usb_suspend_resume_device_hid_mouse

图10所示为调试控制台使用的远程唤醒设置。输入“s”以启用主机的远程唤醒功能。按下作为主机的EVK板上的SW3按钮，即可唤醒设备。

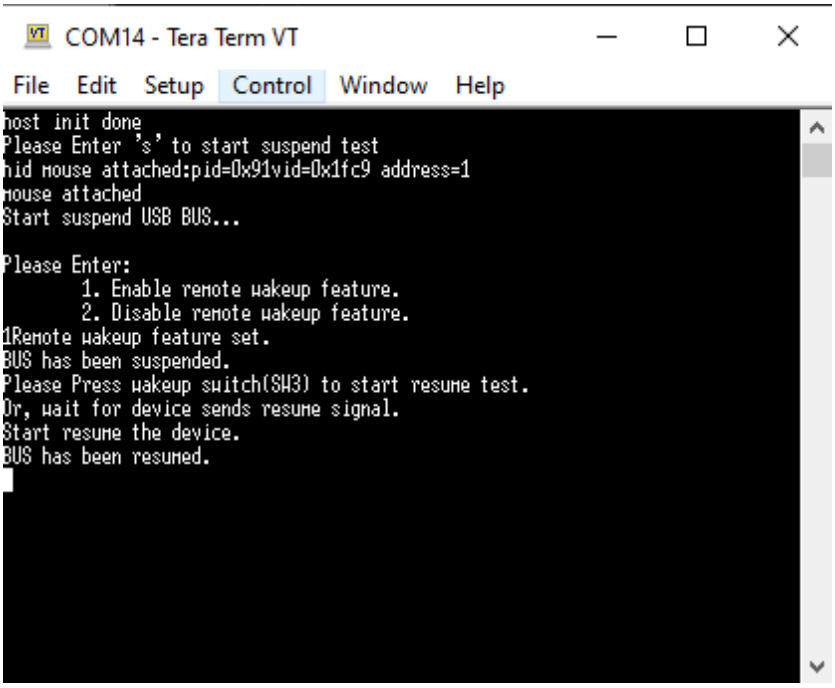

图10. USB主机的远程唤醒设置

图11所示为USB的远程唤醒时序，图11中的P1时序标记表示USB主机驱动的恢复（K状态）时间，P1约为20毫秒。

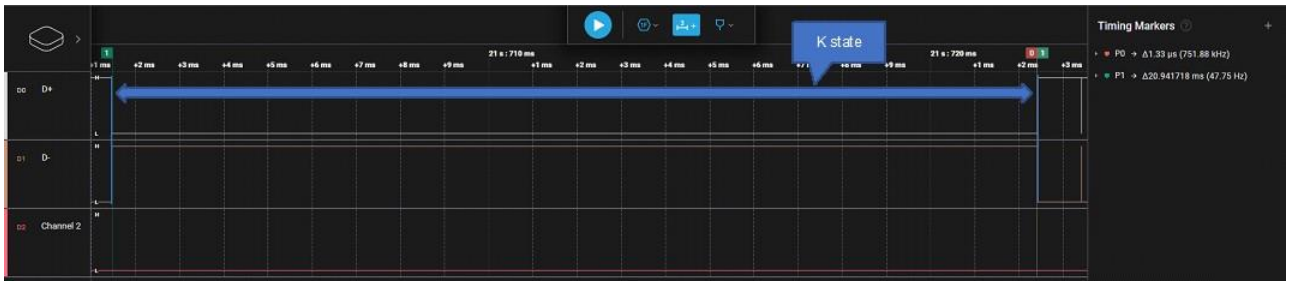

图11. USB FS USB的远程唤醒时序

图12所示为USB LS的EOP时序，当USB LS EOP后，USB总线将重新开始传输数据。P0约为1.33微秒。

图12. USB LS主机的EOP时序

3.3 USB设备远程唤醒主机

USB设备的测试代码位于SDK安装包中，路径为：

- <MCUXpresso_SDK_Install>/boards/<board>/usb_examples/usb_suspend_resume_host_hid_mouse

USB设备的测试代码位于SDK安装包：

- <MCUXpresso_SDK_Install>/boards/<board>/usb_examples/usb_suspend_resume_device_hid_mouse

图13所示为调试控制台所使用的远程唤醒设置。输入“s”以启用主机的远程唤醒功能。按下用作设备的EVK板上的SW3按钮，以唤醒主机。

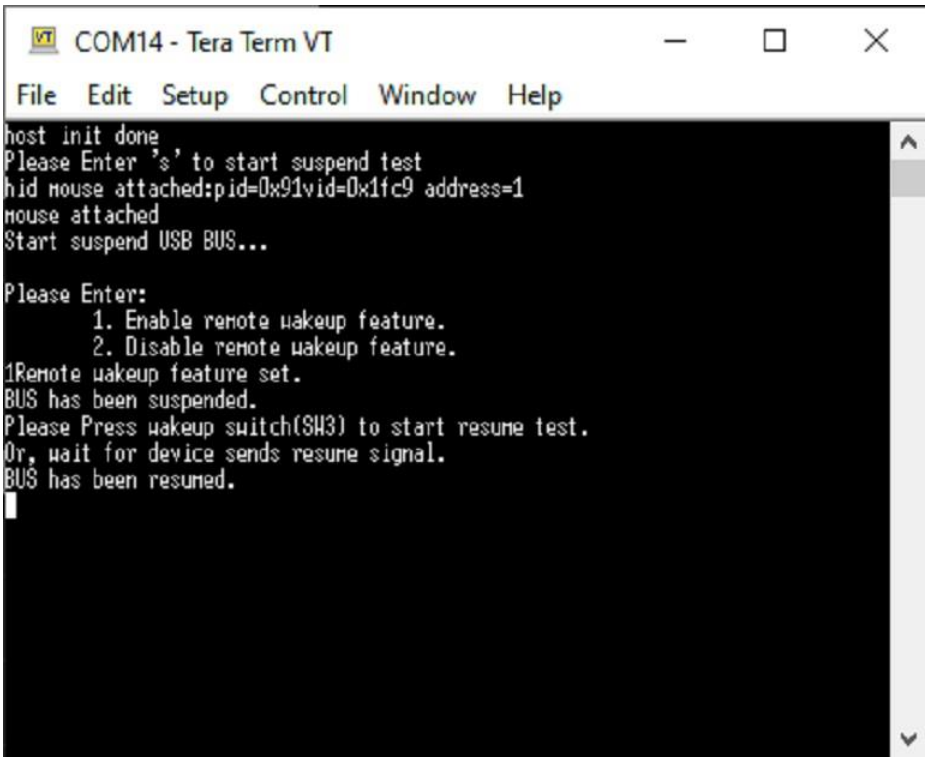

图13. USB主机的远程唤醒设置

图14所示为USB的远程唤醒时序。图15中的P1时序标记表示USB主机驱动的恢复（K状态）时间。P1约为21毫秒。

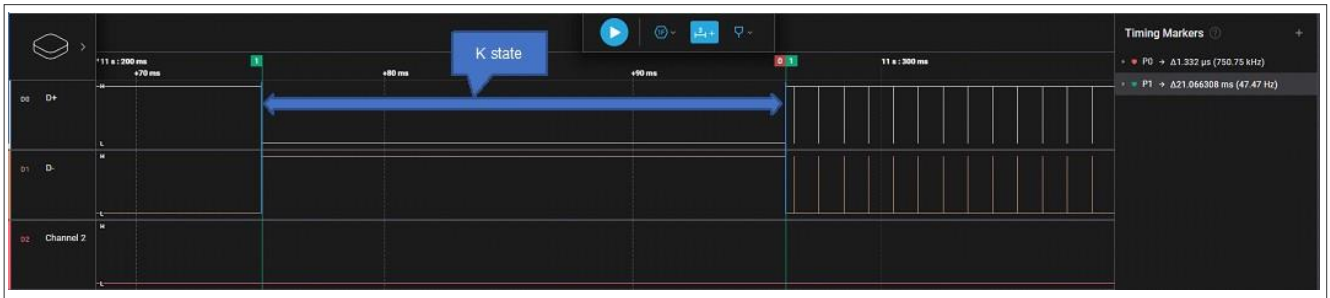

图14. USB FS USB远程唤醒时序

图15所示为USB LS的EOP时序。在USB LS EOP之后，USB总线将重新开始传输数据。P0约为1.33微秒。

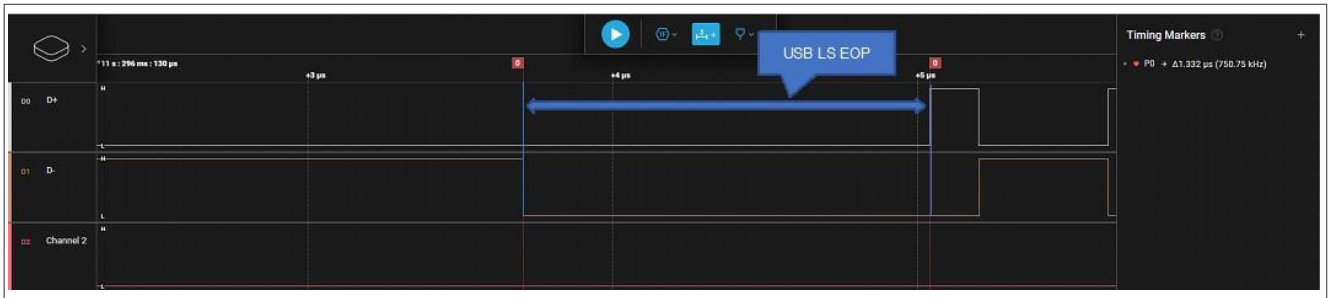

图15. USB LS主机的EOP时序

4 修订历史

表1总结了本文档的修订情况。

表1. 修订历史

文档ID	发布日期	说明
AN14195 v.1	2024年1月24日	首次对外发布。

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