AN14434

如何在MCX N236上实现USB转I3C的演示方案

第1.0版—2024年9月20日

应用笔记

文档信息

信息	内容
关键词	AN14434、MCX N236、USB、I3C、CDC Class
摘要	本文介绍了如何在MCX N236微控制器上实现USB转I3C的桥接功能。

1 介绍

如今在PC和数据中心等某些应用中，计算速度不断提高，导致I²C接口无法满足需求。I3C是一种改进的I²C接口，它只需要两根通信线，但工作速度可达到12.5MHz，远高于I²C。

USB接口广泛应用于多种应用，在HS模式，USB 2.0协议下，速度可达480MHz。因此，这样一个优质的接口可以作为桥梁，将数据从其他接口（如USART、SPI和I²C）传输到USB主机。本应用笔记提供了一个使用USB接口桥接I3C接口的演示方案。MCX N236微控制器有一个HS USB接口和两个I3C接口。

1.1 MCX N236 I3C接口的特性

MCX N236上的I3C接口支持：

- 带内中断（IBI）：这些中断从目标设备传输到主控器（controller），无需额外的连接线，主控器就知道是哪个目标设备发送了中断。
- 通用命令代码（CCC）
- 动态寻址
- 多主控器和多点连接
- 热加入（HJ）
- 兼容I²C

MCX N236 I3C IP支持I3C v1.0和v1.1规范的所有必需功能和多种可选功能，但不包括三元数据速率（HDR-TSP和HDR-TSL）。

2 MCX N236上的USB转I3C演示方案的介绍

在MCX N236上的USB转I3C演示方案中，USB设备使用USB CDC虚拟通讯接口与PC主机进行通讯。可以使用终端工具向控制I3C的接口发送串行数据。下文中使用的终端工具为`pzh-py-com`工具，用户可以从https://github.com/JayHeng/pzh-py-com下载该工具。

此演示提供了一些命令，如“动态地址分配”、“直接写入”、“直接读取”、“带寄存器地址写入”、“带寄存器地址读取”、“IBI/热加入功能”。

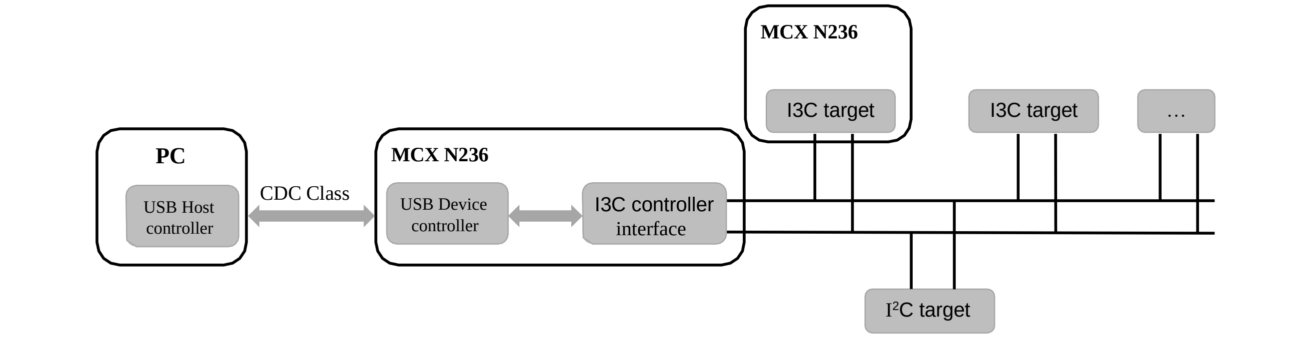

图1. MCX N236上USB转I3C演示方案的硬件结构框图

2.1 MCX N236上USB转I3C演示方案的硬件设置

要运行MCX N236上USB转I3C的演示方案，请使用两块FRDM-MCXN236电路板，一块作为I3C主设备，另一块作为I3C目标设备。该演示方案使用`P1_16(I3C_SDA)`和`P1_17(I3C_SCL)`作为I3C功能引脚。图2所示为硬件连接情况。连接线应尽可能短。

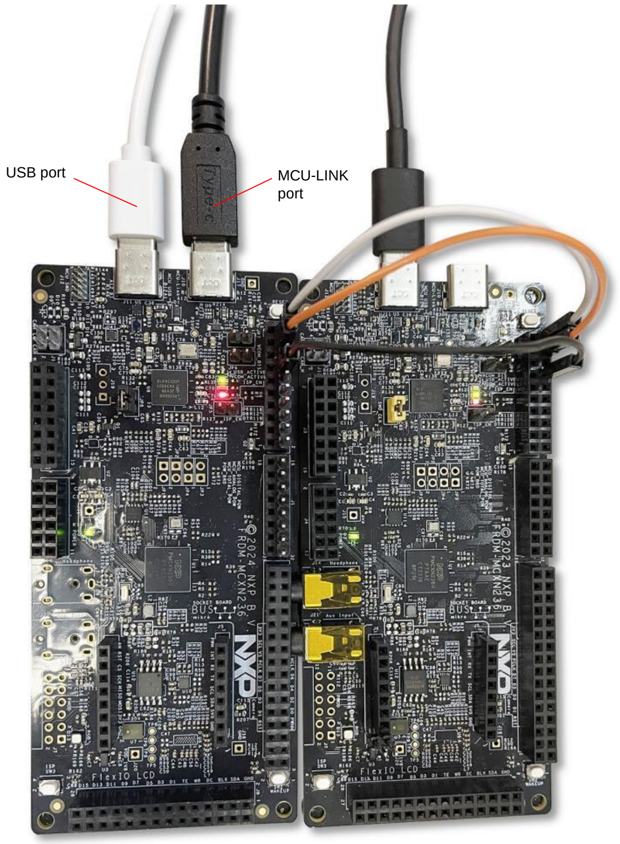

图2. MCX N236上USB转I3C演示方案的硬件设置

2.2 MCX N236上USB转I3C演示方案的软件介绍

MCX N236上USB转I3C演示方案提供了几种通过USB配置I3C的命令，其中包括“ListDAA”/“直接写入”/“直接读取”/“带寄存器地址读取”/“发送CCC命令”/“热加入”和“IBI”命令。客户可以使用这些命令来执行相关的I3C功能。

可以使用支持多字符串发送功能的终端工具来测试此演示方案。

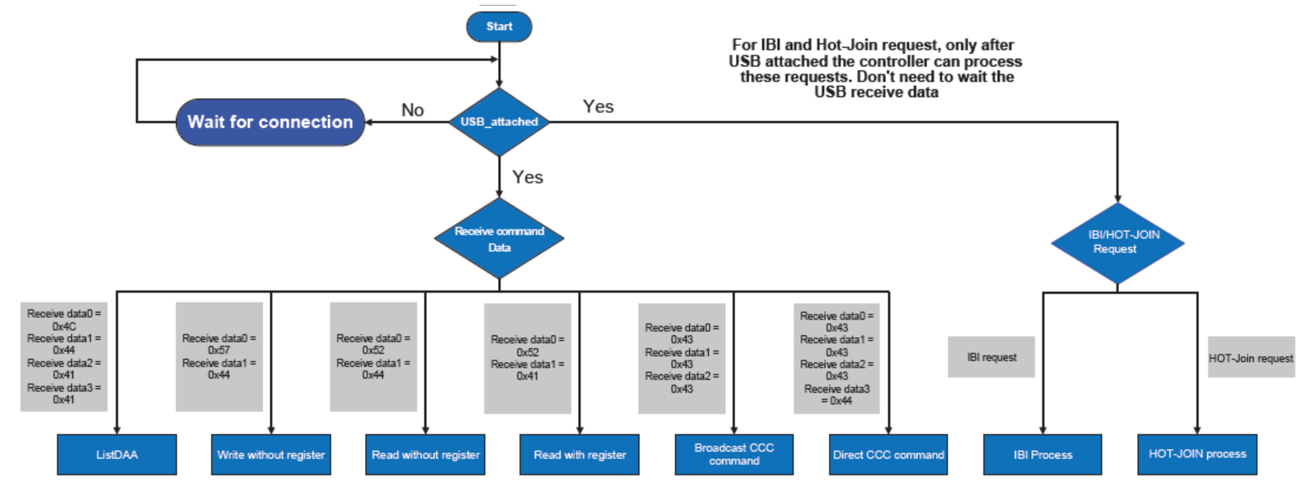

图3. MCX N236上USB转I3C演示方案的软件流程

2.2.1 “List DAA”命令

图4所示为I3C动态地址分配流程。在I3C协议中，主控器执行动态地址分配，为所连接的目标设备分配地址。使用此命令时，需要找出连接了多少台设备，并给出要分配的动态地址。

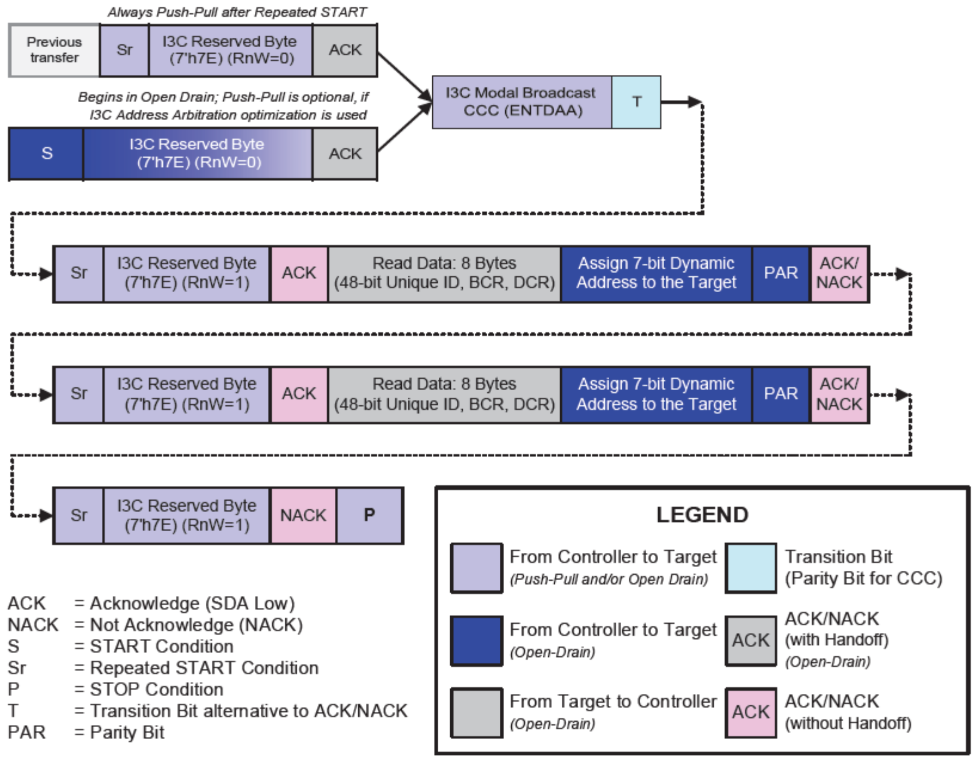

图4. 动态地址分配流程

表1所示为“List DAA”命令（发送ASCII码）的结构。

表1. “List DAA”命令的结构

支持的命令								
ListDAA								
USB virtual com send（USB虚拟通讯接口发送）	L	D	A	A	地址编号	动态地址		
	0x4C	0x44	0x41	0x41				
USB virtual com receive（USB虚拟通讯接口接收）	供应商LSB	供应商MSB	部件号信息			BCR	DCR	
	—	—	—	—	—	—	—	—

在本演示方案中，当终端发送“List DAA”命令时，会收到I3C目标的信息反馈，其中包含目标供应商ID和BCR/DCR值，如图5所示。

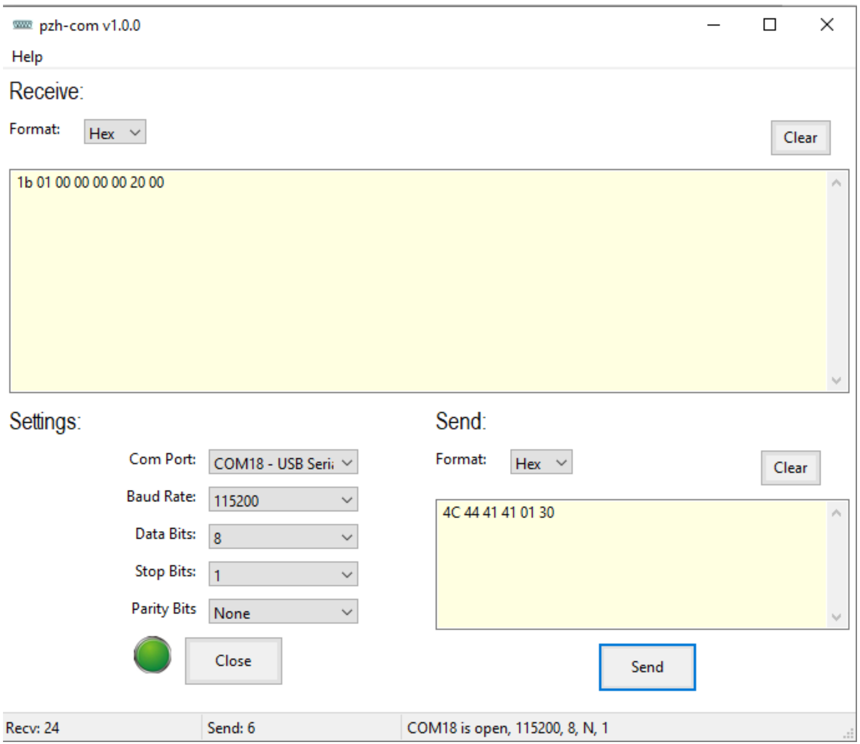

图5. “List DAA”命令的终端显示

图6所示为“List DAA”命令的I3C流程时序。

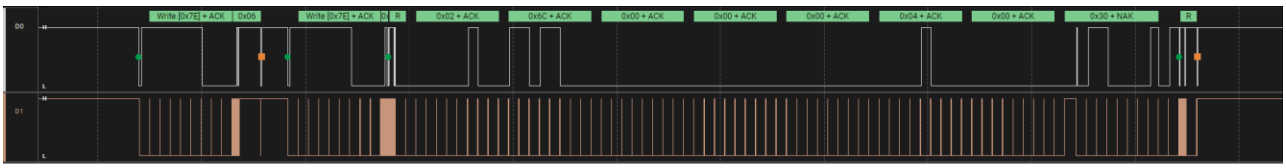

图6. “List DAA”命令的流程时序

2.2.2 “无寄存器地址写入”命令

表2所示为“无寄存器地址写入”命令（发送ASCII码）的结构。使用此命令时，需要提供一些包含目标设备地址/数据大小和写入数据的信息。

表2. “无寄存器地址写入”命令的结构

支持的命令								
无寄存器地址写入								
USB虚拟通讯接口发送	W	D	从设备地址	数据大小	数据（N字节）			
	0x57	0x44						
USB虚拟通讯接口接收	O				K			
	0x4F				0x4B			

图7所示为终端上“无寄存器地址写入”命令的发送和接收结构。命令完成后，终端收到“OK”（0x4F, 0x4B）字符。

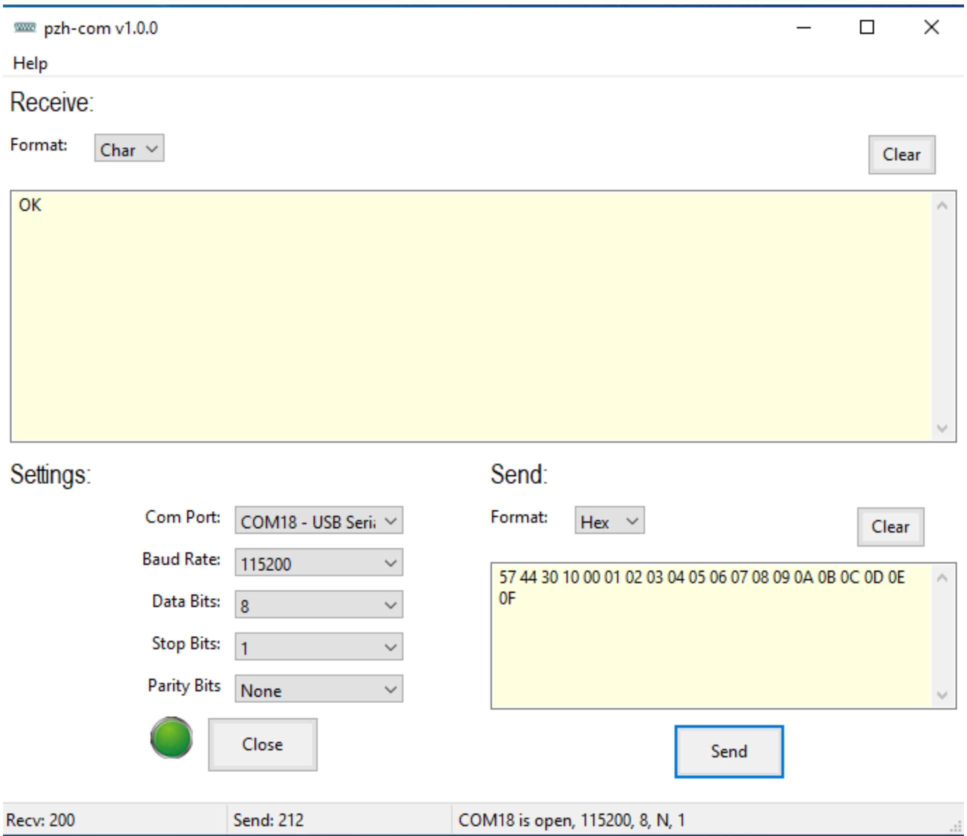

图7. “无寄存器地址写入”命令的终端显示

图8所示为“无寄存器地址写入”命令的I3C流程时序。

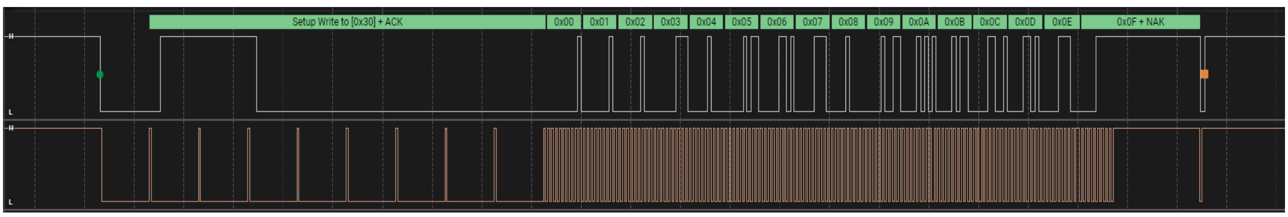

图8. “无寄存器地址写入”命令的流程时序

2.2.3 “无寄存器地址读取”命令

表3所示为“无寄存器地址读取”命令（发送ASCII码）的结构。使用此命令时，需要提供一些信息，包含目标设备地址和读取数据大小。

表3. “无寄存器地址读取”命令的结构

支持的命令								
无寄存器地址读取								
USB虚拟通讯接口发送	R	D	从设备地址	数据大小				
	0x52	0x44						
USB虚拟通讯接口接收	读回数据（N字节）							
	—	—	—	—	—	—	—	—

图9所示为终端上“无寄存器地址读取”命令的发送和接收结构。命令完成后，终端会收到目标设备发送的数据。

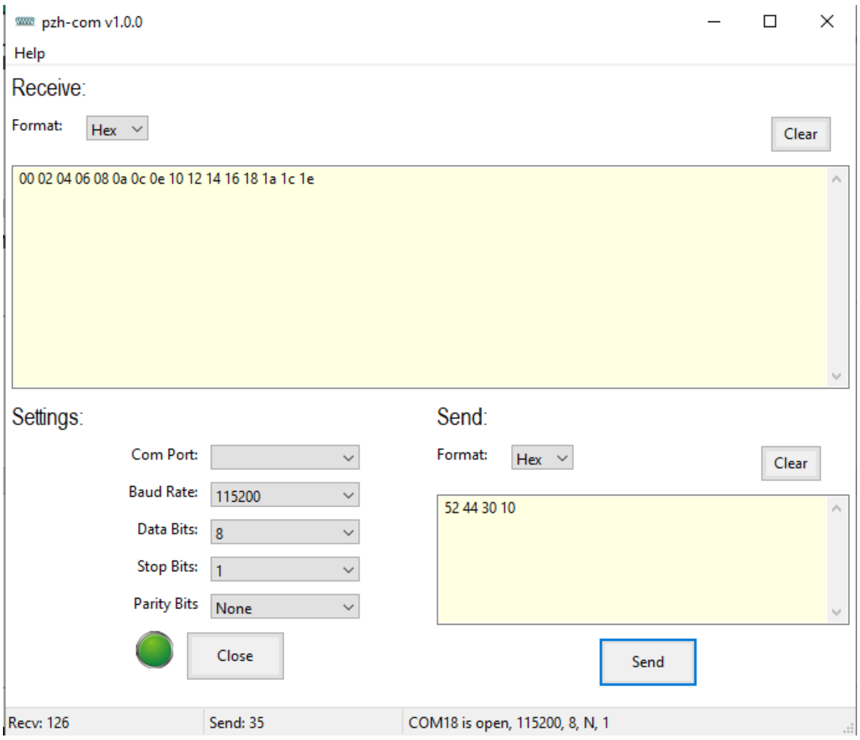

图9. “无寄存器地址读取”命令的终端显示

图10所示为“无寄存器地址读取”命令的I3C流程时序。

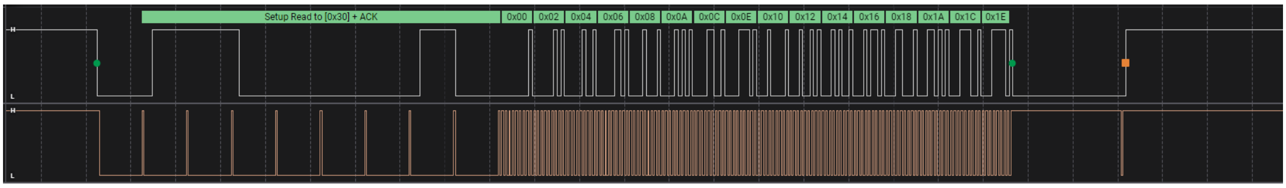

图10. “无寄存器地址读取”命令的流程时序

2.2.4 “带寄存器地址读取”命令

表4所示为“带寄存器地址读取”命令（发送ASCII码）的结构。使用此命令时，需要提供一些信息，包含目标设备地址/寄存器地址和读取数据大小。

表4. “带寄存器地址读取”命令的结构

支持的命令								
带寄存器地址读取								
USB虚拟通讯接口发送	R	A	从设备地址	寄存器地址	数据大小			
	0x52	0x41						
USB虚拟通讯接口接收	读回数据（N字节）							
	—	—	—	—	—	—	—	—

图11所示为终端上“带寄存器地址读取”命令的发送和接收结构。命令完成后，终端将收到目标设备发送的寄存器数据。

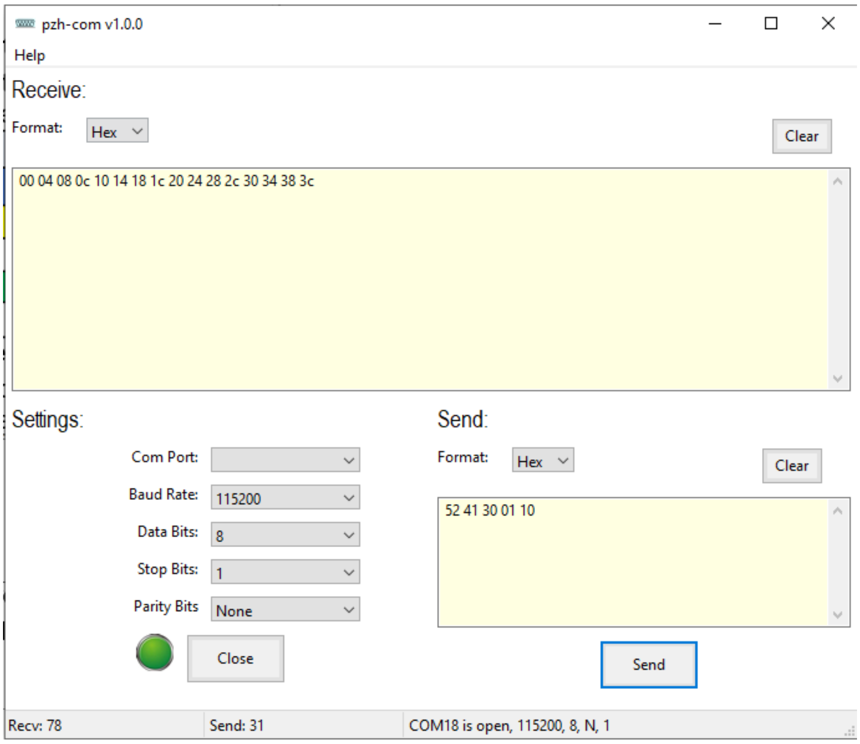

图11. “带寄存器地址读取”命令的终端显示

图12所示为“带寄存器地址读取”命令的I3C流程时序。

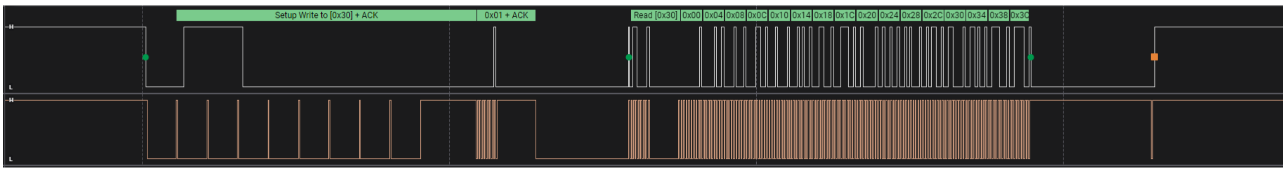

图12. “带寄存器地址读取”命令的流程时序

2.2.5 “CCC广播”命令

图13所示为CCC广播帧格式。当发送“CCC广播”命令时，从设备地址为`0x7E`。I3C规范提供了多个CCC广播命令，如ENTDAA（用于使I3C目标设备处于DAA状态）。`ENTHDR0`命令可用于通知目标设备在HDR-DDR模式下运行。

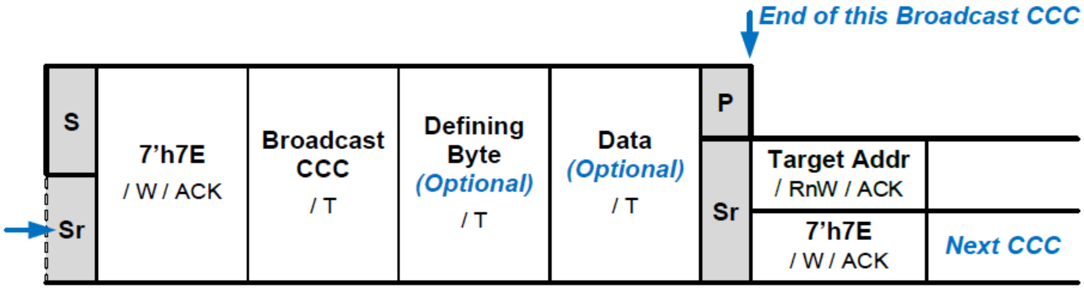

图13. “CCC广播”的通用帧格式

表5所示为“CCC广播”命令（发送ASCII码）的结构。

表5. “CCC广播”命令的结构

支持的命令								
CCC广播								
USB virtual com send（USB虚拟通讯接口发送）	C	C	C	命令代码				
	0x43	0x43	0x43					
USB virtual com receive（USB虚拟通讯接口接收）	O				K			
	–	–	–	–	–	–	–	–

图14所示为终端上“CCC广播”命令的发送和接收结构。在CCC命令发送后，终端收到“OK”（`0x4F`, `0x4B`）字符。

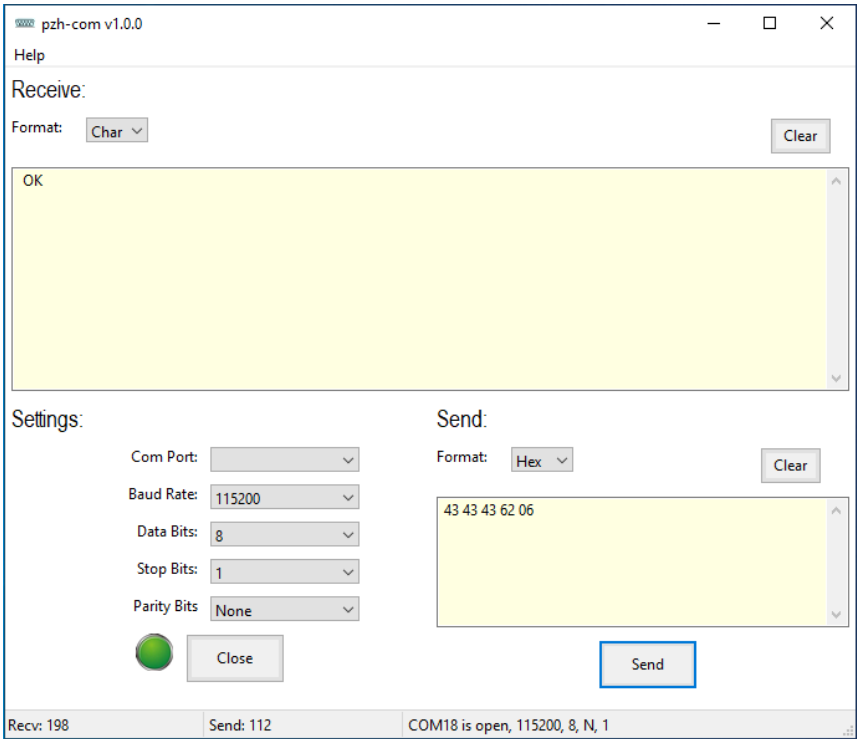

图14. “CCC广播”命令的终端显示

图15所示为“CCC广播”命令的I3C流程时序。

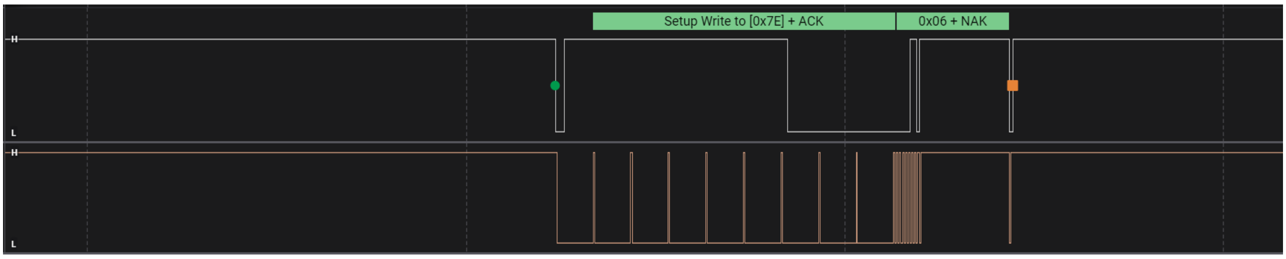

图15. “CCC广播”命令的流程时序

2.2.6 “CCC直接发送”命令

图16所示为“CCC直接发送”命令的通用帧格式。I3C规范提供了多个“CCC直接”命令，如`GET_BCR`（用于获取目标设备的BCR值）。`GET_STATUS`命令可用于获取目标设备的状态值。

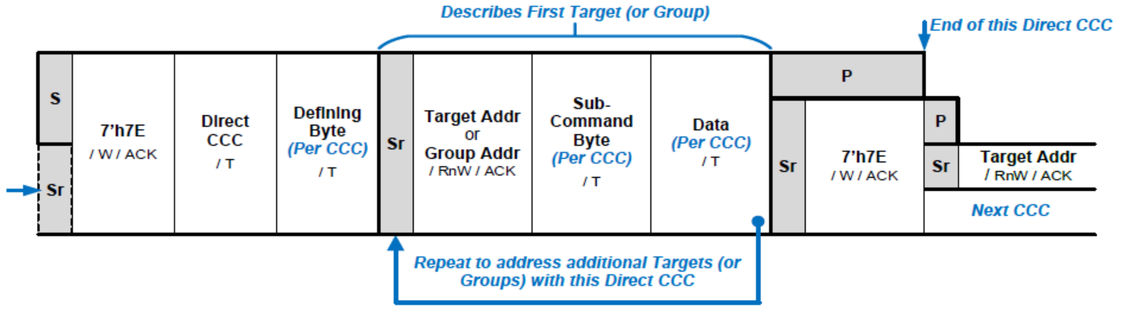

图16．“CCC直接发送”命令的通用帧格式

表6所示为“CCC直接发送”命令（发送ASCII码）的结构。使用此命令时，需要提供I3C规范中规定的CCC直接命令，如`GET_BCR(0x8E)`和目标设备地址。

表6．“CCC广播”命令的结构

支持的命令								
CCC直接命令								
USB虚拟通讯接口发送	C	C	C	D	命令代码			
	0x43	0x43	0x43	0x44				
USB虚拟通讯接口接收	命令返回数据（如BCR/DCR、设备状态）							
	—	—	—	—	—	—	—	—

图17所示为终端上“CCC直接发送”命令的发送和接收结构。命令完成后，终端会收到与发送命令相关的对应数据，如目标设备的BCR值。

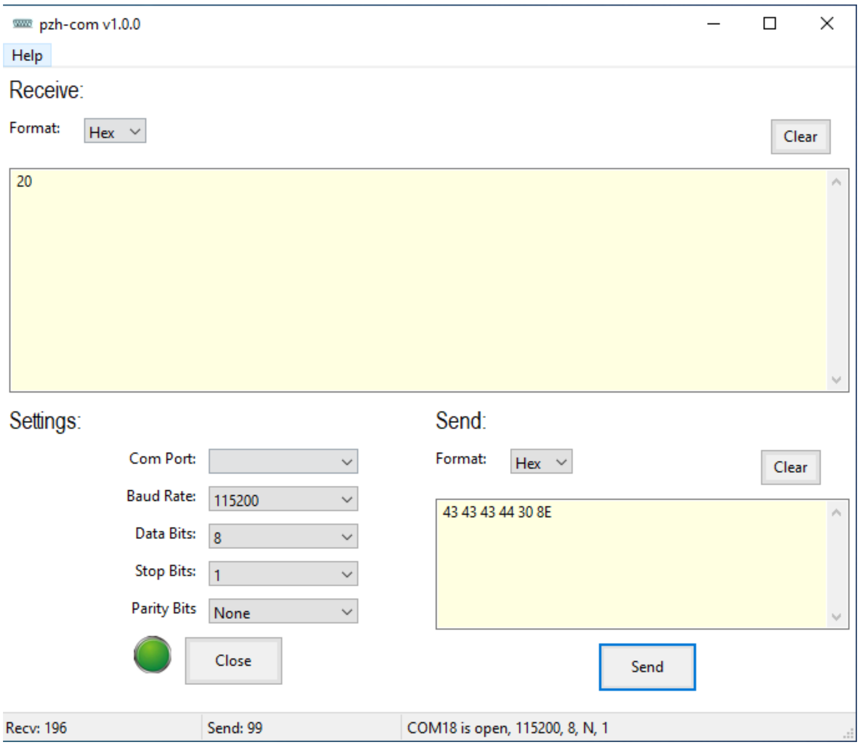

图17. “CCC直接发送”命令的终端显示

图18所示为“CCC直接发送”命令的I3C流程时序。

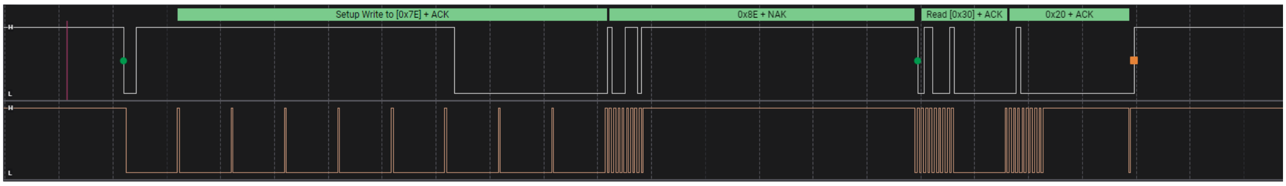

图18. “CCC直接发送”命令的流程时序

2.2.7 IBI命令

图19所示为IBI（目标中断）请求FSM。当目标设备产生IBI信号时，主设备执行IBI响应，然后目标设备发送IBI数据。

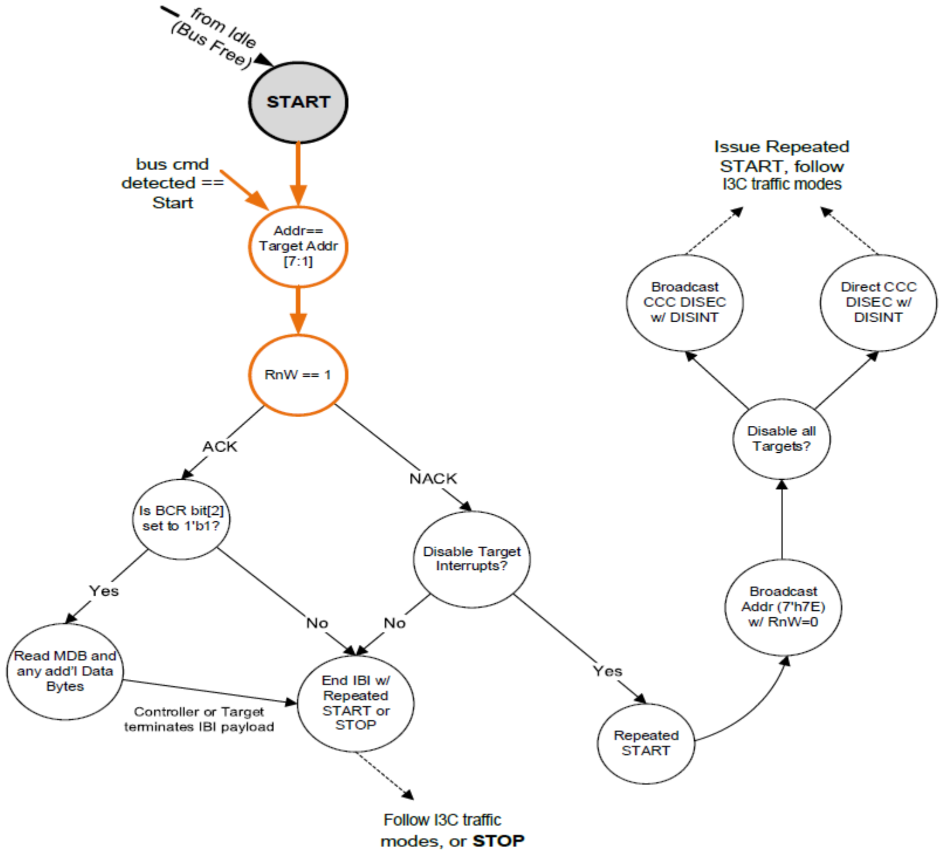

图19. IBI（目标中断）请求FSM

表7所示为IBI命令的结构。实际上，不会发送任何数据用于IBI响应。当USB设备连接到主机时，I3C目标设备可以随时发送IBI信号。当产生IBI信号时，USB主机接收IBI数据。

表7. IBI命令的结构

支持的命令								
IBI								
USB虚拟通讯接口发送	不发送数据（当产生IBI信号时，虚拟通讯接口会接收IBI数据）							
	—	—	—	—	—	—	—	—
USB虚拟通讯接口接收	从设备发送IBI数据							
	—	—	—	—	—	—	—	—

图20所示为终端上IBI命令的接收结构。当目标设备产生IBI信号时，终端会接收目标设备发送的IBI数据。

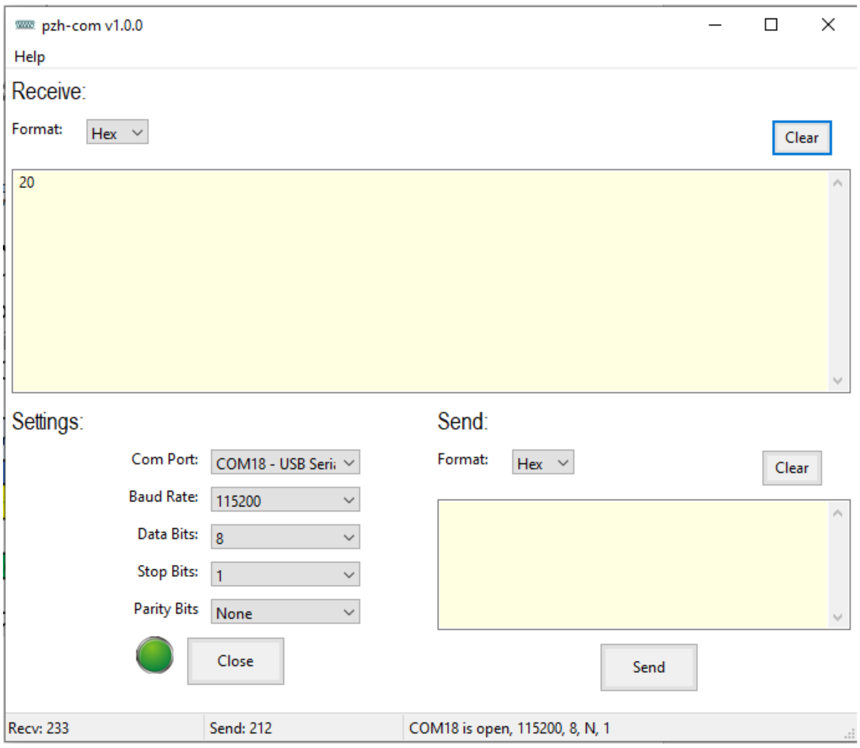

图20. IBI命令的终端显示

图21所示为IBI命令的I3C流程时序。

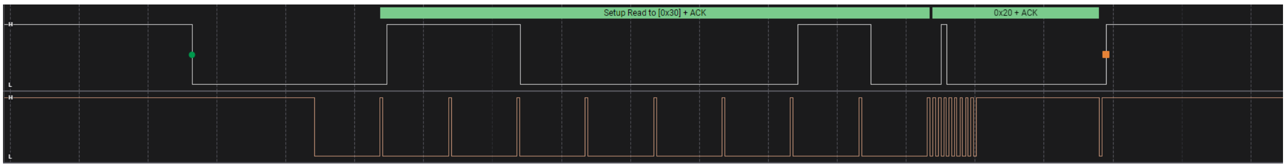

图21. IBI命令的流程时序

2.2.8 “热加入”命令

图22所示为主设备的热加入FSM流程。目标设备发送热加入（0x02）信号后，主设备在确认了热加入请求之后处理动态地址分配。

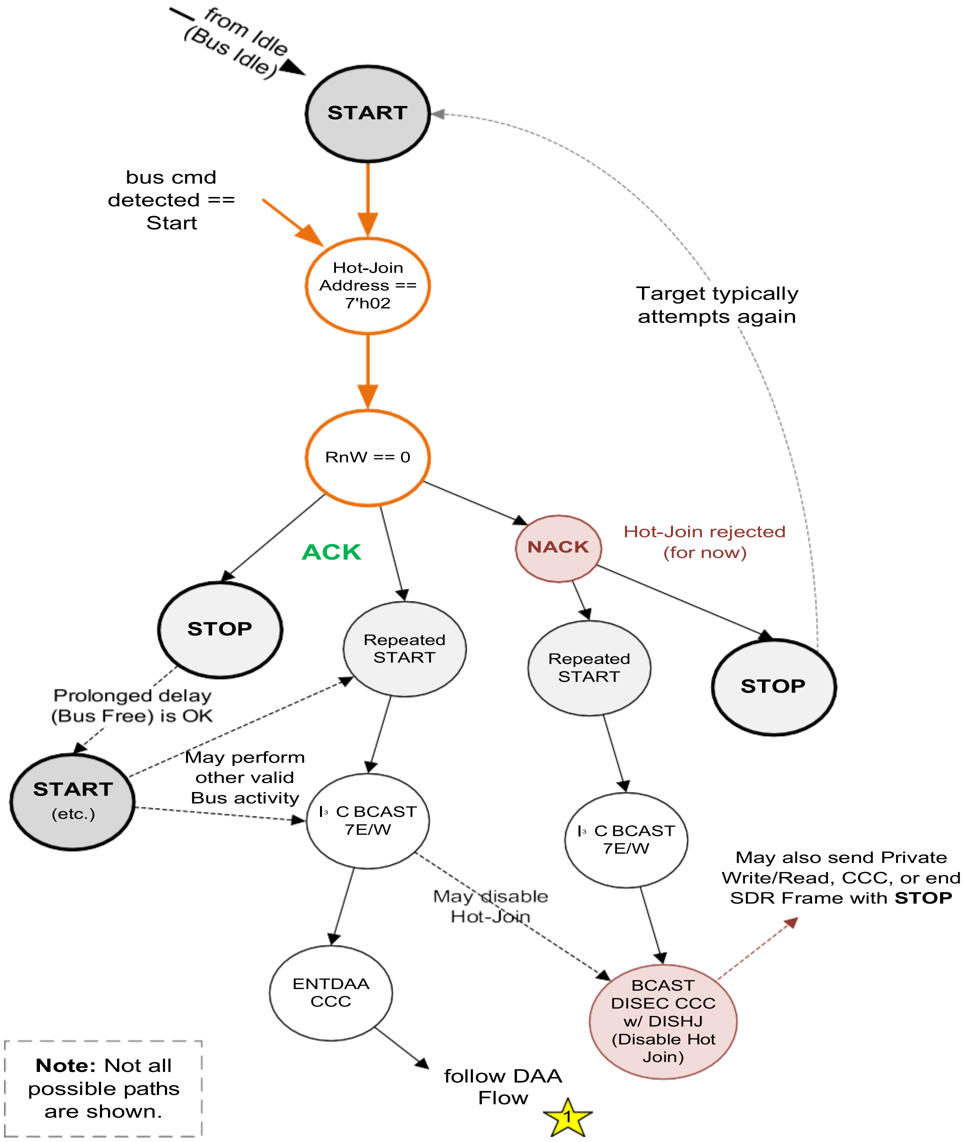

图22. 热加入FSM

表8所示为“热加入”命令的结构，和IBI命令一样，热加入信号由目标设备产生。当USB设备连接到主设备时，I3C目标设备可以随时发送热加入信号。主设备在检测到热加入信号后分配动态地址。与“List DAA”命令的反馈机制相同，USB主设备会接收目标设备的供应商ID/部件号信息/BCR/DCR和从设备地址。

表8. “热加入”命令的结构

支持的命令								
热加入								
USB虚拟通讯接口发送	不发送数据（当产生热加入信号时，虚拟通讯接口会接收IBI数据）							
	—	—	—	—	—	—	—	—
USB虚拟通讯接口接收	供应商LSB	供应商MSB	部件号信息			BCR	DCR	从设备地址
	—	—	—	—	—	—	—	—

图23所示为终端上“热加入”命令的接收结构。当目标设备产生一个热加入信号时，终端设备会接收目标设备信息数据，包括供应商ID、部件号信息、BCR、DCR和从设备地址。

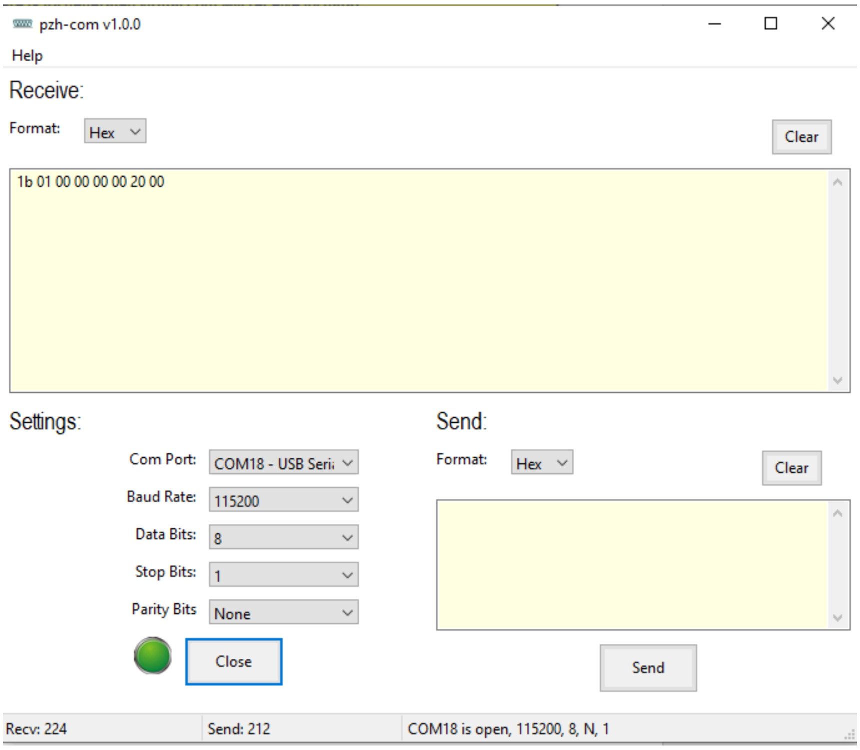

图23. “热加入”命令的终端显示

图24所示为“热加入”命令的I3C流程时序。

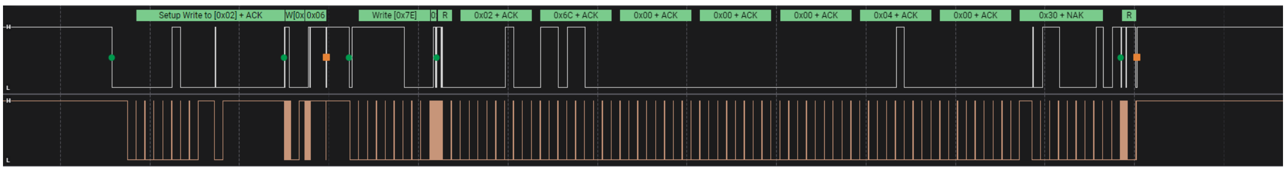

图24. “热加入”命令的流程时序

3 修订历史

表9汇总了本文的修订情况。

表9. 修订历史

文档ID	发布日期	说明
AN14434 v.1.0	2024年9月20日	首次公开发布

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Date of release: 20 September 2024
Document identifier: AN14434