

# AN14177

## 采用MCX Nx4x触控功能的头戴方案

第1.0版—2024年1月20日

应用笔记

### 文档信息

信息	内容
关键词	AN14177、MCX Nx4x、游戏头戴、USB音频、MICFIL、触控
摘要	本应用笔记介绍了如何使用MCX-N5XX-EVK实现带触控功能的USB音频方案。



## 1 介绍

在头戴上添加触控功能可提升用户操作的多样性和便利性。本应用笔记介绍了如何使用MCX-N5XX-EVK实现带触控功能的USB音频方案。

MCX Nx4x系列微控制器融合了Arm Cortex-M33 TrustZone内核、CoolFlux BSP32、PowerQuad DSP协处理器和以150MHz运行的多种高速连接选项。MCX N54x和MCX N947 (VFPGA184)提供了高速(HS) USB、SAI、DMIC和TSI接口。因此，MCX Nx4x芯片适用于游戏头戴解决方案。

**注：**MCX N94x包括MCX N947和MCX N946，其中MCX N946和MCX N947 (100HLQFP)不支持DMIC。

## 2 实施

本应用笔记的系统框图如图1所示，此框图简要介绍了MCXN如何实现带触摸功能的头戴。

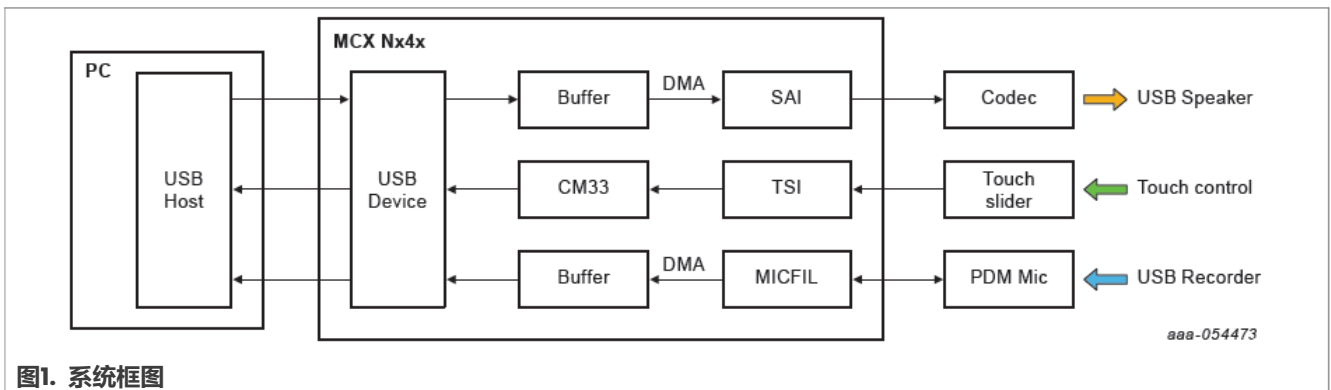


图1. 系统框图

本文的代码基于MCX-N5XX-EVK SDK 2.13的usb\_device\_composite\_hid\_audio\_unified示例进行开发，IDE为IAR 9.40.1。要下载MCX-N5XX-EVK SDK 2.13，请参见[Build SDK for MCX-N5XX-EVK](#)，并确保在MCUXpresso SDK Builder中勾选了USB。

此SDK示例实现了USB扬声器和录音功能。基于此实施方案，本文将介绍如何启用MICFIL模块以及触摸控制。

### 2.1 MICFIL的介绍及使用

USB录音功能的框图如图1所示：

1. MICFIL模块为PDM麦克风提供时钟，并将麦克风生成的PDM数据转换为PCM数据。
2. 然后，DMA将PCM数据传输到环形缓冲区。
3. 最后，MCU通过高速USB接口将PCM数据发送到USB主机。

MICFIL模块以一个可配置的输出采样率，将脉冲密度调制（PDM）麦克风的比特流转换为音频波段的24位PCM信号。图2所示为MICFIL的框图：

1. 内部的时间发生器用于为PDM麦克风生成可编程时钟。PDM数据经过抽取滤波器后转换为PCM数据。
2. 然后，将PCM数据载入到FIFO中。
3. 最后，可通过中断或DMA读取FIFO中的PCM数据。

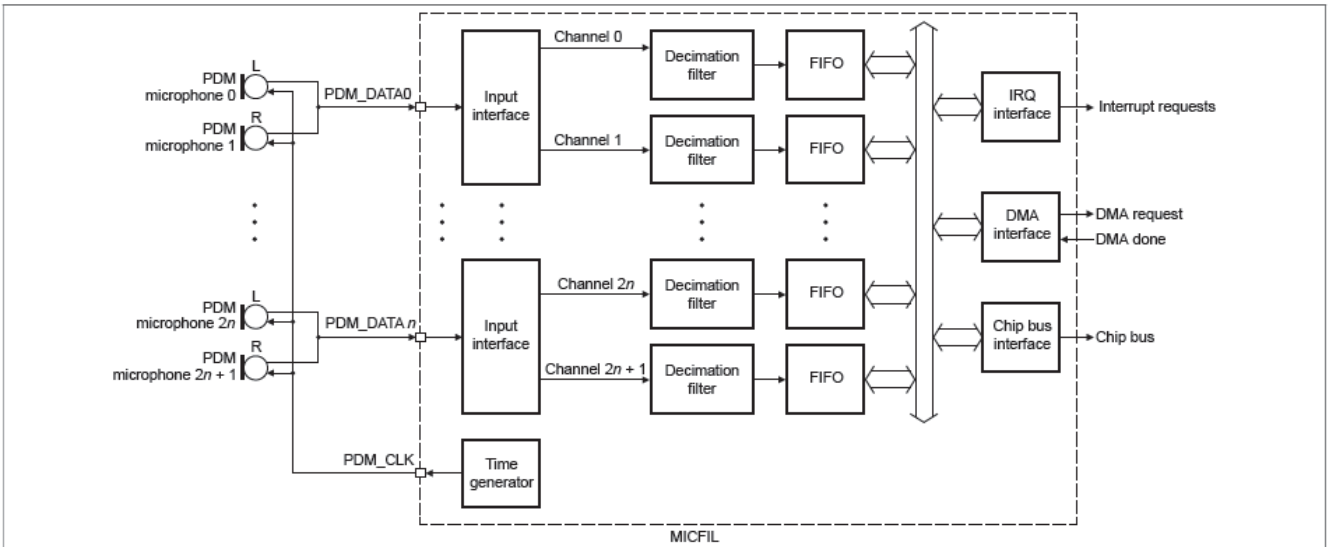


图2. MICFIL的框图

图3所示为启用时钟分频器时输入接口信号的时序图。在PDM\_CLK的上升沿（对应于右侧麦克风），从麦克风数据输入“n”(PDM\_DATA<sub>n</sub>)的比特流被分配到通道“2n+1”。而在下降沿（对应于左侧麦克风）产生的数据被分配到通道“2n”。

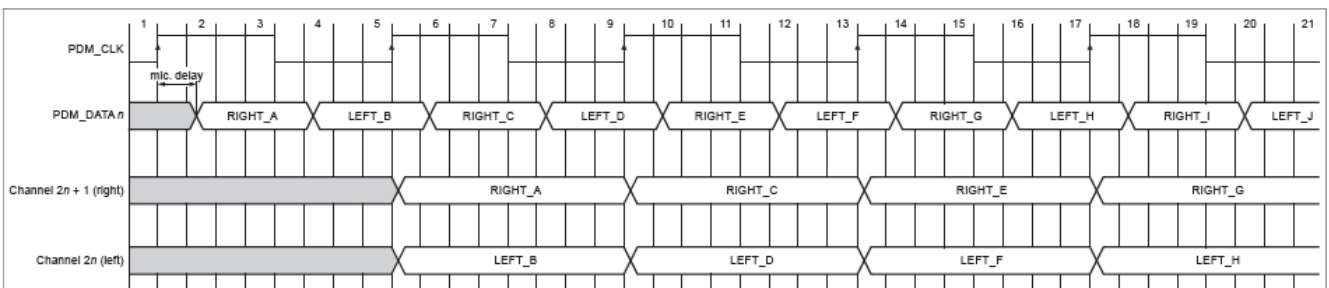


图3. 输入接口信号

图4所示为抽取滤波器的框图：

- 级联积分梳状（CIC）滤波器以给定的采样率将来自数字麦克风的PDM数据转换为PCM数据。
- 每个通道都配备了两个半带滤波器，实现了低通数字滤波器的2倍抽取率，可用于补偿通带中的高CIC衰减。
- 直流消除器是一个高通滤波器，用于消除已处理信号中的直流分量，其截止频率可配置。

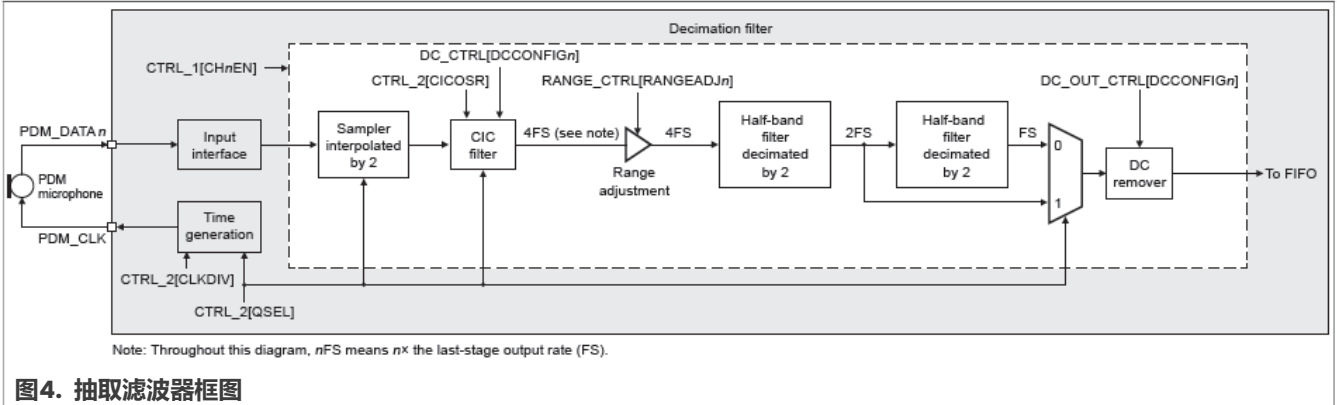


图4. 抽取滤波器框图

OSR是过采样率的缩写。公式(1)和公式(2)所示为由CTRL\_2[CICOSR]和所选的质量模式定义的CIC抽取率：

$$OSR = 16 - CICOSR \tag{1}$$

$$CIC \text{ decimation rate} = \begin{cases} 2 \times OSR ; & \text{If HQ, VLQ0} \\ OSR ; & \text{others} \end{cases} \tag{2}$$

表1所示为质量模式与抽取滤波器中系数之间的关系。

表1. 质量模式

质量模式	CTRL_2[QSEL]	采样器插值	CIC滤波器抽取因子	前半带滤波器抽取因子	后半带滤波器抽取因子	PDM_CLK速率	通带
高质量	001	-	: (2OSR)	: 2	: 2	输出速率 × 8 × OSR	至约0.5倍输出速率
中等质量	000	-	: OSR	: 2	: 2	输出速率 × 4 × OSR	至约0.5倍输出速率
低质量	111	× 2	: OSR	: 2	: 2	输出速率 × 2 × OSR	至约0.5倍输出速率
极低质量0	110	-	: (2OSR)	: 2	-	输出速率 × 4 × OSR	至约0.25倍输出速率
极低质量1	101	-	: OSR	: 2	-	输出速率 × 2 × OSR	至约0.25倍输出速率
极低质量2	100	× 2	: OSR	: 2	-	输出速率 × OSR	至约0.25倍输出速率

如公式(3)所示，总体的滤波器增益取决于质量模式、CIC抽取率和CIC滤波器的动态范围调整。

$$Overall \ filter \ gain \ (dB) = \begin{cases} 100 \times \log_{10} (32 - 2 \times CICOSR) + 6.02 \times RANGE\_CTRL[RANGEADJ_n] - 150.50 ; & \text{if } QSEL \in \{HQ, VLQ0\} \\ 100 \times \log_{10} (16 - CICOSR) + 6.02 \times RANGE\_CTRL[RANGEADJ_n] - 150.50 ; & \text{others} \end{cases} \tag{3}$$

表2显示了不同质量模式下的动态范围调整。

表2. 通道范围调整

QSEL	RANGEADJ <sub>n</sub>
HQ, VLQ0	<= 25 - ceil(5log <sub>2</sub> (2OSR))

表2. 通道范围调整 (续)

QSEL	RANGEADJ <sub>n</sub>
MQ, VLQ1	$\leq 25 - \text{ceil}(5 \log_2(\text{OSR}))$
LQ, VLQ2	$\leq 24 - \text{ceil}(5 \log_2(\text{OSR}))$

公式(4)和公式(5)所示为如何计算CLKDIV值和PDM\_CLK值:

$$\text{CLKDIV} = \frac{\text{MICFIL\_CLK\_ROOT rate}}{8 \times \text{OSR} \times (\text{output rate})} \quad (4)$$

$$\text{PDM\_CLK rate} = \frac{\text{MICFIL\_CLK\_ROOT}}{2 \times \text{floor}(K \times \text{CLKDIV})} \quad (5)$$

**注:** 输出率代表采样率。

有关K因子的值, 请参见表3。

表3. K因子值

质量模式	K因子
高质量	1/2
中等质量、极低质量0	1
低质量、极低质量1	2
极低质量2	4

以下是MICFIL的主要配置代码, 供参考。更多相关代码, 请参考SDK中的pdm\_sai\_edma示例。

```

/* Watermark value for FIFO: half of PDM FIFO depth */
pdmConfig.fifoWatermark = DEMO_PDM_FIFO_WATERMARK;
/* Quality mode: high quality */
pdmConfig.qualityMode = DEMO_PDM_QUALITY_MODE;
/* CIC filter over sampling rate: 0 */
pdmConfig.cicOverSampleRate = DEMO_PDM_CIC_OVERSAMPLE_RATE;
/* output DC remover cut off frequency: Bypass */
channelConfig.outputCutOffFreq = DEMO_PDM_OUTPUTCUTOFFREQ;
/* Configure filter dynamic range */
channelConfig.gain = DEMO_PDM_CHANNEL_GAIN;
/* Initializes the MICFIL peripheral */
PDM_Init(DEMO_PDM, &pdmConfig);
/* Configures the MICFIL channel */
PDM_TransferSetChannelConfigEDMA(DEMO_PDM, &s_pdmRxHandle, DEMO_PDM_ENABLE_CHANNEL_LEFT,
&channelConfig);
PDM_TransferSetChannelConfigEDMA(DEMO_PDM, &s_pdmRxHandle, DEMO_PDM_ENABLE_CHANNEL_RIGHT,
&channelConfig);
/* MICFIL set sample rate */
PDM_SetSampleRateConfig(DEMO_PDM, DEMO_PDM_CLK_FREQ, DEMO_AUDIO_SAMPLE_RATE);
/* Performs a non-blocking PDM receive using eDMA */
PDM_TransferReceiveEDMA(DEMO_PDM, &s_pdmRxHandle, pdmXfer);

```

此外, 用户还需将工程中录音器接口的USB描述符从16位改为32位。具体实现方法可参考本应用笔记附件中的代码。

为了降低延迟, 使用DMA传输MICFIL FIFO中的PCM数据。以下是DMA的主要配置代码, 供参考。更多相关代码, 请参阅SDK中的pdm\_sai\_edma示例。

```

#define DEMO_DMA DMA0
#define DEMO_PDM_EDMA_CHANNEL 0
#define DEMO_PDM_EDMA_SOURCE kDmaRequestMuxMicfil0FifoRequest
/* Initializes the eDMA peripheral */
EDMA_Init(DEMO_DMA, &dmaConfig);

```

```

/* Creates the eDMA handle */
EDMA_CreateHandle(&s_pdmDmaHandle, DEMO_DMA, DEMO_PDM_EDMA_CHANNEL);
/* Set channel request source */
EDMA_SetChannelMux(DEMO_DMA, DEMO_PDM_EDMA_CHANNEL, DEMO_PDM_EDMA_SOURCE);
/* Initializes the PDM Rx eDMA handle */
PDM_TransferCreateHandleEDMA(DEMO_PDM, &s_pdmRxHandle, pdmCallback, NULL, &s_pdmDmaHandle);
/* Install EDMA descriptor memory */
PDM_TransferInstallEDMATCDMemory(&s_pdmRxHandle, s_edmaTcd, 2);

```

表4所示为TCD的具体配置，以双通道MICFIL为例。

表4. TCD配置

寄存器	字段	描述	值
TCDn_SADDR	SADDR	源地址	DATACH[channel]
TCDn_SOFF	SOFF	源地址偏移	FIFO_Width
TCDn_DADDR	DADDR	目的地址	Buffer
TCDn_DOFF	DOFF	目的地址偏移	FIFO_Width
TCDn_ATTR	SSIZE	源数据传输大小	FIFO_Width
	DSIZE	目的数据传输大小	FIFO_Width
TCDn_NBYTES	NBYTES	通道的每次服务请求的传输字节数	channelNums* FIFO_Width
TCDn_BITER	BITER	开始主迭代计数	Data_Size/NBYTES

## 2.2 触控功能的介绍和使用

触摸感应输入 (TSI) 模块提供对电容式触摸传感器的触摸感应检测。TSI模块支持自电容模式和互电容模式。TSI完全支持基于SDK的恩智浦触摸库，为触摸键盘、旋转环和滑条的实现提供了可靠的电容测量模块。TSI模块提供了25个输入通道。

本应用笔记介绍了如何使用MCX-N5XX-EVK上的触摸滑条来实现USB音频的控制。

### 2.2.1 USB主机控制编解码器音量

基于SDK代码，以下将介绍如何实现用USB主机控制编解码器音量。

- 首先，将音量控制范围设置为编解码器对应的范围：

```

g_deviceAudioComposite->audioUnified.volumeControlRange.wMIN =
    USB_VolumeConversion_ConvertVolumeToUsb(AUDIOCODEC_MIN_OUTPUT_VOLUME_DB);
g_deviceAudioComposite->audioUnified.volumeControlRange.wMAX =
    USB_VolumeConversion_ConvertVolumeToUsb(AUDIOCODEC_MAX_OUTPUT_VOLUME_DB);

```

- 然后，添加以下代码来更改设备编解码器的音量：

```

int16_t range_volume_db = 0;
int16_t range_volume_USB = 0;
int16_t codec_min_USB = 0;
int16_t codec_max_db = (int16_t)AUDIOCODEC_MAX_OUTPUT_VOLUME_DB;
int16_t codec_min_db = (int16_t)AUDIOCODEC_MIN_OUTPUT_VOLUME_DB;
range_volume_db = codec_max_db - codec_min_db;
range_volume_USB = USB_VolumeConversion_ConvertVolumeToUsb(range_volume_db);
codec_min_USB = USB_VolumeConversion_ConvertVolumeToUsb(codec_min_db);
uint8_t limit_value = 80;
/*
    0xb300: covert Db-value(-77db) to USB-value
    0x4d00: covert Db-value(77db) to USB-value
*/

```

```
uint8_t volAdj = ((int16_t)ATOS(g_deviceAudioComposite->audioUnified.curSpeakerVolume20) -
(int16_t)codec_min_USB) * limit_value / range_volume_USB;
usb_echo("vol_codec_val = %d\r\n", volAdj);
BOARD_SetCodecVol(volAdj);
```

## 2.2.2 用触摸控制USB主机的音频

要获取SDK触摸演示，请在MCUXpresso SDK构建器中勾选恩智浦触摸传感软件库。然后，参考demo\_apps文件夹中的touch\_sensing演示代码。

**注：**MCX-N5XX-EVK SDK 2.13不支持勾选恩智浦触摸传感软件库，SDK 2.14将支持此库。您也可以在MCX-N9XX-EVK SDK 2.13中勾选恩智浦触摸传感软件库，并参考相应的演示代码。

touch\_sensing演示代码中的aslider\_callback函数会返回一个模拟滑条事件和位置。通过比较释放事件和初始触摸事件的位置，来确定左/右滑动距离或信号触摸事件。

更新USB设备隐藏键盘报告描述符，可实现USB主机音频控制：

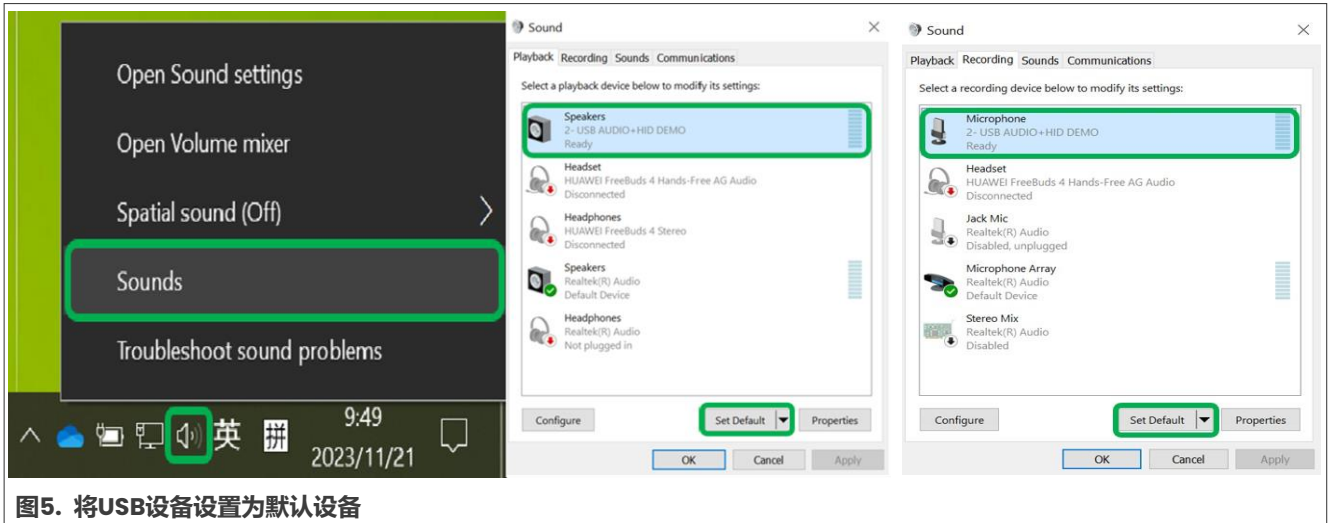
```
uint8_t g_UsbDeviceHidKeyboardReportDescriptor[] = {
    0x05, 0x0c, /* USAGE_PAGE (Consumer Devices) */
    0x09, 0x01, /* USAGE (Consumer Control) */
    0xa1, 0x01, /* COLLECTION (Application) */
    0x15, 0x00, /* LOGICAL_MINIMUM (0) */
    0x25, 0x01, /* LOGICAL_MAXIMUM (1) */
    0x05, 0x0c, /* USAGE_PAGE (Consumer Devices) */
    0x09, 0xcd, /* USAGE (Play/Pause) */
    0x09, 0xe9, /* USAGE (Volume Up) */
    0x09, 0xea, /* USAGE (Volume Down) */
    0x09, 0xb5, /* USAGE (Scan Next Track) */
    0x09, 0xb6, /* USAGE (Scan Previous Track) */
    0x09, 0xb7, /* USAGE (Stop) */
    0x95, 0x06, /* REPORT_COUNT (6) */
    0x75, 0x01, /* REPORT_SIZE (1) */
    0x81, 0x02, /* INPUT (Data,Var,Abs) */
    0x75, 0x02, /* REPORT_SIZE (2) */
    0x95, 0x01, /* REPORT_COUNT (1) */
    0x81, 0x03, /* INPUT (Cnst,Var,Abs) */
    0xc0 /* END_COLLECTION */
};
```

在hid\_keyboard.c中，USB\_DeviceHidKeyboardAction和USB\_DeviceHidKeyboardCallback函数会根据滑动方向和距离发送相应的设备请求。

## 3 测试

要测试SDK演示代码的基本USB音频播放功能，请执行以下步骤：

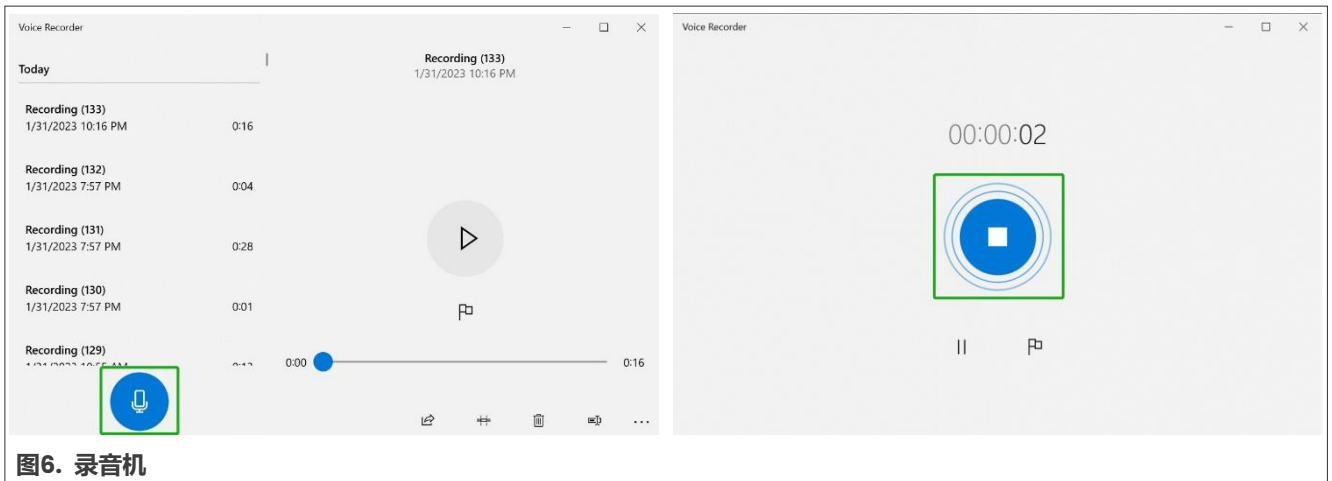
1. 通过USB电缆将MCU Link (J5)和HS USB (J27)连接到计算机。
2. 编译演示程序并将其下载到MCX-N5XX-EVK板后，复位MCU。
3. 将3.5 mm耳机插入EVK的J7。
4. 将USB设备设置为默认播放设备和默认录音设备，如图5所示。
5. 右键单击扬声器图标，然后单击**Sounds**。
6. 选择**Playback**或**Recording**，然后选择“USB AUDIO+HID DEMO”并单击**Set Default**。
7. 现在，USB设备端（EVK）的耳机将听到USB主机端（PC）播放的声音。



### 3.1 测试USB设备录音功能

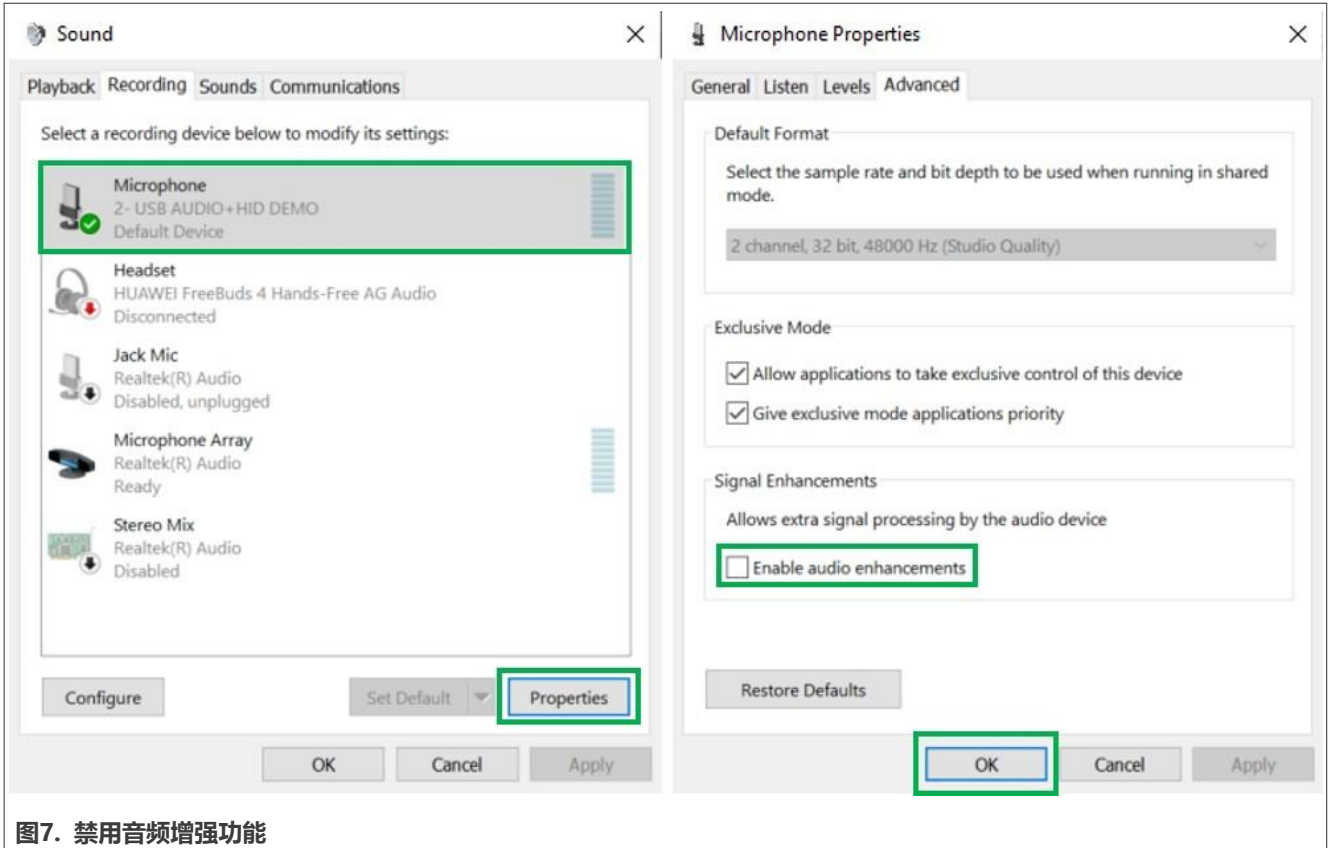
要测试USB设备录音功能，请执行以下步骤：

1. 将JP7、JP8、JP10和JP11的跳线从默认值更改为2-3。
2. 点击Windows的Start按钮，搜索“Voice Recorder”，如图6所示。
3. 靠近MCX-N5XX-EVK上的U30和U32，播放音乐。
4. 播放录音，通过USB设备端（EVK）的耳机会听到DMIC（EVK上的U30和U32）采集到的声音。



如果只有一个DMIC（EVK上为U30或U32）采集声音，请关闭音频增强功能，如图7所示。复位MCU后，用户可以听到左右声道采集的声音。

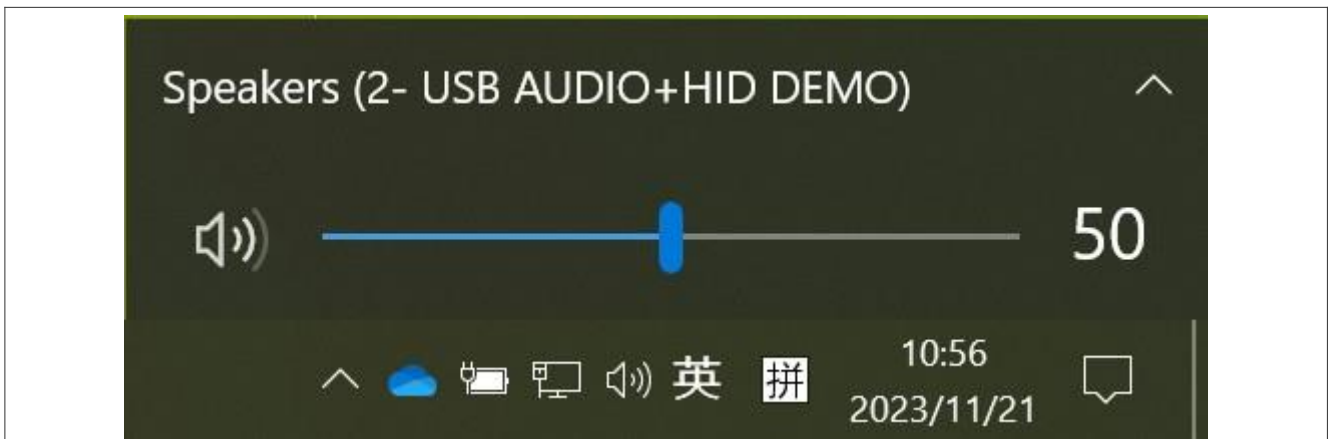


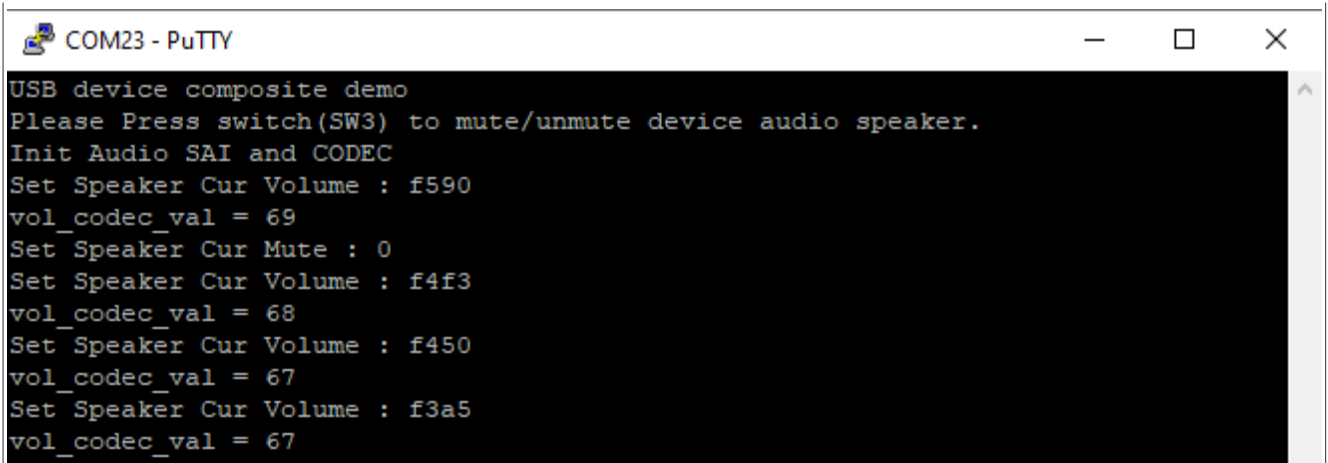


### 3.2 测试USB主机更改音量功能

要测试USB主机更改音量功能，请执行以下步骤：

1. 更改USB主机端（PC）的音量。终端打印音量调节信息，如图8所示。
2. 同时，通过耳机端（EVK上的耳机）可听到音量的变化。





```
COM23 - PuTTY
USB device composite demo
Please Press switch(SW3) to mute/unmute device audio speaker.
Init Audio SAI and CODEC
Set Speaker Cur Volume : f590
vol_codec_val = 69
Set Speaker Cur Mute : 0
Set Speaker Cur Volume : f4f3
vol_codec_val = 68
Set Speaker Cur Volume : f450
vol_codec_val = 67
Set Speaker Cur Volume : f3a5
vol_codec_val = 67
```

图8. USB主机更改音量功能

### 3.3 测试USB主机音频触控功能

要测试USB主机音频触控功能，请执行以下步骤，结果如图9所示：

1. 要调节音量，请左右滑动EVK上的触摸滑块（E1）。
2. 要播放/暂停音乐，请单击EVK上的触摸滑块（E1）。

**注：**当滑动或点击时，手指与滑块的接触面积要尽可能大，且滑动速度不要太快。

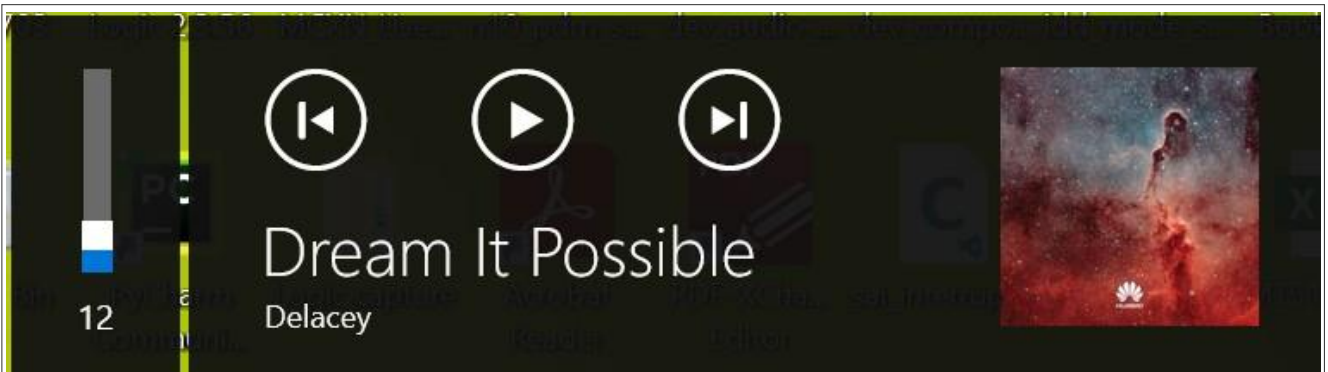


图9. USB主机音频触控功能

## 4 总结

本应用笔记基于SDK示例，介绍了如何启用MICFIL模块以及使用TSI模块来控制音量。为游戏耳机提供了技术参考，并给用户带来了更多的操作多样性和便利性。

## 5 关于本文中源代码的说明

本文中所示的示例代码具有以下版权和BSD-3-Clause许可：

2024年恩智浦版权所有；在满足以下条件的情况下，可以源代码和二进制文件的形式重新分发和使用本源代码（无论是否经过修改）：

1. 重新分发源代码必须保留上述版权声明、这些条件和以下免责声明。
2. 以二进制文件形式重新分发时，必须在文档和/或随分发提供的其他材料中复制上述版权声明、这些条件和以下免责声明。
3. 未经事先书面许可，不得使用版权所有者的姓名或参与者的姓名为本软件的衍生产品进行背书或推广。

本软件由版权所有者和参与者“按原样”提供，不承担任何明示或暗示的担保责任，包括但不限于对适销性和特定用途适用性的暗示保证。在任何情况下，无论因何种原因或根据何种法律条例，版权所有或参与者均不对因使用本软件而导致的任何直接、间接、偶然、特殊、惩戒性或后果性损害（包括但不限于采购替代商品或服务；使用损失、数据损失或利润损失或业务中断）承担责任，无论是因合同、严格责任还是侵权行为（包括疏忽或其他原因）造成的，即使事先被告知有此类损害的可能性也不例外。

## 6 修订历史

[表5](#)总结了本文的修订情况。

表5. 修订历史

文档ID	发布日期	说明
AN14177 v.1.0	2024年1月20日	初版发布

## Legal information

### Definitions

**Draft** — A draft status on a document indicates that the content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included in a draft version of a document and shall have no liability for the consequences of use of such information.

### Disclaimers

**Limited warranty and liability** — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of NXP Semiconductors.

**Right to make changes** — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

**Suitability for use** — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors and its suppliers accept no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

**Applications** — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

**Terms and conditions of commercial sale** — NXP Semiconductors products are sold subject to the general terms and conditions of commercial sale, as published at <https://www.nxp.com.cn/profile/terms>, unless otherwise agreed in a valid written individual agreement. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. NXP Semiconductors hereby expressly objects to applying the customer's general terms and conditions with regard to the purchase of NXP Semiconductors products by customer.

**Export control** — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

**Suitability for use in non-automotive qualified products** — Unless this document expressly states that this specific NXP Semiconductors product is automotive qualified, the product is not suitable for automotive use. It is neither qualified nor tested in accordance with automotive testing or application requirements. NXP Semiconductors accepts no liability for inclusion and/or use of non-automotive qualified products in automotive equipment or applications.

In the event that customer uses the product for design-in and use in automotive applications to automotive specifications and standards, customer (a) shall use the product without NXP Semiconductors' warranty of the product for such automotive applications, use and specifications, and (b) whenever customer uses the product for automotive applications beyond NXP Semiconductors' specifications such use shall be solely at customer's own risk, and (c) customer fully indemnifies NXP Semiconductors for any liability, damages or failed product claims resulting from customer design and use of the product for automotive applications beyond NXP Semiconductors' standard warranty and NXP Semiconductors' product specifications.

**Translations** — A non-English (translated) version of a document, including the legal information in that document, is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

**Security** — Customer understands that all NXP products may be subject to unidentified vulnerabilities or may support established security standards or specifications with known limitations. Customer is responsible for the design and operation of its applications and products throughout their lifecycles to reduce the effect of these vulnerabilities on customer's applications and products. Customer's responsibility also extends to other open and/or proprietary technologies supported by NXP products for use in customer's applications. NXP accepts no liability for any vulnerability. Customer should regularly check security updates from NXP and follow up appropriately. Customer shall select products with security features that best meet rules, regulations, and standards of the intended application and make the ultimate design decisions regarding its products and is solely responsible for compliance with all legal, regulatory, and security related requirements concerning its products, regardless of any information or support that may be provided by NXP.

NXP has a Product Security Incident Response Team (PSIRT) (reachable at [PSIRT@nxp.com](mailto:PSIRT@nxp.com)) that manages the investigation, reporting, and solution release to security vulnerabilities of NXP products.

**NXP B.V.** — NXP B.V. is not an operating company and it does not distribute or sell products.

### Trademarks

Notice: All referenced brands, product names, service names, and trademarks are the property of their respective owners.

**NXP** — wordmark and logo are trademarks of NXP B.V.

AMBA, Arm, Arm7, Arm7TDMI, Arm9, Arm11, Artisan, big.LITTLE, Cordio, CoreLink, CoreSight, Cortex, DesignStart, DynamIQ, Jazelle, Keil, Mali, Mbed, Mbed Enabled, NEON, POP, RealView, SecurCore, Socrates, Thumb, TrustZone, ULINK, ULINK2, ULINK-ME, ULINK-PLUS, ULINKpro,  $\mu$ Vision, Versatile — are trademarks and/or registered trademarks of Arm Limited (or its subsidiaries or affiliates) in the US and/or elsewhere. The related technology may be protected by any or all of patents, copyrights, designs and trade secrets. All rights reserved.

CoolFlux — is a trademark of NXP B.V.

IAR — is a trademark of IAR Systems AB.

MCX — is a trademark of NXP B.V.

## 目录

<b>1</b>	<b>介绍</b> .....	<b>2</b>
<b>2</b>	<b>实施</b> .....	<b>2</b>
2.1	MICFIL的介绍及使用.....	2
2.2	触控功能的介绍和使用.....	6
2.2.1	USB主机控制编解码器音量.....	6
2.2.2	用触摸控制USB主机的音频.....	7
<b>3</b>	<b>测试</b> .....	<b>7</b>
3.1	测试USB设备录音功能.....	8
3.2	测试USB主机更改音量功能.....	9
3.3	测试USB主机音频触控功能.....	10
<b>4</b>	<b>总结</b> .....	<b>10</b>
<b>5</b>	<b>关于本文中源代码的说明</b> .....	<b>10</b>
<b>6</b>	<b>修订历史</b> .....	<b>11</b>
	<b>法律声明</b> .....	<b>12</b>

Please be aware that important notices concerning this document and the product(s) described herein, have been included in section 'Legal information'.

© 2024 NXP B.V.

All rights reserved.

For more information, please visit: <https://www.nxp.com.cn>

Date of release: 20 January 2024  
Document identifier: AN14177