AN14567 How to implement USB microphone on MCX Series MCUs Rev. 1.0 — 18 February 2025

Application note

Document information

Information	Content
Keywords	AN14567, USB, Audio Class, PDM
Abstract	This application note describes how to implement the USB microphone function on MCX series microcontrollers. In this application note, we use USB Audio Class 1.0 and USB Audio Class 2.0 for USB audio transfer class and an external digital microphone or generated data as data source.



1 Introduction

This documentation describes how to implement a USB microphone on MCX Series MCUs. The data source could be an external digital microphone or generated data. A USB Audio Class 1.0 (UAC 1.0) and USB Audio Class 2.0 (UAC 2.0) microphone is used in this document.

The USB microphone function could not only be used as a normal microphone, but as a tool to debug multiple channels time series data. This documentation takes FRDM-MCXN947 as an example of how to implement the USB microphone function.

2 USB Audio Class introduction

Refer to the USB-IF documentation <u>Universal Serial Bus Device Class Definition for Audio Devices</u> that describes how a USB audio device is defined, works properly, and defines the USB descriptors. However, this documentation only defines the functions of the audio devices, the specific operation depends on how the USB Host is implemented. For example, the UAC 2.0 device supports multiple clock sources following the USB-IF's documentation. On Windows OS, the multiple clock source function does not support the following Microsoft's UAC2.0 driver documentation.

2.1 USB Audio Class 1.0

USB Audio Class 1.0 is introduced in 1998. It is the first specification for audio devices. Limited to USB 1.1 speed and platform drivers, the UAC 1.0 device supports only stereo or mono audio.

A UAC 1.0 device must implement exactly one Audio Control interface and one or more Audio Streaming interfaces. They are used to control the configuration of the audio device and perform the actual audio data transmission.

To be able to manipulate the physical properties of audio function, "Unit" and "Terminal" are introduced.

The seven types of standard Units and Terminals in the USB Audio Class 1.0 specification are the following: Input Terminal, Output Terminal, Mixer Unit, Selector Unit, Feature Unit, Processing Unit, Extension Unit. For more information, please visit the <u>USB-IF</u> website.

To build a basic UAC 1.0 microphone device, an Input Terminal and Output Terminal are needed. The Input Terminal (IT) is used to interface between the audio functions' "outside world" and other Units. The Output Terminal (OT) is used to interface between Units and the "outside world".



Figure 1. Basic UAC 1.0 microphone device

Audio Streaming interfaces are used to interchange digital audio data streams between the USB Host and the audio function. Each Audio Streaming interface can have at most one isochronous data endpoint. An Audio Streaming interface can have alternate settings that can be used to change certain characteristics of the

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interface and underlying endpoint. A typical usage is providing an empty endpoint that does not change any data to save the USB bandwidth.

2.2 USB Audio Class 2.0

The USB Audio Class 2.0 is introduced in 2006, it mainly focuses on the limitations of UAC 1.0 in bandwidth, sampling rate, and audio quality. UAC 2.0 supports USB 2.0 HS 480 MHz rather than UAC 1.0 's USB 1.1 FS 12 MHz.

Same as UAC 1.0, UAC 2.0 needs an Audio Control interface and one or more Audio Streaming interfaces. A basic UAC 2.0 microphone device topology is shown in <u>Figure 2</u>. The difference between UAC 1.0 and UAC 2.0 is that there is a Clock Source Unit.



Figure 2. Basic UAC 2.0 microphone device

3 USB Audio Class implementation with MCUXpresso Config Tools

Handwriting USB code is difficult, NXP offers MCUXpresso Config Tools to generate USB-related code to simplify this process. MCUXpresso Config Tools can be download at the <u>NXP website</u>. MCUXpresso IDE provides the built-in version of MCUXpresso Config Tools.

3.1 PDM digital microphone

In this document, an external digital microphone is used to generate audio samples. For the digital microphone module from Adafruit used in this documentation, the following configuration works well.

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PDW				Custom nam
e eDMA		▼ P	eripheral PDM	
Seneral configuration				Preset Custom.
0M configuration				
Clock source	MICFILFCLK - BOAR	D_BootClockFRO12M: Inactive, BOARD_B	ootClockFROHF48M: Inactive, B	80ARD_BootClockFROHF14
Clock source frequency	4096000 Hz (Clocks)	ool_DefaultInit)		•
Quality mode	High			•
Required sample rate	16 kHz			•
Oversampling rate (OSR)	8			
CIC decimation rate	16			
Expected divider	4			
Expected clock source frequency	4.096 MHz			
Actual divider	4 16 kHz			
	TO KHZ	Output clock for microphones —		
Calculated PDM_CLK rate	1.024 MHz	ouput clock for microphones		
Doze mode				
FIFO watermark	8			
 Channels configurations 				
CHANNEL_0 Channel	ID	CHANNEL_0		
HW char	nnel number	0		
Output	OC remover	Bypass		•
Desirent		Gain 12		-

Figure 3. PDM configuration

A ping-pong transfer must be implemented to achieve continuous audio reception. A full code example can be found in SDK.

<pre>uint8_t pdmBuffer[PDM_BUFFER_SIZE_IN_BYTES * PDM_BUFFER_NUM]ALIGNED(4) = {0}; uint32_t pdmBufferPosition = 0;</pre>
diffesz c pambarrerrosteron – 0,
pdm_edma_transfer_t pdmTransfer[] = {
{
.data = &pdmBuffer[0],
.dataSize = PDM BUFFER SIZE IN BYTES,
.linkTransfer = @pdmTransfer[1],
},
{
.data = &pdmBuffer[PDM BUFFER SIZE IN BYTES],
.dataSize = PDM BUFFER SIZE IN BYTES,
.linkTransfer = &pdmTransfer[0],
},
5 r

3.2 Implement UAC 1.0

In this document, MCUXpresso IDE and FRDM-MCXN947 are taken as examples.

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niversal Serie	ai Dus (USD) [Middleware]	
ame USBHS1_USB	c	Custom name
lode Device		Peripheral USBHS1_USBC
³ Common configu	Iration	USBFS0 USBHS1 USBC
MPU initialization	8	USBHS1_USBC - USB
Configuration settin	g reference <u>N/A</u>	
³ Device role		Preset Custom
Vendor ID	0x1FC9	
Product ID	0x0090	
Manufacturer	NXP	
Product	UAC 1.0 microphone	
Self-powered		
Max power [mA]	100	
Device task call	Copy to clipboard	

Figure 4. UAC1.0 device configuration

To implement UAC 1.0, follow the steps below:

- 1. Create a new project in MCUXpresso IDE and enter the MCUXpresso Config Tools page.
- 2. Create a new middleware component under the "Peripherals" subpage.
- 3. Choose "USBHS1_USBC" on the Peripheral select box, because the FRDM-MCXN947 board only exposes the USBHS port.
- 4. Create an MPU component following the tips.
- 5. Modify VID, PID, and names accordingly. In this example, set the Product name to "UAC 1.0 microphone".
- 6. Add interfaces according to the previous introduction. A basic UAC 1.0 microphone device needs an Audio Control interface and an Audio Streaming interface.
- 7. Click the "+" button to create a new interface, then modify the "Class" option and choose "Audio 1.0".
- 8. Select "Audio control" in the "Subclass" option, and get an Audio Control interface.

✓ ³ Supported interfaces	+ × • •		
😢 #0 Audio control	⁸⁰ Class 🏹 ⁸⁰ Audio 1.0		•
	✓ ³ Use case	Preset Custom	•
	Custom interface name	Audio control	
	⁸⁸ Subclass	³³ Audio control	•
	Protocol	None	•
		Class implementation code for interface (Audio con	

Figure 5. Add UAC1.0 Audio Control interface

- 9. An Input Terminal (IT) and Output Terminal (OT) are needed in an Audio Control interface. Create these terminals under the "Audio control interface configuration" block.
- 10. Modify the Terminal ID after creating the Units to prevent conflicts.
- 11. In the Output Terminal configuration block, set "Source ID" to the Input Terminal ID to implement the topology shown in <u>Figure 6</u> and <u>Figure 7</u>. The Audio Control interface settings are now complete.

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1 - Input ten	ninal 2 - Outp	out teminal		
Audio Unit	Input ter	rminal		•
🗸 Input t	erminal			
Terminal	ID	1		
Terminal	type	Microphone		•
Number	of channels	1		
		Left Front (L)	Right Front (R)	
		Center Front (C)	Low Frequency Enhancement (LFE)	
		Left Surround (LS)	Right Surround (RS)	
Spatial lo	cation	Left of Center (LC)	Right of Center (RC)	
		Surround (S)	Side Left (SL)	
		Side Right (SR)	🗌 Тор (Т)	
6. UAC1.0 A	udio Conti	rol terminal/unit configura	ation	
1 - Input ten	ninal 2 - Outp	out teminal		
Audio Unit	Output	terminal		•
🗸 Outpu	t terminal			
Terminal	ID 2			
Terminal	type Stre	aming		•
	1			
Course ID				

The Audio Streaming interface must include at least one endpoint, and a zero bandwidth endpoint is optional. In MCUXpresso Config Tools, the zero bandwidth endpoint is required. To create such an endpoint, create a new endpoint and place it in the first position.

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Custom setting name	Zero bandwidth	
Endpoints +		
Add an item by clicking the	plus button	
Audio stream interface sp	ecific settings No endpoints are available - configuration is disabled	
Link to terminal		
Delay [frames] 0		
Format Und	lefined type l	Ŧ
✓ Audio data format		
Audio data format type	Format I	
Number of channels	0	
Subframe size	1	
Resolution	0	
Sampling frequencies	Continuous range	
Lower bound	0	
Upper bound	0	
✓ Sampling frequencies	s + × • •	
Sample frequency		

Figure 8. Zero bandwidth Audio Stream interface configuration

Create another endpoint called "microphone", this endpoint can be used to send the microphone data. Configure this endpoint as shown in Figure 9. For packet size, make sure it is greater than (channels * sample bits / 4 * sample rate / 1000). An interval could be set to a reasonable value. For USB FS, the actual interval is $1 * 2 ^ (value - 1)$ microseconds, for USB HS the actual interval is $0.125 * 2 ^ (value - 1)$ microseconds. With the configuration in figure, the actual interval is 1 microsecond for both USB FS and HS. The configuration in Figure 9 is enough for a basic UAC 1.0 microphone device.

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n #1		
Direction	In	•
Transfer type	Isochronous	•
Synchronization	Şynchronous	•
Usage	Data	•
Max packet size (FS)	64	•
Interval (FS)	1	
Max packet size (HS)	64	•
Interval (HS)	4	
Refresh	0	
Synchronization endpoint address	No synchronization	•
✓ Class specific audio streaming	data endpoint configuration	
Sampling Frequency Control	0	
Pitch Control		
Allow maximum packets only		
Lock delay units	Undefined	•
Lock delay	0	

Figure 9. Data Audio Stream endpoint configuration

The configuration in Figure 10 is application-specific. For example, the audio format, PCM, is more common, and float can also be used. In this document, an external digital microphone is used. The PDM peripheral can generate a 24-bit sample. The "Subframe size" is set to 3 and "Resolution" to 24 and 16000 is added to Sample Frequency list.

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Link to terminal	2		
Delay [frames]	0		
Format	РСМ		
✓ Audio data form	t		
Audio data format	/pe Format I		
Number of channe	1		
Subframe size	3		
Resolution	24		
		Sampling configuration	
Sampling frequen	es List of frequenc	ies	
Lower bound	0		
Upper bound	0		
✓ Sampling freq	encies + ×		
Sample freqe	псу		
Sample freqe			

Figure 10. Data Audio Stream interface specific configuration

Now, generate code. To build this project successfully, implement these functions defined in generated/usb_device_composite.c.

<pre>extern usb_status_t USB_DeviceInterface0AudioControlInit(usb_device_composite_struct_t *deviceComposite);</pre>
<pre>extern usb_status_t USB_DeviceInterface0AudioControlCallback(class_handle_t handle, uint32_t event, void *param);</pre>
<pre>extern usb_status_t USB_DeviceInterface0AudioControlSetConfiguration(class_handle_t handle, uint8_t configuration_index);</pre>
<pre>extern usb_status_t USB_DeviceInterface0AudioControlSetInterface(class_handle_t handle, uint8_t alternateSetting);</pre>
<pre>extern usb_status_t USB_DeviceInterface0AudioControlBusReset(usb_device_composite_struct_t *deviceComposite);</pre>
<pre>extern usb_status_t USB_DeviceInterfacelAudioStreamingSetInterface(class_handle_t handle, uint8_t alternateSetting);</pre>

An implementation could reference the following content.

#endif

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```
default:
         kStatus USB InvalidRequest;
 error =
 break;
}
return error;
}
usb status t USB DeviceInterface0AudioControlInit(usb device composite struct t *deviceComposite)
 // reset buffer position and start PDM receiving
pdmBufferPosition = 0;
PDM TransferReceiveEDMA(PDM PERIPHERAL, &PDM PDM eDMA Handle, pdmTransfer);
return kStatus USB Success;
}
usb_status_t USB_DeviceInterface0AudioControlCallback(class_handle_t handle, uint32_t event, void
 *param)
{
usb_status_t error = kStatus_USB_InvalidRequest;
usb_device_endpoint_callback_message_struct_t *ep_cb_param;
ep_cb_param = (usb_device_endpoint_callback_message_struct_t *)param;
switch (event)
case kUSB DeviceAudioEventStreamSendResponse:
  if (ep c\overline{b} param->length == USB ISO IN ENDP PACKET SIZE)
  error = USB SendAudioData(handle, USB INTERFACE 1 AUDIO STREAMING INDEX);
 break;
default:
  if (param && (event > 0xFFU))
  {
  error = USB_DeviceAudioRequest(handle, event, param);
 break;
 }
return error;
}
usb status t USB DeviceInterfaceOAudioControlSetConfiguration(class handle t handle, uint8 t
configuration index)
{
return kStatus USB Success;
}
usb status t USB DeviceInterface0AudioControlSetInterface(class handle t handle, uint8 t
alternateSetting)
{
return kStatus USB Success;
}
usb status t USB DeviceInterface0AudioControlBusReset(usb device composite struct t
 *deviceComposite)
{
return kStatus_USB_Success;
}
usb status t USB DeviceInterface1AudioStreamingSetInterface(class handle t handle, uint8 t
alternateSetting)
usb_status_t error = kStatus_USB Success;
if (alternateSetting == USB ALTERNATE SETTING 1)
  error = USB SendAudioData(handle, USB INTERFACE 1 AUDIO STREAMING INDEX);
 }
```

```
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```

return error;
}

Function USB_DeviceAudioRequest is used to receive a request from the Audio Control interface. In this basic UAC 1.0 device demo, there is no feature unit, so there will not be any requests.

Build the project and connect the USB port to the PC. Open System Settings and check connected devices, it must be similar to the one shown Figure 11.

System > Sound > Properties	
麦克风 4- UAC 1.0 microphone Rename	Provider (Generic USB Audio) Driver date 2024/7/19 Driver version 10.0.22621.3958 Check for driver updates
General	
Audio Allow apps and Windows to use this device for audio	Don't allow
Set as default sound device	Is default for audio \checkmark
Input settings	
Format	1 channels, 24 bit, 16000 Hz $$
Input volume	5 4 — • —
Test your microphone Select Start test and talk or play audio at your normal volume for at least a then select Stop test	few seconds, Start test

Use an audio tools like system sound recorder or Audacity to record and playback the sound to confirm it functions properly.



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3.3 Implement UAC 2.0

Same as UAC 1.0, create an Audio Control interface and an Audio Streaming interface with similar configuration. Add a Clock Source Unit in the Audio Control interface, to achieve the topology shown in the UAC 2.0 introduction. The final configurations should be similar to those below.

		•
 Use case 	Preset Custom	•
Custom interface name	Audio Control	
Subclass	Audio control	•
Protocol	Version 2.00	•
	Class implementation code for interface (Audio Control)	
Generate code example <i>?</i>	Disabled	•
Interface control functions	are not generated in the interface files.	
Interface setting	$+ \times \langle \rangle$	
	Default	
custom setting name		
✓ Endpoints +	\times \checkmark	
Add an item by clicking t	he plus button	
✓ AC Interface Descripte	or Header	
Audio Function Category	Microphone	•
Latency Control	Not present	•
Audio control interfac		
Audia Unit Clock so		
		•
Clock ID	1	
Clock type	Internal fixed clock	•
Internal clock mode	Free running	•
	Controls	
	Road Only	-
Clock frequency	Read-Only	-
Clock ID Clock type Internal clock mode	1 Internal fixed clock Free running Controls People Optic	*

Figure 13. Audio Control interface configuration

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 Use case 	Preset Custom	
Custom interface name Audio S	Streaming	
Subclass Audio s	tream	1
Protocol Version	2.00	•
Class	implementation code for interface (Audio Streaming)	
Generate code example ? Disable	d	
Interface control functions are not gene	rated in the interface files.	
#0 Zero bandwidth #1 Microphone	Microphone	
Endpoints H X (In #1		
Direction	In	•
Transfer type	Isochronous	•
Synchronization	Synchronous	•
Usage	Data	•
Max packet size (FS)	64	•
Interval (FS)	1	
Max packet size (HS)	64	•
Interval (HS)	4	
Refresh	0	
Synchronization endpoint address	No synchronization	Ŧ
Class specific audio streaming	data endpoint configuration	

Figure 14. Data Audio Stream interface configuration

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Link to terminal	3	
Active Alternate Setting	Not present	
Valid Alternate Settings	Not present	
Format type	Format I	
Audio data format	РСМ	
	Channel cluster descrip	tor
Number of channel	1	
	Front Left (FL)	Front Right (FR)
	Front Center (FC)	Low Frequency Effects (LFE)
	Back Left (BL)	🗌 Back Right (BR)
	Front Left of Center (FLC)	Front Right of Center (RC)
	Back Center (BC)	Side Left (SL)
	Side Right (SR)	Top Center (TC)
Continuin	Top Front Left (TFL)	Top Front Center (TFC)
Spatial location	Top Front Right (TFR)	Top Back Left (TBL)
	Top Back Center (TBC)	Top Back Right (TBR)
	Top Front Left of Center (TFLC)	Top Front Rifht of Center (TFRC)
	Left Low Frequency Effects (LLFE)	Right Low Frequency Effects (RLFE)
	Top Side Left (TSL)	Top Side Right (TSR)
	Bottom Center (BC)	Back Left of Center (BLC)
	Back Right of Center (BRC)	🗌 Raw Data (RD)
Format Type Descripto	r	
Sub-slot size 3		
Resolution 24		

Figure 15. Data Audio Stream interface configuration

After generating the code, implement the interface defined in generated/usb_device_composite.c. They have the same definition as UAC 1.0.

```
extern usb_status_t USB_DeviceInterface0AudioControlInit(usb_device_composite_struct_t
 *deviceComposite);
extern usb_status_t USB_DeviceInterface0AudioControlCallback(class_handle_t handle, uint32_t
 event, void *param);
extern usb_status_t USB_DeviceInterface0AudioControlSetConfiguration(class_handle_t handle, uint8_t
 configuration_index);
extern usb_status_t USB_DeviceInterface0AudioControlSetInterface(class_handle_t handle, uint8_t
 alternateSetting);
extern usb_status_t USB_DeviceInterface0AudioControlBusReset(usb_device_composite_struct_t
 *deviceComposite);
extern usb_status_t USB_DeviceInterface1AudioStreamingSetInterface(class_handle_t handle, uint8_t
 alternateSetting);
```

The implementation is the same as UAC 1.0, except the USB_DeviceAudioRequest function. In this function, implement the behavior when a specific request is sent.

```
static usb_status_t USB_DeviceAudioRequest(class_handle_t handle, uint32_t event, void *param)
{
    usb_device_control_request_struct_t *request = (usb_device_control_request_struct_t *)param;
    usb_status_t error = kStatus_USB_Success;
    switch (event)
    {
    #if USB_DEVICE_CONFIG_AUDIO_CLASS_2_0
    case USB_DEVICE_AUDIO_CS_GET_RANGE_SAMPLING_FREQ_CONTROL:
    request->buffer = (uint8_t *)&usbAudiofreqRange;
    request->length = sizeof(usbAudiofreqRange);
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```

```
break;
case USB_DEVICE_AUDIO_CS_GET_CUR_SAMPLING_FREQ_CONTROL:
request->buffer = (uint8_t *)&usbAudioCurFreq;
request->length = sizeof(usbAudioCurFreq);
break;
#endif
default:
error = kStatus_USB_InvalidRequest;
break;
}
return error;
```

Build and flash, the USB device must work properly.

		System > Sound > Properties						
		麦克风 2- UAC 2.0 microphone Rename	ProviderMicrosoftDriver date2022/5/6Driver version10.0.22621.1Check for driver updates					
		General						
		Audio Allow apps and Windows to use this device for audio	Don't allow					
		Set as default sound device	Is default for audio \lor					
Figure 16. UAC2.0 microphone device in system settings								
× 音频 1 ~ ··· · · · · · · · · · · · · · · · ·								
Figure 17. Record with UAC2.0 microphone device in Audacity								

4 Revision history

Table 1. Revision history							
Document ID	Release date	Description					
AN14567 v.1.0	18 February 2025	Initial version					

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How to implement USB microphone on MCX Series MCUs

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