# AN12939

## Implementation of 5.1-channel Audio Solution on LPC55xx

Rev. 2 — 5 September 2023 Application note

**Document Information**

| Information | Content |
|---|---|
| Keywords | USB Audio, 5.1 channel |
| Abstract | LPC5500 is very suitable for USB audio applications. |

# 1 Introduction

## 1.1 Background

USB is suited for audio (voice and sound) transport, and PC-based voice telephony is one of the major drivers of USB technology. In addition, high-speed USB has more than enough bandwidth for sound, even high-quality audio. Many applications related to voice telephony, audio playback, and recording can take advantage of the USB.

**Figure 1. USB headphone**

The LPC5500 MCU series use the most recent Cortex-M33 technology of Arm, combining significant product architecture enhancements and greater integration over previous generations of microcontrollers. Most members of the LPC5500 family have both Full Speed (FS) and High Speed (HS) USB and flexible serial interfaces, Flexcomm. Flexcomm interfaces include various serial interface capabilities, including $I^2S$ and $I^2C$. As some of them have DSP accelerators, LPC5500 devices are suitable for USB audio applications.

## 1.2 Surround sound

5.1 surround sound, also known as five-point-one, is the common name for six-channel surround sound audio systems. It is the most commonly used layout in home theaters. It uses five full-bandwidth channels and one low-frequency effects channel.

All 5.1 systems use the same speaker channels and configurations: one front left and right, one center channel, two surround channels (left and right), and the low-frequency effects channel designed for a subwoofer.

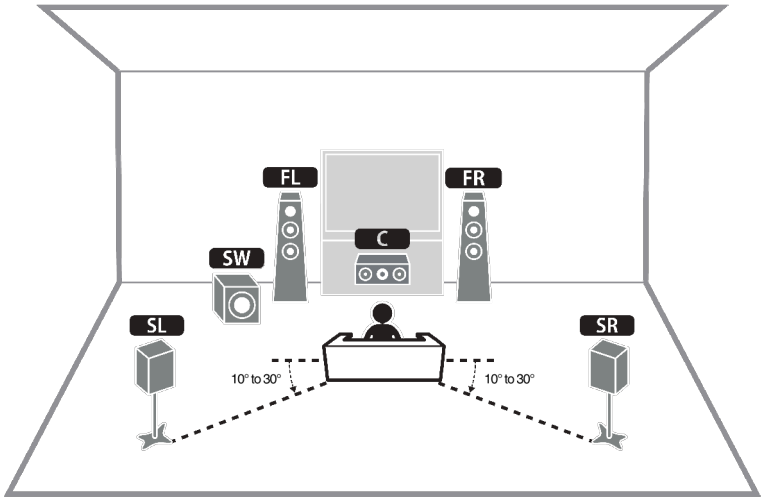


**Figure 2. 5.1 surround sound**

## 2 Mechanism and implementation

This application note introduces how to use the LPC55S69-EVK/LPC55S28-EVK/LPC55S16-EVK to implement 5.1 multichannel USB audio applications. This document references an example that is already integrated in MCUXpresso SDK, named `usb_device_audio_speaker`. See MCUXpresso SDK for the source code.

### 2.1 Mechanism

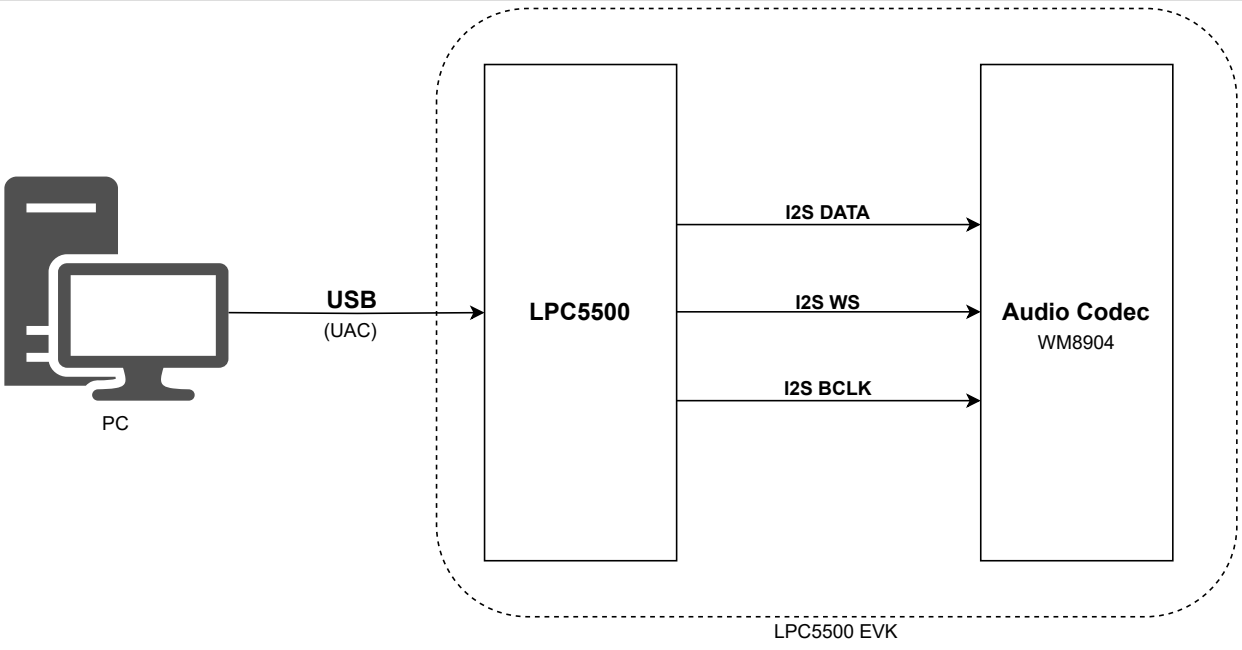


**Figure 3. Block diagram**

Figure 3 shows the block diagram. The PC is used as the USB host, which is also used as an audio source, and also outputs audio data. LPC55S69-EVK/LPC55S28-EVK/LPC55S16-EVK board connects to the PC with USB cable and counts as a USB device.

In USB devices, there is a special class for audio applications, called USB Audio Class (UAC).

UAC is a digital audio connection used to send digital music from your computer to a Digital-to-Analogue Converter (DAC). The reason why many people choose an external UAC device is the poor quality built-in DAC in a computer. Computer manufacturers spend most of the overall budget on the processors and screens, leaving minimal budget for the built-in DAC and audio outputs.

There are two versions of UAC, UAC 1.0 and UAC 2.0. They can both handle high-resolution music. However, there is a clear distinction between the two and the difference is in the resolution of music they can deliver. Compared to the headphone output of the computer, UAC 1.0 devices give a significant improvement in sound. However, UAC 2.0 takes one step further. UAC 1.0 can send up to a maximum of 24- bit/96 kHz data. To play studio master quality files, a step up to Class 2 is required. It supports up to 24 bit/192 kHz resolution data.

The PC sends the audio data over USB to the LPC5500. In turn, it passes the data to the audio `codec` on the evaluation board.

Six-channel data are interlaced in the below format.

| Left Front (L) | Right Front (R) | Center Front (C) | Low Frequency Enhancement (LFE) | Left Surround (LS) | Right Surround (RS) |
|---|---|---|---|---|---|
| Bit resolution | Bit resolution | Bit resolution | Bit resolution | Bit resolution | Bit resolution |

For example, if the bit resolution is 16, each channel has 2 bytes (16 bits) in one subframe.

| Left Front (L) | Right Front (R) | Center Front (C) | Low Frequency Enhancement (LFE) | Left Surround (LS) | Right Surround (RS) |
|---|---|---|---|---|---|
| 2 bytes | 2 bytes | 2 bytes | 2 bytes | 2 bytes | 2 bytes |

LPC5500 family has eight Flexcomms. Each Flexcomm can be configured as $I^2S$. With `sys_ctrl`, $I^2S$ signal sharing, it can output data of six channels.

***Note:***

*Since the LPC55S69-EVK, LPC55S28-EVK, and LPC55S16-EVK are not designed for audio applications, they cannot output five channels of audio at the same time. This is the board limitation. In practical applications, choose the appropriate `codec` and PCB layout according to the situation.*

*To evaluate LPC5500 devices in this type of application, the MCUXpresso SDK examples enable two of the possible six output channels to be routed to the stereo audio `codec` provided on these evaluation boards.*

## 2.2 Implementation

The content of this chapter is based on SDK 2.14.0. Other versions are slightly different.

`usb_device_audio_speaker` in MCUXpresso SDK supports USB Audio Class 5.1 channels, so only configuration modification is required to match the test environment and requirements.

The following two macros in `usb_device_config.h` can decide whether to use USB HS or USB FS. The default value is USB FS. In most audio applications, USB FS can meet the requirements of audio data throughput. For high-resolution, high-quality, and multichannel audio applications, such as, 96 k, 32 bit, 5.1 channels, USB HS is required.

```
/*! @brief LPC USB IP3511 FS instance count */
#ifndef USB_DEVICE_CONFIG_LPCIP3511FS
```

```
#define USB_DEVICE_CONFIG_LPCIP3511FS (1U)
#endif

/*! @brief LPC USB IP3511 HS instance count */
#ifndef USB_DEVICE_CONFIG_LPCIP3511HS
#define USB_DEVICE_CONFIG_LPCIP3511HS (0U)
#endif
```

`USB_DEVICE_CONFIG_AUDIO_CLASS_2_0` in `usb_device_config.h` decides whether the device supports UAC 1.0 or 2.0. By default, UAC 2.0 is used.

```
/*! @brief Whether device supports USB Audio class 2.0. 1U supported, 0U not
 supported */
#if USB_DEVICE_CONFIG_AUDIO
#ifndef USB_DEVICE_CONFIG_AUDIO_CLASS_2_0
#define USB_DEVICE_CONFIG_AUDIO_CLASS_2_0 (1U)
#endif
#endi
```

`USB_AUDIO_UAC5_1` in `usb_device_descriptor.h` decides whether the UAC supports 5.1 channels or two-channel stereo.

```
/*! @brief Whether UAC 5.1 is enabled or not. Note that this macro may be also
 defined in usb_audio_config.h in some
 * cases, make sure the consistent change. */
#define USB_AUDIO_CHANNEL5_1 (0)
```

The default value, (0), supports two-channel stereo. Therefore, modify it to **1U**.

```
/*! @brief Whether UAC 5.1 is enabled or not. Note that this macro may be also
 defined in usb_audio_config.h in some
 * cases, make sure the consistent change. */
#define USB_AUDIO_CHANNEL5_1 (1)
```

Finally, if the USB host meets three conditions in the following code snippet, enable the following macro in `usb_device_descriptor.h` and modify it to **1U**. For Linux or Mac operating systems, disable this macro.

```
/*! @brief Workaround for USB audio 2.0 supported by Windows OS. Please set 1
 when meets the following conditions:
    1. device is full speed running audio 2.0
    2. usb host is Windows OS that supports USB audio 2.0, like Win 10
    3. use feedback endpoint
*/
#ifndef USB_DEVICE_WORKAROUND_AUDIO_20_WINDOWS
#define USB_DEVICE_WORKAROUND_AUDIO_20_WINDOWS (0U)
#endif
```

After completing these modifications, compile and download to the EVK board. Connect the HS or FS port (based on the settings shown above) to the computer via a USB cable. The function can be tested on the computer, as shown in Figure 4.

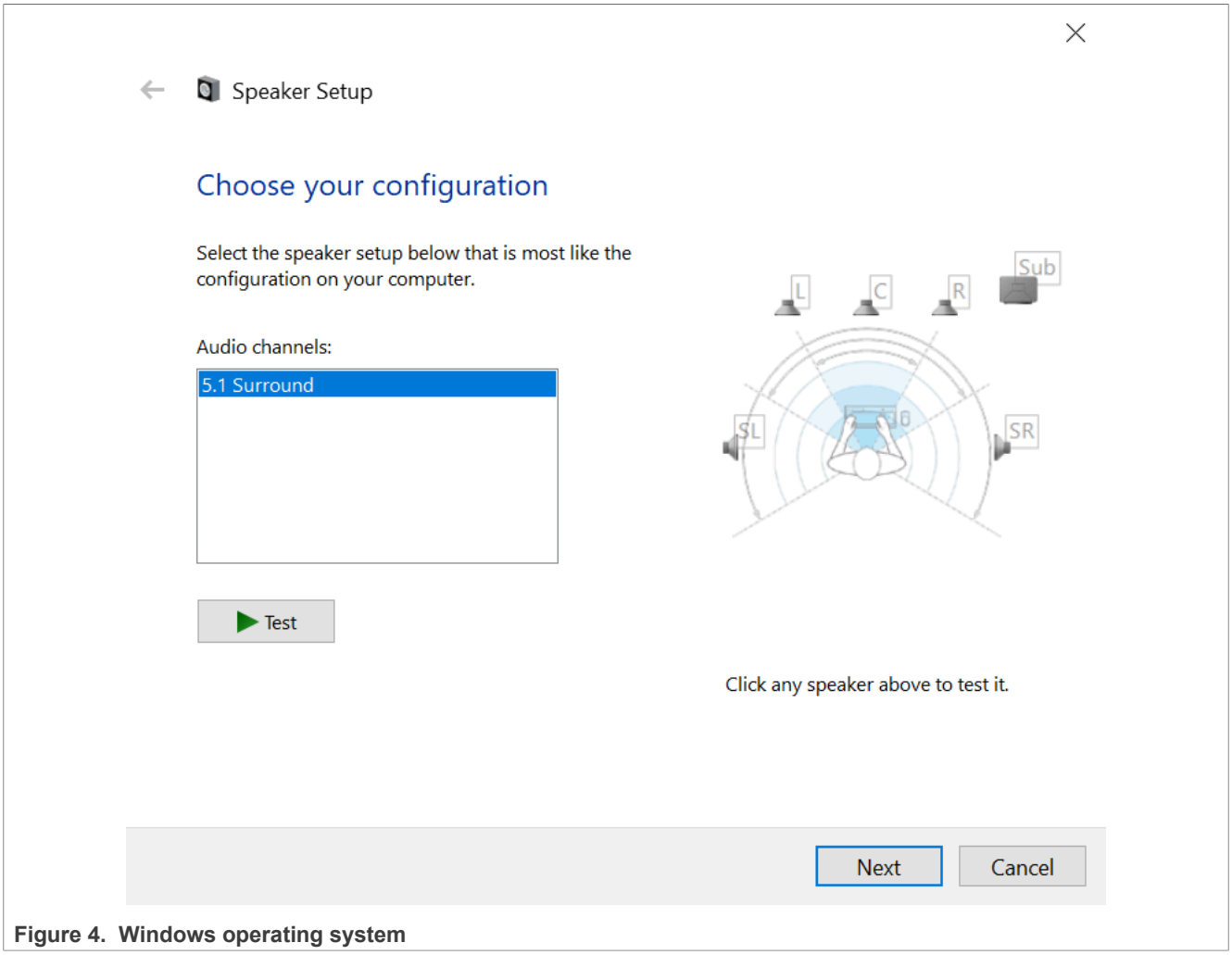


**Figure 4. Windows operating system**

## 3 Summary

As mentioned above, LPC5500 is suitable for USB audio applications. These devices include high-speed and full-speed USB and flexible serial communication peripherals (which can be configured as the $I^2S$ interface). Some of them have the PowerQuad DSP accelerators, which can be used for audio processing. Actually, due to the excellent design, the LPC5500 can handle more than 5.1-channel audio applications.

**Table 1. Flexcomm interfaces**

| Flexcomm interface number | $I^2S$ | | `sys_ctrl` signal sharing |
|---|---|---|---|
| | LPC55S6x/LPC55S2x/LPC552x | LPC55S3x/LPC553x/ LPC55S1x/LPC551x | All LPC5500 |
| Flexcomm 0 | One channel pair (Two channels) | One channel pair (Two channels) | $I^2S$ signal sharing |
| Flexcomm 1 | One channel pair | One channel pair | I2S signal sharing |
| Flexcomm 2 | One channel pair | One channel pair | $I^2S$ signal sharing |
| Flexcomm 3 | One channel pair | One channel pair | **Excluded from $I^2S$ sharing** |
| Flexcomm 4 | One channel pair | One channel pair | $I^2S$ signal sharing |

**Table 1. Flexcomm interfaces**...*continued*

| Flexcomm interface number | $I^2S$ | | `sys_ctrl` signal sharing |
|---|---|---|---|
| | LPC55S6x/LPC55S2x/LPC552x | LPC55S3x/LPC553x/ LPC55S1x/LPC551x | All LPC5500 |
| Flexcomm 5 | One channel pair | One channel pair | $I^2S$ signal sharing |
| Flexcomm 6 | One channel pair | Four channel pairs | $I^2S$ signal sharing |
| Flexcomm 7 | One channel pair | Four channel pairs | $I^2S$ signal sharing |
| Maximum channels can be used together | Seven channel pairs (14 channels) | 13 channel pairs (26 channels) | ***Note:*** *Flexcomm 3 is excluded from $I^2S$ sharing.* |

As shown in Table 1, with the $I^2S$ pin sharing feature, `sys_ctr` module, combine multiple FlexComm to drive a single $I^2S$ interface with different channels served by separate FlexComm. LPC55S6x/LPC55S2x/LPC552x can support up to 13 channels, and LPC55S3x/LPC553x/LPC55S1x/LPC551x can support up to 26 channels.

## 4 Note about the source code in the document

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## 5 Revision history

Table 2 summarizes the revisions to this document.

**Table 2. Revision history**

| Revision number | Release date | Description |
|---|---|---|
| 2 | 05 September 2023 | Updated Section 2.2 |
| 1 | 5 January 2022 | Add LPC55S3x/LPC553x in Table 1 |
| 0 | September 2020 | Initial release |

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