

1 Introduction

1.1 Background

USB is very well 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.

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The LPC5500 MCU series leverages Arm[®]'s most recent Cortex[®]-M33 technology, 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 I²S and I²C. As some of them have DSP accelerator, LPC5500 devices are very 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 and is the most commonly used layout in home theatres. It uses five full bandwidth channels and one low-frequency effects channel.

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



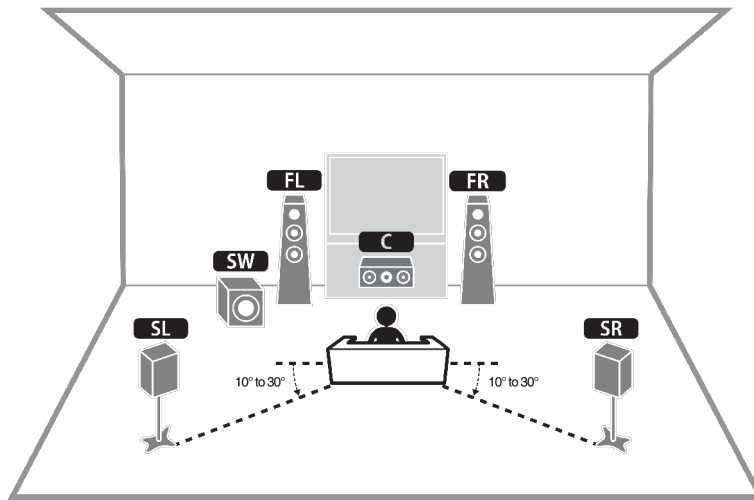


Figure 2. 5.1 surround sound

2 Mechanism and implementation

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

2.1 Mechanism

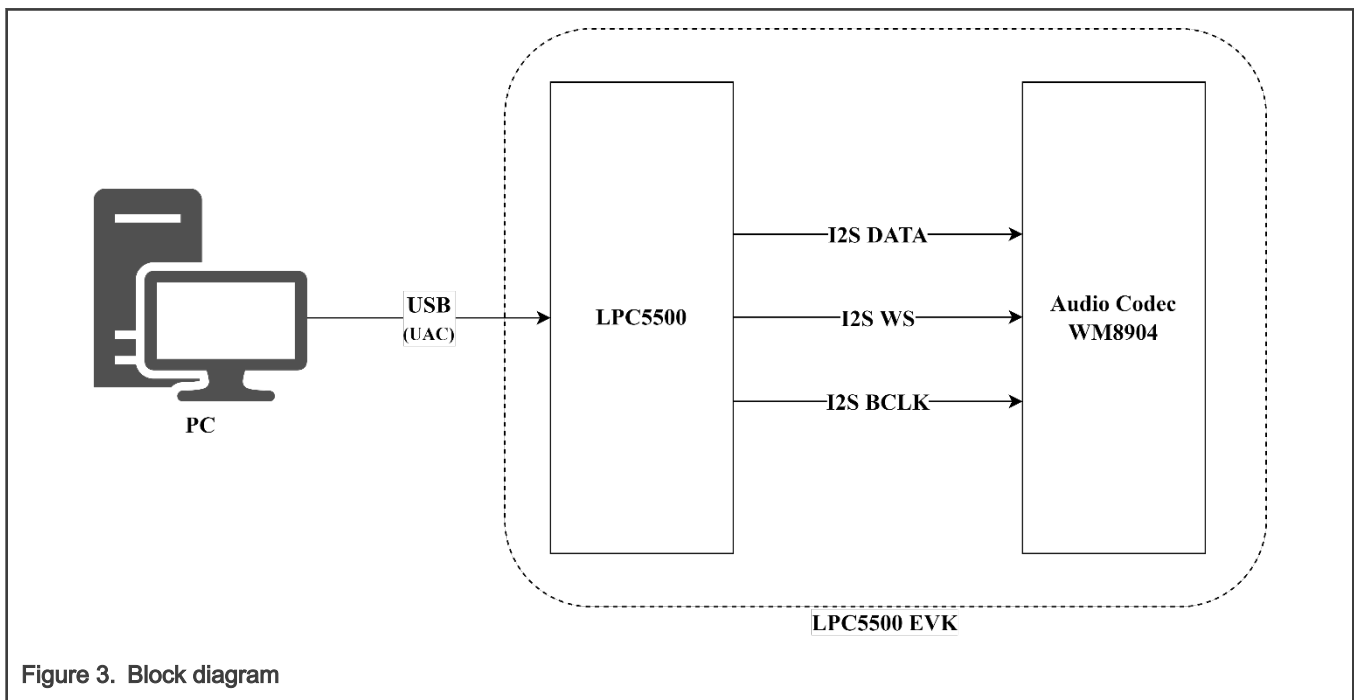


Figure 3. Block diagram

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 enumerates 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. Usually computer manufacturers spend most of the overall budget on the processors and screen, 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. UAC 1.0 devices can give a big improvement in sound compared to computer's own headphone output, however UAC 2.0 will take one step further. UAC 1.0 can send up to a maximum of 24-bit/96kHz data, but playing studio master quality files will require a step up to Class 2, which supports up to 24 bit/192 kHz resolution data.

The PC sends the audio data over USB to the LPC5500, which in turn passes this to the audio codec on the evaluation board.

Six channels 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, it means each channels has two 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 of which can be configured as I²S. With `sys_ctrl`, I²S signal sharing, it can fully output data of six channels.

NOTE

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

In order 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

`usb_device_audio_speaker` in MCUXpresso SDK has supported 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 96k, 32bit, 5.1 channels, USB HS is required.

```

/*! @brief LPC USB IP3511 FS instance count */
#define USB_DEVICE_CONFIG_LPCIP3511FS (1U)

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

```

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
#define USB_DEVICE_CONFIG_AUDIO_CLASS_2_0 (1U)
#endif

```

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. */
#define USB_AUDIO_UAC5_1 (0)

```

The default value, (0), is supporting two-channel stereo. Therefore, we should modify it to 1U.

```

/*! @brief Whether UAC 5.1 is enabled or not. */
#define USB_AUDIO_UAC5_1 (1)

```

Finally, if USB host meets three conditions in the following code snippet, the following macro in usb_device_descriptor.h is required to be enabled and modified to 1U. For Linux or Mac OS, this macro is not required to be enabled.

```

/*! @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
*/
#define USB_DEVICE_WORKAROUND_AUDIO_20_WINDOWS (0U)

```

After completing these modifications, compile and download to the EVK board. Connect HS or FS port (based on the settings shown above) to PC via a USB cable. The function can be tested on PC, as shown in [Figure 4](#) and [Figure 5](#).

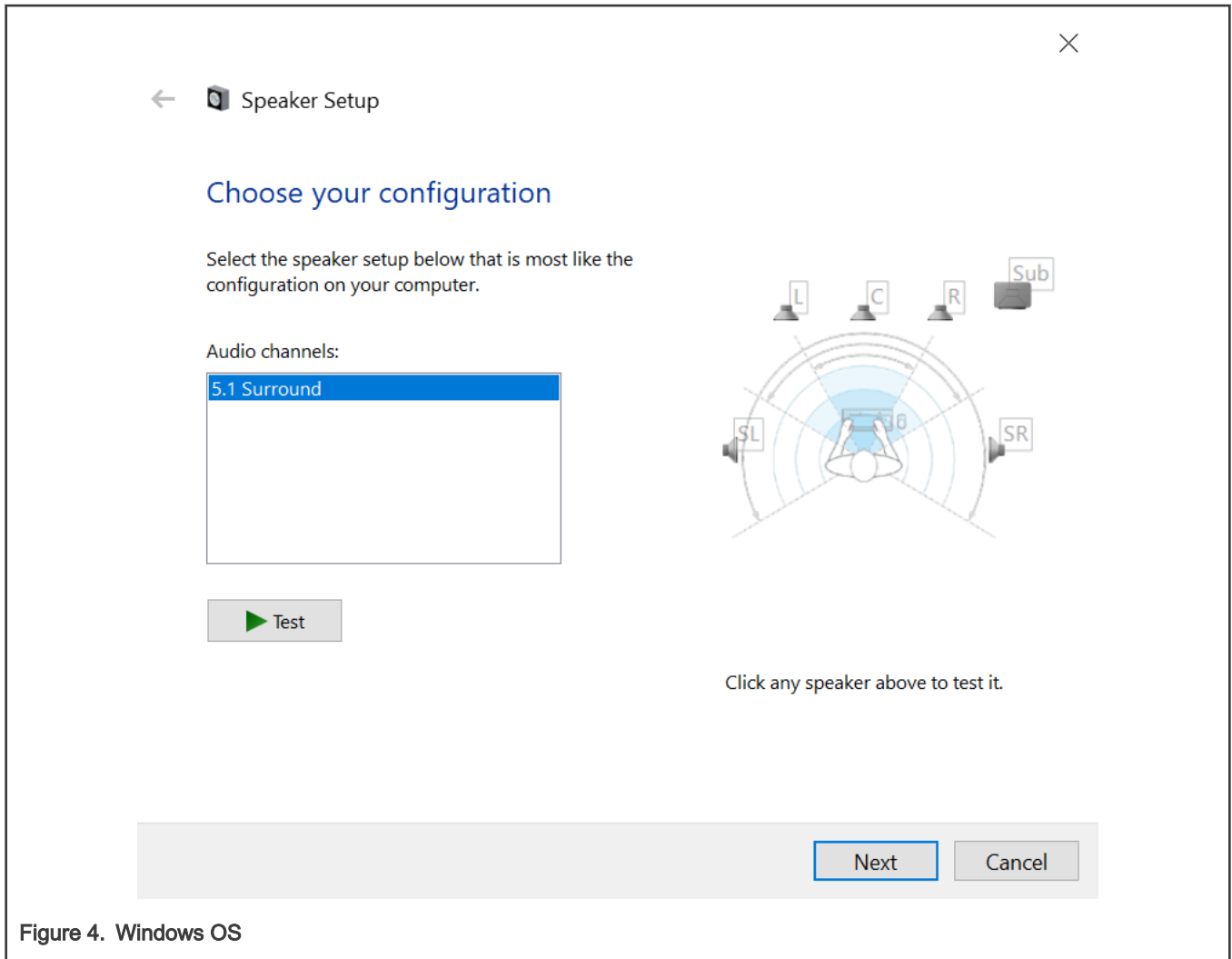


Figure 4. Windows OS

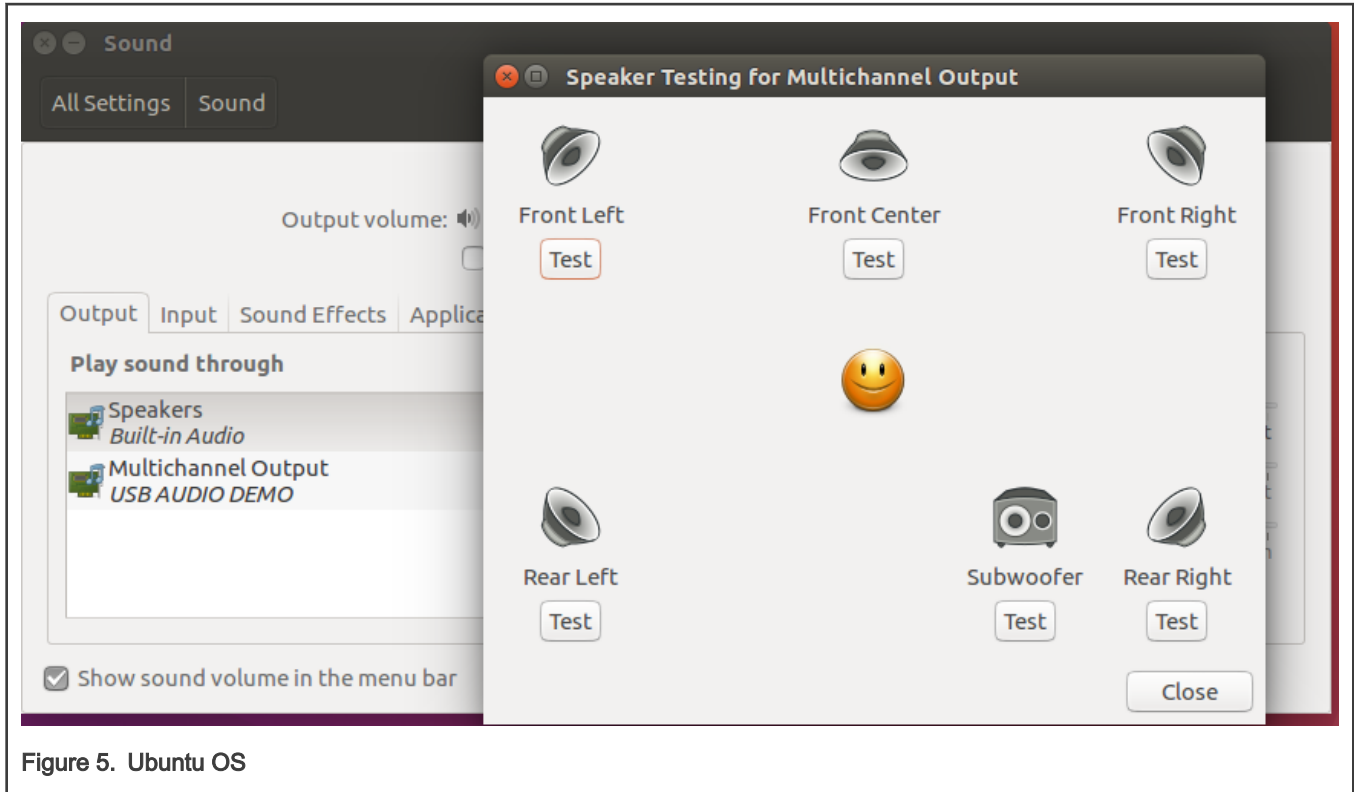


Figure 5. Ubuntu OS

3 Summary

As mentioned above, LPC5500 is very suitable for USB audio applications. These devices include high-speed and full-speed USB and flexible serial communication peripherals (which can be configured as I²S interface). Some of them have the PowerQuad DSP accelerator 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 ² S		sys_ctrl signal sharing
	LPC55S6x/LPC55S2x/LPC552x	LPC55S1x/LPC551x	All LPC5500
Flexcomm 0	1 channel pair (2 channels)	1 channel pair (2 channels)	I ² S signal sharing
Flexcomm 1	1 channel pair	1 channel pair	I ² S signal sharing
Flexcomm 2	1 channel pair	1 channel pair	I ² S signal sharing
Flexcomm 3	1 channel pair	1 channel pair	Excluded from I²S sharing
Flexcomm 4	1 channel pair	1 channel pair	I ² S signal sharing
Flexcomm 5	1 channel pair	1 channel pair	I ² S signal sharing
Flexcomm 6	1 channel pair	4 channel pairs	I ² S signal sharing
Flexcomm 7	1 channel pair	4 channel pairs	I ² S signal sharing

Table continues on the next page...

Table 1. Flexcomm interfaces (continued)

Flexcomm interface number	I ² S		sys_ctrl signal sharing
	LPC55S6x/LPC55S2x/LPC552x	LPC55S1x/LPC551x	All LPC5500
Maximum channels can be used together	7 channel pairs (14 channels)	13 channel pairs (26 channels)	<p style="text-align: center;">— NOTE —</p> <p style="text-align: center;">Flexcomm 3 is excluded from I²S sharing.</p>

As shown in [Table 1](#), with I²S pin sharing feature, `sys_ctrl` module, we could combine multiple FlexComm to drive single I²S interface with different channels served by sperate FleXComm. LPC55S6x/LPC55S2x/LPC552x can support up to 13 channels, and LPC55S1x/LPC551x can support up to 26 channels.

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