Audio Driver Support for Home Theater Speaker Configurations

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Abstract

This paper provides information about audio drivers for the Microsoft® Windows® family of operating systems. It presents guidelines that audio device and system vendors can follow to provide hardware and software support for home theater speaker configurations and multichannel audio stream formats. Beginning with Service Pack 2 for Microsoft Windows XP and in Service Pack 1 for Microsoft Windows Server™ 2003, the Windows multimedia control panel provides support for a new 7.1-channel stream format for home theater systems.

This information applies for the following operating systems:
 Microsoft Windows XP
 Microsoft Windows Server 2003
 Windows Vista®

The current version of this paper is maintained on the Web at:
<http://www.microsoft.com/whdc/device/audio/SpkrConfig.mspx>

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Document History

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Introduction

This paper provides information about audio drivers for the Microsoft® Windows® family of operating systems. It provides guidelines that audio device vendors can follow to provide support for home theater speaker configurations and multichannel audio stream formats.

To help provide audio driver support for home theater systems, Microsoft has defined a new 7.1-channel speaker configuration for Microsoft Windows XP and later. This configuration is supported in Service Pack 2 (SP2) for Windows XP, in SP1 for Microsoft Windows Server™ 2003, and in Microsoft's next-generation operating system, Microsoft Windows Vista®. It is not supported in the original release of Windows XP, in Windows XP with SP1, or in the original release of Windows Server 2003.

As shown on the left side of Figure 1, the Windows multimedia control panel (mmsys.cpl) assigns the name **7.1 home theater speakers** to the new 7.1-channel speaker configuration. The older 7.1-channel configuration, which is supported in Windows 98/Me and in Windows 2000 and later, is shown on the right side of Figure 1. In Windows XP with SP2, the multimedia control panel assigns the name **7.1 wide configuration speakers** to the older configuration.



Figure 1. 7.1-Channel Speaker Configurations in the Multimedia Control Panel

In Windows XP with SP2, you can find the two configurations shown in Figure 1 by following these steps:

1. In Control Panel (category view), click **Sounds, Speech, and Audio Devices**.
2. In the **Sounds, Speech, and Audio Devices** dialog box, under **Pick a task**, click **Adjust the system volume**.
3. In the **Sounds and Audio Devices Properties** dialog box, on the **Volume** tab, under **Speaker settings**, click **Advanced**.
4. In the **Advanced Audio Properties** dialog box, under **Speaker setup**, open the drop-down menu and select one of the two 7.1 speaker configurations.

The configuration on the right side of Figure 1 is the Sony Dynamic Digital Sound (SDDS) configuration, which was introduced in 1993 for use in motion picture theaters. However, few, if any, home theater systems use this configuration. Instead, 8-speaker home theater systems are likely to use the new 7.1 configuration shown on the left side of Figure 1. In addition, little home theater content has been authored for the SDDS configuration, and users can expect most of the available 7.1-channel content to be formatted for the new 7.1 configuration.

Although the new **7.1 home theater speakers** configuration largely supplants the old **7.1 wide configuration speakers** configuration, Windows will continue to support the old configuration, to provide backward compatibility.

In Windows XP with SP2, Windows Server 2003 SP1, and Windows Vista, the 5.1-channel configuration remains unchanged, with channels 5 and 6 assigned to the back-left and back-right speakers, respectively. In contrast to the 7.1-channel configuration, these Windows versions do not define a new 5.1 format descriptor to distinguish the 5.1 side-speaker configuration from the 5.1 back-speaker configuration. Because the two configurations are so similar, defining two 5.1 configurations might have caused confusion among users regarding which configuration to use and whether to play content authored for one configuration on the other configuration. When positioning the speakers in a 6-speaker home theater system, users tend not to distinguish between side and back speaker positions. Instead, speaker positioning is more likely to be determined by the shape of the room and the placement of the furniture in the room. Defining separate 5.1 speaker configurations for side and back speakers would cause unnecessary confusion among typical users for very little benefit.

The 5.1-channel side-speaker configuration is shown in Figure 2, which is taken from the multimedia control panel in Windows XP with SP2. The 5.1-channel speaker configuration is named **5.1 surround sound speakers**.



Figure 2. 5.1-Channel Speaker Configuration in the Multimedia Control Panel

Although the differences between the 5.1-channel side-speaker and back-speaker configurations might be transparent to users, they are not transparent to audio hardware vendors. As mentioned previously, 5.1-channel content is typically authored for side speakers rather than for back speakers. Thus, when playing 5.1-channel content through the **7.1 home theater speakers** configuration shown on the left side of Figure 1, the vendor should ensure that the two side-speaker channels in the 5.1-channel stream play through the side speakers rather than the back speakers. Similarly, when playing content authored for the **7.1 home theater speakers** configuration through a 5.1 speaker configuration with side speakers, the channels for the 7.1 side speakers most naturally map to the side speakers in the 5.1 configuration. For an audio device with stream-processing capabilities, another alternative is for the device to attempt to preserve the content in channels 4 and 5 by mixing them with channels 6 and 7 before playing them through the side speakers in the 5.1 configuration.

# Multichannel Stream Formats

In Windows, the WAVEFORMATEXTENSIBLE structure defines the data format for a multichannel pulse coded modulation (PCM) audio stream. This structure specifies parameters such as the number of bits per PCM sample, the number of channels in the stream, and the channel mask. The channel mask specifies the mapping of channels to speakers. Figure 3 shows the individual bits in the channel mask.



Figure 3. Channel Mask

Each bit in the channel mask represents a particular speaker position. If the mask assigns a channel to a particular speaker position, the mask bit representing that position is set to one; all mask bits for unassigned speaker positions are zero. The WAVEFORMATEXTENSIBLE structure defines additional bits in the channel mask that are not shown in Figure 3, but these bits have no bearing on the discussion in this paper and are omitted for simplicity. For more information, see the Windows Device Driver Kit (DDK).

Table 1 shows the meaning of each mask bit in Figure 3.

Table 1. Channel Mask Bit Definitions

|  |  |  |
| --- | --- | --- |
| Bit number | Speaker position | Description |
| 0 | FL | Front left |
| 1 | FR | Front right |
| 2 | FC | Front center |
| 3 | LFE | Low-frequency effects |
| 4 | BL | Back left |
| 5 | BR | Back right |
| 6 | FLC | Front left of center |
| 7 | FRC | Front right of center |
| 8 | BC | Back center |
| 9 | SL | Side left |
| 10 | SR | Side right |

For example, the **7.1 home theater speakers** configuration shown on the left side of Figure 1 is described by a channel mask value of 0x63F, which indicates that the 8 channels in the stream are assigned to the following speaker positions (and in the following order): FL, FR, FC, LFE, BL, BR, SL, and SR. For another example, the **7.1 wide configuration speakers** configuration shown on the right side of Figure 1 is described by a channel mask value of 0xFF, which indicates that the 8 channels in the stream are assigned to the following speaker positions: FL, FR, FC, LFE, BL, BR, FLC, and FRC.

Figure 4 shows the correspondence between the channel mask 0x63F and the **7.1 home theater speakers** configuration.



Figure 4. 7.1 Home Theater Speakers Recording and Playback

The left side of Figure 4 shows the recording of audio content into the **7.1 home theater speakers** stream format. The small circle at the center of the grid represents the listener's position. Each small, black rectangle represents a microphone. The eight channels are numbered from 0 to 7. The FL microphone records into channel 0, the FR microphone records into channel 1, and so on.

The right side of Figure 4 shows the same 7.1-channel stream being played back through an 8-speaker surround configuration. In this case, each small, black rectangle represents a speaker. Seven of the speakers are mapped to positions on the grid surrounding the listener. The mapping does not assign a grid position to the LFE speaker (subwoofer); this omission is based on the assumption that these speakers typically produce only low-frequency sounds, which are nondirectional.

# Mapping Stream Formats to Speaker Configurations

When asked to play a stream format that does not match the audio device's speaker configuration, the audio driver has several options:

Decline to play the stream.

Play the stream by performing a one-to-one mapping of individual channels to speakers. If any channels are left over after a channel has been mapped to each the speaker, discard the leftover channels. Conversely, if any speakers are left over after all the channels have been assigned to speakers, play silence through the leftover speakers.

Play the stream by mixing the channels in the original stream to generate precisely the number of channels required for the speaker configuration. If there are more channels in the original stream than there are speakers, this approach avoids loss of the content that would result from simply discarding the excess channels. The mixing and format conversion can be performed in software or hardware.

Regarding the third option, the driver should avoid directly performing software mixing. Instead, the hardware vendor should install a software module called a global effects (GFX) filter to process the stream before it reaches the audio device. For more information about GFX filters, see the Windows DDK.

## Playing a 5.1-Channel Stream on a 7.1 Speaker Configuration

For example, Figure 5 shows a stream that is recorded for a **5.1 surround sound speakers** configuration (left) but is played through a **7.1 home theater speakers** configuration (right).



Figure 5. Playing a 5.1 Stream on a 7.1 Speaker Configuration

In Figure 5, the recorded 5.1 format does not contain channel information for the BL and BR speaker positions in the 7.1 speaker configuration. Thus, these two speakers are silent. (Another, more difficult alternative would be for the audio device to synthesize two additional channels for the BL and BR speakers by mixing the content from the original six channels in the recording.)

According to the bit definitions in Figure 3, the channel mask for recording the 5.1 stream shown on the left side of Figure 5 should be 0x60F, which assigns the six channels to the following speaker positions: FL, FR, FC, LFE, SL, and SR. (This is the side-speaker 5.1 configuration discussed earlier.) In fact, the channel mask for the 5.1 stream is 0x3F rather than 0x60F for reasons that were mentioned previously and will now be explained in detail.

In earlier versions of Windows (Windows 98/Me, Windows 2000, Windows XP with SP1, and Windows Server 2003), the interpretation of the channel mask 0x3F is that it assigns the six channels in the 5.1 format to the following speaker positions: FL, FR, FC, LFE, BL, and BR. (This is the back-speaker 5.1 configuration.) However, the interpretation in Windows XP with SP2, Windows Server 2003 with SP1, and Windows Vista is different: by convention, the 5.1 format with the channel mask 0x3F is interpreted to mean the *side*-speaker 5.1 configuration instead of the *back*-speaker 5.1 configuration.

Interpreting the channel mask in this manner eliminates the requirement to introduce a second 5.1-channel format descriptor to distinguish the side-speaker 5.1 configuration from the back-speaker 5.1 configuration. These two configurations are so similar that typical users might have difficulty distinguishing between them. Although having only a single 5.1-channel format descriptor avoids confusing users, it does require hardware vendors to remember to interpret the 0x3F channel mask to mean that channels 5 and 6 are assigned to the SL and SR speaker positions instead of the BL and BR positions. In return for having to remember this special-case interpretation of the channel mask for a 5.1 stream, vendors can spare users the difficulty of distinguishing between two very similar 5.1-channel format descriptors.

Vendors who believe that at least some of their users might want to distinguish between the side-speaker 5.1 configuration and back-speaker 5.1 configuration have the option of providing a user-interface (UI) program for this purpose. Through the UI, users can select whether channels 4 and 5 in a 5.1-channel stream should drive the back speakers rather than the side speakers in a **7.1 home theater speakers** configuration.

## Playing a 7.1-Channel Stream on a 5.1 Speaker Configuration

Figure 5 shows a stream recorded for a **7.1 home theater speakers** configuration (left) being played through a **5.1 surround sound speakers** configuration (right). The channel mask for the 7.1-channel stream is 0x63F.



Figure 6. Playing a 7.1 Stream on a 5.1 Speaker Configuration

In this example, channels 6 and 7, which contain the data for the side speaker positions in the 7.1 configuration, play through the side speaker positions in the 5.1 configuration. The audio device simply discards channels 4 and 5, which contain the data for the back speaker positions in the 7.1 configuration, when it plays the stream on the 5.1 configuration. As mentioned previously, another alternative (not shown in Figure 6) is for the device to attempt to preserve the content in channels 4 and 5 by mixing them with channels 6 and 7 before playing them through the side speakers in the 5.1 configuration.

## System Mixer Behavior

In Windows 98/Me, Windows 2000, Windows XP, and Windows Server 2003, the multichannel audio streams that the audio device plays are typically generated by the software system mixer, kmixer.sys. Before the stream can begin playing, the system mixer and audio driver must negotiate a stream format that both mixer and driver can handle.

When asked to play a multichannel stream with a format that does not match the audio device's speaker configuration, the audio driver can decline the request, in which case the negotiation continues.

The system mixer can convert content from a 5.1-channel input stream into a 7.1-channel output stream (to the audio device), and vice versa, although it prefers to avoid such conversions to preserve the quality of the input stream. Thus, the system mixer begins the negotiation by asking the driver to accept a stream with the same format as the highest quality input stream to the system mixer. Typically, this means that if the system mixer has an input stream in a 5.1- or 7.1-channel format, it will ask the driver to accept a stream in the same format. If the driver rejects this format, the system mixer continues negotiating by asking the driver if it can handle other stream formats.

For example, if the driver for an audio device with a 5.1 speaker configuration declines a request from the system mixer to play a 7.1-channel stream, the system mixer continues the negotiation by offering to convert the 7.1-channel stream to a 5.1-channel stream. If the driver accepts this format, the system mixer performs the stream conversion for the driver.

When designing an audio driver, the driver writer must decide whether to handle its own format conversions (as shown in Figures 4 and 5) or rely on the system mixer to do the conversions. The driver might need to perform its own conversions in either of the following situations:

If the driver requires the conversion to be performed in a manner that differs from the conversion performed by the system mixer.

If the driver must play streams that bypass the system mixer.

In the second situation, a stream can bypass the system mixer if is being played from a Microsoft DirectSound® hardware-accelerated buffer directly to a hardware-mixing pin on the audio device. Also, some "pro audio" applications send their streams directly to the audio device either to avoid the latency of the system mixer or to prevent the mixing process from altering the digital sample values in the original audio stream.

In Windows XP with SP2 and Windows Server 2003 with SP1, if the system mixer produces a 5.1-channel output stream, the mixer always sets the stream's channel mask to 0x3F. The system mixer behaves this way even if it receives a 5.1-channel input stream with a channel mask of 0x60F. With this behavior, an audio driver never receives a 5.1-channel stream with a channel mask of 0x60F from the mixer.

If the system mixer receives a 7.1-channel input stream with a channel mask of 0x63F and produces a 5.1-channel output stream (with a channel mask of 0x3F), the mixer copies channels 6 and 7 in the input stream to channels 4 and 5 in the output stream. The mixer discards channels 4 and 5 (for the two back speakers) from the 7.1-channel input stream. This behavior ensures that the channels containing the content for the two side speakers in the 7.1-channel stream play through the side speakers in the 5.1 speaker configuration.

# Header File Changes

The Windows DDK contains two header files that define the speaker configurations that are supported by the Windows multimedia control panel:

ksmedia.h defines the channel masks for the KSAUDIO\_CHANNEL\_CONFIG structure that is used by the KSPROPERTY\_AUDIO\_CHANNEL\_CONFIG property request.

dsound.h defines a list of speaker-configuration identifiers that can be submitted to the **IDirectSound::SetSpeakerConfig** method.

In earlier versions of Windows (Windows 98/Me, Windows 2000, Windows XP with SP1, and Windows Server 2003), ksmedia.h defines the channel masks shown in Table 2 for 5.1- and 7.1-channel streams.

Table 2. Old Channel Mask Definitions

|  |  |  |
| --- | --- | --- |
| Parameter name | Channel mask | Speaker positions |
| KSAUDIO\_SPEAKER\_5POINT1 | 0x3F | FL, FR, FC, LFE, BL, BR |
| KSAUDIO\_SPEAKER\_7POINT1 | 0xFF | FL, FR, FC, LFE, BL, BR, FLC, FRC |

The two channel masks in Table 2 represent the **5.1 surround sound speakers** configuration in Figure 2 and the **7.1 wide configuration speakers** configuration on the right side of Figure 1. To identify these same two speaker configurations, dsound.h defines the following speaker-configuration IDs:

 #define DSSPEAKER\_5POINT1 0x00000006

 #define DSSPEAKER\_7POINT1 0x00000007

In Windows XP with SP2, Windows Server 2003 with SP1, and Windows Vista, ksmedia.h defines the channel masks shown in Table 3 for 5.1- and 7.1-channel streams.

Table 3. New Channel Mask Definitions

|  |  |  |
| --- | --- | --- |
| Parameter name | Channel mask | Speaker positions |
| KSAUDIO\_SPEAKER\_5POINT1 | 0x3F | FL, FR, FC, LFE, SL, SR |
| KSAUDIO\_SPEAKER\_7POINT1 | 0xFF | FL, FR, FC, LFE, BL, BR, FLC, FRC |
| KSAUDIO\_SPEAKER\_7POINT1\_SURROUND | 0x63F | FL, FR, FC, LFE, BL, BR, SL, SR |

By comparing Tables 2 and 3, two changes are apparent:

The meaning of the channel mask 0x3F in Table 2 has changed to indicate the side-speaker 5.1 configuration (with SL and SR) instead of the back-speaker 5.1 configuration (with BL and BR). This is a special-case interpretation that overrides the usual meaning of the channel mask bits shown in Figure 3.

A new channel mask with the value 0x63F is supported. This channel mask represents the **7.1 home theater speakers** configuration, which is shown on the left side of Figure 1.

To represent the same set of speaker configurations, dsound.h defines the following speaker-configuration IDs:

 #define DSSPEAKER\_5POINT1 0x00000006

 #define DSSPEAKER\_7POINT1 0x00000007

 #define DSSPEAKER\_7POINT1\_SURROUND 0x00000008

 #define DSSPEAKER\_7POINT1\_WIDE DSSPEAKER\_7POINT1

DSSPEAKER\_7POINT1\_SURROUND represents the new **7.1 home theater speakers** configuration in the media control panel. DSSPEAKER\_7POINT1 and DSSPEAKER\_7POINT1\_WIDE are both names for the same **7.1 wide configuration speakers** configuration.

# Call to Action

For system manufacturers: Test your audio drivers with the new 7.1 speaker configuration by playing both 5.1- and 7.1-channel content.

For device manufacturers: Decide how you want your audio device to play 5.1-channel content through a 7.1 speaker configuration and how you want it to play 7.1-channel content through a 5.1 speaker configuration.

For driver developers: Do not simply assume that the channel mask for a 7.1-channel stream is always 0xFF. It is more likely to be 0x63F. Also, remember that Windows treats the channel mask 0x3F for a 5.1-channel stream as a special case.

If you have questions about providing hardware and software support for multichannel audio formats, send e-mail to UAA@microsoft.com.

# References

Multichannel Audio Formats

For information about Windows multichannel audio formats, see the white paper titled *Multiple Channel Audio Data and WAVE Files* at <http://www.microsoft.com/whdc/device/audio>.

For general information about Windows audio formats, channel masks, and the WAVEFORMATEXTENSIBLE structure, see the audio driver design section in the Windows DDK.

For information about DirectSound, see the Platform Software Development Kit (SDK).

Other Resources

Microsoft Hardware and Driver Central

(includes Windows Driver Development Kits [DDK], Windows Hardware Compatibility Test [HCT] Kits, and Windows Logo Program requirements)
<http://www.microsoft.com/whdc/default.mspx>