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EAX® 4.0

Introduction

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EAX 4.0

Introduction

This document describes version 4.0 of Creative®'s EAX™ property sets, which can be used with OpenAL or with the Microsoft® DirectX™ game and multimedia-programming environment. EAX allows applications to apply digital effects processing to 3D sounds. These include both effects for 3D audio, such as environmental reverberation, reflection, occlusion, obstruction, and some studio-style effects like chorus, flanger, echo, EQ, and distortion.

This document introduces EAX, and describes its role in interactive 3D audio experiences. The Guide is also a jumping-off point into the collection of additional documents and tools, which are included in the EAX 4.0 SDK. These include the *EAX 4.0 Sound Designer's Guide*, and the *EAX 4.0 Programmer's Guide*, which feature more in-depth information on acoustical design and technical topics respectively.

Introducing EAX

EAX 4.0 gives the application developer access to a collection of powerful DSP effects for processing sound. Surround sound is today recognized as an essential component in the creation of a believable virtual world. The EAX 4.0 SDK is focused primarily towards the reproduction of realistic positional audio in 3D environments.

The ability to use multiple effects means that with EAX 4.0, the developer can now simulate several different acoustic spaces at once. Add to this the provision of generic studio-style effects, and it becomes clear that the range of sound enhancement possibilities is drastically increased.

Modern graphics processors enable the developer to render beautiful and lifelike scenes in three dimensions. By introducing a completely new level of sophistication into audio processing, EAX 4.0 brings exceptional audio to the table, taking your virtual world a huge step closer to realism.

OpenAL and DirectSound Solutions

OpenAL or Microsoft's DirectSound (the aural component of DirectX) provide a major first step for creating a realistic 3D aural world: each provides an easy-to-use programming interface for 3D aural modeling in C or C++. You can use OpenAL or DirectSound to control separate sound sources, allowing them to move around realistically in the 3D aural world along with their corresponding objects in the 3D visual world: as the berserk warrior falls off the cliff, the player perceives his scream going with him.

OpenAL and DirectSound keep the practical details of audio hardware at arm's length from the programmer. The programmer uses the relatively simple API to create sound sources, set their 3D positions and velocities (if moving), and take care of other decisions about the quality and placement of sounds in the aural world. OpenAL or DirectSound, through the audio driver installed in a computer, does the work of translating sound-source waveforms, positions, velocity, and more into a mix that ultimately comes out in realistic 3D form through the player's speakers or headphones.

Although OpenAL and DirectSound provide a number of sophisticated 3D aural effects such as distance based roll-off, directivity, and Doppler Shift, they lack some very important environmental effects: reverberation, reflections, and sound occlusion or obstruction by intervening objects. Without these environmental effects, a listener can tell the direction of each sound source, but has a more difficult time pinpointing how far away the sources are. In addition, the listener has no idea of the environment where the sources are located.

Consider a sword clanked in a small padded cell. It should sound much different to the same sword clanked in a large cathedral, and reverberation tells the story. Alternatively, consider a scream coming from the next room. The occluded (muffled) quality of the scream tells you there is a wall in between you and the screamer. Without environmental audio effects, sound sources are naked and lack warmth — the aural equivalent of a visual world without shadows, haze, and independent light sources.

OpenAL and DirectSound lack facilities for applying hardware accelerated post-production style effects in real-time. Effects such as distortion, EQ, and pitch shifting

are all vital components in the sound designers' toolbox. With no facilities to apply and tweak this type of effect at run time, it can be cumbersome to generate variations on sound samples. Without variation and change, an application's sound track can become sterile and repetitive.

EAX's Solutions

Creative's EAX API adds a number of audio effects to OpenAL or DirectSound. In the case of OpenAL, EAX is provided as an OpenAL extension. With DirectSound, the EAX property sets rely upon the DirectSound API and COM (Component Object Model), used throughout the DirectX environment.

Multiple 'effects slots' are defined, and using EAX's programming interfaces you can select an effect type for each slot. Available effect types include multi-channel reverberation as well as more generic stereo effects such as chorus, flanger, distortion, and echo.

Each effect type has a number of parameters, which can be adjusted to control the effect's output. For example, with a reverberation effect selected, you can control the overall quality of the reverberation the listener hears, tweaking factors such as:

- The apparent size of the room surrounding the listener.
- The duration and tonal color of the reverberation's decay.
- The amount and delay of reflections and reverberation.

You can adjust EAX properties for each 3D sound source in your application. For example, you can alter the amount of sound sent to the different effect slots, or control occlusion, obstruction, and exclusion effects for individual sources.

Environmental Effects

The Environmental effects such as reverb and reflections combine to add a visceral realism to the 3D aural environment, an often subliminal context that can give an emotional depth to the 3D world of the player. All of this works even when the visual component of the 3D world is out of sight. Think, for example, of a single candle next to a pond of water in dark surroundings. When a drop of water hits the pond and you hear long and luscious reverberation on the plink of the drop, your mind senses the vast cavern surrounding the pond even though you cannot see it.

3D Enhancements

Because EAX is thoroughly integrated with OpenAL and DirectSound, it can greatly enhance the 3D aural world. These enhancements include a much more robust perception of individual sound source distance or proximity that establishes the depth of the sound scene. When you move a sound source in relation to the listener, EAX can automatically adjust the reverberation for the sound source (increasing the ratio of reverberation for a source moving away, for example) to simulate the behavior of natural environments. None of OpenAL or DirectSound's 3D effects are lost in the mix; they are augmented with reverberation calculated to enhance the feeling of three dimensions.

Environmental Filtering

Environmental filtering effects simulate the way that sound is muffled when passing through an intervening wall, around an obstacle or through an opening. These effects are a fundamental part of the positional audio experience. Sound sources that are hidden behind a pillar or a wall are perceived very differently from sound sources that have an unobstructed path to the listener's ears. Without these important audio cues, the virtual 3D world is an artificial and unconvincing place.

EAX also includes extensions to the "sound cone" model that DirectSound and OpenAL provide to represent the radiation pattern of sound sources. This allows you to simulate the distinct muffling and filtering effects that affect the direct-path sound or the environmental reverberation for each source according to its directivity at low and high frequencies and to its orientation with respect to the listener. (Modeling these effects makes a noticeable difference when the source is the voice of a character facing away from the listener, for instance.)

What is new in the EAX 4.0 API?

Version 3.0 of EAX provided solely environmental effects in the form of a single reverberator capable of rendering environmental reverb and per-source filtering. EAX 4.0 does not offer any significant changes to the EAX 3.0 acoustic model – to the way EAX actually simulates acoustics. However, there are two very important innovations introduced by EAX 4.0: -

- *Multiple effect slots* – There are now multiple effect slots, each of which can host a hardware-accelerated environmental reverb or studio-style effect.

- *New studio-style effect types* – There are eleven new studio-style effect types, providing customizable post-production processing on sound sources.

Multiple effect slots

EAX 4.0 has been specifically designed to take advantage of the increasing processing power of modern PC audio hardware. Creative's SoundBlaster Audigy family of soundcards are capable of rendering effects on several independent audio streams simultaneously, and EAX 4.0 allows the developer to leverage this capability.

The previous EAX SDK release, version 3.0, offered the developer a single, fully adjustable environmental reverb effect. EAX 4.0 on Creative's SoundBlaster Audigy / Audigy2 hardware supports four effect slots. What's more, EAX 4.0's extendable interface can easily be updated when hardware becomes available with support for more effect processing. This in turn means that it will also be simple to update EAX 4.0 applications to support extra effect slots, new effect types, and enhanced signal routing features when new hardware and drivers make them available.

With EAX 4.0, multiple environmental reverb effects can be used together. This flexibility allows the developer to create a simulation where several acoustic spaces are realistically modeled. The EAX 4.0 interface allows each sound source to feed multiple effects, too. In the current SDK release, there is a practical limit: a source can feed two effect slots. Again, the extendable nature of the programming interface introduced by EAX 4.0 means that when hardware that is even more powerful is introduced, this number could be raised.

To ensure that concurrently running EAX 4.0 applications cannot interfere with one another's effect slots, causing unpredictable results, an application can designate an effect slot as locked. A program cannot load a new effect type into a slot that was previously locked by another application.

The audio processing configuration supported by EAX 4.0 is analogous to a studio audio mixer with four auxiliary effect sends. With auxiliary effects, each mixer channel can contribute to the input of an effect. The output of each of the effects is then added to the overall audio mix. This is in contrast to per-channel insert effects, which just treat the audio on an individual source channel.

Although EAX does not offer hardware-accelerated insert style effects, on the PC platform it is feasible to carry out the equivalent of insert effect processing on the host CPU. EAX is positioned at the end of the audio path, which means that if you have treated some audio with software insert effects, you can then stream it into hardware 3D sound channels for subsequent EAX auxiliary processing.

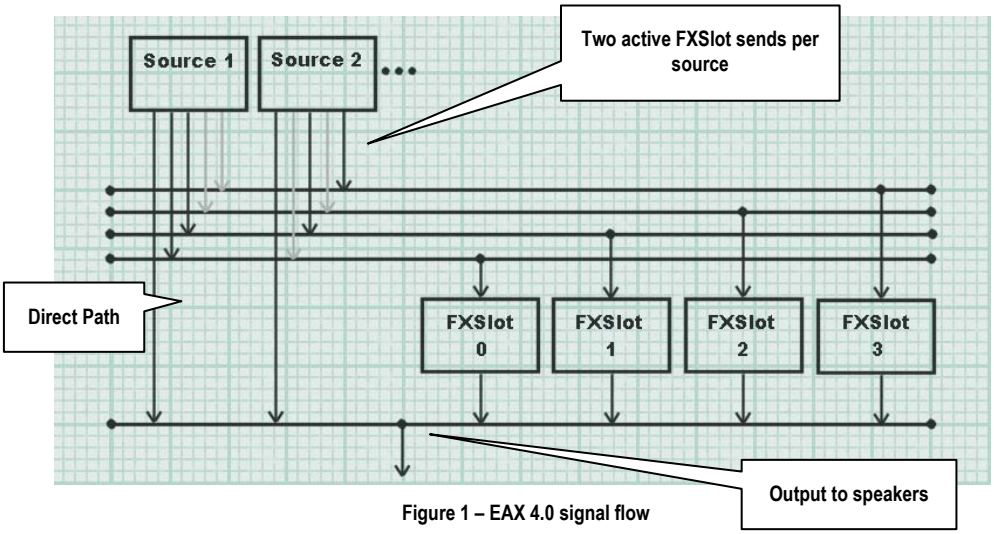

Figure 1 – EAX 4.0 signal flow

Studio-style effect types

The sophisticated environmental reverberation and filtering effects defined in EAX 3.0 have been carried forward largely unchanged to EAX 4.0. The provision of several effect slots opens up new possibilities for developers. However, sound designers might find it desirable to do more than simply render multiple environmental reverberation effects at once.

Studio effects are often employed by sound designers during production to adjust pre-recorded sound samples. For example, ring modulation can be used to make a cleanly recorded speech sample sound like an alien voice. With the right EQ applied, the voice will be perceived as though it has been transmitted through a limited bandwidth communication device like a telephone.

Imagine, then, the possibilities afforded by being able to apply these effects, and even adjust their parameters, in real time. Think of a multi-player on-line game employing Voice-Over-IP technology. Incoming communication streams can be altered with a vocal morpher, disguising other players' voices, making them sound like tinny robots or booming heroes!

Please note that, although the reverb effect provided in EAX is termed here as an 'environmental' reverb, it is not solely intended for use in simulating acoustical

environments in 3D worlds. Even if your application involves no notion of location, for example an audio sequencer, you can still take advantage of the EAX reverb for processing sound. So although it has a multi-channel output, the EAX reverb can be used as a studio-style effect.

The new studio-style effects that EAX 4.0 introduces are listed in Appendix 1 – EAX 4.0 effect types. Furthermore, EAX 4.0's interfaces have been designed to allow applications to support new effect types when they become available, without significant structural changes.

The Multi-environment model

The generic studio-style effects introduced in the previous section will surely be employed by developers and designers to produce fascinating results. However, the manner in which the effects are likely to be implemented will be very much specific to the application. For the purposes of the SDK tutorials and documentation, we will concentrate mainly on using EAX 4.0 to implement a general positional audio system with multiple environments – we will assume that the developer wants to use environmental reverb in all available effect slots.

EAX 3.0 – A single Environment

With EAX 3.0, it was possible to model a scenario where any sound source inside the listener's environment was affected by the acoustics of that environment. However, EAX 3.0 only supported a single reverberation engine. This means that there was no way to audibly indicate the presence of acoustically different spaces until the listener entered them. When the listener moved from one distinct acoustic space to another, parameter interpolation could be used to perform '*environment morphing*', to smooth the transition between different environments.

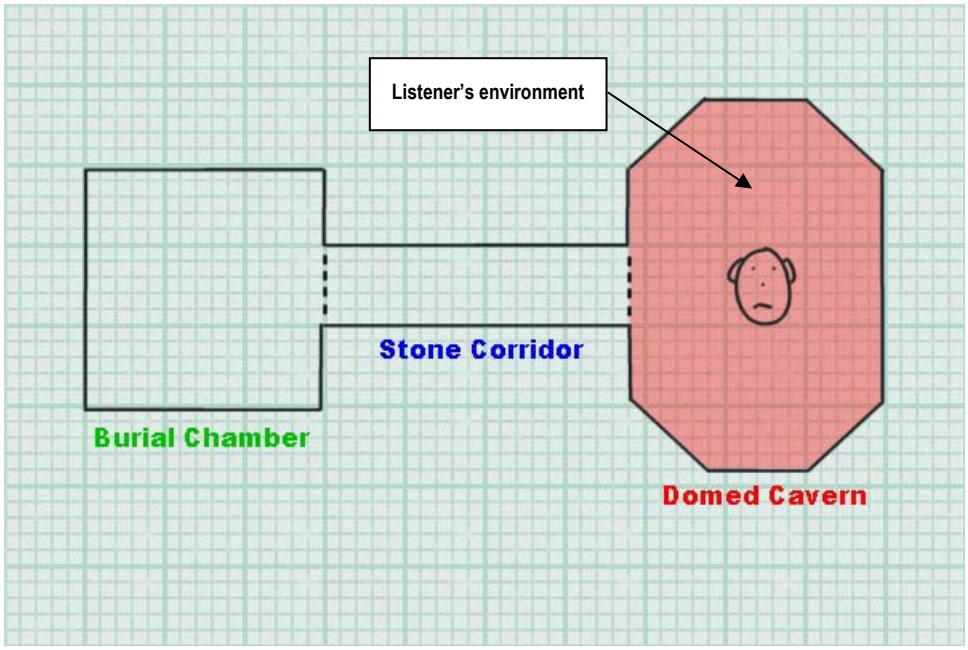

Figure 2 - With EAX 3.0, only a single environmental reverb can be rendered

EAX 4.0 – Multi-environments

An EAX 4.0 multi-environment implementation can provide a more realistic experience by enabling the user to hear acoustic information from rooms other than the one occupied by the listener.

In an EAX 3.0 application, if the player walks around the Domed Cavern in Figure 2, the sounds of the player's footsteps and breathing will be affected by the appropriate environmental reverb, hinting at the lofty proportions of the Cavern. So how can multi-environments enhance an application's soundscape? It becomes clearer when other rooms are also populated with sound sources

Add to our scenario the sound of flaming torches burning in the Stone Corridor. Without multi-environments, the best we can do is to apply some Environment filtering effects such as occlusion or exclusion to muffle the sound if the opening between the Corridor and the Cavern is blocked or if the flaming torch is instead audible through the opening.

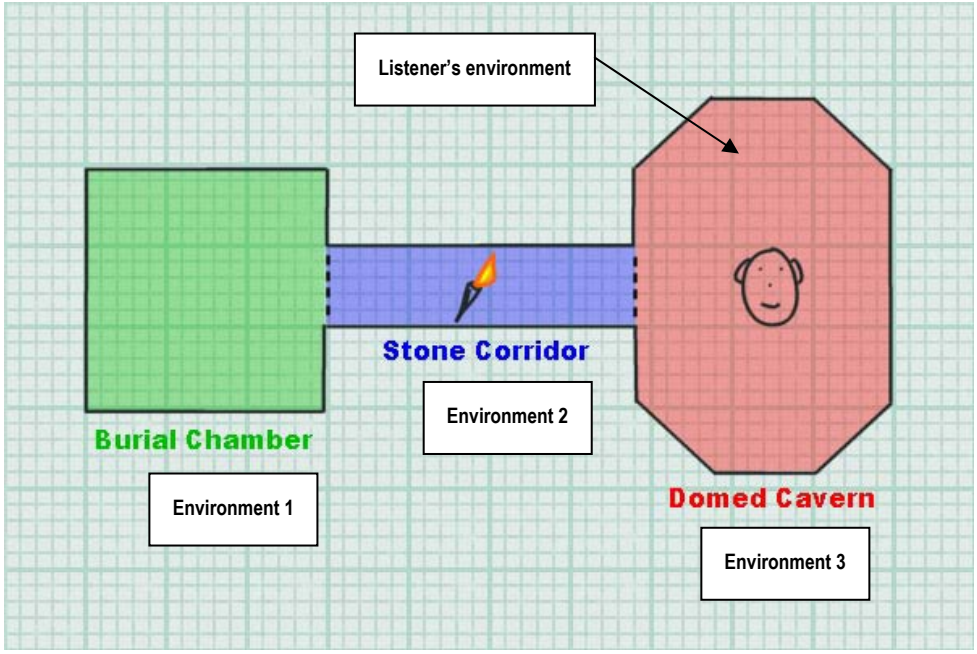

Figure 3 - EAX 4.0 allows multiple environments to be rendered simultaneously

However, in real life, as well as hearing the direct path of sound from the flaming torch to the listener's ear, the listener will also perceive some reflected sound with the acoustic signature of the source's own environment – the Stone Corridor. Of course, sounds generated inside the listener's environment, the Domed Cavern, will be reflected by the walls, generating that room's own acoustic effect too. The flaming torch probably will also contribute to the reverberation in the Domed Cavern. What's more, intervening walls and obstacles will modify each of these components of sound!

Using EAX 4.0's multi-environment capability, environmental reverbs can be rendered for both locations, and filtering effects applied to correctly muffle direct and reflected sound. Each acoustic phenomenon that we have identified can be simulated, resulting in an extremely lifelike aural simulation.

Hardware Compatibility

EAX has evolved considerably since its initial release in 1998. Up to its 2.0 version, EAX has been an open standard, and supported by most PC sound devices, which are capable of hardware-accelerating positional audio. However, EAX 4.0 effects demand considerable DSP power, and are exclusive to Creative Labs' SoundBlaster Audigy and Audigy2 range of soundcards.

Backwards Compatibility

The EAX 4.0 environmental reverb effect properties are a superset of the EAX 2.0 reverb, and this is the key to the EAX backwards compatibility policy. The EAX Unified interface, provided with the EAX 4.0 SDK, is an automatic translation mechanism, which helps developers to enable EAX 4.0 effects to be rendered on systems with less capable audio hardware.

At run-time, EAX Unified intelligently adapts EAX parameters to create 'best fit' versions of your effects on legacy systems. This means you can design your audio specifically for EAX 4.0, safe in the knowledge that it will also sound as good as possible on older systems given the lesser features of previous EAX versions. More information about EAX Unified can be found in the EAX Unified API guide and the EAX 4.0 programmer's guide.

Future Compatibility

The EAX 4.0 API has been specifically designed to be extendable. When hardware becomes available offering more effect slots, more different effect types and even more flexible routing, the EAX 4.0 interfaces can be simply extended to provide access to these extra capabilities. It will not be necessary to adopt a new paradigm, so in many cases it will be relatively trivial to adapt a sensibly written application to take advantage of improved hardware.

Effect Slot availability

Due to the EAX 4.0 effect slot locking policy, developers cannot assume that each slot will always be available for manipulation. Indeed, at the time of writing, Audigy's driver software will require that effect slot 0 must always host a reverb effect. Likewise, effect slot 1 is restricted to a chorus effect. These restrictions are implemented using the locking facility – these slots are flagged as locked by the driver. These limitations are in place to ensure compatibility with legacy applications.

Using EAX

With multiple effect slots available, and a choice of several different customizable effect types for each slot, there are many different approaches to using EAX 4.0 audio in your applications. In designing an EAX 4.0 audio implementation, you have important decisions to make in terms of both how you control the individual effects, and how you combine different effects together, to implement an audio engine capable of rendering the audio features your application demands.

These decisions will involve both the sound designer and the programmer. The designer must decide what audio effects should be heard, under what circumstances they should be heard, and what quality those effects should have. The programmer implements the elements of sound design, integrating them with the dynamic runtime events in the application, whilst managing the sound resources available. The sound designer should then be able to adjust settings to get the acoustic environments and special effects sounding just right.

Controlling effects

Environmental effects

Methods for controlling environmental effects range from a high-level approach where EAX does almost all of the work itself, to low-level approaches where a programmer can directly tweak all the tiny details of any effect. In this section, we will look at the levels of control that EAX offers, and at programming approaches to using those levels of control.

The EAX environmental reverberation effect provides an extensive set of parameters that you can tweak through properties. These parameters are layered. Some are high level, providing large overall effects; others are low level, providing customized control over elementary aspects of the aural sensation. How much direct control of sound design you want determines what parameters you will work with.

High-Level Control

For excellent environmental audio effects with very little programming work, you can use high-level properties. The simplest method is to set an *environmental preset*—that is, to specify the type of room in which you want the listener and/or sound sources located. Once you specify the room (using a single EAX call), the EAX engine can do all the rest of the work necessary to create the aural illusion of being in that room. It automatically controls the lower-level parameters to set the amount and quality of reverberation and reflections, to vary the direct-to-reflected sound ratio for each sound source as that source moves within the room, and much more.

All of the lower-level parameters are automatically computed for each source based on DirectSound's positional parameters and the environmental preset, which means that if you do not add obstruction or occlusion effects, you do not even have to set sound-source properties. In addition, because EAX uses a statistical reverberation model, you get convincing dynamic reverberation changes without having to provide a polygon-based description of room geometry.

If you would like to tweak an environmental preset, you can use other high-level properties to change aspects of the room until you essentially create a new type of room. You can change the size of the room, the amount of air absorption, the directivity settings of each source, and other parameters. The low-level parameters

affected by each of these high-level control methods are automatically adjusted by the EAX-enabled driver.

Low-Level Control

If you have specific intentions about exactly how each effect should sound, you can gain complete control of elementary environmental audio parameters through EAX's low-level properties. These properties set the minutiae of environmental parameters, those that are normally controlled automatically by high-level properties. Low-level properties include reverberation properties that set reverberation decay time, reflection and reverberation levels or delays, and reverberation diffusion. They also include, for each sound source, properties that adjust the intensities and filters of the direct-path sound and of the reverberation or effect sends.

Low-level properties directly control parameters that are additive offsets to the internal parameters set by higher-level properties. An environmental reverberation preset sets initial parameter values. Other high-level environment properties such as room size and air absorption tweak several environmental parameters one way or the other. Moreover, low-level properties tweak the environmental parameters even further in very localized ways.

Controlling studio-style effects

For EAX 4.0's studio-style effects, there is no equivalent to the environmental effect's high-level properties. Each of the studio effects can be controlled with its own unique set of parameters, the equivalent of the environmental reverb's low-level controls. For instance, the EAX 4.0 Chorus effect allows the developer to select a waveform, and set the effect's phase, rate, depth, feedback, and delay.

Configuring the EAX effect slots

EAX 4.0's multi effect capabilities give the programmer and sound designer another set of choices – just which effects will you use to process the sounds in your application? With numerous configurations to choose from, there are many ways that environmental reverb and studio-style effects can be combined to create compelling interactive audio. This section aims to help you make sense of the different strategies available to you, by suggesting some scenarios where applications make different use of the effect slots. First, let us briefly remind ourselves of the EAX 4.0 effect types, and how they relate to effect slot resources:

Environmental Reverberation

Environmental reverberation can be used to give a sense of location to 3D positional audio. Reverb effects can be designed to mimic the acoustic behavior of different rooms or spaces. Applying reverb to each sound, along with filtering on a per-source basis as appropriate, makes an audio scene far more life-like. The EAX reverb is a 3D effect – it works with 3D positioned buffers and it outputs to a surround mix. Each environmental reverb you want to render simultaneously will require one effect slot.

Studio-Style Effects

These effects are not simulations of acoustic phenomena – they have no relationship with the geometry of a three dimensional world. Rather, they are intended to be used to modify a subset of sound effects, or the application's overall aural feel. If you take advantage of their low-level tweak-ability to adjust these effects in real time, you can

add an extra level of interactivity and variability to your sounds, at a low cost in terms of resources. Each studio effect type you want to render simultaneously will require one effect slot. The EAX4 studio-style effect types include chorus, distortion, echo, parametric equalizer, pitch shifter (see Appendix 1 for a complete list).

Environmental and non-environmental effect slots

By default, the EAX engine assumes that effect slots contain "environmental" effects: it adjusts the per-source effect send levels and filters independently from the direct-path level and filter, so that the wet/dry mix is automatically corrected according to the distance, orientation, obstruction, or occlusion of each source. This is typically the desired behavior when the effect slot contains a reverb effect, and it may be applicable with other effect types such as echo and chorus (which can be used to simulate spaces).

If the effect is intended to modify the timbre of the source (such as with a distortion, a pitch shifter or a parametric equalizer), rather than immerse it in a space, then its effect slot should be configured as "non-environmental." In this mode, any attenuation or muffling applied by the EAX engine to the direct-path sound will also apply to the effect sends, thereby preserving the specified wet/dry mix irrespective of the position or orientation of the source. Certain effects types (such as reverb or echo) can be used as environmental effect or non-environmental effects. Other effect types are typically non-environmental and some of these (such as distortion) are most often used with the direct-path sound muted.

In certain scenarios, some of the EAX effect slots may be configured as non-environmental while the remaining effect slots are configured as environmental. This is illustrated in the examples below.

Scenario 1 – A single environmental reverberation effect

The simplest scenario harks back to the earlier versions of EAX, which supported just a single environmental reverb.

Figure 4 – Single environmental reverb

As with an EAX 3.0 application, the environmental reverb in effect slot 0 can be used to simulate the acoustics of a single room. Provided your application only involves one acoustic space, all the designer has to do is select, customize, or design from scratch the EAX environmental preset that most closely matches the desired environment. This simple step by itself substantially enhances the listener's experience, adding life and realism to all an application's sounds. It reinforces the listener's perception of sound-source distance and the depth of the sound scene as well.

With a little more work, even using just one effect slot it is possible to re-create a world consisting of many discrete environments. If your application involves the listener moving from environment to environment (such as going from room to room in a first-

person 3D game), you can create multiple environments, each with its own unique set of acoustic properties. As the listener moves from one room to the next the acoustic quality simulated by the single environmental reverb changes appropriately.

Such a scenario would be relatively simple to design and code for, and could easily work on legacy platforms thanks to EAX Unified. However, this strategy does not take full advantage of the extra power of EAX 4.0.

Scenario 2 – One environmental reverb with studio-style effects

This is an extension of the previous scenario.

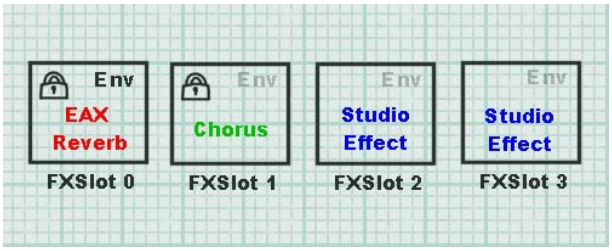

Figure 5 – Single environmental reverb and special effects

If you are content to use just one of the available slots to render environmental reverb, employing the same techniques as in scenario 1, then you can make use of the other slots for enhancing specific sounds with EAX 4.0's studio effects. This scenario would be particularly suitable for an application such as a driving simulation, where environmental effects are useful but not very essential, and just as important are effects such as distortion and EQ, for modifying engine sounds and radio communication. In the example shown in Figure 5, FXSlots 1-3 would typically be configured as non-environmental effect slots.

It is important to note here that in EAX 4.0, effects are not cumulative. They cannot be chained together, so although you can feed two effects from one source, one effect cannot be applied to the output of another. Likewise, it is not currently possible to apply panning to the output of studio-style effects, such as the distortion effect.

Scenario 3 – Multiple environmental reverbs

A strategy where several effect slots are used to render environmental reverb, simulating several different environments simultaneously, can employ the full power of EAX 4.0 compatible audio hardware. As stated in the introduction, the EAX 4.0 SDK focuses particular attention to helping you to implement this approach. There are a number of issues raised by this strategy, which the features of the API aim to elegantly solve.

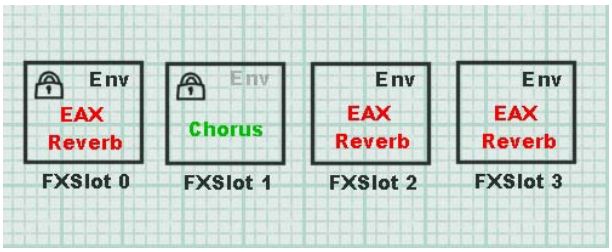

Figure 6 – Multiple environmental reverbs

For instance, the set of environmental reverb effect properties includes vectors for panning the early reflections and late reverb. These panning parameters control both

the perceived direction and the "divergence" of the reflections and reverberation. This facility is essential for helping the listener to perceive how different environments are positioned around them. In this example, FXSlots 0, 2 and 3 would be configured as environmental effect slots.

More details on designing and implementing a multi-environment engine can be found in the next section, Connecting multiple environments, and in the EAX 4.0 Sound Designer's Guide and the EAX 4.0 Programmer's Guide.

Scenario 4 – Multiple studio-style effects

Some applications may not involve the notion of acoustic environments, and will therefore not require an effect slot rendering reverb for environmental simulation. These programs can still take full advantage of EAX 4.0 by dedicating all the available effect slots to studio-style effect processing. In this case, the application would normally configure all effect slots as non-environmental.

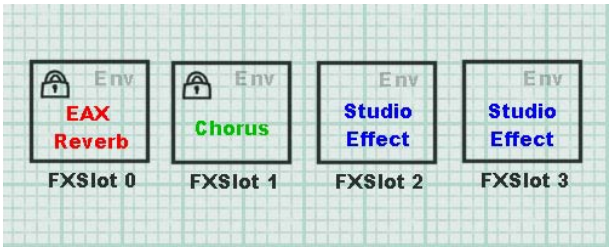

Figure 7 – Multiple studio effects only

Connecting multiple environments

The first three scenarios shown above present the developer with the ability to simulate a world of many acoustically different locations, using one or more simultaneous environmental reverberation effects. However, these scenarios were simplified - there are a few more phenomena that must be replicated before the virtual world sounds truly lifelike. In this section, we will cover how to use EAX 4.0 to connect different environments together to make a fully coherent audio scene.

Panning Environments

In Scenario 3, we briefly alluded to the fact that when the listener hears reflected sound emanating from environments other than his or her own, it is important that the location of each external environment is indicated. After all, if the outputs from each environmental reverb effect were simultaneously presented as being evenly spread around the listener's head, the mix of reflected sounds would make little sense; the extra information produced by the simulation of different acoustic environments would be extremely hard to discern.

For this reason, EAX 4.0 allows you to set the directional panning of each environment's initial reflections and late reverberation decay. These panning parameters control both the perceived direction and the "divergence" of the reflections and reverberation. The "divergence" control allows for variation from diffuse surrounding reflections to reflections focused in a chosen direction.

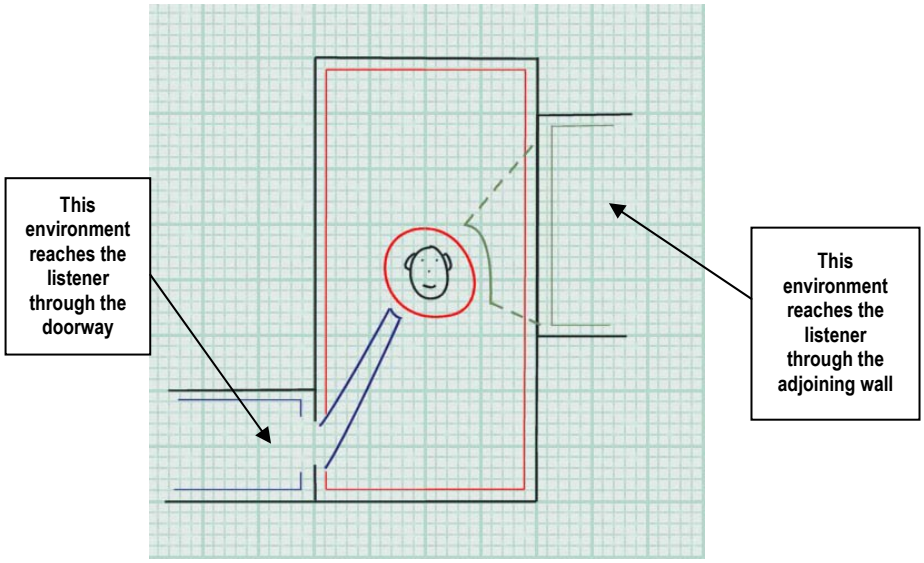

Figure 8 – Navigating environments

By setting these parameters in real time, and altering the level of wet sound, you can imply a direction and distance relating the corresponding environment to the listener. This is most relevant in scenario three, where a number of different environments are active.

The application should identify the location of other environments currently being rendered. If an opening exists in the geometry, making a clear path between another environment and the listener's, the panning parameters for the other environments should be set, making it seem as though the reflected sound is reaching the listener's ears from that opening. If no direct path exists, the nearby environment should simply be panned and occluded to give the impression that the origin is the adjoining wall.

This technique can also be used in an application that only assigns one slot to simulate environmental sound, to imply the existence and location of particularly acoustically reflective features in the world.

Moving between Environments

The environment panning feature explained above has the added effect of allowing EAX 4.0 multi-environment implementations like Scenario 3 to handle in a very natural manner the transition that occurs when the listener moves from one environment to another. Let us imagine a situation in a first-person shooter game employing a multi-environment implementation, where the player is walking towards the doorway between two rooms.

Initially the player is surrounded by the acoustics of the room in which they are currently positioned, so that environment's panning will be set fully diffuse. Reflected sound from the nearby room, on the other hand, should be perceived as emanating from the doorway; that room's environmental reverb must therefore be panned to indicate its presence in front of the listener. Its divergence and overall level will depend on the distance between the listener and the threshold, with the directional panning becoming less emphasized the nearer the listener comes to the doorway.

When the player reaches the doorway, and crosses the threshold between the rooms, the two rooms' roles are swapped. The acoustics of the room into which the player just walked will now surround the listener, so its environment panning will be set totally diffuse. The previous room should appear to be behind the player, so its environment

has to be panned and attenuated appropriate to the distance and direction between listener and opening. Correctly implemented, this spatial cross-fading technique will make seamless and lifelike the transition that occurs when the listener moves between acoustically different zones.

However, for applications that dedicate just one effect slot to environmental reverb, like in Scenario 1 and 2, or in situations where the acoustics of a particular zone are arbitrarily altered, it is possible to smooth these changeovers by performing environment morphing. In fact, because EAX 4.0 exposes all the parameters of the EAX reverberation effect to the programmer, morphing between two environment presets by interpolating on the values of the individual environment properties it is easy and safe to realize. The SDK includes helper functions that aid the programmer in implementing morphing by performing interpolation calculations on EAX parameter sets.

Implementing Occlusion and Exclusion between Environments

In a world of multiple environments, there will be times when the listener is in one room and an audible sound source is in another room. In that case, the listener hears an occluded sound source transmitted through the wall between rooms or, if the source is heard through an opening, it is acoustically excluded from the listener's room (i.e. partly prevented from generating reverberation in that room). You can add occlusion and exclusion effects to any sound source using EAX.

For sound design, you decide what kind of material makes up each partition between adjacent environments: how transmissive it is, and how it attenuates high and low frequencies. You can choose or create a *material preset* (described in the EAX 4.0 Sound Designer's Guide) that matches each material. A material preset, like an environmental preset, controls a number of audio parameters. In this case, it controls low-level sound-source occlusion properties so they create the illusion of the sound coming through the specified material from another room.

You can create a material preset from scratch by directly setting low-level sound-source properties, or you can choose a predefined material preset. The predefined presets specify materials such as concrete, wood, or a thin door. You can then tweak a predefined preset if you wish to get precisely the effect you want.

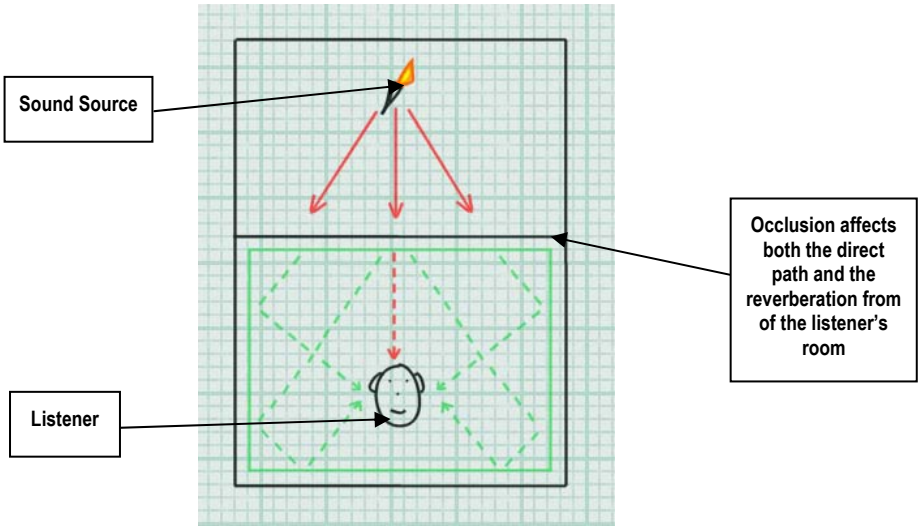

Figure 9 – Occlusion

Programming occlusion requires detecting when a sound source is in an adjacent room to the listener, and then determining which partition separates source and listener. The program should apply the appropriate material preset to the sound source's occlusion properties.

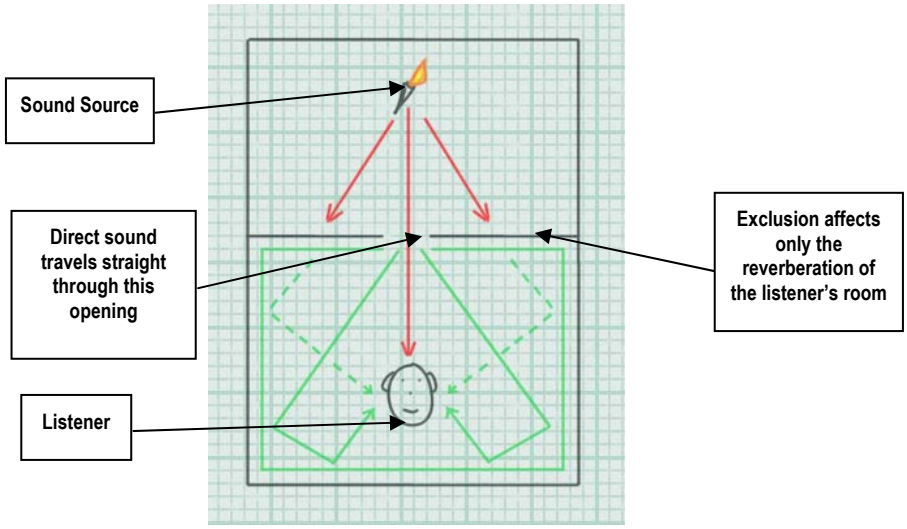

Figure 10 – Exclusion

The Exclusion effect can be applied instead of Occlusion when the program detects that, although the sound source is outside of the current environment, it can be heard through an opening. In this case, the listener room reverberation is muffled but the direct sound path is not.

Implementing Obstruction by Obstacles

When a sound source and the listener are in the same environment but an obstacle blocks the direct sound path from the source to the listener, the sound is obstructed. Its direct-path sound is at the same time diffracted around the edges of the obstruction and transmitted through the obstruction if the object is acoustically transmissive. (Although both occur, generally the diffracted sound is the predominant component, unless the object is thin and made of highly transmissive material, like a set of curtains) You can add obstruction effects to any sound source through EAX in much the same way you add occlusion effects—including using material presets when sound transmits through the obstacle.

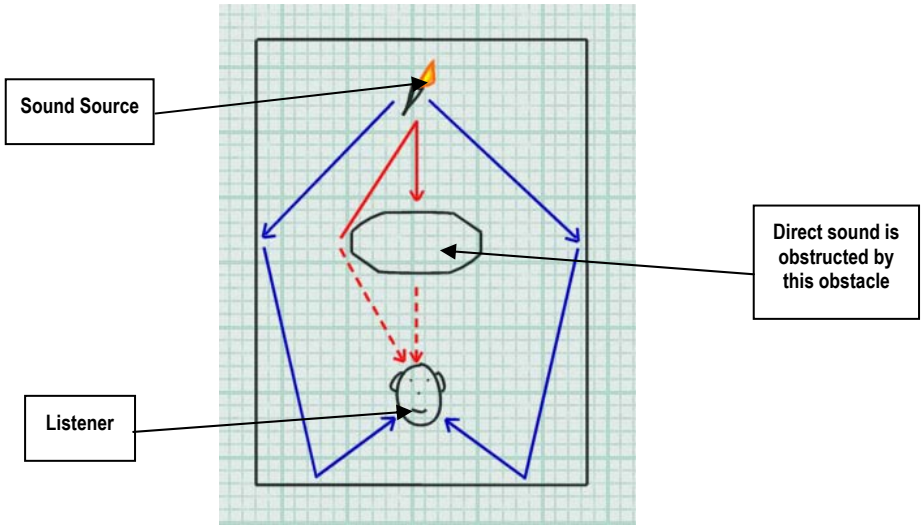

Figure 11 – Obstruction

The sound design for obstruction requires you to adjust obstruction settings to best simulate sound diffraction (how much attenuation and filtering is applied to sound waves as they bend around an obstacle) or—if the object has any acoustic transparency—the kind of material the object is made of.

Programming requires positional detection that checks when an object appears between a sound source and a listener in the same room. When this occurs, the program sets the sound source's diffraction setting appropriately or—if the obstruction is acoustically transmissive—sets a material preset.

Diffraction can also occur when the source and the listener are not located in the same environment such as around an edge of an opening or a corner in a corridor. In this case, Obstruction can be combined with Exclusion, and programmed in the same way as if the source and the listener were in the same environment.

Creating Your Own Low-Level Environmental Audio Effects

EAX's higher-level properties let you effectively create a full set of carefully designed and realistic environmental audio effects. There are times, however, when you may want something that goes beyond realistic for psychological impact—a disembodied spirit voice, for example, or sounds of battle that suddenly mute when the hero enters a mental trance. You can use EAX's low-level properties to create these kinds of effects to match your creative vision.

There are also times, if you are a committed sound designer or programmer with definite ideas about how effects should be implemented, when you may wish to implement on your own higher-level effects that EAX already provides. Although you may duplicate a lot of work that has already been done, EAX gives you the flexibility to do so through low-level properties. For example, you could manipulate for yourself the source parameters, which control each sound's direct level, filtering, and effect sends, to simulate effects like occlusion and exclusion according to your own specifications.

Because control at this level involves many technical issues, there is no recommended procedure for sound design and programming implementation. This flexibility provides a powerful interface for implementing 3D positional and environmental audio effects in an endless range of interactive audio or multimedia applications, including games, music and any computer-generated virtual world.

The primary effect slot

As described above, occlusion and exclusion both involve filtering and attenuating reflected sound. A source's contribution to the listener environment's reflected sound must be muffled when that source is occluded or excluded. When multiple environments are being simulated, it is essential to notify EAX which effect slot models the environment that the listener is located in, so that these environmental filtering effects are rendered correctly.

EAX 4.0 allows you to achieve this by setting a primary effect slot ID parameter, which identifies the listener's effect slot. This has an added benefit when EAX Unified is translating an EAX 4.0 multi-effect implementation on a system with single environment support. It tells EAX Unified which the most important environment is being rendered at any one time, so that the mechanism will make optimum use of the system's DSP resource.

Finding out more

The EAX Guide should have given you a broad outline of the capabilities of the EAX 4.0 API and the exciting audio effects it provides for application developers. Now, if you have not already done so, its time to check out the demo applications and hear those effects. For those who are ready to proceed further with EAX, you can read some more in-depth references on designing with, and programming for, EAX 4.0. We hope that the EAX 4.0 SDK helps you to quickly and easily implement the effects that you want for your application, and that you enjoy working with EAX. If you have any feedback for Creative about the SDK, the contact details are below.

Further Reading - Programming EAX 4.0

Inevitably, the more sophisticated feature set of EAX 4.0 means that the programming interfaces are a little more involved than previous EAX APIs. Programmers will find all the information they need to implement an EAX compatible audio engine in the ***EAX 4.0 Programmer's Guide***. This guide includes full specifications for each EAX Interface. Sample code is included to show how the EAX 4.0 interfaces can be accessed from both DirectSound and OpenAL. The Programmer's Guide also features optimization techniques, helping your ensure that your EAX 4.0 multi-environment audio engine always uses audio hardware resources in the most efficient manner possible.

Further Reading - Designing Effects with EAX 4.0

The ***EAX 4.0 Designer's Guide*** explains more about the principles of acoustic modeling which lie behind EAX 4.0's representation of environmental effects. It also describes in more detail the different studio style-effects you can deploy through the EAX 4.0 interface. This document is essential reading for any audio designer concerned with creating custom digital effects for applications, and will help to give the programmer a deeper understanding of theories behind environmental audio.

Appendices

Appendix 1 – EAX 4.0 effect types

Multi-channel effect types

- **EAX Reverb**
  Environmental Reverb for adding acoustic information to 3D sounds.

Two channel effect types

- **EAX Autowah**
  Low pass filter, cut-off modulated by input level, with adjustable resonance.
- **EAX Chorus**
  LFO controlled chorus, with adjustable phase and wave shape.
- **EAX Distortion**
  Guitar distortion pedal simulator, with adjustable gain, edge, and EQ.
- **EAX Echo**
  Two-tap delay with adjustable delay time, damping and stereo spread.
- **EAX EQ**
  Four band parametric EQ; two middle bands have adjustable frequency.
- **EAX Flanger**
  LFO controlled flanger, with adjustable phase and wave shape
- **EAX Frequency Shifter**
  Split stereo frequency shift.
- **EAX Automatic Gain Control Compressor**
  Automatically evens out volume changes in an audio source.
- **EAX Pitch Shifter**
  Pitch shifting with coarse and fine tune.
- **EAX Ring Modulator**
  Ring modulation with adjustable modulator waveform and high pass filter.
- **EAX Vocal Morpher**
  Vocal morpher with a pair of 4-band formant filters to impose vocal tract effects.