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Chapter 1. Introduction to the NVIDIA Audio Effects SDK

The NVIDIA® Audio Effects SDK provides the following audio effects for broadcast use cases with real-time audio processing:

- **Noise Removal/Denoising**: Recordings of speech made outside of a recording studio can contain a lot of background noise, which causes the speech to be garbled and difficult to understand.

  The audio denoising effect removes this background noise from audio.

- **Room Echo Removal/Dereverb/Room Echo Cancellation**: Recordings of speech might contain reverberations from the recording environment, which can affect speech clarity.

  The dereverb effect helps remove or suppress these reverbs from audio.

- **Noise Removal and Room Echo Removal/Denoise Plus Dereverb**: The effect combines both the above effects to remove/suppress both noise and reverbs from audio.

  This offers much better performance than applying these effects separately.

- **Audio Super-Resolution**: This effect improves the sound quality by adding higher frequency content to the audio stream.

  For low-frequency audio, this feature predicts the higher frequency spectrum of input audio, which improves audio quality.

- **Acoustic Echo Cancellation (AEC)**: This effect removes acoustic echo and feedback from audio, which improves the bidirectional audio quality.

  **Note**: The Windows SDK is optimized for client-side application integration, and the Linux SDK is designed and optimized for server-side (datacenter/cloud) deployments.

  Using these SDKs for testing, experimentation, and production deployment outside these use cases is **not** officially supported.
1.1. About the Noise Removal/Background Noise Suppression Effect

Recordings of speech made outside a recording studio can contain a lot of background noise. The Audio Denoiser Effect removes a variety of background noises from audio recordings. This effect retains emotive tones in speech, such as happy, sad, excited, and angry tones, which were removed as noise in previous releases of the SDK. Extreme emotive cases such as loud laughing, shrieking, screaming, and crying might not be retained.

Note: In this guide, the term Background Noise Suppression is used interchangeably with Denoising and Noise Removal (referred to as denoiser in the API).

This effect supports removing the following types of background noise:

- AC noise
- Babble/crowd noise
- Baby crying
- Bird chirping
- Body noises
- Chatter from other people
- Clapping
- Construction site sounds
- Cooking sounds (cutting, cooker, and so on)
- Door slamming
- Drums
- Fan noise
- Gaussian/white noise
- Keyboard
- Metal sounds
- Mouse clicks
- PC noise
- Pet sounds
- Phone ringing
- Rains
- Sirens
Introduction to the NVIDIA Audio Effects SDK

- Sounds of a train passing by
- Sounds of a vacuum cleaner
- Sounds of furniture moving
- Sounds of glass breaking
- Tapping
- Traffic noise
- Washing machine
- Water taps/running water
- Wrappers (plastic/non-plastic rustling)

This effect has the following characteristics:

- Supported input/output audio format is 32-bit float audio with a sampling rate of 16kHz/48kHz.
- In the Linux SDK, this effect supports the following maximum batch sizes:

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Maximum Batch Size for the 16K Effect</th>
<th>Maximum Batch Size for the 48K Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4</td>
<td>1024</td>
<td>1024</td>
</tr>
<tr>
<td>V100</td>
<td>2560</td>
<td>2560</td>
</tr>
<tr>
<td>A100</td>
<td>5120</td>
<td>5120</td>
</tr>
<tr>
<td>A10</td>
<td>3072</td>
<td>3072</td>
</tr>
</tbody>
</table>

Note: This effect might miss some noises in the first 1-2 seconds of input audio. Low-volume noises during speech might also be missed.

1.2. About the Room Echo Removal/Room Echo Cancellation Effect

Recordings of speech made in a large room/hall contain echoes and reverbs. The Audio Room Echo Cancellation Effect removes/suppresses these echoes and reverbs from audio recordings.

Note: In this guide, the term Room Echo Cancellation is used interchangeably with Dereverb and Room Echo Removal (referred to as dereverb in the API).

This effect has the following characteristics:

- Supported input/output format is 32-bit float audio with a sampling rate of 16kHz/48kHz.
- In the Linux SDK, this effect supports the following maximum batch sizes:
1.3. About the Noise Removal and Room Echo Removal/Room Echo Cancellation + Background Noise Suppression Effect

This effect applies a denoising and a dereverb effect on input audio.

**Note:** In this guide, the term *Room Echo Cancellation + Background Noise Suppression* is used interchangeably with *Dereverb+Denoiser and Noise Removal and Room Echo Removal* (referred to as *dereverb_denoiser* in the API).

This effect has the following characteristics:

- Supported input/output format is 32-bit float audio with a sampling rate of 16kHz/48kHz.
- In the Linux SDK, this effect supports the following maximum batch sizes:

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Maximum Batch Size for the 16K Effect</th>
<th>Maximum Batch Size for the 48K Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4</td>
<td>1024</td>
<td>1024</td>
</tr>
<tr>
<td>V100</td>
<td>2560</td>
<td>2560</td>
</tr>
<tr>
<td>A100</td>
<td>4608</td>
<td>4608</td>
</tr>
<tr>
<td>A10</td>
<td>3072</td>
<td>3072</td>
</tr>
</tbody>
</table>

1.4. About the Audio Super-Resolution Effect (BETA)

The Audio Super-Resolution effect upsamples the audio. For low-frequency audio, this feature predicts the higher frequency spectrum of input audio, which improves audio quality.

**Note:** In this guide, the term *Super-Resolution* is used interchangeably with *Superres/superresolution* (referred to as *superres* in the API).
This effect has the following characteristics:

- Supported input/output format is 32-bit float audio.

**Note:**
The main purpose of this effect is to enhance the sampling rate of input audio. The level of enhancement seen in the output audio depends on the type of audio. Audio that is captured on Windows with the audio enhancement settings disabled produces better superres outputs than when this setting is enabled.

- Supported upsampling of 8kHz input audio to 16kHz output (2x), 8kHz input audio to 48kHz output (6x), and 16kHz input audio to 48kHz output (3x).

- In the Linux SDK, this effect supports the following maximum batch sizes:

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Maximum Batch Size for the 8K to 16K Effect</th>
<th>Maximum Batch Size for the 8K to 48K Effect</th>
<th>Maximum Batch Size for the 48K Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4</td>
<td>160</td>
<td>64</td>
<td>192</td>
</tr>
<tr>
<td>V100</td>
<td>512</td>
<td>192</td>
<td>512</td>
</tr>
<tr>
<td>A100</td>
<td>1024</td>
<td>384</td>
<td>960</td>
</tr>
<tr>
<td>A10</td>
<td>384</td>
<td>128</td>
<td>384</td>
</tr>
</tbody>
</table>

1.5. **About the Acoustic Echo Cancellation Effect (BETA)**

This effect removes acoustic echo and feedback from audio, which improves the bidirectional audio quality.

**Note:** In this guide, the term Acoustic Echo Cancellation is used interchangeably with AEC (referred to as aec in the API).

An acoustic echo occurs when a microphone, also known as a near-end microphone, picks up audio signals from the speaker and sends it back to the original recipient. The original recipient hears his or her own delayed voice mixed with a target signal, which makes the communication unintelligible. The Acoustic Echo Cancellation Effect (AEC) effect cancels/suppresses this delayed voice, also known as an acoustic feedback/echo, from the audio. This process improves the overall quality of the recording.

**Note:** Acoustic Echo Cancellation is useful only for near mic echo. For echo caused by reverberations, use the Room Echo Removal effect (see About the Room Echo Removal/Room Echo Cancellation Effect for more details).

This effect has the following characteristics:

- Supported input/output format is 32-bit float audio with a sampling rate of 16kHz/48kHz.
In the Linux SDK, this effect supports the following maximum batch sizes:

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Maximum Batch Size for the 16K Effect</th>
<th>Maximum Batch Size for the 48K Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4</td>
<td>1024</td>
<td>640</td>
</tr>
<tr>
<td>V100</td>
<td>2560</td>
<td>1536</td>
</tr>
<tr>
<td>A100</td>
<td>5120</td>
<td>3072</td>
</tr>
<tr>
<td>A10</td>
<td>3072</td>
<td>1792</td>
</tr>
</tbody>
</table>

### 1.5.1. Using the Acoustic Echo Cancellation Effect

This section describes the procedure for using the AEC effect.

**Figure 1. Basic AEC Scenario**

The AEC Effect takes the following inputs:

- The near-end microphone signal (denoted by \( y \)).
- The far-end microphone signal (denoted by \( x \)).

The far-end speaker signal \( x \) is the microphone signal of the original recipient. The near-end microphone signal \( y \) can be described as a combination of the near-end speech signal \( s \) and echo signal of the far-end speaker \( e \). The output of the effect is the near-end speech signal \( s' \), which is the input combination \( s + e \) with the far-end echo signal \( e \) removed:

\[
s' = (\text{Mixture of } s + e) - e
\]

If only the far-end echo signal \( e \) is present, and near-end signal \( s \) is silent, the output from this effect will be silent.
When the AEC effect is integrated in a conferencing application server, multiple streams of data need to run in a batch, one for each speaker. Consider the scenario in Figure 2, where \( s(1) \) corresponds to AEC batch 1, and \( s(2) \) corresponds to batch 2:

The AEC Effect takes the following inputs:

- The near-end microphone signal (denoted by \( y \)).
- The far-end microphone signal (denoted by \( x \)).

The far-end speaker signal \( x \) is the microphone signal of the original recipient. The near-end microphone signal \( y \) can be described as a combination of the near-end speech signal \( s \) and echo signal of the far-end speaker \( e \). The output of the effect is the near-end speech signal \( s' \), which is the input combination \( s + e \) with the far-end echo signal \( e \) removed:

\[
s' = (\text{Mixture of } s + e) - e
\]

If only the far-end echo signal \( e \) is present, and near-end signal \( s \) is silent, the output from this effect will be silent.

When the AEC effect is integrated in a conferencing application server, multiple streams of data need to run in a batch, one for each speaker. Consider the scenario in Figure 2, where \( s(1) \) corresponds to AEC batch 1, and \( s(2) \) corresponds to batch 2:

**Figure 2.** Batched Audio Processing by Using the AEC Effect (Linux SDK Only)

The following steps describe how the AEC effect processes audio as seen in Figure 2:

1. The application server receives a microphone recording from Speaker A \( y(1) \).
2. The Application server passes \( y(1) \) to the AEC batch [1].
   
   Silence is passed down as a far-end speech signal \( x(1) \) to the effect because the server does not yet have the far-end speech.
3. The Effect produces processed audio $s'(1)$, which is passed down to Speaker B.
4. Speaker B sends the near-end audio $y(2)$ to the application server.
   This data consists of speech $s(1)$, and audio played on speakers $e(2)$.
5. The Application server processes batch $2$ with $y(1)$ as near-end audio, and the $s'(1)$ that
   was received from Step 3 as far-end audio.
   This is the same audio that was played on the server.
6. The output from batch $s'[2]$ is passed to Speaker A.

Refer to Setting the Parameters of an Audio Effect for the settings that are required for the
AEC effect.
This section provides information about the hardware and software requirements to install the Windows SDK.

### 2.1. Hardware and Software Requirements

The Audio Effects SDK requires specific GPUs, a specific version of the Windows OS, and other software dependencies.

#### 2.1.1. Hardware Requirements

The SDK is supported on NVIDIA GPUs with Tensor Cores.

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Required Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPU</td>
<td>NVIDIA GPUs with Tensor Cores</td>
</tr>
</tbody>
</table>

#### 2.1.2. Software Requirements

The NVIDIA CUDA® and NVIDIA TensorRT™ dependencies are bundled with the SDK Installer (refer to [Installing the Audio Effects SDK for Windows](#)).

The Audio Effects SDK is designed and optimized for client-side application integration and for local deployment. **We do not officially support the testing, experimentation, deployment of this SDK in a datacenter/cloud environment.**

<table>
<thead>
<tr>
<th>Software</th>
<th>Required Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows OS</td>
<td>64-bit Windows 10</td>
</tr>
<tr>
<td>Microsoft Visual Studio</td>
<td>2017 (MSVC15.0) or later</td>
</tr>
<tr>
<td>CMake</td>
<td>3.9 or later</td>
</tr>
</tbody>
</table>
Getting Started with the Audio Effects SDK for Windows

### Software

<table>
<thead>
<tr>
<th>Software</th>
<th>Required Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>NVIDIA Graphics Driver for Windows</td>
<td>465.86 or later</td>
</tr>
</tbody>
</table>

**Note:** All libraries that are required to use the SDK are in the package, under `external`, do not need to be separately installed.

### 2.2. Installing the Audio Effects SDK for Windows

The Audio Effects SDK for Windows is distributed in the following parts:

- **A developer package** that contains the AI models, binaries, header file, and a sample app.
- **A redistributable package** that contains only the AI models and binaries.

  This package streamlines the installation and usage of the SDK on the end-user’s computer.

To develop applications with the Audio Effects SDK, you must install the developer package and provide the path to this package during compilation and linking. Your app will use the SDK functions that are exposed by the SDK header and dynamically link against the provided libraries.

During deployment, the redistributable package installer helps install the necessary runtime components. To help your app access the runtime components on the end-user’s computer, after the redistributable package is installed, the installer completes the following tasks:

- Copies the AI models and binaries to the install location.
- Sets the `NVAFX_SDK_DIR` environment variable, which points to the directory where the redistributable package is installed and contains the AI models and binaries.

  Your app needs to use this environment variable to locate and load the binaries and the AI model.

### 2.3. Audio Effects SDK Sample Application

The sample includes the application `effects_demo.exe` that can be directly executed and also its corresponding `effects_demo.cpp` source file that can optionally be compiled and run.

#### 2.3.1. (Optional) Building the Sample Application

To build the sample application:

1. Start the CMake GUI and specify the source folder and a build folder for the binary files.
   a). For the source folder, ensure that the path ends in `package`.
b). For the build folder, ensure that the path ends in `package/build`.

2. Use CMake to configure and generate the Visual Studio solution file.

   a). Click **Configure**.
   b). When prompted to confirm whether CMake can create the build folder, click **OK**.
   c). To enable CMake to locate the CUDA compiler, select **Visual Studio** for the generator and **x64** for the platform.
   d). To finish configuring the Visual Studio solution file, click **Finish**.
   e). To generate the Visual Studio solution file, click **Generate**.

3. Use Visual Studio to generate the application binary `.exe` file from the solution file that was generated in the previous step.
   a). In CMake, to open Visual Studio, click **Open Project**.
   b). In Visual Studio, click **Build > Build Solution**.

### 2.3.2. Running the Sample Application

To run the application, in a Command Prompt window, enter the following command:

```plaintext
effects_demo.exe -c config-file
```

where `-c config-file` specifies the path of the effect sample config file, for example, `denoise48k_cfg_turing.txt`. A few sample config files are supplied with the sample application.

The following example runs the `effects_demo.exe` sample application:

```plaintext
effects_demo.exe -c denoise48k_cfg_turing.txt
```

The config files contain the following parameters with one pair per line:

- **effect**
  - Specifies the effect that will be applied, for example, denoiser. Refer to *Introduction to the NVIDIA Audio Effects SDK* for a complete list of supported effects.

- **model model-file**
  - Specifies the path of the model file that will be used in the sample application, for example, `denoiser_48k.trtpkg`.

- **input_wav input-audio-file**
  - Specifies the path of the noisy input audio `.wav` file to use, for example, `noisy_48k.wav`. The file should contain mono channel audio in signed 16-bit or 32-bit float format with a basic WAV header.

- **input_farend_wav input-farend-audio-file**
  - Specifies the path of the farend input audio `.wav` file to use, for example, `farend_48k.wav`.

---

**Note:** The `input_farend_wav` audio file is only for the AEC effect, which requires the following inputs:

- Far-end (specified by the `input_farend_wav` parameter)
- Near-end (specified by the `input_wav` parameter)
The near-end input is picked up from the microphone, and the far-end audio might have leaked speaker audio data that is picked up by the microphone.

Note: Sample input audio files are included with the sample application.

**output_wav output-audio-file**
Specifies the path of the file to which the applied effect audio output will be written, for example, denoised_48k.wav.

Note: Only the .wav file format is supported.

**intensity_ratio intensity-ratio**
Specifies the effect intensity ratio. The value of this parameter ranges from 0.0f to 1.0f, where a higher value indicates a stronger suppression of noise/reverb. A value of 0.0f is equivalent to a passthrough of input audio.

**real_time enable**
Simulates real-time audio input, set to 1 to enable or 0 to disable (disabled by default). When this option is enabled, each audio frame is passed to the SDK with a delay of 10ms, similar to how audio is received from a physical device or stream.

### 2.3.2.1. Chaining Effects

This section describes how to run effects in a chain.

The `effects_demo` sample application also provides config files in which multiple effects are run in a chain (refer to Running Multiple Effects in a Chain for more information). For example, the following command runs the 16kHz to 48kHz Superresolution effect followed by the 48kHz Denoiser effect on input audio:

```
effects_demo.exe -c superres16kto48k_denoise48k_chain_cfg.txt
```

To run effects in a chain, the syntax in the configuration file is similar to the syntax that was used when running single effects, with changes in the following parameters:

**effect effect-1 effect-2**
Specifies the effects in sequence to be used for chaining. For more information about possible chaining combinations, refer to Running Multiple Audio Effects in a Chain.

Note: Chaining effects only support combination of Superres and Denoiser/Dereverb/Combined Denoiser+Dereverb effect. Other effect chains are not supported. If combining Denoiser effect and Dereverb effect, use the combined Denoiser+Dereverb model (refer to About the Room Echo Cancellation + Background Noise Suppression Effect for more information).

**model model-file-1 model-file-2**
Specifies the path of the model files in sequence that will be used in the sample application, for example, superres_16kto48k.trtpkg, denoiser_48k.trtpkg.

**intensity_ratio intensity-ratio-1 intensity-ratio-2**
Specifies the intensity ratio for the effects. The value of this parameter ranges from 0.0f to 1.0f, where a higher value indicates a stronger suppression of noise/reverb. A value of 0.0f is equivalent to a passthrough of input audio.
This section provides information about the hardware and software requirements and installing the Linux SDK.

3.1. Hardware and Software Requirements

The Audio Effects SDK requires specific GPUs, a specific version of the Linux OS, and other software dependencies.

3.1.1. Hardware Requirements

The Audio Effects SDK is supported on systems with a minimum of 10 GB RAM and NVIDIA GPUs with Tensor Cores.

Table 1. Hardware Requirements

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Required Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPU</td>
<td>GPUs with Tensor Cores:</td>
</tr>
<tr>
<td></td>
<td>▶ NVIDIA Turing™: NVIDIA Tesla® T4</td>
</tr>
<tr>
<td></td>
<td>▶ NVIDIA Volta™: V100</td>
</tr>
<tr>
<td></td>
<td>▶ NVIDIA Ampere architecture: A2, A10, A16, A30, A40, and A100</td>
</tr>
</tbody>
</table>

**Note:** The SDK supports Multi-Instance GPU (MIG) only on NVIDIA Tesla® A100.

When MIG is enabled, the GPU instance and corresponding compute instance must be defined, regardless of whether...
### 3.1.2. Software Requirements

The SDK has the following requirements:

#### Table 2. Software Requirements

<table>
<thead>
<tr>
<th>Software</th>
<th>Required Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linux distribution</td>
<td>64-bit Linux distribution</td>
</tr>
<tr>
<td></td>
<td>The supported distros are:</td>
</tr>
<tr>
<td></td>
<td>‣ Ubuntu (18.04)</td>
</tr>
<tr>
<td></td>
<td>‣ RHEL7</td>
</tr>
<tr>
<td></td>
<td>‣ RHEL8</td>
</tr>
<tr>
<td></td>
<td>‣ CentOS7</td>
</tr>
<tr>
<td></td>
<td>‣ CentOS8</td>
</tr>
<tr>
<td></td>
<td>‣ Debian 10+</td>
</tr>
<tr>
<td>NVIDIA Graphics Driver for Linux</td>
<td>465.19 or later</td>
</tr>
<tr>
<td></td>
<td>418/440 can be used with NVIDIA CUDA® Forward Compatible Upgrade. Refer to Using Older Drivers (418/440) with CUDA Forward-Compatible Upgrade for more information.</td>
</tr>
<tr>
<td>CUDA/NVIDIA TensorRT™/NVIDIA CUDA Deep Neural Network [cuDNN]</td>
<td>▶ CUDA: 11.3 update 1</td>
</tr>
<tr>
<td></td>
<td>▶ TensorRT™: 8.0.1.6</td>
</tr>
<tr>
<td></td>
<td>▶ cuDNN: 8.2.1</td>
</tr>
</tbody>
</table>

**Note:** All libraries that are required to use the SDK are in the package under `external/cuda`, do not need to be separately installed.

**Note:** The Linux SDK is designed and optimized for server-side (datacenter/cloud) deployment. Using this SDK for testing, experimentation, and production deployment of these SDKs outside this use case is not officially supported.
3.2. Installing the Audio Effects SDK for Linux

To develop applications with the Audio Effects SDK, extract the files from the SDK package and provide the library path to the extracted library during compilation and linking. A sample application is also bundled with the SDK [source/pre-built binaries].

To install the SDK, extract the contents of the Audio Effects SDK archive to the required location on your computer, for example, by using the following command:

```bash
tar xvf --one-top-level Audio_Effects_SDK.tar.gz
```

3.2.1. Using Older Drivers (418/440) with a CUDA Forward-Compatible Upgrade

Applications can use the SDK with older drivers [418/440] by using the CUDA Forward-Compatible upgrade path [refer to CUDA Forward-Compatible Upgrade Path for more information].

To use older supported drivers with the SDK, download the user-mode CUDA libraries [libcuda.so.*] and the JIT compiler libraries for PTX files [libnvidia- ptxjitcompiler.so.*] from one of the following locations:

- The CUDA 11.3u1 Toolkit/datacenter drivers.
- The CUDA network repositories [cuda-compat-11.3].

Before you run the applications by using the SDK, ensure that `LD_LIBRARY_PATH` contains the location that contains these libraries.

For example, to use the CUDA network repository on an Ubuntu 18.04 system with older drivers:

1. To add the CUDA repository to your system, go to CUDA Toolkit 11.3u1 Downloads:
   c). Under Installer Type, click deb [network].
   d). To add the CUDA repository to the system, follow the steps under Installation Instructions.
2. Update the apt repository cache.
   ```bash
   $ sudo apt-get update
   ```
3. Install the compatibility package.
   ```bash
   $ sudo apt-get install -y cuda-compat-11-3
   ```
   The commands in this step will install the compatibility package libraries under the `/usr/local/cuda-11.3/compat` directory.
4. Append this path to `LD_LIBRARY_PATH` when the SDK applications are run.
# Add path to LD_LIBRARY_PATH

# Note: This command works only for the current terminal session, please add to ~/.bashrc or similar to make this permanent. For further details, refer to your distribution's documentation.

$ export LD_LIBRARY_PATH=/usr/local/cuda-11.1/compat:$LD_LIBRARY_PATH

# Run application

$ ./effects_demo -c t4_denoise48k_1_cfg.txt

Refer to CUDA Forward-Compatible Upgrade Path for more information.

3.3. Sample Applications

The SDK provides the following sample applications:

- effects_demo
- effects_delayed_streams_demo

Note: These applications include the source code (effects_demo.cpp/ effects_delayed_streams_demo.cpp) and the pre-built binaries.

3.3.1. effects_demo Application

This application demonstrates how to use the SDK to apply effects to audio.

3.3.1.1. (Optional) Building the Application

To build the sample application:

1. Navigate to the samples/effects_demo directory.
2. Optional: To compile the application instead of running the pre-built binary file, run the make command.

   ./run_effect.sh -g v100 -s 16 -b 1 -e denoiser

   ./run_effect.sh -g v100 -s 48 -b 1 -e dereverb

   ./run_effect.sh -g v100 -s 16 -b 400 -e denoiser

   ./run_effect.sh -g v100 -s 48 -b 400 -e dereverb_denoiser

   ./run_effect.sh -g v100 -s 48 -b 400 -e aec

   ./run_effect.sh -g v100 -s 8 -o 16 -b 400 -e superres

   ./run_effect.sh -g t4 -s 16 -b 1 -e denoiser
Note: Ensure that the application uses the TensorRT (requires the exact version)/CUDA libraries (requires the exact version or later) that is bundled with the SDK (under external/cuda/lib).

If the distro/OS exports LD_LIBRARY_PATH from ~/.bashrc (or similar), the TensorRT and CUDA paths might be overridden. As a result, the SDK might load incompatible CUDA/TensorRT library versions. To avoid this issue, before you run the sample program, append the external directory to LD_LIBRARY_PATH by executing the following command:

```
$ export LD_LIBRARY_PATH=external/cuda/lib:$LD_LIBRARY_PATH
```

Note: The sample app might hit the limit for the maximum number of open files that is imposed by default by the Linux kernel, especially for large batch sizes. When this occurs, the sample application will exit with the following error message:

```
[Error] Unable to read wav file:
../input_files/denoiser/48k/Fan_48k.wav.
Open file limit reached.
```

To increase this limit, before you run the sample application, use the `ulimit` command in the same shell to increase the number of open files. For example, `ulimit -n 20000` will increase the open file limit to 20,000 for that shell. For more information, refer to your distribution’s documentation on how to increase open file descriptor limits.

### 3.3.1.2. Running the Application

The sample application can be run by using the `run_effect.sh` helper script or directly by using the `effects_demo` executable file.

#### 3.3.1.2.1. Running the Sample Application Using the Helper Script

The `run_effect.sh` helper script is a wrapper around the `effects_demo` application. Depending on the arguments that are passed to `run_effect.sh`, the script generates a temporary config file and runs the `effects_demo` application with this config file.

The helper script can be run using the following command:

```
./run_effect.sh -g gpu -e effect -s input_sample_rate -o output_sample_rate -b batch_size
```

For example, to run the sample application on T4 with the 16k denoiser effect that has a batch size of 10, run the following command:

```
./run_effect.sh -g t4 -s 16 -b 10 -e denoiser
```
This command generates a config file at /tmp/tmp_cfg.txt with the above configuration.

The helper script supports the following parameters:

- `-g` / `--gpu` (default=t4) specifies the GPU on which to run the effect. Supported options are a2, v100, a16, a100, a10, t4, a30, and a40.
  
  The helper script selects the appropriate model based on the value of this parameter. If a model is not specified, the default value is t4.

- `-e` / `--effect` (default=denoiser) specifies whether to use the denoiser/dereverb effect or the dereverb_denoiser/aec/superres effect.
  
  If an effect is not specified, the default value is denoiser.

- `-s` / `--sample_rate` (default=16) specifies the sample rate of input audio in kHz, and the values can be 48, 16, or 8.
  
  If an effect is not specified, the default value is 16.

  [Superresolution only] `-o` / `--output_sample_rate` (default=16) specifies the sample rate of output audio.
  
  If the rate is not specified, the default value is 16.

- `-b` / `--batch_size` (default=1, max=1024) specifies the batch size to use.
  
  Depending on this parameter, the script generates an input file list (in samples/input_files) of the specified batch size by using the sample audio files that were provided with the SDK and a corresponding list of the output files.
  
  If the sample audio files have not been specified, the default value is 1.

- `-c` / `--cfg-file` (default=/tmp/tmp_cfg.txt) specifies the path to which the temporary configuration file will be written.
  
  If the path is not specified, the default location is /tmp/tmp_cfg.txt.

- `-f` / `--frame_size` (default=10) specifies the frame size (10 or 20) that will be used in milliseconds.
  
  If the frame size is not specified, the default value is 10.

- `-h` / `--help` prints the parameters that are supported by this script.

3.3.1.2.2. Directly Running the Sample Application

To run the sample application directly, run the following command:

```
./effects_demo -c config-file
```

where `-c config-file` specifies the path of the sample config file, for example, `t4_denoise48k_1Cfg.txt`. Sample config files are provided with the sample application.

Note: Config files that are used by the sample app can be generated by using the run_effects.sh script, which accepts a path specified by the `-c` or the `--cfg-file` flag. If this path is specified, the script writes a config file with the specified configuration parameters to that path. This config file can be reused by the effects_demo sample app.

For example, the following command will write the configuration to the file:

```
./run_effect.sh -e aec -s 48 -g t4 -c t4_aec.cfg
```
For example, to denoise a 48kHz stream on a T4 GPU for a batch size of 1, run:

```
./effects_demo -c t4_denoise48k_1_cfg.txt
```

The configuration files contain pairs of parameters and their values, with one pair per line. Currently, the following parameters are supported:

**reset list-of-stream-ids**
Specifies the stream identifiers to reset, starting with 1. Multiple identifiers are separated by spaces.

**effect effect-name**
Specifies the name of the effect to apply. Supported effects are denoiser, dereverb, dereverb_denoiser, aec, and superres.

**sample_rate audio-sample-rate**
Specifies the sample rate of the audio in Hz. Supported values are 8000, 16000, and 48000.

**model model-file**
Specifies the path of the model file to be used in the sample application, for example, models/volta/denoiser_48k_1152.trtpkg. The model file should match the audio sample rate that was specified in the `sample_rate` parameter and the number of input wav files specified in `input_wav_list` parameter [see Setting the Parameters of an Audio Effect for more information].

**frame_size frame-size-value-in-milliseconds**
Specifies the input frame size (in milliseconds) to be used in the `NvAFX_Run()` call. The supported values are 10 and 20.

**input_wav_list input-audio-file-list**
Specifies a list of paths to input noisy audio .wav files to use. Each file should contain mono channel audio in signed 16-bit or 32-bit float format with a basic WAV header. Multiple files are separated by a space. The number of input files must match the number of streams/batch size. In a stream, the files that are separated by a semicolon (;) are processed one after another in the same stream. In addition, if the stream ID exists in the reset list, `NvAFX_Reset` is called on the stream identifiers when switching between files.

For example, the following configuration specifies that streams 1, 2 and 4 use file1.wav, file2.wav and file6.wav as the input to the stream, and stream 3 uses multiple files (file3.wav, file4.wav, file5.wav) as the input to the stream:

```
input_wav_list file1.wav file2.wav file6.wav
```

**input_farend_wav_list input-farend-audio-file-list** [AEC only] Specifies a list of paths to input noisy audio .wav files to be used as far-end audio. Each entry in this list matches a near-end input that was specified in the `input_wav_list`, and the number of audio samples in this file must be the same as the number of samples in the corresponding near-end input file.

**output_wav_list output-audio-file-list**
Specifies the files to which the output audio will be written. Output files contain mono audio in 32-bit float format. Multiple files are separated by spaces. In a stream, if multiple input files are specified (separated using semicolon), multiple output files will be created with the same name followed by _1, _2, and so on.
For example, in the following configuration, the output will be written to out1.wav (output of file1.wav), out2.wav (output of file2.wav), out3.wav (output of file3.wav), out3_1.wav (output of file4.wav), out3_2.wav (output of file5.wav), and out4.wav (output of file6.wav).

```
input_wav_list file1.wav file2.wav file3.wav;file4.wav;file5.wav file6.wav
output_wav_list out1.wav out2.wav out3.wav out4.wav
```

**Note:** In input/output .wav files, only the basic WAV header is supported.

**real_time enable**
Simulates real-time audio input, set to 1 to enable, or 0 to disable (disabled by default). When this option is enabled, each audio frame is passed to the SDK with a delay, like how audio is received from a physical device or stream. For example, if the frame size is 10ms, each frame is passed in every 10ms, like how audio is received from a microphone [10ms audio received from the mic approximately every 10ms].

**intensity_ratio ratio**
Specifies the denoising intensity ratio. The value of this parameter ranges from 0.0 to 1.0 (inclusive), where a higher value indicates a stronger suppression of noise/reverb. A value of 0.0 is equivalent to passing out input audio without applying noise removal/dereverb.

### 3.3.1.3. Chaining Effects
This sample application also supports chaining multiple effects (refer to Running Multiple Effects in a Chain for more information).

To run the application in chaining mode, use `run_effect_chained.sh`:
```
./run_effect_chained.sh -g gpu -e1 effect1 -s1
input_sample_rate_1 -i1 output_sample_rate_1 -o1
input_sample_rate_2 -i2 output_sample_rate_2 [-c path_to_save_config_file]
```

This script generates a config file that can be used with the `effects_demo` sample to run multiple effects in a chain and runs the application with this file.

The config file that is used for chaining follows the same format and parameters as `effects_demo`, with the following modifications:

**effect effect-name-1 effect-name-2**
Specifies the names of the effects to apply to input audio (effect-name-1 will be applied to input audio first, and effect-name-2 will be applied to this output). For more information about possible chaining combinations, refer to Creating a Chained Audio Effect.

**Note:** Chaining effects only support combination of Superres and Denoiser/Dereverb/Combined Denoiser+Dereverb effect. Other effect chains are not supported. If you combine the Denoiser effect and Dereverb effect, use the combined Denoiser+Dereverb model (refer to About the Room Echo Cancellation + Background Noise Suppression Effect for more information).

**sample_rate audio-sample-rate-1 audio-sample-rate-2**
Specifies the input sample rate of the audio in Hz for the effects. The supported values are 8000, 16000, and 48000.
model model-file-1 model-file-2
Specifies the path of the model file to be used by the effects, for example, models/sm_70/denoiser_48k_1152.trtpkg. The model file should match the audio sample rate that was specified in the sample_rate parameter and the number of input wav files specified in input_wav_list parameter (see Setting the Parameters of an Audio Effect for more information).

intensity_ratio intensity-ratio-1 intensity-ratio-2
Specifies the intensity ratio for the effects. The value of this parameter ranges from 0.0f to 1.0f, where a higher value indicates a stronger suppression of noise/reverb. A value of 0.0f is equivalent to a passthrough of input audio.

chained_effect_gpu_list gpu-1 gpu-2
In a multi-GPU system, specifies the GPU device ID that will be used for the first and the second effect in the chain.

3.3.2. effects_delayed_streams_demo Application
This application demonstrates the use-case for handling delayed streams (refer to Running an Audio Effect on Delayed Streams for more information about delayed streams). In this sample, each of the input streams falls under one of the following categories:

one_step_delay_streams
These streams have a delay of 1 frame. For example, if the frame size is 10ms, these streams will have a delay of 10ms. This means that these streams will be active every alternate iteration. As a result, when data from these streams arrive, NvAFX_Run should be called two times, once with the delayed data and once with the current data.

two_step_delay_streams
These streams have a delay of 2 frames. For example, if the frame size is 10ms, these streams will have a delay of 20ms. This means that these streams will be active after every two iterations. As a result, when data from these streams arrive, NvAFX_Run should be called three times, twice with the delayed data and once with the current data.

always_active_streams
These streams have no delay and are always active, with one NvAFX_Run call per iteration. NvAFX_Run() calls are made based on the description above to generate processed audio output. The configuration files provide a parameter to specify one_step_delay_streams and two_step_delay_streams (refer to Running the Application for more information). These values and the batch size are used to infer the list of always_active_streams.

3.3.2.1. (Optional) Building the Application
To build the sample application:

1. Navigate to the samples/effects_delayed_streams_demo directory.
2. To compile the application, run the make command.

   :/Audio Effects SDK/samples/effects_delayed_streams_demo$ make

3.3.2.2. Running the Application
The sample application can be run using the run_effect.sh helper script or directly by using the effects_delayed_streams_demo executable file.
3.3.2.2.1. Running the Sample Application with the Helper Script

The `run_effect.sh` helper script is a wrapper around the `effects_delayed_streams_demo` application and runs like the helper script in `effects_demo` [refer to Running the Sample Application Using the Helper Script for more information].

This script supports 10 streams that are always preconfigured into active streams, streams with a one-step delay, and streams with a two-step delay. In addition to the parameters in `run_effects.sh` that were specified [refer to Running the Sample Application Using the Helper Script], this script also supports the `-t / --all_streams_active` parameter, which specifies that all 10 streams are always active. If this parameter is not specified, several streams are configured with a one-step or a two-step delay.

For example, to run the sample application on T4 with the 16k denoiser effect, a batch size of 10, and with all streams active, run the following command:

```
./run_effect.sh -g t4 -s 16 -b 10 -e denoiser -a
```

3.3.2.2.2. Directly Running the Sample Application

To run the sample application, run the following command:

```
./effects_delayed_streams_demo -c config-file
```

where `-c config-file` specifies the path of the config file, for example, `t4_denoise48k_10_cfg.txt`.

For example:

```
./effects_delayed_streams_demo -c t4_denoise48k_10_cfg.txt
```

Note: Sample config files for 16kHz and 48kHz audio are provided with the application.

Like `effects_demo`, the configuration files contain pairs of parameters and their values, with one pair per line. In addition to the configuration parameters used by `effects_demo`, `effects_delayed_streams_demo` requires the following parameters:

- **one_step_delay_streams list-of-stream-id**
  - Specifies the stream identifiers that belong to the `one_step_delay_streams` category as mentioned in the previous section. If none of the streams are in this category, this value should be set to none.

- **two_step_delay_streams list-of-stream-id**
  - Specifies the stream identifiers that belong to the `two_step_delay_streams` category as mentioned in the previous section. If none of the streams are in this category, this value should be set to none.

3.3.2.3. Chaining Effects

This sample application also supports chaining multiple effects [refer to Creating a Chained Audio Effect for more information].

To run the application in chaining mode, use `run_effect_chained.sh`:

```
./run_effect_chained.sh -g gpu -e1 effect1 -s1 input_sample_rate_1 -o1 output_sample_rate_1 -e2 effect2 -s2 input_sample_rate_2 -o2 output_sample_rate_2 [-c path_to_save_config_file]
```
The configuration used for this script is the same as the configuration that is used for effects_demo [refer to Chaining Effects for more information]. The script also uses the same parameters that are used by effects_delayed_streams_demo [refer to Running the Application for more information].
Chapter 4. Using the Audio Effects SDK in Applications

The Audio Effects API is a C API but can also be used with applications that are built using C++.

4.1. Creating an Audio Effect

Call the `NvAFX_CreateEffect()` function with the following parameters:

- The `NvAFX_EffectSelector` type `NVAFX_EFFECT_DENOISER`, `NVAFX_EFFECT_DEREVERB`, `NVAFX_EFFECT_DEREVERB_DENOISER`, `NVAFX_EFFECT_AEC`, or `NVAFX_EFFECT_SUPERRES`.
- The pointer to the location that stores the handle to the newly created audio effect.

The `Nvafx_CreateEffect()` function creates a handle to the audio effect instance for use in additional API calls.

The following example creates a denoiser audio effect:

```c
NvAFX_Status err = NvAFX_CreateEffect(NVAFX_EFFECT_DENOISER, &handle);
```

4.2. Creating a Chained Effect

The SDK supports running multiple effects in a chain where the output from one effect is passed as the input to the second effect without performing unnecessary pre and post-processing computations. For example, the SDK can chain the denoiser and Superresolution effects, which will take in 16kHz input data, remove the noise from this audio, and upsample the audio to 48kHz.

This process is more efficient than creating two stand-alone audio effect objects and passing the output of the first object to the second object, and the process also avoids creating unnecessary device-to-host and host-to-device copies.

The following effect chains are supported by the SDK models:

- Superresolution effect [8kHz to 16kHz] + Background Noise Removal effect [16kHz]
- Superresolution effect [8kHz to 16kHz] + Room Echo Removal Removal effect [16kHz]
- Superresolution effect [8kHz to 16kHz] + Combined Background Noise Removal/Room Echo Removal Removal effect [16kHz]
Using the Audio Effects SDK in Applications

- Background Noise Removal effect (16kHz) + Superresolution effect (16kHz to 48kHz)
- Room Echo Removal effect (16kHz) + Superresolution effect (16kHz to 48kHz)
- Combined Background Noise Removal/Room Echo Removal Removal effect (16kHz) + Superresolution effect (16kHz to 48kHz)

Important: No other effect chains are supported by the SDK models and using an unsupported chain might result in degraded audio quality.

To create a chained effect, call `NvAFX_CreateChainedEffect` with one of the following effect selectors:

- `NVAFX_CHAINED_EFFECT_DENOISER_16k_SUPERRES_16k_TO_48k`
- `NVAFX_CHAINED_EFFECT_DEREVERB_16k_SUPERRES_16k_TO_48k`
- `NVAFX_CHAINED_EFFECT_DEREVERB_DENOISER_16k_SUPERRES_16k_TO_48k`
- `NVAFX_CHAINED_EFFECT_SUPERRES_8k_TO_16k_DENOISER_16k`
- `NVAFX_CHAINED_EFFECT_SUPERRES_8k_TO_16k_DEREVERB_16k`
- `NVAFX_CHAINED_EFFECT_SUPERRES_8k_TO_16k_DEREVERB_DENOISER_16k`

The pointer to the location that stores the handle to the newly created audio effect.

The following example creates a chained audio Background Noise Removal effect (16kHz) + Superresolution effect (16kHz to 48kHz) effect:

```c
NvAFX_Status err = NvAFX_CreateChainedEffect(NVAFX_CHAINED_EFFECT_DENOISER_16k_SUPERRES_16k_TO_48k, &handle);
```

Note: Running effects in a chain might impact the performance and latency of the audio pipeline.

4.3. Setting the Parameters of an Audio Effect

An audio effect requires a model to transform the input audio. Each model supports a specific audio sample rate. The input audio sample rate and the path to the model file must be set in the SDK. The Linux SDK also supports several frame sizes (the number of samples per frame), which can be queried and set in the SDK (refer to Getting the Parameters of an Effect for more information).

To set U32 values, call the `NvAFX_SetU32()` function with the following parameters:

- Previously created effect handle.
- The selector string for the parameter to be set:
  - (Linux SDK Only) To set the sample rate, specify:
    ```c
    NVAFX_PARAM_INPUT_SAMPLE_RATE
    ```
To set the number of audio streams, specify:

```
NVAFX_PARAM_NUM_STREAMS
```

To set the number of samples per input frame, specify:

- **For Linux**
  
  ```
  NVafx_param_num_samples_per_input_frame
  ```

- **For Windows**
  
  ```
  NVAFX_PARAM_NUM_INPUT_SAMPLES_PER_FRAME
  ```

To set the number of input channels, specify:

```
NVAFX_PARAM_NUM_INPUT_CHANNELS
```

For the AEC effect, the value should be set to 2, because the effect specifies the near-end and far-end audio as separate channels. The first channel is near-end audio, and the second is far-end audio.

This parameter is not supported by chained effects.

- In a Multi-GPU setup, to have SDK automatically select the GPU compatible with the model set in SDK, set the following parameter to 1:
  
  ```
  Note: The default value is 0.
  NVAFX_PARAM_USE_DEFAULT_GPU
  ```

This parameter is not supported by chained effects.

- **(Windows SDK Only)** To allow users to create and manage their own CUDA context, set the following parameter to 1:
  
  ```
  Note: The default value is 0.
  NVAFX_PARAM_USER_CUDA_CONTEXT
  ```

  **(Windows SDK only)** To disable CUDA graphs, set the following parameter to 1.

  The default value is 0.
  ```
  NVAFX_PARAM_DISABLE_CUDA_GRAPH
  ```

- In a Multi-GPU setup, to have SDK automatically select the GPU compatible with the model set in SDK, set the following parameter to 1:
  
  ```
  NVFX_PARAM_USE_DEFAULT_GPU
  ```

  The default value is 0, and this parameter is not supported by chained effects.

- The Noise Removal and Room Echo Removal/Room Echo Cancellation effect supports VAD, which indicates whether the audio data frame supplied to the SDK through `Nvafx_Run` contains voice data.

  When enabled, this feature also removes low-volume noise and all non-speech data from the `Nvafx_Run` output without degrading performance. To enable this feature, set the following parameter to 1:

  ```
  NVAFX_PARAM_ENABLE_VAD
  ```

  The default value is 0, and this parameter is not supported by chained effects.
The VAD status for the last \texttt{NvAFX_Run} call can also be queried by using the \texttt{Nvafx_GetBoolList()} function. This query can be helpful when the audio output pipeline has an alternative packet loss concealment algorithm. For more information about querying the list, refer to Getting the Parameters of an Effect.

- An unsigned integer value that specifies the value for the selector.

To set the model, call the \texttt{Nvafx_SetString()} function with the following parameters:

- Previously created effect handle.
- A null-terminated string specifying the path to the model file.
  
  - \textbf{For the Linux SDK}
    
    - Each model file supports a specific sample rate and a maximum number of audio streams.
    - Model files for specific GPU compute versions are located in the \texttt{models/} <compute_version> directory in the SDK.

    The following GPU compute versions can be used for the following GPUs:

    - Volta (V100): \texttt{models/sm_70}
    - Turing (T4): \texttt{models/sm_75}
    - Ampere:
      
      - A100 (ga100 based GPUs): \texttt{models/sm_80}
      - A10 (ga102 or later GPUs): \texttt{models/sm_86}

    - The specified model should match the sample rate and a specified number of audio streams.
    - The model file name uses the following naming convention:
      
      \texttt{<effect>_<samplerate>_<max-streams>.trtpkg}

    - For the Superresolution effect, the model file name follows the following naming convention:
      
      \texttt{<effect>_<input_rate>_<output_rate>_<max-streams>.trtpkg}

    - For your convenience, each folder includes a symlink, for example \texttt{denoise_16k.trtpkg} and \texttt{denoiser_48k.trtpkg}, which points to the actual model.
    - \texttt{samplerate} can be 8k, 16k, or 48k.
    - The number of audio streams should be within the range 1 and \texttt{max-streams} (both inclusive).
    - Models give the best throughput performance when the number of audio streams is set to 64 or a multiple of 256 (256, 512, 768, and so on).

    For example, the \texttt{denoiser_48k_1152.trtpkg} model can be used for 48kHz and between 1 to 1152 audio streams but will be optimal for 64, 256, 512, 768, and 1024 streams. Code that uses this model can also directly use the symlink \texttt{denoiser_48k.trtpkg} in the same folder, which allows the underlying model to be changed without code changes.
For the Windows SDK

- Each model file supports a specific sample rate.
- Model files for specific GPU compute versions are located in the `models` directory in the SDK.

For example, the following code sets the sample rate to `sample_rate` and the path to the model specified by the `model_file.c_str()`.

```c
NvAFX_Status err;
err = NvAFX_SetU32(handle, NVAFX_PARAM_INPUT_SAMPLE_RATE, sample_rate);
err = NvAFX_SetString(handle, NVAFX_PARAM_MODEL_PATH, model_file.c_str());
err = Nvafx_SetU32(handle, NVAFX_PARAM_NUM_STREAMS, num_streams);
```

- For chained effects, call the `NvAFX_SetStringList` function with the following parameters:
  - The previously created effect handle.
  - An array of null-terminated strings, each specifying the path to the model file of the effect to be chained.

For example, for a Denoiser 16k + Superres 16k to 48k chain, an array that contains two paths should be passed in the following paths:

- To the 16k Denoiser model.
- To the 16k to 48k Superres model.

The model paths should follow the same conventions as the conventions of the standalone effect.

- The length of the array.

For example, the following code sets the sample rate to `sample_rate` and the path to the model specified by the `model_file.c_str()`.

```c
NvAFX_Status err;
err = NvAFX_SetU32(handle, NVAFX_PARAM_INPUT_SAMPLE_RATE, sample_rate);
err = NvAFX_SetString(handle, NVAFX_PARAM_MODEL_PATH, model_file.c_str());
err = Nvafx_SetU32(handle, NVAFX_PARAM_NUM_STREAMS, num_streams);
```

4.4. Getting the Parameters of an Effect

The number of channels in input/output audio are fixed for the Audio Effect and cannot be changed. Before running an audio effect, the number of channels that are supported by the effect must be queried. The Linux SDK also supports several frame sizes (number of samples per frame), which can be queried and set by using the set API (refer to Setting the Parameters of an Audio Effect for more information). The application can also query and use the default frame size supported by the SDK, as demonstrated in the following sample.

The Linux SDK also supports several frame sizes (number of samples per frame), which can be queried and set by using the set API (refer to Setting the Parameters of an Audio Effect for more information). The application can also query and use the default frame size supported by the SDK, as demonstrated in the following sample.
Chained effects currently **only** support a 10ms frame size.

**Note:** To ensure that the sample rate of the input audio is compatible with the Audio Effect, the sample rate should be queried first.

To query these parameters, call the `NvAFX_GetU32()` function with the following parameters:

- Previously created effect handle.
- The selector string for the parameter to be queried:
  - To get the default number of samples per input frame, specify one of the following options:
    - **For Linux**
      
      `Nvafx_param_num_samples_per_input_frame`
    - **For Windows**
      
      `Nvafx_param_num_input_samples_per_frame`
    - The number of samples for the input frame and output frame will be the same for all effects, except SuperResolution. In the Super Resolution effect, the output frames will contain more data than input frames.
  - To get the default number of samples per output frame per channel, specify one of the following options:
    - **For Linux**
      
      `Nvafx_param_num_samples_per_output_frame`
    - **For Windows**
      
      `Nvafx_param_num_output_samples_per_frame`
  - To get the number of channels in input/output audio, specify:
    
    `Nvafx_param_num_input_channels/Nvafx_param_num_output_channels`
  - To get the sample rate, specify:
    
    `Nvafx_param_output_sample_rate`
- A pointer to the location where the value will be stored.

To query lists, the user must query the list size, allocate memory for the output, and pass the newly allocated memory and size to `Nvafx_GetU32List()` or `Nvafx_GetBoolList()`. To query the list size, call the `Nvafx_GetU32List()` or the `Nvafx_GetBoolList()` function with the following parameters:

- Previously created effect handle.
- The selector string for the parameter to be queried.
  - To get the list of the number of supported samples per frame, specify `Nvafx_param_supported_num_samples_per_frame`.
  - An output pointer, set to `nullptr` (or `NULL`) to query size.
  - A pointer to the location where the size of the list is to be stored.
  - The size should be initialized to zero and will be updated with the actual size when this function is called.
The `Nvafx_GetU32List()` call retrieves the size of the list for the corresponding parameter selector with an NVAFX\_STATUS\_OUTPUT\_BUFFER\_TOO\_SMALL error status. To query the list, allocate memory for the list with the returned size and call the `Nvafx_GetU32List()` function with the following parameters:

- The selector string for the parameter to be queried.
  
  To get the list of supported number of samples per frame, specify:
  
  `NVAFX\_PARAM\_SUPPORTED\_NUM\_SAMPLES\_PER\_FRAME`.
  
  - A pointer to a U32 array of size at least of the list size retrieved from the above call.
  
  - A pointer to a location where the value of the size of the list is stored.

The following example queries an effect for the supported number of samples per frame, the number of channels in input/output audio, the sample rate, and the supported frame sizes.

```c
unsigned num_samples_per_frame, num_channels, sample_rate;
Nvafx_Status err;
err = Nvafx_GetU32(handle, NVAFX\_PARAM\_NUM\_SAMPLES\_PER\_INPUT\_FRAME,
&num_samples_per_frame);
err = Nvafx_GetU32(handle, NVAFX\_PARAM\_NUM\_INPUT\_CHANNELS, &num_channels);
err = Nvafx_GetU32(handle, NVAFX\_PARAM\_OUTPUT\_SAMPLE\_RATE, &sample_rate);

//Linux only
std::unique_ptr<unsigned int[]> supported_list = nullptr;
int list_size = 0;
err = Nvafx_GetU32List(handle, NVAFX\_PARAM\_SUPPORTED\_NUM\_SAMPLES\_PER\_FRAME,
supported_list.get(), &list_size);
if (err != NVAFX\_STATUS\_OUTPUT\_BUFFER\_TOO\_SMALL) {
    // This indicates API failure
    return;
}
supported_list.reset(new unsigned int[list_size]);
err = Nvafx_GetU32List(handle, NVAFX\_PARAM\_SUPPORTED\_NUM\_SAMPLES\_PER\_FRAME,
supported_list.get(), &list_size);

// Querying VAD results
// VAD must be supported and enabled on the handle
Nvafx_Run(...); // Process input first

// Query results for last input
// Note: If no voice is detected, output audio is zeroed by the effect
// However, result is also returned (in case custom packet loss concealment is desired) - returns NVAFX\_TRUE if input audio had voice, NVAFX\_FALSE otherwise
std::vector<Nvafx_Bool> out(num_streams, 0);
uint32_t s = out.size();
auto status = Nvafx_GetBoolList(handle, NVAFX\_PARAM\_VAD\_RESULT, out.data(), &s);
assert(status == NVAFX\_STATUS\_SUCCESS);
// Use VAD result
```
4.5. Getting Supported Devices (Windows SDK Only)

The `NvAFX_GetSupportedDevices()` function can be used to determine the GPUs that are supported by the currently selected model.

> **Note:** This method must be called after you set the model path.

Call this function with the following parameters:

- The effect handle.
- The size of the input array.
  
  If the call succeeds, this value will be set by the function.
- Array of size num.

The function will fill the array with the CUDA device indices of devices that are supported by the model, in descending order of preference, where the first device is the most preferred device.

This example fetches the list of supported GPUs by the model:

```cpp
int numSupportedDevices = 0;
NvFX_GetSupportedDevices(handle, &numSupportedDevices, nullptr);
std::vector<int> ret(num);
NvFX_GetSupportedDevices(handle, &numSupportedDevices, ret.data());
```

4.6. Loading an Audio Effect

Loading an effect involves validating the parameters that were set for the effect and loading the specified model into GPU memory.

To load an audio effect, set the parameters for the effect described in the previous section and call `NvFX_Load()` with the effect handle.

```cpp
NvFX_Status err = NvFX_Load(handle);
```

4.7. Running an Audio Effect

Once the effect is loaded, it can be applied to input audio using the `NvFX_Run()` function. When the effect is run, the contents of the input memory buffer are read, the audio effect is applied, and the output is written to the output memory buffer.

> **Note:** Input/Output memory buffers are in CPU memory. Copying to/from GPU memory is handled internally by the SDK.

To run an audio effect, call the `NvFX_Run()` function with the following parameters:
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- Previously created effect handle.
- The input memory buffer.
  
  For the AEC effect, specify two channels, where the first channel is the batched near-end audio, and the second channel is the batched far-end audio.
- The output memory buffer.
  
  For Super Resolution effect, the size of input and output memory buffer will differ and should be queried by the user using the following:
  
  - NVAFX_PARAM_NUM_OUTPUT_SAMPLES_PER_FRAME
  - NVAFX_PARAM_NUM_INPUT_SAMPLES_PER_FRAME
- The number of samples per frame per stream of input/output data.
- The number of channels in input/output audio.

Refer to Getting the Parameters of an Effect for more information.

The following example runs an audio effect:

```
NvAFX_Status err = NvAFX_Run(handle, input, output, num_samples, num_channels);
```

### 4.8. Running Multiple Audio Effects in a Chain

The SDK supports running multiple effects in a chain where the output from one effect is passed as the input to the second effect without performing unnecessary pre and post-processing computations. For example, the SDK can chain the denoiser and Superresolution effects, which will take in 16kHz input data, remove the noise from this audio, and upsample it to 48kHz.

This process is more efficient than creating two stand-alone audio effect objects and passing the output of the first object to the second object, and the process also avoids creating unnecessary device-to-host and host-to-device copies.

The following effect chains are supported by the SDK models:

- Superresolution effect [8kHz to 16kHz] + Background Noise Removal effect [16kHz]
- Superresolution effect [8kHz to 16kHz] + Room Echo Removal Removal effect [16kHz]
- Superresolution effect [8kHz to 16kHz] + Combined Background Noise Removal/Room Echo Removal Removal effect [16kHz]
- Background Noise Removal effect [16kHz] + Superresolution effect [16kHz to 48kHz]
- Room Echo Removal Removal effect [16kHz] + Superresolution effect [16kHz to 48kHz]
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- Combined Background Noise Removal/Room Echo Removal Removal effect (16kHz) + Superresolution effect (16kHz to 48kHz)

**Important:** No other effect chains are supported by the SDK models and using an unsupported chain might result in degraded audio quality.

**Note:** If you are combining the Denoiser effect and the Dereverber effect, use the combined Denoiser+Dereverb model (refer to About the Room Echo Cancellation + Background Noise Suppression Effect for more information).

The following example demonstrates running two effects in a chain:

```c
NvAFX_Status err;
err = NvAFX_API NvAFX_CreateChainedEffect(NVAFX_CHAINED_EFFECT_DENOISER_16k_SUPERRES_16k_TO_48k, &effect);
// Set effect parameters & load effect
...
NvAFX_Status err = NvAFX_Run(chained_handle, input_audio, intermediate_output, num_samples, num_channels);
```

**Note:** Running effects in a chain might impact the performance and latency of the audio pipeline.

4.9. Running an Audio Effect on Delayed Audio Streams (Linux SDK Only)

The Linux SDK supports cases where some streams do not arrive at the expected time. These streams are referred to as delayed streams. To support handling these streams, the SDK allows applications to specify a list that indicates whether the corresponding stream is currently active or delayed/inactive.

The list can be set by calling `NvAFX_SetBoolList()` with the following function parameters:

- Previously created effect handle.
- The selector string, `NVAFX_PARAM_ACTIVE_STREAMS` for the parameter that will be set.
- An array of type `NVAFX_BOOL` where each element represents the status of the corresponding audio stream. `NVAFX_TRUE` indicates an active stream, and `NVAFX_FALSE` indicates an inactive stream
- Length of the above array, which is equal to the number of audio streams.

For delayed audio streams, the effect can be initially applied on all delayed audio streams by setting them as active and setting the on-time audio streams as inactive. This should be followed by one or more `NvAFX_Run()` calls to apply the effect on the delayed audio streams. After the delayed audio streams are processed, the on-time audio streams are set to active, and `NvAFX_Run()` is executed once to apply the effect.

The following example demonstrates how to process four streams:
1. Consider an effect that accepts 10ms audio inputs.
2. Audio streams 1 and 3 are delayed by 10ms each and arrive with 20ms worth of data.
3. Audio streams 2 and 4 are on time and arrive with 10ms of data.
4. Streams can be processed in one of the following ways:
   - **Option 1**
     - Process the extra 10ms **only** in the delayed streams and then process on-time 10ms data for all streams. Initially, by using `Nvafx_SetBoolList`, streams 1 and 3 are set as active, and 2 and 4 are set as inactive.
       a). An `Nvafx_Run` call is executed where 10ms of data from streams 1 and 3 is populated in the input while the rest of the input is set to 0. This step processes the extra 10ms of data in streams 1 and 3.
       b). A second `Nvafx_SetBoolList` call is executed to set all streams (1, 2, 3, and 4) as active.
       c). An `Nvafx_Run` call is executed with the real-time 10ms data from all four streams.
   - **Option 2**
     - Process 10ms in all streams and then process the extra 10ms data only in delayed streams:
       a). Process 10ms of data from all streams (stale data from stream 1 and 3 and new data from stream 2 and 4 by calling `Nvafx_Run`.
       b). Set streams 1 and 3 to active and 2 and 4 to inactive by calling `Nvafx_SetBoolList`.
       c). Process the extra 10ms from stream 1 and 3 by calling `Nvafx_Run`.

The following example runs an audio effect after setting some of the audio streams as inactive:

```c
Nvafx_Status err = Nvafx_SetBoolList(handle, NVAFX_PARAM_ACTIVE_STREAMS, stream_active_list, num_streams);
Nvafx_Status err = Nvafx_Run(handle, input, output, num_samples, num_channels);
```

The internal state of each stream is updated during each `Nvafx_Run` call only for active streams. Setting a stream to inactive will disable updating this state. If required, this state can also be reset using `Nvafx_Reset`, as described in `Nvafx_Reset`.

### 4.10. Destroying an Audio Effect

When an audio effect is no longer required, it should be destroyed to free the resources and memory used by the effect.

To destroy an audio effect, call `Nvafx_DestroyEffect()` and specify the effect handle to the effect to be destroyed.

```c
Nvafx_Status err = Nvafx_DestroyEffect(handle);
```
4.11. Using Multiple GPUs

Applications that are developed with the Audio Effects SDK can be used with multiple GPUs. By default, the SDK assumes that the application will set the GPU. Optionally, the SDK can select the best GPU to run the effect(s).

4.11.1. Selecting the GPU for Audio Effects Processing in a Multi-GPU Environment

The GPU that will be used to run audio effect(s) in a multi-GPU environment can be controlled by using the cudaSetDevice() and cudaGetDevice() CUDA functions. The device should be set before NvAFX_Load() is called because NvAFX_Load() will succeed only when the currently selected GPU supports the SDK.

```c
int chosenGPU = 0; // or whichever GPU you want to use
cudaSetDevice(chosenGPU);
NvAFX_Handle effect;
err = NvAFX_API NvAFX_CreateEffect(code, &effect);
err = NvAFX_Set...; // set parameters
...
err = Nvafx_API NvAFX_Load(effect);
...
err = Nvafx_API Nvafx_Run(effect, ...);
```

4.11.2. Selecting GPUs for Chained Audio Effects (Linux Only)

When using chained effects in a multi-GPU environment, the SDK can optionally run the effects in the chain on separate GPUs. For example, in a Denoiser 16k + Superres 16k to 48k chain, you can run the denoiser effect entirely on one GPU and run the Superres effect on another GPU.

To use this feature, create the chained effect and set NVAFX_PARAM_CHAINED_EFFECT_GPU_LIST to an array that specifies the GPU IDs that are using NvAFX_SetU32List. This parameter must be set before you call NvAFX_Load on the effect.

The following sample demonstrates use of this parameter:

```c
NvAFX_Handle effect;
err = Nvafx_API Nvafx_CreateChainedEffect(code, &effect);
...
// Run first effect on GPU id 3, second on GPU id 4
uint32_t gpus[] = { 3, 4};
err = Nvafx_API SetU32List(effect, NVAFX_PARAM_CHAINED_EFFECT_GPU_LIST, gpus, sizeof(gpus));
...
err = Nvafx_API Nvafx_Load(effect);
```
4.11.3. Offloading GPU Selection to the SDK for Audio Effects Processing in a Multi-GPU Environment

In a multi-GPU environment, the SDK can optionally determine the optimal GPU on which to run the audio effect(s). To use this feature, call `NvAFX_SetU32` with the `NvAFX_SetU32(effect, NVAFX_PARAM_USE_DEFAULT_GPU, 1)` parameters before loading effects. If `NvAFX_SetU32` is called after an audio effect is loaded, the function will not have any effect.

If the application sets `NVAFX_PARAM_USE_DEFAULT_GPU` to 0, or does not set this parameter, the SDK will explicitly not select the GPU to run the effect. The application can set the device on which SDK calls are to be executed by using the `cudaSetDevice` API. If this parameter is not set or is set to 0, the SDK will use the default device (device 0).

If the application sets `NVAFX_PARAM_USE_DEFAULT_GPU` to 1, the application should not call `cudaSetDevice()`, and the other effects (or multiple instances of an effect) will use the GPU that was determined by the SDK. If the application explicitly calls `cudaSetDevice()` before `NvAFX_Load()`, the SDK might override the application’s device preference. If the client calls `cudaSetDevice()` to set the GPU to a different GPU just before calling `NvAFX_Run()`, the `NvAFX_Run()` call will fail.

```c
NvAFX_Handle effect;
err = NvAFX_API NvAFX_CreateEffect(code, &effect);
err = Nvafx_API SetU32(effect, NVAFX_PARAM_USE_DEFAULT_GPU, 1);
...
err = Nvafx_API Nvafx_Load(effect);
...
```

Note: `NVAFX_PARAM_USE_DEFAULT_GPU` and `NVAFX_PARAM_USER_CUDA_CONTEXT` cannot be used at the same time.

4.11.4. Selecting Different GPUs for Different Tasks

The applications that use the SDK might be designed to perform multiple tasks in a multi-GPU environment in addition to applying the audio effect filter. In this situation, the best GPU for each task should be selected before calling `NvAFX_Load` and be set before each `NvAFX_Run` call.

The application is responsible for switching to the appropriate GPU before executing SDK calls. If the application does not switch to the appropriate GPU before calling `NvAFX_Run`, the call will fail with an error.

The following steps demonstrate how to complete CUDA tasks and SDK calls on different GPUs.

1. Call `cudaGetDeviceCount()` to determine the number of available GPUs.

   ```c
   // Get the number of GPUs
   cuErr = cudaGetDeviceCount(&deviceCount);
   ```

2. Determine the best GPU for the task.
For example, you can use `cudaGetDeviceProperties()` to iterate over the available GPUs and select the GPU with the highest number of SMs.

3. In the loop that completes the application’s tasks, select the best GPU for each task before performing the task by calling `cudaSetDevice()` to select the GPU for the task.

4. Before executing SDK calls, call `cudaSetDevice()` again to set the GPU back to the Audio Effects GPU.

```c
// Select the best GPU for each task and perform the task.
while (!done) {
    cudaSetDevice(gpuOtherTask);
    PerformOtherTask();
    cudaSetDevice(gpuAFX);
    err = NvAFX_Run(effect, ...)
```

4.11.5. CUDA Graph Support (Windows Only)

The Windows SDK supports using CUDA graphs, which improve performance by reducing the CPU overheads that are seen with short-lived CUDA kernels.

By default, graphs are enabled in the Windows SDK, but this can cause issues if the SDK runs in parallel with other applications that are using CUDA graphs. The following example shows you how to disable CUDA graphs:

```c
// Call before loading model (NvAFX_Load) Windows only
err = NvAFX_API SetU32(effect, NVAFX_PARAM_DISABLE_CUDA_GRAPH, 1);
...
Chapter 5. Audio Effects SDK API Reference

This section provides detailed information about the APIs in the Audio Effects SDK.

5.1. Type Definitions

The Audio Effects SDK type definitions provide selector strings for the audio effect and the parameters of an audio effect.

5.1.1. NvAFX_EffectSelector

This type definition provides selector strings for the audio effect types.

```c
typedef const char* NvAFX_EffectSelector;
```

The currently supported selectors are:

- **NVAFX_EFFECT_DENOISER**: "denoiser"
  - Denoiser audio effect (refer to [About the Background Noise Suppression Effect](#)).

- **NVAFX_EFFECT_DEREVERB**: "dereverb"
  - De-reverb effect (refer to [About the Room Echo Cancellation Effect](#)).

- **NVAFX_EFFECT_DEREVERB_DENOISER**: "dereverb_denoiser"
  - Combined De-reverb and Denoiser effects (refer to [About the Noise Removal and Room Echo Removal/Room Echo Cancellation + Background Noise Suppression Effect](#)).

- **NVAFX_EFFECT_AEC**: "aec"
  - AEC effect (refer to [About the Acoustic Echo Cancellation Effect (BETA)](#)).

- **NVAFX_EFFECT_SUPERRES**
  - Audio Super-resolution effect (see [About the Audio Super-Resolution Effect (BETA)](#)).

- **NVAFX_CHAINED_EFFECT_DENOISER_16k_SUPERRES_16k_TO_48k**
  - Chained effect [Denoiser 16k + Superres 16k to 48k]

- **NVAFX_CHAINED_EFFECT_DEREVERB_16k_SUPERRES_16k_TO_48k**
  - Chained effect [Dereverb 16k + Superres 16k to 48k]

- **NVAFX_CHAINED_EFFECT_DEREVERB_DENOISER_16k_SUPERRES_16k_TO_48k**
  - Chained effect [Dereverb+Denoiser 16k + Superres 16k to 48k]

- **NVAFX_CHAINED_EFFECT_SUPERRES_8k_TO_16k_DENOISER_16k**
  - Chained effect [Superres 8k to 16k + Denoiser 16k]

- **NVFX_CHAINED_EFFECT_SUPERRES_8k_TO_16k_DEREVERB_16k**
  - Chained effect [Superres 8k to 16k + Dereverb 16k]
5.1.2. NvAFX_ParameterSelector

This type definition provides selector strings for audio effect parameters.

```c
typedef const char* NvAFX_ParameterSelector;
```

The currently supported selectors are:

- **NVAFX_PARAM_MODEL_PATH**: "model_path"
  
  A character string that specifies the path to the model file for the audio effect.

- **NVAFX_PARAM_INPUT_SAMPLE_RATE**: "input_sample_rate"
  
  An unsigned integer that specifies the audio input sample rate for the audio effect.

- **NVAFX_PARAM_OUTPUT_SAMPLE_RATE**: "output_sample_rate"
  
  An unsigned integer that specifies the audio output sample rate for the audio effect.

- **(Linux SDK only) NVAFX_PARAM_NUM_SAMPLES_PER_INPUT_FRAME**: "num_samples_per_input_frame"
  
  An unsigned integer that specifies the number of samples per input frame per audio stream for the audio effect.

- **(Windows SDK only) NVAFX_PARAM_NUM_INPUT_SAMPLES_PER_FRAME**: "num_input_samples_per_frame"
  
  An unsigned integer that specifies the number of samples per input frame per audio stream for the audio effect.

- **(Linux SDK only) NVAFX_PARAM_NUM_SAMPLES_PER_OUTPUT_FRAME**: "num_samples_per_output_frame"
  
  An unsigned integer that specifies the number of samples per output frame per audio stream for the audio effect.

- **(Windows SDK only) NVAFX_PARAM_NUM_OUTPUT_SAMPLES_PER_FRAME**: "num_output_samples_per_frame"
  
  An unsigned integer that specifies the number of samples per output frame per audio stream for the audio effect.

- **NVAFX_PARAM_NUM_INPUT_CHANNELS**: "num_input_channels"
  
  An unsigned integer that specifies the number of audio channels for the audio effect.

- **NVAFX_PARAM_NUM_OUTPUT_CHANNELS**: "num_output_channels"
  
  An unsigned integer that specifies the number of output audio channels for the audio effect.

- **NVAFX_PARAM_NUM_STREAMS**: "num_streams"
  
  An unsigned integer that specifies the number of audio streams to be processed by the audio effect.

- **NVAFX_PARAM_INTENSITY_RATIO**: "intensity_ratio"
  
  A float value that specifies the factor that ranges from 0.0 to 1.0. Setting the factor to 0.0 is identical to a pass through, and a value of 1.0 provides the maximum possible impact of the effect.

- **(Linux SDK only) NVAFX_PARAM_ACTIVE_STREAMS**: "active_streams"
  
  A list of NvAFX_Bool values that specify whether the corresponding stream is active.

- **(Linux SDK only) NVAFX_PARAM_SUPPORTED_NUM_SAMPLES_PER_FRAME**: "supported_num_samples_per_frame"
  
  A list of U32 values that specifies the supported values for the number of samples per frame.
NVAFX_PARAM_CHAINED_EFFECT_GPU_LIST
A list of U32 values specifying the GPUs to be used in chained effects. Each effect in the chain will use the corresponding GPU from the list.

(Windows SDK Only) NVAFX_PARAM_USER_CUDA_CONTEXT: "user_cuda_context"
An unsigned integer value that allows SDK users to disable the SDK internal context management. To disable the internal context management, set this value to 1. This value cannot be changed after the model is loaded for that particular session.

NVAFX_PARAM_DISABLE_CUDA_GRAPH : "disable_cuda_graph"
An unsigned integer value that specifies whether to enable CUDA graphs (enabled by default):

- To disable CUDA graphs, set this value to 1.
- To enable CUDA graphs, set this value to zero.

For more information about CUDA Graphs, refer to Getting Started with CUDA Graphs.

Note: NVAFX_PARAM_USE_DEFAULT_GPU and NVAFX_PARAM_USER_CUDA_CONTEXT cannot be used at the same time.

The following selectors have been deprecated:

- NVAFX_PARAM_NUM_CHANNELS: "num_channels"
- NVAFX_PARAM_SAMPLE_RATE: "sample_rate"
- NVAFX_PARAM_NUM_SAMPLES_PER_FRAME: "num_samples_per_frame"

5.1.3. NvAFX_Handle
An opaque handle that is associated with an instance of an audio effect.

typedef void* NvAFX_Handle;

5.1.4. NvAFX_Bool (Linux SDK Only)
This type definition is set to NVAFX_TRUE to represent true and NVAFX_FALSE to represent false.

typedef char NvAFX_Bool;

5.1.5. logging_cb_t (Linux SDK Only)
A callback function type that is used in the NvAFX_InitializeLogger API.

typedef void(*logging_cb_t)(LoggingSeverity level, const char* log, void* userdata);

5.1.6. LoggingSeverity (Linux SDK Only)
The levels of the LoggingSeverity that are used in the NvAFX_InitializeLogger API.

typedef enum LoggingSeverity_t {
    LOG_LEVEL_ERROR,
    LOG_LEVEL_WARNING,
    LOG_LEVEL_INFO,
} LoggingSeverity
5.1.7. LoggingTarget (Linux SDK Only)

The logging target used in the `NvAFX_InitializeLogger` API.

typedef enum LoggingTarget_t
{
    LOG_TARGET_NONE = 0x0,
    LOG_TARGET_STDERR = 0x1,
    LOG_TARGET_FILE = 0x2,
    LOG_TARGET_CALLBACK = 0x4,
} LoggingTarget;

5.2. Functions

This section provides information about the functions in the Audio Effects SDK.

5.2.1. NvAFX_GetEffectList

This function retrieves a list of supported audio effects.

```c
NvAFX_Status NvAFX_GetEffectList(
    int* num_effects,
    NvAFX_EffectSelector* effects[]
);
```

Parameters

**num_effects [out]**

Type: int*

Pointer to an integer that contains the number of effects returned.

**effects [out]**

Type: NvAFX_EffectSelector* []

Address to a list of effect selection strings that are supported by the SDK. This list is statically allocated by the SDK, so the caller should not allocate memory for this parameter or free it after use. Refer to `NvAFX_EffectSelector` for more information about the selection strings.

Return Value

`NVAFX_STATUS_SUCCESS` on success.

Remarks

This function retrieves the list of audio effects that are supported by the SDK. The selection strings for the Audio Effects SDK are populated in the `effects` output parameter. The number of available effects are written to the `num_effects` output parameter.
5.2.2. NvAFX_CreateEffect

This function creates an audio effect.

NvAFX_Status NvAFX_CreateEffect(
    NvAFX_EffectSelector code,
    NvAFX_Handle* effect
);

Parameters

code [in]
    Type: NvAFX_EffectSelector
    The selection string for the type of audio effect that will be created. See NvAFX_EffectSelector for more information about the allowed selection strings.

effect [out]
    Type: NvAFX_Handle*
    The pointer to the location where the handle to the newly created audio effect instance will be stored.

Return Value

NVAFX_STATUS_SUCCESS on success.

Remarks

This function creates an instance of the specified type of audio effect and also writes a handle to the audio effect instance to the effect output parameter.

5.2.3. NvAFX_CreateChainedEffect

This function creates a chained effect instance.

NvAFX_Status NvAFX_CreateChainedEffect(
    NvAFX_EffectSelector code,
    NvAFX_Handle* effect
);

Parameters

code [in]
    Type: NvAFX_EffectSelector
    The selection string for the type of chained audio effect that will be created. Refer to NvAFX_EffectSelector for more information about the allowed selection strings.

effect [out]
    Type: NvAFX_Handle*
The pointer to the location where the handle to the newly created chained audio effect instance will be stored.

**Return Value**

`NVAFX_STATUS_SUCCESS` on success.

**Remarks**

This function creates an instance of the specified type of chained audio effect and returns the handle to this effect instance by using the `effect` output parameter.

### 5.2.4. NvAFX_DestroyEffect

This function destroys an effect instance.

```c
NvAFX_Status NvAFX_DestroyEffect(  
    NvAFX_Handle effect
);
```

**Parameters**

- `effect [in]`
  
  **Type:** `NvAFX_Handle`
  
  The handle to the audio effect instance that will be destroyed.

**Return Value**

`NVAFX_STATUS_SUCCESS` on success.

**Remarks**

This function destroys the audio effect instance with the specified handle and frees all resources and memory that were used by that instance.

### 5.2.5. NvAFX_SetString

This function sets a string parameter of the specified effect.

```c
NvAFX_Status NvAFX_SetString(  
    NvAFX_Handle effect,  
    NvAFX_ParameterSelector param_name,  
    const char* val
);
```

**Parameters**

- `effect [in]`
  
  **Type:** `NvAFX_Handle`
  
  The handle to the audio effect instance.
param_name [in]
   Type: NvAFX_ParameterSelector
   Refer to Setting the Parameters of an Audio Effect for a list of the allowed options.
val [in]
   Type: char*
   Pointer to the character string to be set.

Return Value
NVAFX_STATUS_SUCCESS on success.

Remarks
This function sets the value of the specified character string parameter for the specified audio effect to the val parameter.

5.2.6. NvAFX_SetStringList
This function sets a string parameter of the specified effect.

NvAFX_Status NvAFX_SetStringList(
   NvAFX_Handle effect,
   NvAFX_ParameterSelector param_name,
   const char** list, unsigned int list_size
);

Parameters

effect [in]
   Type: NvAFX_Handle
   The handle to the audio effect instance.

param_name [in]
   Type: NvAFX_ParameterSelector
   Refer to Setting the Parameters of an Audio Effect for a list of the allowed options.

list[in]
   Type: char*
   Pointer to the character string to be set.

list_size[in]
   Type: unsigned int
   Size of the character array to be set.
Return Value

NVAFX_STATUS_SUCCESS on success.

Remarks

This function sets the value of the specified character string parameter for the specified audio effect to the `val` parameter.

5.2.7.  NvAFX_SetU32

This function sets a UInt parameter of the specified effect.

```
NvAFX_Status NvFX_SetU32(  
    NvAFX_Handle effect,   
    NvFX_ParameterSelector param_name,  
    unsigned int val   
);
```

Parameters

effect [in]

Type: NvAFX_Handle

The handle to the audio effect.

Param_name [in]

Type: NvFX_ParameterSelector

Refer to Setting the Parameters of an Audio Effect for the list of allowed options.

Any other selector string returns an error.

Note: For the Linux SDK, the valid values for the NVAFX_PARAM_NUM_SAMPLES_PER_INPUT_FRAME setting can be queried by using the NvAFX_GetU32List() function with NVAFX_PARAM_SUPPORTED_NUM_SAMPLES_PER_FRAME as the selector.

Setting any other value will result in an error.

val [in]

Type: unsigned int

Value to be set for the parameter.

Return Value

NVAFX_STATUS_SUCCESS on success.
Remarks
This function sets the value of the specified 32-bit unsigned integer parameter for the specified audio effect to the val parameter.

5.2.8. NvAFX_GetString
This function gets the current value of the set string parameter of the specified effect.

NvAFX_Status NvAFX_GetString(
    NvAFX_Handle effect,
    NvAFX_ParameterSelector param_name,
    char* val,
    int max_length
);

Parameters

effect [in]
    Type: NvAFX_Handle
    The handle to the audio effect instance.

Param_name [in]
    Type: NvAFX_ParameterSelector
    Refer to Setting the Parameters of an Audio Effect for a list of the allowed options.

val [out]
    Type: char*
    The address of the buffer where the requested character string will be stored. This buffer must be allocated and freed by the caller.

max_length [in]
    Type: int
    The length in bytes of the buffer that is specified by the val parameter.

Return Value
NVAFX_STATUS_SUCCESS on success.

Remarks
This function gets the value of the character string parameter for the specified audio effect and writes the retrieved string to the buffer at the location specified by the val parameter.

5.2.9. NvAFX_GetU32
This function gets the value of a uint parameter of the specified effect.

NvAFX_Status NvAFX_GetU32(
NvAFX_Handle effect,
NvAFX_ParameterSelector param_name,
unsigned int* val
);

Parameters

effect [in]

Type: NvAFX_Handle

The handle to the audio effect instance.

param_name [in]

Type: NvAFX_ParameterSelector

Refer to Setting the Parameters of an Audio Effect for a list of the allowed options.

Note: For the Linux SDK, although NVAFX_PARAM_NUM_SAMPLES_PER_INPUT_FRAME can be queried by using this API to get the default number of samples per frame, you should use NvAFX_GetU32List() with the NVAFX_PARAM_SUPPORTED_NUM_SAMPLES_PER_FRAME parameter to get the list of supported values.

You can then use NvAFX_SetU32() with the NVAFX_PARAM_NUM_SAMPLES_PER_FRAME parameter to set the value.

val [out]

Type: unsigned int*

The address of the buffer where the retrieved 32-bit unsigned integer parameter value will be written.

Return Value

NVAFX_STATUS_SUCCESS on success.

Remarks

This function gets the value of the specified 32-bit unsigned integer parameter for the specified audio effect and writes the retrieved value to the buffer that is specified by the val parameter.

5.2.10.  NvAFX_GetU32List (Linux SDK Only)

This function gets the uint list parameter values for the specified effect.

NvAFX_Status NvAFX_GetU32List(
    NvAFX_Handle effect,
    NvAFX_ParameterSelector param_name,
    unsigned int* list[],
    int* list_size
);
Parameters

**effect [in]**

Type: NvAFX_Handle
The handle to the audio effect instance.

**param_name [in]**

Type: NvAFX_ParameterSelector
The following selector:
NVAFX_PARAM_SUPPORTED_NUM_SAMPLES_PER_FRAME
Any other selector string returns an error.

**list [out]**

Type: unsigned int* []
The address to a list that contains the 32-bit unsigned values for the given selector.

**list_size [out]**

Type: int*
Pointer to an integer that contains the number of values that were returned in the list.

Return Value

- NVAFX_STATUS_SUCCESS on success.
- NVAFX_STATUS_OUTPUT_BUFFER_TOO_SMALL when the list_size is less than the minimum required size of the list array.

Remarks

This function gets the list of 32-bit unsigned integer values for the specified audio effect, writes the retrieved values to a buffer specified by list and writes the size of the returned list in the buffer specified by list_size.
5.2.11. **NvAFX_GetBoolList**

This function gets the uint list parameter values for the specified effect.

```c
NvAFX_Status NvAFX_GetBoolList(
    NvAFX_Handle effect,
    NvAFX_ParameterSelector param_name,
    NvAFX_Bool list[]
    int* list_size
);
```

**Parameters**

- **effect [in]**
  
  Type: NvAFX_Handle
  
  The handle to the audio effect instance.

- **param_name [in]**
  
  Type: NvAFX_ParameterSelector
  
  The following selector:
  
  NVAFX_PARAM_VAD_RESULT
  
  Any other selector string returns an error.

- **list [out]**
  
  Type: NvAFX_Bool* []
  
  The address to a list that contains the boolean values for the given selector.

- **list_size [out]**
  
  Type: int*
  
  Pointer to an integer that contains the number of values that were returned in the list.

**Return Value**

- NVAFX_STATUS_SUCCESS on success.
- NVAFX_STATUS_OUTPUT_BUFFER_TOO_SMALL when the list_size is less than the minimum required size of the list array.

---

*Note: The application needs to call this API with list_size initialized to zero, and list set to nullptr to get the size of list to be allocated. The size will be returned in list_size parameter. The application can then allocate an array of at least list_size and call the API again with list pointing to the array. Refer to Create an Audio Effect for an example.*
Remarks
This function gets the list of boolean values for the specified audio effect, writes the retrieved values to a buffer specified by list, and writes the size of the returned list in the buffer specified by list_size.

5.2.12. NvAFX_GetSupportedDevices (Windows SDK Only)
The function gets a list of compatible devices that are supported by the currently set model file.

```c
NvAFX_Status NvAFX_GetSupportedDevices(
    NvAFX_Handle effect,
    int *num,
    int *devices
);
```

Parameters

effect [in]
Type: NvAFX_Handle
The handle to the audio effect instance to load.

num [in, out]
Type: int*
The size of the input array. If the call succeeds, this value will be set by the function.

devices [in, out]
Type: int*
Array of size num. The function will fill the array with CUDA device indices of devices that are supported by the model in descending order of preference, where the first device is the most preferred device.

Return Value
NVAFX_STATUS_SUCCESS on success.

Remarks
This function gets the devices supported by the model.

5.2.13. NvAFX_Load
This function validates effect parameters and loads the specified effect.

```c
NvAFX_Status NvAFX_Load(
    NvAFX_Handle effect
);
```
Parameters

effect [in]

Type: NvAFX_Handle

The handle to the audio effect instance to load.

Return Value

NVAFX_STATUS_SUCCESS on success.

Remarks

This function validates the parameters that are set for the effect and loads the specified audio effect.

5.2.14. NvAFX_Run

This function runs the specified effect.

```c
NvAFX_Status NvAFX_Run(
    NvAFX_Handle effect,
    const float** input,
    float** output,
    unsigned num_samples,
    unsigned num_channels
);
```

Parameters

effect [in]

Type: NvAFX_Handle

The handle to the audio effect instance to run.

input [in]

Type: const float**

Pointer to a user-allocated array of buffers where each buffer holds the audio data for one channel. The size of the array must be equal to the number of input samples in frame (set via NVAFX_PARAM_NUM_SAMPLES_PER_INPUT_FRAME) and multiplied by the number of streams for which the effect is configured (set via NVAFX_PARAM_NUM_STREAMS and is always 1 for the Windows SDK).

The number of channels must be equal to the value of the NVAFX_PARAM_NUM_INPUT_CHANNELS parameter that was obtained by the NvAFX_GetU32() function.

The sample rate of the audio data must be equal to the sample rate that was preset for the effect. For example, for the Audio Effect, the sample rate must be equal to the value of the
NVAFX_PARAM_INPUT_SAMPLE_RATE parameter that was obtained by the NvAFX_GetU32() function.

**output [out]**

Type: `float**`

Pointer to a user-allocated array of buffers to which the output of the effect will be written. The size of the array must be equal to the number of output samples in frame (set via NVAFX_PARAM_NUM_SAMPLES_PER_OUTPUT_FRAME) multiplied by the number of streams the effect is configured for (set via NVAFX_PARAM_NUM_STREAMS).

**Note:** The buffers must be allocated, and later freed, by the calling program. Internally, NvAFX_Run copies the input/output to/from the GPU, so pinning input/output buffers does not have any effect.

**num_samples [in]**

Type: `unsigned`

The number of samples in the input buffer.

**num_channels [in]**

Type: `unsigned`

The number of input channels.

**Return Value**

NVAFX_STATUS_SUCCESS on success.

**Remarks**

This function runs the specified audio effect by reading the contents of the input buffer, applying the audio effect, and writing the output to the output buffer.

### 5.2.15. NvAFX_Reset

This function resets the internal state and flushes the internal history for specified batches in the effect.

**Windows SDK**

```c
NNvAFX_Status NvAFX_Reset(
    NvAFX_Handle effect
);
```

**Linux SDK**

```c
NvAFX_Status NvAFX_Reset(
    NvAFX_Handle effect,
    NvAFX_Bool* list,
    int length
);
```
Parameters

**effect [in]**

Type: NvAFX_Handle

The handle to the audio effect instance to run.

**list [in] (Linux SDK Only)**

Type: NvAFX_Bool *

Pointer to a memory location that indicates the streams to be reset. The i-th element in this array should be set to NVAFX_TRUE to reset the i-th stream and to NVAFX_FALSE otherwise.

**length [in] (Linux SDK Only)**

Type: int

Number of elements in the array specified. The value should be equal to the number of streams (batches).

Return Value

NVAFX_STATUS_SUCCESS on success.

Remarks

Allows the state of an effect to be reset.

5.2.16. **NvAFX_SetBoolList (Linux SDK Only)**

This function sets a list parameter of the specified effect.

```c
NvAFX_Status NvAFX_SetBoolList(
  NvAFX_Handle effect,
  NvAFX_ParameterSelector param_name,
  const NvAFX_Bool* list,
  unsigned int list_size
);
```

Parameters

**effect [in]**

Type: NvAFX_Handle

The handle to the audio effect.

**Param_name [in]**

Type: NvAFX_ParameterSelector

The following:

NVAFX_PARAM_ACTIVE_STREAMS
Any other selector string returns an error.

**list [in]**

Type: NvAFX_Bool*

Array of Boolean values to be set for the parameter.

**list_size [in]**

Type: unsigned int

Size of the Boolean array that was passed as the input.

**Return Value**

NVAFX_STATUS_SUCCESS on success.

**Remarks**

This function sets the boolean values of the list parameter for the specified audio effect to the values from list.

### 5.2.17. NvAFX_SetU32List (Linux SDK only)

This function sets a list parameter of the specified effect.

```c
NvAFX_Status NvAFX_SetU32List(
    NvAFX_Handle effect,
    NvAFX_ParameterSelector param_name,
    const unsigned int* list,
    unsigned int list_size
);
```

**Parameters**

**effect [in]**

Type: NvAFX_Handle

The handle to the audio effect.

**Param_name [in]**

Type: NvAFX_ParameterSelector

The following:

NVAFX_PARAM_CHAINED_EFFECT_GPU_LIST

Any other selector string returns an error.

**list [in]**

Type: unsigned int*

Array of U32 values to be set for the parameter.
list_size [in]

Type: unsigned int

Size of the array that was passed as the input.

Return Value

NVAFX_STATUS_SUCCESS on success.

Remarks

This function sets the U32 values of the list parameter for the specified audio effect to the values from list.

5.2.18. NvAFX_InitializeLogger (Linux SDK Only)

This function initializes the SDK logger.

NvAFX_Status NvAFX_InitializeLogger(
   LoggingSeverity level,
   int target,
   const char *filename,
   logging_cb_t cb,
   void* userdata
);

Parameters

level [in]

Type: LoggingSeverity

The logging level to enable. When you enable a level, it includes the levels before the current level. For example, LOG_LEVEL_INFO also includes LOG_LEVEL_WARNING and LOG_LEVEL_ERROR.

The following levels can be used:

- LOG_LEVEL_ERROR
- LOG_LEVEL_WARNING
- LOG_LEVEL_INFO

Target [in]

Type: int

Logging targets to write logs to LoggingTarget can be binary OR’d to enable multiple targets.

The following targets can be used:

- LOG_TARGET_NONE = 0x0
- LOG_TARGET_STDERR = 0x1
- LOG_LEVEL_FILE = 0x2
LOG_LEVEL_CALLBACK = 0x4

**filename [in]**

Type: const char*

The path of the file where to write logs and is used only when LOG_TARGET_FILE is enabled.

**cb [in]**

Type: const char *

Callback to use if LOG_TARGET_CALLBACK is enabled. A null value can be passed when not using a callback target.

**userdata [in]**

Type: void *

Data passed back with log callback and is used only when LOG_TARGET_CALLBACK is enabled.

A null value can also be passed.

**Return Value**

NVAFX_STATUS_SUCCESS on success.

**Remarks**

This API enables logging in the SDK. Depending on the flags that were passed, logs are redirected to stderr, a file, or a callback. Logging can be disabled by using the NvAFX_UninitializeLogger API.

### 5.2.19. NvAFX_UninitializeLogger (Linux SDK Only)

This function uninitializes the SDK logger.

```
NvAFX_Status NvAFX_UninitializeLogger(void);
```

**Parameters**

NvAFX_UninitializeLogger requires no parameters.

**Return Value**

NVAFX_STATUS_SUCCESS on success.
Remarks

This API disables all logging targets. Logging can be started again by using the `Nvafx_InitializeLogger` API.

5.3. Return Codes

The `Nvafx_Status` enumeration defines the following values that the Audio Effects functions might return to indicate an error or success:

- **NVAFX_STATUS_SUCCESS**
  - Successful execution.

- **NVAFX_STATUS_FAILED**
  - Generic error code, which indicates that the function failed to execute for an unspecified reason.

- **NVAFX_STATUS_INVALID_HANDLE**
  - An invalid effect handle has been supplied.

- **NVAFX_STATUS_INVALID_PARAM**
  - An invalid parameter value has been supplied for this combination of effect and selector string.

- **NVAFX_STATUS_IMMUTABLE_PARAM**
  - User tried to modify an immutable parameter.

- **NVafx_STATUS_INSUFFICIENT_DATA**
  - There is insufficient data to process.

- **NVAFX_STATUS_EFFECT_NOT_AVAILABLE**
  - The specified effect is not supported.

- **NVAFX_STATUS_OUTPUT_BUFFER_TOO_SMALL**
  - The output buffer length is too small to hold the requested data.

- **NVAFX_STATUS_MODEL_LOAD_FAILED**
  - The specified model file cannot be loaded.

- **NVAFX_STATUS_MODEL_NOT_LOADED**
  - Model is not loaded, and it has to be loaded for this operation.

- **NVafx_STATUS_INCOMPATIBLE_MODEL**
  - Selected model is incompatible.

- **NVAFX_STATUS_GPU_UNSUPPORTED**
  - The GPU is unsupported. Audio effects SDK requires Turing or later GPU with Tensor cores.

- **NVAFX_STATUS_NO_SUPPORTED_GPU_FOUND**
  - No supported GPU found on the system.

- **NVAFX_STATUS_WRONG_GPU**
  - Current GPU is not the one selected.

- **NVAFX_STATUS_CUDA_ERROR**
  - CUDA operation failure.

- **NVAFX_STATUS_INVALID_OPERATION**
  - Invalid operation performed.
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