NVIDIA Audio Effects SDK

Programming Guide

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Document History

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v0.1 Alpha	January 2020	Alpha release
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Chapter 1. Introduction to NVIDIA Audio Effects SDK

NVIDIA® Audio Effects SDK is used to apply effects to audio. The SDK is powered by NVIDIA RTX™ graphic processor units (GPUs) with Tensor Cores, so the algorithm throughput is greatly accelerated, and latency is reduced. Refer to Tensor Cores for more information. By leveraging the capabilities of NVIDIA RTX GPUs, developers can use the SDK to build audio plugins and add sound effects for broadcasting.

NVIDIA Audio Effects SDK provides audio denoising for broadcast use cases with real-time audio processing. 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. Audio denoising removes the background noise.

Chapter 2. Getting Started with NVIDIA Audio Effects SDK

2.1 Hardware and Software Requirements

NVIDIA Audio Effects SDK requires specific GPUs and a specific version of the Windows OS and other associated software on which the SDK depends.

2.1.1 Hardware Requirements

The SDK is supported on NVIDIA GPUs with Tensor Cores.

Hardware	Required Version
NVIDIA GPU	NVIDIA GPUs with Tensor Cores

2.1.1 Software Requirements

NVIDIA Audio Effects SDK requires a specific version of the Windows OS and other associated software on which the SDK depends. The NVIDIA CUDA® and TensorRT™ dependencies are bundled with the SDK Installer. See "Installing NVIDIA Audio Effects SDK " on page 3.

Software	Required Version
Windows OS	64-bit Windows 10
Microsoft Visual Studio	2015 (MSVC14.0) or later
CMake	3.9 or later
NVIDIA Graphics Driver for Windows	455.95 or later
NVIDIA CUDA Toolkit	11.1 or later
NVIDIA TensorRT	7.2 or later

2.2 Installing NVIDIA Audio Effects SDK

NVIDIA Audio Effects SDK 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 NVIDIA Audio Effects SDK, you must install the *developer package* and provide the path to this software during compilation and linking. The app will use the SDK functions that are exposed by the SDK header and dynamically link against the provided libraries.

On the end-user's computer, when 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` environmental variable that points to the directory where the *redistributable package* is installed and that contains the AI models and binaries.

  The app needs to use this variable to dynamically link and load the binaries and the AI model.

2.3 NVIDIA Audio Effects SDK Sample Application

To demonstrate the audio denoising feature, the SDK provides the following options:

- `The denoise_wav.cpp` sample application file as source code that you can build.
- The sample application is also available as a binary file that you can run without building.

2.3.1 Building the Sample Application

The SDK includes the source code for building 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 complier, 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, click **Open Project** to open Visual Studio.

b). In Visual Studio, select **Build** > **Build Solution**.

2.3.2 Running the Sample Application

In a Command Prompt window, enter the following command:

```
denoise_wav.exe -c config-file
```

`-c config-file`

Specifies the path of the denoiser 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 `denoise_wav.exe` sample application:

```
denoise_wav.exe -c denoise48k_cfg_turing.txt
```

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

`sample_rate audio-sample-rate`

Specifies the sample rate of the audio, for example, 48000. Currently, the 16 kHz and 48 kHz rates are supported.

`filter_model filter-model-file`

Specifies the path of the model file that will be used in the sample application, for example, `denoiser_48k.trtpkg`. The model file should match the audio sample rate that was specified in the `sample_rate` parameter.

Note: A 48kHz model file and a 16kHz model file is included with the SDK.

`input_wav input-audio-file`

Specifies the path of the noisy input audio `.wav` file to use, for example, `noisy_48k.wav`.

Note: A sample input audio file is included with the sample application.

`output_wav output-audio-file`

Specifies the path of the file to which the denoised audio output is to be written, for example, `denoised_48k.wav`. The audio format of the output file will match the audio format of the input file.

Note: Only the .wav file format is supported.

`intensity_ratio intensity-ratio`

Specifies the denoising intensity ratio. The value of this parameter ranges from `0.0f` to `1.0f`, where a higher value indicates a stronger suppression of noise. A value of `0.0f` is equivalent to a passthrough.

Chapter 3. Using NVIDIA Audio Effects SDK in Applications

By using the NVIDIA Audio Effects SDK, you can enable an application to apply effects to audio. The NVIDIA Audio Effects API is a C API but can also be used with applications that are built using C++.

3.1 About the Background Noise Suppression Effect

Note: In this guide, the term ***Background Noise Suppression*** is used interchangeably with ***Denoising***.

Recordings of speech made outside of a recording studio contain a lot of background noise. The Audio Denoiser Effect removes the following types of background noise from audio recordings:

- AC noise
- PC noise
- Babble / crowd noise
- Chatter from other people
- Typing noise
- Fan noise
- Sirens
- Clapping
- Tapping
- Dog / cat sounds
- Furniture moving sounds
- Glass breaking sounds
- Traffic noise

- Mouse clicks
- Train passing by sounds
- Vacuum cleaner sounds
- Washing machine
- Metal sounds

Here is a list of the Audio Denoiser Effect characteristics:

- The audio format is 48kHz and 16KHz sample rate and 32-bit float type.
- The minimum latency is 74 ms.
- Noise with a signal-to-noise ratio below 10 dB is not supported.

3.2 Creating an Audio Effect

Call the `NvAFX_CreateEffect()` function and specify the following information as parameters:

- The `NvAFX_EffectSelector` type `NVAFX_EFFECT_DENOISER`.
- The location where to store 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.

This example creates a denoiser audio effect:

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

3.3 Setting the Sample Rate and Path to the Model

An audio effect requires a model to transform the input audio, and each model supports a specific audio sample rate. You must set the input audio sample rate and the path to the model file that will be used and that supports this sample rate.

To set the sample rate, call the `NvAFX_SetU32()` function and specify the following information as parameters:

- The effect handle that was created.
  See “Creating an Audio Effect” on page 7 for more information.
- The selector string `NVAFX_PARAM_DENOISER_SAMPLE_RATE`.
- An unsigned integer value that specifies the sample rate of the audio.

Call the `NvAFX_SetString()` function and specify the following information as parameters:

- The effect handle that was created.
  See "Creating an Audio Effect" on page 7 for more information.
- The selector string `NVAFX_PARAM_DENOISER_MODEL_PATH.`
- A null-terminated string that indicates the path to the model file.

This example sets the sample rate to `sample_rate` and the path to the model that was specified by the `denoiser_model_file.c_str()` custom function.

```
NvAFX_Status err;
err = NvAFX_SetU32(handle, NVAFX_PARAM_DENOISER_SAMPLE_RATE, sample_rate);
err = NvAFX_SetString(handle, NVAFX_PARAM_DENOISER_MODEL_PATH,
denoiser_model_file.c_str());
```

3.4 Getting the Parameters of a Denoiser Effect

The number of samples per frame and number of I/O audio channels are preset for the Audio Denoiser Effect and cannot be changed. Before running an audio effect, you must get the number of samples per frame and the number of I/O channels to pass as parameters to the function. See "Running an Audio Effect," on page 9 for more informatoin.

Note: To ensure that the sample rate of the audio that you are transforming is compatible with the Audio Denoiser Effect, you can also get the sample rate.

To get one of these parameters, call the `NvAFX_GetU32()` function and specify the following information as parameters:

- The effect handle that was created.
  See "Creating an Audio Effect," on page 7 for more information.
- The selector string for the parameter that you want to get:
  - To get the number of samples per frame, specify `NVAFX_PARAM_DENOISER_NUM_SAMPLES_PER_FRAME`.
  - To get the number of I/O audio channels, specify `NVAFX_PARAM_DENOISER_NUM_CHANNELS`.
  - To get the sample rate, specify `NVAFX_PARAM_DENOISER_SAMPLE_RATE`.
- A pointer to a location where to store the value that you want to get.

This example gets the number of samples per frame, number of I/O channels, and sample rate for an Audio Denoiser Effect.

```
unsigned num_samples_per_frame, num_channels, sample_rate;
NvAFX_Status err;
err = NvAFX_GetU32(handle, NVAFX_PARAM_DENOISER_NUM_SAMPLES_PER_FRAME,
&num_samples_per_frame);
err = NvAFX_GetU32(handle, NVAFX_PARAM_DENOISER_NUM_CHANNELS,
&num_channels);
err = NvAFX_GetU32(handle, NVAFX_PARAM_DENOISER_SAMPLE_RATE, &sample_rate);
```

3.5 Loading an Audio Effect

Loading an effect selects and loads a model and validates the parameters that were set for the effect.

To load an audio effect, call the `NvAFX_Load()` function and specify the effect handle that was created. See "Creating an Audio Effect" on page 7 for more information.

```
NvAFX_Status err = NvAFX_Load(handle);
```

3.6 Running an Audio Effect

After loading an audio effect, run the effect to apply the desired effect. After an 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.

To run an audio effect, call the `NvAFX_Run()` function and pass the following information as parameters:

- The effect handle that was created.
  See "Creating an Audio Effect" on page 7 for more information.
- The input memory buffer to be read.
- The output memory buffer to be written to.
- The number of samples per frame that were obtained.
  See "Getting the Parameters of a Denoiser Effect" on page 8 for more information.
- The number of I/O audio channels that were obtained.
  See "Getting the Parameters of a Denoiser Effect" on page 8 for more information.

This example runs an audio effect:

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

3.7 Destroying an Audio Effect

When an audio effect is no longer required, destroy it to free the resources and the memory that were allocated for the effect.

To destroy an audio effect, call the `NvAFX_DestroyEffect()` function and specify the effect handle that was created. See "Creating an Audio Effect" on page 7 for more information.

```
NvAFX_Status err = NvAFX_DestroyEffect(handle);
```

Chapter 4. NVIDIA Audio Effects SDK API Reference

4.1 Type Definitions

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

4.1.1 NvAFX_EffectSelector

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

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

`NVAFX_EFFECT_DENOISER : "denoiser"`

Denoiser audio effect.

4.1.2 NvAFX_ParameterSelector

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

This type definition provides selector strings for the parameters of an audio effect.

`NVAFX_PARAM_DENOISER_MODEL_PATH : "denoiser_model_path"`

A character string that specifies the path to the model file for the denoiser effect.

`NVAFX_PARAM_DENOISER_GENERATOR_MODEL_PATH "generator_model_path"`

`NVAFX_PARAM_DENOISER_SAMPLE_RATE : "sample_rate"`

An unsigned integer that specifies the audio sample rate for the denoiser effect.

`NVAFX_PARAM_DENOISER_NUM_SAMPLES_PER_FRAME : "num_samples_per_frame"`

An unsigned integer that specifies the number of samples per frame for the denoiser effect.

`NVAFX_PARAM_DENOISER_NUM_CHANNELS : "num_channels"`

An unsigned integer that specifies the number of I/O audio channels for the denoiser effect.

`NVAFX_PARAM_DENOISER_INTENSITY_RATIO : "intensity_ratio"`

A float value that specifies the denoiser noise suppression 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 noise suppression.

4.1.3 NvAFX_Handle

```
typedef void* NvAFX_Handle;
```

This structure represents the opaque handle that is associated with each instance of an audio effect. Most audio effect function calls include this handle as the first parameter.

4.2 Functions

4.2.1 NvAFX_GetEffectList

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

4.2.1.1 Parameters

`num_effects [out]`

Type: `int*`

Address of the buffer that contains the number of effects that are returned in the effects array.

`effects [out]`

Type: `NvAFX_EffectSelector* []`

Address to a list of effect selection strings that are supported by the SDK. The list is statically allocated by the API implementation, so the caller does not need to allocate. See “NvAFX_EffectSelector” on page 11 for more information about the selection strings.

4.2.1.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.1.3 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` out parameter. The number of available effects are written to the `num_effects` out parameter.

4.2.2 NvAFX_CreateEffect

```
NvAFX_Status NvAFX_CreateEffect(
  NvAFX_EffectSelector code,
  NvAFX_Handle* effect
);
```

4.2.2.1 Parameters

`code [in]`

Type: `NvAFX_EffectSelector`

The selection string for the type of audio effect that will be created. See "NvAFX_EffectSelector" on page 11 for more information about the allowed selection strings.

`effect [out]`

Type: `NvAFX_Handle*`

The location where to store the handle to the newly created audio effect instance.

4.2.2.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.2.3 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` out parameter.

4.2.3 NvAFX_DestroyEffect

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

4.2.3.1 Parameters

`effect [in]`

Type: `NvAFX_Handle`

The handle to the audio effect instance that will be destroyed.

4.2.3.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.3.3 Remarks

This function destroys the audio effect instance with the specified handle and frees resources and memory that were allocated to the instance.

4.2.4 NvAFX_SetString

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

4.2.4.1 Parameters

`effect [in]`

Type: `NvAFX_Handle`

The handle to the audio effect instance for which you want to set the specified character string parameter.

`param_name [in]`

Type: `NvAFX_ParameterSelector`

The selector string `NVAFX_PARAM_DENOISER_MODEL_PATH`.

Any other selector string returns an error.

`val [in]`

Type: `char*`

Pointer to the character string to which you want to set the parameter.

4.2.4.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.4.3 Remarks

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

4.2.5 NvAFX_SetU32

```
NvAFX_Status NvAFX_SetU32(
  NvAFX_Handle effect,
  NvAFX_ParameterSelector param_name,
  unsigned int val
);
```

4.2.5.1 Parameters

`effect [in]`

Type: `NvAFX_Handle`

The handle to the audio effect instance for which you want to set the specified character string parameter.

`Param_name [in]`

Type: `NvAFX_ParameterSelector`

The selector string `NVAFX_PARAM_DENOISER_SAMPLE_RATE`.

Any other selector string returns an error.

`val [in]`

Type: `unsigned int`

Value to be set for the parameter.

4.2.5.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.5.3 Remarks

This function sets the value of the specified 32-bit unsigned integer parameter for the specified audio effect to the `val` parameter.

4.2.6 NvAFX_SetFloat

```
NvAFX_Status NvAFX_SetFloat(
  NvAFX_Handle effect,
  NvAFX_ParameterSelector param_name,
  float val
);
```

4.2.6.1 Parameters

`effect [in]`

Type: `NvAFX_Handle`

The handle to the audio effect instance for which you want to set the specified float parameter.

`Param_name [in]`

Type: `NvAFX_ParameterSelector`

The selector string `NVAFX_PARAM_DENOISER_INTENSITY_RATIO`.

Any other selector string returns an error.

`val [in]`

Type: `float`

Value to be set for the parameter.

4.2.6.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.6.3 Remarks

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

4.2.7 NvAFX_GetString

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

4.2.7.1 Parameters

`effect [in]`

Type: `NvAFX_Handle`

The handle to the audio effect instance from which you want to get the specified character string parameter.

`Param_name [in]`

Type: `NvAFX_ParameterSelector`

The selector string `NVAFX_PARAM_DENOISER_MODEL_PATH`.

Any other selector string returns an error.

`val [out]`

Type: `char*`

The address of the buffer where the requested character string will be stored.

`max_length [in]`

Type: `int`

The length in bytes of the buffer that is specified by the `val` parameter.

4.2.7.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.7.3 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.

4.2.8 NvAFX_GetU32

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

4.2.8.1 Parameters

`effect [in]`

Type: `NvAFX_Handle`

The handle to the audio effect instance from which you want to get the specified 32-bit unsigned integer parameter.

`param_name [in]`

Type: `NvAFX_ParameterSelector`

One of the following selector strings for the specified 32-bit unsigned integer parameter that you want to get:

- `NVAFX_PARAM_DENOISER_NUM_SAMPLES_PER_FRAME`
- `NVAFX_PARAM_DENOISER_NUM_CHANNELS`
- `NVAFX_PARAM_DENOISER_SAMPLE_RATE`

Any other selector string returns an error.

Note: `NVAFX_PARAM_DENOISER_NUM_SAMPLES_PER_FRAME` and `NVAFX_PARAM_DENOISER_NUM_CHANNELS` parameters are preset for the Audio Denoiser Effect and cannot be changed. If you call `NvAFX_SetU32()` to set any of these parameters, the function call returns an error.

`val [out]`

Type: `unsigned int*`

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

4.2.8.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.8.3 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.

4.2.9 NvAFX_GetFloat

```
NvAFX_Status NvAFX_GetFloat(
  NvAFX_Handle effect,
  NvAFX_ParameterSelector param_name,
  float* val
);
```

4.2.9.1 Parameters

`effect [in]`

Type: `NvAFX_Handle`

The handle to the audio effect instance from which you want to get the specified float parameter.

`param_name [in]`

Type: `NvAFX_ParameterSelector`

One of the following selector strings for the specified float parameter that you want to get:

- `NVAFX_PARAM_DENOISER_INTENSITY_RATIO`

Any other selector string returns an error.

`val [out]`

Type: `float*`

The address of the buffer in which the retrieved float parameter value will be written.

4.2.9.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.9.3 Remarks

This function gets the value of the specified float parameter for the specified audio effect and writes the retrieved value to the buffer that is specified by the `val` parameter.

4.2.10 NvAFX_Load

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

4.2.10.1 Parameters

`effect [in]`

Type: `NvAFX_Handle`

The handle to the audio effect instance to load.

4.2.10.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.10.3 Remarks

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

4.2.11 NvAFX_Run

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

4.2.11.1 Parameters

`effect [in]`

Type: `NvAFX_Handle`

The handle to the audio effect instance to run.

`input [in]`

Type: `const float**`

Pointer to an 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 I/O channels that were preset for the effect. For example, for the Audio Denoiser Effect, the number of I/O channels must be equal to the value of the `NVAFX_PARAM_DENOISER_NUM_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 Denoiser Effect, the sample rate must be equal to the value of the `NVAFX_PARAM_DENOISER_SAMPLE_RATE` parameter that was obtained by the `NvAFX_GetU32()` function.

`output [out]`

Type: `float**`

Pointer to an array of buffers to which the output of the effect will be written. After this function returns, each buffer will contain audio data for one channel.

Note: The buffers must already be allocated by the calling program.

The size of each buffer is same as the size of each buffer that was specified by the `input` parameter.

`num_samples [in]`

Type: `unsigned`

The number of samples in the input buffer. After this function returns, the buffer that was specified by the `output` parameter will contain the number of samples that were specified in this parameter.

`num_channels [in]`

Type: `unsigned`

The number of I/O channels.

4.2.11.2 Return Value

`NVAFX_STATUS_SUCCESS` on success.

4.2.11.3 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.

`effect [in]`

`paramName [in]`

`val [in]`

4.3 Return Codes

The `NvAFX_Status` enumeration defines the following values that the NVIDIA Audio Effects functions might return to indicate 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_GPU_UNSUPPORTED`

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

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