# Table of Contents

Chapter 1. Introduction ........................................................................................................ 1

Chapter 2. Basic Encoding Flow .......................................................................................... 2

Chapter 3. Setting Up Hardware for Encoding ................................................................. 3

3.1. Opening an Encode Session .......................................................................................... 3

3.1.1. Initializing encode device ......................................................................................... 3

3.1.1.1. DirectX 9 ............................................................................................................. 3

3.1.1.2. DirectX 10 ............................................................................................................ 3

3.1.1.3. DirectX 11 ............................................................................................................ 4

3.1.1.4. DirectX 12 ............................................................................................................ 4

3.1.1.5. CUDA .................................................................................................................. 4

3.1.1.6. OpenGL .............................................................................................................. 4

3.2. Selecting Encoder Codec GUID ................................................................................... 4

3.3. Encoder TUNING INFO AND Preset Configurations ................................................... 5

3.3.1. Enumerating preset GUIDs ....................................................................................... 5

3.3.2. Selecting encoder preset configuration .................................................................... 6

3.4. Selecting an Encoder Profile ....................................................................................... 6

3.5. Getting Supported List of Input Formats .................................................................... 7

3.6. Querying encoder Capabilities ................................................................................... 7

3.7. Initializing the Hardware Encoder Session ................................................................... 7

3.8. Encode Session Attributes ......................................................................................... 8

3.8.1. Configuring encode session attributes ..................................................................... 8

3.8.1.1. Session parameters ............................................................................................. 8

3.8.1.2. Advanced codec-level parameters ..................................................................... 8

3.8.1.3. Advanced codec-specific parameters ................................................................. 8

3.8.2. Finalizing codec configuration for encoding .......................................................... 8

3.8.2.1. High-level control using presets ....................................................................... 8

3.8.2.2. Finer control by overriding preset parameters .................................................. 9

3.8.3. Rate control ........................................................................................................... 9

3.8.4. Multi pass frame encoding ...................................................................................... 10

3.8.5. Setting encode session attributes .......................................................................... 11

3.8.5.1. Mode of operation ............................................................................................. 11

3.8.5.2. Picture-type decision ........................................................................................ 11

3.9. Creating Resources Required to Hold Input/output Data .......................................... 11

3.10. Retrieving Sequence Parameters ............................................................................. 12

Chapter 4. Encoding the Video Stream .............................................................................. 13
8.8. Emphasis MAP.......................................................................................................................29
8.9. NVENC Output in Video Memory............................................................................................30
8.10. Alpha Layer Encoding support in HEVC.............................................................................32
8.11. Temporal Scalable Video Coding (SVC) in H.264.................................................................33
8.12. Error Resiliency features......................................................................................................34

Chapter 9. Recommended NVENC Settings............................................................................36
Chapter 1. Introduction

NVIDIA® GPUs based on NVIDIA Kepler™ and later GPU architectures contain a hardware-based H.264/HEVC video encoder (hereafter referred to as NVENC). The NVENC hardware takes YUV/RGB as input and generates an H.264/HEVC compliant video bit stream. NVENC hardware’s encoding capabilities can be accessed using the NVENCODE APIs, available in the NVIDIA Video Codec SDK.

This document provides information on how to program the NVENC using the NVENCODE APIs exposed in the SDK. The NVENCODE APIs expose encoding capabilities on Windows (Windows 7 and above) and Linux.

It is expected that developers should understand H.264/HEVC video codecs and be familiar with Windows and/or Linux development environments.

NVENCODE API guarantees binary backward compatibility (and will make explicit reference whenever backward compatibility is broken). This means that applications compiled with older versions of released API will continue to work on future driver versions released by NVIDIA.
Chapter 2. Basic Encoding Flow

Developers can create a client application that calls NVENCODE API functions exposed by nvEncodeAPI.dll for Windows or libnvidia-encode.so for Linux. These libraries are installed as part of the NVIDIA display driver. The client application can either link to these libraries at run-time using LoadLibrary() on Windows or dlopen() on Linux.

The NVENCODE API functions, structures and other parameters are exposed in nvEncodeAPI.h, which is included in the SDK.

NVENCODE API is a C-API, and uses a design pattern like C++ interfaces, wherein the application creates an instance of the API and retrieves a function pointer table to further interact with the encoder. For programmers preferring more high-level API with ready-to-use code, SDK includes sample C++ classes expose important API functions.

Rest of this document focuses on the C-API exposed in nvEncodeAPI.h. NVENCODE API is designed to accept raw video frames (in YUV or RGB format) and output the H.264 or HEVC bitstream. Broadly, the encoding flow consists of the following steps:

1. Initialize the encoder
2. Set up the desired encoding parameters
3. Allocate input/output buffers
4. Copy frames to input buffers and read bitstream from the output buffers. This can be done synchronously (Windows & Linux) or asynchronously (Windows 7 and above only).
5. Clean-up - release all allocated input/output buffers
6. Close the encoding session

These steps are explained in the rest of the document and demonstrated in the sample application included in the Video Codec SDK package.
Chapter 3. Setting Up Hardware for Encoding

3.1. Opening an Encode Session

After loading the DLL or shared object library, the client’s first interaction with the API is to call `NvEncodeAPICreateInstance`. This populates the input/output buffer passed to `NvEncodeAPICreateInstance` with pointers to functions which implement the functionality provided in the interface.

After loading the NVENC Interface, the client should first call `NvEncOpenEncodeSessionEx` to open an encoding session. This function returns an encode session handle which must be used for all subsequent calls to the API functions in the current session.

3.1.1. Initializing encode device

The NVIDIA Encoder supports use of the following types of devices:

3.1.1.1. DirectX 9

- The client should create a DirectX 9 device with behavior flags including: `D3DCREATE_FPU_PRESERVE`, `D3DCREATE_MULTITHREADED` and `D3DCREATE_HARDWARE_VERTEXPROCESSING`.
- The client should pass a pointer to IUnknown interface of the created device (typecast to `void *`) as `NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::device`, and set `NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::deviceType` to `NV_ENC_DEVICE_TYPE_DIRECTX`. Use of DirectX devices is supported only on Windows 7 and later versions of the Windows OS.

3.1.1.2. DirectX 10

- The client should pass a pointer to IUnknown interface of the created device (typecast to `void *`) as `NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::device`, and set `NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::deviceType` to `NV_ENC_DEVICE_TYPE_DIRECTX`. Use of DirectX devices is supported only on Windows 7 and later versions of Windows OS.
3.1.1.3. DirectX 11
- The client should pass a pointer to IUnknown interface of the created device (typecast to void *) as NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::device, and set NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::deviceType to NV_ENC_DEVICE_TYPE_DIRECTX. Use of DirectX devices is supported only on Windows 7 and later versions of Windows OS.

3.1.1.4. DirectX 12
- The client should pass a pointer to IUnknown interface of the created device (typecast to void *) as NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::device, and set NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::deviceType to NV_ENC_DEVICE_TYPE_DIRECTX. Use of DirectX 12 devices is supported only on Windows 10 20H1 and later versions of Windows OS.

3.1.1.5. CUDA
- The client should create a floating CUDA context, and pass the CUDA context handle as NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::device, and set NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::deviceType to NV_ENC_DEVICE_TYPE_CUDA. Use of CUDA device for Encoding is supported on Linux and Windows 7 and later versions of Windows OS.

3.1.1.6. OpenGL
- The client should create an OpenGL context and make it current (in order to associate the context with the thread/process that is making calls to NVENCODER API) to the thread calling into NVENCODER API. NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::device must be NULL and NV_ENC_OPEN_ENCODE_SESSION_EX_PARAMS::deviceType must be set to NV_ENC_DEVICE_TYPE_OPENGL. Use of the OpenGL device type for encoding is supported only on Linux.

3.2. Selecting Encoder Codec GUID

The client should select an Encoding GUID that represents the desired codec for encoding the video sequence in the following manner:

1. The client should call NvEncGetEncodeGUIDCount to get the number of supported Encoder GUIDs from the NVIDIA Video Encoder Interface.
2. The client should use this count to allocate a large-enough buffer to hold the supported Encoder GUIDs.
3. The client should then call NvEncGetEncodeGUIDs to populate this list.

The client should select a GUID that matches its requirement from this list and use that as the encodeGUID for the remainder of the encoding session.
3.3. Encoder TUNING INFO AND Preset Configurations

The NVIDIA Encoder Interface exposes four different tuning info enums (high quality, low latency, ultra-low latency and lossless) to cater to different video encoding use-cases. Table 1 shows the recommended tuning info applicable to some popular use-cases.

Table 1. Tuning info for popular video encoding use-cases

<table>
<thead>
<tr>
<th>Use-case</th>
<th>Recommended value for tuning info parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. High-quality latency-tolerant transcoding</td>
<td>High quality</td>
</tr>
<tr>
<td>2. Video archiving</td>
<td></td>
</tr>
<tr>
<td>3. Encoding for OTT streaming</td>
<td></td>
</tr>
<tr>
<td>1. Cloud gaming</td>
<td>Low latency, with CBR</td>
</tr>
<tr>
<td>2. Streaming</td>
<td></td>
</tr>
<tr>
<td>3. Video conferencing</td>
<td></td>
</tr>
<tr>
<td>In high bandwidth channel with tolerance for bigger occasional frame sizes</td>
<td>Ultra-low latency, with CBR</td>
</tr>
<tr>
<td>1. Preserving original video footage for later editing</td>
<td>Lossless</td>
</tr>
<tr>
<td>2. General lossless data archiving (video or non-video)</td>
<td></td>
</tr>
</tbody>
</table>

For each tuning info, seven presets from P1 (highest performance) to P7 (lowest performance) have been provided to control performance/quality trade off. Using these presets will automatically set all relevant encoding parameters for the selected tuning info. This is a coarse level of control exposed by the API. Specific attributes/parameters within the preset can be tuned, if required. This is explained in next two subsections.

3.3.1. Enumerating preset GUIDs

The client can enumerate supported Preset GUIDs for the selected `encodeGUID` as follows:

1. The client should call `NvEncGetEncodePresetCount` to get the number of supported Encoder GUIDs.
2. The client should use this count to allocate a large-enough buffer to hold the supported Preset GUIDs.
3. The client should then call `NvEncGetEncodePresetGUIDs` to populate this list.

### 3.3.2. Selecting encoder preset configuration

As mentioned above, the client can use the `presetGUID` for configuring the encode session directly. This will automatically set the hardware encoder with appropriate parameters for the use-case implied by the tuning info/preset combination. If required, the client has the option to fine-tune the encoder configuration parameters in the preset and override the preset defaults. This approach is often-times more convenient from programming point of view as the programmer only needs to change the configuration parameters which he/she is interested in, leaving everything else pre-configured as per the preset definition.

Here are the steps to fetch a preset encode configuration and optionally change select configuration parameters:

1. Enumerate the supported presets as described above, in Section [Enumerating preset GUIDs](#).
2. Select the preset GUID for which the encode configuration is to be fetched.
3. The client should call `NvEncGetEncodePresetConfigEx` with the selected `encodeGUID`, `tuningInfo` and `presetGUID` as inputs.
4. The required preset encoder configuration can be retrieved through `NV_ENC_PRESET_CONFIG::presetCfg`.
5. Over-ride the default encoder parameters, if required, using the corresponding configuration APIs.

### 3.4. Selecting an Encoder Profile

The client may specify a profile to encode for specific encoding scenario. For example, certain profiles are required for encoding video for playback on iPhone/iPod, encoding video for blue-ray disc authoring, etc.

The client should do the following to retrieve a list of supported encoder profiles:

1. The client should call `NvEncGetEncodeProfileGUIDCount` to get the number of supported Encoder GUIDs from the NVIDIA Video Encoder Interface.
2. The client should use this count to allocate a buffer of sufficient size to hold the supported Encode Profile GUIDS.
3. The client should then call `NvEncGetEncodeProfileGUIDs` to populate this list.

The client should select the profile GUID that best matches the requirement.
3.5. Getting Supported List of Input Formats

NVENCODE API accepts input frames in several different formats, such as YUV and RGB in specific formats, as enumerated in NV_ENC_BUFFER_FORMAT.

List of supported input formats can be retrieved as follows:

1. The client should call NvEncGetInputFormatCount to get the number of supported input formats.
2. The client should use this count to allocate a buffer to hold the list of supported input buffer formats (which are list elements of type NV_ENC_BUFFER_FORMAT).
3. Retrieve the supported input buffer formats by calling NvEncGetInputFormats.

The client should select a format enumerated in this list for creating input buffers.

3.6. Querying encoder Capabilities

NVIDIA video encoder hardware has evolved over multiple generations, with many features being added in each new generation of the GPU. To facilitate application to dynamically figure out the capabilities of the underlying hardware encoder on the system, NVENCODE API provides a dedicated API to query these capabilities. It is a good programming practice to query for support of the desired encoder feature before making use of the feature.

Querying the encoder capabilities can be accomplished as follows:

1. Specify the capability attribute to be queried in NV_ENC_CAPS_PARAM::capsToQuery parameter. This should be a member of the NV_ENC_CAPS enum.
2. Call NvEncGetEncodeCaps to determine support for the required attribute.

Refer to the API reference NV_ENC_CAPS enum definition for interpretation of individual capability attributes.

3.7. Initializing the Hardware Encoder Session

The client needs to call NvEncInitializeEncoder with a valid encoder configuration specified through NV_ENC_INITIALIZE_PARAMS and encoder handle (returned upon successful opening of encode session).
3.8. Encode Session Attributes

3.8.1. Configuring encode session attributes

Encode session configuration is divided into three parts:

3.8.1.1. Session parameters

Common parameters such as input format, output dimensions, display aspect ratio, frame rate, average bitrate, etc. are available in NV_ENC_INITIALIZE_PARAMS structure. The client should use an instance of this structure as input to NvEncInitializeEncoder.

The client must populate the following members of the NV_ENC_INITIALIZE_PARAMS structure for the encode session to be successfully initialized:

- NV_ENC_INITIALIZE_PARAMS::encodeGUID: The client must select a suitable codec GUID as described in Section Selecting Encoder Codec GUID.
- NV_ENC_INITIALIZE_PARAMS::encodeWidth: The client must specify the desired width of the encoded video.
- NV_ENC_INITIALIZE_PARAMS::encodeHeight: The client must specify the desired height of the encoded video.

NV_ENC_INITIALIZE_PARAMS::reportSliceOffsets can be used to enable reporting of slice offsets. This feature requires NV_ENC_INITIALIZE_PARAMS::enableEncodeAsync to be set to 0, and does not work with MB-based and byte-based slicing on Kepler GPUs.

3.8.1.2. Advanced codec-level parameters

Parameters dealing with the encoded bit stream such as GOP length, encoder profile, rate control mode, etc. are exposed through the structure NV_ENC_CONFIG. The client can pass codec level parameters through NV_ENC_INITIALIZE_PARAMS::encodeConfig as explained below.

3.8.1.3. Advanced codec-specific parameters

Advanced H.264 and HEVC specific parameters are available in structures NV_ENC_CONFIG_H264 and NV_ENC_CONFIG_HEVC respectively.

The client can pass codec-specific parameters through the structure NV_ENC_CONFIG::encodeCodecConfig.

3.8.2. Finalizing codec configuration for encoding

3.8.2.1. High-level control using presets

This is the simplest method of configuring the NVIDIA Video Encoder Interface, and involves minimal setup steps to be performed by the client. This is intended for use cases where the client does not need to fine-tune any codec level parameters.
In this case, the client should follow these steps:

- The client should specify the session parameters as described in Section Session parameters.
- Optionally, the client can enumerate and select preset GUID that best suits the current use case, as described in Section Selecting Encoder Codec GUID. The client should then pass the selected preset GUID using NV_ENC_INITIALIZE_PARAMS::presetGUID. This helps the NVIDIA Video Encoder interface to correctly configure the encoder session based on the encodeGUID, tuning info and presetGUID provided.
- The client should set the advanced codec-level parameter pointer NV_ENC_INITIALIZE_PARAMS::encodeConfig::encodeCodecConfig to NULL.

### 3.8.2.2. Finer control by overriding preset parameters

The client can choose to edit some encoding parameters on top of the parameters set by the individual preset, as follows:

1. The client should specify the session parameters as described in Section Session parameters.
2. The client should enumerate and select a preset GUID that best suits the current use case, as described in Section Selecting Encoder Codec GUID. The client should retrieve a preset encode configuration as described in Section Selecting encoder preset configuration.
3. The client may need to explicitly query the capability of the encoder to support certain features or certain encoding configuration parameters. For this, the client should do the following:
4. Specify the capability desired attribute through NV_ENC_CAPS_PARAM::capsToQuery parameter. This should be a member of the NV_ENC_CAPS enum.
5. Call NvEncGetEncodeCaps to determine support for the required attribute. Refer to NV_ENC_CAPS enum definition in the API reference for interpretation of individual capability attributes.
6. Select a desired tuning info and preset GUID and fetch the corresponding Preset Encode Configuration as described in Section Encoder TUNING INFO AND Preset Configurations.
7. The client can then override any parameters from the preset NV_ENC_CONFIG according to its requirements. The client should pass the fine-tuned NV_ENC_CONFIG structure using NV_ENC_INITIALIZE_PARAMS::encodeConfig::encodeCodecConfig pointer.
8. Additionally, the client should also pass the selected preset GUID through NV_ENC_INITIALIZE_PARAMS::presetGUID. This is to allow the NVIDIA Video Encoder interface to program internal parameters associated with the encoding session to ensure that the encoded output conforms to the client’s request. Note that passing the preset GUID here will not override the fine-tuned parameters.

### 3.8.3. Rate control

NVENC supports several rate control modes and provides control over various parameters related to the rate control algorithm via structure NV_ENC_INITIALIZE_PARAMS::encodeConfig::rcParams. The rate control algorithm is implemented in NVENC firmware.
NVENC supports the following rate control modes:

**Constant bitrate (CBR):** Constant bitrate is specified by setting `rateControlMode` to `NV_ENC_PARAMS_RC_CBR`. In this mode, only `averageBitRate` is required and used as the target output bitrate by the rate control algorithm. Clients can control the ratio of I to P frames using `NV_ENC_RC_PARAMS::lowDelayKeyFrameScale` which is useful to avoid channel congestion in case I frame ends up generating high number of bits. Set `NV_ENC_CONFIG_H264/NV_ENC_CONFIG_HEVC::enableFillerDataInsertion = 1` incase the bitrate needs to be strictly adhered to.

**Variable bitrate (VBR):** Variable bitrate is specified by setting `rateControlMode` to `NV_ENC_PARAMS_RC_VBR`. The encoder tries to conform to average bitrate of `averageBitRate` over the long term while not exceeding `maxBitRate` any time during the encoding. In this mode, `averageBitRate` must be specified. If `maxBitRate` isn’t specified, NVENC will set it to an internally determined default value. It is recommended that the client specify both parameters `maxBitRate` and `averageBitRate` for better control.

**Constant QP:** This mode is specified by setting `rateControlMode` to `NV_ENC_PARAMS_RC_CONSTQP`. In this mode, the entire frame is encoded using QP specified in `NV_ENC_RC_PARAMS::constQP`. In 2-pass rate control modes, NVENC can distribute the bits more optimally within the frame and can reach closer to the

**Target quality:** This mode is specified by setting `rateControlMode` to VBR and desired target quality in `targetQuality`. The range of this target quality is 0 to 51 (fractional values are also supported in Video Codec SDK 8.0 and above). In this mode, the encoder tries to maintain constant quality for each frame, by allowing the bitrate to vary subject to the bitrate parameter specified in `maxBitRate`. The resulting average bitrate can, therefore, vary significantly depending on the video content being encoded. If `maxBitRate` is not specified, the encoder will use as many bits as needed to achieve the target quality. However, if `maxBitRate` is set, it will form an upper bound on the actual bitrate. If `maxBitRate` is set too low in this mode, the bitrate may become constrained, resulting in the desired target quality possibly not being achieved.

### 3.8.4. Multi pass frame encoding

When determining the QP to use for encoding a frame, it is beneficial if NVENC knows the overall complexity of the frame to distribute the available bit budget in the most optimal manner. In some situations, multi-pass encoding may also help catch larger motion between frames. For this purpose, NVENC supports the following types of multi-pass frame encoding modes:

- 1-pass per frame encoding (`NV_ENC_MULTI_PASS_DISABLED`)
- 2-passes per frame, with first pass in quarter resolution and second pass in full resolution (`NV_ENC_TWO_PASS_QUARTER_RESOLUTION`)
- 2-passes per frame, with both passes in full resolution (`NV_ENC_TWO_PASS_FULL_RESOLUTION`).

In 1-pass rate control modes, NVENC estimates the required QP for the macroblock and immediately encodes the macroblock. In 2-pass rate control modes, NVENC estimates the complexity of the frame to be encoded and determines bit distribution across the frame in the first pass. In the second pass, NVENC encodes macroblocks in the frame using the distribution determined in the first pass. As a result, with 2-pass rate control modes, NVENC can distribute the bits more optimally within the frame and can reach closer to the
target bitrate, especially for CBR encoding. Note, however, that everything else being the same, performance of 2-pass rate control mode is lower than that of 1-pass rate control mode. The client application should choose an appropriate multi-pass rate control mode after evaluating various modes, as each of the modes has its own advantages and disadvantages. NV_ENC_TWO_PASS_FULL_RESOLUTION generates better statistics for the second pass, whereas NV_ENC_TWO_PASS_QUARTER_RESOLUTION results in larger motion vectors being caught and fed as hints to second pass.

3.8.5. Setting encode session attributes

Once all Encoder settings have been finalized, the client should populate a NV_ENC_CONFIG structure and use it as an input to NvEncInitializeEncoder to freeze the Encode settings for the current encode session. Some settings such as rate control mode, average bitrate, resolution etc. can be changed on-the-fly.

The client is required to explicitly specify the following while initializing the Encode Session:

3.8.5.1. Mode of operation

The client should set NV_ENC_INITIALIZE_PARAMS::enableEncodeAsync to 1 if it wants to operate in asynchronous mode and 0 for operating in synchronous mode. 

Asynchronous mode encoding is supported only on Windows 7 and later. Refer to Chapter 6 for more detailed explanation.

3.8.5.2. Picture-type decision

If the client wants to send the input buffers in display order, it must set enablePTD = 1. If enablePTD is set to 1 the decision of determining the picture type will be taken by NVENCODE API.

If the client wants to send the input buffers in encode order, it must set enablePTD = 0, and must specify

NV_ENC_PIC_PARAMS::pictureType

NV_ENC_PIC_PARAMS_H264/NV_ENC_PIC_PARAMS_HEVC::displayPOCSyntax

NV_ENC_PIC_PARAMS_H264/NV_ENC_PIC_PARAMS_HEVC::refPicFlag

3.9. Creating Resources Required to Hold Input/output Data

Once the encode session is initialized, the client should allocate buffers to hold the input/output data.

The client may choose to allocate input buffers through NVIDIA Video Encoder Interface by calling NvEncCreateInputBuffer API. In this case, the client is responsible for destroying the allocated input buffers before closing the encode session. It is also the client’s responsibility to fill the input buffer with valid input data according to the chosen input buffer format.
The client should allocate buffers to hold the output encoded bit stream using the
NvEncCreateBitstreamBuffer API. It is the client’s responsibility to destroy these buffers
before closing the encode session.

Alternatively, in scenarios where the client cannot or does not want to allocate input buffers
through the NVIDIA Video Encoder Interface, it can use any externally allocated DirectX resource
as an input buffer. However, the client must perform some simple processing to map these
resources to resource handles that are recognized by the NVIDIA Video Encoder Interface before
use. The translation procedure is explained in Section Input buffers allocated externally.

If the client has used a CUDA device to initialize the encoder session and wishes to use input
buffers NOT allocated through the NVIDIA Video Encoder Interface, the client is required to use
buffers allocated using the cuMemAlloc family of APIs. NVIDIA Video Encoder Interface supports
CUdeviceptr and CUarray input formats.

If the client has used the OpenGL device type to initialize the encoder session and wishes to use
input buffers NOT allocated through the NVIDIA Video Encoder Interface, the client is required
to provide the textures allocated earlier.

The client may generate textures using glGenTextures(), bind it
to either the NV_ENC_INPUT_RESOURCE_OPENGL_TEX::GL_TEXTURE_RECTANGLE or
NV_ENC_INPUT_RESOURCE_OPENGL_TEX::GL_TEXTURE_2D target, allocate storage for it using
glTexImage2D() and copy data to it.

Note that the OpenGL interface for NVENCODE API is only supported on Linux.

If the client has used a DirectX 12 device to initialize encoder session, then client must allocate
input and output buffers using ID3D12Device::CreateCommittedResource() API. The client
must perform some simple processing to map these input and output resources to resource
handles that are recognized by the NVIDIA Video Encoder Interface before use. The translation
procedure is explained in Section Input output buffer allocation for DirectX 12.

Note: The client should allocate at least \((1 + NB)\) input and output buffers, where \(NB\) is the
number of B frames between successive P frames.

### 3.10. Retrieving Sequence Parameters

After configuring the encode session, the client can retrieve the sequence parameter information
(SPS) at any time by calling NvEncGetSequenceParams. It is the client’s responsibility to allocate
and eventually de-allocate a buffer of size MAX_SEQ_HDR_LEN to hold the sequence parameter
information.

By default, SPS/PPS data will be attached to every IDR frame. However, the client can
request the encoder to generate SPS/PPS data on demand as well. To accomplish this,
setNV_ENC_PIC_PARAMS::encodePicFlags=NV_ENC_PIC_FLAG_OUTPUT_SPSPPS. The output
bitstream generated for the current input will then include SPS/PPS.

The client can call NvEncGetSequenceParams at any time, after the encoder has been initialized
(NvEncInitializeEncoder) and the session is active.
Chapter 4. Encoding the Video Stream

Once the encode session is configured and input/output buffers are allocated, the client can start streaming the input data for encoding. The client is required to pass a handle to a valid input buffer and a valid bit stream (output) buffer to the NVIDIA Video Encoder Interface for encoding an input picture.

4.1. Preparing Input Buffers for Encoding

There are two methods to allocate and pass input buffers to the video encoder.

4.1.1. Input buffers allocated through NVIDIA Video Encoder Interface

If the client has allocated input buffers through NvEncCreateInputBuffer, the client needs to fill valid input data before using the buffer as input for encoding. For this, the client should call NvEncLockInputBuffer to get a CPU pointer to the input buffer. Once the client has filled input data, it should call NvEncUnlockInputBuffer. The input buffer should be passed to the encoder only after unlocking it. Any input buffers should be unlocked by calling NvEncUnlockInputBuffer before destroying/reallocating them.

4.1.2. Input buffers allocated externally

To pass externally allocated buffers to the encoder, follow these steps:

1. Populate NV_ENC_REGISTER_RESOURCE with attributes of the externally allocated buffer.
2. Call NvEncRegisterResource with the NV_ENC_REGISTER_RESOURCE populated in the above step.
3. NvEncRegisterResource returns an opaque handle in NV_ENC_REGISTER_RESOURCE::registeredResource which should be saved.
4. Call NvEncMapInputResource with the handle returned above.
5. The mapped handle will then be available in NV_ENC_MAP_INPUT_RESOURCE::mappedResource.
6. The client should use this mapped handle [NV_ENC_MAP_INPUT_RESOURCE::mappedResource] as the input buffer handle in NV_ENC_PIC_PARAMS.
7. After the client has finished using the resource NvEncUnmapInputResource must be called.
8. The client must also call NvEncUnregisterResource with the handle returned by NvEncRegisterResource before destroying the registered resource.

The mapped resource handle (NV_ENC_MAP_INPUT_RESOURCE::mappedResource) should not be used for any other purpose outside the NVIDIA Video Encoder Interface while it is in mapped state. Such usage is not supported and may lead to undefined behavior.

4.1.3. Input output buffer allocation for DirectX 12

Allocation of input and output buffers should be done in following manner:

1. Input buffer should be created using DirectX 12 ID3D12Device::CreateCommittedResource() API, by specifying D3D12_HEAP_PROPERTIES::Type = D3D12_HEAP_TYPE_DEFAULT and D3D12_RESOURCE_DESC::Dimension = D3D12_RESOURCE_DIMENSION_TEXTURE2D.

2. Output buffer should be created using DirectX 12 ID3D12Device::CreateCommittedResource() API, by specifying D3D12_HEAP_PROPERTIES::Type = D3D12_HEAP_TYPE_READBACK and D3D12_RESOURCE_DESC::Dimension = D3D12_RESOURCE_DIMENSION_BUFFER.

3. For HEVC or H.264 encoding, the recommended size for output buffer is:
   \[
   \text{Output buffer size} = 2 \times \text{Input YUV buffer size in bytes.}
   \]

To pass these externally allocated input and output buffers to the encoder, follow these steps:

1. Populate NV_ENC_REGISTER_Resource with attributes of the externally allocated buffer.
2. To enable explicit synchronization in DirectX 12, the API NvEncRegisterResource accepts two NV_ENC_FENCE_POINT_D3D12 pointer type objects [A fence point is a pair of ID3D12Fence pointer and a value], NV_ENC_REGISTER_RESOURCE_PARAMS_D3D12::pInputFencePoint and NV_ENC_REGISTER_RESOURCE_PARAMS_D3D12::pOutputFencePoint, for registering input buffer. NVENC engine waits until pInputFencePoint is reached before processing the NV_ENC_REGISTER_RESOURCE::resourceToRegister. NVENC engine signals the pOutputFencePoint when processing of the resource is completed so that other engines which need to use this resource can start processing.
3. Call NvEncRegisterResource with the NV_ENC_REGISTER_RESOURCE populated in the above step.
4. NvEncRegisterResource returns an opaque handle in NV_ENC_REGISTER_RESOURCE::registeredResource which should be saved.
5. The client should use this registered handle (NV_ENC_REGISTER_RESOURCE::registeredResource) as the input and output buffer handle in NV_ENC_INPUT_RESOURCE_D3D12::pInputBuffer and NV_ENC_INPUT_RESOURCE_D3D12::pOutputBuffer respectively.
6. The client must also call NvEncUnregisterResource with the handle returned by NvEncRegisterResource before destroying the registered resource.
The registered resource handle `NV_ENC_REGISTER_RESOURCE::registeredResource` should not be used for any other purpose outside the NVIDIA Video Encoder Interface while it is in registered state. Such usage is not supported and may lead to undefined behavior.

### 4.2. Configuring Per-Frame Encode Parameters

The client should populate `NV_ENC_PIC_PARAMS` with the parameters to be applied to the current input picture. The client can do the following on a per-frame basis.

#### 4.2.1. Forcing current frame to be encoded as intra frame

To force the current frame as intra (I) frame, set

```c
NV_ENC_PIC_PARAMS::encodePicFlags = NV_ENC_PIC_FLAG_FORCEINTRA
```

#### 4.2.2. Forcing current frame to be used as a reference frame

To force the current frame to be used as a reference frame, set

```c
NV_ENC_PIC_PARAMS_H264/NV_ENC_PIC_PARAMS_HEVC::refPicFlag = 1
```

#### 4.2.3. Forcing current frame to be used as an IDR frame

To force the current frame to be encoded as IDR frame, set

```c
NV_ENC_PIC_PARAMS::encodePicFlags = NV_ENC_PIC_FLAG_FORCEIDR
```

#### 4.2.4. Requesting generation of sequence parameters

To include SPS/PPS along with the currently encoded frame, set

```c
NV_ENC_PIC_PARAMS::encodePicFlags = NV_ENC_PIC_FLAG_OUTPUT_SPSPPS
```

### 4.3. Submitting Input Frame for Encoding

The client should call `NvEncEncodePicture` to perform encoding.

The input picture data will be taken from the specified input buffer, and the encoded bit stream will be available in the specified bit stream (output) buffer once the encoding process completes.
Codec-agnostic parameters such as timestamp, duration, input buffer pointer, etc. are passed via the structure NV_ENC_PIC_PARAMS while codec-specific parameters are passed via the structure NV_ENC_PIC_PARAMS_H264/NV_ENC_PIC_PARAMS_HEVC depending upon the codec in use.

The client should specify the codec-specific structure in NV_ENC_PIC_PARAMS using the NV_ENC_PIC_PARAMS::codecPicParams member.

If the client has used a DirectX 12 device to initialize encoder session, client must pass pointer to NV_ENC_INPUT_RESOURCE_D3D12 in NV_ENC_PIC_PARAMS::inputBuffer containing the registered resource handle and the corresponding input NV_ENC_FENCE_POINT_D3D12 for NVENC to wait before starting encode. Client must pass pointer to NV_ENC_OUTPUT_RESOURCE_D3D12 in NV_ENC_PIC_PARAMS::outputBuffer containing the registered resource handle and the corresponding output NV_ENC_FENCE_POINT_D3D12. NVENC engine waits until the NV_ENC_INPUTRESOURCE_D3D12::inputFencePoint is reached before starting processing of input buffer. NVENC engine signal the NV_ENC_OUTPUTRESOURCE_D3D12::outputFencePoint when processing of the resource is completed so that other engines which need to use these input and output resources can start processing.

4.4. Retrieving Encoded Output

Upon completion of the encoding process for an input picture, the client is required to call NvEncLockBitstream to get a CPU pointer to the encoded bit stream. The client can make a local copy of the encoded data or pass the CPU pointer for further processing (e.g. to a media file writer).

The CPU pointer will remain valid until the client calls NvEncUnlockBitstream. The client should call NvEncUnlockBitstream after it completes processing the output data.

If the client has used a DirectX 12 device to initialize encoder session, client must pass the same NV_ENC_OUTPUTRESOURCE_D3D12 pointer in NV_ENC_LOCK_BITSTREAM::outputBitstream for retrieving the output, which it had sent in NV_ENC_PIC_PARAMS::outputBuffer during encode.

The client must ensure that all bit stream buffers are unlocked before destroying/de-allocating them (e.g. while closing an encode session) or even before reusing them as output buffers for subsequent frames.
Chapter 5. End of Encoding

5.1. Notifying the End of Input Stream

To notify the end of input stream, the client must call NvEncEncodePicture with the flag NV_ENC_PIC_PARAMS::encodePicFlags set to NV_ENC_FLAGS_EOS and all other members of NV_ENC_PIC_PARAMS set to 0. No input buffer is required while calling NvEncEncodePicture for EOS notification.

EOS notification effectively flushes the encoder. This can be called multiple times in a single encode session. This operation however must be done before closing the encode session.

5.2. Releasing Resources

Once encoding completes, the client should destroy all allocated resources.

The client should call NvEncDestroyInputBuffer if it had allocated input buffers through the NVIDIA Video Encoder Interface. The client must ensure that input buffer is first unlocked by calling NvEncUnlockInputBuffer before destroying it.

The client should call NvEncDestroyBitstreamBuffer to destroy each bitstream buffer it had allocated. The client must ensure that the bitstream buffer is first unlocked by calling NvEncUnlockBitstream before destroying it.

5.3. Closing Encode Session

The client should call NvEncDestroyEncoder to close the encoding session. The client should ensure that all resources tied to the encode session being closed have been destroyed before calling NvEncDestroyEncoder. These include input buffers, bit stream buffers, SPS/PPS buffer, etc.

It must also ensure that all registered events are unregistered, and all mapped input buffer handles are unmapped.
Chapter 6. Modes of Operation

The NVIDIA Video Encoder Interface supports the following two modes of operation.

6.1. Asynchronous Mode

This mode of operation is used for asynchronous output buffer processing. For this mode, the client allocates an event object and associates the event with an allocated output buffer. This event object is passed to the NVIDIA Encoder Interface as part of the NvEncEncodePicture API. The client can wait on the event in a separate thread. When the event is signaled, the client calls the NVIDIA Video Encoder Interface to copy output bitstream produced by the encoder. Note that the encoder supports asynchronous mode of operation only for Windows 7 and above, with driver running in WDDM mode. In Linux and Windows with TCC mode (TCC mode is available on Tesla boards\(^1\)), ONLY synchronous mode is supported (refer to Section Synchronous Mode).

The client should set the flag NV_ENC_INITIALIZE_PARAMS::enableEncodeAsync to 1 to indicate that it wants to operate in asynchronous mode. After creating the event objects (one object for each output bitstream buffer allocated), the client needs to register them with the NVIDIA Video Encoder Interface using the NvEncRegisterAsyncEvent. The client is required to pass a bitstream buffer handle and the corresponding event handle as input to NvEncEncodePicture. The NVIDIA Video Encoder Interface will signal this event when the hardware encoder finishes encoding the current input data. The client can then call NvEncLockBitstream in non-blocking mode NV_ENC_LOCK_BITSTREAM::doNotWait flag set to 1 to fetch the output data.

The client should call NvEncUnregisterAsyncEvent to unregister the Event handles before destroying the event objects. Whenever possible, NVIDIA recommends using the asynchronous mode of operation instead of synchronous mode.

A step-by-step control flow for asynchronous mode is as follows:

1. When working in asynchronous mode, the output sample must consist of an event + output buffer and clients must work in multi-threaded manner (D3D9 device should be created with MULTITHREADED flag).
2. The output buffers are allocated using NvEncCreateBitstreamBuffer API. The NVIDIA Video Encoder Interface will return an opaque pointer to the output memory in NV_ENC_CREATE_BITSTREAM_BUFFER::bitstreambuffer. This opaque

\(^1\) To check the mode in which your board is running, run the command-line utility nvidia-smi (nvidia-smi.exe on Windows) included with the driver.
output pointer should be used in \texttt{NvEncEncodePicture} and \texttt{NvEncLockBitsteam}/\texttt{NvEncUnlockBitsteam} calls. For accessing the output memory using CPU, client must call \texttt{NvEncLockBitsteam} API. The number of IO buffers should be at least 4 + number of B frames.

3. The events are windows event handles allocated using Windows’ \texttt{CreateEvent} API and registered using the function \texttt{NvEncRegisterAsyncEvent} before encoding. The registering of events is required only once per encoding session. Clients must unregister the events using \texttt{NvEncUnregisterAsyncEvent} before destroying the event handles. The number of event handles must be same as number of output buffers as each output buffer is associated with an event.

4. Client must create a secondary thread in which it can wait on the completion event and copy the bitstream data from the output sample. Client will have two threads: one is the main application thread which submits encoding work to NVIDIA Encoder while secondary thread waits on the completion events and copies the compressed bitstream data from the output buffer.

5. Client must send the output buffer and event in \texttt{NV_ENC_PIC_PARAMS::outputBitstream} and \texttt{NV_ENC_PIC_PARAMS::completionEvent} fields respectively as part of \texttt{NvEncEncodePicture} API call.

6. Client should then wait on the event on the secondary thread in the same order in which it has called \texttt{NvEncEncodePicture} calls irrespective of input buffer re-ordering [encode order! = display order]. NVIDIA Encoder takes care of the reordering in case of B frames and should be transparent to the encoder clients.

7. When the event gets signalled client must send down the output buffer of sample event it was waiting on in \texttt{NV_ENC_LOCK_BITSTREAM::outputBitstream} field as part of \texttt{NvEncLockBitstream} call.

8. The NVIDIA Encoder Interface returns a CPU pointer and bitstream size in bytes as part of the \texttt{NV_ENC_LOCK_BITSTREAM}.

9. After copying the bitstream data, client must call \texttt{NvEncUnlockBitstream} for the locked output bitstream buffer.

Note:

- The client will receive the event’s signal and output buffer in the same order in which they were queued.
- The \texttt{NV_ENC_LOCK_BITSTREAM::pictureType} notifies the output picture type to the clients.
- Both, the input and output sample (output buffer and the output completion event) are free to be reused once the NVIDIA Video Encoder Interface has signalled the event and the client has copied the data from the output buffer.

### 6.2. Synchronous Mode

This mode of operation is used for synchronous output buffer processing. In this mode the client makes a blocking call to the NVIDIA Video Encoder Interface to retrieve the output bitstream data from the encoder. The client sets the flag \texttt{NV_ENC_INITIALIZE_PARAMS::enableEncodeAsync} to 0 for operation in synchronous mode. The client then must call \texttt{NvEncEncodePicture} without setting a completion event handle. The client must call \texttt{NvEncLockBitstream} with flag
NV_ENC_LOCK_BITSTREAM::doNotWait set to 0, so that the lock call blocks until the hardware encoder finishes writing the output bitstream. The client can then operate on the generated bitstream data and call NvEncUnlockBitstream. This is the only mode supported on Linux.

6.3. Threading Model

To get maximum performance for encoding, the encoder client should create a separate thread to wait on events or when making any blocking calls to the encoder interface. The client should avoid making any blocking calls from the main encoder processing thread. The main encoder thread should be used only for encoder initialization and to submit work to the HW Encoder using NvEncEncodePicture API, which is non-blocking.

Output buffer processing, such as waiting on the completion event in asynchronous mode or calling the blocking API’s such as NvEncLockBitstream/NvEncUnlockBitstream in synchronous mode, should be done in the secondary thread. This ensures that the main encoder thread is never blocked except when the encoder client runs out of resources.

It is also recommended to allocate many input and output buffers in order to avoid resource hazards and improve overall encoder throughput.

On Windows, when encode device type is DirectX, calling DXGI APIs like IDXGIOutputDuplication::AcquireNextFrame from the primary thread and NvEncLockBitstream/NvEncUnlockBitstream from secondary thread, can lead to suboptimal or undefined behavior. This is because NvEncLockBitstream can internally use the application’s DirectX device.

For optimal performance in such applications, the following encoder settings should be used:

- NV_ENC_INITIALIZE_Params::enableEncodeAsync = 1
- NV_ENC_CONFIG_H264/NV_ENC_CONFIG_HEVC::enableFillerDataInsertion = 0
- NV_ENC_CONFIG_H264/NV_ENC_CONFIG_HEVC::outputBufferingPeriodSEI = 0
- NV_ENC_CONFIG_H264/NV_ENC_CONFIG_HEVC::outputPictureTimingSEI = 0
- NV_ENC_CONFIG_H264/NV_ENC_CONFIG_HEVC::outputAUD = 0
- NV_ENC_CONFIG_H264::outputFramePackingSEI = 0
- NV_ENC_CONFIG_H264::outputRecoveryPointSEI = 0
- NV_ENC_CONFIG_H264::enableScalabilityInfoSEI = 0
- NV_ENC_CONFIG_H264::disableSVCPrefixNalu = 1
- NV_ENC_LOCK_BITSTREAM::doNotWait = 0
- NV_ENC_INITIALIZE_Params::enableOutputInVidmem = 0
- NV_ENC_CONFIG_HEVC::enableAlphaLayerEncoding = 0
6.4. Encoder Features using CUDA

Although the core video encoder hardware on GPU is completely independent of CUDA cores or graphics engine on the GPU, following encoder features internally use CUDA for hardware acceleration.

**Note:** The impact of enabling these features on overall CUDA or graphics performance is minimal, and this list is provided purely for information purposes.

- Two-pass rate control modes for high quality presets
- Look-ahead
- All adaptive quantization modes
- Weighted prediction
- Encoding of RGB contents
Chapter 7. Motion Estimation Only Mode

NVENC can be used as a hardware accelerator to perform motion search and generate motion vectors and mode information. The resulting motion vectors or mode decisions can be used, for example, in motion compensated filtering or for supporting other codecs not fully supported by NVENC or simply as motion vector hints for a custom encoder. The procedure to use the feature is explained below.

For use-cases involving computer vision, AI and frame interpolation, Turing and later GPUs contain another hardware accelerator for computing optical flow vectors between frames, which provide better visual matching than the motion vectors.

7.1. Query Motion-Estimation Only Mode Capability

Before using the motion-estimation (ME) only mode, the client should explicitly query the capability of the encoder to support ME only mode. For this, the client should do the following:

1. Specify the capability attribute as NV_ENC_CAPS_SUPPORT_MEONLY_MODE to query through the NV_ENC_CAPS_PARAM::capsToQuery parameter.
2. The client should call NvEncGetEncoderCaps to determine support for the required attribute.

NV_ENC_CAPS_SUPPORT_MEONLY_MODE indicates support of ME only mode in hardware.

0: ME only mode not supported.
1: ME only mode supported.

Motion-estimation (ME) only mode is not supported if DirectX 12 device is used.
7.2. Create Resources for Input/Output Data

The client should allocate at least one buffer for the input picture by calling NvEncCreateInputBuffer API and should also allocate one buffer for the reference frame by using NvEncCreateInputBuffer API. The client is responsible for filling in valid input data.

After input resources are created, client needs to allocate resources for the output data by using NvEncCreateMVBuffer API.

7.3. Populate ME only mode settings

The structure NV_ENC_CODEC_CONFIG::NV_ENC_CONFIG_H264_MEONLY provides the ability to control the partition types of motion vectors and modes returned by NVENC hardware. Specifically, the client can disable intra mode and/or specific MV partition sizes by setting the following flags:

- NV_ENC_CONFIG_H264_MEONLY::disableIntraSearch
- NV_ENC_CONFIG_H264_MEONLY::disablePartition16x16
- NV_ENC_CONFIG_H264_MEONLY::disablePartition8x16
- NV_ENC_CONFIG_H264_MEONLY::disablePartition16x8
- NV_ENC_CONFIG_H264_MEONLY::disablePartition8x8

The API also exposes a parameter NV_ENC_CONFIG::NV_ENC_MV_PRECISION to control the precision of motion vectors returned by the hardware. For full-pel precision, the client must ignore two LSBs of the motion vector. For sub-pel precision, the two LSBs of the motion vector represent fractional part of the motion vector. To get motion vectors for each macroblock, it is recommended to disable intra modes by setting NV_ENC_CONFIG_H264_MEONLY::disableIntraSearch = 1 and let NVENC decide the optimal partition sizes for motion vectors.

7.4. Run Motion Estimation

The client should create an instance of NV_ENC_MEONLY_PARAMS.

The pointers of the input picture buffer and the reference frame buffer need to be fed to NV_ENC_MEONLY_PARAMS::inputBuffer and NV_ENC_MEONLY_PARAMS::referenceFrame respectively.

The pointer returned by NvEncCreateMVBuffer API in the NV_ENC_CREATE_MV_BUFFER::mvBuffer field needs to be fed to NV_ENC_MEONLY_PARAMS::mvBuffer.

In order to operate in asynchronous mode, the client should create an event and pass this event in NV_ENC_MEONLY_PARAMS::completionEvent. This event will be signaled upon completion of motion estimation. Each output buffer should be associated with a distinct event pointer.
Client should call `NvEncRunMotionEstimationOnly` to run the motion estimation on hardware encoder.

For asynchronous mode client should wait for motion estimation completion signal before reusing output buffer and application termination.

Client must lock `NV_ENC_CREATE_MV_BUFFER::mvBuffer` using `NvEncLockBitstream` to get the motion vector data.

Finally, `NV_ENC_LOCK_BITSTREAM::bitstreamBufferPtr` which contains the output motion vectors should be typecast to `NV_ENC_H264_MV_DATA*/NV_ENC_HEVC_MV_DATA*` for H.264/HEVC respectively. Client should then unlock `NV_ENC_CREATE_MV_BUFFER::mvBuffer` by calling `NvEncUnlockBitstream`.

### 7.5. Enabling Motion estimation for stereo usecases

For stereo use cases where in two views need to be processed, we suggest the following approach for better performance and quality of motion vectors:

- Client should create single encode session.
- The client should kick-off the processing of left and right views on separate threads.
- The client should set `NV_ENC_MEONLY_PARAMS::viewID` to 0 and 1 for left and right views.
- The main thread should wait for completion of the threads which have been kicked off NVENC for left and right views.

### 7.6. Release the Created Resources

Once the usage of motion estimation is done, the client should call `NvEncDestroyInputBuffer` to destroy the input picture buffer and the reference frame buffer and should call `NvEncDestroyMVBuffer` to destroy the motion vector data buffer.
Chapter 8. Advanced Features and Settings

8.1. Look-ahead

Look-ahead improves the video encoder’s rate control accuracy by enabling the encoder to buffer the specified number of frames, estimate their complexity and allocate the bits appropriately among these frames proportional to their complexity. This also dynamically allocates B and P frames.

To use this feature, the client must follow these steps:

1. The availability of the feature in the current hardware can be queried using `NvEncGetEncodeCaps` and checking for `NV_ENC_CAPS_SUPPORT_LOOKAHEAD`.
2. Look-ahead needs to be enabled during initialization by setting `NV_ENC_INITIALIZE_PARAMS::encodeconfig->rcParams.enableLookahead = 1`.
3. The number of frames to be looked ahead should be set in `NV_ENC_INITIALIZE_PARAMS::encodeconfig->rcParams.lookaheadDepth` which can be up to 32.
4. By default, look-ahead enables adaptive insertion of intra frames and B frames. They can however be disabled by setting `NV_ENC_INITIALIZE_PARAMS::encodeconfig->rcParams.disableIadapt` and/or `NV_ENC_INITIALIZE_PARAMS::encodeconfig->rcParams.disableBadapt` to 1.
5. When the feature is enabled, frames are queued up in the encoder and hence `NvEncEncodePicture` will return `NV_ENC_ERR_NEED_MORE_INPUT` until the encoder has sufficient number of input frames to satisfy the look-ahead requirement. Frames should be continuously fed in until `NvEncEncodePicture` returns `NV_ENC_SUCCESS`.

8.2. B-Frames As Reference

Using B frame as a reference improves subjective and objective encoded quality with no performance impact. Hence the users enabling multiple B frames are strongly recommended to enable this feature.

To use the feature, follow these steps:
8.3. Reconfigure API

NvEncReconfigureEncoder allows clients to change the encoder initialization parameters in NV_ENC_INITIALIZE_PARAMS without closing existing encoder session and re-creating a new encoding session. This helps clients avoid the latency introduced due to destruction and re-creation of the encoding session. This API is useful in scenarios which are prone to instabilities in transmission mediums during video conferencing, game streaming etc.

Using this API clients can change parameters like bit-rate, frame-rate, resolution dynamically using the same encode session. The reconfigured parameters are passed via NV_ENC_RECONFIGURE_PARAMS::reInitEncodeParams.

However, The API currently doesn’t support reconfiguration of all parameters, some of which are listed below:

- Changing the GOP structure (NV_ENC_CONFIG_H264::idrPeriod, NV_ENC_CONFIG::gopLength, NV_ENC_CONFIG::frameIntervalP)
- Changing from synchronous mode of encoding to asynchronous mode and vice-versa.
- Changing NV_ENC_INITIALIZE_PARAMS::maxEncodeWidth and NV_ENC_INITIALIZE_PARAMS::maxEncodeHeight.
- Changing picture type decision in NV_ENC_INITIALIZE_PARAMS::enablePTD.
- Changing bit-depth.

The API would fail if any attempt is made to reconfigure the parameters which is not supported.

Resolution change is possible only if NV_ENC_INITIALIZE_PARAMS::maxEncodeWidth and NV_ENC_INITIALIZE_PARAMS::maxEncodeHeight are set while creating encoder session.

If the client wishes to change the resolution using this API, it is advisable to force the next frame following the reconfiguration as an IDR frame by setting NV_ENC_RECONFIGURE_PARAMS::forceIDR to 1.

If the client wishes to reset the internal rate control states, set NV_ENC_RECONFIGURE_PARAMS::resetEncoder to 1.

8.4. Adaptive Quantization (AQ)

This feature improves visual quality by adjusting encoding QP (on top of QP evaluated by the Rate Control Algorithm) based on spatial and temporal characteristics of the sequence. The current SDK support two flavors of AQ which are explained as follows:

- Query availability of the feature using NvEncGetEncodeCaps API and checking for NV_ENC_CAPS_SUPPORT_BFRAME_REF_MODE in the return value.
- During encoder initialization, set NV_ENC_CONFIG_H264::useBFramesAsRef = NV_ENC_BFRAME_REF_MODE_MIDDLE. This will set the \((N/2)\)th B frame as reference where \(N\) = number of B frames. In case \(N\) is odd, then \((N-1)/2\)th frame will be picked up as reference.
8.4.1. Spatial AQ

Spatial AQ mode adjusts the QP values based on spatial characteristics of the frame. Since the low complexity flat regions are visually more perceptible to quality differences than high complexity detailed regions, extra bits are allocated to flat regions of the frame at the cost of the regions having high spatial detail. Although spatial AQ improves the perceptible visual quality of the encoded video, the required bit redistribution results in PSNR drop in most of the cases. Therefore, during PSNR-based evaluation, this feature should be turned off.

To use spatial AQ, follow these steps in your application.

‣ Spatial AQ can be enabled during initialization by setting `NV_ENC_INITIALIZE_PARAMS::encodeconfig->rcParams.enableAQ = 1`.

‣ The intensity of QP adjustment can be controlled by setting `NV_ENC_INITIALIZE_PARAMS::encodeconfig->rcParams.aqStrength` which ranges from 1 (least aggressive) to 15 (most aggressive). If not set, strength is auto selected by driver.

8.4.2. Temporal AQ

Temporal AQ tries to adjust encoding QP (on top of QP evaluated by the rate control algorithm) based on temporal characteristics of the sequence. Temporal AQ improves the quality of encoded frames by adjusting QP for regions which are constant or have low motion across frames but have high spatial detail, such that they become better reference for future frames. Allocating extra bits to such regions in reference frames is better than allocating them to the residuals in referred frames because it helps improve the overall encoded video quality. If majority of the region within a frame has little or no motion, but has high spatial details (e.g. high-detail non-moving background) enabling temporal AQ will benefit the most.

One of the potential disadvantages of temporal AQ is that enabling temporal AQ may result in high fluctuation of bits consumed per frame within a GOP. I/P-frames will consume more bits than average P-frame size and B-frames will consume lesser bits. Although target bitrate will be maintained at the GOP level, the frame size will fluctuate from one frame to next within a GOP more than it would without temporal AQ. If a strict CBR profile is required for every frame size within a GOP, it is not recommended to enable temporal AQ. Additionally, since some of the complexity estimation is performed in CUDA, there may be some performance impact when temporal AQ is enabled.

To use temporal AQ, follow these steps in your application.

1. Query the availability of temporal AQ for the current hardware by calling the API `NvEncGetEncodeCaps` and checking for `NV_ENC_CAPS_SUPPORT_TEMPORAL_AQ`.

2. If supported, temporal AQ can be enabled during initialization by setting `NV_ENC_INITIALIZE_PARAMS::encodeconfig->rcParams.enableTemporalAQ = 1`.

Temporal AQ uses CUDA pre-processing and hence requires CUDA processing power, depending upon resolution and content.

Enabling temporal AQ may result in very minor degradation in encoder performance.
8.5. High Bit Depth Encoding

All NVIDIA GPUs support 8-bit encoding (RGB/YUV input with 8-bit precision). NVIDIA GPUs starting from Pascal generation support high-bit-depth HEVC encoding (HEVC main-10 profile with 10-bit input precision). To encode 10-bit content the following steps are to be followed.

1. The availability of the feature can be queried using `NvEncGetEncodeCaps` and checking for `NV_ENC_CAPS_SUPPORT_10BIT_ENCODE`.
2. Create the encoder session with `NV_ENC_HEVC_PROFILE_MAIN10_GUID`.
3. During encoder initialization, set `encodeCodecConfig.hevcConfig.pixelBitDepthMinus8 = 2`.
4. The input surface format needs to be set to `NV_ENC_BUFFER_FORMAT_YUV420_10BIT` or `NV_ENC_BUFFER_FORMAT_ABGR10` or `NV_ENC_BUFFER_FORMAT_ARGB10` or `NV_ENC_BUFFER_FORMAT_YUV444_10BIT`, depending upon nature of input.
5. Other encoding parameters such as preset, rate control mode, etc. can be set as desired.

8.6. Weighted Prediction

Weighted prediction involves calculation of a multiplicative weighting factor and an additive offset to the motion compensated prediction. Weighted prediction provides significant quality gain for contents having illumination changes. NVENCODE API supports weighed prediction for HEVC and H.264 starting from Pascal generation GPUs.

The following steps need to be followed for enabling weighted prediction.

1. The availability of the feature can be queried using `NvEncGetEncodeCaps` and checking for `NV_ENC_CAPS_SUPPORT_WEIGHTED_PREDICTION`.
2. During encoder initialization, set `NV_ENC_INITIALIZE_PARAMS::enableWeightedPrediction = 1`.

Weighted prediction is not supported if the encode session is configured with B frames.

Weighted prediction is not supported if DirectX 12 device is used.

Weighted prediction uses CUDA pre-processing and hence requires CUDA processing power, depending upon resolution and content.

Enabling weighted prediction may also result in very minor degradation in encoder performance.

8.7. Long-Term Reference

NVENCODE API provides the functionality to mark and use specific frames as long-term reference (LTR) frames, which can later be used as reference for encoding the current picture. This helps in error concealment where in the client decoders can predict from the long-
term reference frame in case an intermediate frame loses data. The feature is useful in video streaming applications to recover from frame losses at the receiver.

Following steps are to be followed to enable the feature.

1. During encoder initialization,
   - For H.264, set NV_ENC_CONFIG_H264:enableLTR = 1
   - For HEVC, set NV_ENC_CONFIG_HEVC:enableLTR = 1

2. The maximum number of long-term reference pictures supported in the current hardware can be queried using NvEncGetEncoderCaps and checking for NV_ENC_CAPS_NUM_MAX_LTR_FRAMES.

During normal encoding operation, following steps need to be followed to mark specific frame(s) as LTR frame(s).

1. Configure the number of LTR frames:
   - For H.264, set NV_ENC_CONFIG_H264:ltrNumFrames
   - For HEVC, set NV_ENC_CONFIG_HEVC:ltrNumFrames

2. The client can mark any frame as LTR by setting NV_ENC_PIC_PARAMS_H264::ltrMarkFrame = 1 OR NV_ENC_PIC_PARAMS_HEVC::ltrMarkFrame = 1 for H.264 and HEVC respectively. Each LTR frame needs to be assigned an LTR frame index. This value should be between 0 and ltrNumFrames - 1.

3. The LTR frame index can be assigned by setting NV_ENC_PIC_PARAMS_H264::ltrMarkFrameIdx OR NV_ENC_PIC_PARAMS_HEVC::ltrMarkFrameIdx for H.264 and HEVC respectively.

The frames previously marked as long-term reference frames can be used for prediction of the current frame in the following manner:

1. The LTR frames that are to be used for reference have to be specified using NV_ENC_PIC_PARAMS_H264::ltrUseFrameBitmap OR NV_ENC_PIC_PARAMS_HEVC::ltrUseFrameBitmap for H.264 and HEVC respectively. The bit location specifies the LTR frame index of the frame that will be used as reference. Note that NVENC can only use one frame as a reference frame for prediction. Therefore, only one bit should be set in ltrUseFrameBitmap at any time.

2. Setting NV_ENC_PIC_PARAMS_H264::ltrUsageMode = 1 and NV_ENC_PIC_PARAMS_HEVC::ltrUsageMode = 1 for H.264 and HEVC respectively will clear out all the short term [other than current] reference pictures.

The current SDK does not support LTR when the encoding session is configured with B frames.

8.8. Emphasis MAP

The emphasis map feature in NVENCODE API provides a way to specify regions in the frame to be encoded at varying levels of quality, at macroblock-level granularity. Depending upon the actual emphasis level for each macroblock, the encoder applies an adjustment to the
quantization parameter used to encode that macroblock. The value of this adjustment depends on the following factors:

- Absolute value of the QP as decided by the rate control algorithm, depending upon the rate control constraints. In general, for a given emphasis level, higher the QP determined by the rate control, higher the (negative) adjustment.
- Emphasis level value for the macroblock.

**Note:** The QP adjustment is performed after the rate control algorithm has run. Therefore, there is a possibility of VBV/rate violations when using this feature.

Emphasis level map is useful when the client has prior knowledge of the image complexity (e.g. NVFBC’s Classification Map feature) and encoding those high-complexity areas at higher quality (lower QP) is important, even at the possible cost of violating bitrate/VBV buffer size constraints. This feature is not supported when AQ (Spatial/Temporal) is enabled.

Follow these steps to enable the feature.

1. Query availability of the feature using `NvEncGetEncodeCaps` API and checking for `NV_ENC_CAPS_SUPPORT_EMPHASIS_LEVEL_MAP`.
2. Set `NV_ENC_RC_PARAMS::qpMapMode = NV_ENC_QP_MAP_EMPHASIS`.
3. Fill up the `NV_ENC_PIC_PARAMS::qpDeltaMap` (which is a signed byte array containing value per macroblock in raster scan order for the current picture) with a value from `enum NV_ENC_EMPHASIS_MAP_LEVEL`.

As explained above, higher values of `NV_ENC_EMPHASIS_MAP_LEVEL` imply higher (negative) adjustment made to the QP to emphasize quality of that macroblock. The user can choose higher emphasis level for the regions (s)he wants to encode with a higher quality.

### 8.9. NVENC Output in Video Memory

Starting SDK 9.0, NVENCODE API supports bitstream and H.264 ME-only mode output in video memory. This is helpful in use-cases in which the operation on the output of NVENC is to be performed using CUDA or DirectX shaders. Leaving the output of NVENC in video memory avoids unnecessary PCIe transfers of the buffers. The video memory should be allocated by the client application, as 1-dimensional buffer. This feature is currently supported for H.264 and HEVC encode, and H.264 ME-only mode. The feature is supported for DirectX 11 and CUDA interfaces.

Follow these steps for the output to be available in video memory.

1. Set `NV_ENC_INITIALIZE_PARAMS::enableOutputInVidmem = 1` when calling `nvEncInitializeEncoder()`.
2. Allocate 1-dimensional buffer in video memory for NVENC to write the output.
   - For HEVC or H.264 encoding, the recommended size for this buffer is:
     
     \[
     \text{Output buffer size} = 2 \times \text{Input YUV buffer size} + \text{sizeof(NV_ENC_ENCODE_OUT_PARAMS)}
     \]
     
     First `sizeof(NV_ENC_ENCODE_OUT_PARAMS)` bytes of the output buffer contain `NV_ENC_ENCODE_OUT_PARAMS` structure, followed by encoded bitstream data.
For H.264 ME-only output, the recommended size of output buffer is:

\[
\text{Output buffer size} = \text{HeightInMbs} \times \text{WidthInMbs} \times 
\text{sizeof(NV_ENC_H264_MV_DATA)}
\]

where HeightInMbs and WidthInMbs are picture height and width in number of 16x16 macroblocks, respectively.

For DirectX 11 interface, this buffer can be created using DirectX 11 CreateBuffer() API, by specifying usage = D3D11_USAGE_DEFAULT; BindFlags = {D3D11_BIND_VIDEO_ENCODER | D3D11_BIND_SHADER_RESOURCE}; and CPUAccessFlags = 0;

For CUDA interface, this buffer can be created using cuMemAlloc().

3. Register this buffer using nvEncRegisterResource(), by specifying:
   - NV_ENC_REGISTER_RESOURCE::bufferUsage = NV_ENC_OUTPUT_BITSTREAM if output is encoded bitstream,
   - and as NV_ENC_REGISTER_RESOURCE::bufferUsage=NV_ENC_OUTPUT_MOTION_VECTOR if output is motion vectors in case of H.264 ME only mode.
   - Set NV_ENC_REGISTER_RESOURCE::bufferFormat= NV_ENC_BUFFER_FORMAT_U8.

   NvEncRegisterResource() will return a registered handle in NV_ENC_REGISTER_RESOURCE::registeredResource.

4. SetNV_ENC_MAP_INPUT_RESOURCE::registeredResource = NV_ENC_REGISTER_RESOURCE::registeredResource obtained in the previous step.

5. Call nvEncMapInputResource(), which will return a mapped resource handle in NV_ENC_MAP_INPUTRESOURCE::mappedResource.

6. For HEVC/H.264 encoding mode, call nvEncEncodePicture() by setting NV_ENC_PIC_PARAMS::outputBitstream to NV_ENC_MAP_INPUTRESOURCE::mappedResource.

7. For H.264 ME-only mode, call nvEncRunMotionEstimationOnly() by setting NV_ENC_MEONLY_PARAMS::mvBuffer to NV_ENC_MAP_INPUTRESOURCE::mappedResource.

When reading the output buffer, observe the following:

After calling nvEncEncodePicture() or nvEncRunMotionEstimationOnly(), client can use the output buffer for further processing only after un-mapping this output buffer. NvEncLockBitstream() should not be called.

When operating in asynchronous mode, client application should wait on event before reading the output. In synchronous mode no event is triggered, and the synchronization is handled internally by NVIDIA driver.

To access the output, follow these steps:

1. Client must un-map the input buffer by calling nvEncUnmapInputResource() with mapped resource handle NV_ENC_MAP_INPUTRESOURCE::mappedResource returned by nvEncMapInputResource(). After this, the output buffer can be used for further processing/reading etc.
2. In case of encode, the first `sizeof(NV_ENC_ENCODE_OUT_PARAMS)` bytes of this buffer should be interpreted as `NV_ENC_ENCODE_OUT_PARAMS` structure followed by encode bitstream data. The size of encoded bitstream is given by `NV_ENC_ENCODE_OUT_PARAMS::bitstreamSizeInBytes`.

3. If CUDA mode is specified, all CUDA operations on this buffer must use the default stream. To get the output in system memory, output buffer can be read by calling any CUDA API (e.g. `cuMemcpyDtoH()`) with default stream. The driver ensures that the output buffer is read only after NVENC has finished writing the output in it.

4. For DX11 mode, any DirectX 11 API can be used to read the output. The driver ensures that the output buffer is read only after NVENC has finished writing the output in it. To get the output in system memory, `CopyResource()` (which is a DirectX 11 API) can be used to copy the data in a CPU readable staging buffer. This staging buffer then can be read after calling `Map()` which is a DirectX 11 API.

8.10. Alpha Layer Encoding support in HEVC

NVENCODE API implements support for encoding alpha layer in HEVC. The feature allows an application to encode a base layer which contains YUV data and an auxiliary layer with alpha channel data.

Following steps are to be followed to enable the feature:

1. The availability of the feature can be queried using `nvEncGetEncodeCaps()` and checking for `NV_ENC_CAPS_SUPPORT_ALPHA_LAYER_ENCODING`. Note that only `NV_ENC_BUFFER_FORMAT_NV12`, `NV_ENC_BUFFER_FORMAT_ARGB` and `NV_ENC_BUFFER_FORMAT_ABGR` input formats are supported with alpha layer encoding.

2. During encoder initialization, set `NV_ENC_CONFIG_HEVC::enableAlphaLayerEncoding` = 1. Clients can also specify the ratio in which the bitrate is to be split between YUV and the auxiliary alpha layer by setting `NV_ENC_RC_PARAMS::alphaLayerBitrateRatio`. For example, if `NV_ENC_RC_PARAMS::alphaLayerBitrateRatio = 3` then 75% of the bits will be spent on base layer encoding whereas the other 25% will be spent on alpha layer.

During normal encoding operation, following steps need to be followed to for alpha layer encoding:

1. Passing the alpha input in `nvEncEncodePicture()`:
   - For input format `NV_ENC_BUFFER_FORMAT_NV12`, the YUV data should be passed in `NV_ENC_PIC_PARAMS::inputBuffer` whereas the alpha input data needs to be passed separately using `NV_ENC_PIC_PARAMS::alphaBuffer`. The format of `NV_ENC_PIC_PARAMS::alphaBuffer` should be `NV_ENC_BUFFER_FORMAT_NV12`. The luma plane should contain the alpha data whereas the chroma component should be memset to 0x80.
   - For input format `NV_ENC_BUFFER_FORMAT_ABGR` or `NV_ENC_BUFFER_FORMAT_ARGB`, the input data should be passed in `NV_ENC_PIC_PARAMS::inputBuffer`. The field `NV_ENC_PIC_PARAMS::alphaBuffer` should be set as NULL in this case.

2. The encoded output for YUV as well as the alpha layer is fetched using a call to `NvEncLockBitstream`. The field `NV_ENC_LOCK_BITSTREAM::bitstreamSizeInBytes` will contain the total encoded size i.e. it is the size of YUV layer bitstream data, alpha bitstream
data and any other header data. Clients can get the size of alpha layer separately using the field `NV_ENC_LOCK_BITSTREAM::alphaLayerSizeInBytes`.

Alpha encoding is not supported in the following scenarios:
1. When subframe more is enabled.
2. Input image is YUV 444.
3. The bit-depth of input image is 10 bit.
4. The bit stream output is specified to be in video memory.
5. Weighted prediction is enabled.

### 8.11. Temporal Scalable Video Coding (SVC) in H.264

NVENC CODE API supports temporal scalable video coding(SVC) as specified in Annex G of the H.264/AVC video compression standard. Temporal SVC results in an hierarchical structure with a base layer and multiple auxiliary layers.

To use temporal SVC, follow these steps:
1. Query the availability of temporal SVC for the current hardware by calling the API `NvEncGetEncodeCaps` and checking for `NV_ENC_CAPS_SUPPORT_TEMPORAL_SVC`.
2. If supported, query the maximum number of temporal layers supported in SVC using `nvEncGetEncodeCaps()` and check the value of `NV_ENC_CAPS_NUM_MAX_TEMPORAL_LAYERS`.
3. During encoder initialization, set `NV_ENC_CONFIG_H264::enableTemporalSVC` = 1. Specify the number of temporal layer and maximum number of temporal layers using `NV_ENC_CONFIG_H264::numTemporalLayers` and `NV_ENC_CONFIG_H264::maxTemporalLayers` respectively.
4. If maximum number of temporal layer is greater than 2, then the minimum DPB size for frame reordering needs to be `(maxTemporalLayers - 2) * 2`. Therefore, set the `NV_ENC_CONFIG_H264::maxNumRefFrames` to be greater than or equal to this value. Note that the default value of `NV_ENC_CONFIG_H264::maxNumRefFrames` is `NV_ENC_CAPS::NV_ENC_CAPS_NUM_MAX_TEMPORAL_LAYERS`.
5. By default, SVC prefix NALU is added when temporal SVC is enabled. To disable this, set `NV_ENC_CONFIG_H264::disableSVCPrefixNalu` = 0.
6. NVENC CODE API supports addition of scalability information SEI message in the bitstream. To enable this SEI, set `NV_ENC_CONFIG_H264::enableScalabilityInfoSEI` = 1. This SEI will be added with every IDR frame in the encoded bitstream. Note that only a subset of fields related to temporal scalability is currently supported in this SEI.

When temporal SVC is enabled, only base layer frames can be marked as long term references. Temporal SVC is currently not supported with B-frames. The field `NV_ENC_CONFIG::frameIntervalP` will be ignored when temporal SVC is enabled.
8.12. Error Resiliency features

In a typical scenario involving video streaming, it is common to have bit errors at the client decoder. To minimize the impact of these errors and to recover from such errors, NVENCODE API provides a few error resiliency features which are explained in this section.

Reference Picture Invalidation

NVENCODE API provides a mechanism for invalidating certain pictures when a picture decoded by a client is found to be corrupt by the decoder (client side). Such invalidation is achieved by using the API `NvEncInvalidateRefFrames`. The client can prevent further corruption by asking the encoder on the streaming server to invalidate this frame, which will prevent all the subsequent frames from using the current frame as reference frame for motion estimation. The server then uses older short term and long term frames for reference based on whatever is available for reference. In case no frame is available for reference the current frame will be encoded as intra frame. The parameters `NV_ENC_CONFIG_H264::maxNumRefFrames` and `NV_ENC_CONFIG_HEVC::maxNumRefFramesInDPB` determines the number of frames in DPB and setting this to a large value will allow older frames to be available in the DPB even when some frames have been invalidated, and allow for better picture quality as compared to an intra frame that will be coded in the absence of no reference frames.

The specific frame to be invalidated via API `NvEncInvalidateRefFrames` is identified using a unique number for each frame, referred to as `timestamp`. This is the timestamp sent to the encoder via field `NV_ENC_PIC_PARAMS::inputTimeStamp` when encoding the picture. This can be any monotonically increasing unique number. In its most common incarnation, the unique number can be the presentation timestamp for the picture. The encoder stores the frames in its DPB using `inputTimeStamp` as the unique identifier and uses that identifier to invalidate the corresponding frame when requested via API `NvEncInvalidateRefFrames`.

Intra Refresh

Reference picture invalidation technique described in Section Reference Picture Invalidation depends upon availability of an out-of-band upstream channel to report bitstream errors at the decoder (client side). When such an upstream channel is not available, or in situations where bitstream is more likely to suffer from more frequent errors, intra-refresh mechanism can be used as an error recovery mechanism. Also, when using infinite GOP length, no intra frames are transmitted and intra refresh may be a useful mechanism for recovery from transmission errors.

NVENCODE API provides a mechanism to implement intra refresh. The `enableIntraRefresh` flag should be set to 1 in order to enable intra refresh. `intraRefreshPeriod` determines the period after which intra refresh would happen again and `intraRefreshCnt` sets the number of frames over which intra refresh would happen.

Intra Refresh causes consecutive sections of the frames to be encoded using intra macroblocks, over `intraRefreshCnt` consecutive frames. Then the whole cycle repeats
after `intraRefreshPeriod` frames from the first intra-refresh frame. It is essential to set `intraRefreshPeriod` and `intraRefreshCnt` appropriately based on the probability of errors that may occur during transmission. For example, `intraRefreshPeriod` may be small like 30 for a highly error prone network thus enabling recovery every second for a 30 FPS video stream. For networks that have lesser chances of error, the value may be set higher. Lower value of `intraRefreshPeriod` comes with a slightly lower quality as a larger portion of the overall macroblocks in an intra refresh period are forced to be intra coded, but provides faster recovery from network errors.

`intraRefreshCnt` determines the number of frames over which the intra refresh will happen within an intra refresh period. A smaller value of `intraRefreshCnt` will refresh the entire frame quickly (instead of refreshing it slowly in bands) and hence enable a faster error recovery. However, a lower `intraRefreshCnt` also means sending a larger number of intra macroblocks per frame and hence slightly lower quality.

The default NVENCODE API Intra Refresh behavior is slice based i.e frames in an intra refresh wave will have multiple slices with one slice containing only intra coded MBs / CTUs.

- If the application does not explicitly specify the number of slices or if the specified number of slices are less than 3, during the intra refresh wave, the driver will set 3 slices per frame.
- For `NV_ENC_CONFIG_H264::sliceMode = 0` (MB based slices), 2 (MB row based slices) and 3 (number of slices), the driver will maintain slice count, equal to minimum of: the slice count calculated from slice mode setting and `intraRefreshCnt` number of slices during intra refresh period.
- For `NV_ENC_CONFIG_H264::sliceMode = 1` (byte based slices), the number of slices during an intra refresh wave is always 3.

For certain usecases, clients may want to avoid multiple slices in a frame. In such scenarios, clients can enable single slice intra refresh.

- Query the support for single slice intra refresh for the current driver by calling the API `NvEncGetEncodeCaps` and checking for `NV_ENC_CAPS_SINGLE_SLICE_INTRAREFRESH`.
- If supported, single slice intra refresh can be enabled by setting `NV_ENC_CONFIG_H264::singleSliceIntraRefresh / NV_ENC_CONFIG_HEVC::singleSliceIntraRefresh`.

In case there is a resolution reconfiguration in the middle of an intra refresh wave, the ongoing wave will be terminated immediately. The next wave will start after `NV_ENC_CONFIG_H264::intraRefreshPeriod` number of frames.

Intra refresh is applied in encode order and only on frames which can be used as reference.
Chapter 9. Recommended NVENC Settings

The NVIDIA hardware video encoder is used for several purposes in various applications. Some of the common applications include: Video-recording [archiving], game-casting [broadcasting/multicasting video gameplay online], transcoding [live and video-on-demand] and streaming [games or live content]. Each of these use-cases has its unique requirements for quality, bitrate, latency tolerance, performance constraints etc. Although NVIDIA encoder interface provides flexibility to control the settings with many API’s, the table below can be used as a general guideline for recommended settings for some of the popular use-cases to deliver the best encoded bitstream quality. These recommendations are particularly applicable to GPUs based on second generation Maxwell architecture beyond. For earlier GPUs (Kepler and first-generation Maxwell), it is recommended that clients use the information in Table 2 as a starting point and adjust the settings to achieve appropriate performance-quality tradeoff.

Table 2. Recommended NVENC settings for various use-cases

<table>
<thead>
<tr>
<th>Use-case</th>
<th>Recommended settings for optimal quality and performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recording/Archiving</td>
<td>▶ High quality Tuning Info</td>
</tr>
<tr>
<td></td>
<td>▶ Rate control mode = VBR</td>
</tr>
<tr>
<td></td>
<td>▶ Very large VBV buffer size [4 seconds]</td>
</tr>
<tr>
<td></td>
<td>▶ B Frames*</td>
</tr>
<tr>
<td></td>
<td>▶ Look-ahead</td>
</tr>
<tr>
<td></td>
<td>▶ B frame as reference</td>
</tr>
<tr>
<td></td>
<td>▶ Finite GOP length [2 seconds]</td>
</tr>
<tr>
<td></td>
<td>▶ Adaptive quantization [AQ] enabled**</td>
</tr>
<tr>
<td>Game-casting &amp; cloud transcoding</td>
<td>▶ High quality Tuning Info</td>
</tr>
<tr>
<td></td>
<td>▶ Rate control mode = CBR</td>
</tr>
<tr>
<td></td>
<td>▶ Medium VBV buffer size [1 second]</td>
</tr>
<tr>
<td></td>
<td>▶ B Frames*</td>
</tr>
<tr>
<td></td>
<td>▶ Look-ahead</td>
</tr>
</tbody>
</table>
# Recommended NVENC Settings

## Use-case

<table>
<thead>
<tr>
<th>Use-case</th>
<th>Recommended settings for optimal quality and performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>B frame as reference</td>
<td>- B frame as reference</td>
</tr>
<tr>
<td>Finite GOP length [2 seconds]</td>
<td>- Finite GOP length [2 seconds]</td>
</tr>
<tr>
<td>Adaptive quantization [AQ] enabled**</td>
<td>- Adaptive quantization [AQ] enabled**</td>
</tr>
<tr>
<td>Ultra-low latency or low latency Tuning Info</td>
<td>- Ultra-low latency or low latency Tuning Info</td>
</tr>
<tr>
<td>Rate control mode = CBR</td>
<td>- Rate control mode = CBR</td>
</tr>
<tr>
<td>Multi Pass – Quarter/Full [evaluate and decide]</td>
<td>- Multi Pass – Quarter/Full [evaluate and decide]</td>
</tr>
<tr>
<td>Very low VBV buffer size [e.g. single frame = bitrate/framerate]</td>
<td>- Very low VBV buffer size [e.g. single frame = bitrate/framerate]</td>
</tr>
<tr>
<td>No B Frames</td>
<td>- No B Frames</td>
</tr>
<tr>
<td>Infinite GOP length</td>
<td>- Infinite GOP length</td>
</tr>
<tr>
<td>Adaptive quantization [AQ] enabled**</td>
<td>- Adaptive quantization [AQ] enabled**</td>
</tr>
<tr>
<td>Long term reference pictures***</td>
<td>- Long term reference pictures***</td>
</tr>
<tr>
<td>Intra refresh***</td>
<td>- Intra refresh***</td>
</tr>
<tr>
<td>Non-reference P frames***</td>
<td>- Non-reference P frames***</td>
</tr>
<tr>
<td>Force IDR***</td>
<td>- Force IDR***</td>
</tr>
</tbody>
</table>

### Low-latency use cases like game-streaming, video conferencing etc.

- **: Recommended for low motion games and natural video.
- **: Recommended on second generation Maxwell GPUs and above.
- ***: These features are useful for error recovery during transmission across noisy mediums.

For usecases where the client requires reduced video memory footprint, following guidelines should be followed.

- **Avoid using B-frames.** B-frames requires additional buffers for reordering, hence avoiding B-frames would result to savings in video memory usage.
- **Reduce maximum number of reference frames.** Reducing number of maximum reference frames results in NVIDIA display driver allocating lesser number of buffers internally thereby reducing video memory footprint.
- **Use single pass rate control modes.** Two pass rate control consume additional video memory in comparison to single pass due to additional allocations for first pass encoding. Two pass rate control mode with first pass with full resolution consumes more than first pass with quarter resolution.
- **Avoid Adaptive Quantization / Weighted Prediction.** Features such as Adaptive Quantization / Weighted Prediction allocate additional buffers in video memory. These allocations can be avoided if these features are not used.

Note, however, that the above guidelines may result in some loss in encode quality. Clients are, therefore, recommended to do a proper evaluation to achieve right balance between encoded quality, speed and memory consumption.
Notice

This document is provided for information purposes only and shall not be regarded as a warranty of a certain functionality, condition, or quality of a product. NVIDIA Corporation ("NVIDIA") makes no representations or warranties, expressed or implied, as to the accuracy or completeness of the information contained in this document and assumes no responsibility for any errors contained herein. NVIDIA shall have no liability for the consequences or use of such information or for any infringement of patents or other rights of third parties that may result from its use. This document is not a commitment to develop, release, or deliver any Material (defined below), code, or functionality.

NVIDIA reserves the right to make corrections, modifications, enhancements, improvements, and any other changes to this document, at any time without notice. Customer should obtain the latest relevant information before placing orders and should verify that such information is current and complete.

NVIDIA products are sold subject to the NVIDIA standard terms and conditions of sale supplied at the time of order acknowledgment, unless otherwise agreed in an individual sales agreement signed by authorized representatives of NVIDIA and customer ("Terms of Sale"). NVIDIA hereby expressly objects to applying any customer general terms and conditions with regards to the purchase of the NVIDIA product referenced in this document. No contractual obligations are formed either directly or indirectly by this document.

NVIDIA products are not designed, authorized, or warranted to be suitable for use in medical, military, aircraft, space, or life support equipment, nor in applications where failure or malfunction of the NVIDIA product can reasonably be expected to result in personal injury, death, or property or environmental damage. NVIDIA accepts no liability for the consequences or use of such information or for any infringement of patents or other rights of third parties that may result from its use.

NVIDIA makes no representation or warranty that products based on this document will be suitable for any specified use. Testing of all parameters of each product is not necessarily performed by NVIDIA. It is customer’s sole responsibility to evaluate and determine the applicability of any information contained in this document, ensure the product is suitable and fit for the application planned by customer, and perform the necessary testing for the application in order to avoid a default of the application or the product. Weaknesses in customer’s product designs may affect the quality and reliability of the NVIDIA product and may result in additional or different conditions and/or requirements beyond those contained in this document. NVIDIA accepts no liability related to any default, damage, costs, or problem which may be based on or attributable to: (i) the use of the NVIDIA product in any manner that is contrary to this document or (ii) customer product designs.

Trademarks

NVIDIA, the NVIDIA logo, and cuBLAS, CUDA, CUDA Toolkit, cuDNN, DALI, DIGITS, DGX, DGX-1, DGX-2, DGX Station, DLProf, GPU, Jetson, Kepler, Maxwell, NCCL, Nsight Compute, Nsight Systems, NVCaffe, NVIDIA Deep Learning SDK, NVIDIA Developer Program, NVIDIA GPU Cloud, NVLink, NVSHMEM, PerfWorks, Pascal, SDK Manager, Tegra, TensorRT, TensorRT Inference Server, Tesla, TF-TRT, Triton Inference Server, Turing, and Volta are trademarks and/or registered trademarks of NVIDIA Corporation in the United States and other countries. Other company and product names may be trademarks of the respective companies with which they are associated.

Copyright

© 2010-2021 NVIDIA Corporation. All rights reserved.