



ACCELERATED GSTREAMER USER GUIDE

DA_07303-3.7 | July 23, 2018

Release 28.2



DOCUMENT CHANGE HISTORY

DA_07303-3.7

Version	Date	Authors	Description of Change
v1.0	01 May 2015	NVIDIA	Initial release.
v1.1	30 Jun 2015	mzensius	Added rotation and scaling commands, other new content.
v1.2	03 Nov 2015	emilyh	Changes for 23.1
v1.3	19 Nov 2015	mzensius	Added note for display export.
v1.4	17 Dec 2015	hlang	Updated gst-nvivafilter sample pipelines. Updated steps to build gstreamer manually.
v1.5	08 Jan 2016	kstone	Added nvvidconv interpolation method.
v1.5	29 Jan 2016	hlang	Additional syntax changes for 23.2 release
v2.0	11 May 2016	mzensius	Minor change to nvgstcapture options.
v3.0	11 Aug 2016	mzensius	Versioned for 24.2 release. Gstreamer-0.10 content removed. Also Adds Video Cropping example, interpolation methods for video scaling, EGLStream producer example, and an EGL Image transform example.
v3.1	06 Oct 2016	mzensius	Minor updates to video encoder features.
v3.1.1	21 Nov 2016	mzensius	Changed title of document.
V3.2	12 Jan 2017	mzensius	Adds H.264/H.265 encoder documentation. Also corrects the Gstreamer-1.0 installation procedure.
3.2	03 Mar 2017	hlang	Update date/moniker for L4T 27.1 release. No other updates.
3.3	13 Jul 2017	mzensius	Minor edit to command syntax, and update of date/moniker for L4T 28.1 release.
3.4	01 Dec 2017	mzensius	Includes support for Jetson TX1, previously documented elsewhere. Also includes Overlay Sink information, and formatting enhancements.

3.5	23 Feb 2018	kstone	Added support for the nvarguscamerasrc plugin. Corrected erroneous path. Reformatted commands for line breaks.
3.5	28 Feb 2018	hlang	Update the GStreamer installation and setup table to add nvcompositor.
3.6	20 April 2018	kstone	Added prerequisites for Video Composition.
3.7	23 July 2018	jsachs	Add steps to be performed when testing Wayland based GST Plugin, playing video, or running Wayland based apps on Wayland display server.

TABLE OF CONTENTS

Accelerated GStreamer User Guide	1
Gstreamer-1.0 Installation and Setup	2
Decode Examples	4
Audio Decode Examples Using gst-launch-1.0	4
Video Decode Examples Using gst-launch-1.0	5
Encode Examples	6
Audio Encode Examples Using gst-launch-1.0	6
Video Encode Examples Using gst-launch-1.0	7
Supported H.264/H.265 Encoder Features with Gstreamer-1.0	8
Camera Capture with Gstreamer-1.0	13
Video Playback with Gstreamer-1.0	13
Video Format Conversion with Gstreamer-1.0	16
raw-yuv Input Formats	16
raw-gray Input Formats	16
raw-yuv Output Formats	17
raw-gray Output Formats	17
Video Scaling with Gstreamer-1.0	17
raw-yuv Input Formats	17
raw-gray Input Formats	17
raw-yuv Output Formats	18
raw-gray Output Formats	18
NVIDIA Input and Output Formats	18
Video Cropping with Gstreamer-1.0	19
Video Transcode with Gstreamer-1.0	19
CUDA Video Post-Processing with GStreamer-1.0	22
gst-videocuda	22
gst-nvivafilter	22
Video Rotation with Gstreamer-1.0	23
Video Composition with Gstreamer-1.0	25
Interpolation Methods for Video Scaling	25
EGLStream Producer Example	26
EGL Image Transform Example	26
GStreamer Build Instructions	28
Nvgstcapture-1.0 Option Reference	31
Nvgstcapture Application Options	31
CSI Camera Supported Resolutions	33

Nvcamera Application Options	33
CSI Camera Runtime Commands	36
USB Camera Runtime Commands	41
Notes.....	43
Video Encoder Features	44
Supported Cameras.....	46
CSI Cameras.....	46
USB 2.0 Cameras	46
Industrial Camera Details	47

ACCELERATED GSTREAMER USER GUIDE

This document is a user guide for the Gstreamer version 1.0 based accelerated solution included in NVIDIA® Tegra® Linux Driver Package for NVIDIA® Jetson™ TX1 and NVIDIA® Jetson™ TX2 devices.

Note

References to Gstreamer version 1.0 apply to Gstreamer version 1.8.3 and prior Gstreamer releases of version 1.x.

This document contains the following sections:

- ▶ [Gstreamer-1.0 Installation and Setup](#)
- ▶ [Decode Examples](#)
- ▶ [Encode Examples](#)
- ▶ [Camera Capture with Gstreamer-1.0](#)
- ▶ [Video Playback with Gstreamer-1.0](#)
- ▶ [Video Format Conversion with Gstreamer-1.0](#)
- ▶ [Video Scaling with Gstreamer-1.0](#)
- ▶ [Video Cropping with Gstreamer-1.0](#)
- ▶ [Video Transcode with Gstreamer-1.0](#)
- ▶ [CUDA Video Post-Processing with Gstreamer-1.0](#)
- ▶ [Video Rotation with Gstreamer-1.0](#)
- ▶ [Video Composition with Gstreamer-1.0](#)
- ▶ [Interpolation Methods for Video Scaling](#)
- ▶ [EGLStream Producer Example](#)
- ▶ [EGL Image Transform Example](#)
- ▶ [Gstreamer Build Instructions](#)
- ▶ [Nvgstcapture-1.0 Option Reference](#)
- ▶ [Video Encoder Features](#)
- ▶ [Supported Cameras](#)

GSTREAMER-1.0 INSTALLATION AND SETUP

This section describes how to install and configure Gstreamer.

To install Gstreamer-1.0

- Install Gstreamer-1.0 on the platform with the following commands:

```
sudo add-apt-repository universe
sudo add-apt-repository multiverse
sudo apt-get update
sudo apt-get install gstreamer1.0-tools gstreamer1.0-alsa \
  gstreamer1.0-plugins-base gstreamer1.0-plugins-good \
  gstreamer1.0-plugins-bad gstreamer1.0-plugins-ugly \
  gstreamer1.0-libav
sudo apt-get install libgstreamer1.0-dev \
  libgstreamer-plugins-base1.0-dev \
  libgstreamer-plugins-good1.0-dev \
  libgstreamer-plugins-bad1.0-dev
```

To check the Gstreamer-1.0 version

- Check the Gstreamer-1.0 version with the following command:

```
gst-inspect-1.0 --version
```

Gstreamer version 1.0 includes the following gst-omx video decoders:

Video Decoder	Description
omxh265dec	OpenMAX IL H.265 Video Decoder
omxh264dec	OpenMAX IL H.264 Video Decoder
omxmpeg4videodec	OpenMAX IL MPEG4 Video Decoder
omxvp8dec	OpenMAX IL VP8 Video Decoder
omxvp9dec	OpenMAX IL VP9 video decoder

Gstreamer version 1.0 includes the following gst-omx video encoders:

Video Encoders	Description
omxh264enc	OpenMAX IL H.264/AVC video encoder
omxh265enc	OpenMAX IL H.265/AVC video encoder
omxvp8enc	OpenMAX IL VP8 video encoder

omxvp9enc	OpenMAX IL VP9 video encoder (Supported with Jetson TX2)
-----------	--

GStreamer version 1.0 includes the following gst-omx video sinks:

Video Sink	Description
nvoverlaysink	OpenMAX IL videosink element

GStreamer version 1.0 includes the following EGL image video sinks:

Video Sink	Description
nveglglessink	EGL/GLES videosink element, both the X11 and Wayland backends

GStreamer version 1.0 includes the following proprietary NVIDIA plugins:

NVIDIA Proprietary Plugin	Description
nvarguscamerasrc	Camera plugin for ARGUS API
nvvidconv	Video format conversion & scaling
nvcompositor	Video compositor
nveglstreamsrc	Acts as GStreamer Source Component, accepts EGLStream from EGLStream producer
nvvideosink	Video Sink Component. Accepts YUV-I420 format and produces EGLStream (RGBA)
nvegltransform	Video transform element for NVMM to EGLImage (supported with nveglglessink only)

GStreamer version 1.0 includes the following libjpeg based JPEG image video encode/decode plugins:

JPEG	Description
nvjpegenc	JPEG encoder element
nvjpegdec	JPEG decoder element

Note Execute this command on the target before starting the video decode pipeline using gst-launch or nvgstplayer.
export DISPLAY=:0

Start the X server with `xinit &`, if it is not already running.

DECODE EXAMPLES

The examples in this section show how you can perform audio and video decode with GStreamer.

Note Gstreamer version 0.10 support is deprecated in Linux for Tegra (L4T) Release 24.2. Use of Gstreamer version 1.0 is recommended for development.

Audio Decode Examples Using `gst-launch-1.0`

The following examples show how you can perform audio decode using Gstreamer-1.0.

AAC Decode (OSS software decode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.audio_0 ! \
  queue ! avdec_aac ! audioconvert ! alsasink -e
```

AMR-WB Decode (OSS software decode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.audio_0 ! queue ! avdec_amrwb ! \
  audioconvert ! alsasink -e
```

AMR-NB Decode (OSS software decode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.audio_0 ! queue ! avdec_amrnb ! \
  audioconvert ! alsasink -e
```

MP3 Decode (OSS software decode)

```
gst-launch-1.0 filesrc location=<filename.mp3> ! mpegaudioparse ! \
  avdec_mp3 ! audioconvert ! alsasink -e
```

Note To route audio over HDMI, set the `alsasink` property **device** as follows:
hw:Tegra,3

Video Decode Examples Using gst-launch-1.0

The following examples show how you can perform video decode on Gstreamer-1.0.

H.264 Decode (NVIDIA accelerated decode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! h264parse ! omxh264dec ! \
  nveglglessink -e
```

H.265 Decode (NVIDIA accelerated decode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! h265parse ! omxh265dec ! \
  nvoverlaysink -e
```

10-bit H265 decode

```
gst-launch-1.0 filesrc location==<filename _10bit.mkv> ! \
  matroskademux ! h265parse ! omxh265dec ! nvvidconv ! \
  'video/x-raw(memory:NVMM), format=(string)NV12' ! \
  nvoverlaysink -e
```

Note

Decoding H.265 streams requires Gstreamer version 1.4.x or later, including support for h265parse and qtdemux.

See [Gstreamer Build Instructions](#).

VP8 Decode (NVIDIA accelerated decode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! omxvp8dec ! \
  nvoverlaysink -e
```

Note

If the primary display is NOT used to render video, use the **display-id** property of **nvoverlaysink**.

For example, refer to the pipeline below.

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! omxvp8dec ! \
  nvoverlaysink display-id=1 -e
```

VP9 Decode (NVIDIA accelerated decode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  matroskademux name=demux demux.video_0 ! queue ! omxvp9dec ! \
  nvoverlaysink display-id=1 -e
```

MPEG-4 Decode (NVIDIA accelerated decode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! mpeg4videoparse ! \
  omxmpeg4videodec ! nveglglessink -e
```

Image Decode

```
gst-launch-1.0 filesrc location=<filename.jpg> ! nvjpegdec ! \
  imagefreeze ! xvimagesink -e
```

ENCODE EXAMPLES

The examples in this section show how you can perform audio and video encode with GStreamer.

Audio Encode Examples Using gst-launch-1.0

The following examples show how you can perform audio encode on Gstreamer-1.0.

AAC Encode (OSS software encode)

```
gst-launch-1.0 audiotestsrc ! \
  'audio/x-raw, format=(string)S16LE,
  layout=(string)interleaved, rate=(int)44100, channels=(int)2' ! \
  voaacenc ! qtmux ! filesink location=test.mp4 -e
```

AMR-WB Encode (OSS software encode)

```
gst-launch-1.0 audiotestsrc ! \
  'audio/x-raw, format=(string)S16LE, layout=(string)interleaved, \
  rate=(int)16000, channels=(int)1' ! voamrwbenc ! qtmux ! \
  filesink location=test.mp4 -e
```

Video Encode Examples Using gst-launch-1.0

The following examples show how you can perform video encode with GStreamer-1.0.

H.264 Encode (NVIDIA accelerated encode)

```
gst-launch-1.0 videotestsrc ! \
  'video/x-raw, format=(string)I420, width=(int)640, \
  height=(int)480' ! omxh264enc ! \
  'video/x-h264, stream-format=(string)byte-stream' ! h264parse ! \
  qtmux ! filesink location=test.mp4 -e
```

H.265 Encode (NVIDIA accelerated encode)

```
gst-launch-1.0 videotestsrc ! \
  'video/x-raw, format=(string)I420, width=(int)640, \
  height=(int)480' ! omxh265enc ! filesink location=test.h265 -e
```

10-bit H265 encode

```
gst-launch-1.0 nvcamerasrc fpsRange="30.0 30.0" ! \
  'video/x-raw(memory:NVMM), width=(int)1920, height=(int)1080, \
  format=(string)I420, framerate=(fraction)30/1' ! nvtee ! \
  nvvidconv ! 'video/x-raw(memory:NVMM), format=(string)I420_10LE' ! \
  omxh265enc ! matroskamux ! filesink location=test_10bit.mkv -e
```

VP8 Encode (NVIDIA accelerated encode)

```
gst-launch-1.0 videotestsrc ! \
  'video/x-raw, format=(string)I420, width=(int)640, \
  height=(int)480' ! omxvp8enc ! qtmux ! filesink location=test.mp4 -e
```

VP9 Encode (NVIDIA accelerated, supported with Jetson TX2)

```
gst-launch-1.0 videotestsrc ! \
  'video/x-raw, format=(string)I420, width=(int)640, \
  height=(int)480' ! omxvp9enc ! matroskamux ! \
  filesink location=test.mkv -e
```

MPEG-4 Encode (OSS software encode)

```
gst-launch-1.0 videotestsrc ! \
  'video/x-raw, format=(string)I420, width=(int)640, \
  height=(int)480' ! avenc_mpeg4 ! qtmux ! \
  filesink location=test.mp4 -e
```

H.263 Encode (OSS software encode)

```
gst-launch-1.0 videotestsrc ! \
  'video/x-raw, format=(string)I420, width=(int)704, \
  height=(int)576' ! avenc_h263 ! qtmux ! filesink location=test.mp4 -e
```

Image Encode

```
gst-launch-1.0 videotestsrc num-buffers=1 ! \
  'video/x-raw, width=(int)640, height=(int)480, \
  format=(string)I420' ! nvjpegenc ! filesink location=test.jpg -e
```

Supported H.264/H.265 Encoder Features with Gstreamer-1.0

This section describes example gst-launch-1.0 usage for features supported by the NVIDIA accelerated H.264/H.265 encoder.

Note

Display detailed information on omxh264enc or omxh265enc encoder properties with the `gst-inspect-1.0 [omxh264enc | omxh265enc]` command.

Set I-frame interval

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
  'video/x-raw, width=(int)1280, height=(int)720, \
  format=(string)I420' ! omxh264enc iframeinterval=100 ! qtmux ! \
  filesink location=test.mp4 -e
```

Set temporal-tradeoff (the rate the encoder should drop frames)

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
  'video/x-raw, width=(int)1280, height=(int)720, \
  format=(string)I420' ! omxh264enc temporal-tradeoff=1 ! qtmux ! \
  filesink location=test.mp4 -e
```

Configuring temporal tradeoff causes the encoder to intentionally, periodically, drop input frames. The following modes are supported:

Mode	Description
0	Disable
1	Drop 1 in 5 frames
2	Drop 1 in 3 frames

3	Drop 1 in 2 frames
4	Drop 2 in 3 frames

Set rate control mode

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
  'video/x-raw, width=(int)1280, height=(int)720, \
  format=(string)I420' ! omxh264enc control-rate=1 ! qtmux ! \
  filesink location=test.mp4 -e
```

The following modes are supported:

Mode	Description
0	Disable
1	Variable bit rate
2	Constant bit rate
3	Variable bit rate with frame skip. The encoder skips frames as necessary to meet the target bit rate.
4	Constant bit rate with frame skip

Set peak bitrate

```
gst-launch-1.0 videotestsrc num-buffers=200 is-live=true ! \
  'video/x-raw,width=1280,height=720,format=I420' ! \
  omxh264enc bitrate=6000000 peak-bitrate=6500000 ! qtmux ! \
  filesink location=test.mp4 -e
```

It takes effect only in variable bit rate(control-rate=1) mode. By default, the value is configured as (1.2*bitrate).

Set quantization range for I, P and B frame

The format for the range is the following:

```
"<I_range>:<P_range>:<B_range>"
```

Where <I_range>, <P_range> and <B_range> are each expressed as hyphenated values, as shown in the following example:

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
  'video/x-raw, width=(int)1280, height=(int)720, \
  format=(string)I420' ! \
```

```
omxh264enc qp-range="10,30:10,35:10,35" ! qtmux ! \
filesink location=test.mp4 -e
```

The range of B frames does not take effect if the number of B frames is 0.

Set hardware preset level

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
'video/x-raw, width=(int)1280, height=(int)720, \
format=(string)I420' ! omxh264enc preset-level=0 ! qtmux ! \
filesink location=test.mp4 -e
```

The following modes are supported:

Mode	Description
0	UltraFastPreset
1	FastPreset Only Integer Pixel (integer-pel) block motion is estimated. For I/P macroblock mode decision, only Intra 16 x 16 cost is compared with Inter modes costs. Supports Intra 16 x 16 and Intra 4 x 4 modes.
2	MediumPreset Supports up to Half Pixel (half-pel) block motion estimation. For an I/P macroblock mode decision, only Intra 16 x 16 cost is compared with Inter modes costs. Supports Intra 16 x 16 and Intra 4 x 4 modes.
3	SlowPreset Supports up to Quarter Pixel (Qpel) block motion estimation. For an I/P macroblock mode decision, Intra 4 x 4 as well as Intra 16 x 16 cost is compared with Inter modes costs. Supports Intra 16 x 16 and Intra 4 x 4 modes.

Set profile

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
'video/x-raw, width=(int)1280, height=(int)720, \
format=(string)I420' ! omxh264enc profile=8 ! qtmux ! \
filesink location=test.mp4 -e
```

From omxh264enc, the following profiles are supported:

Profile	Description
1	Baseline profile

2	Main profile
8	High profile

Set level

```
gst-launch-1.0 videotestsrc num-buffers=200 is-live=true ! \
  'video/x-raw, format=(string)I420, width=(int)256, height=(int)256, \
  framerate=(fraction)30/1' ! omxh264enc bitrate=40000 !\
  'video/x-h264, level=(string)2.2' ! qtmux ! \
  filesink location= test.mp4 -e
```

From omxh264enc, the following levels are supported: 1, 1b, 1.2, 1.3, 2, 2.1, 2.2, 3, 3.1, 3.2, 4, 4.1, 4.2, 5, 5.1, and 5.2.

From omxh265enc, the following levels are supported: main1, main2, main2.1, main3, main3.1, main4, main4.1, main5, high1, high2, high2.1, high3, high3.1, high4, high4.1, and high5.

Set number of B frames between two reference frames

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
  'video/x-raw, width=(int)1280, height=(int)720, \
  format=(string)I420' ! omxh264enc num-B-Frames=2 ! qtmux ! \
  filesink location=test.mp4 -e
```

Note

B-frame-encoding is not supported with omxh265enc.

Insert SPS and PPS at IDR

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
  'video/x-raw, width=(int)1280, height=(int)720, \
  format=(string)I420' ! omxh264enc insert-sps-pps=1 ! qtmux ! \
  filesink location=test.mp4 -e
```

If enabled, a sequence parameter set (SPS) and a picture parameter set (PPS) are inserted before each IDR frame in the H.264/H.265 stream.

Enable two-pass CBR

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
  'video/x-raw, width=(int)1280, height=(int)720, \
  format=(string)I420' ! omxh264enc EnableTwopassCBR=1
  control-rate=2 ! qtmux ! filesink location=test.mp4 -e
```

Two-pass CBR must be enabled along with constant bit rate (control-rate=2).

Set virtual buffer size

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
  'video/x-raw, width=(int)1280, height=(int)720, \
  format=(string)I420' ! omxh264enc vbv-size=10 ! qtmux ! \
  filesink location=test.mp4 -e
```

If the buffer size of decoder or network bandwidth is limited, configuring virtual buffer size can cause video stream generation to correspond to the limitations according to the following formula:

```
virtual buffer size = vbv-size * (bitrate/fps)
```

Enable stringent bitrate

```
gst-launch-1.0 nvcamerasrc num-buffers=200 ! \
  'video/x-raw(memory:NVMM),width=1920,height=1080' ! \
  omxh264enc control-rate=2 vbv-size=1 EnableTwopassCBR=true \
  EnableStringentBitrate=true ! qtmux ! filesink location=test.mp4 -e
```

Stringent Bitrate must be enabled along with constant bit rate (control-rate=2), two-pass CBR being enabled, and virtual buffer size being set.

Slice-header-spacing with spacing in terms of MB

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
  'video/x-raw, width=(int)1280, height=(int)720, \
  format=(string)I420' ! \
  omxh264enc slice-header-spacing=200 bit-packetization=0 ! \
  qtmux ! filesink location=test.mp4 -e
```

The parameter `bit-packetization=0` configures the network abstraction layer (NAL) packet as macroblock (MB)-based, and `slice-header-spacing=200` configures each NAL packet as 200 MB at maximum.

Slice header spacing with spacing in terms of number of bits

```
gst-launch-1.0 videotestsrc num-buffers=200 ! \
  'video/x-raw, width=(int)1280, height=(int)720, \
  format=(string)I420' ! \
  omxh264enc slice-header-spacing=1024 bit-packetization=1 ! \
  qtmux ! filesink location=test1.mp4 -e
```

The parameter `bit-packetization=1` configures the network abstraction layer (NAL) packet as size-based, and `slice-header-spacing=1024` configures each NAL packet as 1024 bytes at maximum.

CAMERA CAPTURE WITH GSTREAMER-1.0

For `nvgstcapture-1.0` usage information enter the following command:

```
nvgstcapture-1.0 --help
```

Note

`nvgstcapture-1.0` application default supports ARGUS API using `nvarguscamerasrc` plugin.

For more information, see [Nvgstcapture-1.0 Option Reference](#) in this guide.

Capture using `nvarguscamerasrc` and preview display with `overlaysink`:

```
gst-launch-1.0 nvarguscamerasrc ! 'video/x-raw(memory:NVMM), \
  width=1920, height=1080, format=(string)NV12, \
  framerate=(fraction)30/1' ! nvoverlaysink -e
```

The `nvgstcapture-1.0` application uses the `v4l2src` plugin to capture still images and video.

The following table shows USB camera support.

USB Camera Support	Feature
YUV	Preview display
	Image capture (VGA, 640 x 480)
	Video capture (480p, 720p, H.264/H.265/VP8/VP9 encode)

raw-yuv Capture (I420 format) and preview display with `xvimagesink`

```
gst-launch-1.0 v4l2src device="/dev/video0" ! \
  "video/x-raw, width=640, height=480, format=(string)I420" ! \
  xvimagesink -e
```

VIDEO PLAYBACK WITH GSTREAMER-1.0

For `nvgstplayer-1.0` usage information enter the following command:

```
nvgstplayer-1.0 --help
```

Video can be output to HD displays using the HDMI connector on the platform. The GStreamer-1.0 application supports currently the following video sinks:

Overlay Sink (Video playback on overlay in full-screen mode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux ! h264parse ! omxh264dec ! nvoverlaysink -e
```

Overlay Sink (Video playback using overlay parameters)

Note: The following steps are required to use the “overlay” property on Jetson-TX2.

1. Set win_mask with the following commands:


```
# sudo -s
# cd /sys/class/graphics/fb0
# echo 4 > blank          // Blanks monitor for changing
#                          // display setting.
# echo 0x0 > device/win_mask
#                          // Clears current window setting.
#                          // window setting.
# echo 0x3f > device/win_mask
#                          // Assigns all 6 overlay windows
#                          // in display controller to
#                          // display 0 (fb0).
# echo 0 > blank          // Unblank display.
```
2. Stop X11 using following command:


```
$ sudo service lightdm stop
```

For more introduction about the overlay windows in the display controller, please refer to the *TX2 Technical Reference Manual (TRM)*.

To use all 6 overlays X11 must be disabled, since it occupies one window. Disabling X11 also helps avoid memory bandwidth contention when using a non X11 overlay.

```
gst-launch-1.0 filesrc location=<filename_1080p.mp4> ! \
  qtdemux ! h264parse ! omxh264dec \
  nvoverlaysink overlay-x=100 overlay-y=100 overlay-w=640 \
  overlay-h=480 overlay=1 \
  overlay-depth=0 & gst-launch-1.0 filesrc \
  location=<filename_1080p.mp4> ! qtdemux ! h264parse ! omxh264dec ! \
  nvoverlaysink overlay-x=250 overlay-y=250 overlay-w=640 \
  overlay-h=480 overlay=2 overlay-depth=1 -e

gst-launch-1.0 filesrc location=<filename_1080p.mp4> ! \
  qtdemux ! h264parse ! omxh264dec \
  nvoverlaysink overlay-x=100 overlay-y=100 overlay-w=640 \
```

```
overlay-h=480 overlay=1 overlay-depth=2 & gst-launch-1.0 filesrc \
location=<filename_1080p.mp4> ! qtdemux ! h264parse ! omxh264dec ! \
nvoverlaysink overlay-x=250 overlay-y=250 overlay-w=640 overlay-h=480
overlay=2 overlay-depth=1 -e
```

nveglglessink (Windowed video playback, NVIDIA EGL/GLES videosink using default X11 backend)

Use the following command to start the GStreamer pipeline using `nveglglesink` with the default X11 backend:

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
qtdemux name=demux ! h264parse ! omxh264dec ! nveglglessink -e
```

This `nvgstplayer-1.0` application supports specific window position and dimensions for windowed playback:

```
nvgstplayer-1.0 -i <filename> --window-x=300 --window-y=300 \
--window-width=500 --window-height=500
```

nveglglessink (Windowed video playback, NVIDIA EGL/GLES videosink using Wayland backend)

You can also use `nveglglsink` with the Wayland backend, instead of the default X11 backend.

Ubuntu 16.04 does not support the Wayland display server. That is, there is no UI support to switch to Wayland from Xorg. You must start the Wayland server (Weston) using the target's shell before performing any Weston based operation.

To start Weston:

The following steps are required before you first run the GStreamer pipeline with the Wayland backend. They are not required on subsequent runs.

1. Stop the display manager:

```
sudo service lightdm stop
```

2. Unset the `DISPLAY` environment variable:

```
unset DISPLAY
```

3. Create a temporary `xdg` directory:

```
mkdir /tmp/xdg
chmod 700 /tmp/xdg
```

4. Start the Weston compositor:

```
sudo XDG_RUNTIME_DIR=/tmp/xdg weston --idle-time=0 &
```

To run the GStreamer pipeline with the Wayland backend:

Use the following command to start the GStreamer pipeline using `nveglglesink` with the Wayland backend:

```
sudo XDG_RUNTIME_DIR=/tmp/xdg gst-launch-1.0 filesrc \
  location=<filename.mp4> ! qtdemux name=demux ! h264parse ! \
  omxh264dec ! nveglglesink winsys=wayland
```

VIDEO FORMAT CONVERSION WITH GSTREAMER-1.0

The NVIDIA proprietary `nvvidconv` GStreamer-1.0 plug-in allows conversion between OSS (raw) video formats and NVIDIA video formats. The `nvvidconv` plug-in currently supports the format conversions described in this section

raw-yuv Input Formats

Currently `nvvidconv` supports the I420, UYVY, YUY2, YVYU, NV12, GRAY8, BGRx, and RGBA raw-yuv input formats.

```
gst-launch-1.0 videotestsrc ! 'video/x-raw, format=(string)UYVY, \
  width=(int)1280, height=(int)720' ! nvvidconv ! \
  'video/x-raw(memory:NVMM), format=(string)I420' ! omxh264enc ! \
  'video/x-h264, stream-format=(string)byte-stream' ! h264parse ! \
  qtmux ! filesink location=test.mp4 -e
```

raw-gray Input Formats

Currently `nvvidconv` supports the GRAY8 raw-gray input format.

```
gst-launch-1.0 videotestsrc ! \
  'video/x-raw, format=(string)GRAY8, width=(int)1280, \
  height=(int)720' ! nvvidconv ! \
  'video/x-raw(memory:NVMM), format=(string)I420' ! omxh264enc ! \
  'video/x-h264, \
```

```
stream-format=(string)byte-stream' ! h264parse ! qtmux ! \
filesink location=test.mp4 -e
```

raw-yuv Output Formats

Currently `nvvidconv` supports the I420, UYVY, YUY2, YVYU, NV12, GRAY8, BGRx, and RGBA raw-yuv output formats.

```
gst-launch-1.0 filesrc location=640x480_30p.mp4 ! qtdemux ! queue ! \
h264parse ! omxh264dec ! nvvidconv ! \
'video/x-raw, format=(string)UYVY' ! xvimagesink -e
```

raw-gray Output Formats

Currently `nvvidconv` supports the GRAY8 raw-gray output format.

```
gst-launch-1.0 filesrc location=640x480_30p.mp4 ! qtdemux ! queue ! \
h264parse ! omxh264dec ! nvvidconv ! \
'video/x-raw, format=(string)GRAY8' ! videoconvert ! xvimagesink -e
```

VIDEO SCALING WITH GSTREAMER-1.0

The NVIDIA proprietary `nvvidconv` Gstreamer-1.0 plug-in also allows you to perform video scaling. The `nvvidconv` plug-in currently supports scaling with the format conversions described in this section.

raw-yuv Input Formats

Currently `nvvidconv` supports the I420, UYVY, YUY2, YVYU, NV12, GRAY8, BGRx, and RGBA raw-yuv input formats for scaling.

```
gst-launch-1.0 videotestsrc ! \
'video/x-raw, format=(string)I420, width=(int)1280, \
height=(int)720' ! nvvidconv ! \
'video/x-raw(memory:NVMM), width=(int)640, height=(int)480, \
format=(string)I420' ! omxh264enc ! \
'video/x-h264, stream-format=(string)byte-stream' ! h264parse ! \
qtmux ! filesink location=test.mp4 -e
```

raw-gray Input Formats

Currently `nvvidconv` supports the GRAY8 raw-gray input format for scaling.

```
gst-launch-1.0 videotestsrc ! \
  'video/x-raw, format=(string)GRAY8, \
  width=(int)1280, height=(int)720' ! nvvidconv ! \
  'video/x-raw(memory:NVMM), width=(int)640, height=(int)480, \
  format=(string)I420' ! omxh264enc ! \
  'video/x-h264, stream-format=(string)byte-stream' ! h264parse ! \
  qtmux ! filesink location=test.mp4 -e
```

raw-yuv Output Formats

Currently `nvvidconv` supports the I420, UYVY, YUY2, YVYU, NV12, GRAY8, BGRx, and RGBA raw-yuv output formats for scaling.

```
gst-launch-1.0 filesrc location=1280x720_30p.mp4 ! qtdemux ! queue ! \
  h264parse ! omxh264dec ! nvvidconv ! \
  'video/x-raw, format=(string)I420, width=640, height=480' ! \
  xvimagesink -e
```

raw-gray Output Formats

Currently `nvvidconv` supports the GRAY8 raw-gray output format for scaling.

```
gst-launch-1.0 filesrc location=1280x720_30p.mp4 ! qtdemux ! queue ! \
  h264parse ! omxh264dec ! nvvidconv ! \
  'video/x-raw, format=(string)GRAY8, width=640, height=480' ! \
  videoconvert ! xvimagesink -e
```

NVIDIA Input and Output Formats

Currently `nvvidconv` supports the NVIDIA input and output formats for scaling described in the following table:

Input Format	Output Format
NV12	NV12
I420, I420_10LE	I420, I420_10LE
	RGBA

To scale between NVIDIA formats

- Scale between NVIDIA Formats with the following commands:

```
gst-launch-1.0 filesrc location=1280x720_30p.mp4 ! qtdemux ! \
  h264parse ! omxh264dec ! nvvidconv ! \
  'video/x-raw(memory:NVMM), width=(int)640, height=(int)480, \
```

```

format=(string)I420' ! omxh264enc ! qtmux ! \
filesink location=test.mp4 -e

gst-launch-1.0 filesrc location=1280x720_30p.mp4 ! qtdemux ! \
h264parse ! omxh264dec ! nvvidconv ! \
'video/x-raw(memory:NVMM), width=(int)640, height=(int)480, \
format=(string)RGBA' ! nvoverlaysink -e

gst-launch-1.0 nvcamerasrc fpsRange="30 30" ! \
'video/x-raw(memory:NVMM), width=(int)1920, height=(int)1080, \
format=(string)I420, framerate=(fraction)30/1' ! \
nvtee ! nvvidconv ! \
'video/x-raw(memory:NVMM), width=(int)640, height=(int)480, \
format=(string)NV12' ! omxh264enc ! \
qtmux ! filesink location=test.mp4 -e

```

VIDEO CROPPING WITH GSTREAMER-1.0

The NVIDIA proprietary nvvidconv Gstreamer-1.0 plug-in also allows you to perform video cropping.

To crop video

- Crop video with the following commands:

```

gst-launch-1.0 filesrc location=<filename_1080p.mp4> ! qtdemux ! \
h264parse ! omxh264dec ! \
nvvidconv left=400 right=1520 top=200 bottom=880 ! \
nvoverlaysink display-id=1 -e

```

VIDEO TRANSCODE WITH GSTREAMER-1.0

You can perform video transcoding between the following video formats.

H.264 Decode to VP8 Encode (NVIDIA-accelerated decode to NVIDIA-accelerated encode)

```

gst-launch-1.0 filesrc location=<filename.mp4> ! \
qtdemux name=demux demux.video_0 ! queue ! h264parse ! omxh264dec ! \
omxvp8enc bitrate=20000000 ! qtmux name=mux ! \
filesink location=<Transcoded_filename.mp4> -e

```

H.265 Decode to VP9 Encode (NVIDIA-accelerated decode to NVIDIA-accelerated encode)

```

gst-launch-1.0 filesrc location=<filename.mp4> ! \
qtdemux name=demux demux.video_0 ! queue ! h265parse ! omxh265dec ! \

```



```
omxvp9enc bitrate=20000000 ! matroskamux name=mux ! \
filesink location=<Transcoded_filename.mkv> -e
```

VP8 Decode to H.264 Encode (NVIDIA-accelerated decode to NVIDIA-accelerated encode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! omxvp8dec ! \
  omxh264enc bitrate=20000000 ! qtmux name=mux ! \
  filesink location=<Transcoded_filename.mp4> -e
```

VP9 Decode to H.265 Encode (NVIDIA-accelerated decode to NVIDIA-accelerated encode)

```
gst-launch-1.0 filesrc location=<filename.webm> ! \
  matroskademux name=demux demux.video_0 ! queue ! omxvp9dec ! \
  omxh265enc bitrate=20000000 ! qtmux name=mux ! \
  filesink location=<Transcoded_filename.mp4> -e
```

MPEG-4 Decode to VP8 Encode (NVIDIA-accelerated decode to NVIDIA-accelerated encode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! mpeg4videoparse ! \
  omxmpeg4videodec ! omxvp8enc bitrate=20000000 ! qtmux name=mux ! \
  filesink location=<Transcoded_filename.mp4> -e
```

MPEG-4 Decode to H.264 Encode (NVIDIA-accelerated decode to NVIDIA-accelerated encode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! mpeg4videoparse ! \
  omxmpeg4videodec ! omxh264enc bitrate=20000000 ! qtmux name=mux ! \
  filesink location=<Transcoded_filename.mp4> -e
```

H.264 Decode to MPEG-4 Encode (NVIDIA-accelerated decode to OSS software encode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! h264parse ! omxh264dec ! \
  nvvidconv ! avenc_mpeg4 bitrate=4000000 ! qtmux name=mux ! \
  filesink location=<Transcoded_filename.mp4> -e
```

H.265 Decode to MPEG-4 Encode (NVIDIA-accelerated decode to OSS software encode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! h265parse ! omxh265dec ! \
```

```
nvvidconv ! avenc_mpeg4 bitrate=4000000 ! qtmux name=mux ! \
filesink location=<Transcoded_filename.mp4> -e
```

VP8 Decode to MPEG-4 Encode (NVIDIA-accelerated decode to OSS software encode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! omxvp8dec ! nvvidconv ! \
  avenc_mpeg4 bitrate=4000000 ! qtmux name=mux ! \
  filesink location=<Transcoded_filename.mp4> -e
```

VP9 Decode to MPEG-4 Encode (NVIDIA-accelerated decode to OSS software encode)

```
gst-launch-1.0 filesrc location=<filename.mkv> ! \
  matroskademux name=demux demux.video_0 ! queue ! omxvp9dec ! \
  nvvidconv ! avenc_mpeg4 bitrate=4000000 ! qtmux name=mux ! \
  filesink location=<Transcoded_filename.mp4> -e
```

H.264 Decode to Theora Encode (NVIDIA-accelerated decode to OSS software encode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! h264parse ! omxh264dec ! \
  nvvidconv ! theoraenc bitrate=4000000 ! oggmux name=mux ! \
  filesink location=<Transcoded_filename.ogg> -e
```

H.264 Decode to H.263 Encode (NVIDIA-accelerated decode to OSS software encode)

```
gst-launch-1.0 filesrc location=<filename.mp4> ! \
  qtdemux name=demux demux.video_0 ! queue ! h264parse ! omxh264dec ! \
  nvvidconv ! 'video/x-raw, width=(int)704, height=(int)576, \
  format=(string)I420' ! avenc_h263 bitrate=4000000 ! qtmux ! \
  filesink location=<Transcoded_filename.mp4> -e
```

CUDA VIDEO POST-PROCESSING WITH GSTREAMER-1.0

This section describes Gstreamer-1.0 plug-ins for NVIDIA® CUDA® post-processing operations.

gst-videocuda

This GStreamer-1.0 plug-in performs CUDA post-processing operations on decoder-provided EGL images and render video using nveglglessink.

The following are sample pipeline creation and application usage commands.

Sample decode pipeline

```
gst-launch-1.0 filesrc location=<filename_h264_1080p.mp4> ! \
  qtdemux name=demux ! h264parse ! omxh264dec ! videocuda ! \
  nveglglessink max-lateness=-1 -e
```

Sample decode command

```
nvgstplayer-1.0 -i <filename_h264_1080p.mp4> --svd="omxh264dec" \
  --svc="videocuda" --svs="nveglglessink # max-lateness=-1" \
  --disable-vnative --no-audio --window-x=0 --window-y=0 \
  --window-width=960 --window-height=540
```

gst-nvivafilter

This NVIDIA proprietary GStreamer-1.0 plug-in performs pre/post and CUDA post-processing operations on CSI camera captured or decoded frames, and renders video using overlay video sink or video encode.

Sample decode pipeline

```
gst-launch-1.0 filesrc location=<filename.mp4> ! qtdemux ! \
  h264parse ! omxh264dec ! nvivafilter cuda-process=true \
  customer-lib-name="libnvsample_cudaprocess.so" ! \
  'video/x-raw(memory:NVMM), format=(string)NV12' ! nvoverlaysink -e
```

Sample CSI Camera pipeline

```
gst-launch-1.0 nvcamerasrc fpsRange="30 30" ! \
  'video/x-raw(memory:NVMM), width=(int)3840, height=(int)2160, \
  format=(string)I420, framerate=(fraction)30/1' ! nvtee ! \
  nvivafilter cuda-process=true \
```

```
customer-lib-name="libnvsample_cudaprocess.so" ! \
'video/x-raw(memory:NVMM), format=(string)NV12' ! nvoverlaysink -e
```

Note See `nvsample_cudaprocess_src.tbz2` package for the `libnvsample_cudaprocess.so` library sources. A Sample CUDA implementation of `libnvsample_cudaprocess.so` can be replaced by a custom CUDA implementation.

VIDEO ROTATION WITH GSTREAMER-1.0

The NVIDIA proprietary `nvvidconv` Gstreamer-1.0 plug-in also allows you to perform video rotation operations.

The following table shows the supported values for the `nvvidconv flip-method` property.

Flip Method	Property value
identity - no rotation (default)	0
counterclockwise - 90 degrees	1
rotate - 180 degrees	2
clockwise - 90 degrees	3
horizontal flip	4
upper right diagonal flip	5
vertical flip	6
upper-left diagonal	7

Note Get information on `nvvidconv flip-method` property with the `gst-inspect-1.0 nvvidconv` command.

To rotate video 90 degrees counterclockwise

- To rotate video 90 degrees in a counterclockwise direction, enter the following command.

```
gst-launch-1.0 filesrc location=<filename.mp4> ! qtdemux name=demux ! \
h264parse ! omxh264dec ! nvvidconv flip-method=1 ! \
'video/x-raw(memory:NVMM), format=(string)I420' ! nvoverlaysink -e
```

To rotate video 90 degrees clockwise

- To rotate video 90 degrees in a clockwise direction, enter the following command:

```
gst-launch-1.0 filesrc location=<filename.mp4> ! qtdemux name=demux ! \
  h264parse ! omxh264dec ! nvvidconv flip-method=3 ! \
  'video/x-raw(memory:NVMM), format=(string)I420' ! \
  omxh264enc ! qtmux ! filesink location=test.mp4 -e
```

To rotate 180 degrees

- To rotate video 180 degrees, enter the following command:

```
gst-launch-1.0 nvcamerasrc fpsRange="30.0 30.0" ! \
  'video/x-raw(memory:NVMM), width=(int)1920, height=(int)1080, \
  format=(string)I420, framerate=(fraction)30/1' ! nvtee ! \
  nvvidconv flip-method=2 ! \
  'video/x-raw(memory:NVMM), format=(string)I420' ! nvoverlaysink -e
```

To scale and rotate video 90 degrees counterclockwise

- To scale and rotate video 90 degrees counterclockwise, enter the following command:

```
gst-launch-1.0 filesrc location=<filename_1080p.mp4> ! qtdemux ! \
  h264parse ! omxh264dec ! nvvidconv flip-method=1 ! \
  'video/x-raw(memory:NVMM), width=(int)480, height=(int)640, \
  format=(string)I420' ! nvoverlaysink -e
```

To scale and rotate video 90 degrees clockwise

- To scale and rotate video 90 degrees clockwise, enter the following command:

```
gst-launch-1.0 nvcamerasrc fpsRange="30.0 30.0" ! \
  'video/x-raw(memory:NVMM), width=(int)1920, height=(int)1080, \
  format=(string)I420, framerate=(fraction)30/1' ! nvtee ! \
  nvvidconv flip-method=3 ! 'video/x-raw(memory:NVMM), \
  width=(int)480, height=(int)640, format=(string)I420' ! \
  nvoverlaysink -e
```

To scale and rotate video 180 degrees

- To scale and rotate video 180 degrees, enter the following command:

```
gst-launch-1.0 filesrc location=<filename_1080p.mp4> ! \
  qtdemux ! h264parse ! omxh264dec ! nvvidconv flip-method=2 ! \
  'video/x-raw(memory:NVMM), width=(int)640, height=(int)480, \
  format=(string)I420' ! nvoverlaysink -e
```

Video Composition with Gstreamer-1.0

With the NVIDIA proprietary nvcompositor Gstreamer-1.0 plug-in, you can perform video composition operations on gst-omx video decoded streams.

Note nvcompositor supports video decode (gst-omx) with the overlay render pipeline for gst-1.8.3.

Prerequisites

- Install the following dependent gstreamer package.

```
$ sudo apt-get install gstreamer1.0-plugins-bad
```

- Clear the registry cache file, in case there is an issue with gst-inspect-1.0 nvcompositor.

```
$ rm .cache/gstreamer-1.0/registry.aarch64.bin
```

To composite different formats decoded streams

- Enter the following command:

```
gst-launch-1.0 nvcompositor \
  name=comp sink_0::xpos=0 sink_0::ypos=0 sink_0::width=1920 \
  sink_0::height=1080 sink_1::xpos=0 sink_1::ypos=0 \
  sink_1::width=1600 sink_1::height=1024 sink_2::xpos=0 \
  sink_2::ypos=0 sink_2::width=1366 sink_2::height=768 \
  sink_3::xpos=0 sink_3::ypos=0 sink_3::width=1024 \
  sink_3::height=576 ! nvoverlaysink display-id=1 \
  filesrc location=<filename_h264_1080p_30fps.mp4> ! qtdemux ! \
  h264parse ! omxh264dec ! comp. filesrc \
  location=< filename_h265_1080p_30fps.mp4> ! qtdemux ! h265parse !
\
  omxh265dec ! comp. filesrc \
  location=< filename_vp8_1080p_30fps.webm> matroskademux ! \
  omxvp8dec ! \
  comp. filesrc location=<filename_vp9_1080p_30fps.webm> ! \
  matroskademux ! omxvp9dec ! comp. -e
```

INTERPOLATION METHODS FOR VIDEO SCALING

The NVIDIA proprietary nvvidconv Gstreamer-1.0 plug-in allows you to choose the interpolation method used for scaling.

The following table shows the supported values for the `nvvidconv interpolation-method` property.

Interpolation Method	Property Value
nearest	0
bilinear	1
5-Tap	2
10-Tap	3
smart (default)	4
Nicest	5

Note

Get information on `nvvidconv interpolation-method` property with the `gst-inspect-1.0 nvvidconv` command.

To use bilinear interpolation method for scaling

- Enter the following command:

```
gst-launch-1.0 filesrc location=<filename_1080p.mp4>! \
  qtdemux name=demux ! h264parse ! omxh264dec ! \
  nvvidconv interpolation-method=1 ! \
  'video/x-raw(memory:NVMM), format=(string)I420, width=1280, \
  height=720' ! nvoverlaysink -e
```

EGLSTREAM PRODUCER EXAMPLE

The NVIDIA-proprietary `nveglstreamsrc` and `nvvideosink` Gstreamer-1.0 plug-ins allow simulation of an EGLStream producer pipeline (for preview only.)

To simulate an EGLStream producer pipeline

- Enter the following command:

```
nvgstcapture-1.0 --camsrc=3 --nvvideosink-create-eglstream
```

EGL IMAGE TRANSFORM EXAMPLE

The NVIDIA proprietary `nvegltransform` Gstreamer-1.0 plug-in allows simulation of an EGLImage transform pipeline.

To simulate an EGL Image transform pipeline

- Enter the following command:

```
gst-launch-1.0 filesrc location=<filename_h264_1080p.mp4> ! \
  qtdemux ! h264parse ! omxh264dec ! nvvidconv ! \
  'video/x-raw(memory:NVMM), width=(int)1280, height=(int)720, \
  format=(string)NV12' ! nvegltransform ! nveglglessink -e
```


GSTREAMER BUILD INSTRUCTIONS

This release contains the `gst-install` script to install a specific GStreamer version. This section provides a procedure for building current versions of GStreamer.

To build GStreamer using `gst-install`

1. Execute the following command:

```
gst-install [--prefix=<install_path>] [--version=<version>]
```

Where `<install_path>` is the location where you are installing GStreamer and `<version>` is the GStreamer version. For example:

```
gst-install --prefix=/home/ubuntu/gst-1.12.4 --version=1.12.4
```

2. Export environment variables with the following command:

```
export LD_LIBRARY_PATH=<install_path>/lib/aarch64-linux-gnu
export PATH=<install_path>/bin:$PATH
```

Where `<install_path>` is the location where you are installing GStreamer. For example:

```
export LD_LIBRARY_PATH=/home/ubuntu/gst-1.12.4/lib/aarch64-linux-gnu
export PATH=/home/ubuntu/gst-1.12.4/bin:$PATH
```

To build GStreamer manually

1. Download the latest version of gstreamer available at:

<http://gstreamer.freedesktop.org/src/>

The following are the files you need from version 1.12.4:

- gstreamer-1.12.4.tar.xz
- gst-plugins-base-1.12.4.tar.xz
- gst-plugins-good-1.12.4.tar.xz
- gst-plugins-bad-1.12.4.tar.xz
- gst-plugins-ugly-1.12.4.tar.xz

2. Install needed packages with the following command:

```
sudo apt-get install build-essential dpkg-dev flex bison \
    autotools-dev automake liborc-dev autopoint libtool \
    gtk-doc-tools libgstreamer1.0-dev
```

3. In the ~/ directory, create a gst_<version> directory, where <version> is the version number of gstreamer you are building.
4. Copy the downloaded tar.xz files to the gst_<version> directory.
5. Uncompress the tar.xz files in the gst_<version> directory.
6. Set the PKG_CONFIG_PATH with the following command:

```
export PKG_CONFIG_PATH=/home/ubuntu/gst_1.12.4/out/lib/pkgconfig
```

7. Build gstreamer (in this example, gstreamer-1.12.4) with the following commands:

```
./configure --prefix=/home/ubuntu/gst_1.12.4/out
make
make install
```

8. Build gst-plugins-base-1.12.4 with the following commands:

```
sudo apt-get install libxv-dev libasound2-dev libtheora-dev \
    libogg-dev libvorbis-dev
./configure --prefix=/home/ubuntu/gst_1.12.4/out
make
make install
```

9. Build gst-plugins-good-1.12.4 with the following commands:

```
sudo apt-get install libbz2-dev libv4l-dev libvpx-dev \
    libjack-jackd2-dev libsoup2.4-dev libpulse-dev
./configure --prefix=/home/ubuntu/gst_1.12.4/out
make
make install
```

10. Obtain and build `gst-plugins-bad-1.12.4` with the following commands:

```
sudo apt-get install faad libfaad-dev libfaac-dev
./configure --prefix=/home/ubuntu/gst_1.12.4/out
make
make install
```

11. Obtain and build `gst-plugins-ugly-1.12.4` with the following commands:

```
sudo apt-get install libx264-dev libmad0-dev
./configure --prefix=/home/ubuntu/gst_1.12.4/out
make
make install
```

12. Set the `LD_LIBRARY_PATH` environment variable with the following command:

```
export LD_LIBRARY_PATH=/home/ubuntu/gst_1.12.4/out/lib/
```

13. Copy the `nvidia gstreamer-1.0` libraries to the `gst_1.12.4` plugin directory using the following command:

```
cd /usr/lib/aarch64-linux-gnu/gstreamer-1.0/
cp libgstnv* libnvgst* libgstomx.so \
  ~/gst_1.12.4/out/lib/gstreamer-1.0/
```

The `nvidia gstreamer-1.0` libraries include:

```
libgstnvcamera.so
libgstnveglglessink.so
libgstnveglstreamsrc.so
libgstnvegltransform.so
libgstnvivafilter.so
libgstnvvidconv.so
libgstnvvideosink.so
libnvgstjpeg.so
libgstomx.so
```

NVGSTCAPTURE-1.0 OPTION REFERENCE

This section describes the options available in the `nvgstcapture-1.0` application.

Note: `nvgstcapture-1.0` application default supports ARGUS API using `nvarguscamerasrc` plugin.

NVGSTCAPTURE APPLICATION OPTIONS

Note: Use “`nvgstcapture-1.0 --help`” to list supported options for `Nvarguscamera`

`Nvgstcapture-1.0` command-line options for `Nvarguscamera` are described in the following table.

Application Options		
Option	Description	Notes
<code>--prev_res</code>	Preview width and height, Range: 2 to 12 (5632x4224), e.g., <code>--prev_res=3</code>	-
<code>--cus-prev-res</code>	Custom preview width and height for CSI only, e.g., <code>--cus-prev-res=1920x1080</code>	-
<code>--image_res</code>	Image width and height, Range: 2 to 12 (5632x4224), e.g., <code>--image_res=3</code>	-
<code>--video-res</code>	Video width and height. Range: 2 to 9 (3896x2192) e.g., <code>--video-res=3</code>	-

--csi-source	CSI Camera Plugin	0=NVArgusCamera 1=NVCamera
-m, --mode	Capture mode.	1-Still 2-Video
-v, --video_enc	Video encoder type.	0-H.264 (hardware) 1-VP8(hardware) 2-MPEG-4 (software) 3-H.263 (software)
-b, --enc-bitrate	Video encoding Bit-rate (in bytes)	Example: --enc-bitrate=4000000
--enc-profile	Video encoder profile (only for H.264)	0-Baseline 1-Main 2-High
-j, --image_enc	Image encoder type.	0-jpeg_SW[jpegenc] 1-jpeg_HW[nvjpegenc]
-k, --file_type	Container file type.	0-MP4 1-3GP 2-AVI
--file-name	Captured file name. nvcamtest is used by default	-
--orientation	Camera sensor orientation value	-
-w, --whitebalance	Capture whitebalance value.	-
--timeout	Capture timeout value	-
--saturation	Camera saturation value.	-
Help Options		
Option	Description	Notes
-h, --help	Show help options.	-
--help-all	Show all help options.	-
--help-gst	Show Gstreamer options.	-
--help-nvcamerasrc	Show nvcamerasrc Options	-

CSI CAMERA SUPPORTED RESOLUTIONS

CSI camera supports the following image resolutions for both Nvarguscamera and Nvcamera:

- ▶ 640x480
- ▶ 1280x720
- ▶ 1920x1080
- ▶ 2104x1560
- ▶ 2592x1944
- ▶ 2616x1472
- ▶ 3840x2160
- ▶ 3896x2192
- ▶ 4208x3120
- ▶ 5632x3168
- ▶ 5632x4224

NVCAMERA APPLICATION OPTIONS

Note: Use “nvgstcapture-1.0 --help-nvcamerasrc” to list supported options for Nvcamera

Nvgstcapture-1.0 command-line options for Nvcamera are described in the following table.

Application Options		
Option	Description	Notes
--prev_res	Preview area width and height, Range: 2 to 12 (5632x4224) e.g., --prev_res=3	-
--cus-prev-res	Custom preview width and height for CSI only, e.g., --cus-prev-res=1920x1080	-
--image_res	Image width and height, Range: 2 to 12 (5632x4224) e.g., --image_res=3	-
--video_res	Video width and height, Range: 2 to 9 (3896x2192) e.g., --video_res=3	-
-m, --mode	Capture mode.	1-Still 2-Video

--color-format	Color format type	0-I420[default for V4L2] 1-NV12[For CSI only] 2-YUY2[For V4L2 only]
-v, --video_enc	Video encoder type.	0-H.264 (hardware) 1-VP8(hardware) 2-MPEG-4 (software) 3-H.263 (software)
-b, --enc-bitrate	Video encoding Bit-rate (in bytes)	Example: --enc-bitrate=4000000
--enc-profile	Video encoder profile (only for H.264)	0-Baseline 1-Main 2-High
-j, --image_enc	Image encoder type.	0-jpeg_SW[jpegenc] 1-jpeg_HW[nvjpegenc]
-k, --file_type	Container file type.	0-MP4 1-3GP 2-AVI
--cap-dev-node	Video capture device node.	0=/dev/video0[default] 1=/dev/video1 2=/dev/video2
--svs	Chain for video preview.	-
--file-name	File name for capture.	"nvcamtest" is used by default.
--camsrc	Camera source.	0-v4l2 1-csi (default) 2-videotest 3-eglstream
--nvvideosink-create-eglstream	Enable nvvideosink EGLStream Producer(nvvideosink EGLStream Producer only)	-
--aeLock	Enable auto exposure lock(CSI only)	-
--orientation	Camera sensor orientation value(CSI only)	-
-w, --whitebalance	White balance value for capture. (CSI only)	-

<code>--s, --scene-mode</code>	Camera scene-mode value. (CSI only)	-
<code>--c, --color-effect</code>	Camera color effect value. (CSI only)	-
<code>--auto-exposure</code>	Camera auto-exposure value. (CSI only)	-
<code>--flash</code>	Camera flash value. (CSI only)	-
<code>--flicker</code>	Camera flicker detection and avoidance mode value. (CSI only)	-
<code>--contrast</code>	Camera contrast value. (CSI only)	-
<code>--saturation</code>	Camera saturation value. (CSI only)	-
<code>--edge-enhancement</code>	Camera edge enhancement value. (CSI only)	-
<code>--tnr_strength</code>	Camera TNR strength value. (CSI only)	-
<code>--tnr_mode</code>	Camera TNR mode value. (CSI only)	-
<code>--sensor-id</code>	Camera Sensor ID value. (CSI only)	-
<code>--display-id</code>	Display ID value (for nvoverlaysink only)	-
<code>--eglstream-id</code>	Select EGLStreamProducerID value (for CSI EGLStream). Default is 0.	-
<code>--aeRegion</code>	ROI for AE coordinates (top, left, bottom, right) and weight, in that order. (CSI only)	Example: <code>--aeRegion="30 40 200 200 1.2"</code>
<code>--wbRegion</code>	ROI for AWB coordinates (top, left, bottom, right) and weight in that order. (CSI only)	Example: <code>--wbRegion="30 40 200 200 1.2"</code>
<code>--fpsRange</code>	FPS range values (low, high) (CSI only)	Example: <code>--fpsRange="15 30"</code>

--wbGains	White Balance (WB) gains values (R, GR, GB, B) in that order. (CSI only)	Example: --wbGains="1.2 1.4 0.8 1.6"
--overlayConfig	Overlay Configuration Options index and coordinates in (index, x_pos, y_pos, width, height) order.	Example: --overlayConfig="0, 0, 0, 1280, 720"
--enable-meta	Enables Sensor MetaData reporting if the sensor has the capability to provide the embedded metadata.	-
--eglConfig	EGL window Coordinates (x_pos y_pos) in that order.	Example: --eglConfig="50 100"
--enable-exif	Enable Exif data	-
--dump-bayer	Dump bayer data in addition to image capture	-
--exposure-time	Capture exposure time value. (CSI only)	Example: --exposure-time=0.033
Help Options		
Option	Description	Notes
-h, --help	Show help options.	-
--help-all	Show all help options.	-
--help-gst	Show Gstreamer options.	-
--help-nvcamerasrc	Show nvcamerasrc Options	-

CSI CAMERA RUNTIME COMMANDS

Options for Nvarguscamera

CSI camera runtime commands options for Nvarguscamera are described in the following table.

Command	Description	Notes
h	Help	-

q	Quit	-
mo:<value>	Set capture mode	1-image 2-video
gmo	Get capture mode	-
so:<val>	Set sensor orientation	0-none 1-Rotate counter-clockwise 90 degrees 2-Rotate 180 degrees 3-Rotate clockwise 90 degrees
gso	Get sensor orientation	-
wb:<value>	Set white balance mode	0-off 1-auto 2-incandescent 3-fluorescent 4-warm-fluorescent 5-daylight 6-cloudy-daylight 7-twilight 8-shade 9-manual
gwb	Get white balance mode	-
st:<value>	Set saturation	0-2, e.g., st:1.25
gst	Get saturation	-
j	Capture one image.	-
jx<delay>	Capture after a delay of <delay>, e.g., jx5000 to capture after a 5-second delay	-
j:<value>	Capture <count> number of images in succession, e.g., j:6 to capture 6 images.	-
0	Stop recording video	-
1	Start recording video	-
2	Video snapshot (while recording video)	-

gpcr	Get preview resolution	-
gicr	Get image capture resolution	-
gvcr	Get video capture resolution	-

Options for Nvcamera

CSI camera runtime commands options for Nvcamera are described in the following table.

Command	Description	Notes
h	Help	-
q	Quit	-
mo:<value>	Set capture mode	1-image 2-video
gmo	Get capture mode	-
sid:<value>	Set sensor ID	-
gsid	Get sensor ID	-
so:<val>	Set sensor orientation	0-none 1-Rotate counter-clockwise 90 degrees 2-Rotate 180 degrees 3-Rotate clockwise 90 degrees
gso	Get sensor orientation	-
wb:<value>	Set white balance mode	0-off 1-auto 2-incandescent 3-fluorescent 4-warm-fluorescent 5-daylight 6-cloudy-daylight 7-twilight 8-shade
gwb	Get white balance mode	-

scm:<value>	Set scene mode	0-face-priority 1-action 2-portrait 3-landscape 4-night 5-night-portrait 6-theatre 7-beach 8-snow 9-sunset 10-steady-photo 11-fireworks 12-sports 13-party 14-candle-light 15-barcode
gscm	Get scene mode	-
ce:<value>	Set color effect mode	1-off 2-mono 3-negative 4-solarize 5-sepia 6-posterize 7-aqua
gce	Get color effect mode	-
ae:<value>	Set auto-exposure mode	1-off 2-on 3-OnAutoFlash 4-OnAlwaysFlash 5-OnFlashRedEye
gae	Get auto exposure mode	-
ael	Set auto-exposure lock	0-unlock 1-lock
gael	Get auto-exposure lock	-
f:<value>	Set flash mode	0-off 1-on 2-torch 3-auto
gf	Get flash mode	-

fl:<value>	Set flicker detection and avoidance mode	0-off 1-50 Hz 2-60 Hz 3-auto
gfl	Get flicker detection and avoidance mode	-
ct:<value>	Set contrast	0-1, e.g., ct:0.75
gct	Get contrast	-
st:<value>	Set saturation	0-2, e.g., st:1.25
gst	Get saturation	-
ext:<value>	Set exposure time (in seconds)	e.g., ext:0.033
gext	Get exposure time	-
ee:<value>	Set edge enhancement	0-1, e.g., ee:0.75
gee	Get edge enhancement	-
aer:<value>	Set ROI coordinates for AE (top, left, bottom, right) and weight	e.g., aer:20 20 400 400 1.2
gaer	Get ROI for AE	-
wbr:<value>	Set ROI coordinates for AWB (top, left, bottom, right) and weight	e.g., wbr:20 20 400 400 1.2
gwbr	Get ROI for AE	-
fpsr:<value>	Set FPS range (low, high)	e.g., fpsr:15 30
gfpsr	Get FPS range	-
wbg:<value>	Set WB gains (R, GR, GB, B)	e.g., wbg:1.2 2.2 0.8 1.6
gwbg	Get WB gains	-
ts:<value>	Set TNR strength	0-1, e.g., ts:0.75
gts	Get TNR strength	-

tnr:<value>	Set TNR mode	0-Original 1-Outdoor-low-light 2-Outdoor-medium-light 3-Outdoor-high-light 4-Indoor-low-light 5-Indoor-medium-light 6-Indoor-high-light
gtnr	Get TNR mode	-
j	Capture one image.	-
jx<delay>	Capture after a delay of <delay>, e.g., jx5000 to capture after a 5-second delay	-
j:<value>	Capture <count> number of images in succession, e.g., j:6 to capture 6 images.	-
0	Stop recording video	-
1	Start recording video	-
2	Video snapshot (while recording video)	-
pcr	Set preview resolution	pcr:<0..11>
gpcr	Get preview resolution	-
icr	Set image capture resolution	icr:<0..12>
gicr	Get image capture resolution	-
vcr	Set video capture resolution	vcr:<0..9>
gvcr	Get video capture resolution	-

USB CAMERA RUNTIME COMMANDS

USB Camera Runtime Commands

USB camera runtime commands are described in the following table.

Command	Description	Notes
h	Help	-
q	Quit	-
mo:<value>	Set capture mode	1-image 2-video
gmo	Get capture mode	-
j	Capture one image.	-
jx<delay>	Capture after a delay of <delay>, e.g., jx5000 to capture after a 5-second delay	-
j:<value>	Capture <count> number of images in succession, e.g., j:6 to capture 6 images.	-
1	Start recording video	-
0	Stop recording video	-
pcr:<value>	Set preview resolution	0-176x144 1-320x240 2-640x480 3-1280x720
gpcr	Get preview resolution	-
gicr	Get image capture resolution	-
gvcr	Get video capture resolution	-
br:<value>	Set encoding bit rate (in bytes)	e.g., br:4000000
gbr	Get encoding bit rate	-
cdn:<value>	Set capture device node	0-/dev/video0 1-/dev/video1 2-/dev/video2
gcdn	Get capture device node	-

Runtime Video Encoder Configuration Options

The following table describes runtime video encoder configuration options supported for Nvarguscamera and Nvcamera.

Command	Description	Notes
br:<val>	Sets encoding bit-rate (in bytes)	Example: br:4000000
gbr	Gets encoding bit-rate (in bytes)	-
ep:<val>	Sets encoding profile (for H.264 only)	Example: ep:1 (0): Baseline (1): Main (2): High
gep	Gets encoding profile (for H.264 only)	-
Enter 'f'	Forces IDR frame on video encoder (for H.264 only)	-

NOTES

- ▶ The nvgstcapture-1.0 application generates image and video output files in the same directory as the application itself.
- ▶ Filenames for image and video content are in the formats, respectively:
 - nvcamtest_<pid>_<sensor_id>_<counter>.jpg
 - nvcamtest_<pid>_<sensor_id>_<counter>.mp4

Where:

- <pid> is the process ID.
- <sensor_id> is the sensor ID.
- <counter> is a counter starting from 0 every time you run the application.

Rename or move files between runs to avoid overwriting results you want to save.

- ▶ Default H.263 encode resolution is 704x576(4CIF) in AVI container formats. Use --camsrc=2 for H.263 video encode.
- ▶ The nvgstcapture-1.0 application supports native capture(video only) mode by default.
- ▶ Advance features, like setting zoom, brightness, exposure, and whitebalance levels, are not supported for USB camera.

VIDEO ENCODER FEATURES

The Gstreamer-1.0-based gst-omx video encoders support the following features, respectively:

Video Encoder Feature	H264enc	H265enc	Vp8enc	Vp9enc
profile (Baseline / Main / High)	✓ (all)	✓ (Main)	✓	✓
level	✓	✓	-	-
bitrate	✓	✓	✓	✓
peak bitrate	✓	✓	-	-
stringent bitrate	✓	✓	-	-
insert-spsppsatidr	✓	✓	✓	✓
control-rate	✓	✓	✓	✓
iframeinterval	✓	✓	✓	✓
qp-range	✓	✓	✓	✓
temporal-tradeoff	✓	✓	✓	✓
bit-packetization	✓	✓	✓	✓
preset-level	✓	✓	✓	✓
low-latency	✓	✓	✓	✓
slice-header spacing	✓	✓	-	-
force-IDR	✓	✓	✓	✓

vbv-size	✓	✓	✓	✓
sliceintrarefreshenable	✓	✓	-	-
sliceintrarefreshinterval	✓	✓	-	-
EnableTwoPassCBR	✓	✓	✓	✓
num-B-Frames	✓	-	-	-

SUPPORTED CAMERAS

This section describes the supported cameras.

CSI CAMERAS

- ▶ Jetson TX1 and Jetson TX2 currently support 2 CSI RAW BAYER sensors.
- ▶ The platform has been validated with a single OV5693 sensor and a single IMX185 for capture on L4T.
- ▶ The camera module is interfaced with the Tegra platform via MIPI-CSI.
- ▶ Tested using the nvgstcapture application.

USB 2.0 CAMERAS

The following cameras have been validated on Tegra platforms for Android and L4T with USB 2.0 ports. These cameras are UVC compliant.

- ▶ Logitech c920 (preferred)
<http://www.logitech.com/en-in/product/hd-pro-webcam-c920>
- ▶ Logitech c910
<http://www.amazon.com/Logitech-HD-Pro-Webcam-C910/dp/B003M2YT96>
- ▶ Rocketfish™ HD Webcam Pro
<http://www.rocketfishproducts.com/products/computer-accessories/RF-HDWEB10.html?supportTab=open>
- ▶ Creative Live! Cam Socialize HD 1080
<http://support.creative.com/Products/ProductDetails.aspx?catID=218&CatName=Web+Cameras&subCatID=231&subCatName=MIDI+Keyboards&prodID=20165&prodN>

[ame=Live!+Cam+Socialize+HD+1080&bTopTwenty=1&VARSET=prodfaq:PRODFAQ20165,VARSET=CategoryID:218](http://www.e-consystems.com/UltraHD-USB-Camera.asp?ame=Live!+Cam+Socialize+HD+1080&bTopTwenty=1&VARSET=prodfaq:PRODFAQ20165,VARSET=CategoryID:218)

INDUSTRIAL CAMERA DETAILS

The following USB 3.0 Industrial cameras are supported on Jetson-TX1 under L4T:

► See3CAM_CU130

<http://www.e-consystems.com/UltraHD-USB-Camera.asp>

- USB 3.0
- UVC compliant
- 3840 x 2160 at 30 FPS | 4224 x 3156 at 13 FPS
- Purpose - Embedded Navigation
- Test using the `nvgstcapture` app.
- Issues encountered:
 - FPS cannot be fixed. Changes based on exposure.
 - FPS cannot be changed. Needs payment to vendor to get the support added to their firmware.

► MQ003CG-CM

<http://www.ximea.com/en/products/usb3-vision-cameras-xiq-line/mq003cg-cm>

- USB 3.0
- Non-UVC compliant
- 640 x 480 at 500 FPS
- Purpose - Embedded Robotics
- Installation and Verification on Jetson TX1:

1. Add the user to the plugdev group:

```
sudo gpasswd -a ubuntu plugdev
```

Re-login.

2. Install tools for the application:

```
apt-get install libgstreamer0.10-dev libgstreamer-plugins-base0.10-dev libgtk2.0-dev g++
```

3. Download XIMEA Linux Software Package:

```
wget http://www.ximea.com/downloads/recent/XIMEA_Linux_SP.tgz
```

Untar:

```
tar xzf XIMEA_Linux_SP.tgz
cd package
```

4. Open the install file and replace

```
elif [ "${arch:0:3}" == "arm" ]
    with
```

```
elif [ "$arch" == "aarch64" ]
```

5. Start installation:

```
./install
```

Install USB3 camera:

```
./install -cam_usb30
```

Install graphical desktop:

```
sudo apt-get update
sudo apt-get install ubuntu-desktop
```

6. Reboot. The system boots to the graphical desktop.

7. To access sample applications:

- xiSample: run from /package/bin folder
- streamViewer
 - make from /package/examples/streamViewer folder
 - run from the /package/bin folder

Notice

ALL NVIDIA DESIGN SPECIFICATIONS, REFERENCE BOARDS, FILES, DRAWINGS, DIAGNOSTICS, LISTS, AND OTHER DOCUMENTS (TOGETHER AND SEPARATELY, "MATERIALS") ARE BEING PROVIDED "AS IS." NVIDIA MAKES NO WARRANTIES, EXPRESS, IMPLIED, STATUTORY, OR OTHERWISE WITH RESPECT TO THE MATERIALS, AND ALL EXPRESS OR IMPLIED CONDITIONS, REPRESENTATIONS AND WARRANTIES, INCLUDING ANY IMPLIED WARRANTY OR CONDITION OF TITLE, MERCHANTABILITY, SATISFACTORY QUALITY, FITNESS FOR A PARTICULAR PURPOSE AND NON-INFRINGEMENT, ARE HEREBY EXCLUDED TO THE MAXIMUM EXTENT PERMITTED BY LAW.

Information furnished is believed to be accurate and reliable. However, NVIDIA Corporation assumes no responsibility for the consequences of use of such information or for any infringement of patents or other rights of third parties that may result from its use. No license is granted by implication or otherwise under any patent or patent rights of NVIDIA Corporation. Specifications mentioned in this publication are subject to change without notice. This publication supersedes and replaces all information previously supplied. NVIDIA Corporation products are not authorized for use as critical components in life support devices or systems without express written approval of NVIDIA Corporation.

Trademarks

NVIDIA, the NVIDIA logo, CUDA, Jetson, and Tegra are trademarks 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

© 2015 - 2018 NVIDIA Corporation. All rights reserved.