



Release 440 Studio Driver for Windows, Version 441.28

Windows 10

Release Notes



Table of Contents

1 Introduction to Release Notes.....	1
Structure of the Document	1
Changes in this Edition	1
2 Release 440 Studio Driver Changes.....	2
Version 441.28 WHQL Highlights.....	3
Existing Support	3
Software Module Versions	3
What's New in the NVIDIA Studio Driver Version 441.28 WHQL	4
What's New in Release 440	5
Discontinued Support	7
Limitations in This Release	7
Advanced Driver Information	10
Driver Security.....	14
Restricting/Enabling Access to GPU Performance Counters	14
Changes and Fixed Issues in Studio Driver Version 441.28.....	15
Fixed Issues in this Release	15
Open Issues in Version 441.28 WHQL.....	16
Windows 10 Issues	16
Issues Not Caused by NVIDIA Drivers	17
Windows 10 Considerations.....	17
Operating System Issues	17
Application Issues	17
Known Product Limitations	18
Windowed NVIDIA G-SYNC is Disabled During Video Playback on a Multi-monitor System	19
GPU Temperature Reported Incorrectly on Optimus Systems.....	19
Damaged or Missing WMI Service Prevents NVIDIA Driver Installation	20
Total Available Graphics Memory Reported Incorrectly	20
Increasing 4-way SLI/Multi-GPU Performance	21
No PhysX Acceleration Using the GPU.....	22
NVIDIA PhysX System Software Cannot Be Installed or Uninstalled in Windows Safe Mode	22
Do Not Use Windows Rollback for Graphics Drivers.....	22
Uninstalling Drivers Using Device Manager is Not Supported	22
Changing Primary Display Across SLI GPUs Slower Than Expected	23
Using HDMI Audio with Displays That Have a High Native Resolution	23
Using HDMI/DisplayPort Audio in Dualview or Clone Mode.....	24

Table of Contents

Flat Panel Scaling Controls Not Functional for Some TV Modes in Some Displays	24
GPU Runs at a High Performance Level (full clock speeds) in Multi-display Modes	25
1280 × 1024 @ 60 Hz Not Available on BenQ FP241W Monitors	25
3 The Release 440 Studio Driver	26
About the Release 440 Studio Driver	26
Hardware and Software Support	26
Supported Operating Systems	27
Support for OpenCL 1.2	27
Supported NVIDIA Desktop Products	27
Supported NVIDIA Notebook Products	28
Supported NVIDIA Quadro & NVS Product	29
Supported NVIDIA Quadro Sync II	30
Supported NVIDIA Quadro Sync Products	30
Supported NVIDIA Quadro Blade/Embedded Graphics Board	30
Supported NVIDIA Quadro Notebook GPUs	32
Supported Languages	33
Driver Installation	33
Minimum Hard Disk Space	33
Before You Begin	33
Installation Instructions	34

List of Tables

Table 3.1 Supported NVIDIA Desktop GPUs.....	27
Table 3.2 Supported NVIDIA Notebook GPUs	28
Table 3.3 Supported NVIDIA Quadro & NVS Products	29
Table 3.4 Supported NVIDIA Quadro Sync II Products	30
Table 3.5 Supported NVIDIA Quadro Sync Products	30
Table 3.6 Supported NVIDIA Quadro Blade/Embedded Graphics Board Series.....	30
Table 3.7 NVIDIA Quadro Notebook GPU Support	32

Chapter 1. Introduction to Release Notes

This edition of *Release Notes* describes the Release 440 family of NVIDIA® graphics drivers (versions 440.xx to 444.xx) for Microsoft® Windows® 10. NVIDIA provides these notes to describe performance improvements and bug fixes in each documented version of the driver.

Structure of the Document

This document is organized in the following sections:

- ▶ [“Release 440 Studio Driver Changes” on page 2](#) gives a summary of changes, and fixed and open issues in this version.
- ▶ [“The Release 440 Studio Driver” on page 26](#) describes the NVIDIA products and languages supported by this driver, the system requirements, and how to install the driver.

Changes in this Edition

This edition of the *Release Notes* for Windows includes information about NVIDIA graphics driver version 441.28 WHQL and lists changes made to the driver since driver version 431.86.

These changes are discussed beginning with the chapter [“Release 440 Studio Driver Changes” on page 2](#).

Chapter 2. Release 440 Studio Driver Changes

This chapter describes open issues for version 441.28 WHQL, and resolved issues and driver enhancements for versions of the Release 440 driver up to version 441.28 WHQL

The chapter contains these sections:

- ▶ “Version 441.28 WHQL Highlights” on page 3
- ▶ “Changes and Fixed Issues in Studio Driver Version 441.28” on page 15
- ▶ “Driver Security” on page 14
- ▶ “Open Issues in Version 441.28 WHQL” on page 16
- ▶ “Issues Not Caused by NVIDIA Drivers” on page 17
- ▶ “Known Product Limitations” on page 18

Version 441.28 WHQL Highlights

This section provides highlights of version 441.28 WHQL of the NVIDIA Release 440 Driver for Windows 10¹.

- ▶ [What's New in the NVIDIA Studio Driver Version 441.28 WHQL](#)
- ▶ [What's New in Release 440](#)
- ▶ [Limitations in This Release](#)
- ▶ [Advanced Driver Information](#)

Existing Support

This release supports the following APIs:

- ▶ Open Computing Language (OpenCL™ software) 1.2 for NVIDIA® Kepler™ and later GPUs
- ▶ OpenGL® 4.6
- ▶ Vulkan® 1.1
- ▶ DirectX 11
- ▶ DirectX 12

Software Module Versions

- ▶ nView - 149.77
- ▶ HD Audio Driver - 1.3.38.21
- ▶ NVIDIA PhysX System Software - 9.19.0218
- ▶ GeForce Experience - 3.20.1.57
- ▶ CUDA - 10.2
- ▶ Standard NVIDIA Control Panel - 8.1.940.0
- ▶ DCH NVIDIA Control Panel - 8.1.956.0

1. Includes support for Windows 10 May 2019 Update (Version 1903) (19H1)

What's New in the NVIDIA Studio Driver Version 441.28 WHQL

NVIDIA Studio Drivers provide artists, creators and 3D developers the best performance and reliability when working with creative applications. To achieve the highest level of reliability, Studio Drivers undergo extensive testing against multi-app creator workflows and multiple revisions of the top creative applications from Adobe to Autodesk and beyond.

Applications

Provides optimal support for the upcoming releases of top renderers including Chaos Group's [V-Ray GPU Next](#) and [Blender 2.81](#) which support RTX-accelerated ray tracing.

Application SLI Profiles

Added or updated the following SLI profiles:

- Star Wars Jedi: Fallen Order

Other

- ▶ Added support for CUDA 10.2.
- ▶ See also “What's New in Release 440” on page 5 and “Changes and Fixed Issues in Studio Driver Version 441.28” on page 15.

What's New in Release 440

This section summarizes the driver changes previously introduced in the Release 440 Studio Driver.

Hardware

- ▶ Added support for the following GPUs:
 - GeForce GTX 1660 SUPER
- ▶ Adds support for the HTC VIVE Cosmos VR HMD.

New Features

- ▶ Version 441.12 introduced security updates for driver components.
See the [NVIDIA Security Bulletin 4907](#) for details (bulletin content will be available after 11/06/19).

See also the section “[Driver Security](#)” on page 14 for actions to take to mitigate vulnerabilities.
- ▶ Added **Image Sharpening** control to the *NVIDIA Control Panel->Manage 3D Settings* page.
Increases the level of sharpness, detail, or clarity of images in games and applications.
Note: As with all 3D settings in the NVIDIA Control Panel, you can enable Image Sharpening globally, or [selectively enable/disable per game as needed](#) (using the Program Settings tab).
- ▶ Added Ultra Low Latency G-SYNC+ V-Sync feature
Provides tear-free, low-latency gaming using G-SYNC displays. To enable, set Low Latency Mode to Ultra, turn on V-Sync, and enable the G-SYNC display.
- ▶ Added support for windowed G-SYNC for OpenGL and Vulkan-based applications.
- ▶ Added support for HDMI 2.1 VRR.
- ▶ Fixed flashes or frame drops in several Notebook models when running G-SYNC in the lower of the two system refresh rates.
- ▶ Adds support for new [G-SYNC compatible](#) monitors.
- ▶ Added Beta support for GPU Integer Scaling
New control in the NVIDIA Control Panel->Display->Adjust desktop size and position page. Supported on NVIDIA Turing GPUs and later; Windows 10 April 2018 Update and later.

Integer scaling is a new GPU scaling method which scales smaller-than-native-resolution-size source content by duplicating the pixels at the maximum possible integer factor on the horizontal and vertical directions.
- ▶ Added Beta support for Ultra-Low Latency Mode
New control in the NVIDIA Control Panel->3D->Manage 3D Settings page.

Offers improved latency for DirectX games. Currently not supported under SLI mode, DirectX 12, or on Microsoft Hybrid notebooks.

- ▶ Updated the NVIDIA Control Panel->3D Settings->Texture Filtering-Quality control to default to “High Quality” for Quadro products.
- ▶ Added support for new Freestyle Sharpen Filter
Released as an update to NVCamera (for Freestyle and Ansel).
- ▶ Added GPU paravirtualization support for Microsoft Hybrid notebooks.
- ▶ Added support for 30-bit color.
- ▶ Added driver support for Video Codec SDK 9.1
 - Added a new NVENC API to more detailed error reporting.
 - Added support for CUSTream in NVENC API to facilitate parallel execution of pre-/post-processing of video on CUDA and encoder tasks.
 - Implemented bug-fixes and API enhancement to support H.264 MVC encoding.

Visit <https://developer.nvidia.com/nvidia-video-codec-sdk> for more information about the SDK.

- ▶ Added driver support for Optical Flow SDK 1.1
 - Added new algorithms to improve the quality of flow vectors for “SLOW” preset, especially for flat regions.
 - Added a new API to retrieve the highest Optical Flow SDK version supported by the underlying driver.

Visit <https://developer.nvidia.com/opticalflow-sdk> for more information about the SDK.

- ▶ Added ability to update the NVIDIA VirtualLink PPC firmware from the NVIDIA Control Panel
See the section “[Updating the NVIDIA VirtualLink PPC Firmware](#)” on page 8 for update instructions and a list of changes in the latest firmware version.

Application Profiles

- ▶ Added or updated the following performance profiles:
 - Borderlands 3
 - Red Dead Redemption 2
- ▶ Added or updated the following SLI profiles:
 - BattleTech
 - Close to the Sun
 - Dakar18
 - Darwin Project
 - Deep Rock Galactic
 - Fe
 - Fear the Night

- Heavy Rain
- Nelo
- Overkill's The Walking Dead
- PC Building Simulator
- Remnant: From the Ashes
- Starlink: Battle for Atlas
- The Outer Worlds (NVIDIA Turing GPUs only)
- Warhammer: Chaosbane

Discontinued Support

► Quadro SDI Products

Beginning with Release 440, the NVIDIA Professional Drivers for Windows no longer supports the following Quadro SDI products:

- NVIDIA Quadro SDI Output Card (all versions)
- NVIDIA Quadro SDI Capture Card

► 3D Vision

Beginning with Release 430, the NVIDIA driver no longer supports the following 3D Vision technologies and features:

- NVIDIA 3D Stereoscopic Driver, including the 3D Vision driver and USB (emitter) driver
- NVAPI-based stereo APIs for Direct3D applications.

► NVIDIA Kepler GPUs for Notebooks

Beginning with Release 430, the NVIDIA driver no longer supports NVIDIA GPUs for notebooks based on the Kepler architecture.

► 32-bit Operating Systems

Beginning with Release 396, NVIDIA is no longer releasing Game Ready drivers for 32-bit operating systems for any GPU architecture.

Limitations in This Release

The following features are not currently supported or have limited support in this driver release:

Image Sharpening Feature

NVIDIA Control Panel Image sharpening controls, including GPU upscaling, are introduced in the R440 driver. Currently, the following limitations apply.

- Scaling is not supported on MSHybrid systems.

- ▶ Vulkan / OpenGL applications are currently not supported for sharpening
- ▶ HDR displays driven by pre-Turing GPUs will not support scaling
- ▶ Scaling will not work with VR
- ▶ Scaling will not work with displays using YUV420 format.
- ▶ Scaling uses aspect ration scaling and will not use integer scaling
- ▶ Sharpening will not work with HDR displays
- ▶ GPU scaling engages when games are played only in full-screen mode, and not in windowed or borderless windowed mode.
- ▶ Some monitors, such as R2 and R3 monitors, have a 6-tap/64-phase scaler which scales better than that offered by Turing's 5-tap/32-phase scaler.
- ▶ To avoid accidentally triggering scaling by applications or DWM, first change to the desired (< native) resolution from the NVIDIA Control Panel and then launch the application.
- ▶ Turing's 5-tap upscaler may not engage on certain monitors, based on the monitor's vblank timing.
- ▶ Turing's 5-tap upscaler may not engage if the input resolution is greater than 2560px in either the x or y dimension.
- ▶ Scaling is turned off automatically when switching display devices.
- ▶ "Restore Defaults" option in the control panel currently does not revert the upscaling resolution.

Connecting Displays to NVIDIA Turing GPUs in SLI Mode

To use SLI with NVIDIA Turing GPUs, all displays must be connected to the master GPU.

Behavior Change in `NvEncCreateBitstreamBuffer` API of Video Codec SDK

In the NVIDIA driver, Release 415 and later, the behavior of the Video Codec SDK API (`NvEncCreateBitstreamBuffer`) has been changed to return `NV_ENC_ERR_UNIMPLEMENTED` instead of `NV_ENC_SUCCESS` when the encoder instance is configured to run in the motion estimation-only mode. As an indirect consequence of this change, the AppEncME sample application from the Video Codec SDK prior to SDK version 8.2.16 will crash due to a bug in the `NvEncoder` class.

The latest version of the SDK fixes this bug that affects the AppEncME sample application. NVIDIA recommends downloading the latest version from <https://developer.nvidia.com/nvidia-video-codec-sdk>.

Turing GPU Driver Installation on Windows 10

Drivers for Turing GPUs will not be installed on systems with Windows 10 RS2 or earlier. This includes Windows 10 Threshold 1, Threshold 2, Redstone 1, and Redstone 2 operating systems.

Crescent Bay and OSVR Headsets on Multiple GPU Systems

With Release 367 and future NVIDIA drivers, Crescent Bay and Open Source Virtual Reality development kit headsets will not work with VRWorks Direct Mode in systems that contain GPUs from multiple vendors (for example, NVIDIA and Intel). For such systems, please disable the Intel integrated graphics (from the system BIOS) in order to use Direct Mode.

Experimental OpenCL 2.0 Features

Select features in OpenCL 2.0 are available in the driver for evaluation purposes only. The following are the features as well as a description of known issues with these features in the driver:

► Device side enqueue

- The current implementation is limited to 64-bit platforms only.
- OpenCL 2.0 allows kernels to be enqueued with `global_work_size` larger than the compute capability of the NVIDIA GPU. The current implementation supports only combinations of `global_work_size` and `local_work_size` that are within the compute capability of the NVIDIA GPU.

The maximum supported CUDA grid and block size of NVIDIA GPUs is available at <http://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html#compute-capabilities>. For a given grid dimension, the `global_work_size` can be determined by CUDA grid size x CUDA block size.

- For executing kernels (whether from the host or the device), OpenCL 2.0 supports non-uniform ND-ranges where `global_work_size` does not need to be divisible by the `local_work_size`. This capability is not yet supported in the NVIDIA driver, and therefore not supported for device side kernel enqueues.

► Shared virtual memory

- The current implementation of shared virtual memory is limited to 64-bit platforms only.

Advanced Driver Information

This section contains the following additional information about the driver:

- ▶ [Updating the NVIDIA VirtualLink PPC Firmware](#)
- ▶ [Differing GPU Voltages in SLI Mode](#)
- ▶ [3D Compatibility Mode](#)
- ▶ [Help for Resizing Your HDTV Desktop](#)
- ▶ [Understanding the DirectX Information Shown in the NVIDIA System Information Window](#)

Updating the NVIDIA VirtualLink PPC Firmware

You can update the NVIDIA VirtualLink PPC firmware from the NVIDIA Control Panel by clicking Update from the top menu and then selecting Update VirtualLink firmware.

The following is a description of the changes made in the latest version.

Version 3.2.8 (Notebook)

The following are the changes and fixed issues in the NVIDIA VirtualLink PPC firmware version 3.2.8.

- ▶ [USBC Notebook] [VirtualLink]: Some USB bus-powered type-C monitors won't light up until Windows boots. [2524391]
- ▶ [USBC Notebook] [VirtualLink] Some USB Type-C to HDMI dongles may not work. [200474652]
- ▶ [USBC Notebook] [VirtualLink] USB-C SuperSpeed does not work with Type-C hub which supports multiple (DisplayPort and USB) Alternate Modes. [200482972]

Differing GPU Voltages in SLI Mode

When non-identical GPUs are used in SLI mode, they may run at different voltages. This occurs because the GPU clocks are kept as close as possible, and the clock of the higher performance GPU is limited by that of the other. One benefit is that the higher performance GPU saves power by running at slightly reduced voltages.

An end-user gains nothing by attempting to raise the voltage of the higher performance GPU because its clocks must not exceed those of the other GPU.

3D Compatibility Mode

3D Compatibility Mode is an NVIDIA proprietary rendering mode for 3D Vision that improves the 3D experience for many key DirectX 10 and 11 games. NVIDIA continues to add game support with new driver versions.

Requirements and Compatibility

- ▶ Games must be run in DirectX 10 or DirectX 11 mode.

- Not compatible with 3D Vision Surround.

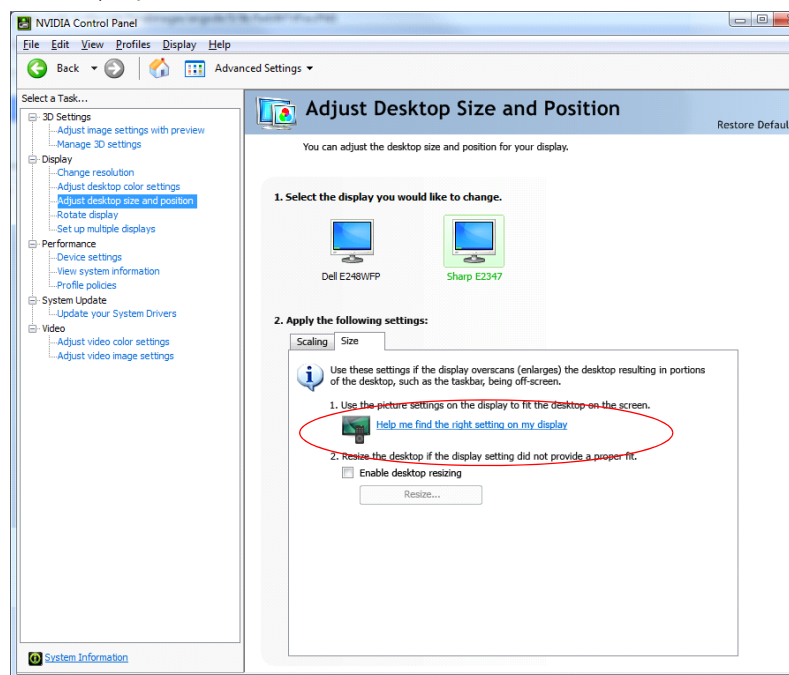
Switching Compatibility Modes

Games with 3D Compatibility Mode will launch in this mode by default. You can switch between 3D Compatibility mode and standard 3D Vision mode as follows:

- 1 Before starting the game, enable Advanced In-game Settings in the NVIDIA Control Panel:
 - a Open the NVIDIA Control Panel and navigate to the *Stereoscopic 3D->Set up stereoscopic 3D* page and click Set Keyboard Shortcuts.
 - b. Click the *Show advanced in-game settings* arrow if the section is not expanded, then select Enable advanced in-game settings.
 - c. Click OK.
2. Press Ctrl+Alt+F11 during the game to toggle between 3D Compatibility mode and standard 3D Vision mode.

Help for Resizing Your HDTV Desktop

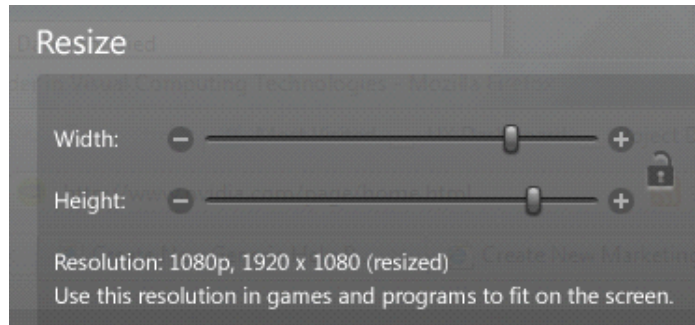
The best way to resize the screen in order to view the entire content is to use the controls provided by the display hardware. Click the link on the Size tab to view a guide to changing the settings on your display hardware.



The resize controls on the NVIDIA Control Panel are provided in case satisfactory results cannot be achieved using the controls on the display.

After resizing the HDTV desktop using the NVIDIA Control Panel Resize controls, the new custom resolution created is now added to the list of available resolutions for that display, and also added to the resolution list within the game or application.

The method for resizing the HDTV desktop was improved to provide better image quality when applying underscan. This method results in a new custom resolution being created which needs to be selected from games or applications to apply the resizing. In the example displayed in the following screen shot, the underscan has created a new resolution (1216 × 682). Although this resolution looks different, it is still in HD format. Remember to select this resolution in your game or other application in order to take advantage of it.



Note: Some games or applications may not support the new resolution.

Understanding the DirectX Information Shown in the NVIDIA System Information Window

The System Information window—accessed by clicking System Information at the bottom left corner of the NVIDIA Control Panel—provides technical information about the NVIDIA graphics cards and driver installed in the system.

It also provides the following system information:

- Operating system: For example, “Windows 7 Enterprise, 64-bit”
- DirectX runtime version: For example, “11.0”

In order to use the version of DirectX reported in the System Information window, the NVIDIA GPU and graphics driver must also support that DirectX version.

This information is provided in the *Graphics card information* section of the System Information window as follows:

- DirectX support

(Provided in previous driver versions)

This is the DirectX version that is supported by the NVIDIA graphics hardware and driver.

- Direct3D API version

(Provided in later driver versions, for Windows 7 and later.)

This is the Direct3D version that is supported by the NVIDIA graphics hardware and driver. The API version is expressed in terms of Direct3D – the graphics subsystem component of DirectX.

► Direct3D feature level

(Provided in later driver versions, for Windows 7 and later)

Direct3D feature levels describe a subset of features within the Direct3D API version that are supported by the NVIDIA graphics hardware and driver.

Driver Security

Follow these safe computing practices:

- ▶ Only download or execute content and programs from trusted third parties.
- ▶ Run your system and programs with the least privilege necessary. Users should run without administrator rights whenever possible.
- ▶ When running as administrator, do not elevate UAC privileges for activities or programs that don't need them.

This section describes additional actions to take to mitigate specific known security issues. For guidance regarding driver or software package updates to address security concerns, visit the [NVIDIA Product Security](#) page.

Restricting/Enabling Access to GPU Performance Counters

The NVIDIA graphics driver contains a vulnerability (CVE-2018-6260) that may allow access to application data processed on the GPU through a side channel exposed by the GPU performance counters. GPU performance counters are needed by developers in order to use NVIDIA developer tools such as CUPTI, Nsight Graphics, and Nsight Compute. In order to address CVE-2018-6260 the driver (starting with version 419.67) automatically disables access for non-admin users.

For more information about CVE-2018-6260 visit the [NVIDIA Security Bulletin 4772](#).

Access to GPU performance counters can be enabled for non-admin users who need to use NVIDIA developer tools. Enabling access to GPU performance counters can be accomplished through the NVIDIA Control Panel->*Developer->Manage GPU Performance Counters* page. Refer to the *Developer->Manage GPU Performance Counters* section of the NVIDIA Control Panel Help for instructions.

Changes and Fixed Issues in Studio Driver Version 441.28

The following sections list the important changes and the most common issues resolved in this version. This list is only a subset of the total number of changes made in this driver version. The NVIDIA bug number is provided for reference.

Fixed Issues in this Release

- ▶ [Avid Media Composer][OpenCL][OpenGL]: The OpenGL/OpenCL driver may hang when exiting the application. [2690096]
- ▶ [V-Ray][OptiX]: Performance regression with V-Ray rendering.[2740159]
- ▶ [IRay]: Some applications using IRay crash when used in a multi-GPU configuration. [2754968]
- ▶ [OptiX]: OptiX unable to select GPUs for use when all GPUs in the system are in TCC mode [2722686]
- ▶ [OptiX]: Applications built against OptiX SDK 7.0.0 throw error message when using OptixBuildInputTriangleArray::preTransform. [2742029]
- ▶ [OptiX denoiser]: Errors occur when using the denoiser and specifying Color + Albedo + Normals.
- ▶ [OptiX denoiser]: The Alpha-denoising path does not support blend mode. [2727732]
- ▶ [OptiX denoiser]: OptiX errors occur when specifying Normals + Albedo for input. [2712572]
- ▶ [OptiX]: noline function calls do not use custom ABI. [2631716]
- ▶ [OptiX]: denoiser device handling preempts user control. [2647842]
- ▶ [OptiX denoiser]: OptiX denoiser produces small color values for black pixels and zero alpha. [2545368]

Open Issues in Version 441.28 WHQL

As with every released driver, version 441.28 WHQL of the Release 440 driver has open issues and enhancement requests associated with it. This section includes lists of issues that are either not fixed or not implemented in this version. Some problems listed may not have been thoroughly investigated and, in fact, may not be NVIDIA issues. Others may have workaround solutions.

For notebook computers, issues can be system-specific and may not be seen on your particular notebook.

Windows 10 Issues

- ▶ [Alchemist]: The application crashes when either changing the display resolution or switching to another display with a different resolution. [2732353]

To workaround, avoid changing the resolution, or disconnecting from or connecting to an external display with the application opened.

- ▶ [Resolve]: The application may crash during timeline playback when using Blackmagic RAW CODEC media. [2753421]

To address this issue, roll back the NVIDIA Driver to version 436.48.

- ▶ [Battlefield V][G-SYNC][HDR]: When G-SYNC and HDR are enabled, the game cannot be maximized to full-screen after being minimized to the taskbar. [200558314]

- ▶ [Grand Theft Auto V]: The game frequently crashes.[2703155]

NVIDIA is working with the application developer to resolve the issue.

Issues Not Caused by NVIDIA Drivers

This section lists issues that are not due to the NVIDIA driver as well as features that are not meant to be supported by the NVIDIA driver.

- ▶ “Windows 10 Considerations” on page 17
- ▶ “Operating System Issues” on page 17
- ▶ “Application Issues” on page 17

Windows 10 Considerations

Cross-adapter Clone Mode

Under Windows 10, clone mode across graphics processors is handled by the Windows OS, and not by the NVIDIA driver. Consequently, there are no controls for cross-adapter clone mode in the NVIDIA Control Panel under Windows 10.

Functionality of some display controls in the NVIDIA Control Panel may be affected if cross-adapter clone mode is enabled through the Windows Control Panel. In this case, use the Windows Control Panel to adjust display settings.

Optimus Systems

Because cross-adapter clone mode is handled by the Windows 10 OS, there are no display controls in the NVIDIA Control Panel if no display is connected to the NVIDIA GPU on Optimus notebooks.

Operating System Issues

- ▶ [Windows 10 Fall Creators Update][HDTV]: 12 bpc is automatically applied even on HDTVs that support only 8 bpc, resulting in a scrambled display. [2007663]

To work around, open the NVIDIA Control Panel->Change Resolution page, select “Use NVIDIA color settings”, then set the Output color depth to 8 bpc.

Application Issues

Fixed Frame Rate Games

Some games and applications are designed to run at a fixed frame rate, and consequently do not take advantage of NVIDIA G-Sync. To prevent issues, G-Sync may be disabled for those applications.

Known Product Limitations

This section describes problems that will not be fixed. Usually, the source of the problem is beyond the control of NVIDIA. Following is the list of problems and where they are discussed in this document:

- ▶ “Windowed NVIDIA G-SYNC is Disabled During Video Playback on a Multi-monitor System” on page 19
- ▶ “GPU Temperature Reported Incorrectly on Optimus Systems” on page 19
- ▶ “Damaged or Missing WMI Service Prevents NVIDIA Driver Installation” on page 20
- ▶ “Total Available Graphics Memory Reported Incorrectly” on page 20
- ▶ “Increasing 4-way SLI/Multi-GPU Performance” on page 21
- ▶ “No PhysX Acceleration Using the GPU” on page 22
- ▶ “NVIDIA PhysX System Software Cannot Be Installed or Uninstalled in Windows Safe Mode” on page 22
- ▶ “Do Not Use Windows Rollback for Graphics Drivers” on page 22
- ▶ “Uninstalling Drivers Using Device Manager is Not Supported” on page 22
- ▶ “Changing Primary Display Across SLI GPUs Slower Than Expected” on page 23
- ▶ “Using HDMI Audio with Displays That Have a High Native Resolution” on page 23
- ▶ “Using HDMI/DisplayPort Audio in Dualview or Clone Mode” on page 24
- ▶ “Flat Panel Scaling Controls Not Functional for Some TV Modes in Some Displays” on page 24
- ▶ “GPU Runs at a High Performance Level (full clock speeds) in Multi-display Modes” on page 25
- ▶ “1280 × 1024 @ 60 Hz Not Available on BenQ FP241W Monitors” on page 25

Windowed NVIDIA G-SYNC is Disabled During Video Playback on a Multi-monitor System

Issue

Beginning with Windows 10 April 2018 Update (RS4), NVIDIA G-SYNC is disabled during active video playback on multi-monitor systems.

Explanation

If hardware accelerated video is playing on one display and an application is launched on another display in windowed mode with NVIDIA G-SYNC or adaptive-sync enabled, the video stutters. This is the result of desktop compositing on displays with differing refresh rates.

To prevent the video stutter in this scenario, the driver disables NVIDIA G-SYNC during active video playback, but re-enables G-SYNC if the video is paused or closed.



Note: The issue can also occur when displays are set to different refresh rates, even when G-SYNC is not used. To resolve in this case, make sure all displays are set to the same refresh rate.

GPU Temperature Reported Incorrectly on Optimus Systems

Issue

On Optimus systems, temperature-reporting tools such as Speccy or GPU-Z report that the NVIDIA GPU temperature is zero when no applications are running.

Explanation

On Optimus systems, when the NVIDIA GPU is not being used then it is put into a low- power state. This causes temperature-reporting tools to return incorrect values.

Waking up the GPU to query the temperature would result in meaningless measurements because the GPU temperature change as a result.

These tools will report accurate temperatures only when the GPU is awake and running.

Damaged or Missing WMI Service Prevents NVIDIA Driver Installation

Issue

“Install failed” or “Install Failed, could not find compatible graphics hardware” message may appear during installation, even if the system has a compatible graphics card. This can occur when installing the NVIDIA driver or GeForce Experience software.

Cause

This issue could be the result of a corrupt WMI service on your system. The NVIDIA Installer requires the WMI service to properly install the driver or other NVIDIA software.

Resolution

You must repair the WMI service on your system in order to successfully install NVIDIA drivers. A future driver release will alert the user during installation that there is a problem with the WMI service on the system.

Total Available Graphics Memory Reported Incorrectly

Background–TAG Memory

In the Windows Display Driver Model (WDDM), Total Available Graphics (TAG) memory is reported as the sum of

- Dedicated Video Memory (video memory dedicated for graphics use)
- Dedicated System Memory (system memory dedicated for graphics use), and
- Shared System Memory (system memory shared between the graphics subsystem and the CPU).

The values for each of these components are computed according to WDDM guidelines when the NVIDIA Display Driver is loaded.

Issue

Some TAG-reporting APIs represent video memory using 32-bits instead of 64-bits, and consequently do not properly report available graphics memory when the TAG would otherwise exceed 4 gigabytes (GB). This results in under reporting of available memory and potentially undesirable behavior of applications that rely on these APIs to report available memory.

The under reporting can be extreme. For example, 6 GB might be reported as 454 MB, and 8 GB might be reported as 1259 MB.

Driver Action for GeForce-based Graphics Systems

On graphics systems with less than 2.75 GB of advertized physical memory, the NVIDIA display driver typically limits the Shared System Memory to maintain a TAG memory value of less than 4 GB¹.

- ▶ This results in reliable reporting of sub-4 GB TAG memory on systems with less than 2.75 GB of advertised physical memory.
- ▶ On systems with 2.75 GB or more of advertized physical memory, you may see different reported TAG memory values between the NVIDIA Control Panel and other reporting APIs.

Increasing 4-way SLI/Multi-GPU Performance

Issue

With some games and applications, you may experience little to no performance gain or even a performance drop with 4-way SLI or multi-GPU configurations.

Resolution

1. Open the NVIDIA Control Panel, then click Manage 3D Settings from the navigation pane.
2. Click the *Global Settings* tab, then scroll to the *Power management mode* feature, click the corresponding list arrow and select Prefer maximum performance, then click Apply.

1. The WDDM guidelines dictate minimum and maximum values for the components, but the display driver may further constrain the values that are reported (within the allowed minimum and maximum).

No PhysX Acceleration Using the GPU

If after installing the PhysX System Software you find that there is no PhysX acceleration on supported applications, repeat the PhysX setup as follows:

1. Reboot the PC.
2. Open the NVIDIA Control Panel and then, under 3D Settings, click Set PhysX configuration to open that page.
3. Under Select a PhysX processor, verify that either auto-select or a specific NVIDIA GPU is selected.
4. Click Apply.

NVIDIA PhysX System Software Cannot Be Installed or Uninstalled in Windows Safe Mode

Issue

The NVIDIA PhysX System Software is not included in the NVIDIA driver installation/uninstallation under safe mode.

Explanation

The NVIDIA PhysX System Software installer is not compatible with Microsoft's policy for Windows Safe Mode. Consequently, installation or uninstallation of the PhysX System Software under safe mode would fail. To allow installation or uninstallation of the graphics driver under safe mode, the NVIDIA PhysX System Software is blocked from the process.

Do Not Use Windows Rollback for Graphics Drivers

To reinstall a previous or older NVIDIA graphics driver, do not use the Windows rollback feature. This method will not reliably restore all the previous driver files.

Instead, use the Windows Add and Remove programs to remove the current driver, and then install the older driver using setup.exe.

Uninstalling Drivers Using Device Manager is Not Supported

Issue

On all supported versions of Microsoft Windows, uninstalling the NVIDIA driver using the Windows Device Manager may not remove associated files or applications.

Explanation

Microsoft has confirmed that this behavior is by design. If you wish to uninstall the NVIDIA driver, it is recommended that you do so using Add and Remove programs.

See the [Microsoft KB article 2278714](#).

Changing Primary Display Across SLI GPUs Slower Than Expected

Issue

On an SLI system, switching the primary (or SLI focus) display when each display in the SLI group is connected to a different GPU takes longer than expected.

Explanation

On an SLI system with each SLI GPU driving a display, the display connected to the slave GPU is the primary display (also the SLI focus display). In order to switch the primary display to the one connected to the other GPU, the master and slave GPU configuration must also switch. In order to reassign which GPU is the master and which is the slave, the driver must be reloaded. It is the process of reloading the driver that takes the additional time.

Using HDMI Audio with Displays That Have a High Native Resolution

To use HDMI audio with some displays that have a native resolution higher than 1920 × 1080, you must set the display to a lower HD resolution.

Some HDMI displays have a native resolution that exceeds the maximum supported HD mode. For example, displays with a native resolution of 1920 × 1200 exceed the maximum supported HD mode of 1920 × 1080.

Applying this native mode results in display overscan which cannot be resized using the NVIDIA Control Panel since the mode is not an HD mode.

To avoid this situation and provide a better user experience, the driver treats certain TVs—such as the Viewsonic VX2835wm and the Westinghouse LVM-37w3—as a DVI monitor when applying the native mode. Because the driver does not treat the TV as an HDMI in this case, the HDMI audio is not used.

Using HDMI/DisplayPort Audio in Dualview or Clone Mode

Two Audio-enabled Ports

In a multi-display configuration where both HDMI/DisplayPort audio ports are enabled, only the primary display will provide the audio.

One Audio-enabled Port

In a multi-display configuration where only one audio port is enabled, such as when one display is a DVI display, then the HDMI/DisplayPort display can provide the audio whether is it the primary or secondary display.

Flat Panel Scaling Controls Not Functional for Some TV Modes in Some Displays

The NVIDIA Control Panel flat panel scaling controls on the “Adjust Size & Position” page are not intended to be used for TV modes, and normally the controls are not available for TV or HDTV displays.

However, Microsoft requires that certain TV/HDTV modes be available for all digital displays, including DVI and HDMI, even if they are not HDTV.

While the NVIDIA flat panel scaling controls are available for those displays, they will not be functional for the TV modes that appear in compliance with the Microsoft requirements. The affected modes are as follows:

- ▶ 1920 × 1080i @ 50/59.94/60 Hz
- ▶ 1280 × 720p @ 50/59.94/60 Hz
- ▶ 720 × 480p @ 59.94/60 Hz
- ▶ 720 × 576p @ 50 Hz

GPU Runs at a High Performance Level (full clock speeds) in Multi-display Modes

This is a hardware limitation with desktop and older notebook GPUs, and not a software bug. When multiple displays are connected and active, the GPU will always operate with full clock speeds in order to efficiently drive multiple displays—even when no 3D programs are running.



Note: NVIDIA notebook GeForce 5xxM series and later GPUs do not have this limitation. For those GPUs the driver can adjust the performance level, depending on demand, even when driving multiple displays.

1280 × 1024 @ 60 Hz Not Available on BenQ FP241W Monitors

Even though the monitor EDID lists 1280 × 1024 @ 60 Hz, the screen turns blank when using an HDMI connection. This is an issue with the monitor and not the NVIDIA driver.

Because of this issue with the monitor, the NVIDIA driver blocks the problem mode (1280 × 1024 @ 60 Hz) and makes it unavailable.

Chapter 3. The Release 440 Studio Driver

This chapter covers the following main topics:

- ▶ “About the Release 440 Studio Driver” on page 26
- ▶ “Hardware and Software Support” on page 26
- ▶ “Driver Installation” on page 33

About the Release 440 Studio Driver

This driver release is from the Release 440 family of drivers (versions 440.xx to 444.xx). See “Supported NVIDIA Desktop Products” on page 27 and “Supported NVIDIA Notebook Products” on page 28 for current products supported in this release.

As part of the NVIDIA Notebook Driver Program, this is a reference driver that can be installed on supported NVIDIA notebook GPUs. However, please note that your notebook original equipment manufacturer (OEM) provides certified drivers for your specific notebook on their website. NVIDIA recommends that you check with your notebook OEM about recommended software updates for your notebook. OEMs may not provide technical support for issues that arise from the use of this driver.

Hardware and Software Support

- ▶ “Supported Operating Systems” on page 27
- ▶ “Support for OpenCL 1.2” on page 27
- ▶ “Supported NVIDIA Desktop Products” on page 27
- ▶ “Supported NVIDIA Notebook Products” on page 28
- ▶ “Supported NVIDIA Quadro & NVS Product” on page 29
- ▶ “Supported NVIDIA Quadro Sync II” on page 30
- ▶ “Supported NVIDIA Quadro Sync Products” on page 30
- ▶ “Supported NVIDIA Quadro Blade/Embedded Graphics Board” on page 30
- ▶ “Supported Languages” on page 33

Supported Operating Systems

This Release 440 Studio driver includes drivers designed for the following Microsoft® operating systems:

- Microsoft Windows® 10¹, 64-bit

Support for OpenCL 1.2

Kepler, Maxwell, Pascal, and Volta GPUs are supported.

Supported NVIDIA Desktop Products

The following table (from <http://www.geforce.com/hardware>) lists current NVIDIA desktop products supported by version 441.28 WHQL of the Release 440 driver. For information about desktop products not shown, please see <http://www.geforce.com/hardware/desktop-gpus>.

Table 3.1 Supported NVIDIA Desktop GPUs

Consumer Products	Architecture
NVIDIA TITAN RTX	Turing
NVIDIA GeForce RTX 2080 SUPER	Turing
NVIDIA GeForce RTX 2070 SUPER	Turing
NVIDIA GeForce RTX 2060 SUPER	Turing
NVIDIA GeForce RTX 2080 Ti	Turing
NVIDIA GeForce RTX 2080	Turing
NVIDIA GeForce RTX 2070	Turing
NVIDIA GeForce RTX 2060	Turing
NVIDIA TITAN V	Volta
NVIDIA TITAN Xp	Pascal
NVIDIA TITAN X	Pascal
GeForce GTX 1660 Ti	Turing
GeForce GTX 1660 SUPER	Turing
GeForce GTX 1660	Turing
GeForce GTX 1650	Turing
GeForce GTX 1080 Ti	Pascal
GeForce GTX 1080	Pascal
GeForce GTX 1070 Ti	Pascal

-
1. Includes support for Windows 10 May 2019 Update (Version 1903) (19H1)

Table 3.1 Supported NVIDIA Desktop GPUs

Consumer Products	Architecture
GeForce GTX 1070	Pascal
GeForce GTX 1060 6GB	Pascal
GeForce GTX 1060 3GB	Pascal
GeForce GTX 1060	Pascal
GeForce GTX 1050 Ti	Pascal
GeForce GTX 1050 3GB	Pascal
GeForce GTX 1050	Pascal

Supported NVIDIA Notebook Products

The following table lists current NVIDIA notebook products supported by version 441.28 WHQL of the Release 440 driver. For information about notebook products not shown, please see <http://www.geforce.com/hardware/notebook-gpus>.

Table 3.2 Supported NVIDIA Notebook GPUs

Consumer Products	Architecture
GeForce RTX 2080	Turing
GeForce RTX 2070	Turing
GeForce RTX 2060	Turing
GeForce GTX 1660 Ti	Turing
GeForce GTX 1650	Turing
GeForce GTX 1080 for notebooks	Pascal
GeForce GTX 1070 for notebooks	Pascal
GeForce GTX 1060 for notebooks	Pascal
GeForce GTX 1050 for notebooks	Pascal
GeForce GTX 1050 Ti for notebooks	Pascal

Supported NVIDIA Quadro & NVS Product

Table 3.3 Supported NVIDIA Quadro & NVS Products

Product	GPU Architecture
NVIDIA Quadro RTX 8000	Turing
NVIDIA Quadro RTX 6000	Turing
NVIDIA Quadro RTX 5000	Turing
NVIDIA Quadro RTX 4000	Turing
NVIDIA Quadro GV100	Volta
NVIDIA Quadro GP100	Pascal
NVIDIA Quadro P6000	Pascal
NVIDIA Quadro P5000	Pascal
NVIDIA Quadro P4000	Pascal
NVIDIA Quadro P2000	Pascal
NVIDIA Quadro P1000	Pascal
NVIDIA Quadro P600	Pascal
NVIDIA Quadro P400	Pascal
NVIDIA Quadro M6000 24GB	Maxwell
NVIDIA Quadro M6000	Maxwell
NVIDIA Quadro M5000	Maxwell
NVIDIA Quadro M4000	Maxwell
NVIDIA Quadro M2000	Maxwell
NVIDIA Quadro K6000	Kepler
NVIDIA Quadro K5200	Kepler
NVIDIA Quadro K5000	Kepler
NVIDIA Quadro K4200	Kepler
NVIDIA Quadro K4000	Kepler
NVIDIA Quadro K2200	Maxwell
NVIDIA Quadro K2000	Kepler
NVIDIA Quadro K1200	Maxwell
NVIDIA Quadro K620	Maxwell
NVIDIA Quadro K600	Kepler
NVIDIA Quadro K420	Kepler
NVIDIA Quadro 410	Kepler
NVIDIA NVS 810	Maxwell
NVIDIA NVS 510	Kepler

Supported NVIDIA Quadro Sync II

Table 3.4 Supported NVIDIA Quadro Sync II Products

Product	GPU Architecture
NVIDIA Quadro RTX 8000	Turing
NVIDIA Quadro RTX 6000	Turing
NVIDIA Quadro RTX 5000	Turing
NVIDIA Quadro RTX 4000	Turing
NVIDIA Quadro GV100	Volta
NVIDIA Quadro GP100	Pascal
NVIDIA Quadro P6000	Pascal
NVIDIA Quadro P5000	Pascal
NVIDIA Quadro P4000	Pascal

Supported NVIDIA Quadro Sync Products

Table 3.5 Supported NVIDIA Quadro Sync Products

Product	GPU Architecture
NVIDIA Quadro M6000 24GB	Maxwell
NVIDIA Quadro M6000	Maxwell
NVIDIA Quadro M5000	Maxwell
NVIDIA Quadro M4000	Maxwell
NVIDIA Quadro K6000	Kepler
NVIDIA Quadro K5200	Kepler
NVIDIA Quadro K5000	Kepler
NVIDIA Quadro K4200	Kepler

Supported NVIDIA Quadro Blade/Embedded Graphics Board

Table 3.6 Supported NVIDIA Quadro Blade/Embedded Graphics Board Series

Product	GPU Architecture
NVIDIA Quadro P5000	Pascal

Table 3.6 Supported NVIDIA Quadro Blade/Embedded Graphics Board Series (continued)

Product	GPU Architecture
NVIDIA Quadro P3000	Pascal
NVIDIA Quadro M5000 SE	Maxwell
NVIDIA Quadro M3000 SE	Maxwell

Supported NVIDIA Quadro Notebook GPUs

The notebook driver is part of the NVIDIA Verde Notebook Driver Program, and can be installed on supported NVIDIA notebook GPUs. However, please note that your notebook original equipment manufacturer (OEM) provides certified drivers for your specific notebook on their website. NVIDIA recommends that you check with your notebook OEM about recommended software updates for your notebook. OEMs may not provide technical support for issues that arise from the use of this driver.

The following tables list the NVIDIA notebook products supported by the Release 440 driver, version 441.28 WHQL:

Table 3.7 NVIDIA Quadro Notebook GPU Support

Notebook Products	GPU Architecture
Quadro RTX 5000	Turing
Quadro RTX 4000	Turing
Quadro RTX 3000	Turing
Quadro T2000	Turing
Quadro T1000	Turing
Quadro P5200	Pascal
Quadro P5000	Pascal
Quadro P4200	Pascal
Quadro P4000	Pascal
Quadro P3200	Pascal
Quadro P3000	Pascal
Quadro P620	Pascal
Quadro P520	Pascal
Quadro P600	Pascal
Quadro P500	Pascal
Quadro M5500	Maxwell
Quadro M5000M	Maxwell
Quadro M4000M	Maxwell
Quadro M3000M	Maxwell
Quadro M2000M	Maxwell
Quadro M1000M	Maxwell
Quadro M600M	Maxwell
Quadro M500M	Maxwell
Quadro K2200M	Maxwell
Quadro K620M	Maxwell

Supported Languages

The Release 440 Graphics Drivers supports the following languages in the main driver Control Panel:

English (USA)	German	Portuguese (Euro/Iberian)
English (UK)	Greek	Russian
Arabic	Hebrew	Slovak
Chinese (Simplified)	Hungarian	Slovenian
Chinese (Traditional)	Italian	Spanish
Czech	Japanese	Spanish (Latin America)
Danish	Korean	Swedish
Dutch	Norwegian	Thai
Finnish	Polish	Turkish
French	Portuguese (Brazil)	

Driver Installation

Minimum Hard Disk Space

The hard disk space requirement is approximately 1.5x the size of the installation download to accommodate extracted and temporary files.

Before You Begin

nTune

If you have previously installed NVIDIA nTune, NVIDIA recommends that you uninstall nTune before installing this driver. After the driver install is complete, you can reinstall NVIDIA nTune.

Notebooks

- ▶ Check to make sure that your notebook has a supported GPU (see [“Supported NVIDIA Notebook Products” on page 28](#)).
- ▶ It is recommended that you back up your current system configuration.
- ▶ If you own a Dell Inspiron 1420, Dell XPS M1330, Dell XPS M1530, or Dell Latitude D630 or D630c, it is highly recommended that you first install this [Dell software update](#).

Installation Instructions

- 1 Follow the instructions on the NVIDIA.com Web site driver download page to locate the appropriate driver to download, based on your hardware and operating system.
- 2 From the driver download page, click the Download button.
The *Download Confirmation* page appears.
- 3 If you agree to the “License For Customer Use of NVIDIA Software”, click the Agree & Download button to begin the download.
The *File Download* dialog appears.
- 4 Either click Save to save the file and then run it from your PC, or click Run.
An extraction path dialog appears prompting you to specify where on your PC you want the driver files to be installed.
- 5 Click OK to use the default location, or click the folder icon and specify an alternate location to install the driver files.
The files are extracted and then the NVIDIA Installer is launched automatically.
- 6 At the *License Agreement* page of the Installer, click Agree and Continue.
- 7 Follow the instructions in the NVIDIA Installer to complete the installation.



Note: The driver presents game screenshots while the driver is installing. If you are not connected to the internet during the installation, you may see a “Navigation to the webpage was cancelled” message instead. The message can be ignored and does not affect the installation. The message won’t appear if the browser cache is cleared.



Note: The NVIDIA PhysX System Software will not be included in the installation if the same version or a later version is already installed.



Note: After the driver installation, Windows 7 may default to 16-bpp color and disable the Desktop Window Manager (DWM). To work around this issue, set the color to 32-bpp and then reboot the PC.

See also the installation/uninstallation considerations explained in “[Known Product Limitations](#)” on page 18.

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, EXPRESSED, IMPLIED, STATUTORY, OR OTHERWISE WITH RESPECT TO THE MATERIALS, AND EXPRESSLY DISCLAIMS ALL IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE.

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 of otherwise under any patent rights of NVIDIA Corporation. Specifications mentioned in this publication are subject to change without notice. This publication supersedes and replaces all other information previously supplied. NVIDIA Corporation products are not authorized as critical components in life support devices or systems without express written approval of NVIDIA Corporation.

Macrovision Compliance Statement

NVIDIA Products that are Macrovision enabled can only be sold or distributed to buyers with a valid and existing authorization from Macrovision to purchase and incorporate the device into buyer's products.

Macrovision copy protection technology is protected by U.S. patent numbers 5,583,936; 6,516,132; 6,836,549; and 7,050,698 and other intellectual property rights. The use of Macrovision's copy protection technology in the device must be authorized by Macrovision and is intended for home and other limited pay-per-view uses only, unless otherwise authorized in writing by Macrovision. Reverse engineering or disassembly is prohibited.

Third Party Notice

Portions of the NVIDIA system software contain components licensed from third parties under the following terms:

Clang & LLVM:

Copyright (c) 2003-2015 University of Illinois at Urbana-Champaign.

All rights reserved.

Portions of LLVM's System library:

Copyright (C) 2004 eXtensible Systems, Inc.

Developed by:

LLVM Team

University of Illinois at Urbana-Champaign

<http://llvm.org>

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal with the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions:

* Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimers.

* Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimers in the documentation and/or other materials provided with the distribution.

* Neither the names of the LLVM Team, University of Illinois at Urbana-Champaign, nor the names of its contributors may be used to endorse or promote products derived from this Software without specific prior written permission.

THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE CONTRIBUTORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS WITH THE SOFTWARE.

Vulkan Notice

Copyright (c) 2015-2016 The Khronos Group Inc.

Copyright (c) 2015-2016 LunarG, Inc.

Copyright (c) 2015-2016 Valve Corporation

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and/or associated documentation files (the "Materials"), to deal in the Materials without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Materials, and to permit persons to whom the Materials are furnished to do so, subject to the following conditions:

The above copyright notice(s) and this permission notice shall be included in all copies or substantial portions of the Materials.

THE MATERIALS ARE PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT.

IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE MATERIALS OR THE USE OR OTHER DEALINGS IN THE MATERIALS.

Unless otherwise noted in the LICENSE.txt file in the install folder, all components of the Vulkan Runtime are licensed under the above license. Licenses for any components not so licensed are listed in the LICENSE.txt file.

Trademarks

NVIDIA, the NVIDIA logo, NVIDIA nForce, GeForce, NVIDIA Quadro, are registered trademarks or trademarks of NVIDIA Corporation in the United States and/or other countries.

HDMI, the HDMI logo, and High-Definition Multimedia Interface are trademarks or registered trademarks of HDMI Licensing LLC.

OpenGL® and the oval logo are trademarks or registered trademarks of Silicon Graphics, Inc. in the United States and/or other countries worldwide. Additional license details are available on the SGI website.

OpenCL and the OpenCL logo are trademarks of Apple Inc. used by permission by Khronos.

Vulkan and the Vulkan logo are trademarks of the Khronos Group Inc.

Other company and product names may be trademarks or registered trademarks of the respective owners with which they are associated.

Copyright

© 2018, 2019 NVIDIA Corporation. All rights reserved.

