



# VIRTUAL GPU SOFTWARE

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## User Guide



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# Chapter 1.

## INTRODUCTION TO NVIDIA vGPU SOFTWARE

NVIDIA vGPU software is a graphics virtualization platform that provides virtual machines (VMs) access to NVIDIA GPU technology.

### 1.1. How NVIDIA vGPU Software Is Used

NVIDIA vGPU software can be used in several ways.

#### 1.1.1. NVIDIA vGPU

NVIDIA Virtual GPU (vGPU) enables multiple virtual machines (VMs) to have simultaneous, direct access to a single physical GPU, using the same NVIDIA graphics drivers that are deployed on non-virtualized operating systems. By doing this, NVIDIA vGPU provides VMs with unparalleled graphics performance, compute performance, and application compatibility, together with the cost-effectiveness and scalability brought about by sharing a GPU among multiple workloads.

For more information, see [Installing and Configuring NVIDIA Virtual GPU Manager](#).

#### 1.1.2. GPU Pass-Through

In GPU pass-through mode, an entire physical GPU is directly assigned to one VM, bypassing the NVIDIA Virtual GPU Manager. In this mode of operation, the GPU is accessed exclusively by the NVIDIA driver running in the VM to which it is assigned. The GPU is not shared among VMs.

For more information, see [Using GPU Pass-Through](#).

#### 1.1.3. Bare-Metal Deployment

In a bare-metal deployment, you can use NVIDIA vGPU software graphics drivers with Quadro vDWS and GRID Virtual Applications licenses to deliver remote virtual

desktops and applications. If you intend to use Tesla boards without a hypervisor for this purpose, use NVIDIA vGPU software graphics drivers, **not** other NVIDIA drivers.

To use NVIDIA vGPU software drivers for a bare-metal deployment, complete these tasks:

1. Install the driver on the physical host.

For instructions, see [Installing the NVIDIA vGPU Software Graphics Driver](#).

2. License any NVIDIA vGPU software that you are using.

For instructions, see [Virtual GPU Client Licensing User Guide](#).

3. Configure the platform for remote access.

To use graphics features with Tesla GPUs, you must use a supported remoting solution, for example, RemoteFX, Citrix Virtual Apps and Desktops, VNC, or similar technology.

4. Use the display settings feature of the host OS to configure the Tesla GPU as the primary display.

NVIDIA Tesla generally operates as a secondary device on bare-metal platforms.

5. If the system has multiple display adapters, disable display devices connected through adapters that are not from NVIDIA.

You can use the display settings feature of the host OS or the remoting solution for this purpose. On NVIDIA GPUs, including Tesla GPUs, a default display device is enabled.

Users can launch applications that require NVIDIA GPU technology for enhanced user experience only after displays that are driven by NVIDIA adapters are enabled.

## 1.2. How this Guide Is Organized

*Virtual GPU Software User Guide* is organized as follows:

- ▶ This chapter introduces the architecture and features of NVIDIA vGPU software.
- ▶ [Installing and Configuring NVIDIA Virtual GPU Manager](#) provides a step-by-step guide to installing and configuring vGPU on supported hypervisors.
- ▶ [Using GPU Pass-Through](#) explains how to configure a GPU for pass-through on supported hypervisors.
- ▶ [Installing the NVIDIA vGPU Software Graphics Driver](#) explains how to install NVIDIA vGPU software graphics driver on Windows and Linux operating systems.
- ▶ [Licensing an NVIDIA vGPU](#) explains how to license NVIDIA vGPU licensed products on Windows and Linux operating systems.
- ▶ [Modifying a VM's NVIDIA vGPU Configuration](#) explains how to remove a VM's vGPU configuration and modify GPU assignments for vGPU-enabled VMs.
- ▶ [Monitoring GPU Performance](#) covers performance monitoring of physical GPUs and virtual GPUs from the hypervisor and from within individual guest VMs.
- ▶ [Citrix Hypervisor vGPU Management](#) covers vGPU management on Citrix Hypervisor.

- ▶ **Citrix Hypervisor Performance Tuning** covers vGPU performance optimization on Citrix Hypervisor.
- ▶ **Troubleshooting** provides guidance on troubleshooting.

### 1.3. NVIDIA vGPU Architecture

The high-level architecture of NVIDIA vGPU is illustrated in [Figure 1](#). Under the control of the NVIDIA Virtual GPU Manager running under the hypervisor, NVIDIA physical GPUs are capable of supporting multiple virtual GPU devices (vGPUs) that can be assigned directly to guest VMs.

Guest VMs use NVIDIA vGPUs in the same manner as a physical GPU that has been passed through by the hypervisor: an NVIDIA driver loaded in the guest VM provides direct access to the GPU for performance-critical fast paths, and a paravirtualized interface to the NVIDIA Virtual GPU Manager is used for non-performance management operations.

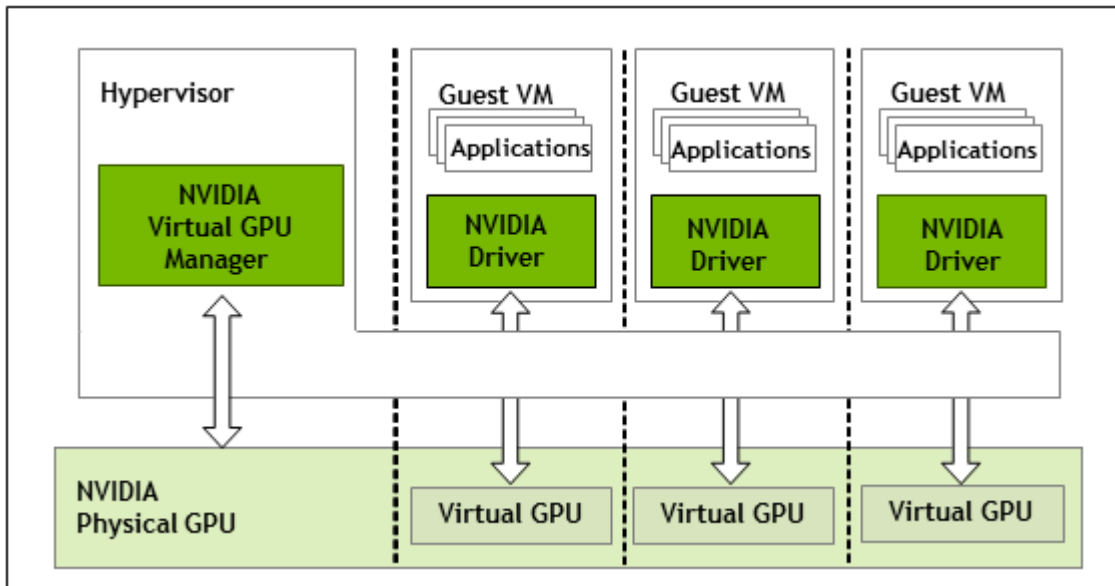


Figure 1 NVIDIA vGPU System Architecture

Each NVIDIA vGPU is analogous to a conventional GPU, having a fixed amount of GPU framebuffer, and one or more virtual display outputs or “heads”. The vGPU’s framebuffer is allocated out of the physical GPU’s framebuffer at the time the vGPU is created, and the vGPU retains exclusive use of that framebuffer until it is destroyed.

All vGPUs resident on a physical GPU share access to the GPU’s engines including the graphics (3D), video decode, and video encode engines.

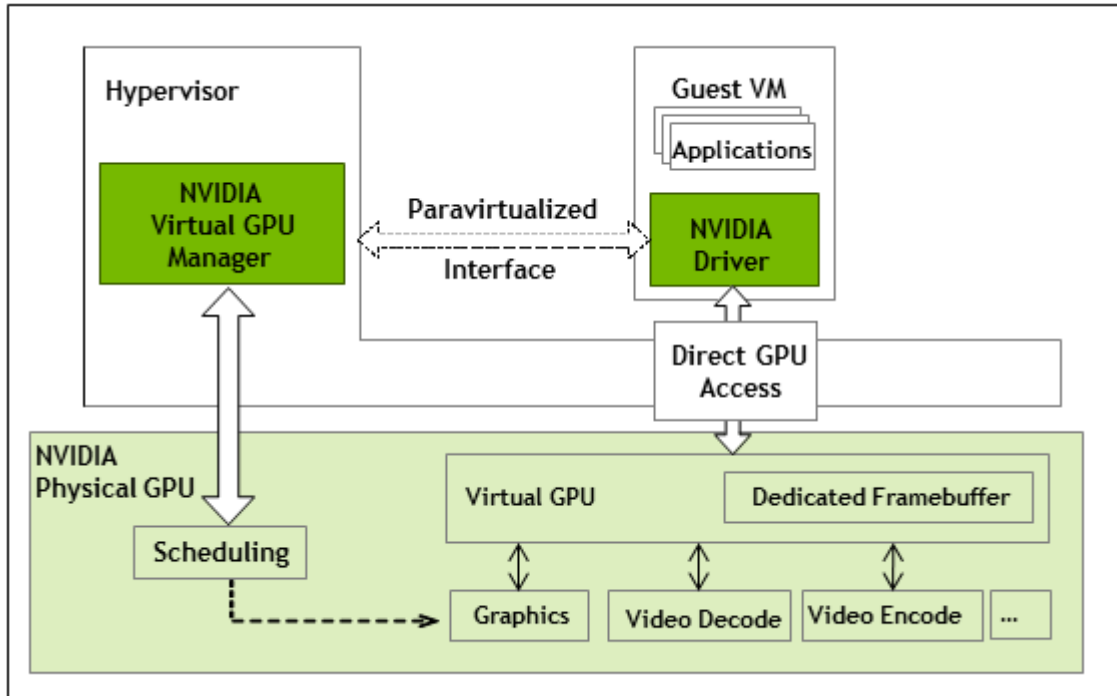


Figure 2 NVIDIA vGPU Internal Architecture

## 1.4. Supported GPUs

NVIDIA vGPU is available as a licensed product on supported Tesla GPUs. For a list of recommended server platforms and supported GPUs, consult the release notes for supported hypervisors at [NVIDIA Virtual GPU Software Documentation](#).

### 1.4.1. Virtual GPU Types

The number of physical GPUs that a board has depends on the board. Each physical GPU can support several different types of virtual GPU (vGPU). vGPU types have a fixed amount of frame buffer, number of supported display heads, and maximum resolutions<sup>1</sup>. They are grouped into different series according to the different classes of workload for which they are optimized. Each series is identified by the last letter of the vGPU type name.

Series	Optimal Workload
Q-series	Virtual workstations for creative and technical professionals who require the performance and features of Quadro technology
C-series	Compute-intensive server workloads, such as artificial intelligence (AI), deep learning, or high-performance computing (HPC) <sup>2, 3</sup>

<sup>1</sup> NVIDIA vGPUs with less than 1 Gbyte of frame buffer support only 1 virtual display head on a Windows 10 guest OS.

<sup>2</sup> C-series vGPU types are NVIDIA vComputeServer vGPU types, which are optimized for compute-intensive workloads. As a result, they support only a single display head and do not provide Quadro graphics acceleration.

Series	Optimal Workload
B-series	Virtual desktops for business professionals and knowledge workers
A-series	App streaming or session-based solutions for virtual applications users <sup>5</sup>

The number after the board type in the vGPU type name denotes the amount of frame buffer that is allocated to a vGPU of that type. For example, a vGPU of type M60-2Q is allocated 2048 Mbytes of frame buffer on a Tesla M60 board.

Due to their differing resource requirements, the maximum number of vGPUs that can be created simultaneously on a physical GPU varies according to the vGPU type. For example, a Tesla M60 board can support up to 4 M60-2Q vGPUs on each of its two physical GPUs, for a total of 8 vGPUs, but only 2 M60-4Q vGPUs, for a total of 4 vGPUs.

When enabled, the frame-rate limiter (FRL) limits the maximum frame rate in frames per second (FPS) for a vGPU as follows:

- ▶ For B-series vGPUs, the maximum frame rate is 45 FPS.
- ▶ For Q-series, C-series, and A-series vGPUs, the maximum frame rate is 60 FPS.

By default, the FRL is enabled for all GPUs. The FRL is disabled when the vGPU scheduling behavior is changed from the default best-effort scheduler on GPUs that support alternative vGPU schedulers. For details, see [Changing vGPU Scheduling Behavior](#). On vGPUs that use the best-effort scheduler, the FRL can be disabled as explained in the release notes for your chosen hypervisor at [NVIDIA Virtual GPU Software Documentation](#).



NVIDIA vGPU is a licensed product on all supported GPU boards. A software license is required to enable all vGPU features within the guest VM. The type of license required depends on the vGPU type.

- ▶ Q-series vGPU types require a Quadro vDWS license.
- ▶ C-series vGPU types require a vComputeServer license but can also be used with a Quadro vDWS license.
- ▶ B-series vGPU types require a GRID Virtual PC license but can also be used with a Quadro vDWS license.
- ▶ A-series vGPU types require a GRID Virtual Applications license.

<sup>3</sup> The maximum number of NVIDIA vComputeServer vGPUs is limited to **eight** vGPUs per physical GPU, irrespective of the available hardware resources of the physical GPU.

<sup>4</sup> The -1B4 and -2B4 vGPU types are deprecated in this release, and may be removed in a future release. In preparation for the possible removal of these vGPU types, use the following vGPU types, which provide equivalent functionality:

- ▶ Instead of -1B4 vGPU types, use -1B vGPU types.
- ▶ Instead of -2B4 vGPU types, use -2B vGPU types.

<sup>5</sup> A-series NVIDIA vGPUs support a single display at low resolution to be used as the console display in remote application environments such as RDSH and Citrix Virtual Apps and Desktops. The maximum resolution and number of virtual display heads for the A-series NVIDIA vGPUs applies only to the console display. The maximum resolution of each RDSH or Citrix Virtual Apps and Desktops session is determined by the remoting solution and is **not** restricted by the maximum resolution of the vGPU. Similarly, the number of virtual display heads supported by each session is determined by the remoting solution and is **not** restricted by the vGPU.

### 1.4.1.1. Tesla M60 Virtual GPU Types

Physical GPUs per board: 2

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
M60-8Q	Virtual Workstations	8192	4	5120×2880	1	2	Quadro vDWS
M60-4Q	Virtual Workstations	4096	4	5120×2880	2	4	Quadro vDWS
M60-2Q	Virtual Workstations	2048	4	5120×2880	4	8	Quadro vDWS
M60-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	8	16	Quadro vDWS
M60-0Q	Virtual Desktops, Virtual Workstations	512	2 <sup>1</sup>	2560×1600	16	32	Quadro vDWS
M60-2B	Virtual Desktops	2048	4	5120×2880	4	8	GRID Virtual PC or Quadro vDWS
M60-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	4	8	GRID Virtual PC or Quadro vDWS
M60-1B	Virtual Desktops	1024	4	5120×2880	8	16	GRID Virtual PC or Quadro vDWS
M60-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	8	16	GRID Virtual PC or Quadro vDWS
M60-0B	Virtual Desktops	512	2 <sup>1</sup>	2560×1600	16	32	GRID Virtual PC or Quadro vDWS
M60-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	2	GRID Virtual Application
M60-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	4	GRID Virtual Application
M60-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	8	GRID Virtual Application
M60-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	16	GRID Virtual Application

### 1.4.1.2. Tesla M10 Virtual GPU Types

Physical GPUs per board: 4

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
M10-8Q	Virtual Workstations	8192	4	5120×2880	1	4	Quadro vDWS
M10-4Q	Virtual Workstations	4096	4	5120×2880	2	8	Quadro vDWS
M10-2Q	Virtual Workstations	2048	4	5120×2880	4	16	Quadro vDWS
M10-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	8	32	Quadro vDWS
M10-0Q	Virtual Desktops, Virtual Workstations	512	2 <sup>1</sup>	2560×1600	16	64	Quadro vDWS
M10-2B	Virtual Desktops	2048	4	5120×2880	4	16	GRID Virtual PC or Quadro vDWS
M10-2B <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	4	16	GRID Virtual PC or Quadro vDWS
M10-1B	Virtual Desktops	1024	4	5120×2880	8	32	GRID Virtual PC or Quadro vDWS
M10-1B <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	8	32	GRID Virtual PC or Quadro vDWS
M10-0B	Virtual Desktops	512	2 <sup>1</sup>	2560×1600	16	64	GRID Virtual PC or Quadro vDWS
M10-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	4	GRID Virtual Application
M10-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	8	GRID Virtual Application
M10-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	16	GRID Virtual Application
M10-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	32	GRID Virtual Application

### 1.4.1.3. Tesla M6 Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
M6-8Q	Virtual Workstations	8192	4	5120×2880	1	1	Quadro vDWS
M6-4Q	Virtual Workstations	4096	4	5120×2880	2	2	Quadro vDWS

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
M6-2Q	Virtual Workstations	2048	4	5120×2880	4	4	Quadro vDWS
M6-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	8	8	Quadro vDWS
M6-0Q	Virtual Desktops, Virtual Workstations	512	2 <sup>1</sup>	2560×1600	16	16	Quadro vDWS
M6-2B	Virtual Desktops	2048	4	5120×2880	4	4	GRID Virtual PC or Quadro vDWS
M6-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	4	4	GRID Virtual PC or Quadro vDWS
M6-1B	Virtual Desktops	1024	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
M6-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
M6-0B	Virtual Desktops	512	2 <sup>1</sup>	2560×1600	16	16	GRID Virtual PC or Quadro vDWS
M6-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
M6-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
M6-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
M6-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application

#### 1.4.1.4. Tesla P100 PCIe 12GB Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P100C-12Q	Virtual Workstations	12288	4	7680×4320	1	1	Quadro vDWS
P100C-6Q	Virtual Workstations	6144	4	7680×4320	2	2	Quadro vDWS
P100C-4Q	Virtual Workstations	4096	4	7680×4320	3	3	Quadro vDWS
P100C-2Q	Virtual Workstations	2048	4	7680×4320	6	6	Quadro vDWS



Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P100C-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	12	12	Quadro vDWS
P100C-12C	Training Workloads	12288	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
P100C-6C	Training Workloads	6144	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
P100C-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	3	3	vComputeServer or Quadro vDWS
P100C-2B	Virtual Desktops	2048	4	5120×2880	6	6	GRID Virtual PC or Quadro vDWS
P100C-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	6	6	GRID Virtual PC or Quadro vDWS
P100C-1B	Virtual Desktops	1024	4	5120×2880	12	12	GRID Virtual PC or Quadro vDWS
P100C-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	12	12	GRID Virtual PC or Quadro vDWS
P100C-12A	Virtual Applications	12288	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
P100C-6A	Virtual Applications	6144	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
P100C-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	3	3	GRID Virtual Application
P100C-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	6	6	GRID Virtual Application
P100C-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	12	12	GRID Virtual Application

### 1.4.1.5. Tesla P100 PCIe 16GB Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P100-16Q	Virtual Workstations	16384	4	7680×4320	1	1	Quadro vDWS
P100-8Q	Virtual Workstations	8192	4	7680×4320	2	2	Quadro vDWS
P100-4Q	Virtual Workstations	4096	4	7680×4320	4	4	Quadro vDWS
P100-2Q	Virtual Workstations	2048	4	7680×4320	8	8	Quadro vDWS

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P100-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	16	16	Quadro vDWS
P100-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
P100-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
P100-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
P100-2B	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
P100-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
P100-1B	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
P100-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
P100-16A	Virtual Applications	16384	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
P100-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
P100-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
P100-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application
P100-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	16	16	GRID Virtual Application

### 1.4.1.6. Tesla P100 SXM2 Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P100X-16Q	Virtual Workstations	16384	4	7680×4320	1	1	Quadro vDWS
P100X-8Q	Virtual Workstations	8192	4	7680×4320	2	2	Quadro vDWS
P100X-4Q	Virtual Workstations	4096	4	7680×4320	4	4	Quadro vDWS
P100X-2Q	Virtual Workstations	2048	4	7680×4320	8	8	Quadro vDWS

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P100X-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	16	16	Quadro vDWS
P100X-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
P100X-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
P100X-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
P100X-2B	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
P100X-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
P100X-1B	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
P100X-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
P100X-16A	Virtual Applications	16384	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
P100X-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
P100X-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
P100X-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application
P100X-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	16	16	GRID Virtual Application

### 1.4.1.7. Tesla P40 Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P40-24Q	Virtual Workstations	24576	4	7680×4320	1	1	Quadro vDWS
P40-12Q	Virtual Workstations	12288	4	7680×4320	2	2	Quadro vDWS
P40-8Q	Virtual Workstations	8192	4	7680×4320	3	3	Quadro vDWS
P40-6Q	Virtual Workstations	6144	4	7680×4320	4	4	Quadro vDWS

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P40-4Q	Virtual Workstations	4096	4	7680×4320	6	6	Quadro vDWS
P40-3Q	Virtual Workstations	3072	4	7680×4320	8	8	Quadro vDWS
P40-2Q	Virtual Workstations	2048	4	7680×4320	12	12	Quadro vDWS
P40-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	24	24	Quadro vDWS
P40-24C	Training Workloads	24576	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
P40-12C	Training Workloads	12288	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
P40-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	3	3	vComputeServer or Quadro vDWS
P40-6C	Training Workloads	6144	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
P40-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	6	6	vComputeServer or Quadro vDWS
P40-2B	Virtual Desktops	2048	4	5120×2880	12	12	GRID Virtual PC or Quadro vDWS
P40-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	12	12	GRID Virtual PC or Quadro vDWS
P40-1B	Virtual Desktops	1024	4	5120×2880	24	24	GRID Virtual PC or Quadro vDWS
P40-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	24	24	GRID Virtual PC or Quadro vDWS
P40-24A	Virtual Applications	24576	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
P40-12A	Virtual Applications	12288	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
P40-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	3	3	GRID Virtual Application
P40-6A	Virtual Applications	6144	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
P40-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	6	6	GRID Virtual Application
P40-3A	Virtual Applications	3072	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application
P40-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	12	12	GRID Virtual Application

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P40-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	24	24	GRID Virtual Application

### 1.4.1.8. Tesla P6 Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P6-16Q	Virtual Workstations	16384	4	7680×4320	1	1	Quadro vDWS
P6-8Q	Virtual Workstations	8192	4	7680×4320	2	2	Quadro vDWS
P6-4Q	Virtual Workstations	4096	4	7680×4320	4	4	Quadro vDWS
P6-2Q	Virtual Workstations	2048	4	7680×4320	8	8	Quadro vDWS
P6-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	16	16	Quadro vDWS
P6-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
P6-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
P6-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
P6-2B	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
P6-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
P6-1B	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
P6-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
P6-16A	Virtual Applications	16384	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
P6-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
P6-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
P6-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P6-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	16	16	GRID Virtual Application

### 1.4.1.9. Tesla P4 Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
P4-8Q	Virtual Workstations	8192	4	7680×4320	1	1	Quadro vDWS
P4-4Q	Virtual Workstations	4096	4	7680×4320	2	2	Quadro vDWS
P4-2Q	Virtual Workstations	2048	4	7680×4320	4	4	Quadro vDWS
P4-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	8	8	Quadro vDWS
P4-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
P4-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
P4-2B	Virtual Desktops	2048	4	5120×2880	4	4	GRID Virtual PC or Quadro vDWS
P4-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	4	4	GRID Virtual PC or Quadro vDWS
P4-1B	Virtual Desktops	1024	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
P4-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
P4-8A	Virtual Applications	8192	5 <sup>1</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
P4-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
P4-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
P4-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application

### 1.4.1.10. Tesla T4 Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
T4-16Q	Virtual Workstations	16384	4	7680×4320	1	1	Quadro vDWS
T4-8Q	Virtual Workstations	8192	4	7680×4320	2	2	Quadro vDWS
T4-4Q	Virtual Workstations	4096	4	7680×4320	4	4	Quadro vDWS
T4-2Q	Virtual Workstations	2048	4	7680×4320	8	8	Quadro vDWS
T4-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	16	16	Quadro vDWS
T4-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
T4-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
T4-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
T4-2B	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
T4-2B <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
T4-1B	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
T4-1B <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
T4-16A	Virtual Applications	16384	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
T4-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
T4-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
T4-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application
T4-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	16	16	GRID Virtual Application

### 1.4.1.11. Tesla V100 SXM2 Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
V100X-16Q	Virtual Workstations	16384	4	7680×4320	1	1	Quadro vDWS
V100X-8Q	Virtual Workstations	8192	4	7680×4320	2	2	Quadro vDWS
V100X-4Q	Virtual Workstations	4096	4	7680×4320	4	4	Quadro vDWS
V100X-2Q	Virtual Workstations	2048	4	7680×4320	8	8	Quadro vDWS
V100X-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	16	16	Quadro vDWS
V100X-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
V100X-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
V100X-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
V100X-2B	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
V100X-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
V100X-1B	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100X-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100X-16A	Virtual Applications	16384	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
V100X-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
V100X-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
V100X-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application
V100X-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	16	16	GRID Virtual Application

### 1.4.1.12. Tesla V100 SXM2 32GB Virtual GPU Types

Physical GPUs per board: 1



Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
V100DX-32Q	Virtual Workstations	32768	4	7680×4320	1	1	Quadro vDWS
V100DX-16Q	Virtual Workstations	16384	4	7680×4320	2	2	Quadro vDWS
V100DX-8Q	Virtual Workstations	8192	4	7680×4320	4	4	Quadro vDWS
V100DX-4Q	Virtual Workstations	4096	4	7680×4320	8	8	Quadro vDWS
V100DX-2Q	Virtual Workstations	2048	4	7680×4320	16	16	Quadro vDWS
V100DX-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	32	32	Quadro vDWS
V100DX-32C	Training Workloads	32768	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
V100DX-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
V100DX-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
V100DX-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	8	8	vComputeServer or Quadro vDWS
V100DX-2B	Virtual Desktops	2048	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100DX-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100DX-1B	Virtual Desktops	1024	4	5120×2880	32	32	GRID Virtual PC or Quadro vDWS
V100DX-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	32	32	GRID Virtual PC or Quadro vDWS
V100DX-32A	Virtual Applications	32768	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
V100DX-16A	Virtual Applications	16384	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
V100DX-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
V100DX-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application
V100DX-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	16	16	GRID Virtual Application
V100DX-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	32	32	GRID Virtual Application

### 1.4.1.13. Tesla V100 PCIe Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
V100-16Q	Virtual Workstations	16384	4	7680×4320	1	1	Quadro vDWS
V100-8Q	Virtual Workstations	8192	4	7680×4320	2	2	Quadro vDWS
V100-4Q	Virtual Workstations	4096	4	7680×4320	4	4	Quadro vDWS
V100-2Q	Virtual Workstations	2048	4	7680×4320	8	8	Quadro vDWS
V100-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	16	16	Quadro vDWS
V100-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
V100-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
V100-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
V100-2B	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
V100-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
V100-1B	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100-16A	Virtual Applications	16384	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
V100-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
V100-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
V100-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application
V100-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	16	16	GRID Virtual Application

### 1.4.1.14. Tesla V100 PCIe 32GB Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
V100D-32Q	Virtual Workstations	32768	4	7680×4320	1	1	Quadro vDWS
V100D-16Q	Virtual Workstations	16384	4	7680×4320	2	2	Quadro vDWS
V100D-8Q	Virtual Workstations	8192	4	7680×4320	4	4	Quadro vDWS
V100D-4Q	Virtual Workstations	4096	4	7680×4320	8	8	Quadro vDWS
V100D-2Q	Virtual Workstations	2048	4	7680×4320	16	16	Quadro vDWS
V100D-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	32	32	Quadro vDWS
V100D-32C	Training Workloads	32768	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
V100D-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
V100D-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
V100D-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	8	8	vComputeServer or Quadro vDWS
V100D-2B	Virtual Desktops	2048	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100D-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100D-1B	Virtual Desktops	1024	4	5120×2880	32	32	GRID Virtual PC or Quadro vDWS
V100D-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	32	32	GRID Virtual PC or Quadro vDWS
V100D-32A	Virtual Applications	32768	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
V100D-16A	Virtual Applications	16384	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
V100D-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
V100D-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application
V100D-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	16	16	GRID Virtual Application
V100D-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	32	32	GRID Virtual Application

### 1.4.1.15. Tesla V100S PCIe 32GB Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
V100S-32Q	Virtual Workstations	32768	4	7680×4320	1	1	Quadro vDWS
V100S-16Q	Virtual Workstations	16384	4	7680×4320	2	2	Quadro vDWS
V100S-8Q	Virtual Workstations	8192	4	7680×4320	4	4	Quadro vDWS
V100S-4Q	Virtual Workstations	4096	4	7680×4320	8	8	Quadro vDWS
V100S-2Q	Virtual Workstations	2048	4	7680×4320	16	16	Quadro vDWS
V100S-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	32	32	Quadro vDWS
V100S-32C	Training Workloads	32768	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
V100S-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
V100S-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
V100S-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	8	8	vComputeServer or Quadro vDWS
V100S-2B	Virtual Desktops	2048	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100S-1B	Virtual Desktops	1024	4	5120×2880	32	32	GRID Virtual PC or Quadro vDWS
V100S-32A	Virtual Applications	32768	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
V100S-16A	Virtual Applications	16384	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
V100S-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
V100S-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application
V100S-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	16	16	GRID Virtual Application
V100S-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	32	32	GRID Virtual Application

### 1.4.1.16. Tesla V100 FHHL Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
V100L-16Q	Virtual Workstations	16384	4	7680×4320	1	1	Quadro vDWS
V100L-8Q	Virtual Workstations	8192	4	7680×4320	2	2	Quadro vDWS
V100L-4Q	Virtual Workstations	4096	4	7680×4320	4	4	Quadro vDWS
V100L-2Q	Virtual Workstations	2048	4	7680×4320	8	8	Quadro vDWS
V100L-1Q	Virtual Desktops, Virtual Workstations	1024	4	5120×2880	16	16	Quadro vDWS
V100L-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
V100L-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
V100L-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
V100L-2B	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
V100L-2B4 <sup>4</sup>	Virtual Desktops	2048	4	5120×2880	8	8	GRID Virtual PC or Quadro vDWS
V100L-1B	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100L-1B4 <sup>4</sup>	Virtual Desktops	1024	4	5120×2880	16	16	GRID Virtual PC or Quadro vDWS
V100L-16A	Virtual Applications	16384	1 <sup>5</sup>	1280×1024 <sup>5</sup>	1	1	GRID Virtual Application
V100L-8A	Virtual Applications	8192	1 <sup>5</sup>	1280×1024 <sup>5</sup>	2	2	GRID Virtual Application
V100L-4A	Virtual Applications	4096	1 <sup>5</sup>	1280×1024 <sup>5</sup>	4	4	GRID Virtual Application
V100L-2A	Virtual Applications	2048	1 <sup>5</sup>	1280×1024 <sup>5</sup>	8	8	GRID Virtual Application
V100L-1A	Virtual Applications	1024	1 <sup>5</sup>	1280×1024 <sup>5</sup>	16	16	GRID Virtual Application

### 1.4.1.17. Quadro RTX 8000 Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
RTX8000-48Q	Virtual Workstations	49152	4	7680×4320	1	1	Quadro vDWS
RTX8000-24Q	Virtual Workstations	24576	4	7680×4320	2	2	Quadro vDWS
RTX8000-16Q	Virtual Workstations	16384	4	7680×4320	3	3	Quadro vDWS
RTX8000-12Q	Virtual Workstations	12288	4	7680×4320	4	4	Quadro vDWS
RTX8000-8Q	Virtual Workstations	8192	4	7680×4320	6	6	Quadro vDWS
RTX8000-6Q	Virtual Workstations	6144	4	7680×4320	8	8	Quadro vDWS
RTX8000-4Q	Virtual Workstations	4096	4	7680×4320	12	12	Quadro vDWS
RTX8000-3Q	Virtual Workstations	3072	4	7680×4320	16	16	Quadro vDWS
RTX8000-2Q	Virtual Workstations	2048	4	7680×4320	24	24	Quadro vDWS
RTX8000-1Q	Virtual Workstations	1024	4	5120×2880	32 <sup>6</sup>	32	Quadro vDWS
RTX8000-48C	Training Workloads	49152	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
RTX8000-24C	Training Workloads	24576	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
RTX8000-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	3	3	vComputeServer or Quadro vDWS
RTX8000-12C	Training Workloads	12288	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
RTX8000-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	6	6	vComputeServer or Quadro vDWS
RTX8000-6C	Training Workloads	6144	1	4096×2160 <sup>2</sup>	8	8	vComputeServer or Quadro vDWS
RTX8000-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	8 <sup>3</sup>	12	vComputeServer or Quadro vDWS

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The maximum vGPUs per GPU is limited to 32.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
RTX8000-2B	Virtual Desktops	2048	4	5120×2880	12	12	GRID Virtual PC or Quadro vDWS
RTX8000-1B	Virtual Desktops	1024	4	5120×2880	24	24	GRID Virtual PC or Quadro vDWS
RTX8000-48A	Virtual Applications	49152	1	1280×1024	1	1	GRID Virtual Application
RTX8000-24A	Virtual Applications	24576	1	1280×1024	2	2	GRID Virtual Application
RTX8000-16A	Virtual Applications	16384	1	1280×1024	3	3	GRID Virtual Application
RTX8000-12A	Virtual Applications	12288	1	1280×1024	4	4	GRID Virtual Application
RTX8000-8A	Virtual Applications	8192	1	1280×1024	6	6	GRID Virtual Application
RTX8000-6A	Virtual Applications	6144	1	1280×1024	8	8	GRID Virtual Application
RTX8000-4A	Virtual Applications	4096	1	1280×1024	12	12	GRID Virtual Application
RTX8000-3A	Virtual Applications	3072	1	1280×1024	16	16	GRID Virtual Application
RTX8000-2A	Virtual Applications	2048	1	1280×1024	24	24	GRID Virtual Application
RTX8000-1A	Virtual Applications	1024	1	1280×1024	32 <sup>6</sup>	32	GRID Virtual Application

#### 1.4.1.18. Quadro RTX 8000 Passive Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
RTX8000P-48Q	Virtual Workstations	49152	4	7680×4320	1	1	Quadro vDWS
RTX8000P-24Q	Virtual Workstations	24576	4	7680×4320	2	2	Quadro vDWS
RTX8000P-16Q	Virtual Workstations	16384	4	7680×4320	3	3	Quadro vDWS
RTX8000P-12Q	Virtual Workstations	12288	4	7680×4320	4	4	Quadro vDWS
RTX8000P-8Q	Virtual Workstations	8192	4	7680×4320	6	6	Quadro vDWS

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
RTX8000P-6Q	Virtual Workstations	6144	4	7680×4320	8	8	Quadro vDWS
RTX8000P-4Q	Virtual Workstations	4096	4	7680×4320	12	12	Quadro vDWS
RTX8000P-3Q	Virtual Workstations	3072	4	7680×4320	16	16	Quadro vDWS
RTX8000P-2Q	Virtual Workstations	2048	4	7680×4320	24	24	Quadro vDWS
RTX8000P-1Q	Virtual Workstations	1024	4	5120×2880	32 <sup>6</sup>	32	Quadro vDWS
RTX8000P-48C	Training Workloads	49152	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
RTX8000P-24C	Training Workloads	24576	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
RTX8000P-16C	Training Workloads	16384	1	4096×2160 <sup>2</sup>	3	3	vComputeServer or Quadro vDWS
RTX8000P-12C	Training Workloads	12288	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
RTX8000P-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	6	6	vComputeServer or Quadro vDWS
RTX8000P-6C	Training Workloads	6144	1	4096×2160 <sup>2</sup>	8	8	vComputeServer or Quadro vDWS
RTX8000P-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	8 <sup>3</sup>	12	vComputeServer or Quadro vDWS
RTX8000P-2B	Virtual Desktops	2048	4	5120×2880	12	12	GRID Virtual PC or Quadro vDWS
RTX8000P-1B	Virtual Desktops	1024	4	5120×2880	24	24	GRID Virtual PC or Quadro vDWS
RTX8000P-48A	Virtual Applications	49152	1	1280×1024	1	1	GRID Virtual Application
RTX8000P-24A	Virtual Applications	24576	1	1280×1024	2	2	GRID Virtual Application

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The maximum vGPUs per GPU is limited to 32.



Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
RTX8000P-16A	Virtual Applications	16384	1	1280×1024	3	3	GRID Virtual Application
RTX8000P-12A	Virtual Applications	12288	1	1280×1024	4	4	GRID Virtual Application
RTX8000P-8A	Virtual Applications	8192	1	1280×1024	6	6	GRID Virtual Application
RTX8000P-6A	Virtual Applications	6144	1	1280×1024	8	8	GRID Virtual Application
RTX8000P-4A	Virtual Applications	4096	1	1280×1024	12	12	GRID Virtual Application
RTX8000P-3A	Virtual Applications	3072	1	1280×1024	16	16	GRID Virtual Application
RTX8000P-2A	Virtual Applications	2048	1	1280×1024	24	24	GRID Virtual Application
RTX8000P-1A	Virtual Applications	1024	1	1280×1024	32 <sup>6</sup>	32	GRID Virtual Application

#### 1.4.1.19. Quadro RTX 6000 Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
RTX6000-24Q	Virtual Workstations	24576	4	7680×4320	1	1	Quadro vDWS
RTX6000-12Q	Virtual Workstations	12288	4	7680×4320	2	2	Quadro vDWS
RTX6000-8Q	Virtual Workstations	8192	4	7680×4320	3	3	Quadro vDWS
RTX6000-6Q	Virtual Workstations	6144	4	7680×4320	4	4	Quadro vDWS
RTX6000-4Q	Virtual Workstations	4096	4	7680×4320	6	6	Quadro vDWS
RTX6000-3Q	Virtual Workstations	3072	4	7680×4320	8	8	Quadro vDWS
RTX6000-2Q	Virtual Workstations	2048	4	7680×4320	12	12	Quadro vDWS
RTX6000-1Q	Virtual Workstations	1024	4	5120×2880	24	24	Quadro vDWS
RTX6000-24C	Training Workloads	24576	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
RTX6000-12C	Training Workloads	12288	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
RTX6000-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	3	3	vComputeServer or Quadro vDWS
RTX6000-6C	Training Workloads	6144	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
RTX6000-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	6	6	vComputeServer or Quadro vDWS
RTX6000-2B	Virtual Desktops	2048	4	5120×2880	12	12	GRID Virtual PC or Quadro vDWS
RTX6000-1B	Virtual Desktops	1024	4	5120×2880	24	24	GRID Virtual PC or Quadro vDWS
RTX6000-24A	Virtual Applications	24576	1	1280×1024	1	1	GRID Virtual Application
RTX6000-12A	Virtual Applications	12288	1	1280×1024	2	2	GRID Virtual Application
RTX6000-8A	Virtual Applications	8192	1	1280×1024	3	3	GRID Virtual Application
RTX6000-6A	Virtual Applications	6144	1	1280×1024	4	4	GRID Virtual Application
RTX6000-4A	Virtual Applications	4096	1	1280×1024	6	6	GRID Virtual Application
RTX6000-3A	Virtual Applications	3072	1	1280×1024	8	8	GRID Virtual Application
RTX6000-2A	Virtual Applications	2048	1	1280×1024	12	12	GRID Virtual Application
RTX6000-1A	Virtual Applications	1024	1	1280×1024	24	24	GRID Virtual Application

#### 1.4.1.20. Quadro RTX 6000 Passive Virtual GPU Types

Physical GPUs per board: 1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
RTX6000P-24Q	Virtual Workstations	24576	4	7680×4320	1	1	Quadro vDWS

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
RTX6000P-12Q	Virtual Workstations	12288	4	7680×4320	2	2	Quadro vDWS
RTX6000P-8Q	Virtual Workstations	8192	4	7680×4320	3	3	Quadro vDWS
RTX6000P-6Q	Virtual Workstations	6144	4	7680×4320	4	4	Quadro vDWS
RTX6000P-4Q	Virtual Workstations	4096	4	7680×4320	6	6	Quadro vDWS
RTX6000P-3Q	Virtual Workstations	3072	4	7680×4320	8	8	Quadro vDWS
RTX6000P-2Q	Virtual Workstations	2048	4	7680×4320	12	12	Quadro vDWS
RTX6000P-1Q	Virtual Workstations	1024	4	5120×2880	24	24	Quadro vDWS
RTX6000P-24C	Training Workloads	24576	1	4096×2160 <sup>2</sup>	1	1	vComputeServer or Quadro vDWS
RTX6000P-12C	Training Workloads	12288	1	4096×2160 <sup>2</sup>	2	2	vComputeServer or Quadro vDWS
RTX6000P-8C	Training Workloads	8192	1	4096×2160 <sup>2</sup>	3	3	vComputeServer or Quadro vDWS
RTX6000P-6C	Training Workloads	6144	1	4096×2160 <sup>2</sup>	4	4	vComputeServer or Quadro vDWS
RTX6000P-4C	Inference Workloads	4096	1	4096×2160 <sup>2</sup>	6	6	vComputeServer or Quadro vDWS
RTX6000P-2B	Virtual Desktops	2048	4	5120×2880	12	12	GRID Virtual PC or Quadro vDWS
RTX6000P-1B	Virtual Desktops	1024	4	5120×2880	24	24	GRID Virtual PC or Quadro vDWS
RTX6000P-24A	Virtual Applications	24576	1	1280×1024	1	1	GRID Virtual Application
RTX6000P-12A	Virtual Applications	12288	1	1280×1024	2	2	GRID Virtual Application
RTX6000P-8A	Virtual Applications	8192	1	1280×1024	3	3	GRID Virtual Application
RTX6000P-6A	Virtual Applications	6144	1	1280×1024	4	4	GRID Virtual Application

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Virtual Display Heads	Maximum Display Resolution	Maximum vGPUs per GPU	Maximum vGPUs per Board	Required License Edition
RTX6000P-4A	Virtual Applications	4096	1	1280×1024	6	6	GRID Virtual Application
RTX6000P-3A	Virtual Applications	3072	1	1280×1024	8	8	GRID Virtual Application
RTX6000P-2A	Virtual Applications	2048	1	1280×1024	12	12	GRID Virtual Application
RTX6000P-1A	Virtual Applications	1024	1	1280×1024	24	24	GRID Virtual Application

## 1.4.2. Virtual Display Resolutions

Q-series and B-series vGPUs support a maximum combined resolution based on their frame buffer size instead of a fixed maximum resolution per display. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPUs.

The number of virtual displays that you can use depends on a combination of the following factors:

- ▶ Virtual GPU series
- ▶ GPU architecture
- ▶ vGPU frame buffer size
- ▶ Display resolution

For details, see the subsections that follow.

High resolution displays consume more GPU frame buffer than low resolution displays. The ability of a vGPU to drive a certain combination of high resolution displays does not guarantee that enough frame buffer remains free for all applications to run. If applications run out of frame buffer, consider changing your setup in one of the following ways:

- ▶ Switching to a vGPU type with more frame buffer
- ▶ Using fewer displays
- ▶ Using lower resolution displays

### 1.4.2.1. Virtual Display Resolutions for B-Series vGPUs

vGPU Frame Buffer Size (MB)	Display Resolution	Maximum Number of Virtual Displays
1024	5120×2880	1
	4096×2160	1
	Lower than 4096×2160	4
2048	5120×2880	1
	4096×2160	2

vGPU Frame Buffer Size (MB)	Display Resolution	Maximum Number of Virtual Displays
	Lower than 4096×2160	4

### 1.4.2.2. Virtual Display Resolutions for Q-Series vGPUs Based on the Maxwell Architecture

vGPU Frame Buffer Size (MB)	Display Resolution	Maximum Number of Virtual Displays
1024	5120×2880	1
	4096×2160	2
	Lower than 4096×2160	4
2048 or more	5120×2880	2
	4096×2160	2
	Lower than 4096×2160	4

### 1.4.2.3. Virtual Display Resolutions for Q-Series vGPUs Based on Architectures after Maxwell

vGPU Frame Buffer Size (MB)	Display Resolution	Maximum Number of Virtual Displays
1024	5120×2880	1
	4096×2160	2
	Lower than 4096×2160	4
2048 to 3072	7680×4320	1
	5120×2880	2
	Lower than 5120×2880	4
4096 to 6144	7680×4320	1
	Lower than 7680×4320	4
8192 or more	7680×4320	2
	Lower than 7680×4320	4

## 1.4.3. Homogeneous Virtual GPUs

This release of NVIDIA vGPU supports only homogeneous virtual GPUs. At any given time, the virtual GPUs resident on a single physical GPU must be all of the same type. However, this restriction doesn't extend across physical GPUs on the same card. Different physical GPUs on the same card may host different types of virtual GPU at the same time, provided that the vGPU types on any one physical GPU are the same.

For example, a Tesla M60 card has two physical GPUs, and can support several types of virtual GPU. Figure 3 shows the following examples of valid and invalid virtual GPU configurations on Tesla M60:

- ▶ A valid configuration with M60-2Q vGPUs on GPU 0 and M60-4Q vGPUs on GPU 1
- ▶ A valid configuration with M60-1B vGPUs on GPU 0 and M60-2Q vGPUs on GPU 1
- ▶ An invalid configuration with mixed vGPU types on GPU 0

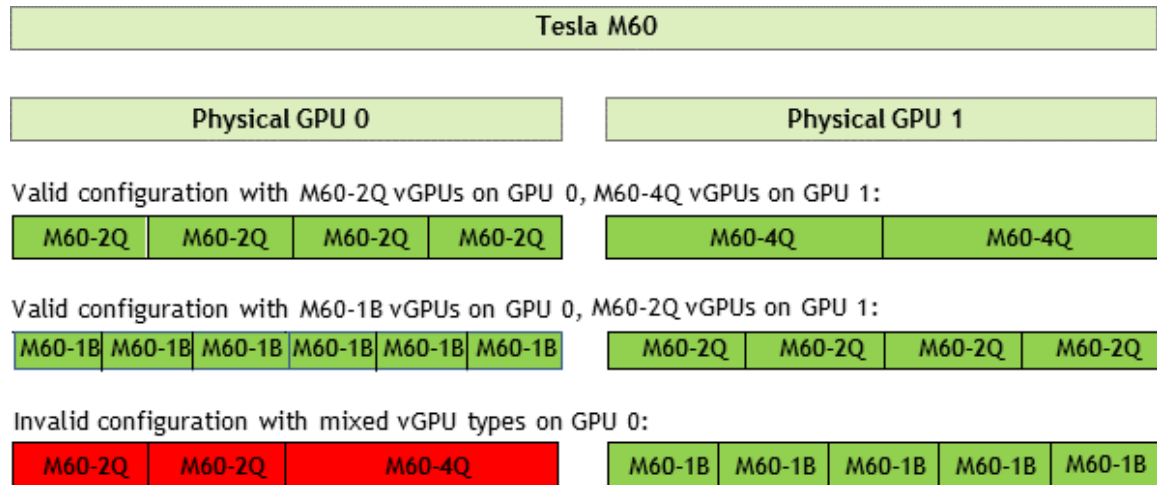


Figure 3 Example vGPU Configurations on Tesla M60

## 1.5. Guest VM Support

NVIDIA vGPU supports Windows and Linux guest VM operating systems. The supported vGPU types depend on the guest VM OS.

For details of the supported releases of Windows and Linux, and for further information on supported configurations, see the driver release notes for your hypervisor at [NVIDIA Virtual GPU Software Documentation](#).

### 1.5.1. Windows Guest VM Support

Windows guest VMs are supported only on Q-series, B-series, and A-series NVIDIA vGPU types. They are **not** supported on C-series NVIDIA vGPU types.

### 1.5.2. Linux Guest VM support

64-bit Linux guest VMs are supported only on Q-series, C-series, and B-series NVIDIA vGPU types. They are **not** supported on A-series NVIDIA vGPU types.

## 1.6. NVIDIA vGPU Software Features

NVIDIA vGPU software includes Quadro vDWS, vComputeServer, GRID Virtual PC, and GRID Virtual Applications.

### 1.6.1. API Support on NVIDIA vGPU

NVIDIA vGPU includes support for the following APIs:

- ▶ Open Computing Language (OpenCL™ software) 1.2
- ▶ OpenGL® 4.6
- ▶ Vulkan® 1.1
- ▶ DirectX 11
- ▶ DirectX 12 (Windows 10)
- ▶ Direct2D
- ▶ DirectX Video Acceleration (DXVA)
- ▶ NVIDIA® CUDA® 10.2
- ▶ NVIDIA vGPU software SDK (remote graphics acceleration)
- ▶ NVIDIA RTX (on GPUs based on the NVIDIA Volta graphic architecture and later architectures)

### 1.6.2. NVIDIA CUDA Toolkit and OpenCL Support on NVIDIA vGPU Software

OpenCL and CUDA applications are supported on the following NVIDIA vGPU types:

- ▶ The 8Q vGPU type on Tesla M6, Tesla M10, and Tesla M60 GPUs
- ▶ All Q-series vGPU types on the following GPUs:
  - ▶ Tesla P4
  - ▶ Tesla P6
  - ▶ Tesla P40
  - ▶ Tesla P100 SXM2 16 GB
  - ▶ Tesla P100 PCIe 16 GB
  - ▶ Tesla P100 PCIe 12 GB
  - ▶ Tesla V100 SXM2
  - ▶ Tesla V100 SXM2 32GB
  - ▶ Tesla V100 PCIe
  - ▶ Tesla V100 PCIe 32GB
  - ▶ Tesla V100S PCIe 32GB
  - ▶ Tesla V100 FHHL
  - ▶ Tesla T4
  - ▶ Quadro RTX 6000
  - ▶ Quadro RTX 6000 passive
  - ▶ Quadro RTX 8000

- ▶ Quadro RTX 8000 passive
- ▶ All C-series vGPU types

NVIDIA vGPU supports the following NVIDIA CUDA Toolkit features if the vGPU type, physical GPU, and the hypervisor software version support the feature:

- ▶ Error-correcting code (ECC) memory
- ▶ Peer-to-peer CUDA transfers over NVLink



To determine the NVLink topology between physical GPUs in a host or vGPUs assigned to a VM, run the following command from the host or VM:

```
$ nvidia-smi topo -m
```

Dynamic page retirement is supported for all vGPU types on physical GPUs that support ECC memory, even if ECC memory is disabled on physical GPU.

NVIDIA vGPU does not support the following NVIDIA CUDA Toolkit features:

- ▶ Unified Memory
- ▶ GPUDirect remote direct memory access (RDMA)
- ▶ Development tools such as IDEs, debuggers, profilers, and utilities as listed under *CUDA Toolkit Major Components* in *CUDA Toolkit 10.2 Release Notes for Windows, Linux, and Mac OS*
- ▶ Tracing and profiling through the CUDA Profiling Tools Interface (CUPTI)



These features are supported in GPU pass-through mode and in bare-metal deployments.

For more information about NVIDIA CUDA Toolkit, see [CUDA Toolkit 10.2 Documentation](#).



If you are using NVIDIA vGPU software with CUDA on Linux, avoid conflicting installation methods by installing CUDA from a distribution-independent runtime package. Do not install CUDA from distribution-specific RPM or Deb package.

To ensure that the NVIDIA vGPU software graphics driver is not overwritten when CUDA is installed, deselect the CUDA driver when selecting the CUDA components to install.

For more information, see [NVIDIA CUDA Installation Guide for Linux](#).

### 1.6.3. Additional Quadro vDWS Features

In addition to the features of GRID Virtual PC and GRID Virtual Applications, Quadro vDWS provides the following features:

- ▶ Workstation-specific graphics features and accelerations
- ▶ Certified drivers for professional applications
- ▶ GPU pass through for workstation or professional 3D graphics



In pass-through mode, Quadro vDWS supports up to four virtual display heads at 4K resolution.

- ▶ 10-bit color for Windows users. (HDR/10-bit color is not currently supported on Linux, NvFBC capture is supported but deprecated.)

## 1.6.4. NVIDIA GPU Cloud (NGC) Containers Support on NVIDIA vGPU Software

NVIDIA vGPU software supports NGC containers in NVIDIA vGPU and GPU pass-through deployments on all supported hypervisors.

In NVIDIA vGPU deployments, the following vGPU types are supported only on GPUs based on NVIDIA GPU architectures **after** the Maxwell architecture:

- ▶ All Q-series vGPU types
- ▶ All C-series vGPU types

In GPU pass-through deployments, all GPUs based on NVIDIA GPU architectures **after** the NVIDIA Maxwell™ architecture that support NVIDIA vGPU software are supported.

The Ubuntu guest operating system is supported.

For more information about setting up NVIDIA vGPU software for use with NGC containers, see *Using NGC with NVIDIA Virtual GPU Software Setup Guide*.

# Chapter 2.

## INSTALLING AND CONFIGURING NVIDIA VIRTUAL GPU MANAGER

The process for installing and configuring NVIDIA Virtual GPU Manager depends on the hypervisor that you are using. After you complete this process, you can install the display drivers for your guest OS and license any NVIDIA vGPU software licensed products that you are using.

### 2.1. Prerequisites for Using NVIDIA vGPU

Before proceeding, ensure that these prerequisites are met:

- ▶ You have a server platform that is capable of hosting your chosen hypervisor and NVIDIA GPUs that support NVIDIA vGPU software.
- ▶ One or more NVIDIA GPUs that support NVIDIA vGPU software is installed in your server platform.
- ▶ You have downloaded the NVIDIA vGPU software package for your chosen hypervisor, which consists of the following software:
  - ▶ NVIDIA Virtual GPU Manager for your hypervisor
  - ▶ NVIDIA vGPU software graphics drivers for supported guest operating systems
- ▶ The following software is installed according to the instructions in the software vendor's documentation:
  - ▶ Your chosen hypervisor, for example, Citrix Hypervisor, Red Hat Enterprise Linux KVM, Red Hat Virtualization (RHV), or VMware vSphere Hypervisor (ESXi)
  - ▶ The software for managing your chosen hypervisor, for example, Citrix XenCenter management GUI, or VMware vCenter Server

- ▶ The virtual desktop software that you will use with virtual machines (VMs) running NVIDIA Virtual GPU, for example, Citrix Virtual Apps and Desktops, or VMware Horizon



If you are using VMware vSphere Hypervisor (ESXi), ensure that the ESXi host on which you will configure a VM with NVIDIA vGPU is not a member of a VMware Distributed Resource Scheduler (DRS) cluster.

- ▶ A VM to be enabled with vGPU is created.



All hypervisors covered in this guide support multiple vGPUs in a VM.

- ▶ Your chosen guest OS is installed in the VM.

For information about supported hardware and software, and any known issues for this release of NVIDIA vGPU software, refer to the *Release Notes* for your chosen hypervisor:

- ▶ *Virtual GPU Software for Citrix Hypervisor Release Notes*
- ▶ *Virtual GPU Software for Red Hat Enterprise Linux with KVM Release Notes*
- ▶ *Virtual GPU Software for VMware vSphere Release Notes*

## 2.2. Switching the Mode of a Tesla M60 or M6 GPU

Tesla M60 and M6 GPUs support compute mode and graphics mode. NVIDIA vGPU requires GPUs that support both modes to operate in graphics mode.



Only Tesla M60 and M6 GPUs require and support mode switching. Other GPUs that support NVIDIA vGPU do not require or support mode switching.

Even in compute mode, Tesla M60 and M6 GPUs do **not** support NVIDIA vComputeServer vGPU types.

Recent Tesla M60 GPUs and M6 GPUs are supplied in graphics mode. However, your GPU might be in compute mode if it is an older Tesla M60 GPU or M6 GPU, or if its mode has previously been changed.

If your GPU supports both modes but is in compute mode, you must use the `gpumodeswitch` tool to change the mode of the GPU to graphics mode. If you are unsure which mode your GPU is in, use the `gpumodeswitch` tool to find out the mode.

For more information, see *gpumodeswitch User Guide*.

## 2.3. Installing and Configuring the NVIDIA Virtual GPU Manager for Citrix Hypervisor

The following topics step you through the process of setting up a single Citrix Hypervisor VM to use NVIDIA vGPU. After the process is complete, you can install

the graphics driver for your guest OS and license any NVIDIA vGPU software licensed products that you are using.

These setup steps assume familiarity with the Citrix Hypervisor skills covered in [Citrix Hypervisor Basics](#).

## 2.3.1. Installing and Updating the NVIDIA Virtual GPU Manager for Citrix Hypervisor

The NVIDIA Virtual GPU Manager runs in the Citrix Hypervisor dom0 domain. The NVIDIA Virtual GPU Manager for Citrix Hypervisor is supplied as an RPM file and as a Supplemental Pack.



**Caution** NVIDIA Virtual GPU Manager and Guest VM drivers must be matched from the same main driver branch. If you update vGPU Manager to a release from another driver branch, guest VMs will boot with vGPU disabled until their guest vGPU driver is updated to match the vGPU Manager version. Consult [Virtual GPU Software for Citrix Hypervisor Release Notes](#) for further details.

### 2.3.1.1. Installing the RPM package for Citrix Hypervisor

The RPM file must be copied to the Citrix Hypervisor dom0 domain prior to installation (see [Copying files to dom0](#)).

1. Use the `rpm` command to install the package:

```
[root@xenserver ~]# rpm -iv NVIDIA-vGPU-xenserver-7.0-440.53.x86_64.rpm
Preparing packages for installation...
NVIDIA-vGPU-xenserver-7.0-440.53
[root@xenserver ~]#
```

2. Reboot the Citrix Hypervisor platform:

```
[root@xenserver ~]# shutdown -r now

Broadcast message from root (pts/1) (Fri Feb 14 14:24:11 2020):

The system is going down for reboot NOW!
[root@xenserver ~]#
```

### 2.3.1.2. Updating the RPM Package for Citrix Hypervisor

If an existing NVIDIA Virtual GPU Manager is already installed on the system and you want to upgrade, follow these steps:

1. Shut down any VMs that are using NVIDIA vGPU.
2. Install the new package using the `-U` option to the `rpm` command, to upgrade from the previously installed package:

```
[root@xenserver ~]# rpm -Uv NVIDIA-vGPU-xenserver-7.0-440.53.x86_64.rpm
Preparing packages for installation...
NVIDIA-vGPU-xenserver-7.0-440.53
```

```
[root@xenserver ~]#
```



You can query the version of the current NVIDIA Virtual GPU Manager package using the `rpm -q` command:

```
[root@xenserver ~]# rpm -q NVIDIA-vGPU-xenserver-7.0-440.53
[root@xenserver ~]#
If an existing NVIDIA GRID package is already installed and you
don't select the upgrade (-U) option when installing a newer GRID
package, the rpm command will return many conflict errors.
Preparing packages for installation...
    file /usr/bin/nvidia-smi from install of NVIDIA-vGPU-
xenserver-7.0-440.53.x86_64 conflicts with file from package NVIDIA-
vGPU-xenserver-7.0-440.43.x86_64
    file /usr/lib/libnvidia-ml.so from install of NVIDIA-vGPU-
xenserver-7.0-440.53.x86_64 conflicts with file from package NVIDIA-
vGPU-xenserver-7.0-440.43.x86_64
    ...
```

### 3. Reboot the Citrix Hypervisor platform:

```
[root@xenserver ~]# shutdown -r now
Broadcast message from root (pts/1) (Fri Feb 14 14:24:11 2020):

The system is going down for reboot NOW!
[root@xenserver ~]#
```

#### 2.3.1.3. Installing or Updating the Supplemental Pack for Citrix Hypervisor

XenCenter can be used to install or update Supplemental Packs on Citrix Hypervisor hosts. The NVIDIA Virtual GPU Manager supplemental pack is provided as an ISO.

1. Select **Install Update** from the **Tools** menu.
2. Click **Next** after going through the instructions on the **Before You Start** section.
3. Click **Select update or supplemental pack from disk** on the **Select Update** section and open NVIDIA's Citrix Hypervisor Supplemental Pack ISO.

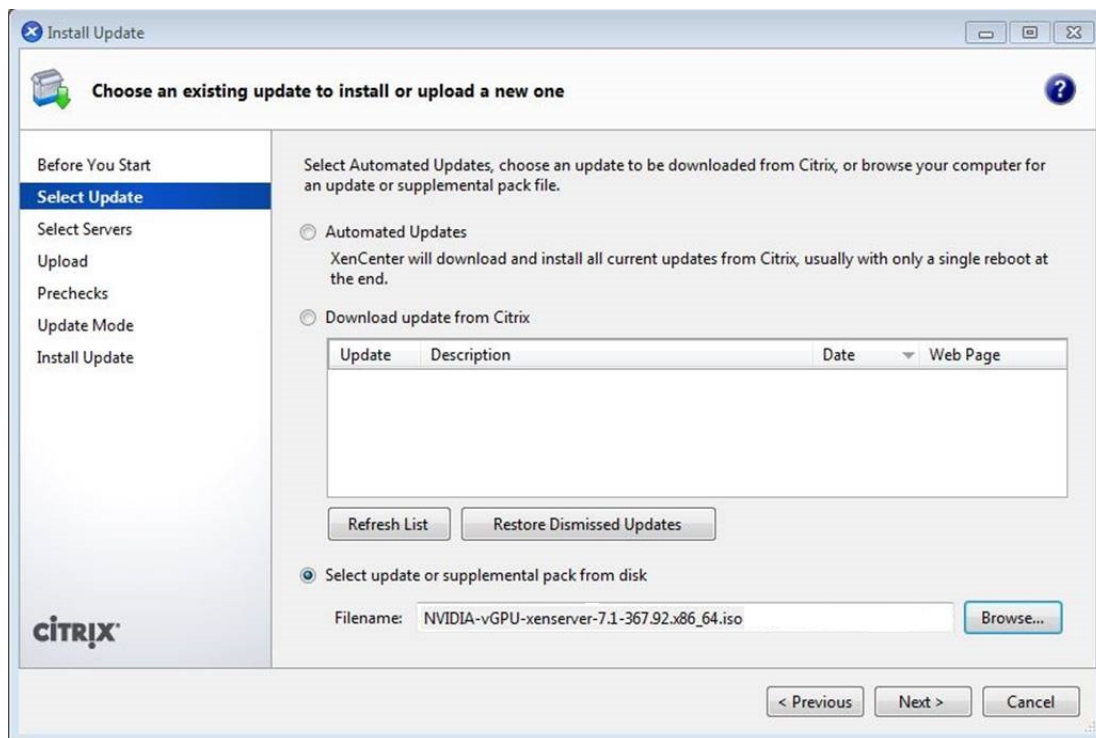


Figure 4 NVIDIA vGPU Manager supplemental pack selected in XenCenter

4. Click **Next** on the **Select Update** section.
5. In the **Select Servers** section select all the Citrix Hypervisor hosts on which the Supplemental Pack should be installed on and click **Next**.
6. Click **Next** on the **Upload** section once the Supplemental Pack has been uploaded to all the Citrix Hypervisor hosts.
7. Click **Next** on the **Prechecks** section.
8. Click **Install Update** on the **Update Mode** section.
9. Click **Finish** on the **Install Update** section.

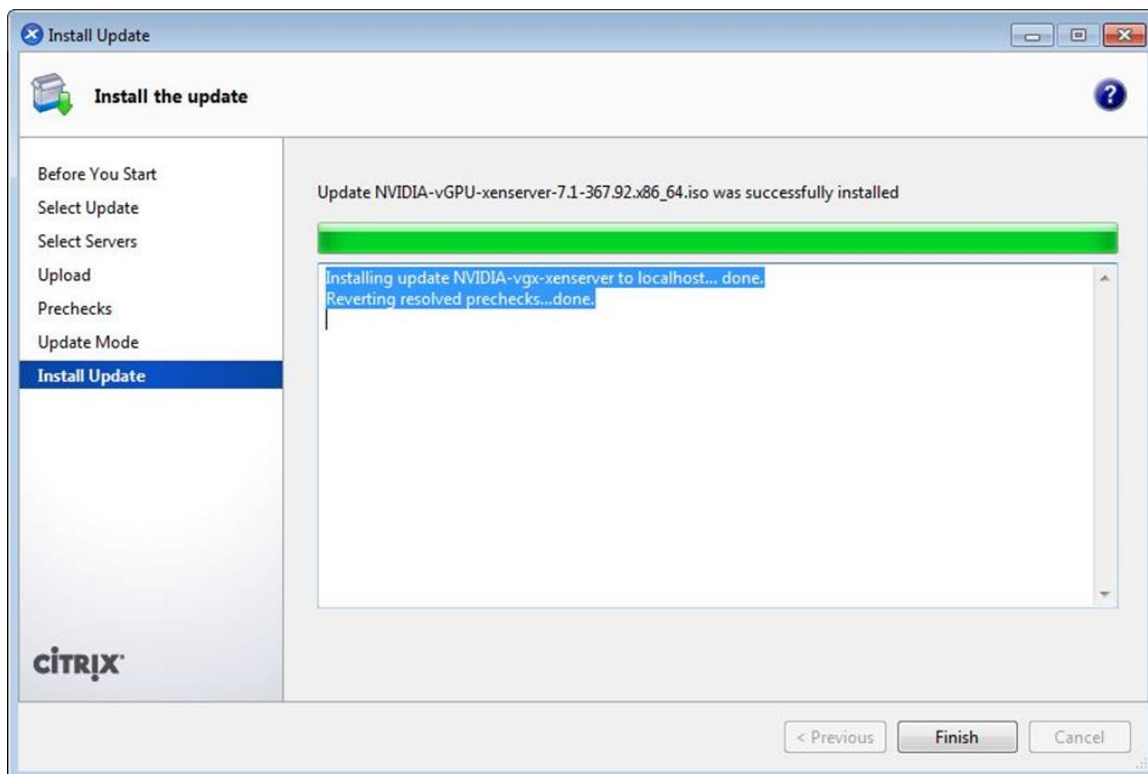


Figure 5 Successful installation of NVIDIA vGPU Manager supplemental pack

### 2.3.1.4. Verifying the Installation of the NVIDIA vGPU Software for Citrix Hypervisor Package

After the Citrix Hypervisor platform has rebooted, verify the installation of the NVIDIA vGPU software package for Citrix Hypervisor.

1. Verify that the NVIDIA vGPU software package is installed and loaded correctly by checking for the NVIDIA kernel driver in the list of kernel loaded modules.

```
[root@xenserver ~]# lsmod | grep nvidia
nvidia                9522927  0
i2c_core              20294    2 nvidia,i2c_i801
[root@xenserver ~]#
```

2. Verify that the NVIDIA kernel driver can successfully communicate with the NVIDIA physical GPUs in your system by running the `nvidia-smi` command. The `nvidia-smi` command is described in more detail in [NVIDIA System Management Interface nvidia-smi](#).

Running the `nvidia-smi` command should produce a listing of the GPUs in your platform.

```
[root@xenserver ~]# nvidia-smi
Fri Feb 14 18:46:50 2020
+-----+
| NVIDIA-SMI 440.53      Driver Version: 440.56      |
```

```

+-----+-----+-----+-----+-----+-----+-----+-----+
| GPU  Name      Persistence-M| Bus-Id      Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|             Memory-Usage | GPU-Util  Compute M. |
+-----+-----+-----+-----+-----+-----+-----+-----+
|   0   Tesla M60          On      | 00000000:05:00.0 Off  |             Off      |
| N/A   25C    P8     24W / 150W |    13MiB / 8191MiB |      0%    Default  |
+-----+-----+-----+-----+-----+-----+-----+
|   1   Tesla M60          On      | 00000000:06:00.0 Off  |             Off      |
| N/A   24C    P8     24W / 150W |    13MiB / 8191MiB |      0%    Default  |
+-----+-----+-----+-----+-----+-----+-----+
|   2   Tesla M60          On      | 00000000:86:00.0 Off  |             Off      |
| N/A   25C    P8     25W / 150W |    13MiB / 8191MiB |      0%    Default  |
+-----+-----+-----+-----+-----+-----+-----+
|   3   Tesla M60          On      | 00000000:87:00.0 Off  |             Off      |
| N/A   28C    P8     24W / 150W |    13MiB / 8191MiB |      0%    Default  |
+-----+-----+-----+-----+-----+-----+-----+

+-----+-----+-----+-----+-----+-----+-----+-----+
| Processes:                                     GPU Memory |
| GPU      PID    Type    Process name                               Usage      |
+-----+-----+-----+-----+-----+-----+-----+-----+
| No running processes found
+-----+-----+-----+-----+-----+-----+-----+

[root@xenserver ~]#

```

If `nvidia-smi` fails to run or doesn't produce the expected output for all the NVIDIA GPUs in your system, see [Troubleshooting](#) for troubleshooting steps.

## 2.3.2. Configuring a Citrix Hypervisor VM with Virtual GPU

To support applications and workloads that are compute or graphics intensive, you can add multiple vGPUs to a single VM.

For details about which Citrix Hypervisor versions and NVIDIA vGPUs support the assignment of multiple vGPUs to a VM, see [Virtual GPU Software for Citrix Hypervisor Release Notes](#).

Citrix Hypervisor supports configuration and management of virtual GPUs using XenCenter, or the `xe` command line tool that is run in a Citrix Hypervisor dom0 shell. Basic configuration using XenCenter is described in the following sections. Command line management using `xe` is described in [Citrix Hypervisor vGPU Management](#).



If you are using Citrix Hypervisor 8.1 or later and need to assign plugin configuration parameters, create vGPUs using the `xe` command as explained in [Creating a vGPU Using xe](#).

1. Ensure the VM is powered off.
2. Right-click the VM in XenCenter, select **Properties** to open the VM's properties, and select the **GPU** property.

The available GPU types are listed in the GPU type drop-down list:



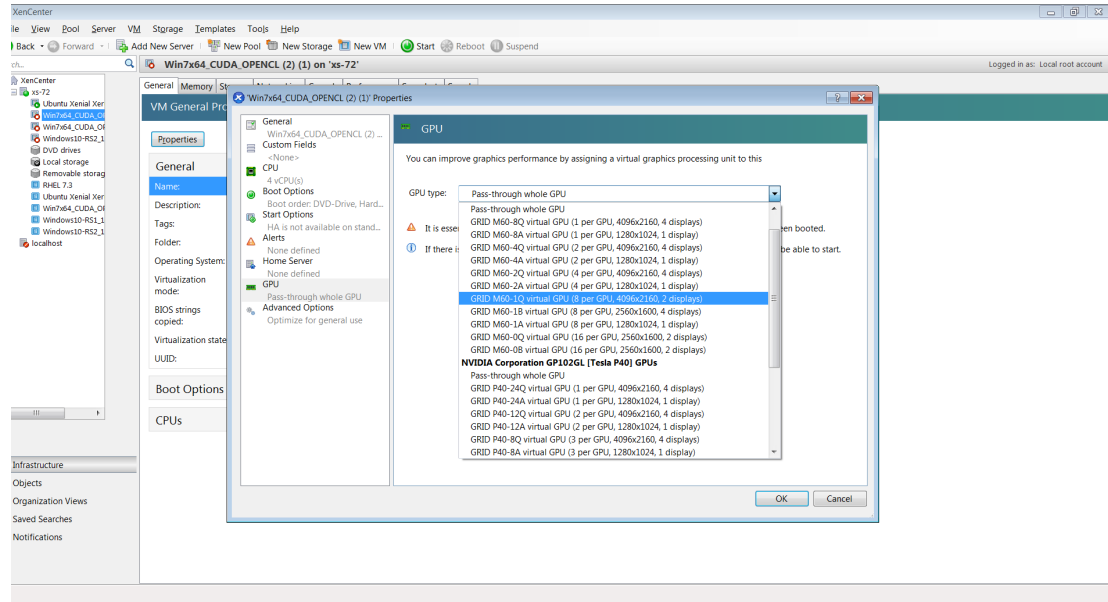


Figure 6 Using Citrix XenCenter to configure a VM with a vGPU

After you have configured a Citrix Hypervisor VM with a vGPU, start the VM, either from XenCenter or by using `xe vm-start` in a `dom0` shell. You can view the VM's console in XenCenter.

After the VM has booted, install the NVIDIA vGPU software graphics driver as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

## 2.4. Installing and Configuring the NVIDIA Virtual GPU Manager for Red Hat Enterprise Linux KVM or RHV

The following topics step you through the process of setting up a single Red Hat Enterprise Linux Kernel-based Virtual Machine (KVM) or Red Hat Virtualization (RHV) VM to use NVIDIA vGPU.

Red Hat Enterprise Linux KVM and RHV use the same Virtual GPU Manager package, but are configured with NVIDIA vGPU in different ways.

**For RHV**, follow this sequence of instructions:

1. [Installing the NVIDIA Virtual GPU Manager for Red Hat Enterprise Linux KVM or RHV](#)
2. [Adding a vGPU to a Red Hat Virtualization \(RHV\) VM](#)

**For Red Hat Enterprise Linux KVM**, follow this sequence of instructions:

1. [Installing the NVIDIA Virtual GPU Manager for Red Hat Enterprise Linux KVM or RHV](#)
2. [Getting the BDF and Domain of a GPU on Red Hat Enterprise Linux KVM](#)

3. [Creating an NVIDIA vGPU on Red Hat Enterprise Linux KVM](#)
4. [Adding One or More vGPUs to a Red Hat Enterprise Linux KVM VM](#)
5. [Setting vGPU Plugin Parameters on Red Hat Enterprise Linux KVM](#)

After the process is complete, you can install the graphics driver for your guest OS and license any NVIDIA vGPU software licensed products that you are using.

## 2.4.1. Installing the NVIDIA Virtual GPU Manager for Red Hat Enterprise Linux KVM or RHV

The NVIDIA Virtual GPU Manager for Red Hat Enterprise Linux KVM and Red Hat Virtualization (RHV) is provided as a `.rpm` file.



**Caution** NVIDIA Virtual GPU Manager and Guest VM drivers must be matched from the same main driver branch. If you update vGPU Manager to a release from another driver branch, guest VMs will boot with vGPU disabled until their guest vGPU driver is updated to match the vGPU Manager version. Consult [Virtual GPU Software for Red Hat Enterprise Linux with KVM Release Notes](#) for further details.

### 2.4.1.1. Installing the Virtual GPU Manager Package for Red Hat Enterprise Linux KVM or RHV

Before installing the RPM package for Red Hat Enterprise Linux KVM or RHV, ensure that the `sshd` service on the Red Hat Enterprise Linux KVM or RHV server is configured to permit root login. If the Nouveau driver for NVIDIA graphics cards is present, disable it before installing the package. For instructions, see [How to disable the Nouveau driver and install the Nvidia driver in RHEL 7](#) (Red Hat subscription required).

Some versions of Red Hat Enterprise Linux KVM have z-stream updates that break Kernel Application Binary Interface (kABI) compatibility with the previous kernel or the GA kernel. For these versions of Red Hat Enterprise Linux KVM, the following Virtual GPU Manager RPM packages are supplied:

- ▶ A package for the GA Linux KVM kernel
- ▶ A package for the updated z-stream kernel

To differentiate these packages, the name of each RPM package includes the kernel version. Ensure that you install the RPM package that is compatible with your Linux KVM kernel version.

1. Securely copy the RPM file from the system where you downloaded the file to the Red Hat Enterprise Linux KVM or RHV server.
  - ▶ From a Windows system, use a secure copy client such as WinSCP.
  - ▶ From a Linux system, use the `scp` command.
2. Use secure shell (SSH) to log in as root to the Red Hat Enterprise Linux KVM or RHV server.

```
# ssh root@kvm-server
```

*kvm-server*

The host name or IP address of the Red Hat Enterprise Linux KVM or RHV server.

3. Change to the directory on the Red Hat Enterprise Linux KVM or RHV server to which you copied the RPM file.

```
# cd rpm-file-directory
```

*rpm-file-directory*

The path to the directory to which you copied the RPM file.

4. Use the `rpm` command to install the package.

```
# rpm -iv NVIDIA-vGPU-rhel-7.5-440.53.x86_64.rpm
Preparing packages for installation...
NVIDIA-vGPU-rhel-7.5-440.53
#
```

5. Reboot the Red Hat Enterprise Linux KVM or RHV server.

```
# systemctl reboot
```

### 2.4.1.2. Verifying the Installation of the NVIDIA vGPU Software for Red Hat Enterprise Linux KVM or RHV

After the Red Hat Enterprise Linux KVM or RHV server has rebooted, verify the installation of the NVIDIA vGPU software package for Red Hat Enterprise Linux KVM or RHV.

1. Verify that the NVIDIA vGPU software package is installed and loaded correctly by checking for the VFIO drivers in the list of kernel loaded modules.

```
# lsmod | grep vfio
nvidia_vgpu_vfio      27099  0
nvidia                12316924 1 nvidia_vgpu_vfio
vfio_mdev             12841  0
mdev                  20414  2 vfio_mdev,nvidia_vgpu_vfio
vfio_iommu_type1     22342  0
vfio                   32331  3 vfio_mdev,nvidia_vgpu_vfio,vfio_iommu_type1
#
```

2. Verify that the `libvirtd` service is active and running.

```
# service libvirtd status
```

3. Verify that the NVIDIA kernel driver can successfully communicate with the NVIDIA physical GPUs in your system by running the `nvidia-smi` command.

The `nvidia-smi` command is described in more detail in [NVIDIA System Management Interface `nvidia-smi`](#).

Running the `nvidia-smi` command should produce a listing of the GPUs in your platform.

```
# nvidia-smi
Fri Feb 14 18:46:50 2020
+-----+
+-----+
+-----+
```

```

| NVIDIA-SMI 440.53      Driver Version: 440.56      |
+-----+-----+-----+-----+-----+-----+
| GPU  Name           Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf    Pwr:Usage/Cap|      Memory-Usage | GPU-Util  Compute M. |
+-----+-----+-----+-----+-----+-----+
|   0   Tesla M60             On          | 0000:85:00.0   Off  |           Off       |
| N/A   23C    P8             23W / 150W | 13MiB / 8191MiB |    0%      Default   |
+-----+-----+-----+-----+-----+-----+
|   1   Tesla M60             On          | 0000:86:00.0   Off  |           Off       |
| N/A   29C    P8             23W / 150W | 13MiB / 8191MiB |    0%      Default   |
+-----+-----+-----+-----+-----+-----+
|   2   Tesla P40             On          | 0000:87:00.0   Off  |           Off       |
| N/A   21C    P8             18W / 250W | 53MiB / 24575MiB |    0%      Default   |
+-----+-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+-----+
| Processes:                                                       GPU Memory |
| GPU      PID  Type  Process name                               Usage      |
+-----+-----+-----+-----+-----+-----+
| No running processes found                                     |
+-----+-----+-----+-----+-----+-----+
#

```

If `nvidia-smi` fails to run or doesn't produce the expected output for all the NVIDIA GPUs in your system, see [Troubleshooting](#) for troubleshooting steps.

## 2.4.2. Adding a vGPU to a Red Hat Virtualization (RHV) VM

Ensure that the VM to which you want to add the vGPU is shut down.

1. Determine the mediated device type (`mdev_type`) identifiers of the vGPU types available on the RHV host.

```

# vdsmd-client Host hostdevListByCaps
...
"mdev": {
    "nvidia-155": {
        "name": "GRID M10-2B",
        "available_instances": "4"
    },
    "nvidia-36": {
        "name": "GRID M10-0Q",
        "available_instances": "16"
    },
    ...
}

```

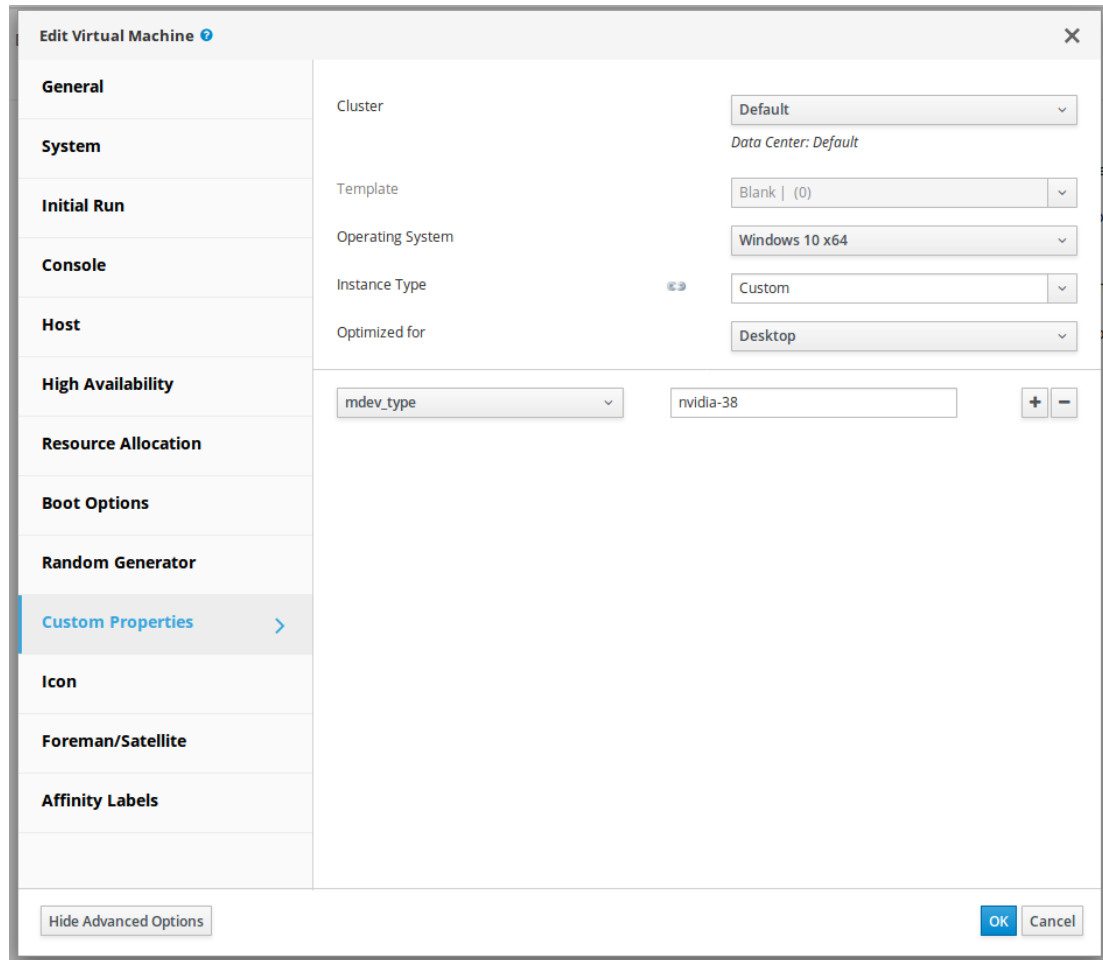
The preceding example shows the `mdev_type` identifiers of the following vGPU types:

- ▶ For the GRID M10-2B vGPU type, the `mdev_type` identifier is `nvidia-155`.
  - ▶ For the GRID M10-0Q vGPU type, the `mdev_type` identifier is `nvidia-36`.
2. Note the `mdev_type` identifier of the vGPU type that you want to add.
  3. Log in to the **RHV Administration Portal**.
  4. From the **Main Navigation Menu**, choose **Compute > Virtual Machines > *virtual-machine-name***.

*virtual-machine-name*

The name of the virtual machine to which you want to add the vGPU.

5. Click **Edit**.
6. In the **Edit Virtual Machine** window that opens, click **Show Advanced Options** and in the list of options, select **Custom Properties**.
7. From the drop-down list, select **mdev\_type**.
8. In the text field, type the `mdev_type` identifier of the vGPU type that you want to add and click **OK**.



After adding a vGPU to an RHV VM, start the VM.

After the VM has booted, install the NVIDIA vGPU software graphics driver as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

### 2.4.3. Getting the BDF and Domain of a GPU on Red Hat Enterprise Linux KVM

Sometimes when configuring a physical GPU for use with NVIDIA vGPU software, you must find out which directory in the `sysfs` file system represents the GPU. This directory is identified by the domain, bus, slot, and function of the GPU.

For more information about the directory in the `sysfs` file system represents a physical GPU, see [NVIDIA vGPU Information in the sysfs File System](#).

1. Obtain the PCI device bus/device/function (BDF) of the physical GPU.

```
# lspci | grep NVIDIA
```

The NVIDIA GPUs listed in this example have the PCI device BDFs `06:00.0` and `07:00.0`.

```
# lspci | grep NVIDIA
06:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M10]
(rev a1)
07:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M10]
(rev a1)
```

2. Obtain the full identifier of the GPU from its PCI device BDF.

```
# virsh nodedev-list --cap pci | grep transformed-bdf
```

*transformed-bdf*

The PCI device BDF of the GPU with the colon and the period replaced with underscores, for example, `06_00_0`.

This example obtains the full identifier of the GPU with the PCI device BDF `06:00.0`.

```
# virsh nodedev-list --cap pci | grep 06_00_0
pci_0000_06_00_0
```

3. Obtain the domain, bus, slot, and function of the GPU from the full identifier of the GPU.

```
virsh nodedev-dumpxml full-identifier | egrep 'domain|bus|slot|function'
```

*full-identifier*

The full identifier of the GPU that you obtained in the previous step, for example, `pci_0000_06_00_0`.

This example obtains the domain, bus, slot, and function of the GPU with the PCI device BDF `06:00.0`.

```
# virsh nodedev-dumpxml pci_0000_06_00_0 | egrep 'domain|bus|slot|function'
<domain>0x0000</domain>
<bus>0x06</bus>
<slot>0x00</slot>
<function>0x0</function>
<address domain='0x0000' bus='0x06' slot='0x00' function='0x0' />
```

## 2.4.4. Creating an NVIDIA vGPU on Red Hat Enterprise Linux KVM

For each vGPU that you want to create, perform this task in a Linux command shell on the Red Hat Enterprise Linux KVM host.



The `mdev` device file that you create to represent the vGPU does not persist when the host is rebooted and must be re-created after the host is rebooted. If necessary, you can use standard features of the operating system to automate the re-creation of this device file when the host is booted, for example, by writing a custom script that is executed when the host is rebooted.

Before you begin, ensure that you have the domain, bus, slot, and function of the GPU on which you are creating the vGPU. For instructions, see [Getting the BDF and Domain of a GPU on Red Hat Enterprise Linux KVM](#).

1. Change to the `mdev_supported_types` directory for the physical GPU.

```
# cd /sys/class/mdev_bus/domain\:bus\:slot.function/mdev_supported_types/
```

*domain*

*bus*

*slot*

*function*

The domain, bus, slot, and function of the GPU, without the `0x` prefix.

This example changes to the `mdev_supported_types` directory for the GPU with the domain `0000` and PCI device BDF `06:00.0`.

```
# cd /sys/bus/pci/devices/0000\:06\:00.0/mdev_supported_types/
```

2. Find out which subdirectory of `mdev_supported_types` contains registration information for the vGPU type that you want to create.

```
# grep -l "vgpu-type" nvidia-*/name
```

*vgpu-type*

The vGPU type, for example, `M10-2Q`.

This example shows that the registration information for the `M10-2Q` vGPU type is contained in the `nvidia-41` subdirectory of `mdev_supported_types`.

```
# grep -l "M10-2Q" nvidia-*/name
nvidia-41/name
```

3. Confirm that you can create an instance of the vGPU type on the physical GPU.

```
# cat subdirectory/available_instances
```

*subdirectory*

The subdirectory that you found in the previous step, for example, `nvidia-41`.

The number of available instances must be at least 1. If the number is 0, either an instance of another vGPU type already exists on the physical GPU, or the maximum number of allowed instances has already been created.

This example shows that four more instances of the M10-2Q vGPU type can be created on the physical GPU.

```
# cat nvidia-41/available_instances
4
```

4. Generate a correctly formatted universally unique identifier (UUID) for the vGPU.

```
# uuidgen
aa618089-8b16-4d01-a136-25a0f3c73123
```

5. Write the UUID that you obtained in the previous step to the `create` file in the registration information directory for the vGPU type that you want to create.

```
# echo "uuid"> subdirectory/create
```

#### *uuid*

The UUID that you generated in the previous step, which will become the UUID of the vGPU that you want to create.

#### *subdirectory*

The registration information directory for the vGPU type that you want to create, for example, `nvidia-41`.

This example creates an instance of the M10-2Q vGPU type with the UUID

```
aa618089-8b16-4d01-a136-25a0f3c73123.
```

```
# echo "aa618089-8b16-4d01-a136-25a0f3c73123" > nvidia-41/create
```

An `mdev` device file for the vGPU is added to the parent physical device directory of the vGPU. The vGPU is identified by its UUID.

The `/sys/bus/mdev/devices/` directory contains a symbolic link to the `mdev` device file.

6. Confirm that the vGPU was created.

```
# ls -l /sys/bus/mdev/devices/
total 0
lrwxrwxrwx. 1 root root 0 Nov 24 13:33 aa618089-8b16-4d01-a136-25a0f3c73123
-> ../../../../devices/
pci0000:00/0000:00:03.0/0000:03:00.0/0000:04:09.0/0000:06:00.0/
aa618089-8b16-4d01-a136-25a0f3c73123
```

## 2.4.5. Adding One or More vGPUs to a Red Hat Enterprise Linux KVM VM

To support applications and workloads that are compute or graphics intensive, you can add multiple vGPUs to a single VM.

For details about which Red Hat Enterprise Linux KVM versions and NVIDIA vGPUs support the assignment of multiple vGPUs to a VM, see [Virtual GPU Software for Red Hat Enterprise Linux with KVM Release Notes](#).



Ensure that the following prerequisites are met:

- ▶ The VM to which you want to add the vGPUs is shut down.
- ▶ The vGPUs that you want to add have been created as explained in [Creating an NVIDIA vGPU on Red Hat Enterprise Linux KVM](#).

You can add vGPUs to a Red Hat Enterprise Linux KVM VM by using any of the following tools:

- ▶ The `virsh` command
- ▶ The QEMU command line

After adding vGPUs to a Red Hat Enterprise Linux KVM VM, start the VM.

```
# virsh start vm-name
```

*vm-name*

The name of the VM that you added the vGPUs to.

After the VM has booted, install the NVIDIA vGPU software graphics driver as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

### 2.4.5.1. Adding One or More vGPUs to a Red Hat Enterprise Linux KVM VM by Using `virsh`

1. In `virsh`, open for editing the XML file of the VM that you want to add the vGPU to.

```
# virsh edit vm-name
```

*vm-name*

The name of the VM to that you want to add the vGPUs to.

2. For each vGPU that you want to add to the VM, add a device entry in the form of an address element inside the source element to add the vGPU to the guest VM.

```
<device>
...
<hostdev mode='subsystem' type='mdev' model='vfio-pci'>
  <source>
    <address uuid='uuid'/>
  </source>
</hostdev>
</device>
```

*uuid*

The UUID that was assigned to the vGPU when the vGPU was created.

This example adds a device entry for the vGPU with the UUID `a618089-8b16-4d01-a136-25a0f3c73123`.

```
<device>
...
<hostdev mode='subsystem' type='mdev' model='vfio-pci'>
  <source>
    <address uuid='a618089-8b16-4d01-a136-25a0f3c73123'/>
  </source>
</hostdev>
```

```
</device>
```

This example adds device entries for two vGPUs with the following UUIDs:

- ▶ c73f1fa6-489e-4834-9476-d70dabd98c40
- ▶ 3b356d38-854e-48be-b376-00c72c7d119c

```
<device>
...
<hostdev mode='subsystem' type='mdev' model='vfio-pci'>
  <source>
    <address uuid='c73f1fa6-489e-4834-9476-d70dabd98c40' />
  </source>
</hostdev>
<hostdev mode='subsystem' type='mdev' model='vfio-pci'>
  <source>
    <address uuid='3b356d38-854e-48be-b376-00c72c7d119c' />
  </source>
</hostdev>
</device>
```

### 2.4.5.2. Adding One or More vGPUs to a Red Hat Enterprise Linux KVM VM by Using the QEMU Command Line

Add the following options to the QEMU command line:

- ▶ For each vGPU that you want to add to the VM, add one `-device` option in the following format:

```
-device vfio-pci,sysfsdev=/sys/bus/mdev/devices/vgpu-uuid
```

*vgpu-uuid*

The UUID that was assigned to the vGPU when the vGPU was created.

- ▶ Add a `-uuid` option to specify the VM as follows:

```
-uuid vm-uuid
```

*vm-uuid*

The UUID that was assigned to the VM when the VM was created.

This example adds the vGPU with the UUID `aa618089-8b16-4d01-a136-25a0f3c73123` to the VM with the UUID `ebb10a6e-7ac9-49aa-af92-f56bb8c65893`.

```
-device vfio-pci,sysfsdev=/sys/bus/mdev/devices/aa618089-8b16-4d01-
a136-25a0f3c73123 \
-uuid ebb10a6e-7ac9-49aa-af92-f56bb8c65893
```

This example adds device entries for two vGPUs with the following UUIDs:

- ▶ 676428a0-2445-499f-9bfd-65cd4a9bd18f
- ▶ 6c5954b8-5bc1-4769-b820-8099fe50aaba

The entries are added to the VM with the UUID `ec5e8ee0-657c-4db6-8775-da70e332c67e`.

```
-device vfio-pci,sysfsdev=/sys/bus/mdev/
devices/676428a0-2445-499f-9bfd-65cd4a9bd18f \
-device vfio-pci,sysfsdev=/sys/bus/mdev/devices/6c5954b8-5bc1-4769-
b820-8099fe50aaba \
-uuid ec5e8ee0-657c-4db6-8775-da70e332c67e
```

## 2.4.6. Setting vGPU Plugin Parameters on Red Hat Enterprise Linux KVM

Plugin parameters for a vGPU control the behavior of the vGPU, such as the frame rate limiter (FRL) configuration in frames per second or whether console virtual network computing (VNC) for the vGPU is enabled. The VM to which the vGPU is assigned is started with these parameters. If parameters are set for multiple vGPUs assigned to the same VM, the VM is started with the parameters assigned to each vGPU.

For each vGPU for which you want to set plugin parameters, perform this task in a Linux command shell on the Red Hat Enterprise Linux KVM host.

1. Change to the `nvidia` subdirectory of the `mdev` device directory that represents the vGPU.

```
# cd /sys/bus/mdev/devices/uuid/nvidia
```

*uuid*

The UUID of the vGPU, for example, `aa618089-8b16-4d01-a136-25a0f3c73123`.

2. Write the plugin parameters that you want to set to the `vgpu_params` file in the directory that you changed to in the previous step.

```
# echo "plugin-config-params" > vgpu_params
```

*plugin-config-params*

A comma-separated list of parameter-value pairs, where each pair is of the form ***parameter-name=value***.

This example disables frame rate limiting and console VNC for a vGPU.

```
# echo "frame_rate_limiter=0, disable_vnc=1" > vgpu_params
```

To clear any vGPU plugin parameters that were set previously, write a space to the `vgpu_params` file for the vGPU.

```
# echo " " > vgpu_params
```

## 2.4.7. Deleting a vGPU on Red Hat Enterprise Linux KVM

For each vGPU that you want to delete, perform this task in a Linux command shell on the Red Hat Enterprise Linux KVM host.

Before you begin, ensure that the following prerequisites are met:

- ▶ You have the domain, bus, slot, and function of the GPU where the vGPU that you want to delete resides. For instructions, see [Getting the BDF and Domain of a GPU on Red Hat Enterprise Linux KVM](#).
- ▶ The VM to which the vGPU is assigned is shut down.

1. Change to the `mdev_supported_types` directory for the physical GPU.

```
# cd /sys/class/mdev_bus/domain\:bus\:slot.function/mdev_supported_types/
```

*domain*

*bus*

*slot*

*function*

The domain, bus, slot, and function of the GPU, without the `0x` prefix.

This example changes to the `mdev_supported_types` directory for the GPU with the PCI device BDF `06:00.0`.

```
# cd /sys/bus/pci/devices/0000\:06\:00.0/mdev_supported_types/
```

2. Change to the subdirectory of `mdev_supported_types` that contains registration information for the vGPU.

```
# cd `find . -type d -name uuid`
```

*uuid*

The UUID of the vGPU, for example, `aa618089-8b16-4d01-a136-25a0f3c73123`.

3. Write the value `1` to the `remove` file in the registration information directory for the vGPU that you want to delete.

```
# echo "1" > remove
```



On the Red Hat Virtualization (RHV) kernel, if you try to remove a vGPU device while its VM is running, the vGPU device might not be removed even if the `remove` file has been written to successfully. To confirm that the vGPU device is removed, confirm that the UUID of the vGPU is not found in the `sysfs` file system.

## 2.4.8. Preparing a GPU Configured for Pass-Through for Use with vGPU

The mode in which a physical GPU is being used determines the Linux kernel module to which the GPU is bound. If you want to switch the mode in which a GPU is being used, you must unbind the GPU from its current kernel module and bind it to the kernel module for the new mode. After binding the GPU to the correct kernel module, you can then configure it for vGPU.

A physical GPU that is passed through to a VM is bound to the `vfio-pci` kernel module. A physical GPU that is bound to the `vfio-pci` kernel module can be used only for pass-through. To enable the GPU to be used for vGPU, the GPU must be unbound from `vfio-pci` kernel module and bound to the `nvidia` kernel module.

Before you begin, ensure that you have the domain, bus, slot, and function of the GPU that you are preparing for use with vGPU. For instructions, see [Getting the BDF and Domain of a GPU on Red Hat Enterprise Linux KVM](#).

1. Determine the kernel module to which the GPU is bound by running the `lspci` command with the `-k` option on the NVIDIA GPUs on your host.

```
# lspci -d 10de: -k
```

The `Kernel driver in use:` field indicates the kernel module to which the GPU is bound.

The following example shows that the NVIDIA Tesla M60 GPU with BDF `06:00.0` is bound to the `vfio-pci` kernel module and is being used for GPU pass through.

```
06:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M60]
(rev a1)
    Subsystem: NVIDIA Corporation Device 115e
    Kernel driver in use: vfio-pci
```

2. Unbind the GPU from `vfio-pci` kernel module.
  - a) Change to the `sysfs` directory that represents the `vfio-pci` kernel module.

```
# cd /sys/bus/pci/drivers/vfio-pci
```

- b) Write the domain, bus, slot, and function of the GPU to the `unbind` file in this directory.

```
# echo domain:bus:slot.function > unbind
```

*domain*

*bus*

*slot*

*function*

The domain, bus, slot, and function of the GPU, without a `0x` prefix.

This example writes the domain, bus, slot, and function of the GPU with the domain `0000` and PCI device BDF `06:00.0`.

```
# echo 0000:06:00.0 > unbind
```

3. Bind the GPU to the `nvidia` kernel module.
  - a) Change to the `sysfs` directory that contains the PCI device information for the physical GPU.

```
# cd /sys/bus/pci/devices/domain\:bus\:slot.function
```

*domain*

*bus*

*slot*

*function*

The domain, bus, slot, and function of the GPU, without a `0x` prefix.

This example changes to the `sysfs` directory that contains the PCI device information for the GPU with the domain `0000` and PCI device BDF `06:00.0`.

```
# cd /sys/bus/pci/devices/0000\:06\:00.0
```

- b) Write the kernel module name `nvidia` to the `driver_override` file in this directory.

```
# echo nvidia > driver_override
```

- c) Change to the `sysfs` directory that represents the `nvidia` kernel module.

```
# cd /sys/bus/pci/drivers/nvidia
```

- d) Write the domain, bus, slot, and function of the GPU to the `bind` file in this directory.

```
# echo domain:bus:slot.function > bind
```

*domain*

*bus*

*slot*

*function*

The domain, bus, slot, and function of the GPU, without a `0x` prefix.

This example writes the domain, bus, slot, and function of the GPU with the domain `0000` and PCI device BDF `06:00.0`.

```
# echo 0000:06:00.0 > bind
```

You can now configure the GPU with vGPU as explained in [Installing and Configuring the NVIDIA Virtual GPU Manager for Red Hat Enterprise Linux KVM or RHV](#).

## 2.4.9. NVIDIA vGPU Information in the `sysfs` File System

Information about the NVIDIA vGPU types supported by each physical GPU in a Red Hat Enterprise Linux KVM host is stored in the `sysfs` file system.

All physical GPUs on the host are registered with the `mdev` kernel module. Information about the physical GPUs and the vGPU types that can be created on each physical GPU is stored in directories and files under the `/sys/class/mdev_bus/` directory.

The `sysfs` directory for each physical GPU is at the following locations:

- ▶ `/sys/bus/pci/devices/`
- ▶ `/sys/class/mdev_bus/`

Both directories are a symbolic link to the real directory for PCI devices in the `sysfs` file system.

The organization the `sysfs` directory for each physical GPU is as follows:

```

/sys/class/mdev_bus/
|-parent-physical-device
|-mdev_supported_types
|  |-nvidia-vgputype-id
|     |-available_instances
|     |-create
|     |-description
|     |-device_api
|     |-devices
|     |-name

```

### ***parent-physical-device***

Each physical GPU on the host is represented by a subdirectory of the `/sys/class/mdev_bus/` directory.

The name of each subdirectory is as follows:

*domain\bus\slot.function*

*domain*, *bus*, *slot*, *function* are the domain, bus, slot, and function of the GPU, for example, `0000\06\00.0`.

Each directory is a symbolic link to the real directory for PCI devices in the `sysfs` file system. For example:

```

# ll /sys/class/mdev_bus/
total 0
lrwxrwxrwx. 1 root root 0 Dec 12 03:20 0000:05:00.0 -> ../../devices/pci0000:00/0000:00:03.0/0000:03:00.0/0000:04:08.0/0000:05:00.0
lrwxrwxrwx. 1 root root 0 Dec 12 03:20 0000:06:00.0 -> ../../devices/pci0000:00/0000:00:03.0/0000:03:00.0/0000:04:09.0/0000:06:00.0
lrwxrwxrwx. 1 root root 0 Dec 12 03:20 0000:07:00.0 -> ../../devices/pci0000:00/0000:00:03.0/0000:03:00.0/0000:04:10.0/0000:07:00.0
lrwxrwxrwx. 1 root root 0 Dec 12 03:20 0000:08:00.0 -> ../../devices/pci0000:00/0000:00:03.0/0000:03:00.0/0000:04:11.0/0000:08:00.0

```

### **mdev\_supported\_types**

After the Virtual GPU Manager is installed on the host and the host has been rebooted, a directory named `mdev_supported_types` is created under the `sysfs` directory for each physical GPU. The `mdev_supported_types` directory contains a subdirectory for each vGPU type that the physical GPU supports. The name of each subdirectory is `nvidia-vgputype-id`, where *vgputype-id* is an unsigned integer serial number. For example:

```

# ll mdev_supported_types/
total 0
drwxr-xr-x 3 root root 0 Dec 6 01:37 nvidia-35
drwxr-xr-x 3 root root 0 Dec 5 10:43 nvidia-36
drwxr-xr-x 3 root root 0 Dec 5 10:43 nvidia-37
drwxr-xr-x 3 root root 0 Dec 5 10:43 nvidia-38
drwxr-xr-x 3 root root 0 Dec 5 10:43 nvidia-39
drwxr-xr-x 3 root root 0 Dec 5 10:43 nvidia-40
drwxr-xr-x 3 root root 0 Dec 5 10:43 nvidia-41
drwxr-xr-x 3 root root 0 Dec 5 10:43 nvidia-42
drwxr-xr-x 3 root root 0 Dec 5 10:43 nvidia-43
drwxr-xr-x 3 root root 0 Dec 5 10:43 nvidia-44
drwxr-xr-x 3 root root 0 Dec 5 10:43 nvidia-45

```

### ***nvidia-vgputype-id***

Each directory represents an individual vGPU type and contains the following files and directories:

**available\_instances**

This file contains the number of instances of this vGPU type that can still be created. This file is updated any time a vGPU of this type is created on or removed from the physical GPU.



When a vGPU is created, the content of the `available_instances` for all other vGPU types on the physical GPU is set to 0. This behavior enforces the requirement that all vGPUs on a physical GPU must be of the same type.

**create**

This file is used for creating a vGPU instance. A vGPU instance is created by writing the UUID of the vGPU to this file. The file is write only.

**description**

This file contains the following details of the vGPU type:

- ▶ The maximum number of virtual display heads that the vGPU type supports
- ▶ The frame rate limiter (FRL) configuration in frames per second
- ▶ The frame buffer size in Mbytes
- ▶ The maximum resolution per display head
- ▶ The maximum number of vGPU instances per physical GPU

For example:

```
# cat description
num_heads=4, frl_config=60, framebuffer=2048M, max_resolution=4096x2160,
max_instance=4
```

**device\_api**

This file contains the string `vfio_pci` to indicate that a vGPU is a PCI device.

**devices**

This directory contains all the `mdev` devices that are created for the vGPU type.

For example:

```
# ll devices
total 0
lrwxrwxrwx 1 root root 0 Dec  6 01:52 aa618089-8b16-4d01-a136-25a0f3c73123
-> ../../../../aa618089-8b16-4d01-a136-25a0f3c73123
```

**name**

This file contains the name of the vGPU type. For example:

```
# cat name
GRID M10-2Q
```

## 2.5. Installing and Configuring the NVIDIA Virtual GPU Manager for VMware vSphere

You can use the NVIDIA Virtual GPU Manager for VMware vSphere to set up a VMware vSphere VM to use NVIDIA vGPU or VMware vSGA. The vGPU Manager vSphere Installation Bundles (VIBs) for VMware vSphere 6.5 and later provide vSGA



and vGPU functionality in a single VIB. For VMware vSphere 6.0, vSGA and vGPU functionality are provided in separate vGPU Manager VIBs.



Some servers, for example, the Dell R740, do not configure SR-IOV capability if the SR-IOV SBIOS setting is disabled on the server. If you are using the Tesla T4 GPU with VMware vSphere on such a server, you must ensure that the SR-IOV SBIOS setting is enabled on the server.

**For NVIDIA vGPU**, follow this sequence of instructions:

1. [Installing and Updating the NVIDIA Virtual GPU Manager for vSphere](#)
2. [Configuring VMware vMotion with vGPU for VMware vSphere](#)
3. [Changing the Default Graphics Type in VMware vSphere 6.5 and Later](#)
4. [Configuring a vSphere VM with NVIDIA vGPU](#)

After configuring a vSphere VM to use NVIDIA vGPU, you can install the NVIDIA vGPU software graphics driver for your guest OS and license any NVIDIA vGPU software licensed products that you are using.

**For VMware vSGA**, follow this sequence of instructions:

1. [Installing and Updating the NVIDIA Virtual GPU Manager for vSphere](#)
2. [Configuring a vSphere VM with VMware vSGA](#)

Installation of the NVIDIA vGPU software graphics driver for the guest OS is not required for vSGA.

## 2.5.1. Installing and Updating the NVIDIA Virtual GPU Manager for vSphere

The NVIDIA Virtual GPU Manager runs on the ESXi host. It is provided in the following formats:

- ▶ As a VIB file, which must be copied to the ESXi host and then installed
- ▶ As an offline bundle that you can import manually as explained in [Import Patches Manually](#) in the VMware vSphere documentation



**Caution** NVIDIA Virtual GPU Manager and Guest VM drivers must be matched from the same main driver branch. If you update vGPU Manager to a release from another driver branch, guest VMs will boot with vGPU disabled until their guest vGPU driver is updated to match the vGPU Manager version. Consult [Virtual GPU Software for VMware vSphere Release Notes](#) for further details.

### 2.5.1.1. Installing the NVIDIA Virtual GPU Manager Package for vSphere

To install the vGPU Manager VIB you need to access the ESXi host via the ESXi Shell or SSH. Refer to VMware's documentation on how to enable ESXi Shell or SSH for an ESXi host.



Before proceeding with the vGPU Manager installation make sure that all VMs are powered off and the ESXi host is placed in maintenance mode. Refer to VMware's documentation on how to place an ESXi host in maintenance mode.

1. Use the `esxcli` command to install the vGPU Manager package:

```
[root@esxi:~] esxcli software vib install -v directory/NVIDIA-vGPU-
VMware_ESXi_6.7_Host_Driver_440.53-1OEM.600.0.0.2159203.vib
Installation Result
  Message: Operation finished successfully.
  Reboot Required: false
  VIBs Installed: NVIDIA-vGPU-
VMware_ESXi_6.7_Host_Driver_440.53-1OEM.600.0.0.2159203
  VIBs Removed:
  VIBs Skipped:
```

*directory* is the absolute path to the directory that contains the VIB file. You must specify the absolute path even if the VIB file is in the current working directory.

2. Reboot the ESXi host and remove it from maintenance mode.

### 2.5.1.2. Updating the NVIDIA Virtual GPU Manager Package for vSphere

Update the vGPU Manager VIB package if you want to install a new version of NVIDIA Virtual GPU Manager on a system where an existing version is already installed.

To update the vGPU Manager VIB you need to access the ESXi host via the ESXi Shell or SSH. Refer to VMware's documentation on how to enable ESXi Shell or SSH for an ESXi host.



Before proceeding with the vGPU Manager update, make sure that all VMs are powered off and the ESXi host is placed in maintenance mode. Refer to VMware's documentation on how to place an ESXi host in maintenance mode.

1. Use the `esxcli` command to update the vGPU Manager package:

```
[root@esxi:~] esxcli software vib update -v directory/NVIDIA-vGPU-
VMware_ESXi_6.7_Host_Driver_440.53-1OEM.600.0.0.2159203.vib
Installation Result
  Message: Operation finished successfully.
  Reboot Required: false
  VIBs Installed: NVIDIA-vGPU-
VMware_ESXi_6.7_Host_Driver_440.53-1OEM.600.0.0.2159203
```



## 2.5.2. Configuring VMware vMotion with vGPU for VMware vSphere

NVIDIA vGPU software supports vGPU migration, which includes VMware vMotion and suspend-resume, for VMs that are configured with vGPU. To enable VMware vMotion with vGPU, an advanced **vCenter Server** setting must be enabled. However, suspend-resume for VMs that are configured with vGPU is enabled by default.

For details about which VMware vSphere versions, NVIDIA GPUs, and guest OS releases support vGPU migration, see *Virtual GPU Software for VMware vSphere Release Notes*.

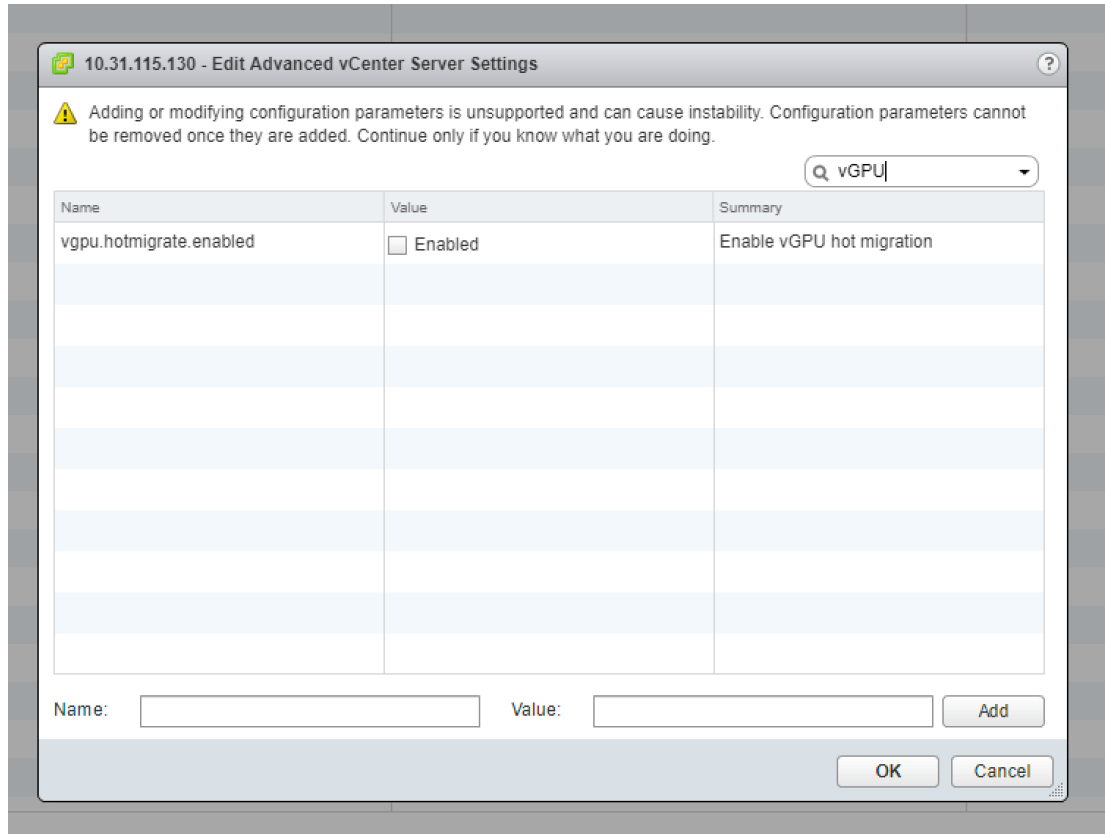
Before configuring VMware vMotion with vGPU for an ESXi host, ensure that the current NVIDIA Virtual GPU Manager for VMware vSphere package is installed on the host.

1. Log in to **vCenter Server** by using the **vSphere Web Client**.
2. In the **Hosts and Clusters** view, select the **vCenter Server** instance.



Ensure that you select the **vCenter Server** instance, not the **vCenter Server VM**.

3. Click the **Configure** tab.
4. In the **Settings** section, select **Advanced Settings** and click **Edit**.
5. In the **Edit Advanced vCenter Server Settings** window that opens, type **vGPU** in the search field.
6. When the **vgpu.hotmigrate.enabled** setting appears, set the **Enabled** option and click **OK**.



### 2.5.3. Changing the Default Graphics Type in VMware vSphere 6.5 and Later

The vGPU Manager VIBs for VMware vSphere 6.5 and later provide vSGA and vGPU functionality in a single VIB. After this VIB is installed, the default graphics type is Shared, which provides vSGA functionality. To enable vGPU support for VMs in VMware vSphere 6.5, you must change the default graphics type to Shared Direct. If you do not change the default graphics type, VMs to which a vGPU is assigned fail to start and the following error message is displayed:

```
The amount of graphics resource available in the parent resource pool is
insufficient for the operation.
```



If you are using a supported version of VMware vSphere earlier than 6.5, or are configuring a VM to use vSGA, omit this task.

Change the default graphics type **before** configuring vGPU. Output from the VM console in the VMware vSphere Web Client is not available for VMs that are running vGPU.

Before changing the default graphics type, ensure that the ESXi host is running and that all VMs on the host are powered off.

1. Log in to vCenter Server by using the vSphere Web Client.
2. In the navigation tree, select your ESXi host and click the **Configure** tab.
3. From the menu, choose **Graphics** and then click the **Host Graphics** tab.
4. On the **Host Graphics** tab, click **Edit**.

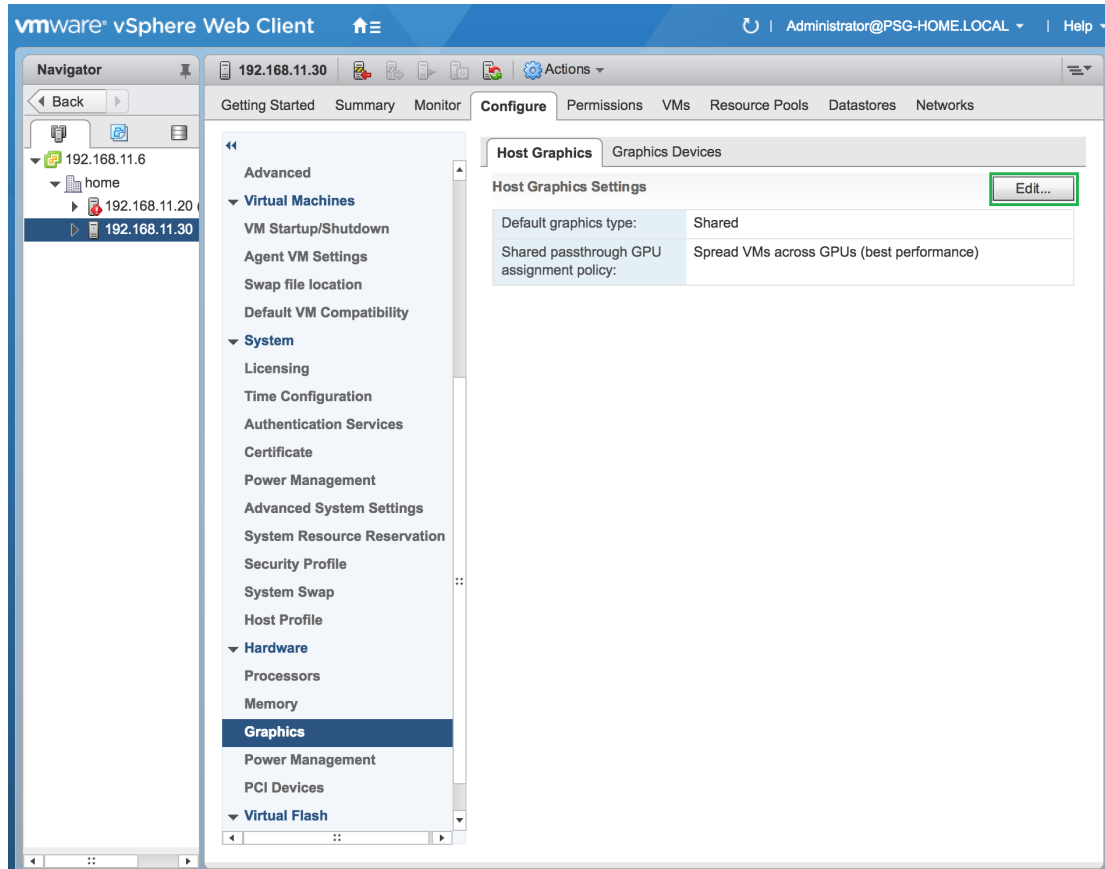


Figure 7 Shared default graphics type

5. In the **Edit Host Graphics Settings** dialog box that opens, select **Shared Direct** and click **OK**.

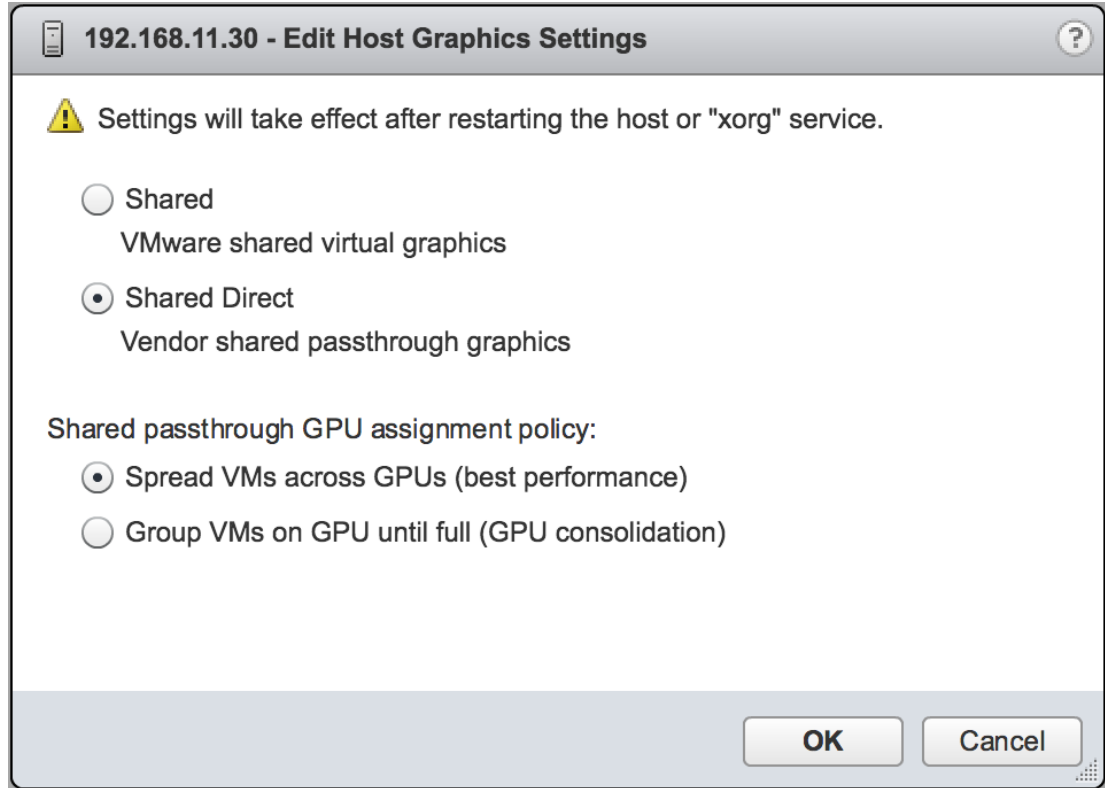
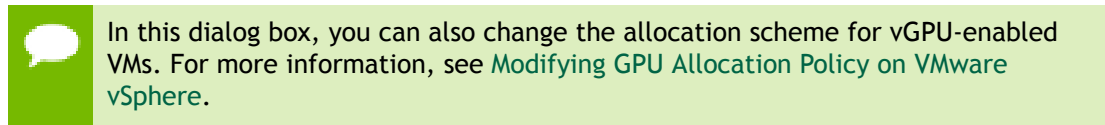


Figure 8 Host graphics settings for vGPU



After you click OK, the default graphics type changes to Shared Direct.

6. Click the **Graphics Devices** tab to verify the configured type of each physical GPU on which you want to configure vGPU.

The configured type of each physical GPU must be Shared Direct. For any physical GPU for which the configured type is Shared, change the configured type as follows:

- a) On the **Graphics Devices** tab, select the physical GPU and click the **Edit icon**.

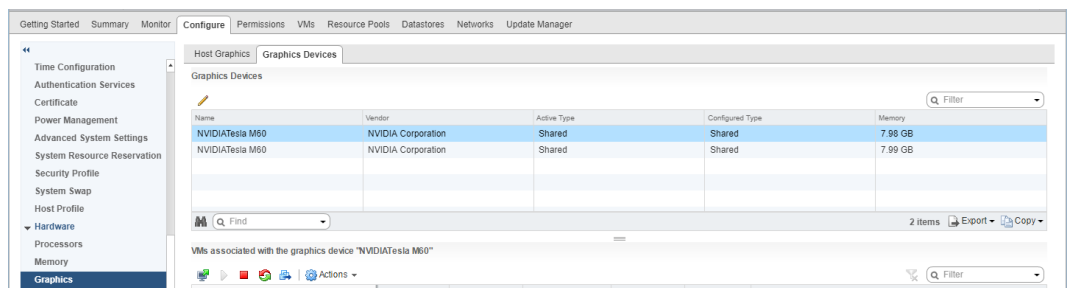


Figure 9 Shared graphics type

- b) In the **Edit Graphics Device Settings** dialog box that opens, select **Shared Direct** and click OK.

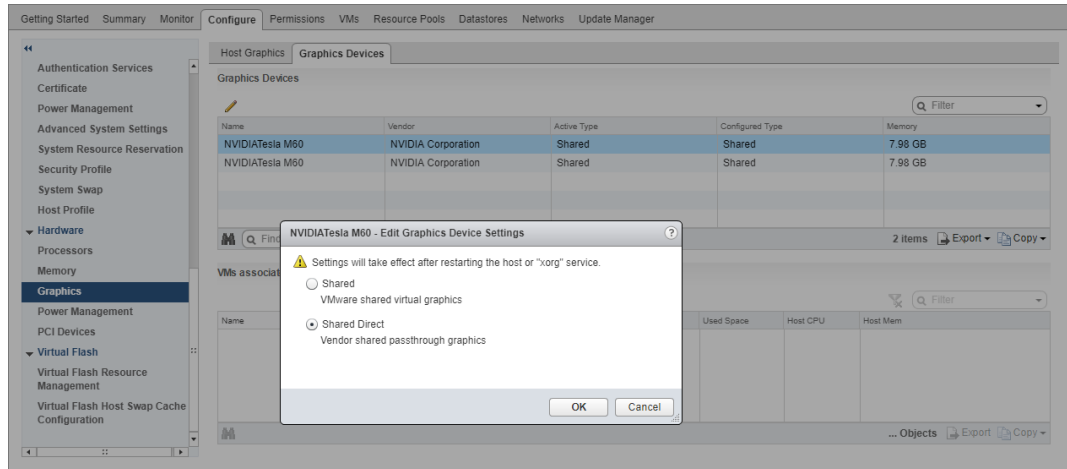


Figure 10 Graphics device settings for a physical GPU

- Restart the ESXi host **or** stop and restart the Xorg service and `nv-hostengine` on the ESXi host.

To stop and restart the Xorg service and `nv-hostengine`, perform these steps:

- Stop the Xorg service.

```
[root@esxi:~] /etc/init.d/xorg stop
```

- Stop `nv-hostengine`.

```
[root@esxi:~] nv-hostengine -t
```

- Wait for 1 second to allow `nv-hostengine` to stop.

- Start `nv-hostengine`.

```
[root@esxi:~] nv-hostengine -d
```

- Start the Xorg service.

```
[root@esxi:~] /etc/init.d/xorg start
```

- In the **Graphics Devices** tab of the VMware vCenter Web UI, confirm that the active type and the configured type of each physical GPU are Shared Direct.

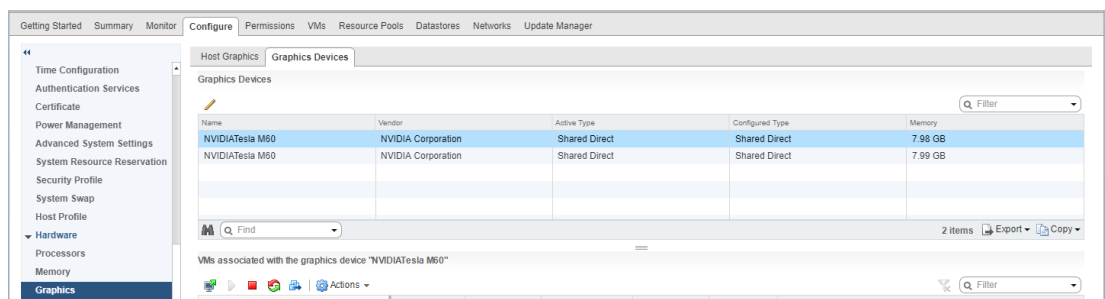


Figure 11 Shared direct graphics type

After changing the default graphics type, configure vGPU as explained in [Configuring a vSphere VM with NVIDIA vGPU](#).

See also the following topics in the VMware vSphere documentation:



- ▶ Log in to vCenter Server by Using the vSphere Web Client
- ▶ Configuring Host Graphics

## 2.5.4. Configuring a vSphere VM with NVIDIA vGPU

To support applications and workloads that are compute or graphics intensive, you can add multiple vGPUs to a single VM.

For details about which VMware vSphere versions and NVIDIA vGPUs support the assignment of multiple vGPUs to a VM, see *Virtual GPU Software for VMware vSphere Release Notes*. If you upgraded to VMware vSphere 6.7 Update 3 from an earlier version and are using VMs that were created with that version, change the VM compatibility to **vSphere 6.7 Update 2 and later**. For details, see *Virtual Machine Compatibility* in the VMware documentation.

If you are adding multiple vGPUs to a single VM, perform this task for each vGPU that you want to add to the VM.



**Caution** Output from the VM console in the VMware vSphere Web Client is not available for VMs that are running vGPU. Make sure that you have installed an alternate means of accessing the VM (such as VMware Horizon or a VNC server) before you configure vGPU.

VM console in vSphere Web Client will become active again once the vGPU parameters are removed from the VM's configuration.



If you are configuring a VM to use VMware vSGA, omit this task.

1. Open the vCenter Web UI.
2. In the vCenter Web UI, right-click the VM and choose **Edit Settings**.
3. Click the **Virtual Hardware** tab.
4. In the **New device** list, select **Shared PCI Device** and click **Add**.

The **PCI device** field should be auto-populated with **NVIDIA GRID vGPU**.

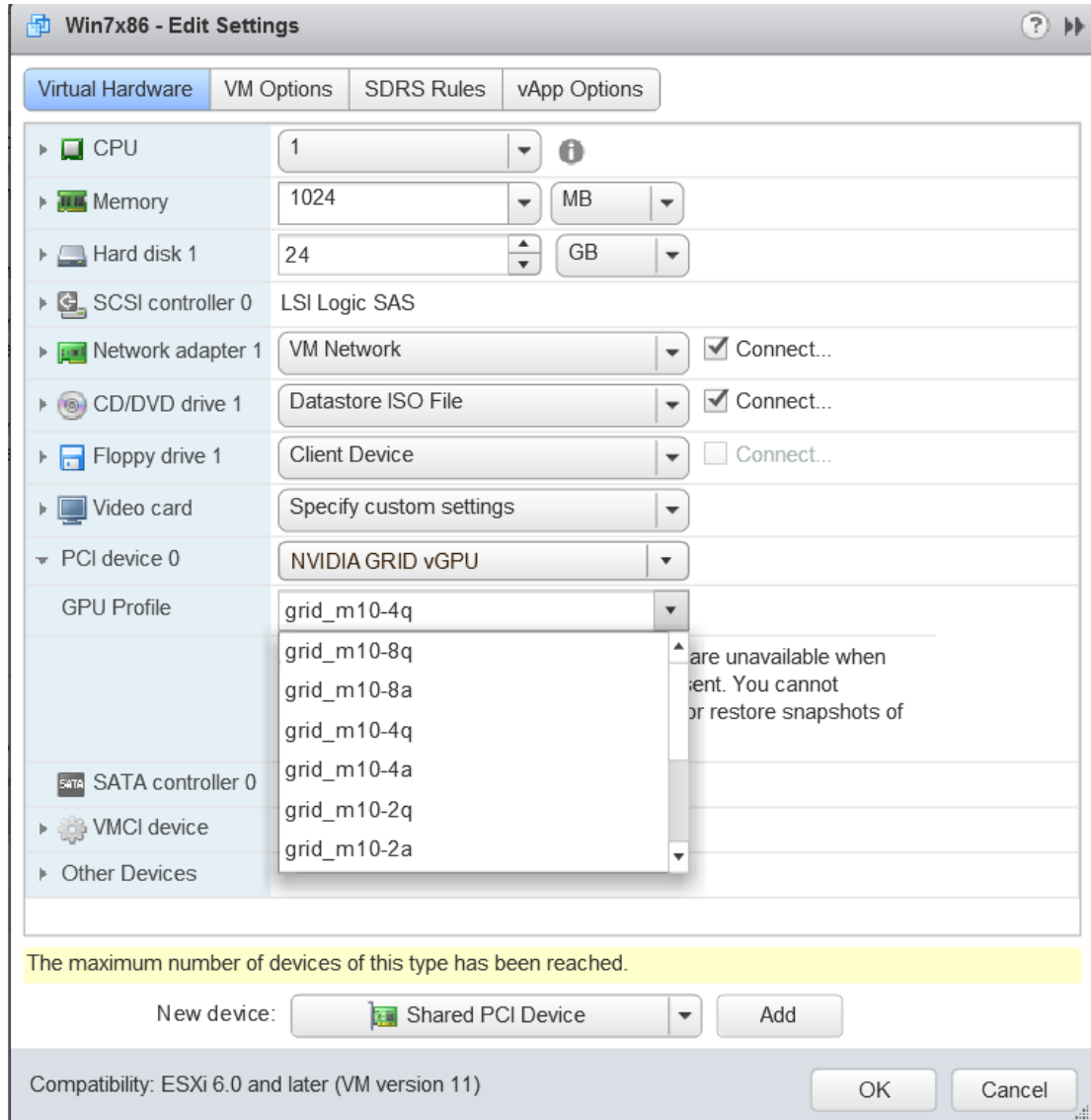


Figure 12 VM settings for vGPU

5. From the **GPU Profile** drop-down menu, choose the type of vGPU you want to configure and click **OK**.
6. Ensure that VMs running vGPU have all their memory reserved:
  - a) Select **Edit virtual machine settings** from the vCenter Web UI.
  - b) Expand the **Memory** section and click **Reserve all guest memory (All locked)**.

After you have configured a vSphere VM with a vGPU, start the VM. VM console in vSphere Web Client is not supported in this vGPU release. Therefore, use VMware Horizon or VNC to access the VM's desktop.

After the VM has booted, install the NVIDIA vGPU software graphics driver as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

## 2.5.5. Configuring a vSphere VM with VMware vSGA

Virtual Shared Graphics Acceleration (vSGA) is a feature of VMware vSphere that enables multiple virtual machines to share the physical GPUs on ESXi hosts.



If you are configuring a VM to use NVIDIA vGPU, omit this task.

Before configuring a vSphere VM with vSGA, ensure that these prerequisites are met:

- ▶ VMware tools are installed on the VM.
  - ▶ The VM is powered off.
  - ▶ The NVIDIA Virtual GPU Manager package for vSphere is installed.
1. Open the vCenter Web UI.
  2. In the vCenter Web UI, right-click the VM and choose **Edit Settings**.
  3. Click the **Virtual Hardware** tab.
  4. In the device list, expand the **Video card** node and set the following options:
    - a) Select the **Enable 3D support** option.
    - b) Set the **3D Renderer** to **Hardware**.

For more information, see [Configure 3D Graphics and Video Cards](#) in the VMware Horizon documentation.

5. Start the VM.
6. After the VM has booted, verify that the VM has been configured correctly with vSGA.
  - a) Under the **Display Adapter** section of **Device Manager**, confirm that **VMware SVGA 3D** is listed.
  - b) Verify that the virtual machine is using the GPU card.

```
# gpudev
```

The output from the command is similar to the following example for a VM named `samplevm1`:

```
Xserver unix:0, GPU maximum memory 4173824KB
pid 21859, VM samplevm1, reserved 131072KB of GPU memory.
GPU memory left 4042752KB.
```

The memory reserved for the VM and the GPU maximum memory depend on the GPU installed in the host and the 3D memory allocated to the virtual machine.

Installation of the NVIDIA vGPU software graphics driver for the guest OS is not required for vSGA.

## 2.6. Disabling and Enabling ECC Memory

Some GPUs that support NVIDIA vGPU software support error correcting code (ECC) memory with NVIDIA vGPU. ECC memory improves data integrity by detecting and handling double-bit errors. However, not all GPUs, vGPU types, and hypervisor software versions support ECC memory with NVIDIA vGPU.

On GPUs that support ECC memory with NVIDIA vGPU, ECC memory is supported with C-series and Q-series vGPUs, but not with A-series and B-series vGPUs. Although A-series and B-series vGPUs start on physical GPUs on which ECC memory is enabled, enabling ECC with vGPUs that do not support it might incur some costs.

On physical GPUs that do not have HBM2 memory, the amount of frame buffer that is usable by vGPUs is reduced. All types of vGPU are affected, not just vGPUs that support ECC memory.

The effects of enabling ECC memory on a physical GPU are as follows:

- ▶ ECC memory is exposed as a feature on all supported vGPUs on the physical GPU.
- ▶ In VMs that support ECC memory, ECC memory is enabled, with the option to disable ECC in the VM.
- ▶ ECC memory can be enabled or disabled for individual VMs. Enabling or disabling ECC memory in a VM does not affect the amount of frame buffer that is usable by vGPUs.

GPUs based on the Pascal GPU architecture and later GPU architectures support ECC memory with NVIDIA vGPU. These GPUs are supplied with ECC memory enabled.

Tesla M60 and M6 GPUs support ECC memory when used without GPU virtualization, but NVIDIA vGPU does not support ECC memory with these GPUs. In graphics mode, these GPUs are supplied with ECC memory disabled by default.

Some hypervisor software versions do not support ECC memory with NVIDIA vGPU.

If you are using a hypervisor software version or GPU that does not support ECC memory with NVIDIA vGPU and ECC memory is enabled, NVIDIA vGPU fails to start. In this situation, you must ensure that ECC memory is disabled on all GPUs if you are using NVIDIA vGPU.

### 2.6.1. Disabling ECC Memory

If ECC memory is unsuitable for your workloads but is enabled on your GPUs, disable it. You must also ensure that ECC memory is disabled on all GPUs if you are using NVIDIA vGPU with a hypervisor software version or a GPU that does not support ECC memory with NVIDIA vGPU. If your hypervisor software version or GPU does not support ECC memory and ECC memory is enabled, NVIDIA vGPU fails to start.

Where to perform this task from depends on whether you are changing ECC memory settings for a physical GPU or a vGPU.

- ▶ For a physical GPU, perform this task from the hypervisor host.

- ▶ For a vGPU, perform this task from the VM to which the vGPU is assigned.



ECC memory must be enabled on the physical GPU on which the vGPUs reside.

Before you begin, ensure that NVIDIA Virtual GPU Manager is installed on your hypervisor. If you are changing ECC memory settings for a vGPU, also ensure that the NVIDIA vGPU software graphics driver is installed in the VM to which the vGPU is assigned.

1. Use `nvidia-smi` to list the status of all physical GPUs or vGPUs, and check for ECC noted as enabled.

```
# nvidia-smi -q
=====NVSMI LOG=====
Timestamp                : Tue Feb 18 18:36:45 2020
Driver Version           : 440.53
Attached GPUs            : 1
GPU 0000:02:00.0
[...]
    Ecc Mode
      Current             : Enabled
      Pending             : Enabled
[...]
```

2. Change the ECC status to off for each GPU for which ECC is enabled.

- ▶ If you want to change the ECC status to off for all GPUs on your host machine or vGPUs assigned to the VM, run this command:

```
# nvidia-smi -e 0
```

- ▶ If you want to change the ECC status to off for a specific GPU or vGPU, run this command:

```
# nvidia-smi -i id -e 0
```

*id* is the index of the GPU or vGPU as reported by `nvidia-smi`.

This example disables ECC for the GPU with index `0000:02:00.0`.

```
# nvidia-smi -i 0000:02:00.0 -e 0
```

3. Reboot the host or restart the VM.

4. Confirm that ECC is now disabled for the GPU or vGPU.

```
# nvidia-smi -q
=====NVSMI LOG=====
Timestamp                : Tue Feb 18 18:37:53 2020
Driver Version           : 440.53
Attached GPUs            : 1
GPU 0000:02:00.0
```

```
[...]
Ecc Mode
  Current           : Disabled
  Pending          : Disabled
[...]
```

If you later need to enable ECC on your GPUs or vGPUs, follow the instructions in [Enabling ECC Memory](#).

## 2.6.2. Enabling ECC Memory

If ECC memory is suitable for your workloads and is supported by your hypervisor software and GPUs, but is disabled on your GPUs or vGPUs, enable it.

Where to perform this task from depends on whether you are changing ECC memory settings for a physical GPU or a vGPU.

- ▶ For a physical GPU, perform this task from the hypervisor host.
- ▶ For a vGPU, perform this task from the VM to which the vGPU is assigned.



ECC memory must be enabled on the physical GPU on which the vGPUs reside.

Before you begin, ensure that NVIDIA Virtual GPU Manager is installed on your hypervisor. If you are changing ECC memory settings for a vGPU, also ensure that the NVIDIA vGPU software graphics driver is installed in the VM to which the vGPU is assigned.

1. Use `nvidia-smi` to list the status of all physical GPUs or vGPUs, and check for ECC noted as disabled.

```
# nvidia-smi -q
=====NVSMI LOG=====
Timestamp                : Tue Feb 18 18:36:45 2020
Driver Version           : 440.53
Attached GPUs            : 1
GPU 0000:02:00.0
[...]
Ecc Mode
  Current                 : Disabled
  Pending                 : Disabled
[...]
```

2. Change the ECC status to on for each GPU or vGPU for which ECC is enabled.
  - ▶ If you want to change the ECC status to on for all GPUs on your host machine or vGPUs assigned to the VM, run this command:

```
# nvidia-smi -e 1
```

- ▶ If you want to change the ECC status to on for a specific GPU or vGPU, run this command:

```
# nvidia-smi -i id -e 1
```

*id* is the index of the GPU or vGPU as reported by `nvidia-smi`.

This example enables ECC for the GPU with index `0000:02:00.0`.

```
# nvidia-smi -i 0000:02:00.0 -e 1
```

3. Reboot the host or restart the VM.
4. Confirm that ECC is now enabled for the GPU or vGPU.

```
# nvidia-smi -q
=====NVSMI LOG=====
Timestamp                : Tue Feb 18 18:37:53 2020
Driver Version           : 440.53
Attached GPUs            : 1
GPU 0000:02:00.0
[...]

  Ecc Mode
    Current                : Enabled
    Pending                 : Enabled
[...]
```

If you later need to disable ECC on your GPUs or vGPUs, follow the instructions in [Disabling ECC Memory](#).

# Chapter 3.

## USING GPU PASS-THROUGH

GPU pass-through is used to directly assign an entire physical GPU to one VM, bypassing the NVIDIA Virtual GPU Manager. In this mode of operation, the GPU is accessed exclusively by the NVIDIA driver running in the VM to which it is assigned; the GPU is not shared among VMs.

In pass-through mode, GPUs based on NVIDIA GPU architectures **after** the Maxwell architecture support error-correcting code (ECC).

GPU pass-through can be used in a server platform alongside NVIDIA vGPU, with some restrictions:

- ▶ A physical GPU can host NVIDIA vGPUs, or can be used for pass-through, but cannot do both at the same time. Some hypervisors, for example VMware vSphere ESXi, require a host reboot to change a GPU from pass-through mode to vGPU mode.
- ▶ A single VM cannot be configured for both vGPU and GPU pass-through at the same time.
- ▶ The performance of a physical GPU passed through to a VM can be monitored only from within the VM itself. Such a GPU cannot be monitored by tools that operate through the hypervisor, such as XenCenter or `nvidia-smi` (see [Monitoring GPU Performance](#)).
- ▶ The following BIOS settings must be enabled on your server platform:
  - ▶ VT-D/IOMMU
  - ▶ SR-IOV in **Advanced Options**



If you are configuring a GPU for pass-through, do **not** install the NVIDIA Virtual GPU Manager.

### 3.1. Using GPU Pass-Through on Citrix Hypervisor

You can configure a GPU for pass-through on Citrix Hypervisor by using XenCenter or by using the `xe` command.



The following additional restrictions apply when GPU pass-through is used in a server platform alongside NVIDIA vGPU:

- ▶ The performance of a physical GPU passed through to a VM cannot be monitored through XenCenter.
- ▶ `nvidia-smi` in `dom0` no longer has access to the GPU.
- ▶ Pass-through GPUs do not provide console output through XenCenter's **VM Console** tab. Use a remote graphics connection directly into the VM to access the VM's OS.

### 3.1.1. Configuring a VM for GPU Pass Through by Using XenCenter

Select the **Pass-through whole GPU** option as the GPU type in the VM's Properties:

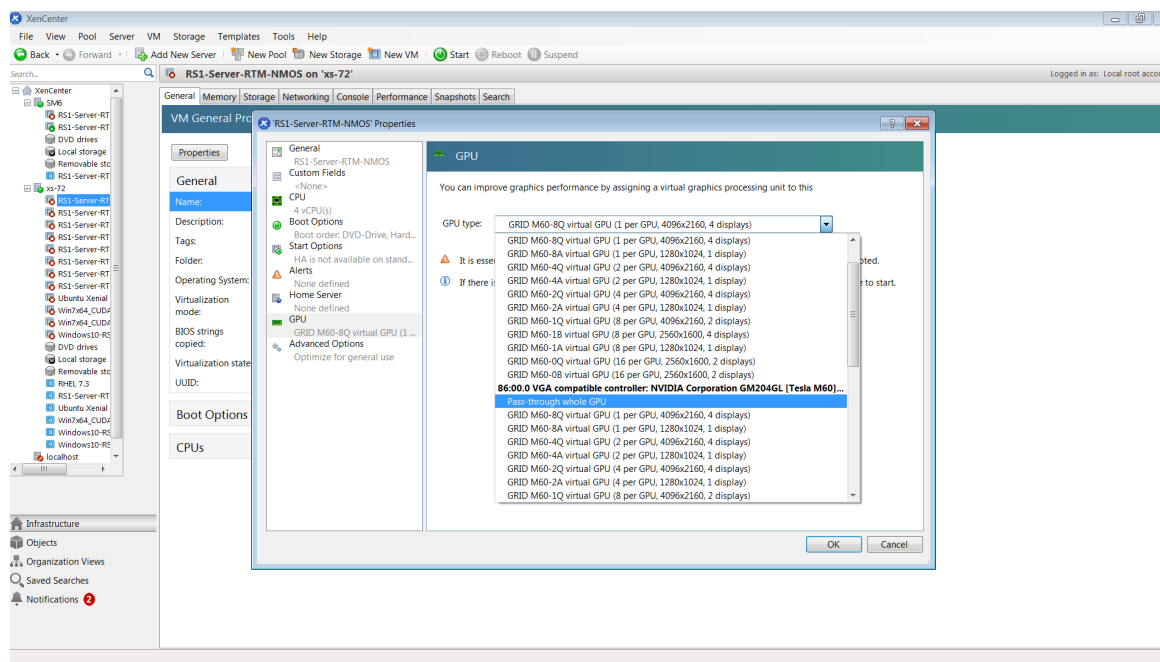


Figure 13 Using XenCenter to configure a pass-through GPU

After configuring a Citrix Hypervisor VM for GPU pass through, install the NVIDIA graphics driver in the guest OS on the VM as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

### 3.1.2. Configuring a VM for GPU Pass Through by Using xe

Create a `vgpu` object with the `passthrough` vGPU type:

```
[root@xenserver ~]# xe vgpu-type-list model-name="passthrough"
uuid ( RO)                : fa50b0f0-9705-6c59-689e-ea62a3d35237
vendor-name ( RO)        :
model-name ( RO)         : passthrough
```

```

framebuffer-size ( RO): 0

[root@xenserver ~]# xe vgpu-create vm-uuid=753e77a9-e10d-7679-f674-65c078abb2eb
vgpu-type-uuid=fa50b0f0-9705-6c59-689e-ea62a3d35237 gpu-group-
uuid=585877ef-5a6c-66af-fc56-7bd525bdc2f6
6aa530ec-8f27-86bd-b8e4-fe4fde8f08f9
[root@xenserver ~]#

```



**Caution** Do not assign pass-through GPUs using the legacy `other-config:pci` parameter setting. This mechanism is not supported alongside the XenCenter UI and `xe vgpu` mechanisms, and attempts to use it may lead to undefined results.

After configuring a Citrix Hypervisor VM for GPU pass through, install the NVIDIA graphics driver in the guest OS on the VM as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

## 3.2. Using GPU Pass-Through on Red Hat Enterprise Linux KVM

You can configure a GPU for pass-through on Red Hat Enterprise Linux Kernel-based Virtual Machine (KVM) by using any of the following tools:

- ▶ The **Virtual Machine Manager** (`virt-manager`) graphical tool
- ▶ The `virsh` command
- ▶ The QEMU command line

Before configuring a GPU for pass-through on Red Hat Enterprise Linux KVM, ensure that the following prerequisites are met:

- ▶ Red Hat Enterprise Linux KVM is installed.
- ▶ A virtual disk has been created.



Do not create any virtual disks in `/root`.

- ▶ A virtual machine has been created.

### 3.2.1. Configuring a VM for GPU Pass-Through by Using Virtual Machine Manager (`virt-manager`)

For more information about using **Virtual Machine Manager**, see the following topics in the documentation for Red Hat Enterprise Linux 7:

- ▶ [Managing Guests with the Virtual Machine Manager \(`virt-manager`\)](#)
- ▶ [Starting `virt-manager`](#)
- ▶ [Assigning a PCI Device with `virt-manager`](#)

1. Start `virt-manager`.

2. In the `virt-manager` main window, select the VM that you want to configure for pass-through.
3. From the **Edit** menu, choose **Virtual Machine Details**.
4. In the virtual machine hardware information window that opens, click **Add Hardware**.
5. In the **Add New Virtual Hardware** dialog box that opens, in the hardware list on the left, select **PCI Host Device**.
6. From the **Host Device** list that appears, select the GPU that you want to assign to the VM and click **Finish**.

If you want to remove a GPU from the VM to which it is assigned, in the virtual machine hardware information window, select the GPU and click **Remove**.

After configuring a Red Hat Enterprise Linux KVM for GPU pass through, install the NVIDIA graphics driver in the guest OS on the VM as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

### 3.2.2. Configuring a VM for GPU Pass-Through by Using `virsh`

For more information about using `virsh`, see the following topics in the documentation for Red Hat Enterprise Linux 7:

- ▶ [Managing Guest Virtual Machines with `virsh`](#)
- ▶ [Assigning a PCI Device with `virsh`](#)

1. Verify that the `vfio-pci` module is loaded.

```
# lsmod | grep vfio-pci
```

2. Obtain the PCI device bus/device/function (BDF) of the GPU that you want to assign in pass-through mode to a VM.

```
# lspci | grep NVIDIA
```

The NVIDIA GPUs listed in this example have the PCI device BDFs `85:00.0` and `86:00.0`.

```
# lspci | grep NVIDIA
85:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M60]
(rev a1)
86:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M60]
(rev a1)
```

3. Obtain the full identifier of the GPU from its PCI device BDF.

```
# virsh nodedev-list --cap pci | grep transformed-bdf
```

*transformed-bdf*

The PCI device BDF of the GPU with the colon and the period replaced with underscores, for example, `85_00_0`.

This example obtains the full identifier of the GPU with the PCI device BDF 85:00.0.

```
# virsh nodedev-list --cap pci | grep 85_00_0
pci_0000_85_00_0
```

4. Obtain the domain, bus, slot, and function of the GPU.

```
virsh nodedev-dumpxml full-identifier | egrep 'domain|bus|slot|function'
```

#### *full-identifier*

The full identifier of the GPU that you obtained in the previous step, for example, pci\_0000\_85\_00\_0.

This example obtains the domain, bus, slot, and function of the GPU with the PCI device BDF 85:00.0.

```
# virsh nodedev-dumpxml pci_0000_85_00_0 | egrep 'domain|bus|slot|function'
<domain>0x0000</domain>
<bus>0x85</bus>
<slot>0x00</slot>
<function>0x0</function>
  <address domain='0x0000' bus='0x85' slot='0x00' function='0x0' />
```

5. In `virsh`, open for editing the XML file of the VM that you want to assign the GPU to.

```
# virsh edit vm-name
```

#### *vm-name*

The name of the VM to that you want to assign the GPU to.

6. Add a device entry in the form of an address element inside the source element to assign the GPU to the guest VM.

You can optionally add a second address element after the source element to set a fixed PCI device BDF for the GPU in the guest operating system.

```
<hostdev mode='subsystem' type='pci' managed='yes'>
  <source>
    <address domain='domain' bus='bus' slot='slot' function='function' />
  </source>
  <address type='pci' domain='0x0000' bus='0x00' slot='0x05'
function='0x0' />
</hostdev>
```

#### *domain*

#### *bus*

#### *slot*

#### *function*

The domain, bus, slot, and function of the GPU, which you obtained in the previous step.

This example adds a device entry for the GPU with the PCI device BDF 85:00.0 and fixes the BDF for the GPU in the guest operating system.

```
<hostdev mode='subsystem' type='pci' managed='yes'>
  <source>
    <address domain='0x0000' bus='0x85' slot='0x00' function='0x0' />
  </source>
  <address type='pci' domain='0x0000' bus='0x00' slot='0x05'
function='0x0' />
```

```
</hostdev>
```

7. Start the VM that you assigned the GPU to.

```
# virsh start vm-name
```

*vm-name*

The name of the VM that you assigned the GPU to.

After configuring a Red Hat Enterprise Linux KVM for GPU pass through, install the NVIDIA graphics driver in the guest OS on the VM as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

### 3.2.3. Configuring a VM for GPU Pass-Through by Using the QEMU Command Line

1. Obtain the PCI device bus/device/function (BDF) of the GPU that you want to assign in pass-through mode to a VM.

```
# lspci | grep NVIDIA
```

The NVIDIA GPUs listed in this example have the PCI device BDFs 85:00.0 and 86:00.0.

```
# lspci | grep NVIDIA
85:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M60]
(rev a1)
86:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M60]
(rev a1)
```

2. Add the following option to the QEMU command line:

```
-device vfio-pci,host=bdf
```

*bdf*

The PCI device BDF of the GPU that you want to assign in pass-through mode to a VM, for example, 85:00.0.

This example assigns the GPU with the PCI device BDF 85:00.0 in pass-through mode to a VM.

```
-device vfio-pci,host=85:00.0
```

After configuring a Red Hat Enterprise Linux KVM for GPU pass through, install the NVIDIA graphics driver in the guest OS on the VM as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

### 3.2.4. Preparing a GPU Configured for vGPU for Use in Pass-Through Mode

The mode in which a physical GPU is being used determines the Linux kernel module to which the GPU is bound. If you want to switch the mode in which a GPU is being used, you must unbind the GPU from its current kernel module and bind it to the kernel module for the new mode. After binding the GPU to the correct kernel module, you can then configure it for pass-through.

When the Virtual GPU Manager is installed on a Red Hat Enterprise Linux KVM host, the physical GPUs on the host are bound to the `nvidia` kernel module. A physical GPU that is bound to the `nvidia` kernel module can be used only for vGPU. To enable the GPU to be passed through to a VM, the GPU must be unbound from `nvidia` kernel module and bound to the `vfiopci` kernel module.

Before you begin, ensure that you have the domain, bus, slot, and function of the GPU that you are preparing for use in pass-through mode. For instructions, see [Getting the BDF and Domain of a GPU on Red Hat Enterprise Linux KVM](#).

1. Determine the kernel module to which the GPU is bound by running the `lspci` command with the `-k` option on the NVIDIA GPUs on your host.

```
# lspci -d 10de: -k
```

The `Kernel driver in use:` field indicates the kernel module to which the GPU is bound.

The following example shows that the NVIDIA Tesla M60 GPU with BDF `06:00.0` is bound to the `nvidia` kernel module and is being used for vGPU.

```
06:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M60]
(rev a1)
Subsystem: NVIDIA Corporation Device 115e
Kernel driver in use: nvidia
```

2. To ensure that no clients are using the GPU, acquire the unbind lock of the GPU.
  - a) Ensure that no VM is running to which a vGPU on the physical GPU is assigned and that no process running on the host is using that GPU.

Processes on the host that use the GPU include the `nvidia-smi` command and all processes based on the NVIDIA Management Library (NVML).
  - b) Change to the directory in the `proc` file system that represents the GPU.

```
# cd /proc/driver/nvidia/gpus/domain\:bus\:slot.function
```

*domain*

*bus*

*slot*

*function*

The domain, bus, slot, and function of the GPU, without a `0x` prefix.

This example changes to the directory in the `proc` file system that represents the GPU with the domain `0000` and PCI device BDF `06:00.0`.

```
# cd /proc/driver/nvidia/gpus/0000\:06\:00.0
```

- c) Write the value `1` to the `unbindLock` file in this directory.

```
# echo 1 > unbindLock
```

- d) Confirm that the `unbindLock` file now contains the value `1`.

```
# cat unbindLock
1
```

If the `unbindLock` file contains the value 0, the unbind lock could not be acquired because a process or client is using the GPU.

3. Unbind the GPU from `nvidia` kernel module.

- a) Change to the `sysfs` directory that represents the `nvidia` kernel module.

```
# cd /sys/bus/pci/drivers/nvidia
```

- b) Write the domain, bus, slot, and function of the GPU to the `unbind` file in this directory.

```
# echo domain:bus:slot.function > unbind
```

*domain*

*bus*

*slot*

*function*

The domain, bus, slot, and function of the GPU, without a `0x` prefix.

This example writes the domain, bus, slot, and function of the GPU with the domain `0000` and PCI device BDF `06:00.0`.

```
# echo 0000:06:00.0 > unbind
```

4. Bind the GPU to the `vfio-pci` kernel module.

- a) Change to the `sysfs` directory that contains the PCI device information for the physical GPU.

```
# cd /sys/bus/pci/devices/domain\:bus\:slot.function
```

*domain*

*bus*

*slot*

*function*

The domain, bus, slot, and function of the GPU, without a `0x` prefix.

This example changes to the `sysfs` directory that contains the PCI device information for the GPU with the domain `0000` and PCI device BDF `06:00.0`.

```
# cd /sys/bus/pci/devices/0000\:06\:00.0
```

- b) Write the kernel module name `vfio-pci` to the `driver_override` file in this directory.

```
# echo vfio-pci > driver_override
```

- c) Change to the `sysfs` directory that represents the `nvidia` kernel module.

```
# cd /sys/bus/pci/drivers/vfio-pci
```

- d) Write the domain, bus, slot, and function of the GPU to the `bind` file in this directory.

```
# echo domain:bus:slot.function > bind
```

*domain*

*bus*

*slot*

*function*

The domain, bus, slot, and function of the GPU, without a 0x prefix.

This example writes the domain, bus, slot, and function of the GPU with the domain 0000 and PCI device BDF 06:00.0.

```
# echo 0000:06:00.0 > bind
```

- e) Change back to the `sysfs` directory that contains the PCI device information for the physical GPU.

```
# cd /sys/bus/pci/devices/domain:bus:slot.function
```

- f) Clear the content of the `driver_override` file in this directory.

```
# echo > driver_override
```

You can now configure the GPU for use in pass-through mode as explained in [Using GPU Pass-Through on Red Hat Enterprise Linux KVM](#).

## 3.3. Using GPU Pass-Through on Microsoft Windows Server

On supported versions of Microsoft Windows Server with Hyper-V role, you can use Discrete Device Assignment (DDA) to enable a VM to access a GPU directly.

### 3.3.1. Assigning a GPU to a VM on Microsoft Windows Server with Hyper-V

Perform this task in Windows PowerShell. If you do not know the location path of the GPU that you want to assign to a VM, use **Device Manager** to obtain it.

Ensure that the following prerequisites are met:

- ▶ Windows Server with Desktop Experience and the Hyper-V role are installed and configured on your server platform, and a VM is created.

For instructions, refer to the following articles on the Microsoft technical documentation site:

- ▶ [Install Server with Desktop Experience](#)
- ▶ [Install the Hyper-V role on Windows Server](#)
- ▶ [Create a virtual switch for Hyper-V virtual machines](#)
- ▶ [Create a virtual machine in Hyper-V](#)
- ▶ The guest OS is installed in the VM.
- ▶ The VM is powered off.



1. Obtain the location path of the GPU that you want to assign to a VM.
  - a) In the device manager, context-click the GPU and from the menu that pops up, choose **Properties**.
  - b) In the **Properties** window that opens, click the **Details** tab and in the **Properties** drop-down list, select **Location paths**.

An example location path is as follows:

```
PCIROOT(80)#PCI(0200)#PCI(0000)#PCI(1000)#PCI(0000)
```

2. Dismount the GPU from host to make it unavailable to the host so that it can be used solely by the VM.

```
Dismount-VMHostAssignableDevice -LocationPath gpu-device-location -force
```

*gpu-device-location*

The location path of the GPU that you obtained in the previous step.

This example dismounts the GPU at the location path

```
PCIROOT(80)#PCI(0200)#PCI(0000)#PCI(1000)#PCI(0000).
```

```
Dismount-VMHostAssignableDevice -LocationPath  
"PCIROOT(80)#PCI(0200)#PCI(0000)#PCI(1000)#PCI(0000)" -force
```

3. Assign the GPU that you dismounted in the previous step to the VM.

```
Add-VMAssignableDevice -LocationPath gpu-device-location -VMName vm-name
```

*gpu-device-location*

The location path of the GPU that you dismounted in the previous step.

*vm-name*

The name of the VM to which you are attaching the GPU.



You can assign a pass-through GPU to **only one** virtual machine at a time.

This example assigns the GPU at the location path

```
PCIROOT(80)#PCI(0200)#PCI(0000)#PCI(1000)#PCI(0000) to the VM  
VM1.
```

```
Add-VMAssignableDevice -LocationPath  
"PCIROOT(80)#PCI(0200)#PCI(0000)#PCI(1000)#PCI(0000)" -VMName VM1
```

4. Power on the VM.  
The guest OS should now be able to use the GPU.

After assigning a GPU to a VM, install the NVIDIA graphics driver in the guest OS on the VM as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

### 3.3.2. Returning a GPU to the Host OS from a VM on Windows Server with Hyper-V

Perform this task in the Windows PowerShell.

1. List the GPUs that are currently assigned to the virtual machine (VM).

```
Get-VMAssignableDevice -VMName vm-name
```

*vm-name*

The name of the VM whose assigned GPUs you want to list.

2. Shut down the VM to which the GPU is assigned.
3. Remove the GPU from VM to which it is assigned.

```
Remove-VMAssignableDevice -LocationPath gpu-device-location -VMName vm-name
```

*gpu-device-location*

The location path of the GPU that you are removing, which you obtained in the previous step.

*vm-name*

The name of the VM from which you are removing the GPU.

This example removes the GPU at the location path

PCIROOT (80) #PCI (0200) #PCI (0000) #PCI (1000) #PCI (0000) from the VM VM1.

```
Remove-VMAssignableDevice -LocationPath  
"PCIROOT (80) #PCI (0200) #PCI (0000) #PCI (1000) #PCI (0000) " -VMName VM1
```

After the GPU is removed from the VM, it is unavailable to the host operating system (OS) until you remount it on the host OS.

4. Remount the GPU on the host OS.

```
Mount-VMHostAssignableDevice -LocationPath gpu-device-location
```

*gpu-device-location*

The location path of the GPU that you are remounting, which you specified in the previous step to remove the GPU from the VM.

This example remounts the GPU at the location path

PCIROOT (80) #PCI (0200) #PCI (0000) #PCI (1000) #PCI (0000) on the host OS.

```
Mount-VMHostAssignableDevice -LocationPath  
"PCIROOT (80) #PCI (0200) #PCI (0000) #PCI (1000) #PCI (0000) "
```

The host OS should now be able to use the GPU.

## 3.4. Using GPU Pass-Through on VMware vSphere

On VMware vSphere, you can use Virtual Dedicated Graphics Acceleration (vDGA) to enable a VM to access a GPU directly. vDGA is a feature of VMware vSphere that dedicates a single physical GPU on an ESXi host to a single virtual machine.

Before configuring a vSphere VM with vDGA, ensure that these prerequisites are met

- ▶ The VM and the ESXi host are configured as explained in [Preparing for vDGA Capabilities](#) in the VMware Horizon documentation.
- ▶ The VM is powered off.

1. Open the vCenter Web UI.
2. In the vCenter Web UI, right-click the ESXi host and choose **Settings**.
3. From the **Hardware** menu, choose **PCI Devices** and click the **Edit** icon.
4. Select all NVIDIA GPUs and click **OK**.
5. Reboot the ESXi host.
6. After the ESXi host has booted, right-click the VM and choose **Edit Settings**.
7. From the **New Device** menu, choose **PCI Device** and click **Add**.
8. On the page that opens, from the **New Device** drop-down list, select the GPU.
9. Click **Reserve all memory** and click **OK**.
10. Start the VM.

For more information about vDGA, see the following topics in the VMware Horizon documentation:

- ▶ [Configuring 3D Rendering for Desktops](#)
- ▶ [Configure RHEL 6 for vDGA](#)

After configuring a vSphere VM with vDGA, install the NVIDIA graphics driver in the guest OS on the VM as explained in [Installing the NVIDIA vGPU Software Graphics Driver](#).

# Chapter 4.

## INSTALLING THE NVIDIA vGPU SOFTWARE GRAPHICS DRIVER

The process for installing the NVIDIA vGPU software graphics driver depends on the OS that you are using. However, for any OS, the process for installing the driver is the same in a VM configured with vGPU, in a VM that is running pass-through GPU, or on a physical host in a bare-metal deployment.

After you install the NVIDIA vGPU software graphics driver, you can license any NVIDIA vGPU software licensed products that you are using.

### 4.1. Installing the NVIDIA vGPU Software Graphics Driver on Windows

**Installation in a VM:** After you create a Windows VM on the hypervisor and boot the VM, the VM should boot to a standard Windows desktop in VGA mode at 800×600 resolution. You can use the Windows screen resolution control panel to increase the resolution to other standard resolutions, but to fully enable GPU operation, the NVIDIA vGPU software graphics driver must be installed. Windows guest VMs are supported only on Q-series, B-series, and A-series NVIDIA vGPU types. They are **not** supported on C-series NVIDIA vGPU types.

**Installation on bare metal:** When the physical host is booted before the NVIDIA vGPU software graphics driver is installed, boot and the primary display are handled by an on-board graphics adapter. To install the NVIDIA vGPU software graphics driver, access the Windows desktop on the host by using a display connected through the on-board graphics adapter.

The procedure for installing the driver is the same in a VM and on bare metal.

1. Copy the NVIDIA Windows driver package to the guest VM or physical host where you are installing the driver.
2. Execute the package to unpack and run the driver installer.



Figure 14 NVIDIA driver installation

3. Click through the license agreement.
4. Select **Express Installation** and click **NEXT**.  
After the driver installation is complete, the installer may prompt you to restart the platform.
5. If prompted to restart the platform, do one of the following:
  - ▶ Select **Restart Now** to reboot the VM or physical host.
  - ▶ Exit the installer and reboot the VM or physical host when you are ready.

After the VM or physical host restarts, it boots to a Windows desktop.

6. Verify that the NVIDIA driver is running.
  - a) Right-click on the desktop.
  - b) From the menu that opens, choose **NVIDIA Control Panel**.
  - c) In the **NVIDIA Control Panel**, from the **Help** menu, choose **System Information**.

**NVIDIA Control Panel** reports the vGPU or physical GPU that is being used, its capabilities, and the NVIDIA driver version that is loaded.

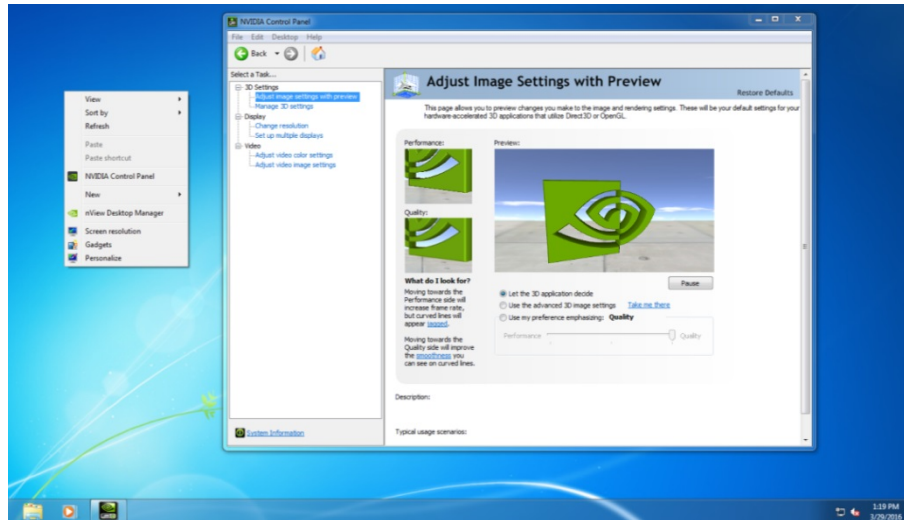


Figure 15 Verifying NVIDIA driver operation using NVIDIA Control Panel

**Installation in a VM:** After you install the NVIDIA vGPU software graphics driver, you can license any NVIDIA vGPU software licensed products that you are using. For instructions, refer to *Virtual GPU Client Licensing User Guide*.

**Installation on bare metal:** After you install the NVIDIA vGPU software graphics driver, complete the bare-metal deployment as explained in *Bare-Metal Deployment*.

## 4.2. Installing the NVIDIA vGPU Software Graphics Driver on Linux

**Installation in a VM:** After you create a Linux VM on the hypervisor and boot the VM, install the NVIDIA vGPU software graphics driver in the VM to fully enable GPU operation. 64-bit Linux guest VMs are supported only on Q-series, C-series, and B-series NVIDIA vGPU types. They are **not** supported on A-series NVIDIA vGPU types.

**Installation on bare metal:** When the physical host is booted before the NVIDIA vGPU software graphics driver is installed, the `vesa` Xorg driver starts the X server. If a primary display device is connected to the host, use the device to access the desktop. Otherwise, use secure shell (SSH) to log in to the host from a remote host. If the Nouveau driver for NVIDIA graphics cards is present, disable it before installing the NVIDIA vGPU software graphics driver.

The procedure for installing the driver is the same in a VM and on bare metal.

Installation of the NVIDIA vGPU software graphics driver for Linux requires:

- ▶ Compiler toolchain
- ▶ Kernel headers

If you are using a Linux OS for which the Wayland display server protocol is enabled by default, disable it as explained in [Disabling the Wayland Display Server Protocol for Red Hat Enterprise Linux](#).

1. Copy the NVIDIA vGPU software Linux driver package, for example `NVIDIA-Linux_x86_64-440.56-grid.run`, to the guest VM or physical host where you are installing the driver.
2. Before attempting to run the driver installer, exit the X server and terminate all OpenGL applications.
  - ▶ On Red Hat Enterprise Linux and CentOS systems, exit the X server by transitioning to runlevel 3:

```
[nvidia@localhost ~]$ sudo init 3
```

- ▶ On Ubuntu platforms, do the following:

1. Use **CTRL-ALT-F1** to switch to a console login prompt.
2. Log in and shut down the display manager:

```
[nvidia@localhost ~]$ sudo service lightdm stop
```

3. From a console shell, run the driver installer as the root user.

```
sudo sh ./ NVIDIA-Linux_x86_64-352.47-grid.run
```

In some instances the installer may fail to detect the installed kernel headers and sources. In this situation, re-run the installer, specifying the kernel source path with the `--kernel-source-path` option:

```
sudo sh ./ NVIDIA-Linux_x86_64-352.47-grid.run \
--kernel-source-path=/usr/src/kernels/3.10.0-229.11.1.el7.x86_64
```

4. When prompted, accept the option to update the X configuration file (`xorg.conf`).

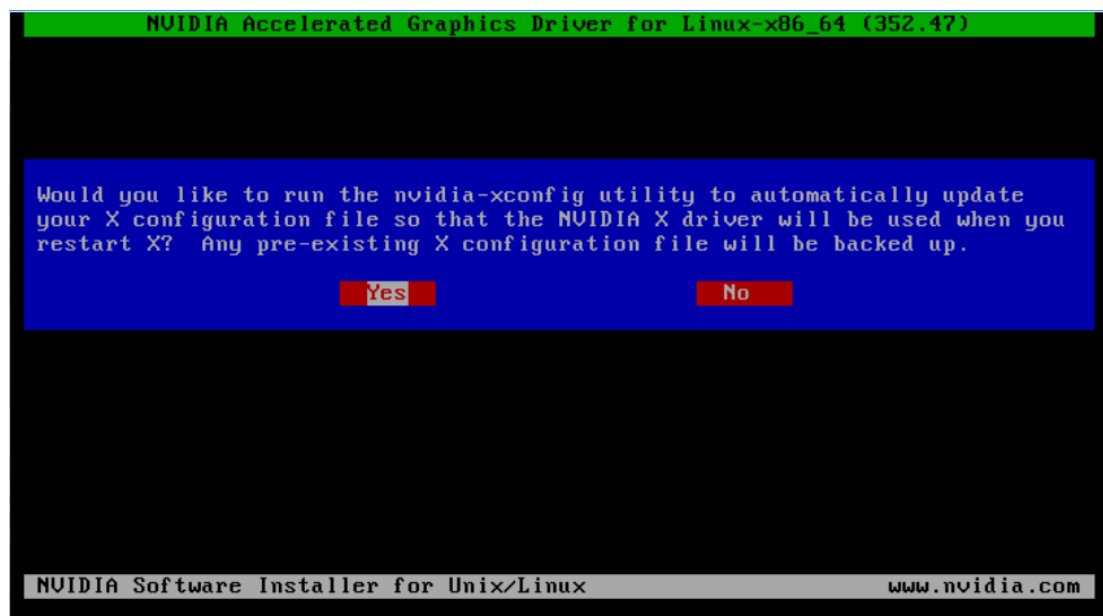


Figure 16 Update `xorg.conf` settings

5. Once installation has completed, select **OK** to exit the installer.
6. Verify that the NVIDIA driver is operational.
  - a) Reboot the system and log in.
  - b) Run `nvidia-settings`.

```
[nvidia@localhost ~]$ nvidia-settings
```

The **NVIDIA X Server Settings** dialog box opens to show that the NVIDIA driver is operational.

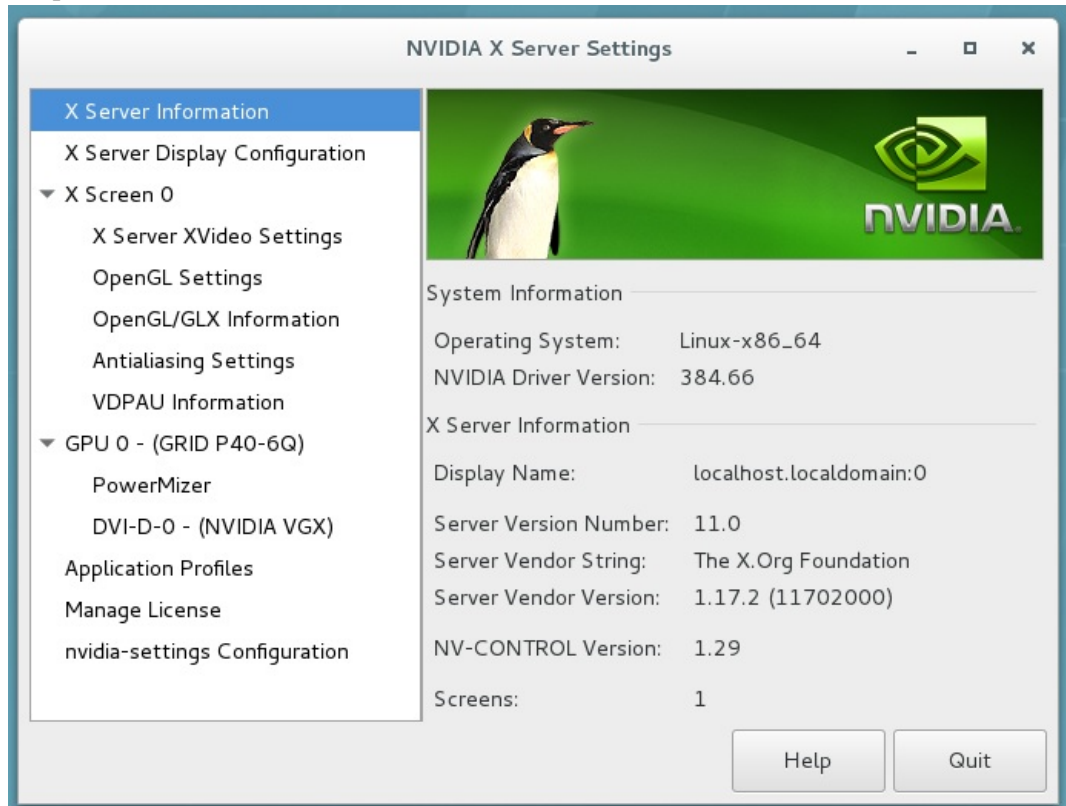


Figure 17 Verifying operation with `nvidia-settings`

**Installation in a VM:** After you install the NVIDIA vGPU software graphics driver, you can license any NVIDIA vGPU software licensed products that you are using. For instructions, refer to *Virtual GPU Client Licensing User Guide*.

**Installation on bare metal:** After you install the NVIDIA vGPU software graphics driver, complete the bare-metal deployment as explained in *Bare-Metal Deployment*.

## 4.3. Disabling the Wayland Display Server Protocol for Red Hat Enterprise Linux

Starting with Red Hat Enterprise Linux Desktop 8.0, the Wayland display server protocol is used by default on supported GPU and graphics driver configurations. However, the NVIDIA vGPU software graphics driver for Linux requires the X Window



System. Before installing the driver, you must disable the Wayland display server protocol to revert to the X Window System.

Perform this task from the host or guest VM that is running Red Hat Enterprise Linux Desktop.

This task requires administrative access.

1. In a plain text editor, edit the file `/etc/gdm/custom.conf` and remove the comment from the option `WaylandEnable=false`.
2. Save your changes to `/etc/gdm/custom.conf`.
3. Reboot the host or guest VM.

# Chapter 5.

## LICENSING AN NVIDIA vGPU

NVIDIA vGPU is a licensed product. When booted on a supported GPU, a vGPU runs at reduced capability until a license is acquired.

The performance of an unlicensed vGPU is restricted as follows:

- ▶ Frame rate is capped at 3 frames per second.
- ▶ GPU resource allocations are limited, which will prevent some applications from running correctly.
- ▶ On vGPUs that support CUDA, CUDA is disabled.

These restrictions are removed when a license is acquired.

After you license NVIDIA vGPU, the VM that is set up to use NVIDIA vGPU is capable of running the full range of DirectX and OpenGL graphics applications.

If licensing is configured, the virtual machine (VM) obtains a license from the license server when a vGPU is booted on these GPUs. The VM retains the license until it is shut down. It then releases the license back to the license server. Licensing settings persist across reboots and need only be modified if the license server address changes, or the VM is switched to running GPU pass through.



For complete information about configuring and using NVIDIA vGPU software licensed features, including vGPU, refer to *Virtual GPU Client Licensing User Guide*.

### 5.1. Licensing an NVIDIA vGPU on Windows

Perform this task from the guest VM to which the vGPU is assigned.

The **NVIDIA Control Panel** tool that you use to perform this task detects that a vGPU is assigned to the VM and, therefore, provides no options for selecting the license type. After you license the vGPU, NVIDIA vGPU software automatically selects the correct type of license based on the vGPU type.

1. Open **NVIDIA Control Panel**:

- ▶ Right-click on the Windows desktop and select **NVIDIA Control Panel** from the menu.
  - ▶ Open **Windows Control Panel** and double-click the **NVIDIA Control Panel** icon.
2. In **NVIDIA Control Panel**, select the **Manage License** task in the **Licensing** section of the navigation pane.

If the **Licensing** section and **Manage License** task are not displayed in **NVIDIA Control Panel**, the system has been configured to hide licensing controls in **NVIDIA Control Panel**. For information about registry settings, see *Virtual GPU Client Licensing User Guide*.

The **Manage License** task pane shows that NVIDIA vGPU is currently unlicensed.

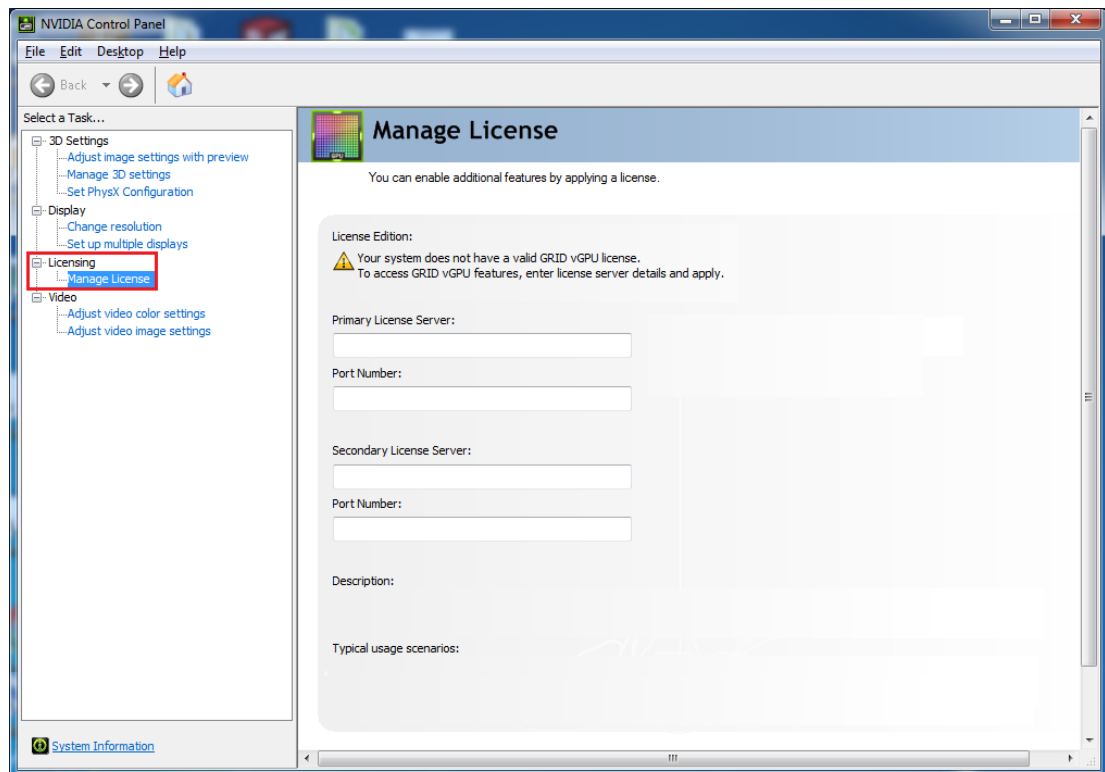


Figure 18 Managing vGPU licensing in NVIDIA Control Panel

3. In the **Primary License Server** field, enter the address of your primary NVIDIA vGPU software License Server.

The address can be a fully-qualified domain name such as `gridlicense1.example.com`, or an IP address such as `10.31.20.45`.

If you have only one license server configured, enter its address in this field.

4. Leave the **Port Number** field under the **Primary License Server** field unset. The port defaults to 7070, which is the default port number used by NVIDIA vGPU software License Server.

5. In the **Secondary License Server** field, enter the address of your secondary NVIDIA vGPU software License Server.  
If you have only one license server configured, leave this field unset.  
The address can be a fully-qualified domain name such as `gridlicense2.example.com`, or an IP address such as `10.31.20.46`.
6. Leave the **Port Number** field under the **Secondary License Server** field unset.  
The port defaults to 7070, which is the default port number used by NVIDIA vGPU software License Server.
7. Click **Apply** to assign the settings.  
The system requests the appropriate license for the current vGPU from the configured license server.

The vGPU within the VM should now exhibit full frame rate, resolution, and display output capabilities. The VM is now capable of running the full range of DirectX and OpenGL graphics applications.

If the system fails to obtain a license, see *Virtual GPU Client Licensing User Guide* for guidance on troubleshooting.

## 5.2. Licensing an NVIDIA vGPU on Linux

Perform this task from the guest VM to which the vGPU is assigned.

The **NVIDIA X Server Settings** tool that you use to perform this task detects that a vGPU is assigned to the VM and, therefore, provides no options for selecting the license type. After you license the vGPU, NVIDIA vGPU software automatically selects the correct type of license based on the vGPU type.

Ensure that the **Manage License** option is enabled as explained in [#unique\\_111](#).



Do not enable the **Manage License** option with Red Hat Enterprise Linux 6.8 and 6.9 or CentOS 6.8 and 6.9. To prevent a segmentation fault in Dbus code from causing the `nvidia-gridd` service from exiting, the GUI for licensing must be disabled with these OS versions.

1. Start **NVIDIA X Server Settings** by using the method for launching applications provided by your Linux distribution.  
For example, on Ubuntu Desktop, open the **Dash**, search for **NVIDIA X Server Settings**, and click the **NVIDIA X Server Settings** icon.
2. In the **NVIDIA X Server Settings** window that opens, click **Manage GRID License**.  
The **License Edition** section of the **NVIDIA X Server Settings** window shows that NVIDIA vGPU is currently unlicensed.
3. In the **Primary Server** field, enter the address of your primary NVIDIA vGPU software License Server.

The address can be a fully-qualified domain name such as `gridlicense1.example.com`, or an IP address such as `10.31.20.45`.

If you have only one license server configured, enter its address in this field.

4. Leave the **Port Number** field under the **Primary Server** field unset.  
The port defaults to 7070, which is the default port number used by NVIDIA vGPU software License Server.
5. In the **Secondary Server** field, enter the address of your secondary NVIDIA vGPU software License Server.  
If you have only one license server configured, leave this field unset.  
The address can be a fully-qualified domain name such as `gridlicense2.example.com`, or an IP address such as `10.31.20.46`.
6. Leave the **Port Number** field under the **Secondary Server** field unset.  
The port defaults to 7070, which is the default port number used by NVIDIA vGPU software License Server.
7. Click **Apply** to assign the settings.  
The system requests the appropriate license for the current vGPU from the configured license server.

The vGPU within the VM should now exhibit full frame rate, resolution, and display output capabilities. The VM is now capable of running the full range of DirectX and OpenGL graphics applications.

If the system fails to obtain a license, see *Virtual GPU Client Licensing User Guide* for guidance on troubleshooting.

# Chapter 6.

## MODIFYING A VM'S NVIDIA vGPU CONFIGURATION

You can modify a VM's NVIDIA vGPU configuration by removing the NVIDIA vGPU configuration from a VM or by modifying GPU allocation policy.

### 6.1. Removing a VM's NVIDIA vGPU Configuration

Remove a VM's NVIDIA vGPU configuration when you no longer require the VM to use a virtual GPU.

#### 6.1.1. Removing a Citrix Virtual Apps and Desktops VM's vGPU configuration

You can remove a virtual GPU assignment from a VM, such that it no longer uses a virtual GPU, by using either XenCenter or the `xe` command.



The VM must be in the powered-off state in order for its vGPU configuration to be modified or removed.

##### 6.1.1.1. Removing a VM's vGPU configuration by using XenCenter

1. Set the **GPU type** to **None** in the VM's **GPU Properties**, as shown in [Figure 19](#).

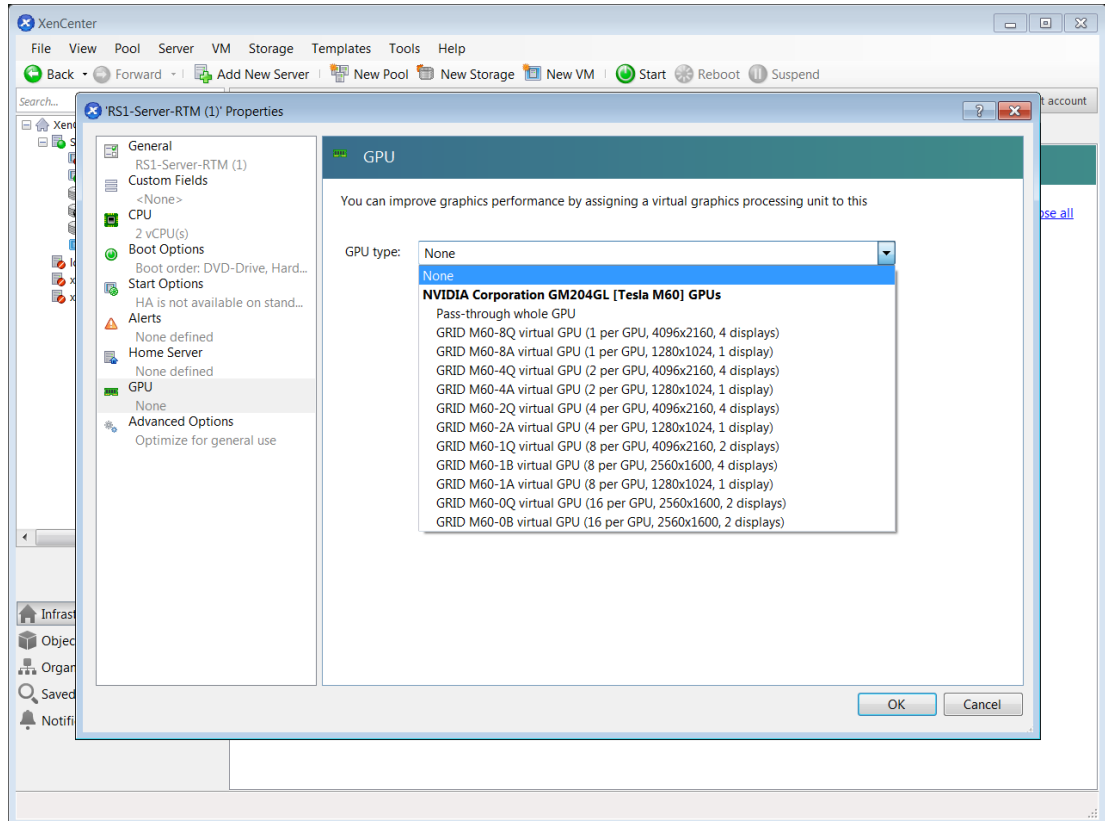


Figure 19 Using XenCenter to remove a vGPU configuration from a VM

2. Click OK.

### 6.1.1.2. Removing a VM's vGPU configuration by using `xe`

1. Use `vgpu-list` to discover the vGPU object UUID associated with a given VM:

```
[root@xenserver ~]# xe vgpu-list vm-uuid=e71afda4-53f4-3a1b-6c92-a364a7f619c2
uuid ( RO)                : c1c7c43d-4c99-af76-5051-119f1c2b4188
vm-uuid ( RO)             : e71afda4-53f4-3a1b-6c92-a364a7f619c2
gpu-group-uuid ( RO)     : d53526a9-3656-5c88-890b-5b24144c3d96
```

2. Use `vgpu-destroy` to delete the virtual GPU object associated with the VM:

```
[root@xenserver ~]# xe vgpu-destroy uuid=c1c7c43d-4c99-af76-5051-119f1c2b4188
[root@xenserver ~]#
```

### 6.1.2. Removing a vSphere VM's vGPU Configuration

To remove a vSphere vGPU configuration from a VM:

1. Select **Edit settings** after right-clicking on the VM in the vCenter Web UI.
2. Select the **Virtual Hardware** tab.

3. Mouse over the **PCI Device** entry showing **NVIDIA GRID vGPU** and click on the **(X)** icon to mark the device for removal.
4. Click **OK** to remove the device and update the VM settings.

## 6.2. Modifying GPU Allocation Policy

Citrix Hypervisor and VMware vSphere both support the *breadth first* and *depth-first* GPU allocation policies for vGPU-enabled VMs.

### breadth-first

The breadth-first allocation policy attempts to minimize the number of vGPUs running on each physical GPU. Newly created vGPUs are placed on the physical GPU that can support the new vGPU and that has the **fewest** vGPUs already resident on it. This policy generally leads to higher performance because it attempts to minimize sharing of physical GPUs, but it may artificially limit the total number of vGPUs that can run.

### depth-first

The depth-first allocation policy attempts to maximize the number of vGPUs running on each physical GPU. Newly created vGPUs are placed on the physical GPU that can support the new vGPU and that has the **most** vGPUs already resident on it. This policy generally leads to higher density of vGPUs, particularly when different types of vGPUs are being run, but may result in lower performance because it attempts to maximize sharing of physical GPUs.

Each hypervisor uses a different GPU allocation policy by default.

- ▶ Citrix Hypervisor uses the depth-first allocation policy.
- ▶ VMware vSphere ESXi uses the breadth-first allocation policy.

If the default GPU allocation policy does not meet your requirements for performance or density of vGPUs, you can change it.

### 6.2.1. Modifying GPU Allocation Policy on Citrix Hypervisor

You can modify GPU allocation policy on Citrix Hypervisor by using XenCenter or the `xe` command.

#### 6.2.1.1. Modifying GPU Allocation Policy by Using `xe`

The allocation policy of a GPU group is stored in the `allocation-algorithm` parameter of the `gpu-group` object.

To change the allocation policy of a GPU group, use `gpu-group-param-set`:

```
[root@xenserver ~]# xe gpu-group-param-get uuid=be825ba2-01d7-8d51-9780-f82cfaa64924 param-name=allocation-algorithmdepth-first
[root@xenserver ~]# xe gpu-group-param-set uuid=be825ba2-01d7-8d51-9780-f82cfaa64924 allocation-algorithm=breadth-first
[root@xenserver ~]#
```



### 6.2.1.2. Modifying GPU Allocation Policy GPU by Using XenCenter

You can modify GPU allocation policy from the **GPU** tab in XenCenter.

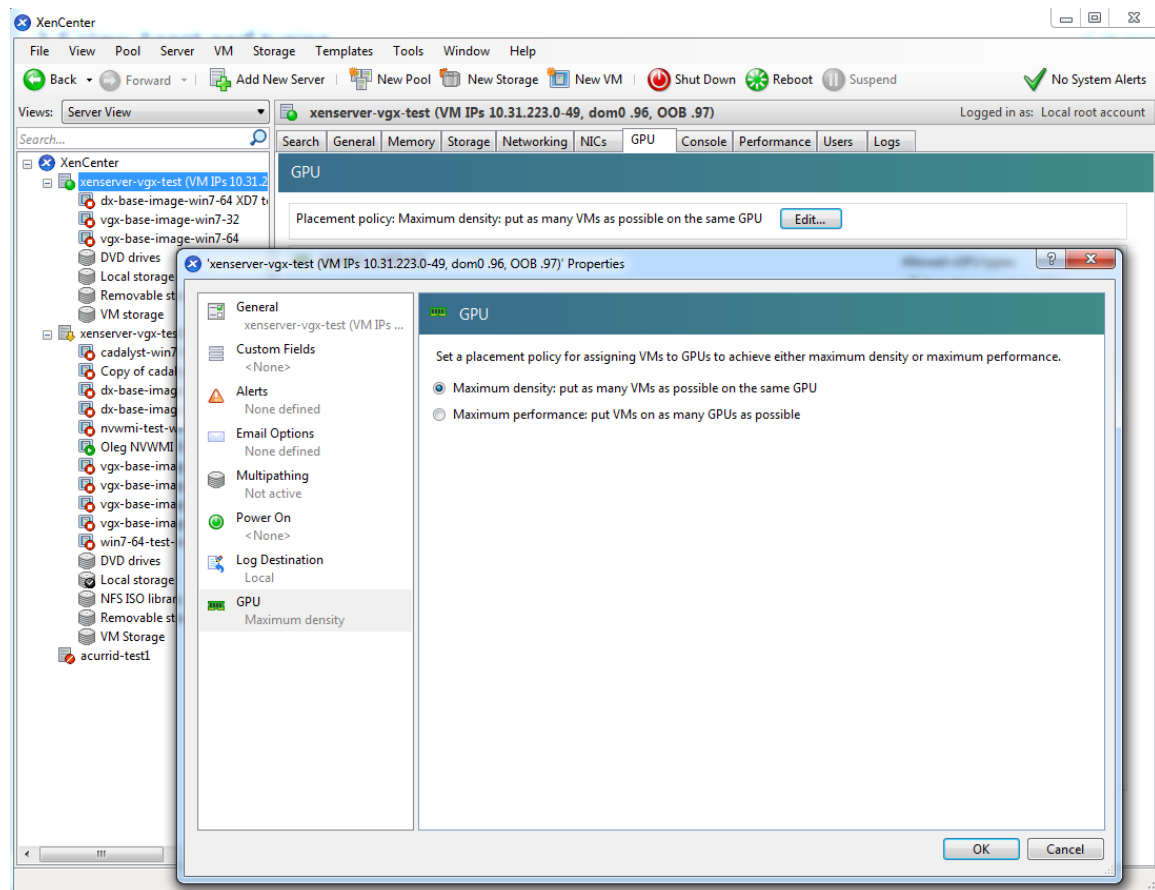


Figure 20 Modifying GPU placement policy in XenCenter

### 6.2.2. Modifying GPU Allocation Policy on VMware vSphere

How to switch to a depth-first allocation scheme depends on the version of VMware vSphere that you are using.

- ▶ Supported versions earlier than 6.5: Add the following parameter to `/etc/vmware/config`:  

```
vGPU.consolidation = true
```
- ▶ Version 6.5: Use the vSphere Web Client.

Before using the vSphere Web Client to change the allocation scheme, ensure that the ESXi host is running and that all VMs on the host are powered off.

1. Log in to vCenter Server by using the vSphere Web Client.
2. In the navigation tree, select your ESXi host and click the **Configure** tab.

3. From the menu, choose **Graphics** and then click the **Host Graphics** tab.
4. On the **Host Graphics** tab, click **Edit**.

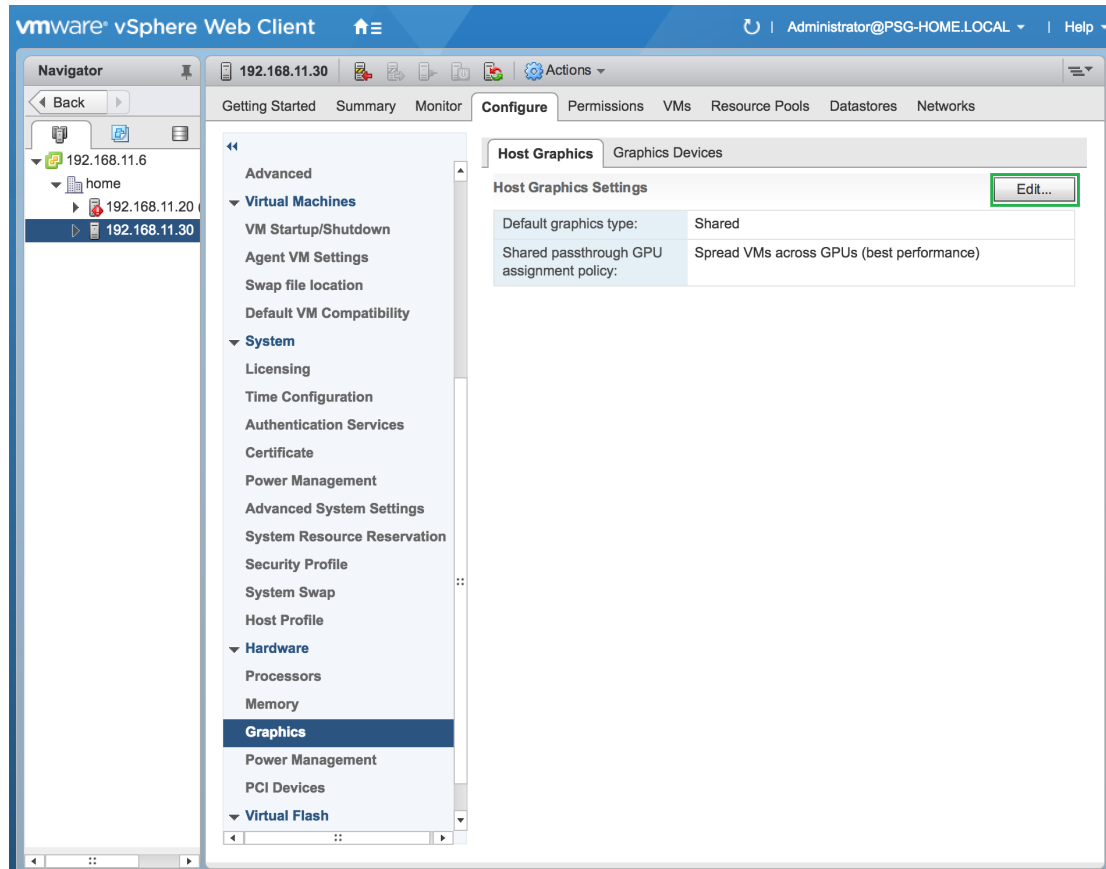


Figure 21 Breadth-first allocation scheme setting for vGPU-enabled VMs

5. In the **Edit Host Graphics Settings** dialog box that opens, select these options and click **OK**.
  - a) If not already selected, select **Shared Direct**.
  - b) Select **Group VMs on GPU until full**.

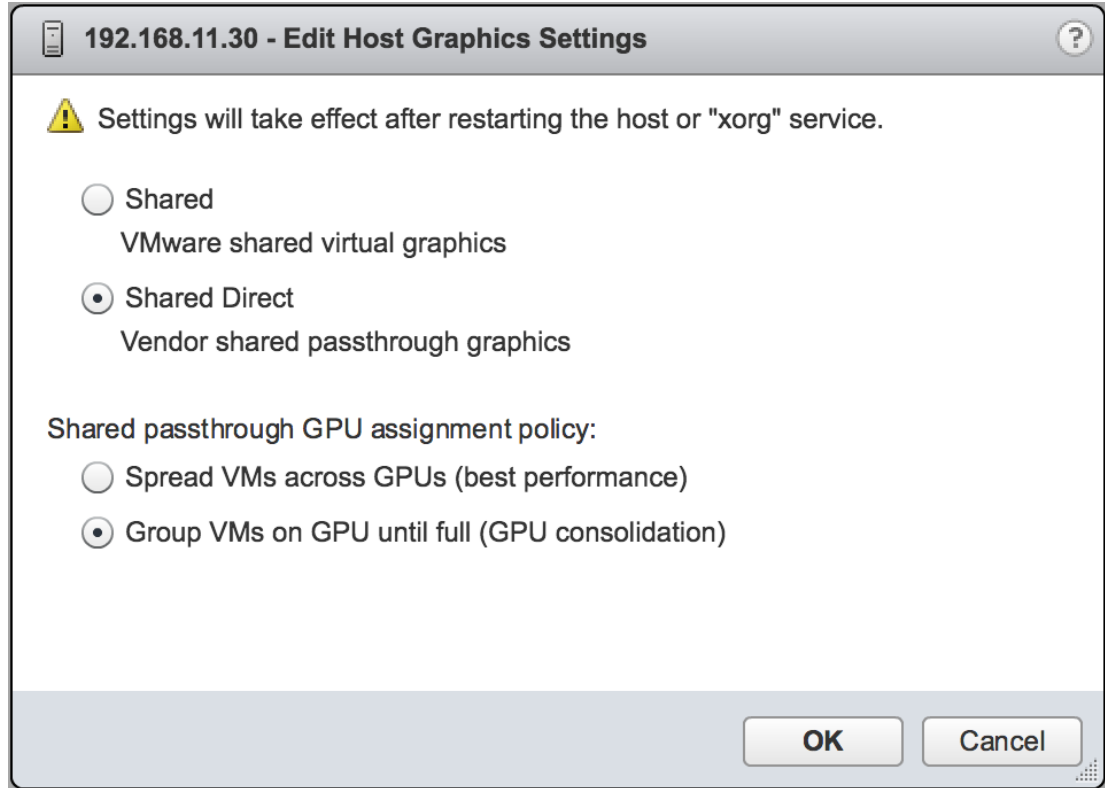


Figure 22 Host graphics settings for vGPU

After you click OK, the default graphics type changes to Shared Direct and the allocation scheme for vGPU-enabled VMs is breadth-first.

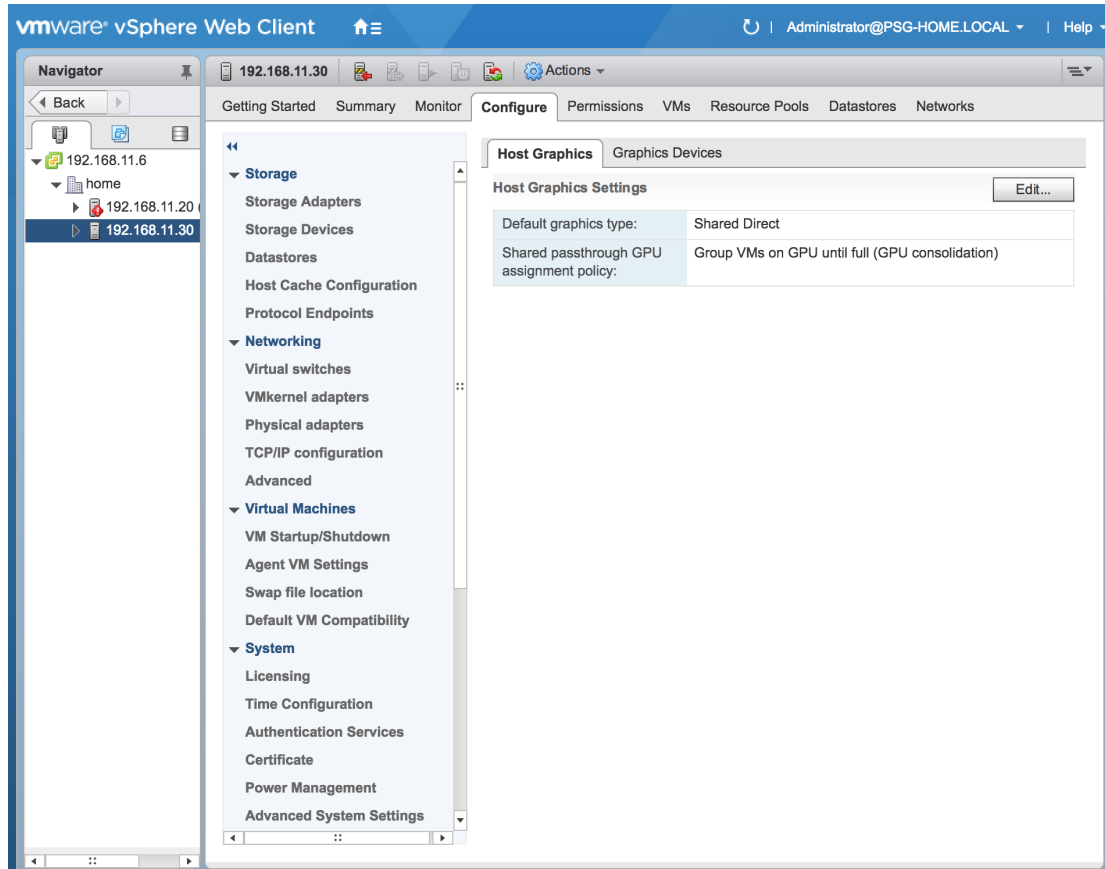


Figure 23 Depth-first allocation scheme setting for vGPU-enabled VMs

6. Restart the ESXi host or the Xorg service on the host.

See also the following topics in the VMware vSphere documentation:

- ▶ [Log in to vCenter Server by Using the vSphere Web Client](#)
- ▶ [Configuring Host Graphics](#)

## 6.3. Migrating a VM Configured with vGPU

On some hypervisors, NVIDIA vGPU software supports migration of VMs that are configured with vGPU.

Before migrating a VM configured with vGPU, ensure that the following prerequisites are met:

- ▶ The VM is configured with vGPU.
- ▶ The VM is running.
- ▶ The VM obtained a suitable vGPU license when it was booted.

- ▶ The destination host has a physical GPU of the same type as the GPU where the vGPU currently resides.
- ▶ ECC memory configuration (enabled or disabled) on both the source and destination hosts must be identical.
- ▶ The GPU topologies (including NVLink widths) on both the source and destination hosts must be identical.

How to migrate a VM configured with vGPU depends on the hypervisor that you are using.

After migration, the vGPU type of the vGPU remains unchanged.

The time required for migration depends on the amount of frame buffer that the vGPU has. Migration for a vGPU with a large amount of frame buffer is slower than for a vGPU with a small amount of frame buffer.

### 6.3.1. Migrating a VM Configured with vGPU on Citrix Hypervisor

NVIDIA vGPU software supports XenMotion for VMs that are configured with vGPU. XenMotion enables you to move a running virtual machine from one physical host machine to another host with very little disruption or downtime. For a VM that is configured with vGPU, the vGPU is migrated with the VM to an NVIDIA GPU on the other host. The NVIDIA GPUs on both host machines must be of the same type.

For details about which Citrix Hypervisor versions, NVIDIA GPUs, and guest OS releases support XenMotion with vGPU, see [Virtual GPU Software for Citrix Hypervisor Release Notes](#).

For best performance, the physical hosts should be configured to use the following:

- ▶ Shared storage, such as NFS, iSCSI, or Fiberchannel
    - If shared storage is not used, migration can take a very long time because vDISK must also be migrated.
  - ▶ 10 GB networking.
1. In Citrix XenCenter, context-click the VM and from the menu that opens, choose **Migrate**.
  2. From the list of available hosts, select the destination host to which you want to migrate the VM.
    - The destination host must have a physical GPU of the same type as the GPU where the vGPU currently resides. Furthermore, the physical GPU must be capable of hosting the vGPU. If these requirements are not met, no available hosts are listed.

## 6.3.2. Migrating a VM Configured with vGPU on VMware vSphere

NVIDIA vGPU software supports VMware vMotion for VMs that are configured with vGPU. VMware vMotion enables you to move a running virtual machine from one physical host machine to another host with very little disruption or downtime. For a VM that is configured with vGPU, the vGPU is migrated with the VM to an NVIDIA GPU on the other host. The NVIDIA GPUs on both host machines must be of the same type.

For details about which VMware vSphere versions, NVIDIA GPUs, and guest OS releases support suspend and resume, see *Virtual GPU Software for VMware vSphere Release Notes*.

Perform this task in the VMware vSphere web client by using the **Migration** wizard.

Before migrating a VM configured with vGPU on VMware vSphere, ensure that the following prerequisites are met:

- ▶ Your hosts are correctly configured for VMware vMotion. See [Host Configuration for vMotion](#) in the VMware documentation.
  - ▶ The prerequisites listed for all supported hypervisors in [Migrating a VM Configured with vGPU](#) are met.
  - ▶ NVIDIA vGPU migration is configured. See [Configuring VMware vMotion with vGPU for VMware vSphere](#).
1. Context-click the VM and from the menu that opens, choose **Migrate**.
  2. For the type of migration, select **Change compute resource only** and click **Next**.  
If you select **Change both compute resource and storage**, the time required for the migration increases.
  3. Select the destination host and click **Next**.  
The destination host must have a physical GPU of the same type as the GPU where the vGPU currently resides. Furthermore, the physical GPU must be capable of hosting the vGPU. If these requirements are not met, no available hosts are listed.
  4. Select the destination network and click **Next**.
  5. Select the migration priority level and click **Next**.
  6. Review your selections and click **Finish**.

For more information, see the following topics in the VMware documentation:

- ▶ [Migrate a Virtual Machine to a New Compute Resource](#)
- ▶ [Using vMotion to Migrate vGPU Virtual Machines](#)

If NVIDIA vGPU migration is not configured, any attempt to migrate a VM with an NVIDIA vGPU fails and a window containing the following error message is displayed:

```
Compatibility Issue/Host
Migration was temporarily disabled due to another
```

```
migration activity.
vGPU hot migration is not enabled.
```

The window appears as follows:



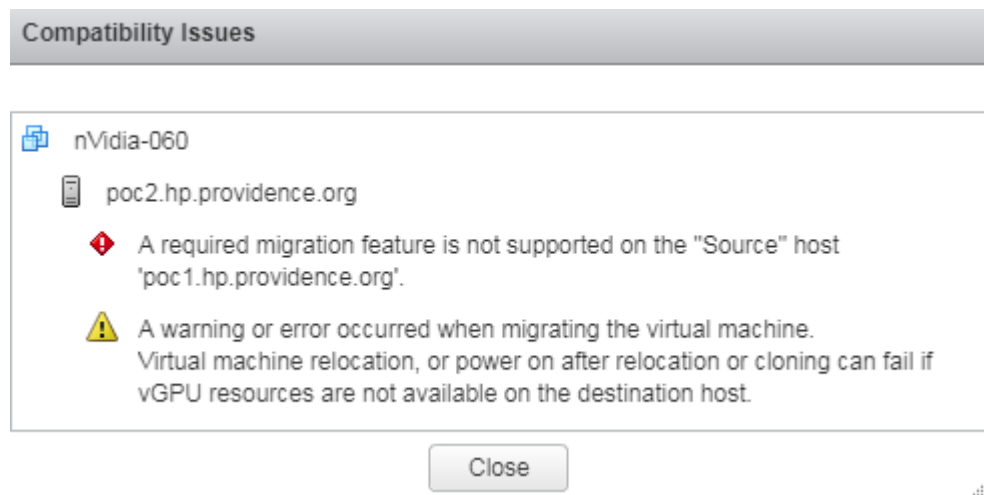
If you see this error, configure NVIDIA vGPU migration as explained in [Configuring VMware vMotion with vGPU for VMware vSphere](#).

If your version of VMware vSphere ESXi does not support vMotion for VMs configured with NVIDIA vGPU, any attempt to migrate a VM with an NVIDIA vGPU fails and a window containing the following error message is displayed:

```
Compatibility Issues
...
A required migration feature is not supported on the "Source" host 'host-name'.

A warning or error occurred when migrating the virtual machine.
Virtual machine relocation, or power on after relocation or cloning can fail if
vGPU resources are not available on the destination host.
```

The window appears as follows:



For details about which VMware vSphere versions, NVIDIA GPUs, and guest OS releases support suspend and resume, see *Virtual GPU Software for VMware vSphere Release Notes*.

### 6.3.3. Suspending and Resuming a VM Configured with vGPU on VMware vSphere

NVIDIA vGPU software supports suspend and resume for VMs that are configured with vGPU.

For details about which VMware vSphere versions, NVIDIA GPUs, and guest OS releases support suspend and resume, see *Virtual GPU Software for VMware vSphere Release Notes*.

Perform this task in the VMware vSphere web client.

- ▶ To suspend a VM, context-click the VM that you want to suspend, and from the context menu that pops up, choose **Power > Suspend**.
- ▶ To resume a VM, context-click the VM that you want to resume, and from the context menu that pops up, choose **Power > Power On**.



# Chapter 7.

## MONITORING GPU PERFORMANCE

NVIDIA vGPU software enables you to monitor the performance of physical GPUs and virtual GPUs from the hypervisor and from within individual guest VMs.

You can use several tools for monitoring GPU performance:

- ▶ From any supported hypervisor, and from a guest VM that is running a 64-bit edition of Windows or Linux, you can use NVIDIA System Management Interface, `nvidia-smi`.
- ▶ From Citrix Hypervisor, you can use Citrix XenCenter.
- ▶ From a Windows guest VM, you can use these tools:
  - ▶ Windows Performance Monitor
  - ▶ Windows Management Instrumentation (WMI)

### 7.1. NVIDIA System Management Interface

#### `nvidia-smi`

NVIDIA System Management Interface, `nvidia-smi`, is a command-line tool that reports management information for NVIDIA GPUs.

The `nvidia-smi` tool is included in the following packages:

- ▶ NVIDIA Virtual GPU Manager package for each supported hypervisor
- ▶ NVIDIA driver package for each supported guest OS

The scope of the reported management information depends on where you run `nvidia-smi` from:

- ▶ From a hypervisor command shell, such as the Citrix Hypervisor dom0 shell or VMware ESXi host shell, `nvidia-smi` reports management information for NVIDIA physical GPUs and virtual GPUs present in the system.




When run from a hypervisor command shell, `nvidia-smi` will not list any GPU that is currently allocated for GPU pass-through.

- ▶ From a guest VM that is running Windows or Linux, `nvidia-smi` retrieves usage statistics for vGPUs or pass-through GPUs that are assigned to the VM.

From a Windows guest VM, you can run `nvidia-smi` from a command prompt by changing to the `C:\Program Files\NVIDIA Corporation\NVSMI` folder and running the `nvidia-smi.exe` command.

## 7.2. Monitoring GPU Performance from a Hypervisor

You can monitor GPU performance from any supported hypervisor by using the NVIDIA System Management Interface `nvidia-smi` command-line utility. On Citrix Hypervisor platforms, you can also use Citrix XenCenter to monitor GPU performance.

 You **cannot** monitor from the hypervisor the performance of GPUs that are being used for GPU pass-through. You can monitor the performance of pass-through GPUs only from within the guest VM that is using them.

### 7.2.1. Using `nvidia-smi` to Monitor GPU Performance from a Hypervisor

You can get management information for the NVIDIA physical GPUs and virtual GPUs present in the system by running `nvidia-smi` from a hypervisor command shell such as the Citrix Hypervisor `dom0` shell or the VMware ESXi host shell.

Without a subcommand, `nvidia-smi` provides management information for **physical** GPUs. To examine **virtual** GPUs in more detail, use `nvidia-smi` with the `vgpu` subcommand.

From the command line, you can get help information about the `nvidia-smi` tool and the `vgpu` subcommand.

Help Information	Command
A list of subcommands supported by the <code>nvidia-smi</code> tool. Note that not all subcommands apply to GPUs that support NVIDIA vGPU software.	<code>nvidia-smi -h</code>
A list of all options supported by the <code>vgpu</code> subcommand.	<code>nvidia-smi vgpu -h</code>

#### 7.2.1.1. Getting a Summary of all Physical GPUs in the System

To get a summary of all physical GPUs in the system, along with PCI bus IDs, power state, temperature, current memory usage, and so on, run `nvidia-smi` without additional arguments.

Each vGPU instance is reported in the `Compute processes` section, together with its physical GPU index and the amount of frame-buffer memory assigned to it.

In the example that follows, three vGPUs are running in the system: One vGPU is running on each of the physical GPUs 0, 1, and 2.

```
[root@vgpu ~]# nvidia-smi
Fri Feb 14 09:26:18 2020
+-----+
| NVIDIA-SMI 440.53                 Driver Version: 440.56          |
+-----+-----+
| GPU  Name            Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf     Pwr:Usage/Cap|      Memory-Usage | GPU-Util  Compute M. |
+-----+-----+-----+-----+-----+-----+
|  0   Tesla M60       On          | 0000:83:00.0  Off  |           Off       |
| N/A   31C    P8      23W / 150W | 1889MiB / 8191MiB |      7%   Default   |
+-----+-----+-----+-----+-----+-----+
|  1   Tesla M60       On          | 0000:84:00.0  Off  |           Off       |
| N/A   26C    P8      23W / 150W |  926MiB / 8191MiB |      9%   Default   |
+-----+-----+-----+-----+-----+-----+
|  2   Tesla M10       On          | 0000:8A:00.0  Off  |           N/A      |
| N/A   23C    P8      10W /  53W | 1882MiB / 8191MiB |     12%   Default   |
+-----+-----+-----+-----+-----+-----+
|  3   Tesla M10       On          | 0000:8B:00.0  Off  |           N/A      |
| N/A   26C    P8      10W /  53W |  10MiB / 8191MiB |      0%   Default   |
+-----+-----+-----+-----+-----+-----+
|  4   Tesla M10       On          | 0000:8C:00.0  Off  |           N/A      |
| N/A   34C    P8      10W /  53W |  10MiB / 8191MiB |      0%   Default   |
+-----+-----+-----+-----+-----+-----+
|  5   Tesla M10       On          | 0000:8D:00.0  Off  |           N/A      |
| N/A   32C    P8      10W /  53W |  10MiB / 8191MiB |      0%   Default   |
+-----+-----+-----+-----+-----+-----+
+-----+-----+-----+-----+-----+
| Processes:                         GPU Memory |
| GPU      PID    Type   Process name                      Usage      |
+-----+-----+-----+-----+-----+-----+
|  0        11924  C+G   /usr/lib64/xen/bin/vgpu           1856MiB   |
|  1        11903  C+G   /usr/lib64/xen/bin/vgpu            896MiB   |
|  2        11908  C+G   /usr/lib64/xen/bin/vgpu           1856MiB   |
+-----+-----+-----+-----+-----+-----+
[root@vgpu ~]#
```

### 7.2.1.2. Getting a Summary of all vGPUs in the System

To get a summary of the vGPUs currently that are currently running on each physical GPU in the system, run `nvidia-smi vgpu` without additional arguments.

```
[root@vgpu ~]# nvidia-smi vgpu
Fri Feb 14 09:27:06 2020
+-----+
| NVIDIA-SMI 440.53                 Driver Version: 440.56          |
+-----+-----+
| GPU  Name            Name          | Bus-Id        VM Name          | GPU-Util  vGPU-Util |
|      vGPU ID         | VM ID         |                |                |
+-----+-----+-----+-----+-----+-----+
|  0   Tesla M60       GRID M60-2Q  | 0000:83:00.0  | 3      Win7-64 GRID test 2 | 7%        6%   |
|      11924           |               |                |                |
+-----+-----+-----+-----+-----+-----+
|  1   Tesla M60       GRID M60-1B  | 0000:84:00.0  | 1      Win8.1-64 GRID test 3 | 9%        8%   |
|      11903           |               |                |                |
+-----+-----+-----+-----+-----+-----+
|  2   Tesla M10       GRID M10-2Q  | 0000:8A:00.0  | 2      Win7-64 GRID test 1 | 12%       10%  |
|      11908           |               |                |                |
+-----+-----+-----+-----+-----+-----+
|  3   Tesla M10       | 0000:8B:00.0  |                |                | 0%        |
+-----+-----+-----+-----+-----+-----+
|  4   Tesla M10       | 0000:8C:00.0  |                |                | 0%        |
+-----+-----+-----+-----+-----+-----+

```

```
+-----+-----+-----+
| 5 Tesla M10 | 0000:8D:00.0 | 0% |
+-----+-----+-----+
[root@vgpu ~]#
```

### 7.2.1.3. Getting vGPU Details

To get detailed information about all the vGPUs on the platform, run `nvidia-smi vgpu` with the `-q` or `--query` option.

To limit the information retrieved to a subset of the GPUs on the platform, use the `-i` or `--id` option to select one or more vGPUs.

```
[root@vgpu ~]# nvidia-smi vgpu -q -i 1
GPU 00000000:86:00.0
  Active vGPUs           : 1
  vGPU ID                : 3251634178
  VM ID                  : 1
  VM Name                 : Win7
  vGPU Name               : GRID M60-8Q
  vGPU Type               : 22
  vGPU UUID               : b8c6d0e1-d167-11e8-b8c9-55705e5a54a6
  Guest Driver Version    : 411.81
  License Status          : Unlicensed
  Accounting Mode         : Disabled
  Accounting Buffer Size   : 4000
  Frame Rate Limit        : 3 FPS
  FB Memory Usage        :
    Total                 : 8192 MiB
    Used                   : 675 MiB
    Free                   : 7517 MiB
  Utilization             :
    Gpu                    : 3 %
    Memory                 : 0 %
    Encoder                 : 0 %
    Decoder                 : 0 %
  Encoder Stats           :
    Active Sessions        : 0
    Average FPS            : 0
    Average Latency        : 0
  FBC Stats               :
    Active Sessions        : 1
    Average FPS            : 227
    Average Latency        : 4403
[root@vgpu ~]#
```

### 7.2.1.4. Monitoring vGPU engine usage

To monitor vGPU engine usage across multiple vGPUs, run `nvidia-smi vgpu` with the `-u` or `--utilization` option.

For each vGPU, the usage statistics in the following table are reported once every second. The table also shows the name of the column in the command output under which each statistic is reported.

Statistic	Column
3D/Compute	sm
Memory controller bandwidth	mem

Statistic	Column
Video encoder	enc
Video decoder	dec

Each reported percentage is the percentage of the physical GPU's capacity that a vGPU is using. For example, a vGPU that uses 20% of the GPU's graphics engine's capacity will report 20%.

To modify the reporting frequency, use the `-l` or `--loop` option.

To limit monitoring to a subset of the GPUs on the platform, use the `-i` or `--id` option to select one or more vGPUs.

```
[root@vgpu ~]# nvidia-smi vgpu -u
# gpu      vgpu      sm      mem      enc      dec
# Idx      Id        %        %        %        %
  0      11924      6        3        0        0
  1      11903      8        3        0        0
  2      11908     10        4        0        0
  3        -         -         -         -         -
  4        -         -         -         -         -
  5        -         -         -         -         -
  0      11924      6        3        0        0
  1      11903      9        3        0        0
  2      11908     10        4        0        0
  3        -         -         -         -         -
  4        -         -         -         -         -
  5        -         -         -         -         -
  0      11924      6        3        0        0
  1      11903      8        3        0        0
  2      11908     10        4        0        0
  3        -         -         -         -         -
  4        -         -         -         -         -
  5        -         -         -         -         -
^C[root@vgpu ~]#
```

### 7.2.1.5. Monitoring vGPU engine usage by applications

To monitor vGPU engine usage by applications across multiple vGPUs, run `nvidia-smi vgpu` with the `-p` option.

For each application on each vGPU, the usage statistics in the following table are reported once every second. Each application is identified by its process ID and process name. The table also shows the name of the column in the command output under which each statistic is reported.

Statistic	Column
3D/Compute	sm
Memory controller bandwidth	mem
Video encoder	enc
Video decoder	dec

Each reported percentage is the percentage of the physical GPU's capacity used by an application running on a vGPU that resides on the physical GPU. For example, an application that uses 20% of the GPU's graphics engine's capacity will report 20%.

To modify the reporting frequency, use the `-l` or `--loop` option.

To limit monitoring to a subset of the GPUs on the platform, use the `-i` or `--id` option to select one or more vGPUs.

```
[root@vgpu ~]# nvidia-smi vgpu -p
# GPU      vGPU process      process      sm  mem  enc  dec
# Idx      Id      Id      name        %   %   %   %
  0      38127  1528      dwm.exe      0   0   0   0
  1      37408  4232  DolphinVS.exe 32  25   0   0
  1      257869 4432   FurMark.exe  16  12   0   0
  1      257969 4552   FurMark.exe  48  37   0   0
  0      38127  1528      dwm.exe      0   0   0   0
  1      37408  4232  DolphinVS.exe 16  12   0   0
  1      257911  656  DolphinVS.exe 32  24   0   0
  1      257969 4552   FurMark.exe  48  37   0   0
  0      38127  1528      dwm.exe      0   0   0   0
  1      257869 4432   FurMark.exe  38  30   0   0
  1      257911  656  DolphinVS.exe 19  14   0   0
  1      257969 4552   FurMark.exe  38  30   0   0
  0      38127  1528      dwm.exe      0   0   0   0
  1      257848 3220   Balls64.exe 16  12   0   0
  1      257869 4432   FurMark.exe  16  12   0   0
  1      257911  656  DolphinVS.exe 16  12   0   0
  1      257969 4552   FurMark.exe  48  37   0   0
  0      38127  1528      dwm.exe      0   0   0   0
  1      257911  656  DolphinVS.exe 32  25   0   0
  1      257969 4552   FurMark.exe  64  50   0   0
  0      38127  1528      dwm.exe      0   0   0   0
  1      37408  4232  DolphinVS.exe 16  12   0   0
  1      257911  656  DolphinVS.exe 16  12   0   0
  1      257969 4552   FurMark.exe  64  49   0   0
  0      38127  1528      dwm.exe      0   0   0   0
  1      37408  4232  DolphinVS.exe 16  12   0   0
  1      257869 4432   FurMark.exe  16  12   0   0
  1      257969 4552   FurMark.exe  64  49   0   0
[root@vgpu ~]#
```

### 7.2.1.6. Monitoring Encoder Sessions



Encoder sessions can be monitored **only** for vGPUs assigned to Windows VMs. No encoder session statistics are reported for vGPUs assigned to Linux VMs.

To monitor the encoder sessions for processes running on multiple vGPUs, run `nvidia-smi vgpu` with the `-es` or `--encodersessions` option.

For each encoder session, the following statistics are reported once every second:

- ▶ GPU ID
- ▶ vGPU ID
- ▶ Encoder session ID
- ▶ PID of the process in the VM that created the encoder session
- ▶ Codec type, for example, H.264 or H.265

- ▶ Encode horizontal resolution
- ▶ Encode vertical resolution
- ▶ One-second trailing average encoded FPS
- ▶ One-second trailing average encode latency in microseconds

To modify the reporting frequency, use the `-l` or `--loop` option.

To limit monitoring to a subset of the GPUs on the platform, use the `-i` or `--id` option to select one or more vGPUs.

```
[root@vgpu ~]# nvidia-smi vgpu -es
# GPU      vGPU Session Process   Codec   H       V Average   Average
# Idx      Id       Id       Id       Type    Res     Res     FPS Latency(us)
  1      21211    2       2308    H.264   1920    1080    424    1977
  1      21206    3       2424    H.264   1920    1080     0       0
  1      22011    1       3676    H.264   1920    1080    374    1589
  1      21211    2       2308    H.264   1920    1080    360     807
  1      21206    3       2424    H.264   1920    1080    325    1474
  1      22011    1       3676    H.264   1920    1080    313    1005
  1      21211    2       2308    H.264   1920    1080    329    1732
  1      21206    3       2424    H.264   1920    1080    352    1415
  1      22011    1       3676    H.264   1920    1080    434    1894
  1      21211    2       2308    H.264   1920    1080    362    1818
  1      21206    3       2424    H.264   1920    1080    296    1072
  1      22011    1       3676    H.264   1920    1080    416    1994
  1      21211    2       2308    H.264   1920    1080    444    1912
  1      21206    3       2424    H.264   1920    1080    330    1261
  1      22011    1       3676    H.264   1920    1080    436    1644
  1      21211    2       2308    H.264   1920    1080    344    1500
  1      21206    3       2424    H.264   1920    1080    393    1727
  1      22011    1       3676    H.264   1920    1080    364    1945
  1      21211    2       2308    H.264   1920    1080    555    1653
  1      21206    3       2424    H.264   1920    1080    295     925
  1      22011    1       3676    H.264   1920    1080    372    1869
  1      21211    2       2308    H.264   1920    1080    326    2206
  1      21206    3       2424    H.264   1920    1080    318    1366
  1      22011    1       3676    H.264   1920    1080    464    2015
  1      21211    2       2308    H.264   1920    1080    305    1167
  1      21206    3       2424    H.264   1920    1080    445    1892
  1      22011    1       3676    H.264   1920    1080    361     906
  1      21211    2       2308    H.264   1920    1080    353    1436
  1      21206    3       2424    H.264   1920    1080    354    1798
  1      22011    1       3676    H.264   1920    1080    373    1310
^C[root@vgpu ~]#
```

### 7.2.1.7. Monitoring Frame Buffer Capture (FBC) Sessions

To monitor the FBC sessions for processes running on multiple vGPUs, run `nvidia-smi vgpu` with the `-fs` or `--fbcsessions` option.

For each FBC session, the following statistics are reported once every second:

- ▶ GPU ID
- ▶ vGPU ID
- ▶ FBC session ID
- ▶ PID of the process in the VM that created the FBC session
- ▶ Display ordinal associated with the FBC session.
- ▶ FBC session type





# GPU	vGPU	Session	Process	Display	Session	Diff. Map	Class. Map		
# Idx	Capture Mode	Max H Res	Max V Res	H Id Res	V Ordinal	Average FPS	Type Latency (us)	State	
0	-	-	-	-	-	-	-	-	
1	3251634178 Unknown	4096	2160	3984 0	0	0	ToSys 0	Disabled 0	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-
1	3251634178 Unknown	4096	2160	3984 0	0	0	ToSys 0	Disabled 0	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-
1	3251634178 Unknown	4096	2160	3984 0	0	0	ToSys 0	Disabled 0	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-
1	3251634178 Unknown	4096	2160	3984 0	0	0	ToSys 0	Disabled 0	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-
1	3251634178 Unknown	4096	2160	3984 0	0	0	ToSys 0	Disabled 0	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-
1	3251634178 Unknown	4096	2160	3984 0	0	0	ToSys 0	Disabled 0	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-
1	3251634178 Unknown	4096	2160	3984 0	0	0	ToSys 0	Disabled 0	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-
1	3251634178 Unknown	4096	2160	3984 0	0	0	ToSys 0	Disabled 0	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-
1	3251634178 Blocking	4096	2160	3984 1600	900	0 25	ToSys	Disabled 39964	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-
1	3251634178 Blocking	4096	2160	3984 1600	900	0 25	ToSys	Disabled 39964	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-
1	3251634178 Blocking	4096	2160	3984 0	0	0	ToSys	Disabled 0	Disabled
2	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-





To limit the retrieved information to a subset of the GPUs on the platform, use the `-i` or `--id` option to select one or more vGPUs.

```
[root@vgpu ~]# nvidia-smi vgpu -s -i 0
GPU 0000:83:00.0
  GRID M60-0B
  GRID M60-0Q
  GRID M60-1A
  GRID M60-1B
  GRID M60-1Q
  GRID M60-2A
  GRID M60-2Q
  GRID M60-4A
  GRID M60-4Q
  GRID M60-8A
  GRID M60-8Q
[root@vgpu ~]#
```

To view detailed information about the supported vGPU types, add the `-v` or `--verbose` option:

```
[root@vgpu ~]# nvidia-smi vgpu -s -i 0 -v | less
GPU 00000000:83:00.0
  vGPU Type ID      : 0xb
  Name              : GRID M60-0B
  Class             : NVS
  Max Instances     : 16
  Device ID        : 0x13f210de
  Sub System ID    : 0x13f21176
  FB Memory        : 512 MiB
  Display Heads    : 2
  Maximum X Resolution : 2560
  Maximum Y Resolution : 1600
  Frame Rate Limit  : 45 FPS
  GRID License     : GRID-Virtual-PC,2.0;GRID-Virtual-WS,2.0;GRID-
Virtual-WS-Ext,2.0;Quadro-Virtual-DWS,5.0
  vGPU Type ID      : 0xc
  Name              : GRID M60-0Q
  Class             : Quadro
  Max Instances     : 16
  Device ID        : 0x13f210de
  Sub System ID    : 0x13f2114c
  FB Memory        : 512 MiB
  Display Heads    : 2
  Maximum X Resolution : 2560
  Maximum Y Resolution : 1600
  Frame Rate Limit  : 60 FPS
  GRID License     : GRID-Virtual-WS,2.0;GRID-Virtual-WS-
Ext,2.0;Quadro-Virtual-DWS,5.0
  vGPU Type ID      : 0xd
  Name              : GRID M60-1A
  Class             : NVS
  Max Instances     : 8
  ...
[root@vgpu ~]#
```

### 7.2.1.9. Listing the vGPU Types that Can Currently Be Created

To list the virtual GPU types that can currently be created on GPUs in the system, run `nvidia-smi vgpu` with the `-c` or `--creatable` option.

This property is a dynamic property that varies according to the vGPUs that are already running on each GPU.

To limit the retrieved information to a subset of the GPUs on the platform, use the `-i` or `--id` option to select one or more vGPUs.

```
[root@vgpu ~]# nvidia-smi vgpu -c -i 0
GPU 0000:83:00.0
  GRID M60-2Q
[root@vgpu ~]#
```

To view detailed information about the vGPU types that can currently be created, add the `-v` or `--verbose` option.

## 7.2.2. Using Citrix XenCenter to monitor GPU performance

If you are using Citrix Hypervisor as your hypervisor, you can monitor GPU performance in XenCenter.

1. Click on a server's **Performance** tab.
2. Right-click on the graph window, then select **Actions** and **New Graph**.
3. Provide a name for the graph.
4. In the list of available counter resources, select one or more GPU counters.

Counters are listed for each physical GPU not currently being used for GPU pass-through.

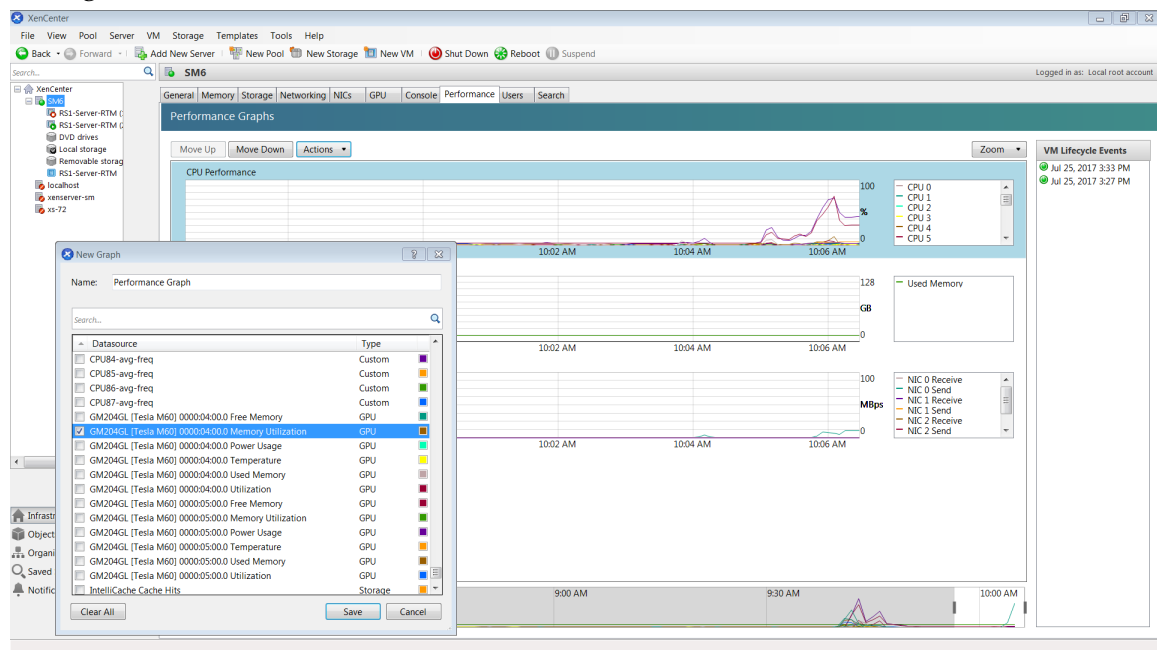


Figure 24 Using Citrix XenCenter to monitor GPU performance

## 7.3. Monitoring GPU Performance from a Guest VM

You can use monitoring tools within an individual guest VM to monitor the performance of vGPUs or pass-through GPUs that are assigned to the VM. The scope of these tools is limited to the guest VM within which you use them. You cannot use monitoring tools within an individual guest VM to monitor any other GPUs in the platform.

For a vGPU, only these metrics are reported in a guest VM:

- ▶ 3D/Compute
- ▶ Memory controller
- ▶ Video encoder
- ▶ Video decoder
- ▶ Frame buffer usage

Other metrics normally present in a GPU are not applicable to a vGPU and are reported as zero or N/A, depending on the tool that you are using.

### 7.3.1. Using `nvidia-smi` to Monitor GPU Performance from a Guest VM

In VMs that are running Windows and 64-bit editions of Linux, you can use the `nvidia-smi` command to retrieve statistics for the total usage by all applications running in the VM and usage by individual applications of the following resources:

- ▶ GPU
- ▶ Video encoder
- ▶ Video decoder
- ▶ Frame buffer

To use `nvidia-smi` to retrieve statistics for the total resource usage by all applications running in the VM, run the following command:

```
nvidia-smi dmon
```

The following example shows the result of running `nvidia-smi dmon` from within a Windows guest VM.

```

C:\Program Files\NVIDIA Corporation\NVSMI>nvidia-smi dmon
# gpu   pwr   temp   sm    mem    enc    dec   mclk  pclk
# Idx   W     C      %     %      %     %    MHz   MHz
  0     -    -      9     0     0     0    3704  1531
  0     -    -      9     0     0     0    3704  1531
  0     -    -      9     0     0     0    3704  1531
  0     -    -      9     0     0     0    3704  1531
  0     -    -      9     0     0     0    3704  1531
  0     -    -      9     0     0     0    3704  1531
  0     -    -      9     0     0     0    3704  1531
  0     -    -      8     0     0     0    3704  1531
  0     -    -      7     0     0     0    3704  1531
  0     -    -      7     0     0     0    3704  1531
  0     -    -      7     0     0     0    3704  1531
  0     -    -      7     0     0     0    3704  1531
  0     -    -      7     0     0     0    3704  1531
  0     -    -      7     0     0     0    3704  1531
  0     -    -      7     0     0     0    3704  1531
  0     -    -      6     0     0     0    3704  1531
  0     -    -      6     0     0     0    3704  1531
C:\Program Files\NVIDIA Corporation\NVSMI>

```

Figure 25 Using `nvidia-smi` from a Windows guest VM to get total resource usage by all applications

To use `nvidia-smi` to retrieve statistics for resource usage by individual applications running in the VM, run the following command:

```
nvidia-smi pmon
```

```

C:\Windows\system32\cmd.exe
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:\Program Files\NVIDIA Corporation\NUSMI>nvidia-smi pmon
# gpu      pid      type      sm      mem      enc      dec      command
# Idx      #        C/G       %        %        %        %        name
  0         656     C+G       0         0         0         0      DolphinUS.exe
  0        2520     C+G       0         0         0         0      chrome.exe
  0        4216     C+G       1         1         0         0      Balls64.exe
  0        4472     C+G       23        20         0         0      FurMark.exe
  0        4868     C+G       0         0         0         0      Balls64.exe
  0         656     C+G       0         0         0         0      DolphinUS.exe
  0        2520     C+G       0         0         0         0      chrome.exe
  0        4216     C+G       0         0         0         0      Balls64.exe
  0        4472     C+G       22        19         0         0      FurMark.exe
  0        4868     C+G       0         0         0         0      Balls64.exe
  0         656     C+G       0         0         0         0      DolphinUS.exe
  0        2520     C+G       0         0         0         0      chrome.exe
  0        4216     C+G       0         0         0         0      Balls64.exe
  0        4472     C+G       23        20         0         0      FurMark.exe
  0        4868     C+G       0         0         0         0      Balls64.exe
  0         656     C+G       0         0         0         0      DolphinUS.exe
  0        2520     C+G       0         0         0         0      chrome.exe
  0        4216     C+G       0         0         0         0      Balls64.exe
  0        4472     C+G       22        19         0         0      FurMark.exe
  0        4868     C+G       0         0         0         0      Balls64.exe
  0         656     C+G       0         0         0         0      DolphinUS.exe
  0        2520     C+G       0         0         0         0      chrome.exe
  0        4216     C+G       0         0         0         0      Balls64.exe
  0        4472     C+G       19        16         0         0      FurMark.exe
  0        4868     C+G       0         0         0         0      Balls64.exe
  0         656     C+G       0         0         0         0      DolphinUS.exe
  0        2520     C+G       0         0         0         0      chrome.exe
  0        4216     C+G       0         0         0         0      Balls64.exe
  0        4472     C+G       19        16         0         0      FurMark.exe
  0        4868     C+G       0         0         0         0      Balls64.exe
  0         656     C+G       0         0         0         0      DolphinUS.exe
  0        2520     C+G       0         0         0         0      chrome.exe
  0        4216     C+G       0         0         0         0      Balls64.exe
  0        4472     C+G       20        17         0         0      FurMark.exe
  0        4868     C+G       0         0         0         0      Balls64.exe
  0         656     C+G       0         0         0         0      DolphinUS.exe
  0        2520     C+G       0         0         0         0      chrome.exe
  0        4216     C+G       0         0         0         0      Balls64.exe
  0        4472     C+G       20        17         0         0      FurMark.exe
  0        4868     C+G       0         0         0         0      Balls64.exe
  0         656     C+G       0         0         0         0      DolphinUS.exe
  0        2520     C+G       0         0         0         0      chrome.exe
  0        4216     C+G       0         0         0         0      Balls64.exe
  0        4472     C+G       20        17         0         0      FurMark.exe

```

Figure 26 Using `nvidia-smi` from a Windows guest VM to get resource usage by individual applications

### 7.3.2. Using Windows Performance Counters to monitor GPU performance

In Windows VMs, GPU metrics are available as [Windows Performance Counters](#) through the `NVIDIA GPU` object.

Any application that is enabled to read performance counters can access these metrics. You can access these metrics directly through the [Windows Performance Monitor](#) application that is included with the Windows OS.

The following example shows GPU metrics in the **Performance Monitor** application.



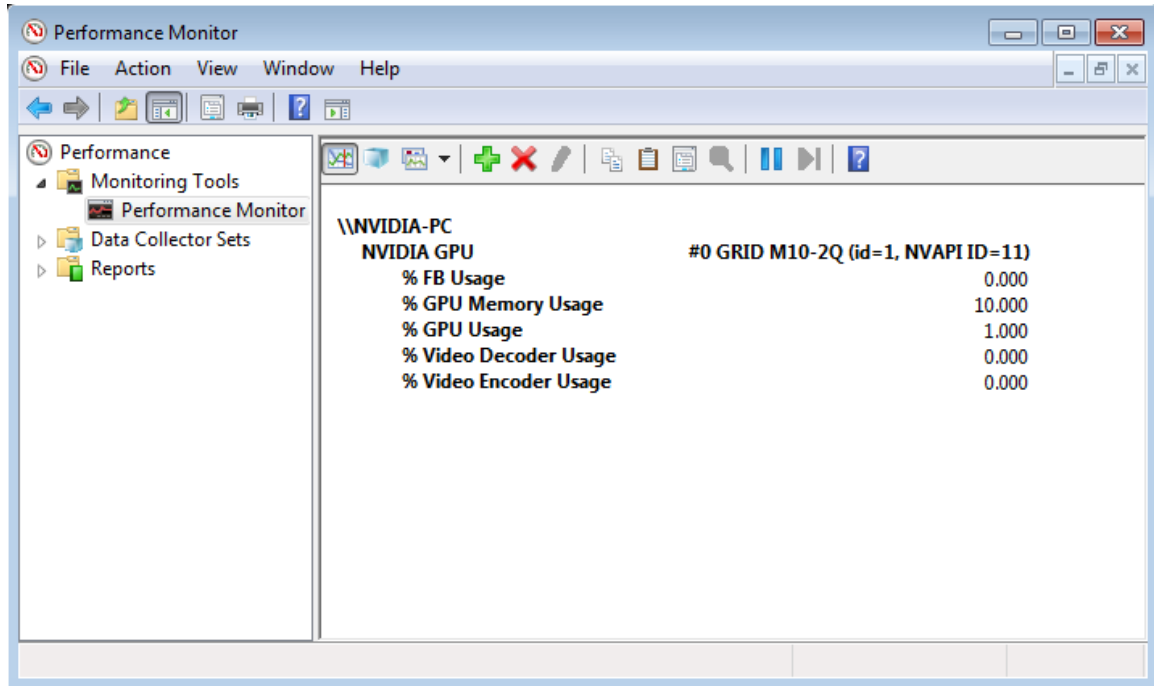


Figure 27 Using Windows Performance Monitor to monitor GPU performance

On vGPUs, the following GPU performance counters read as 0 because they are not applicable to vGPUs:

- ▶ % Bus Usage
- ▶ % Cooler rate
- ▶ Core Clock MHz
- ▶ Fan Speed
- ▶ Memory Clock MHz
- ▶ PCI-E current speed to GPU Mbps
- ▶ PCI-E current width to GPU
- ▶ PCI-E downstream width to GPU
- ▶ Power Consumption mW
- ▶ Temperature C

### 7.3.3. Using NVWMI to monitor GPU performance

In Windows VMs, [Windows Management Instrumentation \(WMI\)](#) exposes GPU metrics in the `ROOT\CIMV2\NV` namespace through NVWMI. NVWMI is included with the NVIDIA driver package. After the driver is installed, NVWMI help information in Windows Help format is available as follows:

```
C:\Program Files\NVIDIA Corporation\NVIDIA WMI Provider>nvwmi.chm
```

Any WMI-enabled application can access these metrics. The following example shows GPU metrics in the third-party application WMI Explorer, which is available for download from the [CodePlex WMI Explorer](#) page.

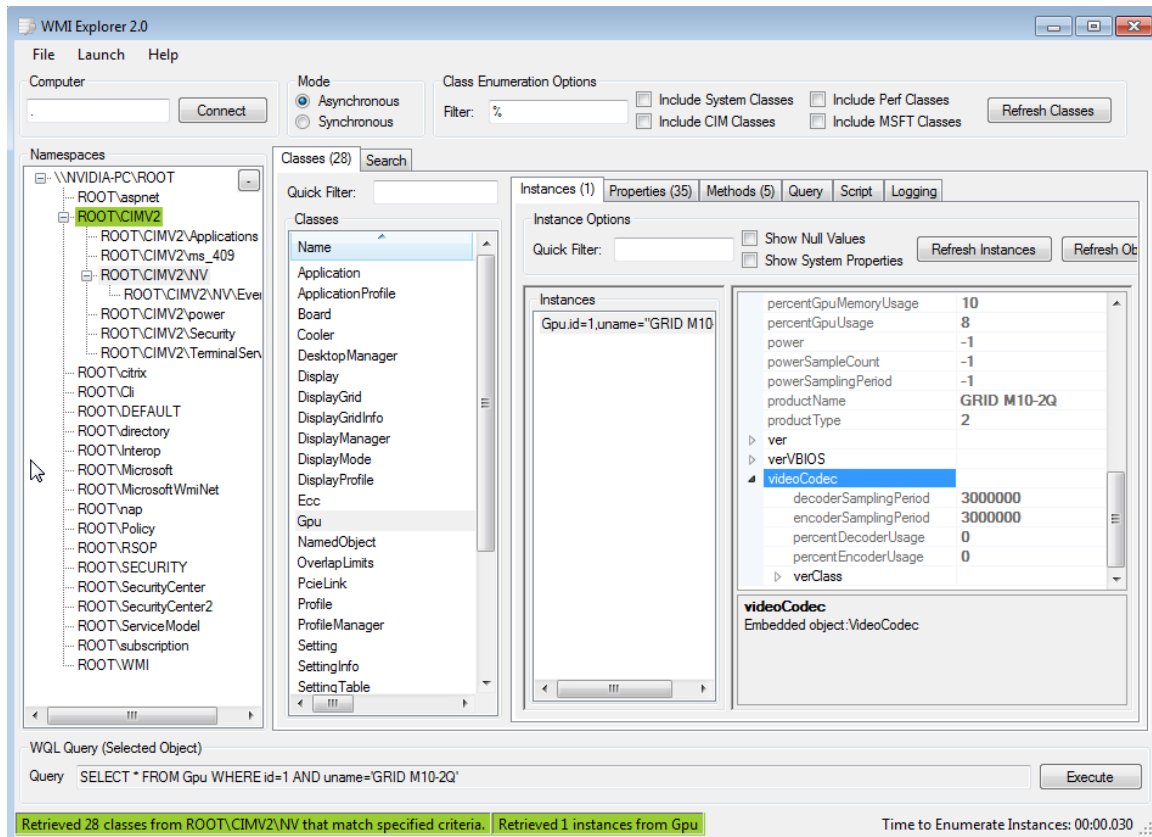


Figure 28 Using WMI Explorer to monitor GPU performance

On vGPUs, some instance properties of the following classes do not apply to vGPUs:

- ▶ Gpu
- ▶ PcieLink

#### Gpu instance properties that do not apply to vGPUs

Gpu Instance Property	Value reported on vGPU
gpuCoreClockCurrent	-1
memoryClockCurrent	-1
pciDownstreamWidth	0
pcieGpu.curGen	0
pcieGpu.curSpeed	0
pcieGpu.curWidth	0

Gpu Instance Property	Value reported on vGPU
pcieGpu.maxGen	1
pcieGpu.maxSpeed	2500
pcieGpu.maxWidth	0
power	-1
powerSampleCount	-1
powerSamplingPeriod	-1
verVBIOS.orderedValue	0
verVBIOS.strValue	-
verVBIOS.value	0

### **PcieLink** instance properties that do not apply to vGPUs

No instances of PcieLink are reported for vGPU.

# Chapter 8.

## CITRIX HYPERVISOR vGPU MANAGEMENT

You can perform Citrix Hypervisor advanced vGPU management techniques by using XenCenter and by using `xe` command line operations.

### 8.1. Management objects for GPUs

Citrix Hypervisor uses four underlying management objects for GPUs: physical GPUs, vGPU types, GPU groups, and vGPUs. These objects are used directly when managing vGPU by using `xe`, and indirectly when managing vGPU by using XenCenter.

#### 8.1.1. `pgpu` - Physical GPU

A `pgpu` object represents a physical GPU, such as one of the multiple GPUs present on a Tesla M60 or M10 card. Citrix Hypervisor automatically creates `pgpu` objects at startup to represent each physical GPU present on the platform.

##### 8.1.1.1. Listing the `pgpu` Objects Present on a Platform

To list the physical GPU objects present on a platform, use `xe pgpu-list`.

For example, this platform contains a Tesla P40 card with a single physical GPU and a Tesla M60 card with two physical GPUs:

```
[root@xenserver ~]# xe pgpu-list
uuid ( RO)                : f76d1c90-e443-4bfc-8f26-7959a7c85c68
  vendor-name ( RO)       : NVIDIA Corporation
  device-name ( RO)       : GP102GL [Tesla P40]
  gpu-group-uuid ( RW)    : 134a7b71-5ceb-8066-ef1b-3b319fb2bef3

uuid ( RO)                : 4c5e05d9-60fa-4fe5-9cfc-c641e95c8e85
  vendor-name ( RO)       : NVIDIA Corporation
  device-name ( RO)       : GM204GL [Tesla M60]
  gpu-group-uuid ( RW)    : 3df80574-c303-f020-efb3-342f969da5de

uuid ( RO)                : 4960e63c-c9fe-4a25-add4-ee697263e04c
  vendor-name ( RO)       : NVIDIA Corporation
  device-name ( RO)       : GM204GL [Tesla M60]
  gpu-group-uuid ( RW)    : d32560f2-2158-42f9-d201-511691e1cb2b
[root@xenserver ~]#
```

### 8.1.1.2. Viewing Detailed Information About a pgpu Object

To view detailed information about a pgpu, use `xe pgpu-param-list`:

```
[root@xenserver ~]# xe pgpu-param-list uuid=4960e63c-c9fe-4a25-add4-ee697263e04c
uuid ( RO)                : 4960e63c-c9fe-4a25-add4-ee697263e04c
    vendor-name ( RO)      : NVIDIA Corporation
    device-name ( RO)      : GM204GL [Tesla M60]
    dom0-access ( RO)      : enabled
    is-system-display-device ( RO) : false
    gpu-group-uuid ( RW)    : d32560f2-2158-42f9-d201-511691e1cb2b
    gpu-group-name-label ( RO) : 86:00.0 VGA compatible controller: NVIDIA
    Corporation GM204GL [Tesla M60] (rev a1)
    host-uuid ( RO)        : b55452df-1ee4-4e4e-bd97-3aee97b2123a
    host-name-label ( RO)  : xs7.1
    pci-id ( RO)           : 0000:86:00.0
    dependencies (SRO)     :
    other-config (MRW)     :
    supported-VGPU-types ( RO) : 5b9acd25-06fa-43e1-8b53-c35bceb8515c;
    16326fcb-543f-4473-a4ae-2d30516a2779; 0f9fc39a-0758-43c8-88cc-54c8491aa4d4;
    cecb2033-3b4a-437c-a0c0-c9dfdb692d9b; 095d8939-5f84-405d-a39a-684738f9b957;
    56c335be-4036-4a38-816c-c246a60556ac; ef0a94fd-2230-4fd4-ae0-d6d3f6ced4ef;
    11615f73-47b8-4494-806e-2a7b5e1d7bea; dbd8f2ac-f548-4c40-804b-9133cfda8090;
    a33189f1-1417-4593-aa7d-978c4f25b953; 3f437337-3682-4897-a7ba-6334519f4c19;
    99900aab-42b0-4cc4-8832-560ff6b60231
    enabled-VGPU-types (SRW) : 5b9acd25-06fa-43e1-8b53-c35bceb8515c;
    16326fcb-543f-4473-a4ae-2d30516a2779; 0f9fc39a-0758-43c8-88cc-54c8491aa4d4;
    cecb2033-3b4a-437c-a0c0-c9dfdb692d9b; 095d8939-5f84-405d-a39a-684738f9b957;
    56c335be-4036-4a38-816c-c246a60556ac; ef0a94fd-2230-4fd4-ae0-d6d3f6ced4ef;
    11615f73-47b8-4494-806e-2a7b5e1d7bea; dbd8f2ac-f548-4c40-804b-9133cfda8090;
    a33189f1-1417-4593-aa7d-978c4f25b953; 3f437337-3682-4897-a7ba-6334519f4c19;
    99900aab-42b0-4cc4-8832-560ff6b60231
    resident-VGPUs ( RO)   :
```

### 8.1.1.3. Viewing physical GPUs in XenCenter

To view physical GPUs in XenCenter, click on the server's **GPU** tab:

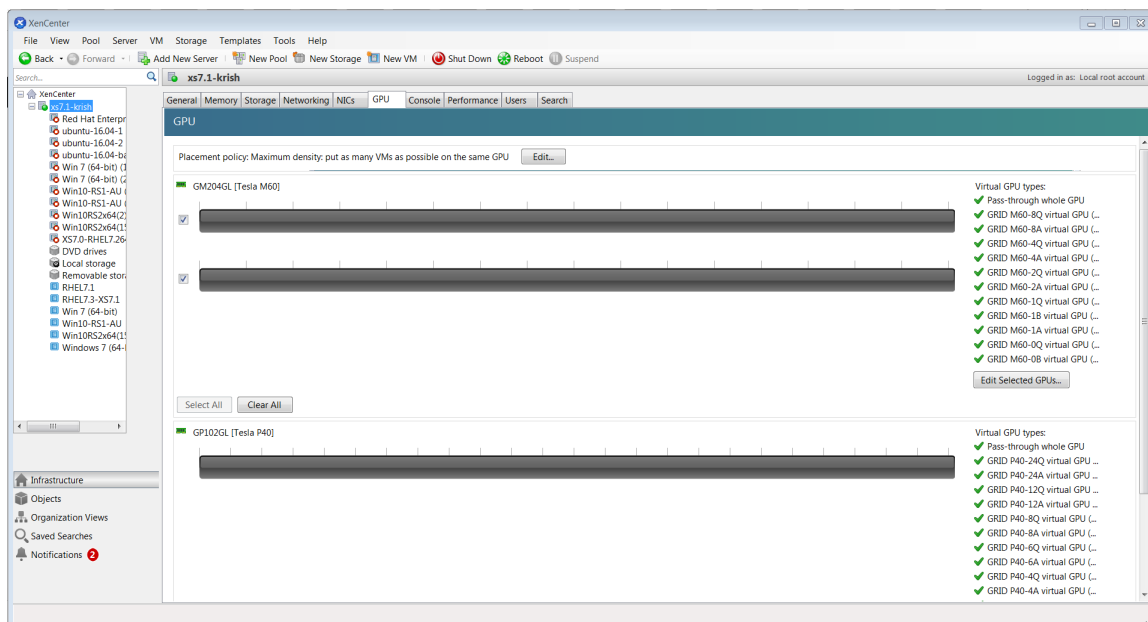


Figure 29 Physical GPU display in XenCenter

## 8.1.2. `vgpu-type` - Virtual GPU Type

A `vgpu-type` represents a type of virtual GPU, such as M60-0B, P40-8A, and P100-16Q. An additional, pass-through vGPU type is defined to represent a physical GPU that is directly assignable to a single guest VM.

Citrix Hypervisor automatically creates `vgpu-type` objects at startup to represent each virtual type supported by the physical GPUs present on the platform.

### 8.1.2.1. Listing the `vgpu-type` Objects Present on a Platform

To list the `vgpu-type` objects present on a platform, use `xe vgpu-type-list`.

For example, as this platform contains Tesla P100, Tesla P40, and Tesla M60 cards, the vGPU types reported are the types supported by these cards:

```
[root@xenserver ~]# xe vgpu-type-list
uuid ( RO)                : d27f84a2-53f8-4430-ad15-0eca225cd974
vendor-name ( RO)         : NVIDIA Corporation
model-name ( RO)          : GRID P40-12A
max-heads ( RO)           : 1
max-resolution ( RO)      : 1280x1024

uuid ( RO)                : 57bb231f-f61b-408e-a0c0-106bddd91019
vendor-name ( RO)         : NVIDIA Corporation
model-name ( RO)          : GRID P40-3Q
max-heads ( RO)           : 4
max-resolution ( RO)      : 4096x2160

uuid ( RO)                : 9b2eaba5-565f-4cb4-ad9b-6347cfb03e93
vendor-name ( RO)         : NVIDIA Corporation
model-name ( RO)          : GRID P40-2Q
```

```

        max-heads ( RO): 4
        max-resolution ( RO): 4096x2160

uuid ( RO)          : af593219-0800-42da-a51d-d13b35f589e1
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P40-4A
  max-heads ( RO): 1
  max-resolution ( RO): 1280x1024

uuid ( RO)          : 5b9acd25-06fa-43e1-8b53-c35bceb8515c
  vendor-name ( RO):
  model-name ( RO): passthrough
  max-heads ( RO): 0
  max-resolution ( RO): 0x0

uuid ( RO)          : af121387-0b58-498a-8d04-fe0305e4308f
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P40-3A
  max-heads ( RO): 1
  max-resolution ( RO): 1280x1024

uuid ( RO)          : 3b28a628-fd6c-4cda-b0fb-80165699229e
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P100-4Q
  max-heads ( RO): 4
  max-resolution ( RO): 4096x2160

uuid ( RO)          : 99900aab-42b0-4cc4-8832-560ff6b60231
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID M60-1Q
  max-heads ( RO): 2
  max-resolution ( RO): 4096x2160

uuid ( RO)          : 0f9fc39a-0758-43c8-88cc-54c8491aa4d4
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID M60-4A
  max-heads ( RO): 1
  max-resolution ( RO): 1280x1024

uuid ( RO)          : 4017c9dd-373f-431a-b36f-50e4e5c9f0c0
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P40-6A
  max-heads ( RO): 1
  max-resolution ( RO): 1280x1024

uuid ( RO)          : 125fbbdf-406e-4d7c-9de8-a7536aa1a838
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P40-24A
  max-heads ( RO): 1
  max-resolution ( RO): 1280x1024

uuid ( RO)          : 88162a34-1151-49d3-98ae-afcd963f3105
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P40-2A
  max-heads ( RO): 1
  max-resolution ( RO): 1280x1024

```

```

uuid ( RO)                : ad00a95c-d066-4158-b361-487abf57dd30
  vendor-name ( RO) : NVIDIA Corporation
  model-name ( RO) : GRID P40-1A
  max-heads ( RO) : 1
  max-resolution ( RO) : 1280x1024

uuid ( RO)                : 11615f73-47b8-4494-806e-2a7b5e1d7bea
  vendor-name ( RO) : NVIDIA Corporation
  model-name ( RO) : GRID M60-0Q
  max-heads ( RO) : 2
  max-resolution ( RO) : 2560x1600

uuid ( RO)                : 6ea0cd56-526c-4966-8f53-7e1721b95a5c
  vendor-name ( RO) : NVIDIA Corporation
  model-name ( RO) : GRID P40-4Q
  max-heads ( RO) : 4
  max-resolution ( RO) : 4096x2160

uuid ( RO)                : 095d8939-5f84-405d-a39a-684738f9b957
  vendor-name ( RO) : NVIDIA Corporation
  model-name ( RO) : GRID M60-4Q
  max-heads ( RO) : 4
  max-resolution ( RO) : 4096x2160

uuid ( RO)                : 9626e649-6802-4396-976d-94c0ead1f835
  vendor-name ( RO) : NVIDIA Corporation
  model-name ( RO) : GRID P40-12Q
  max-heads ( RO) : 4
  max-resolution ( RO) : 4096x2160

uuid ( RO)                : a33189f1-1417-4593-aa7d-978c4f25b953
  vendor-name ( RO) : NVIDIA Corporation
  model-name ( RO) : GRID M60-0B
  max-heads ( RO) : 2
  max-resolution ( RO) : 2560x1600

uuid ( RO)                : dbd8f2ac-f548-4c40-804b-9133cfda8090
  vendor-name ( RO) : NVIDIA Corporation
  model-name ( RO) : GRID M60-1A
  max-heads ( RO) : 1
  max-resolution ( RO) : 1280x1024

uuid ( RO)                : ef0a94fd-2230-4fd4-ae0-d6d3f6ced4ef
  vendor-name ( RO) : NVIDIA Corporation
  model-name ( RO) : GRID M60-8Q
  max-heads ( RO) : 4
  max-resolution ( RO) : 4096x2160

uuid ( RO)                : 67fa06ab-554e-452b-a66e-a4048a5bdfd7
  vendor-name ( RO) : NVIDIA Corporation
  model-name ( RO) : GRID P40-6Q
  max-heads ( RO) : 4
  max-resolution ( RO) : 4096x2160

uuid ( RO)                : 739d7b8e-50e2-48a1-ae0d-5047aa490f0e
  vendor-name ( RO) : NVIDIA Corporation
  model-name ( RO) : GRID P40-8A
  max-heads ( RO) : 1

```



```
max-resolution ( RO): 1280x1024

uuid ( RO)          : 9fb62f31-7dfb-46f8-a4a9-cca8db48147e
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P100-8Q
  max-heads ( RO): 4
  max-resolution ( RO): 4096x2160

uuid ( RO)          : 56c335be-4036-4a38-816c-c246a60556ac
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID M60-1B
  max-heads ( RO): 4
  max-resolution ( RO): 2560x1600

uuid ( RO)          : 3f437337-3682-4897-a7ba-6334519f4c19
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID M60-8A
  max-heads ( RO): 1
  max-resolution ( RO): 1280x1024

uuid ( RO)          : 25dbb2d3-a074-4f9f-92ce-b42d8b3d1de2
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P40-1B
  max-heads ( RO): 4
  max-resolution ( RO): 2560x1600

uuid ( RO)          : cecb2033-3b4a-437c-a0c0-c9dfdb692d9b
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID M60-2Q
  max-heads ( RO): 4
  max-resolution ( RO): 4096x2160

uuid ( RO)          : 16326fcb-543f-4473-a4ae-2d30516a2779
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID M60-2A
  max-heads ( RO): 1
  max-resolution ( RO): 1280x1024

uuid ( RO)          : 7ca2399f-89ab-49dd-bf96-75071ced28fc
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P40-24Q
  max-heads ( RO): 4
  max-resolution ( RO): 4096x2160

uuid ( RO)          : 9611a3f4-d130-4a66-a61b-21d4a2ca4663
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P40-8Q
  max-heads ( RO): 4
  max-resolution ( RO): 4096x2160

uuid ( RO)          : d0e4a116-a944-42ef-a8dc-62a54c4d2d77
  vendor-name ( RO): NVIDIA Corporation
  model-name ( RO): GRID P40-1Q
  max-heads ( RO): 2
  max-resolution ( RO): 4096x2160

[root@xenserver ~]#
```

### 8.1.2.2. Viewing Detailed Information About a `vgpu-type` Object

To see detailed information about a `vgpu-type`, use `xe vgpu-type-param-list`:

```
[root@xenserver ~]# xe xe vgpu-type-param-list uuid=7ca2399f-89ab-49dd-bf96-75071ced28fc
uuid ( RO)                : 7ca2399f-89ab-49dd-bf96-75071ced28fc
  vendor-name ( RO)       : NVIDIA Corporation
  model-name ( RO)        : GRID P40-24Q
  framebuffer-size ( RO)  : 24092082176
  max-heads ( RO)         : 4
  max-resolution ( RO)    : 4096x2160
  supported-on-PGPUs ( RO) : f76d1c90-e443-4bfc-8f26-7959a7c85c68
  enabled-on-PGPUs ( RO)  : f76d1c90-e443-4bfc-8f26-7959a7c85c68
  supported-on-GPU-groups ( RO) : 134a7b71-5ceb-8066-ef1b-3b319fb2bef3
  enabled-on-GPU-groups ( RO) : 134a7b71-5ceb-8066-ef1b-3b319fb2bef3
  VGPU-uuids ( RO)        :
  experimental ( RO)      : false
[root@xenserver ~]#
```

### 8.1.3. `gpu-group` - collection of physical GPUs

A `gpu-group` is a collection of physical GPUs, all of the same type. Citrix Hypervisor automatically creates `gpu-group` objects at startup to represent the distinct types of physical GPU present on the platform.

#### 8.1.3.1. Listing the `gpu-group` Objects Present on a Platform

To list the `gpu-group` objects present on a platform, use `xe gpu-group-list`.

For example, a system with a single Tesla P100 card, a single Tesla P40 card, and two Tesla M60 cards contains a single GPU group of type Tesla P100, a single GPU group of type Tesla P40, and two GPU groups of type Tesla M60:

```
[root@xenserver ~]# xe gpu-group-list
uuid ( RO)                : 3d652a59-beaf-ddb3-3b19-c8c77ef60605
  name-label ( RW)         : Group of NVIDIA Corporation GP100GL [Tesla P100 PCIe
  16GB] GPUs
  name-description ( RW)   :
uuid ( RO)                : 3df80574-c303-f020-efb3-342f969da5de
  name-label ( RW)         : 85:00.0 VGA compatible controller: NVIDIA
  Corporation GM204GL [Tesla M60] (rev a1)
  name-description ( RW)   : 85:00.0 VGA compatible controller: NVIDIA
  Corporation GM204GL [Tesla M60] (rev a1)
uuid ( RO)                : 134a7b71-5ceb-8066-ef1b-3b319fb2bef3
  name-label ( RW)         : 87:00.0 3D controller: NVIDIA Corporation GP102GL
  [TESLA P40] (rev a1)
  name-description ( RW)   : 87:00.0 3D controller: NVIDIA Corporation GP102GL
  [TESLA P40] (rev a1)
uuid ( RO)                : d32560f2-2158-42f9-d201-511691e1cb2b
  name-label ( RW)         : 86:00.0 VGA compatible controller: NVIDIA
  Corporation GM204GL [Tesla M60] (rev a1)
  name-description ( RW)   : 86:00.0 VGA compatible controller: NVIDIA
  Corporation GM204GL [Tesla M60] (rev a1)
[root@xenserver ~]#
```

### 8.1.3.2. Viewing Detailed Information About a `gpu-group` Object

To view detailed information about a `gpu-group`, use `xe gpu-group-param-list`:

```
[root@xenserver ~]# xe gpu-group-param-list uuid=134a7b71-5ceb-8066-ef1b-3b319fb2bef3
uuid ( RO)                               : 134a7b71-5ceb-8066-ef1b-3b319fb2bef3
name-label ( RW)                          : 87:00.0 3D controller: NVIDIA Corporation
GP102GL [TESLA P40] (rev a1)
name-description ( RW)                    : 87:00.0 3D controller: NVIDIA Corporation
GP102GL [TESLA P40] (rev a1)
VGPU-uuids (SRO)                          : 101fb062-427f-1999-9e90-5a914075e9ca
PGPU-uuids (SRO)                          : f76dlc90-e443-4bfc-8f26-7959a7c85c68
other-config (MRW)                         :
enabled-VGPU-types ( RO)                  : d0e4a116-a944-42ef-a8dc-62a54c4d2d77;
9611a3f4-d130-4a66-a61b-21d4a2ca4663; 7ca2399f-89ab-49dd-bf96-75071ced28fc;
25dbb2d3-a074-4f9f-92ce-b42d8b3d1de2; 739d7b8e-50e2-48a1-ae0d-5047aa490f0e;
67fa06ab-554e-452b-a66e-a4048a5bfd7; 9626e649-6802-4396-976d-94c0ead1f835;
6ea0cd56-526c-4966-8f53-7e1721b95a5c; ad00a95c-d066-4158-b361-487abf57dd30;
88162a34-1151-49d3-98ae-afcd963f3105; 125fbbdf-406e-4d7c-9de8-a7536aa1a838;
4017c9dd-373f-431a-b36f-50e4e5c9f0c0; af121387-0b58-498a-8d04-fe0305e4308f;
5b9acd25-06fa-43e1-8b53-c35bceb8515c; af593219-0800-42da-a51d-d13b35f589e1;
9b2eaba5-565f-4cb4-ad9b-6347cfb03e93; 57bb231f-f61b-408e-a0c0-106bdd91019;
d27f84a2-53f8-4430-ad15-0eca225cd974
supported-VGPU-types ( RO)                : d0e4a116-a944-42ef-a8dc-62a54c4d2d77;
9611a3f4-d130-4a66-a61b-21d4a2ca4663; 7ca2399f-89ab-49dd-bf96-75071ced28fc;
25dbb2d3-a074-4f9f-92ce-b42d8b3d1de2; 739d7b8e-50e2-48a1-ae0d-5047aa490f0e;
67fa06ab-554e-452b-a66e-a4048a5bfd7; 9626e649-6802-4396-976d-94c0ead1f835;
6ea0cd56-526c-4966-8f53-7e1721b95a5c; ad00a95c-d066-4158-b361-487abf57dd30;
88162a34-1151-49d3-98ae-afcd963f3105; 125fbbdf-406e-4d7c-9de8-a7536aa1a838;
4017c9dd-373f-431a-b36f-50e4e5c9f0c0; af121387-0b58-498a-8d04-fe0305e4308f;
5b9acd25-06fa-43e1-8b53-c35bceb8515c; af593219-0800-42da-a51d-d13b35f589e1;
9b2eaba5-565f-4cb4-ad9b-6347cfb03e93; 57bb231f-f61b-408e-a0c0-106bdd91019;
d27f84a2-53f8-4430-ad15-0eca225cd974
allocation-algorithm ( RW)                 : depth-first
[root@xenserver ~]
```

### 8.1.4. `vgpu` - Virtual GPU

A `vgpu` object represents a virtual GPU. Unlike the other GPU management objects, `vgpu` objects are not created automatically by Citrix Hypervisor. Instead, they are created as follows:

- ▶ When a VM is configured through XenCenter or through `xe` to use a vGPU
- ▶ By cloning a VM that is configured to use vGPU, as explained in [Cloning vGPU-Enabled VMs](#)

## 8.2. Creating a vGPU Using `xe`

Use `xe vgpu-create` to create a `vgpu` object, specifying the type of vGPU required, the GPU group it will be allocated from, and the VM it is associated with:

```
[root@xenserver ~]# xe vgpu-create vm-uuid=e71afda4-53f4-3a1b-6c92-a364a7f619c2 gpu-group-uuid=be825ba2-01d7-8d51-9780-f82cfaa64924 vgpu-type-uuid=3f318889-7508-c9fd-7134-003d4d05ae56b73cbd30-096f-8a9a-523e-a800062f4ca7
[root@xenserver ~]#
```

Creating the `vgpu` object for a VM does not immediately cause a virtual GPU to be created on a physical GPU. Instead, the `vgpu` object is created whenever its associated VM is started. For more details on how vGPUs are created at VM startup, see [Controlling vGPU allocation](#).



The owning VM must be in the powered-off state in order for the `vgpu-create` command to succeed.

A `vgpu` object's owning VM, associated GPU group, and vGPU type are fixed at creation and cannot be subsequently changed. To change the type of vGPU allocated to a VM, delete the existing `vgpu` object and create another one.

## 8.3. Controlling vGPU allocation

Configuring a VM to use a vGPU in XenCenter, or creating a `vgpu` object for a VM using `xe`, does not immediately cause a virtual GPU to be created; rather, the virtual GPU is created at the time the VM is next booted, using the following steps:

- ▶ The GPU group that the `vgpu` object is associated with is checked for a physical GPU that can host a vGPU of the required type (i.e. the `vgpu` object's associated `vgpu-type`). Because vGPU types cannot be mixed on a single physical GPU, the new vGPU can only be created on a physical GPU that has no vGPUs resident on it, or only vGPUs of the same type, and less than the limit of vGPUs of that type that the physical GPU can support.
- ▶ If no such physical GPUs exist in the group, the `vgpu` creation fails and the VM startup is aborted.
- ▶ Otherwise, if more than one such physical GPU exists in the group, a physical GPU is selected according to the GPU group's *allocation policy*, as described in [Modifying GPU Allocation Policy](#).

### 8.3.1. Determining the Physical GPU on Which a Virtual GPU is Resident

The `vgpu` object's `resident-on` parameter returns the UUID of the `pgpu` object for the physical GPU the vGPU is resident on.

To determine the physical GPU that a virtual GPU is resident on, use `vgpu-param-get`:

```
[root@xenserver ~]# xe vgpu-param-get uuid=101fb062-427f-1999-9e90-5a914075e9ca
param-name=resident-on
f76d1c90-e443-4bfc-8f26-7959a7c85c68

[root@xenserver ~]# xe pgpu-param-list uuid=f76d1c90-e443-4bfc-8f26-7959a7c85c68
uuid ( RO)                : f76d1c90-e443-4bfc-8f26-7959a7c85c68
    vendor-name ( RO)      : NVIDIA Corporation
    device-name ( RO)      : GP102GL [Tesla P40]
    gpu-group-uuid ( RW)   : 134a7b71-5ceb-8066-ef1b-3b319fb2bef3
    gpu-group-name-label ( RO) : 87:00.0 3D controller: NVIDIA Corporation
    GP102GL [TESLA P40] (rev a1)
```

```

        host-uuid ( RO): b55452df-1ee4-4e4e-bd97-3aee97b2123a
    host-name-label ( RO): xs7.1-krish
        pci-id ( RO): 0000:87:00.0
    dependencies (SRO):
    other-config (MRW):
    supported-VGPU-types ( RO): 5b9acd25-06fa-43e1-8b53-c35bceb8515c;
88162a34-1151-49d3-98ae-afcd963f3105; 9b2eaba5-565f-4cb4-ad9b-6347cfb03e93;
739d7b8e-50e2-48a1-ae0d-5047aa490f0e; d0e4a116-a944-42ef-a8dc-62a54c4d2d77;
7ca2399f-89ab-49dd-bf96-75071ced28fc; 67fa06ab-554e-452b-a66e-a4048a5bfd7;
9611a3f4-d130-4a66-a61b-21d4a2ca4663; d27f84a2-53f8-4430-ad15-0eca225cd974;
125fbbdf-406e-4d7c-9de8-a7536aa1a838; 4017c9dd-373f-431a-b36f-50e4e5c9f0c0;
6ea0cd56-526c-4966-8f53-7e1721b95a5c; af121387-0b58-498a-8d04-fe0305e4308f;
9626e649-6802-4396-976d-94c0ead1f835; ad00a95c-d066-4158-b361-487abf57dd30;
af593219-0800-42da-a51d-d13b35f589e1; 25dbb2d3-a074-4f9f-92ce-b42d8b3d1de2;
57bb231f-f61b-408e-a0c0-106bddd91019
    enabled-VGPU-types (SRW): 5b9acd25-06fa-43e1-8b53-c35bceb8515c;
88162a34-1151-49d3-98ae-afcd963f3105; 9b2eaba5-565f-4cb4-ad9b-6347cfb03e93;
739d7b8e-50e2-48a1-ae0d-5047aa490f0e; d0e4a116-a944-42ef-a8dc-62a54c4d2d77;
7ca2399f-89ab-49dd-bf96-75071ced28fc; 67fa06ab-554e-452b-a66e-a4048a5bfd7;
9611a3f4-d130-4a66-a61b-21d4a2ca4663; d27f84a2-53f8-4430-ad15-0eca225cd974;
125fbbdf-406e-4d7c-9de8-a7536aa1a838; 4017c9dd-373f-431a-b36f-50e4e5c9f0c0;
6ea0cd56-526c-4966-8f53-7e1721b95a5c; af121387-0b58-498a-8d04-fe0305e4308f;
9626e649-6802-4396-976d-94c0ead1f835; ad00a95c-d066-4158-b361-487abf57dd30;
af593219-0800-42da-a51d-d13b35f589e1; 25dbb2d3-a074-4f9f-92ce-b42d8b3d1de2;
57bb231f-f61b-408e-a0c0-106bddd91019
    resident-VGPUs ( RO): 101fb062-427f-1999-9e90-5a914075e9ca
[root@xenserver ~]#

```



If the vGPU is not currently running, the `resident-on` parameter is not instantiated for the vGPU, and the `vgpu-param-get` operation returns:

```
<not in database>
```

## 8.3.2. Controlling the vGPU types enabled on specific physical GPUs

Physical GPUs support several vGPU types, as defined in [Supported GPUs](#) and the “pass-through” type that is used to assign an entire physical GPU to a VM (see [Using GPU Pass-Through on Citrix Hypervisor](#)).

### 8.3.2.1. Controlling vGPU types enabled on specific physical GPUs by using XenCenter

To limit the types of vGPU that may be created on a specific physical GPU:

1. Open the server’s **GPU** tab in XenCenter.
2. Select the box beside one or more GPUs on which you want to limit the types of vGPU.
3. Select **Edit Selected GPUs**.

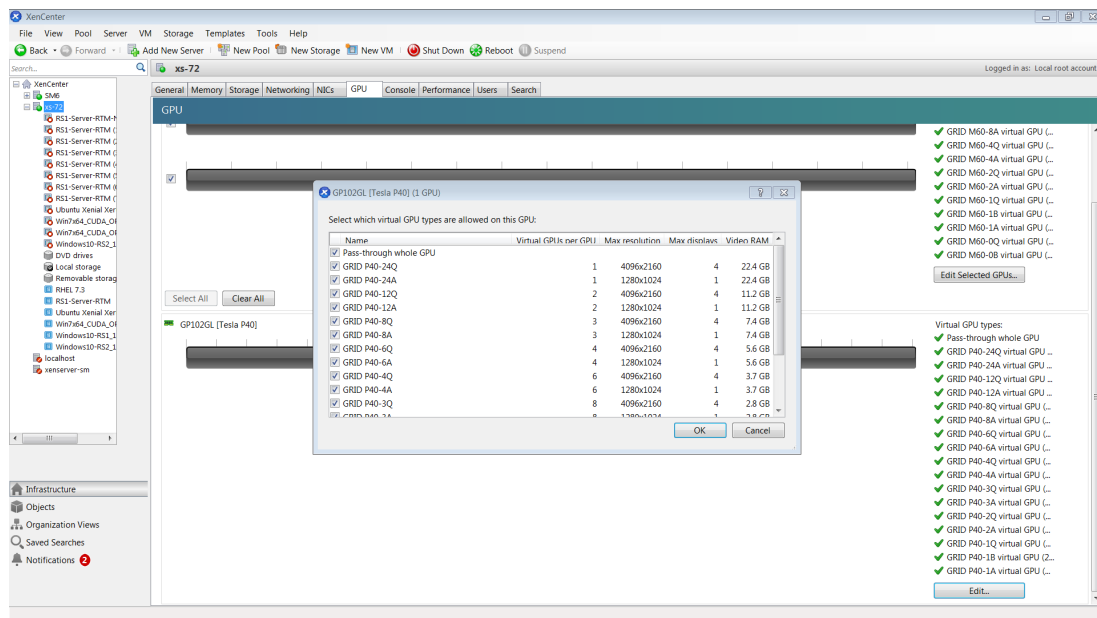


Figure 30 Editing a GPU's enabled vGPU types using XenCenter

### 8.3.2.2. Controlling vGPU Types Enabled on Specific Physical GPUs by Using `xe`

The physical GPU's `pgpu` object's `enabled-vGPU-types` parameter controls the vGPU types enabled on specific physical GPUs.

To modify the `pgpu` object's `enabled-vGPU-types` parameter, use `xe pgpu-param-set`:

```
[root@xenserver ~]# xe pgpu-param-list uuid=cb08aaae-8e5a-47cb-888e-60dcc73c01d3
uuid ( RO)                               : cb08aaae-8e5a-47cb-888e-60dcc73c01d3
      vendor-name ( RO)                   : NVIDIA Corporation
      device-name ( RO)                   : GP102GL [Tesla P40]
      dom0-access ( RO)                   : enabled
is-system-display-device ( RO)           : false
      gpu-group-uuid ( RW)                 : bfe1603d-c526-05f3-e64f-951485ef3b49
      gpu-group-name-label ( RO)          : 87:00.0 3D controller: NVIDIA Corporation GP102GL
      [Tesla P40] (rev al)
      host-uuid ( RO)                     : fdeb6bbb-e460-4cfl-ad43-49ac81c20540
      host-name-label ( RO)               : xs-72
      pci-id ( RO)                        : 0000:87:00.0
      dependencies (SRO)                  :
      other-config (MRW)                  :
      supported-VGPU-types ( RO)          : 23e6b80b-1e5e-4c33-bedb-e6dlae472fec;
      f5583e39-2540-440d-a0ee-dde9f0783abf; a18e46ff-4d05-4322-b040-667ce77d78a8;
      adell9a9-84e1-435f-b0e9-14c162e212fb; 2560d066-054a-48a9-a44d-3f3f90493a00;
      47858f38-045d-4a05-9b1c-9128fee6b0ab; 1fb527f6-493f-442b-abe2-94a6fafd49ce;
      78b8e044-09ae-4a4c-8a96-b20c7a585842; 18ed7e7e-f8b7-496e-9784-8ba4e35aac3;
      48681d88-c4e5-4e39-85ff-c9ba12e8e484 ; cc3dbbfb-4b83-400d-8c52-811948b7f8c4;
      8elad75a-ed5f-4609-83ff-5f9bca9aac2; 840389a0-f511-4f90-8153-8a749d85b09e;
      a2042742-da67-4613-a538-1d17d30ccb9; 299e47c2-8fcl-4edf-aa31-e29db84168c6;
      e95c636e-06e6-4 47e-8b49-14b37d308922; 0524a5d0-7160-48c5-a9e1-cc33e76dc0de;
      09043fb2-6d67-4443-b312-25688f13e012
      enabled-VGPU-types (SRW)           : 23e6b80b-1e5e-4c33-bedb-e6dlae472fec;
      f5583e39-2540-440d-a0ee-dde9f0783abf; a18e46ff-4d05-4322-b040-667ce77d78a8;
      adell9a9-84e1-435f-b0e9-14c162e212fb; 2560d066-054a-48a9-a44d-3f3f90493a00;
```

```
47858f38-045d-4a05-9b1c-9128fee6b0ab; Ifb527f6-493f-442b-abe2-94a6fafd49ce;
78b8e044-09ae-4a4c-8a96-b20c7a585842; 18ed7e7e-f8b7-496e-9784-8ba4e35acaa3;
48681d88-c4e5-4e39-85ff-c9ba12e8e484 ; cc3dbbfb-4b83-400d-8c52-811948b7f8c4;
8elad75a-ed5f-4609-83ff-5f9bca9aaca2; 840389a0-f511-4f90-8153-8a749d85b09e;
a2042742-da67-4613-a538-1d17d30dccb9; 299e47c2-8fc1-4edf-aa31-e29db84168c6;
e95c636e-06e6-4 47e-8b49-14b37d308922; 0524a5d0-7160-48c5-a9e1-cc33e76dc0de;
09043fb2-6d67-4443-b312-25688f13e012
resident-VGPUs ( RO):
```

```
[root@xenserver-vgx-test ~]# xe pgpu-param-set
  uuid=cb08aaae-8e5a-47cb-888e-60dcc73c01d3 enabled-VGPU-types=23e6b80b-
  1e5e-4c33-bedb-e6d1ae472fec
```

### 8.3.3. Creating vGPUs on Specific Physical GPUs

To precisely control allocation of vGPUs on specific physical GPUs, create separate GPU groups for the physical GPUs you wish to allocate vGPUs on. When creating a virtual GPU, create it on the GPU group containing the physical GPU you want it to be allocated on.

For example, to create a new GPU group for the physical GPU at PCI bus ID 0000:87:00.0, follow these steps:

1. Create the new GPU group with an appropriate name:

```
[root@xenserver ~]# xe gpu-group-create name-label="GRID P40 87:0.0"
  3f870244-41da-469f-71f3-22bc6d700e71
[root@xenserver ~]#
```

2. Find the UUID of the physical GPU at 0000:87:0.0 that you want to assign to the new GPU group:

```
[root@xenserver ~]# xe pgpu-list pci-id=0000:87:00.0
uuid ( RO)                : f76d1c90-e443-4bfc-8f26-7959a7c85c68
  vendor-name ( RO): NVIDIA Corporation
  device-name ( RO): GP102GL [Tesla P40]
  gpu-group-uuid ( RW): 134a7b71-5ceb-8066-ef1b-3b319fb2bef3
[root@xenserver ~]
```



The `pci-id` parameter passed to the `pgpu-list` command must be in the exact format shown, with the PCI domain fully specified (for example, 0000) and the PCI bus and devices numbers each being two digits (for example, 87:00.0).

3. Ensure that no vGPUs are currently operating on the physical GPU by checking the `resident-VGPUs` parameter:

```
[root@xenserver ~]# xe pgpu-param-get uuid=f76d1c90-
  e443-4bfc-8f26-7959a7c85c68 param-name=resident-VGPUs
[root@xenserver ~]#
```

4. If any vGPUs are listed, shut down the VMs associated with them.
5. Change the `gpu-group-uuid` parameter of the physical GPU to the UUID of the newly-created GPU group:

```
[root@xenserver ~]# xe pgpu-param-set uuid=7c1e3cff-1429-0544-df3d-
  bf8a086fb70a gpu-group-uuid=585877ef-5a6c-66af-fc56-7bd525bdc2f6
[root@xenserver ~]#
```

Any vgpu object now created that specifies this GPU group UUID will always have its vGPUs created on the GPU at PCI bus ID 0000:05:0.0.

You can add more than one physical GPU to a manually-created GPU group - for example, to represent all the GPUs attached to the same CPU socket in a multi-socket server platform - but as for automatically-created GPU groups, all the physical GPUs in the group must be of the same type.

In XenCenter, manually-created GPU groups appear in the GPU type listing in a VM's GPU Properties. Select a GPU type within the group from which you wish the vGPU to be allocated:

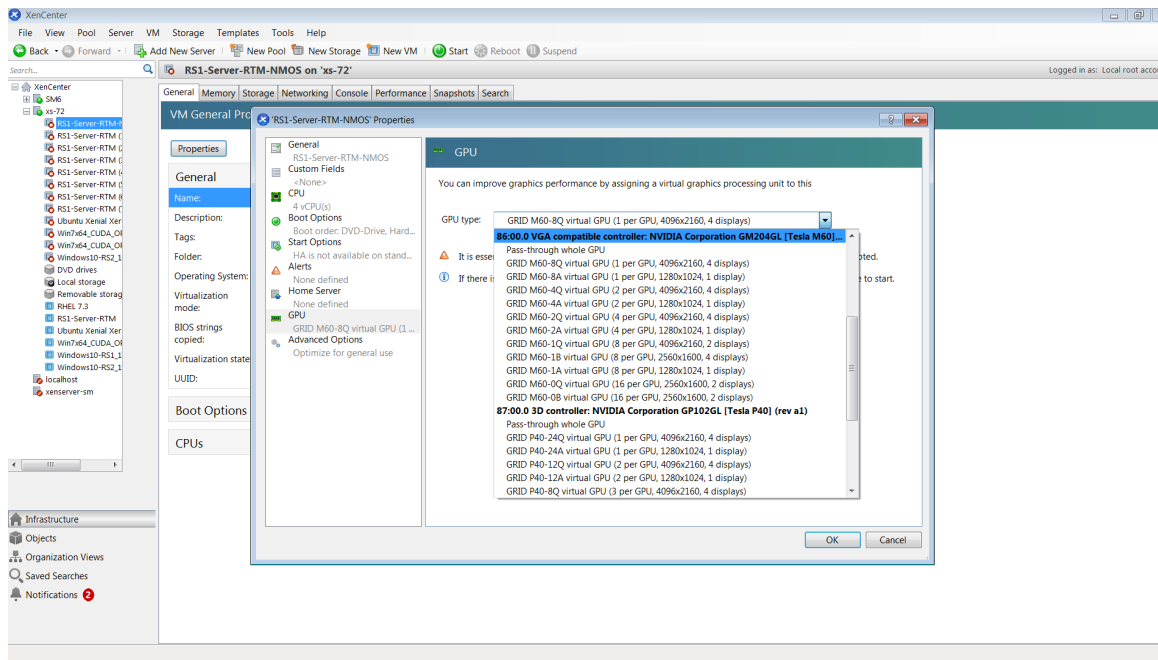


Figure 31 Using a custom GPU group within XenCenter

## 8.4. Cloning vGPU-Enabled VMs

The fast-clone or copying feature of Citrix Hypervisor can be used to rapidly create new VMs from a “golden” base VM image that has been configured with NVIDIA vGPU, the NVIDIA driver, applications, and remote graphics software.

When a VM is cloned, any vGPU configuration associated with the base VM is copied to the cloned VM. Starting the cloned VM will create a vGPU instance of the same type as the original VM, from the same GPU group as the original vGPU.

### 8.4.1. Cloning a vGPU-enabled VM by using xe

To clone a vGPU-enabled VM from the dom0 shell, use `vm-clone`:



```
[root@xenserver ~]# xe vm-clone new-name-label="new-vm" vm="base-vm-name"
7f7035cb-388d-1537-1465-1857fb6498e7
[root@xenserver ~]#
```

## 8.4.2. Cloning a vGPU-enabled VM by using XenCenter

To clone a vGPU-enabled VM by using XenCenter, use the VM's **Copy VM** command as shown in Figure 32.

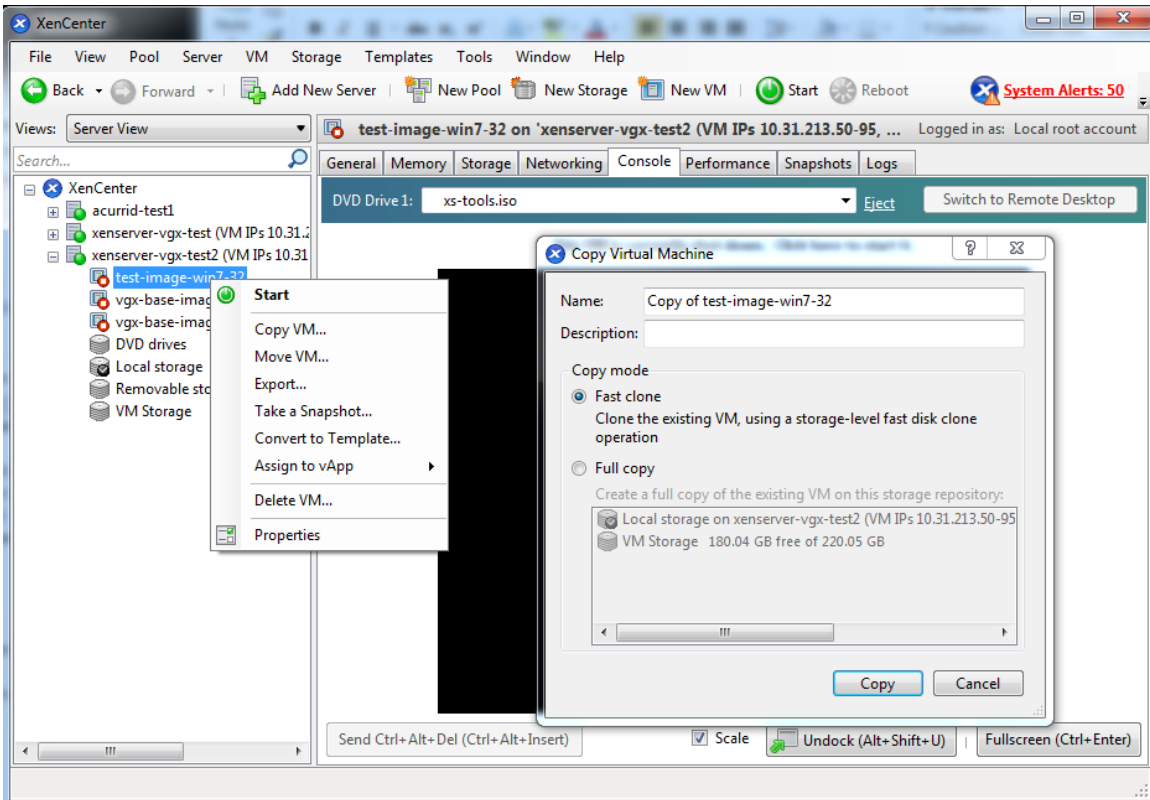


Figure 32 Cloning a VM using XenCenter

# Chapter 9.

## CITRIX HYPERVISOR PERFORMANCE TUNING

This chapter provides recommendations on optimizing performance for VMs running with NVIDIA vGPU on Citrix Hypervisor.

### 9.1. Citrix Hypervisor Tools

To get maximum performance out of a VM running on Citrix Hypervisor, regardless of whether you are using NVIDIA vGPU, you must install Citrix Hypervisor tools within the VM. Without the optimized networking and storage drivers that the Citrix Hypervisor tools provide, remote graphics applications running on NVIDIA vGPU will not deliver maximum performance.

### 9.2. Using Remote Graphics

NVIDIA vGPU implements a console VGA interface that permits the VM's graphics output to be viewed through XenCenter's **console** tab. This feature allows the desktop of a vGPU-enabled VM to be visible in XenCenter before any NVIDIA graphics driver is loaded in the virtual machine, but it is intended solely as a management convenience; it only supports output of vGPU's primary display and isn't designed or optimized to deliver high frame rates.

To deliver high frames from multiple heads on vGPU, NVIDIA recommends that you install a high-performance remote graphics stack such as Citrix Virtual Apps and Desktops with HDX 3D Pro remote graphics and, after the stack is installed, disable vGPU's console VGA.



**Caution** Using Windows Remote Desktop (RDP) to access Windows 7 or Windows Server 2008 VMs running NVIDIA vGPU will cause the NVIDIA driver in the VM to be unloaded. GPU-accelerated DirectX, OpenGL, and the NVIDIA control panel will be unavailable

whenever RDP is active. Installing a VNC server in the VM will allow for basic, low-performance remote access while leaving the NVIDIA driver loaded and vGPU active, but for high performance remote accesses, use an accelerated stack such as Citrix Virtual Apps and Desktops.

## 9.2.1. Disabling Console VGA

The console VGA interface in vGPU is optimized to consume minimal resources, but when a system is loaded with a high number of VMs, disabling the console VGA interface entirely may yield some performance benefit.

Once you have installed an alternate means of accessing a VM (such as Citrix Virtual Apps and Desktops or a VNC server), its vGPU console VGA interface can be disabled as follows, depending on the version of Citrix Hypervisor that you are using:

- ▶ **Citrix Hypervisor 8.1 or later:** Create the vGPU by using the `xe` command, and specify plugin parameters for the group to which the vGPU belongs:

1. Create the vGPU.

```
[root@xenserver ~]# xe vgpu-create gpu-group-uuid=$gpu_group_uuid vgpu-type-uuid=$vgpu_type_uuid vm-uuid=$vm_uuid
```

This command returns `vgpu_uuid` as stored in XAPI.

2. Specify plugin parameters for the group to which the vGPU belongs.

```
[root@xenserver ~]# xe vgpu-param-set uuid=$vgpu_uuid extra_args=disable_vnc=1
```

- ▶ **Citrix Hypervisor earlier than 8.1:** Specify `disable_vnc=1` in the VM's `platform:vgpu_extra_args` parameter:

```
[root@xenserver ~]# xe vm-param-set uuid=e71afda4-53f4-3a1b-6c92-a364a7f619c2 platform:vgpu_extra_args="disable_vnc=1"
[root@xenserver ~]#
```

The new console VGA setting takes effect the next time the VM is started or rebooted. With console VGA disabled, the Citrix Hypervisor console will display the Windows boot splash screen for the VM, but nothing beyond that.



### Caution

If you disable console VGA before you have installed or enabled an alternate mechanism to access the VM (such as Citrix Virtual Apps and Desktops), you will not be able to interact with the VM once it has booted.

You can recover console VGA access by making one of the following changes:

- ▶ Removing the `vgpu_extra_args` key from the `platform` parameter
- ▶ Removing `disable_vnc=1` from the `vgpu_extra_args` key
- ▶ Setting `disable_vnc=0`, for example:

```
[root@xenserver ~]# xe vm-param-set uuid=e71afda4-53f4-3a1b-6c92-
a364a7f619c2 platform:vgpu_extra_args="disable_vnc=0"
```

## 9.3. Allocation Strategies

Strategies for pinning VM CPU cores to physical cores on Non-Uniform Memory Access (NUMA) platforms and for allocating VMs to CPUs and vGPUs to physical GPUs can improve performance for VMs running with NVIDIA vGPU.

### 9.3.1. NUMA considerations

Server platforms typically implement multiple CPU sockets, with system memory and PCI Express expansion slots local to each CPU socket, as illustrated in [Figure 33](#):

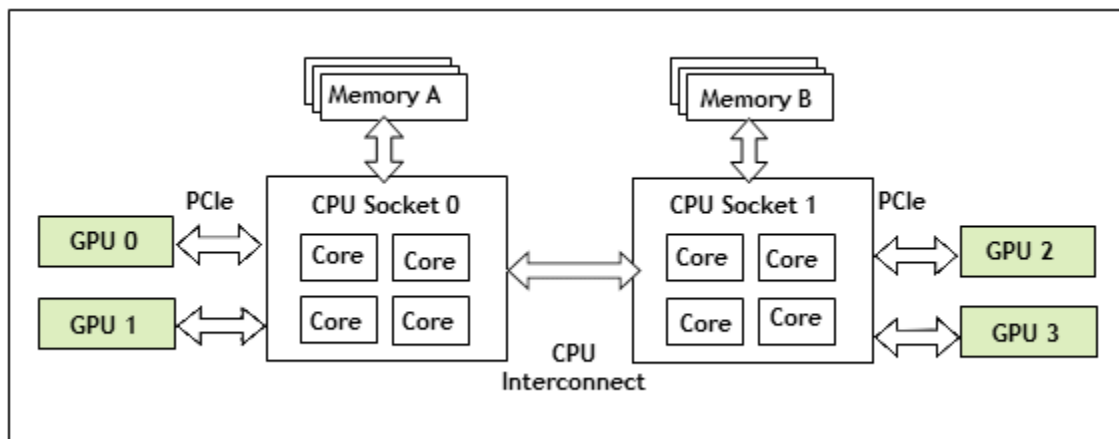


Figure 33 A NUMA server platform

These platforms are typically configured to operate in Non-Uniform Memory Access (NUMA) mode; physical memory is arranged sequentially in the address space, with all the memory attached to each socket appearing in a single contiguous block of addresses. The cost of accessing a range of memory from a CPU or GPU varies; memory attached to the same socket as the CPU or GPU is accessible at lower latency than memory on another CPU socket, because accesses to remote memory must additionally traverse the interconnect between CPU sockets.

To obtain best performance on a NUMA platform, NVIDIA recommends pinning VM vCPU cores to physical cores on the same CPU socket to which the physical GPU hosting the VM's vGPU is attached. For example, using as a reference, a VM with a vGPU allocated on physical GPU 0 or 1 should have its vCPUs pinned to CPU cores on CPU socket 0. Similarly, a VM with a vGPU allocated on physical GPU 2 or 3 should have its vCPUs pinned to CPU cores on socket 1.

See [Pinning VMs to a specific CPU socket and cores](#) for guidance on pinning vCPUs, and [How GPU locality is determined](#) for guidance on determining which CPU socket a GPU is connected to. [Controlling the vGPU types enabled on specific physical GPUs](#)

describes how to precisely control which physical GPU is used to host a vGPU, by creating GPU groups for specific physical GPUs.

### 9.3.2. Maximizing performance

To maximize performance as the number of vGPU-enabled VMs on the platform increases, NVIDIA recommends adopting a *breadth-first* allocation: allocate new VMs on the least-loaded CPU socket, and allocate the VM's vGPU on an available, least-loaded, physical GPU connected via that socket.

Citrix Hypervisor creates GPU groups with a default allocation policy of *depth-first*. See [Modifying GPU Allocation Policy on Citrix Hypervisor](#) for details on switching the allocation policy to breadth-first.



Due to vGPU's requirement that only one type of vGPU can run on a physical GPU at any given time, not all physical GPUs may be available to host the vGPU type required by the new VM.

# Chapter 10.

## TROUBLESHOOTING

This chapter describes basic troubleshooting steps for NVIDIA vGPU on Citrix Hypervisor, Red Hat Enterprise Linux KVM, Red Hat Virtualization (RHV), and VMware vSphere, and how to collect debug information when filing a bug report.

### 10.1. Known issues

Before troubleshooting or filing a bug report, review the release notes that accompany each driver release, for information about known issues with the current release, and potential workarounds.

### 10.2. Troubleshooting steps

If a vGPU-enabled VM fails to start, or doesn't display any output when it does start, follow these steps to narrow down the probable cause.

#### 10.2.1. Verifying the NVIDIA Kernel Driver Is Loaded

1. Use the command that your hypervisor provides to verify that the kernel driver is loaded:

- ▶ On Citrix Hypervisor, Red Hat Enterprise Linux KVM, and RHV, use `lsmod`:

```
[root@xenserver ~]# lsmod|grep nvidia
nvidia          9604895  84
i2c_core        20294  2 nvidia,i2c_i801
[root@xenserver ~]#
```

- ▶ On VMware vSphere, use `vmkload_mod`:

```
[root@esxi:~] vmkload_mod -l | grep nvidia
nvidia          5  8420
```

2. If the `nvidia` driver is not listed in the output, check `dmesg` for any load-time errors reported by the driver (see [Examining NVIDIA kernel driver output](#)).
3. On Citrix Hypervisor, Red Hat Enterprise Linux KVM, and RHV, also use the `rpm -q` command to verify that the NVIDIA GPU Manager package is correctly installed.

```
rpm -q vgpu-manager-rpm-package-name
```

*vgpu-manager-rpm-package-name*

The RPM package name of the NVIDIA GPU Manager package, for example NVIDIA-vGPU-xenserver-7.0-440.53 for Citrix Hypervisor.

This example verifies that the NVIDIA GPU Manager package for Citrix Hypervisor is correctly installed.

```
[root@xenserver ~]# rpm -q NVIDIA-vGPU-xenserver-7.0-440.53
[root@xenserver ~]#
If an existing NVIDIA GRID package is already installed and you don't select
the upgrade (-U) option when installing a newer GRID package, the rpm
command will return many conflict errors.
Preparing packages for installation...
    file /usr/bin/nvidia-smi from install of NVIDIA-vGPU-
xenserver-7.0-440.53.x86_64 conflicts with file from package NVIDIA-vGPU-
xenserver-7.0-440.43.x86_64
    file /usr/lib/libnvidia-ml.so from install of NVIDIA-vGPU-
xenserver-7.0-440.53.x86_64 conflicts with file from package NVIDIA-vGPU-
xenserver-7.0-440.43.x86_64
    ...
```

## 10.2.2. Verifying that `nvidia-smi` works

If the NVIDIA kernel driver is correctly loaded on the physical GPU, run `nvidia-smi` and verify that all physical GPUs not currently being used for GPU passthrough are listed in the output. For details on expected output, see [NVIDIA System Management Interface `nvidia-smi`](#).

If `nvidia-smi` fails to report the expected output, check `dmesg` for NVIDIA kernel driver messages.

## 10.2.3. Examining NVIDIA kernel driver output

Information and debug messages from the NVIDIA kernel driver are logged in kernel logs, prefixed with `NVRM` or `nvidia`.

Run `dmesg` on Citrix Hypervisor, Red Hat Enterprise Linux KVM, RHV, and VMware vSphere and check for the `NVRM` and `nvidia` prefixes:

```
[root@xenserver ~]# dmesg | grep -E "NVRM|nvidia"
[  22.054928] nvidia: module license 'NVIDIA' taints kernel.
[  22.390414] NVRM: loading
[  22.829226] nvidia 0000:04:00.0: enabling device (0000 -> 0003)
[  22.829236] nvidia 0000:04:00.0: PCI INT A -> GSI 32 (level, low) -> IRQ 32
[  22.829240] NVRM: This PCI I/O region assigned to your NVIDIA device is
invalid:
[  22.829241] NVRM: BAR0 is 0M @ 0x0 (PCI:0000:00:04.0)
[  22.829243] NVRM: The system BIOS may have misconfigured your GPU.
```

## 10.2.4. Examining NVIDIA Virtual GPU Manager Messages

Information and debug messages from the NVIDIA Virtual GPU Manager are logged to the hypervisor's log files, prefixed with `vmiop`.

### 10.2.4.1. Examining Citrix Hypervisor vGPU Manager Messages

For Citrix Hypervisor, NVIDIA Virtual GPU Manager messages are written to `/var/log/messages`.

Look in the `/var/log/messages` file for the `vmiop` prefix:

```
[root@xenserver ~]# grep vmiop /var/log/messages
Feb 18 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: gpu-pci-id :
0000:05:00.0
Feb 18 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: vgpu_type : quadro
Feb 18 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: Framebuffer:
0x74000000
Feb 18 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: Virtual Device Id:
0x13F2:0x114E
Feb 18 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: ##### vGPU
Manager Information: #####
Feb 18 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: Driver
Version: 440.53
Feb 18 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: Init frame copy
engine: syncing...
Feb 18 10:35:31 localhost vgpu-11[25698]: notice: vmiop_log: ##### Guest
NVIDIA Driver Information: #####
Feb 18 10:35:31 localhost vgpu-11[25698]: notice: vmiop_log: Driver
Version: 442.06
Feb 18 10:35:36 localhost vgpu-11[25698]: notice: vmiop_log: Current max guest
pfn = 0x11bc84!
Feb 18 10:35:40 localhost vgpu-11[25698]: notice: vmiop_log: Current max guest
pfn = 0x11eff0!
[root@xenserver ~]#
```

### 10.2.4.2. Examining Red Hat Enterprise Linux KVM vGPU Manager Messages

For Red Hat Enterprise Linux KVM and RHV, NVIDIA Virtual GPU Manager messages are written to `/var/log/messages`.

Look in these files for the `vmiop_log`: prefix:

```
# grep vmiop_log: /var/log/messages
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: vmiop-env:
guest_max_gpfn:0x11f7ff
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: pluginconfig: /
usr/share/nvidia/vgx/grid_m60-1q.conf,gpu-pci-id=0000:06:00.0
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: Loading Plugin0:
libnvidia-vgpu
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: Successfully
update the env symbols!
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: vmiop_log: gpu-
pci-id : 0000:06:00.0
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: vmiop_log:
vgpu_type : quadro
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: vmiop_log:
Framebuffer: 0x38000000
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: vmiop_log:
Virtual Device Id: 0x13F2:0x114D
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: vmiop_log:
##### vGPU Manager Information: #####
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: vmiop_log: Driver
Version: 440.53
```



```
[2020-02-14 04:46:12] vmiop_log: [2020-02-14 04:46:12] notice: vmiop_log: Init
frame copy engine: syncing...
[2020-02-14 05:09:14] vmiop_log: [2020-02-14 05:09:14] notice: vmiop_log:
##### Guest NVIDIA Driver Information: #####
[2020-02-14 05:09:14] vmiop_log: [2020-02-14 05:09:14] notice: vmiop_log: Driver
Version: 442.06
[2020-02-14 05:09:14] vmiop_log: [2020-02-14 05:09:14] notice: vmiop_log:
Current max guest pfn = 0x11a71f!
[2020-02-14 05:12:09] vmiop_log: [2020-02-14 05:12:09] notice: vmiop_log: vGPU
license state: (0x00000001)
#
```

### 10.2.4.3. Examining VMware vSphere vGPU Manager Messages

For VMware vSphere, NVIDIA Virtual GPU Manager messages are written to the `vmware.log` file in the guest VM's storage directory.

Look in the `vmware.log` file for the `vmiop` prefix:

```
[root@esxi:~] grep vmiop /vmfs/volumes/datastore1/win7-vgpu-test1/vmware.log
2020-02-14T14:02:21.275Z| vmx| I120: DICT pciPassthru0.virtualDev = "vmiop"
2020-02-14T14:02:21.344Z| vmx| I120: GetPluginPath testing /usr/lib64/vmware/
plugin/libvmx-vmiop.so
2020-02-14T14:02:21.344Z| vmx| I120: PluginLdr_LoadShared: Loaded shared plugin
libvmx-vmiop.so from /usr/lib64/vmware/plugin/libvmx-vmiop.so
2020-02-14T14:02:21.344Z| vmx| I120: VMIOP: Loaded plugin libvmx-
vmiop.so:VMIOP_InitModule
2020-02-14T14:02:21.359Z| vmx| I120: VMIOP: Initializing plugin vmiop-display
2020-02-14T14:02:21.365Z| vmx| I120: vmiop_log: gpu-pci-id : 0000:04:00.0
2020-02-14T14:02:21.365Z| vmx| I120: vmiop_log: vgpu_type : quadro
2020-02-14T14:02:21.365Z| vmx| I120: vmiop_log: Framebuffer: 0x74000000
2020-02-14T14:02:21.365Z| vmx| I120: vmiop_log: Virtual Device Id: 0x11B0:0x101B
2020-02-14T14:02:21.365Z| vmx| I120: vmiop_log: ##### vGPU Manager
Information: #####
2020-02-14T14:02:21.365Z| vmx| I120: vmiop_log: Driver Version: 440.53
2020-02-14T14:02:21.365Z| vmx| I120: vmiop_log: VGX Version: 10.1
2020-02-14T14:02:21.445Z| vmx| I120: vmiop_log: Init frame copy engine:
syncing...
2020-02-14T14:02:37.031Z| vthread-12| I120: vmiop_log: ##### Guest NVIDIA
Driver Information: #####
2020-02-14T14:02:37.031Z| vthread-12| I120: vmiop_log: Driver Version: 442.06
2020-02-14T14:02:37.031Z| vthread-12| I120: vmiop_log: VGX Version: 10.1
2020-02-14T14:02:37.093Z| vthread-12| I120: vmiop_log: Clearing BAR1 mapping
2020-02-18T23:39:55.726Z| vmx| I120: VMIOP: Shutting down plugin vmiop-display
[root@esxi:~]
```

## 10.3. Capturing configuration data for filing a bug report

When filing a bug report with NVIDIA, capture relevant configuration data from the platform exhibiting the bug in one of the following ways:

- ▶ On any supported hypervisor, run `nvidia-bug-report.sh`.
- ▶ On Citrix Hypervisor, create a Citrix Hypervisor server status report.

### 10.3.1. Capturing configuration data by running `nvidia-bug-report.sh`

The `nvidia-bug-report.sh` script captures debug information into a gzip-compressed log file on the server.

Run `nvidia-bug-report.sh` from the Citrix Hypervisor dom0 shell, the Red Hat Enterprise Linux KVM host shell, the Red Hat Virtualization (RHV) host shell, or the VMware ESXi host shell.

This example runs `nvidia-bug-report.sh` on Citrix Hypervisor, but the procedure is the same on Red Hat Enterprise Linux KVM, RHV, or VMware vSphere ESXi.

```
[root@xenserver ~]# nvidia-bug-report.sh

nvidia-bug-report.sh will now collect information about your
system and create the file 'nvidia-bug-report.log.gz' in the current
directory. It may take several seconds to run. In some
cases, it may hang trying to capture data generated dynamically
by the Linux kernel and/or the NVIDIA kernel module. While
the bug report log file will be incomplete if this happens, it
may still contain enough data to diagnose your problem.

For Xen open source/XCP users, if you are reporting a domain issue,
please run: nvidia-bug-report.sh --domain-name <"domain_name">

Please include the 'nvidia-bug-report.log.gz' log file when reporting
your bug via the NVIDIA Linux forum (see devtalk.nvidia.com)
or by sending email to 'linux-bugs@nvidia.com'.

Running nvidia-bug-report.sh...

If the bug report script hangs after this point consider running with
--safe-mode command line argument.

complete

[root@xenserver ~]#
```

### 10.3.2. Capturing Configuration Data by Creating a Citrix Hypervisor Status Report

1. In XenCenter, from the **Tools** menu, choose **Server Status Report**.
2. Select the Citrix Hypervisor instance from which you want to collect a status report.
3. Select the data to include in the report.
4. To include NVIDIA vGPU debug information, select **NVIDIA-logs** in the **Report Content Item** list.
5. Generate the report.

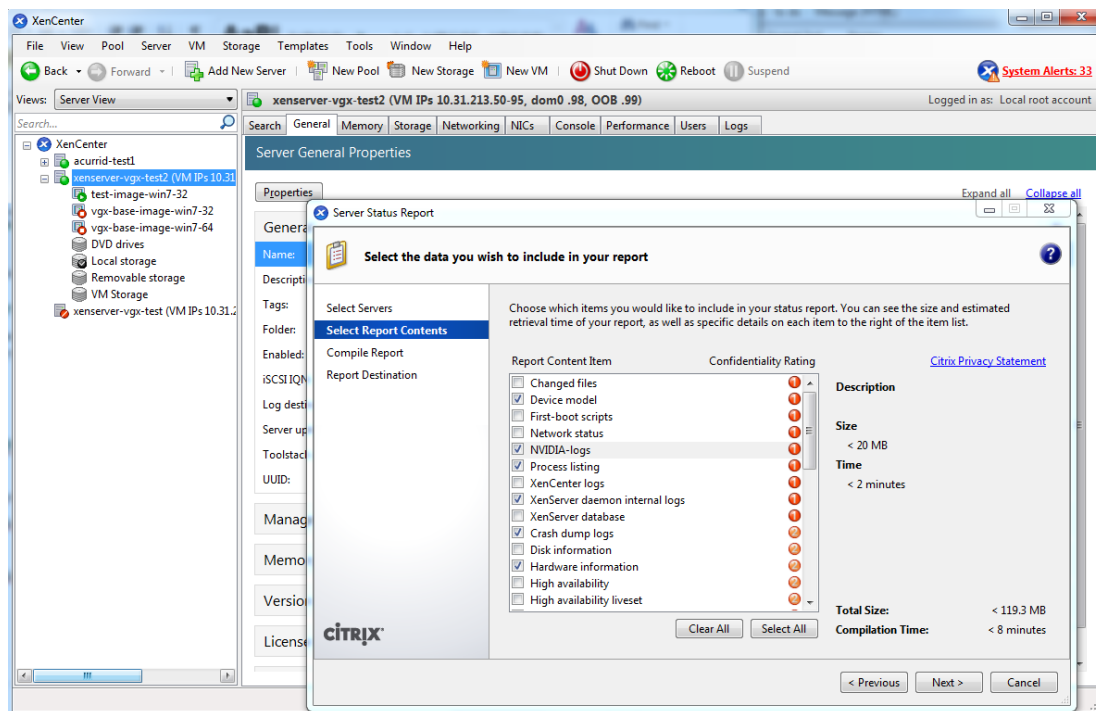


Figure 34 Including NVIDIA logs in a Citrix Hypervisor status report

# Appendix A.

## CHANGING vGPU SCHEDULING BEHAVIOR

GPUs based on the NVIDIA Maxwell™ graphic architecture implement a best effort vGPU scheduler that aims to balance performance across vGPUs. The best effort scheduler allows a vGPU to use GPU processing cycles that are not being used by other vGPUs. Under some circumstances, a VM running a graphics-intensive application may adversely affect the performance of graphics-light applications running in other VMs.

GPUs based on NVIDIA GPU architectures **after** the Maxwell architecture additionally support equal share and fixed share vGPU schedulers. These schedulers impose a limit on GPU processing cycles used by a vGPU, which prevents graphics-intensive applications running in one VM from affecting the performance of graphics-light applications running in other VMs. On GPUs that support multiple vGPU schedulers, you can select the vGPU scheduler to use. You can also set the length of the time slice for the equal share and fixed share vGPU schedulers.



If you use the equal share or fixed share vGPU scheduler, the frame-rate limiter (FRL) is disabled.

The best effort scheduler is the default scheduler for all supported GPU architectures.

If you are unsure of the NVIDIA GPU architecture of your GPU, consult the release notes for your hypervisor at [NVIDIA Virtual GPU Software Documentation](#).

### A.1. vGPU Scheduling Policies

In addition to the default best effort scheduler, GPUs based on NVIDIA GPU architectures **after** the Maxwell architecture support equal share and fixed share vGPU schedulers.

#### **Equal share scheduler**

The physical GPU is shared equally amongst the running vGPUs that reside on it. As vGPUs are added to or removed from a GPU, the share of the GPU's processing cycles allocated to each vGPU changes accordingly. As a result, the performance of a vGPU may increase as other vGPUs on the same GPU are stopped, or decrease as other vGPUs are started on the same GPU.

### Fixed share scheduler

Each vGPU is given a fixed share of the physical GPU's processing cycles, the amount of which depends on the vGPU type, which in turn determines the maximum number of vGPUs per physical GPU. For example, the maximum number of P40-4Q vGPUs per physical GPU is 6. When the scheduling policy is fixed share, each P40-4Q vGPU is given one sixth, or approximately 16.7%, the physical GPU's processing cycles. As vGPUs are added to or removed from a GPU, the share of the GPU's processing cycles allocated to each vGPU remains constant. As a result, the performance of a vGPU remains unchanged as other vGPUs are stopped or started on the same GPU.

## A.2. vGPU Scheduler Time Slice

When multiple VMs access the vGPUs on a single GPU, the GPU performs the work for each VM **serially**. The vGPU scheduler time slice represents the amount of time that the work of a VM is allowed to run on the GPU before it is preempted and the work of the next VM is performed.

For the equal share and fixed share vGPU schedulers, you can set the length of the time slice. The length of the time slice affects latency and throughput. The optimal length of the time slice depends the workload that the GPU is handling.

- ▶ For workloads that require low latency, a shorter time slice is optimal. Typically, these workloads are applications that must generate output at a fixed interval, such as graphics applications that generate output at a frame rate of 60 FPS. These workloads are sensitive to latency and should be allowed to run at least once per interval. A shorter time slice reduces latency and improves responsiveness by causing the scheduler to switch more frequently between VMs.
- ▶ For workloads that require maximum throughput, a longer time slice is optimal. Typically, these workloads are applications that must complete their work as quickly as possible and do not require responsiveness, such as CUDA applications. A longer time slice increases throughput by preventing frequent switching between VMs.

## A.3. RmPVMRL Registry Key

The RmPVMRL registry key controls the scheduling behavior for NVIDIA vGPUs by setting the scheduling policy and the length of the time slice.



You can change the vGPU scheduling behavior only on GPUs that support multiple vGPU schedulers, that is, GPUs based on NVIDIA GPU architectures **after** the Maxwell architecture.

### Type

Dword

## Contents

Value	Meaning
0x00 (default)	Best effort scheduler
0x01	Equal share scheduler with the default time slice length
0x00 <i>TT</i> 0001	Equal share scheduler with a user-defined time slice length <i>TT</i>
0x11	Fixed share scheduler with the default time slice length
0x00 <i>TT</i> 0011	Fixed share scheduler with a user-defined time slice length <i>TT</i>

The default time slice length depends on the maximum number of vGPUs per physical GPU allowed for the vGPU type.

Maximum Number of vGPUs	Default Time Slice Length
Less than or equal to 8	2 ms
Greater than 8	1 ms

### *TT*

Two hexadecimal digits in the range 01 to 1E that set the length of the time slice in milliseconds (ms) for the equal share and fixed share schedulers. The minimum length is 1 ms and the maximum length is 30 ms.

If *TT* is 00, the length is set to the default length for the vGPU type.

If *TT* is greater than 1E, the length is set to 30 ms.

## Examples

This example sets the vGPU scheduler to equal share scheduler with the default time slice length.

```
RmPVMRL=0x01
```

This example sets the vGPU scheduler to equal share scheduler with a time slice that is 3 ms long.

```
RmPVMRL=0x00030001
```

This example sets the vGPU scheduler to fixed share scheduler with the default time slice length.

```
RmPVMRL=0x11
```

This example sets the vGPU scheduler to fixed share scheduler with a time slice that is 24 (0x18) ms long.

```
RmPVMRL=0x00180011
```

## A.4. Changing the vGPU Scheduling Behavior for All GPUs



You can change the vGPU scheduling behavior only on GPUs that support multiple vGPU schedulers, that is, GPUs based on NVIDIA GPU architectures **after** the Maxwell architecture.

Perform this task in your hypervisor command shell.

1. Open a command shell as the root user on your hypervisor host machine.  
On all supported hypervisors, you can use secure shell (SSH) for this purpose. Individual hypervisors may provide additional means for logging in. For details, refer to the documentation for your hypervisor.
2. Set the `RmPVMRL` registry key to the value that sets the GPU scheduling policy and the length of the time slice that you want.

- ▶ On Citrix Hypervisor, Red Hat Enterprise Linux KVM, or Red Hat Virtualization (RHV), add the following entry to the `/etc/modprobe.d/nvidia.conf` file.

```
options nvidia NVreg_RegistryDwords="RmPVMRL=value"
```

If the `/etc/modprobe.d/nvidia.conf` file does not already exist, create it.

- ▶ On VMware vSphere, use the `esxcli set` command.

```
# esxcli system module parameters set -m nvidia -p  
"NVreg_RegistryDwords=RmPVMRL=value"
```

### *value*

The value that sets the GPU scheduling policy and the length of the time slice that you want, for example:

#### **0x01**

Sets the vGPU scheduling policy to equal share scheduler with the default time slice length.

#### **0x00030001**

Sets the GPU scheduling policy to equal share scheduler with a time slice that is 3 ms long.

#### **0x11**

Sets the vGPU scheduling policy to fixed share scheduler with the default time slice length.

#### **0x00180011**

Sets the GPU scheduling policy to fixed share scheduler with a time slice that is 24 (0x18) ms long.

For all supported values, see [RmPVMRL Registry Key](#).

3. Reboot your hypervisor host machine.

## A.5. Changing the vGPU Scheduling Behavior for Select GPUs



You can change the vGPU scheduling behavior only on GPUs that support multiple vGPU schedulers, that is, GPUs based on NVIDIA GPU architectures **after** the Maxwell architecture.

Perform this task in your hypervisor command shell.

1. Open a command shell as the root user on your hypervisor host machine.  
On all supported hypervisors, you can use secure shell (SSH) for this purpose. Individual hypervisors may provide additional means for logging in. For details, refer to the documentation for your hypervisor.
2. Use the `lspci` command to obtain the PCI domain and bus/device/function (BDF) of each GPU for which you want to change the scheduling behavior.
  - ▶ On Citrix Hypervisor, Red Hat Enterprise Linux KVM, or Red Hat Virtualization (RHV), add the `-D` option to display the PCI domain and the `-d 10de:` option to display information only for NVIDIA GPUs.

```
# lspci -D -d 10de:
```

- ▶ On VMware vSphere, pipe the output of `lspci` to the `grep` command to display information only for NVIDIA GPUs.

```
# lspci | grep NVIDIA
```

The NVIDIA GPU listed in this example has the PCI domain 0000 and BDF 86:00.0.

```
0000:86:00.0 3D controller: NVIDIA Corporation GP104GL [Tesla P4] (rev a1)
```

3. Use the module parameter `NVreg_RegistryDwordsPerDevice` to set the `pci` and `RmPVMRL` registry keys for each GPU.

- ▶ On Citrix Hypervisor, Red Hat Enterprise Linux KVM, or RHV, add the following entry to the `/etc/modprobe.d/nvidia.conf` file.

```
options nvidia NVreg_RegistryDwordsPerDevice="pci=pci-domain:pci-bdf;RmPVMRL=value\n\n[;pci=pci-domain:pci-bdf;RmPVMRL=value...]"
```

If the `/etc/modprobe.d/nvidia.conf` file does not already exist, create it.

- ▶ On VMware vSphere, use the `esxcli set` command.

```
# esxcli system module parameters set -m nvidia \n\n-p "NVreg_RegistryDwordsPerDevice=pci=pci-domain:pci-bdf;RmPVMRL=value\n\n[;pci=pci-domain:pci-bdf;RmPVMRL=value...]"
```

For each GPU, provide the following information:

***pci-domain***

The PCI domain of the GPU.



***pci-bdf***

The PCI device BDF of the GPU.

***value***

The value that sets the GPU scheduling policy and the length of the time slice that you want, for example:

**0x01**

Sets the GPU scheduling policy to equal share scheduler with the default time slice length.

**0x00030001**

Sets the GPU scheduling policy to equal share scheduler with a time slice that is 3 ms long.

**0x11**

Sets the GPU scheduling policy to fixed share scheduler with the default time slice length.

**0x00180011**

Sets the GPU scheduling policy to fixed share scheduler with a time slice that is 24 (0x18) ms long.

For all supported values, see [RmPVMRL Registry Key](#).

This example adds an entry to the `/etc/modprobe.d/nvidia.conf` file to change the scheduling behavior of a single GPU. The entry sets the GPU scheduling policy of the GPU at PCI domain 0000 and BDF 86:00.0 to fixed share scheduler with the default time slice length.

```
options nvidia NVreg_RegistryDwordsPerDevice=
"pci=0000:86:00.0;RmPVMRL=0x11"
```

This example adds an entry to the `/etc/modprobe.d/nvidia.conf` file to change the scheduling behavior of a single GPU. The entry sets the scheduling policy of the GPU at PCI domain 0000 and BDF 86:00.0 to fixed share scheduler with a time slice that is 24 (0x18) ms long.

```
options nvidia NVreg_RegistryDwordsPerDevice=
"pci=0000:86:00.0;RmPVMRL=0x00180011"
```

4. Reboot your hypervisor host machine.

## A.6. Restoring Default vGPU Scheduler Settings

Perform this task in your hypervisor command shell.

1. Open a command shell as the root user on your hypervisor host machine.  
On all supported hypervisors, you can use secure shell (SSH) for this purpose. Individual hypervisors may provide additional means for logging in. For details, refer to the documentation for your hypervisor.
2. Unset the `RmPVMRL` registry key.
  - ▶ On Citrix Hypervisor, Red Hat Enterprise Linux KVM, or Red Hat Virtualization (RHV), comment out the entries in the `/etc/modprobe.d/nvidia.conf` file that set `RmPVMRL` by prefixing each entry with the `#` character.
  - ▶ On VMware vSphere, set the module parameter to an empty string.

```
# esxcli system module parameters set -m nvidia -p "module-parameter="
```

### *module-parameter*

The module parameter to set, which depends on whether the scheduling behavior was changed for all GPUs or select GPUs:

- ▶ For all GPUs, set the `NVreg_RegistryDwords` module parameter.
- ▶ For select GPUs, set the `NVreg_RegistryDwordsPerDevice` module parameter.

For example, to restore default vGPU scheduler settings after they were changed for all GPUs, enter this command:

```
# esxcli system module parameters set -m nvidia -p  
"NVreg_RegistryDwords="
```

3. Reboot your hypervisor host machine.

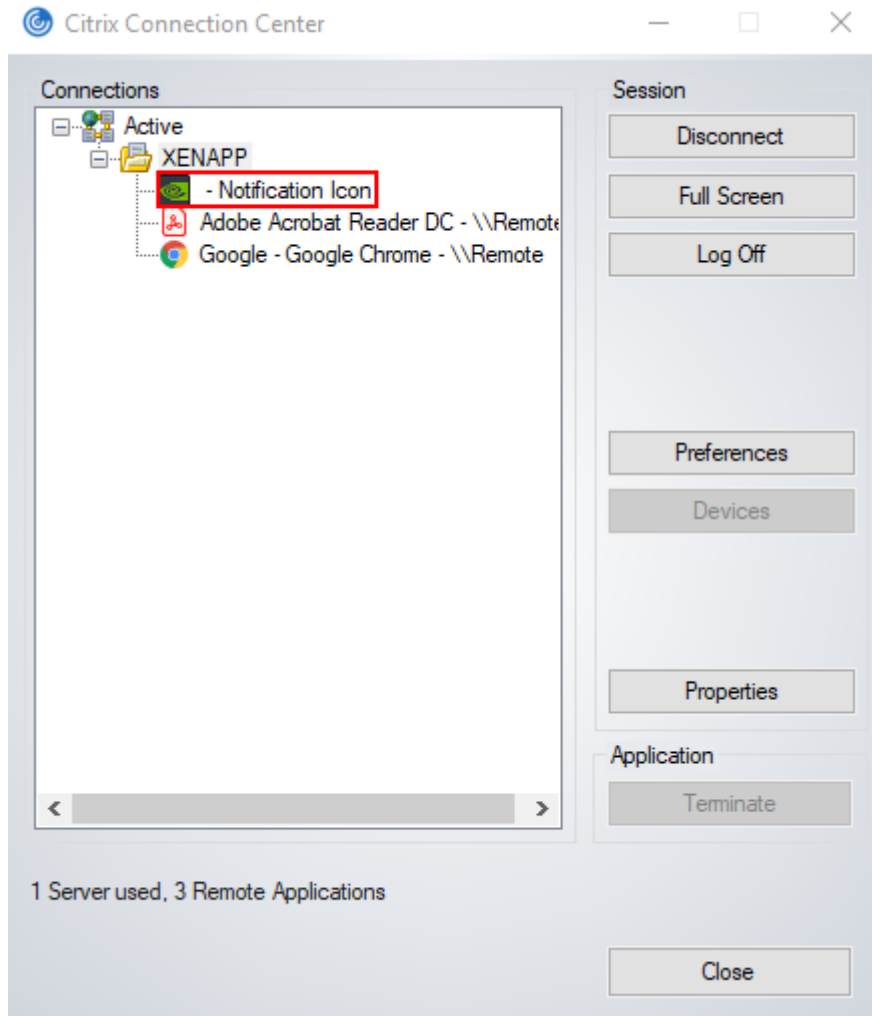
# Appendix B.

## DISABLING NVIDIA NOTIFICATION ICON FOR CITRIX PUBLISHED APPLICATION USER SESSIONS

By default on Windows Server operating systems, the **NVIDIA Notification Icon** application is started with every Citrix Published Application user session. This application might prevent the Citrix Published Application user session from being logged off even after the user has quit all other applications.

The **NVIDIA Notification Icon** application appears in **Citrix Connection Center** on the endpoint client that is running **Citrix Receiver** or **Citrix Workspace**.

The following image shows the **NVIDIA Notification Icon** in **Citrix Connection Center** for a user session in which the **Adobe Acrobat Reader DC** and **Google Chrome** applications are published.



Administrators can disable the **NVIDIA Notification Icon** application for all users' sessions as explained in [Disabling NVIDIA Notification Icon for All Users' Citrix Published Application Sessions](#).

Individual users can disable the **NVIDIA Notification Icon** application for their own sessions as explained in [Disabling NVIDIA Notification Icon for your Citrix Published Application User Sessions](#).

## B.1. Disabling NVIDIA Notification Icon for All Users' Citrix Published Application Sessions

Administrators can set a registry key to disable the **NVIDIA Notification Icon** application for all users' Citrix Published Application sessions on a VM. To ensure that the **NVIDIA Notification Icon** application is disabled on any virtual delivery agent (VDA) that is created from a master image, set this key in the master image.

Perform this task from the VM on which the Citrix Published Application sessions will be created.

Before you begin, ensure that the NVIDIA vGPU software graphics driver is installed in the VM.

1. Set the system-level `StartOnLogin` Windows registry key to 0.

```
[HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\nvlddmkm\NvTray]
Value: "StartOnLogin"
Type: DWORD
Data: 00000000
```

The data value 0 disables the **NVIDIA Notification Icon**, and the data value 1 enables it.

2. Restart the VM.

You must restart the VM to ensure that the registry key is set before the NVIDIA service in the user session starts.

## B.2. Disabling NVIDIA Notification Icon for your Citrix Published Application User Sessions

Individual users can disable the **NVIDIA Notification Icon** for their own Citrix Published Application sessions.

Before you begin, ensure that you are logged on to a Citrix Published Application session.

1. Set the current user's `StartOnLogin` Windows registry key to 0.

```
[HKEY_CURRENT_USER\SOFTWARE\NVIDIA Corporation\NvTray\]
Value: "StartOnLogin"
Type: DWORD
Data: 00000000
```

The data value 0 disables the **NVIDIA Notification Icon**, and the data value 1 enables it.

2. Log off and log on again or restart the VM.

You must log on and log off again or restart the VM to ensure that the registry key is set before the NVIDIA service in the user session starts.

# Appendix C.

## CITRIX HYPERVISOR BASICS

To install and configure NVIDIA vGPU software and optimize Citrix Hypervisor operation with vGPU, some basic operations on Citrix Hypervisor are needed.

### C.1. Opening a dom0 shell

Most configuration commands must be run in a command shell in the Citrix Hypervisor dom0 domain. You can open a shell in the Citrix Hypervisor dom0 domain in any of the following ways:

- ▶ Using the console window in XenCenter
- ▶ Using a standalone secure shell (SSH) client

#### C.1.1. Accessing the dom0 shell through XenCenter

1. In the left pane of the **XenCenter** window, select the Citrix Hypervisor host that you want to connect to.
2. Click on the **Console** tab to open the Citrix Hypervisor console.
3. Press **Enter** to start a shell prompt.

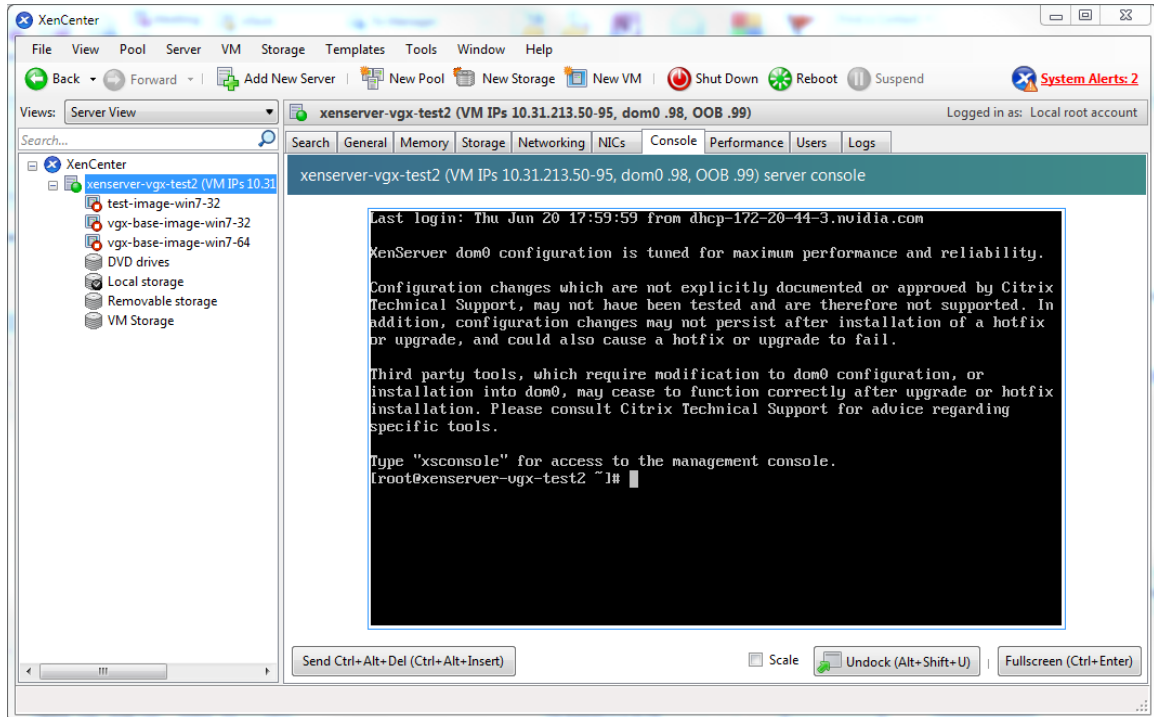


Figure 35 Connecting to the dom0 shell by using XenCenter

## C.1.2. Accessing the dom0 shell through an SSH client

1. Ensure that you have an SSH client suite such as PuTTY on Windows, or the SSH client from OpenSSH on Linux.
2. Connect your SSH client to the management IP address of the Citrix Hypervisor host.
3. Log in as the root user.

## C.2. Copying files to dom0

You can easily copy files to and from Citrix Hypervisor dom0 in any of the following ways:

- ▶ Using a Secure Copy Protocol (SCP) client
- ▶ Using a network-mounted file system

### C.2.1. Copying files by using an SCP client

The SCP client to use for copying files to dom0 depends on where you are running the client from.

- ▶ If you are running the client from dom0, use the secure copy command `scp`.

The `scp` command is part of the SSH suite of applications. It is implemented in `dom0` and can be used to copy from a remote SSH-enabled server:

```
[root@xenserver ~]# scp root@10.31.213.96:/tmp/somefile .
The authenticity of host '10.31.213.96 (10.31.213.96)' can't be established.
RSA key fingerprint is 26:2d:9b:b9:bf:6c:81:70:36:76:13:02:c1:82:3d:3c.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '10.31.213.96' (RSA) to the list of known hosts.
root@10.31.213.96's password:
somefile                               100% 532      0.5KB/s   00:00
[root@xenserver ~]#
```

- ▶ If you are running the client from Windows, use the `pscp` program.

The `pscp` program is part of the PuTTY suite and can be used to copy files from a remote Windows system to Citrix Hypervisor:

```
C:\Users\nvidia>pscp somefile root@10.31.213.98:/tmp
root@10.31.213.98's password:
somefile          | 80 kB | 80.1 kB/s | ETA: 00:00:00 | 100%
C:\Users\nvidia>
```

## C.2.2. Copying files by using a CIFS-mounted file system

You can copy files to and from a CIFS/SMB file share by mounting the share from `dom0`.

The following example shows how to mount a network share `\myserver.example.com\myshare` at `/mnt/myshare` on `dom0` and how to copy files to and from the share. The example assumes that the file share is part of an Active Directory domain called `example.com` and that user `myuser` has permissions to access the share.

1. Create the directory `/mnt/myshare` on `dom0`.

```
[root@xenserver ~]# mkdir /mnt/myshare
```

2. Mount the network share `\\myserver.example.com\myshare` at `/mnt/myshare` on `dom0`.

```
[root@xenserver ~]# mount -t cifs -o
username=myuser,workgroup=example.com //myserver.example.com/myshare /mnt/
myshare
Password:
[root@xenserver ~]#
```

3. When prompted for a password, enter the password for `myuser` in the `example.com` domain.
4. After the share has been mounted, copy files to and from the file share by using the `cp` command to copy them to and from `/mnt/myshare`:

```
[root@xenserver ~]# cp /mnt/myshare/NVIDIA-vGPU-
xenserver-7.0-440.53.x86_64.rpm .
[root@xenserver ~]#
```



## C.3. Determining a VM's UUID

You can determine a virtual machine's UUID in any of the following ways:

- ▶ Using the `xe vm-list` command in a dom0 shell
- ▶ Using XenCenter

### C.3.1. Determining a VM's UUID by using `xe vm-list`

Use the `xe vm-list` command to list all VMs and their associated UUIDs or to find the UUID of a specific named VM.

- ▶ To list all VMs and their associated UUIDs, use `xe vm-list` without any parameters:

```
[root@xenserver ~]# xe vm-list
uuid ( RO)           : 6b5585f6-bd74-2e3e-0e11-03b9281c3ade
  name-label ( RW)   : vgx-base-image-win7-64
  power-state ( RO) : halted

uuid ( RO)           : fa3d15c7-7e88-4886-c36a-cdb23ed8e275
  name-label ( RW)   : test-image-win7-32
  power-state ( RO) : halted

uuid ( RO)           : 501bb598-a9b3-4afc-9143-ff85635d5dc3
  name-label ( RW)   : Control domain on host: xenserver
  power-state ( RO) : running

uuid ( RO)           : 8495adf7-be9d-eee1-327f-02e4f40714fc
  name-label ( RW)   : vgx-base-image-win7-32
  power-state ( RO) : halted
```

- ▶ To find the UUID of a specific named VM, use the `name-label` parameter to `xe vm-list`:

```
[root@xenserver ~]# xe vm-list name-label=test-image-win7-32
uuid ( RO)           : fa3d15c7-7e88-4886-c36a-cdb23ed8e275
  name-label ( RW)   : test-image-win7-32
  power-state ( RO) : halted
```

### C.3.2. Determining a VM's UUID by using XenCenter

1. In the left pane of the **XenCenter** window, select the VM whose UUID you want to determine.
2. In the right pane of the **XenCenter** window, click the **General** tab.

The UUID is listed in the VM's General Properties.

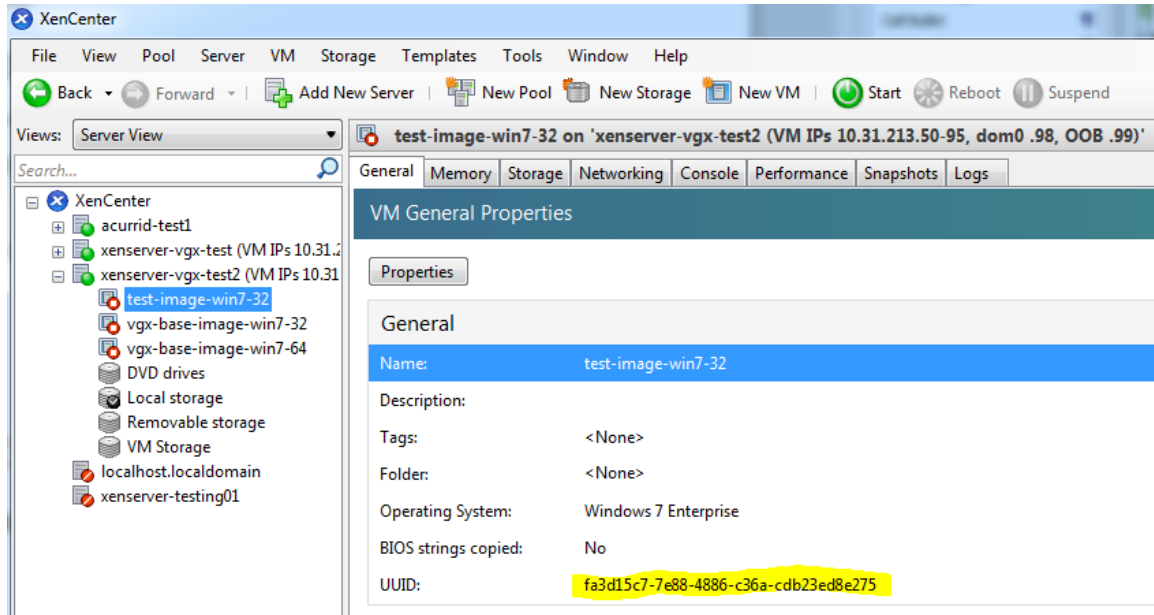


Figure 36 Using XenCenter to determine a VM's UUID

## C.4. Using more than two vCPUs with Windows client VMs

Windows client operating systems support a maximum of two CPU sockets. When allocating vCPUs to virtual sockets within a guest VM, Citrix Hypervisor defaults to allocating one vCPU per socket. Any more than two vCPUs allocated to the VM won't be recognized by the Windows client OS.

To ensure that all allocated vCPUs are recognized, set `platform:cores-per-socket` to the number of vCPUs that are allocated to the VM:

```
[root@xenserver ~]# xe vm-param-set uuid=vm-uuid platform:cores-per-socket=4
VCPUs-max=4 VCPUs-at-startup=4
```

`vm-uuid` is the VM's UUID, which you can obtain as explained in [Determining a VM's UUID](#).

## C.5. Pinning VMs to a specific CPU socket and cores

1. Use `xe host-cpu-info` to determine the number of CPU sockets and logical CPU cores in the server platform.  
In this example the server implements 32 logical CPU cores across two sockets:

```
[root@xenserver ~]# xe host-cpu-info
cpu_count : 32
```

```

socket_count: 2
  vendor: GenuineIntel
  speed: 2600.064
  modelname: Intel(R) Xeon(R) CPU E5-2670 0 @ 2.60GHz
  family: 6
  model: 45
  stepping: 7
  flags: fpu de tsc msr pae mce cx8 apic sep mtrr mca
cmov pat clflush acpi mmx fxsr sse sse2 ss ht nx constant_tsc nonstop_tsc
aperfmpperf pni pclmulqdq vmx est ssse3 sse4_1 sse4_2 x2apic popcnt aes
hypervisor ida arat tpr_shadow vnmi flexpriority ept vpid
  features: 17bee3ff-bfebfbff-00000001-2c100800
  features_after_reboot: 17bee3ff-bfebfbff-00000001-2c100800
  physical_features: 17bee3ff-bfebfbff-00000001-2c100800
  maskable: full

```

2. Set `VCPUs-params:mask` to pin a VM's vCPUs to a specific socket or to specific cores within a socket.

This setting persists over VM reboots and shutdowns. In a dual socket platform with 32 total cores, cores 0-15 are on socket 0, and cores 16-31 are on socket 1.

In the examples that follow, *vm-uuid* is the VM's UUID, which you can obtain as explained in [Determining a VM's UUID](#).

- ▶ To restrict a VM to only run on socket 0, set the mask to specify cores 0-15:

```
[root@xenserver ~]# xe vm-param-set uuid=vm-uuid VCPUs-params:mask=0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15
```

- ▶ To restrict a VM to only run on socket 1, set the mask to specify cores 16-31:

```
[root@xenserver ~]# xe vm-param-set uuid=vm-uuid VCPUs-params:mask=16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31
```

- ▶ To pin vCPUs to specific cores within a socket, set the mask to specify the cores directly:

```
[root@xenserver ~]# xe vm-param-set uuid=vm-uuid VCPUs-params:mask=16,17,18,19
```

3. Use `xl vcpu-list` to list the current assignment of vCPUs to physical CPUs:

```
[root@xenserver ~]# xl vcpu-list
```

Name	ID	VCPU	CPU	State	Time (s)	CPU
Affinity						
Domain-0	0	0	25	-b-	9188.4	any cpu
Domain-0	0	1	19	r--	8908.4	any cpu
Domain-0	0	2	30	-b-	6815.1	any cpu
Domain-0	0	3	17	-b-	4881.4	any cpu
Domain-0	0	4	22	-b-	4956.9	any cpu
Domain-0	0	5	20	-b-	4319.2	any cpu
Domain-0	0	6	28	-b-	5720.0	any cpu
Domain-0	0	7	26	-b-	5736.0	any cpu
test-image-win7-32	34	0	9	-b-	17.0	4-15
test-image-win7-32	34	1	4	-b-	13.7	4-15

## C.6. Changing dom0 vCPU Default configuration

By default, dom0 vCPUs are configured as follows:

- ▶ The number of vCPUs assigned to dom0 is 8.

- ▶ The dom0 shell's vCPUs are unpinned and able to run on any physical CPU in the system.

## C.6.1. Changing the number of dom0 vCPUs

The default number of vCPUs assigned to dom0 is 8.

1. Modify the `dom0_max_vcpus` parameter in the Xen boot line.

For example:

```
[root@xenserver ~]# /opt/xensource/libexec/xen-cmdline --set-xen
dom0_max_vcpus=4
```

2. After applying this setting, reboot the system for the setting to take effect by doing one of the following:
  - ▶ Run the following command:

```
shutdown -r
```

- ▶ Reboot the system from XenCenter.

## C.6.2. Pinning dom0 vCPUs

By default, dom0's vCPUs are unpinned, and able to run on any physical CPU in the system.

1. To pin dom0 vCPUs to specific physical CPUs, use `xl vcpu-pin`.

For example, to pin dom0's vCPU 0 to physical CPU 18, use the following command:

```
[root@xenserver ~]# xl vcpu-pin Domain-0 0 18
```

CPU pinnings applied this way take effect immediately but do not persist over reboots.

2. To make settings persistent, add `xl vcpu-pin` commands into `/etc/rc.local`.

For example:

```
xl vcpu-pin 0 0 0-15
xl vcpu-pin 0 1 0-15
xl vcpu-pin 0 2 0-15
xl vcpu-pin 0 3 0-15
xl vcpu-pin 0 4 16-31
xl vcpu-pin 0 5 16-31
xl vcpu-pin 0 6 16-31
xl vcpu-pin 0 7 16-31
```

## C.7. How GPU locality is determined

As noted in [NUMA considerations](#), current multi-socket servers typically implement PCIe expansion slots local to each CPU socket and it is advantageous to pin VMs to the same socket that their associated physical GPU is connected to.

For current Intel platforms, CPU socket 0 typically has its PCIe root ports located on bus 0, so any GPU below a root port located on bus 0 is connected to socket 0. CPU socket 1

has its root ports on a higher bus number, typically bus 0x20 or bus 0x80 depending on the specific server platform.

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