



# Virtual GPU Software

## User Guide

# Table of Contents

<b>Chapter 1. Introduction to NVIDIA vGPU Software.....</b>	<b>1</b>
1.1. How NVIDIA vGPU Software Is Used.....	1
1.1.2. GPU Pass-Through.....	1
1.1.3. Bare-Metal Deployment.....	1
1.2. Primary Display Adapter Requirements for NVIDIA vGPU Software Deployments.....	2
1.3. NVIDIA vGPU Software Features.....	3
1.3.1. Since 11:1: GPU Instance Support on NVIDIA vGPU Software.....	3
1.3.2. API Support on NVIDIA vGPU.....	4
1.3.3. NVIDIA CUDA Toolkit and OpenCL Support on NVIDIA vGPU Software.....	5
1.3.4. Additional Quadro vDWS Features.....	6
1.3.5. NVIDIA GPU Cloud (NGC) Containers Support on NVIDIA vGPU Software.....	7
1.4. How this Guide Is Organized.....	7
<b>Chapter 2. Installing and Configuring NVIDIA Virtual GPU Manager.....</b>	<b>9</b>
2.1. About NVIDIA Virtual GPUs.....	9
2.1.1. NVIDIA vGPU Architecture.....	9
2.1.1.1. Time-Sliced NVIDIA vGPU Internal Architecture.....	10
2.1.1.2. Since 11.1: MIG-Backed NVIDIA vGPU Internal Architecture.....	11
2.1.2. About Virtual GPU Types.....	12
2.1.3. Virtual Display Resolutions for Q-series and B-series vGPUs.....	14
2.1.4. Valid Virtual GPU Configurations on a Single GPU.....	15
2.1.4.1. Valid Time-Sliced Virtual GPU Configurations on a Single GPU.....	15
2.1.4.2. Since 11.1: Valid MIG-Backed Virtual GPU Configurations on a Single GPU..	16
2.1.5. Guest VM Support.....	16
2.1.5.1. Windows Guest VM Support.....	17
2.1.5.2. Linux Guest VM support.....	17
2.2. Prerequisites for Using NVIDIA vGPU.....	17
2.3. Switching the Mode of a Tesla M60 or M6 GPU.....	18
2.4. Installing and Configuring the NVIDIA Virtual GPU Manager for Citrix Hypervisor....	18
2.4.1. Installing and Updating the NVIDIA Virtual GPU Manager for Citrix Hypervisor.	19
2.4.1.1. Installing the RPM package for Citrix Hypervisor.....	19
2.4.1.2. Updating the RPM Package for Citrix Hypervisor.....	19
2.4.1.3. Installing or Updating the Supplemental Pack for Citrix Hypervisor.....	20
2.4.1.4. Verifying the Installation of the NVIDIA vGPU Software for Citrix Hypervisor Package.....	22
2.4.2. Configuring a Citrix Hypervisor VM with Virtual GPU.....	23

2.5. Installing the Virtual GPU Manager Package for Linux KVM.....	24
2.6. Installing and Configuring the NVIDIA Virtual GPU Manager for Red Hat Enterprise Linux KVM or RHV.....	25
2.6.1. Installing the NVIDIA Virtual GPU Manager for Red Hat Enterprise Linux KVM or RHV.....	26
2.6.1.1. Installing the Virtual GPU Manager Package for Red Hat Enterprise Linux KVM or RHV.....	26
2.6.1.2. Verifying the Installation of the NVIDIA vGPU Software for Red Hat Enterprise Linux KVM or RHV.....	27
2.6.2. Adding a vGPU to a Red Hat Virtualization (RHV) VM.....	28
2.6.3. Getting the BDF and Domain of a GPU on Red Hat Enterprise Linux KVM.....	30
2.6.4. Creating an NVIDIA vGPU on Red Hat Enterprise Linux KVM.....	30
2.6.4.1. Creating a Legacy NVIDIA vGPU on Red Hat Enterprise Linux KVM.....	31
2.6.4.2. Creating an NVIDIA vGPU that Supports SR-IOV on Red Hat Enterprise Linux KVM.....	33
2.6.5. Adding One or More vGPUs to a Red Hat Enterprise Linux KVM VM.....	36
2.6.5.1. Adding One or More vGPUs to a Red Hat Enterprise Linux KVM VM by Using virsh.....	36
2.6.5.2. Adding One or More vGPUs to a Red Hat Enterprise Linux KVM VM by Using the QEMU Command Line.....	38
2.6.6. Setting vGPU Plugin Parameters on Red Hat Enterprise Linux KVM.....	38
2.6.7. Deleting a vGPU on Red Hat Enterprise Linux KVM.....	39
2.6.8. Preparing a GPU Configured for Pass-Through for Use with vGPU.....	40
2.6.9. NVIDIA vGPU Information in the sysfs File System.....	41
2.7. Installing and Configuring the NVIDIA Virtual GPU Manager for VMware vSphere...	44
2.7.1. Installing and Updating the NVIDIA Virtual GPU Manager for vSphere.....	45
2.7.1.1. Installing the NVIDIA Virtual GPU Manager Package for vSphere.....	46
2.7.1.2. Updating the NVIDIA Virtual GPU Manager Package for vSphere.....	47
2.7.1.3. Verifying the Installation of the NVIDIA vGPU Software Package for vSphere.....	47
2.7.2. Configuring VMware vMotion with vGPU for VMware vSphere.....	48
2.7.3. Changing the Default Graphics Type in VMware vSphere 6.5 and Later.....	49
2.7.4. Configuring a vSphere VM with NVIDIA vGPU.....	54
2.7.5. Configuring a vSphere VM with VMware vSGA.....	57
2.8. Since 11.1: Configuring a GPU for MIG-Backed vGPUs.....	58
2.9. Since 11.1: Disabling MIG Mode for One or More GPUs.....	61
2.10. Disabling and Enabling ECC Memory.....	62
2.10.1. Disabling ECC Memory.....	63
2.10.2. Enabling ECC Memory.....	64

<b>Chapter 3. Using GPU Pass-Through.....</b>	<b>66</b>
3.1. Display Resolutions for Physical GPUs.....	67
3.2. Using GPU Pass-Through on Citrix Hypervisor.....	68
3.2.1. Configuring a VM for GPU Pass Through by Using XenCenter.....	69
3.2.2. Configuring a VM for GPU Pass Through by Using xe.....	69
3.3. Using GPU Pass-Through on Red Hat Enterprise Linux KVM.....	70
3.3.1. Configuring a VM for GPU Pass-Through by Using Virtual Machine Manager (virt-manager).....	70
3.3.2. Configuring a VM for GPU Pass-Through by Using virsh.....	71
3.3.3. Configuring a VM for GPU Pass-Through by Using the QEMU Command Line....	73
3.3.4. Preparing a GPU Configured for vGPU for Use in Pass-Through Mode.....	73
3.4. Using GPU Pass-Through on Microsoft Windows Server.....	76
3.4.1. Assigning a GPU to a VM on Microsoft Windows Server with Hyper-V.....	76
3.4.2. Returning a GPU to the Host OS from a VM on Windows Server with Hyper-V..	78
3.5. Using GPU Pass-Through on VMware vSphere.....	79
<b>Chapter 4. Installing the NVIDIA vGPU Software Graphics Driver.....</b>	<b>80</b>
4.1. Installing the NVIDIA vGPU Software Graphics Driver on Windows.....	80
4.2. Installing the NVIDIA vGPU Software Graphics Driver on Linux.....	82
4.3. Disabling the Nouveau Driver for NVIDIA Graphics Cards.....	84
4.4. Disabling the Wayland Display Server Protocol for Red Hat Enterprise Linux.....	85
<b>Chapter 5. Licensing an NVIDIA vGPU.....</b>	<b>86</b>
5.1. Licensing an NVIDIA vGPU on Windows.....	86
5.2. Licensing an NVIDIA vGPU on Linux.....	88
<b>Chapter 6. Modifying a VM's NVIDIA vGPU Configuration.....</b>	<b>90</b>
6.1. Removing a VM's NVIDIA vGPU Configuration.....	90
6.1.1. Removing a Citrix Virtual Apps and Desktops VM's vGPU configuration.....	90
6.1.1.1. Removing a VM's vGPU configuration by using XenCenter.....	90
6.1.1.2. Removing a VM's vGPU configuration by using xe.....	91
6.1.2. Removing a vSphere VM's vGPU Configuration.....	91
6.2. Modifying GPU Allocation Policy.....	92
6.2.1. Modifying GPU Allocation Policy on Citrix Hypervisor.....	92
6.2.1.1. Modifying GPU Allocation Policy by Using xe.....	92
6.2.1.2. Modifying GPU Allocation Policy GPU by Using XenCenter.....	93
6.2.2. Modifying GPU Allocation Policy on VMware vSphere.....	93
6.3. Migrating a VM Configured with vGPU.....	96
6.3.1. Migrating a VM Configured with vGPU on Citrix Hypervisor.....	97
6.3.2. Migrating a VM Configured with vGPU on VMware vSphere.....	98
6.3.3. Suspending and Resuming a VM Configured with vGPU on VMware vSphere...	100

6.4. Since 11.1: Modifying a MIG-Backed vGPU's Configuration.....	100
<b>Chapter 7. Monitoring GPU Performance.....</b>	<b>104</b>
7.1. NVIDIA System Management Interface nvidia-smi.....	104
7.2. Monitoring GPU Performance from a Hypervisor.....	105
7.2.1. Using nvidia-smi to Monitor GPU Performance from a Hypervisor.....	105
7.2.1.1. Getting a Summary of all Physical GPUs in the System.....	105
7.2.1.2. Getting a Summary of all vGPUs in the System.....	106
7.2.1.3. Getting vGPU Details.....	107
7.2.1.4. Monitoring vGPU engine usage.....	107
7.2.1.5. Monitoring vGPU engine usage by applications.....	108
7.2.1.6. Monitoring Encoder Sessions.....	109
7.2.1.7. Monitoring Frame Buffer Capture (FBC) Sessions.....	110
7.2.1.8. Listing Supported vGPU Types.....	115
7.2.1.9. Listing the vGPU Types that Can Currently Be Created.....	116
7.2.2. Using Citrix XenCenter to monitor GPU performance.....	116
7.3. Monitoring GPU Performance from a Guest VM.....	117
7.3.1. Using nvidia-smi to Monitor GPU Performance from a Guest VM.....	118
7.3.2. Using Windows Performance Counters to monitor GPU performance.....	119
7.3.3. Using NVWMI to monitor GPU performance.....	120
<b>Chapter 8. Changing Scheduling Behavior for Time-Sliced vGPUs.....</b>	<b>123</b>
8.1. Scheduling Policies for Time-Sliced vGPUs.....	123
8.2. Scheduler Time Slice for Time-Sliced vGPUs.....	124
8.3. RmPVMRL Registry Key.....	124
8.4. Getting the Current Time-Sliced vGPU Scheduling Behavior for All GPUs.....	126
8.5. Changing the Time-Sliced vGPU Scheduling Behavior for All GPUs.....	127
8.6. Changing the Time-Sliced vGPU Scheduling Behavior for Select GPUs.....	128
8.7. Restoring Default Time-Sliced vGPU Scheduler Settings.....	130
<b>Chapter 9. Troubleshooting.....</b>	<b>131</b>
9.1. Known issues.....	131
9.2. Troubleshooting steps.....	131
9.2.1. Verifying the NVIDIA Kernel Driver Is Loaded.....	131
9.2.2. Verifying that nvidia-smi works.....	132
9.2.3. Examining NVIDIA kernel driver output.....	132
9.2.4. Examining NVIDIA Virtual GPU Manager Messages.....	132
9.2.4.1. Examining Citrix Hypervisor vGPU Manager Messages.....	133
9.2.4.2. Examining Red Hat Enterprise Linux KVM vGPU Manager Messages.....	133
9.2.4.3. Examining VMware vSphere vGPU Manager Messages.....	134
9.3. Capturing configuration data for filing a bug report.....	134

9.3.1. Capturing configuration data by running nvidia-bug-report.sh.....	135
9.3.2. Capturing Configuration Data by Creating a Citrix Hypervisor Status Report...	135
<b>Appendix A. Virtual GPU Types Reference.....</b>	<b>137</b>
A.1. Virtual GPU Types for Supported GPUs.....	137
A.1.1. NVIDIA A100 PCIe 40GB Virtual GPU Types.....	137
A.1.2. NVIDIA A100 HGX 40GB Virtual GPU Types.....	138
A.1.3. Tesla M60 Virtual GPU Types.....	139
A.1.4. Tesla M10 Virtual GPU Types.....	142
A.1.5. Tesla M6 Virtual GPU Types.....	144
A.1.6. Tesla P100 PCIe 12GB Virtual GPU Types.....	147
A.1.7. Tesla P100 PCIe 16GB Virtual GPU Types.....	150
A.1.8. Tesla P100 SXM2 Virtual GPU Types.....	153
A.1.9. Tesla P40 Virtual GPU Types.....	156
A.1.10. Tesla P6 Virtual GPU Types.....	159
A.1.11. Tesla P4 Virtual GPU Types.....	162
A.1.12. Tesla T4 Virtual GPU Types.....	165
A.1.13. Tesla V100 SXM2 Virtual GPU Types.....	168
A.1.14. Tesla V100 SXM2 32GB Virtual GPU Types.....	171
A.1.15. Tesla V100 PCIe Virtual GPU Types.....	174
A.1.16. Tesla V100 PCIe 32GB Virtual GPU Types.....	177
A.1.17. Tesla V100S PCIe 32GB Virtual GPU Types.....	180
A.1.18. Tesla V100 FHHL Virtual GPU Types.....	183
A.1.19. Quadro RTX 8000 Virtual GPU Types.....	186
A.1.20. Quadro RTX 8000 Passive Virtual GPU Types.....	190
A.1.21. Quadro RTX 6000 Virtual GPU Types.....	193
A.1.22. Quadro RTX 6000 Passive Virtual GPU Types.....	196
A.2. Mixed Display Configurations for B-Series and Q-Series vGPUs.....	200
A.2.1. Mixed Display Configurations for B-Series vGPUs.....	200
A.2.2. Mixed Display Configurations for Q-Series vGPUs Based on the NVIDIA Maxwell Architecture.....	200
A.2.3. Mixed Display Configurations for Q-Series vGPUs Based on Architectures after NVIDIA Maxwell.....	201
<b>Appendix B. Allocation Strategies.....</b>	<b>202</b>
B.1. NUMA Considerations.....	202
B.1.1. Obtaining Best Performance on a NUMA Platform with Citrix Hypervisor.....	203
B.1.2. Obtaining Best Performance on a NUMA Platform with VMware vSphere ESXi.....	203
B.2. Maximizing Performance.....	203
<b>Appendix C. Configuring x11vnc for Checking the GPU in a Linux Server.....</b>	<b>205</b>

C.1. Configuring the Xorg Server on the Linux Server.....	206
C.2. Installing and Configuring x11vnc on the Linux Server.....	207
C.3. Using a VNC Client to Connect to the Linux Server.....	208
<b>Appendix D. Disabling NVIDIA Notification Icon for Citrix Published Application User Sessions.....</b>	<b>211</b>
D.1. Disabling NVIDIA Notification Icon for All Users' Citrix Published Application Sessions.....	213
D.2. Disabling NVIDIA Notification Icon for your Citrix Published Application User Sessions.....	213
<b>Appendix E. Citrix Hypervisor Basics.....</b>	<b>215</b>
E.1. Opening a dom0 shell.....	215
E.1.1. Accessing the dom0 shell through XenCenter.....	215
E.1.2. Accessing the dom0 shell through an SSH client.....	216
E.2. Copying files to dom0.....	216
E.2.1. Copying files by using an SCP client.....	216
E.2.2. Copying files by using a CIFS-mounted file system.....	217
E.3. Determining a VM's UUID.....	217
E.3.1. Determining a VM's UUID by using xe vm-list.....	218
E.3.2. Determining a VM's UUID by using XenCenter.....	218
E.4. Using more than two vCPUs with Windows client VMs.....	219
E.5. Pinning VMs to a specific CPU socket and cores.....	219
E.6. Changing dom0 vCPU Default configuration.....	220
E.6.1. Changing the number of dom0 vCPUs.....	221
E.6.2. Pinning dom0 vCPUs.....	221
E.7. How GPU locality is determined.....	221
<b>Appendix F. Citrix Hypervisor vGPU Management.....</b>	<b>222</b>
F.1. Management objects for GPUs.....	222
F.1.1. pgpu - Physical GPU.....	222
F.1.1.1. Listing the pgpu Objects Present on a Platform.....	222
F.1.1.2. Viewing Detailed Information About a pgpu Object.....	223
F.1.1.3. Viewing physical GPUs in XenCenter.....	223
F.1.2. vgpu-type - Virtual GPU Type.....	224
F.1.2.1. Listing the vgpu-type Objects Present on a Platform.....	224
F.1.2.2. Viewing Detailed Information About a vgpu-type Object.....	228
F.1.3. gpu-group - collection of physical GPUs.....	228
F.1.3.1. Listing the gpu-group Objects Present on a Platform.....	228
F.1.3.2. Viewing Detailed Information About a gpu-group Object.....	229
F.1.4. vgpu - Virtual GPU.....	229

F.2. Creating a vGPU Using xe.....	229
F.3. Controlling vGPU allocation.....	230
F.3.1. Determining the Physical GPU on Which a Virtual GPU is Resident.....	230
F.3.2. Controlling the vGPU types enabled on specific physical GPUs.....	231
F.3.2.1. Controlling vGPU types enabled on specific physical GPUs by using XenCenter.....	231
F.3.2.2. Controlling vGPU Types Enabled on Specific Physical GPUs by Using xe.....	232
F.3.3. Creating vGPUs on Specific Physical GPUs.....	233
F.4. Cloning vGPU-Enabled VMs.....	234
F.4.1. Cloning a vGPU-enabled VM by using xe.....	235
F.4.2. Cloning a vGPU-enabled VM by using XenCenter.....	235
<b>Appendix G. Citrix Hypervisor Performance Tuning.....</b>	<b>236</b>
G.1. Citrix Hypervisor Tools.....	236
G.2. Using Remote Graphics.....	236
G.2.1. Disabling Console VGA.....	236



# List of Figures

Figure 1. GPU Instances Configured with NVIDIA vGPU.....	4
Figure 2. NVIDIA vGPU System Architecture.....	10
Figure 3. Time-Sliced NVIDIA vGPU Internal Architecture.....	11
Figure 4. MIG-Backed NVIDIA vGPU Internal Architecture.....	12
Figure 5. Example Time-Sliced vGPU Configurations on Tesla M60.....	15
Figure 6. Example MIG-Backed vGPU Configurations on NVIDIA A100 PCIe 40GB.....	16
Figure 7. NVIDIA vGPU Manager supplemental pack selected in XenCenter.....	21
Figure 8. Successful installation of NVIDIA vGPU Manager supplemental pack.....	22
Figure 9. Using Citrix XenCenter to configure a VM with a vGPU.....	24
Figure 10. Shared default graphics type.....	51
Figure 11. Host graphics settings for vGPU.....	52
Figure 12. Shared graphics type.....	53
Figure 13. Graphics device settings for a physical GPU.....	53
Figure 14. Shared direct graphics type.....	54
Figure 15. VM settings for vGPU.....	56
Figure 16. Using XenCenter to configure a pass-through GPU.....	69
Figure 17. NVIDIA driver installation.....	81
Figure 18. Verifying NVIDIA driver operation using NVIDIA Control Panel.....	82
Figure 19. Update xorg.conf settings.....	84
Figure 20. Managing vGPU licensing in NVIDIA Control Panel.....	87
Figure 21. Using XenCenter to remove a vGPU configuration from a VM.....	91
Figure 22. Modifying GPU placement policy in XenCenter.....	93
Figure 23. Breadth-first allocation scheme setting for vGPU-enabled VMs.....	94
Figure 24. Host graphics settings for vGPU.....	95

Figure 25. Depth-first allocation scheme setting for vGPU-enabled VMs.....	96
Figure 26. Using Citrix XenCenter to monitor GPU performance.....	117
Figure 27. Using nvidia-smi from a Windows guest VM to get total resource usage by all applications.....	118
Figure 28. Using nvidia-smi from a Windows guest VM to get resource usage by individual applications.....	119
Figure 29. Using Windows Performance Monitor to monitor GPU performance.....	120
Figure 30. Using WMI Explorer to monitor GPU performance.....	121
Figure 31. Including NVIDIA logs in a Citrix Hypervisor status report.....	136
Figure 32. A NUMA Server Platform.....	202
Figure 33. Connecting to the dom0 shell by using XenCenter.....	216
Figure 34. Using XenCenter to determine a VM's UUID.....	219
Figure 35. Physical GPU display in XenCenter.....	224
Figure 36. Editing a GPU's enabled vGPU types using XenCenter.....	232
Figure 37. Using a custom GPU group within XenCenter.....	234
Figure 38. Cloning a VM using XenCenter.....	235

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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. Primary Display Adapter Requirements for NVIDIA vGPU Software Deployments

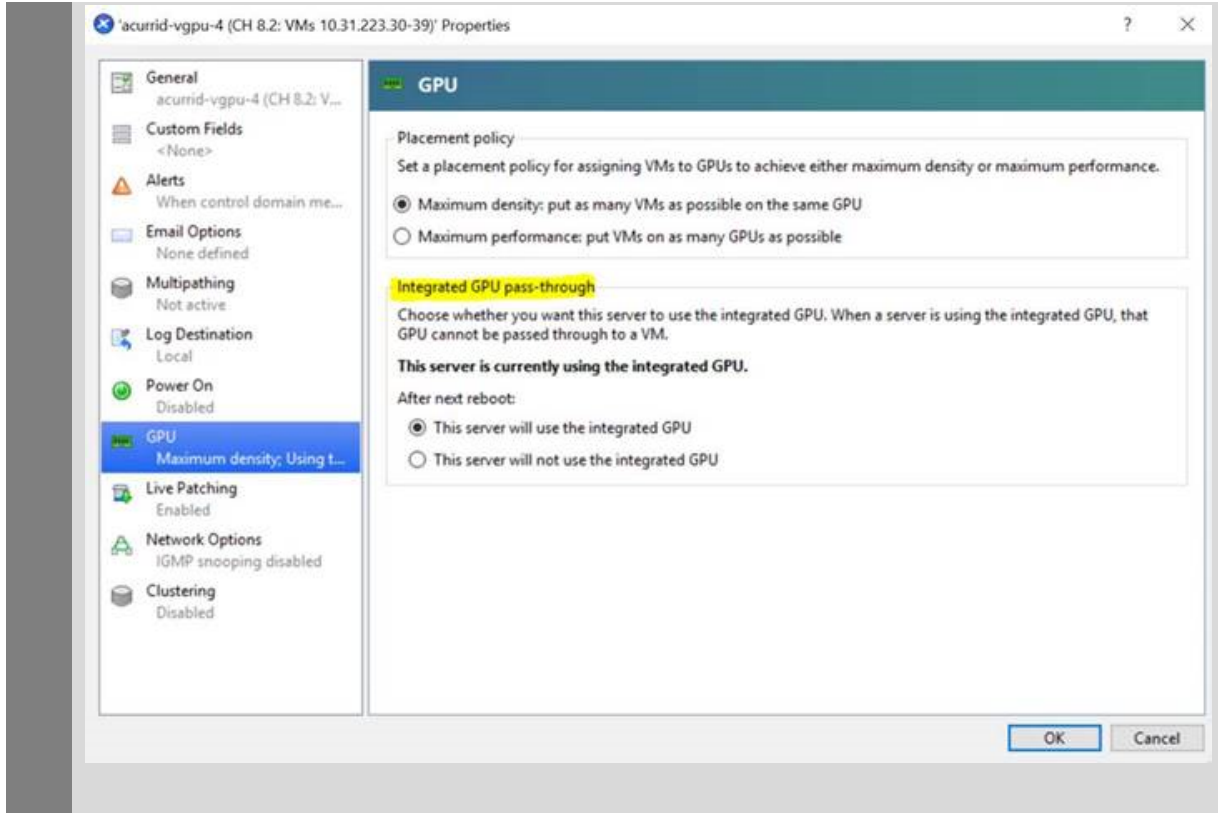
The GPU that is set as the primary display adapter cannot be used for NVIDIA vGPU deployments or GPU pass through deployments. The primary display is the boot display of the hypervisor host, which displays SBIOS console messages and then boot of the OS or hypervisor.

Any GPU that is being used for NVIDIA vGPU deployments or GPU pass through deployments must be set as a **secondary** display adapter.



### Note:

Citrix Hypervisor provides a specific setting to allow the primary display adapter to be used for GPU pass through deployments.



Only the following GPUs are supported as the primary display adapter:

- ▶ Tesla M6
- ▶ Quadro RTX 6000
- ▶ Quadro RTX 8000

All other GPUs that support NVIDIA vGPU software cannot function as the primary display adapter because they are 3D controllers, not VGA devices.

If the hypervisor host does not have an extra graphics adapter, consider installing a low-end display adapter to be used as the primary display adapter. If necessary, ensure that the primary display adapter is set correctly in the BIOS options of the hypervisor host.

## 1.3. NVIDIA vGPU Software Features

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

### 1.3.1. Since 11:1: GPU Instance Support on NVIDIA vGPU Software

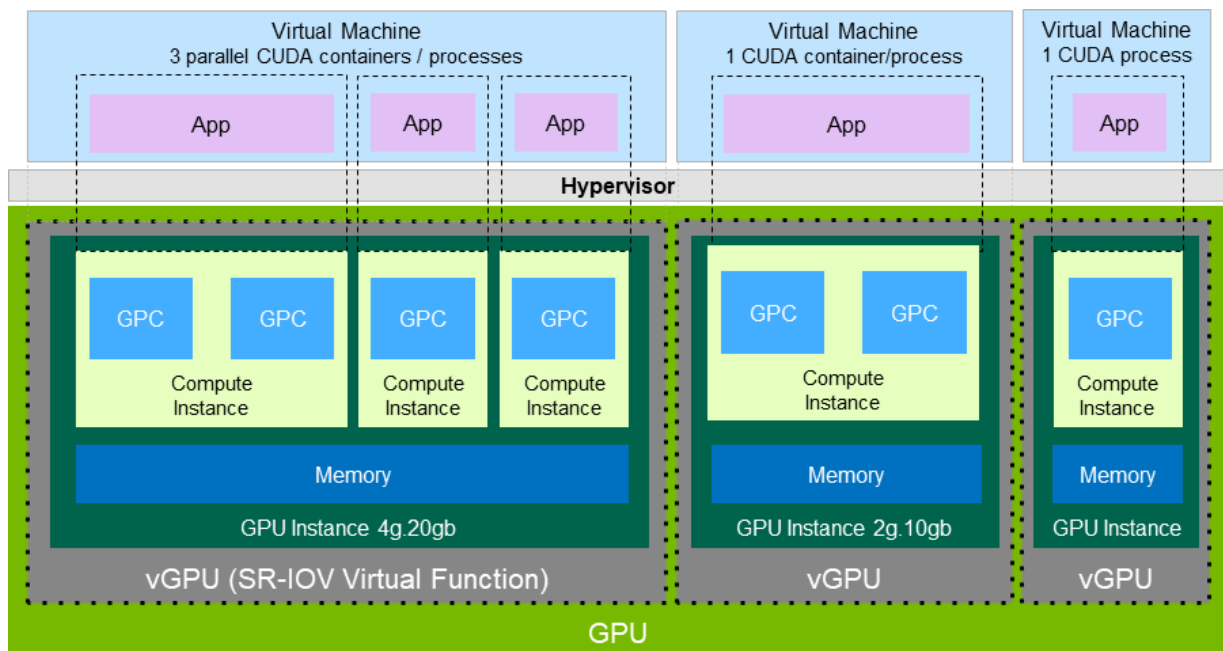
NVIDIA vGPU software supports GPU instances on GPUs that support the Multi-Instance GPU (MIG) feature in NVIDIA vGPU and GPU pass through deployments. MIG enables a

physical GPU to be securely partitioned into multiple separate GPU instances, providing multiple users with separate GPU resources to accelerate their applications.

In addition to providing all the benefits of MIG, NVIDIA vGPU software adds virtual machine security and management for workloads. Single Root I/O Virtualization (SR-IOV) virtual functions enable full IOMMU protection for the virtual machines that are configured with vGPUs.

[Figure 1](#) shows a GPU that is split into three GPU instances of different sizes, with each instance mapped to one vGPU. Although each GPU instance is managed by the hypervisor host and is mapped to one vGPU, each virtual machine can further subdivide the compute resources into smaller compute instances and run multiple containers on top of them in parallel, even within each vGPU.

Figure 1. GPU Instances Configured with NVIDIA vGPU



Not all hypervisors support GPU instances in NVIDIA vGPU deployments. To determine if your chosen hypervisor supports GPU instances in NVIDIA vGPU deployments, consult the release notes for your hypervisor at [NVIDIA Virtual GPU Software Documentation](#).

NVIDIA vGPU software supports GPU instances only with NVIDIA Virtual Compute Server and Linux guest operating systems.

To support GPU instances with NVIDIA vGPU, a GPU must be configured with MIG mode enabled and GPU instances must be created and configured on the physical GPU. For more information, see [Since 11.1: Configuring a GPU for MIG-Backed vGPUs](#). For general information about the MIG feature, see: [NVIDIA Multi-Instance GPU User Guide](#).

### 1.3.2. API Support on NVIDIA vGPU

NVIDIA vGPU includes support for the following APIs:

- ▶ Open Computing Language (OpenCL™ software) 1.2
- ▶ OpenGL® 4.6
- ▶ Vulkan® 1.2
- ▶ DirectX 11
- ▶ DirectX 12 (Windows 10)
- ▶ Direct2D
- ▶ DirectX Video Acceleration (DXVA)
- ▶ NVIDIA® CUDA® 11.0
- ▶ NVIDIA vGPU software SDK (remote graphics acceleration)
- ▶ NVIDIA RTX (on GPUs based on the NVIDIA Volta graphic architecture and later architectures)



**Note:** These APIs are backwards compatible. Older versions of the API are also supported.

### 1.3.3. 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



**Note:** 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
```

- ▶ **Since 11.1:** GPUDirect<sup>®</sup> technology remote direct memory access (RDMA)

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
- ▶ **11.0 only:** GPUDirect technology RDMA
- ▶ Development tools such as IDEs, debuggers, profilers, and utilities as listed under *CUDA Toolkit Major Components* in [CUDA Toolkit 11.0 Release Notes for Windows, Linux, and Mac OS](#)
- ▶ Tracing and profiling through the CUDA Profiling Tools Interface (CUPTI)



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

For more information about NVIDIA CUDA Toolkit, see [CUDA Toolkit 11.0 Documentation](#).



**Note:**

If you are using NVIDIA vGPU software with CUDA on Linux, avoid conflicting installation methods by installing CUDA from a distribution-independent runfile package. Do not install CUDA from a 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](#).

## 1.3.4. 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 multiple virtual display heads at resolutions up to 8K and flexible virtual display resolutions based on the number of available pixels. For details, see [Display Resolutions for Physical GPUs](#).
- ▶ 10-bit color for Windows users. (HDR/10-bit color is not currently supported on Linux, NvFBC capture is supported but deprecated.)

### 1.3.5. 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](#).

## 1.4. How this Guide Is Organized

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

- ▶ This chapter introduces the capabilities 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.

- ▶ [Changing Scheduling Behavior for Time-Sliced vGPUs](#) describes the scheduling behavior of NVIDIA vGPUs and how to change it.
- ▶ [Troubleshooting](#) provides guidance on troubleshooting.
- ▶ [Virtual GPU Types Reference](#) provides details of each vGPU available from each supported GPU and provides examples of mixed virtual display configurations for B-series and Q-series vGPUs.
- ▶ [Configuring x11vnc for Checking the GPU in a Linux Server](#) explains how to use x11vnc to confirm that the NVIDIA GPU in a Linux server to which no display devices are directly connected is working as expected.
- ▶ [Disabling NVIDIA Notification Icon for Citrix Published Application User Sessions](#) explains how to ensure that the **NVIDIA Notification Icon** application does not prevent the Citrix Published Application user session from being logged off even after the user has quit all ot
- ▶ [Citrix Hypervisor Basics](#) explains how to perform basic operations on Citrix Hypervisor to install and configure NVIDIA vGPU software and optimize Citrix Hypervisor operation with vGPU.
- ▶ [Citrix Hypervisor vGPU Management](#) covers vGPU management on Citrix Hypervisor.
- ▶ [Citrix Hypervisor Performance Tuning](#) covers vGPU performance optimization on Citrix Hypervisor.

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# 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.

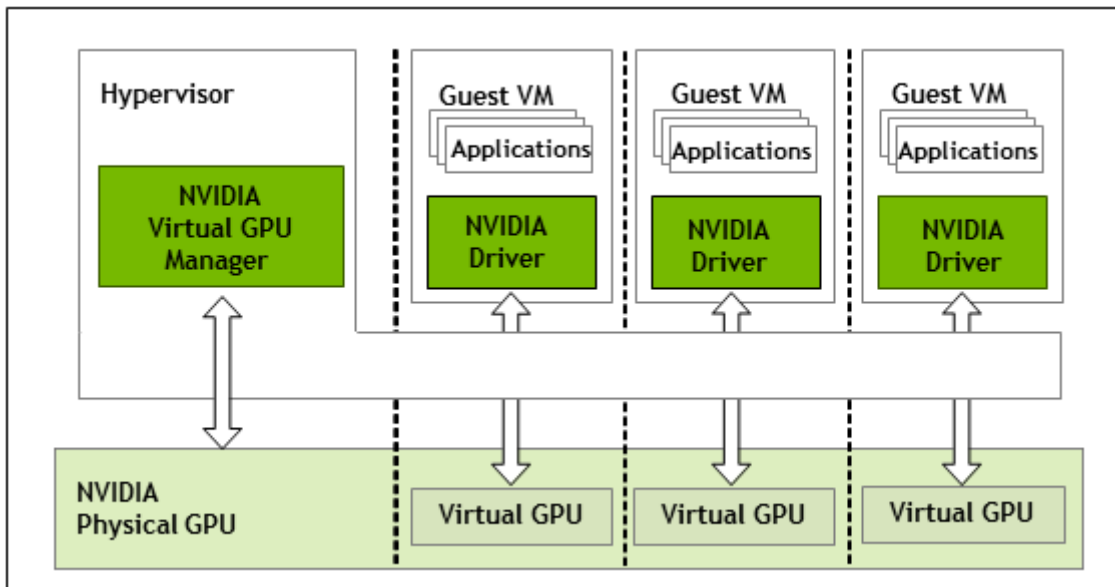
## 2.1. About NVIDIA Virtual GPUs

### 2.1.1. NVIDIA vGPU Architecture

The high-level architecture of NVIDIA vGPU is illustrated in [Figure 2](#). 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-performant management operations.

Figure 2. 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.

Depending on the physical GPU, different types of vGPU can be created on the vGPU:

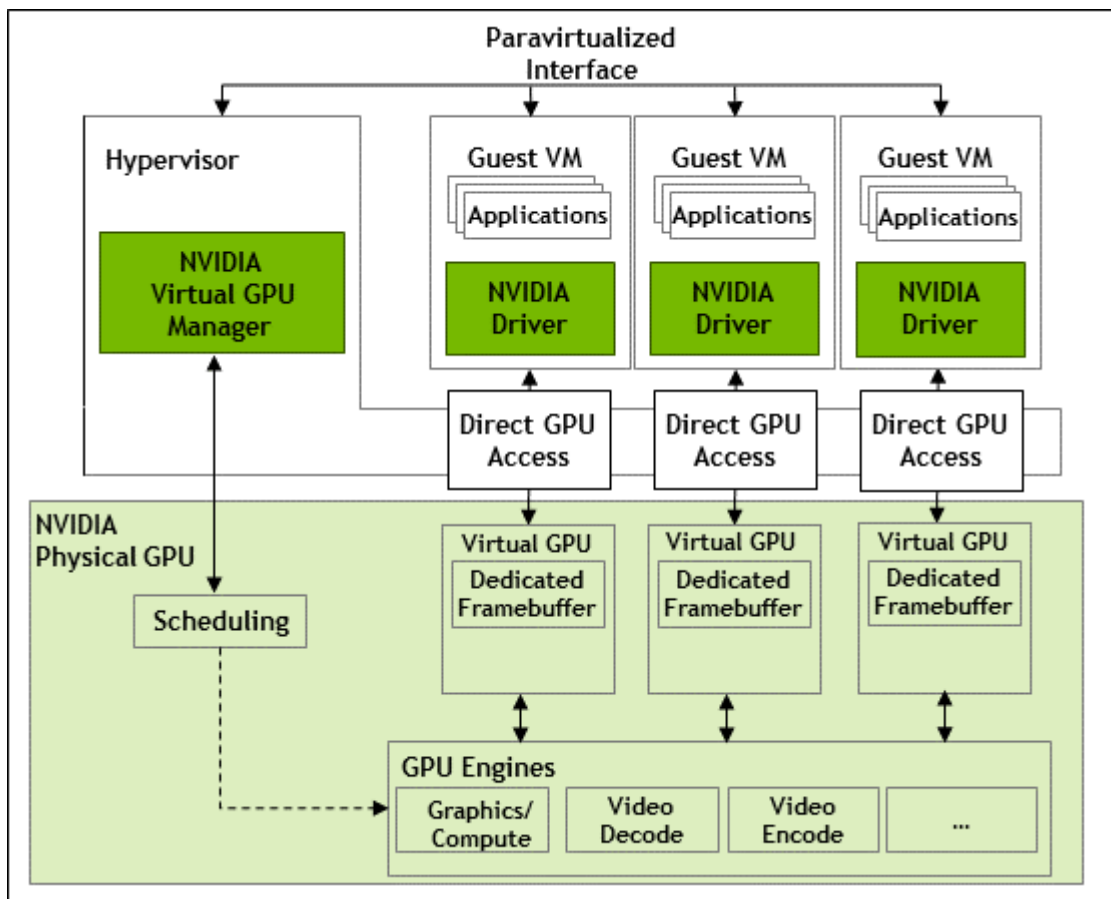
- ▶ On all GPUs that support NVIDIA vGPU software, time-sliced vGPUs can be created.
- ▶ Additionally, on GPUs that support the Multi-Instance GPU (MIG) feature, MIG-backed vGPUs can be created. The MIG feature is introduced on GPUs that are based on the NVIDIA Ampere GPU architecture.

### 2.1.1.1. Time-Sliced NVIDIA vGPU Internal Architecture

A time-sliced vGPU is a vGPU that resides on a physical GPU that is not partitioned into multiple GPU instances. All time-sliced vGPUs resident on a GPU share access to the GPU’s engines including the graphics (3D), video decode, and video encode engines.

In a time-sliced vGPU, processes that run on the vGPU are scheduled to run in series. Each vGPU waits while other processes run on other vGPUs. While processes are running on a vGPU, the vGPU has exclusive use of the GPU’s engines. You can change the default scheduling behavior as explained in [Changing Scheduling Behavior for Time-Sliced vGPUs](#).

Figure 3. Time-Sliced NVIDIA vGPU Internal Architecture

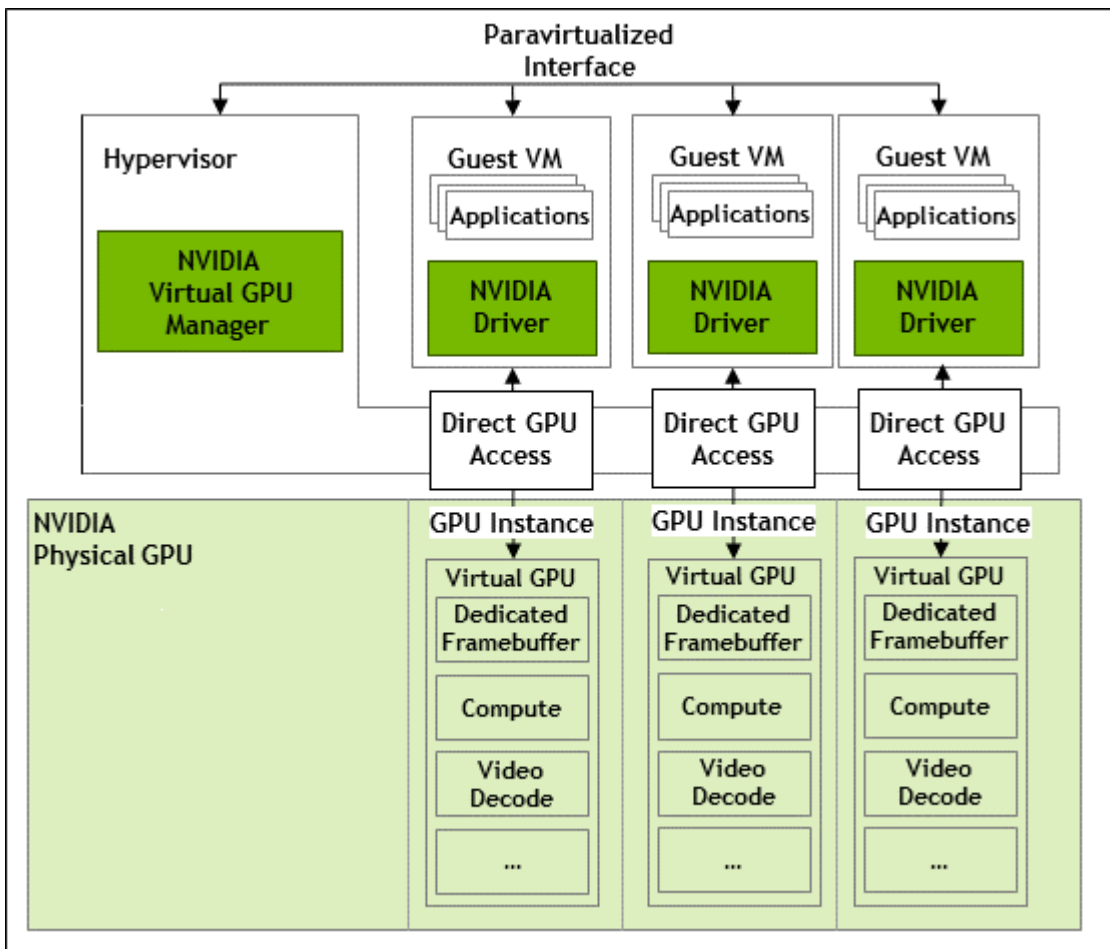


### 2.1.1.2. Since 11.1: MIG-Backed NVIDIA vGPU Internal Architecture

A MIG-backed vGPU is a vGPU that resides on a GPU instance in a MIG-capable physical GPU. Each MIG-backed vGPU resident on a GPU has exclusive access to the *GPU instance's* engines, including the compute and video decode engines.

In a MIG-backed vGPU, processes that run on the vGPU run in parallel with processes running on other vGPUs on the GPU. Process run on all vGPUs resident on a physical GPU simultaneously.

Figure 4. MIG-Backed NVIDIA vGPU Internal Architecture



### 2.1.2. About 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 Virtual Compute Server 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>6</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 Scheduling Behavior for Time-Sliced vGPUs](#). 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](#).



#### Note:

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 an NVIDIA Virtual Compute Server (vCS) 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.

<sup>3</sup> The maximum number of NVIDIA Virtual Compute Server 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> With many workloads, -1B and -1B4 vGPUs perform adequately with only 2 2560×1600 virtual displays per vGPU. If you want to use more than 2 2560×1600 virtual displays per vGPU, use a vGPU with more frame buffer, such as a -2B or -2B4 vGPU. For more information, see [NVIDIA GRID vPC Sizing Guide \(PDF\)](#).

<sup>6</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.

- ▶ A-series vGPU types require a GRID Virtual Applications license.

For details of the virtual GPU types available from each supported GPU, see [Virtual GPU Types for Supported GPUs](#).

### 2.1.3. Virtual Display Resolutions for Q-series and B-series vGPUs

Instead of a fixed maximum resolution per display, Q-series and B-series vGPUs support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. 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



**Note:** You cannot use more than the maximum number of displays that a vGPU supports even if the combined resolution of the displays is less than the number of available pixels from the vGPU. For example, because -OQ and -OB vGPUs support a maximum of only two displays, you cannot use four 1280×1024 displays with these vGPUs even though the combined resolution of the displays (6220800) is less than the number of available pixels from these vGPUs (8192000).

Various factors affect the consumption of the GPU frame buffer, which can impact the user experience. These factors include and are not limited to the number of displays, display resolution, workload and applications deployed, remoting solution, and guest OS. The ability of a vGPU to drive a certain combination of 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

The maximum number of displays per vGPU listed in [Virtual GPU Types for Supported GPUs](#) is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).



## 2.1.4. Valid Virtual GPU Configurations on a Single GPU

Valid vGPU configurations on a single GPU depend on whether the vGPUs are time sliced or, on GPUs that support MIG, are MIG-backed.

### 2.1.4.1. Valid Time-Sliced Virtual GPU Configurations on a Single GPU

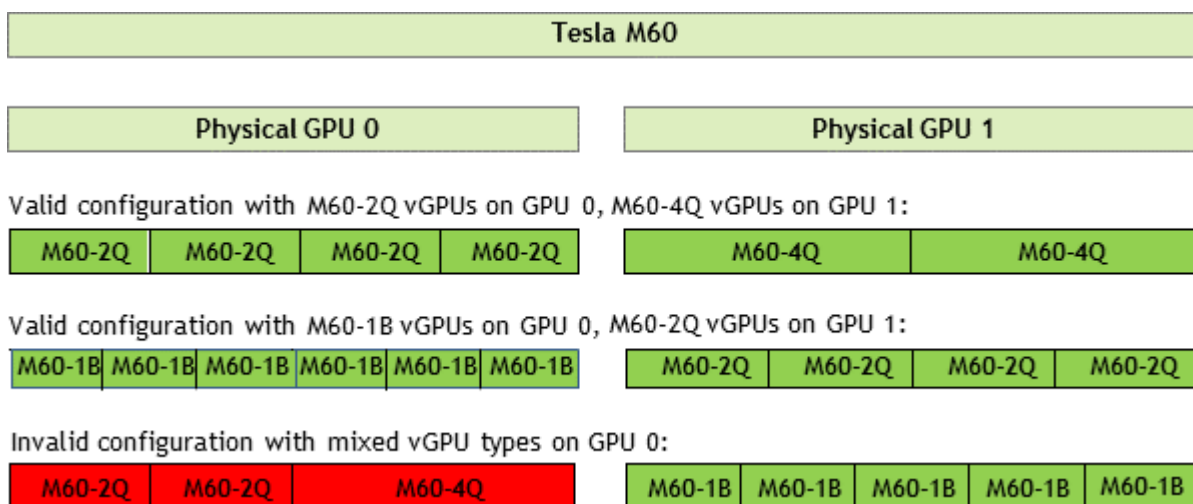
This release of NVIDIA vGPU supports only homogeneous time-sliced virtual GPUs. At any given time, the virtual GPUs resident on a single physical GPU must be all of the same type.

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 5](#) 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 5. Example Time-Sliced vGPU Configurations on Tesla M60



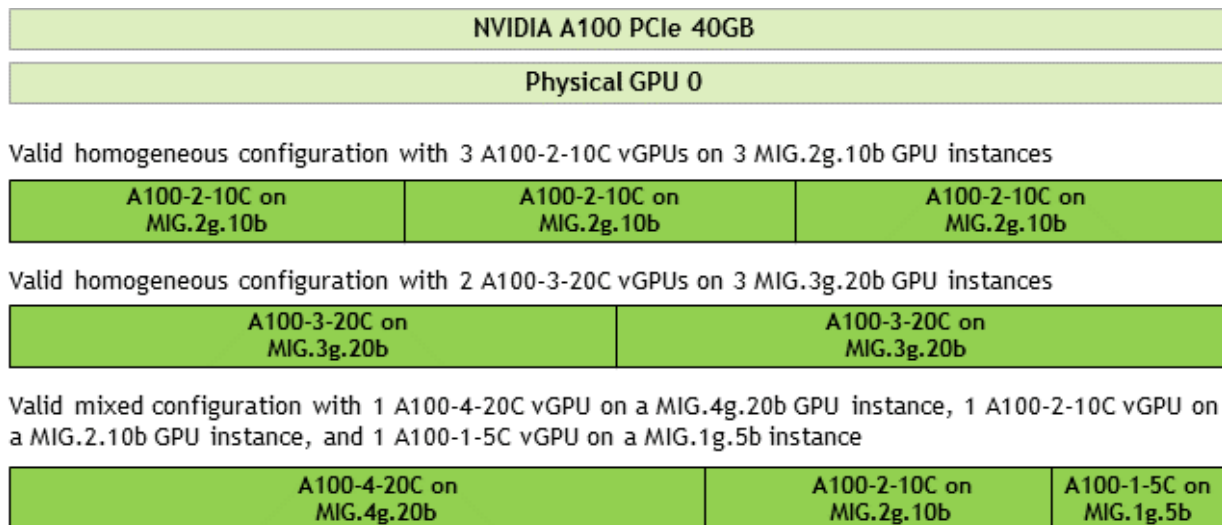
## 2.1.4.2. Since 11.1: Valid MIG-Backed Virtual GPU Configurations on a Single GPU

This release of NVIDIA vGPU supports both homogeneous and mixed MIG-backed virtual GPUs based on the underlying GPU instance configuration.

For example, an NVIDIA A100 PCIe 40GB card has one physical GPU, and can support several types of virtual GPU. [Figure 6](#) shows the following examples of valid homogeneous and mixed MIG-backed virtual GPU configurations on NVIDIA A100 PCIe 40GB.

- ▶ A valid homogeneous configuration with 3 A100-2-10C vGPUs on 3 MIG.2g.10b GPU instances
- ▶ A valid homogeneous configuration with 2 A100-3-20C vGPUs on 3 MIG.3g.20b GPU instances
- ▶ A valid mixed configuration with 1 A100-4-20C vGPU on a MIG.4g.20b GPU instance, 1 A100-2-10C vGPU on a MIG.2.10b GPU instance, and 1 A100-1-5C vGPU on a MIG.1g.5b instance

**Figure 6. Example MIG-Backed vGPU Configurations on NVIDIA A100 PCIe 40GB**



## 2.1.5. 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](#).

### 2.1.5.1. 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.

### 2.1.5.2. 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.

## 2.2. 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.
- ▶ **Since 11.1:** If you are using GPUs based on the NVIDIA Ampere architecture, the following BIOS settings are enabled on your server platform:
  - ▶ VT-D/IOMMU
  - ▶ SR-IOV
- ▶ 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



**Note:** 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 fully automated VMware Distributed Resource Scheduler (DRS) cluster. For more information, see [Installing and Configuring the NVIDIA Virtual GPU Manager for VMware vSphere](#).

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



**Note:** 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](#)

## 2.3. 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.



**Note:**

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 Virtual Compute Server 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, refer to [gpumodeswitch User Guide](#).

## 2.4. 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](#).

## 2.4.1. 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 compatible. If you update vGPU Manager to a release that is incompatible with the guest VM drivers, guest VMs will boot with vGPU disabled until their guest vGPU driver is updated to a compatible version. Consult [Virtual GPU Software for Citrix Hypervisor Release Notes](#) for further details.

### 2.4.1.1. 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-8.2-450.248.03.x86_64.rpm
Preparing packages for installation...
NVIDIA-vGPU-xenserver-8.2-450.248.03
[root@xenserver ~]#
```

2. Reboot the Citrix Hypervisor platform:

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

Broadcast message from root (pts/1) (Fri Jul 14 14:24:11 2023):

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

### 2.4.1.2. 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-8.2-450.248.03.x86_64.rpm
Preparing packages for installation...
NVIDIA-vGPU-xenserver-8.2-450.248.03
[root@xenserver ~]#
```



#### Note:

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-8.2-450.248.03
[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-8.2-450.248.03.x86_64 conflicts with file from package NVIDIA-
vGPU-xenserver-8.2-450.236.03.x86_64
   file /usr/lib/libnvidia-ml.so from install of NVIDIA-vGPU-
xenserver-8.2-450.248.03.x86_64 conflicts with file from package NVIDIA-
vGPU-xenserver-8.2-450.236.03.x86_64
   ...
```

### 3. Reboot the Citrix Hypervisor platform:

```
[root@xenserver ~]# shutdown -r now
Broadcast message from root (pts/1) (Fri Jul 14 14:24:11 2023):

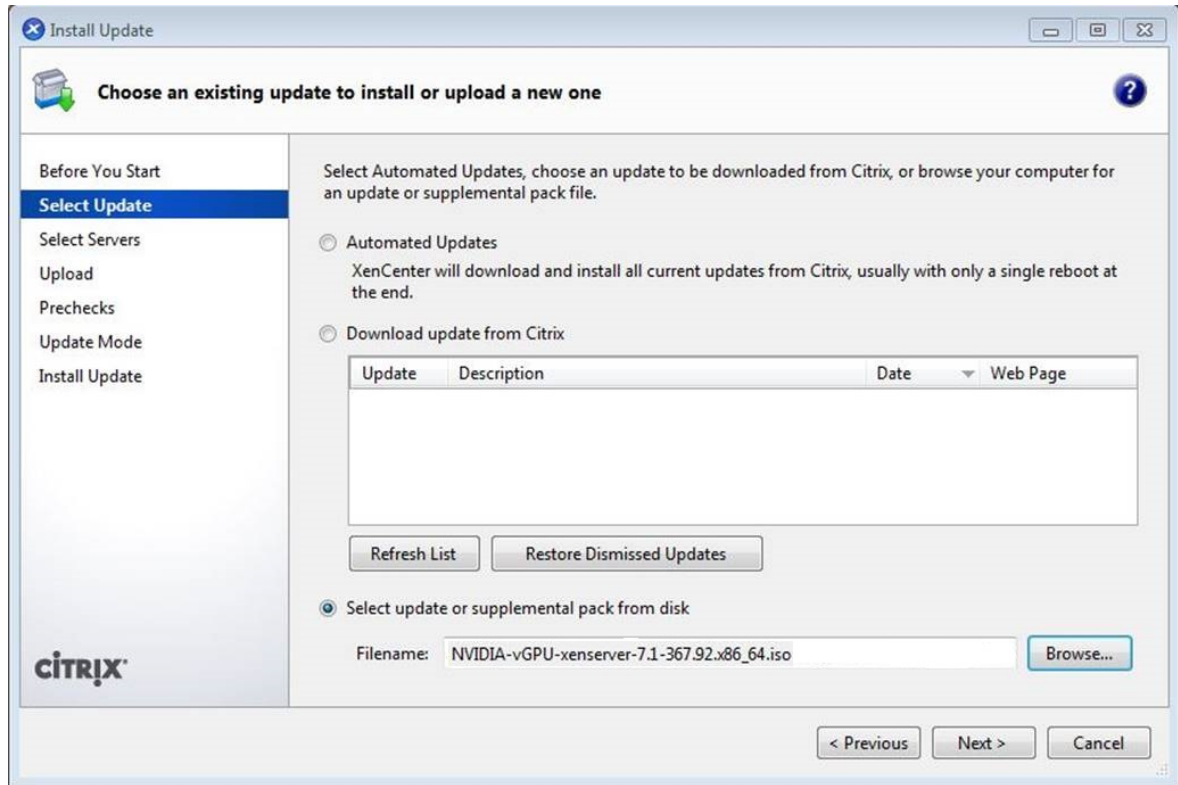
The system is going down for reboot NOW!
[root@xenserver ~]#
```

## 2.4.1.3. 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.

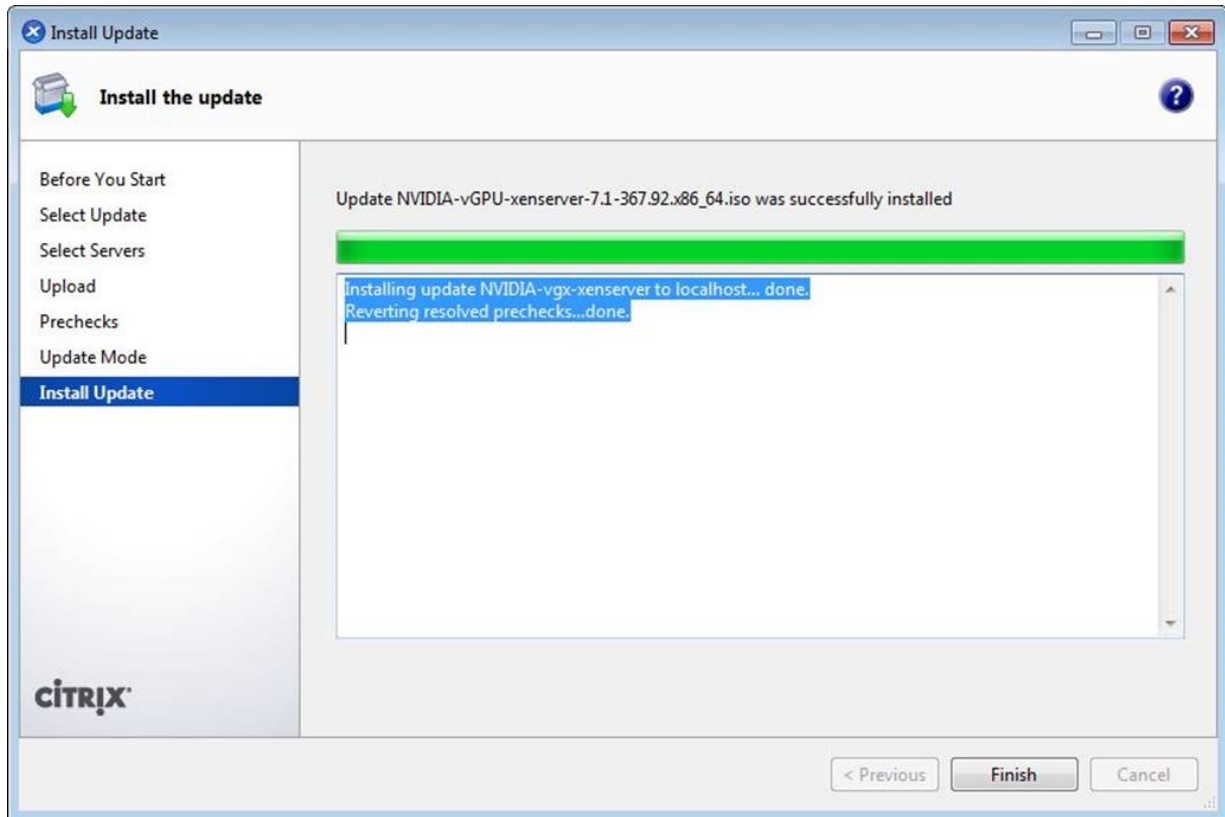
1. Select **Install Update** from the **Tools** menu.
2. Click **Next** after going through the instructions on the **Before You Start** section.
3. Click **Select update or supplemental pack from disk** on the **Select Update** section and open NVIDIA's Citrix Hypervisor Supplemental Pack ISO.

Figure 7. 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 8. Successful installation of NVIDIA vGPU Manager supplemental pack



#### 2.4.1.4. 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 Jul 14 18:46:50 2023
+-----+
| NVIDIA-SMI 450.248.03   Driver Version: 450.248.03   |
+-----+-----+
```



```

| 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      PID  Type  Process name      GPU Memory |
|-----|-----|-----|-----|-----|
| 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.

## 2.4.2. 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](#).

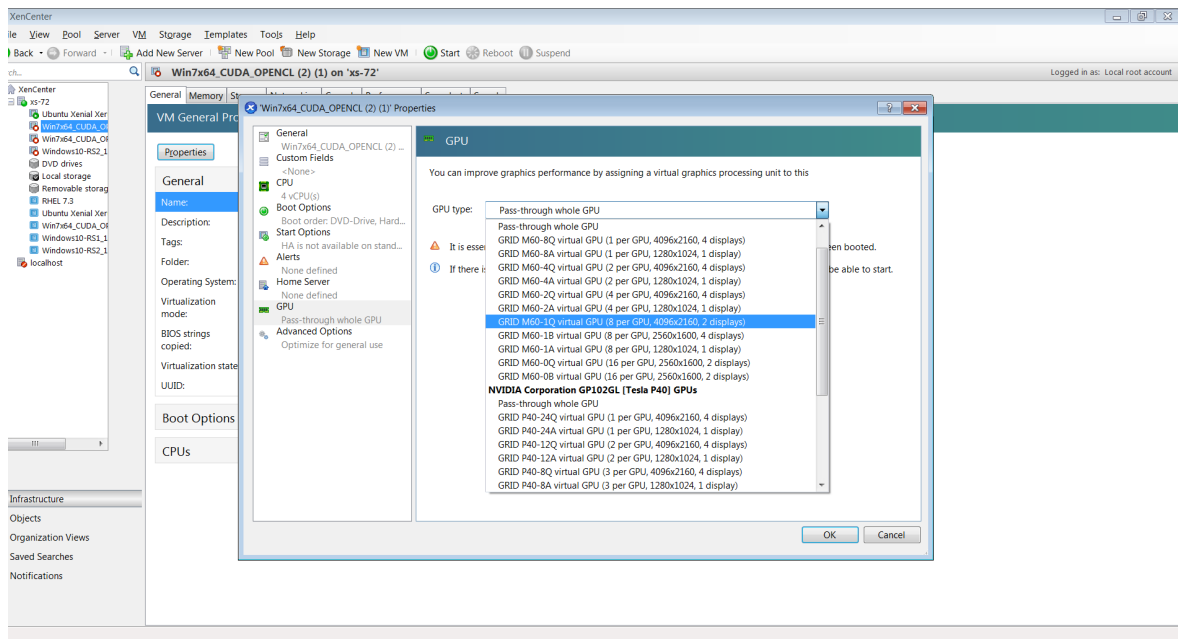


**Note:** If you are using Citrix Hypervisor 8.1 or later and need to assign plugin configuration parameters, create vGPUs using the `xe` command as explained in [Creating a vGPU Using xe](#).

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 9. 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](#).

## 2.5. Installing the Virtual GPU Manager Package for Linux KVM

NVIDIA vGPU software for Linux Kernel-based Virtual Machine (KVM) (Linux KVM) is intended **only** for use with supported versions of Linux KVM hypervisors. For details about which Linux KVM hypervisor versions are supported, see [Virtual GPU Software for Generic Linux with KVM Release Notes](#).

**Note:** If you are using Red Hat Enterprise Linux KVM, follow the instructions in [Installing and Configuring the NVIDIA Virtual GPU Manager for Red Hat Enterprise Linux KVM or RHV](#).

Before installing the Virtual GPU Manager package for Linux KVM, ensure that the following prerequisites are met:

- ▶ The following packages are installed on the Linux KVM server:

- ▶ The `x86_64` build of the GNU Compiler Collection (GCC)
- ▶ Linux kernel headers
- ▶ The package file is copied to a directory in the file system of the Linux KVM server.

If the Nouveau driver for NVIDIA graphics cards is present, disable it before installing the package.

1. Change to the directory on the Linux KVM server that contains the package file.

```
# cd package-file-directory
```

***package-file-directory***

The path to the directory that contains the package file.

2. Make the package file executable.

```
# chmod +x package-file-name
```

***package-file-name***

The name of the file that contains the Virtual GPU Manager package for Linux KVM, for example `NVIDIA-Linux-x86_64-390.42-vgpu-kvm.run`.

3. Run the package file as the root user.

```
# sudo sh ./package-file-name
```

The package file should launch and display the license agreement.

4. Accept the license agreement to continue with the installation.
5. When installation has completed, select **OK** to exit the installer.
6. Reboot the Linux KVM server.

```
# systemctl reboot
```

## 2.6. 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.



**CAUTION:** Output from the VM console is not available for VMs that are running vGPU. Make sure that you have installed an alternate means of accessing the VM (such as a VNC server) before you configure vGPU.

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

1. [Installing the NVIDIA Virtual GPU Manager for Red Hat Enterprise Linux KVM or RHV](#)

2. **MIG-backed vGPUs only:** [Since 11.1: Configuring a GPU for MIG-Backed vGPUs](#)
3. [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. **MIG-backed vGPUs only:** [Since 11.1: Configuring a GPU for MIG-Backed vGPUs](#)
3. [Getting the BDF and Domain of a GPU on Red Hat Enterprise Linux KVM](#)
4. [Creating an NVIDIA vGPU on Red Hat Enterprise Linux KVM](#)
5. [Adding One or More vGPUs to a Red Hat Enterprise Linux KVM VM](#)
6. [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.



**Note:** If you are using a generic Linux KVM hypervisor, follow the instructions in [Installing the Virtual GPU Manager Package for Linux KVM](#).

## 2.6.1. 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 compatible. If you update vGPU Manager to a release that is incompatible with the guest VM drivers, guest VMs will boot with vGPU disabled until their guest vGPU driver is updated to a compatible version. Consult [Virtual GPU Software for Red Hat Enterprise Linux with KVM Release Notes](#) for further details.

### 2.6.1.1. 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-8.4-450.248.03.x86_64.rpm
Preparing packages for installation...
NVIDIA-vGPU-rhel-8.4-450.248.03
#
```

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

```
# systemctl reboot
```

## 2.6.1.2. 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 Jul 14 18:46:50 2023
+-----+
| NVIDIA-SMI 450.248.03   Driver Version: 450.248.03   |
+-----+
| 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  |           0%      Off |
| N/A   23C    P8             23W / 150W | 13MiB / 8191MiB |           0%      Default |
+-----+-----+
|   1   Tesla M60             On          | 0000:86:00.0  Off  |           0%      Off |
| N/A   29C    P8             23W / 150W | 13MiB / 8191MiB |           0%      Default |
+-----+-----+
|   2   Tesla P40             On          | 0000:87:00.0  Off  |           0%      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.

## 2.6.2. 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.

```
# vdsm-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**.

The screenshot shows the 'Edit Virtual Machine' dialog box with the following configuration:

- Cluster:** Default
- Data Center:** Default
- Template:** Blank | (0)
- Operating System:** Windows 10 x64
- Instance Type:** Custom
- Optimized for:** Desktop
- Custom Properties:** mdev\_type (dropdown), nvidia-38 (text field), + - (buttons)

At the bottom of the dialog, there is a 'Hide Advanced Options' button on the left and 'OK' and 'Cancel' buttons on the right.

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](#).

## 2.6.3. 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 that 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
al)
07:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M10] (rev
al)
```

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' />
```

## 2.6.4. 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.



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](#).

How to create an NVIDIA vGPU on Red Hat Enterprise Linux KVM depends on whether the NVIDIA vGPU supports single root I/O virtualization (SR-IOV). For details, refer to:

- ▶ [Creating a Legacy NVIDIA vGPU on Red Hat Enterprise Linux KVM](#)
- ▶ [Creating an NVIDIA vGPU that Supports SR-IOV on Red Hat Enterprise Linux KVM](#)

### 2.6.4.1. Creating a Legacy NVIDIA vGPU on Red Hat Enterprise Linux KVM

A legacy NVIDIA vGPU does not support SR-IOV.

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. Make the `mdev` device file that you created to represent the vGPU persistent.

```
# mdevctl define --auto --uuid uuid
```

#### **uuid**

The UUID that you specified in the previous step for the vGPU that you are creating.



**Note:** Not all Red Hat Enterprise Linux KVM releases include the `mdevctl` command. If your release does not include the `mdevctl` command, 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, you can write a custom script that is executed when the host is rebooted.

7. Confirm that the vGPU was created.

- a). Confirm that the `/sys/bus/mdev/devices/` directory contains the `mdev` device file for the vGPU.

```
# 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
```

- b). If your release includes the `mdevctl` command, list the active mediated devices on the hypervisor host.

```
# mdevctl list
aa618089-8b16-4d01-a136-25a0f3c73123 0000:06:00.0 nvidia-41
```

## 2.6.4.2. Creating an NVIDIA vGPU that Supports SR-IOV on Red Hat Enterprise Linux KVM

An NVIDIA vGPU that supports SR-IOV resides on a physical GPU that supports SR-IOV, such as a GPU based on the NVIDIA Ampere architecture.

1. Enable the virtual functions for the physical GPU in the `sysfs` file system.



### Note:

- ▶ Before performing this step, ensure that the GPU is not being used by any other processes, such as CUDA applications, monitoring applications, or the `nvidia-smi` command.
- ▶ The virtual functions for the physical GPU in the `sysfs` file system are disabled after the hypervisor host is rebooted or if the driver is reloaded or upgraded.

Use **only** the custom script `sriov-manage` provided by NVIDIA vGPU software for this purpose. Do **not** try to enable the virtual function for the GPU by any other means.

```
# /usr/lib/nvidia/sriov-manage -e domain:bus:slot.function
```

**domain**

**bus**

**slot**

**function**

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



**Note:** Only one `mdev` device file can be created on a virtual function.

This example enables the virtual functions for the GPU with the domain `00`, bus `41`, slot `0000`, and function `0`.

```
# /usr/lib/nvidia/sriov-manage -e 00:41:0000.0
```

2. Obtain the domain, bus, slot, and function of the available virtual functions on the GPU.

```
# ls -l /sys/bus/pci/devices/domain\:bus\:slot.function/ | grep virtfn
```

**domain**

**bus**

**slot**

**function**

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

This example shows the output of this command for a physical GPU with slot `00`, bus `41`, domain `0000`, and function `0`.

```
# ls -l /sys/bus/pci/devices/0000:41:00.0/ | grep virtfn
lrwxrwxrwx. 1 root root      0 Jul 16 04:42 virtfn0 -> ../0000:41:00.4
lrwxrwxrwx. 1 root root      0 Jul 16 04:42 virtfn1 -> ../0000:41:00.5
lrwxrwxrwx. 1 root root      0 Jul 16 04:42 virtfn10 -> ../0000:41:01.6
lrwxrwxrwx. 1 root root      0 Jul 16 04:42 virtfn11 -> ../0000:41:01.7
lrwxrwxrwx. 1 root root      0 Jul 16 04:42 virtfn12 -> ../0000:41:02.0
lrwxrwxrwx. 1 root root      0 Jul 16 04:42 virtfn13 -> ../0000:41:02.1
lrwxrwxrwx. 1 root root      0 Jul 16 04:42 virtfn14 -> ../0000:41:02.2
lrwxrwxrwx. 1 root root      0 Jul 16 04:42 virtfn15 -> ../0000:41:02.3
lrwxrwxrwx. 1 root root      0 Jul 16 04:42 virtfn16 -> ../0000:41:02.4
```

```

lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn17 -> ../0000:41:02.5
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn18 -> ../0000:41:02.6
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn19 -> ../0000:41:02.7
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn2  -> ../0000:41:00.6
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn20 -> ../0000:41:03.0
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn21 -> ../0000:41:03.1
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn22 -> ../0000:41:03.2
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn23 -> ../0000:41:03.3
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn24 -> ../0000:41:03.4
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn25 -> ../0000:41:03.5
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn26 -> ../0000:41:03.6
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn27 -> ../0000:41:03.7
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn28 -> ../0000:41:04.0
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn29 -> ../0000:41:04.1
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn3  -> ../0000:41:00.7
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn30 -> ../0000:41:04.2
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn31 -> ../0000:41:04.3
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn4  -> ../0000:41:01.0
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn5  -> ../0000:41:01.1
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn6  -> ../0000:41:01.2
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn7  -> ../0000:41:01.3
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn8  -> ../0000:41:01.4
lrwxrwxrwx. 1 root root          0 Jul 16 04:42 virtfn9  -> ../0000:41:01.5

```

- Choose the available virtual function on which you want to create the vGPU and note its domain, bus, slot, and function.
- Change to the `mdev_supported_types` directory for the virtual function on which you want to create the vGPU.

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

**domain**  
**bus**

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

**vf-slot**  
**v-function**

The slot and function of the virtual function.

This example changes to the `mdev_supported_types` directory for the first virtual function (`virtfn0`) for the GPU with the domain 0000 and bus 41. The first virtual function (`virtfn0`) has slot 00 and function 4.

```
# cd /sys/class/mdev_bus/0000\:41\:00.4/mdev_supported_types
```

- 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, A40-2Q.

This example shows that the registration information for the A40-2Q vGPU type is contained in the `nvidia-558` subdirectory of `mdev_supported_types`.

```
# grep -l "A40-2Q" nvidia-*/name
```

`nvidia-558/name`

- Confirm that you can create an instance of the vGPU type on the virtual function.

```
# cat subdirectory/available_instances
```

**subdirectory**

The subdirectory that you found in the previous step, for example, `nvidia-558`.

The number of available instances must be 1. If the number is 0, a vGPU has already been created on the virtual function. Only one instance of any vGPU type can be created on a virtual function.

This example shows that an instance of the A40-2Q vGPU type can be created on the virtual function.

```
# cat nvidia-558/available_instances
1
```

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

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

8. 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-558`.

This example creates an instance of the A40-2Q vGPU type with the UUID

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

```
# echo "aa618089-8b16-4d01-a136-25a0f3c73123" > nvidia-558/create
```

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

9. **Time-sliced vGPUs only:** Make the `mdev` device file that you created to represent the vGPU persistent.

```
# mdevctl define --auto --uuid uuid
uuid
```

The UUID that you specified in the previous step for the vGPU that you are creating.



#### **Note:**

- ▶ If you are using a GPU that supports SR-IOV, the `mdev` device file persists after a host reboot only if you perform Step 1 before rebooting any VM that is configured with a vGPU on the GPU.
- ▶ You **cannot** use the `mdevctl` command to make the `mdev` device file for a MIG-backed vGPU persistent. The `mdev` device file for a MIG-backed vGPU is not retained after the host is rebooted because MIG instances are no longer available.
- ▶ Not all Red Hat Enterprise Linux KVM releases include the `mdevctl` command. If your release does not include the `mdevctl` command, 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, you can write a custom script that is executed when the host is rebooted.

10. Confirm that the vGPU was created.

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

```
# ls -l /sys/bus/mdev/devices/
total 0
lrwxrwxrwx. 1 root root 0 Jul 16 05:57 aa618089-8b16-4d01-a136-25a0f3c73123
-> ../../../../devices/pci0000:40/0000:40:01.1/0000:41:00.4/aa618089-8b16-4d01-a136-25a0f3c73123
```

- b). If your release includes the `mdevctl` command, list the active mediated devices on the hypervisor host.

```
# mdevctl list
aa618089-8b16-4d01-a136-25a0f3c73123 0000:06:00.0 nvidia-558
```

## 2.6.5. 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](#).

### 2.6.5.1. 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.

- 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>
```

- Optional:** Add a `video` element that contains a `model` element in which the `type` attribute is set to `none`.

```
<video>
<model type='none' />
</video>
```

Adding this `video` element prevents the default video device that `libvirt` adds from being loaded into the VM. If you don't add this `video` element, you must configure the Xorg server or your remoting solution to load only the vGPU devices you added and not the default video device.

## 2.6.5.2. 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
```

## 2.6.6. 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
```

## 2.6.7. 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
```



**Note:** 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.

## 2.6.8. 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
al)
    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](#).

## 2.6.9. 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**

A directory named `mdev_supported_types` is required under the `sysfs` directory for each physical GPU that will be configured with NVIDIA vGPU. How this directory is created for a GPU depends on whether the GPU supports SR-IOV.

- ▶ For a GPU that does not support SR-IOV, this directory is created automatically after the Virtual GPU Manager is installed on the host and the host has been rebooted.
- ▶ For a GPU that supports SR-IOV, such as a GPU based on the NVIDIA Ampere architecture, you must create this directory by enabling the virtual function for the

GPU as explained in [Creating an NVIDIA vGPU on Red Hat Enterprise Linux KVM](#).

The `mdev_supported_types` directory itself is never visible on the physical function.

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.



**Note:** When a time-sliced vGPU is created, the content of the `available_instances` for all other time-sliced vGPU types on the physical GPU is set to 0. This behavior enforces the requirement that all time-sliced vGPUs on a physical GPU must be of the same type. However, this requirement does not apply to MIG-backed vGPUs. Therefore, when a MIG-backed vGPU is created, `available_instances` for all other MIG-backed vGPU types on the physical GPU is not set to 0

##### **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
```

## 2.7. 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.

**Note:**

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.

However, with any server hardware, do not enable SR-IOV in VMware vCenter Server for the Tesla T4 GPU. If SR-IOV is enabled in VMware vCenter Server for T4, VMware vCenter Server lists the status of the GPU as needing a reboot. You can ignore this status message.

### NVIDIA vGPU Instructions



**Note:** As of VMware vSphere 7.0 Update 1, the Xorg service is no longer required for graphics devices in NVIDIA vGPU mode. For more information, see [Installing and Updating the NVIDIA Virtual GPU Manager for vSphere](#).

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.

## VMware vSGA Instructions

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.

## Requirements for Configuring NVIDIA vGPU in a DRS Cluster

You can configure a VM with NVIDIA vGPU on an ESXi host in a VMware Distributed Resource Scheduler (DRS) cluster. However, you must ensure that the automation level of the cluster supports VMs configured with NVIDIA vGPU:

- ▶ For any supported VMware vSphere release, set the automation level to **Manual**.
- ▶ For VMware vSphere 6.7 Update 1 or later, set the automation level to **Partially Automated** or **Manual**.

For more information about these settings, see [Edit Cluster Settings](#) in the VMware documentation.

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

The NVIDIA Virtual GPU Manager runs on the ESXi host. How the NVIDIA Virtual GPU Manager package is distributed depends on the release of VMware vSphere.

- ▶ For all supported VMware vSphere releases, the NVIDIA Virtual GPU Manager package is distributed as a software component in a ZIP archive, which you can install in one of the following ways:
  - ▶ By copying the software component to the ESXi host and then installing it as explained in [Installing the NVIDIA Virtual GPU Manager Package for vSphere](#)
  - ▶ By importing the software component manually as explained in [Import Patches Manually](#) in the VMware vSphere documentation
- ▶ For supported releases **before** VMware vSphere 7.0, the NVIDIA Virtual GPU Manager package is also distributed as a vSphere Installation Bundle (VIB) file, which you must copy to the ESXi host and then install as explained in [Installing the NVIDIA Virtual GPU Manager Package for vSphere](#).



**CAUTION:** NVIDIA Virtual GPU Manager and guest VM drivers must be compatible. If you update vGPU Manager to a release that is incompatible with the guest VM drivers,

guest VMs will boot with vGPU disabled until their guest vGPU driver is updated to a compatible version. Consult [Virtual GPU Software for VMware vSphere Release Notes](#) for further details.

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

To install the vGPU Manager package 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 you begin, ensure that the following prerequisites are met:

- ▶ The ZIP archive that contains NVIDIA vGPU software has been downloaded from the NVIDIA Licensing Portal.
- ▶ The NVIDIA Virtual GPU Manager package has been extracted from the downloaded ZIP archive.

1. Copy the NVIDIA Virtual GPU Manager package file to the ESXi host.
2. Put the ESXi host into maintenance mode.

```
$ esxcli system maintenanceMode set --enable true
```

3. Use the `esxcli` command to install the vGPU Manager package.

For more information about the `esxcli` command, see [esxcli software Commands](#) in the VMware vSphere documentation.

- ▶ For a software component, run the following command:

```
[root@esxi:~] esxcli software vib install -d /vmfs/volumes/datastore/software-  
component.zip
```

#### **datastore**

The name of the VMFS datastore to which you copied the software component.

#### **software-component**

The name of the file that contains the NVIDIA Virtual GPU Manager package in the form of a software component. Ensure that you specify the file that was extracted from the downloaded ZIP archive. For example, for

VMware vSphere 7.0, *software-component* is **NVD.NVIDIA\_bootbank\_NVIDIA-VMware\_450.248.03-1OEM.700.0.0.8169922-offline\_bundle-build-number**.

- ▶ For a VIB file, run the following command:

```
[root@esxi:~] esxcli software vib install -v directory/NVIDIA-vGPU-  
VMware_ESXi_7.0_Host_Driver_450.248.03-1OEM.700.0.0.8169922.vib
```

Installation Result

Message: Operation finished successfully.

Reboot Required: false

VIBs Installed: NVIDIA-vGPU-

VMware\_ESXi\_7.0\_Host\_Driver\_450.248.03-1OEM.700.0.0.8169922

VIBs Removed:

VIBs Skipped:

#### **directory**

The absolute path to the directory to which you copied the VIB file. You must specify the absolute path even if the VIB file is in the current working directory.

4. Exit maintenance mode.

```
$ esxcli system maintenanceMode set --enable false
```



5. Reboot the ESXi host.

```
$ reboot
```

### 2.7.1.2. 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.



**CAUTION:** Do not perform this task on a system where an existing version isn't already installed. If you perform this task on a system where an existing version isn't already installed, the Xorg service (when required) fails to start after the NVIDIA vGPU software driver is installed. Instead, install the vGPU Manager VIB package as explained in [Installing the NVIDIA Virtual GPU Manager Package for vSphere](#).

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.



**Note:** 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_7.0_Host_Driver_450.248.03-1OEM.700.0.0.8169922.vib
```

```
Installation Result
Message: Operation finished successfully.
Reboot Required: false
VIBs Installed: NVIDIA-vGPU-
VMware_ESXi_7.0_Host_Driver_450.248.03-1OEM.700.0.0.8169922
VIBs Removed: NVIDIA-vGPU-
VMware_ESXi_6.7_Host_Driver_450.236.03-1OEM.670.0.0.8169922
VIBs Skipped:
```

`directory` is the path to the directory that contains the VIB file.

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

### 2.7.1.3. Verifying the Installation of the NVIDIA vGPU Software Package for vSphere

After the ESXi host has rebooted, verify the installation of the NVIDIA vGPU software package for vSphere.

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

```
[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.
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.

```
[root@esxi:~] nvidia-smi
Fri Jul 14 17:56:22 2023
+-----+
| NVIDIA-SMI 450.248.03   Driver Version: 450.248.03   |
+-----+
| 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  |      13MiB / 8191MiB |      0%      Default |
| N/A   25C    P8            24W / 150W |      13MiB / 8191MiB |      0%      Default |
+-----+-----+
|   1   Tesla M60           On          | 00000000:06:00.0 Off  |      13MiB / 8191MiB |      0%      Default |
| N/A   24C    P8            24W / 150W |      13MiB / 8191MiB |      0%      Default |
+-----+-----+
|   2   Tesla M60           On          | 00000000:86:00.0 Off  |      13MiB / 8191MiB |      0%      Default |
| N/A   25C    P8            25W / 150W |      13MiB / 8191MiB |      0%      Default |
+-----+-----+
|   3   Tesla M60           On          | 00000000:87:00.0 Off  |      13MiB / 8191MiB |      0%      Default |
| N/A   28C    P8            24W / 150W |      13MiB / 8191MiB |      0%      Default |
+-----+-----+
+-----+
| Processes:
| GPU      PID     Type    Process name                      GPU Memory
|-----|-----|-----|-----|-----|
| No running processes found
+-----+
+-----+
```

If `nvidia-smi` fails to report the expected output for all the NVIDIA GPUs in your system, see [Troubleshooting](#) for troubleshooting steps.

## 2.7.2. 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.

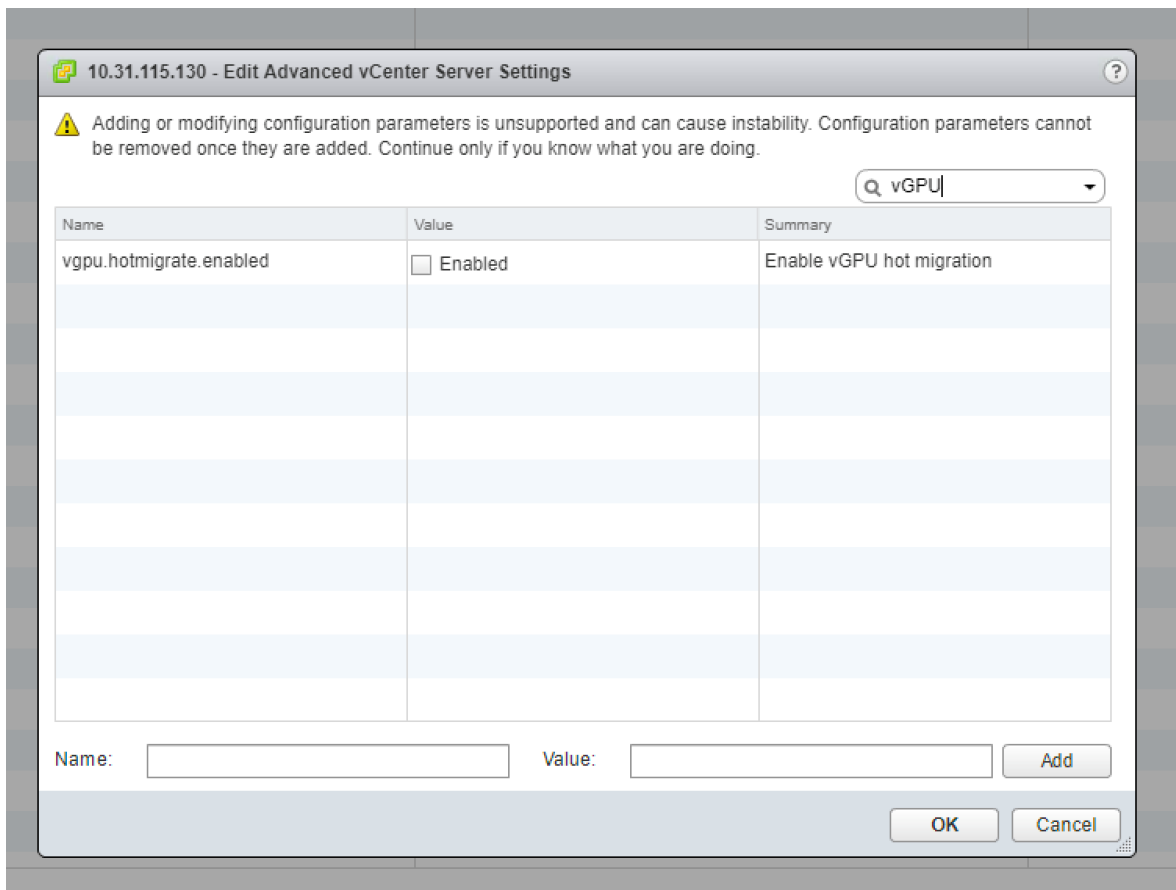
1. Log in to **vCenter Server** by using the **vSphere Web Client**.

- In the **Hosts and Clusters** view, select the **vCenter Server** instance.



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

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



### 2.7.3. 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.
```

**Note:**

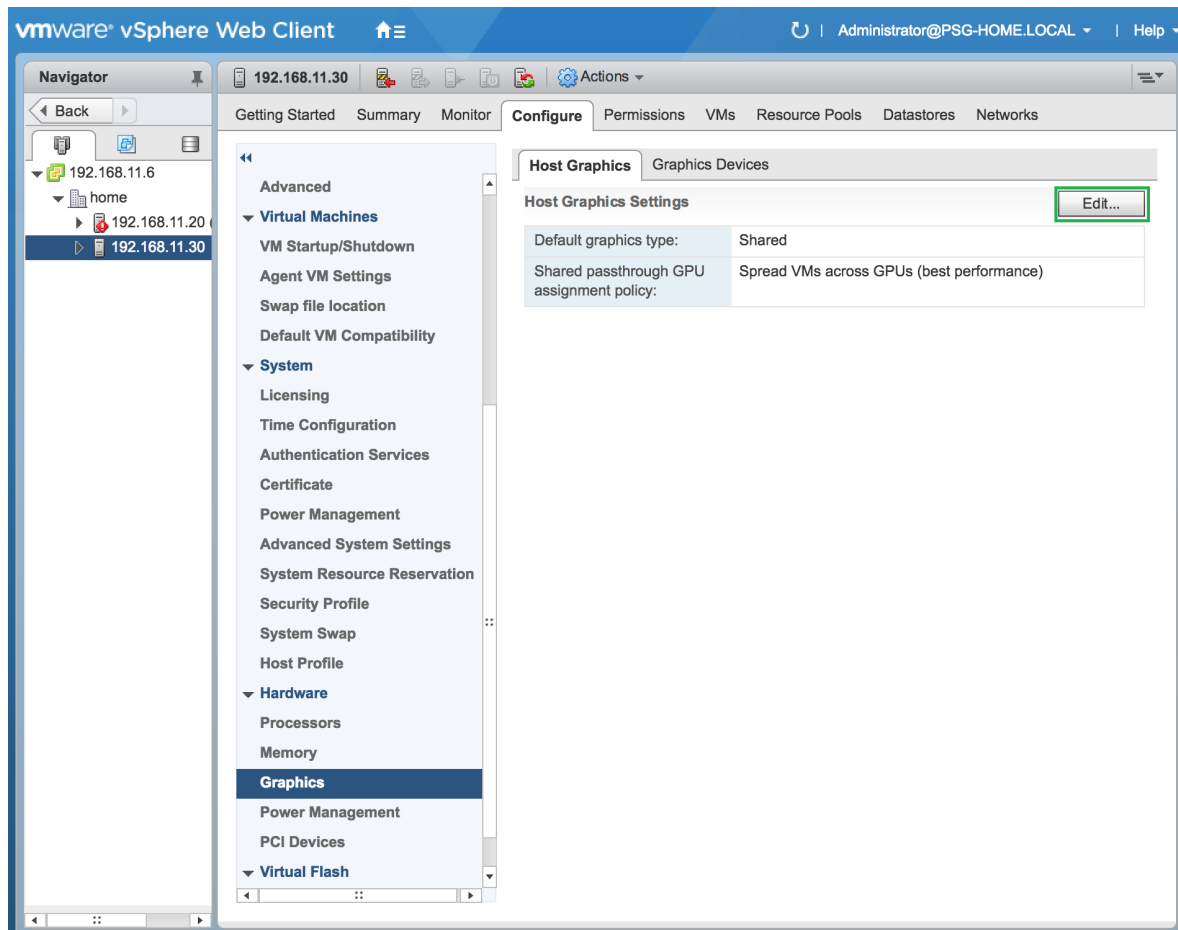
If you are using a supported version of VMware vSphere earlier than 6.5, or are configuring a VM to use vSGA, omit this task.

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.

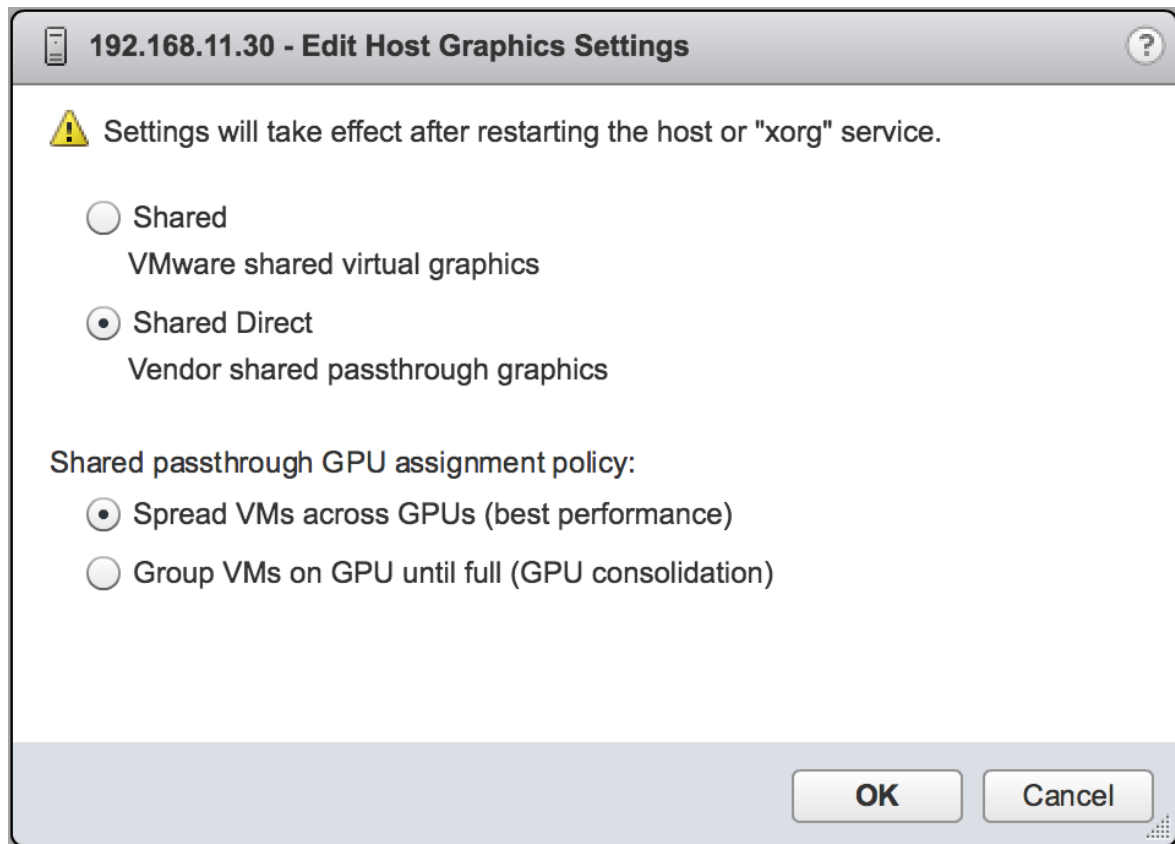
1. Log in to vCenter Server by using the vSphere Web Client.
2. In the navigation tree, select your ESXi host and click the **Configure** tab.
3. From the menu, choose **Graphics** and then click the **Host Graphics** tab.
4. On the **Host Graphics** tab, click **Edit**.

Figure 10. Shared default graphics type



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

Figure 11. Host graphics settings for vGPU



**Note:** In this dialog box, you can also change the allocation scheme for vGPU-enabled VMs. For more information, see [Modifying GPU Allocation Policy on VMware vSphere](#).

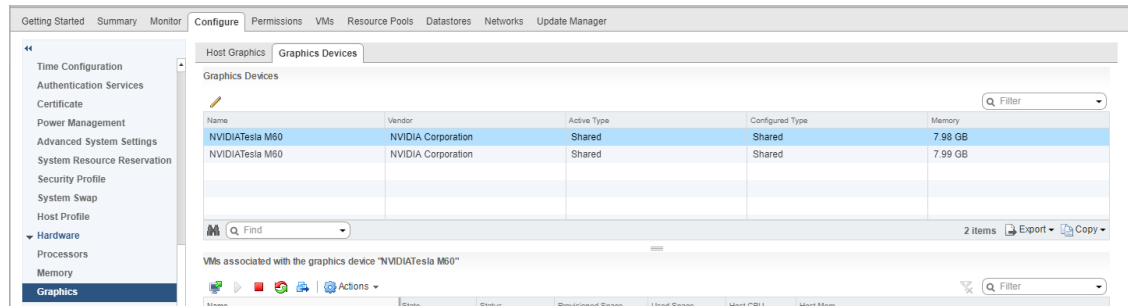
After you click OK, the default graphics type changes to Shared Direct.

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:

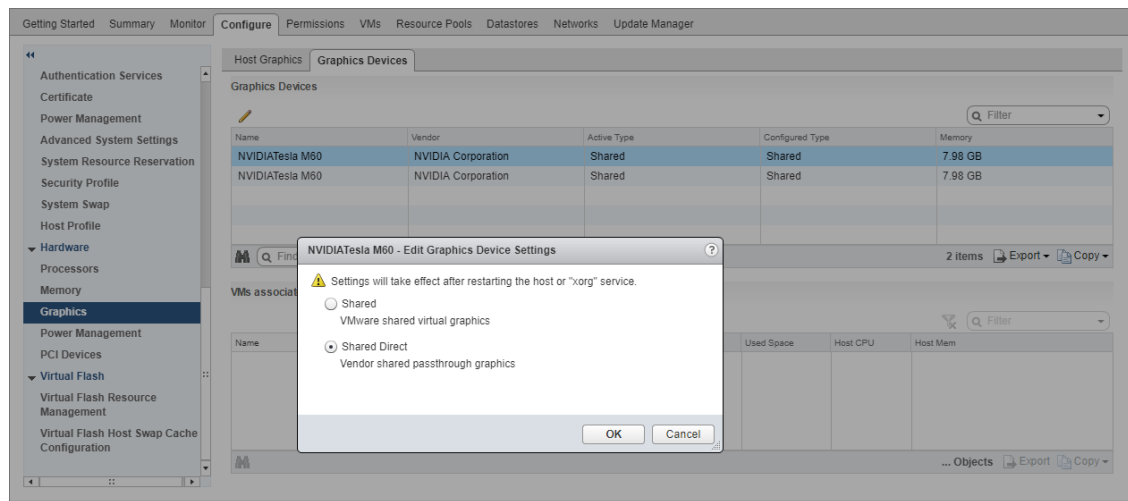
- a). On the **Graphics Devices** tab, select the physical GPU and click the **Edit icon**.

Figure 12. Shared graphics type



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

Figure 13. Graphics device settings for a physical GPU



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

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

- a). **VMware vSphere releases before 7.0 Update 1 only:** Stop the Xorg service.

As of VMware vSphere 7.0 Update 1, the Xorg service is no longer required for graphics devices in NVIDIA vGPU mode.

- b). Stop `nv-hostengine`.

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

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

- d). Start `nv-hostengine`.

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

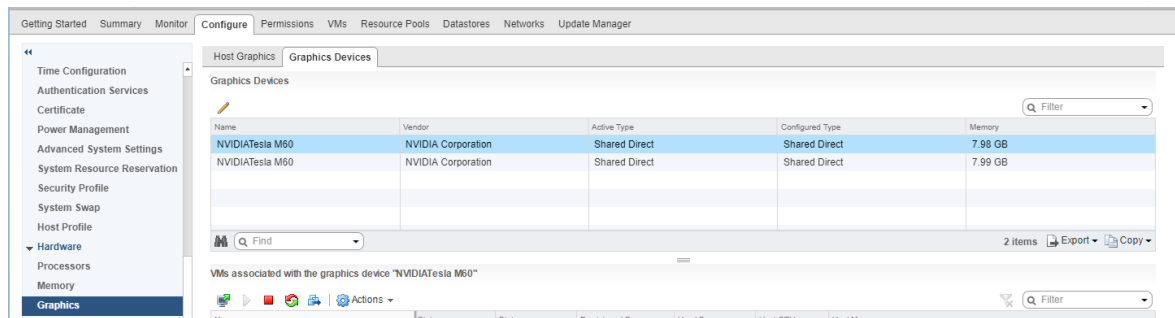
- e). **VMware vSphere releases before 7.0 Update 1 only:** Start the Xorg service.

As of VMware vSphere 7.0 Update 1, the Xorg service is no longer required for graphics devices in NVIDIA vGPU mode.

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

8. 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 14. 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](#)

## 2.7.4. 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.

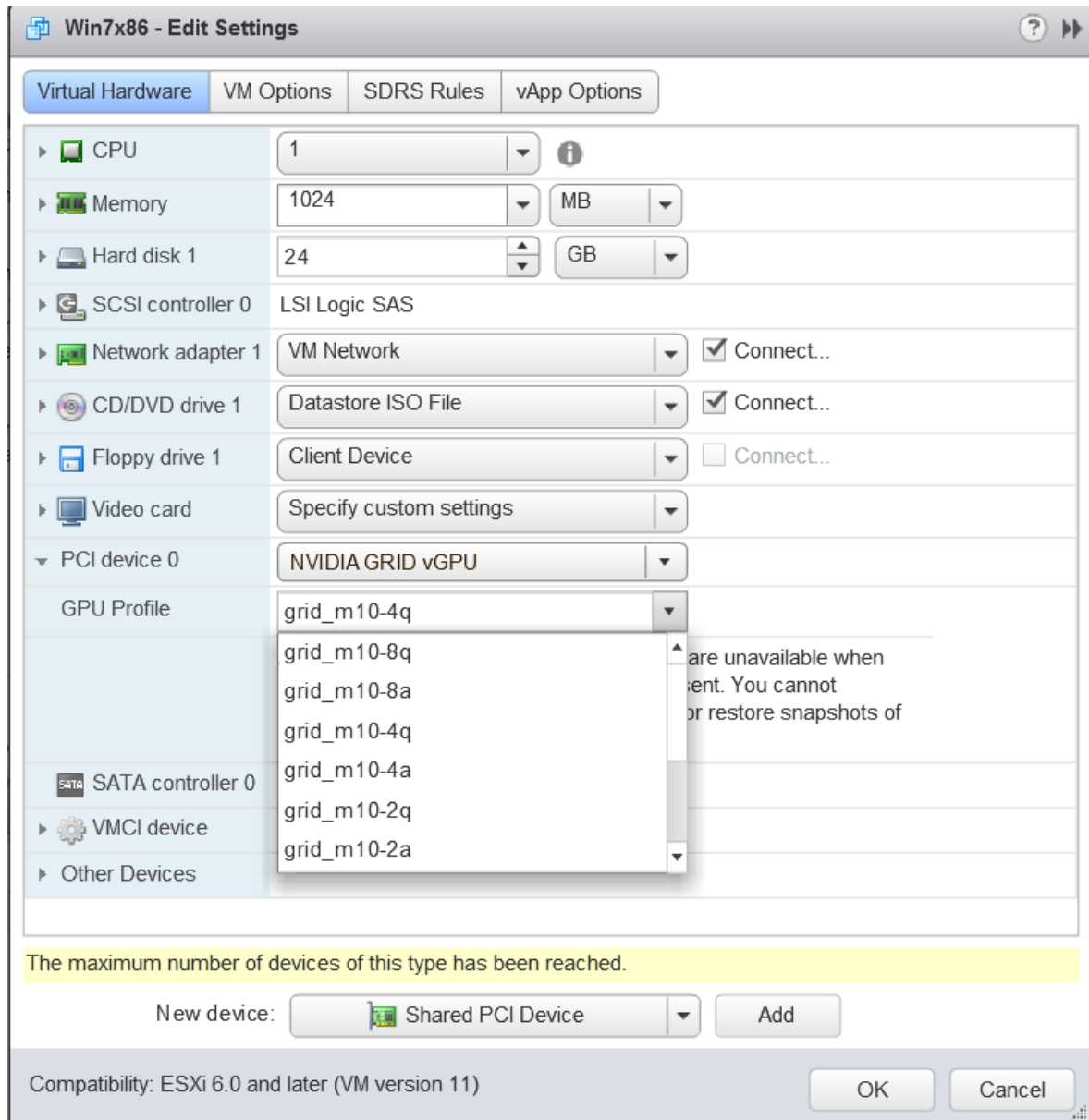
VM console in vSphere Web Client will become active again once the vGPU parameters are removed from the VM's configuration.



**Note:** 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 15. 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](#).

## 2.7.5. 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.



**Note:** 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.

```
# gpuvm
```

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.

## 2.8. Since 11.1: Configuring a GPU for MIG-Backed vGPUs

To support GPU instances with NVIDIA vGPU, a GPU must be configured with MIG mode enabled and GPU instances must be created and configured on the physical GPU. Optionally, you can create compute instances within the GPU instances. If you don't create compute instances within the GPU instances, they can be added later for individual vGPUs from within the guest VMs.

Ensure that the following prerequisites are met:

- ▶ The NVIDIA Virtual GPU Manager is installed on the hypervisor host.
- ▶ You have root user privileges on your hypervisor host machine.
- ▶ You have determined which GPU instances correspond to the vGPU types of the MIG-backed vGPUs that you will create.

To get this information, consult the table of MIG-backed vGPUs for your GPU in [Virtual GPU Types for Supported GPUs](#).

- ▶ The GPU is not being used by any other processes, such as CUDA applications, monitoring applications, or the `nvidia-smi` command.

Perform this task in your hypervisor command shell.

1. Open a command shell as the root user on your hypervisor host machine.  
You can use secure shell (SSH) for this purpose.
2. Determine whether MIG mode is enabled.  
Use the `nvidia-smi` command for this purpose. By default, MIG mode is disabled.  
This example shows that MIG mode is disabled on GPU 0.



**Note:** In the output from output from `nvidia-smi`, the NVIDIA A100 HGX 40GB GPU is referred to as A100-SXM4-40GB.

```
$ nvidia-smi -i 0
+-----+
| NVIDIA-SMI 450.248.03   Driver Version: 450.248.03   CUDA Version:  11.0   |
+-----+-----+
| GPU   Name               Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf    Pwr:Usage/Cap|      Memory-Usage | GPU-Util  Compute M. |
|                                           MIG M.         |
+-----+-----+-----+
|    0  A100-SXM4-40GB      On          | 00000000:36:00:0 Off  |            6%      0 | |
| N/A   29C    P0         62W / 400W |  0MiB / 40537MiB |           | Default |
|                                           |                 |           | Disabled |
+-----+-----+-----+
```

3. If MIG mode is disabled, enable it.

```
$ nvidia-smi -i [gpu-ids] -mig 1
```

**gpu-ids**

A comma-separated list of GPU indexes, PCI bus IDs or UUIDs that specifies the GPUs on which you want to enable MIG mode. If *gpu-ids* is omitted, MIG mode is enabled on all GPUs on the system.

This example enables MIG mode on GPU 0.

```
$ nvidia-smi -i 0 -mig 1
Enabled MIG Mode for GPU 00000000:36:00.0
All done.
```



**Note:** If the GPU is being used by another process, this command fails and displays a warning message that MIG mode for the GPU is in the pending enable state. In this situation, stop all processes that are using the GPU and retry the command.

4. Query the GPUs on which you enabled MIG mode to confirm that MIG mode is enabled.

This example queries GPU 0 for the PCI bus ID and MIG mode in comma-separated values (CSV) format.

```
$ nvidia-smi -i 0 --query-gpu=pci.bus_id,mig.mode.current --format=csv
pci.bus_id, mig.mode.current
00000000:36:00.0, Enabled
```

5. List the GPU instance profiles that are available on your GPU.

You will need to specify the profiles by their IDs, not their names, when you create them.

```
$ nvidia-smi mig -lgip
+-----+
| GPU instance profiles:                |
| GPU   Name           ID   Instances  Memory   P2P   SM   DEC   ENC   |
|      Name           ID   Free/Total  GiB     No    CE   JPEG  OFA   |
+-----+-----+-----+-----+-----+-----+-----+-----+
|  0  MIG 1g.5gb       19   7/7        4.95    No    14   0    0    |
|                                     1    0    0    |
+-----+-----+-----+-----+-----+-----+
|  0  MIG 2g.10gb      14   3/3        9.90    No    28   1    0    |
|                                     2    0    0    |
+-----+-----+-----+-----+-----+-----+
|  0  MIG 3g.20gb       9   2/2       19.79    No    42   2    0    |
|                                     3    0    0    |
+-----+-----+-----+-----+-----+-----+
|  0  MIG 4g.20gb       5   1/1       19.79    No    56   2    0    |
|                                     4    0    0    |
+-----+-----+-----+-----+-----+-----+
|  0  MIG 7g.40gb       0   1/1       39.59    No    98   5    0    |
|                                     7    1    1    |
+-----+-----+-----+-----+-----+-----+
+-----+

```

6. Create the GPU instances that correspond to the vGPU types of the MIG-backed vGPUs that you will create.

```
$ nvidia-smi mig -cgi gpu-instance-profile-ids
```

**gpu-instance-profile-ids**

A comma-separated list of GPU instance profile IDs that specifies the GPU instances that you want to create.

This example creates two GPU instances of type 2g.10gb, which has profile ID 14.

```
$ nvidia-smi mig -cgi 14,14
Successfully created GPU instance ID 5 on GPU 2 using profile MIG 2g.10gb (ID 14)
```

Successfully created GPU instance ID 3 on GPU 2 using profile MIG 2g.10gb (ID 14)

7. **Optional:** List the available GPU instances.

```
$ nvidia-smi mig -lgi
```

GPU instances:				
GPU	Name	Profile ID	Instance ID	Placement Start:Size
2	MIG 2g.10gb	14	3	0:2
2	MIG 2g.10gb	14	5	4:2

8. **Optional:** Create the compute instances that you need within each GPU instance.

```
$ nvidia-smi mig -cci -gi gpu-instance-ids
```

#### **gpu-instance-ids**

A comma-separated list of GPU instance IDs that specifies the GPU instances within which you want to create the compute instances.



**CAUTION:** To avoid an inconsistent state between a guest VM and the hypervisor host, do **not** create compute instances from the hypervisor on a GPU instance on which an active guest VM is running. Instead, create the compute instances from within the guest VM as explained in [Since 11.1: Modifying a MIG-Backed vGPU's Configuration](#).

This example creates a compute instance on each of GPU instances 3 and 5.

```
$ nvidia-smi mig -cci -gi 3,5
Successfully created compute instance on GPU 0 GPU instance ID 1 using profile ID 2
Successfully created compute instance on GPU 0 GPU instance ID 2 using profile ID 2
```

9. **Optional:** Verify that the compute instances were created within each GPU instance.

```
$ nvidia-smi
```

MIG devices:												
GPU	GI ID	CI ID	MIG Dev	Memory-Usage BAR1-Usage	SM	Vol Unc ECC	CE	ENC	DEC	OFA	JPG	Shared
2	3	0	0	0MiB / 9984MiB 0MiB / 16383MiB	28	0	2	0	1	0	0	
2	5	0	1	0MiB / 9984MiB 0MiB / 16383MiB	28	0	2	0	1	0	0	

Processes:							GPU Memory Usage
GPU	GI ID	CI ID	PID	Type	Process name		

Create the vGPUs that you need and add them to their VMs.

## 2.9. Since 11.1: Disabling MIG Mode for One or More GPUs

If a GPU that you want to use for time-sliced vGPUs or GPU pass through has previously been configured for MIG-backed vGPUs, disable MIG mode on the GPU.

Ensure that the following prerequisites are met:

- ▶ The NVIDIA Virtual GPU Manager is installed on the hypervisor host.
- ▶ You have root user privileges on your hypervisor host machine.
- ▶ The GPU is not being used by any other processes, such as CUDA applications, monitoring applications, or the `nvidia-smi` command.

Perform this task in your hypervisor command shell.

1. Open a command shell as the root user on your hypervisor host machine.  
You can use secure shell (SSH) for this purpose.
2. Determine whether MIG mode is disabled.

Use the `nvidia-smi` command for this purpose. By default, MIG mode is disabled, but might have previously been enabled.

This example shows that MIG mode is enabled on GPU 0.

**Note:** In the output from output from `nvidia-smi`, the NVIDIA A100 HGX 40GB GPU is referred to as A100-SXM4-40GB.

```
$ nvidia-smi -i 0
```

NVIDIA-SMI 450.248.03 Driver Version: 450.248.03 CUDA Version: 11.0									
GPU	Name	Persistence-M	Bus-Id	Disp.A	Volatile	Uncorr.	ECC		
Fan	Temp	Perf	Pwr:Usage/Cap	Memory-Usage	GPU-Util	Compute M.	MIG M.		
0	A100-SXM4-40GB	Off	00000000:36:00.0	Off				0	
N/A	29C	P0	62W / 400W	0MiB / 40537MiB	6%	Default	<b>Enabled</b>		

3. If MIG mode is enabled, disable it.

```
$ nvidia-smi -i [gpu-ids] -mig 0
```

### **gpu-ids**

A comma-separated list of GPU indexes, PCI bus IDs or UUIDs that specifies the GPUs on which you want to disable MIG mode. If `gpu-ids` is omitted, MIG mode is disabled on all GPUs on the system.

This example disables MIG mode on GPU 0.

```
$ sudo nvidia-smi -i 0 -mig 0
Disabled MIG Mode for GPU 00000000:36:00.0
All done.
```

4. Confirm that MIG mode was disabled.

Use the `nvidia-smi` command for this purpose.

This example shows that MIG mode is disabled on GPU 0.

```
$ nvidia-smi -i 0
```

NVIDIA-SMI 450.248.03 Driver Version: 450.248.03 CUDA Version: 11.0									
GPU	Name	Persistence-M	Bus-Id	Disp.A	Volatile	Uncorr.	ECC		
Fan	Temp	Perf	Pwr:Usage/Cap	Memory-Usage	GPU-Util	Compute	M.	MIG M.	
0	A100-SXM4-40GB	Off	00000000:36:00.0	Off			0		
N/A	29C	P0	62W / 400W	0MiB / 40537MiB	6%		Default	<b>Disabled</b>	

## 2.10. 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. To determine whether ECC memory is enabled for a GPU, run `nvidia-smi -q` for the GPU.

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.

## 2.10.1. 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 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.



**Note:** 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                : Mon Jul 17 18:36:45 2023
Driver Version           : 450.248.03
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                : Mon Jul 17 18:37:53 2023
Driver Version           : 450.248.03

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](#).

## 2.10.2. 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 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.



**Note:** 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                : Mon Jul 17 18:36:45 2023
Driver Version           : 450.248.03

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                : Mon Jul 17 18:37:53 2023
Driver Version           : 450.248.03

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**
- ▶ All GPUs directly connected to each other through NVLink must be assigned to the same VM.

You can assign multiple physical GPUs to one VM. The maximum number of physical GPUs that you can assign to a VM depends on the maximum number of PCIe pass-through devices per VM that your chosen hypervisor can support. For more information, refer to the documentation for your hypervisor, for example:

- ▶ **Citrix Hypervisor:** [Configuration limits](#)
- ▶ **Red Hat Enterprise Linux:**
  - ▶ **Red Hat Enterprise Linux 8 releases:** [Assigning a GPU to a virtual machine, Known Issues](#)
  - ▶ **Red Hat Enterprise Linux 7 releases:** [GPU PCI Device Assignment](#)

- ▶ **Red Hat Virtualization (RHV):** [Device Assignment Requirements](#)
- ▶ **VMware vSphere:** [vSphere 7.0 Configuration Limits](#)



**Note:** If you intend to configure all GPUs in your server platform for pass-through, you do not need to install the NVIDIA Virtual GPU Manager.

## 3.1. Display Resolutions for Physical GPUs

The display resolutions supported by a physical GPU depend on the NVIDIA GPU architecture and the NVIDIA vGPU software license that is applied to the GPU.

### Quadro vDWS Physical GPU Resolutions

GPUs that are licensed with a Quadro vDWS license support a maximum combined resolution based on the number of available pixels, which is determined by the NVIDIA GPU architecture. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these GPUs.

The following table lists the maximum number of displays per GPU at each supported display resolution for configurations in which all displays have the same resolution.

NVIDIA GPU Architecture	Available Pixels	Display Resolution	Displays per GPU
Pascal and later	66355200	7680×4320	2
		5120×2880 or lower	4
Maxwell	35389440	5120×2880	2
		4096×2160 or lower	4

The following table provides examples of configurations with a mixture of display resolutions.

NVIDIA GPU Architecture	Available Pixels	Available Pixel Basis	Maximum Displays	Sample Mixed Display Configurations
Pascal and later	66355200	2 7680×4320 displays	4	1 7680×4320 display plus 2 5120×2880 displays
				1 7680×4320 display plus 3 4096×2160 displays

NVIDIA GPU Architecture	Available Pixels	Available Pixel Basis	Maximum Displays	Sample Mixed Display Configurations
Maxwell	35389440	4 4096×2160 displays	4	1 5120×2880 display plus 2 4096×2160 displays



**Note:** You cannot use more than four displays even if the combined resolution of the displays is less than the number of available pixels from the GPU. For example, you cannot use five 4096×2160 displays with a GPU based on the NVIDIA Pascal architecture even though the combined resolution of the displays (44236800) is less than the number of available pixels from the GPU (66355200).

### GRID Virtual Applications or vCS Physical GPU Resolutions

GPUs that are licensed with a GRID Virtual Applications or a vCS license support a single display with a fixed maximum resolution. The maximum resolution depends on the following factors:

- ▶ NVIDIA GPU architecture
- ▶ The NVIDIA vGPU Software license that is applied to the GPU
- ▶ The operating system that is running in the on the system to which the GPU is assigned

License	NVIDIA GPU Architecture	Operating System	Maximum Display Resolution	Displays per GPU
GRID Virtual Applications	Pascal or later	Linux	2560×1600	1
	Pascal or later	Windows	1280×1024	1
	Maxwell	Windows and Linux	2560×1600	1
vCS	Pascal or later	Linux	4096×2160	1

## 3.2. 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:

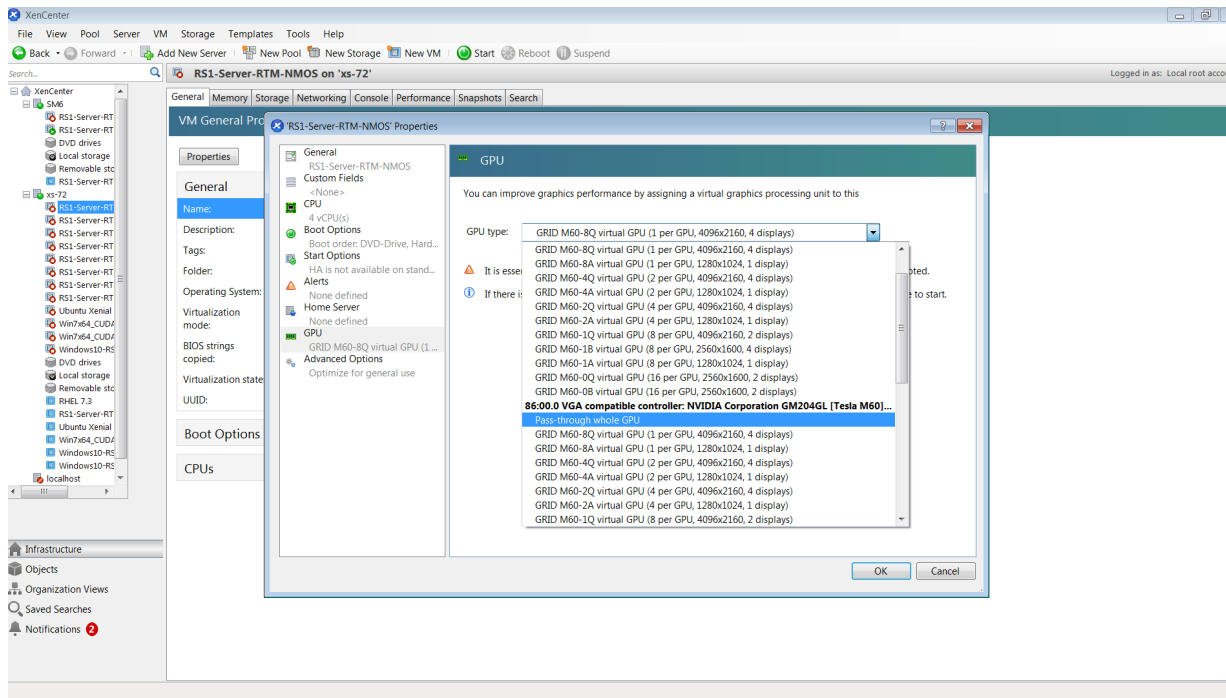
- ▶ The performance of a physical GPU passed through to a VM cannot be monitored through XenCenter.
- ▶ `nvidia-smi` in dom0 no longer has access to the GPU.

- ▶ 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.

### 3.2.1. 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 16. 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](#).

### 3.2.2. 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](#).

## 3.3. 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.



**Note:** Do not create any virtual disks in `/root`.

- ▶ A virtual machine has been created.

### 3.3.1. 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](#).

### 3.3.2. 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
al)
86:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M60] (rev
al)
```

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](#).

### 3.3.3. 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
al)
86:00.0 VGA compatible controller: NVIDIA Corporation GM204GL [Tesla M60] (rev
al)
```

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](#).

### 3.3.4. 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 `vfio-pci` 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. If you are using a GPU that supports SR-IOV, such as a GPU based on the NVIDIA Ampere architecture, disable the virtual function for the GPU in the `sysfs` file system. If your GPU does not support SR-IOV, omit this step.



**Note:** Before performing this step, ensure that the GPU is not being used by any other processes, such as CUDA applications, monitoring applications, or the `nvidia-smi` command.

Use the custom script `sriov-manage` provided by NVIDIA vGPU software for this purpose.

```
# /usr/lib/nvidia/sriov-manage -d domain:bus:slot.function
```

**domain**

**bus**

**slot**

**function**

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

This example disables the virtual function for the GPU with the domain `00`, bus `06`, slot `0000`, and function `0`.

```
# /usr/lib/nvidia/sriov-manage -d 00:06:0000.0
```

2. 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
al)
    Subsystem: NVIDIA Corporation Device 115e
    Kernel driver in use: nvidia
```

3. 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.

4. 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
```

5. 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](#).

## 3.4. 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.

### 3.4.1. 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.

If you are using an actively cooled NVIDIA Quadro graphics card such as the RTX 8000 or RTX 6000, you must also pass through the audio device on the graphics card.

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. If you are using an actively cooled NVIDIA Quadro graphics card, obtain the location path of the audio device on the graphics card and disable the device.
  - a). In the device manager, from the **View** menu, choose **Devices by connection**.
  - b). Navigate to **ACPI x64-based PC > Microsoft ACPI-Compliant System > PCI Express Root Complex > PCI-to-PCI Bridge**.
  - c). Context-click **High Definition Audio Controller** and from the menu that pops up, choose **Properties**.
  - d). In the **Properties** window that opens, click the **Details** tab and in the **Properties** drop-down list, select **Location paths**.
  - e). Context-click **High Definition Audio Controller** again and from the menu that pops up, choose **Disable device**.
3. Dismount the GPU and, if present, the audio device from host to make them unavailable to the host so that they can be used solely by the VM.

For each device that you are dismounting, type the following command:

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

The location path of the GPU or the audio device that you obtained previously.

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
```

4. Assign the GPU and, if present, the audio device that you dismounted in the previous step to the VM.

For each device that you are assigning, type the following command:

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

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

***vm-name***

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



**Note:** You can assign a pass-through GPU and, if present, its audio device 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
```

5. Power on the VM.  
The guest OS should now be able to use the GPU and, if present, the audio device.

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](#).

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

Perform this task in the Windows PowerShell.

If you are using an actively cooled NVIDIA Quadro graphics card such as the RTX 8000 or RTX 6000, you must also return the audio device on the graphics card.

1. List the GPUs and, if present, the audio devices that are currently assigned to the virtual machine (VM).

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

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

2. Shut down the VM to which the GPU and any audio devices are assigned.
3. Remove the GPU and, if present, the audio device from the VM to which they are assigned.

For each device that you are removing, type the following command:

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

The location path of the GPU or the audio device that you are removing, which you obtained previously.

***vm-name***

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

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 and, if present, its audio device are removed from the VM, they are unavailable to the host operating system (OS) until you remount them on the host OS.

4. Remount the GPU and, if present, its audio device on the host OS.

For each device that you are remounting, type the following command:

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

The location path of the GPU or the audio device that you are remounting, which you specified in the previous step to remove the GPU or the audio device 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 and, if present, its audio device.



## 3.5. 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

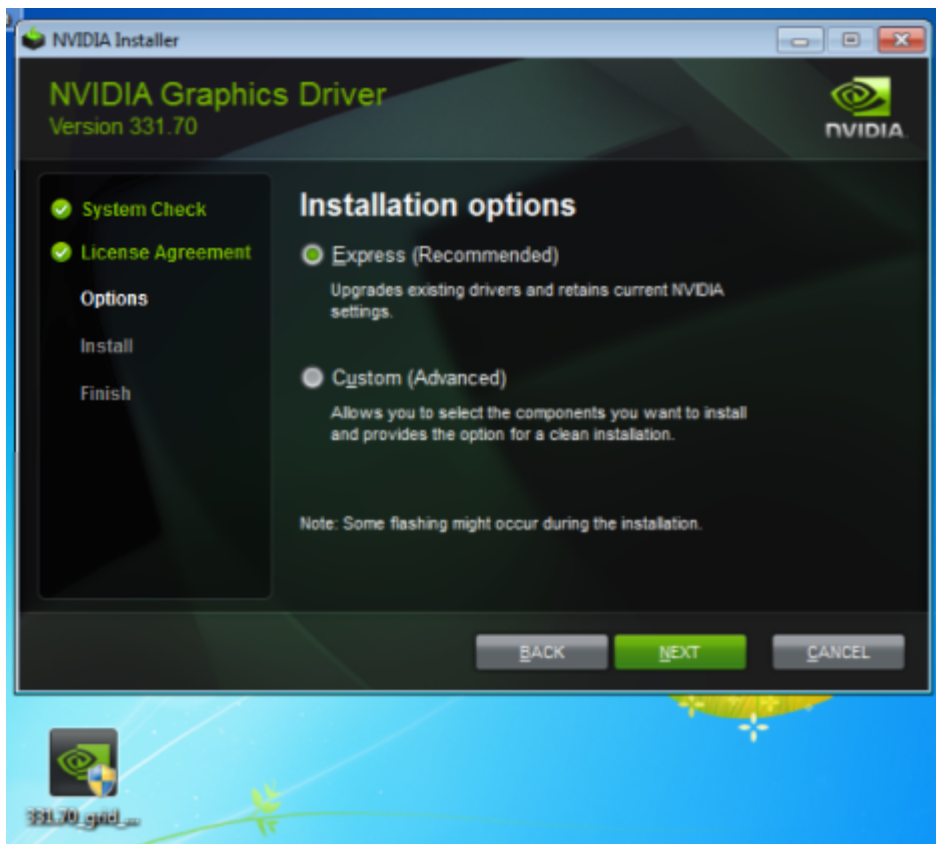
**Installation in a VM:** After you create a Windows VM on the hypervisor and boot the VM, the VM should boot to a standard Windows desktop in VGA mode at 800×600 resolution. You can use the Windows screen resolution control panel to increase the resolution to other standard resolutions, but to fully 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 17. NVIDIA driver installation



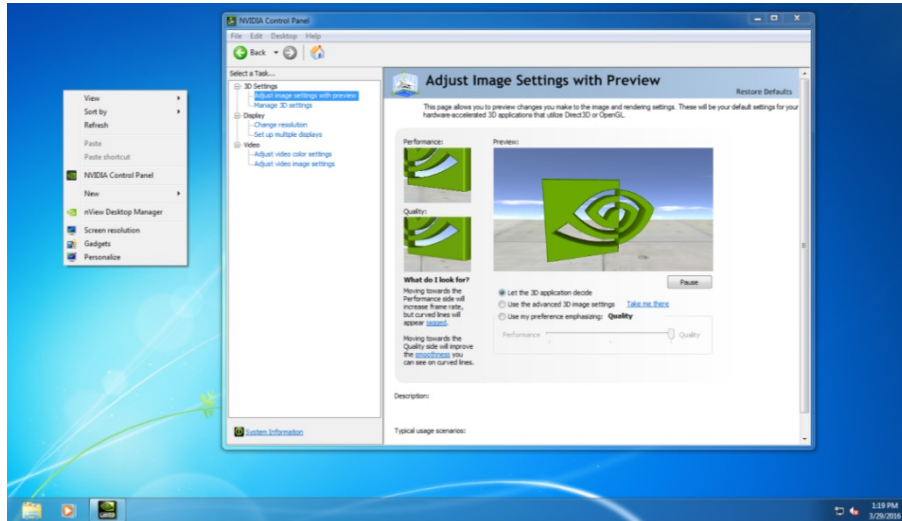
3. Click through the license agreement.
4. Select **Express Installation** and click **NEXT**.  
After the driver installation is complete, the installer may prompt you to restart the platform.
5. If prompted to restart the platform, do one of the following:
  - ▶ Select **Restart Now** to reboot the 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 18. 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. For instructions, refer to [Disabling the Nouveau Driver for NVIDIA Graphics Cards](#).

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

Ensure that NVIDIA Direct Rendering Manager Kernel Modesetting (DRM KMS) is disabled. By default, DRM KMS is disabled. However, if it has been enabled, remove `nvidia-drm.modeset=1` from the kernel command-line options.

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](#).

If Dynamic Kernel Module Support (DKMS) is enabled, ensure that the `dkms` package is installed.

1. Copy the NVIDIA vGPU software Linux driver package, for example `NVIDIA-Linux_x86_64-450.248.02-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:

a). Switch to a console login prompt.

- ▶ If you have access to the terminal's function keys, press **CTRL-ALT-F1**.
- ▶ If you are accessing the guest VM or physical host through VNC or a web browser and do not have access to the terminal's function keys, run the `chvt` command of the OS as root.

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

b). Log in and shut down the display manager:

- ▶ For Ubuntu 18 and later releases, stop the `gdm` service

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

- ▶ For releases earlier than Ubuntu 18, stop the `lightdm` service.

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

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

```
sudo sh ./NVIDIA-Linux_x86_64-450.248.02-grid.run
```

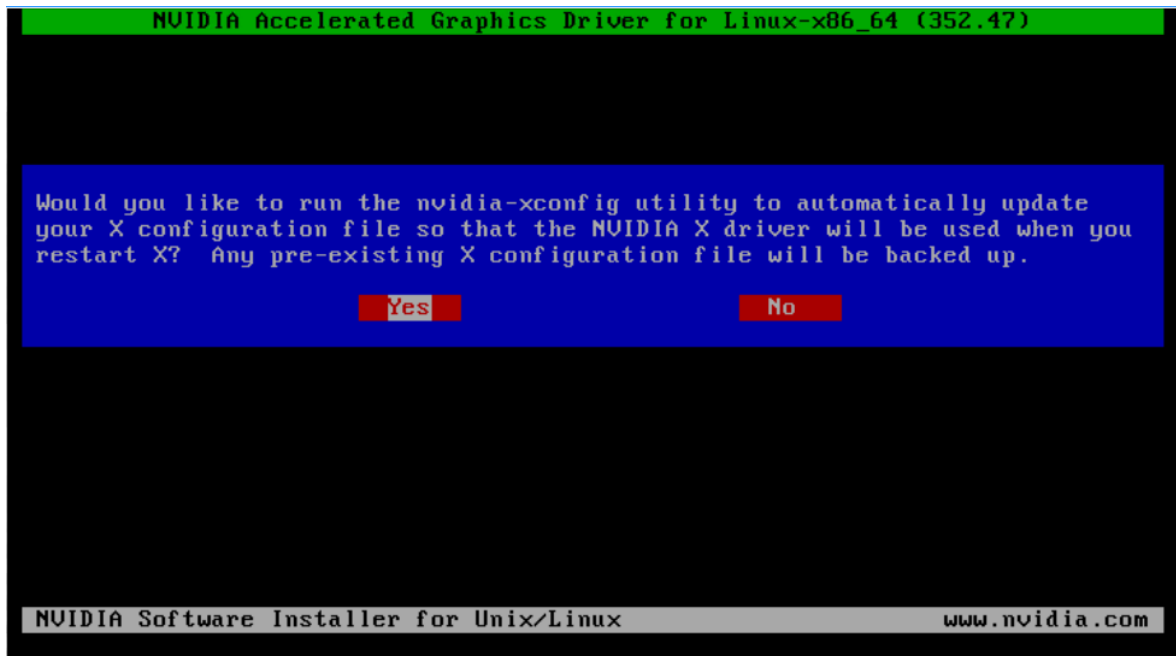
If DKMS is enabled, set the `-dkms` option. This option requires the `dkms` package to be installed.

```
sudo sh ./NVIDIA-Linux_x86_64-450.248.02-grid.run -dkms
```

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_64-450.248.02-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 19. 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.

**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 Nouveau Driver for NVIDIA Graphics Cards

If the Nouveau driver for NVIDIA graphics cards is present, disable it before installing the NVIDIA vGPU software graphics driver.



**Note:** If you are using SUSE Linux Enterprise Server, you can skip this task because the Nouveau driver is not present in SUSE Linux Enterprise Server.

Run the following command and if the command prints any output, the Nouveau driver is present and must be disabled.

```
$ lsmod | grep nouveau
```

1. Create the file `/etc/modprobe.d/blacklist-nouveau.conf` with the following contents:

```
blacklist nouveau
options nouveau modeset=0
```

2. Regenerate the kernel initial RAM file system (initramfs).

The command to run to regenerate the kernel initramfs depends on the Linux distribution that you are using.

#### Linux Distribution

#### Command

##### CentOS

```
$ sudo dracut --force
```

##### Debian

```
$ sudo update-initramfs -u
```

##### Red Hat Enterprise Linux

```
$ sudo dracut --force
```

##### Ubuntu

```
$ sudo update-initramfs -u
```

3. Reboot the host or guest VM.

## 4.4. 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 initially operates at full capability but its performance is degraded over time if the VM fails to obtain a license. If the performance of a vGPU has been degraded, the full capability of the vGPU is restored when a license is acquired. For information about how the performance of an unlicensed vGPU is degraded, see [Virtual GPU Client Licensing User Guide](#).

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.



**Note:** 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.

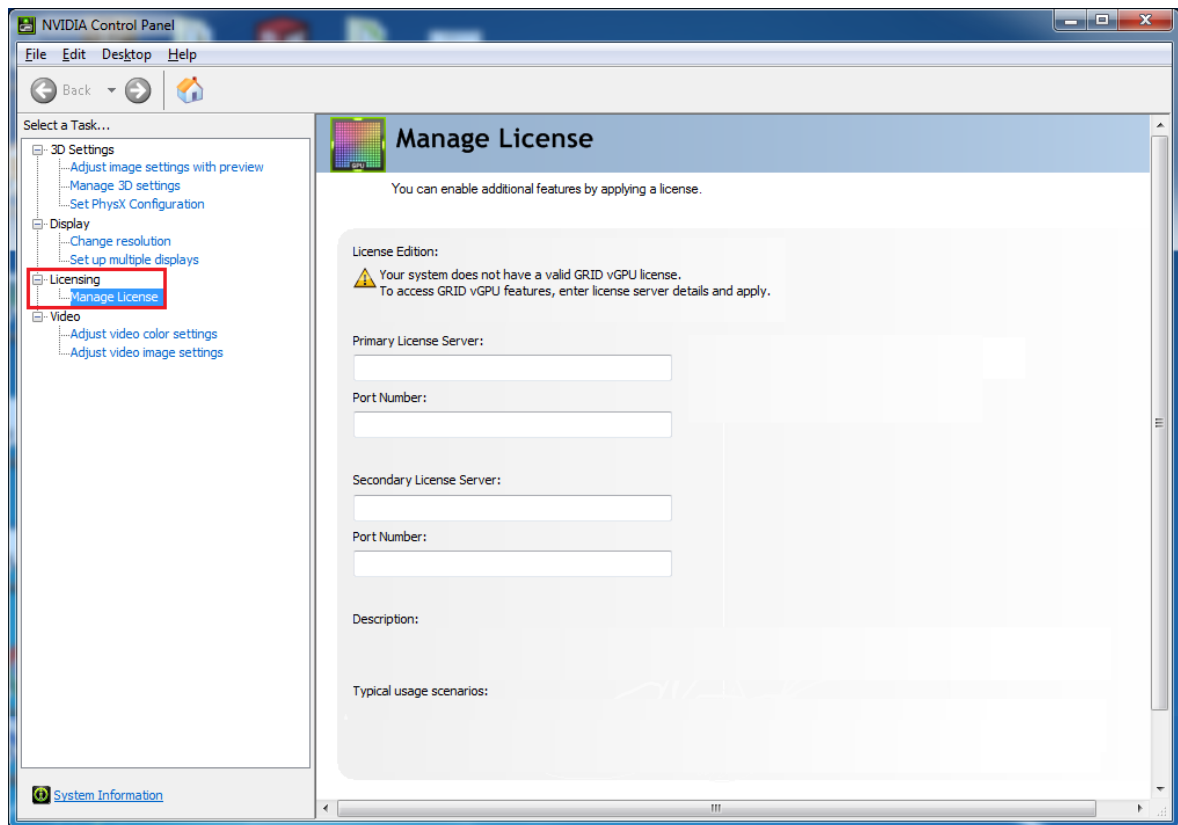


- In **NVIDIA Control Panel**, select the **Manage License** task in the **Licensing** section of the navigation pane.

**Note:** 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, refer to [Virtual GPU Client Licensing User Guide](#).

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

Figure 20. Managing vGPU licensing in NVIDIA Control Panel



- 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.

- 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.
- 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 operate at full capability without any performance degradation over time for as long as the vGPU is licensed.

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 [Virtual GPU Client Licensing User Guide](#).



**Note:** 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 operate at full capability without any performance degradation over time for as long as the vGPU is licensed.

If the system fails to obtain a license, refer to [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.

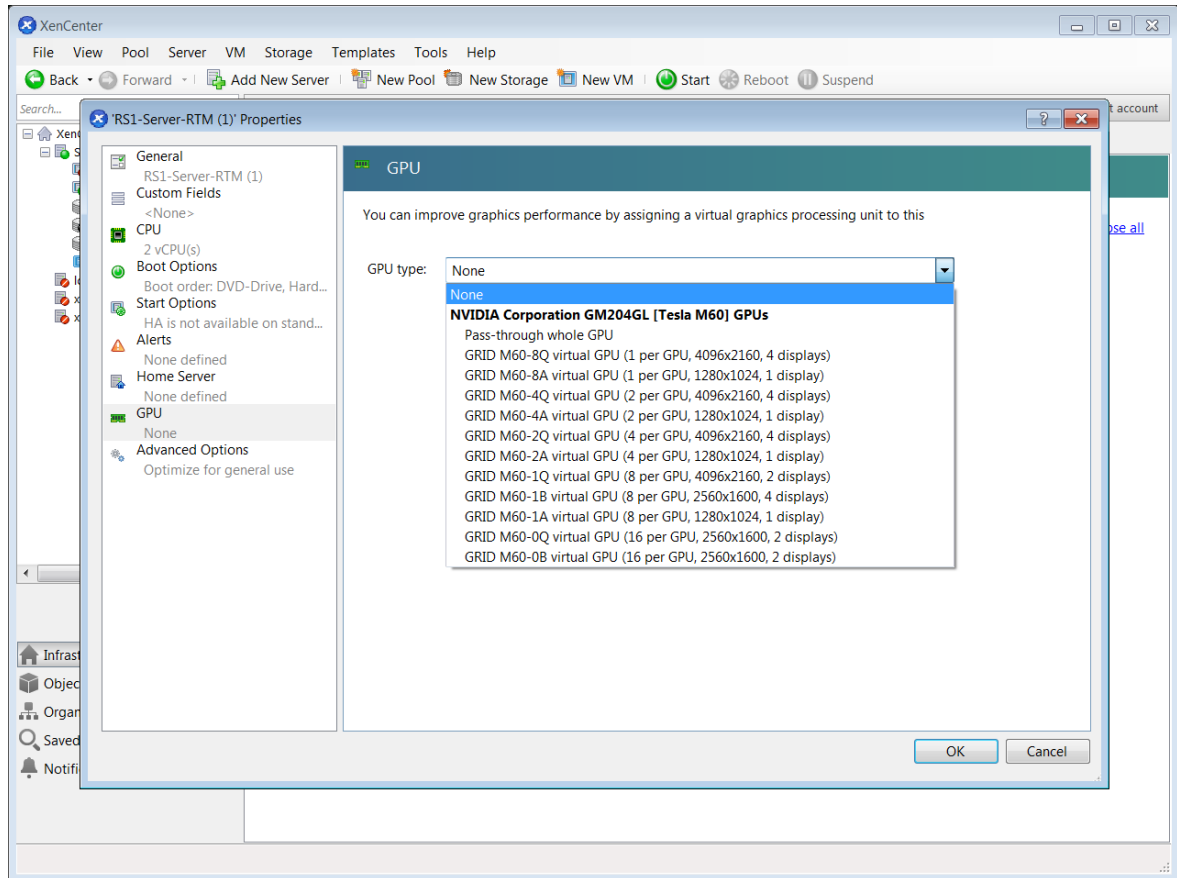


**Note:** The VM must be in the powered-off state in order for its vGPU configuration to be modified or removed.

#### 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 21](#).

Figure 21. 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`:

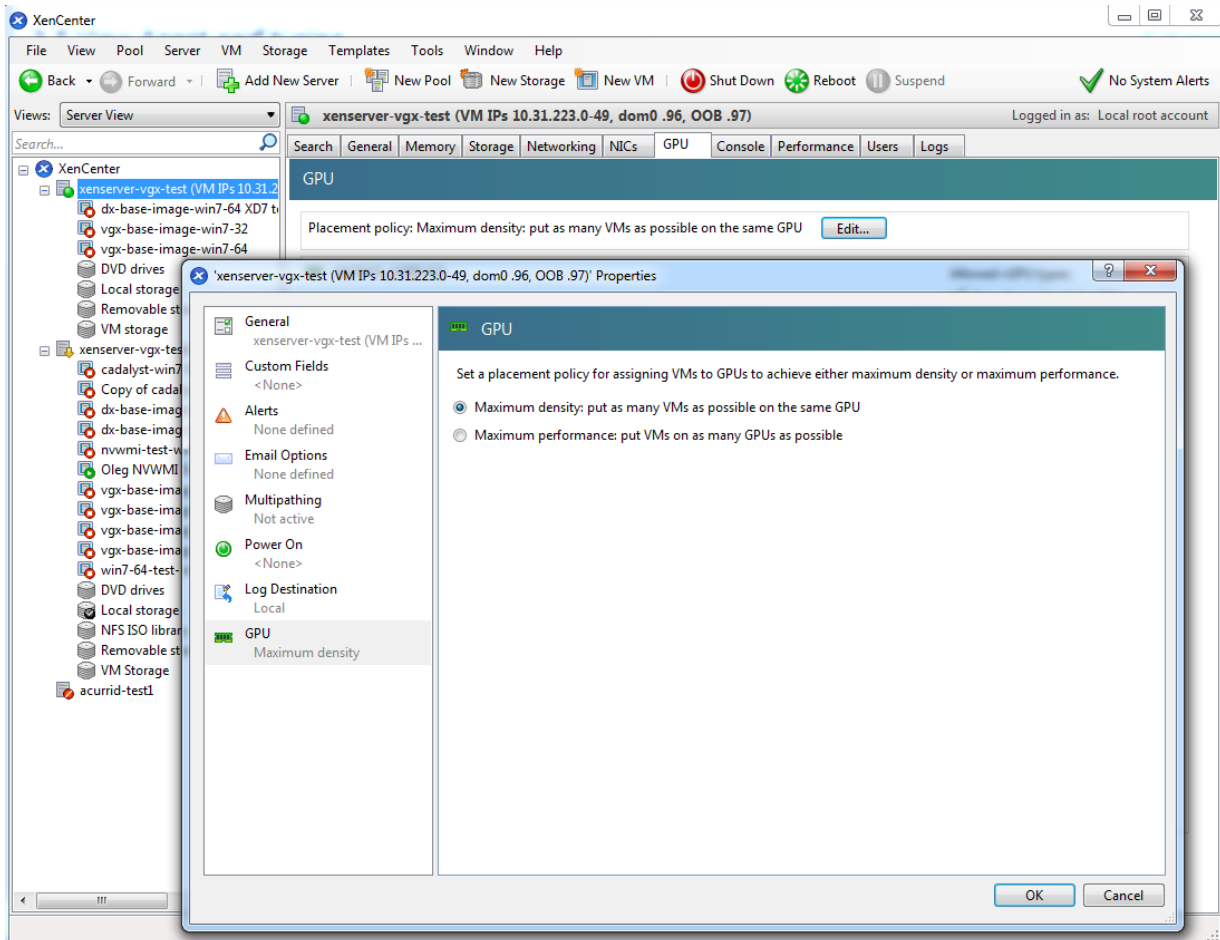
```
[root@xenserver ~]# xe gpu-group-param-get uuid=be825ba2-01d7-8d51-9780-f82cfaa64924 param-name=allocation-algorithmdepth-first
[root@xenserver ~]# xe gpu-group-param-set uuid=be825ba2-01d7-8d51-9780-f82cfaa64924 allocation-algorithm=breadth-first
```

```
[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 22. 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.

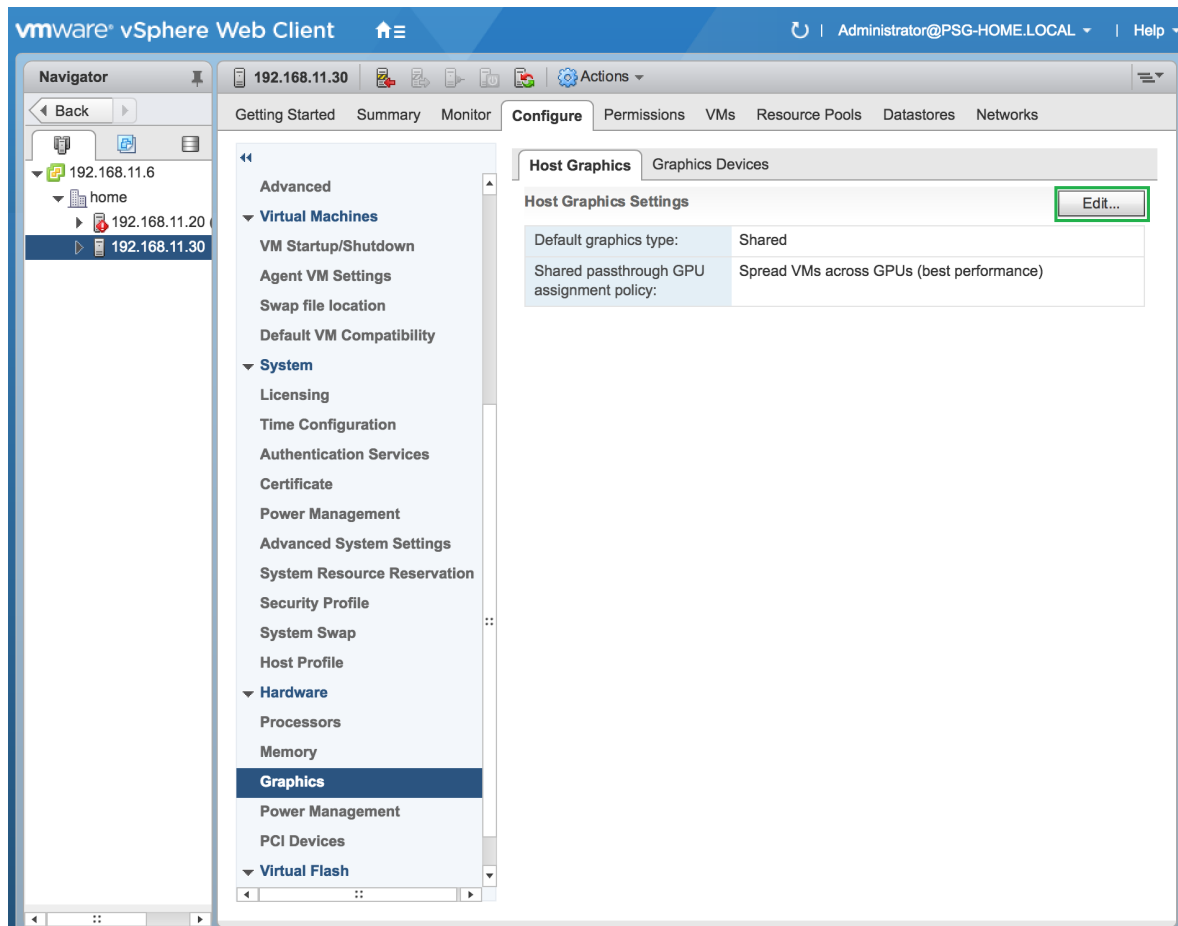
- ▶ Supported versions earlier than 6.5: Add the following parameter to `/etc/vmware/config`:
 

```
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**.

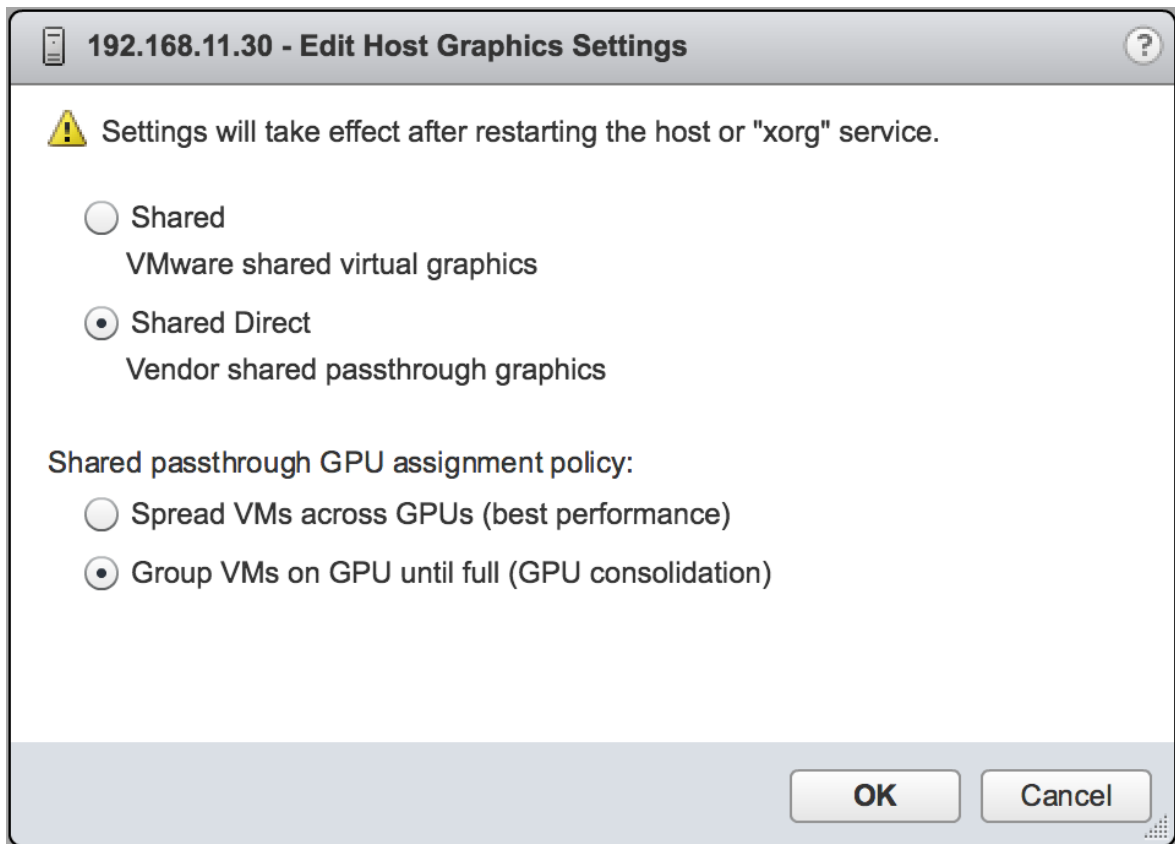
Figure 23. Breadth-first allocation scheme setting for vGPU-enabled VMs



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**.

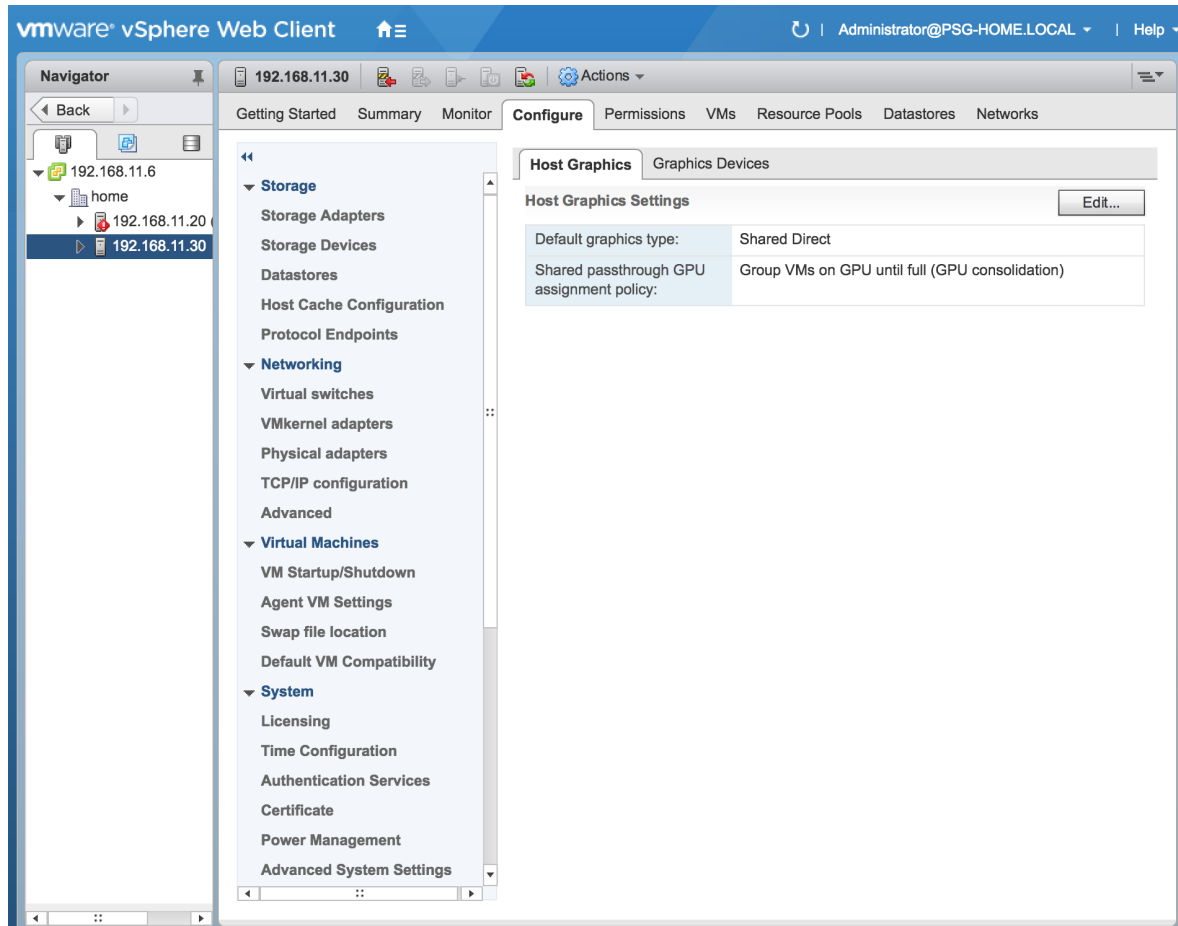


Figure 24. Host graphics settings for vGPU



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

Figure 25. 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:



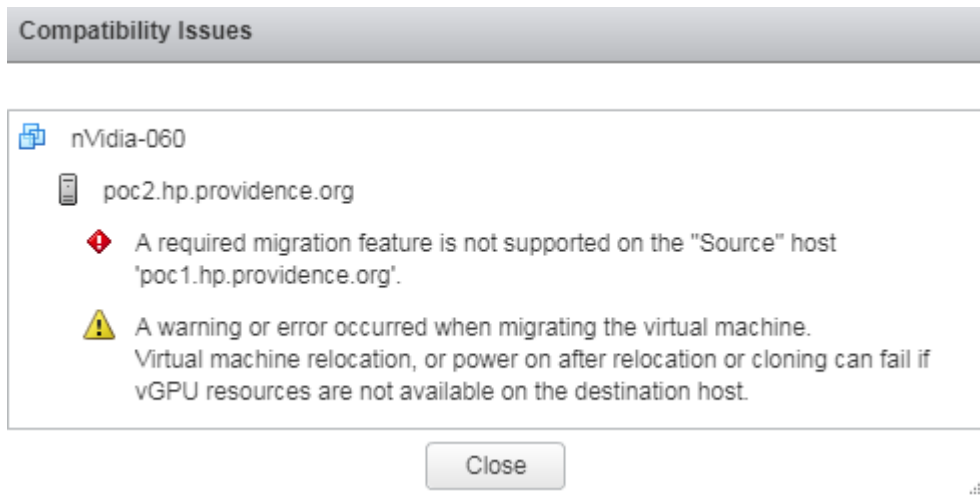
If you see this error, configure NVIDIA vGPU migration as explained in [Configuring VMware vMotion with vGPU for VMware vSphere](#).

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**.

## 6.4. Since 11.1: Modifying a MIG-Backed vGPU's Configuration

If compute instances weren't created within the GPU instances when the GPU was configured for MIG-backed vGPUs, you can add the compute instances for an individual vGPU from within the guest VM. If you want to replace the compute instances that were created when the GPU was configured for MIG-backed vGPUs, you can delete them before adding the compute instances from within the guest VM.

Ensure that the following prerequisites are met:

- ▶ You have root user privileges in the guest VM.
- ▶ The GPU instance is not being used by any other processes, such as CUDA applications, monitoring applications, or the `nvidia-smi` command.

Perform this task in a guest VM command shell.

1. Open a command shell as the root user in the guest VM.  
You can use secure shell (SSH) for this purpose.
2. List the available GPU instance.

```
$ nvidia-smi mig -lgi
+-----+
| GPU instances:                               |
| GPU   Name           Profile  Instance  Placement |
|           ID           ID           Start:Size |
+-----+-----+-----+-----+
| 0   MIG 2g.10gb      0         0         0:8     |
+-----+-----+-----+-----+
```

3. **Optional:** If compute instances were created when the GPU was configured for MIG-backed vGPUs that you no longer require, delete them.

```
$ nvidia-smi mig -dci -ci compute-instance-id -gi gpu-instance-id
```

**compute-instance-id**

The ID of the compute instance that you want to delete.

**gpu-instance-id**

The ID of the GPU instance from which you want to delete the compute instance.



**Note:** If the GPU instance is being used by another process, this command fails. In this situation, stop all processes that are using the GPU instance and retry the command.

This example deletes compute instance 0 from GPU instance 0 on GPU 0.

```
$ nvidia-smi mig -dci -ci 0 -gi 0
Successfully destroyed compute instance ID 0 from GPU 0 GPU instance ID 0
```

- List the compute instance profiles that are available for your GPU instance.

```
$ nvidia-smi mig -lcip
```

This example shows that one MIG 2g.10gb compute instance or two MIG 1c.2g.10gb compute instances can be created within the GPU instance.

```
$ nvidia-smi mig -lcip
+-----+
| Compute instance profiles:                                     |
| GPU   GPU   Name      Profile  Instances  Exclusive  Shared  |
|      Instance  ID      ID      Free/Total  SM        DEC    ENC  OFA  |
|      ID                                     CE    JPEG  |
+-----+-----+-----+-----+-----+-----+-----+
| 0     0     MIG 1c.2g.10gb  0       2/2        14        1     0   0   |
|                                     2     0   |
+-----+-----+-----+-----+-----+-----+
| 0     0     MIG 2g.10gb    1*     1/1        28        1     0   0   |
|                                     2     0   |
+-----+-----+-----+-----+-----+-----+

```

- Create the compute instances that you need within the available GPU instance.

Create each compute instance individually by running the following command.

```
$ nvidia-smi mig -cci compute-instance-profile-id -gi gpu-instance-id
```

**compute-instance-profile-id**

The compute instance profile ID that specifies the compute instance.

**gpu-instance-id**

The GPU instance ID that specifies the GPU instance within which you want to create the compute instance.



**Note:** If the GPU instance is being used by another process, this command fails. In this situation, stop all processes that are using the GPU and retry the command.

This example creates a MIG 2g.10gb compute instance on GPU instance 0.

```
$ nvidia-smi mig -cci 1 -gi 0
Successfully created compute instance ID 0 on GPU 0 GPU instance ID 0 using
profile MIG 2g.10gb (ID 1)
```

This example creates two MIG 1c.2g.10gb compute instances on GPU instance 0 by running the same command twice.

```
$ nvidia-smi mig -cci 0 -gi 0
Successfully created compute instance ID 0 on GPU 0 GPU instance ID 0 using
profile MIG 1c.2g.10gb (ID 0)
$ nvidia-smi mig -cci 0 -gi 0
Successfully created compute instance ID 1 on GPU 0 GPU instance ID 0 using
profile MIG 1c.2g.10gb (ID 0)
```

- Verify that the compute instances were created within the GPU instance.

Use the `nvidia-smi` command for this purpose.

This example confirms that a MIG 2g.10gb compute instance was created on GPU instance 0.

```
nvidia-smi
Mon Jul 17 19:01:24 2023
+-----+
| NVIDIA-SMI 450.248.03   Driver Version: 450.248.03   CUDA Version:  11.0   |
+-----+
| GPU  Name           Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf    Pwr:Usage/Cap|      Memory-Usage | GPU-Util  Compute M. |
|                                           MIG M.         |
+-----+-----+
|    0  GRID A100X-2-10C      On      | 00000000:00:08.0 Off  |          N/A         On |
| N/A   N/A    P0     N/A /  N/A | 1058MiB / 10235MiB |          N/A         Default |
|                                           |                      Enabled |
+-----+-----+

+-----+
| MIG devices:           |
+-----+-----+
| GPU  GI  CI  MIG |           Memory-Usage | SM      Vol |           Shared | | | |
|      ID  ID  Dev |           BAR1-Usage   |         Unc| CE  ENC  DEC  OFA  JPG |
|                                           |           ECC|          |          |          |          |          |
+-----+-----+
|    0   0   0   0 | 1058MiB / 10235MiB | 28      0 | 2   0   1   0   0 |
|                                           | 0MiB / 4096MiB   |          |          |          |          |
+-----+-----+

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

This example confirms that two MIG 1c.2g.10gb compute instances were created on GPU instance 0.

```
$ nvidia-smi
Mon Jul 17 19:01:24 2023
+-----+
| NVIDIA-SMI 450.248.03   Driver Version: 450.248.03   CUDA Version:  11.0   |
+-----+
| GPU  Name           Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf    Pwr:Usage/Cap|      Memory-Usage | GPU-Util  Compute M. |
|                                           MIG M.         |
+-----+-----+
|    0  GRID A100X-2-10C      On      | 00000000:00:08.0 Off  |          N/A         On |
| N/A   N/A    P0     N/A /  N/A | 1058MiB / 10235MiB |          N/A         Default |
|                                           |                      Enabled |
+-----+-----+

+-----+
| MIG devices:           |
+-----+-----+
| GPU  GI  CI  MIG |           Memory-Usage | SM      Vol |           Shared | | | |
|      ID  ID  Dev |           BAR1-Usage   |         Unc| CE  ENC  DEC  OFA  JPG |
|                                           |           ECC|          |          |          |          |          |
+-----+-----+
|    0   0   0   0 | 1058MiB / 10235MiB | 14      0 | 2   0   1   0   0 |
|                                           | 0MiB / 4096MiB   |          |          |          |          |
+-----+-----+
|    0   0   1   1 |                   | 14      0 | 2   0   1   0   0 |
+-----+-----+
```



```
+-----+-----+-----+-----+
| Processes:                                     |
| GPU  GI  CI          PID  Type  Process name          GPU Memory |
|      ID ID          |          |      |                    | Usage    |
|=====|=====|=====|=====|
| No running processes found                    |
+-----+-----+-----+-----+
```

---

# 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.



**Note:** 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.



**Note:** 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 Jul 14 09:26:18 2023
```

NVIDIA-SMI 450.248.03		Driver Version: 450.248.03				
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	1889MiB / 8191MiB		7%	Default
1	Tesla M60	On	0000:84:00.0	Off		Off
N/A	26C	P8	926MiB / 8191MiB		9%	Default
2	Tesla M10	On	0000:8A:00.0	Off		N/A
N/A	23C	P8	1882MiB / 8191MiB		12%	Default
3	Tesla M10	On	0000:8B:00.0	Off		N/A
N/A	26C	P8	10MiB / 8191MiB		0%	Default
4	Tesla M10	On	0000:8C:00.0	Off		N/A
N/A	34C	P8	10MiB / 8191MiB		0%	Default
5	Tesla M10	On	0000:8D:00.0	Off		N/A
N/A	32C	P8	10MiB / 8191MiB		0%	Default

```

Processes:
GPU      PID  Type  Process name                      GPU Memory 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 Jul 14 09:27:06 2023
```

NVIDIA-SMI 450.248.03		Driver Version: 450.248.03	
GPU	Name	Bus-Id	GPU-Util
vGPU ID	Name	VM ID	VM Name
			vGPU-Util
0	Tesla M60	0000:83:00.0	7%
11924	GRID M60-2Q	3	Win7-64 GRID test 2
1	Tesla M60	0000:84:00.0	9%
11903	GRID M60-1B	1	Win8.1-64 GRID test 3
2	Tesla M10	0000:8A:00.0	12%
11908	GRID M10-2Q	2	Win7-64 GRID test 1
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

Statistic	Column
Memory controller bandwidth	mem
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 `-i` 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
# Idx      Id       Id       process name    sm  mem  enc  dec
#         %      %       %      %
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



**Note:** 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
- ▶ FBC session flags
- ▶ Capture mode
- ▶ Maximum horizontal resolution supported by the session
- ▶ Maximum vertical resolution supported by the session
- ▶ Horizontal resolution requested by the caller in the capture call
- ▶ Vertical resolution requested by the caller in the capture call
- ▶ Moving average of new frames captured per second by the session
- ▶ Moving average new frame capture latency in microseconds for the session

To modify the reporting frequency, use the `-i` 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 -fs
```

# GPU	vGPU	Session	Process	Display	Session Diff. Map	Class. Map
Capture	Max H	Max V	H	V	Average	Map
# Idx	Id	Id	Id	Id	Ordinal	State
Mode	Res	Res	Res	Res	FPS	Latency (us)
State						
0	-	-	-	-	-	-
1	3251634178	-	-	-	-	-
2	-	-	-	-	-	-
0	-	-	-	-	-	-
1	3251634178	-	-	-	-	-
2	-	-	-	-	-	-
0	-	-	-	-	-	-
1	3251634178	-	-	-	-	-
2	-	-	-	-	-	-
0	-	-	-	-	-	-
1	3251634178	-	-	-	-	-
2	-	-	-	-	-	-
0	-	-	-	-	-	-
1	3251634178	-	-	-	-	-
2	-	-	-	-	-	-
0	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled
Unknown	4096	2160	0	0	0	0
2	-	-	-	-	-	-
0	-	-	-	-	-	-
-	-	-	-	-	-	-

	1	3251634178		1	3984	0	ToSys	Disabled	Disabled
	Unknown	4096		2160	0	0		0	
	2	-		-	-	-		-	-
	-	-		-	-	-		-	-
# GPU	3251634178	vGPU	Session	Process	Display	Session	Diff. Map	Class. Map	
Capture	Max H	Max V	Max V	H	V	Average	Average		
# Idx	Id	Id	Id	Id	Ordinal	Type	State	State	
Mode	Res	Res	Res	Res	FPS	Latency(us)			
0	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
	1	3251634178		1	3984	0	ToSys	Disabled	Disabled
	Unknown	4096		2160	0	0		0	
	2	-		-	-	-		-	-
	-	-		-	-	-		-	-
	0	-		-	-	-		-	-
	-	-		-	-	-		-	-
	1	3251634178		1	3984	0	ToSys	Disabled	Disabled
	Unknown	4096		2160	0	0		0	
	2	-		-	-	-		-	-
	-	-		-	-	-		-	-
	0	-		-	-	-		-	-
	-	-		-	-	-		-	-
	1	3251634178		1	3984	0	ToSys	Disabled	Disabled
	Unknown	4096		2160	0	0		0	
	2	-		-	-	-		-	-
	-	-		-	-	-		-	-
	0	-		-	-	-		-	-
	-	-		-	-	-		-	-
	1	3251634178		1	3984	0	ToSys	Disabled	Disabled
	Unknown	4096		2160	0	0		0	
	2	-		-	-	-		-	-
	-	-		-	-	-		-	-
	0	-		-	-	-		-	-
	-	-		-	-	-		-	-
	1	3251634178		1	3984	0	ToSys	Disabled	Disabled
	Unknown	4096		2160	0	0		0	
	2	-		-	-	-		-	-
	-	-		-	-	-		-	-
	0	-		-	-	-		-	-
	-	-		-	-	-		-	-
	1	3251634178		1	3984	0	ToSys	Disabled	Disabled
	Blocking	4096		2160	1600	900	25	39964	
	2	-		-	-	-		-	-
	-	-		-	-	-		-	-
	0	-		-	-	-		-	-
	-	-		-	-	-		-	-
	1	3251634178		1	3984	0	ToSys	Disabled	Disabled
	Blocking	4096		2160	1600	900	25	39964	
	2	-		-	-	-		-	-
	-	-		-	-	-		-	-
	0	-		-	-	-		-	-
	-	-		-	-	-		-	-
	1	3251634178		1	3984	0	ToSys	Disabled	Disabled
	Blocking	4096		2160	0	0		0	

# GPU	Capture	vGPU Max H	Session Max V	Process H	Process V	Display Average Ordinal	Session Average Latency (us)	Diff. Type	Map State	Class. Map State
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-
1	3251634178	4096	2160	1	3984	0	ToSys	Disabled	Disabled	Disabled
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-
1	3251634178	4096	2160	1	3984	0	ToSys	Disabled	Disabled	Disabled
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-
1	3251634178	4096	2160	1	3984	0	ToSys	Disabled	Disabled	Disabled
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-
1	3251634178	4096	2160	1	3984	0	ToSys	Disabled	Disabled	Disabled
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-
1	3251634178	4096	2160	1	3984	0	ToSys	Disabled	Disabled	Disabled
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-
1	3251634178	4096	2160	1600	900	135	ToSys	Disabled	Disabled	Disabled
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-
1	3251634178	4096	2160	1600	900	227	ToSys	Disabled	Disabled	Disabled
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-
1	3251634178	4096	2160	1	3984	0	ToSys	Disabled	Disabled	Disabled
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-
1	3251634178	4096	2160	1	3984	0	ToSys	Disabled	Disabled	Disabled
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-
1	3251634178	4096	2160	1	3984	0	ToSys	Disabled	Disabled	Disabled
2	-	-	-	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-	-	-	-

# GPU	vGPU	Session	Process	Display	Session	Diff. Map	Class. Map
Capture	Max H	Max V	H	Average	Average		
# Idx	Id	Id	Id	Ordinal	Type	State	State
Mode	Res	Res	Res	FPS	Latency(us)		
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-
1	3251634178	1	3984	0	ToSys	Disabled	Disabled
Blocking	4096	2160	0	0		0	
2	-	-	-	-	-	-	-
0	-	-	-	-	-	-	-

^C[root@vgpu ~]#

## 7.2.1.8. Listing Supported vGPU Types

To list the virtual GPU types that the GPUs in the system support, run `nvidia-smi vgpu` with the `-s` or `--supported` option.

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 for each GPU depending on whether MIG mode is enabled for the GPU.

- ▶ If MIG mode is **not** enabled for the GPU, or if the GPU does not support MIG, this property reflects the number and type of vGPUs that are already running on the GPU.
  - ▶ If no vGPUs are running on the GPU, all vGPU types that the GPU supports are listed.
  - ▶ If one or more vGPUs are running on the GPU, but the GPU is not fully loaded, only the type of the vGPUs that are already running is listed.
  - ▶ If the GPU is fully loaded, no vGPU types are listed.
- ▶ **Since 11.1:** If MIG mode is enabled for the GPU, the result reflects the number and type of GPU instances on which no vGPUs are already running.
  - ▶ If no GPU instances have been created, no vGPU types are listed.
  - ▶ If GPU instances have been created, only the vGPU types that correspond to GPU instances on which no vGPU is running are listed.
  - ▶ If a vGPU is running on every GPU instance, no vGPU types are listed.

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.

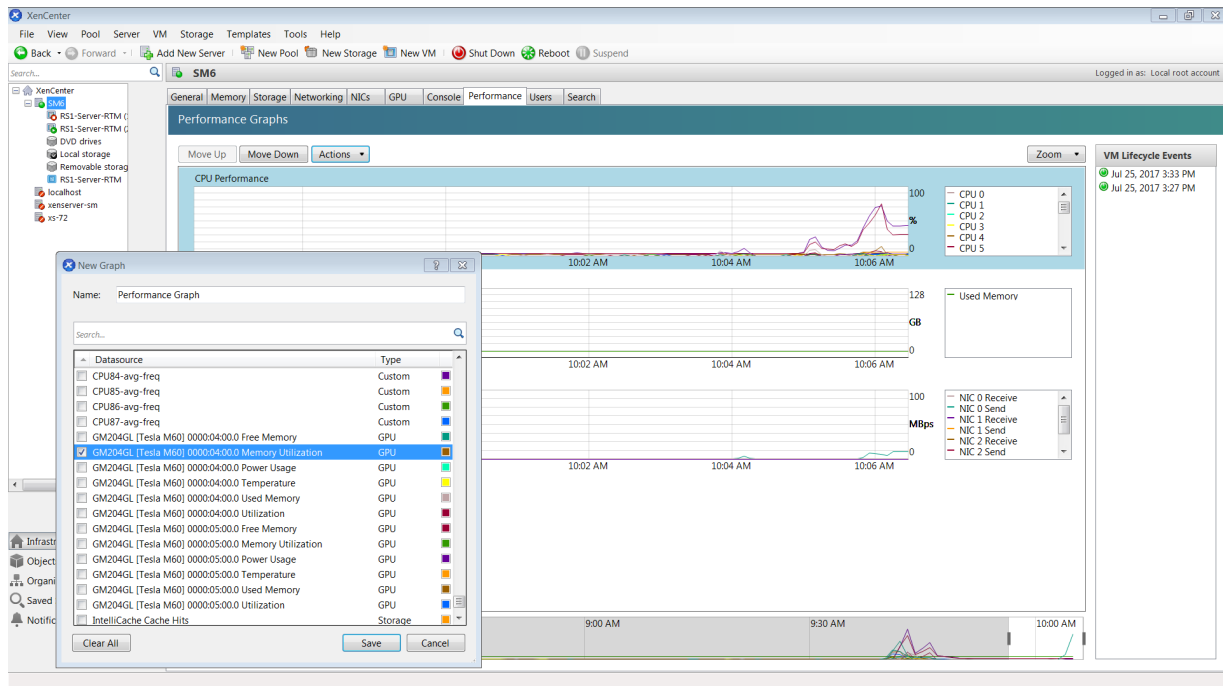
### 7.2.2. Using Citrix XenCenter to monitor GPU performance

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 26. 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.

Figure 27. Using `nvidia-smi` from a Windows guest VM to get total resource usage by all applications

```

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>

```

To use `nvidia-smi` to retrieve statistics for resource usage by individual applications running in the VM, run the following command:

```
nvidia-smi pmon
```



Figure 28. Using `nvidia-smi` from a Windows guest VM to get resource usage by individual applications

```

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      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

```

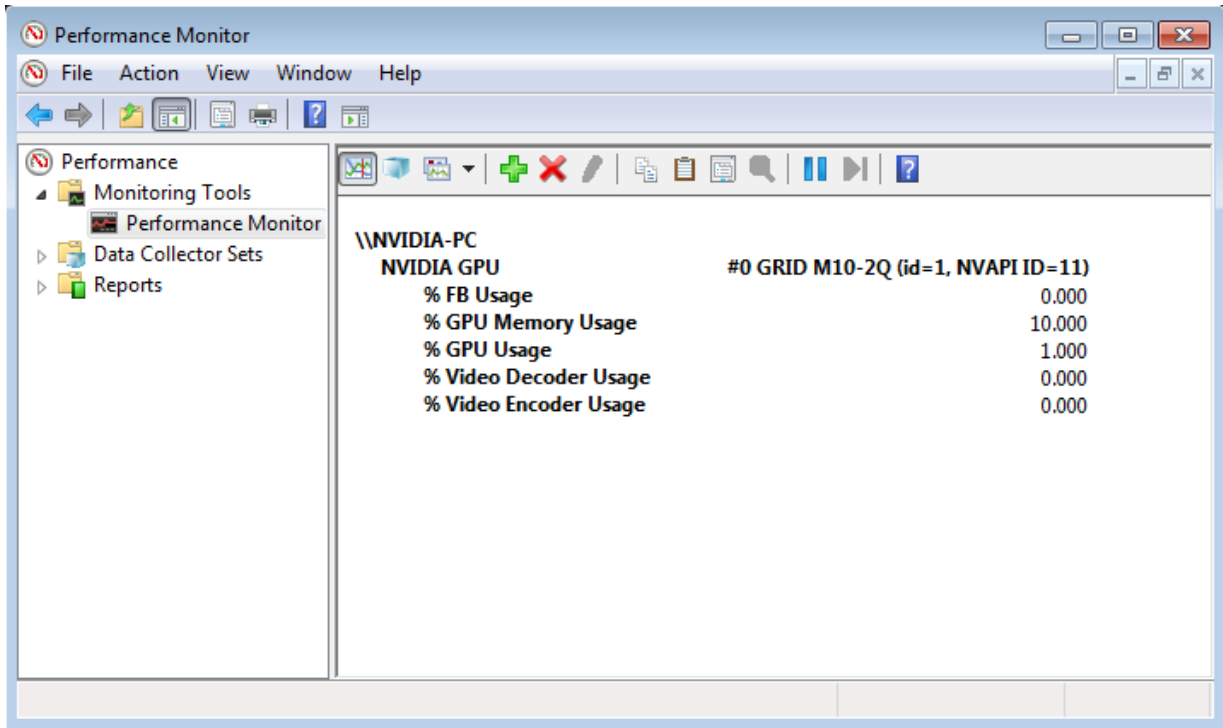
### 7.3.2. Using Windows Performance Counters to monitor GPU performance

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 29. 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

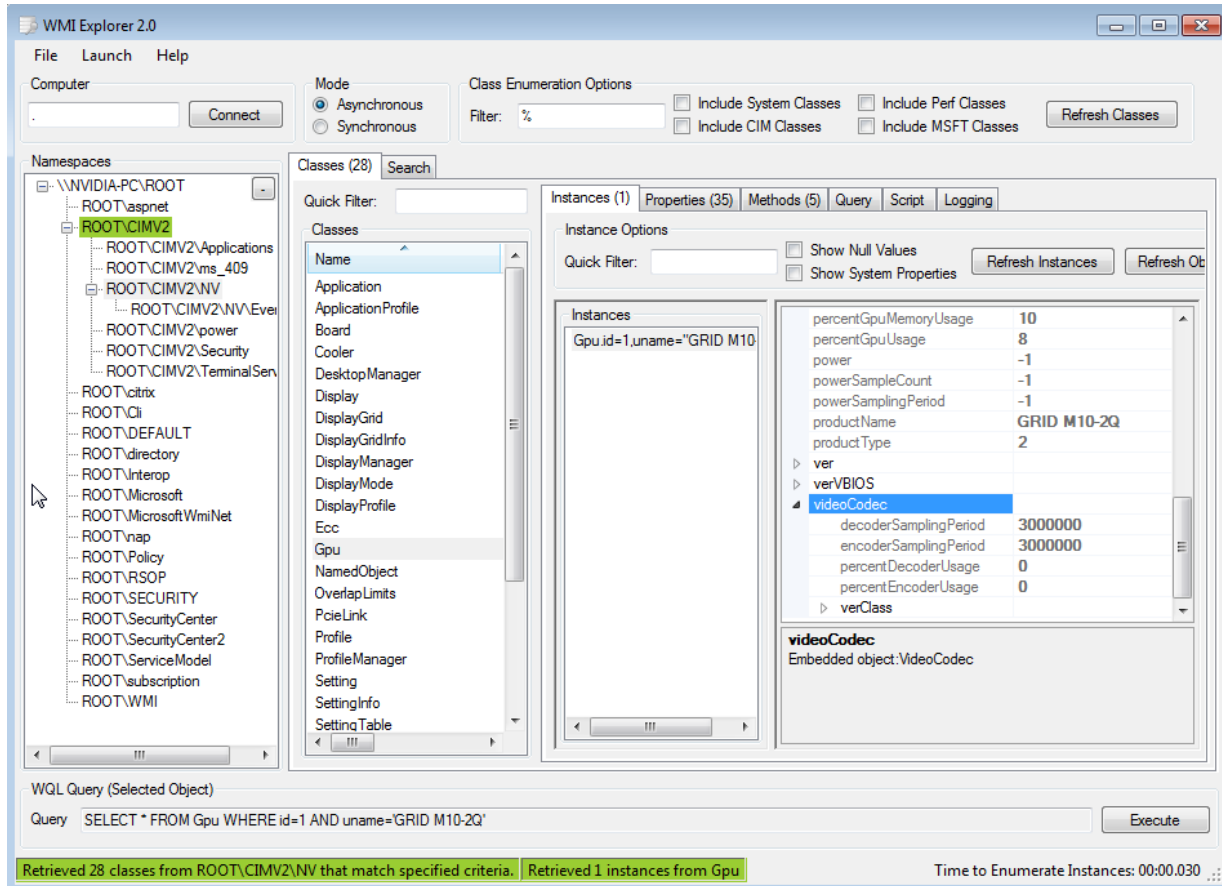
In Windows VMs, [Windows Management Instrumentation](#) (WMI) exposes GPU metrics in the `ROOT\CIMV2\NV` namespace through NVWMI. NVWMI is included with the NVIDIA

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 30. 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

Gpu Instance Property	Value reported on vGPU
pciDownstreamWidth	0
pcieGpu.curGen	0
pcieGpu.curSpeed	0
pcieGpu.curWidth	0
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. Changing Scheduling Behavior for Time-Sliced vGPUs

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.



**Note:** 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](#).

## 8.1. Scheduling Policies for Time-Sliced vGPUs

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.

## 8.2. Scheduler Time Slice for Time-Sliced vGPUs

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.

## 8.3. 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.



**Note:** 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
0x00TT0001	Equal share scheduler with a user-defined time slice length <i>TT</i>
0x11	Fixed share scheduler with the default time slice length
0x00TT0011	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
```

## 8.4. Getting the Current Time-Sliced vGPU Scheduling Behavior for All GPUs

Get the current scheduling behavior before changing the scheduling behavior of one or more GPUs to determine if you need to change it or after changing it to confirm the change.

Perform this task in your hypervisor command shell.

1. Open a command shell 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 `dmesg` command to display messages from the kernel that contain the strings `NVRM` and `scheduler`.

```
$ dmesg | grep NVRM | grep scheduler
```

The scheduling behavior is indicated in these messages by the following strings:

**NONE**

Best effort

**VGPU\_RELATIVE**

Equal share

**PGPU\_SHARE**

Fixed share

If the scheduling behavior is equal share or fixed share, the scheduler time slice in ms is also displayed.

This example gets the scheduling behavior of the GPUs in a system in which the behavior of one GPU is set to best effort, one GPU is set to equal share, and one GPU is set to fixed share.

```
$ dmesg | grep NVRM | grep scheduler
2020-10-05T02:58:08.928Z cpu79:2100753)NVRM: GPU at 0000:3d:00.0 has software
scheduler DISABLED with policy NONE.
2020-10-05T02:58:09.818Z cpu79:2100753)NVRM: GPU at 0000:5e:00.0 has software
scheduler ENABLED with policy VGPU_RELATIVE.
NVRM: Software scheduler timeslice set to 1 ms.
2020-10-05T02:58:12.115Z cpu79:2100753)NVRM: GPU at 0000:88:00.0 has software
scheduler ENABLED with policy PGPU_SHARE.
NVRM: Software scheduler timeslice set to 1 ms.
```



## 8.5. Changing the Time-Sliced vGPU Scheduling Behavior for All GPUs



**Note:** 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.

Confirm that the scheduling behavior was changed as required as explained in [Getting the Current Time-Sliced vGPU Scheduling Behavior for All GPUs](#).

## 8.6. Changing the Time-Sliced vGPU Scheduling Behavior for Select GPUs



**Note:** 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  
[;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 \  
-p "NVreg_RegistryDwordsPerDevice=pci=pci-domain:pci-bdf;RmPVMRL=value\  
[;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"
```

This example changes the scheduling behavior of a single GPU on a hypervisor host that is running VMware vSphere. The command sets the scheduling policy of the GPU at PCI domain 0000 and BDF 15:00.0 to fixed share scheduler with the default time slice length.

```
# esxcli system module parameters set -m nvidia -p \
"NVreg_RegistryDwordsPerDevice=pci=0000:15:00.0;RmPVMRL=0x11[;pci=0000:15:00.0;RmPVMRL=0x11]"
```

This example changes the scheduling behavior of a single GPU on a hypervisor host that is running VMware vSphere. The command sets the scheduling policy of the GPU at PCI domain 0000 and BDF 15:00.0 to fixed share scheduler with a time slice that is 24 (0x18) ms long.

```
# esxcli system module parameters set -m nvidia -p \
"NVreg_RegistryDwordsPerDevice=pci=0000:15:00.0;RmPVMRL=0x11[;pci=0000:15:00.0;RmPVMRL=0x00180011]"
```

4. Reboot your hypervisor host machine.

Confirm that the scheduling behavior was changed as required as explained in [Getting the Current Time-Sliced vGPU Scheduling Behavior for All GPUs](#).

## 8.7. Restoring Default Time-Sliced 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.

---

# Chapter 9. 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.

## 9.1. 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.

## 9.2. 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.

### 9.2.1. 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-8.2-450.248.03` 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-8.2-450.248.03
[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-8.2-450.248.03.x86_64 conflicts with file from package NVIDIA-vGPU-
xenserver-8.2-450.236.03.x86_64
file /usr/lib/libnvidia-ml.so from install of NVIDIA-vGPU-
xenserver-8.2-450.248.03.x86_64 conflicts with file from package NVIDIA-vGPU-
xenserver-8.2-450.236.03.x86_64
...
```

## 9.2.2. 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 pass-through 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.

## 9.2.3. 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.
```

## 9.2.4. 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`.

## 9.2.4.1. 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_log` prefix:

```
[root@xenserver ~]# grep vmiop /var/log/messages
Jul 17 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: gpu-pci-id :
0000:05:00.0
Jul 17 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: vgpu_type : quadro
Jul 17 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: Framebuffer: 0x74000000
Jul 17 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: Virtual Device Id:
0x13F2:0x114E
Jul 17 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: ##### vGPU Manager
Information: #####
Jul 17 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: Driver
Version: 450.248.03
Jul 17 10:34:03 localhost vgpu-11[25698]: notice: vmiop_log: Init frame copy engine:
syncing...
Jul 17 10:35:31 localhost vgpu-11[25698]: notice: vmiop_log: ##### Guest NVIDIA
Driver Information: #####
Jul 17 10:35:31 localhost vgpu-11[25698]: notice: vmiop_log: Driver Version: 454.14
Jul 17 10:35:36 localhost vgpu-11[25698]: notice: vmiop_log: Current max guest pfn =
0x11bc84!
Jul 17 10:35:40 localhost vgpu-11[25698]: notice: vmiop_log: Current max guest pfn =
0x11eff0!
[root@xenserver ~]#
```

## 9.2.4.2. 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
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: vmiop-env:
guest_max_gpfn:0x11f7ff
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: pluginconfig: /usr/
share/nvidia/vgx/grid_m60-1q.conf,gpu-pci-id=0000:06:00.0
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: Loading Plugin0:
libnvidia-vgpu
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: Successfully update
the env symbols!
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: vmiop_log: gpu-pci-
id : 0000:06:00.0
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: vmiop_log:
vgpu_type : quadro
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: vmiop_log:
Framebuffer: 0x38000000
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: vmiop_log: Virtual
Device Id: 0x13F2:0x114D
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: vmiop_log: #####
vGPU Manager Information: #####
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: vmiop_log: Driver
Version: 450.248.03
[2023-07-14 04:46:12] vmiop_log: [2023-07-14 04:46:12] notice: vmiop_log: Init frame
copy engine: syncing...
```

```
[2023-07-14 05:09:14] vmiop_log: [2023-07-14 05:09:14] notice: vmiop_log: #####
Guest NVIDIA Driver Information: #####
[2023-07-14 05:09:14] vmiop_log: [2023-07-14 05:09:14] notice: vmiop_log: Driver
Version: 454.14
[2023-07-14 05:09:14] vmiop_log: [2023-07-14 05:09:14] notice: vmiop_log: Current
max guest pfn = 0x11a71f!
[2023-07-14 05:12:09] vmiop_log: [2023-07-14 05:12:09] notice: vmiop_log: vGPU
license state: (0x00000001)
#
```

### 9.2.4.3. 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
2023-07-14T14:02:21.275Z| vmx| I120: DICT pciPassthru0.virtualDev = "vmiop"
2023-07-14T14:02:21.344Z| vmx| I120: GetPluginPath testing /usr/lib64/vmware/plugin/
libvmx-vmiop.so
2023-07-14T14:02:21.344Z| vmx| I120: PluginLdr_LoadShared: Loaded shared plugin
libvmx-vmiop.so from /usr/lib64/vmware/plugin7/libvmx-vmiop.so
2023-07-14T14:02:21.344Z| vmx| I120: VMIOP: Loaded plugin libvmx-
vmiop.so:VMIOP_InitModule
2023-07-14T14:02:21.359Z| vmx| I120: VMIOP: Initializing plugin vmiop-display
2023-07-14T14:02:21.365Z| vmx| I120: vmiop_log: gpu-pci-id : 0000:04:00.0
2023-07-14T14:02:21.365Z| vmx| I120: vmiop_log: vgpu_type : quadro
2023-07-14T14:02:21.365Z| vmx| I120: vmiop_log: Framebuffer: 0x74000000
2023-07-14T14:02:21.365Z| vmx| I120: vmiop_log: Virtual Device Id: 0x11B0:0x101B
2023-07-14T14:02:21.365Z| vmx| I120: vmiop_log: ##### vGPU Manager Information:
#####
2023-07-14T14:02:21.365Z| vmx| I120: vmiop_log: Driver Version: 450.248.03
2023-07-14T14:02:21.365Z| vmx| I120: vmiop_log: VGX Version: 11.13
2023-07-14T14:02:21.445Z| vmx| I120: vmiop_log: Init frame copy engine: syncing...
2023-07-14T14:02:37.031Z| vthread-12| I120: vmiop_log: ##### Guest NVIDIA Driver
Information: #####
2023-07-14T14:02:37.031Z| vthread-12| I120: vmiop_log: Driver Version: 454.14
2023-07-14T14:02:37.031Z| vthread-12| I120: vmiop_log: VGX Version: 11.13
2023-07-14T14:02:37.093Z| vthread-12| I120: vmiop_log: Clearing BAR1 mapping
2023-07-17T23:39:55.726Z| vmx| I120: VMIOP: Shutting down plugin vmiop-display
[root@esxi:~]
```

## 9.3. 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.



### 9.3.1. 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.

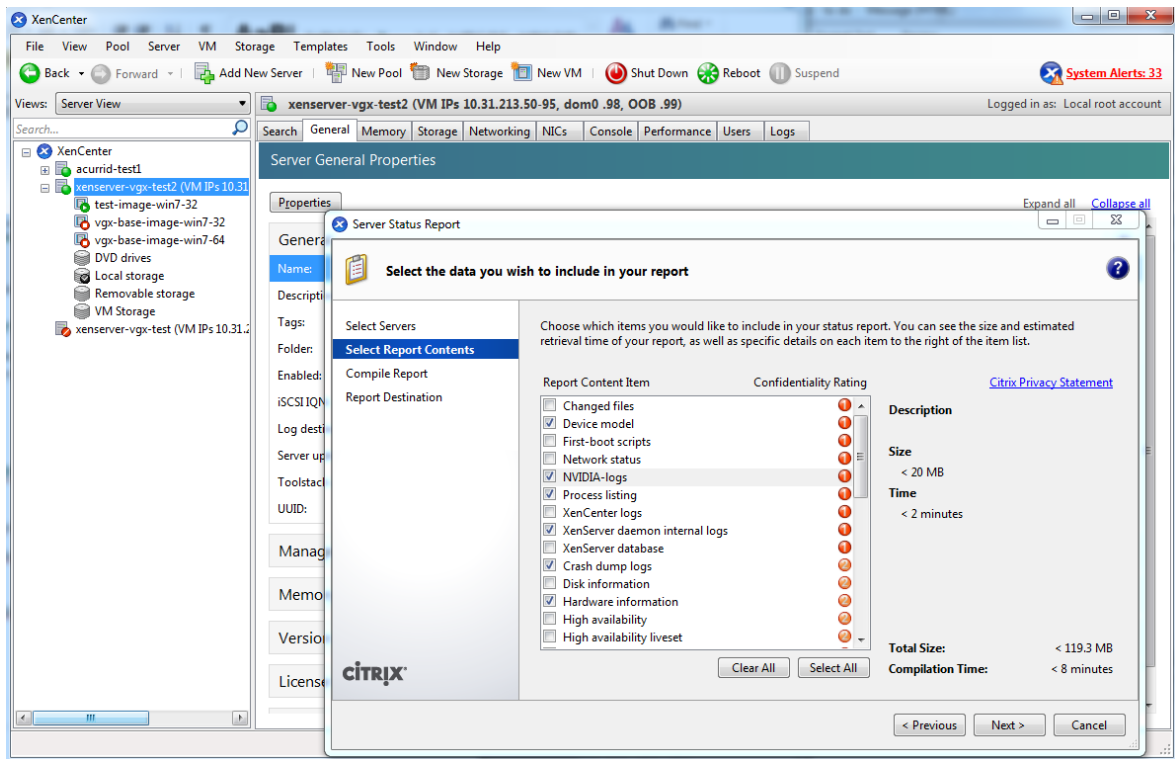
complete

[root@xenserver ~]#
```

### 9.3.2. 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 31. Including NVIDIA logs in a Citrix Hypervisor status report



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# Appendix A. Virtual GPU Types Reference

## A.1. Virtual GPU Types for Supported GPUs

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

### A.1.1. NVIDIA A100 PCIe 40GB Virtual GPU Types

Physical GPUs per board: 1

This GPU supports MIG-backed virtual GPUs and time-sliced virtual GPUs.

#### MIG-Backed C-Series Virtual GPU Types for NVIDIA A100 PCIe 40GB

Required license edition: vCS or Quadro vDWS

For details of GPU instance profiles, see [NVIDIA Multi-Instance GPU User Guide](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Slices per vGPU	Compute Instances per vGPU	Corresponding GPU Instance Profile
A100-7-40C	Training Workloads	40960	1	7	7	MIG 7g.40gb
A100-4-20C	Training Workloads	20480	1	4	4	MIG 4g.20gb
A100-3-20C	Training Workloads	20480	2	3	3	MIG 3g.20gb
A100-2-10C	Training Workloads	10240	3	2	2	MIG 2g.10gb

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Slices per vGPU	Compute Instances per vGPU	Corresponding GPU Instance Profile
A100-1-5C	Inference Workloads	5120	7	1	1	MIG 1g.5gb

### Time-Sliced C-Series Virtual GPU Types for NVIDIA A100 PCIe 40GB

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
A100-40C	Training Workloads	40960	1	1	4096×2160 <sup>2</sup>	1
A100-20C	Training Workloads	20480	2	2	4096×2160 <sup>2</sup>	1
A100-10C	Training Workloads	10240	4	4	4096×2160 <sup>2</sup>	1
A100-8C	Training Workloads	8192	5	5	4096×2160 <sup>2</sup>	1
A100-5C	Inference Workloads	5120	8	8	4096×2160 <sup>2</sup>	1
A100-4C	Inference Workloads	4096	10	10	4096×2160 <sup>2</sup>	1

### A.1.2. NVIDIA A100 HGX 40GB Virtual GPU Types

Physical GPUs per board: 1

This GPU supports MIG-backed virtual GPUs and time-sliced virtual GPUs.

#### MIG-Backed C-Series Virtual GPU Types for NVIDIA A100 HGX 40GB

Required license edition: vCS or Quadro vDWS

For details of GPU instance profiles, see [NVIDIA Multi-Instance GPU User Guide](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Slices per vGPU	Compute Instances per vGPU	Corresponding GPU Instance Profile
A100X-7-40C	Training Workloads	40960	1	7	7	MIG 7g.40gb
A100X-4-20C	Training Workloads	20480	1	4	4	MIG 4g.20gb
A100X-3-20C	Training Workloads	20480	2	3	3	MIG 3g.20gb
A100X-2-10C	Training Workloads	10240	3	2	2	MIG 2g.10gb
A100X-1-5C	Inference Workloads	5120	7	1	1	MIG 1g.5gb

### Time-Sliced C-Series Virtual GPU Types for NVIDIA A100 HGX 40GB

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
A100X-40C	Training Workloads	40960	1	1	4096×2160 <sup>2</sup>	1
A100X-20C	Training Workloads	20480	2	2	4096×2160 <sup>2</sup>	1
A100X-10C	Training Workloads	10240	4	4	4096×2160 <sup>2</sup>	1
A100X-8C	Training Workloads	8192	5	5	4096×2160 <sup>2</sup>	1
A100X-5C	Inference Workloads	5120	8	8	4096×2160 <sup>2</sup>	1
A100X-4C	Inference Workloads	4096	10	10	4096×2160 <sup>2</sup>	1

### A.1.3. Tesla M60 Virtual GPU Types

Physical GPUs per board: 2

## Q-Series Virtual GPU Types for Tesla M60

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
M60-8Q	Virtual Workstations	8192	1	2	35389440	5120×2880	2
						4096×2160 or lower	4
M60-4Q	Virtual Workstations	4096	2	4	35389440	5120×2880	2
						4096×2160 or lower	4
M60-2Q	Virtual Workstations	2048	4	8	35389440	5120×2880	2
						4096×2160 or lower	4
M60-1Q	Virtual Desktops, Virtual Workstations	1024	8	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
M60-0Q	Virtual Desktops, Virtual Workstations	512	16	32	8192000	2560×1600	2 <sup>1</sup>

## B-Series Virtual GPU Types for Tesla M60

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution

displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
M60-2B	Virtual Desktops	2048	4	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
M60-2B4 <sup>4</sup>	Virtual Desktops	2048	4	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
M60-1B	Virtual Desktops	1024	8	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
M60-1B4 <sup>4</sup>	Virtual Desktops	1024	8	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
M60-0B	Virtual Desktops	512	16	32	8192000	2560×1600	2 <sup>1</sup>

### A-Series Virtual GPU Types for Tesla M60

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
M60-8A	Virtual Applications	8192	1	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
M60-4A	Virtual Applications	4096	2	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
M60-2A	Virtual Applications	2048	4	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
M60-1A	Virtual Applications	1024	8	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.1.4. Tesla M10 Virtual GPU Types

Physical GPUs per board: 4

### Q-Series Virtual GPU Types for Tesla M10

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
M10-8Q	Virtual Workstations	8192	1	4	35389440	5120×2880	2
						4096×2160 or lower	4
M10-4Q	Virtual Workstations	4096	2	8	35389440	5120×2880	2
						4096×2160 or lower	4
M10-2Q	Virtual Workstations	2048	4	16	35389440	5120×2880	2
						4096×2160 or lower	4



Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
M10-1Q	Virtual Desktops, Virtual Workstations	1024	8	32	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
M10-0Q	Virtual Desktops, Virtual Workstations	512	16	64	8192000	2560×1600	2 <sup>1</sup>

## B-Series Virtual GPU Types for Tesla M10

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
M10-2B	Virtual Desktops	2048	4	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
M10-2B4 <sup>4</sup>	Virtual Desktops	2048	4	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
M10-1B	Virtual Desktops	1024	8	32	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
M10-1B4 <sup>4</sup>	Virtual Desktops	1024	8	32	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
M10-0B	Virtual Desktops	512	16	64	8192000	2560×1600	2 <sup>1</sup>

### A-Series Virtual GPU Types for Tesla M10

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
M10-8A	Virtual Applications	8192	1	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
M10-4A	Virtual Applications	4096	2	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
M10-2A	Virtual Applications	2048	4	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>
M10-1A	Virtual Applications	1024	8	32	1280×1024 <sup>6</sup>	1 <sup>6</sup>

### A.1.5. Tesla M6 Virtual GPU Types

Physical GPUs per board: 1

## Q-Series Virtual GPU Types for Tesla M6

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
M6-8Q	Virtual Workstations	8192	1	1	35389440	5120×2880	2
						4096×2160 or lower	4
M6-4Q	Virtual Workstations	4096	2	2	35389440	5120×2880	2
						4096×2160 or lower	4
M6-2Q	Virtual Workstations	2048	4	4	35389440	5120×2880	2
						4096×2160 or lower	4
M6-1Q	Virtual Desktops, Virtual Workstations	1024	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
M6-0Q	Virtual Desktops, Virtual Workstations	512	16	16	8192000	2560×1600	2 <sup>1</sup>

## B-Series Virtual GPU Types for Tesla M6

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution

displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
M6-2B	Virtual Desktops	2048	4	4	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
M6-2B4 <sup>4</sup>	Virtual Desktops	2048	4	4	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
M6-1B	Virtual Desktops	1024	8	8	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
M6-1B4 <sup>4</sup>	Virtual Desktops	1024	8	8	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
M6-0B	Virtual Desktops	512	16	16	8192000	2560×1600	2 <sup>1</sup>

### A-Series Virtual GPU Types for Tesla M6

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
M6-8A	Virtual Applications	8192	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
M6-4A	Virtual Applications	4096	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
M6-2A	Virtual Applications	2048	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
M6-1A	Virtual Applications	1024	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.1.6. Tesla P100 PCIe 12GB Virtual GPU Types

Physical GPUs per board: 1

### Q-Series Virtual GPU Types for Tesla P100 PCIe 12GB

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P100C-12Q	Virtual Workstations	12288	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
P100C-6Q	Virtual Workstations	6144	2	2	58982400	7680×4320	1
						5120×2880 or lower	4
P100C-4Q	Virtual Workstations	4096	3	3	58982400	7680×4320	1
						5120×2880 or lower	4

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P100C-2Q	Virtual Workstations	2048	6	6	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
P100C-1Q	Virtual Desktops, Virtual Workstations	1024	12	12	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

### B-Series Virtual GPU Types for Tesla P100 PCIe 12GB

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P100C-2B	Virtual Desktops	2048	6	6	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
P100C-2B4 <sup>4</sup>	Virtual Desktops	2048	6	6	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P100C-1B	Virtual Desktops	1024	12	12	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
P100C-1B4 <sup>4</sup>	Virtual Desktops	1024	12	12	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla P100 PCIe 12GB

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P100C-12C	Training Workloads	12288	1	1	4096×2160 <sup>2</sup>	1
P100C-6C	Training Workloads	6144	2	2	4096×2160 <sup>2</sup>	1
P100C-4C	Inference Workloads	4096	3	3	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Tesla P100 PCIe 12GB

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P100C-12A	Virtual Applications	12288	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100C-6A	Virtual Applications	6144	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100C-4A	Virtual Applications	4096	3	3	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100C-2A	Virtual Applications	2048	6	6	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100C-1A	Virtual Applications	1024	12	12	1280×1024 <sup>6</sup>	1 <sup>6</sup>

### A.1.7. Tesla P100 PCIe 16GB Virtual GPU Types

Physical GPUs per board: 1

#### Q-Series Virtual GPU Types for Tesla P100 PCIe 16GB

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P100-16Q	Virtual Workstations	16384	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
P100-8Q	Virtual Workstations	8192	2	2	66355200	7680×4320	2
						5120×2880 or lower	4



Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P100-4Q	Virtual Workstations	4096	4	4	58982400	7680×4320	1
						5120×2880 or lower	4
P100-2Q	Virtual Workstations	2048	8	8	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
P100-1Q	Virtual Desktops, Virtual Workstations	1024	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

### B-Series Virtual GPU Types for Tesla P100 PCIe 16GB

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P100-2B	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
P100-2B4 <sup>4</sup>	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
						3840×2160	2
						2560×1600 or lower	4
P100-1B	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
P100-1B4 <sup>4</sup>	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla P100 PCIe 16GB

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P100-16C	Training Workloads	16384	1	1	4096×2160 <sup>2</sup>	1
P100-8C	Training Workloads	8192	2	2	4096×2160 <sup>2</sup>	1
P100-4C	Inference Workloads	4096	4	4	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Tesla P100 PCIe 16GB

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P100-16A	Virtual Applications	16384	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100-8A	Virtual Applications	8192	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100-4A	Virtual Applications	4096	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100-2A	Virtual Applications	2048	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100-1A	Virtual Applications	1024	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.1.8. Tesla P100 SXM2 Virtual GPU Types

Physical GPUs per board: 1

### Q-Series Virtual GPU Types for Tesla P100 SXM2

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P100X-16Q	Virtual Workstations	16384	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
P100X-8Q	Virtual Workstations	8192	2	2	66355200	7680×4320	2
						5120×2880 or lower	4

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P100X-4Q	Virtual Workstations	4096	4	4	58982400	7680×4320	1
						5120×2880 or lower	4
P100X-2Q	Virtual Workstations	2048	8	8	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
P100X-1Q	Virtual Desktops, Virtual Workstations	1024	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

### B-Series Virtual GPU Types for Tesla P100 SXM2

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P100X-2B	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
P100X-2B4 <sup>4</sup>	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
						3840×2160	2
						2560×1600 or lower	4
P100X-1B	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
P100X-1B4 <sup>4</sup>	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla P100 SXM2

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P100X-16C	Training Workloads	16384	1	1	4096×2160 <sup>2</sup>	1
P100X-8C	Training Workloads	8192	2	2	4096×2160 <sup>2</sup>	1
P100X-4C	Inference Workloads	4096	4	4	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Tesla P100 SXM2

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P100X-16A	Virtual Applications	16384	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100X-8A	Virtual Applications	8192	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100X-4A	Virtual Applications	4096	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100X-2A	Virtual Applications	2048	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P100X-1A	Virtual Applications	1024	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.1.9. Tesla P40 Virtual GPU Types

Physical GPUs per board: 1

### Q-Series Virtual GPU Types for Tesla P40

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P40-24Q	Virtual Workstations	24576	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
P40-12Q	Virtual Workstations	12288	2	2	66355200	7680×4320	2
						5120×2880 or lower	4

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P40-8Q	Virtual Workstations	8192	3	3	66355200	7680×4320	2
						5120×2880 or lower	4
P40-6Q	Virtual Workstations	6144	4	4	58982400	7680×4320	1
						5120×2880 or lower	4
P40-4Q	Virtual Workstations	4096	6	6	58982400	7680×4320	1
						5120×2880 or lower	4
P40-3Q	Virtual Workstations	3072	8	8	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
P40-2Q	Virtual Workstations	2048	12	12	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
P40-1Q	Virtual Desktops, Virtual Workstations	1024	24	24	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

## B-Series Virtual GPU Types for Tesla P40

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P40-2B	Virtual Desktops	2048	12	12	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
P40-2B4 <sup>4</sup>	Virtual Desktops	2048	12	12	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
P40-1B	Virtual Desktops	1024	24	24	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
P40-1B4 <sup>4</sup>	Virtual Desktops	1024	24	24	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla P40

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P40-24C	Training Workloads	24576	1	1	4096×2160 <sup>2</sup>	1
P40-12C	Training Workloads	12288	2	2	4096×2160 <sup>2</sup>	1



Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P40-8C	Training Workloads	8192	3	3	4096×2160 <sup>2</sup>	1
P40-6C	Training Workloads	6144	4	4	4096×2160 <sup>2</sup>	1
P40-4C	Inference Workloads	4096	6	6	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Tesla P40

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P40-24A	Virtual Applications	24576	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P40-12A	Virtual Applications	12288	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P40-8A	Virtual Applications	8192	3	3	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P40-6A	Virtual Applications	6144	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P40-4A	Virtual Applications	4096	6	6	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P40-3A	Virtual Applications	3072	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P40-2A	Virtual Applications	2048	12	12	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P40-1A	Virtual Applications	1024	24	24	1280×1024 <sup>6</sup>	1 <sup>6</sup>

### A.1.10. Tesla P6 Virtual GPU Types

Physical GPUs per board: 1

## Q-Series Virtual GPU Types for Tesla P6

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P6-16Q	Virtual Workstations	16384	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
P6-8Q	Virtual Workstations	8192	2	2	66355200	7680×4320	2
						5120×2880 or lower	4
P6-4Q	Virtual Workstations	4096	4	4	58982400	7680×4320	1
						5120×2880 or lower	4
P6-2Q	Virtual Workstations	2048	8	8	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
P6-1Q	Virtual Desktops, Virtual Workstations	1024	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

## B-Series Virtual GPU Types for Tesla P6

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between

using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P6-2B	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
P6-2B4 <sup>4</sup>	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
P6-1B	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
P6-1B4 <sup>4</sup>	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla P6

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P6-16C	Training Workloads	16384	1	1	4096×2160 <sup>2</sup>	1
P6-8C	Training Workloads	8192	2	2	4096×2160 <sup>2</sup>	1
P6-4C	Inference Workloads	4096	4	4	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Tesla P6

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P6-16A	Virtual Applications	16384	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P6-8A	Virtual Applications	8192	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P6-4A	Virtual Applications	4096	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P6-2A	Virtual Applications	2048	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P6-1A	Virtual Applications	1024	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>

### A.1.11. Tesla P4 Virtual GPU Types

Physical GPUs per board: 1

#### Q-Series Virtual GPU Types for Tesla P4

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based

on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P4-8Q	Virtual Workstations	8192	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
P4-4Q	Virtual Workstations	4096	2	2	58982400	7680×4320	1
						5120×2880 or lower	4
P4-2Q	Virtual Workstations	2048	4	4	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
P4-1Q	Virtual Desktops, Virtual Workstations	1024	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

### B-Series Virtual GPU Types for Tesla P4

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
P4-2B	Virtual Desktops	2048	4	4	17694720	5120×2880	1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
P4-2B4 <sup>4</sup>	Virtual Desktops	2048	4	4	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
P4-1B	Virtual Desktops	1024	8	8	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
P4-1B4 <sup>4</sup>	Virtual Desktops	1024	8	8	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla P4

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P4-8C	Training Workloads	8192	1	1	4096×2160 <sup>2</sup>	1
P4-4C	Inference Workloads	4096	2	2	4096×2160 <sup>2</sup>	1

## A-Series Virtual GPU Types for Tesla P4

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
P4-8A	Virtual Applications	8192	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P4-4A	Virtual Applications	4096	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P4-2A	Virtual Applications	2048	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
P4-1A	Virtual Applications	1024	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.1.12. Tesla T4 Virtual GPU Types

Physical GPUs per board: 1

### Q-Series Virtual GPU Types for Tesla T4

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
T4-16Q	Virtual Workstations	16384	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
T4-8Q	Virtual Workstations	8192	2	2	66355200	7680×4320	2

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
						5120×2880 or lower	4
T4-4Q	Virtual Workstations	4096	4	4	58982400	7680×4320	1
						5120×2880 or lower	4
T4-2Q	Virtual Workstations	2048	8	8	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
T4-1Q	Virtual Desktops, Virtual Workstations	1024	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

### B-Series Virtual GPU Types for Tesla T4

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
T4-2B	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4



Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
T4-2B4 <sup>4</sup>	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
T4-1B	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
T4-1B4 <sup>4</sup>	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla T4

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
T4-16C	Training Workloads	16384	1	1	4096×2160 <sup>2</sup>	1
T4-8C	Training Workloads	8192	2	2	4096×2160 <sup>2</sup>	1
T4-4C	Inference Workloads	4096	4	4	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Tesla T4

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
T4-16A	Virtual Applications	16384	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
T4-8A	Virtual Applications	8192	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
T4-4A	Virtual Applications	4096	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
T4-2A	Virtual Applications	2048	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
T4-1A	Virtual Applications	1024	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>

### A.1.13. Tesla V100 SXM2 Virtual GPU Types

Physical GPUs per board: 1

#### Q-Series Virtual GPU Types for Tesla V100 SXM2

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100X-16Q	Virtual Workstations	16384	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
V100X-8Q	Virtual Workstations	8192	2	2	66355200	7680×4320	2
						5120×2880 or lower	4

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100X-4Q	Virtual Workstations	4096	4	4	58982400	7680×4320	1
						5120×2880 or lower	4
V100X-2Q	Virtual Workstations	2048	8	8	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
V100X-1Q	Virtual Desktops, Virtual Workstations	1024	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

### B-Series Virtual GPU Types for Tesla V100 SXM2

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100X-2B	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
V100X-2B4 <sup>4</sup>	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
						3840×2160	2
						2560×1600 or lower	4
V100X-1B	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
V100X-1B4 <sup>4</sup>	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla V100 SXM2

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100X-16C	Training Workloads	16384	1	1	4096×2160 <sup>2</sup>	1
V100X-8C	Training Workloads	8192	2	2	4096×2160 <sup>2</sup>	1
V100X-4C	Inference Workloads	4096	4	4	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Tesla V100 SXM2

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100X-16A	Virtual Applications	16384	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100X-8A	Virtual Applications	8192	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100X-4A	Virtual Applications	4096	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100X-2A	Virtual Applications	2048	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100X-1A	Virtual Applications	1024	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.1.14. Tesla V100 SXM2 32GB Virtual GPU Types

Physical GPUs per board: 1

### Q-Series Virtual GPU Types for Tesla V100 SXM2 32GB

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100DX-32Q	Virtual Workstations	32768	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
V100DX-16Q	Virtual Workstations	16384	2	2	66355200	7680×4320	2
						5120×2880 or lower	4

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100DX-8Q	Virtual Workstations	8192	4	4	66355200	7680×4320	2
						5120×2880 or lower	4
V100DX-4Q	Virtual Workstations	4096	8	8	58982400	7680×4320	1
						5120×2880 or lower	4
V100DX-2Q	Virtual Workstations	2048	16	16	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
V100DX-1Q	Virtual Desktops, Virtual Workstations	1024	32	32	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

### B-Series Virtual GPU Types for Tesla V100 SXM2 32GB

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100DX-2B	Virtual Desktops	2048	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
						2560×1600 or lower	4
V100DX-2B4 <sup>4</sup>	Virtual Desktops	2048	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
V100DX-1B	Virtual Desktops	1024	32	32	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
V100DX-1B4 <sup>4</sup>	Virtual Desktops	1024	32	32	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla V100 SXM2 32GB

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100DX-32C	Training Workloads	32768	1	1	4096×2160 <sup>2</sup>	1
V100DX-16C	Training Workloads	16384	2	2	4096×2160 <sup>2</sup>	1
V100DX-8C	Training Workloads	8192	4	4	4096×2160 <sup>2</sup>	1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100DX-4C	Inference Workloads	4096	8	8	4096×2160 <sup>2</sup>	1

## A-Series Virtual GPU Types for Tesla V100 SXM2 32GB

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100DX-32A	Virtual Applications	32768	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100DX-16A	Virtual Applications	16384	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100DX-8A	Virtual Applications	8192	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100DX-4A	Virtual Applications	4096	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100DX-2A	Virtual Applications	2048	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100DX-1A	Virtual Applications	1024	32	32	1280×1024 <sup>6</sup>	1 <sup>6</sup>

### A.1.15. Tesla V100 PCIe Virtual GPU Types

Physical GPUs per board: 1

#### Q-Series Virtual GPU Types for Tesla V100 PCIe

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of



configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100-16Q	Virtual Workstations	16384	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
V100-8Q	Virtual Workstations	8192	2	2	66355200	7680×4320	2
						5120×2880 or lower	4
V100-4Q	Virtual Workstations	4096	4	4	58982400	7680×4320	1
						5120×2880 or lower	4
V100-2Q	Virtual Workstations	2048	8	8	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
V100-1Q	Virtual Desktops, Virtual Workstations	1024	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

## B-Series Virtual GPU Types for Tesla V100 PCIe

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100-2B	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
V100-2B4 <sup>4</sup>	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
V100-1B	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
V100-1B4 <sup>4</sup>	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla V100 PCIe

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100-16C	Training Workloads	16384	1	1	4096×2160 <sup>2</sup>	1
V100-8C	Training Workloads	8192	2	2	4096×2160 <sup>2</sup>	1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100-4C	Inference Workloads	4096	4	4	4096×2160 <sup>2</sup>	1

## A-Series Virtual GPU Types for Tesla V100 PCIe

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100-16A	Virtual Applications	16384	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100-8A	Virtual Applications	8192	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100-4A	Virtual Applications	4096	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100-2A	Virtual Applications	2048	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100-1A	Virtual Applications	1024	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>

### A.1.16. Tesla V100 PCIe 32GB Virtual GPU Types

Physical GPUs per board: 1

#### Q-Series Virtual GPU Types for Tesla V100 PCIe 32GB

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100D-32Q	Virtual Workstations	32768	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
V100D-16Q	Virtual Workstations	16384	2	2	66355200	7680×4320	2
						5120×2880 or lower	4
V100D-8Q	Virtual Workstations	8192	4	4	66355200	7680×4320	2
						5120×2880 or lower	4
V100D-4Q	Virtual Workstations	4096	8	8	58982400	7680×4320	1
						5120×2880 or lower	4
V100D-2Q	Virtual Workstations	2048	16	16	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
V100D-1Q	Virtual Desktops, Virtual Workstations	1024	32	32	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

## B-Series Virtual GPU Types for Tesla V100 PCIe 32GB

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100D-2B	Virtual Desktops	2048	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
V100D-2B4 <sup>4</sup>	Virtual Desktops	2048	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
V100D-1B	Virtual Desktops	1024	32	32	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
V100D-1B4 <sup>4</sup>	Virtual Desktops	1024	32	32	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla V100 PCIe 32GB

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100D-32C	Training Workloads	32768	1	1	4096×2160 <sup>2</sup>	1
V100D-16C	Training Workloads	16384	2	2	4096×2160 <sup>2</sup>	1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100D-8C	Training Workloads	8192	4	4	4096×2160 <sup>2</sup>	1
V100D-4C	Inference Workloads	4096	8	8	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Tesla V100 PCIe 32GB

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100D-32A	Virtual Applications	32768	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100D-16A	Virtual Applications	16384	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100D-8A	Virtual Applications	8192	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100D-4A	Virtual Applications	4096	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100D-2A	Virtual Applications	2048	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100D-1A	Virtual Applications	1024	32	32	1280×1024 <sup>6</sup>	1 <sup>6</sup>

### A.1.17. Tesla V100S PCIe 32GB Virtual GPU Types

Physical GPUs per board: 1

#### Q-Series Virtual GPU Types for Tesla V100S PCIe 32GB

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based

on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100S-32Q	Virtual Workstations	32768	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
V100S-16Q	Virtual Workstations	16384	2	2	66355200	7680×4320	2
						5120×2880 or lower	4
V100S-8Q	Virtual Workstations	8192	4	4	66355200	7680×4320	2
						5120×2880 or lower	4
V100S-4Q	Virtual Workstations	4096	8	8	58982400	7680×4320	1
						5120×2880 or lower	4
V100S-2Q	Virtual Workstations	2048	16	16	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
V100S-1Q	Virtual Desktops, Virtual Workstations	1024	32	32	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

### B-Series Virtual GPU Types for Tesla V100S PCIe 32GB

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of

configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100S-2B	Virtual Desktops	2048	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
V100S-1B	Virtual Desktops	1024	32	32	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla V100S PCIe 32GB

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100S-32C	Training Workloads	32768	1	1	4096×2160 <sup>2</sup>	1
V100S-16C	Training Workloads	16384	2	2	4096×2160 <sup>2</sup>	1
V100S-8C	Training Workloads	8192	4	4	4096×2160 <sup>2</sup>	1
V100S-4C	Inference Workloads	4096	8	8	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Tesla V100S PCIe 32GB

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.



Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100S-32A	Virtual Applications	32768	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100S-16A	Virtual Applications	16384	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100S-8A	Virtual Applications	8192	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100S-4A	Virtual Applications	4096	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100S-2A	Virtual Applications	2048	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100S-1A	Virtual Applications	1024	32	32	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.1.18. Tesla V100 FHHL Virtual GPU Types

Physical GPUs per board: 1

### Q-Series Virtual GPU Types for Tesla V100 FHHL

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100L-16Q	Virtual Workstations	16384	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
V100L-8Q	Virtual Workstations	8192	2	2	66355200	7680×4320	2

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
						5120×2880 or lower	4
V100L-4Q	Virtual Workstations	4096	4	4	58982400	7680×4320	1
						5120×2880 or lower	4
V100L-2Q	Virtual Workstations	2048	8	8	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
V100L-1Q	Virtual Desktops, Virtual Workstations	1024	16	16	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

### B-Series Virtual GPU Types for Tesla V100 FHHL

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100L-2B	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
V100L-2B4 <sup>4</sup>	Virtual Desktops	2048	8	8	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
V100L-1B	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>
V100L-1B4 <sup>4</sup>	Virtual Desktops	1024	16	16	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Tesla V100 FHHL

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100L-16C	Training Workloads	16384	1	1	4096×2160 <sup>2</sup>	1
V100L-8C	Training Workloads	8192	2	2	4096×2160 <sup>2</sup>	1
V100L-4C	Inference Workloads	4096	4	4	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Tesla V100 FHHL

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
V100L-16A	Virtual Applications	16384	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100L-8A	Virtual Applications	8192	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100L-4A	Virtual Applications	4096	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100L-2A	Virtual Applications	2048	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
V100L-1A	Virtual Applications	1024	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.1.19. Quadro RTX 8000 Virtual GPU Types

Physical GPUs per board: 1

### Q-Series Virtual GPU Types for Quadro RTX 8000

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
RTX8000-48Q	Virtual Workstations	49152	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
RTX8000-24Q	Virtual Workstations	24576	2	2	66355200	7680×4320	2
						5120×2880 or lower	4

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
RTX8000-16Q	Virtual Workstations	16384	3	3	66355200	7680×4320	2
						5120×2880 or lower	4
RTX8000-12Q	Virtual Workstations	12288	4	4	66355200	7680×4320	2
						5120×2880 or lower	4
RTX8000-8Q	Virtual Workstations	8192	6	6	66355200	7680×4320	2
						5120×2880 or lower	4
RTX8000-6Q	Virtual Workstations	6144	8	8	58982400	7680×4320	1
						5120×2880 or lower	4
RTX8000-4Q	Virtual Workstations	4096	12	12	58982400	7680×4320	1
						5120×2880 or lower	4
RTX8000-3Q	Virtual Workstations	3072	16	16	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
RTX8000-2Q	Virtual Workstations	2048	24	24	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
RTX8000-1Q	Virtual Workstations	1024	32 <sup>L</sup>	32	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

## B-Series Virtual GPU Types for Quadro RTX 8000

Required license edition: GRID Virtual PC or Quadro vDWS

<sup>7</sup>

The maximum vGPUs per GPU is limited to 32.

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
RTX8000-2B	Virtual Desktops	2048	24	24	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
RTX8000-1B	Virtual Desktops	1024	32	32	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Quadro RTX 8000

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
RTX8000-48C	Training Workloads	49152	1	1	4096×2160 <sup>2</sup>	1
RTX8000-24C	Training Workloads	24576	2	2	4096×2160 <sup>2</sup>	1
RTX8000-16C	Training Workloads	16384	3	3	4096×2160 <sup>2</sup>	1
RTX8000-12C	Training Workloads	12288	4	4	4096×2160 <sup>2</sup>	1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
RTX8000-8C	Training Workloads	8192	6	6	4096×2160 <sup>2</sup>	1
RTX8000-6C	Training Workloads	6144	8	8	4096×2160 <sup>2</sup>	1
RTX8000-4C	Inference Workloads	4096	8 <sup>3</sup>	8	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Quadro RTX 8000

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
RTX8000-48A	Virtual Applications	49152	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000-24A	Virtual Applications	24576	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000-16A	Virtual Applications	16384	3	3	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000-12A	Virtual Applications	12288	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000-8A	Virtual Applications	8192	6	6	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000-6A	Virtual Applications	6144	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000-4A	Virtual Applications	4096	12	12	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000-3A	Virtual Applications	3072	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000-2A	Virtual Applications	2048	24	24	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000-1A	Virtual Applications	1024	32 <sup>7</sup>	32	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.1.20. Quadro RTX 8000 Passive Virtual GPU Types

Physical GPUs per board: 1

### Q-Series Virtual GPU Types for Quadro RTX 8000 Passive

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
RTX8000P-48Q	Virtual Workstations	49152	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
RTX8000P-24Q	Virtual Workstations	24576	2	2	66355200	7680×4320	2
						5120×2880 or lower	4
RTX8000P-16Q	Virtual Workstations	16384	3	3	66355200	7680×4320	2
						5120×2880 or lower	4
RTX8000P-12Q	Virtual Workstations	12288	4	4	66355200	7680×4320	2
						5120×2880 or lower	4
RTX8000P-8Q	Virtual Workstations	8192	6	6	66355200	7680×4320	2
						5120×2880 or lower	4
RTX8000P-6Q	Virtual Workstations	6144	8	8	58982400	7680×4320	1
						5120×2880 or lower	4



Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
RTX8000P-4Q	Virtual Workstations	4096	12	12	58982400	7680×4320	1
						5120×2880 or lower	4
RTX8000P-3Q	Virtual Workstations	3072	16	16	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
RTX8000P-2Q	Virtual Workstations	2048	24	24	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
RTX8000P-1Q	Virtual Workstations	1024	32 <sup>8</sup>	32	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

## B-Series Virtual GPU Types for Quadro RTX 8000 Passive

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
RTX8000P-2B	Virtual Desktops	2048	24	24	17694720	5120×2880	1
						4096×2160	2

<sup>8</sup>

The maximum vGPUs per GPU is limited to 32.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
						3840×2160	2
						2560×1600 or lower	4
RTX8000P-1B	Virtual Desktops	1024	32	32	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Quadro RTX 8000 Passive

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
RTX8000P-48C	Training Workloads	49152	1	1	4096×2160 <sup>2</sup>	1
RTX8000P-24C	Training Workloads	24576	2	2	4096×2160 <sup>2</sup>	1
RTX8000P-16C	Training Workloads	16384	3	3	4096×2160 <sup>2</sup>	1
RTX8000P-12C	Training Workloads	12288	4	4	4096×2160 <sup>2</sup>	1
RTX8000P-8C	Training Workloads	8192	6	6	4096×2160 <sup>2</sup>	1
RTX8000P-6C	Training Workloads	6144	8	8	4096×2160 <sup>2</sup>	1
RTX8000P-4C	Inference Workloads	4096	8 <sup>3</sup>	8	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Quadro RTX 8000 Passive

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
RTX8000P-48A	Virtual Applications	49152	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000P-24A	Virtual Applications	24576	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000P-16A	Virtual Applications	16384	3	3	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000P-12A	Virtual Applications	12288	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000P-8A	Virtual Applications	8192	6	6	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000P-6A	Virtual Applications	6144	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000P-4A	Virtual Applications	4096	12	12	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000P-3A	Virtual Applications	3072	16	16	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000P-2A	Virtual Applications	2048	24	24	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX8000P-1A	Virtual Applications	1024	32 <sup>B</sup>	32	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.1.21. Quadro RTX 6000 Virtual GPU Types

Physical GPUs per board: 1

### Q-Series Virtual GPU Types for Quadro RTX 6000

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
RTX6000-24Q	Virtual Workstations	24576	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
RTX6000-12Q	Virtual Workstations	12288	2	2	66355200	7680×4320	2
						5120×2880 or lower	4
RTX6000-8Q	Virtual Workstations	8192	3	3	66355200	7680×4320	2
						5120×2880 or lower	4
RTX6000-6Q	Virtual Workstations	6144	4	4	58982400	7680×4320	1
						5120×2880 or lower	4
RTX6000-4Q	Virtual Workstations	4096	6	6	58982400	7680×4320	1
						5120×2880 or lower	4
RTX6000-3Q	Virtual Workstations	3072	8	8	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
RTX6000-2Q	Virtual Workstations	2048	12	12	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
RTX6000-1Q	Virtual Workstations	1024	24	24	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4

## B-Series Virtual GPU Types for Quadro RTX 6000

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
RTX6000-2B	Virtual Desktops	2048	12	12	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
RTX6000-1B	Virtual Desktops	1024	24	24	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Quadro RTX 6000

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
RTX6000-24C	Training Workloads	24576	1	1	4096×2160 <sup>2</sup>	1
RTX6000-12C	Training Workloads	12288	2	2	4096×2160 <sup>2</sup>	1
RTX6000-8C	Training Workloads	8192	3	3	4096×2160 <sup>2</sup>	1
RTX6000-6C	Training Workloads	6144	4	4	4096×2160 <sup>2</sup>	1

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
RTX6000-4C	Inference Workloads	4096	6	6	4096×2160 <sup>2</sup>	1

## A-Series Virtual GPU Types for Quadro RTX 6000

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
RTX6000-24A	Virtual Applications	24576	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000-12A	Virtual Applications	12288	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000-8A	Virtual Applications	8192	3	3	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000-6A	Virtual Applications	6144	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000-4A	Virtual Applications	4096	6	6	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000-3A	Virtual Applications	3072	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000-2A	Virtual Applications	2048	12	12	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000-1A	Virtual Applications	1024	24	24	1280×1024 <sup>6</sup>	1 <sup>6</sup>

### A.1.22. Quadro RTX 6000 Passive Virtual GPU Types

Physical GPUs per board: 1

#### Q-Series Virtual GPU Types for Quadro RTX 6000 Passive

Required license edition: Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
RTX6000P-24Q	Virtual Workstations	24576	1	1	66355200	7680×4320	2
						5120×2880 or lower	4
RTX6000P-12Q	Virtual Workstations	12288	2	2	66355200	7680×4320	2
						5120×2880 or lower	4
RTX6000P-8Q	Virtual Workstations	8192	3	3	66355200	7680×4320	2
						5120×2880 or lower	4
RTX6000P-6Q	Virtual Workstations	6144	4	4	58982400	7680×4320	1
						5120×2880 or lower	4
RTX6000P-4Q	Virtual Workstations	4096	6	6	58982400	7680×4320	1
						5120×2880 or lower	4
RTX6000P-3Q	Virtual Workstations	3072	8	8	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
RTX6000P-2Q	Virtual Workstations	2048	12	12	35389440	7680×4320	1
						5120×2880	2
						4096×2160 or lower	4
RTX6000P-1Q	Virtual Workstations	1024	24	24	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
						2560×1600 or lower	4

### B-Series Virtual GPU Types for Quadro RTX 6000 Passive

Required license edition: GRID Virtual PC or Quadro vDWS

These vGPU types support a maximum combined resolution based on the number of available pixels, which is determined by their frame buffer size. You can choose between using a small number of high resolution displays or a larger number of lower resolution displays with these vGPU types. The maximum number of displays per vGPU is based on a configuration in which all displays have the same resolution. For examples of configurations with a mixture of display resolutions, see [Mixed Display Configurations for B-Series and Q-Series vGPUs](#).

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Available Pixels	Display Resolution	Virtual Displays per vGPU
RTX6000P-2B	Virtual Desktops	2048	12	12	17694720	5120×2880	1
						4096×2160	2
						3840×2160	2
						2560×1600 or lower	4
RTX6000P-1B	Virtual Desktops	1024	24	24	16384000	5120×2880	1
						4096×2160	1
						3840×2160	1
						2560×1600 or lower	4 <sup>5</sup>

### C-Series Virtual GPU Types for Quadro RTX 6000 Passive

Required license edition: vCS or Quadro vDWS

These vGPU types support a single display with a fixed maximum resolution.



Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
RTX6000P-24C	Training Workloads	24576	1	1	4096×2160 <sup>2</sup>	1
RTX6000P-12C	Training Workloads	12288	2	2	4096×2160 <sup>2</sup>	1
RTX6000P-8C	Training Workloads	8192	3	3	4096×2160 <sup>2</sup>	1
RTX6000P-6C	Training Workloads	6144	4	4	4096×2160 <sup>2</sup>	1
RTX6000P-4C	Inference Workloads	4096	6	6	4096×2160 <sup>2</sup>	1

### A-Series Virtual GPU Types for Quadro RTX 6000 Passive

Required license edition: GRID Virtual Applications

These vGPU types support a single display with a fixed maximum resolution.

Virtual GPU Type	Intended Use Case	Frame Buffer (MB)	Maximum vGPUs per GPU	Maximum vGPUs per Board	Maximum Display Resolution	Virtual Displays per vGPU
RTX6000P-24A	Virtual Applications	24576	1	1	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000P-12A	Virtual Applications	12288	2	2	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000P-8A	Virtual Applications	8192	3	3	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000P-6A	Virtual Applications	6144	4	4	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000P-4A	Virtual Applications	4096	6	6	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000P-3A	Virtual Applications	3072	8	8	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000P-2A	Virtual Applications	2048	12	12	1280×1024 <sup>6</sup>	1 <sup>6</sup>
RTX6000P-1A	Virtual Applications	1024	24	24	1280×1024 <sup>6</sup>	1 <sup>6</sup>

## A.2. Mixed Display Configurations for B-Series and Q-Series vGPUs

### A.2.1. Mixed Display Configurations for B-Series vGPUs

Virtual GPU Type	Available Pixels	Available Pixel Basis	Maximum Displays	Sample Mixed Display Configurations
-2B	17694720	2 4096×2160 displays	4	1 4096×2160 display plus 2 2560×1600 displays
-2B4	17694720	2 4096×2160 displays	4	1 4096×2160 display plus 2 2560×1600 displays
-1B	16384000	4 2560×1600 displays	4	1 4096×2160 display plus 1 2560×1600 display
-1B4	16384000	4 2560×1600 displays	4	1 4096×2160 display plus 1 2560×1600 display
-0B	8192000	2 2560×1600 displays	2	1 2560×1600 display plus 1 1280×1024 display

### A.2.2. Mixed Display Configurations for Q-Series vGPUs Based on the NVIDIA Maxwell Architecture

Virtual GPU Type	Available Pixels	Available Pixel Basis	Maximum Displays	Sample Mixed Display Configurations
-8Q	35389440	4 4096×2160 displays	4	1 5120×2880 display plus 2 4096×2160 displays
-4Q	35389440	4 4096×2160 displays	4	1 5120×2880 display plus 2 4096×2160 displays
-2Q	35389440	4 4096×2160 displays	4	1 5120×2880 display plus 2 4096×2160 displays
-1Q	17694720	2 4096×2160 displays	4	1 4096×2160 display plus 2 2560×1600 displays
-0Q	8192000	2 2560×1600 displays	2	1 2560×1600 display plus 1 1280×1024 display

### A.2.3. Mixed Display Configurations for Q-Series vGPUs Based on Architectures after NVIDIA Maxwell

Virtual GPU Type	Available Pixels	Available Pixel Basis	Maximum Displays	Sample Mixed Display Configurations
-8Q and above	66355200	2 7680×4320 displays	4	1 7680×4320 display plus 2 5120×2880 displays
				1 7680×4320 display plus 3 4096×2160 displays
-6Q	58982400	4 5120×2880 displays	4	1 7680×4320 display plus 1 5120×2880 display
-4Q	58982400	4 5120×2880 displays	4	1 7680×4320 display plus 1 5120×2880 display
-3Q	35389440	4 4096×2160 displays	4	1 5120×2880 display plus 2 4096×2160 displays
-2Q	35389440	4 4096×2160 displays	4	1 5120×2880 display plus 2 4096×2160 displays
-1Q	17694720	2 4096×2160 displays	4	1 4096×2160 display plus 2 2560×1600 displays

---

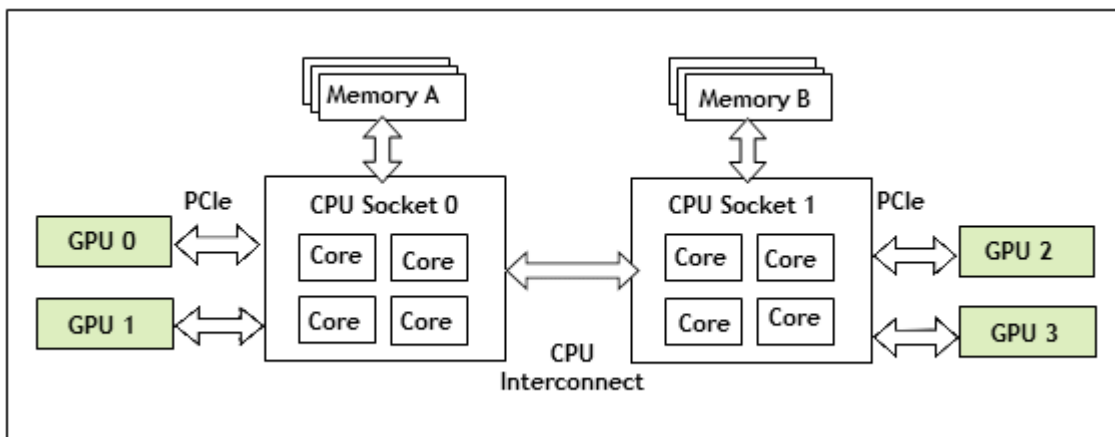
# Appendix B. Allocation Strategies

Strategies for allocating physical hardware resources to VMs and vGPUs can improve the performance of VMs running with NVIDIA vGPU. They include strategies for pinning VM CPU cores to physical cores on Non-Uniform Memory Access (NUMA) platforms, allocating VMs to CPUs, and allocating vGPUs to physical GPUs. These allocation strategies are supported by Citrix Hypervisor and VMware vSphere.

## B.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 32](#):

Figure 32. 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.

## B.1.1. Obtaining Best Performance on a NUMA Platform with Citrix Hypervisor

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.

## B.1.2. Obtaining Best Performance on a NUMA Platform with VMware vSphere ESXi

For some types of workloads or system configurations, you can optimize performance by specifying the placement of VMs explicitly. For best performance, pin each VM to the NUMA node to which the physical GPU hosting the VM's vGPU is attached.

The following types of workloads and system configurations benefit from explicit placement of VMs:

- ▶ Memory-intensive workloads, such as an in-memory database or an HPC application with a large data set
- ▶ A hypervisor host configured with a small number of virtual machines

VMware vSphere ESXi provides the **NUMA Node Affinity** option for specifying the placement of VMs explicitly. For general information about the options in VMware vSphere ESXi for NUMA placement, see [Specifying NUMA Controls](#) in the VMware documentation.

Before setting the **NUMA Node Affinity** option, run the `nvidia-smi topo -m` command in the ESXi host shell to determine the NUMA affinity of the GPU device.

After determining the NUMA affinity of the GPU device, set the **NUMA Node Affinity** option as explained in [Associate Virtual Machines with Specified NUMA Nodes](#) in the VMware documentation.

## B.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 and VMware vSphere ESXi use a different GPU allocation policy by default.

- ▶ 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.
- ▶ VMware vSphere ESXi creates GPU groups with a default allocation policy of *breadth-first*.  
See [Modifying GPU Allocation Policy on VMware vSphere](#) for details on switching the allocation policy to depth-first.



**Note:** 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.

---

# Appendix C. Configuring x11vnc for Checking the GPU in a Linux Server

x11vnc is a virtual network computing (VNC) server that provides remote access to an existing X session with any VNC viewer. You can use x11vnc to confirm that the NVIDIA GPU in a Linux server to which no display devices are directly connected is working as expected. Examples of servers to which no display devices are directly connected include a VM that is configured with NVIDIA vGPU, a VM that is configured with a pass-through GPU, and a headless physical host in a bare-metal deployment.

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

- ▶ The NVIDIA vGPU software graphics driver for Linux is installed on the server.
- ▶ A secure shell (SSH) client is installed on your local system:
  - ▶ On Windows, you must use a third-party SSH client such as PuTTY.
  - ▶ On Linux, you can run the SSH client that is included with the OS from a shell or terminal window.

Configuring x11vnc involves following the sequence of instructions in these sections:

1. [Configuring the Xorg Server on the Linux Server](#)
2. [Installing and Configuring x11vnc on the Linux Server](#)
3. [Using a VNC Client to Connect to the Linux Server](#)

After connecting to the server, you can use **NVIDIA X Server Settings** to confirm that the NVIDIA GPU is working as expected.

## C.1. Configuring the Xorg Server on the Linux Server

You must configure the Xorg server to specify which GPU or vGPU is to be used by the Xorg server if multiple GPUs are installed in your server and to allow the Xorg server to start even if no connected display devices can be detected.

1. Log in to the Linux server.
2. Determine the PCI bus identifier of the GPUs or vGPUs on the server.

```
# nvidia-xconfig --query-gpu-info
Number of GPUs: 1

GPU #0:
Name      : GRID T4-2Q
UUID     : GPU-ea80de2d-1dd8-11b2-8305-c955f034e718
PCI BusID : PCI:2:2:0

Number of Display Devices: 0
```

3. In a plain text editor, edit the `/etc/X11/xorg.conf` file to specify the GPU is to be used by the Xorg server and allow the Xorg server to start even if no connected display devices can be detected.
  - a). In the `Device` section, add the PCI bus identifier of GPU to be used by the Xorg server.

```
Section "Device"
    Identifier      "Device0"
    Driver          "nvidia"
    VendorName     "NVIDIA Corporation"
    BusID           "PCI:2:2:0"
EndSection
```



**Note:** The three numbers in the `PCI BusID` obtained by `nvidia-xconfig` in the previous step are hexadecimal numbers. They must be converted to decimal numbers in the PCI bus identifier in the `Device` section. For example, if the PCI bus identifier obtained in the previous step is `PCI:A:10:0`, it must be specified as `PCI:10:16:0` in the PCI bus identifier in the `Device` section.

- b). In the `Screen` section, ensure that the `AllowEmptyInitialConfiguration` option is set to `True`.

```
Section "Screen"
    Identifier      "Screen0"
    Device         "Device0"
    Option          "AllowEmptyInitialConfiguration" "True"
EndSection
```

4. Restart the Xorg server in one of the following ways:
  - ▶ Restart the server.
  - ▶ Run the `startx` command.
  - ▶ If the Linux server is in run level 3, run the `init 5` command to run the server in graphical mode.
5. Confirm that the Xorg server is running.



```
# ps -ef | grep X
```

On Ubuntu, this command displays output similar to the following example.

```
root      16500 16499  2 03:01 tty2      00:00:00 /usr/lib/xorg/Xorg -nolisten
tcp :0 -auth /tmp/serverauth.s7CE4mMeIz
root      1140  1126  0 18:46 tty1      00:00:00 /usr/lib/xorg/Xorg vt1 -displayfd
3 -auth /run/user/121/gdm/Xauthority -background none -noreset -keeppty -verbose
3
root      17011 17108  0 18:50 pts/0      00:00:00 grep --color=auto X
```

On Red Hat Enterprise Linux, this command displays output similar to the following example.

```
root      5285  5181  0 16:29 pts/0      00:00:00 grep --color=auto X
root      5880    1  0 Jun13 ?          00:00:00 /usr/bin/abrt-watch-log -F
Backtrace /var/log/Xorg.0.log -- /usr/bin/abrt-dump-xorg -xD
root      7039  6289  0 Jun13 tty1      00:00:03 /usr/bin/X :0 -background none -
noreset -audit 4 -verbose -auth /run/gdm/auth-for-gdm-vr4MFC/database -seat seat0
vt1
```

## C.2. Installing and Configuring x11vnc on the Linux Server

Unlike other VNC servers, such as TigerVNC or Vino, x11vnc does not create an extra X session for remote access. Instead, x11vnc provides remote access to the existing X session on the Linux server.

1. Install the required `x11vnc` package and any dependent packages.
  - ▶ For distributions based on Red Hat, use the `yum` package manager to install the `x11vnc` package.

```
# yum install x11vnc
```

- ▶ For distributions based on Debian, use the `apt` package manager to install the `x11vnc` package.

```
# sudo apt install x11vnc
```

- ▶ For SuSE Linux distributions, install x11vnc from the [x11vnc openSUSE Software](#) page.

2. Get the display numbers of the servers for the Xorg server.

```
# cat /proc/*/environ 2>/dev/null | tr '\0' '\n' | grep '^DISPLAY=:' | uniq
DISPLAY=:0
DISPLAY=:100
```

3. Start the x11vnc server, specifying the display number to use.

The following example starts the x11vnc server on display 0 on a Linux server that is running the Gnome desktop.

```
# x11vnc -display :0 -auth /run/user/121/gdm/Xauthority -forever \
-shared -ncache -bg
```



**Note:** If you are using a C-series vGPU, omit the `-ncache` option.

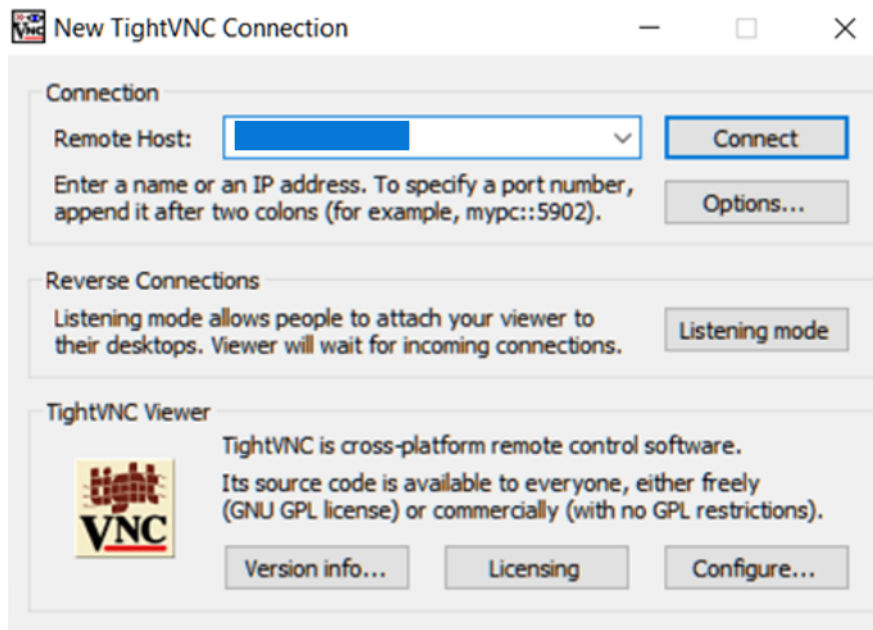
The x11vnc server starts on display `hostname:0`, for example, `my-linux-host:0`.

```
26/03/20200 04:23:13
The VNC desktop is:      my-linux-host:0
```

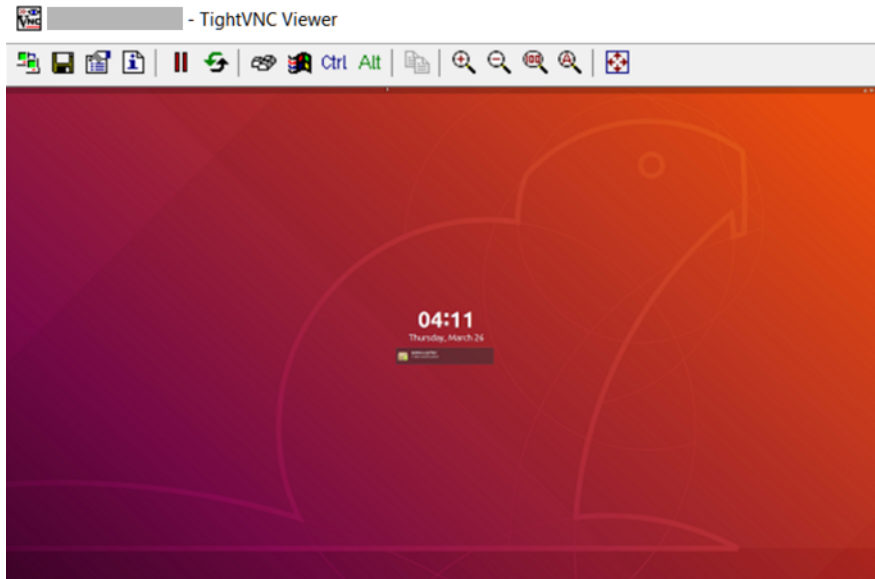
PORT=5900

## C.3. Using a VNC Client to Connect to the Linux Server

1. On your client computer, install a VNC client such as TightVNC.
2. Start the VNC client and connect to the Linux server.



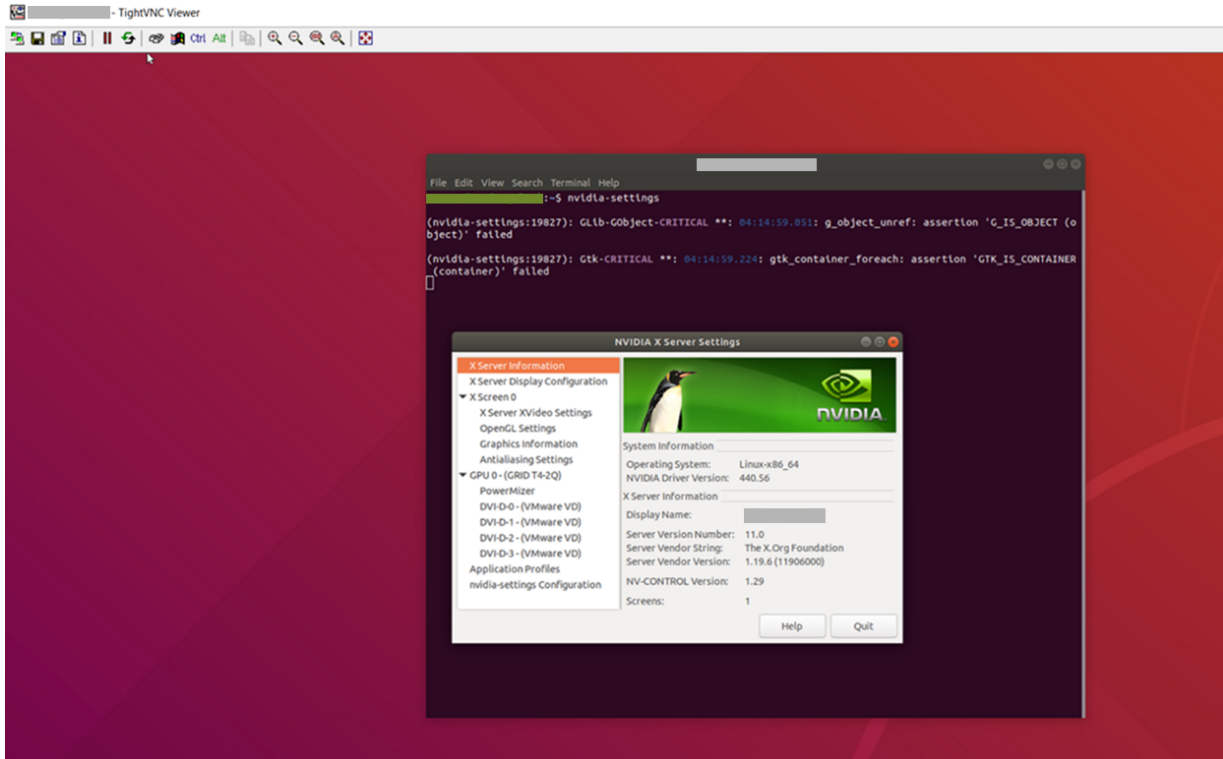
The X session on the server opens in the VNC client.



**Troubleshooting:** If your VNC client cannot connect to the server, change permissions **on the Linux server** as follows:

1. Allow the VNC client to connect to the server by making one of the following changes:
  - ▶ Disable the firewall and the `iptables` service.
  - ▶ Open the VNC port in the firewall.
2. Ensure that permissive mode is enabled for Security Enhanced Linux (SELinux).

After connecting to the server, you can use **NVIDIA X Server Settings** to confirm that the NVIDIA GPU is working as expected.



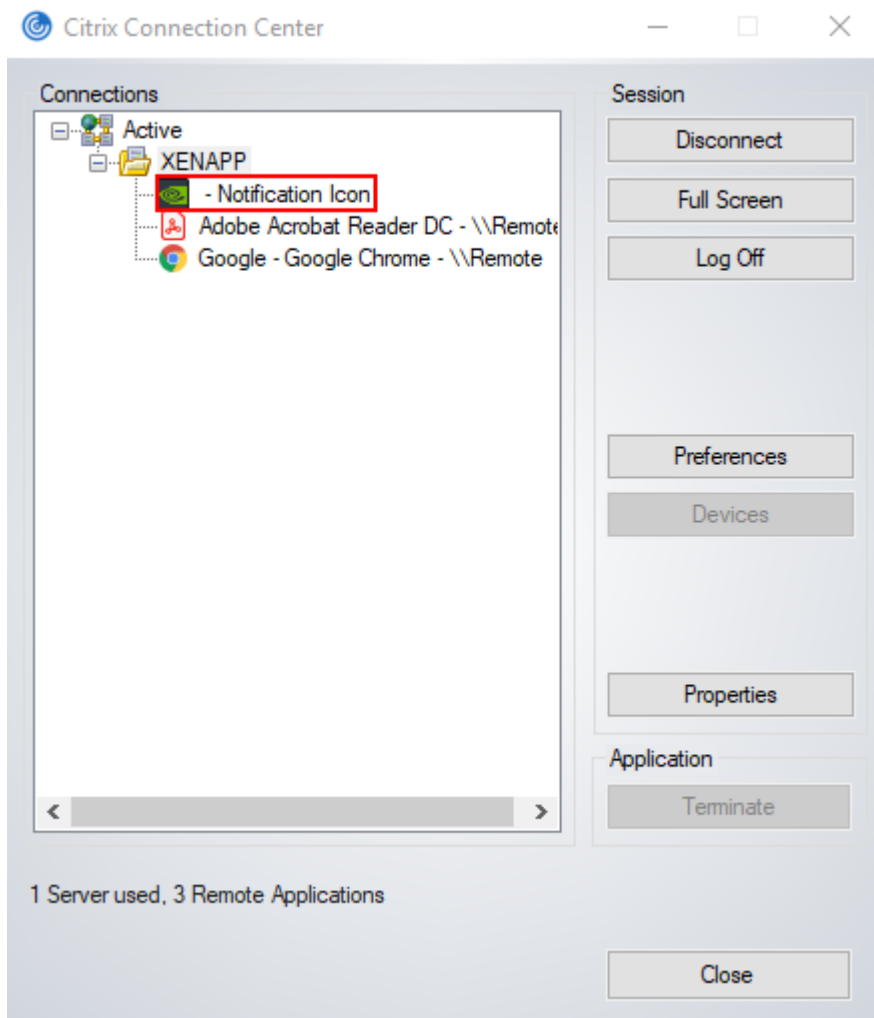
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# Appendix D. Disabling **NVIDIA** **Notification Icon** for Citrix Published Application User Sessions

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](#).



**Note:** If an administrator has enabled the **NVIDIA Notification Icon** application for the administrator's own session, the application is enabled for all users' sessions, even the sessions of users who have previously disabled the application.

## D.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.

## D.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 E. 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.

## E.1. Opening a dom0 shell

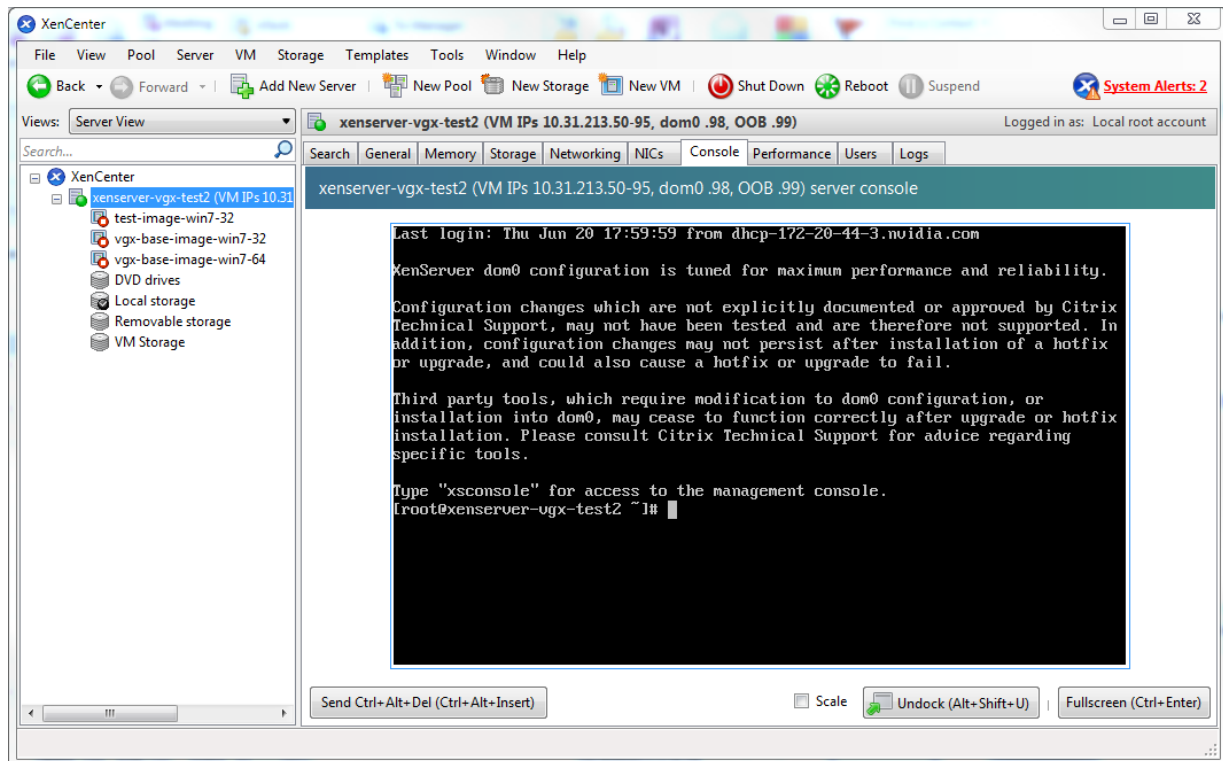
Most configuration commands must be run in a command shell in the Citrix Hypervisor dom0 domain. You can open a shell in the Citrix Hypervisor dom0 domain in any of the following ways:

- ▶ Using the console window in XenCenter
- ▶ Using a standalone secure shell (SSH) client

### E.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 33. Connecting to the dom0 shell by using XenCenter



## E.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.

## E.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

### E.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>
```

## E.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-8.2-450.248.03.x86_64.rpm .
[root@xenserver ~]#
```

## E.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

### E.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`:

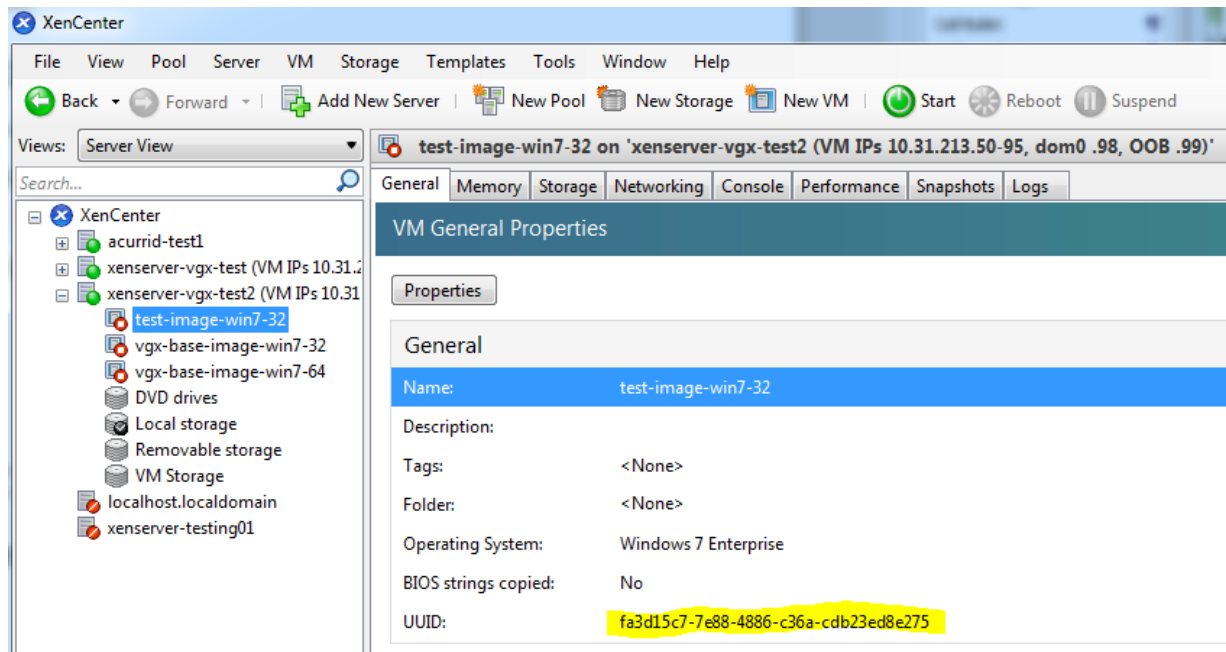
```
[root@xenserver ~]# xe vm-list name-label=test-image-win7-32
uuid ( RO)           : fa3d15c7-7e88-4886-c36a-cdb23ed8e275
  name-label ( RW): test-image-win7-32
  power-state ( RO): halted
```

### E.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 34. Using XenCenter to determine a VM's UUID



## E.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](#).

## E.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 aperfmperf
    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

## E.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.

## E.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.

## E.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
```

## E.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.

---

# Appendix F. Citrix Hypervisor vGPU Management

You can perform Citrix Hypervisor advanced vGPU management techniques by using XenCenter and by using `xe` command line operations.

## F.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.

### F.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.

#### F.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 ~]#
```



### F.1.1.2. Viewing Detailed Information About a pgpu Object

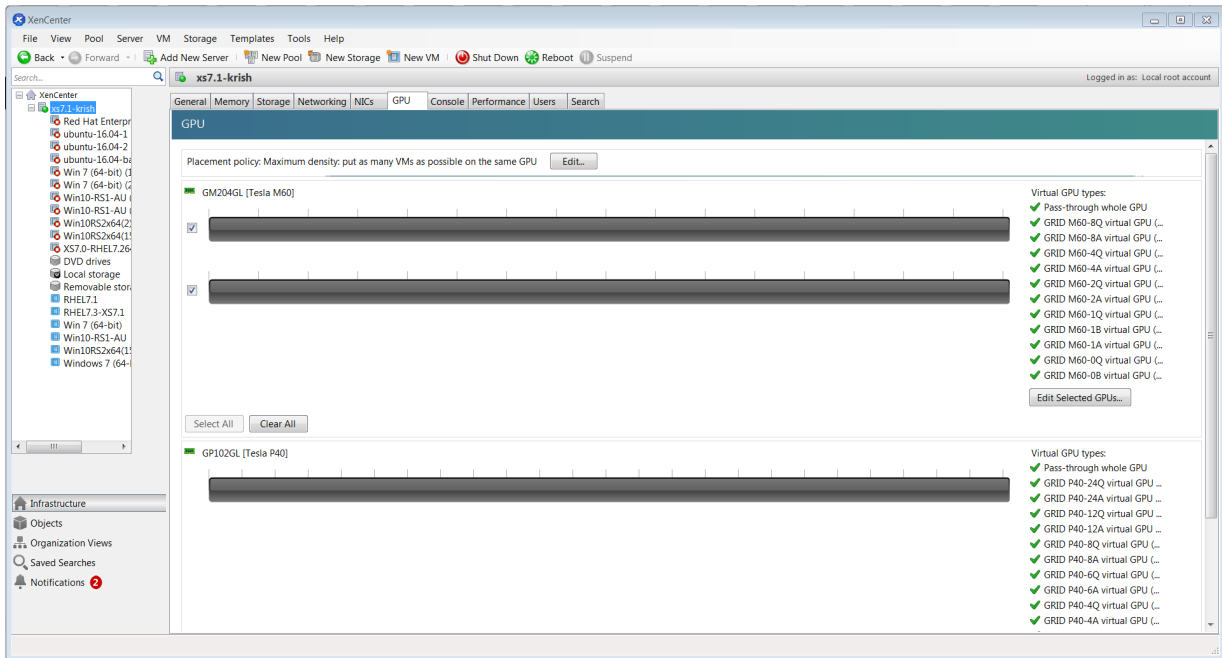
To view detailed information about a pgpu, use `xe pgpu-param-list`:

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

### F.1.1.3. Viewing physical GPUs in XenCenter

To view physical GPUs in XenCenter, click on the server's **GPU** tab:

Figure 35. Physical GPU display in XenCenter



## F.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.

### F.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
uid ( 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

uid ( 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 ~]#
```

## F.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 ~]#
```

## F.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.

### F.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 ~]#
```

### F.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-a4048a5bdfd7; 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-a0c0-106bddd91019;
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-a4048a5bdfd7; 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-a0c0-106bddd91019;
d27f84a2-53f8-4430-ad15-0eca225cd974
allocation-algorithm ( RW): depth-first
[root@xenserver ~]
```

### F.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](#)

## F.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](#).



#### Note:

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.

## F.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](#).

### F.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-a7536a1a838; 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-a7536a1a838; 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 ~]#

```



**Note:** 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>
```

## F.3.2. Controlling the vGPU types enabled on specific physical GPUs

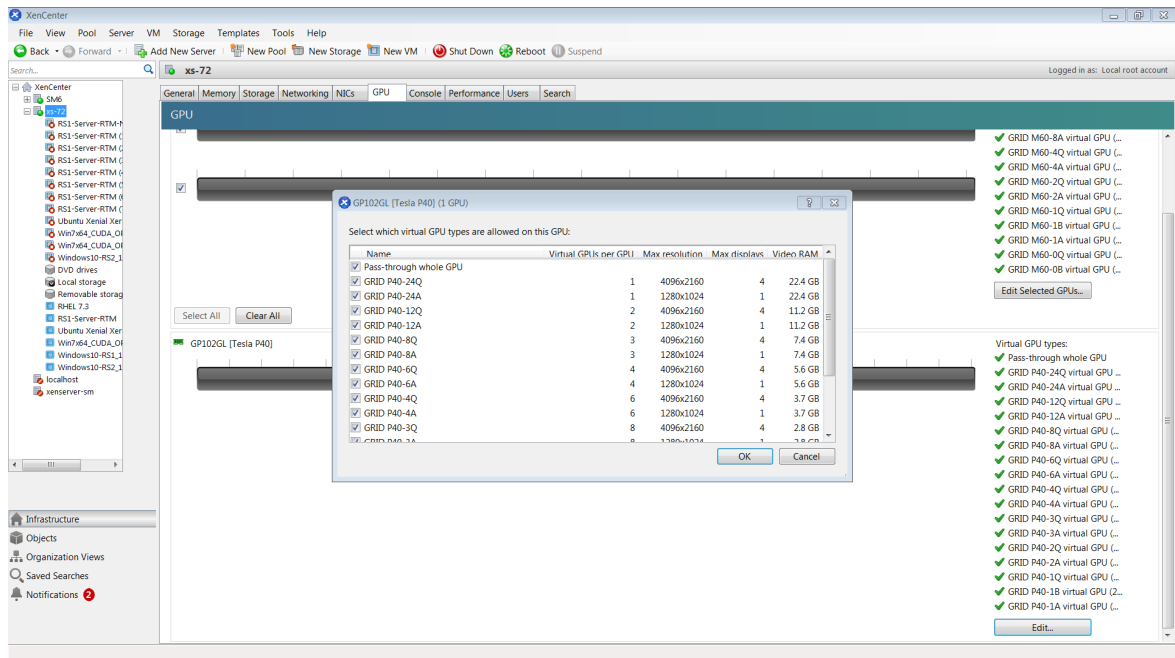
Physical GPUs support several vGPU types, as defined in [Virtual GPU Types for Supported GPUs](#) and the “pass-through” type that is used to assign an entire physical GPU to a VM (see [Using GPU Pass-Through on Citrix Hypervisor](#)).

### F.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 36. Editing a GPU's enabled vGPU types using XenCenter



### F.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)    : bfel603d-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-le5e-4c33-bedb-e6dlae472fec;
f5583e39-2540-440d-a0ee-dde9f0783abf; a18e46ff-4d05-4322-b040-667ce77d78a8;
ade119a9-84e1-435f-b0e9-14c162e212fb; 2560d066-054a-48a9-a44d-3f3f90493a00;
47858f38-045d-4a05-9blc-9128fee6b0ab; lfb527f6-493f-442b-abe2-94a6fafd49ce;
78b8e044-09ae-4a4c-8a96-b20c7a585842; 18ed7e7e-f8b7-496e-9784-8ba4e35acaa3;
48681d88-c4e5-4e39-85ff-c9ba12e8e484 ; cc3dbbf-4b83-400d-8c52-811948b7f8c4;
8elad75a-ed5f-4609-83ff-5f9bca9aaca2; 840389a0-f511-4f90-8153-8a749d85b09e;
a2042742-da67-4613-a538-ld17d30dccb9; 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-e6d1ae472fec;
f5583e39-2540-440d-a0ee-dde9f0783abf; a18e46ff-4d05-4322-b040-667ce77d78a8;
ade119a9-84e1-435f-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-a538-1d17d30dcc9; 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

```

### F.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 ~]#

```



**Note:** 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 device 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 ~]#

```

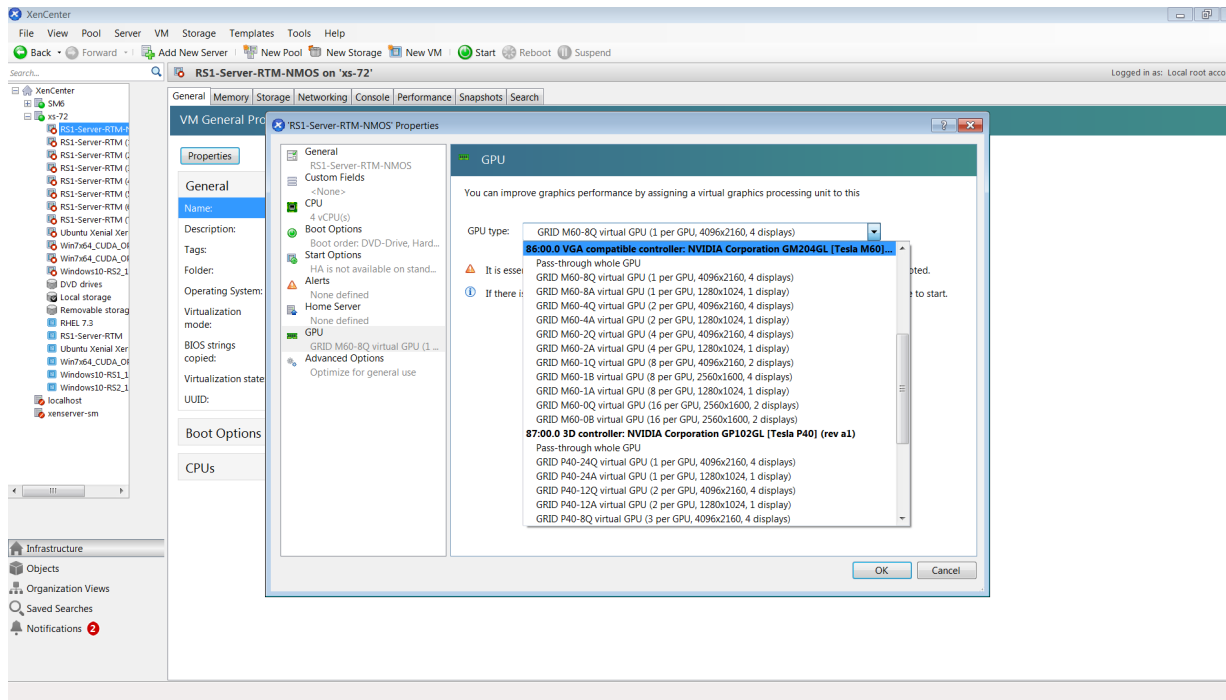
Any `vgpu` object now created that specifies this GPU group UUID will always have its vGPUs created on the GPU at PCI bus ID `0000:05:0.0`.



**Note:** 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 37. Using a custom GPU group within XenCenter



## F.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.

## F.4.1. Cloning a vGPU-enabled VM by using xe

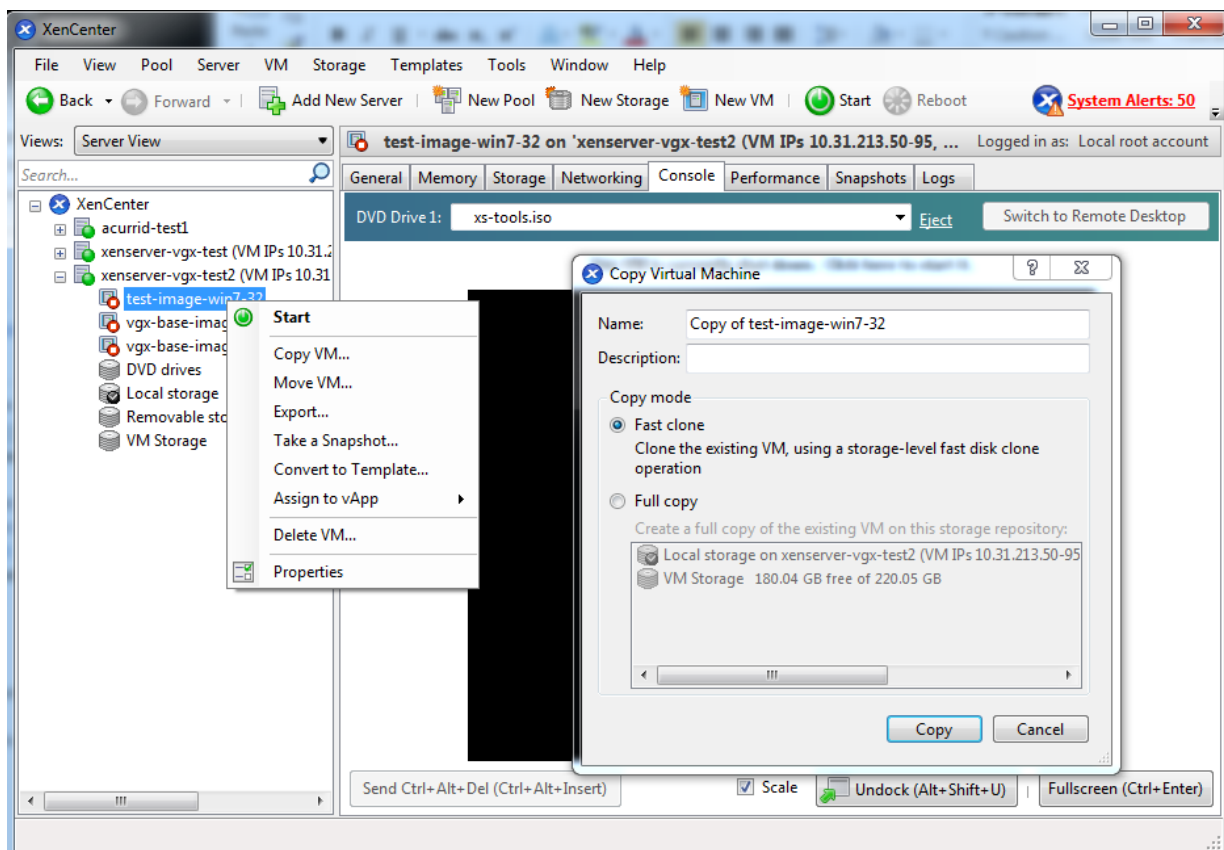
To clone a vGPU-enabled VM from the dom0 shell, use `vm-clone`:

```
[root@xenserver ~]# xe vm-clone new-name-label="new-vm" vm="base-vm-name"
7f7035cb-388d-1537-1465-1857fb6498e7
[root@xenserver ~]#
```

## F.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 38](#).

Figure 38. Cloning a VM using XenCenter



---

# Appendix G. Citrix Hypervisor Performance Tuning

This chapter provides recommendations on optimizing performance for VMs running with NVIDIA vGPU on Citrix Hypervisor.

## G.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.

## G.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.

### G.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=vm-uuid  
platform:vgpu_extra_args="disable_vnc=1"
```

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 plugin's parameters:
  - ▶ **Citrix Hypervisor 8.1 or later:** Removing the `extra_args` key from the group to which the vGPU belongs
  - ▶ **Citrix Hypervisor earlier than 8.1:** Removing the `vgpu_extra_args` key from the `platform` parameter
- ▶ Removing `disable_vnc=1` from the `extra_args` or `vgpu_extra_args` key
- ▶ Setting `disable_vnc=0`, for example:

- ▶ **Citrix Hypervisor 8.1 or later:**

```
[root@xenserver ~]# xe vgpu-param-set uuid=vgpu-uuid extra_args=disable_vnc=0
```

- ▶ **Citrix Hypervisor earlier than 8.1:**

```
[root@xenserver ~]# xe vm-param-set uuid=vm-uuid  
platform:vgpu_extra_args="disable_vnc=0"
```

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