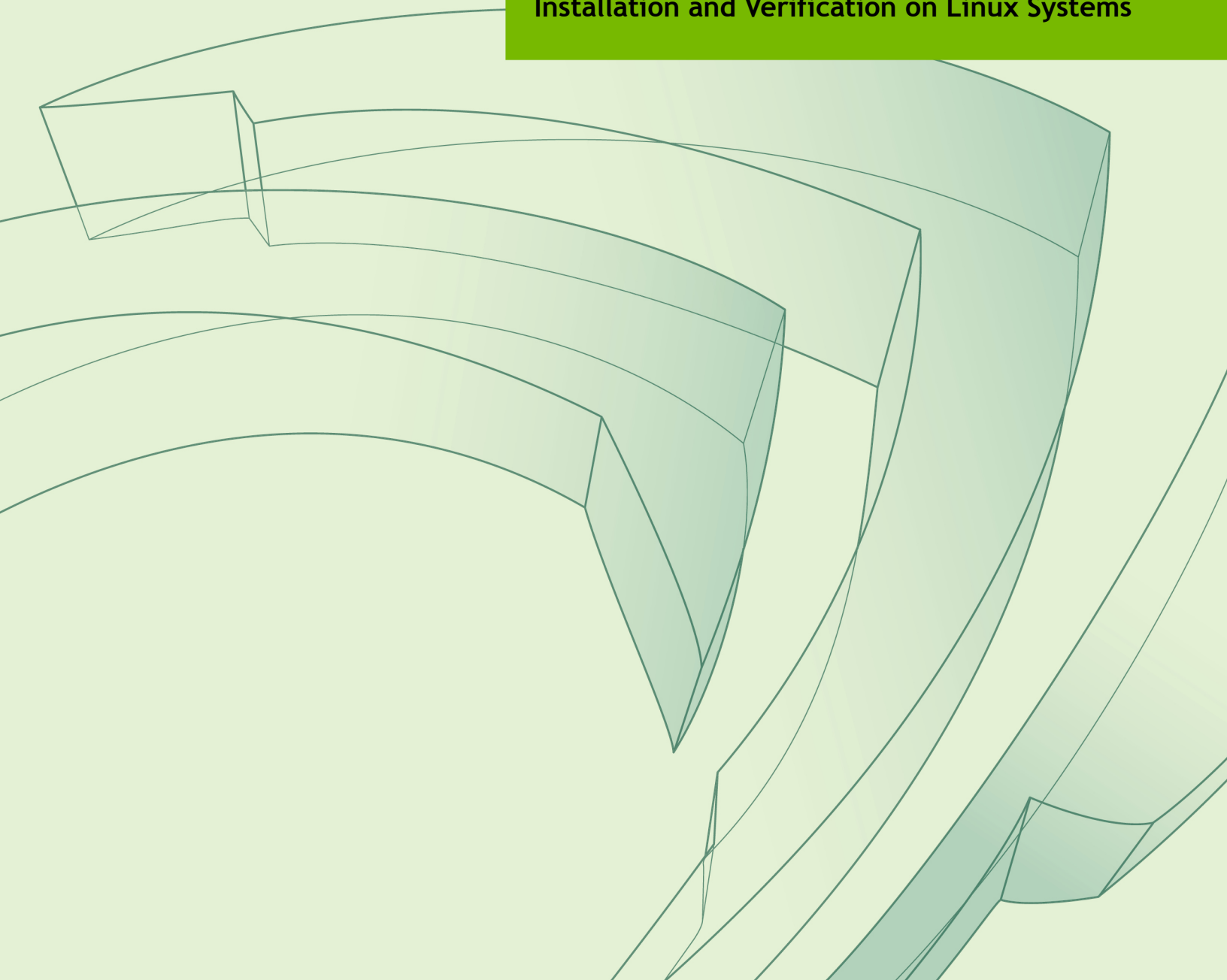




# NVIDIA CUDA GETTING STARTED GUIDE FOR LINUX

DU-05347-001\_v7.0 | March 2015

**Installation and Verification on Linux Systems**



# TABLE OF CONTENTS

<b>Chapter 1. Introduction.....</b>	<b>1</b>
1.1. System Requirements.....	1
1.1.1. x86 32-bit Support.....	2
1.2. About This Document.....	3
<b>Chapter 2. Pre-installation Actions.....</b>	<b>4</b>
2.1. Verify You Have a CUDA-Capable GPU.....	4
2.2. Verify You Have a Supported Version of Linux.....	4
2.3. Verify the System Has gcc Installed.....	5
2.4. Choose an Installation Method.....	5
2.5. Download the NVIDIA CUDA Toolkit.....	6
2.6. Handle Conflicting Installation Methods.....	6
<b>Chapter 3. Package Manager Installation.....</b>	<b>8</b>
3.1. Overview.....	8
3.2. Redhat/CentOS.....	8
3.3. Fedora.....	9
3.4. SLES.....	10
3.5. OpenSUSE.....	11
3.6. Ubuntu.....	12
3.7. Additional Package Manager Capabilities.....	12
3.7.1. Available Packages.....	12
3.7.2. Package Upgrades.....	13
<b>Chapter 4. Runfile Installation.....</b>	<b>14</b>
4.1. Overview.....	14
4.2. Installation.....	14
4.3. Disabling Nouveau.....	16
4.3.1. Fedora.....	16
4.3.2. RHEL/CentOS.....	16
4.3.3. OpenSUSE.....	16
4.3.4. SLES.....	17
4.3.5. Ubuntu.....	17
4.4. Device Node Verification.....	17
4.5. Advanced Options.....	18
4.6. Uninstallation.....	19
<b>Chapter 5. CUDA Cross-Platform Environment.....</b>	<b>21</b>
5.1. CUDA Cross-Platform Installation.....	21
5.2. CUDA Cross-Platform Samples.....	22
TARGET_ARCH.....	22
TARGET_OS.....	22
TARGET_FS.....	22
Copying Libraries.....	23

5.3. Nsight Eclipse Edition.....	23
<b>Chapter 6. Post-installation Actions.....</b>	<b>24</b>
6.1. Mandatory Actions.....	24
6.1.1. Environment Setup.....	24
6.2. Recommended Actions.....	24
6.2.1. Install Writable Samples.....	24
6.2.2. Verify the Installation.....	25
6.2.2.1. Verify the Driver Version.....	25
6.2.2.2. Compiling the Examples.....	25
6.2.2.3. Running the Binaries.....	25
6.3. Optional Actions.....	27
6.3.1. Install Third-party Libraries.....	27
6.3.2. Install the source code for cuda-gdb.....	27
<b>Chapter 7. Frequently Asked Questions.....</b>	<b>29</b>
How do I install the Toolkit in a different location?.....	29
Why do I see "nvcc: No such file or directory" when I try to build a CUDA application?.....	29
Why do I see "error while loading shared libraries: <lib name>: cannot open shared object file: No such file or directory" when I try to run a CUDA application that uses a CUDA library?..	30
How can I extract the contents of the installers?.....	30
How can I tell X to ignore a GPU for compute-only use?.....	30
Why doesn't the cuda-repo package install the CUDA Toolkit and Drivers?.....	31
How do I get CUDA to work with Bumblebee?.....	31
<b>Chapter 8. Additional Considerations.....</b>	<b>32</b>



# Chapter 1.

## INTRODUCTION

CUDA<sup>®</sup> is a parallel computing platform and programming model invented by NVIDIA. It enables dramatic increases in computing performance by harnessing the power of the graphics processing unit (GPU).

CUDA was developed with several design goals in mind:

- ▶ Provide a small set of extensions to standard programming languages, like C, that enable a straightforward implementation of parallel algorithms. With CUDA C/C++, programmers can focus on the task of parallelization of the algorithms rather than spending time on their implementation.
- ▶ Support heterogeneous computation where applications use both the CPU and GPU. Serial portions of applications are run on the CPU, and parallel portions are offloaded to the GPU. As such, CUDA can be incrementally applied to existing applications. The CPU and GPU are treated as separate devices that have their own memory spaces. This configuration also allows simultaneous computation on the CPU and GPU without contention for memory resources.

CUDA-capable GPUs have hundreds of cores that can collectively run thousands of computing threads. These cores have shared resources including a register file and a shared memory. The on-chip shared memory allows parallel tasks running on these cores to share data without sending it over the system memory bus.

This guide will show you how to install and check the correct operation of the CUDA development tools.

## 1.1. System Requirements

To use CUDA on your system, you will need the following installed:

- ▶ CUDA-capable GPU
- ▶ A supported version of Linux with a gcc compiler and toolchain
- ▶ NVIDIA CUDA Toolkit (available at <http://developer.nvidia.com/cuda-downloads>)

The CUDA development environment relies on tight integration with the host development environment, including the host compiler and C runtime libraries, and

is therefore only supported on distribution versions that have been qualified for this CUDA Toolkit release.

**Table 1 Native Linux Distribution Support in CUDA 7.0**

Distribution	Kernel	GCC	GLIBC	ICC	PGI	XLC
x86_64						
Fedora 21	3.17.4	4.9.2	2.20	15.0.0	>=14.9	NO
RHEL 7.x	3.10	4.8.2	2.17			
RHEL 6.x	2.6.32	4.4.7	2.12			
CentOS 7.x	3.10	4.8.2	2.17			
CentOS 6.x	2.6.32	4.4.7	2.12			
OpenSUSE 13.2	3.16.6	4.8.3	2.19			
OpenSUSE 13.1	3.11.6	4.8.1	2.18			
SLES 12	3.12.28	4.8.6	2.19			
SLES 11 SP3	3.0.76	4.3.4	2.11.3			
Ubuntu 14.10	3.16	4.9.1	2.19			
Ubuntu 14.04	3.13	4.8.2	2.19			
SteamOS 1.0-beta	3.10.11	4.7.2	2.17			
Ubuntu 12.04 (DEPRECATED)	3.2	4.6.3	2.15			
ARMv7 (aarch32)						
Ubuntu 14.04	3.13	4.8.2	2.19	NO	NO	NO
POWER8(*)						
Ubuntu 14.10	3.16	4.9.1	2.19	NO	NO	13.1.1
Ubuntu 14.04	3.16	4.8.2	2.19	NO	NO	13.1.1

**Table 2 Cross-build Environment Linux Distribution Support in CUDA 7.0**

Host Distribution	Targeting Architectures (Linux)		
	x86(**)	ARMv7	POWER8
Ubuntu 14.04	DEPRECATED	YES	YES
Ubuntu 12.04	DEPRECATED	DEPRECATED	NO
SteamOS 1.0-beta	DEPRECATED	NO	NO

(\*) Only the Tesla K40m GPU is supported for CUDA 7.0 on POWER8.

(\*\*) x86 support is limited. See the [x86 32-bit Support](#) section for details.

### 1.1.1. x86 32-bit Support

Support for x86 32-bit applications on x86\_64 Linux is limited to use with:

- ▶ GeForce GPUs with Kepler or higher architecture
- ▶ CUDA Driver
- ▶ CUDA Runtime (cudart)
- ▶ CUDA Math Library (math.h)
- ▶ CUDA C++ Compiler (nvcc)
- ▶ CUDA Development Tools

Support for this configuration is only available in the .run file installer.

## 1.2. About This Document

This document is intended for readers familiar with the Linux environment and the compilation of C programs from the command line. You do not need previous experience with CUDA or experience with parallel computation. Note: This guide covers installation only on systems with X Windows installed.



Many commands in this document might require *superuser* privileges. On most distributions of Linux, this will require you to log in as root. For systems that have enabled the sudo package, use the sudo prefix for all necessary commands.

# Chapter 2.

## PRE-INSTALLATION ACTIONS

Some actions must be taken before the CUDA Toolkit and Driver can be installed on Linux:

- ▶ Verify the system has a CUDA-capable GPU.
- ▶ Verify the system is running a supported version of Linux.
- ▶ Verify the system has gcc installed.
- ▶ Download the NVIDIA CUDA Toolkit.
- ▶ Handle conflicting installation methods.



You can override the install-time prerequisite checks by running the installer with the `-override` flag. Remember that the prerequisites will still be required to use the NVIDIA CUDA Toolkit.

### 2.1. Verify You Have a CUDA-Capable GPU

To verify that your GPU is CUDA-capable, go to your distribution's equivalent of System Properties, or, from the command line, enter:

```
$ lspci | grep -i nvidia
```

If you do not see any settings, update the PCI hardware database that Linux maintains by entering **update-pciids** (generally found in `/sbin`) at the command line and rerun the previous **lspci** command.

If your graphics card is from NVIDIA and it is listed in <http://developer.nvidia.com/cuda-gpus>, your GPU is CUDA-capable.

The Release Notes for the CUDA Toolkit also contain a list of supported products.

### 2.2. Verify You Have a Supported Version of Linux

The CUDA Development Tools are only supported on some specific distributions of Linux. These are listed in the CUDA Toolkit release notes.



To determine which distribution and release number you're running, type the following at the command line:

```
$ uname -m && cat /etc/*release
```

You should see output similar to the following, modified for your particular system:

```
x86_64
Red_Hat Enterprise Linux Workstation release 6.0 (Santiago)
```

The **x86\_64** line indicates you are running on a 64-bit system. The remainder gives information about your distribution.

## 2.3. Verify the System Has gcc Installed

The **gcc** compiler is required for development using the CUDA Toolkit. It is not required for running CUDA applications. It is generally installed as part of the Linux installation, and in most cases the version of gcc installed with a supported version of Linux will work correctly.

To verify the version of gcc installed on your system, type the following on the command line:

```
$ gcc --version
```

If an error message displays, you need to install the *development tools* from your Linux distribution or obtain a version of **gcc** and its accompanying toolchain from the Web.

## 2.4. Choose an Installation Method

The CUDA Toolkit can be installed using either of two different installation mechanisms: distribution-specific packages, or a distribution-independent package. The distribution-independent package has the advantage of working across a wider set of Linux distributions, but does not update the distribution's native package management system. The distribution-specific packages interface with the distribution's native package management system. It is recommended to use the distribution-specific packages, where possible.



Distribution-specific packages and repositories are not provided for Redhat 5. For Redhat 5, the stand-alone installer must be used.



Standalone installers are not provided for architectures other than the x86 and x86\_64 releases. For both native as well as cross development, the toolkit must be installed using the distribution-specific installer. See the [CUDA Cross-Platform Installation](#) section for more details.

## 2.5. Download the NVIDIA CUDA Toolkit

The NVIDIA CUDA Toolkit is available at <http://developer.nvidia.com/cuda-downloads>.

Choose the platform you are using and download the NVIDIA CUDA Toolkit

The CUDA Toolkit contains the CUDA driver and tools needed to create, build and run a CUDA application as well as libraries, header files, CUDA samples source code, and other resources.

### Download Verification

The download can be verified by comparing the MD5 checksum posted at <http://developer.nvidia.com/cuda-downloads/checksums> with that of the downloaded file. If either of the checksums differ, the downloaded file is corrupt and needs to be downloaded again.

To calculate the MD5 checksum of the downloaded file, run the following:

```
$ md5sum <file>
```

## 2.6. Handle Conflicting Installation Methods

Before installing CUDA, any previously installations that could conflict should be uninstalled. This will not affect systems which have not had CUDA installed previously, or systems where the installation method has been preserved (RPM/Deb vs. Runfile). See the following charts for specifics.

Table 3 CUDA Toolkit Installation Compatibility Matrix

		Installed Toolkit Version == X.Y		Installed Toolkit Version != X.Y	
		RPM/Deb	run	RPM/Deb	run
Installing Toolkit Version X.Y	RPM/Deb	No Action	Uninstall Run	No Action	No Action
	run	Uninstall RPM/Deb	Uninstall Run	No Action	No Action

Table 4 NVIDIA Driver Installation Compatibility Matrix

		Installed Driver Version == X.Y		Installed Driver Version != X.Y	
		RPM/Deb	run	RPM/Deb	run
Installing Driver Version X.Y	RPM/Deb	No Action	Uninstall Run	No Action	Uninstall Run
	run	Uninstall RPM/Deb	No Action	Uninstall RPM/Deb	No Action

Use the following command to uninstall a Toolkit runfile installation:

```
$ sudo /usr/local/cuda-X.Y/bin/uninstall_cuda_X.Y.pl
```

Use the following command to uninstall a Driver runfile installation:

```
$ sudo /usr/bin/nvidia-uninstall
```

Use the following commands to uninstall a RPM/Deb installation:

```
$ sudo apt-get --purge remove <package_name>           # Ubuntu
$ sudo yum remove <package_name>                       # Fedora/Redhat/CentOS
$ sudo zypper remove <package_name>                   # OpenSUSE/SLES
```

# Chapter 3.

## PACKAGE MANAGER INSTALLATION

### 3.1. Overview

The Package Manager installation interfaces with your system's package management system. When using RPM or Deb, the downloaded package is a repository package. Such a package only informs the package manager where to find the actual installation packages, but will not install them.

If those packages are available in an online repository, they will be automatically downloaded in a later step. Otherwise, the repository package also installs a local repository containing the installation packages on the system. Whether the repository is available online or installed locally, the installation procedure is identical and made of several steps.

Distribution-specific instructions detail how to install CUDA:

- ▶ [Redhat/CentOS](#)
- ▶ [Fedora](#)
- ▶ [SLES](#)
- ▶ [OpenSUSE](#)
- ▶ [Ubuntu](#)

Finally, some helpful [package manager capabilities](#) are detailed.

These instructions are for native development only. For cross-platform development, see the [CUDA Cross-Platform Environment](#) section.

### 3.2. Redhat/CentOS

1. Perform the [pre-installation actions](#).
2. **Satisfy DKMS dependency**

The NVIDIA driver RPM packages depend on other external packages, such as DKMS and libvdpa. Those packages are only available on third-party repositories,

such as [EPEL](#). Any such third-party repositories must be added to the package manager repository database before installing the NVIDIA driver RPM packages, or missing dependencies will prevent the installation from proceeding.

3. **Address custom xorg.conf, if applicable**

The driver relies on an automatically generated xorg.conf file at /etc/X11/xorg.conf. If a custom-built xorg.conf file is present, this functionality will be disabled and the driver may not work. You can try removing the existing xorg.conf file, or adding the contents of /etc/X11/xorg.conf.d/00-nvidia.conf to the xorg.conf file. The xorg.conf file will most likely need manual tweaking for systems with a non-trivial GPU configuration.

4. **Install repository meta-data**

```
$ sudo rpm --install cuda-repo-<distro>-<version>.<architecture>.rpm
```

5. **Clean Yum repository cache**

```
$ sudo yum clean expire-cache
```

6. **Install CUDA**

```
$ sudo yum install cuda
```

If the i686 libvdpau package dependency fails to install, try using the following steps to fix the issue:

```
$ yumdownloader libvdpau.i686
$ sudo rpm -U --oldpackage libvdpau*.rpm
```

7. **Add libcuda.so symbolic link, if necessary**

The libcuda.so library is installed in the /usr/lib{,64}/nvidia directory. For pre-existing projects which use libcuda.so, it may be useful to add a symbolic link from libcuda.so in the /usr/lib{,64} directory.

8. Perform the [post-installation actions](#).

## 3.3. Fedora

1. Perform the [pre-installation actions](#).

2. **Address custom xorg.conf, if applicable**

The driver relies on an automatically generated xorg.conf file at /etc/X11/xorg.conf. If a custom-built xorg.conf file is present, this functionality will be disabled and the driver may not work. You can try removing the existing xorg.conf file, or adding the contents of /etc/X11/xorg.conf.d/00-nvidia.conf to the xorg.conf file. The xorg.conf file will most likely need manual tweaking for systems with a non-trivial GPU configuration.

3. **Satisfy Akmods dependency**

The NVIDIA driver RPM packages depend on the Akmods framework which is provided by the [RPMFusion free repository](#). The RPMFusion free repository must be added to the package manager repository database before installing the NVIDIA driver RPM packages, or missing dependencies will prevent the installation from proceeding.

#### 4. Install repository meta-data

```
$ sudo rpm --install cuda-repo-<distro>-<version>.<architecture>.rpm
```

#### 5. Clean Yum repository cache

```
$ sudo yum clean expire-cache
```

#### 6. Install CUDA

```
$ sudo yum install cuda
```

The CUDA driver installation may fail if the RPMFusion non-free repository is enabled. In this case, CUDA installations should temporarily disable the RPMFusion non-free repository:

```
$ sudo yum --disablerepo="rpmfusion-nonfree*" install cuda
```

If also installing the **gpu-deployment-kit** package, the **cuda** and **gpu-deployment-kit** packages should be either installed using separate instances of **yum**:

```
$ sudo yum install cuda
$ sudo yum install gpu-deployment-kit
```

Or, installed while also specifying the **cuda-drivers** package:

```
$ sudo yum install cuda cuda-drivers gpu-deployment-kit
```

If a system has installed both packages with the same instance of **yum**, some driver components may be missing. Such an installation can be corrected by running:

```
$ sudo yum install cuda-drivers
```

If the i686 libvdpau package dependency fails to install, try using the following steps to fix the issue:

```
$ yumdownloader libvdpau.i686
$ sudo rpm -U --oldpackage libvdpau*.rpm
```

#### 7. Add libcuda.so symbolic link, if necessary

The libcuda.so library is installed in the /usr/lib{,64}/nvidia directory. For pre-existing projects which use libcuda.so, it may be useful to add a symbolic link from libcuda.so in the /usr/lib{,64} directory.

#### 8. Perform the [post-installation actions](#).

## 3.4. SLES

#### 1. Perform the [pre-installation actions](#).

#### 2. Install repository meta-data

```
$ sudo rpm --install cuda-repo-<distro>-<version>.<architecture>.rpm
```

#### 3. Refresh Zypper repository cache

```
$ sudo zypper refresh
```

#### 4. Install CUDA

```
$ sudo zypper install cuda
```

The driver is provided in multiple packages, `nvidia-gfxG03-kmp-desktop`, `nvidia-gfxG03-kmp-default`, `nvidia-gfxG03-kmp-trace`, and their Unified Memory variants. When installing `cuda`, the correct driver packages should also be specified. Without doing this, `zypper` will select packages that may not work on the system. Run the following to detect the flavor of kernel and install `cuda` with the appropriate driver packages:

```
$ uname -r
3.4.6-2.10-<flavor>
$ sudo zypper install cuda nvidia-gfxG03-kmp-<flavor> \
nvidia-uvvm-gfxG03-kmp-<flavor>
```

#### 5. Add the user to the video group

```
$ sudo usermod -a -G video <username>
```

#### 6. Install CUDA Samples GL dependencies

The CUDA Samples package on SLES does not include dependencies on GL and X11 libraries as these are provided in the SLES SDK. These packages must be installed separately, depending on which samples you want to use.

#### 7. Perform the [post-installation actions](#).

## 3.5. OpenSUSE

1. Perform the [pre-installation actions](#).
2. Install repository meta-data

```
$ sudo rpm --install cuda-repo-<distro>-<version>.<architecture>.rpm
```

#### 3. Refresh Zypper repository cache

```
$ sudo zypper refresh
```

#### 4. Install CUDA

```
$ sudo zypper install cuda
```

The driver is provided in multiple packages, `nvidia-gfxG03-kmp-desktop`, `nvidia-gfxG03-kmp-default`, `nvidia-gfxG03-kmp-trace`, and their Unified Memory variants. When installing `cuda`, the correct driver packages should also be specified. Without doing this, `zypper` will select packages that may not work on the system. Run the following to detect the flavor of kernel and install `cuda` with the appropriate driver packages:

```
$ uname -r
3.4.6-2.10-<flavor>
$ sudo zypper install cuda nvidia-gfxG03-kmp-<flavor> \
nvidia-uvvm-gfxG03-kmp-<flavor>
```

#### 5. Add the user to the video group

```
$ sudo usermod -a -G video <username>
```

#### 6. Perform the [post-installation actions](#).

## 3.6. Ubuntu

1. Perform the [pre-installation actions](#).
2. **Install repository meta-data**



When using a proxy server with aptitude, ensure that **wget** is set up to use the same proxy settings before installing the cuda-repo package.

```
$ sudo dpkg -i cuda-repo-<distro>_<version>_<architecture>.deb
```

3. **Update the Apt repository cache**

```
$ sudo apt-get update
```

4. **Install CUDA**

```
$ sudo apt-get install cuda
```

5. Perform the [post-installation actions](#).

## 3.7. Additional Package Manager Capabilities

Below are some additional capabilities of the package manager that users can take advantage of.

### 3.7.1. Available Packages

The recommended installation package is the **cuda** package. This package will install the full set of other CUDA packages required for native development and should cover most scenarios.

The **cuda** package installs all the available packages for native developments. That includes the compiler, the debugger, the profiler, the math libraries,... For x86\_64 platforms, this also include NSight Eclipse Edition and the visual profiler It also includes the NVIDIA driver package.

On supported platforms, the **cuda-cross-armhf** and **cuda-cross-ppc64le** packages install all the packages required for cross-platform development to ARMv7 and POWER8, respectively. The libraries and header files of the target architecture's display driver package are also installed to enable the cross compilation of driver applications. The **cuda-cross-<arch>** packages do not install the native display driver.

The packages installed by the packages above can also be installed individually by specifying their names explicitly. The list of available packages be can obtained with:

```
$ yum --disablerepo="*" --enablerepo="cuda*" list available      # RedHat & Fedora
$ zypper packages -r cuda                                       # OpenSUSE & SLES
$ cat /var/lib/apt/lists/*cuda*Packages | grep "Package:"      # Ubuntu
```



### 3.7.2. Package Upgrades

The **cuda** package points to the latest stable release of the CUDA Toolkit. When a new version is available, use the following commands to upgrade the toolkit and driver:

```
$ sudo yum install cuda                                # RedHat & Fedora
$ sudo zypper install cuda                             # OpenSUSE & SLES
$ sudo apt-get install cuda                            # Ubuntu
```

The **cuda-cross-*<arch>*** packages can also be upgraded in the same manner.

The **cuda-drivers** package points to the latest driver release available in the CUDA repository. When a new version is available, use the following commands to upgrade the driver:

```
$ sudo yum install cuda-drivers                        # RedHat & Fedora
$ sudo zypper install cuda-drivers \                  \
    nvidia-gfxG03-kmp-<flavor> \                    \
    nvidia-uvm-gfxG03-kmp-<flavor>                  # OpenSUSE & SLES
$ sudo apt-get install cuda-drivers                   # Ubuntu
```

Some desktop environments, such as GNOME or KDE, will display an notification alert when new packages are available.

To avoid any automatic upgrade, and lock down the toolkit installation to the X.Y release, install the **cuda-X-Y** or **cuda-cross-*<arch>*-X-Y** package.

Side-by-side installations are supported. For instance, to install both the X.Y CUDA Toolkit and the X.Y+1 CUDA Toolkit, install the **cuda-X.Y** and **cuda-X.Y+1** packages.

# Chapter 4.

## RUNFILE INSTALLATION

This section describes the installation and configuration of CUDA when using the standalone installer. The standalone installer is a ".run" file and is completely self-contained.

### 4.1. Overview

The Runfile installation installs the NVIDIA Driver, CUDA Toolkit, and CUDA Samples via an interactive text-based interface.

The [installation steps](#) are listed below. Distribution-specific instructions on [disabling the Nouveau drivers](#) as well as steps for [verifying device node creation](#) are also provided.

Finally, [advanced options](#) for the installer and [uninstallation steps](#) are detailed below.

The Runfile installation does not include support for cross-platform development. For cross-platform development, see the [CUDA Cross-Platform Environment](#) section.

### 4.2. Installation

1. Perform the [pre-installation actions](#).
2. [Disable the Nouveau drivers](#).
3. Reboot into text mode (runlevel 3).

This can usually be accomplished by adding the number "3" to the end of the system's kernel boot parameters.

Since the NVIDIA drivers are not yet installed, the text terminals may not display correctly. Temporarily adding "nomodeset" to the system's kernel boot parameters may fix this issue.

Consult your system's bootloader documentation for information on how to make the above boot parameter changes.

The reboot is required to completely unload the Nouveau drivers and prevent the graphical interface from loading. The CUDA driver cannot be installed while the Nouveau drivers are loaded or while the graphical interface is active.

4. Verify that the Nouveau drivers are not loaded. If the Nouveau drivers are still loaded, consult your distribution's documentation to see if further steps are needed to disable Nouveau.
5. Run the installer and follow the on-screen prompts:

```
$ sudo sh cuda_<version>_linux.run
```

The installer will prompt for the following:

- ▶ EULA Acceptance
- ▶ CUDA Driver installation
- ▶ CUDA Toolkit installation, location, and **/usr/local/cuda** symbolic link
- ▶ CUDA Samples installation and location

The default installation locations for the toolkit and samples are:

Component	Default Installation Directory
CUDA Toolkit	/usr/local/cuda-7.0
CUDA Samples	\$(HOME)/NVIDIA_CUDA-7.0_Samples

The **/usr/local/cuda** symbolic link points to the location where the CUDA Toolkit was installed. This link allows projects to use the latest CUDA Toolkit without any configuration file update.

The installer must be executed with sufficient privileges to perform some actions. When the current privileges are insufficient to perform an action, the installer will ask for the user's password to attempt to install with root privileges. Actions that cause the installer to attempt to install with root privileges are:

- ▶ installing the CUDA Driver
- ▶ installing the CUDA Toolkit to a location the user does not have permission to write to
- ▶ installing the CUDA Samples to a location the user does not have permission to write to
- ▶ creating the **/usr/local/cuda** symbolic link

Running the installer with **sudo**, as shown above, will give permission to install to directories that require root permissions. Directories and files created while running the installer with **sudo** will have root ownership.

If installing the driver, the installer will also ask if the OpenGL libraries should be installed. If the GPU used for display is not an NVIDIA GPU, the NVIDIA OpenGL libraries should not be installed. Otherwise, the OpenGL libraries used by the graphics driver of the non-NVIDIA GPU will be overwritten and the GUI will not work. If performing a silent installation, the **--no-opengl-libs** option should be used to prevent the OpenGL libraries from being installed. See the [Advanced Options](#) section for more details.

If the GPU used for display is an NVIDIA GPU, the X server configuration file, `/etc/X11/xorg.conf`, may need to be modified. In some cases, `nvidia-xconfig` can be used to automatically generate a `xorg.conf` file that works for the system. For non-standard systems, such as those with more than one GPU, it is recommended to manually edit the `xorg.conf` file. Consult the `xorg.conf` documentation for more information.



Installing Mesa may overwrite the `/usr/lib/libGL.so` that was previously installed by the NVIDIA driver, so a reinstallation of the NVIDIA driver might be required after installing these libraries.

6. Reboot the system to reload the graphical interface.
7. Verify the [device nodes](#) are created properly.
8. Perform the [post-installation actions](#).

## 4.3. Disabling Nouveau

To install the Display Driver, the Nouveau drivers must first be disabled. Each distribution of Linux has a different method for disabling Nouveau.

The Nouveau drivers are loaded if the following command prints anything:

```
$ lsmod | grep nouveau
```

### 4.3.1. Fedora

1. Create a file at `/usr/lib/modprobe.d/blacklist-nouveau.conf` with the following contents:

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

2. Regenerate the kernel initramfs:

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

### 4.3.2. RHEL/CentOS

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

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

2. Regenerate the kernel initramfs:

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

### 4.3.3. OpenSUSE

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

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

2. Regenerate the kernel initrd:

```
$ sudo /sbin/mkinitrd
```

### 4.3.4. SLES

No actions to disable Nouveau are required as Nouveau is not installed on SLES.

### 4.3.5. Ubuntu

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

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

2. Regenerate the kernel initramfs:

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

## 4.4. Device Node Verification

Check that the device files `/dev/nvidia*` exist and have the correct (0666) file permissions. These files are used by the CUDA Driver to communicate with the kernel-mode portion of the NVIDIA Driver. Applications that use the NVIDIA driver, such as a CUDA application or the X server (if any), will normally automatically create these files if they are missing using the `setuid nvidia-modprobe` tool that is bundled with the NVIDIA Driver. However, some systems disallow `setuid` binaries, so if these files do not

exist, you can create them manually either by running the command **nvidia-smi** as root at boot time or by using a startup script such as the one below:

```
#!/bin/bash

/sbin/modprobe nvidia

if [ "$?" -eq 0 ]; then
    # Count the number of NVIDIA controllers found.
    NVDEVS=`lspci | grep -i NVIDIA`
    N3D=`echo "$NVDEVS" | grep "3D controller" | wc -l`
    NVGA=`echo "$NVDEVS" | grep "VGA compatible controller" | wc -l`

    N=`expr $N3D + $NVGA - 1`
    for i in `seq 0 $N`; do
        mknod -m 666 /dev/nvidia$i c 195 $i
    done

    mknod -m 666 /dev/nvidiactl c 195 255
else
    exit 1
fi

/sbin/modprobe nvidia-vm

if [ "$?" -eq 0 ]; then
    # Find out the major device number used by the nvidia-vm driver
    D=`grep nvidia-vm /proc/devices | awk '{print $1}'`

    mknod -m 666 /dev/nvidia-vm c $D 0
else
    exit 1
fi
```

## 4.5. Advanced Options

Action	Options Used	Explanation
Silent Installation	--silent	Required for any silent installation. Performs an installation with no further user-input and minimal command-line output based on the options provided below. Silent installations are useful for scripting the installation of CUDA. Using this option implies acceptance of the EULA. The following flags can be used to customize the actions taken during installation. At least one of --driver, --uninstall, --toolkit, and --samples must be passed if running with non-root permissions.
	--driver	Install the CUDA Driver.
	--toolkit	Install the CUDA Toolkit.

Action	Options Used	Explanation
	--toolkitpath=<path>	Install the CUDA Toolkit to the <path> directory. If not provided, the default path of <code>/usr/local/cuda-7.0</code> is used.
	--samples	Install the CUDA Samples.
	--samplespath=<path>	Install the CUDA Samples to the <path> directory. If not provided, the default path of <code>\$(HOME)/NVIDIA_CUDA-7.0_Samples</code> is used.
	--uninstall ( <b>DEPRECATED</b> )	Uninstall the CUDA Driver.
Extraction	--extract=<path>	Extracts the individual driver, toolkit, and samples runfile installers to <path>.
Overriding Installation Checks	--override	Ignores compiler, third-party library, and toolkit detection checks.
No OpenGL Libraries	--no-opengl-libs	Prevents the driver installation from installing NVIDIA's GL libraries. Useful for systems where the display is driven by a non-NVIDIA GPU. In such systems, NVIDIA's GL libraries could prevent X from loading properly.
Overriding Kernel Source	--kernel-source-path=<path>	Tells the driver installation to use <path> as the kernel source directory when building the NVIDIA kernel module. Required for systems where the kernel source is installed to a non-standard location.
Custom Temporary Directory Selection	--tmpdir=<path>	Performs any temporary actions within <path> instead of <code>/tmp</code> . Useful in cases where <code>/tmp</code> cannot be used (doesn't exist, is full, is mounted with 'noexec', etc.).
Show Verbose Output	--verbose	Prints all logging information to stdout as well as the log file.
Show Installer Options	--help	Prints the list of command-line options to stdout.

## 4.6. Uninstallation

To uninstall the CUDA Toolkit, run the uninstallation script provided in the bin directory of the toolkit. By default, it is located in `/usr/local/cuda-7.0/bin`:

```
$ sudo /usr/local/cuda-7.0/bin/uninstall_cuda_7.0.pl
```

To uninstall the NVIDIA Driver, run **nvidia-uninstall**:

```
$ sudo /usr/bin/nvidia-uninstall
```

To enable the Nouveau drivers, remove the blacklist file created in the [Disabling Nouveau](#) section, and regenerate the kernel initramfs/initrd again as described in that section.



# Chapter 5.

## CUDA CROSS-PLATFORM ENVIRONMENT

Cross-platform development is only supported on Ubuntu systems, and is only provided via the Package Manager installation process.

We recommend selecting Ubuntu 14.04 as your cross-platform development environment. This selection helps prevent host/target incompatibilities, such as GCC or GLIBC version mismatches.

### 5.1. CUDA Cross-Platform Installation

Some of the following steps may have already been performed as part of the [native Ubuntu installation](#). Such steps can safely be skipped.

These steps should be performed on the x86\_64 host system, rather than the target system. To install the native CUDA Toolkit on the target system, refer to the [native Ubuntu installation](#) section.

1. Perform the [pre-installation actions](#).
2. **Enable the foreign architecture**

The foreign architecture must be enabled in order to install the cross-platform toolkit. To enable armhf or ppc64el as a foreign architecture, the following commands must be executed, replacing <arch> with the desired architecture:

```
$ sudo dpkg --add-architecture <arch>
$ sudo apt-get update
```

3. **Install repository meta-data**



When using a proxy server with aptitude, ensure that `wget` is set up to use the same proxy settings before installing the `cuda-repo` package.

```
$ sudo dpkg -i cuda-repo-<distro>_<version>_amd64.deb
```

4. **Update the Apt repository cache**

```
$ sudo apt-get update
```

5. **Install the cross-platform CUDA Toolkit**

To install the cross-platform toolkit for armhf or ppc64el, the following command must be executed, replacing <arch> with the desired architecture:

```
$ sudo apt-get install cuda-cross-<arch>
```

6. Perform the [post-installation actions](#).

## 5.2. CUDA Cross-Platform Samples

This section describes the options used to build cross-platform samples.

**TARGET\_ARCH**=<arch> and **TARGET\_OS**=<os> should be chosen based on the supported targets shown below. **TARGET\_FS**=<path> can be used to point nvcc to libraries and headers used by the sample.

Table 5 Supported Target Arch/OS Combinations

		TARGET OS			
		linux	darwin	android	qnx
TARGET ARCH	x86_64	YES	YES	NO	NO
	armv7l	YES	NO	YES	YES
	aarch64	NO	NO	YES	NO
	ppc64le	YES	NO	NO	NO

### TARGET\_ARCH

The target architecture must be specified when cross-compiling applications. If not specified, it defaults to the host architecture. Allowed architectures are:

- ▶ **x86\_64** - 64-bit x86 CPU architecture
- ▶ **armv7l** - 32-bit ARM CPU architecture, like that found on Jetson TK1
- ▶ **aarch64** - 64-bit ARM CPU architecture, found on certain Android systems
- ▶ **ppc64le** - 64-bit little-endian IBM POWER8 architecture

### TARGET\_OS

The target OS must be specified when cross-compiling applications. If not specified, it defaults to the host OS. Allowed OSes are:

- ▶ **linux** - for any Linux distributions
- ▶ **darwin** - for Mac OS X
- ▶ **android** - for any supported device running Android
- ▶ **qnx** - for any supported device running QNX

### TARGET\_FS

The most reliable method to cross-compile the CUDA Samples is to use the **TARGET\_FS** variable. To do so, mount the target's filesystem on the host, say at **/mnt/target**. This is

typically done using **exportfs**. In cases where **exportfs** is unavailable, it is sufficient to copy the target's filesystem to **/mnt/target**. To cross-compile a sample, execute:

```
$ make TARGET_ARCH=<arch> TARGET_OS=<os> TARGET_FS=/mnt/target
```

## Copying Libraries

If the **TARGET\_FS** option is not available, the libraries used should be copied from the target system to the host system, say at **/opt/target/libs**. If the sample uses GL, the GL headers must also be copied, say at **/opt/target/include**. The linker must then be told where the libraries are with the **-rpath-link** and/or **-L** options. To ignore unresolved symbols from some libraries, use the **--unresolved-symbols** option as shown below. **SAMPLE\_ENABLED** should be used to force the sample to build. For example, to cross-compile a sample which uses such libraries, execute:

```
$ make TARGET_ARCH=<arch> TARGET_OS=<os> \
    EXTRA_LDFLAGS="-rpath-link=/opt/target/libs -L/opt/target/libs --\
unresolved-symbols=ignore-in-shared-libs" \
    EXTRA_CCFLAGS="-I /opt/target/include" \
    SAMPLE_ENABLED=1
```

## 5.3. Nsight Eclipse Edition

Nsight Eclipse Edition supports cross-platform development. See the [Nsight Eclipse Edition Getting Started Guide](#) for more details.

# Chapter 6.

## POST-INSTALLATION ACTIONS

The post-installation actions must be manually performed. These actions are split into mandatory, recommended, and optional sections.

### 6.1. Mandatory Actions

Some actions must be taken after installing the CUDA Toolkit and Driver before they can be completely used.

#### 6.1.1. Environment Setup

The **PATH** variable needs to include `/usr/local/cuda-7.0/bin`

The **LD\_LIBRARY\_PATH** variable needs to contain `/usr/local/cuda-7.0/lib64` on a 64-bit system, and `/usr/local/cuda-7.0/lib` on a 32-bit system

- ▶ To change the environment variables for 64-bit operating systems:

```
$ export PATH=/usr/local/cuda-7.0/bin:$PATH
$ export LD_LIBRARY_PATH=/usr/local/cuda-7.0/lib64:$LD_LIBRARY_PATH
```

- ▶ To change the environment variables for 32-bit operating systems:

```
$ export PATH=/usr/local/cuda-7.0/bin:$PATH
$ export LD_LIBRARY_PATH=/usr/local/cuda-7.0/lib:$LD_LIBRARY_PATH
```

### 6.2. Recommended Actions

Other actions are recommended to verify the integrity of the installation.

#### 6.2.1. Install Writable Samples

In order to modify, compile, and run the samples, the samples must be installed with write permissions. A convenience installation script is provided:

```
$ cuda-install-samples-7.0.sh <dir>
```

This script is installed with the `cuda-samples-7-0` package. The `cuda-samples-7-0` package installs only a read-only copy in `/usr/local/cuda-7.0/samples`.

## 6.2.2. Verify the Installation

Before continuing, it is important to verify that the CUDA toolkit can find and communicate correctly with the CUDA-capable hardware. To do this, you need to compile and run some of the included sample programs.



Ensure the `PATH` and `LD_LIBRARY_PATH` variables are [set correctly](#).

### 6.2.2.1. Verify the Driver Version

If you installed the driver, verify that the correct version of it is loaded. If you did not install the driver, or are using an operating system where the driver is not loaded via a kernel module, such as L4T, skip this step.

When the driver is loaded, the driver version can be found by executing the command

```
$ cat /proc/driver/nvidia/version
```

Note that this command will not work on an iGPU/dGPU system.

### 6.2.2.2. Compiling the Examples

The version of the CUDA Toolkit can be checked by running `nvcc -V` in a terminal window. The `nvcc` command runs the compiler driver that compiles CUDA programs. It calls the `gcc` compiler for C code and the NVIDIA PTX compiler for the CUDA code.

The NVIDIA CUDA Toolkit includes sample programs in source form. You should compile them by changing to `~/NVIDIA_CUDA-7.0_Samples` and typing `make`. The resulting binaries will be placed under `~/NVIDIA_CUDA-7.0_Samples/bin`.

### 6.2.2.3. Running the Binaries

After compilation, find and run `deviceQuery` under `~/NVIDIA_CUDA-7.0_Samples`. If the CUDA software is installed and configured correctly, the output for `deviceQuery` should look similar to that shown in [Figure 1](#).

```

./deviceQuery Starting...

  CUDA Device Query (Runtime API) version (CUDA static linking)

Detected 1 CUDA Capable device(s)

Device 0: "Tesla K20c"
  CUDA Driver Version / Runtime Version      6.0 / 6.0
  CUDA Capability Major/Minor version number: 3.5
  Total amount of global memory:              4800 MBytes (5032768048 bytes)
  (13) Multiprocessors, (192) CUDA Cores/MP: 2496 CUDA Cores
  GPU Clock rate:                            706 MHz (0.71 GHz)
  Memory Clock rate:                          2600 Mhz
  Memory Bus Width:                           320-bit
  L2 Cache Size:                             1310720 bytes
  Maximum Texture Dimension Size (x,y,z)     1D=(65536), 2D=(65536, 65536), 3D=(4096, 4096, 4096)
  Maximum Layered 1D Texture Size, (num) layers 1D=(16384), 2048 layers
  Maximum Layered 2D Texture Size, (num) layers 2D=(16384, 16384), 2048 layers
  Total amount of constant memory:            65536 bytes
  Total amount of shared memory per block:    49152 bytes
  Total number of registers available per block: 65536
  Warp size:                                 32
  Maximum number of threads per multiprocessor: 2048
  Maximum number of threads per block:        1024
  Max dimension size of a thread block (x,y,z): (1024, 1024, 64)
  Max dimension size of a grid size    (x,y,z): (2147483647, 65535, 65535)
  Maximum memory pitch:                      2147483647 bytes
  Texture alignment:                          512 bytes
  Concurrent copy and kernel execution:       Yes with 2 copy engine(s)
  Run time limit on kernels:                   No
  Integrated GPU sharing Host Memory:          No
  Support host page-locked memory mapping:     Yes
  Alignment requirement for Surfaces:          Yes
  Device has ECC support:                      Enabled
  Device supports Unified Addressing (UVA):    Yes
  Device PCI Bus ID / PCI location ID:        2 / 0
  Compute Mode:
    < Default (multiple host threads can use ::cudaSetDevice() with device simultaneously) >

deviceQuery, CUDA Driver = CUDART, CUDA Driver Version = 6.0, CUDA Runtime Version = 6.0, NumDevs = 1, Device0 = Tesla K20c
Result = PASS

```

Figure 1 Valid Results from deviceQuery CUDA Sample

The exact appearance and the output lines might be different on your system. The important outcomes are that a device was found (the first highlighted line), that the device matches the one on your system (the second highlighted line), and that the test passed (the final highlighted line).

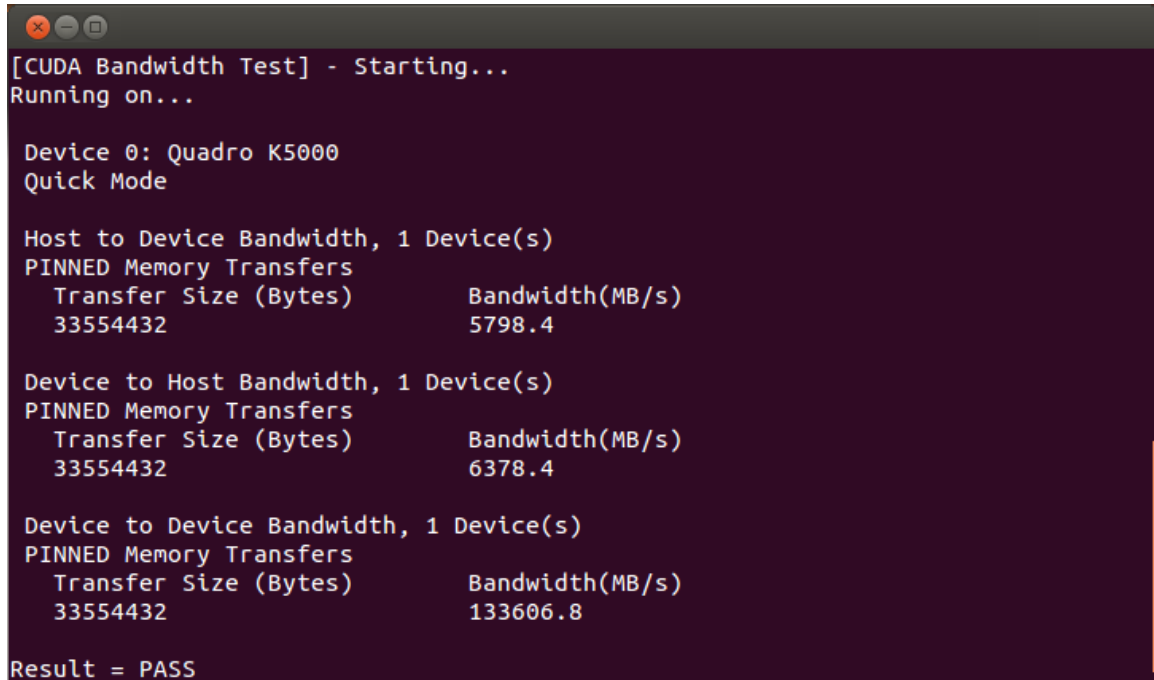
If a CUDA-capable device and the CUDA Driver are installed but **deviceQuery** reports that no CUDA-capable devices are present, this likely means that the **/dev/nvidia\*** files are missing or have the wrong permissions.

On systems where **SELinux** is enabled, you might need to temporarily disable this security feature to run **deviceQuery**. To do this, type:

```
$ setenforce 0
```

from the command line as the *superuser*.

Running the **bandwidthTest** program ensures that the system and the CUDA-capable device are able to communicate correctly. Its output is shown in [Figure 2](#).



```
[CUDA Bandwidth Test] - Starting...
Running on...

Device 0: Quadro K5000
Quick Mode

Host to Device Bandwidth, 1 Device(s)
PINNED Memory Transfers
  Transfer Size (Bytes)      Bandwidth(MB/s)
  33554432                  5798.4

Device to Host Bandwidth, 1 Device(s)
PINNED Memory Transfers
  Transfer Size (Bytes)      Bandwidth(MB/s)
  33554432                  6378.4

Device to Device Bandwidth, 1 Device(s)
PINNED Memory Transfers
  Transfer Size (Bytes)      Bandwidth(MB/s)
  33554432                  133606.8

Result = PASS
```

Figure 2 Valid Results from bandwidthTest CUDA Sample

Note that the measurements for your CUDA-capable device description will vary from system to system. The important point is that you obtain measurements, and that the second-to-last line (in [Figure 2](#)) confirms that all necessary tests passed.

Should the tests not pass, make sure you have a CUDA-capable NVIDIA GPU on your system and make sure it is properly installed.

If you run into difficulties with the link step (such as libraries not being found), consult the *Linux Release Notes* found in the **doc** folder in the CUDA Samples directory.

## 6.3. Optional Actions

Other options are not necessary to use the CUDA Toolkit, but are available to provide additional features.

### 6.3.1. Install Third-party Libraries

Some CUDA samples use third-party libraries which may not be installed by default on your system. These samples attempt to detect any required libraries when building. If a library is not detected, it waives itself and warns you which library is missing. To build and run these samples, you must install the missing libraries.

### 6.3.2. Install the source code for cuda-gdb

The cuda-gdb source is automatically installed with the runfile installation method.

To obtain a copy of the source code for `cuda-gdb` using the RPM and Debian installation methods, the **`cuda-gdb-src`** package must be installed.

The source code is installed as a tarball in the `/usr/local/cuda-7.0/extras` directory.



## Chapter 7.

# FREQUENTLY ASKED QUESTIONS

### How do I install the Toolkit in a different location?

The Runfile installation asks where you wish to install the Toolkit and the Samples during an interactive install. If installing using a non-interactive install, you can use the `--toolkitpath` and `--samplespath` parameters to change the install location:

```
$ ./runfile.run --silent \  
    --toolkit --toolkitpath=/my/new/toolkit \  
    --samples --samplespath=/my/new/samples
```

The RPM packages don't support custom install locations though the package managers (Yum and Zypper), but it is possible to install the RPM packages in custom locations using rpm's `--relocate` parameter:

```
$ rpm --install --relocate /usr/local/cuda-7.0=/my/new/toolkit rpmpackage.rpm
```

You will need to install the packages in the correct dependency order; this task is normally taken care of by the package managers. For example, if package "foo" has a dependency on package "bar", you should install package "bar" first, and package "foo" second. You can check the dependencies of a RPM package as follows:

```
$ rpm -qRp rpmpackage.rpm
```

The Deb packages do not support custom install locations. It is however possible to extract the contents of the Deb packages and move the files to the desired install location. See [here](#) for more details on extracting Deb packages.

### Why do I see "nvcc: No such file or directory" when I try to build a CUDA application?

Your PATH environment variable is not set up correctly. Ensure that your PATH includes the bin directory where you installed the Toolkit, usually `/usr/local/cuda-7.0/bin`.

```
$ export PATH=/usr/local/cuda-7.0/bin:$PATH
```

## Why do I see "error while loading shared libraries: <lib name>: cannot open shared object file: No such file or directory" when I try to run a CUDA application that uses a CUDA library?

Your LD\_LIBRARY\_PATH environment variable is not set up correctly. Ensure that your LD\_LIBRARY\_PATH includes the lib and/or lib64 directory where you installed the Toolkit, usually /usr/local/cuda-7.0/lib{,64}:

```
$ export LD_LIBRARY_PATH=/usr/local/cuda-7.0/lib:$LD_LIBRARY_PATH
```

## How can I extract the contents of the installers?

The Runfile can be extracted into the standalone Toolkit, Samples and Driver Runfiles by using the --extract parameter. These standalone Runfiles can be further extracted by running:

```
$ ./runfile.run --tar mxvf
```

The RPM packages can be extracted by running:

```
$ rpm2cpio rpm_package.rpm | cpio -idmv
```

The Deb packages can be extracted by running:

```
$ dpkg-deb -x deb_package.deb output_dir
```

## How can I tell X to ignore a GPU for compute-only use?

To make sure X doesn't use a certain GPU for display, you need to specify which **other** GPU to use for display. This is done by editing the xorg.conf file located at /etc/xorg/xorg.conf.

You will need to add a section that resembles the following to your xorg.conf file:

```
Section "Device"
    Identifier      "Device0"
    Driver          "driver_name"
    VendorName      "vendor_name"
    BusID           "bus_id"
EndSection
```

The exact details of what you will need to add differ on a case-by-case basis. For example, if you have two NVIDIA GPUs and you want the first GPU to be used for display, you would replace "driver\_name" with "nvidia", "vendor\_name" with "NVIDIA Corporation" and "bus\_id" with the Bus ID of the GPU.

The Bus ID will resemble "PCI:00:02.0" and can be found by running `lspci`.

## Why doesn't the cuda-repo package install the CUDA Toolkit and Drivers?

When using RPM or Deb, the downloaded package is a repository package. Such a package only informs the package manager where to find the actual installation packages, but will not install them.

See the [Package Manager Installation](#) section for more details.

## How do I get CUDA to work with Bumblebee?

Bumblebee works by establishing the right runtime environment to execute the targeted application through the `optirun` command. To run, debug, or profile a CUDA application, `optirun` must set up the correct runtime environment, which includes, among other items, loading the appropriate kernel modules. The Bumblebee project should provide the information on how to proceed. Please see the [Bumblebee Documentation](#) for more information.

## Chapter 8.

# ADDITIONAL CONSIDERATIONS

Now that you have CUDA-capable hardware and the NVIDIA CUDA Toolkit installed, you can examine and enjoy the numerous included programs. To begin using CUDA to accelerate the performance of your own applications, consult the *CUDA C Programming Guide*, located in `/usr/local/cuda-7.0/doc`.

A number of helpful development tools are included in the CUDA Toolkit to assist you as you develop your CUDA programs, such as NVIDIA® Nsight™ Eclipse Edition, NVIDIA Visual Profiler, `cuda-gdb`, and `cuda-memcheck`.

For technical support on programming questions, consult and participate in the developer forums at <http://developer.nvidia.com/cuda/>.

## **Notice**

ALL NVIDIA DESIGN SPECIFICATIONS, REFERENCE BOARDS, FILES, DRAWINGS, DIAGNOSTICS, LISTS, AND OTHER DOCUMENTS (TOGETHER AND SEPARATELY, "MATERIALS") ARE BEING PROVIDED "AS IS." NVIDIA MAKES NO WARRANTIES, EXPRESSED, IMPLIED, STATUTORY, OR OTHERWISE WITH RESPECT TO THE MATERIALS, AND EXPRESSLY DISCLAIMS ALL IMPLIED WARRANTIES OF NONINFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE.

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

## **Trademarks**

NVIDIA and the NVIDIA logo are trademarks or registered trademarks of NVIDIA Corporation in the U.S. and other countries. Other company and product names may be trademarks of the respective companies with which they are associated.

## **Copyright**

© 2009-2015 NVIDIA Corporation. All rights reserved.