



# NVIDIA CUDA GETTING STARTED GUIDE FOR MICROSOFT WINDOWS

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**Installation and Verification on Windows**



# TABLE OF CONTENTS

<b>Chapter 1. Introduction.....</b>	<b>1</b>
1.1. System Requirements.....	1
1.2. About This Document.....	2
<b>Chapter 2. Installing CUDA Development Tools.....</b>	<b>3</b>
2.1. Verify You Have a CUDA-Capable GPU.....	3
2.2. Download the NVIDIA CUDA Toolkit.....	3
2.3. Install the CUDA Software.....	3
2.3.1. Uninstalling the CUDA Software.....	5
2.4. Use a Suitable Driver Model.....	5
2.5. Verify the Installation.....	6
2.5.1. Running the Compiled Examples.....	6
<b>Chapter 3. Compiling CUDA Programs.....</b>	<b>9</b>
3.1. Compiling Sample Projects.....	9
3.2. Sample Projects.....	9
3.3. Build Customizations for New Projects.....	10
3.4. Build Customizations for Existing Projects.....	10
<b>Chapter 4. Additional Considerations.....</b>	<b>12</b>

## LIST OF FIGURES

Figure 1 Valid Results from deviceQuery CUDA Sample .....	7
Figure 2 Valid Results from bandwidthTest CUDA Sample .....	7



# Chapter 1.

## INTRODUCTION

CUDA™ 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
- ▶ Microsoft Windows XP, Vista, 7, or 8 or Windows Server 2003 or 2008
- ▶ NVIDIA CUDA Toolkit (available at <http://developer.nvidia.com/cuda-downloads>)
- ▶ Microsoft Visual Studio 2008, 2010, or 2012

## 1.2. About This Document

This document is intended for readers familiar with Microsoft Windows operating systems and the Microsoft Visual Studio environment. You do not need previous experience with CUDA or experience with parallel computation.

# Chapter 2.

## INSTALLING CUDA DEVELOPMENT TOOLS

The setup of CUDA development tools on a system running the appropriate version of Windows consists of a few simple steps:

- ▶ Verify the system has a CUDA-capable GPU.
- ▶ Download the NVIDIA CUDA Toolkit.
- ▶ Install the NVIDIA CUDA Toolkit.
- ▶ Test that the installed software runs correctly and communicates with the hardware.

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

To verify that your GPU is CUDA-capable, open the **Control Panel** ( **Start** > **Control Panel** ) and double click on **System**. In the **System Properties** window that opens, click the **Hardware** tab, then **Device Manager**. Expand the **Display adapters** entry. There you will find the vendor name and model of your graphics card. If it is an NVIDIA card that 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. 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.

### 2.3. Install the CUDA Software

Before installing the toolkit, you should read the *Release Notes*, as they provide details on installation and software functionality.



The driver and toolkit must be installed for CUDA to function. If you have not installed a stand-alone driver, install the driver from the NVIDIA CUDA Toolkit.

## Graphical Installation

Install the CUDA Software by executing the CUDA installer and following the on-screen prompts.

## Silent Installation

Alternatively, the installer can be executed in silent mode by executing the package with the **-s** flag. Additional flags can be passed which will install specific subpackages instead of all packages. Allowed subpackage names are: `CUDAToolkit_5.5`, `CUDADocumentation_5.5`, `CUDASamples_5.5`, `Nsight`, and `Display.Driver`.

## Subpackage Details

### ► Display Driver

Required to run CUDA applications.

### ► CUDA Toolkit

The CUDA Toolkit installation defaults to **C:\Program Files\NVIDIA GPU Computing Toolkit\CUDA\v5.5**. This directory contains the following:

**Bin\**

the compiler executables and runtime libraries

**Include\**

the header files needed to compile CUDA programs

**Lib\**

the library files needed to link CUDA programs

### ► CUDA Documentation

The CUDA Documentation installation defaults to **C:\Program Files\NVIDIA GPU Computing Toolkit\CUDA\v5.5\Doc**. This directory contains the following:

- *CUDA C Programming Guide*
- *CUDA C Best Practices Guide*
- documentation for the CUDA libraries
- other CUDA Toolkit-related documentation

### ► CUDA Samples

The CUDA Samples contain source code for many example problems and templates with Microsoft Visual Studio 2008, 2010, and 2012 projects.

On Windows XP, the CUDA Samples installation defaults to **C:\Documents and Settings\All Users\Application Data\NVIDIA Corporation\CUDA Samples\v5.5**.



On Windows Vista, Windows 7, Windows 8, and Windows Server 2008, the CUDA Samples installation defaults to `C:\ProgramData\NVIDIA Corporation\CUDA Samples\v5.5`.



`C:\ProgramData\` is a hidden folder. It can be made visible within Windows Explorer by enabling it through the menu options within Windows Explorer (Tools | Options).

► **NVIDIA Nsight Visual Studio Edition**

Installs Nsight Visual Studio Edition plugins for Visual Studio development.

### Extracting and Inspecting the Files Manually

Sometimes it may be desirable to extract or inspect the installable files directly, such as in enterprise deployment, or to browse the files before installation. The installation package can be extracted using a decompression tool which supports the LZMA compression method, such as [7-zip](#) or [WinZip](#).

Once extracted, the CUDA Toolkit files will be in the `CUDAToolkit` folder, and similarly for the CUDA Samples and CUDA Documentation. Within each directory is a `.dll` and `.nvi` file that can be ignored as they are not part of the installable files.



Accessing the files in this manner does not set up any environment settings, such as variables or Visual Studio integration. This is intended for enterprise-level deployment.

## 2.3.1. Uninstalling the CUDA Software

All subpackages can be uninstalled through the Windows Control Panel.

On Windows XP, use the Add or Remove Programs widget to select and remove individual subpackages.

On Windows Vista, Windows 7, Windows 8 and Windows Server 2008, use the Programs and Features widget to select and remove individual subpackages.

## 2.4. Use a Suitable Driver Model

On Windows Vista and later, the operating system provides two *driver models* under which the NVIDIA Driver may operate:

- The *WDDM* driver model is used for display devices.
- The *Tesla Compute Cluster (TCC)* mode of the NVIDIA Driver is available for non-display devices such as NVIDIA Tesla GPUs; it uses the Windows WDM driver model.

The TCC driver mode provides a number of advantages for CUDA applications on GPUs that support this mode. For example:

- ▶ TCC eliminates the timeouts that can occur when running under WDDM due to the Windows [Timeout Detection and Recovery](#) mechanism for display devices.
- ▶ TCC allows the use of CUDA with Windows Remote Desktop, which is not possible for WDDM devices.
- ▶ TCC allows the use of CUDA from within processes running as Windows services, which is not possible for WDDM devices.
- ▶ TCC reduces the latency of CUDA kernel launches.

TCC is enabled by default on most recent NVIDIA Tesla GPUs. To check which driver mode is in use and/or to switch driver modes, use the `nvidia-smi` tool that is included with the NVIDIA Driver installation (see `nvidia-smi -h` for details).



Keep in mind that when TCC mode is enabled for a particular GPU, that GPU *cannot* be used as a display device.



NVIDIA GeForce GPUs do not support TCC mode.

## 2.5. 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.

### 2.5.1. Running the Compiled Examples

The version of the CUDA Toolkit can be checked by running `nvcc -v` in a **Command Prompt** window. You can display a **Command Prompt** window by going to:

**Start > All Programs > Accessories > Command Prompt**

CUDA Samples include sample programs in both *source* and *compiled* form. To verify a correct configuration of the hardware and software, it is highly recommended that you run the `deviceQuery` program located here:

Windows XP:

```
C:\Documents and Settings\All Users\Application Data\NVIDIA Corporation\CUDA
Samples\v5.5\bin\win32\Release
```

Windows Vista, Windows 7, Windows 8, Windows Server 2003, and Windows Server 2008:

```
C:\ProgramData\NVIDIA Corporation\CUDA Samples\v5.5\bin\win32\Release
```

This assumes that you used the default installation directory structure. (On 64-bit versions of Windows, the directory name ends with `\win64\Release`.) If CUDA is installed and configured correctly, the output should look similar to [Figure 1](#).

```

C:\Windows\system32\cmd.exe
DeviceQuery Starting...
CUDA Device Query (Runtime API) version (CUDART static linking)
Detected 1 CUDA Capable device(s)
Device 0: "Quadro K5000"
  CUDA Driver Version / Runtime Version      5.5 / 5.5
  CUDA Capability Major/Minor version number: 3.0
  Total amount of global memory:              4096 MBytes (4294967296 bytes)
  < 8> Multiprocessors, (192) CUDA Cores/MP:  1536 CUDA Cores
  GPU Clock rate:                             706 MHz (0.71 GHz)
  Memory Clock rate:                          2700 Mhz
  Memory Bus Width:                          256-bit
  L2 Cache Size:                             524288 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:                  Yes
  Integrated GPU sharing Host Memory:          No
  Support host page-locked memory mapping:     Yes
  Alignment requirement for Surfaces:          Yes
  Device has ECC support:                     Disabled
  CUDA Device Driver Mode (TCC or WDDM):       WDDM (Windows Display Driver Model)
  Device supports Unified Addressing (UVA):    Yes
  Device PCI Bus ID / PCI location ID:         3 / 0
  Compute Mode:
    < Default (multiple host threads can use ::cudaSetDevice()) with device simultaneously >
deviceQuery, CUDA Driver = CUDART, CUDA Driver Version = 5.5, CUDA Runtime Version = 5.5, NumDevs = 1, Device0 = Quadro K5000
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, that the device(s) match what is installed in your system, and that the test passed.

If a CUDA-capable device and the CUDA Driver are installed but **deviceQuery** reports that no CUDA-capable devices are present, ensure the device and driver are properly installed.

Running the **bandwidthTest** program, located in the same directory as **deviceQuery** above, ensures that the system and the CUDA-capable device are able to communicate correctly. The output should resemble [Figure 2](#).

```

C:\Windows\system32\cmd.exe
[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                  5751.2

Device to Host Bandwidth, 1 Device(s)
PINNED Memory Transfers
  Transfer Size (Bytes)      Bandwidth(MB/s)
  33554432                  6342.7

Device to Device Bandwidth, 1 Device(s)
PINNED Memory Transfers
  Transfer Size (Bytes)      Bandwidth(MB/s)
  33554432                  131928.7

Result = PASS

```

Figure 2 Valid Results from bandwidthTest CUDA Sample

The device name (second line) and the bandwidth numbers vary from system to system. The important items are the second line, which confirms a CUDA device was found, and the second-to-last line, which confirms that all necessary tests passed.

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

To see a graphical representation of what CUDA can do, run the sample Particles executable in:

- For Windows XP:

```
c:\Documents and Settings\All Users\Application Data\CUDA Samples\v5.5\bin  
\win32\Release
```

(or ...\**win64\Release** on 64-bit Windows)

- For Windows Vista, Windows 7, Windows 8, Windows Server 2003, and Windows Server 2008:

```
C:\ProgramData\NVIDIA Corporation\CUDA Samples\v5.5\bin\win32\Release
```

(or ...\**win64\Release** on 64-bit Windows)

# Chapter 3.

## COMPILING CUDA PROGRAMS

The project files in the CUDA Samples have been designed to provide simple, one-click builds of the programs that include all source code. To build the 32-bit or 64-bit Windows projects (for release or debug mode), use the provided **\*.sln** solution files for Microsoft Visual Studio 2008, 2010, or 2012 (and likewise for the corresponding versions of Microsoft Visual C++ Express Edition). You can use either the solution files located in each of the examples directories in

```
C:\ProgramData\NVIDIA Corporation\CUDA Samples\v5.5\<category>\<sample_name>
```

or the global solution files **Samples\*.sln** located in

```
C:\ProgramData\NVIDIA Corporation\CUDA Samples\v5.5
```

CUDA Samples are organized according to **<category>**. Each sample is organized into one of the following folders: (**0\_Simple**, **1\_Utilities**, **2\_Graphics**, **3\_Imaging**, **4\_Finance**, **5\_Simulations**, **6\_Advanced**, **7\_CUDALibraries**).

### 3.1. Compiling Sample Projects

The **bandwidthTest** project is a good sample project to build and run. It is located in the **NVIDIA Corporation\CUDA Samples\v5.5\1\_Utilities\bandwidthTest** directory.

The output is placed in **CUDA Samples\v5.5\bin\win32\Release**. (As mentioned previously, the **\win32** segment of this address will be **\win64** on 64-bit versions of Windows.) This location presumes that you used the default installation directory structure. Build the program using the appropriate solution file and run the executable. If all works correctly, the output should be similar to [Figure 2](#).

### 3.2. Sample Projects

The sample projects come in two configurations: debug and release (where release contains no debugging information).

A few of the example projects require some additional setup. The **simpleD3D9** example requires the system to have a Direct3D SDK installed and the Visual C++ directory paths

(located in **Tools > Options...**) properly configured. Consult the Direct3D documentation for additional details.

These sample projects also make use of the `$CUDA_PATH` environment variable to locate the CUDA Toolkit and a `.rules` file to locate and configure the `nvcc` compiler. The environment variable is set automatically and the `.rules` file is installed automatically as part of the CUDA Toolkit installation process. The `.rules` file is installed into `$VisualStudioInstallDir\VC\VCProjectDefaults`. You can reference this `.rules` file from your Visual Studio project files when building your own CUDA applications.

### 3.3. Build Customizations for New Projects

When creating a new CUDA application, the Visual Studio project file must be configured to include CUDA build customizations. To accomplish this, click **File-> New | Project... NVIDIA-> CUDA->**, then select a template for your CUDA Toolkit version. For example, selecting the "CUDA 5.5 Runtime" template will configure your project for use with the CUDA 5.5 Toolkit. The new project is technically a C++ project (`.vcxproj`) that is preconfigured to use NVIDIA's Build Customizations. All standard capabilities of Visual Studio C++ projects will be available.

To specify a custom CUDA Toolkit location, under **CUDA C/C++**, select **Common**, and set the **CUDA Toolkit Custom Dir** field as desired. Note that the selected toolkit must match the version of the Build Customizations.

### 3.4. Build Customizations for Existing Projects

When adding CUDA acceleration to existing applications, the relevant Visual Studio project files must be updated to include CUDA build customizations. For Visual Studio 2010 or 2012, this can be done using one of the following two methods:

1. Open the Visual Studio 2010 or 2012 project, right click on the project name, and select **Build Customizations...**, then select the CUDA Toolkit version you would like to target.
2. Alternatively, you can configure your project always to build with the most recently installed version of the CUDA Toolkit. First add a CUDA build customization to your project as above. Then, right click on the project name and select **Properties**. Under **CUDA C/C++**, select **Common**, and set the **CUDA Toolkit Custom Dir** field to `$ (CUDA_PATH)`. Note that the `$ (CUDA_PATH)` environment variable is set by the installer.

While Option 2 will allow your project to automatically use any new CUDA Toolkit version you may install in the future, selecting the toolkit version explicitly as in Option 1 is often better in practice, because if there are new CUDA configuration options added to the build customization rules accompanying the newer toolkit, you would not see those new options using Option 2.

If you use the `$ (CUDA_PATH)` environment variable to target a version of the CUDA Toolkit for building, and you perform an installation or uninstallation of any version of the CUDA Toolkit, you should validate that the `$ (CUDA_PATH)` environment variable

points to the correct installation directory of the CUDA Toolkit for your purposes. You can access the value of the `$ (CUDA_PATH)` environment variable via the following steps:

1. Open a run window from the Start Menu
2. Run:  

```
control sysdm.cpl
```
3. Select the "Advanced" tab at the top of the window
4. Click "Environment Variables" at the bottom of the window

**Note for advanced users:** If you wish to try building your project against a newer CUDA Toolkit without making changes to any of your project files, go to the Visual Studio 2010 or 2012 command prompt, change the current directory to the location of your project, and execute a command such as the following:

```
msbuild <projectname.extension> /t:Rebuild /p:CudaToolkitDir="drive:/path/to/new/toolkit/"
```

## Chapter 4.

# 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 the CUDA Toolkit documentation directory.

A number of helpful development tools are included in the CUDA Toolkit or are available for download from the NVIDIA Developer Zone to assist you as you develop your CUDA programs, such as NVIDIA® Nsight™ Visual Studio Edition, NVIDIA Visual Profiler, and cuda-memcheck.

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



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