



INTEL[®] DPC++ COMPATIBILITY TOOL

Demo & Tutorial: Migrating CUDA Codes to DPC++

Edward Mascarenhas, Sunny Gogar, Auber (Jie) Lin | Intel Corporation

October 2020



NOTICES AND DISCLAIMERS

Optimization Notice: Intel's compilers may or may not optimize to the same degree for non-Intel microprocessors for optimizations that are not unique to Intel microprocessors. These optimizations include SSE2, SSE3, and SSSE3 instruction sets and other optimizations. Intel does not guarantee the availability, functionality, or effectiveness of any optimization on microprocessors not manufactured by Intel. Microprocessor-dependent optimizations in this product are intended for use with Intel microprocessors. Certain optimizations not specific to Intel microarchitecture are reserved for Intel microprocessors. Please refer to the applicable product User and Reference Guides for more information regarding the specific instruction sets covered by this notice.

All product plans and roadmaps are subject to change without notice.

Intel technologies may require enabled hardware, software or service activation.

Results have been estimated or simulated.

No product or component can be absolutely secure.

Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.

No license (express or implied, by estoppel or otherwise) to any intellectual property rights is granted by this document.

Intel disclaims all express and implied warranties, including without limitation, the implied warranties of merchantability, fitness for a particular purpose, and non-infringement, as well as any warranty arising from course of performance, course of dealing, or usage in trade.

Intel and the Intel logo are trademarks of Intel Corporation in the U.S. and/or other countries. Other names and brands may be claimed as the property of others. © Intel Corporation.

Agenda

- oneAPI Brief Overview
- Intel® DPC++ Compatibility Tool Workflow
- Migration Flow and Vector-Add Example
- Demo Tutorial
 - Migrate Single CUDA* File Project
 - Migrate Multi CUDA Files Project
- Code Review and Best Known Methods for Migration
- Eclipse and Visual Studio Integration
- Key Takeaways

oneAPI Core Concept

Project oneAPI delivers a unified programming model to simplify development across diverse architectures

oneAPI has two main parts:

oneAPI Industry Initiative

oneAPI Intel Product

Common developer experience across Scalar, Vector, Matrix, and Spatial (SVMS) architectures

Unified and simplified language and libraries for expressing parallelism

Uncompromised native high-level language performance

Support for CPU, GPU, AI, and FPGA

Based on industry standards and open specifications



Refer to software.intel.com/articles/optimization-notice for more information regarding performance & optimization choices in Intel software products.
Copyright © Intel Corporation 2020

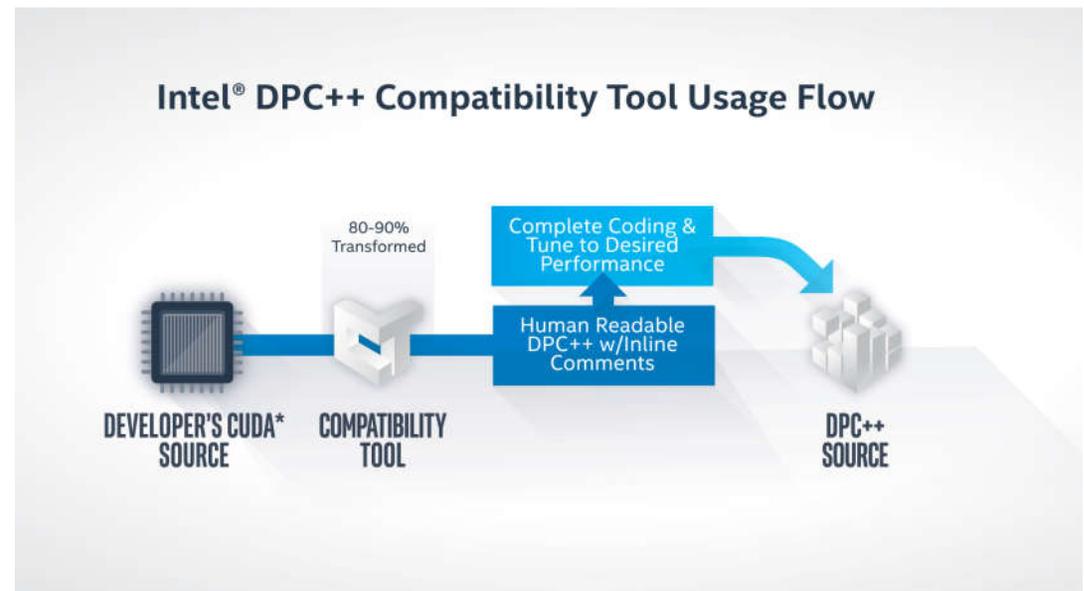
Intel® DPC++ Compatibility Tool

Minimizes Code-Migration Time

Assists developers migrating code written in CUDA to DPC++ by generating DPC++ code wherever possible

Expect up to **80-90%** of code to migrate automatically

Inline comments are provided to help developer complete code



MIGRATING VECTOR ADD EXAMPLE

Vector-Add Example: Migration with Intel® DPC++ Compatibility Tool

CUDA

```
#include <cuda.h>
#include <stdio.h>
#define VECTOR_SIZE 256
```

```
> global void VectorAddKernel(float* A, float* B, float* C)
{
  A[threadIdx.x] = threadIdx.x + 1.0f;
  B[threadIdx.x] = threadIdx.x + 1.0f;
  C[threadIdx.x] = A[threadIdx.x] + B[threadIdx.x];
}
```

```
int main()
{
  float *d_A, *d_B, *d_C;
  cudaMalloc(&d_A, VECTOR_SIZE*sizeof(float));
  cudaMalloc(&d_B, VECTOR_SIZE*sizeof(float));
  cudaMalloc(&d_C, VECTOR_SIZE*sizeof(float));
}
```

DPC++

```
>#include <CL/sycl.hpp>
#include <dpct/dpct.hpp>
#define VECTOR_SIZE 256
```

```
void VectorAddKernel(float* A, float* B, float* C, sycl::nd_item<3>
item_ct1)
{
  A[item_ct1.get_local_id(2)] = item_ct1.get_local_id(2) + 1.0f;
  B[item_ct1.get_local_id(2)] = item_ct1.get_local_id(2) + 1.0f;
  C[item_ct1.get_local_id(2)] =
    A[item_ct1.get_local_id(2)] + B[item_ct1.get_local_id(2)];
}
```

```
int main()
{
  dpct::device_ext &dev_ct1 = dpct::get_current_device();
  sycl::queue &q_ct1 = dev_ct1.default_queue();
  float *d_A, *d_B, *d_C;
  d_A = sycl::malloc_device<float>(VECTOR_SIZE, q_ct1);
  d_B = sycl::malloc_device<float>(VECTOR_SIZE, q_ct1);
  d_C = sycl::malloc_device<float>(VECTOR_SIZE, q_ct1);
}
```

Vector-Add Migration Example (continued)

CUDA

```
VectorAddKernel<<<1, VECTOR_SIZE>>>(d_A, d_B, d_C);
```

```
float Result[VECTOR_SIZE] = { };  
cudaMemcpy(Result, d_C, VECTOR_SIZE*sizeof(float),  
           cudaMemcpyDeviceToHost);
```

```
cudaFree(d_A);  
cudaFree(d_B);  
cudaFree(d_C);
```

```
for (int i = 0; i < VECTOR_SIZE; i++) {  
    if (i % 16 == 0) {  
        printf("\n");  
    }  
    printf("%f ", Result[i]);  
}  
  
return 0;  
}
```

DPC++

```
q_ct1.submit([&](sycl::handler &cgh) {  
    cgh.parallel_for(sycl::nd_range<3>(  
        sycl::range<3>(1, 1, VECTOR_SIZE),  
        sycl::range<3>(1, 1, VECTOR_SIZE)),  
        [=](sycl::nd_item<3> item_ct1) {  
            VectorAddKernel(d_A, d_B, d_C, item_ct1);  
        });  
});
```

```
float Result[VECTOR_SIZE] = { };  
q_ct1.memcpy(Result, d_C, VECTOR_SIZE * sizeof(float)).wait();
```

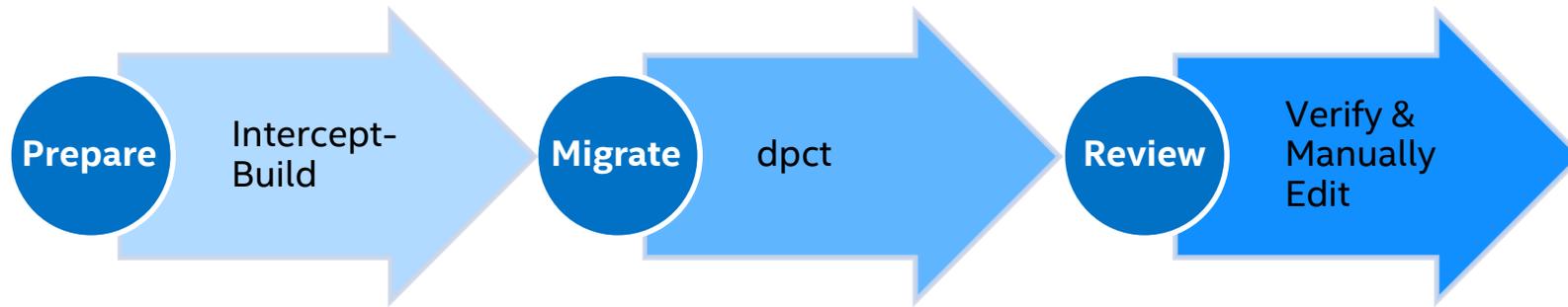
```
sycl::free(d_A, q_ct1);  
sycl::free(d_B, q_ct1);  
sycl::free(d_C, q_ct1);
```

```
for (int i = 0; i < VECTOR_SIZE; i++) {  
    if (i % 16 == 0) {  
        printf("\n");  
    }  
    printf("%f ", Result[i]);  
}  
  
return 0;  
}
```

MIGRATING NEEDLEMAN WUNSCH AND HYDROC EXAMPLES

Migration Flow

Typical preparation steps for simple to complex projects



Demo: Single CUDA File Project Migration

- Rodinia Benchmark Suite v3.1 – Introduction
- Setting/Verifying the Environment for Intel® DPC++ Compatibility Tool
- Demo
 - Planning for Migration
 - Compatibility Tool Options
 - Migrating Needleman Wunsch Application

<http://rodinia.cs.virginia.edu/doku.php>

<https://software.intel.com/en-us/get-started-with-intel-dpcpp-compatibility-tool>

<https://software.intel.com/en-us/intel-dpcpp-compatibility-tool-user-guide-usage-workflow-overview>

Demo: HydroC - Multi CUDA Files Project Migration

- Setting/Verifying the Environment for Intel® DPC++ Compatibility Tool
- Demo
 - Planning for Migration; Understanding the Application File ...
 - *intercept-build* Options
 - Compatibility Tool Options
 - Migrating HydroC Application

https://github.com/HydroBench/Hydro/tree/master/HydroC/cuHydroC_2DMpi/Src
<https://github.com/HydroBench/Hydro>
<https://github.com/HydroBench/Hydro/blob/master/License.txt>

Code Review or Rewrite Needed

Diagnostic Reference

- Error code logic replaced with (*,0) code or commented out
- Equivalent DPC++ API not available
- CUDA Compute Capability-dependent logic
- Hardware-dependent API (clock())
- Missing features (Unsupported API)
- Execution time measurement logic
- Handling built-in vector type conflicts
- Migration of cuBLAS API (Review arguments list)

General Best Known Methods (BKM)s

- Migrate Incrementally
 - If you see *dpct* generate multiple errors when migrating a long list of CUDA source files in one run, do it one-by-one
- Start with a clean project - “make clean” before running “intercept-build make”

USING PLUGINS WITH IDE

Eclipse: Gaussian

The screenshot shows the Eclipse IDE interface. The main editor displays the file `gaussian.dp.cpp` with the following code snippet:

```
212     memset( &deviceProp, 0, sizeof(deviceProp));
213     /*
214     DPCT1003:0: Migrated API does not return error code.
215     may need to rewrite this code.
216     */
217     if (0 == (dpct::dev_mgr::instance()
218             .get_device(nDeviceIdx)
219             .get_device_info(deviceProp),
220             0))
221     {
222         printf("\nDevice Name \t\t - %s ", deviceProp.g
223               printf( "\n*****
224               printf("\nTotal Global Memory\t\t\t - %lu KB",
225               deviceProp.get_global_mem_size() / 1024)
226     /*
```

Below the editor, the Intel(R) DPC++ Compatibility Tool window is open, displaying a table of warnings:

Migrated Source File Location	Source File Location	Type	ID	Message	Actions
/home/intel...p, Line 216	/home/int... Line 210	warning	DPCT1003	Migrated API does not return error code. (*	Fix Help
/home/intel...p, Line 229	/home/int... Line 215	warning	DPCT1019	local_mem_size in SYCL is not a complete e	Fix Help
/home/intel...p, Line 242	/home/int... Line 221	warning	DPCT1022	There is no exact match between the maxG	Fix Help
/home/intel...p, Line 251	/home/int... Line 223	warning	DPCT1005	The device version is different. You need to	Fix Help
/home/intel...p, Line 266	/home/int... Line 230	warning	DPCT1009	SYCL uses exceptions to report errors and e	Fix Help
/home/intel...p, Line 271	/home/int... Line 230	warning	DPCT1010	SYCL uses exceptions to report errors and e	Fix Help
/home/intel...p, Line 569	/home/int... Line 462	warning	DPCT1010	SYCL uses exceptions to report errors and e	Fix Help

Refer to software.intel.com/articles/optimization-notice for more information regarding performance & optimization choices in Intel software products.
Copyright © Intel Corporation 2020

Visual Studio 2019: Gaussian

```
219     int nDevCount = 0;
220
221     /* DPCT_ORIG  cudaGetDeviceCount( &nDevCount ); */
222     nDevCount = dpct::dev_mgr::instance().device_count();
223     printf( "Total Device found: %d", nDevCount );
224     for (int nDeviceIdx = 0; nDeviceIdx < nDevCount; ++nDeviceIdx )
225     {
226         memset( &deviceProp, 0, sizeof(deviceProp));
227         /* DPCT_ORIG  if( cudaSuccess ==
228            * cudaGetDeviceProperties(&deviceProp, nDeviceIdx)) */
229         /*
230            DPCT1003:0: Migrated API does not return error code. (*, 0) is inserted.
231            You may need to rewrite this code.
232            */
233         if (0 == (dpct::dev_mgr::instance()
234                 .get_device(nDeviceIdx)
235                 .get_device_info(deviceProp),
236                 0))
237         {
238             /* DPCT_ORIG  printf( "\nDevice Name \t\t - %s ",
239                * deviceProp.name ); */
240             printf("\nDevice Name \t\t - %s ", deviceProp.get_name());
241             printf( "\n*****");
242             /* DPCT_ORIG  printf( "\nTotal Global Memory\t\t\t - %lu
243                * KB", deviceProp.totalGlobalMem/1024 ); */
244             printf("\nTotal Global Memory\t\t\t - %lu KB",
245                   deviceProp.get_global_mem_size() / 1024);
```

Intel(R) DPC++ Compatibility Tool

DPCT1003 : The migrated API does not return an error code, so (*, 0) is inserted

Typically, this happens because the CUDA API returns an error code and then it is consumed by the program logic.

SYCL uses exceptions to report errors and does not return the error code.

The Intel® DPC++ Compatibility Tool inserts a (*, 0) operator, so that the resulting application could be compiled. This operator returns 0 and is inserted if the return code is expected by the program logic and the new API does not return it. The recommendation is to review all such places in the code.

If in a DPC++ application you:

- Do not need the code that consumes the error code, remove the code and the (*, 0) operator.
- Need the code that consumes the error code, try to replace it with an exception handling code and use your logic in an exception handler.

Migrated Source File Location	Source File Location	Type	ID	Message	Actions
C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	Warning	DPCT1003	Migrated API does not return error code. (*, 0) is inserted.	Help
C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	Warning	DPCT1019	local_mem_size in SYCL is not a complete equivalent of	Help
C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	Warning	DPCT1022	There is no exact match between the maxGridSize and the	Help
C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	Warning	DPCT1005	The device version is different. You need to rewrite	Help
C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	Warning	DPCT1009	SYCL uses exceptions to report errors and does not use	Help
C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	Warning	DPCT1010	SYCL uses exceptions to report errors and does not use	Help
C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	C:\temp\SampleCode\rodenia_3.1\cuda\ga\C\temp\SampleCode\rodenia_3.1\cuda\ga	Warning	DPCT1010	SYCL uses exceptions to report errors and does not use the error	Help

Refer to software.intel.com/articles/optimization-notice for more information regarding performance & optimization choices in Intel software products.
Copyright © Intel Corporation 2020



Key Takeaways

- OneAPI delivers a unified programming model to simplify development across diverse architectures
- Intel DPC++ Compatibility tool assists developers in migrating code written in CUDA to DPC++, increasing developer productivity
- DPC++ is an open specification for a portable, architecture-neutral language for expressing parallelism; it is based on industry standards

Are You Ready to Try oneAPI?

1. Identify potential workloads/candidates for testing
 - a. Download DPCT and migrate code to DPC++ on-prem, if applicable
 - b. Test, tune and optimize your code or test samples in the Intel® DevCloud—a cloud-based development sandbox environment that gives you full access to the latest Intel® hardware and oneAPI software
<https://software.intel.com/devcloud/oneapi>
2. Learn more at <http://software.intel.com/oneapi> the channel to documentation, downloads, access to Intel® Devcloud, and access to support forum

QUESTIONS?

THANK YOU