



# NVIDIA DOCA DPACC Compiler

## User Guide

# Table of Contents

<b>Chapter 1. Introduction.....</b>	<b>1</b>
1.1. Glossary.....	1
1.2. Offloading Work on DPA.....	1
1.3. Writing DPA Applications.....	2
1.3.1. Language Support.....	2
1.3.2. Restrictions on DPA Code.....	2
1.3.3. DPA RPC Functions.....	3
1.3.4. DPA Global Functions.....	3
1.3.5. Characteristics of DPA Global Functions.....	3
1.3.6. Handling User-defined Data Types.....	3
1.3.7. Characteristics of Annotated Types.....	3
1.3.8. DPA Intrinsics.....	3
<b>Chapter 2. Prerequisites.....</b>	<b>5</b>
2.1. Supported Versions.....	5
<b>Chapter 3. Description.....</b>	<b>6</b>
3.1. DPACC Inputs and Outputs.....	6
3.1.1. DPA Program.....	7
3.1.2. DPA Object.....	7
3.2. DPACC Trajectory.....	7
3.3. Modes of Operation.....	8
3.3.1. Compile-and-link Mode.....	8
3.3.2. Compile-only Mode.....	9
<b>Chapter 4. Execution.....</b>	<b>10</b>
4.1. Mandatory Arguments.....	10
4.2. Commonly Used Arguments.....	10
4.3. Examples.....	11
4.3.1. Link with Device Libraries.....	11
4.3.2. Include Headers.....	12
4.4. DPA Compiler Usage.....	12
4.4.1. Compiler Driver Command Line Options.....	12
4.4.2. Linker Command Line Options.....	12
4.4.3. dpacc-extract Command Line Options.....	12
4.4.4. Objdump Command Line Options.....	13
4.4.5. Archiver Command Line Options.....	13
4.4.6. NM Tool Command Line Options.....	13

4.4.7. Common Compiler Options.....	13
4.4.8. Common Linker Options.....	14
4.4.9. Debugging Options.....	14
4.4.10. Miscellaneous Notes.....	14



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# Chapter 1. Introduction

DPACC is a high-level compiler for the DPA processor. It compiles code targeted for the data-path accelerator (DPA) processor into an executable called as 'device executable' and generates a DPA program.

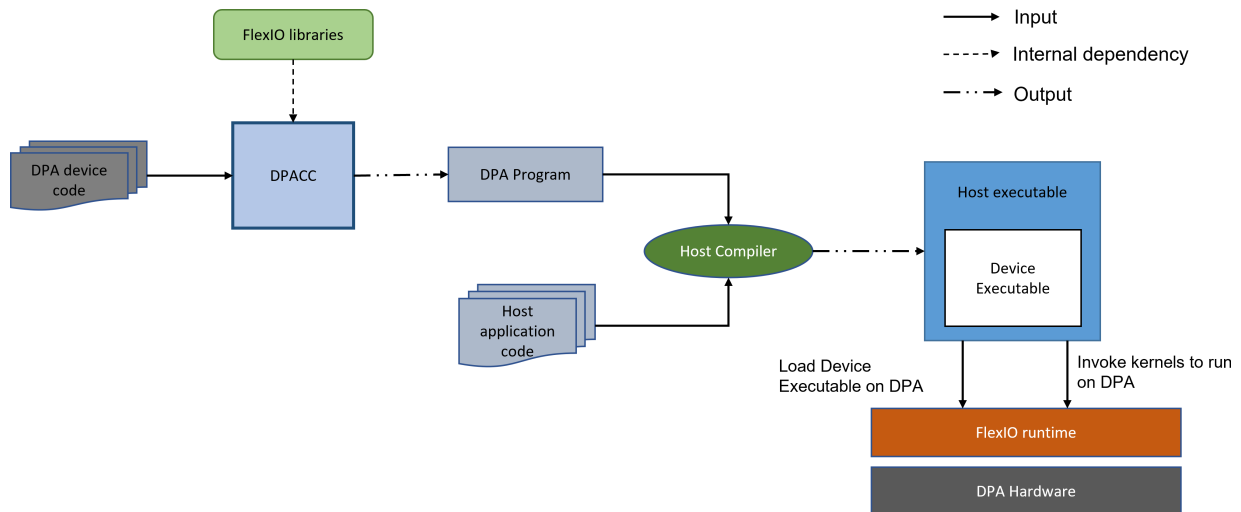
The DPA program is a host library with interfaces encapsulating the device executable. This DPA program is linked with the host application to generate a host executable. The host executable can invoke the DPA code through FlexIO runtime API.

DPACC uses DPA compiler (`dpa-clang`) to compile code targeted for DPA. `dpa-clang` is part of the DPA toolchain package which is an LLVM-based cross-compiling bare-metal toolchain. It provides Clang compiler, LLD linker targeting DPA architecture, and other utilities.

## 1.1. Glossary

Term	Definition
Device	DPA as present on the BlueField DPU
Host	CPU that launches the device code to run on the DPA
Device function	Any C function that runs on the DPA device
DPA global function	Device function that is the point of entry when offloading any work on DPA
Host compiler	Compiler used to compile the code targeting the host CPU
Device compiler	Compiler used to compile code targeting the DPA
DPA program	Host library that encapsulates the DPA device executable ( <code>.elf</code> ) and host stubs which are used to access the device executable

## 1.2. Offloading Work on DPA



To invoke a DPA function from host, the following things are required:

- ▶ DPA device code – C programs, targeted to run on the DPA. DPA device code may contain one or more entry functions.
- ▶ Host application code – the corresponding host application. Please refer to [NVIDIA DOCA DPA Subsystem Programming Guide](#) for more details
- ▶ Runtime – FlexIO or DOCA DPA library provides the runtime

The generated DPA program, when linked with host application, results in a host executable containing both the host and device executables. The host application is in charge of loading the device executable on the device.

## 1.3. Writing DPA Applications

DPA device code is a C code with some restrictions and special definitions.

FlexIO or DOCA-DPA APIs provide interfaces to DPA.

### 1.3.1. Language Support

The DPA is programmed using a subset of the C11 language standard. The compiler documents any constructs that are not available. Language constructs, where available, retain their standard definitions.

### 1.3.2. Restrictions on DPA Code

- ▶ Use of C thread local storage is not allowed for any variables
- ▶ Identifiers with `_dpacc` prefix are reserved by the compiler. Use of such identifiers may result in an error or undefined behavior.
- ▶ DPA processor does not have native floating-point support; use of floating point operations is disabled

### 1.3.3. DPA RPC Functions

A remote procedure call function is a synchronous call that triggers work in DPA and waits for its completion. It is annotated with a `__dpa_rpc__` attribute.

For more information, please refer to [NVIDIA DOCA DPA Subsystem Programming Guide](#).

### 1.3.4. DPA Global Functions

A DPA global function is a device function referenced from the host code. They are annotated with a `__dpa_global__` attribute.

### 1.3.5. Characteristics of DPA Global Functions

- ▶ Global functions cannot explicitly return a value. They must have `void` return type.
- ▶ Global functions cannot accept C pointers and arrays as arguments (e.g., `void my_global (int *ptr, int arr[])`)
- ▶ Global functions cannot accept a variable number of arguments
- ▶ Inline specifier is not allowed on global functions

### 1.3.6. Handling User-defined Data Types

User-defined data types, when used as global function arguments, require special handling. They must be annotated with a `__dpa_global__` attribute.

If the user-defined data type is `typedef`'d, the `typedef` statement must be annotated with a `__dpa_global__` attribute along the data type itself.

### 1.3.7. Characteristics of Annotated Types

- ▶ They must have a copy of the definition in all translation units where they are used as global function arguments
- ▶ They cannot have pointers, variable length arrays, and flexible arrays as members
- ▶ Fixed-size arrays as C structure members are supported
- ▶ These characteristics apply recursively to any user-defined/`typedef`'d types that are members of an annotated type

DPACC processes all DPA global functions and annotated data structures and generates host and device interfaces to facilitate the function launch.

### 1.3.8. DPA Intrinsics

DPA features such as fences and processor-specific instructions are exposed via intrinsics by the DPA compiler. All intrinsics defined in the header file `dpaintrin.h` are guarded by the `DPA_INTRIN_VERSION_USED` macro. The current `DPA_INTRIN_VERSION` is 1.3.

**Example:**



```
#define DPA_INTRIN_VERSION_USED (DPA_INTRIN_VERSION(1, 3))
#include <dpaintrin.h>
...
__dpa_thread_writeback_window(); // Fence for write barrier
```

For more information, please refer to [NVIDIA DOCA DPA Subsystem Programming Guide](#).



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# Chapter 2. Prerequisites

Package	Instructions
Host compiler	<p>Compiler specified through <code>hostcc</code> option. Both <code>gcc</code> and <code>clang</code> are supported.</p> <p> Note: Minimum supported version for <code>clang</code> as <code>hostcc</code> is <code>clang 3.8.0</code>.</p>
Device compiler	<p>The default device compiler is the "DPA compiler". Installing the DPACC package also installs the DPA compiler binaries <code>dpa-clang</code>, <code>dpa-ar</code>, <code>dpa-nm</code> and <code>dpa-objdump</code>.</p> <p> Note: <code>dpa-clang</code> is the only supported device compiler.</p>
FlexIO SDK and C library	<p>Available as part of the DOCA software package. DPA toolchain does not provide C library and corresponding headers. Users are expected to use the C library for DPA from the FlexIO SDK.</p>

## 2.1. Supported Versions

- ▶ DPACC version 1.3.0
- ▶ See [NVIDIA DOCA DPA Subsystem Programming Guide](#) for more

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# Chapter 3. Description

## 3.1. DPACC Inputs and Outputs

DPACC can produce DPA programs in a single command by accepting all source files as input. DPACC also offers the flexibility of producing DPA object files from individual source files.

DPA object files contain both host stub objects (DPACC-generated interfaces) and device objects. These DPA object files can later be given to DPACC as input to produce the DPA library.

Phase	Option Name	Default Output File Name
Compile input device code files to DPA object files	<code>--compile</code> or <code>-c</code>	<code>.dpa.o</code> appended to the name of each input source file
Compile and link the input device code files/DPA object files, and produce a DPA program	No specific option	No default name, output file name must be specified

DPACC can accept the following three file types as input:

File Extension	File Type	Description
<code>.c</code>	C source file	DPA device code
<code>.dpa.o</code>	DPA object file	Object file generated by DPACC, containing both host and device objects

Based on the mode of operations, DPACC can generate the two following output files:

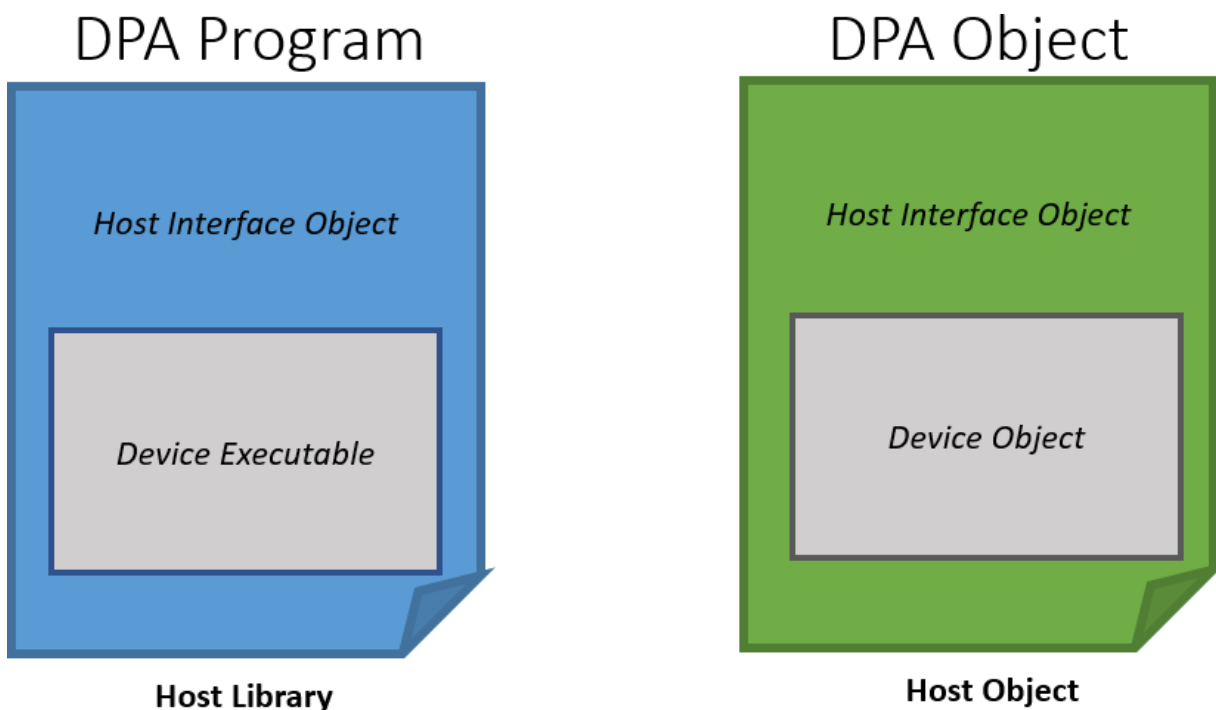
Output File Type	Input Files
DPA program	C source files, DPA object files, and/or DPA object archives
DPA object file	C source files

### 3.1.1. DPA Program

DPACC produces a DPA program in compile-and-link mode. A DPA program is a host library which contains:

- ▶ DPACC-generated host stubs which facilitate invoking a DPA global function from the host application
- ▶ Device executable, generated by DPACC by compiling input DPA device code

DPA program library has to be linked with the host application that contains appropriate runtime APIs to load the device executable onto DPA memory.

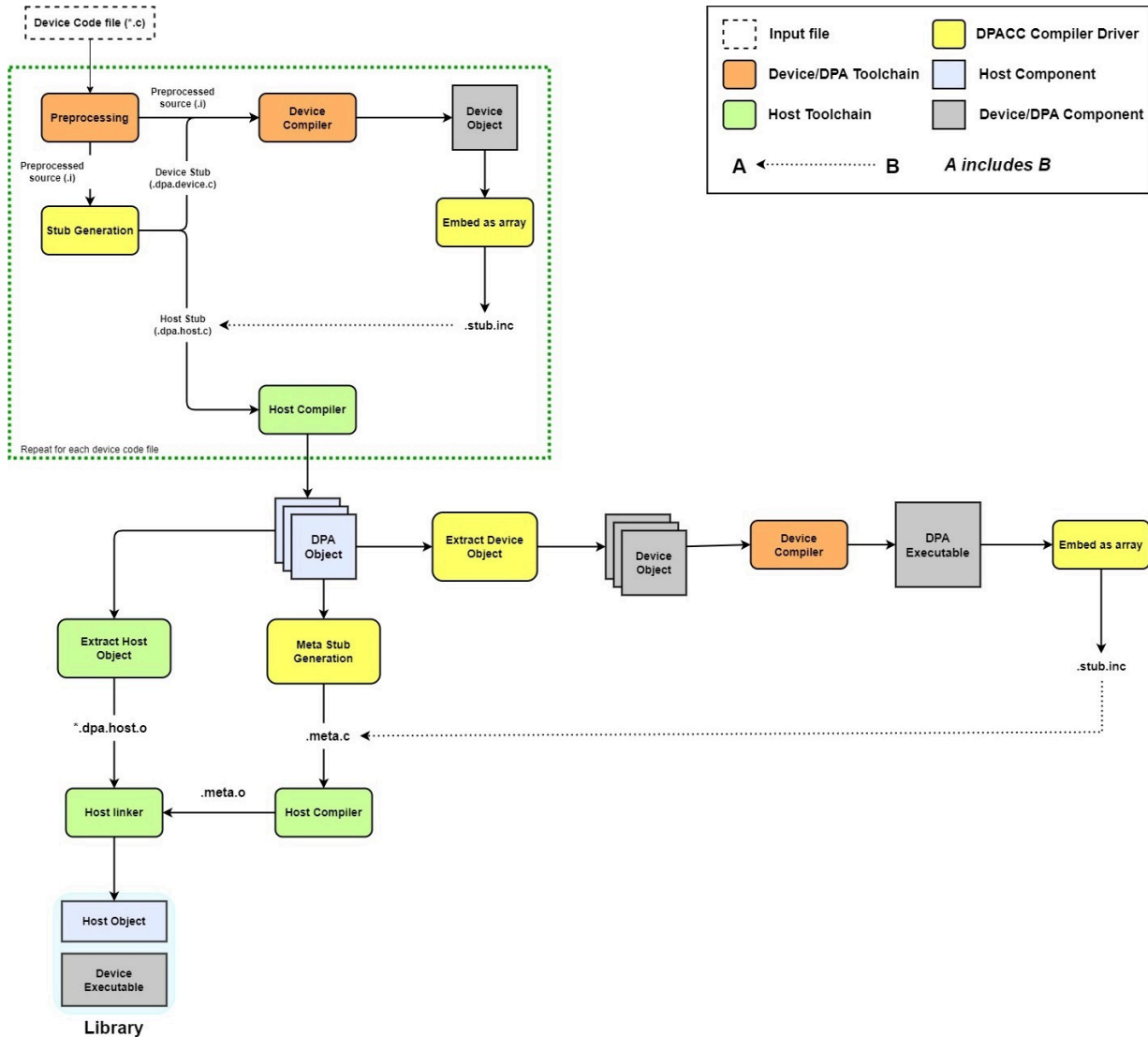


### 3.1.2. DPA Object

DPACC produces DPA object files in compile-only mode. A DPA object is an object file for the host machine. In a DPA object, the device object generated by compiling the input device code file is placed inside a specific section of the generated host stubs object. This process is repeated for each input file.

## 3.2. DPACC Trajectory

The following diagram illustrates DPACC compile-and-link mode trajectory.



## 3.3. Modes of Operation

### 3.3.1. Compile-and-link Mode

This is a one-step mode that accepts C source files or DPA object files and produces the DPA program. Specifying the output library name is mandatory in this mode.

Example commands:

```
$ dpacc in1.c in2.c -o myLib1.a -hostcc=gcc # Takes C sources to produce myLib1.a library
$ dpacc in3.dpa.o in4.dpa.o -o myLib2.a -hostcc=gcc # Takes DPA object files to produce myLib2.a library
$ dpacc in1.c in3.dpa.o -o myLib3.a -hostcc=gcc # Takes C source and DPA object to produce myLib3.a library
```

### 3.3.2. Compile-only Mode

This mode accepts C source code and produces `.dpa.o` object files. These files can be given to DPACC to produce the DPA program. The mode is invoked by the `--compile` or `-c` option.

The user can explicitly provide the output object file name using the `--output-file` or `-o` option.

Example commands:

```
$ dpacc -c input1.c -hostcc=gcc # Produces input1.dpa.o
$ dpacc -c input3.c input4.c -hostcc=gcc # Produces input3.dpa.o and
input4.dpa.o
$ dpacc -c input2.c -o myObj.dpa.o -hostcc=gcc # Produces myObj.dpa.o
```

# Chapter 4. Execution

To execute DOCA DPACC Compiler:

```
Usage: dpacc <list-of-input-files> -hostcc=<path> [other options]
Helper Flags:
-h, --help                Print help information about DPACC
-V, --version             Print DPACC version information
-v, --verbose             List the compilation commands generated by
this invocation while also executing every command in verbose mode
-dryrun, --dryrun        Only list the compilation commands generated
by DPACC, without executing them
-keep, --keep             Keep all intermediate files that are generated
during internal compilation steps in the current directory
-keep-dir, --keep-dir    Keep all intermediate files that are generated
during internal compilation steps in the given directory
-optf, --options-file <file>,... Include command line options from the
specified file
```

## 4.1. Mandatory Arguments

Flag	DPACC Mode	Description
List of one or more input files	All	List of C source files or DPA object file names. Specifying at least one input file is mandatory. A file with an unknown extension is treated as a DPA object file.
-hostcc, --hostcc <path>	All	Specify the host compiler. This is typically the native compiler present on the host system.
-o, --output-file <file>	Compile-and-link	Specify name and location of the output DPA program.

## 4.2. Commonly Used Arguments

Flag	Description
-app-name, --app-name <name>	Specify DPA application name for the DPA program. This option is required if multiple DPA programs are part of a host application

Flag	Description
	because each DPA application must have a unique name. Default name is <code>__dpa_a_out</code> .
<code>-devicecc-options, --devicecc-options &lt;options&gt;,...</code>	Specify the list of options to pass to the device compiler.
<code>-devicelink-options, --devicelink-options &lt;options&gt;, ...</code>	Specify the list of options to pass during device linking stage. FlexIO libraries are linked by DPACC by default.
<code>-I, --common-include-path &lt;path&gt;, ...</code>	Specify include search paths common to host and device code compilation. FlexIO headers paths are included by DPACC by default.
<code>-devicecc, --devicecc &lt;path&gt;</code>	Specify the device compiler. By default, DPACC invokes <a href="#">dpa-clang</a> .
<code>-o, --output-file &lt;file&gt;</code>	Specify name and location of the output file. <ul style="list-style-type: none"> <li>▶ Compile-only mode – name of the output DPA object file. If not specified, <code>.dpa.o</code> is generated for each <code>.c</code> file.</li> <li>▶ Compiler-and-link mode – name of the output DPA program. This is a mandatory option in compiler-and-link mode.</li> </ul>
<code>-hostcc-options, --hostcc-options &lt;options&gt;, ...</code>	Specify the list of options to pass to the host compiler.



Important: The `devicecc-options` option allows passing any option to the device compiler. However, passing options that prevent compilation of the input file may lead to unexpected behavior (e.g., `-devicecc-options="-version"` makes the device compiler print the version and not process input files).



Important: Incompatible options that affect DPA global function argument sizes during DPACC invocation and host application compilation may lead to undefined behavior during execution (e.g., passing `-hostcc-options="-fshort-enums"` to DPACC and missing this option when building the host application).

## 4.3. Examples

This section provides some common use cases of DPACC and showcases the `dpacc` command.

### 4.3.1. Link with Device Libraries

This example specifies the names and paths of the libraries using `devicelink-options`:

```
dpacc input.c -hostcc=gcc -o libInput.a -devicelink-options="-L <path-to-library> -l<libName>"
```

## 4.3.2. Include Headers

This example includes headers for device compilation using `devicecc-options` and host compilation using `hostcc-options`. You may also specify headers for any compilation on both the host and device side using the `-I` option.

```
dpacc input.c -hostcc=gcc -o libInput.a -I <common-headers-path> -devicecc-
options="-I <device-headers-path>" -hostcc-options="-I <host-headers-path>"
```

## 4.4. DPA Compiler Usage

`dpa-clang` is a compiler driver for accessing the Clang/LLVM compiler, assembler, and linker which accepts C code files or object files and generates an output according to different usage modes.



Note: Invoking the compiler, assembler, or linker directly may lead to unexpected errors.

Refer to the following resources for detailed user guide and command line references:

- ▶ [Clang Compiler User's Manual](#)
- ▶ [Clang command line argument reference](#)
- ▶ [Target-dependent compilation options](#)

### 4.4.1. Compiler Driver Command Line Options

```
dpa-clang <list-of-input-files> [other-options]
```

### 4.4.2. Linker Command Line Options

LLD is the default linker provided in the DPA toolchain. Linker-related options are passed to through the compiler driver.

```
dpa-clang -Wl,<linker-option>
```

For more information, please refer to the [LLD command line reference](#).

### 4.4.3. dpacc-extract Command Line Options

`dpacc-extract` is a tool for extracting a device executable out of a DPA program or a host executable containing DPA program(s).

To execute `dpacc-extract`:

```
Usage: dpacc-extract <input-file> -o=<output-file> [other options]
```

Helper Flags:

<code>-o, --output-file</code>	Specify name of the output file
<code>-app-name, --app-name &lt;name&gt;</code>	Specify name of the DPA application to extract
<code>-h, --help</code>	Print help information about <code>dpacc-extract</code>
<code>-V, --version</code>	Print <code>dpacc-extract</code> version information
<code>-optf, --options-file &lt;file&gt;,...</code>	Include command line options from the specified file



Mandatory arguments:

Flag	Description
Input file	DPA program or host executable containing DPA program. Specifying one input file is mandatory.
<code>-o, --output-file &lt;file&gt;</code>	Specify name and location of the output device executable.
<code>-app-name, --app-name &lt;name&gt;</code>	Specify name of the DPA application to extract. Mandatory if input file has multiple DPA apps.

#### 4.4.4. Objdump Command Line Options

The `dpa-objdump` utility prints the contents of object files and final linked images named on the command line.

For more information, please refer to the [Objdump command line reference](#).

Commonly used `dpa-objdump` options:

Flag	Description
<code>--mcpu=nv-dpa-bf3</code>	Option to choose micro-architecture for DPA processor. This option is not turned on by default.

#### 4.4.5. Archiver Command Line Options

`dpa-ar` is a Unix `ar`-compatible archiver.

For more information, please refer to the [Archiver command line reference](#).

#### 4.4.6. NM Tool Command Line Options

The `dpa-nm` utility lists the names of symbols from object files and archives.

For more information, please refer to the [NM tool command line reference](#).

#### 4.4.7. Common Compiler Options

Flag	Description
<code>-mcpu=nv-dpa-bf3</code>	Option to choose micro-architecture and ABI for DPA processor. This is the default option for the compiler.
<code>-mrelax/-mno-relax</code>	Option to enable/disable linker relaxations.
<code>-I &lt;dir&gt;</code>	Option to include header files present in <code>&lt;dir&gt;</code> .

## 4.4.8. Common Linker Options

Flag	Description
<code>-Wl, -L &lt;path-to-library&gt; -Wl, -l&lt;library-name&gt;</code>	Option to link against libraries



Note: Linker options are provided through the compiler driver dpa-clang.



Note: The LLD linker script is honored in addition to the default configuration rather than replacing the whole configuration like in GNU ID. Hence, additional options may be required to override some default behaviors.

## 4.4.9. Debugging Options

Flag	Description
<code>-fdebug-macro</code>	Option to emit macro debugging information. This option enables macro-debugging similar to GCC option <code>-g3</code> .

## 4.4.10. Miscellaneous Notes

- ▶ DPA toolchain provides the ability to invoke GNU linker instead of the default LLD linker via the `--fuse-ld=<arg>` option in the [command line reference](#). However, doing so is not recommended as it has not been tested.
- ▶ Objects produced by LLD are not compatible with those generated by any other linker.

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