Intel® Integrated Performance Primitives

Developer Guide

Intel IPP 2017 Update 2

Legal Information

Contents

Legal Information

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Introducing the Intel® Integrated Performance Primitives

Use the Intel® Integrated Performance Primitives (Intel® IPP) to improve performance of multimedia, enterprise data, embedded, communications, and scientific/technical applications. The primitives are a common interface for thousands of commonly used algorithms. Using these primitives enables you to automatically tune your application to many generations of processors without changes in your application.

Intel IPP library provides high performance implementations of signal, image, and data processing functions for several hardware/instruction set generations. Code written with Intel IPP automatically takes advantage of available CPU capabilities. This can provide tremendous development and maintenance savings. You can write programs with one optimized execution path, avoiding the alternative of multiple paths (Intel® Streaming SIMD Extensions 2, Supplemental Streaming SIMD Extensions 3, Intel® Advanced Vector Extensions , etc.) to achieve optimal performance across multiple generations of processors.

The goal of the Intel IPP software is to provide algorithmic building blocks with

- a simple "primitive" C interface and data structures to enhance usability and portability
- faster time-to-market
- scalability with Intel® hardware

Intel IPP library is available as part of Intel® Parallel Studio XE and Intel® System Studio. It is also provided as a standalone package under the Community Licensing Program.

The majority of Intel IPP functions offered in different product suites are the same. But there are several Intel IPP libraries or domains that are only included in some product packages. The following table provides a summary of Intel IPP functionality for different product suites:

Intel IPP Functionality	**Intel® Parallel Studio XE**	**Intel® System Studio**	**Intel® IPP Standalone**
Common function domains (string operations, cryptography, computer vision, data compression, image processing, signal processing, etc.)	Yes	Yes	Yes
Long Term Evolution functions for the embedded domain	No	Yes	No
Intel® IPP libraries for Android* and Intel® Quark™ platforms	No	Yes	No
Intel® IPP libraries for Intel® Xeon Phi™ Coprocessor	Yes	No	Yes
Intel® IPP libraries for macOS*	Yes	No	Yes

What's New

This Developer Guide documents the Intel® Integrated Performance Primitives (Intel® IPP) 2017 Update 2 release.

Intel® IPP 2017 Update 2

Updated instructions on how to build the threading layer (TL) library and example. For details, see Building Intel® IPP Threading Layer Libraries from Source Code.

Intel® IPP 2017 Update 1

Minor updates have been made to fix inaccuracies in the document.

Intel® IPP 2017

The document has been updated with the following changes to the product:

- Added information about platform-aware functions. For details, see Using Intel® Integrated Performance Primitives Platform-Aware Functions.
- Added instructions on how to use threading layer (TL) functions. For details, see Using Intel® Integrated Performance Primitives Threading Layer Functions
- Added description of integration wrappers for image processing and computer vision functions. For details, see Using Integration Wrappers for Intel Integrated Performance Primitives.

Getting Help and Support

If you did not register your Intel® software product during installation, please do so now at the Intel® Software Development Products Registration Center. Registration entitles you to free technical support, product updates, and upgrades for the duration of the support term.

For general information about Intel technical support, product updates, FAQs, tips and tricks and other support questions, please visit http://www.intel.com/software/products/support/ and the Intel IPP forum http://software.intel.com/en-us/forums/intel-integrated-performance-primitives/.

NOTE
If your distributor provides technical support for this product, please contact them rather than Intel.

On Windows*, you can get context-sensitive help when editing your code the Microsoft Visual Studio* IDE. See Accessing Intel IPP Documentation in Visual Studio* IDE.

Notational Conventions

The following font and symbols conventions are used in this document:

Italic	*Italic* is used for emphasis and also indicates document names in body text, for example: see *Intel IPP Developer Reference*.
`Monospace lowercase`	Indicates filenames, directory names, and pathnames, for example: `/tools/ia32/perfsys`
`Monospace lowercase mixed with UPPERCASE`	Indicates commands and command-line options, for example: `ps_ipps.exe -f FIRLMS_32f -r firlms.csv`
`UPPERCASE MONOSPACE`	Indicates system variables, for example: `$PATH`.
`monospace italic`	Indicates a parameter in discussions, such as routine parameters, for example: *`pSrc`*; makefile parameters, for example: *`function_list`*. When enclosed in angle brackets, indicates a placeholder for an identifier, an expression, a string, a symbol, or a value, for example: *`<ipp directory>`*.
[items]	Square brackets indicate that the items enclosed in brackets are optional.
{ item | item }	Braces indicate that only one of the items listed between braces can be selected. A vertical bar (|) separates the items.

The following notations are used to refer to Intel IPP directories:

	The installation directory for the larger product that includes Intel IPP.
`<ipp directory>`	The main directory where Intel IPP is installed: *`<ipp directory>`*=. Replace this placeholder with the specific pathname in the configuring, linking, and building instructions.

Getting Started with Intel® Integrated Performance Primitives

1

This chapter helps you start using Intel® Integrated Performance Primitives (Intel® IPP) by giving a quick overview of some fundamental concepts and showing how to build an Intel® IPP program.

Finding Intel® IPP on Your System

Intel® Integrated Performance Primitives (Intel® IPP) installs in the subdirectory referred to as *<ipp directory>* inside *<install_dir>*. By default, the *<install_dir>* is:

- On Windows* OS: `C:/Program files (x86)/IntelSWTools/compilers_and_libraries_2017.x.xxx/<target_os>` (on certain systems, instead of `Program Files (x86)`, the directory name is `Program Files`)
- On Linux* OS and macOS*: `/opt/intel/compilers_and_libraries_2017.x.xxx/<linux|mac>`

The tables below describe the structure of the high-level directories on:

- Windows* OS
- Linux* OS
- macOS*

Windows* OS:

Directory	Contents
Subdirectories of *<ipp directory>*	
`bin`	Batch files to set environmental variables in the user shell
`include`	Header files for the library functions
`lib/ia32`	Single-threaded static libraries for the IA-32 architecture
`lib/intel64`	Single-threaded static libraries for the Intel® 64 architecture
`lib/<arch>/threaded`, where *<arch>* is one of `{ia32, intel64}`	Multi-threaded static libraries
`examples`	Symbolic link to Intel IPP example files
`components`	Intel IPP interfaces and example files
`tool/<arch>/perfsys`	Command-line tools for Intel IPP performance testing
`tool/<arch>/staticlib`	Header files for redefining Intel IPP functions to processor-specific counterparts
Subdirectories of *<install_dir>*	

Directory	Contents
`redist/ia32/ipp`	Single-threaded DLLs for applications running on processors with the IA-32 architecture
`redist/intel64/ipp`	Single-threaded DLLs for applications running on processors with the Intel® 64 architecture
`redist/`*<arch>*`/threaded`	Multi-threaded DLLs
`documentation/`*<locale>*`/ipp`, where *<locale>* is one of `{en, ja}`	Intel IPP documentation

Linux* OS:

Directory	Contents
Subdirectories of *<ipp directory>*	
`bin`	Scripts to set environmental variables in the user shell
`include`	Header files for the library functions
`lib/ia32`	Single-threaded static libraries for the IA-32 architecture
`lib/intel64`	Single-threaded static libraries for the Intel® 64 architecture
`lib/`*<arch>*`/threaded`	Multi-threaded static libraries
`lib/`*<arch>*`/nonpic`	Non-PIC single-threaded static libraries
`examples`	Symbolic link to Intel IPP example files
`components`	Intel IPP interfaces and example files
`tool/`*<arch>*`/perfsys`	Command-line tools for Intel IPP performance testing
`tool/`*<arch>*`/staticlib`	Header files for redefining Intel IPP functions to processor-specific counterparts
Subdirectories of *<install_dir>*	
`documentation/`*<locale>*`/ipp`, where *<locale>* is one of `{en, ja}`	Intel IPP documentation

macOS*:

Directory	Contents
Subdirectories of *<ipp directory>*	
`bin`	Scripts to set environmental variables in the user shell
`include`	Header files for the library functions
`lib`	Single-threaded static FAT libraries
`lib/threaded`	Multi-threaded static FAT libraries
`examples`	Symbolic link to Intel IPP example files
`components`	Intel IPP interfaces and example files

Directory	Contents
`tool/<arch>/perfsys`	Command-line tools for Intel IPP performance testing
Subdirectories of *`<install_dir>`*	
`documentation/<locale>/ipp`, where *`<locale>`* is one of `{en, ja}`	Intel IPP documentation

See Also

Notational Conventions

Setting Environment Variables

When the installation of Intel IPP is complete, set the environment variables in the command shell using one of the script files in the `bin` subdirectory of the Intel IPP installation directory:

On Windows* OS:

`ippvars.bat`	for the IA-32 and Intel® 64 architectures.

On Linux* OS and macOS*:

Architecture	Shell	Script File
IA-32 and Intel® 64	C	`ippvars.csh`
IA-32 and Intel® 64	Bash	`ippvars.sh`

When using the `ippvars` script, you need to specify the architecture as a parameter. For example:

- `ippvars.bat ia32`

  sets the environment for Intel IPP to use the IA-32 architecture on Windows* OS.
- `. ippvars.sh intel64`

  sets the environment for Intel IPP to use the Intel® 64 architecture on Linux* OS and macOS*.

The scripts set the following environment variables:

Windows* OS	Linux* OS	macOS*	Purpose
`IPPROOT`	`IPPROOT`	`IPPROOT`	Point to the Intel IPP installation directory
`LIB`	n/a	n/a	Add the search path for the Intel IPP single-threaded libraries
`PATH`	`LD_LIBRARY_PATH`	`DYLD_LIBRARY_PATH`	Add the search path for the Intel IPP single-threaded DLLs
`INCLUDE`	n/a	n/a	Add the search path for the Intel IPP header files

Compiler Integration

Intel® C++ Compiler and Microsoft Visual Studio* compilers simplify developing with Intel® IPP.

On Windows* OS, a default installation of Intel® Parallel Studio XE Composer Edition and Intel® IPP installs integration plug-ins. These enable the option to configure your Microsoft Visual Studio* project for automatic linking with Intel IPP.

Intel® C++ Compiler also provides command-line parameters to set the link/include directories:

- On Windows* OS:

  `/Qipp-link` and `/Qipp`
- On Linux* OS and macOS*:

  `-ipp-link` and `-ipp`

See Also

Automatically Linking Your Microsoft* Visual Studio* Project with Intel IPP
Linking Your Application with Intel® Integrated Performance Primitives

Building Intel® IPP Applications

The code example below represents a short application to help you get started with Intel® IPP:

```
#include "ipp.h"
#include <stdio.h>
int main(int argc, char* argv[])
{
   const IppLibraryVersion *lib;
   IppStatus status;
   Ipp64u mask, emask;

   /* Init IPP library */
   ippInit();
   /* Get IPP library version info */
   lib = ippGetLibVersion();
   printf("%s %s\n", lib->Name, lib->Version);

   /* Get CPU features and features enabled with selected library level */
   status = ippGetCpuFeatures( &mask, 0 );
   if( ippStsNoErr == status ) {
      emask = ippGetEnabledCpuFeatures();
      printf("Features supported by CPU\tby IPP\n");
      printf("-----------------------------------------\n");
      printf("  ippCPUID_MMX        = ");
      printf("%c\t%c\t",( mask & ippCPUID_MMX ) ? 'Y':'N',( emask & ippCPUID_MMX ) ? 'Y':'N');
      printf("Intel(R) Architecture MMX technology supported\n");
      printf("  ippCPUID_SSE        = ");
      printf("%c\t%c\t",( mask & ippCPUID_SSE ) ? 'Y':'N',( emask & ippCPUID_SSE ) ? 'Y':'N');
      printf("Intel(R) Streaming SIMD Extensions\n");
      printf("  ippCPUID_SSE2       = ");
      printf("%c\t%c\t",( mask & ippCPUID_SSE2 ) ? 'Y':'N',( emask & ippCPUID_SSE2 ) ? 'Y':'N');
      printf("Intel(R) Streaming SIMD Extensions 2\n");
      printf("  ippCPUID_SSE3       = ");
      printf("%c\t%c\t",( mask & ippCPUID_SSE3 ) ? 'Y':'N',( emask & ippCPUID_SSE3 ) ? 'Y':'N');
      printf("Intel(R) Streaming SIMD Extensions 3\n");
      printf("  ippCPUID_SSSE3      = ");
      printf("%c\t%c\t",( mask & ippCPUID_SSSE3 ) ? 'Y':'N',( emask & ippCPUID_SSSE3 ) ? 'Y':'N');
      printf("Intel(R) Supplemental Streaming SIMD Extensions 3\n");
      printf("  ippCPUID_MOVBE      = ");
      printf("%c\t%c\t",( mask & ippCPUID_MOVBE ) ? 'Y':'N',( emask & ippCPUID_MOVBE ) ? 'Y':'N');
      printf("The processor supports MOVBE instruction\n");
      printf("  ippCPUID_SSE41      = ");
      printf("%c\t%c\t",( mask & ippCPUID_SSE41 ) ? 'Y':'N',( emask & ippCPUID_SSE41 ) ? 'Y':'N');
      printf("Intel(R) Streaming SIMD Extensions 4.1\n");
      printf("  ippCPUID_SSE42      = ");
      printf("%c\t%c\t",( mask & ippCPUID_SSE42 ) ? 'Y':'N',( emask & ippCPUID_SSE42 ) ? 'Y':'N');
      printf("Intel(R) Streaming SIMD Extensions 4.2\n");
      printf("  ippCPUID_AVX        = ");
      printf("%c\t%c\t",( mask & ippCPUID_AVX ) ? 'Y':'N',( emask & ippCPUID_AVX ) ? 'Y':'N');
```

```
      printf("Intel(R) Advanced Vector Extensions instruction set\n");
      printf("  ippAVX_ENABLEDBYOS  = ");
      printf("%c\t%c\t",( mask & ippAVX_ENABLEDBYOS ) ? 'Y':'N',( emask & ippAVX_ENABLEDBYOS ) ? 
'Y':'N');
      printf("The operating system supports Intel(R) AVX\n");
      printf("  ippCPUID_AES       = ");
      printf("%c\t%c\t",( mask & ippCPUID_AES ) ? 'Y':'N',( emask & ippCPUID_AES ) ? 'Y':'N');
      printf("Intel(R) AES instruction\n");
      printf("  ippCPUID_SHA       = ");
      printf("%c\t%c\t",( mask & ippCPUID_SHA ) ? 'Y':'N',( emask & ippCPUID_SHA ) ? 'Y':'N');
      printf("Intel(R) SHA new instructions\n");
      printf("  ippCPUID_CLMUL     = ");
      printf("%c\t%c\t",( mask & ippCPUID_CLMUL ) ? 'Y':'N',( emask & ippCPUID_CLMUL ) ? 'Y':'N');
      printf("PCLMULQDQ instruction\n");
      printf("  ippCPUID_RDRAND    = ");
      printf("%c\t%c\t",( mask & ippCPUID_RDRAND ) ? 'Y':'N',( emask & ippCPUID_RDRAND ) ? 
'Y':'N');
      printf("Read Random Number instructions\n");
      printf("  ippCPUID_F16C      = ");
      printf("%c\t%c\t",( mask & ippCPUID_F16C ) ? 'Y':'N',( emask & ippCPUID_F16C ) ? 'Y':'N');
      printf("Float16 instructions\n");
      printf("  ippCPUID_AVX2      = ");
      printf("%c\t%c\t",( mask & ippCPUID_AVX2 ) ? 'Y':'N',( emask & ippCPUID_AVX2 ) ? 'Y':'N');
      printf("Intel(R) Advanced Vector Extensions 2 instruction set\n");
      printf("  ippCPUID_AVX512F   = ");
      printf("%c\t%c\t",( mask & ippCPUID_AVX512F ) ? 'Y':'N',( emask & ippCPUID_AVX512F ) ? 
'Y':'N');
      printf("Intel(R) Advanced Vector Extensions 3.1 instruction set\n");
      printf("  ippCPUID_AVX512CD  = ");
      printf("%c\t%c\t",( mask & ippCPUID_AVX512CD ) ? 'Y':'N',( emask & ippCPUID_AVX512CD ) ? 
'Y':'N');
      printf("Intel(R) Advanced Vector Extensions CD (Conflict Detection) instruction set\n");
      printf("  ippCPUID_AVX512ER  = ");
      printf("%c\t%c\t",( mask & ippCPUID_AVX512ER ) ? 'Y':'N',( emask & ippCPUID_AVX512ER ) ? 
'Y':'N');
      printf("Intel(R) Advanced Vector Extensions ER instruction set\n");
      printf("  ippCPUID_ADCOX     = ");
      printf("%c\t%c\t",( mask & ippCPUID_ADCOX ) ? 'Y':'N',( emask & ippCPUID_ADCOX ) ? 'Y':'N');
      printf("ADCX and ADOX instructions\n");
      printf("  ippCPUID_RDSEED    = ");
      printf("%c\t%c\t",( mask & ippCPUID_RDSEED ) ? 'Y':'N',( emask & ippCPUID_RDSEED ) ? 
'Y':'N');
      printf("The RDSEED instruction\n");
      printf("  ippCPUID_PREFETCHW  = ");
      printf("%c\t%c\t",( mask & ippCPUID_PREFETCHW ) ? 'Y':'N',( emask & ippCPUID_PREFETCHW ) ? 
'Y':'N');
      printf("The PREFETCHW instruction\n");
      printf("  ippCPUID_KNC       = ");
      printf("%c\t%c\t",( mask & ippCPUID_KNC ) ? 'Y':'N',( emask & ippCPUID_KNC ) ? 'Y':'N');
      printf("Intel(R) Xeon Phi(TM) Coprocessor instruction set\n");
   }
   return 0;
}
```

This application consists of three sections:

1. Initialize the Intel IPP library. This stage is required to take advantage of full Intel IPP optimization. The `ippInit()` function detects the processor type and sets the dispatcher to use the processor-specific code of the Intel® IPP library corresponding to the instruction set capabilities available. If your application runs without `ippInit()`, the Intel IPP library is auto-initialized with the first call of the Intel IPP function from any domain that is different from ippCore.

In certain debugging scenarios, it is helpful to force a specific implementation layer using `ippSetCpuFeatures()`, instead of the best as chosen by the dispatcher.

2. Get the library layer name and version. You can also get the version information using the `ippversion.h` file located in the `/include` directory.
3. Show the hardware optimizations used by the selected library layer and supported by CPU.

Building the First Example with Microsoft Visual Studio* Integration on Windows* OS

On Windows* OS, Intel IPP applications are significantly easier to build with Microsoft* Visual Studio*. To build the code example above, follow the steps:

1. Start Microsoft Visual Studio* and create an empty C++ project.
2. Add a new c file and paste the code into it.
3. Set the include directories and the linking model as described in Automatically Linking Your Microsoft* Visual Studio* Project with Intel IPP.
4. Compile and run the application.

If you did not install the integration plug-in, configure your Microsoft* Visual Studio* IDE to build Intel IPP applications following the instructions provided in Configuring the Microsoft Visual Studio* IDE to Link with Intel® IPP.

Building the First Example on Linux* OS

To build the code example above on Linux* OS, follow the steps:

1. Paste the code into the editor of your choice.
2. Make sure the compiler and Intel IPP variables are set in your shell. For information on how to set environment variables see Setting Environment Variables.
3. Compile with the following command: `icc ipptest.cpp -o ipptest -I $IPPROOT/include -L $IPPROOT/lib/<arch> -lippi -lipps -lippcore`. For more information about which Intel IPP libraries you need to link to, see Library Dependencies by Domain and Linking Options.

   For offload compilation on Intel® Xeon Phi™ Coprocessors, use the following command: `icc -qoption,link,"--no-undefined" $< -o application test.o -qoffload-option,mic,link," -L$(IPPROOT)/lib/mic -lippi -lipps -lippcore"`. For more information on how to use Intel IPP on Intel® Xeon Phi™ Coprocessors, refer to the Multi-threading Example for Intel® Xeon Phi™ Coprocessor (`ipp_thread_mic`) and respective documentation (`ipp-examples.html`) available in the `components_and_examples_<target>.zip` archive at the `<ipp directory>/examples/` subdirectory.
4. Run the application.

Building the First Example on macOS*

To build the code example above on macOS*, follow the steps:

1. Paste the code into the editor of your choice.
2. Make sure the compiler and Intel IPP variables are set in your shell. For information on how to set environment variables see Setting Environment Variables.
3. Compile with the following command: `icc ipptest.cpp -o ipptest -I $IPPROOT/include -L $IPPROOT/lib/ -lippi -lipps -lippcore`. For more information about which Intel IPP libraries you need to link to, see Library Dependencies by Domain and Linking Options.
4. Run the application.

See Also

Automatically Linking Your Microsoft* Visual Studio* Project with Intel IPP
Configuring the Microsoft* Visual Studio* IDE to Link with Intel® IPP
Setting Environment Variables
Library Dependencies by Domain

[Linking Options](#)
[Dispatching](#)
[Intel® IPP Examples Directory Structure](#)

Using Intel® IPP Examples

This section provides information on Intel IPP examples directory structure and examples build system.

Intel® IPP Examples Directory Structure

The Intel IPP package includes code examples, located in the `components_and_examples_<target>.zip` archive at the `<ipp directory>/components/` subdirectory. You can also access the archive using the symbolic link located at `<ipp directory>/examples/`.The `examples_core` subdirectory inside the archive contains the following files and directories:

Directory	Contents
`common`	Common code files for all examples
`documentation`	Documentation for the Intel IPP examples (`ipp-examples.html`)
`ipp_custom_dll`	Custom Dynamic Library example
`ipp_fft`	Fast Fourier transformation example
`ipp_resize_mt`	Image resizing example
`ipp_thread`	Example of external threading of Intel IPP functions
`ipp_thread_mic`	Multi-threading example for Intel® Xeon Phi™ Coprocessor
`lena.bmp`	Test image

NOTE
Intel® IPP samples are no longer in active development and available as a separate download.

See Also

Finding Intel® IPP on Your System

Building Intel® IPP Examples

For building instructions refer to `examples_core/documentation/ipp-examples.html` provided with the `/<ipp directory>/components/components_and_examples_<target>.zip` archive.

See Also

Intel® IPP Examples Directory Structure

Finding the Intel® IPP Documentation

The `<install_dir>/documentation/en/ipp` directory, set up during installation, includes a lot of helpful documentation related to Intel® IPP. See the `get_started.htm` file for a listing of all the available documents with links or pointers to their locations.

Additional documentation on the Intel IPP examples (`documentation/ipp-examples.html`) is available in the `<ipp directory>/components/components_and_examples_<target>.zip` archive.

The Intel IPP forum and knowledge base can be useful locations to search for questions not answered by the documents above. Please see: http://software.intel.com/en-us/forums/intel-integrated-performance-primitives/ .

See Also

Finding Intel® IPP on Your System

Intel® Integrated Performance Primitives Theory of Operation

2

This section discusses dispatching of the Intel® Integrated Performance Primitives (Intel® IPP) libraries to specific processors, provides functions and parameters naming conventions, and explains the data types on which Intel IPP performs operations. This section also provides Intel IPP domain details, including existing library dependencies by domain.

Dispatching

Intel® IPP uses multiple function implementations optimized for various CPUs. Dispatching refers to detection of your CPU and selecting the corresponding Intel IPP binary path. For example, the `ippie9` library in the `/redist/intel64/ipp` directory contains the image processing libraries optimized for 64-bit applications on processors with Intel® Advanced Vector Extensions (Intel® AVX) enabled such as the 2nd Generation Intel® Core™ processor family.

A single Intel IPP function, for example `ippsCopy_8u()`, may have many versions, each one optimized to run on a specific Intel® processor with specific architecture, for example, the 64-bit version of this function optimized for the 2nd Generation Intel® Core™ processor is `e9_ippsCopy_8u()`, and version optimized for 64-bit applications on processors with Intel® Streaming SIMD Extensions 4.2 (Intel® SSE 4.2) is `y8_ippsCopy_8u()`. This means that a prefix before the function name determines CPU model. However, during normal operation the dispatcher determines the best version and you can call a generic function (`ippsCopy_8u` in this example).

Intel® IPP is designed to support application development on various Intel® architectures. This means that the API definition is common for all processors, while the underlying function implementation takes into account the strengths of each hardware generation.

By providing a single cross-architecture API, Intel IPP enables you to port features across Intel® processor-based desktop, server, and mobile platforms. You can use your code developed for one processor architecture for many processor generations.

The following table shows processor-specific codes that Intel IPP uses:

Description of Codes Associated with Processor-Specific Libraries

IA-32 Intel® architecture	Intel® 64 architecture	Windows*	Linux* OS	Android*	macOS*	Description
px*	**mx***	+	+			Generic code optimized for processors with Intel® Streaming SIMD Extensions (Intel® SSE)
w7	**my**	+	+			Optimized for processors with Intel SSE2
s8	**n8**	+	+	+		Optimized for processors with Supplemental Streaming SIMD Extensions 3 (SSSE3)
	m7	+	+	+	+	Optimized for processors with Intel SSE3
p8	**y8**	+	+	+	+	Optimized for processors with Intel SSE4.2

IA-32 Intel® architecture	Intel® 64 architecture	Windows*	Linux* OS	Android*	macOS*	Description
g9	**e9**	+	+	+	+	Optimized for processors with Intel® Advanced Vector Extensions (Intel® AVX) and Intel® Advanced Encryption Standard New Instructions (Intel® AES-NI)
h9	**l9**	+	+	+	+	Optimized for processors with Intel® Advanced Vector Extensions 2 (Intel® AVX2)
	k0	+	+		+	Optimized for processors with Intel® Advanced Vector Extensions 512 (Intel® AVX-512)
	n0	+	+			Optimized for processors with Intel® Advanced Vector Extensions 512 (Intel(R) AVX-512) for Intel(R) Many Integrated Core Architecture (Intel(R) MIC Architecture)

* - Support for **px** and **mx** optimization is deprecated and will be removed in 2018 releases.

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. Notice revision #20110804

Function Naming Conventions

Intel IPP functions have the same naming conventions for all domains.

Function names in Intel IPP have the following general format:

```
ipp<data-domain><name>_<datatype>[_<descriptor>](<parameters>)
```

> **NOTE**
> The core functions in Intel IPP do not need an input data type. These functions have `ipp` as a prefix without the data-domain field. For example, `ippGetStatusString`.

See Also

Core and Support Functions

Data-domain

The *data-domain* element is a single character indicating type of input data. Intel IPP supports the following data-domains:

`s`	one-dimensional operations on signals, vectors, buffers

`i`	two-dimensional operations on images, video frames
`m`	vector or matrix operations

Primitive vs. Variant Name

The *`name`* element identifies the algorithm or operation of the function. The low-level algorithm that function implements is a *primitive*. This algorithm often has several *variants* for different data types and implementation variations.

For example, the `CToC` modifier in the `ippsFFTInv_CToC_32fc` function signifies that the inverse fast Fourier transform operates on complex floating point data, performing the complex-to-complex (CToC) transform.

Data Types

The *`datatype`* element indicates data types used by the function, in the following format:

`<bit depth><bit interpretation>,`

where

`bit depth = <1|8|16|32|64>`

and

`bit interpretation<u|s|f>[c]`

Here *`u`* indicates "unsigned integer", *`s`* indicates "signed integer", *`f`* indicates "floating point", and *`c`* indicates "complex".

For functions that operate on a single data type, the *`datatype`* element contains only one value.

If a function operates on source and destination signals that have different data types, the respective data type identifiers are listed in the function name in order of source and destination as follows:

`<datatype> = <src1Datatype>[src2Datatype][dstDatatype]`

For more information about supported data types see the *Intel® IPP Reference Manual* available in the Intel® Software Documentation Library.

See Also

Intel® Software Documentation Library

Descriptor

The optional *`descriptor`* element describes the data associated with the operation. Descriptors are individual characters that indicate additional details of the operation.

The Intel IPP functions use the following descriptors:

Descriptor	Description	Example
`A`	Image data contains an alpha channel as the last channel, requires `C4`, alpha-channel is not processed.	`ippiFilterMax_8u_AC4R`
`A`*xx*	Advanced arithmetic operations with *xx* bits of accuracy.	`ippsPowx_32f_A11`
`C`	The function operates on a specified channel of interest (COI) for each source image.	`ippiSet_8u_C3CR`

Descriptor	Description	Example
C*n*	Image data consists of *n* channels. Possible values for *n*: 1, 2, 3, 4.	`ippiFilterBorder_32f_C1R`
D*x* D	Signal is x-dimensional (default is `D1`).	`ippsConcat_8u_D2`
`I`	Operation is in-place (default is not-in-place).	`ippsAdd_16s_I`
`L`	Function operates on 64-bit object sizes.	`ippiAdd_8u_C1RSfsL`
`M`	Operation uses a mask to determine pixels to be processed.	`ippiCopy_8u_C1MR`
P*n*	Image data consists of *n* discrete planar (not-interleaved) channels with a separate pointer to each plane. Possible values for *n*: 1, 2, 3, 4.	`ippiAlphaPremul_8u_AP4R`
`R`	Function operates on a defined region of interest (ROI) for each source image.	`ippiMean_8u_C4R`
`s`	Saturation and no scaling (default).	`ippiConvert_16s16u_C1Rs`
`Sfs`	Saturation and fixed scaling mode (default is saturation and no scaling).	`ippsConvert_16s8s_Sfs`

The descriptors in function names are presented in the function name in alphabetical order.

Some data descriptors are default for certain operations and not added to the function names. For example, the image processing functions always operate on a two-dimensional image and saturate the results without scaling them. In these cases, the implied descriptors `D2` (two-dimensional signal) and `s` (saturation and no scaling) are not included in the function name.

Parameters

The *parameters* element specifies the function parameters (arguments).

The order of parameters is as follows:

- All source operands. Constants follow vectors.
- All destination operands. Constants follow vectors.
- Other, operation-specific parameters.

A parameter name has the following conventions:

- All parameters defined as pointers start with *p*, for example, *pPhase*, *pSrc*; parameters defined as double pointers start with *pp*, for example, *ppState*. All parameters defined as values start with a lowercase letter, for example, *val*, *src*, *srcLen*.
- Each new part of a parameter name starts with an uppercase character, without underscore; for example, *pSrc*, *lenSrc*, *pDlyLine*.
- Each parameter name specifies its functionality. Source parameters are named *pSrc* or *src*, in some cases followed by names or numbers, for example, *pSrc2*, *srcLen*. Output parameters are named *pDst* or *dst* followed by names or numbers, for example, *pDst2*, *dstLen*. For in-place operations, the input/output parameter contains the name *pSrcDst* or *srcDst*.

Intel® Integrated Performance Primitives Domain Details

Intel IPP is divided into groups of related functions. Each subdivision is called *domain*, and has its own header file, static libraries, dynamic libraries, and tests. The table below lists each domain's code, header and functional area.

The file `ipp.h` includes Intel IPP header files with the exception of cryptography and generated functions. If you do not use cryptography and generated functions, include `ipp.h` in your application for forward compatibility. If you want to use cryptography functions, you must directly include `ippcp.h` in your application.

Code of Domain	Header file	Threading Layer (TL) Header File	Prefix	Description
CC	ippcc.h	N/A	ippi	color conversion
CH	ippch.h	N/A	ipps	string operations
CORE	ippcore.h	ippcore_tl.h	ipp	core functions
CP	ippcp.h	N/A	ipps	cryptography
CV	ippcv.h	N/A	ippi	computer vision
DC	ippdc.h	N/A	ipps	data compression
I	ippi.h	ippi_tl.h	ippi	image processing
S	ipps.h	N/A	ipps	signal processing
VM	ippvm.h	N/A	ipps	vector math
E*	ippe.h	N/A	ipps	embedded functionality

* available only within the Intel® System Studio suite

Library Dependencies by Domain

When you link to a certain Intel® IPP domain library, you must also link to the libraries on which it depends. The following table lists library dependencies by domain.

Library Dependencies by Domain

Domain	Domain Code	Depends on
Color Conversion	CC	Core, VM, S, I
String Operations	CH	Core, VM, S
Cryptography	CP	Core
Computer Vision	CV	Core, VM, S, I
Data Compression	DC	Core, VM, S
Image Processing	I	Core, VM, S
Image Processing TL	I_TL	Core, I, VM, S
Signal Processing	S	Core, VM
Vector Math	VM	Core

The figure below represents the domain internal dependencies graph.

To find which domain your function belongs to, refer to the *Intel® IPP Reference Manual* available in the Intel® Software Documentation Library.

See Also

Intel® Software Documentation Library

Linking Your Application with Intel® Integrated Performance Primitives

3

This section discusses linking options available in Intel® Integrated Performance Primitives (Intel® IPP).

The Intel IPP library supports the following linking options:

- Single-threaded dynamic
- Single-threaded static
- Multi-threaded dynamic
- Multi-threaded static

Optimization Notice
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Linking Options

Intel® Integrated Performance Primitives (Intel® IPP) is distributed as:

- **Static library:** static linking results in a standalone executable
- **Dynamic/shared library:** dynamic linking defers function resolution until runtime and requires that you bundle the redistributable libraries with your application

The following table provides description of libraries available for linking.

	Single-threaded (non-threaded)	**Multi-threaded** (internally threaded)
Description	Suitable for application-level threading	Use only when no other form of threading is active
Found in	Main package After installation: *<ipp directory>*/lib/*<arch>*	Separate download After installation: *<ipp directory>*/lib/*<arch>*/threaded
Static linking	Windows* OS: mt suffix in a library name (ipp*<domain>*mt.lib) Linux* OS and macOS*: no suffix in a library name (libipp*<domain>*.a)	Windows* OS: mt suffix in a library name (ipp*<domain>*mt.lib) Linux* OS and macOS*: no suffix in a library name (libipp*<domain>*.a)
Dynamic Linking	Default (no suffix)	Default (no suffix)

Windows* OS: ipp<*domain*>.lib Linux* OS: libipp<*domain*>.a macOS*: libipp<*domain*>.dylib	Windows* OS: ipp<*domain*>.lib Linux* OS: libipp<*domain*>.a macOS*: libipp<*domain*>.dylib

To switch between single- or multi-threaded Intel IPP libraries, set the path to the preferred library in system variables or in your project, for example:

- **Windows* OS** :

  Single-threaded: SET LIB=<*ipp directory*>/lib/<*arch*>

  Multi-threaded: SET LIB=<*ipp directory*>/lib/<*arch*>/threaded
- **Linux* OS/macOS***

  Single-threaded: gcc <*options*> -L <*ipp directory*>/lib/<*arch*>

  Multi-threaded: gcc <*options*> -L <*ipp directory*>/lib/<*arch*>/threaded

NOTE
On Linux* OS and macOS* Intel IPP library depends on the following Intel® C++ Compiler runtime libraries: libirc.a, libsvml.a, and libimf.a. You should add a link to these libraries into your project. You can find these libraries in <*ipp directory*>/lib or <*intel compiler directory*>/lib folders.

Intel IPP Threading Layer (TL) Library

Intel IPP Threading Layer (TL) pre-built library is distributed as a multi-threaded static library. You can find the library files in <*ipp directory*>/lib/<*arch*>:

- Windows* OS: ipp<*domain*>_tl.lib
- Linux* OS and macOS*: libipp<*domain*>_tl.a

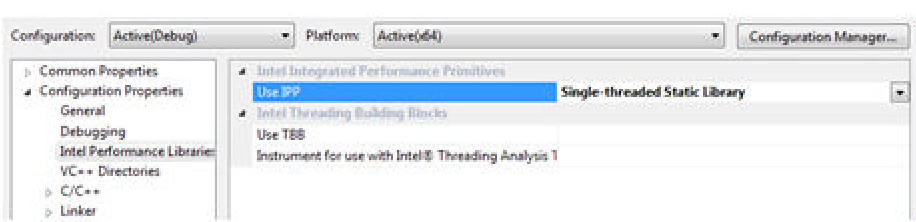
NOTE
Intel IPP TL library depends on Intel IPP libraries. For more information about dependencies, refer to Library Dependencies by Domain.

See Also
Automatically Linking Your Microsoft* Visual Studio* Project with Intel IPP
Configuring the Microsoft* Visual Studio* IDE to Link with Intel® IPP
Library Dependencies by Domain

Automatically Linking Your Microsoft* Visual Studio* Project with Intel IPP

After a default installation of the Intel® IPP and Intel® Parallel Studio XE Composer Edition for C++, you can easily configure your project to automatically link with Intel IPP. Configure your Microsoft* Visual Studio* project for automatic linking with Intel IPP as follows:

1. Go to **Project**>**Properties**>**Configuration Properties**>**Intel Performance Libraries**.
2. Change the **Use IPP** property setting by selecting one of the options to set the include directories and the linking model, as shown on the screen shot below.



Using Intel® Integrated Performance Primitives Platform-Aware Functions

4

Intel® Integrated Performance Primitives (Intel® IPP) library provides so-called platform-aware functions for signal and image processing. While the rest of Intel IPP functions support only signals or images of 32-bit integer size, Intel IPP platform-aware functions work with 64-bit object sizes if it is supported by the target platform.

The API of platform-aware functions is similar to the API of other Intel IPP functions and has only slight differences. You can distinguish Intel IPP platform-aware functions by the `L` suffix in the function name, for example, `ippiAdd_8u_C1RSfs_L`. With Intel IPP platform-aware functions you can overcome 32-bit size limitations.

Intel IPP platform-aware functions are declared in separate header files with the `_l` suffix, for example, `ippi_l.h`. However, you do not have to additionally include these headers in your application because they are already included in standard Intel IPP headers (without the `_l` suffix). Platform-aware functions cover only the functionality that is implemented in standard Intel IPP functions, and can be considered as additional flavors to the existing functions declared in standard Intel IPP headers.

Using Intel® Integrated Performance Primitives Threading Layer (TL) Functions

5

Intel® Integrated Performance Primitives (Intel® IPP) library provides threading layer (TL) functions for image processing. Intel IPP TL functions are visual examples of external threading for Intel IPP functions. Taking advantage of multithreaded execution and tile processing, Intel IPP TL functions enable you to overcome 32-bit size limitations.

TL functions are provided as:

- **Pre-built binaries:** header and library files have the `_tl` suffix and can be found in:
  - Header files: `<ipp directory>/include`
  - Library files: `<ipp directory>/lib/<arch>`
- **Source code samples:** the source code and corresponding header files are available in the `components_and_examples_<target>.zip` archive inside the `<ipp directory>/components` subdirectory. For more information about the archive contents and source code building instructions, refer to Finding Intel® IPP TL Source Code Files and Building Intel® IPP TL Libraries from Source Code, respectively.

The API of TL functions is similar to the API of other Intel IPP functions and has only slight differences. You can distinguish Intel IPP TL functions by the `_LT` suffix in the function name, for example, `ippiAdd_8u_C1RSfs_LT`. Intel IPP TL functions are implemented as wrappers over Intel IPP platform-aware functions by using tiling and multithreading with OpenMP*. For implementation details, please see the corresponding source code files.

Intel IPP TL functions cover only the functionality that is declared in Intel IPP platform-aware headers (with the `_l` suffix), and can be considered as additional flavors to the existing Intel IPP functions.

NOTE
To use the Intel® IPP TL library on macOS*, you need to link your application with the Intel® OpenMP* `libiomp5` library, which is available at `<install_dir>/lib`.

Optimization Notice
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Finding Intel® IPP TL Source Code Files

You can find the Intel IPP TL source code files in the `components_and_examples_<target>.zip` archive available in the `<ipp directory>/components` subdirectory. The library source code and header files are located in the `interfaces/tl` subdirectory.

Building Intel® IPP TL Libraries from Source Code

You can find the TL libraries source code and the `tl_resize` example in the `/components/interfaces/tl` directory inside the `components_and_examples_<target>` archive available in `<ipp directory>/components/`. Before building an application that uses TL, make sure that the `IPPROOT` environment variable is set correctly and points to the Intel IPP library location, for more information see Setting Environment Variables.

To build Intel IPP TL libraries and the `tl_resize` example, do the following:

Windows* OS

Prerequisites: The `tl_resize` example uses OpenGL rendering to display results. This requires Windows* SDK to be installed on your system. Usually Windows* SDK is provided with the Microsoft* Visual Studio* distribution. Alternatively, you can download Windows* SDK for your version of Windows* OS from https://www.microsoft.com. To disable the rendering part of `tl_resize`, remove the `ENABLE_RENDERING` macro from the preprocessors definitions.

1. Open the `tl.sln` file in Microsoft* Visual Studio* 2012 or higher.
2. Build the solution using the **Build** command. The example will be linked with the newly built TL libraries from the same solution.

Linux* OS

Prerequisites: The `tl_resize` example uses OpenGL rendering to display results. This requires the following packages to be installed:

- `libx11-dev`
- `libgl1-mesa-dev`

Execute the following commands using gcc4 or higher:

- To build TL libraries:

```
make libs [ARCH=ia32|intel64] [CONF=release|debug]
```

- To build the `tl_resize` example and TL libraries:

```
make all [ARCH=ia32|intel64] [CONF=release|debug] [RENDERER=0|1]
```

macOS*

You can build TL libraries and the `tl_resize` example using the Apple Xcode* workspace provided in the `/components/interfaces/tl` directory. Alternatively, you can use makefiles:

- To build TL libraries:

```
make libs [ARCH=ia32|intel64] [CONF=release|debug]
```

- To build the `tl_resize` example and TL libraries:

```
make all [ARCH=ia32|intel64] [CONF=release|debug] [RENDERER=0|1]
```

TL libraries are based on the OpenMP* library. Because the macOS* Clang compiler does not support OpenMP*, you need to use the custom compiler. You can do one of the following:

- Use Intel® Compiler (installed with Intel® Parallel Studio XE) with Makefile scripts:

  1. Change directory to the `/components/interfaces/tl` folder
  2. Run the following command:

     ```
     make CC=icc CXX=icc
     ```

  3. Before running the application, specify the path to the OpenMP* library: `DYLD_LIBRARY_PATH=/opt/intel/compilers_and_libraries/mac/lib/`

- Use mainline Clang compiler that can work with Xcode*:

  1. Install Homebrew* from http://brew.sh/
  2. Run `brew install llvm`. The latest mainline `llvm` version will be installed to `/usr/local/opt/llvm` (if the installation folder is different, you will need to update Xcode* paths for **CC** and **Library Search Paths** properties).
  3. Build Xcode* projects for TL libraries.

See Also

Setting Environment Variables

Using Integration Wrappers for Intel® Integrated Performance Primitives

6

Intel® Integrated Performance Primitives (Intel® IPP) Integration Wrappers aggregate Intel IPP functionality in easy-to-use functions and help to reduce effort required to integrate Intel IPP into your code.

Integration Wrappers consist of C and C++ interfaces:

- **C interface** aggregates Intel IPP functions of similar functionality with various data types and channels into one function. Initialization steps required by several Intel IPP functions are implemented in one initialization function for each functionality. To reduce the size of your code and save time required for integration, the wrappers handle all memory management and Intel IPP function selection routines.
- **C++ interface** wraps around the C interface to provide default parameters, easily initialized objects as parameters, exception handling, and objects for complex Intel IPP functions with automatic memory management for specification structures.

In general, Integration Wrappers are designed to improve user experience with threading of Intel IPP functions and tiling.

Integration Wrappers are provided as a separate download. For more information about the main concepts, usage, and implementation details, refer to the *Developer Guide and Reference for Intel IPP Integration Wrappers* document available with the Integration Wrappers package.

Programming Considerations 7

Core and Support Functions

There are several general purpose functions that simplify using the library and report information on how it is working:

- `Init`/`GetCpuFeatures`/ `SetCpuFeatures`/`GetEnabledCpuFeatures`
- `GetStatusString`
- `GetLibVersion`
- `Malloc`/`Free`

Init/GetCpuFeatures/ SetCpuFeatures/GetEnabledCpuFeatures

The `ippInit` function detects the processor type and sets the dispatcher to use the processor-specific code of the Intel® IPP library corresponding to the instruction set capabilities available. If your application does not call the `ippInit` function, initialization of the library to the available instruction set capabilities is performed automatically with the first call of any Intel IPP function from the domain different from `ippCore`.

In some cases like debugging and performance analysis, you may want to get the data on the difference between various processor-specific codes on the same machine. Use the `ippSetCpuFeatures` function for this. This function sets the dispatcher to use the processor-specific code according to the specified set of CPU features. You can obtain features supported by CPU using `ippGetCpuFeatures` and obtain features supported by the currently dispatched Intel IPP code using `ippGetEnabledCpuFeatures`. If you need to enable support of some CPU features without querying the system (without CPUID instruction call), you must set the `ippCPUID_NOCHECK` bit for `ippSetCpuFeatures`, otherwise, only supported by the current CPU features are set.

The `ippInit`, `ippGetCpuFeatures`, `ippGetEnabledCpuFeatures`, and `ippSetCpuFeatures` functions are a part of the `ippCore` library.

GetStatusString

The `ippGetStatusString` function decodes the numeric status return value of Intel® IPP functions and converts them to a human readable text:

```
        status= ippInit();
        if( status != ippStsNoErr ) {
                printf("IppInit() Error:\n");
                printf("%s\n", ippGetStatusString(status) );
                return -1;
        }
```

The `ippGetStatusString` function is a part of the `ippCore` library.

GetLibVersion

Each domain has its own `GetLibVersion` function that returns information about the library layer in use from the dispatcher. The code snippet below demonstrates the usage of the `ippiGetLibVersion` from the image processing domain:

```
const IppLibraryVersion* lib = ippiGetLibVersion();
printf("%s %s %d.%d.%d.%d\n", lib->Name, lib->Version,
lib->major, lib->minor, lib->majorBuild, lib->build);
```

Use this function in combination with `ippInitCpu` to compare the output of different implementations on the same machine.

Malloc/Free

Intel IPP functions provide better performance if they process data with aligned pointers. Intel IPP provides the following functions to ensure that data is aligned appropriately - 16-byte for CPU that does not support Intel® Advanced Vector Extensions (Intel® AVX) instruction set, 32-byte for Intel AVX and Intel® Advanced Vector Extensions 2 (Intel® AVX2), and 64-byte for Intel® Many Integrated Core instructions.

```
void* ippMalloc(int length)
void ippFree(void* ptr)
```

The `ippMalloc` function provides appropriately aligned buffer, and the `ippFree` function frees it.

The signal and image processing libraries provide `ippsMalloc` and `ippiMalloc` functions, respectively, to allocate appropriately aligned buffer that can be freed by the `ippsFree` and `ippiFree` functions.

NOTE

- When using buffers allocated with routines different from Intel IPP, you may get better performance if the starting address is aligned. If the buffer is created without alignment, use the `ippAlignPtr` function.
- To allocate larger buffers (of size more than 2GB-1) on Intel® 64 architecture, use the _L flavors of the `Malloc` functions, because other flavors of `Malloc` have 32-bit signed integers for size parameters. It is recommended to use larger buffers from other allocators only with platform-aware and threading layer (TL) functions.

For more information about the Intel IPP functions see the *Intel® Integrated Performance Primitives for Intel® Architecture Developer Reference* available in Intel® Software Documentation Library.

See Also

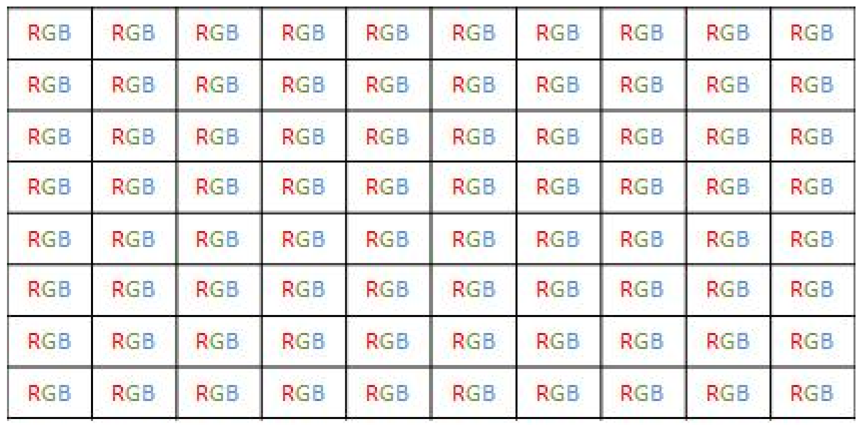
Cache Optimizations
Intel® Software Documentation Library

Channel and Planar Image Data Layouts

Intel® IPP functions operate on two fundamental data layouts: channel and planar.

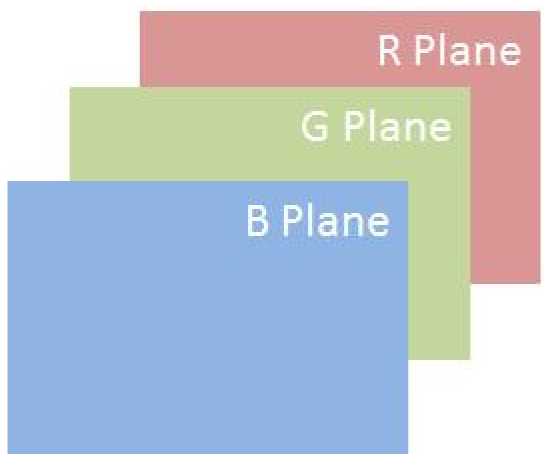
In channel format, all values share the same buffer and all values for the same pixel position are interleaved together. Functions working with channel data have a `_Cn` descriptor, where *n* can take one of the following values: 1, 2, 3, or 4. The figure below shows 24 bit per pixel RGB data, which is represented as `_C3`.

RGB data in `_C3` layout



For planar format, there is one value per pixel but potentially several related planes. Functions working with planar data have a `_Pn` descriptor, where *n* can take one of the following values: 1, 2, 3, or 4. The figure below shows 24 bit per pixel RGB data represented as `_P3`.

RGB data in `_P3` layout



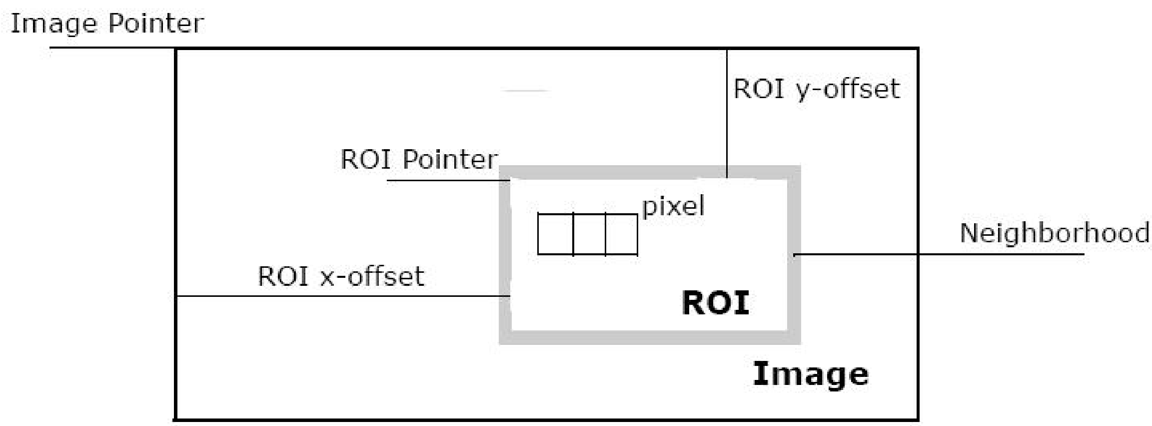
NOTE
For many video and image processing formats planes may have different sizes.

Regions of Interest

Many Intel® IPP image processing functions operate with a region of interest (ROI). These functions include an `R` descriptor in their names.

A ROI can be the full image or a subset. This can simplify thread or cache blocking.

Many functions sample a neighborhood and cannot provide values for an entire image. In this case a ROI must be defined for the subset of the destination image that can be computed.



Managing Memory Allocations

Depending on implementation layer and specific parameters, some Intel® IPP functions need different amount of memory for coefficients storage and working buffers. To address this, follow the steps below:

1. Compute the size of the required buffer using the <*operation function*>`GetSize` function.
2. Set up any buffers needed for initialization.
3. Initialize the specification structure for the operation.
4. Free the buffers need for initialization only.
5. Set up working buffers for the main operation.
6. Do the main operation.
7. Free the specification and working buffers.

If you use several Intel IPP functions with the *`pBuffer`* parameter (external memory buffer), for better efficiency and performance it is recommended to call all <*operation function*>`GetSize` APIs in one single place of your application and allocate only one buffer that has the largest size. This approach guarantees optimal use of system memory and all cache levels.

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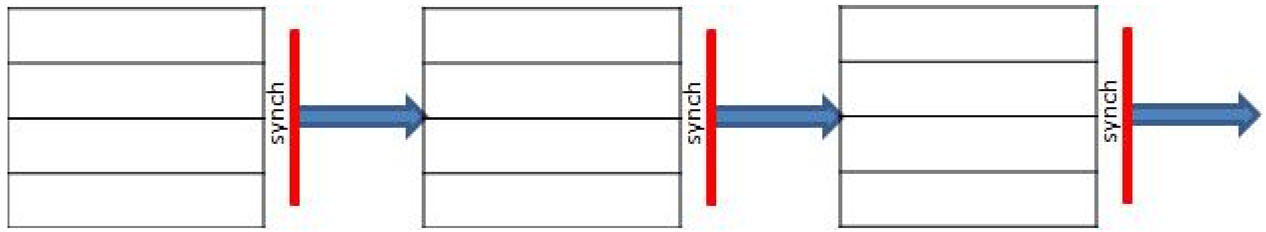
Cache Optimizations

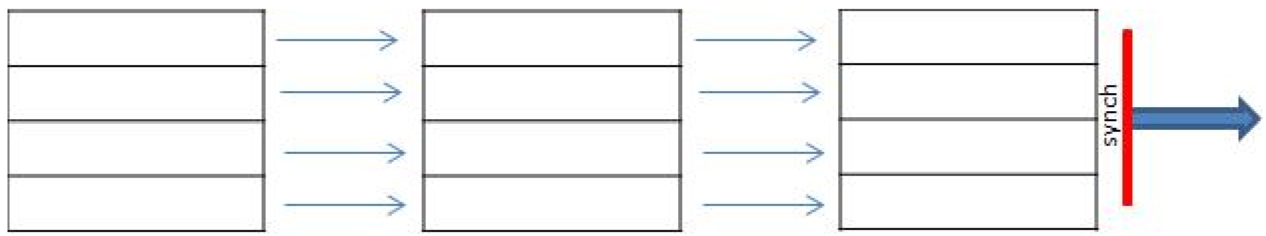
To get better performance, work should be grouped to take advantage of locality in the lowest/fastest level of cache possible. This is the same for threading or cache blocking optimizations.

For example, when operations on each pixels in an image processing pipeline are independent, the entire image is processed before moving to the next step. This may cause many inefficiencies, as shown in a figure below.



In this case cache may contain wrong data, requiring re-reading from memory. If threading is used, the number of synchronization point/barriers is more than the algorithm requires.

You can get better performance after combining steps on local data, as shown in a figure below. In this case each thread or cache-blocking iteration operates with ROIs, not full image.



NOTE
It is recommended to subdivide work into smaller regions considering cache sizes, especially for very large images/buffers.

Programming with Intel® Integrated Performance Primitives in the Microsoft* Visual Studio* IDE

8

This section provides instructions on how to configure your Microsoft* Visual Studio* IDE to link with the Intel® IPP, explains how to access Intel IPP documentation and use IntelliSense* Sense features.

Configuring the Microsoft* Visual Studio* IDE to Link with Intel® IPP

Steps for configuring Microsoft Visual C/C++* development system for linking with Intel® Integrated Performance Primitives (Intel® IPP) depend on whether you installed the C++ Integration(s) in Microsoft Visual Studio* component of the Intel® Parallel Studio XE Composer Edition:

- If you installed the integration component, see Automatically Linking Your Microsoft* Visual Studio* Project with Intel IPP
- If you did not install the integration component or need more control over Intel IPP libraries to link, you can configure the Microsoft Visual Studio* by performing the following steps. Though some versions of the Visual Studio* development system may vary slightly in the menu items mentioned below, the fundamental configuring steps are applicable to all these versions.

  1. In Solution Explorer, right-click your project and click **Properties**.
  2. Select **Configuration Properties**>**VC++ Directories** and set the following from the **Select directories for** drop down menu:

     - **Include Files** menu item, and then type in the directory for the Intel IPP include files (default is `<ipp directory>\include`)
     - **Library Files** menu item, and then type in the directory for the Intel IPP library files (default is `<ipp directory>\lib`)
     - **Executable Files** menu item, and then type in the directory for the Intel IPP executable files (default is `<install_dir>\redist\<arch>\ipp\`)

Accessing Intel® IPP Documentation in Visual Studio* IDE

Accessing Intel IPP Documentation in Visual Studio* 2012 and higher

To access the Intel IPP documentation in Visual Studio* 2012 and higher, do the following:

- Configure the IDE (once). To do this, go to **Help**>**Set Help Preference** and check **Launch in Help Viewer**.
- Select **Help**>**View Help** menu item to view a list of available help collections and open Intel IPP documentation.

Using Context-sensitive Help

You can get context-sensitive help when typing your code in the Visual Studio* IDE Code Editor. To open the help topic describing an Intel IPP function called in your code, select the function name and press F1. The topic with the function description opens in the Microsoft Help Viewer or your Web browser depending on the Visual Studio IDE Help settings.

Using the IntelliSense* Features

Intel IPP supports two Microsoft* Visual Studio IntelliSense* features that support language references: Complete Word and Parameter Info.

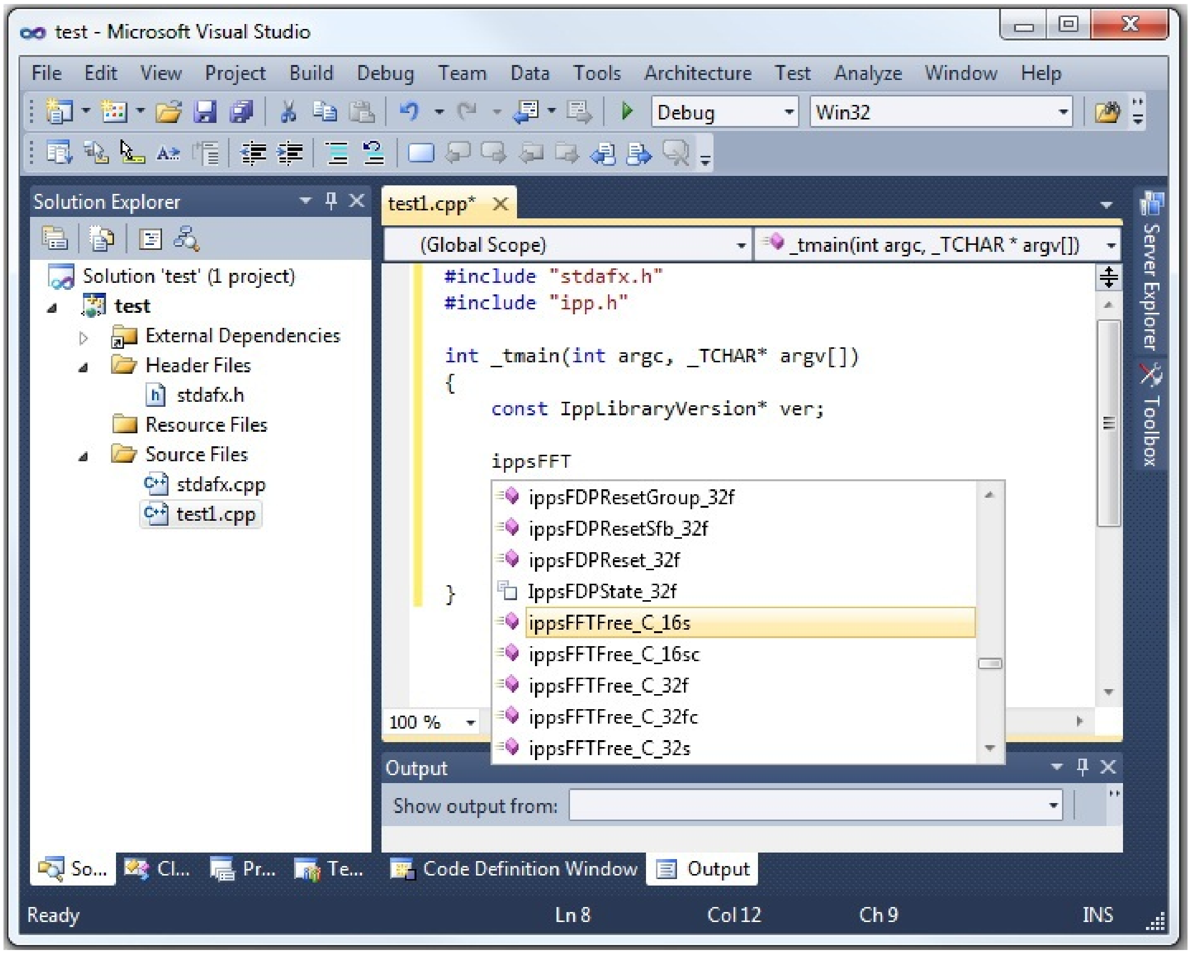
NOTE
Both features require header files. Therefore, to benefit from IntelliSense, make sure the path to the include files is specified in the Visual Studio solution settings. On how to do this, see Configuring the Microsoft Visual Studio* IDE to Link with Intel® IPP.

Complete Word

For a software library, the *Complete Word* feature types or prompts for the rest of the name defined in the header file once you type the first few characters of the name in your code.

Provided your C/C++ code contains the include statement with the appropriate Intel IPP header file, to complete the name of the function or named constant specified in the header file, follow these steps:

1. Type the first few characters of the name (for example, `ippsFFT`).
2. Press **Alt** + **RIGHT ARROW** or **Ctrl** + **SPACEBAR** If you have typed enough characters to eliminate ambiguity in the name, the rest of the name is typed automatically. Otherwise, the pop-up list of the names specified in the header file opens - see the figure below.



3. Select the name from the list, if needed.

Parameter Info

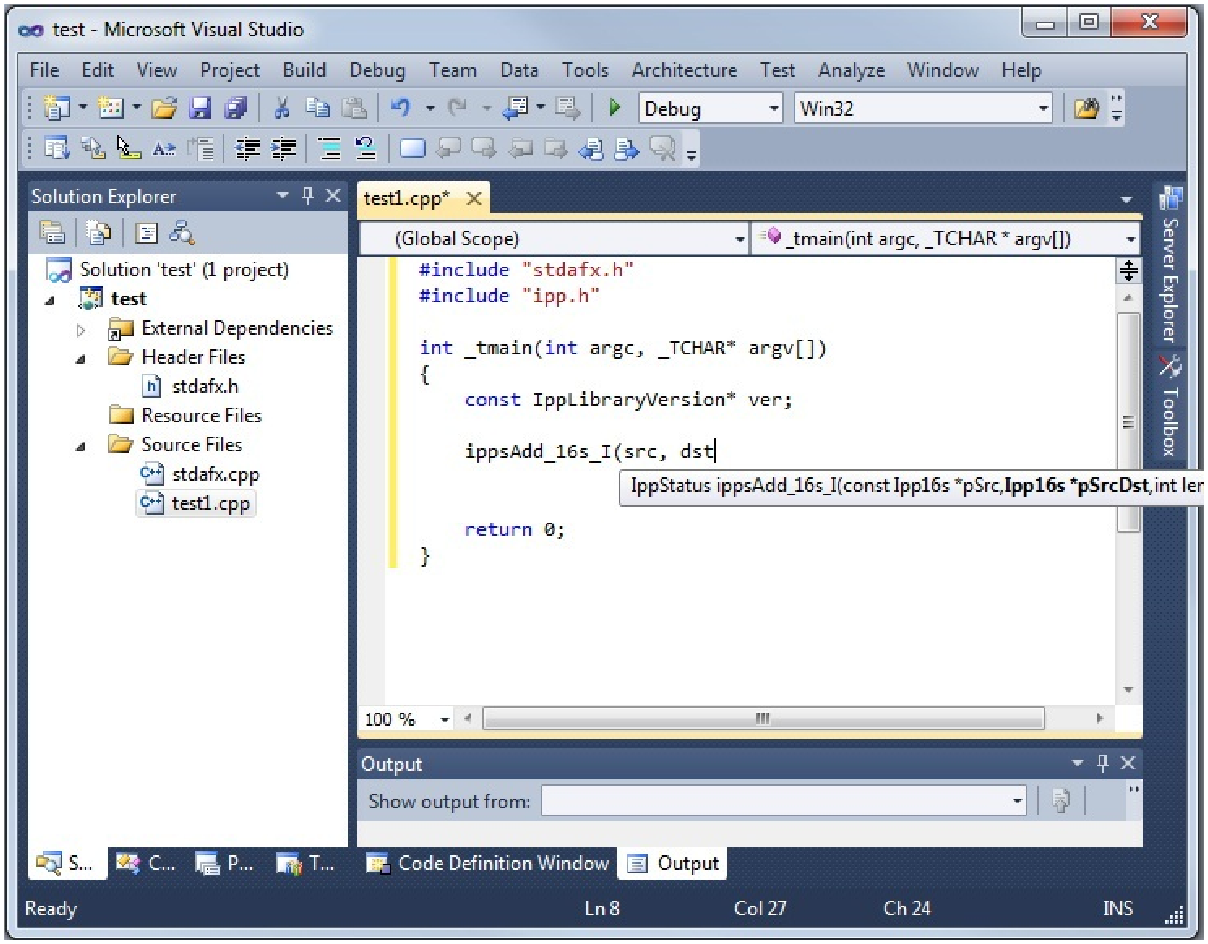
The *Parameter Info* feature displays the parameter list for a function to give information on the number and types of parameters.

To get the list of parameters of a function specified in the header file, follow these steps:

1. Type the function name

2. Type the opening parenthesis

A tooltip appears with the function API prototype, and the current parameter in the API prototype is highlighted - see the figure below.



See Also

Configuring the Microsoft* Visual Studio* IDE to Link with Intel® IPP

Appendix A: Performance Test Tool (perfsys) Command Line Options

Intel® Integrated Performance Primitives (Intel® IPP) installation includes command-line tools for performance testing in the `<install_dir>/tools/perfsys` directory. There is one perfsys tool for each domain. For example, `ps_ipps` executable measures performance for all Intel IPP signal processing domain functions.

Many factors may affect Intel IPP performance. One of the best way to understand them is to run multiple tests in the specific environment you are targeting for optimization. The purpose of the perfsys tools is to simplify performance experiments and empower developers with useful information to get the best performance from Intel IPP functions.

With the command-line options you can:

- Create a list of functions to test
- Set parameters for each function
- Set image/buffer sizes

To simplify re-running specific tests, you can define the functions and parameters in the initialization file, or enter them directly from the console.

The command-line format is:

```
ps_ipp*.exe [option_1] [option_2] ... [option_n]
```

To invoke the short reference for the command-line options, use `-?` or `-h` commands:

```
ps_ipp*.exe -h
```

The command-line options are divided into several groups by functionality. You can enter options in arbitrary order with at least one space between each option name. Some options (like `-r`, `-R`, `-o`, `-O`) may be entered several times with different file names, and option `-f` may be entered several times with different function patterns. For detailed descriptions of the perfsys command-line options see the following table:

Performance Test Tool Command Line Options

Group	Option	Description
Set optimization layer to test	`-T[`*cpu-features*`]`	Call `ippSetCpuFeatures`
Report Configuration	`-A<Timing|Params|Misalign|All>`	Prompt for the parameters before every test from console
	`-o[`*<file-name>*`]`	Create *<file-name>*`.txt` file and write console output to it
	`-O[`*<file-name>*`]`	Add console output to the file *<file-name>*`.txt`
	`-L` *<ERR|WARN|PARM|INFO|TRACE>*	Set detail level of the console output
	`-r[`*<file-name>*`]`	Create *<file-name>*`.csv` file and write perfsys results to it
	`-R[`*<file-name>*`]`	Add test results to the file *<file-name>*`.csv`
	`-q[`*<file-name>*`]`	Create *<file-name>*`.csv` and write function parameter name lines to it

Group	Option	Description
	-q+	Add function parameter name lines to perfsys results table file
	-Q	Exit after creation of the function parameter name table
	-u[<file-name>]	Create <file-name>.csv file and write summary table ('_sum' is added to default file name)
	-U[<file-name>]	Add summary table to the file <file-name>.csv ('_sum' is added to default file name)
	-g[<file-name>]	Create signal file at the end of the whole testing
	-l<dir-name>	Set default directory for output files
	-k<and|or>	Compose different keys (-f, -t, -m) by logical operation
	-F<func-name>	Start testing from function with func-name full name
	-Y<HIGH/NORMAL>	Set high or normal process priority (normal is default)
	-H[ONLY]	Add 'Interest' column to .csv file [and run only hot tests]
	-N<num-threads>	Call ippSetNumThreads(<num-treads>)
	-s[-]	Sort or do not sort functions (sort mode is default)
	-e	Enumerate tests and exit
	-v	Display the version number of the perfsys and exit
	-@<file-name>	Read command-line options for the specified file
Set function parameters	-d<name>=<value>	Set perfsys parameter value
Initialization files	-i[<file-name>]	Read perfsys parameters from the file <file-name>.ini
	-I[<file-name>]	Write perfsys parameters to the file <file-name>.ini and exit
	-P	Read tested function names from the .ini file
	-n<title-name>	Set default title name for .ini file and output files
	-p<dir-name>	Set default directory for .ini file and input test data files
Select functions	-f <or-pattern>	Run tests for functions with pattern in their names, case sensitive
	-f-<not-pattern>	Do not test functions with pattern in their names, case sensitive

Group	Option	Description
	`-f+`*<and-pattern>*	Run tests only for functions with `pattern` in their names, case sensitive
	`-f=`*<eq-pattern>*	Run tests for functions with `pattern` full name
	`-t[-|+|=]`*<pattern>*	Run (do not run) tests with `pattern` in test name
	`-m[-|+|=]`*<pattern>*	Run (do not run) tests registered in file with `pattern` in file name
Help	`-h`	Display short help and exit
	`-hh`	Display extended help and exit
	`-h`*<key>*	Display extended help for the key and exit

Appendix B: Intel® IPP Threading and OpenMP* Support

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All Intel® Integrated Performance Primitives functions are thread-safe. They support multithreading in both dynamic and static libraries and can be used in multi-threaded applications. However, if an application has its own threading model or if other threaded applications are expected to run at the same time on the system, it is strongly recommended to use non-threaded/single-threaded libraries.

Some Intel IPP functions contain OpenMP* code, which increases performance on multi-processor and multi-core systems. These functions include color conversion, filtering, convolution, cryptography, cross-correlation, matrix computation, square distance, and bit reduction.

To see the list of all threaded APIs, refer to the *ThreadedFunctionsList.txt* file located in the documentation directory of the Intel IPP installation.

Optimization Notice
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Setting Number of Threads

By default, the number of threads for Intel IPP threaded libraries follows the OpenMP* default, which is the number of logical processors visible to the operating system. If the value of the `OMP_NUM_THREADS` environment variable is less than the number of processors, then the number of threads for Intel IPP threaded libraries equals the value of the `OMP_NUM_THREADS` environment variable.

To configure the number of threads used by Intel IPP internally, at the very beginning of an application call the `ippSetNumThreads(n)` function, where `n` is the desired number of threads (1, ...). To disable internal parallelization, call the `ippSetNumThreads(1)` function. To configure the number of threads used by Intel IPP internally for threading layer (TL) functions, use functions with the `LT` suffix.

Getting Information on Number of Threads

To find the number of threads created by the Intel IPP, call the `ippGetNumThreads` function.

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Using a Shared L2 Cache

Several functions in the signal processing domain are threaded on two threads intended for the Intel(R) Core™ 2 processor family, and make use of the merged L2 cache. These functions (single and double precision `FFT`, `Div`, `and Sqrt`) achieve the maximum performance if both two threads are executed on the same die. In this case, the threads work on the same shared L2 cache. For processors with two cores on the die, this condition is satisfied automatically. For processors with more than two cores, set the following OpenMP* environmental variable to avoid performance degradation:

```
KMP_AFFINITY=compact
```

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Avoiding Nested Parallelization

Nested parallelization may occur if you use a threaded Intel IPP function in a multithreaded application. Nested parallelization may cause performance degradation because of thread oversubscription.

For applications that use OpenMP threading, nested threading is disabled by default, so this is not an issue.

However, if your application uses threading created by a tool other than OpenMP*, you must disable multi-threading in the threaded Intel IPP function to avoid this issue.

Disabling Multi-threading (Recommended)

The best option to disable multi-threading is to link your application with the Intel® IPP single-threaded (non-threaded) libraries included in the default package and sdiscontinue use of the separately downloaded multi-threaded versions.

You may also call the `ippSetNumThreads` function with parameter `1`, but this method may still incur some OpenMP* overhead.

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