Intel® High Level Synthesis Compiler Pro Edition

Getting Started Guide

Updated for Intel® Quartus® Prime Design Suite: 19.4
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1. Intel® High Level Synthesis (HLS) Compiler Pro Edition Getting Started Guide

The Intel® High Level Synthesis (HLS) Compiler is separately-installable component of Intel Quartus® Prime Pro Edition design software. The Intel HLS Compiler synthesizes a C++ function into an RTL implementation that is optimized for Intel FPGA products. The compiler is sometimes referred to as the i++ compiler, reflecting the name of the compiler command.

The Intel High Level Synthesis Compiler Pro Edition Getting Started Guide describes the procedures to set up the Intel HLS Compiler and to run an HLS design example.

In this publication, `<quartus_installdir>` refers to the location where you installed Intel Quartus Prime Design Suite.

The default Intel Quartus Prime Design Suite installation location depends on your operating system:

Windows C:\intelFPGA_pro\19.4

Linux /home/<username>/intelFPGA_pro/19.4

About the Intel HLS Compiler Documentation Library

Documentation for the Intel HLS Compiler is split across a few publications. Use the following table to find the publication that contains the Intel HLS Compiler information that you are looking for:

<table>
<thead>
<tr>
<th>Title and Description</th>
<th>PRO</th>
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<tbody>
<tr>
<td>Release Notes</td>
<td></td>
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<tr>
<td>Provide late-breaking information about the HLS Compiler.</td>
<td>Link</td>
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<td>Getting Started Guide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Get up and running with the HLS Compiler by learning how to initialize your compiler environment and reviewing the various design examples and tutorials provided with the HLS Compiler.</td>
<td>Link</td>
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</tr>
<tr>
<td>User Guide</td>
<td></td>
<td></td>
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<tr>
<td>Provides instructions on synthesizing, verifying, and simulating intellectual property (IP) that you design for Intel FPGA products. Go through the entire development flow of your component from creating your component and testbench up to integrating your component IP into a larger system with the Intel Quartus Prime software.</td>
<td>Link</td>
<td>Link</td>
</tr>
</tbody>
</table>

continued...
<table>
<thead>
<tr>
<th>Title and Description</th>
<th>PRO</th>
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</thead>
<tbody>
<tr>
<td>Reference Manual</td>
<td>Link</td>
<td>Link</td>
</tr>
<tr>
<td>Provides reference information about the features supported by the Intel HLS Compiler. Find details on Intel HLS Compiler command options, header files, pragmas, attributes, macros, declarations, arguments, and template libraries.</td>
<td></td>
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<tr>
<td>Best Practices Guide</td>
<td>Link</td>
<td>Link</td>
</tr>
<tr>
<td>Provides techniques and practices that you can apply to improve the FPGA area utilization and performance of your HLS component. Typically, you apply these best practices after you verify the functional correctness of your component.</td>
<td></td>
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<tr>
<td>Quick Reference</td>
<td>Link</td>
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<tr>
<td>Provides a brief summary of Intel HLS Compiler declarations and attributes on a single two-sided page.</td>
<td></td>
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</tr>
</tbody>
</table>

### 1.1. Intel High Level Synthesis Compiler Pro Edition Prerequisites

The Intel HLS Compiler Pro Edition is part of the Intel Quartus Prime Pro Edition Design Suite. You can install it as part of your Intel Quartus Prime software installation or install it separately. It requires Intel Quartus Prime and additional software to use.

For detailed instructions about installing Intel Quartus Prime Pro Edition software, including system requirements, prerequisites, and licensing requirements, see Intel FPGA Software Installation and Licensing.

The Intel HLS Compiler requires the following software in addition to Intel Quartus Prime:

**C++ Compiler**

For Linux, install GCC 5.4.0 including the GNU C++ library:

You must install these libraries manually. See Installing the Intel HLS Compiler on Linux Systems for instructions.

**Important:** The Intel HLS Compiler software does not support versions of the GCC compiler other than GCC 5.4.0.

For Windows, install one of the following versions of the Microsoft Visual Studio Professional:
- Microsoft Visual Studio 2017 Professional
- Microsoft Visual Studio 2017 Community

**Important:** The Intel HLS Compiler software does not support versions of Microsoft Visual Studio other than those specified for the edition of the software.

**Mentor Graphics* ModelSim* Software**

On Windows and RedHat Linux systems, you can install the ModelSim* software from the Intel Quartus Prime software installer. The available options are:
- ModelSim - Intel FPGA Edition
- ModelSim - Intel FPGA Starter Edition

Alternatively, you can use your own licensed version of Mentor Graphics* ModelSim software.
On RedHat Linux systems, ModelSim software requires the Red Hat development tools packages. Additionally, any 32-bit versions of ModelSim software (including those provided with Intel Quartus Prime) require additional 32-bit libraries. The commands to install these requirements are provided in Installing the Intel HLS Compiler on Linux Systems.

On SUSE Linux systems, you must use your own licensed version of Mentor Graphics ModelSim software.

For information about all the ModelSim software versions that the Intel software supports, refer to the EDA Interface Information section in the Software and Device Support Release Notes for your edition of Intel Quartus Prime Pro Edition.

**Related Information**
- Supported Operating Systems
- Software Requirements in *Intel FPGA Software Installation and Licensing*
- EDA Interface Information (Intel Quartus Prime Pro Edition)
- Mentor Graphics ModelSim Website

### 1.1.1. Intel HLS Compiler Pro Edition Backwards Compatibility


To install Intel HLS Compiler Pro Edition Version 19.4 into an older version of Intel Quartus Prime Pro Edition:

1. Backup the existing `<quartus_installdir>/hls` directory. For example, rename `<quartus_installdir>/hls` to `<quartus_installdir>/hls_old`.


3. Run the Intel HLS Compiler standalone installer, and specify your `<quartus_installdir>` directory when prompted.

You can revert to your previous version of the Intel HLS Compiler by renaming your backup directory. Whatever version of the the Intel HLS Compiler that in a directory called `<quartus_installdir>/hls` is the active version of the Intel HLS Compiler.

### 1.2. Downloading the Intel HLS Compiler Pro Edition

Download the Intel HLS Compiler Pro Edition from the Intel Quartus Prime Download Center.

---

(1) Where `<quartus_installdir>` is the directory where you installed the Intel Quartus Prime Pro Edition Design Suite. For example, `C:\intelFPGA_pro\19.4`. 

**Send Feedback**
The Intel HLS Compiler Pro Edition is installed as part of your Intel Quartus Prime Pro Edition installation package or from a separate standalone installer.


- Download the Intel HLS Compiler from the Intel Quartus Prime Download Center:

The Intel HLS Compiler Pro Edition standalone installation package is available on the Additional Software tab.

To include the Intel HLS Compiler Pro Edition in your Intel Quartus Prime Pro Edition installation, download one of the following combinations of installation packages:

- Download a complete installation package from the Combined Files tab.
- Download a Quartus Prime installation package from the Individual Files tab and download the Intel HLS Compiler installation package from the Additional Software tab. Place both installation packages in the same directory.

For detailed instructions about installing Intel Quartus Prime software, including system requirements, prerequisites, and licensing requirements, refer to Intel FPGA Software Installation and Licensing.

The Intel HLS Compiler standalone installation package requires you to have an existing Intel Quartus Prime Pro Edition installation as a target for the Intel HLS Compiler installation.

### 1.3. Installing the Intel HLS Compiler Pro Edition on Linux Systems

You must have administrator privileges to install the Intel HLS Compiler Pro Edition prerequisites. However, the Intel HLS Compiler and Intel Quartus Prime do not require administrator privileges to install.

To install the Intel HLS Compiler on Linux Systems:

1. Confirm that your operating system version is supported by the Intel HLS Compiler:
   - Red Hat Enterprise Linux 6.x, or a community equivalent
   - Red Hat Enterprise Linux 7.x, or a community equivalent
   - SUSE Linux Enterprise Server 12

2. (SUSE Linux only) Ensure that you have the Toolchain Module available.

3. Depending on your current system and what installation package or packages you have downloaded, you might have to complete some additional steps to prepare your installation:
   - If you are installing the complete Intel Quartus Prime installation package (from the Combined Files tab of the Quartus Prime download page at the Download Center for FPGAs):
     No additional steps are needed before running the installation package.
If you are installing separately downloaded Intel Quartus Prime (from Individual Files tab of the Quartus Prime download page at the Download Center for FPGAs) and Intel HLS Compiler (from Additional Software tab of the Quartus Prime download page at the Download Center for FPGAs) installation packages:

Ensure that you have both installation packages in the same directory. The Intel Quartus Prime installer detects the Intel HLS Compiler installation package and installs both software packages for you.

If you are updating the Intel HLS Compiler in an existing Intel Quartus Prime Pro Edition installation:

a. Ensure that you have Intel Quartus Prime Pro Edition already installed.

b. Take note of the path to your Intel Quartus Prime installation.

You need this path information to complete the Intel HLS Compiler installation wizard.

c. Rename the HLS directory in your current Intel Quartus Prime version to keep that version as a backup.

For example, if you are installing Intel HLS Compiler Version 19.4 into an Intel Quartus Prime Pro Edition Version 19.3 installation, rename `/home/<username>/intelFPGA_pro/19.3/hls` to `/home/<username>/intelFPGA_pro/19.3/hls_old`.

4. Install the package that you downloaded in Downloading the Intel HLS Compiler Pro Edition on page 5.

For detailed instructions about installing Intel Quartus Prime software, including system requirements, prerequisites, and licensing requirements, refer to Intel FPGA Software Installation and Licensing.

5. Update your Linux repositories with the following command:

```
sudo yum update
```

6. Install GCC 5.4.0:

To download the required tools and source files, and compile GCC 5.4.0, run the following commands:

```bash
$ sudo yum groupinstall "Development Tools" "Additional Development"
$ cd <quartus_installdir>/hls/
$ ./install_gcc
```

The `install_gcc` command runs a script that downloads and compiles the GCC 5.4.0 in the `/home/<username>/build/gcc` folder. The script installs this version of the GCC compiler alongside the Intel HLS Compiler so that the Intel HLS Compiler can access the required libraries without any further action on your part.

**Maintaining Your Own GCC Installation:**

If you want to maintain your own GCC installation, run the script with the `--i` flag to specify a different GCC installation directory. However, if you specify a different GCC installation directory, you must specify the `--gcc-toolchain` option every time you run the Intel HLS Compiler `i++` command. For details about the `--gcc-toolchain` option, see Intel HLS Compiler Command Options in Intel HLS Compiler Reference Manual.
Installing GCC requires an Internet connection. If you are installing Intel HLS Compiler on a system without Internet access, see Installing GCC Offline on page 8 for instructions.

For more options of the `install_gcc` command, use the command help option: `./install_gcc -h`.

7. (RedHat Linux Only) If you want the Intel HLS Compiler to simulate your components with the 32-bit Mentor Graphics ModelSim software provided with Intel Quartus Prime (ModelSim - Intel FPGA Edition), install the required additional 32-bit libraries with the following command:

   • Red Hat Enterprise Linux 6.x, or a community equivalent
     ```bash
     $ sudo yum install -y glibc.i686 glibc-devel.i686 libX11.i686 libXext.i686 libXft.i686 libgcc.i686 libgcc.x86_64 libstdc++.i686 libstdc++-devel.i686 ncurses-devel.i686 qt.i686 qt-x11.i686
     ```
   • Red Hat Enterprise Linux 7.x, or a community equivalent
     ```bash
     $ sudo yum install -y glibc.i686 glibc-devel.i686 libX11.i686 libXext.i686 libXft.i686 libgcc.i686 libgcc.x86_64 libstdc++.i686 libstdc++-devel.i686 ncurses-devel.i686 qt.i686
     ```
   • SUSE Linux Enterprise Server 12
     ModelSim - Intel FPGA Edition is not supported on SUSE Linux. Use your own licensed version of Mentor Graphics ModelSim software.

8. (RedHat Linux Only) If you use the Mentor Graphics ModelSim software provided with Intel Quartus Prime, add the path to ModelSim to your `PATH` environment variable

   For example:
   ```bash
   $ export PATH=$PATH:<quartus_installdir>/modelsim_ase/bin
   ```

9. Optional: If you plan to use Platform Designer to integrate your component with a system, add the path to Platform Designer to your `PATH` environment variable.

   For example:
   ```bash
   $ export PATH=$PATH:<quartus_installdir>/qsys/bin
   ```

After completing these steps, the Intel HLS Compiler is installed on your system. Before you can compile your component with the Intel HLS Compiler `i++` command, you must initialize your Intel HLS Compiler environment for the `i++` command to run successfully. For details, see Initializing the Intel HLS Compiler Pro Edition Environment on page 11.

### 1.3.1. Installing GCC Offline

If needed, you can compile and build GCC 5.4.0 offline. You must still download required packages to a system with an Internet connection, then transfer the files to the system without an Internet connection.

To install GCC offline:

1. Obtain the required packages and transfer them to the offline system in one of the following ways:
— Run the following command on an Intel HLS Compiler system with Internet access to download and extract the required GCC tarballs:

```bash
cd <quartus_installdir>/hls/
$ ./install_gcc -d
```

Transfer the extracted tarballs to the offline system. By default, the tarballs are extracted to `/tmp/gcc/source`.

— Obtain and extract the required tarballs manually:

a. On any system with Internet access, download the following tarballs:

- https://ftp.gnu.org/gnu/gcc/gcc-5.4.0/gcc-5.4.0.tar.gz
- ftp://gcc.gnu.org/pub/gcc/infrastructure/gmp-4.3.2.tar.bz2
- ftp://gcc.gnu.org/pub/gcc/infrastructure/mpfr-2.4.2.tar.bz2
- ftp://gcc.gnu.org/pub/gcc/infrastructure/mpc-0.8.1.tar.gz

b. Transfer the tarballs to the source directory on the offline system. For example, `/tmp/gcc/source`.

c. On the offline system, extract and delete the tarballs:

```bash
$ for f in $(ls)
do
tar -xf ${f}
rm ${f}
done
```

d. Create required symbolic links in the `gcc` directory:

```bash
$ for d in gmp isl mpc mpfr; do
    ln -s ../$d* $d
done
```

2. On the offline system where you installed the Intel HLS Compiler, run the following commands:

```bash
$ cd <quartus_installdir>/hls/
$ ./install_gcc -c
```

The `install_gcc` script skips its usual download step and uses the tarballs that you provided.

### 1.4. Installing the Intel HLS Compiler Pro Edition on Microsoft* Windows* Systems

To install the Intel HLS Compiler on Microsoft* Windows* Systems:

1. Confirm that your operating system version is supported by the Intel HLS Compiler (Microsoft* Windows* 7 SP1, 8.1 or 10).

2. Install one of the following software products, depending on your edition of the Intel Quartus Prime software:

   — Microsoft Visual Studio 2017 Professional
   — Microsoft Visual Studio 2017 Community

   **Important:** The Intel HLS Compiler software does not support versions of Microsoft Visual Studio other than those specified for the edition of the software.
If you have multiple versions of Visual Studio, Microsoft recommends installing Visual Studio versions in the order in which the versions were released. For example, install Visual Studio 2010 before installing Visual Studio 2015. For details, see Install Visual Studio Versions Side-by-Side in the MSDN Library.

3. Depending on your current system and what installation package or packages you have downloaded, you might have to complete some additional steps to prepare your installation:
   - If you are installing complete Intel Quartus Prime installation package (from the Combined Files tab of the Quartus Prime download page at the Download Center for FPGAs):
     No additional steps are needed before running the installation package.
   - Installing separately downloaded Intel Quartus Prime (from Individual Files tab of the Quartus Prime download page at the Download Center for FPGA) and Intel HLS Compiler (from the Additional Software tab of the Quartus Prime download page at the Download Center for FPGA) installation packages:
     Ensure that you have both installation packages in the same directory. The Intel Quartus Prime installer detects the Intel HLS Compiler installation package and installs both software packages for you.
   - Updating the Intel HLS Compiler in your Intel Quartus Prime Pro Edition installation:
     a. Ensure that you have Intel Quartus Prime Pro Edition already installed.
     b. Take note of the path to your Intel Quartus Prime installation.
        You need this path information to complete the Intel HLS Compiler installation wizard.
     c. Rename the HLS directory in your current Intel Quartus Prime version to keep that version as a backup.
        For example, if you are installing Intel HLS Compiler Version 19.4 into an Intel Quartus Prime Pro Edition Version 19.3 installation, rename C:\intelFPGA_pro\19.3\hls to C:\intelFPGA_pro \19.3\hls_old.

4. Install the package that you downloaded in Downloading the Intel HLS Compiler Pro Edition on page 5.
   For detailed instructions about installing Intel Quartus Prime software, including system requirements, prerequisites, and licensing requirements, refer to the Intel FPGA Software Installation and Licensing.

5. If you use the Mentor Graphics ModelSim software provided with Intel Quartus Prime, add the path to ModelSim to your PATH environment variable.
   For example:
   ```
   set PATH=%PATH%:\<quartus_installdir>\modelsim_ase\win32aloem
   ```

6. Optional: If you plan to use Platform Designer to integrate your component with a system, add the path to Platform Designer to your PATH environment variable.
   For example:
   ```
   set PATH=%PATH%:\<quartus_installdir>\qsys\bin
   ```
After completing these steps, the Intel HLS Compiler is installed on your system. Before you can compile your component with the Intel HLS Compiler `i++` command, you must initialize your Intel HLS Compiler environment for the `i++` command to run successfully. For details, see Initializing the Intel HLS Compiler Pro Edition Environment on page 11.

### 1.5. Initializing the Intel HLS Compiler Pro Edition Environment

Before you can compile your component with the Intel HLS Compiler `i++` command, a number of environment variables must be set for the `i++` command to run successfully.

The Intel HLS Compiler environment initialization script applies only to the environment variable settings in your current terminal or command prompt session. You must initialize the Intel HLS Compiler environment each time that you start a terminal or command prompt session to develop your design.

To initialize your current terminal or command prompt session so that you can run the Intel HLS Compiler:

- **On Linux systems**, initialize your environment as follows:
  
  a. Start a terminal session and run the following command from the command prompt, change directories to the `hls` directory in your Intel Quartus Prime installation directory.

  ```
  source <quartus_installdir>/hls/init_hls.sh
  ```

  Where `<quartus_installdir>` is the path to your Intel Quartus Prime installation. For example, `/home/<username>/intelFPGA_pro/19.4`.

  The environment initialization script shows the environment variables that it set, and you can now run the `i++` command from this terminal session.

- **On Windows systems**, initialize your environment as follows:
  
  a. Start a Visual Studio x64 Native Tools Command Prompt session. For example, `C:\Program Files (x86)\Microsoft Visual Studio \2017\Professional\VC\Auxiliary\Build\vcvars64.bat` or `C:\Program Files (x86)\Microsoft Visual Studio \2017\Community\VC\Auxiliary\Build\vcvars64.bat`

  b. In your x64 Native Tools Command Prompt session, run the following command: change directories to the `hls` directory in your Intel Quartus Prime installation directory.

  ```
  <quartus_installdir>\hls\init_hls.bat
  ```

  Where `<quartus_installdir>` is the path to your Intel Quartus Prime installation. For example, `C:\intelFPGA_pro\19.4`.

  You can now run the `i++` command from this command prompt session.

**Tip:**

To set the environment variables permanently, follow your operating system’s standard procedure for making persistent changes to environment variable settings. Review the output of the environment initialization script to determine the environment variables to set permanently.
2. High Level Synthesis (HLS) Design Examples and Tutorials

The Intel High Level Synthesis (HLS) Compiler Pro Edition includes design examples and tutorials to provide you with example components and demonstrate ways to model or code your components to get the best results from the Intel HLS Compiler for your design.

High Level Synthesis Design Examples

The high level synthesis (HLS) design examples give you a quick way to see how various algorithms can be effectively implemented to get the best results from the Intel HLS Compiler.

You can find the HLS design examples in the following location:

<quartus_installdir>/hls/examples/<design_example_name>

Where <quartus_installdir> is the directory where you installed the Intel Quartus Prime Design Suite. For example, /home/<username>/intelFPGA_pro/19.4 or C:\intelFPGA_pro\19.4.

For instructions on running the examples, see the following sections:
- Running a Intel HLS Compiler Design Example (Linux) on page 17
- Running an Intel HLS Compiler Design Example (Windows) on page 18

Table 2. HLS design examples

<table>
<thead>
<tr>
<th>Focus area</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear algebra</td>
<td>QRD</td>
<td>Uses the Modified Gram-Schmidt algorithm for QR factorization of a matrix.</td>
</tr>
<tr>
<td>Signal processing</td>
<td>interp_decim_filter</td>
<td>Implements a simple and efficient interpolation/decimation filter.</td>
</tr>
<tr>
<td>Simple design</td>
<td>counter</td>
<td>Implements a simple and efficient 32-bit counter component.</td>
</tr>
<tr>
<td>Video processing</td>
<td>YUV2RGB</td>
<td>Implements a basic YUV422 to RGB888 color space conversion.</td>
</tr>
<tr>
<td>Video processing</td>
<td>image_downsample</td>
<td>Implements an image downsampling algorithm to scale an image to a smaller size using bilinear interpolation.</td>
</tr>
</tbody>
</table>

HLS Design Tutorials

The HLS design tutorials show you important HLS-specific programming concepts as well demonstrating good coding practices.

Each tutorial has a README file that gives you details about what the tutorial covers and instructions on how to run the tutorial.
Table 3. **Arbitrary precision datatypes design tutorials**

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ac_fixed_constructor</td>
<td>Demonstrates the use of the ac_fixed constructor where you can get a better QoR by using minor variations in coding style.</td>
</tr>
<tr>
<td>ac_fixed_math_library</td>
<td>Demonstrates the use of the Intel HLS Compiler ac_fixed_math fixed point math library functions.</td>
</tr>
<tr>
<td>ac_int_basic_ops</td>
<td>Demonstrates the operators available for the ac_int class.</td>
</tr>
<tr>
<td>ac_int_overflow</td>
<td>Demonstrates the usage of the DEBUG_AC_INT_WARNING and DEBUG_AC_INT_ERROR keywords to help detect overflow during emulation runtime.</td>
</tr>
</tbody>
</table>

You can find these tutorials in the following location on your Intel Quartus Prime system:

<quartus_installdir>/hls/examples/tutorials/ac_datatypes

You can find these tutorials in the following location on your Intel Quartus Prime system:

<quartus_installdir>/hls/examples/tutorials/hls_float

1_reduced_double     | Demonstrates how your application can benefit from hls_float by changing the underlining type from double to hls_float<11, 44> (reduced double). |
2_explicit_arithmetic| Demonstrates how to use the explicit versions of hls_float binary operators to perform floating-point arithmetic operations based on your needs.                                      |
3_conversions        | Demonstrates when conversions appear in designs with hls_float types and how to use different conversion modes to generate compile-type constants using various hls_float types. |

Table 4. **Component memories design tutorials**

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>memory_implementation</td>
<td>Demonstrates how to implement variables or arrays in registers, MLABs, or RAMs by using the following memory attributes:</td>
</tr>
<tr>
<td></td>
<td>• hls_register</td>
</tr>
<tr>
<td></td>
<td>• hls_memory</td>
</tr>
<tr>
<td></td>
<td>• hls_memory_impl</td>
</tr>
<tr>
<td>memory_bank_configuration</td>
<td>Demonstrates how to control the number of load/store ports of each memory bank and optimize your component area usage, throughput, or both by using one or more of the following memory attributes:</td>
</tr>
<tr>
<td></td>
<td>• hls_max_replicates</td>
</tr>
<tr>
<td></td>
<td>• hls_singlepump</td>
</tr>
<tr>
<td></td>
<td>• hls_doublepump</td>
</tr>
<tr>
<td></td>
<td>• hls_simple_dual_port_memory</td>
</tr>
<tr>
<td>memory_geometry</td>
<td>Demonstrates how to split your memory into banks and control the number of load/store ports of each memory bank by using one or more of the following memory attributes:</td>
</tr>
<tr>
<td></td>
<td>• hls_bankwidth</td>
</tr>
<tr>
<td></td>
<td>• hls_numbanks</td>
</tr>
<tr>
<td></td>
<td>• hls_bankbits</td>
</tr>
</tbody>
</table>

continued...
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>memory_merging</td>
<td>Demonstrates how to improve resource utilization by implementing two logical</td>
</tr>
<tr>
<td></td>
<td>memories as a single physical memory by merging them depth-wise or width-</td>
</tr>
<tr>
<td></td>
<td>wise with the hls_merge memory attribute.</td>
</tr>
<tr>
<td>static_var_init</td>
<td>Demonstrates how to control the initialization behavior of statics in a</td>
</tr>
<tr>
<td></td>
<td>component using the hls_init_on_reset or hls_init_on_powerup memory</td>
</tr>
<tr>
<td></td>
<td>attribute.</td>
</tr>
<tr>
<td>exceptions</td>
<td>Demonstrates how to use memory attributes on constants and struct members.</td>
</tr>
<tr>
<td>attributes_on_mm_slave_arg</td>
<td>Demonstrates how to apply memory attributes to Avalon® Memory Mapped (MM)</td>
</tr>
<tr>
<td></td>
<td>slave arguments.</td>
</tr>
</tbody>
</table>

Table 5. Interfaces design tutorials

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>overview</td>
<td>Demonstrates the effects on quality-of-results (QoR) of choosing different</td>
</tr>
<tr>
<td></td>
<td>component interfaces even when the component algorithm remains the same.</td>
</tr>
<tr>
<td>explicit_streams_buffer</td>
<td>Demonstrates how to use explicit stream_in and stream_out interfaces in the</td>
</tr>
<tr>
<td></td>
<td>component and testbench.</td>
</tr>
<tr>
<td>explicit_streams_packets_empty</td>
<td>Demonstrates how to use the usesPackets, usesEmpty, and</td>
</tr>
<tr>
<td></td>
<td>firstSymbolInHighOrderBits stream template parameters.</td>
</tr>
<tr>
<td>explicit_streams_packets_read_valid</td>
<td>Demonstrates how to use the usesPackets, usesValid, and usesReady</td>
</tr>
<tr>
<td></td>
<td>stream template parameters.</td>
</tr>
<tr>
<td>mm_master_testbench_operators</td>
<td>Demonstrates how to invoke a component at different indices of an Avalon</td>
</tr>
<tr>
<td></td>
<td>Memory Mapped (MM) Master (mm_master class) interface.</td>
</tr>
<tr>
<td>mm_slaves</td>
<td>Demonstrates how to create Avalon-MM Slave interfaces (slave registers and</td>
</tr>
<tr>
<td></td>
<td>slave memories).</td>
</tr>
<tr>
<td>multiple_stream_call_sites</td>
<td>Demonstrates the benefits of using multiple stream call sites.</td>
</tr>
<tr>
<td>pointer_mm_master</td>
<td>Demonstrates how to create Avalon-MM Master interfaces and control their</td>
</tr>
<tr>
<td></td>
<td>parameters.</td>
</tr>
<tr>
<td>stable_arguments</td>
<td>Demonstrates how to use the stable attribute for unchanging arguments to</td>
</tr>
<tr>
<td></td>
<td>improve resource utilization.</td>
</tr>
</tbody>
</table>

Table 6. Best practices design tutorials

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ac_datatypes</td>
<td>Demonstrates the effect of using ac_int datatype instead of int datatype.</td>
</tr>
<tr>
<td>const_global</td>
<td>Demonstrates the performance and resource utilization improvements of using</td>
</tr>
<tr>
<td></td>
<td>const qualified global variables.</td>
</tr>
<tr>
<td>divergent_loops</td>
<td>Demonstrates a source-level optimization for designs with divergent loops.</td>
</tr>
<tr>
<td>floating_point_contract</td>
<td>Demonstrates how to use the fp_contract option to improve the performance</td>
</tr>
<tr>
<td></td>
<td>of your design for double-precision floating-point operations.</td>
</tr>
</tbody>
</table>

continued...
## Usability design tutorials

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>floating_point_ops</td>
<td>Demonstrates the impact of --fpc and --fp-relaxed flags in i++ on floating point operations using a 32-tap finite impulse response (FIR) filter design that is optimized for throughput.</td>
</tr>
<tr>
<td>fpga_reg</td>
<td>Demonstrates how to use the fpga_reg macro to precisely tune pipelining in your design.</td>
</tr>
<tr>
<td>hyper_optimized_handshaking</td>
<td>Demonstrates how to use the --hyper-optimized-handshaking option of the Intel HLS Compiler i++ command.</td>
</tr>
<tr>
<td>loop_coalesce</td>
<td>Demonstrates the performance and resource utilization improvements of using loop_coalesce pragma on nested loops. While the #pragma loop_coalesce is provided with both Standard and Pro edition, the design tutorial is provided only with Pro edition.</td>
</tr>
<tr>
<td>loop_memory_dependency</td>
<td>Demonstrates breaking loop carried dependencies using the ivdep pragma.</td>
</tr>
<tr>
<td>lsu_control</td>
<td>Demonstrates the effects of controlling the types of LSUs instantiated for variable-latency Avalon MM Master interfaces.</td>
</tr>
<tr>
<td>parameter_aliasing</td>
<td>Demonstrates the use of the __restrict keyword on component arguments.</td>
</tr>
<tr>
<td>random_number_generator</td>
<td>Demonstrates how to use the random number generator library.</td>
</tr>
<tr>
<td>relax_reduction_dependency</td>
<td>Demonstrates a method to reduce the II of a loop that includes a floating point accumulator, or other reduction operation that cannot be computed at high speed in a single clock cycle.</td>
</tr>
<tr>
<td>resource_sharing_filter</td>
<td>Demonstrates an optimized-for-area variant of a 32-tap finite impulse response (FIR) filter design.</td>
</tr>
<tr>
<td>set_component_target_fmax</td>
<td>Demonstrate how to use the hls_scheduler_target_fmax_mhz component attribute and how it interacts with the ii loop pragma.</td>
</tr>
<tr>
<td>shift_register</td>
<td>Demonstrates the recommended coding style for implementing shift registers.</td>
</tr>
<tr>
<td>sincos_func</td>
<td>Demonstrates the effects of using sinpi or cospi functions in your component instead of sin or cos functions.</td>
</tr>
<tr>
<td>single_vs_double_precision_math</td>
<td>Demonstrates the effect of using single precision literals and functions instead of double precision literals and functions.</td>
</tr>
<tr>
<td>struct_interface</td>
<td>Demonstrates how to use ac_int to implement interfaces with no padding bits.</td>
</tr>
<tr>
<td>swap_vs_copy</td>
<td>Demonstrates the impact of using deep copying with registers on the performance and resource utilization of a component design.</td>
</tr>
<tr>
<td>triangular_loop</td>
<td>Demonstrates a method for describing triangular loop patterns with dependencies.</td>
</tr>
</tbody>
</table>

You can find these tutorials in the following location on your Intel Quartus Prime system:

```
<quartus_installdir>/hls/examples/tutorials/usability
```

(Continued...
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>enqueue_call</td>
<td>Demonstrates how to run components asynchronously and exercise their pipeline performance in the test bench using enqueue functionality.</td>
</tr>
<tr>
<td>platform_designer_2xclock</td>
<td>Demonstrates the recommended clock and reset generation for a component with a clock2x input.</td>
</tr>
<tr>
<td>platform_designer_stitching</td>
<td>Demonstrates how to combine multiple components to function as a single cohesive design.</td>
</tr>
</tbody>
</table>

### Table 8. System of tasks design tutorials

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>balancing_loop_delay</td>
<td>Demonstrates how to improve the throughput of a component that uses a system of tasks by buffering streams.</td>
</tr>
<tr>
<td>balancing_pipeline_latency</td>
<td>Demonstrates how to improve the throughput of a component that uses a system of tasks by buffering streams.</td>
</tr>
<tr>
<td>interfaces_sot</td>
<td>Demonstrates how to transfer information between into and out of tasks using Avalon streaming and Avalon memory-mapped master interfaces.</td>
</tr>
<tr>
<td>internal_stream</td>
<td>Demonstrates how to use &quot;internal streams&quot; in HLS tasks with the ihc::stream object.</td>
</tr>
<tr>
<td>parallel_loop</td>
<td>Demonstrates how you can run sequential loops in a pipelined manner by using a system of HLS tasks in your component.</td>
</tr>
<tr>
<td>resource_sharing</td>
<td>Demonstrates how you can share expensive compute blocks in your component to save area usage.</td>
</tr>
<tr>
<td>task_reuse</td>
<td>Demonstrates how to invoke multiple copies of the same task function.</td>
</tr>
</tbody>
</table>

### Table 9. HLS Libraries design tutorials

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>basic_rtl_library_flow</td>
<td>Demonstrates the process of developing an RTL library and using it in an HLS component.</td>
</tr>
<tr>
<td>rtl_struct_mapping</td>
<td>Demonstrates how to obtain a mapping from C++ struct fields to bit-slices of RTL module interface signals.</td>
</tr>
</tbody>
</table>

### Table 10. HLS Loop Control tutorials

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>max_interleaving</td>
<td>Demonstrates a method to reduce the area utilization of a loop that meets the following conditions:</td>
</tr>
<tr>
<td></td>
<td>• The loop has an II &gt; 1</td>
</tr>
<tr>
<td></td>
<td>• The loop is contained in a pipelined loop</td>
</tr>
<tr>
<td></td>
<td>• The loop execution is serialized across the invocations of the pipelined loop</td>
</tr>
</tbody>
</table>
2.1. Running a Intel HLS Compiler Design Example (Linux)

To run an Intel HLS Compiler design example on Linux systems:

1. Start a terminal session and initialize the Intel HLS Compiler environment.
   
   For instructions how to initialize the environment, see Initializing the Intel HLS Compiler Pro Edition Environment on page 11.

2. Navigate to the `<quartus_installdir>/hls/examples/ <design_example_name>` directory, where `<quartus_installdir>` is the directory where you installed Intel Quartus Prime software.

   For example, `/home/<username>/intelFPGA_pro/19.4`.

3. Run the `make test-x86-64` command. This command compiles the C++ source code to an x86-64 binary executable. Then, run the generated executable on your CPU.

   Expected outcome after you run the `make test-x86-64` command:
   
   • The console displays the command used to generate the binary. For example,  
     `i++ -march=x86-64 -o test-x86-64 <source_files>`.  
   
   • The HLS compiler creates an executable file (for example, `test-x86-64`) in the current working directory.

   • The console displays the output of the executable to signify a successful execution.

   ```bash
   $ make test-x86-64
   i++ MGS.cpp QRD_Testbench.cpp TestbenchHelpers.cpp --fpc --fp-relaxed -march=x86-64 -o test-x86-64
   +----------------------------------------+ 
   | Run ./test-x86-64 to execute the test. | 
   +----------------------------------------+
   ```

4. Run the `make test-fpga` command. The command compiles the C++ source code to a hardware executable and then runs a simulation of the generated HDL.

   Expected outcome after you run the `make test-fpga` command:
   
   • The console displays the command it uses to generate the testbench binary and the contents of the project directory. For example,  
     `i++ -march="<FPGA_family_or_part_number>" <source_files> -o test-fpga`.  
   
   • The HLS compiler creates a `.prj` directory (for example, `test-fpga.prj`) in the current working directory.

   • The console displays the output of the executable to signify a successful execution.

   ```bash
   $ make test-fpga
   i++ MGS.cpp QRD_Testbench.cpp TestbenchHelpers.cpp -v --fpc --fp-relaxed -march=Arria10 -o test-fpga
   Target FPGA part name: 10AX115U1F45I1SG  
   Target FPGA family name: Arria 10  
   Target FPGA speed grade: -2  
   Analyzing MGS.cpp for testbench generation  
   Creating x86-64 testbench  
   Analyzing MGS.cpp for hardware generation  
   Analyzing QRD_Testbench.cpp for testbench generation  
   Creating x86-64 testbench  
   Analyzing QRD_Testbench.cpp for hardware generation
   ```
2.2. Running an Intel HLS Compiler Design Example (Windows)

To run an Intel HLS Compiler design example on Windows systems:

1. Start a terminal session and initialize the Intel HLS Compiler environment.
   For instructions how to initialize the environment, see Initializing the Intel HLS
   Compiler Pro Edition Environment on page 11.

2. Navigate to the `<quartus_installdir>\hls\examples
   \<design_example_name>` directory, where `<quartus_installdir>` is the directory
   where you installed Intel Quartus Prime software.
   For example, C:\intelFPGA_pro\19.4.

3. Run the `build.bat test-x86-64`. This command compiles the C++ source
code to an x86-64 binary executable. Then, run the generated executable on your
CPU.
   Expected outcome after you run the `build.bat test-x86-64` command:
   • The console displays the command it uses to generate the binary. For
     example, `i++ --fpc --fp-relaxed -march=x86-64 MGS.cpp QRD_Testbench.cpp
     TestbenchHelpers.cpp -o test-x86-64.exe`.
   • The HLS compiler creates an executable file (for example, `test-
x86-64.exe`) in the current working directory.
   • The console displays the output of the executable to signify a successful
     execution.

   C:\intelFPGA_pro\19.4\hls\examples\QRD>build.bat test-x86-64
   i++ --fpc --fp-relaxed -march=x86-64 MGS.cpp QRD_Testbench.cpp
   TestbenchHelpers.cpp -o test-x86-64.exe
   Run test-x86-64.exe to execute the test.

4. Run the `build.bat test-fpga` command. The command compiles the C++
source code to a hardware executable and then runs a simulation of the generated
HDL.
   Expected outcome after you run the `build.bat test-fpga` command:
• The console displays the command it uses to generate the testbench binary and the contents of the project directory. For example,
  
i++ -march="<FPGA_family_or_part_number>" <source_files>
  -o test-fpga.

• The HLS compiler creates a .prj directory (for example, test-fpga.prj) in the current working directory.

• The console displays the output of the executable to signify a successful execution.

```bash
C:\intelFPGA_pro\19.4\hls\examples\QRD>build.bat test-fpga
i++ --fpc --fp-relaxed -march=Arria10 MGS.cpp QRD_Testbench.cpp
TestbenchHelpers.cpp -o test-fpga.exe
Run test-fpga.exe to execute the test.
```
3. Troubleshooting the Setup of the Intel HLS Compiler

This section provides information that can help you troubleshoot problems you might encounter when setting up the HLS compiler.

3.1. Intel HLS Compiler Licensing Issues

The Intel High Level Synthesis (HLS) Compiler is licensed as part of your Intel Quartus Prime license. However, the Intel HLS Compiler depends on ModelSim software. If you use a version of ModelSim software other than ModelSim - Intel FPGA Edition or ModelSim - Intel FPGA Starter Edition, ensure that your version of ModelSim software is licensed correctly.

In some cases, you might encounter problems with the licensing for ModelSim software.

3.1.1. ModelSim Licensing Error Messages

The HLS compiler issues error messages if it cannot locate the license for the installed version of ModelSim software.

If the HLS compiler fails to locate the ModelSim software license, it issues the following error message when you compile your design to the FPGA architecture:

```
$ i++ -march="<FPGA_family_or_part_number>" program.cpp
HLS Elaborate cosim.testbench. FAILED.
See ./a.prj/a.log for details.
Error: Missing simulator license. Either:
1) Ensure you have a valid ModelSim license
2) Use the --simulator none flag to skip the verification flow
```

Common causes for these errors include:

- Missing, expired, or invalid licenses
- Incorrect license server name in the license.dat file
- Unspecified or incorrectly-specified license location

**Note:** The running speed of the HLS compiler might decrease if the compiler has to search the network for missing or corrupted licenses. If this problem occurs, correct the license file or license location accordingly.

3.1.2. LM_LICENSE_FILE Environment Variable

Intel and third-party software use the `LM_LICENSE_FILE` environment variable to specify the locations of license files or license servers. For example, both the Intel Quartus Prime software and the ModelSim software use the `LM_LICENSE_FILE` variable to specify the locations of their licenses.

Intel Corporation. All rights reserved. Agilex, Altera, Arria, Cyclone, Enpirion, Intel, the Intel logo, MAX, Nios, Quartus and Stratix words and logos are trademarks of Intel Corporation or its subsidiaries in the U.S. and/or other countries. Intel warrants performance of its FPGA and semiconductor products to current specifications in accordance with Intel’s standard warranty, but reserves the right to make changes to any products and services at any time without notice. Intel assumes no responsibility or liability arising out of the application or use of any information, product, or service described herein except as expressly agreed to in writing by Intel. Intel customers are advised to obtain the latest version of device specifications before relying on any published information and before placing orders for products or services.

*Other names and brands may be claimed as the property of others.*
Note: The time it takes for your development machine to communicate with the license server directly affects compilation time. If your LM_LICENSE_FILE environment variable setting includes paths to many license servers, or if the license server is hosted in a distant locale, you will notice a significant increase in compilation time.

On Linux or UNIX systems, insert a colon (:) after each license file or license server location that you append to the LM_LICENSE_FILE environment variable.

On Windows systems, insert a semicolon (;) after each license file or license server location that you append to the LM_LICENSE_FILE environment variable.

Note: When modifying the LM_LICENSE_FILE setting to include the locations of your software licenses, do not remove any existing license locations appended to the variable.

3.1.2.1. ModelSim Software License-Specific Considerations

When setting up the ModelSim software license, you need to append the license location to the LM_LICENSE_FILE environment variable. However, you can also append the location of the ModelSim software license to the MGLS_LICENSE_FILE environment variable.

For Mentor Graphics applications, including the ModelSim software, you can specify the paths to license files and license servers in five different locations. If you specify paths to license files or license servers in multiple locations, the following search order is used to find the first valid path:

- MGLS_LICENSE_FILE environment variable you set in the user environment
- MGLS_LICENSE_FILE environment variable you set in the registry
- LM_LICENSE_FILE environment variable you set in the environment
- LM_LICENSE_FILE environment variable you set in the registry
- <path to FLEXlm>\license.dat, where <path to FLEXlm> is the default location of the FLEXlm license file.

When you install a Mentor Graphics product license on a computer, the MGLS_LICENSE_FILE environment variable settings take precedence over the LM_LICENSE_FILE environment variable settings. If you set both environment variables, set LM_LICENSE_FILE to point to the ModelSim license server and set MGLS_LICENSE_FILE to only point to the license server for other Mentor Graphics applications. If you only use the MGLS_LICENSE_FILE environment variable, ensure that the ModelSim license server and the license servers for other Mentor Graphics applications are on the same machine.
A. Intel HLS Compiler Pro Edition Getting Started Guide

Archives

<table>
<thead>
<tr>
<th>Intel HLS Compiler Version</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>19.3</td>
<td>Intel High Level Synthesis Compiler Getting Started Guide</td>
</tr>
<tr>
<td>19.2</td>
<td>Intel High Level Synthesis Compiler Getting Started Guide</td>
</tr>
<tr>
<td>19.1</td>
<td>Intel High Level Synthesis Compiler Getting Started Guide</td>
</tr>
<tr>
<td>18.1.1</td>
<td>Intel High Level Synthesis Compiler Getting Started Guide</td>
</tr>
<tr>
<td>18.1</td>
<td>Intel High Level Synthesis Compiler Getting Started Guide</td>
</tr>
<tr>
<td>18.0</td>
<td>Intel High Level Synthesis Compiler Getting Started Guide</td>
</tr>
<tr>
<td>17.1.1</td>
<td>Intel High Level Synthesis Compiler Getting Started Guide</td>
</tr>
<tr>
<td>17.1</td>
<td>Intel High Level Synthesis Compiler Getting Started Guide</td>
</tr>
</tbody>
</table>

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*Other names and brands may be claimed as the property of others.
B. Document Revision History for Intel HLS Compiler Pro Edition Getting Started Guide

|------------------|----------------------------------------|---------|
• Added Installing GCC Offline on page 8. |

Document Revision History for Intel HLS Compiler Getting Started Guide


<table>
<thead>
<tr>
<th>Document Version</th>
<th>Intel Quartus Prime Version</th>
<th>Changes</th>
</tr>
</thead>
</table>
| 2019.09.30       | 19.3                       | • Removed the following tutorials:  
— bank_bits  
— mm_slave  
— rom  
— struct_member_attributes  
• Added the following tutorials:  
— memory_bank_configuration  
— memory_geometry  
— memory_implementation  
— memory_merging  
— static_var_init  
— attributes_on_mm_slave_arg  
— exceptions  
— lsu_control  
— relax_reduction_dependency  
• Added Microsoft Visual Studio 2017 Professional and Microsoft Visual Studio 2017 Community as supported C++ compilers.  
• Removed Microsoft Visual Studio 2015 Professional and Microsoft Visual Studio 2015 Community as supported C++ compilers. |
| 2019.07.01       | 19.2                       | • Updated Installing the Intel HLS Compiler Pro Edition on Linux Systems on page 6 to clarify the command to run to install the 32-bit libraries required by ModelSim - Intel FPGA Edition. |

continued...
## Document Revision History for Intel HLS Compiler Pro Edition Getting Started Guide

<table>
<thead>
<tr>
<th>Document Version</th>
<th>Intel Quartus Prime Version</th>
<th>Changes</th>
</tr>
</thead>
</table>
| 2019.04.01       | 19.1                       | • The Intel HLS Compiler can now be installed separately from Intel Quartus Prime. The following sections were added or updated:  
  — Downloading the Intel HLS Compiler Pro Edition on page 5  
  — Installing the Intel HLS Compiler Pro Edition on Linux Systems on page 6  
  — Installing the Intel HLS Compiler Pro Edition on Microsoft* Windows* Systems on page 9  
• The Intel HLS Compiler is now backwards-compatible with earlier versions of Intel Quartus Prime. See Intel HLS Compiler Pro Edition Backwards Compatibility on page 5 for details.  
• Updated Initializing the Intel HLS Compiler Pro Edition Environment on page 11 to include the requirement that you must initialize your Intel HLS Compiler environment on Windows operating systems from a Visual Studio x64 Native Tools command prompt.  
• Revised and updated the list of tutorials that are provided with the Intel HLS Compiler in High Level Synthesis (HLS) Design Examples and Tutorials on page 12. |
| 2018.12.24       | 18.1                       | • Added Microsoft Visual Studio 2015 Community to the list of supported C++ compilers on Microsoft Windows systems.  
• Added step to add path to Mentor Graphics ModelSim software provided with Intel Quartus Prime to operating system PATH environment variable in Installing the Intel HLS Compiler Pro Edition on Linux Systems on page 6 and Installing the Intel HLS Compiler Pro Edition on Microsoft* Windows* Systems on page 9. |
| 2018.09.24       | 18.1                       | • The Intel HLS Compiler has a new front end. For a summary of the changes introduced by this new front end, see Improved Intel HLS Compiler Front End in the Intel High Level Synthesis Compiler Version 18.1 Release Notes.  
• The Intel HLS Compiler provided with Intel Quartus Prime Pro Edition has new prerequisites. Review Intel High Level Synthesis Compiler Pro Edition Prerequisites on page 4 to learn more.  
• The installation instructions for Linux systems have changed. See Installing the Intel HLS Compiler Pro Edition on Linux Systems on page 6 for details.  
• The best_practices/parameter_aliasing tutorial description in High Level Synthesis (HLS) Design Examples and Tutorials on page 12 changed to cover the __restrict keyword. The restrict keyword is no longer supported in the Intel HLS Compiler Pro Edition.  
• Removed the best_practices/integer_promotion tutorial. Integer promotion is now done by default when use the Intel HLS Compiler Pro Edition. |

continued...
• Starting with Intel Quartus Prime Version 18.0, the features and devices supported by the Intel HLS Compiler depend on what edition of Intel Quartus Prime you have. Intel HLS Compiler publications now use icons to indicate content and features that apply only to a specific edition as follows:

  PRO Indicates that a feature or content applies only to the Intel HLS Compiler provided with Intel Quartus Prime Pro Edition.

  STD Indicates that a feature or content applies only to the Intel HLS Compiler provided with Intel Quartus Prime Standard Edition.

• Added the following tutorials to the list of tutorials in High Level Synthesis (HLS) Design Examples and Tutorials on page 12:
  — interfaces/explicit_streams_packets_empty
  — interfaces/explicit_streams_ready_latency
  — best_practices/ac_datatypes
  — best_practices/loop_coalesce
  — best_practices/random_number_generator

• Renamed the following tutorials to reflect some Intel Quartus Prime component name changes:
  — usability/qsys_2xclock is now usability/platform_designer_2xclock
  — usability/qsys_stitching is now usability/platform_designer_stitching

• Renamed the following tutorials:
  — The explicit_streams tutorial is now called explicit_streams_buffer.
  — The explicit_streams_2 tutorial is now called explicit_streams_packets_ready_valid.

• Added the interfaces/overview tutorial to the list of tutorials in High Level Synthesis (HLS) Design Examples and Tutorials on page 12.

• Updated the Mentor Graphics ModelSim software requirements to include the required Red Hat development tools packages.
<table>
<thead>
<tr>
<th>Document Version</th>
<th>Intel Quartus Prime Version</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017.03.01</td>
<td>—</td>
<td>• Added installation of required packages and libraries needed for Linux.</td>
</tr>
</tbody>
</table>
| 2017.02.03       | —                           | • Changed success message in Quick Start sections to PASSED.  
• Added HLS Design Examples and Tutorials section.  
• Moved Running an HLS Design Example on Linux and Running an HLS Design Example on Windows to HLS Design Examples and Tutorials. |
| 2016.11.30       | —                           | • In HLS Compiler Prerequisites, updated software requirements to note that the HLS compiler supports all ModelSim software editions that the Intel Quartus Prime software supports.  
• In HLS Compiler Quick Start, added a note that you must run the init_hls script each time you start a shell or terminal to develop your design.  
• In HLS Compiler Quick Start, separated the Linux and Windows instructions.  
• In Running an HLS Design Example, separated the Linux and Windows instructions. For Linux, run the make command; for Windows, run the build.bat command.  
• Changed the test_x86-64 command option to test-x86-64.  
• Changed the test_fpga command option to test-fpga.  
• Removed the instruction to run the make test_qii command for Linux and the build.bat test_qii command for Windows because it is no longer necessary.  
• In HLS Licensing Error Messages, updated the error message you will see if the HLS compiler fails to locate the ModelSim software license. |
| 2016.09.12       | —                           | • Initial release. |