Intel® Quartus® Prime Pro Edition User Guide

Design Constraints

Updated for Intel® Quartus® Prime Design Suite: 19.3
1. Constraining Designs

The design constraints, assignments, and logic options that you specify influence how the Intel® Quartus® Prime Compiler implements your design. The Compiler attempts to synthesize and place logic in a manner than meets your constraints. In addition, design constraints also have an impact on how the Timing Analyzer and the Power Analyzer influence synthesis, placement, and routing.

You can specify design constraints in the GUI, with scripts, or directly in the files that store the constraints. The Intel Quartus Prime software preserves the constraints that you specify in the GUI in the following files:

- Intel Quartus Prime Settings file (<project_directory>/<revision_name>.qsf)—contains project-wide and instance-level assignments for the current revision of the project, in Tcl syntax. Each revision of a project has a separate .qsf file.
- Synopsys* Design Constraints file (<project_directory>/<revision_name>.sdc)—the Timing Analyzer uses industry-standard Synopsys Design Constraint format and stores those constraints in .sdc files.

By combining the syntax of the .qsf files and the .sdc files with procedural Tcl, you can automate iterations over several different settings, changing constraints and recompiling.

Related Information

  For information about all settings and constraints in the Intel Quartus Prime software.
- Tcl Scripting
  In Intel Quartus Prime Pro Edition User Guide: Scripting
- Command Line Scripting
  In Intel Quartus Prime Pro Edition User Guide: Scripting

1.1. Specifying Design Constraints Designs in the GUI

Intel Quartus Prime software provides tools that help you manually implement your project. These tools can also support design visualization, pre-filled parameters, and window cross probing, facilitating design exploration and debugging.

When you create or update a constraint in the Intel Quartus Prime software, the System tab of the Messages window displays the equivalent Tcl command. Utilize these commands as references for future scripted design definition and compilation.
1.1.1. Global Constraints and Assignments

Global constraints and project settings affect the entire Intel Quartus Prime project and all the applicable logic in the design. You often define global constraints in early project development; for example, when running the New Project Wizard. Intel Quartus Prime software stores global constraints in .qsf files, one for each project revision.

Table 1. Intel Quartus Prime Tools to Set Global Constraints

<table>
<thead>
<tr>
<th>Setting Type</th>
<th>New Project Wizard</th>
<th>Device Dialog Box</th>
<th>Settings Dialog Box</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project-wide</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Synthesis</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Fitter</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Third-party Tools</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>IP Settings</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Related Information

Managing Project Settings
In Intel Quartus Prime Pro Edition User Guide: Getting Started

1.1.2. Node, Entity, and Instance-Level Constraints

Node, entity, and instance-level constraints apply to a subset of the design hierarchy. These constraints take precedence over any global assignment that affects the same sections of the design hierarchy.

Table 2. Intel Quartus Prime Pro Edition Tools to Set Node, Entity and Instance Level Constraints

<table>
<thead>
<tr>
<th>Assignment Type</th>
<th>Assignment Editor</th>
<th>Interface Planner</th>
<th>Chip Planner</th>
<th>Pin Planner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Routing</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

1.1.2.1. Specify Instance-Specific Constraints in Assignment Editor

Intel Quartus Prime Assignment Editor (Assignments ➤ Assignment Editor) provides a spreadsheet-like interface for assigning all instance-specific settings and constraints. To help you explore your design, the Assignment Editor allows you to filter assignments by node name or category.
Use the Assignment Editor to:

- Add, edit, or delete assignments for selected nodes
- Display information about specific assignments
- Enable or disable individual assignments
- Add comments to an assignment

Additionally, you can export assignments to a Comma-Separated Value File (.csv).

### 1.1.2.2. Specifying Multi-Dimensional Bus Constraints

The Intel Quartus Prime Pro Edition software traditionally supports only 1- and 2-dimensional bus names for specifying constraints. The Intel Quartus Prime Pro Edition version 19.3 and later now supports multi-dimensional bus names for more efficient constraints.

For example, you can specify the following assignment to apply a constraint to all bits in the `reg [31:0] r [0:2][4:5]` three-dimensional bus:

```
set_instance_assignment -name PRESERVE_REGISTER ON -to r
```

The constraint then applies to all bits `r: [0][4][31], r[0][4][30], …, r[1][5][0]`.

### 1.1.2.3. Specify I/O Constraints in Pin Planner

Intel Quartus Prime Pin Planner allows you to assign design elements to I/O pins. You can also plan and assign IP interface or user nodes not yet defined in the design.
Figure 2. Pin Planner GUI

Related Information
Managing Device I/O Pins on page 43

1.1.2.4. Plan Interface Constraints in Interface Planner

The Interface Planner simplifies the planning of accurate constraints for physical implementation. Use Interface Planner to prototype interface implementations, plan clocks, and rapidly define a legal device floorplan.

Interface Planner interacts dynamically with the Intel Quartus Prime Fitter to accurately verify placement legality while you plan. You can evaluate different floorplans, using interactive reports to accurately plan the best implementation without iterative compilation. Fitter verification ensures the highest correlation between your interface plan and actual implementation results. You can apply the interface plan constraints to your project with high confidence in the final implementation.
1.1.2.5. Adjust Constraints with the Chip Planner

With the Chip Planner you can adjust existing assignments to device resources, such as pins, logic cells, and LABs in a graphical representation of the device floorplan. You can also view equations and routing information and demote assignments by dragging and dropping to Logic Lock regions in the Logic Lock Regions Window.
1. Constraining Designs

UG-20142 | 2019.10.16

Figure 4. Chip Planner GUI

1.1.2.6. Constraining Designs with the Design Partition Planner

The Design Partition Planner allows you to view design connectivity and hierarchy and can assist you in creating effective design partitions.

Additionally, the Design Partition Planner allows you to optimize design performance by isolating and resolving failing paths on a partition-by-partition basis.

Related Information
Creating Partitions and Logic Lock Regions with the Design Partition Planner and the Chip Planner
In Intel Quartus Prime Pro Edition User Guide: Design Optimization

1.1.3. Probing Between Components of the Intel Quartus Prime GUI

Intel Quartus Prime software allows you to locate nodes and instances across windows and source files.

When you are in the Project Navigator, Assignment Editor, Chip Planner, or Pin Planner, and want to display a given resource in other Intel Quartus Prime tool:
1. Right-click the resource you want to display.
2. Click Locate Node, and then click any of the menu options.
The corresponding window opens—or appears in the foreground if it is already open—and shows the element you clicked.

### Example 1. Locate a Resource Selected in the Project Navigator

In the **Entity** list of the **Hierarchy** tab, right-click any object, and click **Locate ➤ Locate in Chip Planner**.

The Chip Planner opens and displays the instance you selected.

---

**1.1.4. Specifying Timing Constraints in the GUI**

You can specify timing constraints in the Timing Analyzer GUI. Click the **Constraints** menu in the Timing Analyzer to specify timing constraints that you can apply to your project.
When you specify a constraint in the GUI, the dialog box displays the equivalent SDC command syntax.

**Example 2. Create Clock Dialog Box**

Individual timing assignments override project-wide requirements.
- To avoid reporting incorrect or irrelevant timing violations, you can assign timing exceptions to nodes and paths.
- The Timing Analyzer supports point-to-point timing constraints, wildcards to identify specific nodes when making constraints, and assignment groups to make individual constraints to groups of nodes.

**Related Information**

*Using Timing Constraints*
For descriptions of all Constraints menu commands
1.2. Constraining Designs with Tcl Scripts

You can perform all your design assignments using .sdc and .qsf setting files. To integrate these files in compilation and optimization flows, use Tcl scripts. Even though .sdc and .qsf files are written in Tcl syntax, they are not executable by themselves.

When you use Intel Quartus Prime Tcl packages, your scripts can open projects, make the assignments, compile the design, and compare compilation results against known goals and benchmarks. Furthermore, such a script can automate the iterative design process by modifying constraints and recompiling the design.

1.2.1. Create a Project and Apply Constraints

The command-line executables include options for common global project settings and commands. You can use a Tcl script to apply constraints such as pin locations and timing assignments. You can write a Tcl constraint file, or generate one for an existing project by clicking Project ➤ Generate Tcl File for Project.

The example creates a project with a Tcl script and applies project constraints using the tutorial design files in the <Intel Quartus Prime installation directory>/qdesigns/fir_filter/directory.

```tcl
project_new filtref -overwrite
# Assign family, device, and top-level file
set_global_assignment -name FAMILY "Arria 10"
set_global_assignment -name DEVICE <Device>
set_global_assignment -name VERILOG_FILE filtref.v
# Assign pins
set_location_assignment -to clk Pin_28
set_location_assignment -to clkx2 Pin_29
set_location_assignment -to d[0] Pin_139
set_location_assignment -to d[1] Pin_140
# project_close
```

Save the script in a file called setup_proj.tcl and type the commands illustrated in the example at a command prompt to create the design, apply constraints, compile the design, and perform fast-corner and slow-corner timing analysis. Timing analysis results are saved in two files, filtref_sta_1.rpt and filtref_sta_2.rpt.

```bash
quartus_sh -t setup_proj.tcl
quartus_syn filtref
quartus_fit filtref
quartus_asm filtref
quartus_sta filtref --model=fast --export_settings=off
mv filtref_sta.rpt filtref_sta_1.rpt
quartus_sta filtref --export_settings=off
mv filtref_sta.rpt filtref_sta_2.rpt
```

Type the following commands to create the design, apply constraints, and compile the design, without performing timing analysis:

```bash
quartus_sh -t setup_proj.tcl
quartus_sh --flow compile filtref
```

The quartus_sh --flow compile command performs a full compilation, and is equivalent to clicking the Start Compilation button in the toolbar.
1.2.2. Assigning a Pin

To assign a signal to a pin or device location, use the Tcl command shown in this example:

```tcl
set_location_assignment -to <signal name> <location>
```

Valid locations are pin location names. Some device families also support edge and I/O bank locations. Edge locations are `EDGE_BOTTOM`, `EDGE_LEFT`, `EDGE_TOP`, and `EDGE_RIGHT`. I/O bank locations include `IOBANK_1` to `IOBANK_n`, where `n` is the number of I/O banks in a device.

1.2.3. Generating Intel Quartus Prime Settings Files

Intel Quartus Prime software allows you to generate .qsf files from your revision. You can embed these constraints in a scripted compilation flow, and even create sets of .qsf files for design optimization.

To generate a .qsf file from the Intel Quartus Prime software, click Assignments ➤ Export Assignments.

To organize the .qsf in a human readable form, Project ➤ Organize Intel Quartus Prime Settings File.

Example 3. Organized .qsf File

This example shows how .qsf files characterize a design revision. The `set_global_assignment` command makes all global constraints and software settings and `set_location_assignment` constrains each I/O node in the design to a physical pin on the device.

```
# Project-Wide Assignments
# ========================
set_global_assignment -name SYSTEMVERILOG_FILE top.sv
set_global_assignment -name SYSTEMVERILOG_FILE blinking_led.sv
set_global_assignment -name SDC_FILE blinking_led.sdc
set_global_assignment -name SDC_FILE jtag.sdc
set_global_assignment -name PROJECT_OUTPUT_DIRECTORY output_files
set_global_assignment -name LAST_QUARTUS_VERSION "17.1.0 Pro Edition"
set_global_assignment -name TEXT_FILE blinking_led_generated.txt

# Pin & Location Assignments
# ===========================
set_location_assignment PIN_AN18 -to clock
set_location_assignment PIN_AR23 -to led_zero_on
set_location_assignment PIN_AM21 -to led_two_on
set_location_assignment PIN_AR22 -to led_one_on
set_location_assignment PIN_AL20 -to led_three_on

# Analysis & Synthesis Assignments
# ---------------------------------
set_global_assignment -name FAMILY "Arria 10"
set_global_assignment -name TOP_LEVEL_ENTITY top

# Fitter Assignments
# ------------------
set_global_assignment -name DEVICE 10AS066N3F40E2SG
```

1. Constraining Designs
UG-20142 | 2019.10.16

Send Feedback

Related Information

For information about all settings and constraints in the Intel Quartus Prime software.

1.2.4. Synopsys Design Constraint (.sdc) Files

Intel Quartus Prime software keeps timing constraints in .sdc files, which use Tcl syntax. You can embed these constraints in a scripted compilation flow, and even create sets of .sdc files for timing optimization.

Example 4. .sdc File

The example shows the timing constrains of a small design.

```tcl
## PROGRAM "Quartus Prime"
## VERSION "Version 17.1.0 Internal Build 91 05/07/2017 SJ Pro Edition"
## DATE "Wed May 10 14:22:08 2017"
##
## DEVICE "10AX115R4F40I3SG"
##
## Time Information
#*************************************************************
set_time_format -unit ns -decimal_places 3 
#*************************************************************
# Create Clock
create_clock -name {clk_in} -period 10.000 -waveform { 0.000 5.000 } [get_ports {clk_in}]
#*************************************************************
# Create Generated Clock
derive_pll_clocks
#*************************************************************
# Set Clock Uncertainty
derive_clock_uncertainty
#*************************************************************
# Set Input Delay
set_input_delay -add_delay -clock [get_clocks {clk_in}] 1.500 [get_ports {async_rst}]
set_input_delay -add_delay -clock [get_clocks {clk_in}] 1.200 [get_ports {data_in}]
#*************************************************************
# Set Output Delay
set_output_delay -add_delay -clock [get_clocks {clk_in}] 2.000 [get_ports {data_out}]
#*************************************************************
```

1. Constraining Designs

UG-20142 | 2019.10.16
# Set Multicycle Path
set_multicycle_path -setup -end -from [get_keepers *] -to [get_keepers {reg2}] 2

Related Information
Constraining and Analyzing with Tcl Commands
In Intel Quartus Prime Pro Edition User Guide: Timing Analyzer

1.2.5. Tcl-only Script Flows
As an alternative to .sdc and .qsf files, you can perform all design assignments and timing constraints inside the Tcl scripts. In this case, the script that automates compilation and custom results reporting also contains the design constraints.

You can export a design's contents to a procedural, executable Tcl (.tcl) file, and then use the generated script to restore settings after experimenting with other constraints.

To export your constraints as an executable Tcl script, click Project ➤ Generate Tcl File for Project.

Example 5. blinking_led_generated.tcl File

```tcl
# Quartus Prime: Generate Tcl File for Project
# File: blinking_led_generated.tcl
# Generated on: Wed May 10 10:14:44 2017
# Load Quartus Prime Tcl Project package
package require ::quartus::project
set need_to_close_project 0
set make_assignments 1
# Check that the right project is open
if {[is_project_open]} {
  if {[string compare $quartus(project) "blinking_led"]} {
    puts "Project blinking_led is not open"
    set make_assignments 0
  }
} else {
  # Only open if not already open
  if {[project_exists blinking_led]} {
    project_open -revision blinking_led blinking_led
  } else {
    project_new -revision blinking_led blinkingLed
  }
  set need_to_close_project 1
}

# Make assignments
if {$make_assignments} {
  set_global_assignment -name SYSTEMVERILOG_FILE top.sv
  set_global_assignment -name SYSTEMVERILOG_FILE blinking_led.sv
  set_global_assignment -name SDC_FILE blinking_led.sdc
  set_global_assignment -name SDC_FILE jtag.sdc
  set_global_assignment -name PROJECT_OUTPUT_DIRECTORY output_files
  set_global_assignment -name LAST_QUARTUS_VERSION "17.1.0 Pro Edition"
  set_global_assignment -name TEXT_FILE blinking_led_generated.txt
  set_global_assignment -name FAMILY "Arria 10"
  set_global_assignment -name TOP_LEVEL_ENTITY top
  set_global_assignment -name DEVICE 10AS066N3F40E2SG
  set_location_assignment PIN_AN18 -to clock
  set_location_assignment PIN_AR23 -to led_zero_on
  set_location_assignment PIN_AM21 -to led_two_on
  set_location_assignment PIN_AR22 -to led_one_on
  set_location_assignment PIN_AL20 -to led_three_on
  set_instance_assignment -name IO_STANDARD "1.8 V" -to led_zero_on
```
The example:
- Opens the project
- Assigns Constraints
- Writes assignments to QSF file
- Closes project

1.2.5.1. Tcl-only Timing Analysis

To avoid using a separated file to keep your timing constraints, copy and paste the .sdc file into your executable timing analysis script.

1.3. A Fully Iterative Scripted Flow

The `::quartus::flow` Tcl package in the Intel Quartus Prime Tcl API allows you to modify design constraints and recompile in an iterative flow.

Related Information
- `::quartus::flow` in [Intel Quartus Prime Help](#)

1.4. Constraining Designs Revision History

<table>
<thead>
<tr>
<th>Document Version</th>
<th>Intel Quartus Prime Version</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019.10.16</td>
<td>19.3.0</td>
<td>Added &quot;Specifying Multi-Dimensional Bus Constraints&quot; topic. Updated examples in &quot;Create a Project and Apply Constraints.&quot;</td>
</tr>
<tr>
<td>2019.08.21</td>
<td>18.1.0</td>
<td>Corrected minor typo in &quot;Tcl-only Script Flows&quot; topic.</td>
</tr>
</tbody>
</table>

continued...
<table>
<thead>
<tr>
<th>Document Version</th>
<th>Intel Quartus Prime Version</th>
<th>Changes</th>
</tr>
</thead>
</table>
| 2019.01.04       | 18.1.0                      | • Clarified default location of .sdc and .qsf files in "Constraining Designs" topic.  
• Added "Plan Interface Constraints with Interface Planner" topic.  
• Added screenshots to "Constrain Designs with the Pin Planner" and "Constrain Designs with the Chip Planner."  
• Added two new "Assigning a Pin" and "Creating a Project and Applying Constraints" topics showing Tcl examples.  
• Added link to Using Timing Constraints topic in Timing Analyzer UG that explains all of the commands |
| 2017.11.06       | 17.1.0                      | • Renamed topic: Constraining Designs with the GUI to Constraining Designs with Quartus Prime Tools.  
• Renamed topic: Global Constraints to Global Constraints and Assignments.  
• Added table: Quartus Prime Tools to Set Global Constraints.  
• Removed topic: Common Types of Global Constraints.  
• Removed topic: Settings That Direct Compilation and Analysis Flows.  
• Updated topic: Node, Entity and Instance-Level Constraints.  
• Added table: Quartus Prime Tools to Set Node, Entity and Instance Level Constraints.  
• Added topic: Assignment Editor.  
• Updated topic: Constraining Designs with the Pin Planner.  
• Updated topic: Constraining Designs with the Chip Planner.  
• Added topic: Constraining designs with the Design Partition Planner.  
• Updated topic: Probing Between Components of the Quartus Prime GUI.  
• Added example: Locate a Resource Selected in the Project Navigator.  
• Updated topic: SDC and the Timing Analyzer, and renamed to Specifying Individual Timing Constraints.  
• Added figure: Constraint Menu in Timing Analyzer.  
• Added example: Create Clock Dialog Box.  
• Updated topic: Constraining Designs with Tcl, and renamed to Generating Quartus Prime Settings Files.  
• Added example: blinking_led.qsf File.  
• Updated topic: Timing Analysis with Synopsys Design Constraints and Tcl Scripts, and renamed to Timing Analysis with .sdc Files and Tcl Scripts.  
• Added example: .sdc File with Timing Constraints.  
• Added topic: Tcl-only Script Flows.  
• Updated topic: A Fully Iterative Scripted Flow. |
| 2017.05.08       | 17.0.0                      | • Removed references to deprecated Fitter Effort logic option. |
| 2016.10.31       | 16.1.0                      | • Implemented Intel rebranding. |
| 2015.11.02       | 15.1.0                      | • Changed instances of Quartus II to Intel Quartus Prime. |
| June 2014        | 14.0.0                      | Formatting updates. |
| November 2012    | 12.1.0                      | Update Pin Planner description for task and report windows. |
| June 2012        | 12.0.0                      | Removed survey link. |
| November 2011    | 10.0.2                      | Template update. |
| December 2010    | 10.0.1                      | Template update. |
| July 2010        | 10.0.0                      | Rewrote chapter to more broadly cover all design constraint methods.  
Removed procedural steps and user interface details, and replaced with links to Quartus II Help. |

continued...
<table>
<thead>
<tr>
<th>Document Version</th>
<th>Intel Quartus Prime Version</th>
<th>Changes</th>
</tr>
</thead>
</table>
| November 2009    | 9.1.0                       | • Added two notes.  
|                  |                             | • Minor text edits. |
| March 2009       | 9.0.0                       | • Revised and reorganized the entire chapter.  
|                  |                             | • Added section “Probing to Source Design Files and Other Quartus Windows” on page1–2.  
|                  |                             | • Added description of node type icons (Table1–3).  
|                  |                             | • Added explanation of wildcard characters. |
| November 2008    | 8.1.0                       | Changed to 8½” × 11” page size. No change to content. |
| May 2008         | 8.0.0                       | Updated Quartus II software 8.0 revision and date. |
2. Interface Planning

Interface planning—the feasibility analysis of interface physical constraints—is a fundamental early step in advanced FPGA design. Periphery placement can be a complex process involving many variables. The Intel Quartus Prime Interface Planner simplifies the planning of accurate constraints for physical implementation. Use Interface Planner to prototype interface implementations, plan clocks, and rapidly define a legal device floorplan.

Interface Planner interacts dynamically with the Intel Quartus Prime Fitter to accurately verify placement legality while you plan. You can evaluate different floorplans, using interactive reports to accurately plan the best implementation without iterative compilation. Fitter verification ensures the highest correlation between your interface plan and actual implementation results. You can apply the interface plan constraints to your project with high confidence in the final implementation.

Figure 6. Interface Planner GUI

Run Interface Planner Commands
Drag Elements to Legal Locations

Selected Element's Properties

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.
**Interface Planner Features**

Interface Planner provides support for the following:

- Plan legal design periphery floorplans at any stage of the design process.
- Analyze and modify clock network scenarios to direct the placement of high fan-out signals.
- Automatically evaluate all placement legality using the Fitter.
- Save and reload various floorplan files.
- GUI and Tcl command-line operation.

*Note:* Intel now refers to BluePrint as Interface Planner.

**Related Information**

Video Demo: Using Interface Planner to Place DDR-3 and PCI Express Gen3

### 2.1. Interface Planning Overview

After design synthesis, use Interface Planner to rapidly define a legal device floorplan.

**Figure 7.** Interface Planner Streamlines Legal Placement

Intel FPGAs contain core and periphery device locations. The device core locations are adaptive look-up tables (ALUTs), core flip-flops, RAMs, and digital signal processors (DSPs). Device periphery locations include I/O elements, phase-locked loops (PLLs), clock buffers, and hard processor systems (HPS).

Intel FPGAs contain many silicon features in the device periphery, such as hard PCI Express® IP cores, high speed transceivers, hard memory interface circuitry, and embedded processors. Interactions among these periphery elements can be complex. Interface Planner simplifies this complexity and allows you to quickly visualize and place I/O interface and periphery elements, such as:

- I/O elements
- LVDS interfaces
- PLLs
- Clocks
- Hard interface IP Cores
- High-Speed Transceivers
- Hard Memory Interface IP Cores
- Embedded Processors

After initialization, Interface Planner displays your project’s logical hierarchy, post-synthesis design elements, and Fitter-created design elements, alongside a view of target device locations. The GUI supports a variety of methods for placing design elements in the floorplan. As you place elements in the floorplan, the Fitter verifies legality in real time to ensure accurate correlation with the final implementation.

**Related Information**

Managing Device I/O Pins on page 43

### 2.2. Using Interface Planner

Interface Planner's user interface guides you through the design planning steps. Use Interface Planner's **Flow** control to execute the main initialization, planning, and validation functions of the flow in sequence.

**Figure 8. Interface Planner Flow Control**

As you run each step in the **Flow** control, downstream commands and the **Assignments**, **Plan**, and **Reports** tabs become available. Interface Planner only allows you to run commands after completing any prerequisite steps in the flow.

After you **Initialize Interface Planner**, you are prompted to confirm any project assignments that you made before planning starts. Disable or enable any imported project assignments on the **Assignments** tab to resolve any conflicts and evaluate different implementations.
After you **Update Plan** with the project assignments, you are ready to place design elements onto the target device **Chip View** or **Package View** on the **Plan** tab. As you place design elements in the **Plan** tab, the Fitter verifies placement legality in real-time. Once planning is complete and validated, you export the constraints as a Tcl script for application in your project.

**Note:** The Interface Planner constraints you define do not apply to your project until you export and source them with the generated Tcl script.
The following topics describe these interface planning flow steps in detail:

Step 1: Setup and Synthesize the Project on page 24
Step 2: Initialize Interface Planner on page 24
Step 3: Update Plan with Project Assignments on page 25
Step 4: Plan Periphery Placement on page 25
Step 5: Report Placement Data on page 29
Step 6: Validate and Export Plan Constraints on page 30
2.2.1. Step 1: Setup and Synthesize the Project

Interface Planner requires at least a partially complete, synthesized Intel Quartus Prime project as input. You can also use Interface Planner to adjust placement for a fully complete design project.

Follow these steps to setup the project and run synthesis:

1. Complete at least the following steps for your design:
   - Fully define known device periphery interfaces.
   - Instantiate all known interface IP cores.
   - Declare all general purpose I/Os.
   - Define the I/O standard, voltage, drive strength, and slew rate for all general purpose I/Os.
   - Define the core clocking (optional, but recommended).
   - Connect all interfaces of the periphery IP to virtual pins or test logic. This technique creates loop backs on any interfaces in the shell design, helping to ensure that periphery interfaces persist after synthesis optimization.

2. To synthesize the design, click Processing ➤ Start ➤ Start Analysis & Synthesis. You must run at least Analysis & Synthesis before running Interface Planner.

2.2.2. Step 2: Initialize Interface Planner

Initializing Interface Planner loads the compilation database for the synthesis snapshot, and enables the View Assignments command and Assignments tab for reconciling project assignments.

To initialize Interface Planner:

1. Click Tools ➤ Interface Planner. The Interface Planner opens, displaying the Home tab.
2. On the Flow control, click Initialize Interface Planner. After initialization, the Fitter dynamically validates your interface plan as you make changes.

Figure 12. Interface Planner Home Tab
2.2.3. Step 3: Update Plan with Project Assignments

Before periphery planning in Interface Planner, you must reconcile any conflicting imported project assignments and Update Plan with the assignments you want to retain in the plan.

Follow these steps to review imported project assignments and reconcile any conflicts:

1. On the Flow control, click View Assignments.
2. On the Assignments tab, enable or disable specific or groups of project assignments to resolve any conflicts or experiment with different settings. You can filter the list of assignments by assignment name or status.
3. After resolving all conflicts, click Update Plan on the Flow control to apply the enabled project assignments to your interface plan.

Figure 13. Interface Planner (Assignments Tab)

Related Information
- Home Tab Controls on page 31
- Assignments Tab Controls on page 32

2.2.4. Step 4: Plan Periphery Placement

Click Plan Design on the Flow control to interactively place IP cores and other design elements in legal locations in the device periphery. The Plan tab displays a list of your project's design elements, alongside a graphical abstraction of the target device architecture.
For efficiency, place design elements in the following order in Interface Planner:
1. Place all I/O pins or elements, such as PLLs, that have known, specific location requirements.
2. Place all known periphery interface IP.
3. (Optional) Place all remaining unplaced cells.

Use the following controls to place design elements in the Interface Planner floorplan:
1. Locate design elements that you want to place in the Design Element list. You can search and filter the list by name, IP, placement status, I/Os, and other criteria.
2. To customize design element color coding definitions, click the Highlight column.

Figure 14. Interface Planner (Plan Tab)

3. Use any of the following methods to place design elements in the floorplan:
   - Drag elements from the Design Elements list and drop them onto available device resources in the Chip or Package view. Use Ctrl+Click to drag and pan across the Chip or Package views. You may experience a small delay while dragging as Interface Planner calculates the legal locations.
   - To allow Interface Planner to place an unplaced design element in a legal location, right-click and select Autoplace Selected. You must use Autoplace Selected for all unplaced clocks.
   - Click the button next to the Design Elements to display a list of Legal Locations. Click any legal location in the list to highlight the location in the floorplan. Double-click any location in the list to place the element in the location.
4. To step forward and backward though your plan changes, click the **Undo** and **Redo** buttons.

5. To visualize and traverse design connectivity (for example, to view the reference clock pin and driven destination cells of a PLL), select any design element and then click the **Link Info** tab. Click the **Back** and **Forward** buttons to traverse design connectivity.

6. To generate a report that shows the placement locations the Fitter prefers, select a design element and click **Report Placeability of Selected Element**.

---

**Figure 15.  Listing Legal Locations**

![Image showing legal locations](image)

**Figure 16.  Link Info Tab for Traversing Connectivity**

![Image showing link info tab](image)

---

**Note:** Changes made in Interface Planner do not apply to your Intel Quartus Prime project until you apply the generated interface plan constraints script to your project.

---

**Related Information**

- [Plan Tab Controls](#) on page 32
2.2.4.1. Plan Clock Networks

Interface Planner allows you to visualize and plan clock networks. For Intel Arria® 10 and Intel Cyclone® 10 GX devices, you can locate, highlight, place, and edit the type of clock elements in the Plan tab.

*Note:* The Intel Stratix® 10 device family does not support the Clocking filter in Interface Planner. For Intel Stratix 10 designs, use the Autoplace Selected command to place all unplaced clock elements.

Interface Planner generates a Clocks report that details the signals using low-skew routing networks (clock networks) in the device.

To identify and place clocking elements in your design, click the Clocking filter in the Plan tab. You can refine the list further by entering search text in the Design Element Filter. Interface Planner represents clock networks as groupings of the following clock network elements:

- Clock source
- Clock mux
- Clock region

**Figure 17. Clocking Design Elements**

You can place an entire clock group or individual clock elements by dragging into the location, or using the Report Legal Locations of Selected Element or the Autoplace Selected commands. After placement, hover the cursor over the item in the Design Element list to highlight the placement. The placement of clock elements impacts the placement of dependent core and periphery elements.
You can edit the clock type for clocking design elements. The clock type impacts the placement of dependent core and periphery elements. Right-click any clock element to specify one of the following clock types:

- Not Set
- Locally Routed
- Global
- Large Periphery
- Periphery
- Regional

### 2.2.4.2. Saving & Loading Floorplans

You can save the state of your Interface Planner floorplan for use in subsequent Interface Planner sessions. Interface Planner saves your plan in Interface Planner Floorplan Format (.plan). You can load a .plan file in Interface Planner to reopen the floorplan.

1. To save an Interface Planner floorplan, click **File ➤ Save Floorplan** and specify a file name.
2. To load an Interface Planner floorplan, click **File ➤ Load Floorplan** and browse for the .plan file.

*Note:* .plan files are for use only in Interface Planner and are not for use directly in the Intel Quartus Prime software. Interface Planner generates an error if you attempt to load a .plan file that is not associated with the current Interface Planner project.

### 2.2.5. Step 5: Report Placement Data

Generate Interface Planner placement and connectivity reports to help locate cells and make the best decisions about placement for the interfaces and elements in your design. Click **View Reports** on the **Flow** control to open the **Reports** tab from which you can generate a range of reports.

Follow these steps to report Interface Planner placement data:

1. In the **Flow** control, click **View Reports**. The list of reports appears in the **Tasks** pane.
2. In the **Tasks** pane, double-click any report name to generate the report in the **Table of Contents** pane.
3. Select design elements in the report and click **Place**, **Unplace**, or report detailed data about the selected elements or locations.
2.2.6. Step 6: Validate and Export Plan Constraints

You must validate your interface plan before exporting the plan constraints to your project as a generated Tcl script. Validation must confirm that the Fitter can place all remaining unplaced design elements before you can generate the script. When you are satisfied with your interface plan, follow these steps to validate and apply the interface plan to your Intel Quartus Prime project:

1. In the Flow control, click Validate Plan. The Fitter confirms placement of all remaining unplaced design elements. You must correct any errors before you can export constraints.

2. After validation, click Export Constraints to generate a Tcl script that applies the plan to your project. The output Tcl file contains instructions to apply the interface plan to your Intel Quartus Prime project.

3. Close Interface Planner.

4. To apply the exported interface plan constraints to your Intel Quartus Prime project, click Tools ➤ Tcl Scripts and select the `<project name>.pdp_assignments.tcl` script file.

5. Click Run. The script runs, applying the Interface Planner constraints to the project. Alternatively, you can run the script from the project directory:

   `quartus_sh -t <assignments_file>.tcl`
To run synthesis and apply the interface plan in your project, click **Start ➤ Start Analysis & Synthesis**.

Confirm the implementation of your plan by reviewing the Compilation Report.

### 2.3. Interface Planner User Interface Controls

The Interface Planner user interface includes the following controls for planning your design platform.

- **Flow Controls** on page 31
- **Home Tab Controls** on page 31
- **Assignments Tab Controls** on page 32
- **Plan Tab Controls** on page 32
- **Reports Tab Controls** on page 34

#### 2.3.1. Flow Controls

The **Flow** control panel provides immediate access to common Interface Planner commands from anywhere within Interface Planner. The **Flow** controls appear in order of a typical interface planning flow.

**Table 3. Flow Controls**

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Project</td>
<td>Allows you to select and open an Intel Quartus Prime project in Interface Planner. Use of <strong>Open Project</strong> command is only required when using Interface Planner in standalone mode.</td>
</tr>
<tr>
<td>Initialize Interface Planner</td>
<td>Loads the synthesis netlist, starts the Fitter verification engine, and imports assignments from your Intel Quartus Prime project.</td>
</tr>
<tr>
<td>View Assignments</td>
<td>Opens the <strong>Assignments</strong> tab, which allows you to review and reconcile any conflicting assignments that Interface Planner imports from your project. Enable or disable specific project assignments to resolve any conflicts.</td>
</tr>
<tr>
<td>Update Plan</td>
<td>Applies the enabled project assignments to your interface plan. You cannot perform periphery planning on the <strong>Plan</strong> tab until you update the plan.</td>
</tr>
<tr>
<td>Plan Design</td>
<td>Opens the <strong>Plan</strong> tab for placing logic in the interface plan.</td>
</tr>
<tr>
<td>Export Constraints</td>
<td>Saves your interface plan as a Tcl script file for subsequent application in your project. This command is available only after successfully running <strong>Validate Plan</strong>.</td>
</tr>
<tr>
<td>Validate Plan</td>
<td>Verifies that all constraints in the interface plan are compatible with placement of all remaining unplaced design elements. You can then directly locate and resolve the source of any reported validation errors. You must successfully validate the plan before running <strong>Write Plan File</strong>.</td>
</tr>
<tr>
<td>View Reports</td>
<td>Opens the <strong>Reports</strong> tab for filtering data and finding entities and locations.</td>
</tr>
</tbody>
</table>

#### 2.3.2. Home Tab Controls

The Interface Planner **Home** tab contains controls for opening projects in Interface Planner. You only need the **Home** tab when Interface Planner is in standalone mode.
Table 4. Home Tab Controls

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent Projects</td>
<td>Provides quick access to recently opened Intel Quartus Prime projects. A named tile represents each project. Click the tile to display Details about the project. Double-click the tile to open the project in Interface Planner.</td>
</tr>
<tr>
<td>Browse</td>
<td>Allows you to locate and open an Intel Quartus Prime project in Interface Planner. Interface Planner requires the project’s synthesized netlist for operation.</td>
</tr>
<tr>
<td>Details</td>
<td>Provides project and file details such as the file path, revision, and creation date of the Intel Quartus Prime project. You can select a specific project revision.</td>
</tr>
</tbody>
</table>

2.3.3. Assignments Tab Controls

The Assignments tab contains controls for resolving potential conflicts with project assignments. Click View Assignments to display the Assignments tab.

You can enable or disable specific or classes of assignments until you resolve all potential conflicts. After you are satisfied with the status of all project assignments, click Update Plan to update your interface plan with the enabled project assignments. Interface Planner reports an error for any remaining assignment conflicts.

Table 5. Assignments Tab Controls

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter field</td>
<td>Supports creation of wildcard expressions for assignment targets. Enabled and Disabled buttons filter only enabled or disabled assignments in the list.</td>
</tr>
<tr>
<td>Enable All Project Assignments</td>
<td>Enables all imported project assignments in your interface plan.</td>
</tr>
<tr>
<td>Disable All Project Assignments</td>
<td>Disables all imported project assignments in the plan.</td>
</tr>
<tr>
<td>Clear</td>
<td>Clears any filter from the Assignments list.</td>
</tr>
</tbody>
</table>

2.3.4. Plan Tab Controls

The Plan tab contains the following controls to help you locate and place logic in the interface plan. Click Plan Design to display the Plan tab.

Placement or unplacement in the interface plan does not apply to your Intel Quartus Prime project until you add the generated Interface Planner constraints script to your project.

Table 6. Plan Tab Controls

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lists legal locations for placement.</td>
<td></td>
</tr>
<tr>
<td>Locate Node</td>
<td>Display a list of Intel Quartus Prime Pro Edition tools where the selected design element is referenced in the hierarchical database. If the Locate Node command is disabled for a specific element in the Design Elements list, it is because that element is not represented as an element in the design.</td>
</tr>
<tr>
<td>Autoplaces All</td>
<td>Attempts to place all unplaced design elements in legal locations in the interface plan.</td>
</tr>
<tr>
<td>Command</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Autoplace Fixed</td>
<td>Attempts to place all unplaced design elements that have only one legal location into the interface plan.</td>
</tr>
<tr>
<td>Unplace All</td>
<td>Unplaces all placed design elements in the interface plan.</td>
</tr>
<tr>
<td>Right-click ➤ Auto-place selected element</td>
<td>Attempts to place the selected design element and all its children in a legal location in the interface plan.</td>
</tr>
<tr>
<td>Chip View</td>
<td>Displays the target device chip. Zoom in to display chip details.</td>
</tr>
<tr>
<td>Package View</td>
<td>Displays the target device package. Zoom in to display chip details.</td>
</tr>
<tr>
<td>Show I/O Banks</td>
<td>Selects and color codes the I/O banks in the Plan tab.</td>
</tr>
<tr>
<td>Show Differential Pin Pair Connections</td>
<td>Displays a red connection line between a pair of differential pins. The Package View labels the positive and negative pins with the letters p and n, respectively.</td>
</tr>
<tr>
<td>Show PCIe Hard IP Interface Pins</td>
<td>Selects and color codes the PCIe Hard IP interface pins in the Plan tab. To access this command, right-click in the Plan tab package view, and select x1 Lanes, x2 Lanes, x4 Lanes, x8 Lanes, or by 16 Lanes. After enabling, view color coding in the Color Legend.</td>
</tr>
<tr>
<td>Show DQ/DQS Pins</td>
<td>Selects and color codes the PCIe Hard IP interface pins in the Plan tab. To access this command, right-click in the Plan tab package view, and select x4 Mode, x8/x9 Mode, x16/x16 Mode, or x32/x36 Mode. After enabling, view color coding in the Color Legend.</td>
</tr>
<tr>
<td>Right-click ➤ Report Placeability of Selected Element</td>
<td>Displays detailed information on the Reports tab, showing legal locations in the interface plan for the selected cell in order of suitability for fitting.</td>
</tr>
<tr>
<td>Copy Current View</td>
<td>Copies the current interface plan to the clipboard for pasting into other files, such as word processing or presentation files.</td>
</tr>
<tr>
<td>Reset Plan</td>
<td>Unplaces all placed design elements and removes applied project assignments from the interface plan. Resets all project assignments to the enabled state. You must subsequently run Update Plan prior to placing design elements. This command only applies to your interface plan and does not impact your Intel Quartus Prime project assignments until you apply the Interface Planner script.</td>
</tr>
<tr>
<td>Load Floorplan</td>
<td>Allows you to select and load an Interface Planner Floorplan Format (.plan) file. You can save Interface Planner floorplan files in the format by clicking Save Floorplan.</td>
</tr>
<tr>
<td>Save Floorplan</td>
<td>Allows you to save your Interface Planner floorplan as a .plan file.</td>
</tr>
<tr>
<td>Undo/Redo buttons</td>
<td>The Undo button reverts the last change made in the Plan tab. Redo re-implements the last undo. Use these commands to step forward and backward though your plan changes.</td>
</tr>
</tbody>
</table>
2.3.5. Reports Tab Controls

The Interface Planner Reports tab contains the following Task pane controls to help you filter data and find entities and locations.

Table 7. Reports Tab Controls

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create all Summary Reports</td>
<td>Creates the following summary reports:</td>
</tr>
<tr>
<td></td>
<td>• Interface Planner Summary</td>
</tr>
<tr>
<td></td>
<td>• All Periphery Cells</td>
</tr>
<tr>
<td></td>
<td>• Placed/Unplaced Periphery Cells</td>
</tr>
<tr>
<td></td>
<td>• Periphery Location Types.</td>
</tr>
<tr>
<td>Report All Placed/Unplaced Pins</td>
<td>Reports the name, parent (if any), and type of all placed (Report All Placed Pins) or unplaced (Report All Unplaced Pins) pins in the interface plan, respectively. The Placed Pins report includes the placement location name. The Unplaced Pins report includes the number of potential placement locations. Right-click any cell to place, unplace, or report connectivity or location information.</td>
</tr>
</tbody>
</table>

*continued...*
### 2.4. Interface Planner Reports

Use Interface Planner reports to locate cells and assign suitable placement locations for specific interfaces and elements in your design. Interface Planner reports provide detailed, actionable feedback to help you quickly implement the best plan for your design. You can access placement and further reporting functions directly from Interface Planner reports. Interface Planner generates the following reports that provide detailed planning information:

- **Report Summary** on page 35
- **Report Pins** on page 36
- **Report HSSI Channels** on page 38
- **Report Clocks** on page 38
- **Report Periphery Locations** on page 39
- **Report Cell Connectivity** on page 40
- **Report Instance Assignments** on page 40

#### 2.4.1. Report Summary

Click **Create all Summary Reports** on the **Reports** tab to generate summary reports about periphery cells in the interface plan. Right-click any cell type to report placed, unplaced, connectivity, or location information.
2.4.2. Report Pins

Generate reports about I/O pins in the design. Right-click any cell type to place, unplace, or report connectivity or location information.

Table 9. Report Pin Commands

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report All Placed Pins</td>
<td>Generates the Placed Pins report. This report lists the name, parent, type, and location of all placed pins in the interface plan.</td>
</tr>
<tr>
<td>Report All Unplaced Pins</td>
<td>Generates the Unplaced Pins report. This report lists the name, parent, type, and the number of potential placements for all unplaced pins in the interface plan.</td>
</tr>
</tbody>
</table>
2. Interface Planning

Figure 21. Placed Pins Report

Right-Click To
Unplace Placed Pins

Figure 22. Unplaced Pins Report

Right-Click to
Place Unplaced Pins
2.4.3. Report HSSI Channels

Generate reports about HSSI channels in the interface plan. Right-click any cell type to place, unplace, or report connectivity or location information.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report All Placed HSSI Channels</td>
<td>Generates the Placed HSSI Channels report. This report lists the name, parent, type, and location of all placed HSSI RX/TX channels in the interface plan.</td>
</tr>
<tr>
<td>Report All Unplaced HSSI Channels</td>
<td>Generates the Unplaced HSSI Channels report. This report lists the name, parent, type, and location of all unplaced HSSI RX/TX channels in the interface plan.</td>
</tr>
</tbody>
</table>

Figure 23. Unplaced HSSI Channels Report

2.4.4. Report Clocks

Generate reports showing clock networks in the plan. Use this report to analyze clock network scenarios and ensure that specific device regions are fed by high fan-out signals.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report Clocks</td>
<td>Generates the Global and other Fast Signals report.</td>
</tr>
</tbody>
</table>
2.4.5. Report Periphery Locations

Generate reports that show the status of periphery cells in the interface plan.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right-click ➤ Report Placed Periphery Cells of Selected Type</td>
<td>Accessible from the All Periphery Cells report. This command reports the name, parent (if any), type, and location of the selected placed periphery cells matching the selected type. Right-click any cell to place, unplace, or report connectivity or location information.</td>
</tr>
<tr>
<td>Right-click ➤ Report Unplaced Periphery Cells of Selected Type</td>
<td>Accessible from the All Periphery Cells report. This command reports the name, parent (if any), type, and number of suitable locations for the selected unplaced periphery cells matching the selected type. Right-click any cell to place, unplace, or report connectivity or location information.</td>
</tr>
<tr>
<td>Right-click ➤ Report Periphery Locations of Selected Type</td>
<td>Reports all locations in the device of the selected type, and whether the location supports merging.</td>
</tr>
</tbody>
</table>

Figure 25. Placed Periphery Cells Report

<table>
<thead>
<tr>
<th>Name</th>
<th>Parent Name</th>
<th>Cell Type</th>
<th>Location Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>clock~CLUSTER</td>
<td></td>
<td>I/O pin cluster</td>
<td>AU33</td>
</tr>
<tr>
<td>clock</td>
<td>clock~CLUSTER</td>
<td>I/O pad</td>
<td>PIN AU33</td>
</tr>
<tr>
<td>clock~input</td>
<td>clock~CLUSTER</td>
<td>I/O input buffer</td>
<td>IOBUF_X78_Y125_N32</td>
</tr>
<tr>
<td>altera reserved trm~CLUS</td>
<td></td>
<td>I/O pin cluster</td>
<td>AL24</td>
</tr>
<tr>
<td>altera reserved trms</td>
<td>altera reserved trms</td>
<td>I/O pad</td>
<td>PIN_AL24</td>
</tr>
<tr>
<td>altera reserved trms~input</td>
<td>altera reserved trms</td>
<td>I/O input buffer</td>
<td>IOBUF_X115_Y0_N65</td>
</tr>
<tr>
<td>altera reserved tdi~CLUST</td>
<td></td>
<td>I/O pin cluster</td>
<td>AN21</td>
</tr>
<tr>
<td>altera reserved tdi</td>
<td>altera reserved tdi</td>
<td>I/O pad</td>
<td>PIN_AN21</td>
</tr>
<tr>
<td>altera reserved tdi~input</td>
<td>altera reserved tdi</td>
<td>I/O input buffer</td>
<td>IOBUF_X115_Y0_N47</td>
</tr>
<tr>
<td>led one on~CLUSTER</td>
<td></td>
<td>I/O pin cluster</td>
<td>K25</td>
</tr>
<tr>
<td>led one on</td>
<td>led one on~CLUSTE</td>
<td>I/O pad</td>
<td>PIN K25</td>
</tr>
<tr>
<td>led one on~output</td>
<td>led one on~CLUSTE</td>
<td>I/O output buffer</td>
<td>IOOBUF_X142_Y205_N18</td>
</tr>
</tbody>
</table>
2.4.6. Report Cell Connectivity

Generate reports showing the connections between all cells in the interface plan.

Table 13. Report Cell Connectivity Command

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right-click ➤ Report Periphery</td>
<td>Reports all enabled instance assignments in your design. Right-click any cell to delete the assignment or to delete all assignments of the same type.</td>
</tr>
<tr>
<td>Cell Connectivity</td>
<td>The report lists the source and destination ports and type of connections to the selected cell. Right-click any cell to report all connections to the cell.</td>
</tr>
</tbody>
</table>

Figure 26. Periphery Cell Connectivity Report

2.4.7. Report Instance Assignments

Click Report Instance Assignments to show all imported project assignments in the interface plan. You can delete these assignments from the plan.

Table 14. Report Instance Assignments Command

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report Instance Assignments</td>
<td>Reports all enabled instance assignments in your design. Right-click any cell to delete the assignment or to delete all assignments of the same type.</td>
</tr>
</tbody>
</table>
2.5. Interface Planning Revision History

This document has the following revision history:

<table>
<thead>
<tr>
<th>Document Version</th>
<th>Intel Quartus Prime Version</th>
<th>Changes</th>
</tr>
</thead>
</table>
| 2019.04.01       | 19.1.0                      | • Updated "Plan Tab Controls" to describe new color coding controls for I/O banks, differential pin pairs, DQ/DQS pins, and PCIe hard IP pins.  
• Update screenshots and procedure steps for latest user interface. |
| 2018.05.07       | 18.0.0                      | • Initial release in Design Constraints User Guide: Intel Quartus Prime Pro Edition.  
• Updated Step 2: Initialize Interface Planner to remove the requirement to close Intel Quartus Prime.  
• Updated Step 4: Plan Periphery Placement to describe when the Locate Node command is disabled. |
| 2017.11.06       | 17.1.0                      | • Removed support for the Clocking feature for Intel Stratix 10. Intel Stratix 10 clocks must use Autoplace Selected.  
• Renamed BluePrint to Interface Planner.  
• Renamed chapter from BluePrint Design Planning to Interface Planning. |
| 2016.10.31       | 16.1.0                      | • Implemented Intel rebranding. |
| 2016.05.03       | 16.0.0                      | • Added Plan Clock Networks topic.  
• Added Saving and Loading Floorplans topic.  
• Added Undo/Redo command descriptions.  
• Added Flow control description.  
• Added note about panning feature.  
• Updated all screenshots for latest GUI. |

continued...
### Document Version

<table>
<thead>
<tr>
<th>Document Version</th>
<th>Intel Quartus Prime Version</th>
<th>Changes</th>
</tr>
</thead>
</table>
| 2015.11.02       | 15.1.0                      | • Changed instances of Quartus II to Quartus Prime.  
                                 • Integration of content into Quartus Prime Handbook.  
                                 • Added descriptions of new dynamic reports.  
                                 • Added Package View description.  
                                 • Added GUI controls reference. |
| 2015.05.04       | 15.0.0                      | Second beta release of document on Molson. Added information about the following subjects:  
                                 • Overview information  
                                 • Reset Plan command  
                                 • Legal Assignments list and prompt  
                                 • Tcl console |

### Related Information

**Altera Documentation Archive**

For previous versions of the *Intel Quartus Prime Handbook*, search the Altera documentation archives.
3. Managing Device I/O Pins

This chapter describes efficient planning and assignment of I/O pins in your target device. Consider I/O standards, pin placement rules, and your PCB characteristics early in the design phase.

Figure 28. Pin Planner GUI

Table 15. Intel Quartus Prime I/O Pin Planning Tools

<table>
<thead>
<tr>
<th>I/O Planning Task</th>
<th>Click to Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan interfaces and device periphery</td>
<td>Tools ➤ Interface Planner</td>
</tr>
<tr>
<td>Edit, validate, or export pin assignments</td>
<td>Assignments ➤ Pin Planner</td>
</tr>
</tbody>
</table>


Related Information

- Interface Planning Overview on page 20
- Instantiating the HPS Component
3.1. I/O Planning Overview

On FPGA design, I/O planning includes creating pin-related assignments and validating them against pin placement guidelines. This process ensures a successful fit in your target device. When you plan and assign I/O pins in the initial stages of your project, you design for compatibility with your target device and PCB characteristics. As a result, your design process goes through fewer iterations, and you develop an accurate PCB layout sooner.

You can plan your I/O pins even before defining design files. Assign expected nodes not yet defined in design files, including interface IP core signals, and then generate a top-level file. The top-level file instantiates the next level of design hierarchy and includes interface port information like memory, high-speed I/O, device configuration, and debugging tools.

Assign design elements, I/O standards, interface IP, and other properties to the device I/O pins by name or by dragging to cells. You can then generate a top-level design file for I/O validation.

Use I/O assignment validation to fully analyze I/O pins against VCCIO, VREF, electromigration (current density), Simultaneous Switching Output (SSO), drive strength, I/O standard, PCI_IO clamp diode, and I/O pin direction compatibility rules.

Intel Quartus Prime software provides the Pin Planner tool to view, assign, and validate device I/O pin logic and properties. Alternatively, you can enter I/O assignments in a Tcl script, or directly in HDL code.

3.1.1. Basic I/O Planning Flow

The following steps describe the basic flow for assigning and verifying I/O pin assignments:

1. Click Assignments ➤ Device and select a target device that meets your logic, performance, and I/O requirements. Consider and specify I/O standards, voltage and power supply requirements, and available I/O pins.
2. Click Assignments ➤ Pin Planner.
3. Assign I/O properties to match your device and PCB characteristics, including assigning logic, I/O standards, output loading, slew rate, and current strength.
4. Click Run I/O Assignment Analysis in the Tasks pane to validate assignments and generate a synthesized design netlist. Correct any problems reported.
5. Click Processing ➤ Start Compilation. During compilation, the Intel Quartus Prime software runs I/O assignment analysis.

3.1.2. Integrating PCB Design Tools

You can integrate PCB design tools into your work flow to map pin assignments to symbols in your system circuit schematics and board layout.

The Intel Quartus Prime software integrates with board layout tools by allowing import and export of pin assignment information in Intel Quartus Prime Settings Files (.qsf), Pin-Out File (.pin), and FPGA Xchange-Format File (.fx) files.
Table 16. Integrating PCB Design Tools

<table>
<thead>
<tr>
<th>PCB Tool Integration</th>
<th>Supported PCB Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define and validate I/O assignments in the Pin Planner, and then export the assignments to the PCB tool for validation</td>
<td>Mentor Graphics* I/O Designer</td>
</tr>
<tr>
<td></td>
<td>Cadence Allegro</td>
</tr>
<tr>
<td>Define I/O assignments in your PCB tool, and then import the assignments into the Pin Planner for validation</td>
<td>Mentor Graphics I/O Designer</td>
</tr>
<tr>
<td></td>
<td>Cadence Allegro</td>
</tr>
</tbody>
</table>

Figure 29. PCB Tool Integration

Related Information
Cadence PCB Design Tools Support
3.1.3. Intel Device Terms

The following terms describe Intel device and I/O structures:

<table>
<thead>
<tr>
<th>Terms</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device Package (BGA example)</td>
<td>Ceramic or plastic heat sink surface mounted with FPGA die and I/O pins or solder balls. In a wire bond BGA example, copper wires connect the bond pads to the solder balls of the package. Click View &gt; Show &gt; Package Top or View &gt; Show &gt; Package Bottom in Pin Planner.</td>
</tr>
<tr>
<td>I/O Bank</td>
<td>I/O pins are grouped in I/O banks for assignment of I/O standards. Each numbered bank has its own voltage source pins, called VCCIO pins, for high I/O performance. The specified VCCIO pin voltage is between 1.5 V and 3.3 V. Each bank supports multiple pins with different I/O standards. All pins in a bank must use the same VCCIO signal. Click View &gt; Show &gt; I/O Banks in Pin Planner.</td>
</tr>
<tr>
<td>I/O Pin</td>
<td>A wire lead or small solder ball on the package bottom or periphery. Each pin has an alphanumeric row and column number. I, O, Q, S, X, and Z are never used. The alphabet is repeated and prefixed with the letter A when exceeded. All I/O pins display by default.</td>
</tr>
<tr>
<td>Pad</td>
<td>I/O pins are connected to pads located on the perimeter of the top metal layer of the silicon die. Each pad is numbered with an ID starting at 0, and increments by one in a counterclockwise direction around the device. Click View &gt; Pad View in Pin Planner.</td>
</tr>
<tr>
<td>VREF Pin Group</td>
<td>A group of pins including one dedicated VREF pin required by voltage-referenced I/O standards. A VREF group contains a smaller number of pins than an I/O bank. This maintains the signal integrity of the VREF pin. One or more VREF groups exist in an I/O bank. The pins in a VREF group share the same VCCIO and VREF voltages. Click View &gt; Show &gt; Show VREF Groups in Pin Planner.</td>
</tr>
</tbody>
</table>

3.2. Assigning I/O Pins

Use the Pin Planner to visualize, modify, and validate I/O assignments in a graphical representation of the target device. You can increase the accuracy of I/O assignment analysis by reserving specific device pins to accommodate undefined but expected I/O.
To assign I/O pins in the Pin Planner, follow these steps:

1. Open an Intel Quartus Prime project, and then click **Assignments ➤ Pin Planner**.

2. Click **Processing ➤ Start Analysis & Elaboration** to elaborate the design and display **All Pins** in the device view.

3. To locate or highlight pins for assignment, click **Pin Finder** or a pin type under **Highlight Pins** in the **Tasks** pane.

4. (Optional) To define a custom group of nodes for assignment, select one or more nodes in the **Groups** or **All Pins** list, and click **Create Group**.

5. Enter assignments of logic, I/O standards, interface IP, and properties for device I/O pins in the **All Pins** spreadsheet, or by dragging into the package view.

6. To assign properties to differential pin pairs, click **Show Differential Pin Pair Connections**. A red connection line appears between positive (p) and negative (n) differential pins.

7. (Optional) To create board trace model assignments:
   a. Right-click an output or bidirectional pin, and click **Board Trace Model**. For differential I/O standards, the board trace model uses a differential pin pair with two symmetrical board trace models.
   b. Specify board trace parameters on the positive end of the differential pin pair. The assignment applies to the corresponding value on the negative end of the differential pin pair.

8. To run a full I/O assignment analysis, click **Run I/O Assignment Analysis**. The Fitter reports analysis results. Only reserved pins are analyzed prior to design synthesis.

### 3.2.1. Assigning to Exclusive Pin Groups

You can designate groups of pins for exclusive assignment. When you assign pins to an **Exclusive I/O Group**, the Fitter does not place the signals in the same I/O bank with any other exclusive I/O group. For example, if you have a set of signals assigned exclusively to **group_a**, and another set of signals assigned to **group_b**, the Fitter ensures placement of each group in different I/O banks.

### 3.2.2. Assigning Slew Rate and Drive Strength

You can designate the device pin slew rate and drive strength. These properties affect the pin’s outgoing signal integrity. Use either the **Slew Rate** or **Slow Slew Rate** assignment to adjust the drive strength of a pin with the **Current Strength** assignment.

*Note:* The slew rate and drive strength apply during I/O assignment analysis.

### 3.2.3. Assigning Differential Pins

When you assign a differential I/O standard to a single-ended top-level pin in your design, the Pin Planner automatically recognizes the negative pin as part of the differential pin pair assignment and creates the negative pin for you. The Intel Quartus Prime software writes the location assignment for the negative pin to the `.qsf`; however, the I/O standard assignment is not added to the `.qsf` for the negative pin of the differential pair.
The following example shows a design with `lvds_in` top-level pin, to which you assign a differential I/O standard. The Pin Planner automatically creates the differential pin, `lvds_in(n)` to complete the differential pin pair.

**Note:** If you have a single-ended clock that feeds a PLL, assign the pin only to the positive clock pin of a differential pair in the target device. Single-ended pins that feed a PLL and are assigned to the negative clock pin device cause the design to not fit.

**Figure 30. Creating a Differential Pin Pair in the Pin Planner**

If your design contains a large bus that exceeds the pins available in a particular I/O bank, you can use edge location assignments to place the bus. Edge location assignments improve the circuit board routing ability of large buses, because they are close together near an edge. The following figure shows Intel device package edges.

**Figure 31. Die View and Package View of the Four Edges on an Intel Device**

3.2.3.1. Overriding I/O Placement Rules on Differential Pins

I/O placement rules ensure that noisy signals do not corrupt neighboring signals. Each device family has predefined I/O placement rules.
I/O placement rules define, for example, the allowed placement of single-ended I/O with respect to differential pins, or how many output and bidirectional pins you can place within a VREF group when using voltage referenced input standards.

Use the `IO_MAXIMUM_TOGGLE_RATE` assignment to override I/O placement rules on pins, such as system reset pins that do not switch during normal design activity. Setting a value of 0 MHz for this assignment causes the Fitter to recognize the pin at a DC state throughout device operation. The Fitter excludes the assigned pin from placement rule analysis. Do not assign an `IO_MAXIMUM_TOGGLE_RATE` of 0 MHz to any actively switching pin, or your design may not function as you intend.

### 3.2.4. Entering Pin Assignments with Tcl Commands

You can apply pin assignments with Tcl scripts, by either entering individual Tcl commands in the Tcl Console, or creating a `.tcl` script and typing the following in the command line:

**Example 6. Applying Tcl Script Assignments**

```tcl
quartus_sh -t <my_tcl_script>.tcl
```

**Example 7. Scripted Pin Assignment**

The following example uses `set_location_assignment` and `set_instance_assignment` Tcl commands to assign a pin to a specific location, I/O standard, and drive strength.

```tcl
set_location_assignment PIN M20 -to address[10]
set_instance_assignment -name IO_STANDARD "2.5 V" -to address[10]
set_instance_assignment -name CURRENT_STRENGTH_NEW "MAXIMUM CURRENT" -to address[10]
```

### Related Information

**Tcl Scripting**

In *Intel Quartus Prime Pro Edition User Guide: Scripting*

### 3.2.5. Entering Pin Assignments in HDL Code

You can use synthesis attributes or low-level I/O primitives to embed I/O pin assignments directly in your HDL code. When you analyze and synthesize the HDL code, the information is converted into the appropriate I/O pin assignments. You can use either of the following methods to specify pin-related assignments with HDL code:

- Assigning synthesis attributes for signal names that are top-level pins
- Using low-level I/O primitives, such as `ALT_BUF_IN`, to specify input, output, and differential buffers, and for setting parameters or attributes

#### 3.2.5.1. Using Low-Level I/O Primitives

You can alternatively enter I/O pin assignments using low-level I/O primitives. You can assign pin locations, I/O standards, drive strengths, slew rates, and on-chip termination (OCT) value assignments. You can also use low-level differential I/O primitives to define both positive and negative pins of a differential pair in the HDL code for your design.
Primitive-based assignments do not appear in the Pin Planner until after you perform a full compilation and back-annotate pin assignments (Assignments > Back Annotate Assignments).

Related Information
Designing with Low Level Primitives User Guide

3.3. Importing and Exporting I/O Pin Assignments

The Intel Quartus Prime software supports transfer of I/O pin assignments across projects, or for analysis in third-party PCB tools. You can import or export I/O pin assignments in the following ways:

Table 17. Importing and Exporting I/O Pin Assignments

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Import Assignments</th>
<th>Export Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• From your PCB design tool or spreadsheet into Pin Planner during early pin planning or after optimization in PCB tool</td>
<td>• From Intel Quartus Prime project for optimization in a PCB design tool</td>
<td></td>
</tr>
<tr>
<td>• From another Intel Quartus Prime project with common constraints</td>
<td>• From Intel Quartus Prime project for spreadsheet analysis or use in scripting assignments</td>
<td></td>
</tr>
<tr>
<td>• From Intel Quartus Prime project for optimization in a PCB design tool</td>
<td>• From Intel Quartus Prime project for import into another Intel Quartus Prime project with similar constraints</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Command</th>
<th>Assignments ➤ Import Assignments</th>
<th>Assignments ➤ Export Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>File formats</td>
<td>.qsf, .esf, .acf, .csv, .txt, .sdc</td>
<td>.pin, .fx, .csv, .tcl, .qsf</td>
</tr>
</tbody>
</table>

Notes: N/A

Exported .csv files retain column and row order and format. Do not modify the row of column headings if importing the .csv file.

3.3.1. Importing and Exporting for PCB Tools

The Pin Planner supports import and export of assignments with PCB tools. You can export valid assignments as a .pin file for analysis in other supported PCB tools. You can also import optimized assignment from supported PCB tools. The .pin file contains pin name, number, and detailed properties.

Mentor Graphics I/O Designer requires you to generate and import both an .fx and a .pin file to transfer assignments. However, the Intel Quartus Prime software requires only the .fx to import pin assignments from I/O Designer.

Table 18. Contents of .pin File

<table>
<thead>
<tr>
<th>File Column Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin Name/Usage</td>
<td>The name of the design pin, or whether the pin is GND or VCC pin</td>
</tr>
<tr>
<td>Location</td>
<td>The pin number of the location on the device package</td>
</tr>
<tr>
<td>Dir</td>
<td>The direction of the pin</td>
</tr>
<tr>
<td>I/O Standard</td>
<td>The name of the I/O standard to which the pin is configured</td>
</tr>
<tr>
<td>Voltage</td>
<td>The voltage level that is required to be connected to the pin</td>
</tr>
<tr>
<td>I/O Bank</td>
<td>The I/O bank to which the pin belongs</td>
</tr>
<tr>
<td>User Assignment</td>
<td>Y or N indicating if the location assignment for the design pin was user assigned (Y) or assigned by the Fitter (N)</td>
</tr>
</tbody>
</table>
3. Managing Device I/O Pins

3.3.2. Migrating Assignments to Another Target Device

Click **View ➤ Pin Migration Window** to verify whether pin assignments are compatible with migration to a different Intel device.

You can migrate compatible pin assignments from one target device to another. You can migrate to a different density and the same device package. You can also migrate between device packages with different densities and pin counts.

The Intel Quartus Prime software ignores invalid assignments and generates an error message during compilation. After evaluating migration compatibility, modify any incompatible assignments, and then click **Export** to export the assignments to another project.

**Figure 32. Device Migration Compatibility (AC24 does not exist in migration device)**

The migration result for the pin function of highlighted PIN_AC23 is not an NC but a voltage reference VREFB1N2 even though the pin is an NC in the migration device. VREF standards have a higher priority than an NC, thus the migration result displays the voltage reference. Even if you do not use that pin for a port connection in the design, you must use the VREF standard for I/O standards that require it on the actual board for the migration device.
If one of the migration devices has pins intended for connection to V\textsubscript{CC} or GND and these same pins are I/O pins on a different device in the migration path, the Intel Quartus Prime software ensures these pins are not used for I/O. Ensure that these pins are connected to the correct PCB plane.

When migrating between two devices in the same package, pins that are not connected to the smaller die may be intended to connect to V\textsubscript{CC} or GND on the larger die. To facilitate migration, you can connect these pins to V\textsubscript{CC} or GND in the original design because the pins are not physically connected to the smaller die.

Related Information
AN90: SameFrame PinOut Design for FineLine BGA Packages

3.4. Validating Pin Assignments

The Intel Quartus Prime software validates I/O pin assignments against predefined I/O rules for your target device. You can use the following tools to validate your I/O pin assignments throughout the pin planning process:

Table 19. I/O Validation Tools

<table>
<thead>
<tr>
<th>I/O Validation Tool</th>
<th>Description</th>
<th>Click to Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced I/O Timing</td>
<td>Fully validates I/O assignments against all I/O and timing checks during compilation</td>
<td>Processing ➤ Start Compilation</td>
</tr>
</tbody>
</table>

3.4.1. I/O Assignment Validation Rules

I/O Assignment Analysis validates your assignments against the following rules:

Table 20. Examples of I/O Rule Checks

<table>
<thead>
<tr>
<th>Rule</th>
<th>Description</th>
<th>HDL Required?</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O bank capacity</td>
<td>Checks the number of pins assigned to an I/O bank against the number of pins allowed in the I/O bank.</td>
<td>No</td>
</tr>
<tr>
<td>I/O bank VCCIO voltage compatibility</td>
<td>Checks that no more than one VCCIO is required for the pins assigned to the I/O bank.</td>
<td>No</td>
</tr>
<tr>
<td>I/O bank VREF voltage compatibility</td>
<td>Checks that no more than one VREF is required for the pins assigned to the I/O bank.</td>
<td>No</td>
</tr>
<tr>
<td>I/O standard and location conflicts</td>
<td>Checks whether the pin location supports the assigned I/O standard.</td>
<td>No</td>
</tr>
<tr>
<td>I/O standard and signal direction conflicts</td>
<td>Checks whether the pin location supports the assigned I/O standard and direction. For example, certain I/O standards on a particular pin location can only support output pins.</td>
<td>No</td>
</tr>
<tr>
<td>Differential I/O standards cannot have open drain turned on</td>
<td>Checks that open drain is turned off for all pins with a differential I/O standard.</td>
<td>No</td>
</tr>
<tr>
<td>I/O standard and drive strength conflicts</td>
<td>Checks whether the drive strength assignments are within the specifications of the I/O standard.</td>
<td>No</td>
</tr>
<tr>
<td>Drive strength and location conflicts</td>
<td>Checks whether the pin location supports the assigned drive strength.</td>
<td>No</td>
</tr>
<tr>
<td>BUSHOLD and location conflicts</td>
<td>Checks whether the pin location supports BUSHOLD. For example, dedicated clock pins do not support BUSHOLD.</td>
<td>No</td>
</tr>
</tbody>
</table>

continued...
### Signal Switching Noise Rules

<table>
<thead>
<tr>
<th>Rule</th>
<th>Description</th>
<th>HDL Required?</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEAK_PULLUP and location conflicts</td>
<td>Checks whether the pin location supports WEAK_PULLUP (for example, dedicated clock pins do not support WEAK_PULLUP).</td>
<td>No</td>
</tr>
<tr>
<td>Electromigration check</td>
<td>Checks whether combined drive strength of consecutive pads exceeds a certain limit. For example, the total current drive for 10 consecutive pads on a Stratix II device cannot exceed 200 mA.</td>
<td>No</td>
</tr>
<tr>
<td>PCI_IO clamp diode, location, and I/O standard conflicts</td>
<td>Checks whether the pin location along with the I/O standard assigned supports PCI_IO clamp diode.</td>
<td>No</td>
</tr>
<tr>
<td>SERDES and I/O pin location compatibility check</td>
<td>Checks that all pins connected to a SERDES in your design are assigned to dedicated SERDES pin locations.</td>
<td>Yes</td>
</tr>
<tr>
<td>PLL and I/O pin location compatibility check</td>
<td>Checks whether pins connected to a PLL are assigned to the dedicated PLL pin locations.</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### 3.4.2. I/O Assignment Analysis

I/O assignment analysis validates I/O assignments against the complete set of I/O system and board layout rules. Full I/O assignment analysis validates blocks that directly feed or are fed by resources such as a PLL, LVDS, or gigabit transceiver blocks. In addition, the checker validates the legality of proper VREF pin use, pin locations, and acceptable mixed I/O standards.

Run I/O assignment analysis during early pin planning to validate initial reserved pin assignments before compilation. Once you define design files, run I/O assignment analysis to perform more thorough legality checks with respect to the synthesized netlist. Run I/O assignment analysis whenever you modify I/O assignments.
The Fitter assigns pins to accommodate your constraints. For example, if you assign an edge location to a group of LVDS pins, the Fitter assigns pin locations for each LVDS pin in the specified edge location and then performs legality checks. To display the Fitter-placed pins, click **Show Fitter Placements** in the Pin Planner. To accept these suggested pin locations, you must back-annotate your pin assignments.

View the I/O Assignment Warnings report to view and resolve all assignment warnings. For example, a warning that some design pins have undefined drive strength or slew rate. The Fitter recognizes undefined, single-ended output and bidirectional pins as non-calibrated OCT. To resolve the warning, assign the **Current Strength**, **Slew Rate** or **Slow Slew Rate** for the reported pin. Alternatively, can assign the **Termination** to the pin. You cannot assign drive strength or slew rate settings when a pin has an OCT assignment.

### 3.4.2.1. Early I/O Assignment Analysis Without Design Files

You can perform basic I/O legality checks before defining HDL design files. This technique produces a preliminary board layout. For example, you can specify a target device and enter pin assignments that correspond to PCB characteristics. You can reserve and assign I/O standards to each pin, and then run I/O assignment analysis to ensure that there are no I/O standard conflicts in each I/O bank.

#### Figure 33. Assigning and Analyzing Pin-Outs without Design Files

You must reserve all pins you intend to use as I/O pins, so that the Fitter can determine each pin type. After performing I/O assignment analysis, correct any errors reported by the Fitter and rerun I/O assignment analysis until all errors are corrected. A complete I/O assignment analysis requires all design files.

### 3.4.2.2. I/O Assignment Analysis With Design Files

I/O assignment analysis allows you to perform full I/O legality checks after fully defining HDL design files. When you run I/O assignment analysis on a complete design, the tool verifies all I/O pin assignments against all I/O rules. When you run
I/O assignment analysis on a partial design, the tool checks legality only for defined portions of the design. The following figure shows the work flow for analyzing pin-outs with design files.

**Figure 34. I/O Assignment Analysis Flow**

Even if I/O assignment analysis passes on incomplete design files, you may still encounter errors during full compilation. For example, you can assign a clock to a user I/O pin instead of assigning to a dedicated clock pin, or design the clock to drive a PLL that you have not yet instantiated in the design. This issues occur because I/O assignment analysis does not account for the logic that the pin drives and does not verify that only dedicated clock inputs can drive the a PLL clock port.

To obtain better coverage, analyze as much of the design as possible over time, especially logic that connects to pins. For example, if your design includes PLLs or LVDS blocks, define these files prior to full analysis. After performing I/O assignment analysis, correct any errors reported by the Fitter and rerun I/O assignment analysis until all errors are corrected.

The following figure shows the compilation time benefit of performing I/O assignment analysis before running a full compilation.
3.4.2.3. Overriding Default I/O Pin Analysis

You can override the default I/O analysis of pins to accommodate I/O rule exceptions, such as for analyzing VREF or inactive pins.

Each device contains VREF pins, each supporting one or more I/O pins. A VREF pin and its I/O pins comprise a VREF bank. The VREF pins are typically assigned inputs with VREF I/O standards, such as HSTL- and SSTL-type I/O standards. Conversely, VREF outputs do not require the VREF pin. When a voltage-referenced input is present in a VREF bank, only a certain number of outputs can be present in that VREF bank. I/O assignment analysis treats bidirectional signals controlled by different output enables as independent output enables.

To assign the Output Enable Group option to bidirectional signals to analyze the signals as a single output enable group, follow these steps:

1. To access this assignment in the Pin Planner, right-click the All pins list and click Customize Columns.
2. Under Available columns, add Output Enable Group to Show these columns in this order. The column appears in the All Pins list.
3. Enter the same integer value for the Output Enable Group assignment for all sets of signals that are driving in the same direction.

Related Information

Using the Timing Analyzer
In Intel Quartus Prime Pro Edition User Guide: Timing Analyzer
3.4.3. Understanding I/O Analysis Reports

The detailed I/O assignment analysis reports include the affected pin name and a problem description. The Fitter section of the Compilation report contains information generated during I/O assignment analysis, including the following reports:

- **I/O Assignment Warnings**—lists warnings generated for each pin
- **Resource Section**—quantifies use of various pin types and I/O banks
- **I/O Rules Section**—lists summary, details, and matrix information about the I/O rules tested

The **Status** column indicates whether rules passed, failed, or were not checked. A severity rating indicates the rule’s importance for effective analysis. “Inapplicable” rules do not apply to the target device family.

**Figure 36. I/O Rules Matrix**

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>D-000000</th>
<th>D-000001</th>
<th>D-000002</th>
<th>D-000003</th>
<th>D-000004</th>
<th>D-000005</th>
<th>D-000006</th>
<th>D-000007</th>
<th>D-000008</th>
<th>D-000009</th>
<th>D-000010</th>
<th>D-000011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Pass</td>
<td>21</td>
<td>0</td>
<td>21</td>
<td>8</td>
<td>0</td>
<td>21</td>
<td>0</td>
<td>21</td>
<td>21</td>
<td>0</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>Total Warnings</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total Inapplicable</td>
<td>22</td>
<td>0</td>
<td>32</td>
<td>22</td>
<td>9</td>
<td>0</td>
<td>22</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total Fail</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

3.5. Verifying I/O Timing

You must verify board-level signal integrity and I/O timing when assigning I/O pins. High-speed interface operation requires a quality signal and low propagation delay at the far end of the board route. Click **Tools ➤ Timing Analyzer** to confirm timing after making I/O pin assignments.

For example, if you change the slew rates or drive strengths of some I/O pins with ECOs, you can verify timing without recompiling the design. You must understand I/O timing and what factors affect I/O timing paths in your design. The accuracy of the output load specification of the output and bidirectional pins affects the I/O timing results.
The Intel Quartus Prime software supports three different methods of I/O timing analysis:

### Table 22. I/O Timing Analysis Methods

<table>
<thead>
<tr>
<th>I/O Timing Analysis</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced I/O timing analysis</td>
<td>Analyze I/O timing with your board trace model to report accurate, &quot;board-aware&quot; simulation models. Configures a complete board trace model for each I/O standard or pin. Timing Analyzer applies simulation results of the I/O buffer, package, and board trace model to generate accurate I/O delays and system level signal information. Use this information to improve timing and signal integrity.</td>
</tr>
<tr>
<td>I/O timing analysis</td>
<td>Analyze I/O timing with default or specified capacitive load without signal integrity analysis. Timing Analyzer reports tCO to an I/O pin using a default or user-specified value for a capacitive load.</td>
</tr>
<tr>
<td>Full board routing simulation</td>
<td>Use Intel-provided or Intel Quartus Prime software-generated IBIS or HSPICE I/O models for simulation in Mentor Graphics HyperLynx* and Synopsys HSPICE.</td>
</tr>
</tbody>
</table>

For more information about advanced I/O timing support, refer to the appropriate device handbook for your target device. For more information about board-level signal integrity and tips on how to improve signal integrity in your high-speed designs, refer to the Signal Integrity and Power Integrity – Support Center website.

For information about creating IBIS and HSPICE models with the Intel Quartus Prime software and integrating those models into HyperLynx and HSPICE simulations, refer to the Signal Integrity Analysis with Third Party Tools chapter.

**Related Information**
- Literature and Technical Documentation
- Signal Integrity and Power Integrity – Support Center

### 3.5.1. Running Advanced I/O Timing

Advanced I/O timing analysis uses your board trace model and termination network specification to report accurate output buffer-to-pin timing estimates, FPGA pin and board trace signal integrity and delay values. Advanced I/O timing runs automatically for supported devices during compilation.

### 3.5.1.1. Board Trace Models

The Intel Quartus Prime software provides board trace model templates for various I/O standards.

The following figure shows the template for a 2.5 V I/O standard. This model consists of near-end and far-end board component parameters.

Near-end board trace modeling includes the elements which are close to the device. Far-end modeling includes the elements which are at the receiver end of the link, closer to the receiving device. Board trace model topology is conceptual and does not necessarily match the actual board trace for every component. For example, near-end model parameters can represent device-end discrete termination and breakout traces. Far-end modeling can represent the bulk of the board trace to discrete external memory components, and the far end termination network. You can analyze the same circuit with near-end modeling of the entire board, including memory component termination, and far-end modeling of the actual memory component.
The following figure shows the template for the **LVDS** I/O standard. The far-end capacitance (Cf) represents the external-device or multiple-device capacitive load. If you have multiple devices on the far-end, you must find the equivalent capacitance at the far-end, taking into account all receiver capacitances. The far-end capacitance can be the sum of all the receiver capacitances.

The Intel Quartus Prime software models of transmission lines do not consider transmission-line resistance (lossless models). You only need to specify distributed inductance (L) and capacitance (C) values on a per-inch basis, which you can obtain from the PCB vendor or manufacturer, the CAD Design tool, or a signal integrity tool, such as the Mentor Graphics HyperLynx software.
3.5.1.2. Defining the Board Trace Model

The board trace model describes a board trace and termination network as a set of capacitive, resistive, and inductive parameters.

Advanced I/O Timing uses the model to simulate the output signal from the output buffer to the far end of the board trace. You can define the capacitive load, any termination components, and trace impedances in the board routing for any output pin or bidirectional pin in output mode. You can configure an overall board trace model for each I/O standard or for specific pins. Define an overall board trace model for each I/O standard in your design. Use that model for all pins that use the I/O standard. You can customize the model for specific pins using the Board Trace Model window in the Pin Planner.

1. Click Assignments ➤ Device ➤ Device and Pin Options.
2. Click Board Trace Model and define board trace model values for each I/O standard.
3. Click I/O Timing and define default I/O timing options at board trace near and far ends.
4. Click Assignments ➤ Pin Planner and assign board trace model values to individual pins.

Example 8. Specifying Board Trace Model

```bash
## setting the near end series resistance model of sel_p output pin to 25 ohms
set_instance_assignment -name BOARD_MODEL_NEAR_SERIES_R 25 -to sel_p
## Setting the far end capacitance model for sel_p output signal to 6 picofarads
set_instance_assignment -name BOARD_MODEL_FAR_C 6P -to sel_p
```
3.5.1.3. Modifying the Board Trace Model

To modify the board trace model, click View ➤ Board Trace Model in the Pin Planner.

You can modify any of the board trace model parameters within a graphical representation of the board trace model.

The Board Trace Model window displays the routing and components for positive and negative signals in a differential signal pair. Only modify the positive signal of the pair, as the setting automatically applies to the negative signal. Use standard unit prefixes such as \( p \), \( n \), and \( k \) to represent pico, nano, and kilo, respectively. Use the short or open value to designate a short or open circuit for a parallel component.

3.5.1.4. Specifying Near-End vs Far-End I/O Timing Analysis

You can select a near-end or far-end point for I/O timing analysis. Near-end timing analysis extends to the device pin. You can apply the set_output_delay constraint during near-end analysis to account for the delay across the board.

With far-end I/O timing analysis, the advanced I/O timing analysis extends to the external device input, at the far-end of the board trace. Whether you choose a near-end or far-end timing endpoint, the board trace models are taken into account during timing analysis.

3.5.1.5. Advanced I/O Timing Analysis Reports

The following reports show advanced I/O timing analysis information:

Table 23. Advanced I/O Timing Reports

<table>
<thead>
<tr>
<th>I/O Timing Report</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing Analyzer Report</td>
<td>Reports signal integrity and board delay data.</td>
</tr>
<tr>
<td>Board Trace Model Assignments</td>
<td>Summarizes the board trace model component settings for each output and bidirectional signal.</td>
</tr>
<tr>
<td>Signal Integrity Metrics report</td>
<td>Contains all the signal integrity metrics calculated during advanced I/O timing analysis based on the board trace model settings for each output or bidirectional pin. Includes measurements at both the FPGA pin and at the far-end load of board delay, steady state voltages, and rise and fall times.</td>
</tr>
</tbody>
</table>

Note: By default, the Timing Analyzer generates the Slow-Corner Signal Integrity Metrics report. To generate a Fast-Corner Signal Integrity Metrics report you must change the delay model by clicking Tools ➤ Timing Analyzer.

Related Information
Using the Timing Analyzer
In Intel Quartus Prime Pro Edition User Guide: Timing Analyzer

3.5.2. Adjusting I/O Timing and Power with Capacitive Loading

When calculating \( t_{CO} \) and power for output and bidirectional pins, the Timing Analyzer and the Power Analyzer use a bulk capacitive load. You can adjust the value of the capacitive load per I/O standard to obtain more precise \( t_{CO} \) and power measurements, reflecting the behavior of the output or bidirectional net on your PCB. The Intel Quartus Prime software ignores capacitive load settings on input pins. You can adjust the capacitive load settings per I/O standard, in picofarads (pF), for your entire
design. During compilation, the Compiler measures power and \( t_{CO} \) measurements based on your settings. You can also adjust the capacitive load on an individual pin with the **Output Pin Load** logic option.

### 3.6. Viewing Routing and Timing Delays

Right-click any node and click **Locate > Locate in Chip Planner** to visualize and adjust I/O timing delays and routing between user I/O pads and \( V_{CC} \), GND, and \( V_{REF} \) pads. The Chip Planner graphically displays logic placement, Logic Lock regions, relative resource usage, detailed routing information, fan-in and fan-out, register paths, and high-speed transceiver channels. You can view physical timing estimates, routing congestion, and clock regions. Use the Chip Planner to change connections between resources and make post-compilation changes to logic cell and I/O atom placement. When you select items in the Pin Planner, the corresponding item is highlighted in Chip Planner.

### 3.7. Scripting API

The Intel Quartus Prime software allows you to access I/O management functions through Tcl commands, rather than with the GUI. For detailed information about scripting command options and Tcl API packages, type the following at a system command prompt to view the Tcl API Help browser:

```
quartus_sh --qhelp
```

**Related Information**
- **Tcl Scripting**
- **Command Line Scripting**

#### 3.7.1. Generate Mapped Netlist

Enter the following in the Tcl console or in a Tcl script:

```
execute_module -tool map
```

The `execute_module` command is in the flow package.

Type the following at a system command prompt:

```
quartus_syn <project name>
```

#### 3.7.2. Reserve Pins

Use the following Tcl command to reserve a pin:

```
set_instance_assignment -name RESERVE_PIN <value> -to <signal name>
```
3. Managing Device I/O Pins

Use one of the following valid reserved pin values:

- "AS BIDIRECTIONAL"
- "AS INPUT TRI STAT ED"
- "AS OUTPUT DRIVING AN UNSPECIFIED SIGNAL"
- "AS OUTPUT DRIVING GROUND"
- "AS SIGNALPROBE OUTPUT"

Note: You must include the quotation marks when specifying the reserved pin value.

3.7.3. Set Location

Use the following Tcl command to assign a signal to a pin or device location:

```tcl
set_location_assignment <location> -to <signal name>
```

Valid locations are pin locations, I/O bank locations, or edge locations. Pin locations include pin names, such as PIN_A3. I/O bank locations include IOBANK_1 up to IOBANK_ n, where n is the number of I/O banks in the device.

Use one of the following valid edge location values:

- EDGE_BOTTOM
- EDGE_LEFT
- EDGE_TOP
- EDGE_RIGHT

3.7.4. Exclusive I/O Group

The following Tcl command creates an exclusive I/O group assignment:

```tcl
set_instance_assignment -name "EXCLUSIVE_IO_GROUP" -to pin
```

3.7.5. Slew Rate and Current Strength

Use the following Tcl commands to create a slew rate and drive strength assignments:

```tcl
set_instance_assignment -name CURRENT_STRENGTH_NEW 8MA -to e[0]
set_instance_assignment -name SLEW_RATE 2 -to e[0]
```

Related Information

Package Information Datasheet for Mature Altera Devices

Send Feedback
3.8. Managing Device I/O Pins Revision History

The following table shows the revision history for this chapter:

<table>
<thead>
<tr>
<th>Document Version</th>
<th>Intel Quartus Prime Version</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018.05.07</td>
<td>18.0.0</td>
<td>• First release as part of the stand-alone Design Constraints User Guide</td>
</tr>
</tbody>
</table>
| 2017.11.06        | 17.1.0                     | • Revised topic: I/O Planning Overview.  
• Revised topic: Basic I/O Planning Flow with the Pin Planner and renamed to Basic I/O Planning Flow with the Pin Planner. |
| 2017.05.08        | 17.0.0                     | • Renamed command: Run I/O Assignment Analysis to Start Fitter (Plan). |
| 2016.10.31        | 16.1.0                     | • Implemented Intel rebranding. |
| 2015.11.02        | 15.1.0                     | • Removed early pin planning and Live I/O Check support from Quartus Prime Pro Edition handbook  
• Changed instances of Quartus II to Quartus Prime. |
| 2014.12.15        | 14.1.0                     | • Updated Live I/O check device support to include only limited device families. |
| 2014.08.30        | 14.0a10.0                  | • Added link to information about special pin assignment features for Arria 10 SoC devices. |
| November 2013     | 13.1.0                     | • Reorganization and conversion to DITA. |
| May 2013          | 13.0.0                     | • Added information about overriding I/O placement rules. |
| November 2012     | 12.1.0                     | • Updated Pin Planner description for new task and report windows. |
| June 2012         | 12.0.0                     | • Removed survey link. |
| November 2011     | 11.1.0                     | • Minor updates and corrections.  
• Updated the document template. |
| December 2010     | 10.0.1                     | Template update |
| July 2010         | 10.0.0                     | • Reorganized and edited the chapter  
• Added links to Help for procedural information previously included in the chapter  
• Added information on rules marked Inapplicable in the I/O Rules Matrix Report  
• Added information on assigning slew rate and drive strength settings to pins to fix I/O assignment warnings |
| November 2009     | 9.1.0                      | • Reorganized entire chapter to include links to Help for procedural information previously included in the chapter  
• Added documentation on near-end and far-end advanced I/O timing |
| March 2009        | 9.0.0                      | • Updated "Pad View Window" on page 5–20  
• Added new figures:  
  • Figure 5–15  
  • Figure 5–16  
• Added new section "Viewing Simultaneous Switching Noise (SSN) Results" on page 5–17  
• Added new section "Creating Exclusive I/O Group Assignments" on page 5–18 |

Related Information

Documentation Archive

For previous versions of the Intel Quartus Prime Handbook, search the documentation archives.
A. Intel Quartus Prime Pro Edition User Guides

Refer to the following user guides for comprehensive information on all phases of the Intel Quartus Prime Pro Edition FPGA design flow.

Related Information

- **Intel Quartus Prime Pro Edition User Guide: Getting Started**
  Introduces the basic features, files, and design flow of the Intel Quartus Prime Pro Edition software, including managing Intel Quartus Prime Pro Edition projects and IP, initial design planning considerations, and project migration from previous software versions.

  Describes creating and optimizing systems using Platform Designer, a system integration tool that simplifies integrating customized IP cores in your project. Platform Designer automatically generates interconnect logic to connect intellectual property (IP) functions and subsystems.

  Describes best design practices for designing FPGAs with the Intel Quartus Prime Pro Edition software. HDL coding styles and synchronous design practices can significantly impact design performance. Following recommended HDL coding styles ensures that Intel Quartus Prime Pro Edition synthesis optimally implements your design in hardware.

- **Intel Quartus Prime Pro Edition User Guide: Design Compilation**
  Describes set up, running, and optimization for all stages of the Intel Quartus Prime Pro Edition Compiler. The Compiler synthesizes, places, and routes your design before generating a device programming file.

  Describes Intel Quartus Prime Pro Edition settings, tools, and techniques that you can use to achieve the highest design performance in Intel FPGAs. Techniques include optimizing the design netlist, addressing critical chains that limit retiming and timing closure, optimizing device resource usage, device floorplanning, and implementing engineering change orders (ECOs).

  Describes operation of the Intel Quartus Prime Pro Edition Programmer, which allows you to configure Intel FPGA devices, and program CPLD and configuration devices, via connection with an Intel FPGA download cable.

- **Intel Quartus Prime Pro Edition User Guide: Block-Based Design**
  Describes block-based design flows, also known as modular or hierarchical design flows. These advanced flows enable preservation of design blocks (or logic that comprises a hierarchical design instance) within a project, and reuse of design blocks in other projects.
• **Intel Quartus Prime Pro Edition User Guide: Partial Reconfiguration**
  Describes Partial Reconfiguration, an advanced design flow that allows you to reconfigure a portion of the FPGA dynamically, while the remaining FPGA design continues to function. Define multiple personas for a particular design region, without impacting operation in other areas.

• **Intel Quartus Prime Pro Edition User Guide: Third-party Simulation**
  Describes RTL- and gate-level design simulation support for third-party simulation tools by Aldec*, Cadence*, Mentor Graphics, and Synopsys that allow you to verify design behavior before device programming. Includes simulator support, simulation flows, and simulating Intel FPGA IP.

• **Intel Quartus Prime Pro Edition User Guide: Third-party Synthesis**
  Describes support for optional synthesis of your design in third-party synthesis tools by Mentor Graphics, and Synopsys. Includes design flow steps, generated file descriptions, and synthesis guidelines.

• **Intel Quartus Prime Pro Edition User Guide: Third-party Logic Equivalence Checking Tools**
  Describes support for optional logic equivalence checking (LEC) of your design in third-party LEC tools by OneSpin*.

• **Intel Quartus Prime Pro Edition User Guide: Debug Tools**
  Describes a portfolio of Intel Quartus Prime Pro Edition in-system design debugging tools for real-time verification of your design. These tools provide visibility by routing (or "tapping") signals in your design to debugging logic. These tools include System Console, Signal Tap logic analyzer, Transceiver Toolkit, In-System Memory Content Editor, and In-System Sources and Probes Editor.

• **Intel Quartus Prime Pro Edition User Guide: Timing Analyzer**
  Explains basic static timing analysis principals and use of the Intel Quartus Prime Pro Edition Timing Analyzer, a powerful ASIC-style timing analysis tool that validates the timing performance of all logic in your design using an industry-standard constraint, analysis, and reporting methodology.

• **Intel Quartus Prime Pro Edition User Guide: Power Analysis and Optimization**
  Describes the Intel Quartus Prime Pro Edition Power Analysis tools that allow accurate estimation of device power consumption. Estimate the power consumption of a device to develop power budgets and design power supplies, voltage regulators, heat sink, and cooling systems.

• **Intel Quartus Prime Pro Edition User Guide: Design Constraints**
  Describes timing and logic constraints that influence how the Compiler implements your design, such as pin assignments, device options, logic options, and timing constraints. Use the Interface Planner to prototype interface implementations, plan clocks, and quickly define a legal device floorplan. Use the Pin Planner to visualize, modify, and validate all I/O assignments in a graphical representation of the target device.

• **Intel Quartus Prime Pro Edition User Guide: PCB Design Tools**
  Describes support for optional third-party PCB design tools by Mentor Graphics and Cadence*. Also includes information about signal integrity analysis and simulations with HSPICE and IBIS Models.

• **Intel Quartus Prime Pro Edition User Guide: Scripting**
  Describes use of Tcl and command line scripts to control the Intel Quartus Prime Pro Edition software and to perform a wide range of functions, such as managing projects, specifying constraints, running compilation or timing analysis, or generating reports.