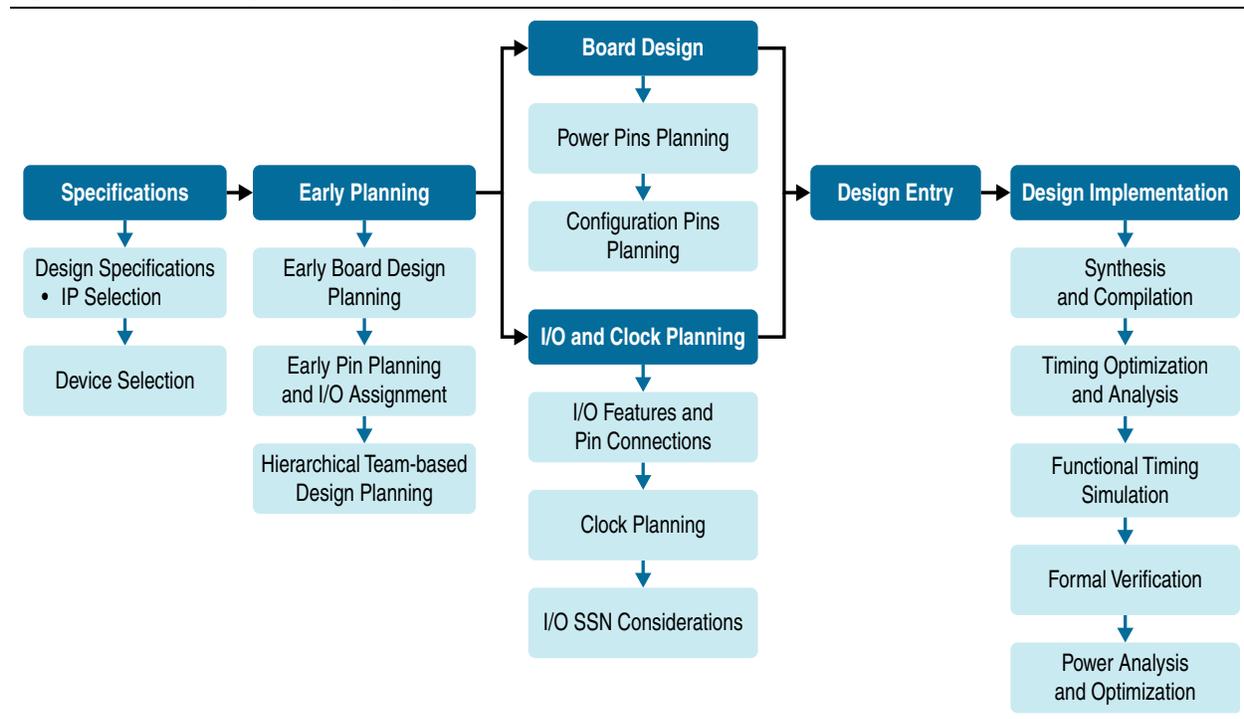


This application note provides a set of checklists that consist of design guidelines, recommendations, and factors to consider when you create designs using the Arria® V or Cyclone® V FPGAs.

- Use this document to help you plan the FPGA and system early in the design process, which is crucial for a successful design.
- Follow Altera’s recommendations throughout the design process to achieve good results, avoid common issues, and improve your design productivity.

Figure 1 shows the Arria V and Cyclone V design flow. The sections in this document provide the checklists and guidelines for each part of the design flow.

Figure 1. Arria V and Cyclone V Design Flow



For the Arria V and Cyclone V SoC device variants, the guidelines in this document are applicable only to the FPGA portion of the devices.

Before You Begin

Before you begin planning and designing your FPGA system, familiarize yourself with the FPGA device features, and the design tools and IP that are available for the Arria V or Cyclone V device family.

Table 1. Prerequisites Checklist (Part 1 of 2)

No.	✓ Checklist items
1.	<p data-bbox="505 485 1019 520"><input type="checkbox"/> <i>Read through the Device Overview of the FPGA</i></p> <p data-bbox="548 527 1421 621">The Device Overview provides an overview of the capabilities and options available for a device family. Read through the document to familiarize yourself with the device family offerings and general features.</p> <p data-bbox="548 632 1325 663">For an overview of each FPGA device family, refer to the following documents:</p> <ul style="list-style-type: none"> <li data-bbox="548 674 821 705">■ Arria V Device Overview <li data-bbox="548 716 850 747">■ Cyclone V Device Overview
2.	<p data-bbox="505 768 850 804"><input type="checkbox"/> <i>Estimate design requirements</i></p> <p data-bbox="548 810 1149 842">Create a rough estimate of the design in the following terms:</p> <ul style="list-style-type: none"> <li data-bbox="548 852 878 884">■ Basic functions of the product <li data-bbox="548 894 824 926">■ Similar previous designs <li data-bbox="548 936 862 968">■ General device requirements
3.	<p data-bbox="505 989 846 1024"><input type="checkbox"/> <i>Review available design tools</i></p> <p data-bbox="548 1031 1398 1094">Consider the available design, estimators, system builders, and verification tools. The following items are some of the available tools provided by Altera:</p> <ul style="list-style-type: none"> <li data-bbox="548 1104 1354 1167">■ The Quartus® II software for design, synthesis, simulation, and programming; including integration with Qsys, simulation tools, and verification tools. <li data-bbox="548 1178 1406 1262">■ The Qsys system integration tool—next generation SOPC Builder that automatically generates interconnect logic to connect intellectual property (IP) functions and subsystems. <li data-bbox="548 1272 1211 1304">■ The Mentor Graphics® ModelSim®-Altera® simulation software. <li data-bbox="548 1314 1421 1377">■ The TimeQuest Timing Analyzer for static timing analysis with support for Synopsys® Design Constraints (SDC) format. <li data-bbox="548 1388 1252 1419">■ The PowerPlay Power Analyzer for power analysis and optimization. <li data-bbox="548 1430 1235 1461">■ The SignalProbe and SignalTap II Logic Analyzer debugging tools. <li data-bbox="548 1472 1312 1503">■ The External Memory Interface Toolkit available in the Quartus II software. <li data-bbox="548 1514 1382 1545">■ The Transceiver Toolkit for real-time validation of transceiver link signal integrity. <p data-bbox="548 1556 1235 1587">For more information, visit the following pages on the Altera website:</p> <ul style="list-style-type: none"> <li data-bbox="548 1598 824 1629">■ Design Tools & Services <li data-bbox="548 1640 829 1671">■ Design Software Support <li data-bbox="548 1682 769 1713">■ Transceiver Toolkit <p data-bbox="548 1724 1421 1787">For a guideline to migrate from SOPC Builder to Qsys, refer to AN 632: SOPC Builder to Qsys Migration Guidelines.</p>

Table 1. Prerequisites Checklist (Part 2 of 2)

No.	✓	Checklist items
4.	<input type="checkbox"/>	<p><i>Review available IP</i></p> <p>Altera and its third-party IP partners offer a large selection of parameterized blocks of IP cores optimized for Altera devices that you can implement to reduce your implementation and verification time.</p> <p>Based on your estimated requirements, refer to the All Intellectual Property page on Altera's website to check if there are available IP that can provide the functions that you need.</p>

Design Specifications

Typically, the FPGA is an important part of the overall system and affects the rest of the system design. Use the following checklist to start your design process.

Table 2. Design Specifications Checklist (Part 1 of 2)

No.	✓	Checklist items
1.	<input type="checkbox"/>	<p><i>Create detailed design specifications</i></p> <p>Before you create your logic design or complete your system design, perform the following:</p> <ul style="list-style-type: none"> ■ Specify the I/O interfaces for the FPGA ■ Identify the different clock domains ■ Include a block diagram of basic design functions ■ Consider a common design directory structure—if your design includes multiple designers, a common design directory structure eases the design integration stages.
2.	<input type="checkbox"/>	<p><i>Create detailed functional verification or test plan</i></p> <p>A functional verification plan ensures the team knows how to verify the system. Creating a test plan at an early stage helps you design for testability and manufacturability.</p> <p>For example, if you plan to perform built-in-self test (BIST) functions to drive interfaces, you can plan to use a UART interface with a Nios® II processor inside the FPGA device.</p> <p>For more information, refer to "Review available on-chip debugging tools" on page 10.</p>
3.	<input type="checkbox"/>	<p><i>Select IP that affects system design, especially I/O interfaces</i></p> <p>Include intellectual property (IP) blocks in your detailed design specifications. Taking the time to create these specifications improves design efficiency.</p> <p>For a list of available IP offered by Altera and third-party IP partners, refer to the All Intellectual Property page on Altera's website.</p>

Table 2. Design Specifications Checklist (Part 2 of 2)

No.	✓	Checklist items
4.	<input type="checkbox"/>	<p><i>Ensure your board design supports the OpenCore Plus tethered mode</i></p> <p>You can program your FPGA and verify your design in hardware before you purchase an IP license by using the OpenCore Plus feature available for many IP cores. OpenCore Plus supports the following modes:</p> <ul style="list-style-type: none"> ■ Untethered—your design runs for a limited time. ■ Tethered—your design runs for the duration of the hardware evaluation period. This mode requires an Altera download cable connected to the JTAG port on your board and a host computer that runs the Quartus II Programmer. If you plan to use this mode, ensure that your board design supports this mode.
5.	<input type="checkbox"/>	<p><i>Review available system development tools</i></p> <p>For more information, visit the following pages on the Altera website:</p> <ul style="list-style-type: none"> ■ Design Tools & Services ■ Design Software Support

Device Selection

Use the following checklist to determine the device variant, density, and package combination that is suitable for your design.

Table 3. Device Selection Checklist (Part 1 of 3)

No.	✓	Checklist items
1.	<input type="checkbox"/>	<p><i>Consider the available device variants</i></p> <p>The Arria V and Cyclone V device families consist of several device variants that are optimized for different application requirements.</p> <p>Select a device based on transceivers, I/O pin count, LVDS channels, package offering, logic/memory/multiplier density, PLLs, clock routing, and speed grade.</p> <p>For more information, refer to the following documents:</p> <ul style="list-style-type: none"> ■ Arria V Device Overview ■ Cyclone V Device Overview
2.	<input type="checkbox"/>	<p><i>Estimate the required logic, memory, and multiplier density</i></p> <p>Arria V or Cyclone V devices offer a range of densities that provide different amounts of device logic resources. Determining the required logic density can be a challenging part of the design planning process. Devices with more logic resources can implement larger and potentially more complex designs but generally have a higher cost. Smaller devices have lower static power utilization.</p>

Table 3. Device Selection Checklist (Part 2 of 3)

No.	✓ Checklist items
3.	<p data-bbox="503 294 1421 325"><input type="checkbox"/> <i>Consider vertical device migration availability and requirements</i></p> <p data-bbox="503 336 1421 430">Determine whether you want the flexibility of migrating your design to another device density. Choose your device density and package to accommodate any possible future device migration to allow flexibility when the design nears completion.</p> <p data-bbox="503 441 1421 535">To verify the pin migration compatibility, use the Pin Migration View window in the Quartus II software Pin Planner. The Pin Migration View window helps you identify the difference in pins that can exist between migration devices:</p> <ul data-bbox="503 546 1421 735" style="list-style-type: none"> <li data-bbox="503 546 1421 640">■ If one device has pins for connection to V_{CC} or GND but are I/O pins on a different device, the Quartus II software ensures these pins are not used for I/O. For migration, ensure that these pins are connected to the correct PCB plane. <li data-bbox="503 651 1421 735">■ If you are migrating between two devices in the same package, connect the pins that are not connected to the smaller die to V_{CC} or GND on the larger die in your original design. <p data-bbox="503 745 1421 829">For more information about verifying the pin migration compatibility, refer to the “I/O Management” chapter of the <i>Quartus II Handbook</i>.</p>
4.	<p data-bbox="503 829 1421 861"><input type="checkbox"/> <i>Review resource utilization reports of similar designs</i></p> <p data-bbox="503 871 1421 997">If you have other designs that target an Altera device, you can use their resource utilization as an estimate for your new design. Coding style, device architecture, and optimization options used in the Quartus II software can significantly affect resource utilization and timing performance of a design.</p> <p data-bbox="503 1008 1421 1113">To estimate resource utilization for certain configurations of Altera’s IP designs, refer to the relevant Altera megafunctions and IP MegaCores user guides at the IP and Megafunctions page on the Altera website.</p>
5.	<p data-bbox="503 1113 1421 1144"><input type="checkbox"/> <i>Reserve device resources for future development and debugging</i></p> <p data-bbox="503 1155 1421 1291">Select a device that meets your design requirements with some safety margin in case you want to add more logic later in the design cycle, upgrade, or expand your design. You may also want additional space in the device to ease design floorplan creation for an incremental or team-based design.</p> <p data-bbox="503 1302 1421 1375">Consider reserving resources for debugging, as described in “Consider the guidelines to plan for debugging tools” on page 10.</p>
6.	<p data-bbox="503 1375 1421 1407"><input type="checkbox"/> <i>Estimate the number of I/O pins that you require</i></p> <p data-bbox="503 1417 1421 1522">Determine the required number of I/O pins for your application, considering the design’s interface requirements with other system blocks. You can compile any existing designs in the Quartus II software to determine how many I/O pins are used.</p> <p data-bbox="503 1533 1421 1659">Other factors can also affect the number of I/O pins required for a design, including simultaneous switching noise (SSN) concerns, pin placement guidelines, pins used as dedicated inputs, I/O standard availability for each I/O bank, differences between I/O standards and speed for row and column I/O banks, and package migration options.</p> <p data-bbox="503 1669 1421 1743">For more details about choosing pin locations, refer to relevant topics under “Board Design” on page 7 and “I/O and Clock Planning” on page 20.</p>
7.	<p data-bbox="503 1743 1421 1774"><input type="checkbox"/> <i>Consider the I/O pins you need to reserve for debugging</i></p> <p data-bbox="503 1785 1421 1858">Consider reserving I/O pins for debugging, as described in “Consider the guidelines to plan for debugging tools” on page 10.</p>

Table 3. Device Selection Checklist (Part 3 of 3)

No.	✓	Checklist items
8.	<input type="checkbox"/>	<p data-bbox="544 294 1079 325"><i>Verify that the number of LVDS channels are enough</i></p> <p data-bbox="544 336 1421 430">Larger densities and package pin counts offer more full-duplex LVDS channels for differential signaling. Ensure that your device density-package combination includes enough LVDS channels.</p>
9.	<input type="checkbox"/>	<p data-bbox="544 451 1096 483"><i>Verify the number of PLLs and clock routing resources</i></p> <p data-bbox="544 493 1421 588">Verify that your chosen device density package combination includes enough PLLs and clock routing resources for your design. GCLK resources are shared between certain PLLs, which can affect the inputs that are available for use.</p> <p data-bbox="544 598 1421 661">For more details and references regarding clock pins and global routing resources, refer to “I/O and Clock Planning” on page 20.</p>
10.	<input type="checkbox"/>	<p data-bbox="544 682 1055 714"><i>Determine the device speed grade that you require</i></p> <p data-bbox="544 724 1421 819">The device speed grade affects the device timing performance and timing closure, as well as power utilization. One way to determine which speed grade your design requires is to consider the supported clock rates for specific I/O interfaces.</p> <p data-bbox="544 829 1421 924">For information about supported clock rates for memory interfaces using I/O pins on different sides of the device in different device speed grades, use the estimator tool on the External Memory Interface Spec Estimator page.</p> <p data-bbox="544 934 1421 1050">You can use the fastest speed grade while prototyping to reduce compilation time because less time is spent optimizing the design to meet timing requirements. If the design meets the timing requirements, you can then move to a slower speed grade for production to reduce cost.</p> <p data-bbox="544 1060 1421 1092">For information about the available speed grades, refer to the following documents:</p> <ul data-bbox="544 1102 860 1176" style="list-style-type: none"> <li data-bbox="544 1102 828 1134">■ Arria V Device Datasheet <li data-bbox="544 1144 860 1176">■ Cyclone V Device Datasheet

Board Design

Use the checklists in this section as guidelines to design your board.

Early Board Design

Early planning allows the FPGA team to provide early information to PCB board and system designers.

Table 4. Early Board Design Planning Checklist (Part 1 of 5)

No.	✓	Checklist items
1.	<input type="checkbox"/>	<p data-bbox="544 590 987 621"><i>Review the available configuration schemes</i></p> <p data-bbox="544 632 1386 695">You can configure the Arria V or Cyclone V devices with one of several configuration schemes.</p> <p data-bbox="544 705 1365 793">For the list of available configuration schemes for each device family, refer to the “Enhanced Configuration and Configuration via Protocol” sections in the following documents:</p> <ul data-bbox="544 804 850 877" style="list-style-type: none"> <li data-bbox="544 804 821 835">■ <i>Arria V Device Overview</i> <li data-bbox="544 846 850 877">■ <i>Cyclone V Device Overview</i>
2.	<input type="checkbox"/>	<p data-bbox="544 905 850 936"><i>Select a configuration scheme</i></p> <p data-bbox="544 947 1419 1035">For information about the configuration schemes, the execution of the required configuration schemes, and the necessary and optional pin settings, including the MSEL pin settings, refer to the following documents:</p> <ul data-bbox="544 1045 1419 1119" style="list-style-type: none"> <li data-bbox="544 1045 1386 1077">■ <i>Configuration, Design Security, and Remote System Upgrades in Arria V Devices</i> <li data-bbox="544 1087 1419 1119">■ <i>Configuration, Design Security, and Remote System Upgrades in Cyclone V Devices</i> <p data-bbox="544 1129 1312 1192">For more information about selecting the configuration schemes, refer to the <i>Configuring Altera FPGAs</i> document.</p>

Table 4. Early Board Design Planning Checklist (Part 2 of 5)

No.	✓ Checklist items
3.	<p data-bbox="503 294 1412 325"> <input type="checkbox"/> <i>Consider the configuration device support and availability</i> </p> <ul style="list-style-type: none"> <li data-bbox="552 336 1412 451"> ■ All configuration schemes use a configuration device, a download cable, or an external controller (for example, a MAX[®] II device or microprocessor). For the active serial (AS) configuration scheme, you can use the Altera serial configuration devices (EPCS) and quad-serial configuration devices (EPCQ). <li data-bbox="552 472 1412 619"> ■ The Quartus II programmer supports configuration of devices directly using PS or JTAG interfaces with the USB-Blaster[™], EthernetBlaster II, or the ByteBlaster[™] II download cable. You can download design changes directly to the device and use the same download cable to program configuration devices on the board, and use JTAG debugging tools such as the SignalTap[™] II Embedded Logic Analyzer. <li data-bbox="552 640 1412 840"> ■ Serial configuration devices do not directly support the JTAG interface but you can program the device with JTAG download cables using the Serial FlashLoader (SFL) feature in the Quartus II software. This feature uses the FPGA as a bridge between the JTAG interface and the configuration device, allowing both devices to use the same JTAG interface. However, programming the EPCS using the SFL solution is slower than standard AS interface because it must configure the FPGA before programming EPCS or EPCQ configuration devices. <li data-bbox="552 861 1412 1039"> ■ If your system contains common flash interface (CFI) flash memory, you can use it for device configuration storage. You can program CFI flash memory devices through the JTAG interface with the parallel flash loader (PFL) megafunction in MAX II and MAX V devices. The PFL can also control configuration from the flash memory device to the Arria V or Cyclone V device and it supports data compression. PS and FPP configuration modes are supported using PFL. <li data-bbox="552 1060 1412 1197"> ■ Alternatively, you can use the Altera programming unit (APU), supported third-party programmers such as BP Microsystems and System General, or a microprocessor with the SRunner software driver—a software driver developed for embedded serial configuration device programming that designers can customize to fit in different embedded systems. <p data-bbox="552 1218 1412 1270"> For a list of documents about configuration devices, including the SRunner software and Altera download cables, refer to the Configuration Devices page on the Altera website. </p>

Table 4. Early Board Design Planning Checklist (Part 3 of 5)

No.	✓ Checklist items
4.	<p data-bbox="505 296 1287 327"><input type="checkbox"/> <i>Ensure the configuration scheme and board support the required features:</i></p> <ul style="list-style-type: none"> <li data-bbox="548 338 1427 489">■ Data decompression—if you enable data compression, the storage requirement and the time to transmit the configuration bitstream are reduced. The DCLK to DATA ratio changes accordingly, based on the selected FPP configuration scheme. For successful configuration, the configuration controller must send the DCLK that meets the DCLK to DATA ratio. <li data-bbox="548 499 1427 621">■ Design security—this feature utilizes a 256-bit security key. The devices can decrypt configuration bitstreams using the AES algorithm that is FIPS-197 certified. Design security is available for the FPP, AS, or PS configuration schemes but not available for the JTAG configuration scheme. <li data-bbox="548 632 1427 722">■ Remote system upgrade—this feature is supported only in the single-device AS configuration scheme with EPCS and EPCQ devices. To implement the remote system upgrade interface, use the ALTREMOTE_UPDATE megafunction. <li data-bbox="548 732 1427 884">■ SEU mitigation—dedicated circuitry in the devices perform cyclic redundancy check (CRC) error detection and optionally check for SEU errors automatically. To detect SEU errors, use the CRC_ERROR pin to flag errors and design your system to take appropriate action. If you do not enable the CRC error detection feature, you can also use the CRC_ERROR pin as a design I/O pin. <p data-bbox="548 894 1105 926">For more information, refer to the following documents:</p> <ul style="list-style-type: none"> <li data-bbox="548 936 1382 968">■ Configuration, Design Security, and Remote System Upgrades in Arria V Devices <li data-bbox="548 978 1414 1010">■ Configuration, Design Security, and Remote System Upgrades in Cyclone V Devices <li data-bbox="548 1020 1333 1052">■ Remote System Upgrade (ALTREMOTE_UPDATE) Megafunction User Guide <li data-bbox="548 1062 911 1094">■ SEU Mitigation in Arria V Devices <li data-bbox="548 1104 943 1136">■ SEU Mitigation in Cyclone V Devices
5.	<p data-bbox="505 1157 1390 1188"><input type="checkbox"/> <i>Plan for support of optional configuration pins (CLKUSR and INIT_DONE), if required</i></p> <p data-bbox="548 1199 1114 1230">You can enable the following optional configuration pins:</p> <ul style="list-style-type: none"> <li data-bbox="548 1241 1427 1392">■ CLKUSR—the Enable user-supplied start-up clock (CLKUSR) option allows you to select the clock source to use for initialization: the internal oscillator or an external clock provided on the CLKUSR pin. CLKUSR also allow you to drive the AS configuration clock (DCLK) at 125 MHz maximum. In the Quartus II software, enable this feature in the Configuration page of the Device and Pins Option dialog box. <li data-bbox="548 1402 1427 1587">■ INIT_DONE—you can monitor the INIT_DONE pin to check if the device has completed initialization and is in user mode. The INIT_DONE pin is an open drain output and requires an external pull-up to V_{CCPGM}. During reset, after the device exits POR and in the beginning of configuration, the INIT_DONE pin is tri-stated and pulled high by the external pull-up resistor. To enable the INIT_DONE pin, turn on the Enable INIT_DONE output option.
6.	<p data-bbox="505 1608 1117 1640"><input type="checkbox"/> <i>Plan for the Auto-restart after configuration error option</i></p> <p data-bbox="548 1650 1427 1820">To reset the device internally by driving the nSTATUS pin low when a configuration error occurs, enable the Auto-restart after configuration error option. The device releases its nSTATUS pin after the reset time-out period. This behavior allows you to re-initiate the configuration cycle. The nSTATUS pin requires an external 10-kΩ pull-up resistor to V_{CCPGM}.</p>

Table 4. Early Board Design Planning Checklist (Part 4 of 5)

No.	✓ Checklist items
7.	<p data-bbox="505 296 964 327"><input type="checkbox"/> <i>Review available on-chip debugging tools</i></p> <p data-bbox="548 338 1403 401">Take advantage of on-chip debugging features to analyze internal signals and perform advanced debugging techniques.</p> <p data-bbox="548 411 1419 533">Different debugging tools work better for different systems and different designers. Early planning can reduce the time spent debugging, and eliminates design changes later to accommodate your preferred debugging methodologies. Adding debug pins may not be enough, because of internal signal and I/O pin accessibility on the device.</p> <p data-bbox="548 543 1414 606">For more information about in-system debugging tools in the Quartus II software, refer to the following documents:</p> <ul data-bbox="548 617 1203 680" style="list-style-type: none"> <li data-bbox="548 617 1203 648">■ <i>System Debugging Tools Overview</i> in the <i>Quartus II Handbook</i> <li data-bbox="548 659 1138 690">■ <i>Virtual JTAG (sld_virtual_jtag) Megafunction User Guide</i>
8.	<p data-bbox="505 716 1060 747"><input type="checkbox"/> <i>Consider the guidelines to plan for debugging tools</i></p> <ul data-bbox="548 758 1419 1711" style="list-style-type: none"> <li data-bbox="548 758 1419 821">■ Select on-chip debugging schemes early to plan memory and logic requirements, I/O pin connections, and board connections. <li data-bbox="548 831 1419 953">■ If you want to use SignalProbe incremental routing, the SignalTap II Embedded Logic Analyzer, Logic Analyzer Interface, In-System Memory Content Editor, In-System Sources and Probes, or Virtual JTAG megafunction, plan your system and board with JTAG connections that are available for debugging. <li data-bbox="548 963 1419 1026">■ Plan for the small amount of additional logic resources used to implement the JTAG hub logic for JTAG debugging features. <li data-bbox="548 1037 1354 1100">■ For debugging with the SignalTap II Embedded Logic Analyzer, reserve device memory resources to capture data during system operation. <li data-bbox="548 1110 1403 1194">■ Reserve I/O pins for debugging with SignalProbe or the Logic Analyzer Interface so that you do not have to change the design or board to accommodate debugging signals later. <li data-bbox="548 1205 1419 1268">■ Ensure the board supports a debugging mode where debugging signals do not affect system operation. <li data-bbox="548 1278 1419 1341">■ Incorporate a pin header or micro connector as required for an external logic analyzer or mixed signal oscilloscope. <li data-bbox="548 1352 1403 1436">■ To use debug tools incrementally and reduce compilation time, ensure incremental compilation is on so you do not have to recompile the design to modify the debug tool. <li data-bbox="548 1446 1419 1509">■ To use the Virtual JTAG megafunction for custom debugging applications, instantiate it in the HDL code as part of the design process. <li data-bbox="548 1520 1419 1583">■ To use the In-System Sources and Probes feature, instantiate the megafunction in the HDL code. <li data-bbox="548 1593 1419 1711">■ To use the In-System Memory Content Editor for RAM or ROM blocks or the LPM_CONSTANT megafunction, turn on the Allow In-System Memory Content Editor option to capture and update content independently of the system clock option for the memory block in the MegaWizard Plug-In Manager.

Table 4. Early Board Design Planning Checklist (Part 5 of 5)

No.	✓ Checklist items
9.	<p data-bbox="505 296 1419 359"><input type="checkbox"/> <i>Use the PowerPlay Early Power Estimator (EPE) to estimate power supplies and cooling solution</i></p> <p data-bbox="548 369 1419 520">FPGA power consumption depends on logic design and is challenging to estimate during early board specification and layout. However, it is an important design consideration and must be estimated accurately to develop an appropriate power budget to design the power supplies, voltage regulators, decoupling capacitors, heat sink, and cooling system.</p> <p data-bbox="548 531 1419 682">Use the Altera PowerPlay EPE spreadsheet to estimate power, current, and device junction temperature before you have a complete design. The EPE calculates the estimated information based on device information, planned device resources, operating frequency, toggle rates, ambient temperature, heat sinks information, air flow, board thermal model, and other environmental considerations.</p> <ul data-bbox="548 693 1419 919" style="list-style-type: none"> <li data-bbox="548 693 1419 785">■ If you have an existing or partially-completed and compiled design—use the Generate PowerPlay Early Power Estimator File command in the Quartus II software to provide input to the EPE spreadsheet. <li data-bbox="548 795 1419 919">■ If you do not have an existing design—estimate manually the number of device resources used in your design and input into the EPE spreadsheet. If the device resources information changes during or after the design phase, your power estimation results will be less accurate. <p data-bbox="548 930 1419 1022">For more information, the EPE user guide, and to download the appropriate PowerPlay EPE spreadsheet for your device, visit the PowerPlay Early Power Estimators (EPE) and Power Analyzer page on the Altera website.</p> <p data-bbox="548 1033 1419 1096">For guidelines about proper power supply design, refer to “Use PDN tool to plan for power distribution and decoupling capacitor selection” on page 14.</p>
10.	<p data-bbox="505 1115 1419 1146"><input type="checkbox"/> <i>Review the transceiver design guidelines</i></p> <p data-bbox="548 1157 1419 1308">The Quartus II software support models for Arria V and Cyclone V transceivers takes into account the way designers use processors to handle data flow. In the Quartus II software, high-speed transceivers are represented by PHY IP cores. Instead of the PHY IP cores, the transceiver voltage, termination, and PLL settings are handled by the Quartus II Settings File (.qsf).</p> <p data-bbox="548 1318 1419 1381">For more information about the Arria V and Cyclone V transceivers, refer to the following documents:</p> <ul data-bbox="548 1392 1419 1465" style="list-style-type: none"> <li data-bbox="548 1392 1419 1423">■ Arria V Device Handbook, Volume 2: Transceivers <li data-bbox="548 1434 1419 1465">■ Cyclone V Device Handbook, Volume 2: Transceivers <p data-bbox="548 1476 1419 1598">PHY IP design is modular and uses standard interfaces. All PHY IP include an Avalon® Memory-Mapped (Avalon-MM) interface or conduit interface to access the control and status registers, and an Avalon Streaming (Avalon-ST) interface to connect to the MAC layer design for data transfer. For more information, refer to the following documents:</p> <ul data-bbox="548 1608 1419 1682" style="list-style-type: none"> <li data-bbox="548 1608 1419 1640">■ Altera Transceiver PHY IP Core User Guide <li data-bbox="548 1650 1419 1682">■ Avalon Interface Specifications <p data-bbox="548 1692 1419 1843">For a description of the requirements for simulating a transceiver design using the custom PHY IP core, moving to a design, and how to change settings in the .qsf, refer to the “Appendix: Stratix® V Transceiver Design Guidelines” section in the Stratix V Device Design Guidelines. The guidelines in the document are applicable to the Arria V and Cyclone V transceivers.</p>

Power Pin Connections

The Arria V and Cyclone V devices require various voltage supplies depending on your design requirements. Use the following checklist to design the board for the FPGA power pin connections.

Table 5. Power Pin Connections Checklist (Part 1 of 3)

No.	✓ Checklist items
1.	<p data-bbox="505 485 857 516"> <input type="checkbox"/> <i>Design the board for power-up</i> </p> <p data-bbox="548 527 1386 615"> The Arria V and Cyclone V devices support hot socketing (hot plug-in/hot swap) and power sequencing without the use of external devices. Consider the following guidelines: </p> <ul style="list-style-type: none"> <li data-bbox="548 632 1409 688"> ■ The output buffers are tri-stated with weak pull-up resistors enabled until the device is configured and configuration pins drive out. <li data-bbox="548 705 1414 821"> ■ Design the voltage power supply ramps to be monotonic—ensure that the minimum current requirement for the power-on-reset (POR) supplies is available during device power up. If the following voltages share the same power supply and there is not enough current available during power up, these results apply: <ul style="list-style-type: none"> <li data-bbox="576 835 1162 867"> ■ V_{CCIO}, V_{CCPD}, and V_{CCPGM}—the devices do not enter POR <li data-bbox="576 877 1057 909"> ■ V_{CCIO} and V_{CCPD}—the devices do not exit POR <li data-bbox="548 919 1414 1066"> ■ Set the POR delay to ensure power supplies are stable—use the MSEL pin settings to select between a typical POR delay of 4 ms or 100 ms. In both cases, you can extend the POR delay by using an external component to assert the $nSTATUS$ pin low. To ensure the device configures properly and enters user mode, extend the POR delay if the board cannot meet the maximum power ramp time specifications. <li data-bbox="548 1077 1398 1134"> ■ For the device to exit POR, you must power the V_{CCBAT} power supply even if you do not use the volatile key. <li data-bbox="548 1144 1406 1270"> ■ Design power sequencing and voltage regulators for the best device reliability—although power sequencing is not required for correct operation, consider the power-up timing of each rail to prevent excessive transient current on power rails if you are designing a multi-rail powered system. <li data-bbox="548 1281 1414 1465"> ■ Connect the GND between boards before connecting the power supplies—Altera uses GND as a reference for hot-socketing operations and I/O buffer designs. Connecting the GND between boards before connecting the power supplies prevents the GND on your board from being pulled up inadvertently by a path to power through other components on your board. A pulled up GND could otherwise cause an out-of-specification I/O voltage or current condition with the device. <p data-bbox="548 1476 1105 1507"> For more information, refer to the following documents: </p> <ul style="list-style-type: none"> <li data-bbox="548 1518 959 1549"> ■ Power Management in Arria V Devices <li data-bbox="548 1560 992 1591"> ■ Power Management in Cyclone V Devices <li data-bbox="548 1602 1057 1633"> ■ Arria V Device Family Pin Connection Guidelines <li data-bbox="548 1644 1089 1675"> ■ Cyclone V Device Family Pin Connection Guidelines <li data-bbox="548 1686 1382 1717"> ■ Configuration, Design Security, and Remote System Upgrades in Arria V Devices <li data-bbox="548 1728 1414 1759"> ■ Configuration, Design Security, and Remote System Upgrades in Cyclone V Devices

Table 5. Power Pin Connections Checklist (Part 2 of 3)

No.	✓ Checklist items
2.	<input type="checkbox"/> <i>Review the list of required supply voltages</i> For a list of the required supply voltages and the recommended operating conditions, refer to the following documents: <ul style="list-style-type: none"> ■ Arria V Device Datasheet ■ Cyclone V Device Datasheet
3.	<input type="checkbox"/> <i>Ensure I/O power pin compatibility with I/O standards</i> The output pins of the devices will not conform to the I/O standard specifications if the V_{CCIO} level is out of the recommended operating range of the I/O standard. For a complete list of the supported I/O standards and V_{CCIO} voltages, refer to the following documents: <ul style="list-style-type: none"> ■ I/O Features in Arria V Devices ■ I/O Features in Cyclone V Devices
4.	<input type="checkbox"/> <i>Ensure correct power pin connections</i> <ul style="list-style-type: none"> ■ Connect all power pins correctly as specified in the following documents: <ul style="list-style-type: none"> ■ Arria V Device Family Pin Connection Guidelines ■ Cyclone V Device Family Pin Connection Guidelines ■ Connect V_{CCIO} pins and V_{REF} pins to support the I/O standards of each bank. ■ For unused supplies, consider whether there is a need to ground, open, or retain the power connection.
5.	<input type="checkbox"/> <i>Determine power rail sharing</i> <ul style="list-style-type: none"> ■ Explore unique requirements for FPGA power pins or other power pins on your board, and determine which devices on your board can share a power rail. It is especially important for you to consider the power supply sharing ability of devices from different device families. ■ Follow the suggested power supply sharing and isolation guidance, and the specific guidelines for each pin in the following documents: <ul style="list-style-type: none"> ■ Arria V Device Family Pin Connection Guidelines ■ Cyclone V Device Family Pin Connection Guidelines ■ AN 583: Designing Power Isolation Filters with Ferrite Beads for Altera FPGAs

Table 5. Power Pin Connections Checklist (Part 3 of 3)

No.	✓ Checklist items
6.	<p data-bbox="503 294 1412 325"><input type="checkbox"/> <i>Use PDN tool to plan for power distribution and decoupling capacitor selection</i></p> <p data-bbox="503 336 1412 399">Arria V and Cyclone V devices include embedded on-package and on-die decoupling capacitors to provide high-frequency decoupling.</p> <p data-bbox="503 409 1412 598">To plan power distribution and return currents from the voltage regulating module (VRM) to the FPGA power supplies, you can use the power distribution network (PDN) design tool that optimizes the board-level PDN graphically. Although you can use SPICE simulation to simulate the circuit, the PDN design tool provides a fast, accurate, and interactive way to determine the right number of decoupling capacitors for optimal cost and performance trade-off.</p> <p data-bbox="503 609 1412 640">Download the appropriate PDN tool and documentation from the Altera website:</p> <ul data-bbox="503 651 1412 871" style="list-style-type: none"> <li data-bbox="503 651 1412 714">■ Power Delivery Network (PDN) Tool Version 12.0 for Arria V, Cyclone V, Cyclone IV, and Arria II GZ Devices <li data-bbox="503 724 1412 787">■ AN 574: Printed Circuit Board (PCB) Power Delivery Network (PDN) Design Methodology <li data-bbox="503 798 1412 829">■ Device-Specific Power Delivery Network (PDN) Tool User Guide <li data-bbox="503 840 1412 871">■ Power Delivery Network (PDN) Tool User Guide (device agnostic)
7.	<p data-bbox="503 882 1412 913"><input type="checkbox"/> <i>Review the following guidelines for PLL board design</i></p> <ul data-bbox="503 924 1412 1155" style="list-style-type: none"> <li data-bbox="503 924 1412 987">■ Connect all PLL power pins to reduce noise even if the design does not use all the PLLs. For pin voltage requirements, refer to the following documents: <ul data-bbox="503 997 1412 1071" style="list-style-type: none"> <li data-bbox="503 997 1412 1029">■ Arria V Device Family Pin Connection Guidelines <li data-bbox="503 1039 1412 1071">■ Cyclone V Device Family Pin Connection Guidelines <li data-bbox="503 1081 1412 1155">■ Power supply nets should be provided by an isolated power plane, a power plane cut out, or a thick trace.
8.	<p data-bbox="503 1165 1412 1197"><input type="checkbox"/> <i>Review the transceiver design guidelines</i></p> <p data-bbox="503 1207 1412 1270">For more information about the Arria V and Cyclone V transceivers, refer to the following documents:</p> <ul data-bbox="503 1281 1412 1438" style="list-style-type: none"> <li data-bbox="503 1281 1412 1312">■ Arria V Device Handbook, Volume 2: Transceivers <li data-bbox="503 1323 1412 1354">■ Cyclone V Device Handbook, Volume 2: Transceivers <li data-bbox="503 1365 1412 1396">■ Altera Transceiver PHY IP Core User Guide <li data-bbox="503 1407 1412 1438">■ Avalon Interface Specifications <p data-bbox="503 1449 1412 1596">For a description of the requirements for simulating a transceiver design using the custom PHY IP core, moving to a design, and how to change settings in the <code>.qsf</code>, refer to the “Appendix: Stratix V Transceiver Design Guidelines” section in the Stratix V Device Design Guidelines. The guidelines in the document are applicable to the Arria V and Cyclone V transceivers.</p>

Configuration Pin Connections

Depending on your configuration scheme, different pull-up or pull-down resistor, signal integrity, and specific pin requirements apply. Connecting the configurations pins correctly is important. Use the following checklist to address common issues.

Table 6. Configuration Pin Connections Checklist (Part 1 of 3)

No.	✓	Checklist items
1.	<input type="checkbox"/>	<p><i>Verify configuration pin connections and pull-up or pull-down resistors are correct for your configuration schemes</i></p> <p>For specifics about each configuration pin, refer to the following documents:</p> <ul style="list-style-type: none"> ■ Arria V Device Family Pin Connection Guidelines ■ Cyclone V Device Family Pin Connection Guidelines
2.	<input type="checkbox"/>	<p><i>Design configuration DCLK and TCK pins to using the same technique as in designing high-speed signal or system clock</i></p> <ul style="list-style-type: none"> ■ Noise on the TCK signal can affect JTAG configuration. ■ Noisy DCLK signal can affect configuration and cause a CRC error. ■ For a chain of devices, noise on the TCK or DCLK pins in the chain can cause JTAG programming or configuration to fail for the entire chain.
3.	<input type="checkbox"/>	<p><i>Verify the JTAG pins are connected to a stable voltage level if not in use</i></p> <p>JTAG configuration takes precedence over all configuration methods. If you do not use the JTAG interface, do not leave the JTAG pins floating or toggling during configuration.</p>
4.	<input type="checkbox"/>	<p><i>Verify the JTAG pin connections to the download cable header</i></p> <p>A device operating in JTAG mode uses the required TDI, TDO, TMS, and TCK pins, and the optional TRST pin. The TCK pin has an internal weak pull-down resistor. The TDI, TMS, and TRST pins have weak internal pull-up resistors. The JTAG output pin (TDO) and all JTAG input pins are powered by the 2.5 or 3.0-V V_{CCPD}.</p>
5.	<input type="checkbox"/>	<p><i>Review the following JTAG pin connections guidelines:</i></p> <ul style="list-style-type: none"> ■ If you have multiple devices in the chain, connect the TDO pin of a device to the TDI pin of the next device in the chain. ■ Noise on the JTAG pins during configuration, user mode, or power-up can cause the device to go into an undefined state or mode. ■ To disable the JTAG state machine during power-up, pull the TCK pin low through a 1-kΩ resistor to ensure that an unexpected rising edge does not occur on TCK. ■ Pull TMS and TDI high through a 1-kΩ to 10-kΩ resistor. ■ Connect TRST directly to V_{CCPD}. Connecting the pin low disables the JTAG circuitry.

Table 6. Configuration Pin Connections Checklist (Part 2 of 3)

No.	✓ Checklist items
6.	<p data-bbox="505 296 1203 327"><input type="checkbox"/> <i>Ensure the download cable and JTAG pin voltages are compatible</i></p> <p data-bbox="548 338 1419 464">The download cable interfaces with the JTAG pins of your device. The operating voltage supplied to the Altera download cable by the target board through the 10-pin header determines the operating voltage level of the download cable. The JTAG pins are powered by V_{CCPD}.</p> <p data-bbox="548 474 1419 600">In a JTAG chain containing devices with different V_{CCIO} levels, the devices with a higher V_{CCIO} level should drive the devices with the same or lower V_{CCIO} level. A one-level shifter is required at the end of the chain with this device arrangement. If this arrangement is not possible, you have to add more level shifters into the chain.</p> <p data-bbox="548 611 1419 663">For recommendations about connecting a JTAG chain with multiple voltages across the devices in the chain, refer to the following documents:</p> <ul data-bbox="548 674 1084 747" style="list-style-type: none"> <li data-bbox="548 674 1052 705">■ JTAG Boundary-Scan Testing in Arria V Devices <li data-bbox="548 716 1084 747">■ JTAG Boundary-Scan Testing in Cyclone V Devices
7.	<p data-bbox="505 768 1154 800"><input type="checkbox"/> <i>Buffer the JTAG signal according to the following guidelines:</i></p> <ul data-bbox="548 810 1419 1052" style="list-style-type: none"> <li data-bbox="548 810 1419 873">■ If a cable drives three or more devices, buffer the JTAG signal at the cable connector to prevent signal deterioration. <li data-bbox="548 884 1419 947">■ Anything added to the board that affects the inductance or capacitance of the JTAG signals increases the likelihood that a buffer should be added to the chain. <li data-bbox="548 957 1419 1052">■ Each buffer should drive no more than eight loads for the TCK and TMS signals, which drive in parallel. If jumpers or switches are added to the path, decrease the number of loads.
8.	<p data-bbox="505 1073 1084 1104"><input type="checkbox"/> <i>Ensure all devices in the chain are connected properly</i></p> <p data-bbox="548 1115 1419 1178">If your device is in a configuration chain, ensure all devices in the chain are connected properly.</p>
9.	<p data-bbox="505 1199 1390 1230"><input type="checkbox"/> <i>Ensure that the MSEL pins are not left floating and do not use weak pull-up resistors</i></p> <ul data-bbox="548 1241 1419 1377" style="list-style-type: none"> <li data-bbox="548 1241 1179 1272">■ Connect the MSEL pins directly to the power or GND planes. <li data-bbox="548 1283 1227 1314">■ If you are using pull-up or pull-down resistors, use $0\text{-}\Omega$ resistors. <li data-bbox="548 1325 1419 1388">■ If the MSEL pins are floating or weakly pulled, you may not be able to configure the device.
10.	<p data-bbox="505 1409 1149 1440"><input type="checkbox"/> <i>Review the following guidelines for other configuration pins:</i></p> <ul data-bbox="548 1451 1419 1598" style="list-style-type: none"> <li data-bbox="548 1451 1419 1482">■ Hold the nCE (chip enable) pin low during configuration, initialization, and user mode: <ul data-bbox="578 1493 1419 1598" style="list-style-type: none"> <li data-bbox="578 1493 1263 1524">■ In single device configuration or JTAG programming—tie nCE low <li data-bbox="578 1535 1419 1598">■ In multi-device configuration chain—tie nCE low on the first device and connect the $nCEO$ pin of the first device to the nCE pin of the next device

Table 6. Configuration Pin Connections Checklist (Part 3 of 3)

No.	✓	Checklist items
11.	<input type="checkbox"/>	<p data-bbox="548 296 1138 327"><i>Determine if you need to turn on device-wide output enable</i></p> <p data-bbox="548 338 1427 432">The Arria V or Cyclone V device support an optional chip-wide output enable that allows you to override all tri-states on the device I/Os. When the <code>DEV_OE</code> pin is driven low, all I/O pins are tri-stated; when this pin is driven high, all pins behave as programmed.</p> <p data-bbox="548 443 980 474">To use the chip-wide output enable feature:</p> <ul style="list-style-type: none"> <li data-bbox="548 485 1427 579">■ Turn on Enable device-wide output enable (DEV_OE) under the General category of the Device and Pin Options dialog box in the Quartus II software before compiling your design <li data-bbox="548 590 1289 621">■ Ensure that the <code>DEV_OE</code> pin is driven to a valid logic level on your board <li data-bbox="548 632 938 663">■ Do not leave the <code>DEV_OE</code> pin floating

General I/O Pin Connections

Use the following checklist to plan your general I/O pin connections and to improve signal integrity.

Table 7. General I/O Pin Connections Checklist (Part 1 of 4)

No.	✓	Checklist items
1.	<input type="checkbox"/>	<p data-bbox="548 978 1284 1010"><i>Specify the state of unused I/O pins according to the following guidelines:</i></p> <ul style="list-style-type: none"> <li data-bbox="548 1020 1427 1115">■ To reduce power dissipation, set clock pins and other unused I/O pins As inputs tri-stated. By default, the Quartus II software set the input pins tri-stated with weak pull-up resistor enabled. <li data-bbox="548 1125 1427 1304">■ To improve signal integrity, in the Reserve all unused pins option under the Unused Pins category of the Device and Pin Options dialog box of the Quartus II software, set the unused pins As output driving ground. This setting reduces inductance by creating a shorter return path and reduces noise on the neighboring I/Os. However, do not use this approach if it results in many via paths that causes congestion for signals under the device. <li data-bbox="548 1314 1427 1440">■ Carefully check the pin connections in the pin report file (<code>.pin</code>) generated by the Quartus II software when you compile your design. The <code>.pin</code> specifies how you should connect the device pins. I/O pins specified as GND can be left unconnected or connected to ground for improved noise immunity. Do not connect <code>RESERVED</code> pins.

Table 7. General I/O Pin Connections Checklist (Part 2 of 4)

No.	✓ Checklist items
2.	<p data-bbox="505 300 980 323"> <input type="checkbox"/> <i>Refer to the Board Design Resource Center</i> </p> <p data-bbox="548 338 1419 470"> If your design has high-speed signals, especially with Arria V or Cyclone V high-speed transceivers, the board design has a major impact on the signal integrity in the system. For detailed information about signal integrity and board design, refer to the Board Design Resource Center on the Altera website. </p> <p data-bbox="548 485 1419 541"> For example, Altera provides the following application notes that offer information about high-speed board stack-up and signal routing layers: </p> <ul data-bbox="548 556 1382 724" style="list-style-type: none"> <li data-bbox="548 556 1382 613">■ AN 528: PCB Dielectric Material Selection and Fiber Weave Effect on High-Speed Channel Routing <li data-bbox="548 627 1279 655">■ AN 529: Via Optimization Techniques for High-Speed Channel Designs <li data-bbox="548 669 1382 724">■ AN 530: Optimizing Impedance Discontinuity Caused by Surface Mount Pads for High-Speed Channel Designs <p data-bbox="548 739 1419 835"> You can also refer to the I/O Management, Board Development Support, and Signal Integrity Analysis Resource Center on the Altera website for board-level signal integrity information related to the Quartus II software. </p>
3.	<p data-bbox="505 856 889 879"> <input type="checkbox"/> <i>Design VREF pins to be noise free</i> </p> <p data-bbox="548 894 1419 989"> Voltage deviation on a VREF pin can affect the threshold sensitivity for inputs. For more information about VREF pins and I/O standards, refer to “I/O Features and Pin Connections” on page 21. </p>
4.	<p data-bbox="505 1010 1068 1033"> <input type="checkbox"/> <i>Refer to the Board Design Guideline Solution Center</i> </p> <p data-bbox="548 1056 1419 1150"> Noise generated by SSN—when too many pins in close proximity change voltage levels at the same time—can reduce the noise margin and cause incorrect switching. For example, consider these board layout recommendations: </p> <ul data-bbox="548 1165 1409 1262" style="list-style-type: none"> <li data-bbox="548 1165 1409 1192">■ Break out large bus signals on board layers close to the device to reduce cross talk. <li data-bbox="548 1207 1409 1262">■ If possible, route traces orthogonally if two signal layers are next to each other, and use a separation of two to three times the trace width. <p data-bbox="548 1276 1419 1333"> For more board layout recommendations that can help with noise reduction, refer to the PCB guidelines in the Board Design Guidelines Solution Center on the Altera website. </p> <p data-bbox="548 1348 1419 1398"> For a list of recommendations for I/O and clock connections, refer to “I/O Simultaneous Switching Noise” on page 29. </p>

Table 7. General I/O Pin Connections Checklist (Part 3 of 4)

No.	✓ Checklist items
5.	<p data-bbox="505 296 1019 327"><input type="checkbox"/> <i>Verify I/O termination and impedance matching</i></p> <p data-bbox="548 338 1403 428">Voltage-referenced I/O standards require both a VREF and a termination voltage (V_{TT}). The reference voltage of the receiving device tracks the termination voltage of the transmitting device. Consider the following items:</p> <ul data-bbox="548 443 1419 764" style="list-style-type: none"> <li data-bbox="548 443 1419 533">■ Each voltage-referenced I/O standard requires a unique termination setup. For example, a proper resistive signal termination scheme is critical in SSTL-2 standards to produce a reliable DDR memory system with superior noise margin. <li data-bbox="548 548 1419 638">■ Although single-ended, non-voltage-referenced I/O standards do not require termination, impedance matching is necessary to reduce reflections and improve signal integrity. <li data-bbox="548 653 1419 764">■ Differential I/O standards typically require a termination resistor between the two signals at the receiver. The termination resistor must match the differential load impedance of the signal line. Arria V and Cyclone V devices provide an optional differential on-chip resistor when using LVDS. <p data-bbox="548 779 1403 869">The Arria V and Cyclone V on-chip series and parallel termination provides the convenience of no external components. You can also use external pull-up resistors to terminate the voltage-referenced I/O standards such as SSTL and HSTL.</p> <p data-bbox="548 884 1403 940">For a complete list of on-chip termination (OCT) support for each I/O standard, refer to the following documents:</p> <ul data-bbox="548 955 915 1024" style="list-style-type: none"> <li data-bbox="548 955 915 982">■ <i>I/O Features in Arria V Devices</i> <li data-bbox="548 997 915 1024">■ <i>I/O Features in Cyclone V Devices</i>
6.	<p data-bbox="505 1052 1110 1083"><input type="checkbox"/> <i>Perform full board routing simulation using IBIS models</i></p> <p data-bbox="548 1094 1419 1184">To ensure that the I/O signaling meets receiver threshold levels on your board setup, perform full board routing simulation with third-party board-level simulation tools using an IBIS model.</p> <p data-bbox="548 1199 1403 1289">To select the IBIS output in the Quartus II software, on the Assignments menu, click Settings. Navigate to the Board-Level page of the EDA Tool Settings category. Under the Board-level signal integrity analysis section, in the Format option, select IBIS.</p> <p data-bbox="548 1304 1354 1360">For more information, refer to the <i>Signal Integrity Analysis with Third-Party Tools</i> chapter of the <i>Quartus II Handbook</i>.</p>
7.	<p data-bbox="505 1388 1240 1419"><input type="checkbox"/> <i>Configure board trace models for Quartus II advanced timing analysis</i></p> <p data-bbox="548 1430 1419 1520">The signal integrity and board routing propagation delay is important for you to design proper system operation. If you use an FPGA with high-speed interfaces in your board design, analyze the board level timing as part of the I/O and board planning.</p> <p data-bbox="548 1535 1419 1688">To generate a more accurate I/O delays and extra reports to gain better insights into the signal behavior at the system level, turn on Enable Advanced I/O Timing under the TimeQuest Timing Analyzer category in the Settings dialog box of your Quartus II project. With this option turned on, the TimeQuest Timing Analyzer uses simulation results for the I/O buffer, package, and board trace model to generate the I/O delays.</p> <p data-bbox="548 1703 1338 1759">You can use the advanced timing reports as a guide to make changes to the I/O assignments and board design to improve timing and signal integrity.</p>

Table 7. General I/O Pin Connections Checklist (Part 4 of 4)

No.	✓ Checklist items
8.	<input type="checkbox"/> <i>Review your pin connections</i> Altera provides schematic review worksheets based on the device Pin Connection Guidelines and other board-level pin connections literature that you need to consider when you finalize your schematics. Use the following worksheets to help you find mistakes in your schematic and adhere to Altera's guidelines: <ul style="list-style-type: none"> ■ Arria V Device Schematic Review Worksheet ■ Cyclone V Schematic Review Worksheet

I/O and Clock Planning

Use the checklists in this section as guidelines to plan your I/O and clocking.

Early Pin Planning and I/O Assignment Analysis

In many design environments, FPGA designers want to plan top-level FPGA I/O pins early so that board designers can start developing the PCB design and layout.

Table 8. Early Pin Planning and I/O Assignment Analysis Checklist (Part 1 of 2)

No.	✓ Checklist items
1.	<input type="checkbox"/> <i>Verify pin locations in the FPGA place-and-route software early</i> The FPGA I/O capabilities and board layout guidelines influence pin locations and other types of assignments. Starting FPGA pin planning early improves the confidence in early board layouts, reduces the chance of error, and improves the overall time-to-market.

Table 8. Early Pin Planning and I/O Assignment Analysis Checklist (Part 2 of 2)

No.	✓ Checklist items
2.	<p data-bbox="505 296 1328 327"> <input type="checkbox"/> <i>Use the Quartus II Pin Planner for I/O pin planning, assignment, and validation</i> </p> <p data-bbox="548 338 1417 428"> Early in the design process, the system architect typically has information about the standard I/O interfaces (such as memory and bus interfaces), IP cores to be used in the design, and any other I/O-related assignments defined by system requirements. </p> <p data-bbox="548 443 1417 499"> You can use the Quartus II Pin Planner for I/O pin assignment planning, assignment, and validation: </p> <ul data-bbox="548 514 1417 1052" style="list-style-type: none"> <li data-bbox="548 514 1417 604">■ The Quartus II Start I/O Assignment Analysis command checks that the pin locations and assignments are supported in the target FPGA architecture. Checks include reference voltage pin usage, pin location assignments, and mixing of I/O standards. <li data-bbox="548 619 1417 676">■ You can use I/O Assignment Analysis to validate I/O-related assignments that you make or modify throughout the design process. <li data-bbox="548 690 1417 781">■ The Create/Import Megafunction feature of the Pin Planner interfaces with the MegaWizard Plug-In Manager, and enables you to create or import custom megafunctions and IP cores that use I/O interfaces. <li data-bbox="548 795 1417 886">■ Enter PLL and LVDS blocks, including options such as dynamic phase alignment (DPA) because the options affect the pin placement rules. Then, use the Create Top-Level Design File command to generate a top-level design netlist file. <li data-bbox="548 900 1417 991">■ You can use the I/O analysis results to change pin assignments or IP parameters and repeat the checking process until the I/O interface meets your design requirements and passes the pin checks in the Quartus II software. <li data-bbox="548 1005 1417 1052">■ You can create a transceiver instance together with its interface and check the transceiver pin or bank placement. <p data-bbox="548 1066 1417 1123"> After planning is complete, you can pass the preliminary pin location information to PCB designers. </p> <p data-bbox="548 1138 1417 1194"> After the design is complete, you can use the reports and messages generated by the Quartus II Fitter for the final sign-off of the pin assignments. </p> <p data-bbox="548 1209 1417 1268"> For more information about I/O assignment and analysis, refer to the <i>I/O Management</i> chapter of the Quartus II Handbook. </p>

I/O Features and Pin Connections

Use the checklist in this section for guidelines related to I/O features and pin connections:

- Support for different I/O signal types and I/O standards in device I/O banks, and other I/O features available for your design
- Information about memory interfaces, pad placement guidelines, and special pin connections



For a list of I/O pin locations and connection guidelines, refer to the following documents:

- *Arria V Device Family Pin Connection Guidelines*

■ *Cyclone V Device Family Pin Connection Guidelines*

Table 9. I/O Features and Pin Connections Checklist (Part 1 of 5)

No.	✓ Checklist items
1.	<input type="checkbox"/> <i>Determine if your system requires single-ended I/O signaling</i> <ul style="list-style-type: none"> ■ Single-ended I/O signaling provides a simple rail-to-rail interface. ■ The speed is limited by the large voltage swing and noise. ■ Single-ended I/Os do not require termination, unless reflection in the system causes undesirable effects.
2.	<input type="checkbox"/> <i>Determine if your system requires voltage-referenced signaling</i> <ul style="list-style-type: none"> ■ Voltage-referenced signaling reduces the effects of simultaneous switching outputs (SSO) from pins changing voltage levels at the same time (for example, external memory interface data and address buses). ■ Voltage-referenced signaling provides an improved logic transition rate with a reduced voltage swing, and minimizes noise caused by reflection with a termination requirement. ■ Additional termination components are required for the reference voltage source (V_{TT}).
3.	<input type="checkbox"/> <i>Determine if your system requires differential signaling</i> <ul style="list-style-type: none"> ■ Differential signaling eliminates the interface performance barrier of single-ended and voltage-referenced signaling, with superior speed using an additional inverted closely-coupled data pair. ■ Differential signaling avoids the requirement for a clean reference voltage. This is possible because of lower swing voltage and noise immunity with a common mode noise rejection capability. ■ Considerations for this implementation include the requirements for a dedicated PLL to generate a sampling clock, and matched trace lengths to eliminate the phase difference between an inverted and non-inverted pair. ■ Allow the software to assign locations for the negative pin in differential pin pairs.
4.	<input type="checkbox"/> <i>Select a suitable signaling type and I/O standard for each I/O pin</i> Ensure that the appropriate I/O standard support is supported in the targeted I/O bank. For more information, refer to the following documents: <ul style="list-style-type: none"> ■ <i>I/O Features in Arria V Devices</i> ■ <i>High-Speed Differential I/O Interfaces and DPA in Arria V Devices</i> ■ <i>I/O Features in Cyclone V Devices</i>
5.	<input type="checkbox"/> <i>Place I/O pins that share voltage levels in the same I/O bank</i> <ul style="list-style-type: none"> ■ Certain I/O banks on support different I/O standards and voltage levels. ■ You can assign I/O standards and make other I/O-related settings in the Pin Planner. ■ Use the correct dedicated pin inputs for signals such as clocks and global control signals.

Table 9. I/O Features and Pin Connections Checklist (Part 2 of 5)

No.	✓ Checklist items
6.	<input type="checkbox"/> <i>Verify that all output signals in each I/O bank are intended to drive out at the bank's V_{CCIO} voltage level</i> <ul style="list-style-type: none"> ■ The board must supply each bank with one V_{CCIO} voltage level for every V_{CCIO} pin in a bank. ■ Each I/O bank is powered by the V_{CCIO} pins of that particular bank and is independent of the V_{CCIO} of other I/O banks. ■ A single I/O bank supports output signals that are driving at the same voltage as the V_{CCIO}. ■ An I/O bank can simultaneously support any number of input signals with different I/O standards.
7.	<input type="checkbox"/> <i>Verify that all voltage-referenced signals in each I/O bank are intended to use the bank's VREF voltage</i> <ul style="list-style-type: none"> ■ To accommodate voltage-referenced I/O standards, each I/O bank supports multiple VREF pins feeding a common VREF bus. Set the VREF pins to the correct voltage for the I/O standards in the bank. ■ Each I/O bank can only have a single V_{CCIO} voltage level and a single VREF voltage level at a given time. If the VREF pins are not used as voltage references, the pins cannot be used as generic I/O pins and must be tied to the V_{CCIO} of that same bank or GND. ■ An I/O bank, including single-ended or differential standards, can support voltage-referenced standards as long as all voltage-referenced standards use the same VREF setting. ■ For performance reasons, voltage-referenced input standards use their own V_{CCPD} level as the power source. You can place voltage-referenced input signals in a bank with a V_{CCIO} of 2.5 V or below. ■ Voltage-referenced bidirectional and output signals must drive out at the V_{CCIO} voltage level of the I/O bank.
8.	<input type="checkbox"/> <i>Check the I/O bank support for LVDS and transceiver features</i> <p>Different I/O banks include different support for LVDS signaling. The Arria V and Cyclone V transceiver banks include additional support.</p> <p>For more information, refer to the following documents:</p> <ul style="list-style-type: none"> ■ High-Speed Differential I/O Interfaces and DPA in Arria V Devices ■ Transceiver Architecture in Arria V Devices ■ I/O Features in Cyclone V Devices ■ Transceiver Architecture in Cyclone V Devices
9.	<input type="checkbox"/> <i>Verify the usage of the VREF pins that are used as regular I/Os</i> <p>VREF pins have higher pin capacitance that results in a different I/O timing:</p> <ul style="list-style-type: none"> ■ Do not use these pins in a grouped interface such as a bus. ■ Do not use these pins for high edge rate signals such as clocks.

Table 9. I/O Features and Pin Connections Checklist (Part 3 of 5)

No.	✓ Checklist items
10.	<p data-bbox="503 294 1412 357"><input type="checkbox"/> <i>Use the UniPHY megafunction (or IP core) for each memory interface, and follow connection guidelines</i></p> <p data-bbox="503 367 1412 514">The self-calibrating UniPHY megafunction is optimized to take advantage of the Arria V or Cyclone V I/O structure. The UniPHY megafunction allows you to set external memory interface features and helps set up the physical interface (PHY) best suited for your system. When you use the Altera memory controller MegaCore functions, the UniPHY megafunction is instantiated automatically.</p> <p data-bbox="503 525 1412 619">If you design multiple memory interfaces into the device using Altera IP, generate a unique interface for each instance to ensure good results instead of designing it once and instantiating it multiple times.</p> <p data-bbox="503 630 1412 693">For more information, refer to the <i>Planning Pin and FPGA Resources</i> chapter in the <i>External Memory Interface Handbook</i>.</p>
11.	<p data-bbox="503 714 1412 756"><input type="checkbox"/> <i>Use dedicated DQ/DQS pins and DQ groups for memory interfaces</i></p> <p data-bbox="503 766 1412 882">The data strobe DQS and data DQ pin locations are fixed in Arria V and Cyclone V devices. Before you design your device pin-out, refer to the memory interface guidelines for details and important restrictions related to the connections for these and other memory related signals.</p> <p data-bbox="503 892 1412 955">For more information about specific external memory interface topic, refer to the following documents:</p> <ul data-bbox="503 966 1412 1113" style="list-style-type: none"> ■ <i>Volume 2: Design Guidelines</i> in the <i>External Memory Interface Handbook</i> ■ <i>External Memory Interface Spec Estimator</i> on the Altera website ■ <i>Introduction to UniPHY IP</i> in the <i>External Memory Interface Handbook</i> ■ <i>External Memory Solutions Center</i> on the Altera website
12.	<p data-bbox="503 1134 1412 1197"><input type="checkbox"/> <i>Make dual-purpose pin settings and check for any restrictions when using these pins as regular I/O</i></p> <p data-bbox="503 1207 1412 1396">You can use dual-purpose configuration pins as general I/Os after device configuration is complete. Select the desired setting for each of the dual-purpose pins on the Dual-Purpose Pins category of the Device and Pin Options dialog box. Depending on the configuration scheme, these pins can be reserved as regular I/O pins, as inputs that are tri-stated, as outputs that drive ground, or as outputs that drive an unspecified signal.</p> <p data-bbox="503 1407 1412 1533">You can also use dedicated clock inputs, which drive the GCLK networks, as general purpose input pins if they are not used as clock pins. If you use the clock inputs as general inputs, the I/O registers use ALM-based registers because the clock input pins do not include dedicated I/O registers.</p> <p data-bbox="503 1543 1412 1659">The device-wide reset and clear pins are available as design I/Os if they are not enabled. For more information, refer to “<i>Determine if you need to turn on device-wide output enable</i>” on page 17 and “<i>Enable the chip-wide reset to clear all registers if required</i>” on page 31.</p>

Table 9. I/O Features and Pin Connections Checklist (Part 4 of 5)

No.	✓ Checklist items
13.	<p data-bbox="505 296 1177 325"> <input type="checkbox"/> <i>Review available device I/O features that can help I/O interfaces</i> </p> <p data-bbox="548 338 1242 367">Check the available I/O features and consider the following guidelines:</p> <ul style="list-style-type: none"> <li data-bbox="548 380 1421 535">■ Programmable current strength—ensure that the output buffer current strength is sufficiently high, but does not cause excessive overshoot or undershoot that violates voltage threshold parameters for the I/O standard. Altera recommends performing an IBIS or SPICE simulations to determine the right current strength setting for your specific application. <li data-bbox="548 548 1421 661">■ Programmable slew rate—confirm that your interface meets its performance requirements if you use slower slew rates. Altera recommends performing IBIS or SPICE simulations to determine the right slew rate setting for your specific application. <li data-bbox="548 674 1421 766">■ Programmable input/output element (IOE) delays—helps read and time margins by minimizing the uncertainties between signals in the bus. For delay specifications, refer to the relevant device datasheet. <li data-bbox="548 779 1421 892">■ Open-drain output—if configured as an open-drain, the logic value of the output is either high-Z or 0. This feature is used in system-level control signals that can be asserted by multiple devices in the system. Typically, an external pull-up resistor is required to provide logic high. <li data-bbox="548 905 1421 1060">■ Bus hold—If the bus-hold feature is enabled, you cannot use the programmable pull-up option. Disable the bus-hold feature if the I/O pin is configured for differential signals. For the specific sustaining current driven through this resistor and the overdrive current used to identify the next driven input and level for each V_{CCIO} voltage, refer to the relevant device datasheet. <li data-bbox="548 1073 1421 1186">■ Programmable pull-up resistors—weakly holds the I/O to the V_{CCIO} level when in user mode. This feature can be used with the open-drain output to eliminate the need for an external pull-up resistor. If the programmable pull-up option is enabled, you cannot use the bus-hold feature. <li data-bbox="548 1199 1421 1291">■ Programmable pre-emphasis—increases the amplitude of the high frequency component of the output signal, and thus helps to compensate for the frequency-dependent attenuation along the transmission line. <li data-bbox="548 1304 1421 1396">■ Programmable differential output voltage—allows you to adjust output eye height to optimize trace length and power consumption. A higher V_{OD} swing improves voltage margins at the receiver end while a smaller V_{OD} swing reduces power consumption. <p data-bbox="548 1409 1096 1438">For more information, refer to the following document:</p> <ul style="list-style-type: none"> <li data-bbox="548 1451 885 1480">■ I/O Features in Arria V Devices <li data-bbox="548 1493 917 1522">■ I/O Features in Cyclone V Devices

Table 9. I/O Features and Pin Connections Checklist (Part 5 of 5)

No.	✓	Checklist items
14.	<input type="checkbox"/>	<p data-bbox="548 296 980 327"><i>Consider OCT features to save board space</i></p> <p data-bbox="548 338 1398 457">Driver-impedance matching provides the I/O driver with controlled output impedance that closely matches the impedance of the transmission line to significantly reduce reflections. OCT maintains signal quality, saves board space, and reduces external component costs.</p> <ul style="list-style-type: none"> <li data-bbox="548 468 1414 531">■ OCT R_S and R_T are supported in the same I/O bank for different I/O standards if they use the same V_{CCIO} supply voltage <li data-bbox="548 541 1333 604">■ Each I/O in an I/O bank can be independently configured to support OCT R_S, programmable current strength, or OCT R_T <li data-bbox="548 615 1406 678">■ You cannot configure both OCT R_S and programmable current strength or slew rate control for the same I/O buffer <li data-bbox="548 688 1019 720">■ Differential OCT R_D is available in all I/O pins <p data-bbox="548 730 1406 793">For details about the support and implementation of this feature, refer to the following documents:</p> <ul style="list-style-type: none"> <li data-bbox="548 804 883 835">■ I/O Features in Arria V Devices <li data-bbox="548 846 1227 877">■ High-Speed Differential I/O Interfaces and DPA in Arria V Devices <li data-bbox="548 888 915 919">■ I/O Features in Cyclone V Devices
15.	<input type="checkbox"/>	<p data-bbox="548 940 1308 972"><i>Verify that the required termination scheme is supported for all pin locations</i></p>
16.	<input type="checkbox"/>	<p data-bbox="548 1003 1373 1066"><i>Choose the appropriate mode of DPA, non-DPA, or soft-CDR for high-speed LVDS interfaces</i></p> <p data-bbox="548 1077 1105 1108">For more information, refer to the following documents:</p> <ul style="list-style-type: none"> <li data-bbox="548 1119 1227 1150">■ High-Speed Differential I/O Interfaces and DPA in Arria V Devices <li data-bbox="548 1161 915 1192">■ I/O Features in Cyclone V Devices

Clock Planning

The first stage in planning your clocking scheme is to determine your system clock requirements:

- Understand your device's available clock resources and correspondingly plan the design clocking scheme. Consider your requirements for timing performance, and how much logic is driven by a particular clock.
- Based on your system requirements, define the required clock frequencies for your FPGA design and the input frequencies available to the FPGA. Use these specifications to determine your PLL scheme.

- Use the Quartus II MegaWizard Plug-In Manager to enter your settings in Altera PLL megafunctions, and check the results to verify whether particular features and input/output frequencies can be implemented in a particular PLL.

Table 10. Clock Planning Checklist (Part 1 of 2)

No.	✓ Checklist items
1.	<p data-bbox="505 422 1081 457"><input type="checkbox"/> <i>Use the device fractional PLLs for clock management</i></p> <p data-bbox="548 464 1421 590">Connect clock inputs to specific PLLs to drive specific low-skew routing networks. Analyze the global resource availability for each PLL and the PLL availability for each clock input pin. Use the following descriptions to help determine which clock networks are appropriate for the clock signals in your design:</p> <ul data-bbox="548 596 1421 1192" style="list-style-type: none"> ■ The GCLK networks can drive throughout the entire device, serving as low-skew clock sources for device logic. This clock region has the maximum delay compared to other clock regions but allows the signal to reach everywhere within the device. This option is good for routing global reset/clear signals or routing clocks throughout the device. ■ The RCLK networks only pertain to the quadrant they drive into and provide the lowest clock delay and skew for logic contained within a single device quadrant. ■ IOEs and internal logic can also drive GCLKs and RCLKs to create internally generated GCLKs or RCLKs and other high fan-out control signals; for example, synchronous or asynchronous clears and clock enables. ■ PLLs cannot be driven by internally-generated GCLKs or RCLKs. The input clock to the PLL must come from dedicated clock input pins or from another pin/PLL-fed GCLK or RCLK. ■ PCLK networks are a collection of individual clock networks driven from the periphery of the device. Clock outputs from the DPA block, PLD-transceiver interface, I/O pins, and internal logic can drive the PCLK networks. These PCLKs have higher skew compared to GCLK and RCLK networks and can be used instead of general purpose routing to drive signals into and out of the device.
2.	<p data-bbox="505 1220 1305 1255"><input type="checkbox"/> <i>Enable PLL features and check settings in the MegaWizard Plug-In Manager</i></p> <p data-bbox="548 1262 1421 1325">You can configure the fractional PLLs in the Arria V and Cyclone V to function in integer or enhanced fractional mode.</p> <p data-bbox="548 1331 1338 1362">Take note that to drive LVDS channels, you must use the PLLs in integer mode.</p> <p data-bbox="548 1369 1370 1432">For more information about the fractional PLL features, refer to the “Fractional PLL Architecture” section in the following documents:</p> <ul data-bbox="548 1438 1049 1528" style="list-style-type: none"> ■ Clock Networks and PLLs in Arria V Devices ■ Clock Networks and PLLs in Cyclone V Devices
3.	<p data-bbox="505 1535 1235 1570"><input type="checkbox"/> <i>Ensure that you select the correct PLL feedback compensation mode</i></p> <p data-bbox="548 1577 1403 1640">Arria V and Cyclone V PLLs support six different clock feedback modes. For more information, refer to the “Clock Feedback Modes” section in the following documents:</p> <ul data-bbox="548 1646 1049 1738" style="list-style-type: none"> ■ Clock Networks and PLLs in Arria V Devices ■ Clock Networks and PLLs in Cyclone V Devices
4.	<p data-bbox="505 1745 1421 1808"><input type="checkbox"/> <i>Check that the PLL offers the required number of clock outputs and use dedicated clock output pins</i></p> <p data-bbox="548 1814 1349 1866">You can connect clock outputs to dedicated clock output pins or clock networks.</p>

Table 10. Clock Planning Checklist (Part 2 of 2)

No.	✓ Checklist items
5.	<p data-bbox="505 296 1182 327"> <input type="checkbox"/> <i>Use the clock control block for clock selection and power-down</i> </p> <p data-bbox="548 338 1427 457"> Every GCLK and RCLK network has its own clock control block. The control block provides the following features that you can use to select different clock input signals or power-down clock networks to reduce power consumption without using any combinational logic in your design: </p> <ul data-bbox="548 468 1235 583" style="list-style-type: none"> <li data-bbox="548 468 1159 499">■ Clock source selection (with dynamic selection for GCLKs) <li data-bbox="548 510 764 541">■ GCLK multiplexing <li data-bbox="548 552 1235 583">■ Clock power down (with static or dynamic clock enable or disable) <p data-bbox="548 594 1427 714"> In Arria V and Cyclone V devices, the <code>clkena</code> signals are supported at the clock network level instead of at the PLL output counter level. This allows you to gate off the clock even when you are not using a PLL. You can also use the <code>clkena</code> signals to control the dedicated external clocks from the PLLs. </p> <p data-bbox="548 724 1427 844"> To disable the PLL output clock from driving the registers in your design when the PLL is not locked, connect the lock output port of the PLL to the <code>ena</code> input port of the ALTCLKCTRL IP core. With this connection, the output clock from the ALTCLKCTRL IP core is enabled only when the PLL is locked. </p> <p data-bbox="548 854 1386 919"> For more information, refer to the Clock Control Block (ALTCLKCTRL) Megafunction User Guide. </p>

I/O Simultaneous Switching Noise

SSN is a concern when too many I/Os (in close proximity) change voltage levels at the same time. Use the checklist in this section for recommendations to plan I/O and clock connections.

Table 11. I/O Simultaneous Switching Noise Checklist

No.	✓	Checklist item
1.	<input type="checkbox"/>	<p><i>Consider the following recommendations to mitigate I/O simultaneous switching noise:</i></p> <ul style="list-style-type: none"> ■ Analyze the design for possible SSN problems. ■ Reduce the number of pins that switch the voltage level at exactly the same time whenever possible. ■ Use differential I/O standards and lower-voltage standards for high-switching I/Os. ■ Use lower drive strengths for high-switching I/Os. The default drive strength setting might be higher than your design requires. ■ Reduce the number of simultaneously switching output pins within each bank. Spread output pins across multiple banks if possible. ■ Spread the switching I/Os evenly throughout the bank to reduce the number of aggressors in a given area to reduce SSN if bank usage is substantially below 100%. ■ Separate simultaneously switching pins from input pins that are susceptible to SSN. ■ Place important clock and asynchronous control signals near ground signals and away from large switching buses. ■ Avoid using I/O pins one or two pins away from PLL power supply pins for high-switching or high-drive strength pins. ■ Use staggered output delays to shift the output signals through time, or use adjustable slew rate settings. <p>For information and guidelines on using available I/O features, refer to “I/O Features and Pin Connections” on page 21.</p> <p>For signal integrity design techniques to mitigate SSN, view the Signal & Power Integrity Design Techniques for SSN webcast on the Altera website.</p>

Design Entry

In complex FPGA design development, design practices, coding styles, and megafunction usage have an enormous impact on your device's timing performance, logic utilization, and system reliability. In addition, while planning and creating the design, plan for a hierarchical or team-based design to improve design productivity.

Table 12. Design Entry Checklist (Part 1 of 6)

No.	✓	Checklist items
1.	<input type="checkbox"/>	<p><i>Use synchronous design practices</i></p> <p>In a synchronous design, a clock signal triggers all events. When all of the registers' timing requirements are met, a synchronous design behaves in a predictable and reliable manner for all process, voltage, and temperature (PVT) conditions. You can easily target synchronous designs to different device families or speed grades.</p>

Table 12. Design Entry Checklist (Part 2 of 6)

No.	✓ Checklist items
2.	<p data-bbox="503 294 1412 325"><input type="checkbox"/> <i>Consider the following recommendations to avoid clock signals problems:</i></p> <ul style="list-style-type: none"> <li data-bbox="552 336 1412 493">■ Use dedicated clock pins and clock routing for best results—dedicated clock pins drive the clock network directly, ensuring lower skew than other I/O pins. Use the dedicated routing network to have a predictable delay with less skew for high fan-out signals. You can also use the clock pins and clock network to drive control signals like asynchronous reset. <li data-bbox="552 504 1412 535">■ For clock inversion, multiplication, and division use the device PLLs. <li data-bbox="552 546 1412 598">■ For clock multiplexing and gating, use the dedicated clock control block or PLL clock switchover feature instead of combinational logic. <li data-bbox="552 609 1412 735">■ If you must use internally generated clock signals, register the output of any combinational logic used as a clock signal to reduce glitches. For example, if you divide a clock using combinational logic, clock the final stage with the clock signal that was used to clock the divider circuit. <li data-bbox="552 745 1412 924">■ Consider the following recommendations for transceivers: <ul style="list-style-type: none"> <li data-bbox="576 787 1412 819">■ Use the transceiver dedicated <code>refclk</code> pins. <li data-bbox="576 829 1412 924">■ For easier timing closure, clock the transmit logic in the fabric using the transmitter recovered clock, and the receive logic using the receiver recovered clock.
3.	<p data-bbox="503 945 1412 976"><input type="checkbox"/> <i>Use the Quartus II Design Assistant to check design reliability</i></p> <p data-bbox="552 987 1412 1050">The Design Assistant is a design-rule checking tool that checks your design according to Altera recommendations and helps you avoid design issues early in your design flow:</p> <ul style="list-style-type: none"> <li data-bbox="552 1060 1412 1123">■ To run the tool, on the Processing menu, point to Start and click Start Design Assistant. <li data-bbox="552 1134 1412 1197">■ To set the Design Assistant to run automatically during compilation, turn on Run Design Assistant during compilation in the Settings dialog box. <p data-bbox="552 1207 1412 1239">You can also use third-party “lint” tools to check your coding styles.</p> <p data-bbox="552 1249 1412 1333">For more information, refer to the “Checking Design Violations with the Design Assistant” section in the <i>Recommended Design Practices</i> chapter of the <i>Quartus II Handbook</i>.</p> <p data-bbox="552 1344 1412 1407">You can also refer to industry papers for more information about multiple clock design. For a good analysis, refer to www.sunburst-design.com/papers.</p>
4.	<p data-bbox="503 1428 1412 1459"><input type="checkbox"/> <i>Use megafunctions with the MegaWizard Plug-In Manager</i></p> <p data-bbox="552 1470 1412 1596">Instead of coding your own logic, save your design time by using Altera’s megafunctions—a library of parameterized modules and device-specific megafunctions. The megafunctions are optimized for Altera device architectures and can offer more efficient logic synthesis and device implementation.</p> <p data-bbox="552 1606 1412 1669">To ensure that you set all ports and parameters correctly, use the Quartus II Megawizard Plug-In Manager to build or change megafunctions parameters.</p> <p data-bbox="552 1680 1412 1743">For detailed information about a specific megafunction, refer to the relevant user guide on the IP and Megafunctions page at the Altera website.</p>

Table 12. Design Entry Checklist (Part 3 of 6)

No.	✓ Checklist items
5.	<p data-bbox="505 296 1256 327"><input type="checkbox"/> <i>Review the information on dynamic and partial reconfiguration features</i></p> <p data-bbox="548 338 1338 369">The Arria V and Cyclone V devices support dynamic and partial reconfiguration:</p> <ul data-bbox="548 380 1386 516" style="list-style-type: none"> <li data-bbox="548 380 1386 443">■ Dynamic reconfiguration—dynamically change the transceiver data rates, PMA settings, or protocols of a channel affecting data transfer on adjacent channels. <li data-bbox="548 453 1386 516">■ Partial reconfiguration—reconfigure part of the device while other sections of the device remain operational. <p data-bbox="548 527 1419 590">For more information, refer to Increasing Design Functionality with Partial and Dynamic Reconfiguration in 28-nm FPGAs.</p>
6.	<p data-bbox="505 611 1406 642"><input type="checkbox"/> <i>Consider the Altera's recommended coding styles to achieve optimal synthesis results</i></p> <p data-bbox="548 653 1419 768">HDL coding styles can have a significant impact on the quality of results for programmable logic designs. For example, when designing memory and digital system processing (DSP) functions, understanding the device architecture helps you to take advantage of the dedicated logic block sizes and configurations.</p> <ul data-bbox="548 779 1419 1020" style="list-style-type: none"> <li data-bbox="548 779 1419 842">■ For specific HDL coding examples and recommendations, refer to the Recommended HDL Coding Styles chapter in the <i>Quartus II Handbook</i>. <li data-bbox="548 852 1419 947">■ You can use the HDL templates provided in the Quartus II software as examples for your reference. To access the templates, right click the editing area in the Quartus II text editor and click Insert Template. <li data-bbox="548 957 1419 1020">■ For additional tool-specific guidelines, refer to the documentation of your synthesis tool.
7.	<p data-bbox="505 1052 1122 1083"><input type="checkbox"/> <i>Enable the chip-wide reset to clear all registers if required</i></p> <p data-bbox="548 1094 1406 1178">Arria V and Cyclone V devices support an optional chip-wide reset that enables you to override all clears on all device registers, including the registers of the memory blocks (but not the memory contents).</p> <ul data-bbox="548 1188 1370 1325" style="list-style-type: none"> <li data-bbox="548 1188 1370 1283">■ DEV_CLRn pin is driven low—all registers are cleared or reset to 0. The affected register behave as if they are preset to a high value when synthesis performs an optimization called NOT-gate-push back due to register control signals. <li data-bbox="548 1293 1370 1325">■ DEV_CLRn pin is driven high—all registers behave as programmed. <p data-bbox="548 1335 1419 1430">To enable chip-wide reset, before compiling your design, turn on Enable device-wide reset (DEV_CLRn) under the Options list of the General category in the Device and Pin Options dialog box of the Quartus II software.</p>
8.	<p data-bbox="505 1451 1101 1482"><input type="checkbox"/> <i>Use device architecture-specific register control signals</i></p> <p data-bbox="548 1493 1419 1608">Each Arria V and Cyclone V logic array block (LAB) contains dedicated logic for driving register control signals to its ALMs. It is important that the control signals use the dedicated control signals in the device architecture. In some cases, you may be required to limit the number of different control signals in your design.</p> <p data-bbox="548 1619 1308 1682">For more information about LAB and ALM architecture, refer to the following documents:</p> <ul data-bbox="548 1692 1268 1766" style="list-style-type: none"> <li data-bbox="548 1692 1235 1724">■ Logic Array Blocks and Adaptive Logic Modules in Arria V Devices <li data-bbox="548 1734 1268 1766">■ Logic Array Blocks and Adaptive Logic Modules in Cyclone V Devices

Table 12. Design Entry Checklist (Part 4 of 6)

No.	✓ Checklist items
9.	<p data-bbox="505 296 951 327"> <input type="checkbox"/> <i>Review recommended reset architecture</i> </p> <ul style="list-style-type: none"> <li data-bbox="548 338 1398 401">■ If the clock signal is not available when reset is asserted, an asynchronous reset is typically used to reset the logic. <li data-bbox="548 411 1317 474">■ The recommended reset architecture allows the reset signal to be asserted asynchronously and deasserted synchronously. <li data-bbox="548 485 1414 548">■ The source of the reset signal is connected to the asynchronous port of the registers, which can be directly connected to global routing resources. <li data-bbox="548 558 1398 621">■ The synchronous deassertion allows all state machines and registers to start at the same time. <li data-bbox="548 632 1414 716">■ Synchronous deassertion avoids an asynchronous reset signal from being released at, or near, the active clock edge of a flipflop that can cause the output of the flipflop to go to a metastable unknown state. <p data-bbox="548 726 1373 789">For more information about good reset design, refer to industry papers such as the analysis of reset architecture at www.sunburst-design.com/papers.</p>
10.	<p data-bbox="505 810 1154 842"> <input type="checkbox"/> <i>Review the synthesis options available in your synthesis tool</i> </p> <p data-bbox="548 852 1406 915">If you force a particular power-up condition for your design, use the synthesis options available in your synthesis tool:</p> <ul style="list-style-type: none"> <li data-bbox="548 926 1414 1020">■ By default, the Quartus II software Integrated Synthesis turns on the Power-Up Don't Care logic option that assumes your design does not depend on the power-up state of the device architecture. Other synthesis tools might use similar assumptions. <li data-bbox="548 1031 1414 1146">■ Designers typically use an explicit reset signal for the design that forces all registers into their appropriate values after reset but not necessarily at power-up. You can create your design with asynchronous reset that allows you to power up the design safely with the reset active, regardless of the power-up conditions of the device. <li data-bbox="548 1157 1414 1314">■ Some synthesis tools can also read the default or initial values for registered signals in your source code and implement the behavior in the device. For example, the Quartus II software Integrated Synthesis converts HDL default and initial values for registered signals into Power-Up Level settings. The synthesized behavior matches the power-up conditions of the HDL code during a functional simulation. <li data-bbox="548 1325 1414 1535">■ Registers in the device core always power up to a low (0) logic level in the physical device architecture. If you specify a high power-up level or a non-zero reset value (preset signal), synthesis tools typically use the clear signals available on the registers and perform the NOT-gate push back optimization technique. If you assign a high power-up level to a register that is reset low, or assign a low power-up value to a register that is preset high, synthesis tools cannot use the NOT-gate push back optimization technique and might ignore the power-up conditions. <p data-bbox="548 1545 1406 1640">For more information about the Power-Up Level settings and the <code>altera_attribute</code> assignment that sets the power-up state, refer to the <i>Quartus II Integrated Synthesis</i> chapter of the <i>Quartus II Handbook</i>.</p>

Table 12. Design Entry Checklist (Part 5 of 6)

No.	✓ Checklist items
11.	<input type="checkbox"/> <i>Consider resources available for register power-up and control signals</i> To implement a reset and preset signal on the same register, synthesis tools emulate the controls with logic and latches that can be prone to glitches because of the different delays between the different paths to the register. In addition, the power-up value is undefined for these registers. For more information about reset logic and power up conditions, refer to the <i>Recommended HDL Coding Styles</i> chapter in the <i>Quartus II Handbook</i> .
12.	<input type="checkbox"/> <i>Consider Altera's recommendations for creating design partitions</i> Partitioning a design for an FPGA requires planning to ensure optimal results when the partitions are integrated and ensures that each partition is well placed, relative to other partitions in the device. Follow Altera's recommendations for creating design partitions to improve the overall quality of results. For example, registering partition I/O boundaries keeps critical timing paths inside one partition that can be optimized independently. Plan your source code so that each design block is defined in a separate file. The software can automatically detect changes to each block separately. Use hierarchy in your design to provide more flexibility when partitioning. Keep your design logic in the leaves of the hierarchy trees; that is, the top level of the hierarchy should have very little logic, and the lower-level design blocks contain the logic. For guidelines to help you create design partitions, refer to the <i>Best Practices for Incremental Compilation Partitions and Floorplan Assignments</i> chapter in the <i>Quartus II Handbook</i> .
13.	<input type="checkbox"/> <i>Perform timing budgeting and resource balancing between partitions</i> If your design is created in multiple projects, it is important that the system architect provide guidance to designers of lower-level blocks to ensure that each partition uses the appropriate device resources: <ul style="list-style-type: none"> ■ Because the designs are developed independently, each lower-level designer has no information about the overall design or how their partition connects with other partitions, which can lead to problems during system integration. ■ The top-level project information, including pin locations, physical constraints, and timing requirements, should be communicated to the designers of lower-level partitions before they start their design. ■ The system architect can plan design partitions at the top level and use the Quartus II software Generate Bottom-Up Design Partition Scripts option on the Project menu to automate the process of transferring top-level project information to lower-level modules.

Table 12. Design Entry Checklist (Part 6 of 6)

No.	✓	Checklist items
14.	<input type="checkbox"/>	<p data-bbox="548 296 1179 327"><i>Create a design floorplan for incremental compilation partitions</i></p> <ul data-bbox="548 338 1419 810" style="list-style-type: none"><li data-bbox="548 338 1419 432">■ A design floorplan avoids conflicts between design partitions and ensure that each partition is well-placed relative to other partitions. When you create different location assignments for each partition, no location conflicts occur.<li data-bbox="548 443 1419 537">■ A design floorplan helps avoid situations in which the Fitter is directed to place or replace a portion of the design in an area of the device where most resources have already been claimed.<li data-bbox="548 548 1419 642">■ Floorplan assignments are recommended for timing-critical partitions in top-down flows. You can use the Quartus II Chip Planner to create a design floorplan using LogicLock region assignments for each design partition.<li data-bbox="548 653 1419 747">■ With a basic design framework for the top-level design, the floorplan editor enables you to view connections between regions, estimate physical timing delays on the chip, and move regions around the device floorplan.<li data-bbox="548 758 1419 810">■ After you compiled the full design, you can also view logic placement and locate areas of routing congestion to improve the floorplan assignments. <p data-bbox="548 821 1419 873">For more information and guidelines in creating a design floorplan and placement assignments in the floorplan, refer to the following chapters in the <i>Quartus II Handbook</i>:</p> <ul data-bbox="548 884 1419 961" style="list-style-type: none"><li data-bbox="548 884 1419 915">■ <i>Best Practices for Incremental Compilation Partitions and Floorplan Assignments</i><li data-bbox="548 926 1419 961">■ <i>Analyzing and Optimizing the Design Floorplan with the Chip Planner</i>

Design Implementation

Use the checklists in the this section as guidelines while implementing your design.

Synthesis and Compilation

Table 13. Synthesis and Compilation Checklist (Part 1 of 3)

No.	✓	Checklist items
1.	<input type="checkbox"/>	<p data-bbox="548 506 1166 537"><i>Specify your synthesis tool and use correct supported version</i></p> <p data-bbox="548 548 1421 695">The Quartus II software includes integrated synthesis that fully supports Verilog HDL, VHDL, Altera hardware description language (AHDL), and schematic design entry. You can also use industry-leading third-party EDA synthesis tools to synthesize your Verilog HDL or VHDL design, and then compile the resulting output netlist file in the Quartus II software:</p> <ul style="list-style-type: none"> <li data-bbox="548 709 1365 800">■ Specify a third-party synthesis tool in the New Project Wizard or the EDA Tools Settings page of the Settings dialog box to use the correct Library Mapping File (.lmf) for your synthesis netlist. <li data-bbox="548 814 1409 898">■ Altera recommends that you use the most recent version of third-party synthesis tools because tool vendors are continuously adding new features, fixing tool issues, and enhancing performance for Altera devices. <li data-bbox="548 913 1421 1003">■ Different synthesis tools can give different results. If you want to select the best-performing tool for your application, you can experiment by synthesizing typical designs for your application and coding style, and comparing the results. <li data-bbox="548 1018 1370 1073">■ Perform placement and routing in the Quartus II software to get accurate timing analysis and logic utilization results. <li data-bbox="548 1087 1409 1207">■ Your synthesis tool may offer the capability to create a Quartus II project and pass constraints such as the EDA tool setting, device selection, and timing requirements that you specified in your synthesis project. You can use this capability to save time when setting up your Quartus II project for placement and routing. <p data-bbox="548 1222 1421 1276">For more information about supported synthesis tools, refer to the following chapters of the Quartus II Handbook:</p> <ul style="list-style-type: none"> <li data-bbox="548 1291 889 1318">■ <i>Quartus II Integrated Synthesis</i> <li data-bbox="548 1333 850 1360">■ <i>Synopsys Synplify Support</i> <li data-bbox="548 1375 1036 1402">■ <i>Mentor Graphics Precision Synthesis Support</i> <li data-bbox="548 1417 1029 1444">■ <i>Mentor Graphics LeonardoSpectrum Support</i> <p data-bbox="548 1459 1421 1543">For information about the officially supported version of each synthesis tool in a Quartus II software version, refer to the relevant Quartus II software release notes on the Release Notes page at the Altera website.</p>

Table 13. Synthesis and Compilation Checklist (Part 2 of 3)

No.	✓ Checklist items
2.	<p data-bbox="505 296 1068 327"><input type="checkbox"/> <i>Review resource utilization reports after compilation</i></p> <p data-bbox="548 338 1357 401">After compilation in the Quartus II software, review the device resource utilization information:</p> <ul data-bbox="548 411 1427 842" style="list-style-type: none"> <li data-bbox="548 411 1427 474">■ Use the information to determine whether the future addition of extra logic or other design changes introduce fitting difficulties. <li data-bbox="548 485 1427 548">■ If your compilation results in a no-fit error, use the information to analyze fitting problems. <li data-bbox="548 558 1427 674">■ To determine resource usage, refer to the Flow Summary section of the Compilation Report for a percentage representing the total logic utilization, which includes an estimation of resources that cannot be used due to existing connections or logic usage. <li data-bbox="548 684 1427 842">■ For more detailed resource information, view the reports under Resource Section in the Fitter section of the Compilation Report. The Fitter Resource Usage Summary report breaks down the logic utilization information and indicates the number of fully and partially used ALMs, and provides other resource information including the number of bits in each type of memory block. <p data-bbox="548 852 1427 1031">There are also reports that describe some of the optimizations that occurred during compilation. For example, if you use the Quartus II Integrated Synthesis, the reports under the Optimization Results folder in the Analysis & Synthesis section provide information that includes registers that were removed during synthesis. Use this report to estimate device resource utilization for a partial design to ensure that registers were not removed due to missing connections with other parts of the design.</p> <p data-bbox="548 1041 1427 1220">Low logic utilization does not mean the lowest possible ALM utilization. A design that is reported to be close to 100% may still have space for extra logic. The Fitter uses ALUTs in different ALMs, even when the logic can be placed within one ALM, so that it can achieve the best timing and routability results. Logic might be spread throughout the device when achieving these results. As the device fills up, the Fitter automatically searches for logic that can be placed together in one ALM.</p>
3.	<p data-bbox="505 1251 1247 1283"><input type="checkbox"/> <i>Review all Quartus II messages, especially warning or error messages</i></p> <p data-bbox="548 1293 1427 1377">Each stage of the compilation flow generates messages, including informational notes, warnings, and critical warnings. Understand the significance of warning messages and make changes to the design or settings if required.</p> <p data-bbox="548 1388 1427 1482">In the Quartus II user interface, you can use the Message window tabs to look at only certain types of messages. You can suppress the messages if you have determined that your action is not required.</p> <p data-bbox="548 1493 1427 1556">For more information about messages and message suppression, refer to the <i>Managing Quartus II Projects</i> chapter in the <i>Quartus II Handbook</i>.</p>
4.	<p data-bbox="505 1587 943 1619"><input type="checkbox"/> <i>Consider using incremental compilation</i></p> <p data-bbox="548 1629 1427 1757">Use the incremental compilation feature to preserve logic in unchanged parts of your design, preserve timing performance, and reach timing closure more efficiently. You can speed up design iteration time by an average of 60% when making changes to the design with the incremental compilation feature.</p>

Table 13. Synthesis and Compilation Checklist (Part 3 of 3)

No.	✓	Checklist items
5.	<input type="checkbox"/>	<p><i>Ensure parallel compilation is enabled</i></p> <p>The Quartus II software can run some algorithms in parallel to take advantage of multiple processors and reduce compilation time when more than one processor is available to compile the design. Set the Parallel compilation option on the Compilation Process Settings page of the Settings dialog box, or change the default setting in the Options dialog box in the Processing page from the Tools menu.</p>
6.	<input type="checkbox"/>	<p><i>Use the Compilation Time Advisor</i></p> <p>The Compilation Time Advisor provides guidance in making settings that reduce your design compilation time. On the Tools menu, point to Advisors and click Compilation Time Advisor. Using some of these techniques to reduce compilation time can reduce the overall quality of results.</p> <p>For more information, refer to the <i>Area and Timing Optimization</i> chapter in the Quartus II Handbook.</p>

Timing Optimization and Analysis

Use the guidelines in the following checklist for analyzing your design timing and optimizing your timing performance.

Table 14. Timing Optimization and Analysis Checklist (Part 1 of 2)

No.	✓	Checklist items
1.	<input type="checkbox"/>	<p><i>Ensure timing constraints are complete and accurate</i></p> <p>In an FPGA design flow, accurate timing constraints allow timing-driven synthesis software and place-and-route software to obtain optimal results. Timing constraints are critical to ensure designs meet their timing requirements, which represent actual design requirements that must be met for the device to operate correctly.</p> <p>The Quartus II software optimizes and analyzes your design using different timing models for each device speed grade, so you must perform timing analysis for the correct speed grade. The final programmed device might not operate as expected if the timing paths are not fully constrained, analyzed, and verified to meet requirements.</p> <p>For more information, refer to the <i>Timing Analysis Overview</i> chapter of the <i>Quartus II Handbook</i>.</p>
2.	<input type="checkbox"/>	<p><i>Review the TimeQuest Timing Analyzer reports after compilation</i></p> <p>The Quartus II software includes the Quartus II TimeQuest Timing Analyzer, a powerful ASIC-style timing analysis tool that validates the timing performance of all logic in your design. It supports the industry standard Synopsys Design Constraints (SDC) format timing constraints, and has an easy-to-use GUI with interactive timing reports. It is ideal for constraining high-speed source-synchronous interfaces and clock multiplexing design structures.</p> <p>The software also supports static timing analysis in the industry-standard Synopsys Primetime software. To generate the required timing netlist, specify the tool in the New Project Wizard or the EDA Tools Settings page of the Settings dialog box.</p>

Table 14. Timing Optimization and Analysis Checklist (Part 2 of 2)

No.	✓ Checklist items
3.	<p data-bbox="505 300 1325 331"><input type="checkbox"/> <i>Ensure that the I/O timings are not violated when data is provided to the FPGA</i></p> <p data-bbox="548 342 1419 432">A comprehensive static timing analysis includes analysis of register to register, I/O, and asynchronous reset paths. It is important to specify the frequencies and relationships for all clocks in your design.</p> <p data-bbox="548 443 1406 533">Use input and output delay constraints to specify external device or board timing parameters. Specify accurate timing requirements for external interfacing components to reflect the exact system intent.</p> <p data-bbox="548 543 1409 730">The TimeQuest Timing Analyzer performs static timing analysis on the entire system, using data required times, data arrival times, and clock arrival times to verify circuit performance and detect possible timing violations. It determines the timing relationships that must be met for the design to correctly function. You can use the <code>report_datasheet</code> command to generate a datasheet report that summarizes the I/O timing characteristics of the entire design.</p>
4.	<p data-bbox="505 751 1203 783"><input type="checkbox"/> <i>Perform Early Timing Estimation before running a full compilation</i></p> <p data-bbox="548 793 1406 915">If the timing analysis reports that your design requirements were not met, you must make changes to your design or settings and recompile the design to achieve timing closure. If your compilation results in no-fit messages, you must make changes to get successful placement and routing.</p> <p data-bbox="548 926 1419 1056">You can use the Early Timing Estimation feature in the Quartus II software to estimate your design's timing results before the software performs full placement and routing. On the Processing menu, point to Start and click Start Early Timing Estimate to generate initial compilation results after you have run analysis and synthesis.</p>
5.	<p data-bbox="505 1077 1321 1136"><input type="checkbox"/> <i>Consider the following recommendations for timing optimization and analysis assignment:</i></p> <ul data-bbox="548 1146 1419 1709" style="list-style-type: none"> <li data-bbox="548 1146 1377 1205">■ Turn on Optimize multi-corner timing on the Fitter Settings page in the Settings dialog box. <li data-bbox="548 1220 1419 1278">■ Use <code>create_clock</code> and <code>create_generated_clock</code> to specify the frequencies and relationships for all clocks in your design. <li data-bbox="548 1293 1393 1352">■ Use <code>set_input_delay</code> and <code>set_output_delay</code> to specify the external device or board timing parameters <li data-bbox="548 1367 1409 1457">■ Use <code>derive_pll_clocks</code> to create generated clocks for all PLL outputs, according to the settings in the PLL megafunctions. Specify multicycle relationships for LVDS transmitters or receiver deserialization factors. <li data-bbox="548 1472 1393 1530">■ Use <code>derive_clock_uncertainty</code> to automatically apply inter-clock, intra-clock, and I/O interface uncertainties. <li data-bbox="548 1545 1406 1604">■ Use <code>check_timing</code> to generate a report on any problem with the design or applied constraints, including missing constraints <li data-bbox="548 1619 1382 1677">■ Use the Quartus II optimization features to achieve timing closure or improve the resource utilization. <li data-bbox="548 1692 1377 1709">■ Use the Timing and Area Optimization Advisors to suggest optimization settings. <p data-bbox="548 1724 1419 1780">For more guidelines about timing constraints, refer to <i>The Quartus II TimeQuest Timing Analyzer</i> chapter in the <i>Quartus II Handbook</i>.</p>

Functional and Timing Simulation

Use the following checklist for guidelines about functional and timing simulation.

Table 15. Functional and Timing Simulation Checklist

No.	✓ Checklist items
1.	<input type="checkbox"/> <i>Perform functional simulation at the beginning of your design flow</i> Perform the simulation to check the design functionality or logical behavior of each design block. You do not have to fully compile your design; you can generate a functional simulation netlist that does not contain timing information.
2.	<input type="checkbox"/> <i>Perform timing simulation to ensure your design works in targeted device</i> Timing simulation uses the timing netlist generated by the TimeQuest Timing Analyzer, which includes the delay of different device blocks and placement and routing information. You can perform timing simulation for the top-level design at the end of your design flow to ensure that your design works in the targeted device.
3.	<input type="checkbox"/> <i>Specify your simulation tool and use correct supported version</i> <ul style="list-style-type: none"> ■ Altera provides the ModelSim®-Altera simulator Starter Edition and offers the higher-performance ModelSim-Altera Edition that enable you to take advantage of advanced testbench capabilities and other features. ■ In addition, the Quartus II EDA Netlist Writer can generate timing netlist files to support other third-party simulation tools such as Synopsys VCS, Cadence NC-Sim, and Aldec Active-HDL. ■ If you use a third-party simulation tool, use the software version that is supported with your Quartus II software version. ■ Specify your simulation tool in the EDA Tools Settings page of the Settings dialog box to generate the appropriate output simulation netlist. The software can also generate scripts to help you setup libraries in your tool with NativeLink integration. ■ Use only the model libraries provided with your Quartus II software version. Libraries may change between versions and this can cause a mismatch with your simulation netlist. ■ To create a testbench in the Quartus II software, on the Processing menu, point to Start and click Start Testbench Template Writer. <p>For information about the officially supported version of each simulation tool in a Quartus II software version, refer to the relevant Quartus II software release notes on the Release Notes page at the Altera website.</p> <p>For more information, refer to the following documents in the <i>Quartus II Handbook</i>:</p> <ul style="list-style-type: none"> ■ Simulating Altera Designs ■ Mentor Graphics ModelSim and QuestaSim Support ■ Synopsys VCS and VCS MX Support ■ Cadence Incisive Enterprise Simulator Support ■ Aldec Active-HDL and Rivera-PRO Support

Formal Verification

Use the following guidelines if your design requires formal verification.

Table 16. Formal Verification Checklist

No.	✓	Checklist items
1.	<input type="checkbox"/>	<p data-bbox="552 409 1136 451"><i>Determine if you require formal verification for your design</i></p> <p data-bbox="552 451 1429 535">If formal verification is required for your design, it is easier to plan for limitations and restrictions in the beginning than to make changes later in the design flow.</p>
2.	<input type="checkbox"/>	<p data-bbox="552 546 1169 588"><i>Check for support and design limitations for formal verification</i></p> <p data-bbox="552 588 1429 714">The Quartus II software supports some formal verification flows. Using a formal verification flow can impact performance results because it requires that certain logic optimizations be turned off, such as register retiming, and forces hierarchy blocks to be preserved, which can restrict optimization.</p> <p data-bbox="552 714 1429 798">For more information, refer to the Cadence Encounter Conformal Support chapter in the <i>Quartus II Handbook</i>.</p>
3.	<input type="checkbox"/>	<p data-bbox="552 808 1250 850"><i>Specify your formal verification tool and use correct supported version</i></p> <p data-bbox="552 850 1429 913">Specify your formal verification tool in the EDA Tools Settings page of the Settings dialog box to generate the appropriate output netlist.</p> <p data-bbox="552 913 1429 1018">For information about the officially supported version of each formal verification tool in a Quartus II software version, refer to the relevant Quartus II software release notes on the Release Notes page at the Altera website.</p>

Power Analysis and Optimization

After compiling your design, analyze the power consumption and heat dissipation with the Quartus II PowerPlay Power Analyzer to calculate the dynamic, static, and I/O thermal power consumption and ensure the design has not violated power supply and thermal budgets.

Power optimization in the Quartus II software depends on accurate power analysis results. Use the following guidelines to ensure the software optimizes the power utilization correctly for the design's operating behavior and conditions.

Table 17. Power Analysis and Optimization Checklist (Part 1 of 3)

No.	✓ Checklist items
1.	<p><input type="checkbox"/> <i>Provide accurate typical signal activities to get accurate power analysis result</i></p> <p>You need to provide accurate typical signal activities to PowerPlay Power Analyzer:</p> <ul style="list-style-type: none"> ■ Compile a design to derive the information about design resources, placement and routing, and I/O standards. ■ Derive signal activity data (toggle rates and static probabilities) from simulation results or a user-defined default toggle rate and vectorless estimation. The signal activities used for analysis must be representative of the actual operating behavior. <p>For the most accurate power estimation, use gate-level simulation results with a .vcd output file from a third-party simulation tool. The simulation activity should include typical input vectors over a realistic time period and not the corner cases often used during functional verification. Use the recommended simulator settings, such as glitch filtering, to ensure good results.</p>
2.	<p><input type="checkbox"/> <i>Specify the correct operating conditions for power analysis</i></p> <p>Specify the operating conditions, including the core voltage, device power characteristics, ambient and junction temperature, cooling solution, and the board thermal model.</p> <p>In the Quartus II software, select the appropriate settings on the Operating Settings and Conditions page in the Settings dialog box.</p>
3.	<p><input type="checkbox"/> <i>Analyze power consumption and heat dissipation in the PowerPlay Power Analyzer</i></p> <p>In the Quartus II software, on the Processing menu, click PowerPlay Power Analyzer Tool. The tool also provides a summary of the signal activities used for analysis and a confidence metric that reflects the overall quality of the data sources for signal activities.</p> <p>For more information about power analysis and recommendations for simulation settings for creating signal activity information, refer to the <i>PowerPlay Power Analysis</i> chapter in the <i>Quartus II Handbook</i>.</p> <p>The PowerPlay Power Analyzer report is a power estimate and is not a power specification. Always refer to the device datasheet for the power specification.</p>
4.	<p><input type="checkbox"/> <i>Review recommended design techniques and Quartus II options to optimize power consumption</i></p> <p>For information about design techniques to optimize power consumption, refer to the <i>Power Optimization</i> chapter of the <i>Quartus II Handbook</i>.</p>

Table 17. Power Analysis and Optimization Checklist (Part 2 of 3)

No.	✓ Checklist items
5.	<input type="checkbox"/> <i>Use the Power Optimization Advisor to suggest optimization settings</i> The Power Optimization Advisor provides specific power optimization advice and recommendations based on the current design project settings and assignments. For more information, refer to the <i>Power Optimization</i> chapter in the Quartus II Handbook.
6.	<input type="checkbox"/> <i>Consider using a faster speed grade device</i> If your design includes many critical timing paths that require the high-performance mode, you might be able to reduce power consumption by using a faster speed grade device if available. With a faster device, the software might be able to set more device tiles to use the low-power mode.
7.	<input type="checkbox"/> <i>Optimize the clock power management</i> Clocks represent a significant portion of dynamic power consumption, because of their high switching activity and long paths. The Quartus II software automatically optimizes clock routing power by enabling only the portions of a clock network that are required to feed downstream registers. You can also use clock control blocks to dynamically enable or disable the clock network. When a clock network is powered down, all the logic fed by that clock network does not toggle, thereby reducing the overall power consumption of the device. For more information about using clock control blocks, refer to the <i>Clock Control Block (ALTCLKCTRL) Megafunction User Guide</i> . To reduce LAB-wide clock power consumption without disabling the entire clock tree, use the LAB-wide clock enable signal to gate the LAB wide clock. The Quartus II software automatically promotes register-level clock enable signals to the LAB level.
8.	<input type="checkbox"/> <i>Reduce the number of memory clocking events</i> Reduce the number of memory clocking events to reduce memory power consumption. You can use clock gating or the clock enable signals in the memory ports.

Table 17. Power Analysis and Optimization Checklist (Part 3 of 3)

No.	✓ Checklist items
9.	<input type="checkbox"/> <i>Consider the following I/O power guidelines:</i> <ul style="list-style-type: none"> ■ The dynamic power consumed in the I/O buffer is proportional to the total load capacitance—lower capacitance reduces power consumption. ■ Dynamic power is proportional to the square of the voltage. Use lower voltage I/O standards to reduce dynamic power. Non-terminated I/O standards such as LVTTL and LVC MOS have a rail-to-rail output swing equal to the V_{CCIO} supply voltage and consume little static power. ■ Dynamic power is proportional to the output transition frequency. Use resistively-terminated I/O standards such as SSTL for high-frequency applications. The output load voltage swings by an amount smaller than the V_{CCIO} around a bias point. Because of this, the dynamic power is lower than for non-terminated I/O under similar conditions. ■ Resistively-terminated I/O standards dissipate significant static power because current is constantly driven into the termination network. Use the lowest drive strength that meets your speed and waveform requirements to minimize static power when using resistively terminated I/O standards. ■ The power used by external devices is not included in the PowerPlay Power Analyzer calculations. Ensure that you include the external devices power separately in your system power calculations.
10.	<input type="checkbox"/> <i>Review the information on power-driven compilation and Power Optimization Advisor</i> For more information, refer to the <i>Power Optimization</i> chapter in the Quartus II Handbook.

Document Revision History

Table 18 lists the revision history for this document.

Table 18. Document Revision History

Date	Version	Changes
November 2016	1.3	Added information about disabling PLL output clock when the PLL is locked in Table 10.
August 2016	1.2	Updated power sequencing recommendation for multi-rail powered system in Table 5.
January 2014	1.1	Changed “SoC FPGA” to “SoC”.
January 2013	1.0	Initial release.

