



OCT Intel[®] FPGA IP User Guide

Updated for Intel[®] Quartus[®] Prime Design Suite: **19.2**

IP Version: **19.1**



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OCT Intel® FPGA IP User Guide

The OCT Intel FPGA IP allows you to dynamically calibrate I/O with reference to an external resistor. The OCT IP improves signal integrity, reduces board space, and is necessary for communicating with external devices such as memory interfaces.

The OCT IP is available for Intel Stratix® 10, Intel Arria® 10, and Intel Cyclone® 10 GX devices. If you are migrating designs from Stratix V, Arria V, and Cyclone V devices, you need to migrate the IP. For more details, refer to the related information.

Related Information

- [Migrating Your ALTOCT IP to the OCT Intel FPGA IP](#) on page 13
Provides steps to migrate your ALTOCT IP core to the OCT IP core.
- [Dynamic Calibrated On-Chip Termination \(ALTOCT\) IP Core User Guide](#)
Provides information about the ALTOCT IP core.
- [Introduction to Intel FPGA IP Cores](#)
Provides general information about all Intel FPGA IP cores, including parameterizing, generating, upgrading, and simulating IP cores.
- [Creating Version-Independent IP and Platform Designer Simulation Scripts](#)
Create simulation scripts that do not require manual updates for software or IP version upgrades.
- [Project Management Best Practices](#)
Guidelines for efficient management and portability of your project and IP files.
- [OCT Intel FPGA IP User Guide Archives](#) on page 13
Provides a list of user guides for previous versions of the OCTIntel FPGA IP.

OCT Intel FPGA IP Features

The OCT IP supports the following features:

- Support for up to 12 on-chip termination (OCT) blocks
- Support for calibrated on-chip series termination (R_S) and calibrated on-chip parallel termination (R_T) on all I/O pins
- Calibrated termination values of 25 Ω and 50 Ω
- Support for OCT calibration in power-up and user modes

OCT Intel FPGA IP Overview

Figure 1. OCT IP Top-Level Diagram

This figure shows the top-level diagram of the OCT IP.

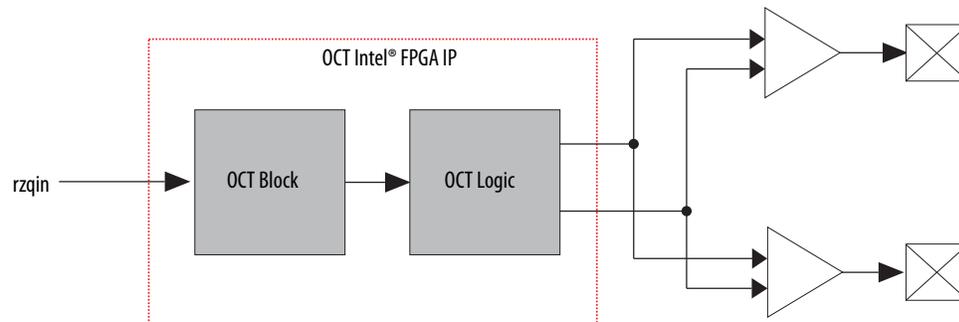


Table 1. OCT IP Components

Component	Description
RZQ pin	<ul style="list-style-type: none"> Dual-purpose pin. When used with OCT, the pin connects to an external reference resistor to calculate the calibration codes to implement the required impedance.
OCT block	Generates and sends calibration code words to the I/O buffer blocks.
OCT logic	Receives the calibration code words serially from the OCT block and sends the calibration code words in parallel to the buffers.

RZQ Pin

Each OCT block has one RZQ pin.

- RZQ pins are dual-purpose pins. If the pins are not connected to the OCT block, you can use the pins as regular I/O pins.
- Calibrated pins must have the same V_{CCIO} voltage as the OCT block and the RZQ pin. Calibrated pins connected to the same OCT block must have the same series and parallel termination values.
- You can apply location constraints on the RZQ pins to determine the placement of the OCT block because the RZQ pin can only be connected to its corresponding OCT block.

OCT Block

The OCT block is a component that generates calibration codes to terminate the I/Os.

During calibration, the OCT matches the impedance seen on the external resistor through the `rzqin` port. Then, the OCT block generates two 16-bit calibration code words—one word calibrates the series termination and the other word calibrates the parallel termination. A dedicated bus sends the words serially to the OCT logic.

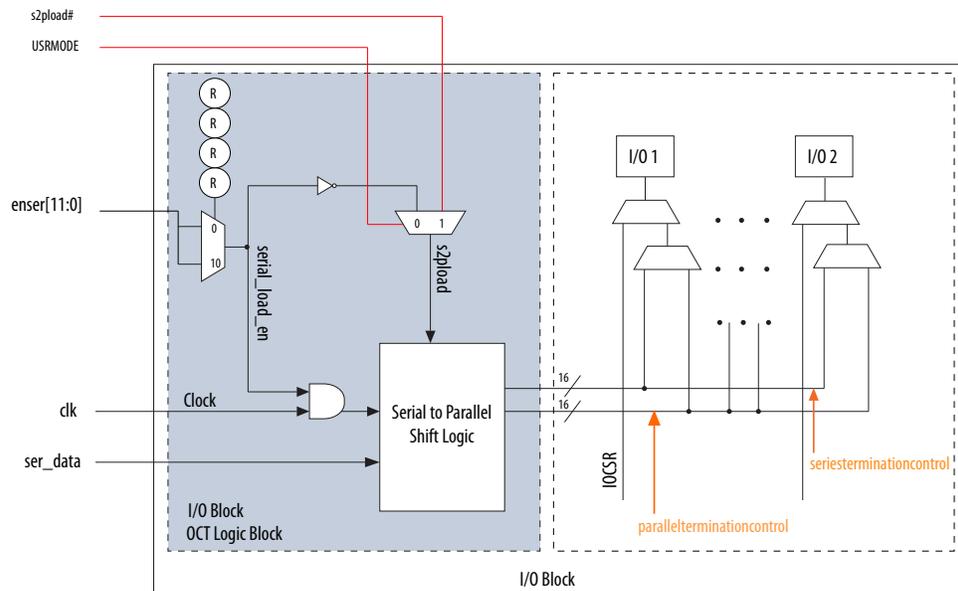
OCT Logic

The OCT block sends the calibration code words serially to the OCT logic through the `ser_data` ports.

The `enser` signal, when triggered, specifies from which OCT block to read the calibration code words. The calibration code words are then buffered into the serial-to-parallel shift logic. After that, the `s2pload` signal automatically asserts to send the calibration code words in parallel to the I/O buffers.

The calibration code words activate or deactivate the transistors in the I/O block, which will emulate series or parallel resistance to match the impedance.

Figure 2. Internals of OCT Logic



OCT Intel FPGA IP Functional Description

To meet DDR memory specification, Intel Stratix 10, Intel Arria 10, and Intel Cyclone 10 GX devices support on-chip series termination (R_S OCT) and on-chip parallel termination (R_T OCT) for single-ended I/O standards. OCT can be supported on any I/O bank. The V_{CCIO} must be compatible for all I/Os in a given bank.

In an Intel Stratix 10, Intel Arria 10, or Intel Cyclone 10 GX device, there is one OCT block in each I/O bank. Each OCT block requires an association with an external 240 Ω reference resistor through an RZQ pin.

The RZQ pin shares the same V_{CCIO} supply with the I/O bank where the pin is located. An RZQ pin is a dual function I/O pin that you can use as a regular I/O if you do not use OCT calibration. When you use the RZQ pin for OCT calibration, the RZQ pin connects the OCT block to ground through an external 240 Ω resistor.

The following figures show how OCTs are connected in a single I/O column (in a daisy chain). An OCT can calibrate an I/O belonging to any bank, provided that the bank is in the same column and meets the voltage requirements. Because there are no connections between columns, OCT can only be shared if the pins belong to the same I/O column of the OCT.

Figure 3. OCT Bank-to-Bank Connections

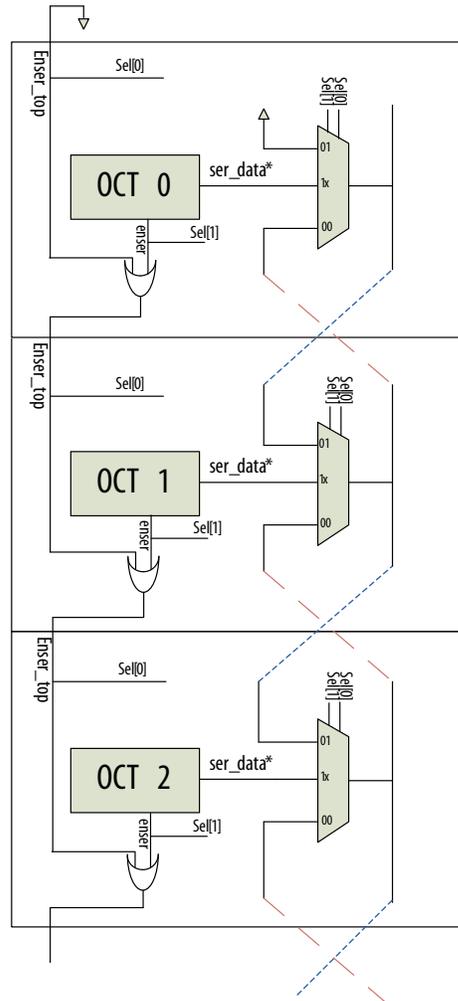
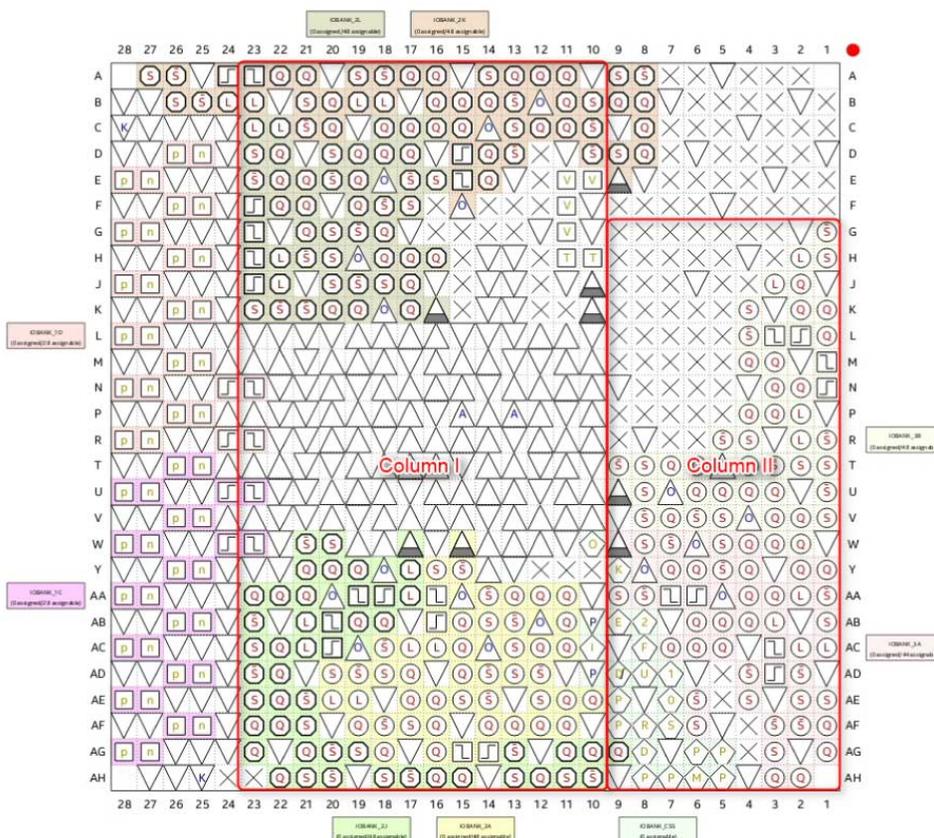


Figure 4. I/O Columns in Intel Quartus® Prime Pin Planner

This figure is an example. The layout varies between different Intel Stratix 10, Intel Arria 10, or Intel Cyclone 10 GX devices.

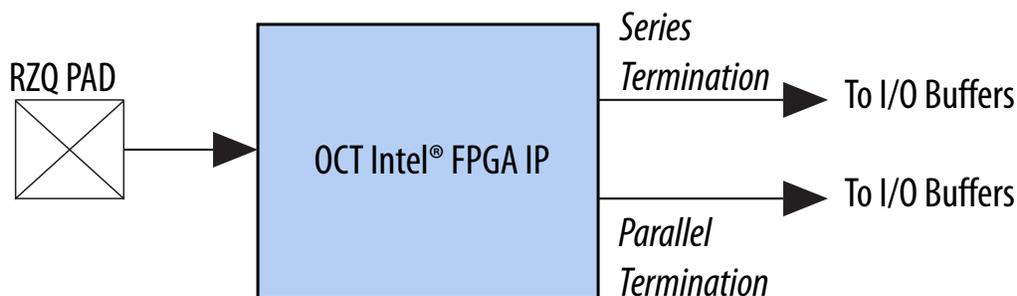


Power-Up Mode Interfaces

The OCT IP in power-up mode has two main interfaces:

- One input interface connecting the FPGA RZQ pad to the OCT block
- Two 16-bit words output which connect to I/O buffers

Figure 5. OCT Interfaces

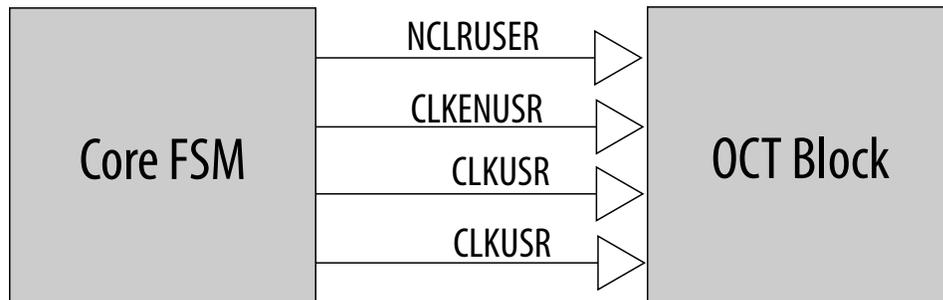


User Mode OCT

User mode OCT operates the same way as power-up OCT mode, with the addition of user controllability.

Figure 6. FSM Signals

This figure shows a finite state machine (FSM) in the core controls the dedicated user signals on the OCT block. The FSM ensures that the OCT block calibrates or sends controlling code words as per your request.



The Fitter does not infer a user-mode OCT. If you want your OCT block to use the user mode OCT feature, you must generate the OCT IP. However, because of hardware limitations, you can only use one OCT IP in user mode OCT in your design.

Note: A single OCT IP can control up to 12 OCT blocks.

The FSM provides the following signals:

- clock
- reset
- s2pload
- calibration_busy
- calibration_shift_busy
- calibration_request

Note: These signals are only available in user-mode and not power-up mode.

Related Information

[OCT Intel FPGA IP Signals](#) on page 11

Provides more information about the FSM signals.



Core FSM

Figure 7. FSM Flow

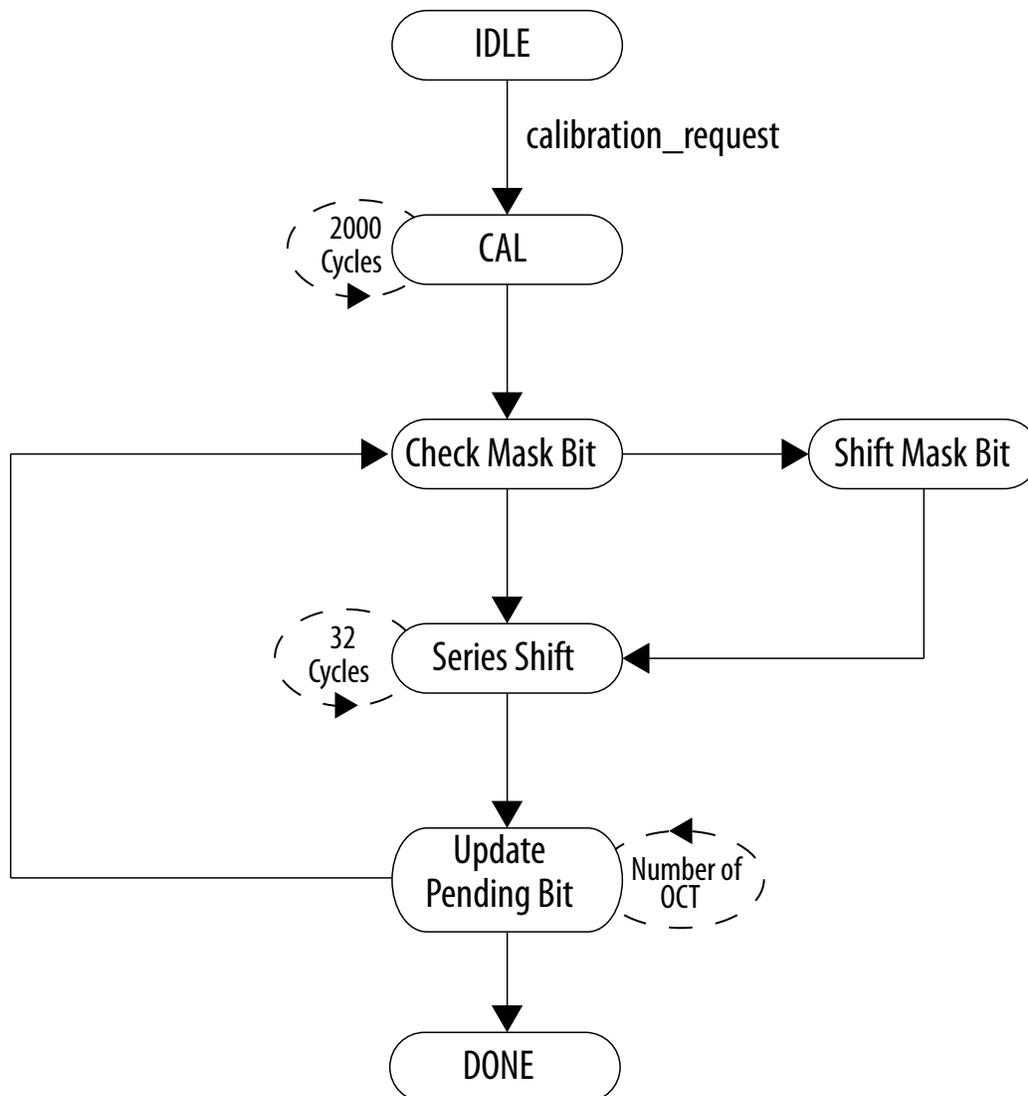


Table 2. FSM States

State	Description
IDLE	When you set the calibration_request vector, the FSM moves from IDLE state to CAL state. Keep the calibration_request vector at its value for two clock cycles. After two clock cycles, the FSM contains a copy of the vector. You must reset the vector to avoid reinitiating the calibration process.
CAL	During this state, the FSM checks which bits in the calibration_request vector were asserted and services them. The corresponding OCT blocks starts the calibration process that takes around 2,000 clock cycles to complete. After calibration completes, the calibration_busy signal is released.
Check Mask bit	The FSM checks each bit in the vector if the bit is set or not.
<i>continued...</i>	

State	Description
Shift Mask bit	This state simply loops over all the bits in the vector until it hits a 1.
Series Shift	This state serially sends the termination code from the OCT block to the termination logic. It takes 32 cycles to complete the transfer. After each transfer, the FSM check for any pending bits in the vector and services them accordingly.
Update Pending Bit	The pending register holds bits that corresponds to every OCT block in the OCT Intel FPGA IP. This state updates the pending register by resetting the serviced request.
DONE	When the <code>calibration_shift_busy</code> signal is deasserted, you can assert <code>s2pload</code> automatically asserts to transfer the new termination codes into the buffers. The <code>s2pload</code> signal asserts for at least 25 ns. Because of hardware limitations, you cannot request another calibration until all bits in <code>calibration_shift_busy</code> vector are low.

OCT Intel FPGA IP Design Example

The OCT IP can generate a design example that matches the same configuration chosen for the IP.

The design example is a simple design that does not target any specific application. You can use the design example as a reference on how to instantiate the IP.

To generate the design example files, turn on the **Generate Example Design** option in the **Generation** dialog box during IP generation.

Note: The OCT IP does not support VHDL generation.

- The software generates the `<instance>_example_design` directory along with the IP, where `<instance>` is the name of your IP.
- The `<instance>_example_design` directory contains the `make_qii_design.tcl` scripts.

Note: The `.qsys` files are for internal use during design example generation only. You cannot edit the files.

Generating the Intel Quartus® Prime Design Example

The `make_qii_design.tcl` script generates a synthesizable design example along with an Intel Quartus® Prime project, ready for compilation.

To generate synthesizable design example, follow these steps.

1. After generating the IP together with the design example files, run the following script at the command prompt: `quartus_sh -t make_qii_design.tcl`.
2. If you want to specify an exact device to use, use the following command: `quartus_sh -t make_qii_design.tcl <device_name>`.

The script generates a `qii` directory that contains the `ed_synth.qpf` project file. You can open and compile this project in the Intel Quartus Prime software.



OCT Intel FPGA IP References

OCT Intel FPGA IP Parameter Settings

Table 3. OCT IP Parameters

Name	Value	Description
Number of OCT blocks	1 to 12	Specifies the number of OCT blocks to be generated. The default value is 1 .
Use backwards-compatible port names	<ul style="list-style-type: none"> On Off 	Check this to use legacy top-level names compatible with the ALTOCT IP. This parameter is disabled by default.
OCT mode	<ul style="list-style-type: none"> Power-up User 	Specifies whether OCT is user-controllable or not. The default value is Power-up .
OCT block x calibration mode	<ul style="list-style-type: none"> Single Double POD 	Specifies the calibration mode for the OCT. X corresponds to the number of the OCT block. The default value is Single .

OCT Intel FPGA IP Signals

Table 4. Input Interface Signals

Signal Name	Direction	Description
rzqin	Input	Input connection from RZQ pad to the OCT block. RZQ pad is connected to an external resistance. The OCT block uses impedance connected to the rzqin port as a reference to generate the calibration code. This signal is available for power-up and user modes.
clock	Input	Input clock for user mode OCT. The clock must be 20 MHz or less.
reset	Input	Input reset signal. Reset is synchronous.
calibration_request	Input	Input vector for [NUMBER_OF_OCT:0]. Every bit corresponds to an OCT block. When a bit is set to 1, the corresponding OCT calibrates, then serially shift the code word into the termination logic block. The request has to be held for two clock cycles. Due to hardware limitations, you must wait until the calibration_shift_busy vector to be zero until another request is issued; otherwise your request will not be processed.
calibration_shift_busy	Output	Output vector for [NUMBER_OF_OCT:0] indicating which OCT block is currently working on calibration and shifting termination codes to the termination logic block. When a bit is 1, it indicates that an OCT block is calibrating and shifting the code word to the termination logic block.
calibration_busy	Output	Output vector for [NUMBER_OF_OCT:0] indicating which OCT block is currently working on calibration. When a bit is 1, it indicates that an OCT block is calibrating.
oct_<x>_series_termination_control[15:0]	Output	16-bit output signal, with <x> ranging from 0 to 11. This signal connects to the seriesterminationcontrol port on the input/output buffer. This port sends the series termination code that calibrates R _s .
oct_<x>_parallel_termination_control[15:0]	Output	16-bit output signal, with <x> ranging from 0 to 11. This signal connects to the parallelterminationcontrol port on the input/output buffer. This port sends the parallel termination code that calibrates R _t .

QSF Assignments

Intel Stratix 10, Intel Arria 10, and Intel Cyclone 10 GX devices have the following termination-related Intel Quartus Prime settings file (.qsf) assignments:

- INPUT_TERMINATION
- OUTPUT_TERMINATION
- TERMINATION_CONTROL_BLOCK
- RZQ_GROUP

Table 5. QSF Assignments

QSF Assignment	Details
INPUT_TERMINATION OUTPUT_TERMINATION	<p>The input/output termination assignment specifies the termination value in ohm on the pin in question.</p> <p>Example:</p> <pre>set_instance_assignment -name INPUT_TERMINATION <value> -to <pin name> set_instance_assignment -name OUTPUT_TERMINATION <value> -to <pin name></pre> <p>To enable the series/parallel termination ports, include these assignments, which specify the series and parallel termination values for the pins.</p> <p>Make sure to connect the <code>seriesterminationcontrol</code> and <code>parallelerminationcontrol</code> ports from the OCT Intel FPGA IP to the GPIO Intel FPGA IP.</p> <p>Example:</p> <pre>set_instance_assignment -name INPUT_TERMINATION "PARALLEL <VALUE> OHM WITH CALIBRATION" -to <pin> set_instance_assignment -name OUTPUT_TERMINATION "SERIES <VALUE> OHM WITH CALIBRATION" -to <pin></pre>
TERMINATION_CONTROL_BLOCK	<p>Directs the Fitter to make the proper connection from the desired OCT block to the specified pins. This assignment is useful when I/O buffers are not explicitly instantiated and you need to associate the pins with a specific OCT block.</p> <p>Example:</p> <pre>set_instance_assignment -name TERMINATION_CONTROL_BLOCK <desired OCT BLK> -to <pin name></pre>
RZQ_GROUP	<p>This assignment is supported in Intel Stratix 10, Intel Arria 10, and Intel Cyclone 10 GX devices only. This assignment creates an OCT IP without modifying the RTL.</p> <p>The Fitter searches for the <code>rzq</code> pin name in the netlist. If the pin does not exist, the Fitter creates the pin name along with the OCT IP and its corresponding connections. This allows you to create a group of pins to be calibrated by an existing or non-existing OCT and the Fitter ensures the legality of the design.</p> <p>Example:</p> <pre>set_instance_assignment -name RZQ_GROUP <rzq pin name> -to <pin name></pre>

Termination can exist on input and output buffers, and sometimes simultaneously.

There are two methods to associate pin groups with an OCT block:

- Use a .qsf assignment to indicate which pin (bus) is associated with which OCT block. You can use the `TERMINATION_CONTROL_BLOCK` or `RZQ_GROUP` assignment. The former assignment associates a pin with an OCT instantiated in the RTL while the latter associates the pin with a newly created OCT without modifying the RTL.
- Instantiate the I/O buffer primitives at the top level and connect them to the appropriate OCT blocks.



Note: All I/O banks with the same V_{CCIO} can share one OCT block even if that particular I/O bank has its own OCT block. You can connect any number of I/O pins that support calibrated termination to an OCT block. Ensure that you connect I/Os with compatible configuration to an OCT block. You must also ensure that the OCT block and its corresponding I/Os have the same V_{CCIO} and series or parallel termination values. With these settings, the Fitter places the I/Os and OCT block in the same column. The Intel Quartus Prime software generates warning messages if there is no pin connected to the block.

IP Migration Flow for Arria V, Cyclone V, and Stratix V Devices

The IP migration flow allows you to migrate the ALTOCT IP of Arria V, Cyclone V, and Stratix V devices to the OCT Intel FPGA IP of Intel Stratix 10, Intel Arria 10, or Intel Cyclone 10 GX devices.

The IP migration flow configures the OCT IP to match the settings of the ALTOCT IP, allowing you to regenerate the IP.

Note: This IP supports the IP migration flow in single OCT calibration mode only. If you are using double or POD calibration mode, you do not need to migrate the IP.

Migrating Your ALTOCT IP to the OCT Intel FPGA IP

To migrate your ALTOCT IP to the OCT IP, follow these steps:

1. Open your ALTOCT IP in the IP Catalog.
2. In **Currently selected device family**, select **Stratix 10, Arria 10, or Cyclone 10 GX**.
3. Click **Finish** to open the OCT IP in the parameter editor. The parameter editor configures the OCT IP settings similar to the ALTOCT IP settings.
4. If there are any incompatible settings between the two, select **new supported settings**.
5. Click **Finish** to regenerate the IP.
6. Replace your ALTOCT IP instantiation in RTL with the OCT IP.

Note: The OCT IP port names may not match the ALTOCT IP port names. Therefore, simply changing the IP name in the instantiation is not sufficient.

OCT Intel FPGA IP User Guide Archives

If an IP core version is not listed, the user guide for the previous IP core version applies.

IP Core Version	User Guide
17.1	Intel FPGA OCT IP Core User Guide



Document Revision History for OCT Intel FPGA IP User Guide

Document Version	Intel Quartus Prime Version	IP Version	Changes
2019.07.03	19.2	19.1	<ul style="list-style-type: none">• Added support for Intel Stratix 10 devices.• Updated the following IP names:<ul style="list-style-type: none">– "Intel FPGA OCT" to "OCT Intel FPGA IP"– "Intel FPGA GPIO" to "GPIO Intel FPGA IP"• Updated the <code>s2pload</code> signal:<ul style="list-style-type: none">– Removed <code>s2pload</code> from available user signals.– Updated descriptions regarding the <code>s2pload</code> signal behavior.

Date	Version	Changes
November 2017	2017.11.06	<ul style="list-style-type: none">• Added support for Intel Cyclone 10 GX devices.• Renamed Altera OCT IP core to Intel FPGA OCT IP core.• Renamed Qsys to Platform Designer.• Updated text for additional Intel rebranding.
May 2017	2017.05.08	Rebranded as Intel.
December, 2015	2015.12.07	<ul style="list-style-type: none">• Changed instances of "megafunction" to "IP core".• Changed instances of <i>Quartus II</i> to <i>Quartus Prime</i>.• Various edits to contents and links to improve style and clarity.
August, 2014	2014.08.18	<ul style="list-style-type: none">• Added information about OCT calibration in user mode.• Updated the IP core signals and parameters:<ul style="list-style-type: none">– <code>core_rzqin_export</code> changed to <code>rzqin</code>– <code>core_series_termination_control_export</code> changed to <code>oct_<x>_series_termination_control[15:0]</code>– <code>core_parallel_termination_control_export</code> changed to <code>oct_<x>_parallel_termination_control[15:0]</code>
November, 2013	2013.11.29	Initial release.