OpenCPI
Tutorial 8hw: Using Third-Party HDL Primitive Cores

OpenCPI Release: v2.4.7

Revision History

Revision	Description of Change	Date
1.0	Creation from Lab 8 developed by BIA	2019-10-01
1.1	Add content, test CLI instructions, update/test GUI instructions	2021-12-28
1.2	Update GUI screenshots, correct GUI section variable name, prepare for 2.4.1	2022-02-28
1.3	Update GUI and CLI to reflect ocpidev changes	2022-08-30

Table of Contents

1 Overview

Note: This tutorial demonstrates the same steps as Tutorial 8, but it includes a hardware platform in the demonstration; in this case, the ADALM-PLUTO (**`plutosdr`**) HDL platform.

This tutorial describes how to create an HDL worker that uses HDL primitive cores imported from a third party; in this example, Vivado. It demonstrates how to design, build and test a complex mixer HDL worker (**`complex_mixer.hdl`**) for execution on a Xilinx XSIM simulator. The HDL worker is a “work-alike” to the complex mixer RCC worker discussed in Tutorial 4.

The tutorial shows you how to:

- Set OCS and OWD properties (XML)
- Convert the data port interface from interleaved to parallel (OWD)
- Route data/messages through the worker "pass-through" (VHDL)
- Wrap Vivado IP (third-party) cores (netlist, VHDL)
- Run the OpenCPI unit test framework on multiple platforms (XML, Python)

A third-party core is an HDL primitive core that is not included in the OpenCPI framework. These cores allow you to implement functions that you couldn’t do otherwise and are optimized for the technology so that they make best use of the available resources. In this tutorial, Vivado is the third-party core that we are using.

1.1 What's Provided for This Tutorial

In this tutorial, you will re-use the **`complex_mixer.test/`** directory that you implemented in Tutorial 4. Remember that there is one <*component*>**.test/** directory per component specification.

The OpenCPI built-in tutorial project **`ocpi.tutorial`** provides the following items for this tutorial:

- The **`complex_mixer`** HDL worker VHDL source code annotated with information on how it is designed, located in **`projects/tutorial/components/complex_mixer_tutorial.hdl/complex_mixer_tutorial.vhd`**
- The following third-party core files (Vivado IP output files) located in **`/projects/tutorial/components/complex_mixer_tutorial.hdl/vivado_ip/`**:

  `complex_multiplier[_stub.vhd|.edf]` and **`dds_complier[_stub.vhd|.edf]`**

  `complex_multiplier_sim_net.vhd` and **`dds_compiler_sim_net.vhd`**

The tutorial also provides the XML source for all of the assets used to build and run the example component, worker and tests described in this tutorial.

Instructions for copying these items from the **`ocpi.tutorial`** project into the "demo" tutorial project are provided in the relevant sections of this document. The source code for these items is also available as text in the relevant sections of this document that you can copy and paste into the relevant files following the instructions given in the section.

Note: when copying and pasting text from this document, be sure to remove any line breaks in code or command lines. The backslash character (\) is used in command lines (where feasible) to indicate a line break.

This tutorial uses Vivado IP cores. Information on how to generate these cores and their usage within OpenCPI can be found in sections 5-7 of the OpenCPI Vivado Usage Notes.

1.2 Prerequisites to Using This Tutorial

This tutorial (Tutorial 8hw) has the same system prerequisites as ***OpenCPI Tutorial 1: Component-based Development***. See the prerequisites section in Tutorial 1 for details. In addition to these requirements, this tutorial uses the **`plutosdr`** platform, and so the corresponding OSP should be downloaded and installed. See the section "Installation Steps for Platforms" in the ***OpenCPI Installation Guide***.

Before you begin this tutorial, you should have successfully completed Tutorials 1 through 7.

We recommend reading the following briefings before getting started:

- Briefing 9 HDL Assemblies
- Briefing 10 HDL Primitives

1.3 Documentation References

The documents listed in the following table provide detailed information about subjects discussed in this tutorial. The documents listed here are not required reading for this tutorial but will likely be of interest for more in-depth learning.

Table 1 - OpenCPI Reference Documentation

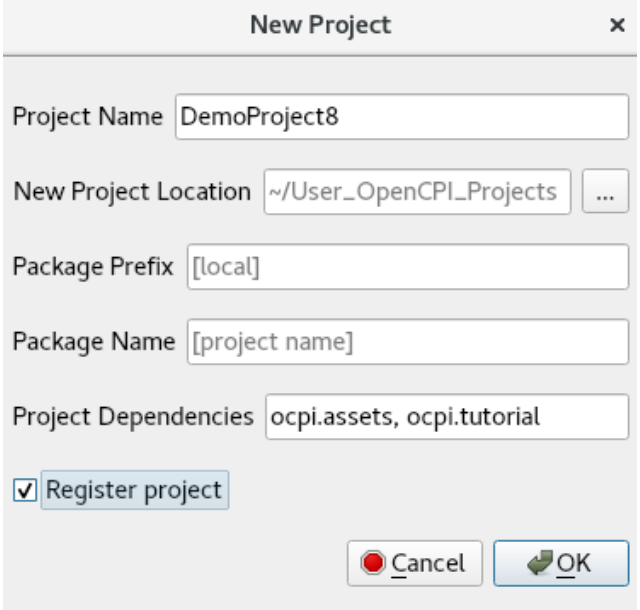
Title	Published By	Public URL
OpenCPI User Guide	OpenCPI	https://opencpi.gitlab.io/releases/v2.4.7/docs/OpenCPI_User_Guide.pdf
OpenCPI Application Development Guide	OpenCPI	https://opencpi.gitlab.io/releases/v2.4.7/docs/OpenCPI_Application_Development_Guide.pdf
OpenCPI Component Development Guide	OpenCPI	https://opencpi.gitlab.io/releases/v2.4.7/docs/OpenCPI_Component_Development_Guide.pdf
OpenCPI HDL Development Guide	OpenCPI	https://opencpi.gitlab.io/releases/v2.4.7/docs/OpenCPI_HDL_Development_Guide.pdf
OpenCPI RCC Development Guide	OpenCPI	https://opencpi.gitlab.io/releases/v2.4.7/docs/OpenCPI_RCC_Development_Guide.pdf

2 Create New Project

As we did in Tutorial 4, we'll create a new, clean project for Tutorial 8; we'll call it **`DemoProject8`**. This project has the same requirements as the project we created for Tutorial 3.

To create **`DemoProject8`** using the OpenCPI GUI:

- Start OpenCPI GUI.
- From the top menu bar, select **Create** > **Project…**



- In the **New Project** dialog, enter the **Project Name**, **DemoProject8**.
- In **Project Dependencies**, enter **ocpi.assets, ocpi.tutorial**.
- Check **Register project**.
- Leave all of the other fields as they are and click **OK**.
- You should now see **DemoProject8** displayed in the OpenCPI Project Explorer panel.

To create the **`DemoProject8`** project with **`ocpidev`**, use the command:

```
ocpidev -D ocpi.assets -D ocpi.tutorial create project DemoProject8
--register
```

We need to make the same modifications to the **`Project.xml`** file as we did in Tutorial 4. Open the **`Project.xml`** file with a text editor and add the following two lines after the **`ProjectDependencies`** attribute:

```
HdlLibraries='prims'
ComponentLibraries='util_comps'
```

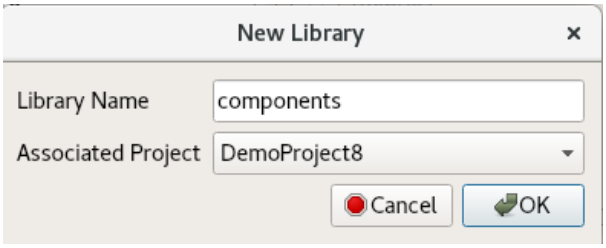
Now save and close the file.

3 Create Component Library

We can use the top-level **`components`** directory as our library like we did in Tutorial 4.

To create the **`components`** library with the OpenCPI GUI:

- From the GUI menu bar at the top of the window, select **Create** > **Component Library…**
- In **Library Name**, enter **components**.
- In **Associated Project**, select **DemoProject8**. Click **OK** to create the component library.



- The **`components`** library is displayed in the Project Explorer panel.

Again, notice that the GUI executes **`ocpidev`** commands to carry out its operations and that they are visible in the output console panel on the right. You can follow along and familiarize yourself with the **`ocpidev`** commands by checking the output console after you perform an operation.

To create the **`components`** library with **`ocpidev`**, run the following command in the **`DemoProject8/`** directory:

```
ocpidev create library components
```

4 Create Component

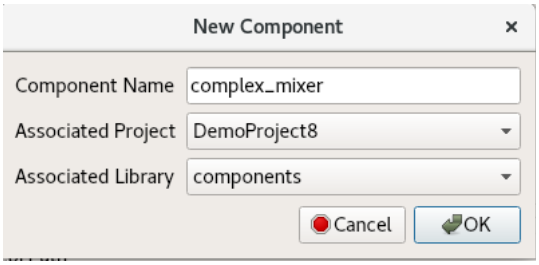
Like we did in Tutorial 4, we need to create the OCS (OpenCPI Component Specification) for our complex mixer function that defines its properties and ports.

4.1 Create Component Spec

As we did for the **`peak_detector`** component in Tutorial 3, we'll create the complex mixer component spec in the **`components`** library.

To create the complex mixer component spec with the OpenCPI GUI:

- From the GUI menu bar at the top of the window, select **Create** > **Component Spec…**
- The **New Component** dialog appears. In **Component Name**, enter **complex_mixer**.
- In **Associated Library**, select **DemoProject8**.
- Leave **Associated Library** set to **components**.



- Click **OK**. When the operation completes, you should see a **complex_mixer.comp-** subdirectory in the **components** directory displayed in the Project Explorer panel.

To create the component spec with **`ocpidev`**, run the following command from the **`DemoProject8/components/`** directory:

```
ocpidev create component complex_mixer
```

The command creates the component spec **`complex_mixer-spec.xml`** in **`components/complex_mixer.comp/`**. We'll add properties and ports to the component spec in the next step.

4.2 Add Properties and Ports

The **complex_mixer** component function needs to define two properties:

- The **phs_inc** ("phase increment") property, which stores the results of the computation (that is, setting the tune frequency for the input signal using the output of the internal NCO). This property is valid for both RCC and HDL component implementations.
- The **enable** property, which controls whether a worker implementation performs the computation on the incoming data or simply passes the incoming data through without any processing ("bypass" mode). This property is valid for both RCC and HDL component implementations.

We want to set default values for the **phs_inc** and **enable** properties in the component spec and allow the worker implementation to override these values. We'll use the **default** attribute in our property definitions to specify the default values and use the **writeable** attribute to indicate that the worker can override them. You can read more about how the framework interprets these attributes in the ***OpenCPI Component Development Guide***.

The **complex_mixer** component has the same simple port configuration as the **peak_detector** component and uses the same OPS. It requires one input port and one output port for communication with other components in an application and both ports will use the **iqstream** protocol.

To add properties and ports from the command line, open the spec with a text editor and add the following XML code (highlighted in red) between the **ComponentSpec** elements:

```
<ComponentSpec>
  <Property Name="enable" Type="bool" Writable="true"
    Default="true"/>
  <Property Name="phs_inc" Type="short" Writable="true"
    Default="-8192"/>
   <Port Name="in" Protocol="iqstream_protocol"/>
  <Port Name="out" Protocol="iqstream_protocol"
    Producer="true"/>
</ComponentSpec>
```

5 Create Worker

To create the worker using the OpenCPI GUI:

- **Create** > **Worker**...

  Worker Name: **complex_mixer**

  Associated Project: **DemoProject8**

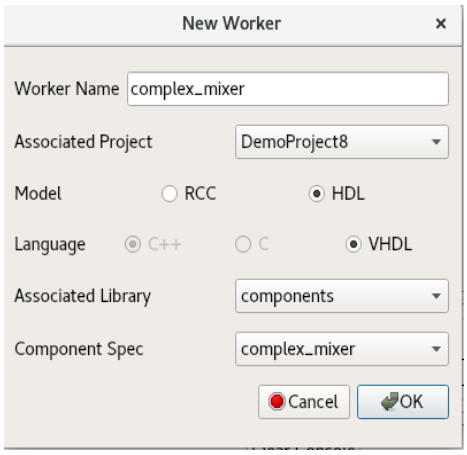
  Model: **HDL**

  Language: **VHDL**

  Associated Library: **components**

  Component: **complex_mixer** (**`ocpi.tutorial`**)

- Click **OK**.



To create the worker with **`ocpidev`**, run the following command in the **`DemoProject8/components/`** directory:

```
ocpidev create worker complex_mixer.hdl -S complex_mixer
```

Now examine the auto-generated directories and files:

- **`components/complex_mixer.hdl/`** - Worker directory with authoring model suffix (**`.hdl`**)
- **`components/complex_mixer.hdl/complex_mixer.xml`** - OWD XML file
- **`components/complex_mixer.hdl/complex_mixer.vhd`** - VHDL (architecture) skeleton file
- **`components/complex_mixer.hdl/gen/`** - OpenCPI worker build artifacts (**`complex_mixer-impl.vhd`** contains the entity)

6 Edit Worker OWD

Now we'll add the worker properties to the skeleton worker OWD.

6.1 Add data_select Property

First, reference the “Worker Properties” table in the complex mixer component data sheet. The worker has the **`data_select`** property, which selects the data to output in bypass mode (input or NCO). The default value for this property is 0 (false).

Ensure that all attributes and default values are set for each property/parameter according to the component's data sheet.

In the OpenCPI GUI, right-click **`complex_mixer.xml`** and then click **Edit File**. This action opens the XML file using your system's default handler for XML files, where you can edit the file if the GUI supports that function for the handler. Make the changes described below. When you finish editing the file, click **Save** and then close the file.

To add the properties from the command line, open **`complex_mixer.xml`** with a text editor.

Now add the properties and parameters according to the data sheet.

Next, add the **`data_select`** property (highlighted in red):

```
<HdlWorker language='vhdl' spec='complex_mixer-spec' Version="2">
<Property Name="data_select" Type="bool" Default="false"
Writable="true" Description="In Bypass Mode: selects data to
output: 0=input data, 1=output of NCO"></Property>
</HdlWorker>
```

6.2 Convert Data Port Interface for Parallel Transmission

By default, the **`iqstream_protocol`** is interleaved 16-bit I/Q sample data. We need to convert the data port interface from interleaved to parallel.

Determine the port configuration settings by examining the "Worker Interfaces" table in the component using the data sheet.

Using the OpenCPI GUI, right click **`complex_mixer.xml`** and click **Edit File**. This action opens the XML file using your system's default handler for XML files, where you can edit the file if the GUI supports that function for the handler. Make the changes described below. When you finish editing the file, click **Save** and then close the file.

From the command line, open **`complex_mixer.xml`** with a text editor.

Add the port configurations shown in the “Worker Interfaces” table in the data sheet.

Now you can add **`StreamInterfaces`** for each port as shown below.

```
<HdlWorker language='vhdl' spec='complex_mixer-spec' Version="2">
<Property Name="data_select" Type="bool" Default="false"
Writable="true" Description="In Bypass Mode: selects data to
output: 0=input data, 1=output of NCO"></Property>
<StreamInterface Name="in" DataWidth="32"></StreamInterface>
<StreamInterface Name="out" DataWidth="32"
InsertEOM="1"></StreamInterface>
</HdlWorker>
```

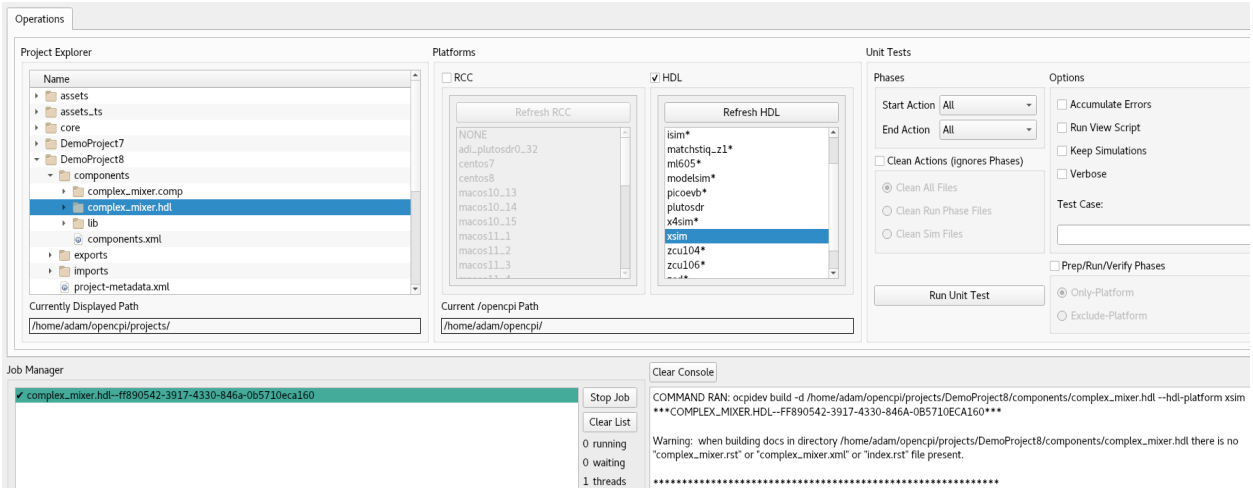
Expanding the data interface to 32 bit allows 16-bit I and 16-bit Q data to be transmitted simultaneously; that is, in parallel.

7 Build Worker

Now we'll build the worker with the changes to the OWD for the simulator and hardware platforms.

To build the worker using the OpenCPI GUI:

- In the Platforms panel, check **HDL** and select **xsim**.
- In the Project Explorer panel, right-click on **`complex_mixer.hdl`** and then click **Build**.
- Review the output console messages to ensure this step is error free and check the Job Manager and look for the green color that signals success.
- Repeat the previous steps for the **plutosdr** platform.



To build the worker for **`xsim`** using **`ocpidev`**, run the following command from the **`DemoProject8/components/complex_mixer.hdl/`** directory:

```
ocpidev build --hdl-platform xsim
```

To build the worker for **`plutosdr`** using **`ocpidev`**, run the following command from the **`DemoProject8/components/complex_mixer.hdl/`** directory:

```
ocpidev build --hdl-platform plutosdr
```

8 Copy Third-Party Cores to Worker

Now we'll copy the third-party HDL primitive core directory **`vivado_ip`** provided in the tutorial project into the **`complex_mixer.hdl/`** directory in **`DemoProject8`**:

```
cd
$OCPI_ROOT_DIR/projects/DemoProject8/components/complex_mixer.hdl/
cp -r
$OCPI_ROOT_DIR/projects/tutorial/components/complex_mixer_tutorial.
hdl/vivado_ip/ .
```

9 Copy VHDL Source Code

The skeleton **<worker-name>-skel.vhd** file is an empty architecture. The entity is generated VHDL based on the OCS and OWD and is located in **gen/<worker-name>-impl.vhd**. To implement the worker source code, we'll simply copy the reference worker source code (and the worker Makefile) from the **complex_mixer_tutorial.hdl/** directory in the tutorial project as follows:

- Replace the skeleton **.vhd** file with the provided **.vhd**. It contains descriptions of how the VHDL source code is designed:

```
cd
$OCPI_ROOT_DIR/projects/DemoProject8/components/complex_mixer.hdl

cp
$OCPI_ROOT_DIR/projects/tutorial/components/complex_mixer_tutorial.
hdl/complex_mixer_tutorial.vhd complex_mixer.vhd
```

- Copy the provided Makefile. This tutorial requires this makefile in order to be run correctly; it is not a simple component and thus has not currently been converted into a **make**-less implementation:

```
cp
$OCPI_ROOT_DIR/projects/tutorial/components/complex_mixer_tutorial
.hdl/Makefile .
```

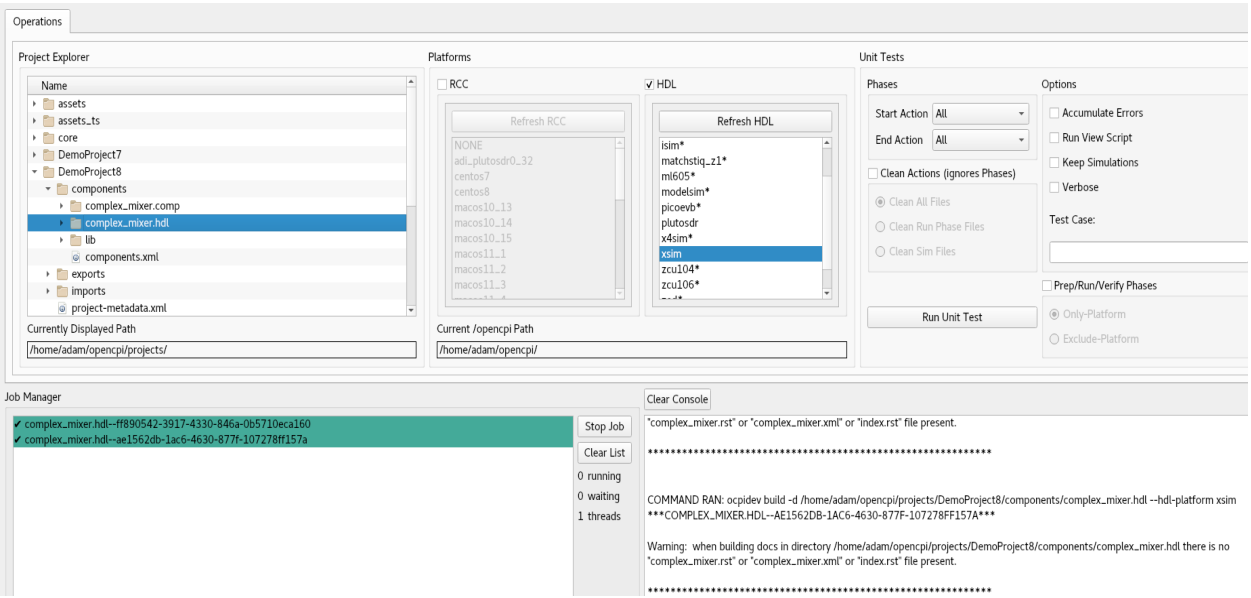
Now look at the VHDL source code. Starting at the top, look at the source code following the commented instructions. These lines are focused on the ports and properties added in this tutorial. Read the comments so you have an idea of how and why these things were done.

10 Rebuild Worker

Now we'll build our updated **`complex_mixer`** HDL worker for the target platforms.

To build the worker using the OpenCPI GUI:

- In the Platforms panel, check **HDL** and then scroll down and select **xsim**.
- In the Project Explorer panel, right-click **`complex_mixer.hdl`** and then click **Build**.
- Review the output console messages to ensure this step is error free and check the Job Manager and look for the green color that signals success.
- Repeat the previous steps for the **plutosdr** platform.



To build the worker for **`xsim`** with **`ocpidev`**, run the following command from the **`DemoProject8/components/complex_mixer.hdl/`** directory:

```
ocpidev build --hdl-platform xsim
```

To build the worker for **`plutosdr`** with **`ocpidev`**, run the following command from the **`DemoProject8/components/complex_mixer.hdl/`** directory:

```
ocpidev build --hdl-platform plutosdr
```

11 Review Build Log and Artifacts

The end of build log should look like the following example, if free of errors:

```
COMMAND RAN: ocpidev build --hdl-platform xsim

***COMPLEX_MIXER.HDL--27503D3E-015A-4975-BA54-071D9FEEBD8D***
Building the complex_mixer worker for xsim (target-
xsim/complex_mixer) 0:(complex_mixer_ocpi_max_opcode_out=0
complex_mixer_ocpi_endian=little complex_mixer_ocpi_version=2
complex_mixer_ocpi_max_bytes_in=8192
complex_mixer_ocpi_max_latency_out=256
complex_mixer_ocpi_max_bytes_out=8192
complex_mixer_ocpi_max_opcode_in=0
complex_mixer_ocpi_debug=false)
Tool "xsim" for target "xsim" succeeded.  0:05.24 at 11:40:16

COMMAND RAN:  ocpidev build --hdl-platform plutosdr

***COMPLEX_MIXER.HDL--0F21414A-6884-4719-95E2-4AEC5D8DB402***

Generating the definition file: gen/complex_mixer-defs.vhd
Generating the implementation header file: gen/complex_mixer-
impl.vhd from complex_mixer.xml
Generating the implementation skeleton file:
gen/complex_mixer-skel.vhd
Generating the VHDL constants file for config 0: target-
zynq/generics.vhd
Generating the opposite language definition file:
gen/complex_mixer-defs.vh
Generating the Verilog constants file for config 0: target-
zynq/generics.vh
Building worker core "complex_mixer" for target "zynq" 0:
(complex_mixer_ocpi_endian=little
complex_mixer_ocpi_max_opcode_out=0
complex_mixer_ocpi_version=2
complex_mixer_ocpi_max_bytes_in=8192
complex_mixer_ocpi_max_latency_out=256
complex_mixer_ocpi_max_bytes_out=8192
complex_mixer_ocpi_max_opcode_in=0
complex_mixer_ocpi_debug=false) target-zynq/complex_mixer.edf
Tool "vivado" for target "zynq" succeeded.  2:36.89 at
13:10:24
```

```
Creating link to export worker binary:
../lib/hdl/zynq/complex_mixer.edf -> target-
zynq/complex_mixer.edf
```

Observe the new artifacts directory complex_mixer.hdl/: "target-xsim/". This directory contains output files from their respective FPGA vendor tools (in this case, simply Xilinx Vivado) in addition to a framework auto-generated file named **`generics.vhd`** that contains parameter configuration settings of the HDL worker for the particular "target-".

If you're using the OpenCPI GUI, the second line with the random letters and numbers is just the thread represented by the GUI. It will be different every time you run the worker.

There also is a new directory “target-zynq”. This directory contains the generated files for the **`zynq`** target, in our case, the **`plutosdr`** platform.

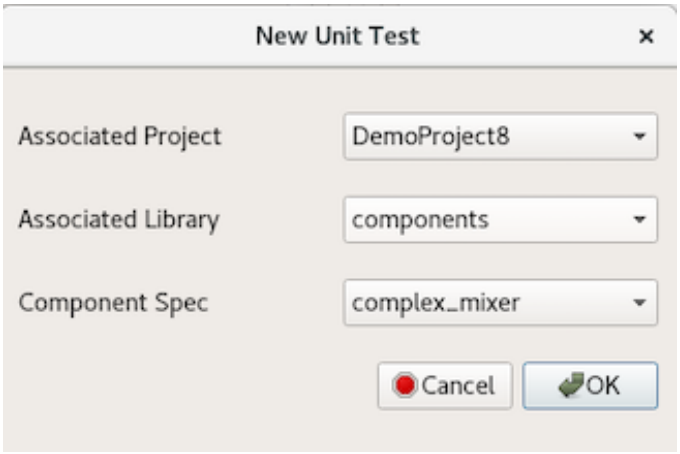
12 Create Unit Test

For this tutorial, we will copy the reference component unit test suite (aka “unit test”) contents from the tutorial project under **`$OCPI_ROOT_DIR/projects/tutorial/components/complex_mixer_tutorial.test/`**.

First, we'll create our **`complex_mixer`** unit test.

To create the unit test with the OpenCPI GUI:

- From the GUI menu bar at the top of the window, select **Create** > **Component Test Suite...**
- Choose **DemoProject8** from the **Associated Project** drop-down list.
- Choose **components** from the **Associated Library** drop-down list.
- Choose **complex_mixer** from the **Component Spec** drop-down list.



- Click **OK**. When the operation completes, you’ll see a new **`complex_mixer.test`** subdirectory in **`components`** in the Project Explorer panel.

To create the unit test with **`ocpidev`**, run the following command from the **`DemoProject8/components/`** directory:

```
ocpidev create test complex_mixer
```

Recall from previous tutorials that this step creates an OpenCPI Test Suite Description (OTSD) XML file **`complex_mixer-test.xml`** in the **`complex_mixer.test/`** directory. We need to change this XML file to add the OWD **`data_select`** property. Open the unit test description file **`complex_mixer-test.xml`** with a text editor and change it to include all of the content shown below:

```
<Tests UseHDLFileIo='true'>
  <Input Port='in' Script='generate.py 100 12.5 32767
16384'></Input>
  <Output Port='out' Script='verify.py 100 16384'
View='view.sh'></Output>
  <Property Name='phs_inc' Values='8192'></Property>
  <Property Name='enable' Values='0,1'></Property>
  <Property Name='data_select' Values='0,1'></Property>
</Tests>
```

When "**bypass**" is enabled, "**data_select**" routes either the input data or NCO output to the output data port.

Next, run the following commands to copy the contents of the tutorial project's unit test directory to our **DemoProject8** unit test directory and then delete the redundant OTSD XML file **complex_mixer_tutorial-test.xml**:

```
cd $OCPI_ROOT_DIR/<your-top-level-projects-
dir>/DemoProject8/components/complex_mixer.test

cp
$OCPI_ROOT_DIR/projects/tutorial/components/complex_mixer_
tutorial.test/* .

rm complex_mixer_tutorial-test.xml
```

Finally, change the permissions of the copied files as shown below.

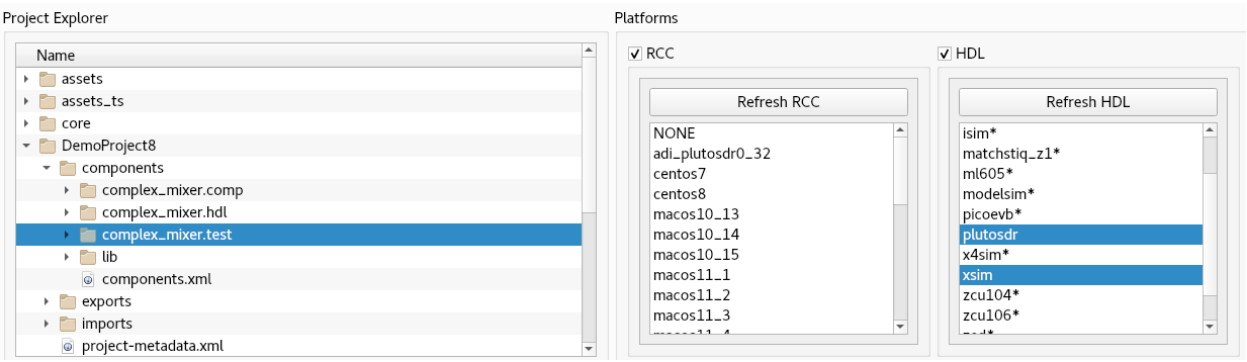
```
$ chmod 777 generate.py
$ chmod 777 verify.py
$ chmod 777 view.sh
```

13 Build Unit Test

First, we'll build the unit test for the target platforms.

Using the OpenCPI GUI:

- Highlight **complex_mixer.test** in the Project Explorer.
- Highlight **xsim** and **plutosdr** in the HDL Platforms panel.
- Right-click **complex_mixer.test** and select **Build**.



To build the unit test with **`ocpidev`**, run the following command from the **`DemoProject8/components/complex_mixer.test/`** directory:

```
ocpidev build --hdl-platform xsim --hdl-platform plutosdr
```

14 Review OCS and Build Artifacts

Next, we'll review the artifacts generated by the unit test build process.

First, observe the new artifacts in **`complex_mixer.test/gen/`**:

- **`cases.txt`** – "human-readable" file that lists various test configurations.
- **`cases.xml`** – used by the framework to execute tests.
- **`cases.xml.deps`** – list of dependent files.
- **`applications/`** – OpenCPI Application Specification (OAS) files and scripts used by the framework to execute applications.
- **`assemblies/`** – used by the framework to build bitstreams.

Now observe the new artifacts in
`complex_mixer.test/gen/assemblies/complex_mixer_0_frw/`:

- **`complex_mixer_0_frw.xml`** – generated OpenCPI HDL Assembly Description (OHAD).
- **`gen/`** - artifacts generated/used by the framework.
- **`lib/`** - artifacts generated/used by the framework.
- **`target-xsim/`** and **`target-zynq/`** - artifacts generated/used by the framework and FPGA tools.
- **`container-complex_mixer_0_frw_xsim_base/`**:

  `gen/` - artifacts generated/used by the framework

  `target_xsim/`:

  - Artifacts generated/used by the framework and output files from FPGA tools

  - Execution file for execution on the **`xsim`** platform
- **`container-complex_mixer_0_frw_plutosdr_base/`**:

  `gen/` - artifacts generated/used by the framework

  `target_zynq/`:

  - Artifacts generated/used by the framework and output files from FPGA tools

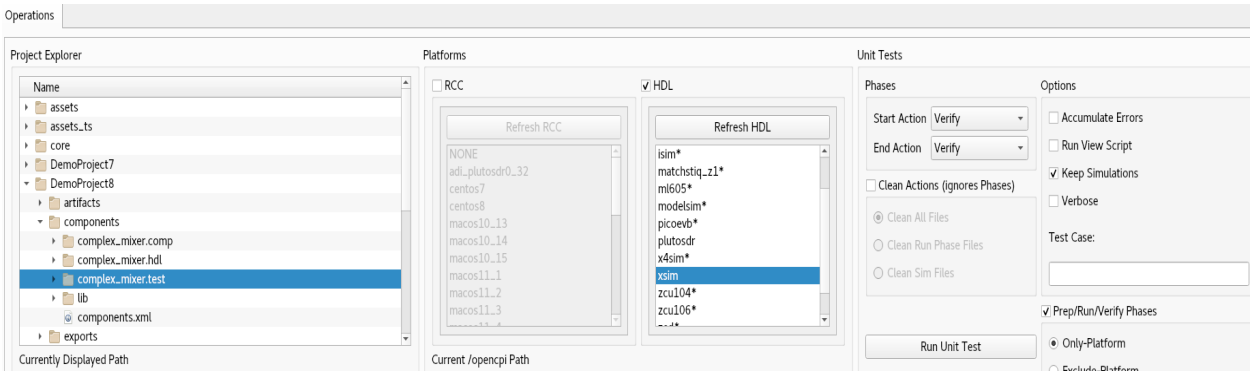
  - Execution file for execution on the **`plutosdr`** platform

15 Run Unit Test (XSIM)

In this step, we'll run the unit test for the target simulation platform, which is the **`xsim`** HDL platform for this tutorial.

To run the unit test using the OpenCPI GUI:

- **Note:** currently you can only do two modes in the GUI at the same time.
- Highlight **complex_mixer.test** in the Project Explorer.
- Highlight **xsim** in the HDL Platforms panel.
- Check **Keep Simulations**.
- Select **All** in both **Start Action** and **End Action**.
- Click **Run Unit Test**.
- Review the output console messages and address any errors.
- Now switch **Start Action** to **Verify** and **End Action** to **Verify** and click **Run Unit Test** again.
- Review the output console messages and address any errors.



To run the unit test using the **`ocpidev`** command, execute the following command within the **`complex_mixer.test/`** directory:

```
ocpidev run --mode prep_run_verify --only-platform xsim
--keep-simulations --view
```

16 Examine I/O Test Plots

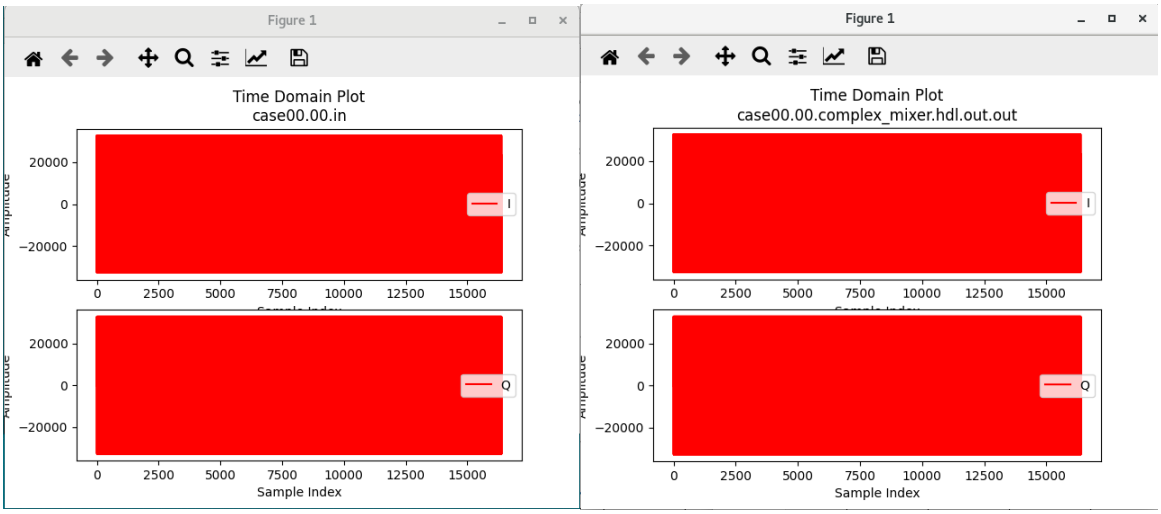
The following table shows the test case variables.

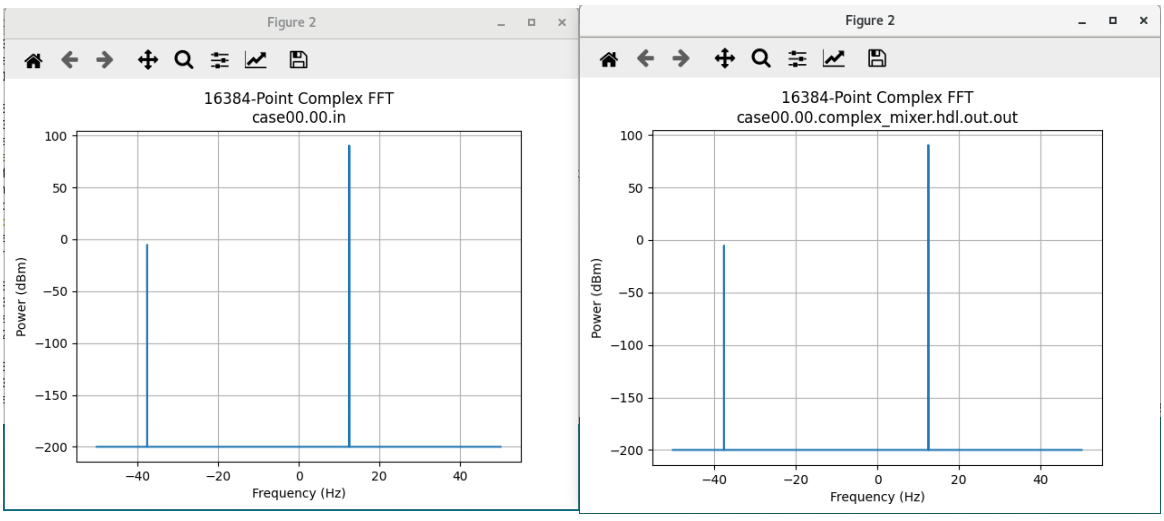
Test Case Variables

Test Case	enable	data_select	Output
case00.00	0	0	input signal
case00.001	0	1	NCO signal
case00.02	1	0	input signal
case00.03	1	0	input signal

Here are the I/O test plots:

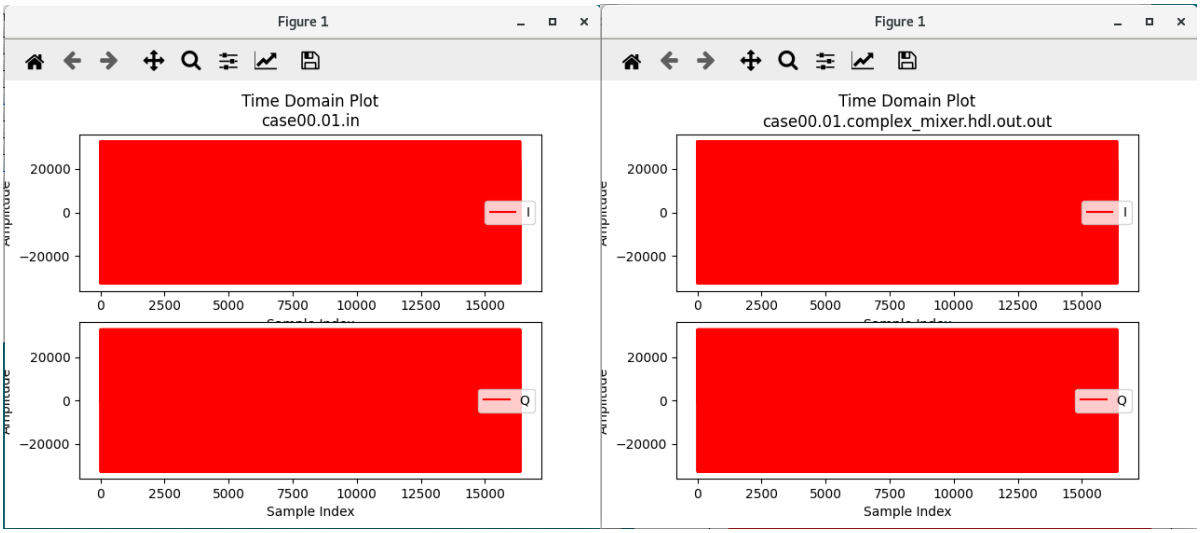
Case00.00 (enable = 0, data_select = 0)

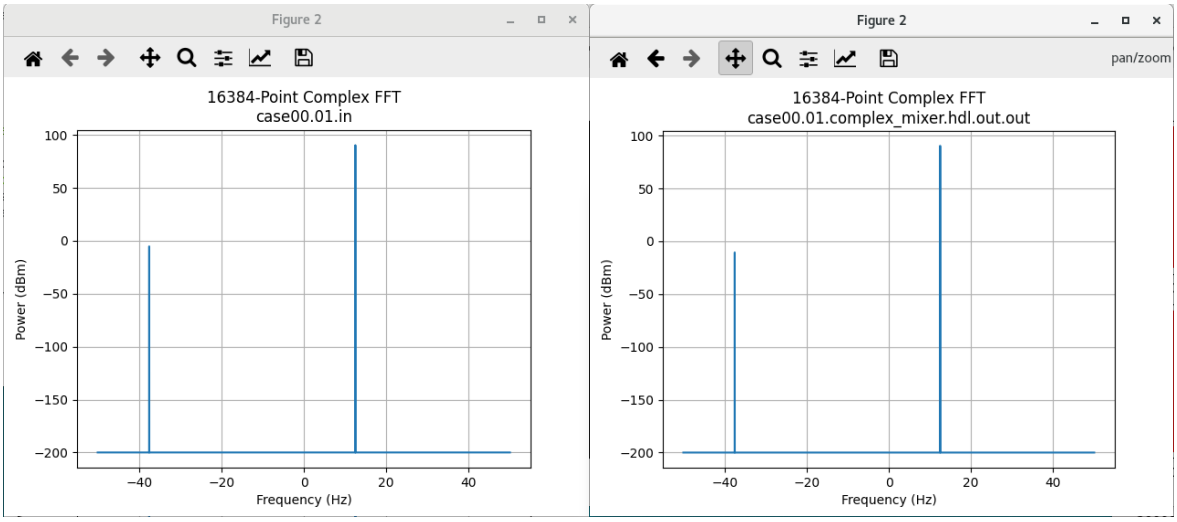




Input signal is passed through with no conversion.

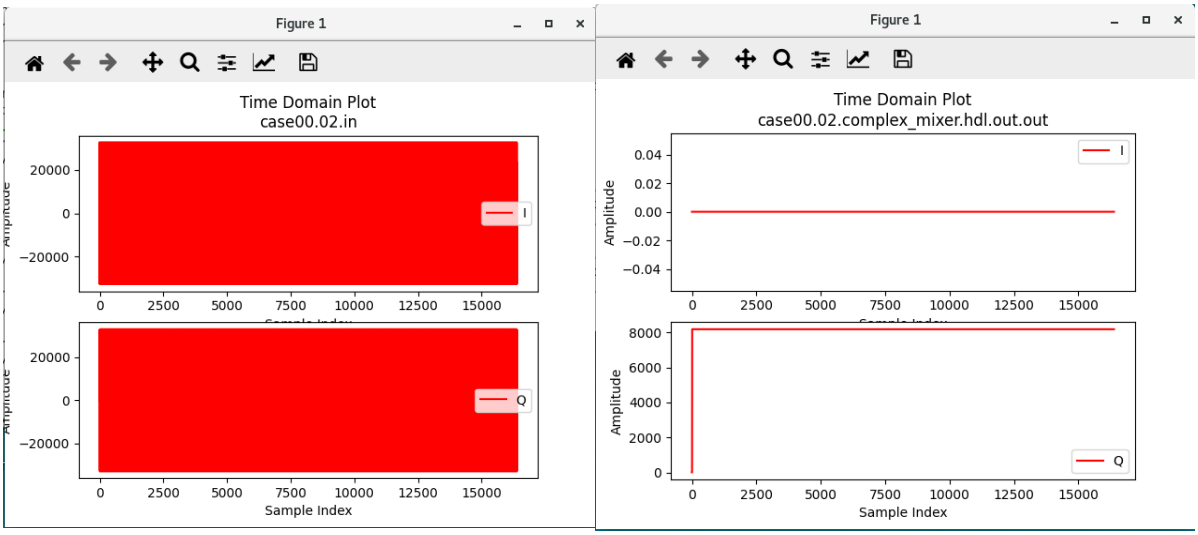
Case00.01 (enable = 0, data_select = 1)

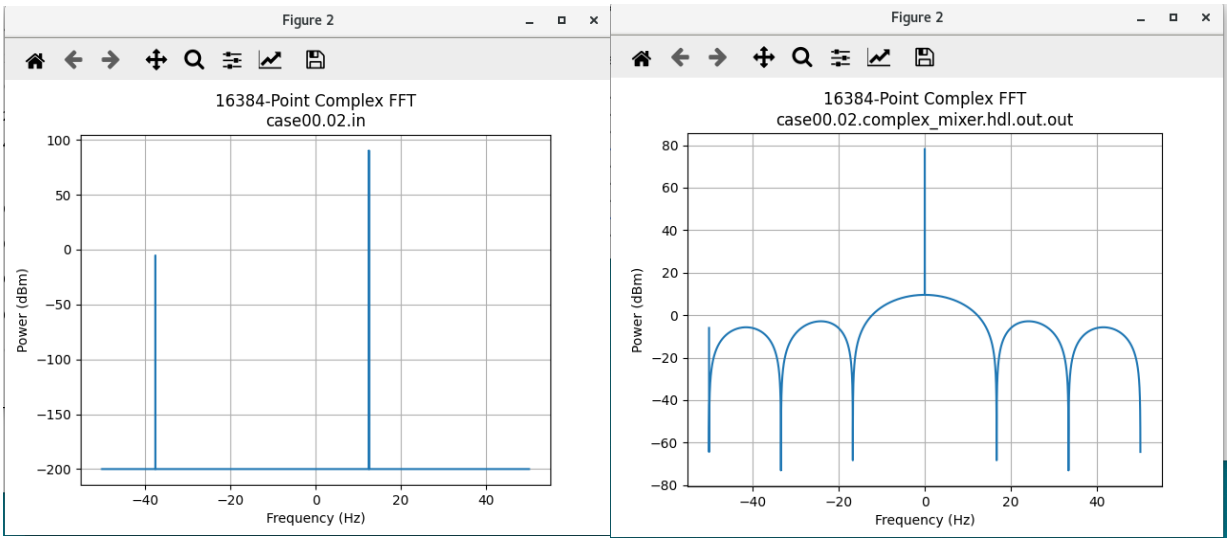




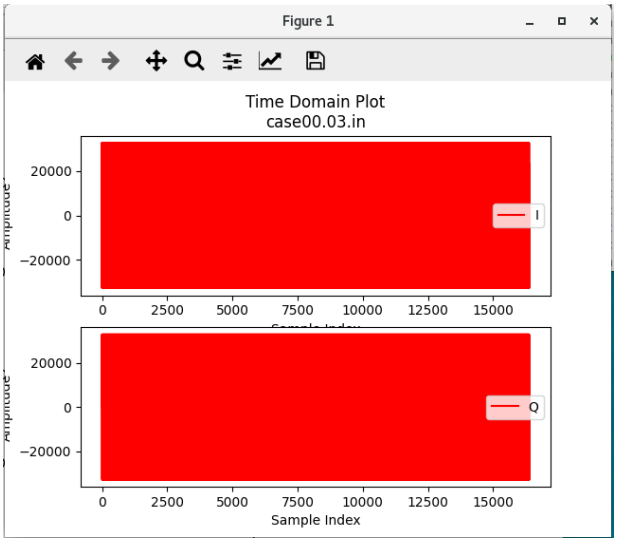
NCO signal is passed to output.

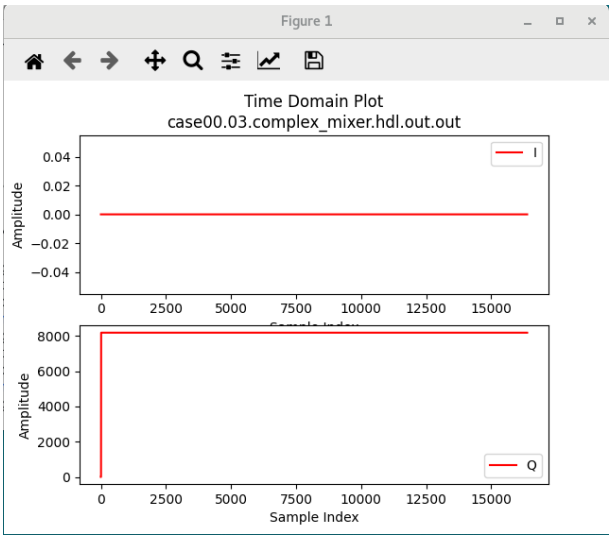
Case00.02 (enable = 1, data_select = 0)

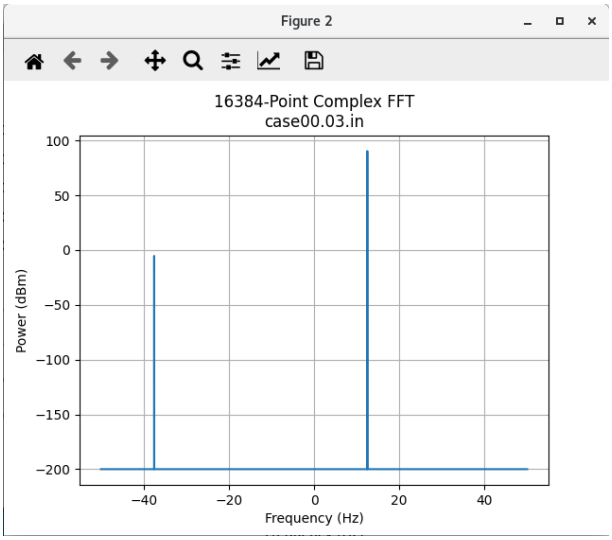


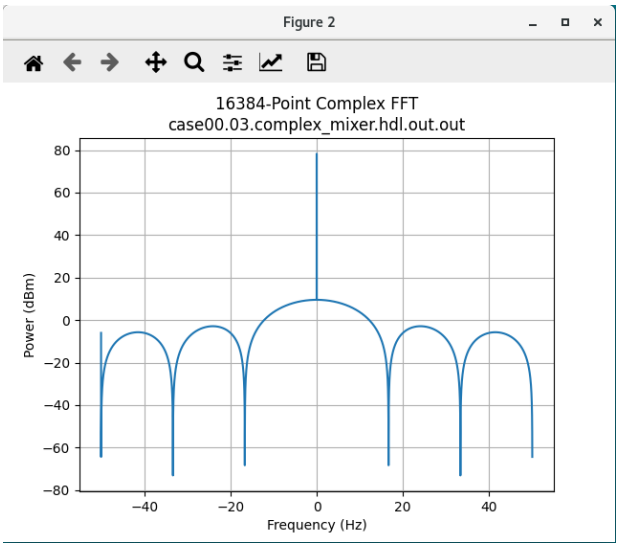


Case00.03 (enable = 1, data_select = 1)









17 View Simulation Waveforms

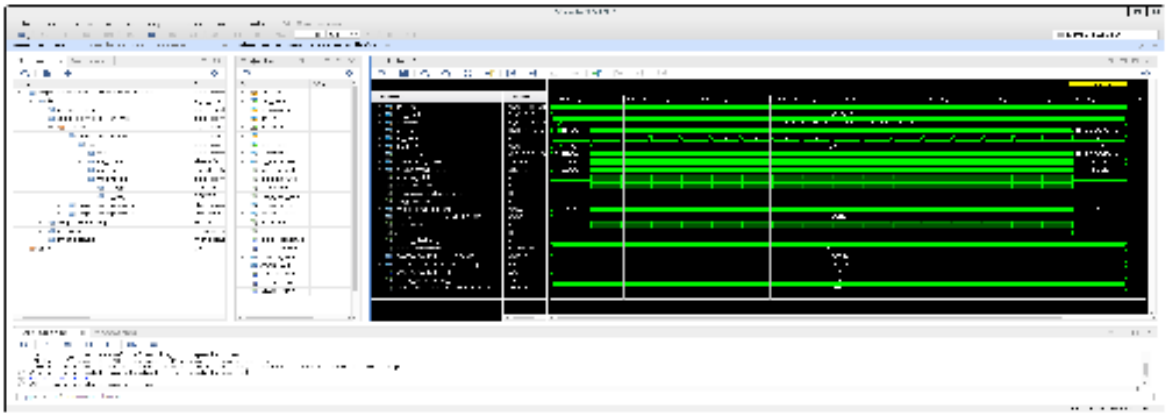
Note: In order to view simulation waveforms, you must have checked **Keep Simulations** in the OpenCPI GUI or have used the **`--keep-simulations`** option on the **`ocpidev`** command line when you ran the unit test.

To view the simulation waveforms:

- In a terminal window, browse to the **`complex_mixer.test/`** directory.
- Execute the following **`ocpiview`** command:

```
ocpiview run/xsim/case00.00.complex_mixer.hdl.simulation/ &
```

You should see the following output:



Note: Basic **`ocpiview`** "driving instructions" can be found in the section "Navigating the Simulator" in OpenCPI Tutorial 6.

18 Run Unit Test (ADALM-PLUTO)

First we'll check to see that the ADALM-PLUTO device is connected.

Note: Details of how to set up and configure this platform are beyond the scope of this tutorial. See the section "Installation Steps for Platforms" in the ***OpenCPI Installation Guide*** for instructions on downloading and installing the corresponding OSP.

Execute the commands:

```
export OCPI_SERVER_ADDRESSES=<Pluto_IP>:12345
ocpiremote status -p analog
```

There should be output that reads something similar to:

```
Executing remote configuration command: status
Server is running with port: 12345 and pid: 26224
```

Now we can run the unit test and view the results. From the command line in the **DemoProject8/components/complex_mixer.test/** directory, run the following **ocpidev** command:

```
ocpidev run --mode prep_run_verify --only-platform plutosdr \
--keep-simulations --view
```

You should see that the test runs much faster on hardware when compared to the simulator. The output should look the same as in the **xsim** section.

19 Tutorial Summary

In this tutorial, you created a **`complex_mixer`** component. Once you created this component, we showed you how to create a **`complex_mixer`** HDL application worker that uses the Vivado third-party cores. You were also able to build the worker and successfully create and run a unit test for the worker on both simulator and hardware platforms. Overall, you were able to see the power of using third-party cores for workers. Now you can move on to Tutorial 9, which demonstrates how to debug an HDL application worker using OpenCPI tools.