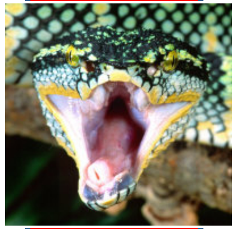
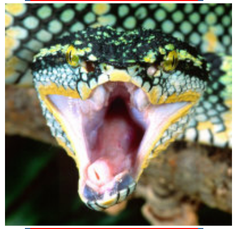


Lab 3: Peak Detector

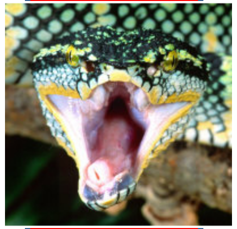
Simple RCC Worker

Objectives



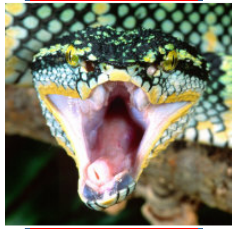
- Design, Build and Test an RCC Application worker that
  - Implements the peak detector function – reports signed min/max peaks
  - Routes data/messages through the worker (pass-thru)
- Unit Test the RCC Application worker
  - Unit tests performed on multiple platforms
    - CentOS7
    - Xilinx13_3
- Introduce:
  - C++ conventions
    - Accessing port data and Properties
  - Framework interactions
    - RCC_ADVANCE vs. RCC_OK vs. RCC_ADVANCE_DONE

What's Provided?



- Component's Datasheet
  - /home/training/provided/doc/Peak_Detector.pdf
- Scripts for generating and validating data
  - /home/training/provided/lab3/peak_detector.test/
- Script for plotting I/Q data
  - /home/training/provided/scripts/plotAndFft.py

Application Worker Development Flow



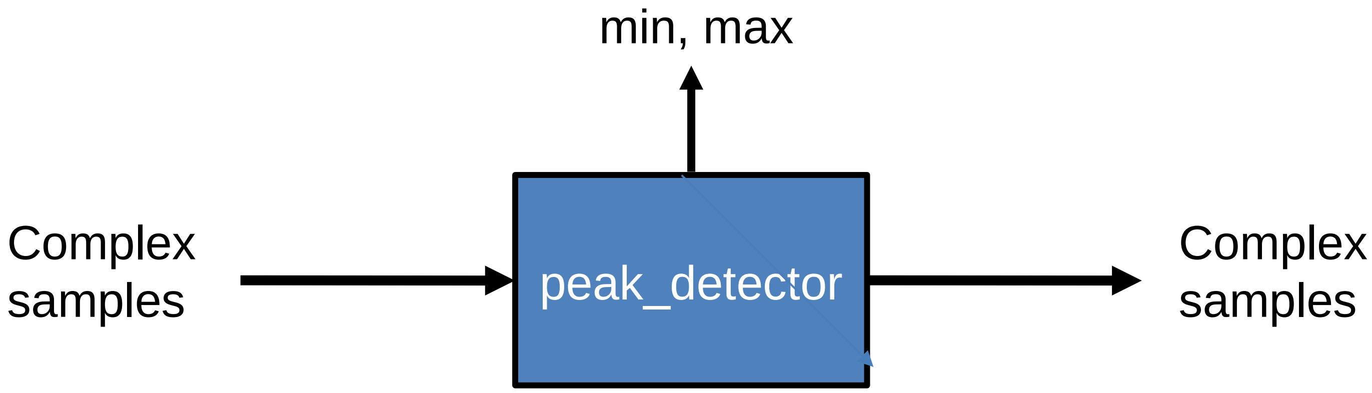
1. Protocol (OPS): Create new or select pre-existing
2. Component (OCS): Create new or select pre-existing
3. Create new App Worker (Modify OWD, Makefile, and source RCC/HDL code)
4. Build the App Worker for target device(s)
5. Create Unit Test (<component>-test.xml, generate, verify and view scripts)
6. Build Unit Test
7. Run Unit Test

Overview

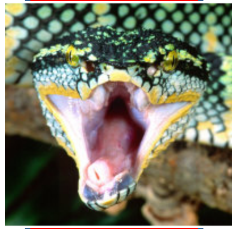
- What are the requirements of this component?
  - Given an input of complex numbers, the “peak_detector” component is meant to find the biggest I or Q sample and the smallest I or Q sample. The basic idea is:

current_biggest = max(current_biggest,max(I,Q))
current_smallest = min(current_smallest,min(I,Q))

  - Pass input of complex numbers to the output ports

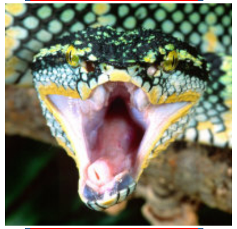


Step 1 - Create new or select pre-existing OPS



- Identify the OPS(s) declared by this component
  - HINT: Examine the “Ports” table in the Component Datasheet
- Is the OPS(s) available in this project's component library?
  - HINT: Examine available protocols /home/training/training_project/components/specs/
- Is the OPS(s) available from the framework or another Project?
  - HINT: check the top-level “specs” of the Core Project
- If **NO** to all questions ⇨ custom OPS XML file must be created
- **ANSWER: OPS is available from framework. REUSE!**

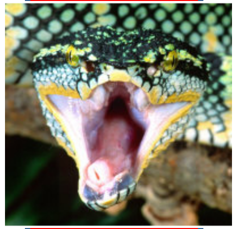
Step 1 – Create new or select pre-existing OPS (cont.)



- In the Ports section, identify which Protocol is being used
- The Protocols are located in the Core Project
- For convenience, the Protocol specified in the datasheet is also here: File name: `iqstream_protocol.xml`

```xml
<Protocol datavaluegranularity="2" zerolengthmessages='1'>
 <Operation Name="iq" >
     <Argument name="data" type="Struct" SequenceLength="2048">
       <member name="I" type="Short"/>
       <member name="Q" type="Short"/>
     </Argument>
 </Operation>
</Protocol>
```

Step 1 – Create new or select pre-existing OPS (cont.)



How to decode the Protocol for data types and accessing data

<ProtocolName> = “Iqstream”
<OpName> = “Iq” when used in a type, “iq” when used to access data
<ArgName> = “Data” when used in a type, “data” when used to access data
<ProtocolNameOpNameArgName> = “IqstreamIqData”

<ProtocolName>

File name: **iqstream**_protocol.xml

<OpName>

<ArgName>

```
<Protocol datavaluegranularity="2" zerolengthmessages='1'>
 <Operation Name="iq" >
     <Argument name="data" type="Struct" SequenceLength="2048">
       <member name="I" type="Short"/>
       <member name="Q" type="Short"/>
     </Argument>
 </Operation>
</Protocol>
```

Recall: to access members in a struct, need the **<MemberName>**

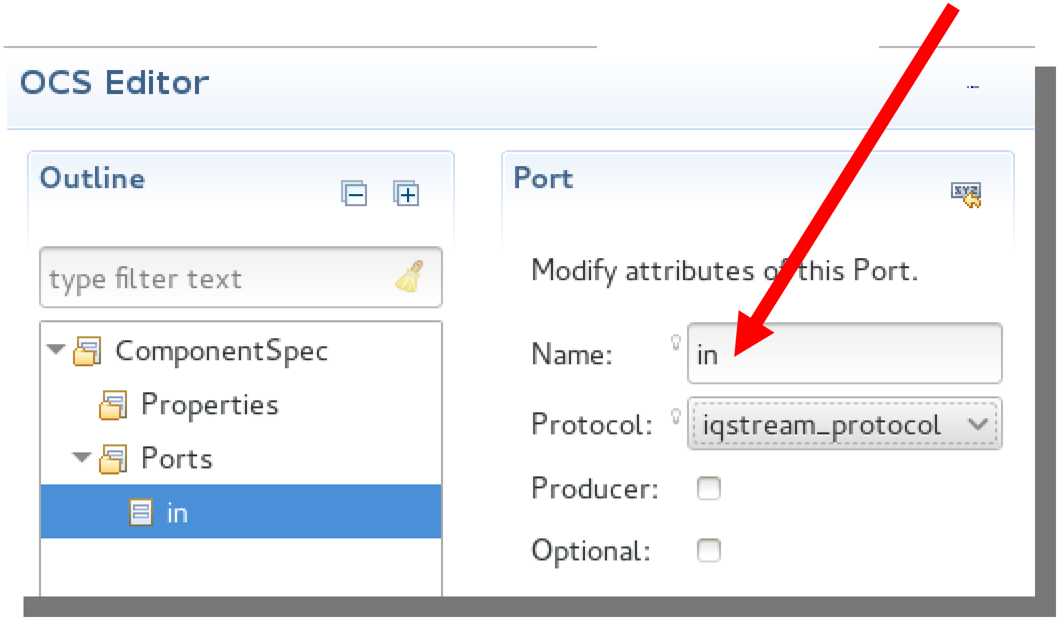
myStructPtr->I;
myStructPtr->Q;
Or
(*myStructPtr).I;
(*myStructPtr).Q;

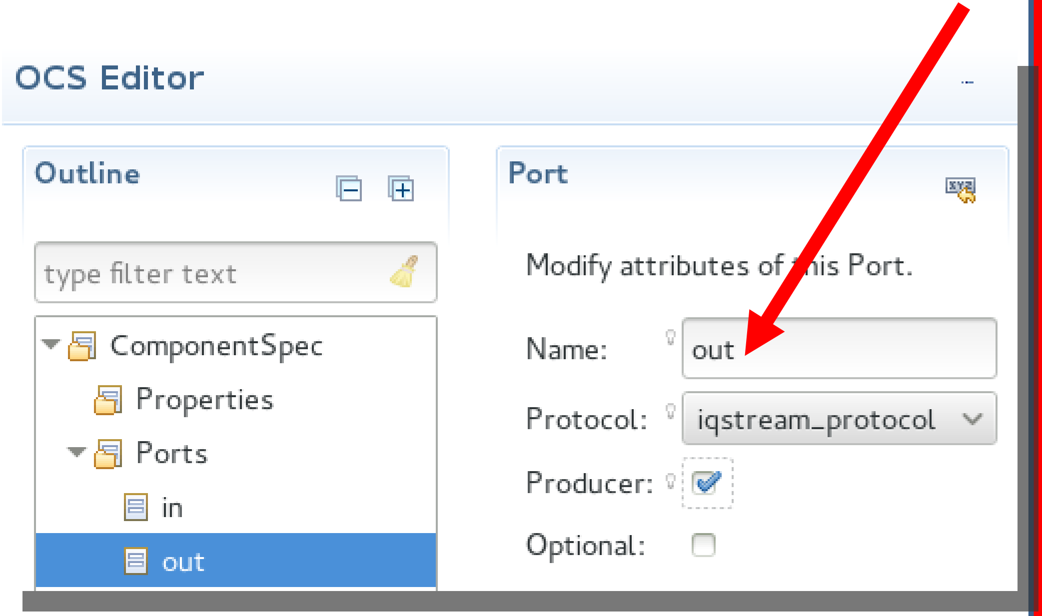
Step 1 – Create new or select pre-existing OPS (cont.)

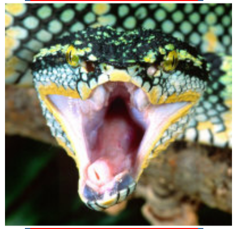
How to decode the Protocol for data types and accessing data

<PortInName> = the Name of the Consumer Port defined in the OCS, example “in”

<PortOutName> = the Name of the Producer Port defined in the OCS, example “out”





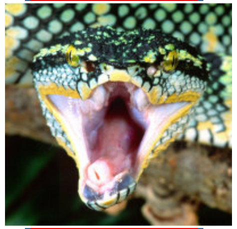


Step 2 - Create new or select pre-existing OCS

- Examine the Properties and Ports listed in the Component Datasheet
    - Use Properties/Ports information to answer the following questions
- Is the OCS XML file available in this project's component library?
    - HINT: Browse /home/training/training_project/components/specs/
- Is the OCS XML file available from the framework?
    - HINT: Browse IDE options
- If **NO** to all questions ⇨ custom OCS XML file must be created

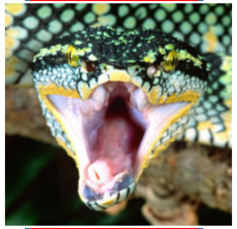
- **ANSWER: Custom OCS XML file must be created.**

Step 3 – Create new App Worker



- Create new Asset Type: Worker
  - Worker Name: peak_detector
  - Library: components
  - Component: peak_detector-spec.xml
  - Model: **RCC**
  - Prog. Lang: C++
- In the OWD RCC Editor
  - Add ControlOperations: start

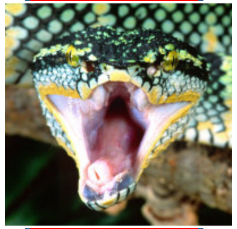
Step 3 – Create new App Worker (cont.)



- The auto-generated skeleton source code contains the default function calls, in this case 'run'. By modifying the OWD top-level attribute ControlOperations to support the 'start' function, the skeleton should be updated by performing a rebuild of the worker so that the framework's auto code generation feature is leveraged to create the 'start' function call.

- Rebuild the Worker:
  - Use the IDE's Perspective

Step 3 – Create new App Worker (cont.)



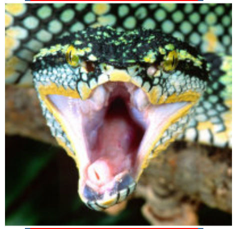
Before adding the ‘start’ Control Operation

```
class Peak_detectorWorker : public Peak_detectorWorkerBase {
  RCCResult run(bool /*timedout*/) {
    return RCC_DONE; // change this as needed for this worker to do something useful
    // return RCC_ADVANCE; when all inputs/outputs should be advanced each time "run" is called.
    // return RCC_ADVANCE_DONE; when all inputs/outputs should be advanced, and there is nothing more to do.
    // return RCC_DONE; when there is nothing more to do, and inputs/outputs do not need to be advanced.
  }
};
```

After adding the ‘start’ Control Operation

```
class Peak_detectorWorker : public Peak_detectorWorkerBase {
  RCCResult start() {
    return RCC_OK;
  }
  RCCResult run(bool /*timedout*/) {
    return RCC_DONE; // change this as needed for this worker to do something useful
    // return RCC_ADVANCE; when all inputs/outputs should be advanced each time "run" is called.
    // return RCC_ADVANCE_DONE; when all inputs/outputs should be advanced, and there is nothing more to do.
    // return RCC_DONE; when there is nothing more to do, and inputs/outputs do not need to be advanced.
  }
};
```

Step 3 – Create new App Worker (cont.)



In the body of the *Peak_detectorWorker* class, put any persistent local variables needed:

```
int16_t max_buff, min_buff; // internal buffers match type “short” in the OCS
```

Then, in the Start RCC Worker Method, initialize them:

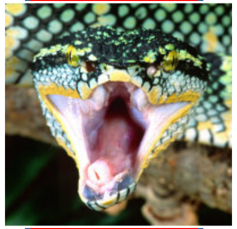
```
class Peak_detectorWorker : public Peak_detectorWorkerBase {

  int16_t max_buff, min_buff;

  RCCResult start(){
    max_buff = -32768; // initialize max to most neg
    min_buff = 32767;  // initialize min to most pos
    return RCC_OK;
  }

...
```

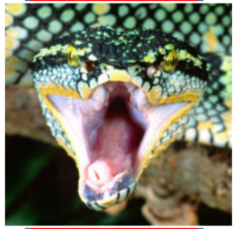
Step 3 – Create new App Worker (cont.)



In the Run RCC Worker Method

1. Make sure there is room on the output port
2. Do work
3. Advance ports

Step 3 – Create new App Worker (cont.)



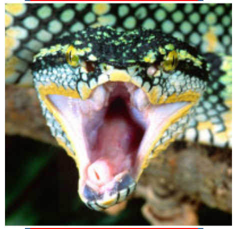
In the Run RCC Worker Method

1. Make sure there is room on the output port

```
const size_t num_of_elements = <PortInName>.<OpName>().<ArgName>().size();
<PortOutName>.<OpName>().<ArgName>().resize(num_of_elements);
<PortOutName>.setOpCode(<PortInName>.opCode());
```

```
    // 1. Make sure there is room on the output port
    const size_t num_of_elements = in.iq().data().size();
    out.iq().data().resize(num_of_elements);
    out.setOpCode(in.opCode());
```

Step 3 – Create new App Worker (cont.)



In the Run RCC Worker Method

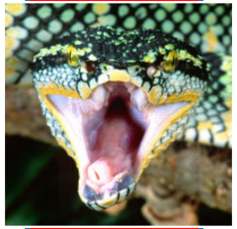
2. Do work

- Create pointer objects for reading input data and writing output data

```
const <ProtocolNameOpNameArgName> * idata =
<PortInName>.<OpName>().<ArgName>().data();
<ProtocolNameOpNameArgName> * odata =
<PortOutName>.<OpName>().<ArgName>().data();
```

```
    // 2. Do work
    const IqstreamIqData *idata = in.iq().data().data();
    IqstreamIqData *odata = out.iq().data().data();
```

Step 3 – Create new App Worker (cont.)



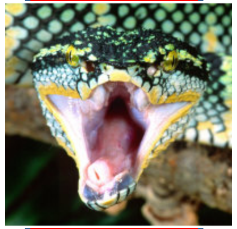
In the Run RCC Worker Method

2. Do work (continued)

- Is the input a Sequence or Array? If so, we need to iterate through the elements.
- Recall max_peak is the greatest value of either I or Q and the min_peak is the smallest value of either I or Q.

```
for ( ) { // decrement through num_of_elements
   // 1. determine max peak and min peak
    *odata++=*idata++ // 2. copy this message to output buffer
}
// 3. set properties().max_peak & set properties().min_peak
// to the calculated max_buff and min_buff
```

Step 3 – Create new App Worker (cont.)



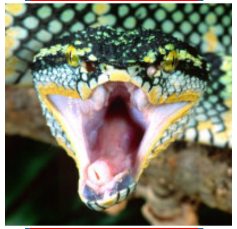
In the Run RCC Worker Method

2. Do work (continued)

```
#include <algorithm>
#include "peak_detector-worker.hh"
```

include the standard template library "algorithm" to use the max and min functions over sequences

```
// 2. Do work
const IqstreamIqData *idata = in.iq().data().data();
IqstreamIqData *odata = out.iq().data().data();
for (unsigned n = num_of_elements; n; n--) {
  max_buff = std::max(std::max(idata->I,idata->Q),max_buff);
  min_buff = std::min(std::min(idata->I,idata->Q),min_buff);
  *odata++ = *idata++; // copy this message to output buffer
}
properties().max_peak = max_buff;
properties().min_peak = min_buff;
```



Step 3 – Create new App Worker (cont.)

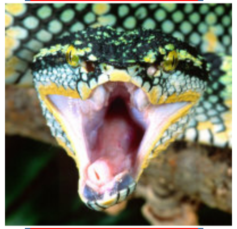
In the Run RCC Worker Method

3. Advance port

We are *done* when the length of the input buffer is zero.

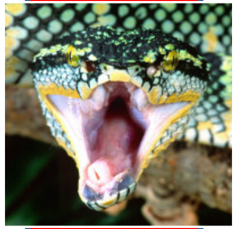
```
// 3. Advance ports
return num_of_elements ? RCC_ADVANCE : RCC_ADVANCE_DONE;
```

Step 4(a) – Build the App Worker for x86



- Execute build for CentOS7-x86
  1. Use the IDE to “**Add**” the App Worker to the Project Operations Panel
  2. **Highlight** “centos7” in RCC Platforms panel
  3. **Check** “Assets” Radio button
  4. **Click** “Build”
  5. Review the Console window messages

Step 4(a) – Build the App Worker for x86 (cont.)



- If the build was free from errors, the end of the build log messages should resemble the following:

```
Compiling peak_detector.cc for target linux-c7-x86_64, configuration 0
Generating dispatch file: target-centos7/peak_detector_dispatch.c
Compiling target-centos7/peak_detector_dispatch.c for target linux-c7-x86_64, configuration 0
Generating artifact/runtime xml file target-centos7/peak_detector_assy-art.xml for all workers in one binary
Linking final artifact file "target-centos7/peak_detector.so" and adding metadata to it...
```

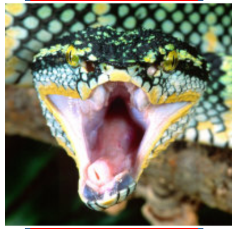
Step 4(a) – Build the App Worker for x86 (cont.)

- To confirm that the RCC Worker artifact was built, check to see that the "target-centos7" directory was created *and* the .so was generated.
  - Navigate to components/{worker}.rcc and observe new artifacts in "target-centos7/"

```
$ ls -l target-centos7
peak_detector_assy-art.xml
peak_detector_assy.xml
peak_detector_dispatch.c
peak_detector_dispatch.o
peak_detector_dispatch.o.deps
peak_detector.o
peak_detector.o.deps
peak_detector.so
peak_detector_s.so
```

The x86 version was built

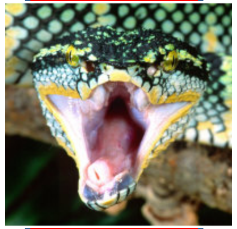
Step 4(b) – Build the App Worker for ARM



- Execute build for ARM
  - Browse to the top-level of the project's directory and execute
  - Same operations in IDE except different platform
  - Command-line alternative:

```
$ ocpidev build worker peak_detector.rcc --rcc-platform xilinx13_3
```

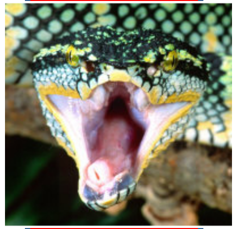
Step 4(a) – Build the App Worker for ARM (cont.)



- If the build was free from errors, the end of the build log messages should resemble the following:

```
Compiling target-xilinx13_3/peak_detector_dispatch.c for target linux-x13_3-arm, configuration 0
Generating artifact/runtime xml file target-xilinx13_3/peak_detector_assy-art.xml for all workers in
one binary
Linking final artifact file "target-xilinx13_3/peak_detector.so" and adding metadata to it...
```

Step 4(b) – Build the App Worker for ARM

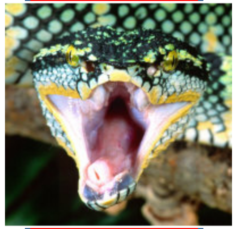


- To confirm that the RCC Worker ARM artifact was built, check to see that the “target-xilinx13_3” directory was created *and* the .so was generated.
  - Navigate to components/{worker}.hdl and observe new artifacts in “target-xilinx13_3/”

```
$ ls -l target-xilinx13_3
peak_detector_assy-art.xml
peak_detector_assy.xml
peak_detector_dispatch.c
peak_detector_dispatch.o
peak_detector_dispatch.o.deps
peak_detector.o
peak_detector.o.deps
peak_detector.so
peak_detector_s.so
```

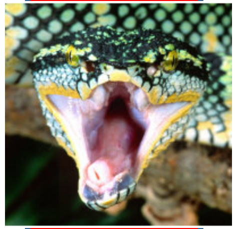
The ARM version was built

Step 5(a) – 7(a) CentOS7 - x86



- These slides cover employing the framework’s Unit Test Suite to generate:
  - OAS (OpenCPI Application Specification) XML file(s)
    - Used by the framework for running the Worker on a given platform
  - Input test data file(s)

Step 5(a) - Create Unit Test

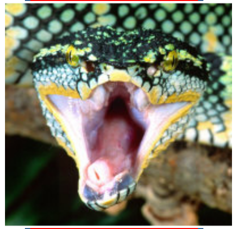


- Create a unit test for the “peak_detector” component, which results in generation of the “peak_detector.test/” directory
  - **File → New → Other → ANGRYVIPER → OpenCPI Asset Wizard → Unit Test**
  - **Add to Project:** *training_project*
  - **Add to Library:** *components*
  - **Component Spec:** *peak_detector-spec.xml*

- **OR** in a terminal window
  `$ ocpidev create test peak_detector`

  - Note the Makefile and stub files `peak_detector-test.xml`, `generate.py`, `verify.py`, `view.sh`

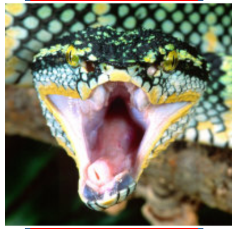
Step 5(a) - Create Unit Test



- Copy `generate.py`, `verify.py`, and `view.sh`

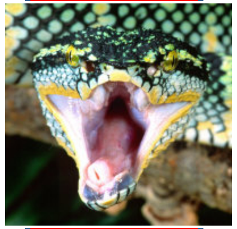
```
$ cp -a ~/provided/lab3/peak_detector.test/* ~/training_project/components/peak_detector.test/
```

Step 5(a) - Create Unit Test



- Edit the Unit Test Description XML file to declare the default test case:
  - Name: peak_detector-test.xml
  - Located in the “peak_detector.test/” directory
    - Uncomment the Input and Output tags
    - **Edit** the “Input” element
      - Add the sample size as a parameter to the generate script
        - script=“generate.py 32768”
      - Add an attribute “messagesize” with a size of 8192
    - **Edit** the “Output” element
      - Add the sample size as a parameter to the verify script
        - script=“verify.py 32768”

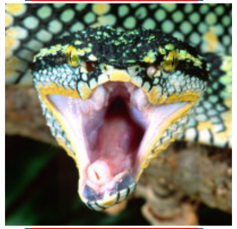
Step 5(a) - Create Unit Test (cont)



- `peak_detector-test.xml` result

```
<tests useHDLFileIo='true'>
  <input port='in' script='generate.py 32768' messagesize='8192'/>
  <output port='out' script='verify.py 32768' view='view.sh'/>
</tests>
```

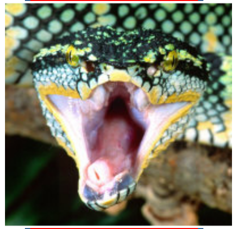
Step 6(a) – Build Unit Test (x86)



- Build the Unit Test Suite for the target software platform
  1. Use the IDE to “**Add**” the Unit Test to the Project Operations panel
  2. **Highlight** “centos7” in the RCC Platforms panel
  3. Select “Tests” Radio button
  4. Click “gen + build”
  5. Review the Console window messages and address any errors

- Observe new artifacts in peak_detector.test/gen/
  - cases.txt – “Human-readable” file which lists various test configurations.
  - cases.xml – Used by framework to execute tests.
  - cases.xml.deps – List of dependent files
  - applications/ - OAS files and scripts used by framework to execute applications.

Step 7(a) – Run Unit Test (x86)

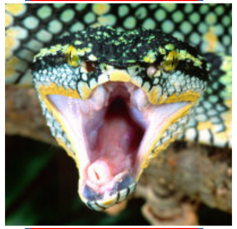


- Click “prep + run + verify” button to run the test
- Click the “view” button to view the test results
- The test should run quickly. Upon completion, you should see “**PASSED**” along with final values for the min/max peaks. Plots of input and output (time and frequency domain) will pop up.
- OR in a terminal, browse to {component}.test/ and execute

`$ make run View=1` (This uses the default centos7)

- Also try:
  - `$ make run OnlyPlatforms=centos7 View=1` {limits platforms to test}
  - `$ make run` {run on all available platforms, no plotting}
  - `$ make verify` {verify previous results}
  - `$ make view` {plot previous results}

Step 7(a) – Run Unit Test (x86) (cont.)



- Input data is generated

```
Generating for case00.00:
  Generating input port "in" file: "gen/inputs/case00.00.in"
             Using command:  ./generate.py 32768 gen/inputs/case00.00.in
         ******************************************
         *** Python: Peak Detector ***
         *** Generate input (binary data file) ***
         Output filename:  gen/inputs/case00.00.in
         Number of samples:  32768
```

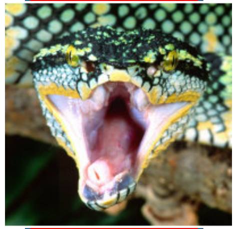
Target platform is chosen

```
Generating run script for platform: centos7
```

- The Component Unit Test is run on CentOS7
- Python script verifies output data from the Unit Test

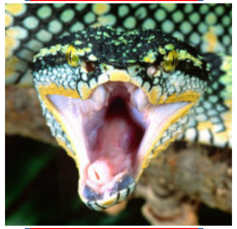
```
*** Python: Peak Detector ***
*** Validate output against expected data ***
File to validate:  case00.00.peak_detector.rcc.out.out
uut_min_peak =  -31129
uut_max_peak =  31129
file_min_peak =  -31129
file_max_peak =  31129
Data matched expected results.
PASSED
*** End validation ***
```

Step 5(b) – 7(b) Xilinx13_3 - ARM



- These slides cover employing the framework’s Unit Test Suite to generate:
  - OAS (OpenCPI Application Specification) XML file(s)
    - Used by the framework for running the Worker on a given platform
  - Input test data file(s)
  - Various scripts to manage the execution of the applications onto the target platform(s)

Step 5(b) - Create Unit Test

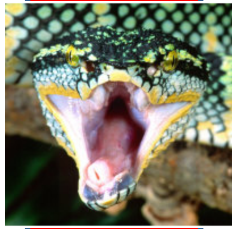


- Located in “peak_detector.test/” directory
  - Same as used for CentOS7
    - **REUSE!**

- Reuse peak_detector.test

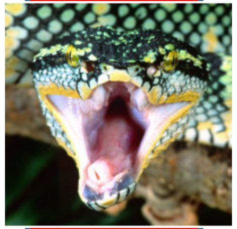
```
<tests useHDLFileIo='true'>
    <input port='in' script='generate.py 32768' messagesize='8192'/>
    <output port='out' script='verify.py 32768' view='view.sh'/>
</tests>
```

Step 6(b) – Build Unit Test (ARM)



- Build the Unit Test Suite for the target software platform
  1. Use the IDE to "**Add**" the Unit Test to the Project Operations panel
  2. Highlight "xilinx13_3" the RCC Platforms panel
  3. Ensure "Tests" Radio button is selected.
  4. Click "gen + build"
  5. Review the Console window messages and address any errors

- Observe possibly-updated artifacts in peak_detector.test/gen/
  - cases.txt – "Human-readable" file which lists various test configurations.
  - cases.xml – Used by framework to execute tests.
  - cases.xml.deps – List of dependent files
  - applications/ - OAS files and scripts used by framework to execute applications.

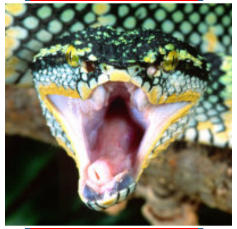


Step 7(b) – Run Unit Test (ARM)

- Setup deployment platform
  1. Connect to serial port via USB on rear of Matchstiq-Z1 using host
     - `screen /dev/matchstiq_z1_0 115200`
  2. Boot and login into Petalinux
     - User/Password = root:root
  3. Verify host and Matchstiq-Z1 have valid IP addresses
     - For training, they should both be on the same subnet
  4. Run setup script on Matchstiq-Z1
     - `source /mnt/card/opencpi/mynetsetup.sh <host ip address>`

More detail on this process can be found in the **Matchstiq-Z1 Getting Started Guide** document

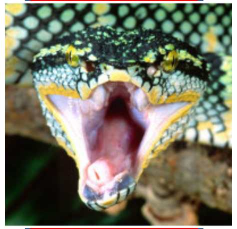
Step 7(b) – Run Unit Test (ARM) (cont.)



- GUI approach to running unit tests on remote platforms:
  - In the Project Operations Panel
    - **Select** “remotes” radio button
    - **Click** “+remotes”
    - **Change** remote variable text to use matchstiq ip and point to the training project:

      {IP of Matchstiq-Z1}=root=root=/mnt/training_project
    - **Select** the newly created remote. This will be the target remote test system. Unselected remotes will not be run.
    - **Check** “run view script” to view the output after verification.
    - **Click** “prep + run + verify” to run the unit test scripts.

Step 7(b) – Run Unit Test (ARM) (cont.)



- Terminal approach to running unit tests.
  - On the Development Host, set OCPI_REMOTE_TEST_SYSTEMS, as shown:

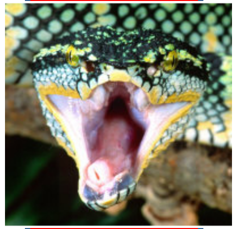
  $ export OCPI_REMOTE_TEST_SYSTEMS={IP of Matchstiq-Z1}=root=root=/mnt/training_project
  - If using the IDE to run the tests, the above must be set **before launching**!

  - On the Development Host, browse to the peak_detector.test/

  `$ make run OnlyPlatforms=xilinx13_3 View=1`
    - This will run the unit test remotely (over ssh) on the Matchstiq-Z1's ARM

    - Also try:
      - `$ make run` {run on all available platforms, no plotting}
      - `$ make verify` {verify previous results}
      - `$ make view` {plot previous results}

Step 7(b) – Run Unit Test (ARM) (cont.)



- Python script verifies output data from the Unit Test

```
*** Python: Peak Detector ***
*** Validate output against expected data ***
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uut_min_peak =  -31129
uut_max_peak =  31129
file_min_peak =  -31129
file_max_peak =  31129
Data matched expected results.
PASSED
*** End validation ***
```