Hardware Processing Platform (HPP) Applications - Oscillation Detection

User Guide

Introduction

The HPP Applications project provides a set of packaged applications for common real-time feedback loop and analysis methods that target the Neuralynx Hardware Processing Platform (HPP) for researchers using the Digital Lynx SX system.

The Oscillation Detection application runs on the HPP, allowing the detection of oscillation power within the sharp wave band (150 to 250 Hz), gamma band (30 to 90 Hz) and theta band (4 to 12 Hz). The low cut and high cut frequencies and number of filter taps for each oscillation detection module can also be customized. A stimulus is triggered by a TTL pulse when an oscillation has been confirmed. Confirmation occurs when the oscillation power remains above a threshold for a defined time period.

This User Guide walks through the process of programming the oscillation detection application to the HPP, and getting started with the oscillation detection application.

1 Installing and Licensing Xilinx Software

For this project, the Xilinx SDK 2014.1 tool will be used to program the oscillation detection application ELF on the HPP Xilinx processor over the JTAG interface. Refer to Section 2 of the HPP Getting Started Guide document for instructions on how to download, install and license the required Xilinx SDK tools.

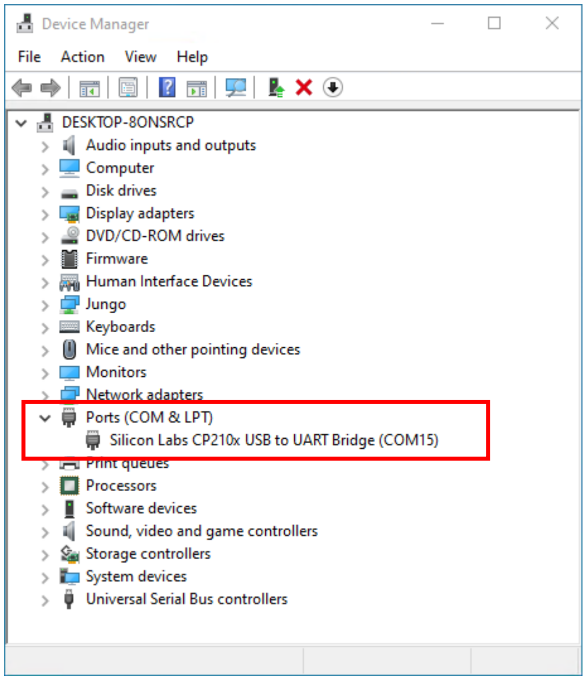
2 Setting up HPP Hardware Connections

The application uses a serial command-line interface (CLI) to interact with the program running on the HPP. The UART Bridge Virtual COM Port (VCP) driver must be installed on your PC.

Download and install the latest Silicon Labs CP210x Windows VCP driver from:
https://www.silabs.com/products/development-tools/software/usb-to-uart-bridge-vcp-drivers

Attach a USB cable from the application PC to Digital Lynx SX port “HPP Terminal.”
Attach a USB cable from the application PC to Digital Lynx SX port “HPP JTAG.”

In Windows' Device Manager, make a note of the COM port number "Silicon Labs CP210x USB to UART Bridge" connected to your HPP USB Serial Terminal. The baud rate is 115200.



HPP connected to Silicon Labs CP210x USB to UART Bridge COM port.

3 Installing MATLAB® Runtime

The HPP Applications project requires the MATLAB Runtime version 9.3 (R2017b) to be installed on your PC in order to run the oscillation detection application control interface.

Download and install the 64-bit Windows version of the MATLAB Runtime for R2017b from the following link on the Mathworks website.
https://www.mathworks.com/products/compiler/matlab-runtime.html

4 Neuralynx Cheetah Acquisition Software

Neuralynx Cheetah 6.0 is required for the HPP Applications project (version compatible with your DLSX motherboard firmware installed on your system). You can download the Cheetah reference from the Neuralynx website.

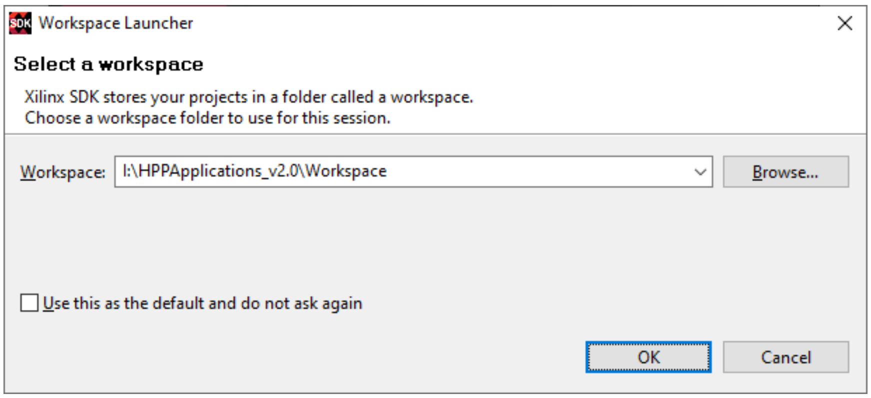
Start Cheetah acquisition in order to allow the HPP to receive input acquisition data from the Digital Lynx SX system.

5 Programming the Application to the HPP Hardware

Download the ***HPPApplications_v2.0.zip*** project from the Neuralynx website and extract the compressed project contents to a folder on your local PC.

Setting up the SDK Workspace

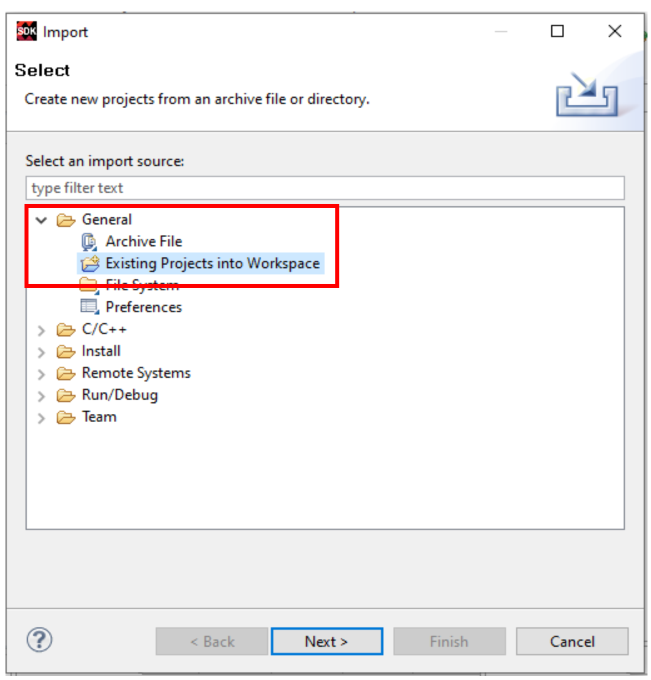
Open the Xilinx SDK 2014.1 software.



Browse to the *Workspace* directory in the extracted project located at *<your project directory>\HPPApplications_v2.0\Workspace* and click "OK" to continue.

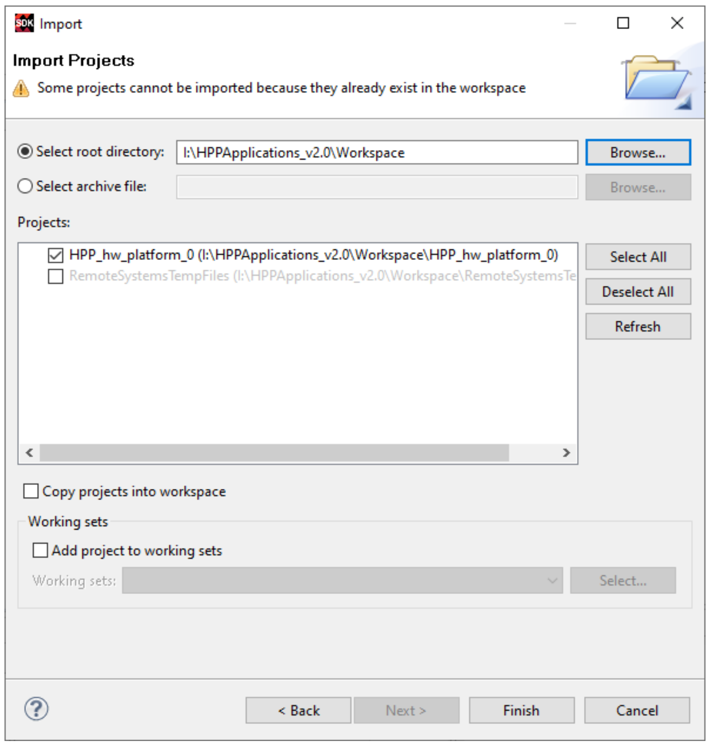
Importing the HPP Hardware Platform into the SDK Workspace Environment

From the "File -> Import..." menu option, or by right-clicking in Project Explorer and selecting "Import…," choose "Existing Project into Workspace" under "General" and click "Next" to continue.



In "Select root directory," browse to the Workspace directory location containing the provided HPP hardware platform and click OK.

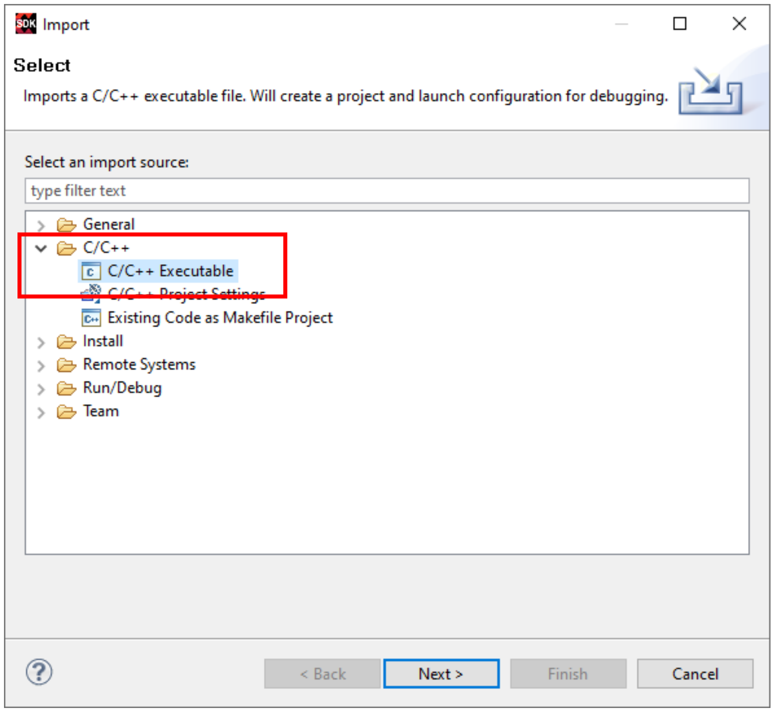
Verify that ***HPP_hw_platform_0*** is selected in the "Projects" list, and click "Finish" to continue.

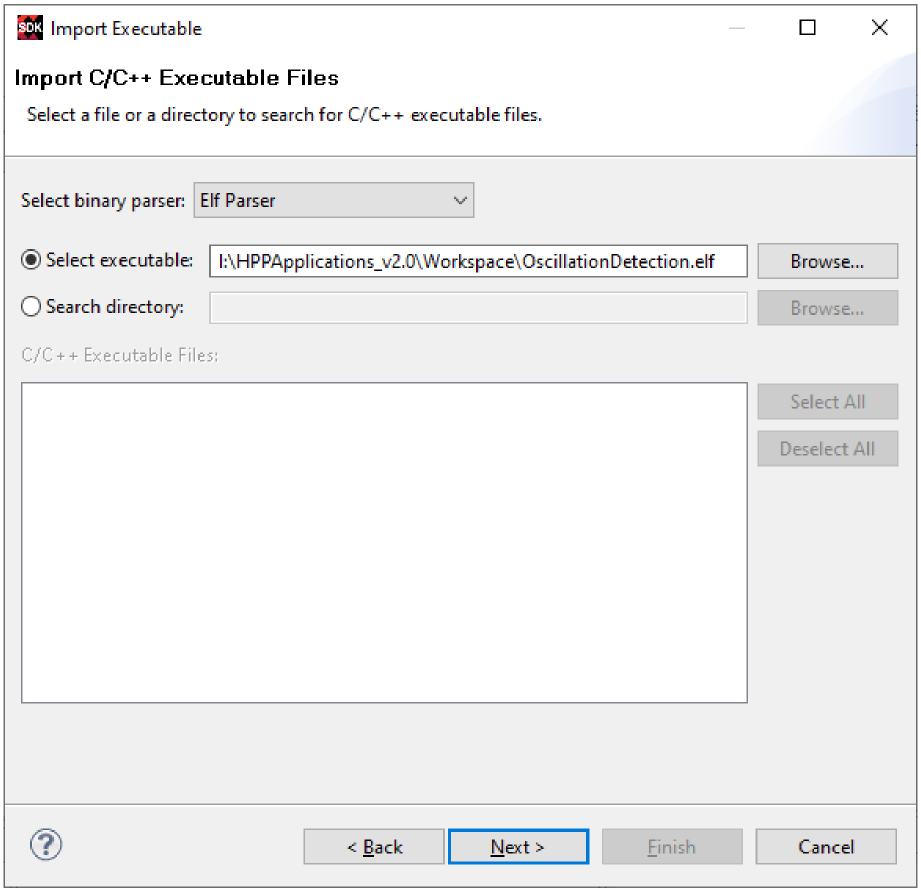


Importing the Oscillation Detection Application into the SDK Workspace Environment

Select the "File -> Import..." menu option or right-click in Project Explorer and select "Import ..."

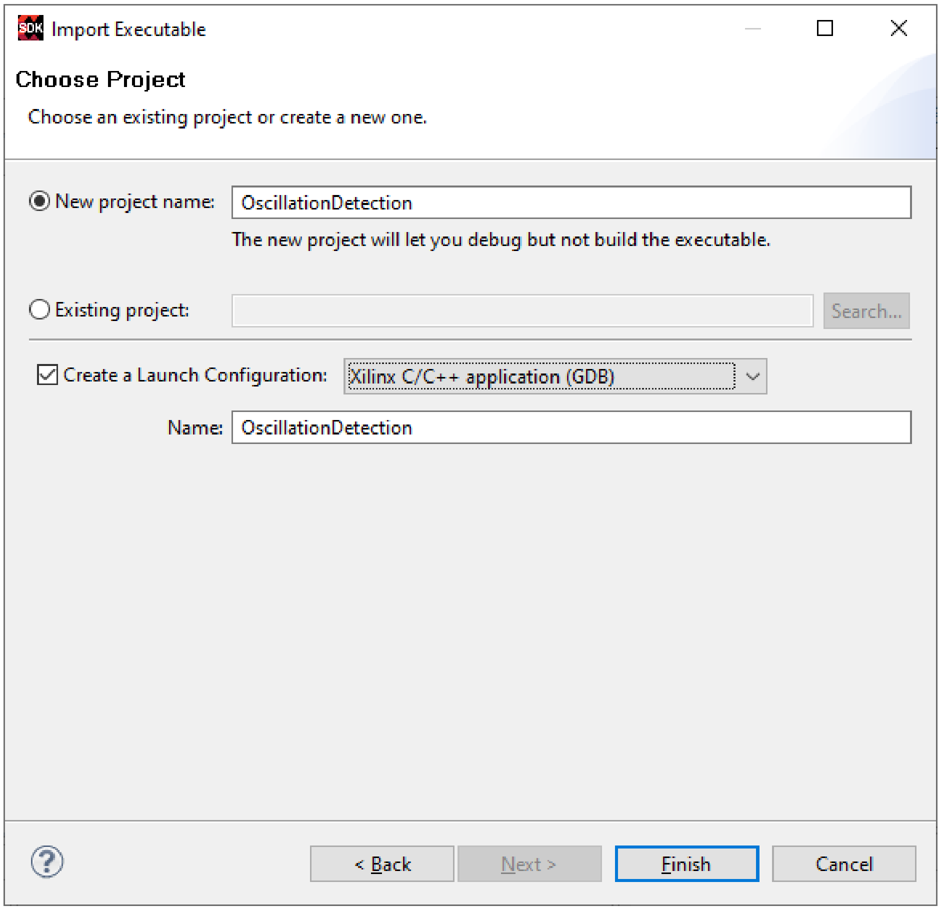
Choose "C/C++ Executable" under "C\C++" and click "Next" to continue.





Confirm that "Elf Parser" is selected in the "Select binary parser" option.

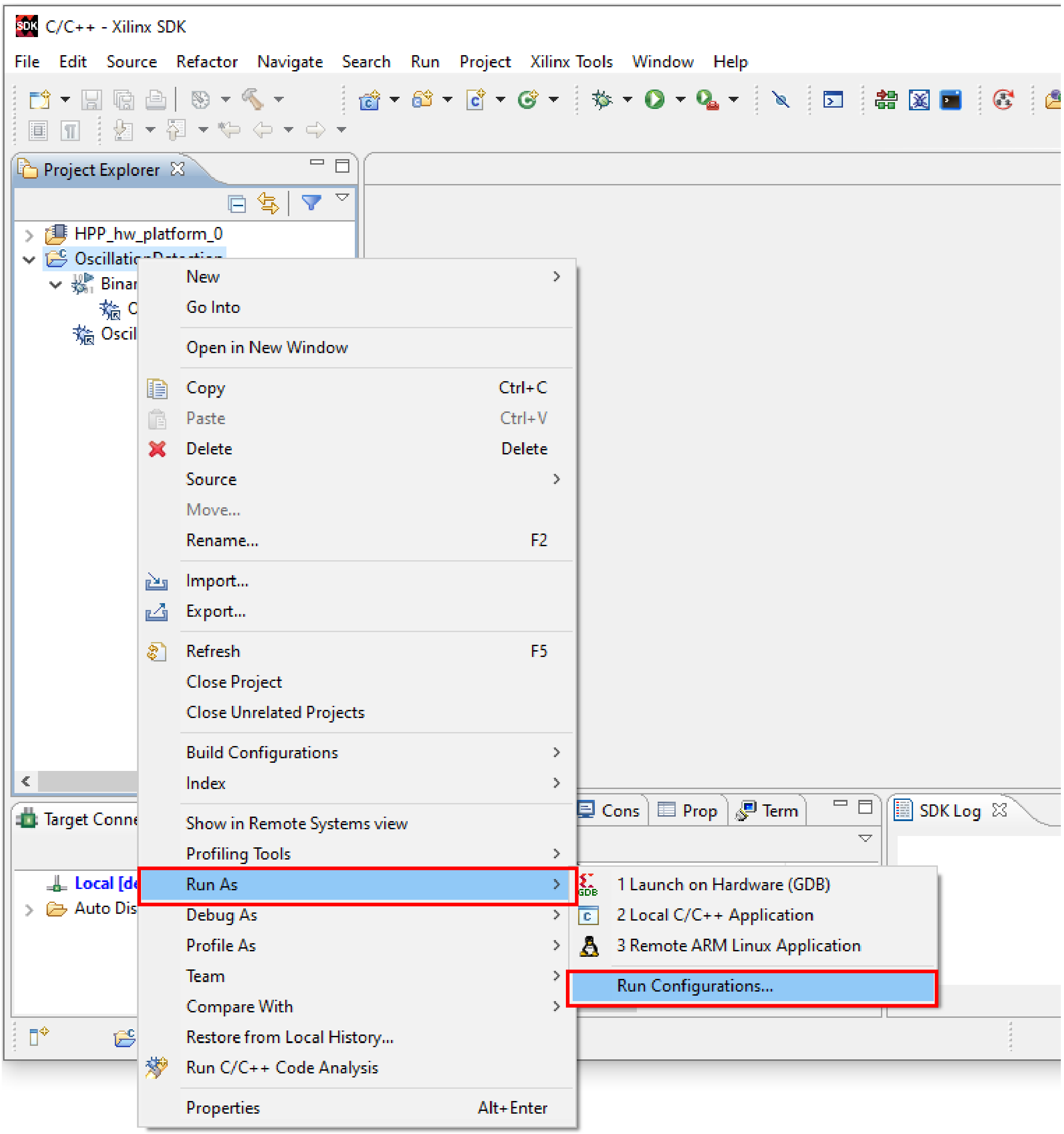
In the "Select executable," "Browse" to the provided application ELF file, ***OscillationDetection.elf***, located in *<your project directory>\HPPApplications_v2.0*, and click "Next" to continue.



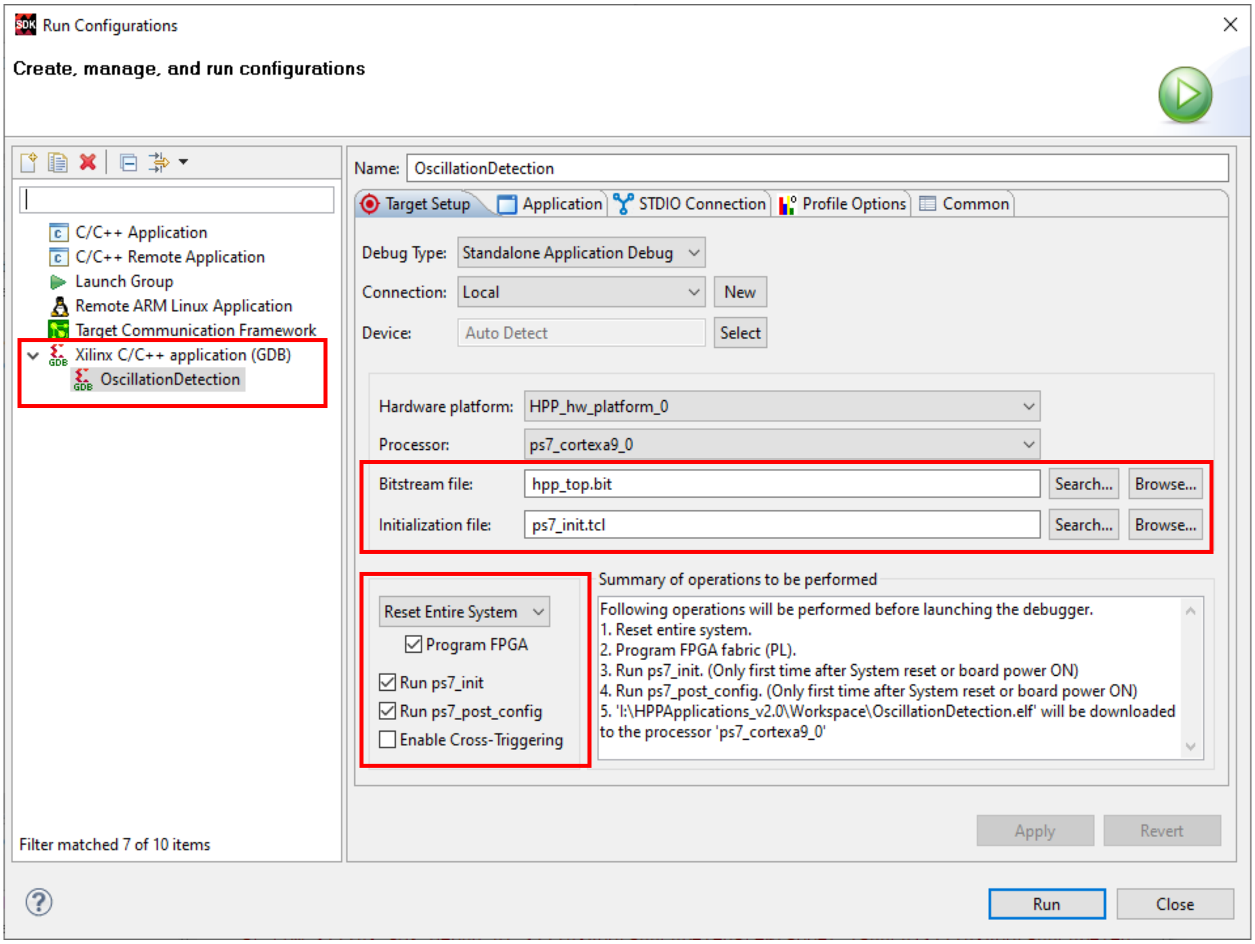
In the “New project name” field, enter “*OscillationDetection*” as the new project name.

Check “Create a Launch Configuration” and select the “Xilinx C/C++ application (GDB)” option.
Enter “*OscillationDetection*” as the Launch Configuration “Name.”

Click “Finish” to continue and “Close” the Debug Configurations window that pops up.



In the SDK Project Explorer on the left, right-click on the "*OscillationDetection*" folder and select "Run As -> Run Configurations…" from the menu.



In the "Run Configurations" window select "*OscillationDetection*" under "*Xilinx C/C++ application (GDB).*"

Next to the "Bitstream file" field click on "Search…" and select *hpp_top.bit* and click "OK" to continue. This is the bitstream file that will be programmed to the Xilinx FPGA.

Next to the "Initialization file" field click on "Search…" and select *ps7_init.tcl* and click "OK" to continue. This is the initialization file for setting up the Xilinx processor.

Select "Reset Entire System" and check the "Program FPGA," "Run ps7_init" and "Run ps7_post_config" options as shown in the figure above.

Click the "Apply" button to save the "Run Configuration" settings, and "Run" to download and program the HPP Xilinx processor and FPGA hardware.

6 Running the Oscillation Detection Application Software

The HPP Applications software interacts with the oscillation detection algorithm programmed on the HPP through a serial CLI communication interface. The oscillation detection application provides up to four (4) independent detection modules that are able to detect oscillations from the input acquisition channels of the Digital Lynx SX system. Individual parameters can be changed to adjust the oscillation detection sensitivity for each module. Each detection module triggers a TTL bit output response on the Digital Lynx SX when an oscillation has been confirmed.

Double-click on ***HPPApplications.exe*** in *<your project directory>\HPPApplications_v2.0* to start the HPP Applications software program.

Confirm that "Start Acquisition" has been selected in the Cheetah Data Acquisition software running on your PC to allow the HPP to acquire input acquisition data from the Digital Lynx SX system.

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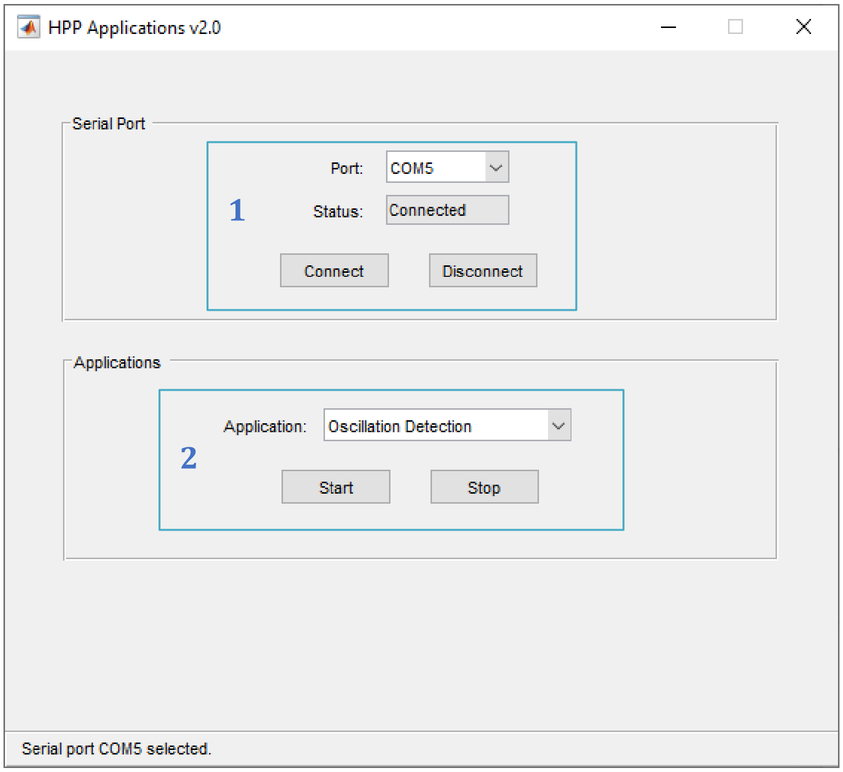
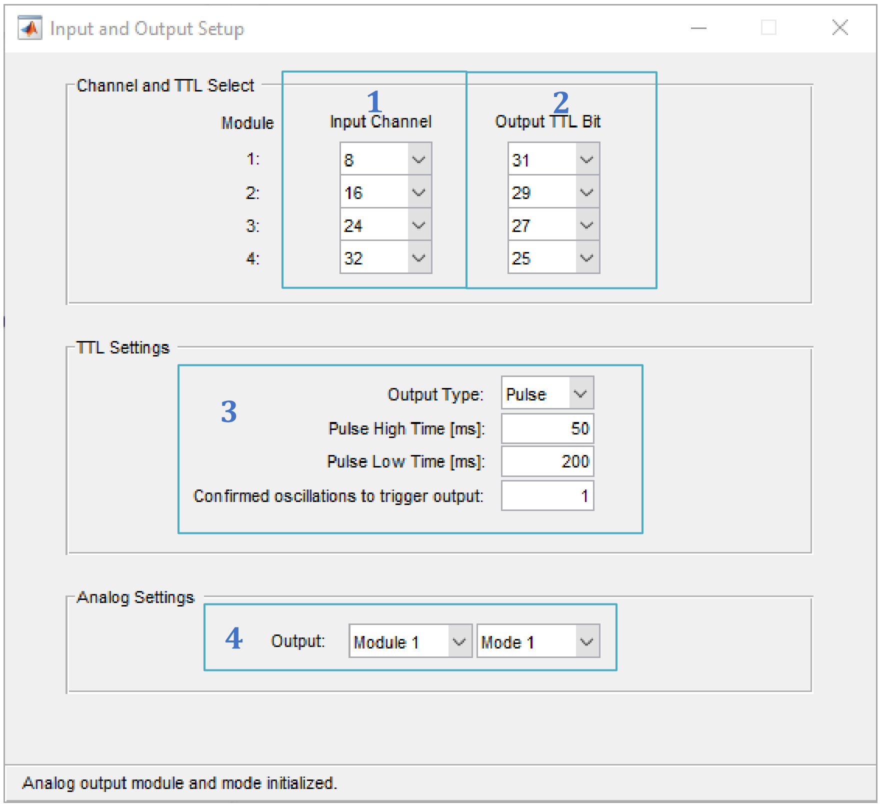


HPP Application v2.0 startup window

1. Select the “COM Port” connected to the HPP from the “Port” drop-down menu, and click the “Connect” button to open to the serial port connection. Refer to Section 3 of this User Guide to determine which COM port is connected to your HPP through Windows Device Manager. Click “Disconnect” to close the selected serial port connection.

2. Select “Oscillation Detection” from the “Application” drop-down, and click the “Start” button to begin running the oscillation detection application. Click the “Stop” button to stop the oscillation detection application running on the hardware.

After waiting a few seconds for initialization of parameters between the application and the hardware, the following three (3) interface windows will appear to allow the user to control and interact with the oscillation detection application.



Input Channels, TTL Outputs and Analog Output Setup interface window

1. Select input channels

The “Input Channel” fields for Modules 1 to 4 allow the user to select the Digital Lynx SX input channels (1 through 512) for each of the four (4) oscillation detection modules. The input channel acquisition data is downsampled from 32kHz to 2kHz, which is passed to the detection bandpass filters of each of the oscillation detection modules.

2. Select TTL output bits

The “Output TTL Bit” fields for Modules 1 to 4 allow the user to set the TTL output bit (0 through 31, or None) for which an output response is triggered on the Digital Lynx SX TTL ports when an oscillation has been confirmed for each of the four (4) oscillation detection modules. The HPP takes control and sets the direction to output for the corresponding TTL Ports (0 through 3) based on the TTL output bits selected. The remaining TTL ports can be controlled by Cheetah.

> ⚠The TTL Port directions are set to **input** by default!

3. Set TTL output response parameters

- The TTL response “Output Type” drop-down allows the user to select among outputting a single TTL “Pulse,” a TTL “Pulse Train” or a TTL “High when oscillation power is above detection threshold” while an oscillation has been confirmed.
- The “Pulse High Time [ms]” field allows the user to set the time in milliseconds that the output TTL pulse remains high when triggered.
- The “Pulse Low Time [ms]” field allows the user to set the time in milliseconds that the output TTL pulse remains low when triggered. Detection of new oscillations is blocked during this time while the TTL pulse is low.
- The “Confirmed oscillations to trigger output” field allows the user to set the number of oscillations that must be detected before triggering a TTL output response. A value of “1” triggers the TTL output for every detected oscillation, while a value of “2” triggers the TTL output every-other-detected oscillation. A value of “0” disables any TTL output response from being triggered when an oscillation has been detected.

4. Select analog output module and set analog output mode

In order to display waveform signals while the application is running, the analog outputs on the Digital Lynx SX front panel have been integrated into the design. A single audio stereo-to-dual BNC cable and a 2-channel oscilloscope, or two (2) audio stereo-to -dual BNC cables and a 4-channel oscilloscope can be used to view application waveforms in real-time.

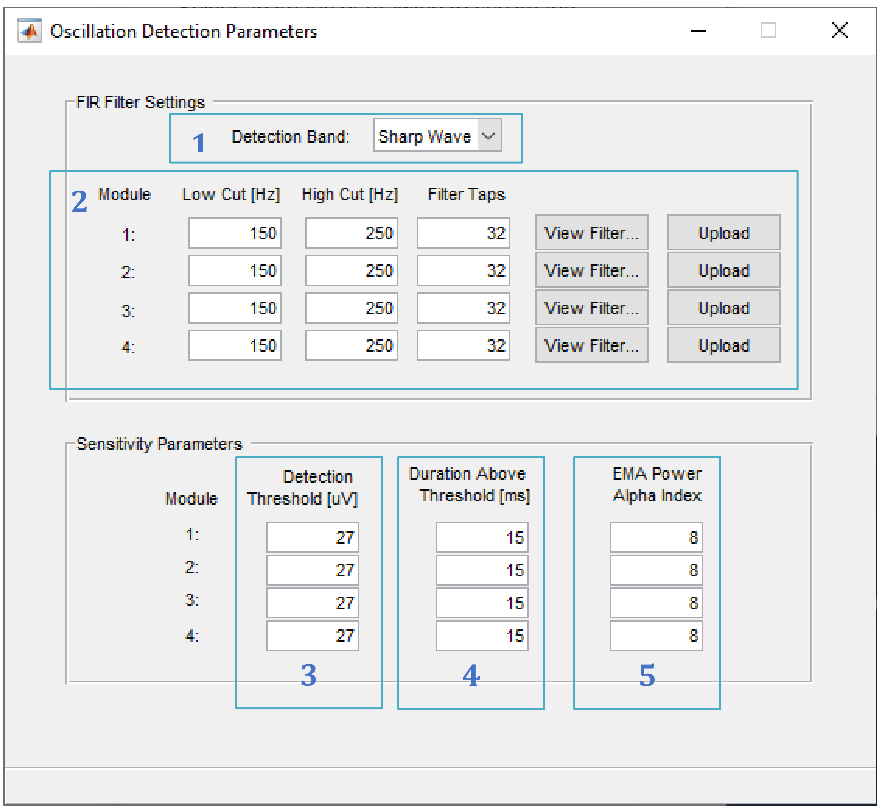
The first analog output drop-down menu allows the user to select which of the four (4) oscillation detection modules should be output for the corresponding waveform signals. When output modules 1-4 are selected, the HPP has control of the Digital Lynx SX analog ports. When output “None” is selected, Cheetah has control of the Digital Lynx SX analog output ports.

The second analog output drop-down menu allows the user to select the output waveform signals. These have been grouped into logical pairs (Modes) to be output through each of the two stereo analog output ports of the Digital Lynx SX.

The table below shows the modes defined, input ranges and the corresponding output waveform signals.

	Input Range (Scale)	**AN1**	**AN2**	**AN3**	**AN4**
MODE 0:	2048 uV (x64)	Power Mean	EMA Power	Power Std Dev	EMA Power
MODE 1:	2048 uV (x64)	Filtered Output	A/D Ch Input	Filtered Output	EMA Power
MODE 2:	2048 uV (x64)	Filtered Output	EMA Power	Threshold	EMA Power
MODE 3:	132 mV (x1)	Filtered Output	A/D Ch Input	Filtered Output	EMA Power
MODE 4:	132 mV (x1)	Filtered Output	EMA Power	Threshold	EMA Power
MODE 5:	132 mV (x1)	Power Mean	EMA Power	Power Std Dev	EMA Power
MODE 6:	2048 uV (x64)	Filtered Output	A/D Ch Input	Threshold	EMA Power

AN1 and AN2 refer to the left and right stereo outputs of the first output jack. AN3 and AN4 refer to the left and right stereo outputs of the second output jack located on the Digital Lynx SX front panel.
At full scale (x1), the full 131,072uV input range of the acquisition system is mapped to +/- 1V analog output. In (x64) scale, the input acquisition range +/- 2048uV is mapped to the +/-1V analog output range.



Oscillation detection parameters interface window

1. Oscillation detection band selection

The "Detection Band" drop-down allows the user to select between "Theta," "Gamma" and "Sharp Wave" oscillation detection bands. A "Custom" option is also provided.

2. Set oscillation detection filter settings

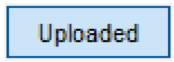
The user can customize the FIR bandpass filters by defining the "Low Cut [Hz]" and "High Cut [Hz]" frequencies and the number of "Filter Taps" for each of the four (4) oscillation detection modules. The filters are generated based on a 2kHz sampling frequency.
Note: The maximum allowable number of filter taps for this implementation is 1,024. The low cut frequency must be greater than 0, and less than the high cut frequency. The high cut frequency must be less than 1,000Hz ($f_s/2$).

The “View Filter…” button allows the user to view the magnitude and phase responses for each of the filters generated for each of the four (4) detection modules.

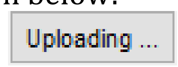
The “Upload” button allows the user to upload the generated filter coefficients to each of the reloadable FIR filters for each of the four (4) oscillation detection modules implemented in hardware.

The Upload button can indicate three (3) possible states to the user:

(i) When the current filter coefficients have been uploaded to the hardware, the upload button changes to a pressed “Uploaded” state as shown below:



(ii) When filter coefficients is in the process of being uploaded to the hardware, the upload button shows “Uploading” as shown below:



(iii) When the “Low Cut,” “High Cut” or “Filter Taps” fields have been edited in the software interface for a particular module, the upload button shows an un-pressed “Upload” state as shown below:

3. Set oscillation detection thresholds

The “Detection Threshold [uV]” fields for Modules 1 to 4 allow the user to define the threshold in microvolts that the oscillation power must be above the detection threshold to confirm that an oscillation has been detected for each of the four (4) oscillation detection modules.

4. Set duration oscillation must be above threshold

The “Duration Above Threshold [ms]” fields for Modules 1 to 4 allow the user to define the duration of time in milliseconds that the oscillation power must be above the detection threshold to confirm that an oscillation has been detected for each of the four (4) detection modules.

5. Set oscillation power EMA smoothing index

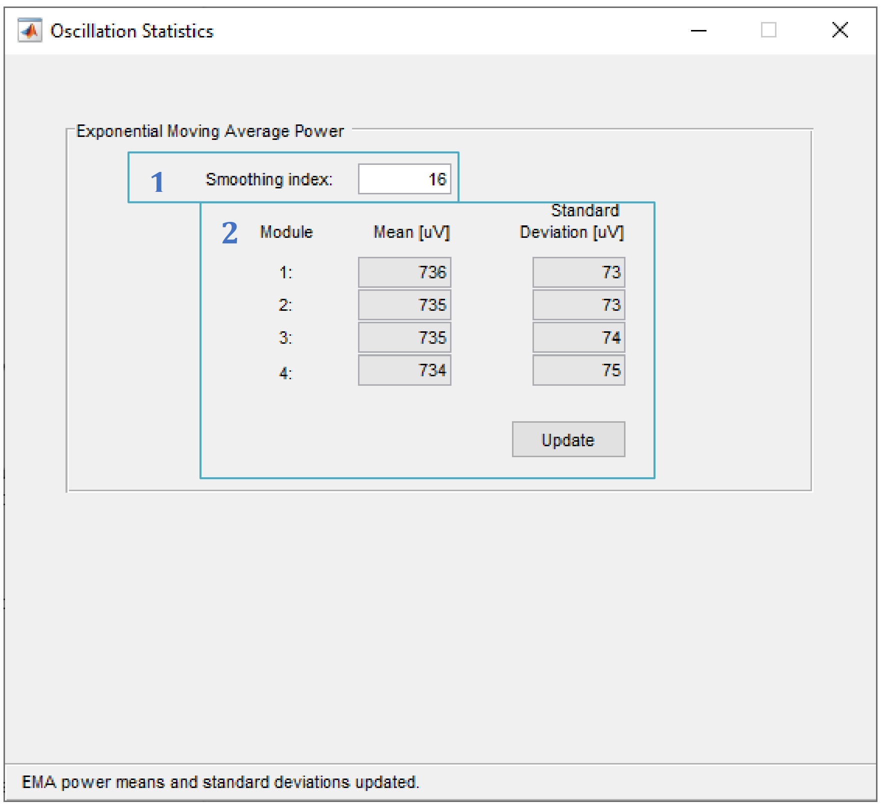
The oscillation power is calculated using an integrated exponential moving averaging (EMA) method applied to the bandpass filtered signal as shown below:

$$\textit{current power} = \textit{previous power} + \{\boldsymbol{\alpha lpha} \times [\, \textit{abs}(\textit{current sample}) - \textit{previous power}\,]\,\},$$
$$\text{where } \boldsymbol{alpha} = 1/(2\hat{}\boldsymbol{N}), \quad 0 >= \boldsymbol{N} >= 31$$

The index ***N*** is referred to as the “EMA power alpha index” in this application.

The "EMA power alpha index" fields for Modules 1 to 4 allow the user to define the value of *N*, defined as the EMA power alpha index, for each of the four (4) detection modules.
The larger the *N* is set, the smaller the alpha becomes and the smoother the oscillation power signal becomes over time. As *N* is made smaller, the *alpha* value approaches 1, and the calculated oscillation power approaches the oscillation signal. Making *N* too large reduces the overall oscillation power signal. Typical values for the EMA power alpha index range from 8 to 16.

A combination of setting the oscillation power smoothing index and adjusting the threshold level provides the user with the ability to adjust the sensitivity of the oscillation detection algorithm.



Oscillation Statistics interface window

1. Set number of samples over which the mean and standard deviation is calculated
The "Smoothing index" value allows the user to set the number of samples over which the running mean and standard deviation is calculated for the oscillation power signal.

$$\textit{Number of samples} = 2^{\wedge}(\textbf{\textit{Smoothing index}})$$

For a downsampled rate of 2kHz, a *Smoothing index* value of 16 calculates the mean and standard deviation of the oscillation power over 65,536 (~32s) of samples.

2. Update mean and standard deviation values

The "Update" button gets the mean and standard deviation values for each of the four (4) modules.
The "Mean [uV]" fields for Modules 1 to 4 return the calculated mean values of the oscillation EMA power to the user in microvolts for each detection module when the "Update" button is pressed.
The "Standard Deviation [uV]" fields for Modules 1 to 4 return the calculated standard deviation values of the oscillation EMA power to the user in microvolts for each detection module when the "Update" button is pressed.

The mean and standard deviation values can be useful for setting the threshold values as follows:

$$detection\_threshold = mean + (k \times stdev),$$ where *k* is a user defined constant.

7 Testing the Oscillation Detection Application.

Two (2) sample audio WAV files - "*test_swr_detection.wav*" and "*test_theta_detection.wav*" - converted from CSC acquisition recordings, have been provided to test and demonstrate the functionality of the oscillation detection application.

The WAV files can be played from a PC or media device with audio output. With no filters applied from the audio software, outputting at 100% volume will result in an output signal in the range of +/-1000uV. The audio signal is fed through a stereo-to-BNC cable to an input Signal Mouse connected to the Digital Lynx SX acquisition system.

Revision History

06 May 2020	Revision 1.0	Initial Release for HPP Applications v1.0.
04 Mar 2021	Revision 2.0	Updates introduced to HPP Applications v2.0, ECO 2641. Added Oscillation Detection to document title. Removed date, address and support information from title page and last page. Updated introduction section to include gamma detection and customizable filters functionality. Replaced references to *HPPApplications-OscillationDectection_v1.0* to *HPPApplications_v2.0*. Replaced references to *OscillationDetectionApplication* to *OscillationDetection*. Refreshed SDK images to reflect *HPPApplications_v2.0*. Added section for importing hardware platform into the SDK workspace environment in programming the application to the HPP hardware section. Updated Matlab GUI windows to reflect changes for HPP Applications v2.0 interface. Updated TTL output response section to reflect updated TTL output parameters. Moved select analog output module and mode to Input and Output Setup window section. Added set oscillation detection filter settings section to Oscillation Detection Parameters section.