

Pulse Detector HDL Workflow Tutorial

R2023a - R2023b

MathWorks Application Engineering

Example Overview

In this tutorial, you are provided the MATLAB® reference of a pulse detection algorithm. The algorithm detects a known waveform in a received signal using a matched filter, and finding the resulting peak. It is a commonly used technique in radar or wireless communication systems.

MATLAB golden reference

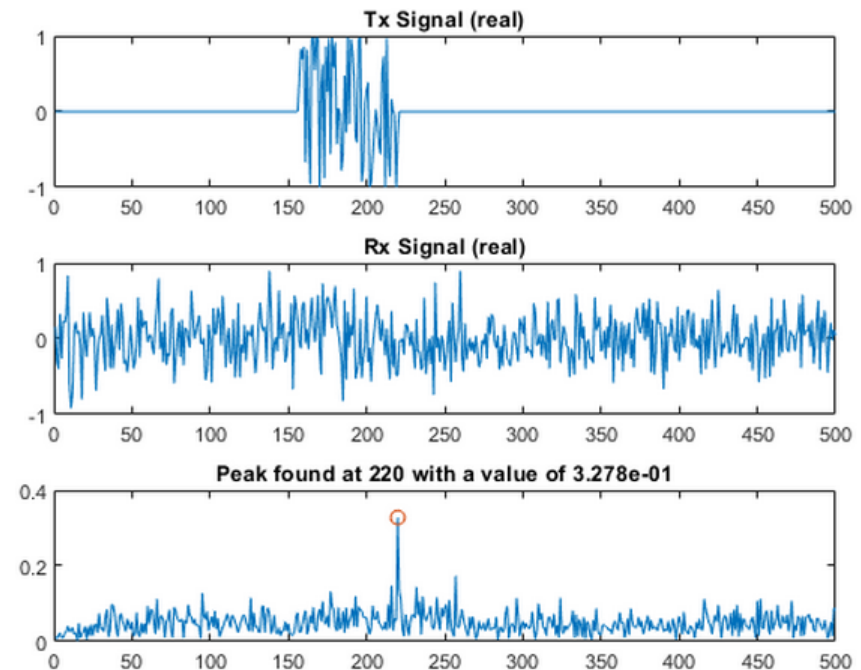
```
% Create matched filter coefficients
CorrFilter = conj(flip(pulse))/PulseLen;

% Correlate Rx signal against matched filter
FilterOut = filter(CorrFilter,1,RxSignal);

% Find peak magnitude & location
[peak, location] = max(abs(FilterOut));

% Print results
figure(1)
subplot(311); plot(real(TxSignal)); title('Tx Signal (real)');
subplot(312); plot(real(RxSignal)); title('Rx Signal (real)');

t = 1:length(FilterOut);
str = sprintf('Peak found at %d with a value of %.3d',location,peak);
subplot(313); plot(t,abs(FilterOut),location,peak,'o'); title(str);
```



Example Overview

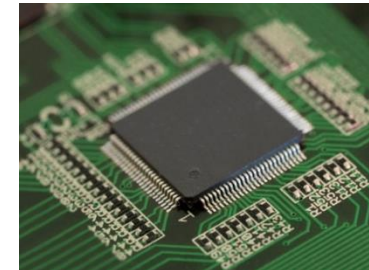
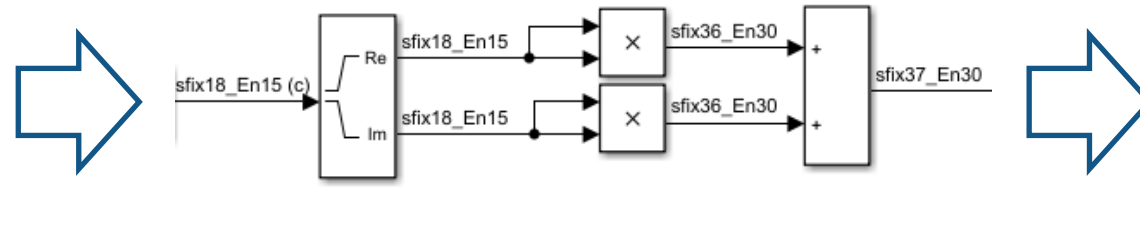
This tutorial will guide you through the steps necessary to implement the algorithm in FPGA hardware, including:

- Create a Simulink® model for the algorithm
- Implement the hardware architecture
- Convert the design to fixed-point
- Generate and synthesize the HDL code

```
% Create matched filter coefficients
CorrFilter = conj(flip(pulse))/PulseLen;

% Correlate Rx signal against matched filter
FilterOut = filter(CorrFilter,1,RxSignal);

% Find peak magnitude & location
[peak, location] = max(abs(FilterOut));
```



Software Requirements

- You will need the following MathWorks products:
 - MATLAB® (R2023a or R2023b)
 - Simulink®
 - Fixed-Point Designer™
 - MATLAB Coder™
 - HDL Coder™
 - Signal Processing Toolbox™
 - DSP System Toolbox™
 - DSP HDL Toolbox™

- Xilinx® Vivado® 2022.1 is used for the last step (step 4)
 - Other Vivado versions typically work, but synthesis results may be different.

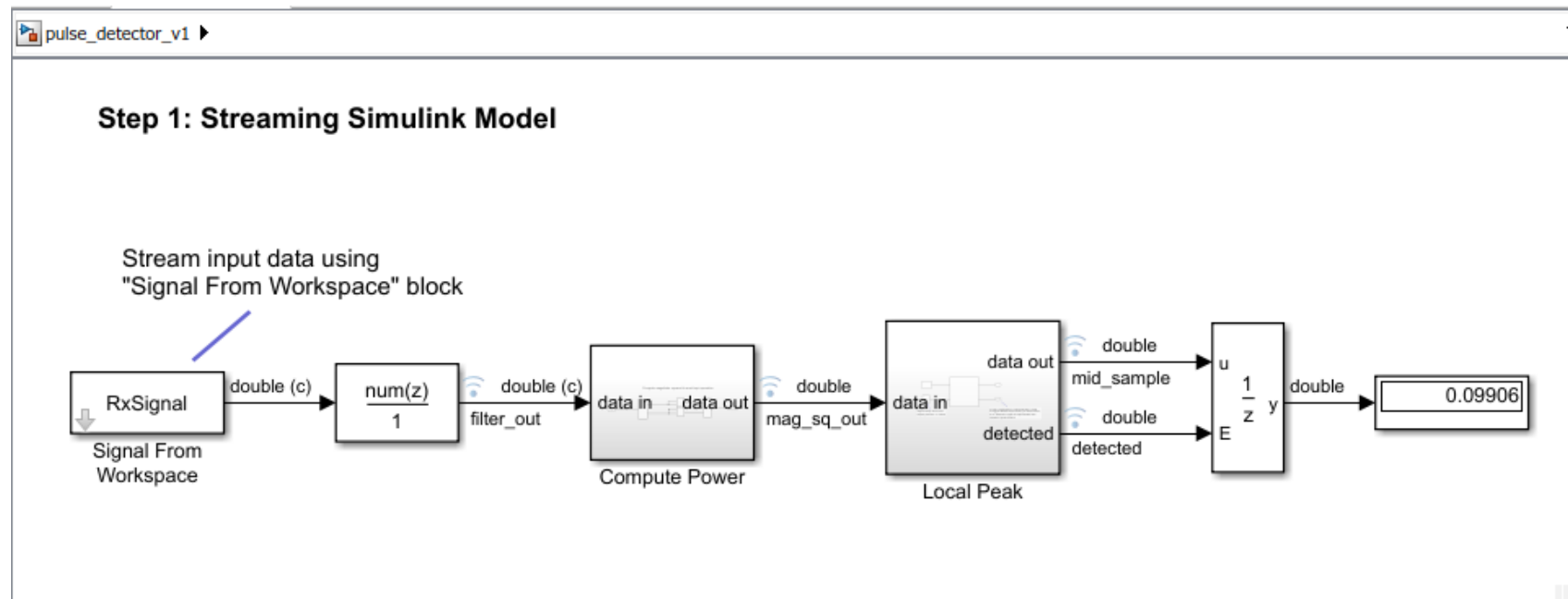
Preparation

- You should be familiar with MATLAB and have basic knowledge of Simulink such as:
 - Creating Simulink models (adding & connecting blocks, creating subsystem, etc)
 - Setting block and model-level parameters
 - Updating, simulating model and viewing simulation results
 - Interacting with MATLAB using workspace variables and signal logging
 - Using fixed-point data type in Simulink
- Use the following resources as needed to prepare for this tutorial:
 - [MATLAB Onramp](#)
 - [Simulink Onramp](#)
 - [HDL Coder Tutorial Overview \(video series\)](#)
 - [HDL Coder Evaluation Reference Guide](#)
- Locate the example files in the folder: **/pulse_detector/work**

Step 1: Streaming Simulink model

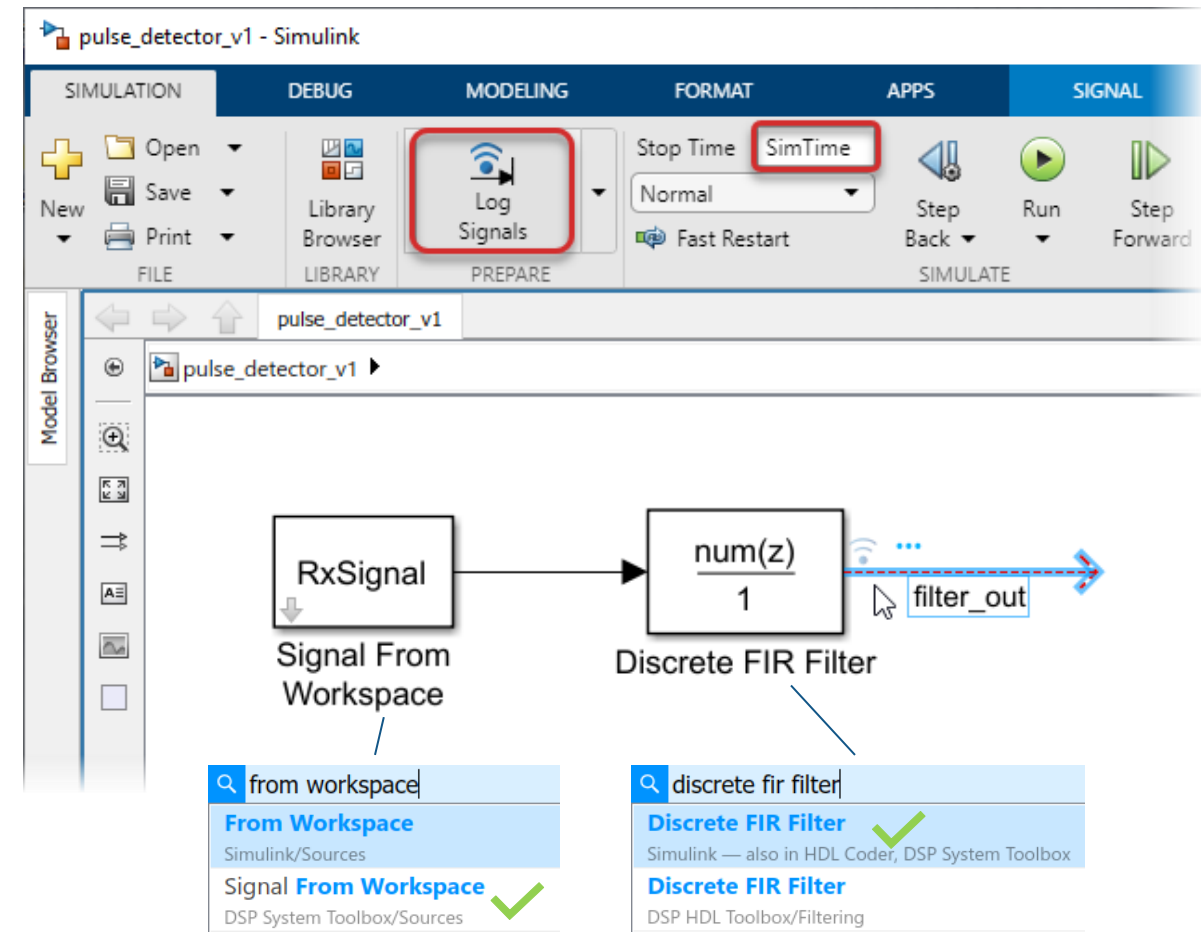
In this step, you will:

- Create a Simulink model with streaming input
- Implement a hardware-friendly peak finder
- Compare the Simulink pulse detector to the MATLAB golden reference



Step 1.1: Stream and filter input signal

1. Run **pulse_detector_reference.mlx** to initialize parameters needed in this step.
2. Create a new Simulink model and name it **pulse_detector_v1.slx**
3. Add a **Signal From Workspace** block, and enter **RxSignal** for Signal1 on the block dialog. This will stream the vector RxSignal one sample at a time.
4. Implement the filter function using a **Discrete FIR Filter** block from the **Simulink** library. Enter **CorrFilter** for Coefficients.
5. Name the filter block output signal **filter_out**, and enable data logging for the signal.
6. Enter **SimTime** for simulation stop time.



Tip: Make sure to choose the right blocks

Step 1.1: Stream and filter input signal

7. Compare the Simulink filter output against the MATLAB reference. Verifying your Simulink model incrementally helps catch mistakes early on.
 - Run the test bench script **pulse_detector_v1_tb.mlx**. An error is expected at line 16 as the model is incomplete.
 - Verify the Simulink filter output matches the MATLAB reference (max error $\sim 1e^{-16}$).

Simulate model and compare results to reference

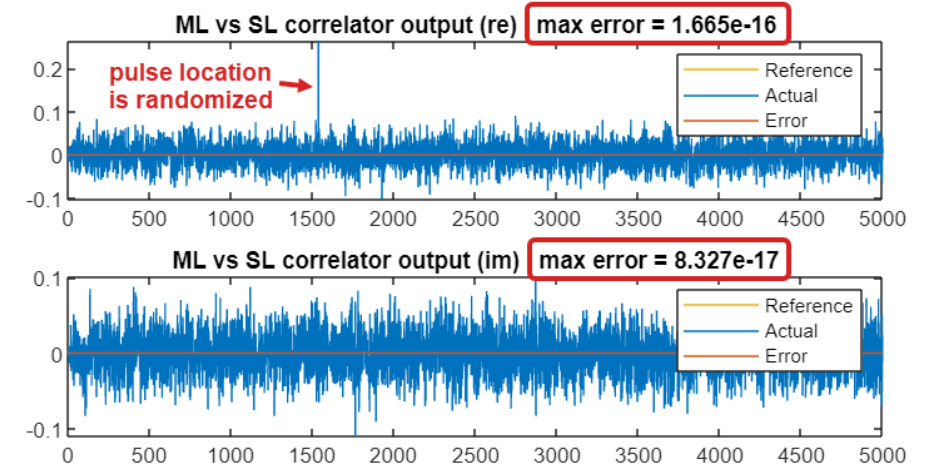
```

2  if iscolumn(CorrFilter)
3      CorrFilter = transpose(CorrFilter); % need row vector for filter block
4  end
5  SimTime = length(RxSignal) + WindowLen;
6
7  % Simulate model
8  slout = sim('pulse_detector_v1');
9
10 % Correlation filter output
11 FilterOutSL = getLogged(slout, 'filter_out');
12 compareData(real(FilterOut), real(FilterOutSL), {2 3 1}, 'ML vs SL correlator output
13 compareData(imag(FilterOut), imag(FilterOutSL), {2 3 2}, 'ML vs SL correlator output
14
15 % Magnitude squared output
16 MagSqSL = getLogged(slout, 'mag_sq_out');
17 compareData(MagSqOut, MagSqSL, {2 3 3}, 'ML vs SL mag-squared output');
18
19 % Peak value
20 MidSampleSL = getLogged(slout, 'mid_sample');
21

```

Maximum error for ML vs SL correlator output (re) out of 5000 values
1.665335e-16 (absolute), 6.301458e-14 (percentage)

Maximum error for ML vs SL correlator output (im) out of 5000 values
8.326673e-17 (absolute), 7.535410e-14 (percentage)

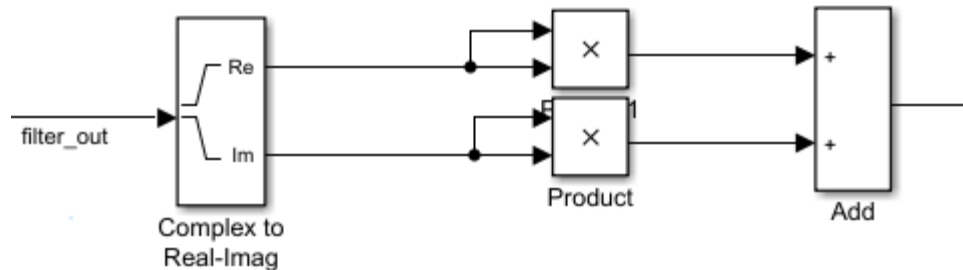


Warning: Did not find any Dataset element using 'mag_sq_out'.

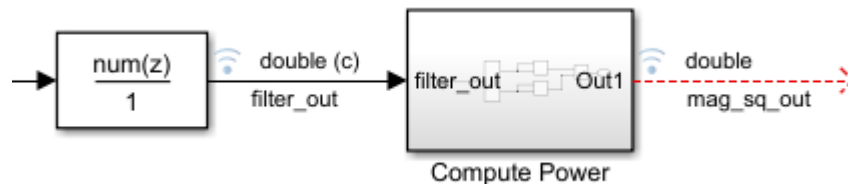
Error using **getLogged**
Signal 'mag_sq_out' not found. Make sure it is logged and named correctly.

Step 1.2: Hardware-friendly peak finder (magnitude-squared)

1. Review the section *Hardware friendly implementation of peak finder* in **pulse_detector_reference.mlx**.
2. At the filter block output, implement magnitude-squared using the following blocks:



3. Group the blocks in a subsystem and name it **Compute Power**. Log the subsystem output as **mag_sq_out**.

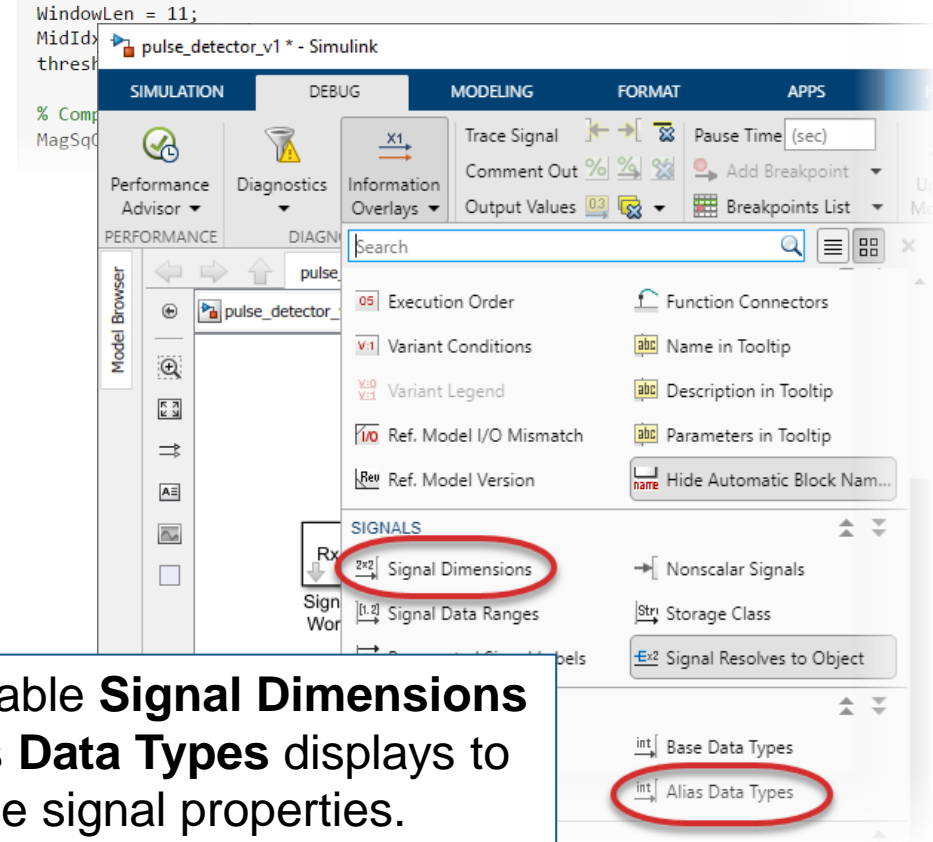


Hardware friendly implementation of peak finder

Instead of calculating the maximum value of the entire frame, we look for a local peak within a sliding samples using the following criteria:

- The middle sample is the largest
- The middle sample is greater than a pre-defined threshold

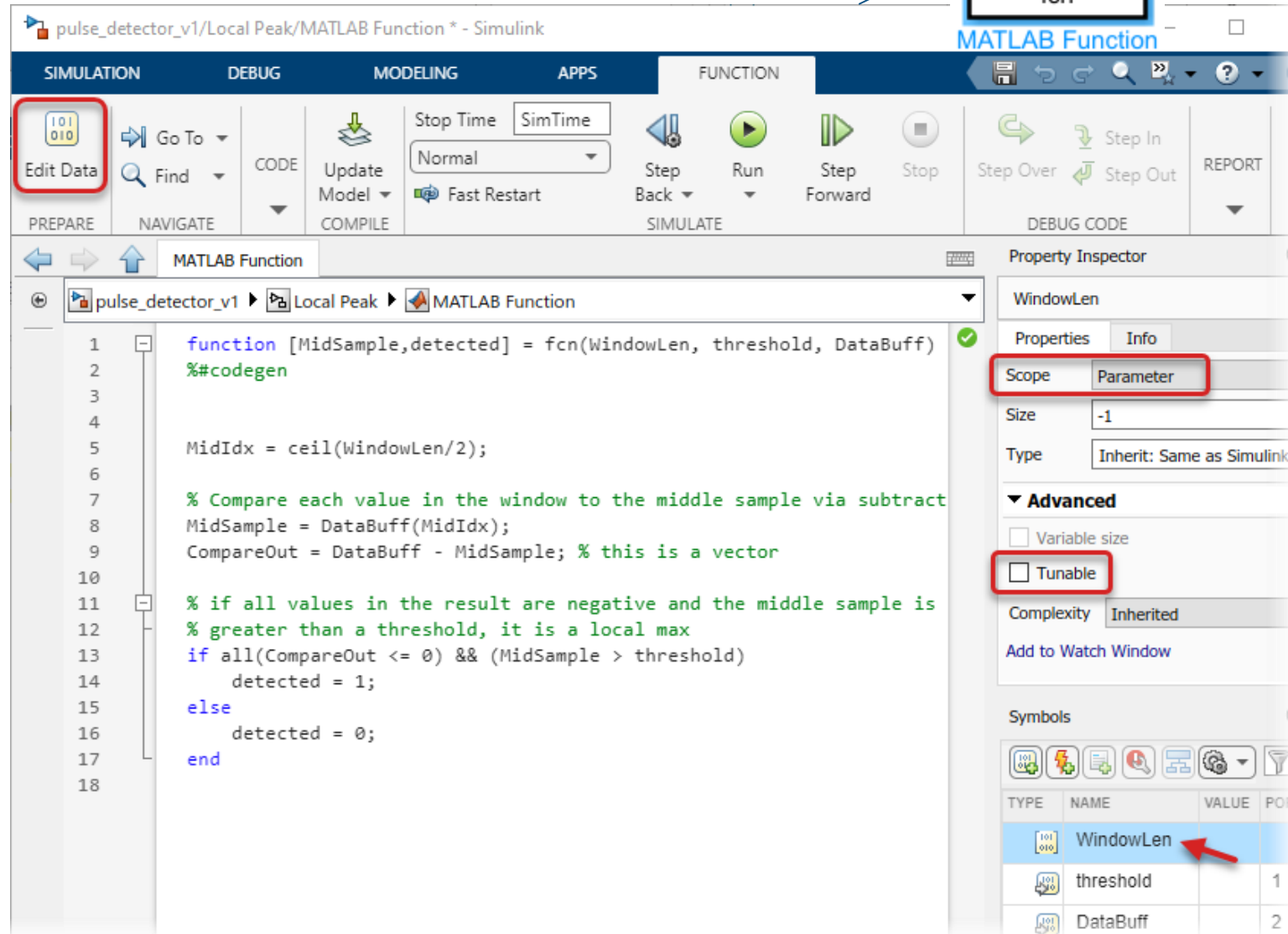
42
43
44
45
46
47
48



Tip: Enable **Signal Dimensions** & **Alias Data Types** displays to visualize signal properties.

Step 1.3: Hardware-friendly peak finder (local peak)

1. Connect mag_sq_out to a **Tapped Delay** block for the sliding window buffer. Set Number of delays to **WindowLen**.
2. Implement the rest of the hardware-friendly peak finder using a **MATLAB Function** block. Copy and paste the code from **pulse_detector_reference.mlx** (line 42 to the end) to the block, and modify it to match the screenshot.
3. Click on **Edit Data** to open the **Symbols** pane and the **Property Inspector**. Select WindowLen, change its Scope to Parameter and uncheck Tunable.



The screenshot shows the MATLAB Function block editor for 'pulse_detector_v1/Local Peak/MATLAB Function'. The code is as follows:

```

1 function [MidSample,detected] = fcn(WindowLen, threshold, DataBuff)
2 %#codegen
3
4
5 MidIdx = ceil(WindowLen/2);
6
7 % Compare each value in the window to the middle sample via subtract
8 MidSample = DataBuff(MidIdx);
9 CompareOut = DataBuff - MidSample; % this is a vector
10
11 % if all values in the result are negative and the middle sample is
12 % greater than a threshold, it is a local max
13 if all(CompareOut <= 0) && (MidSample > threshold)
14     detected = 1;
15 else
16     detected = 0;
17 end
18

```

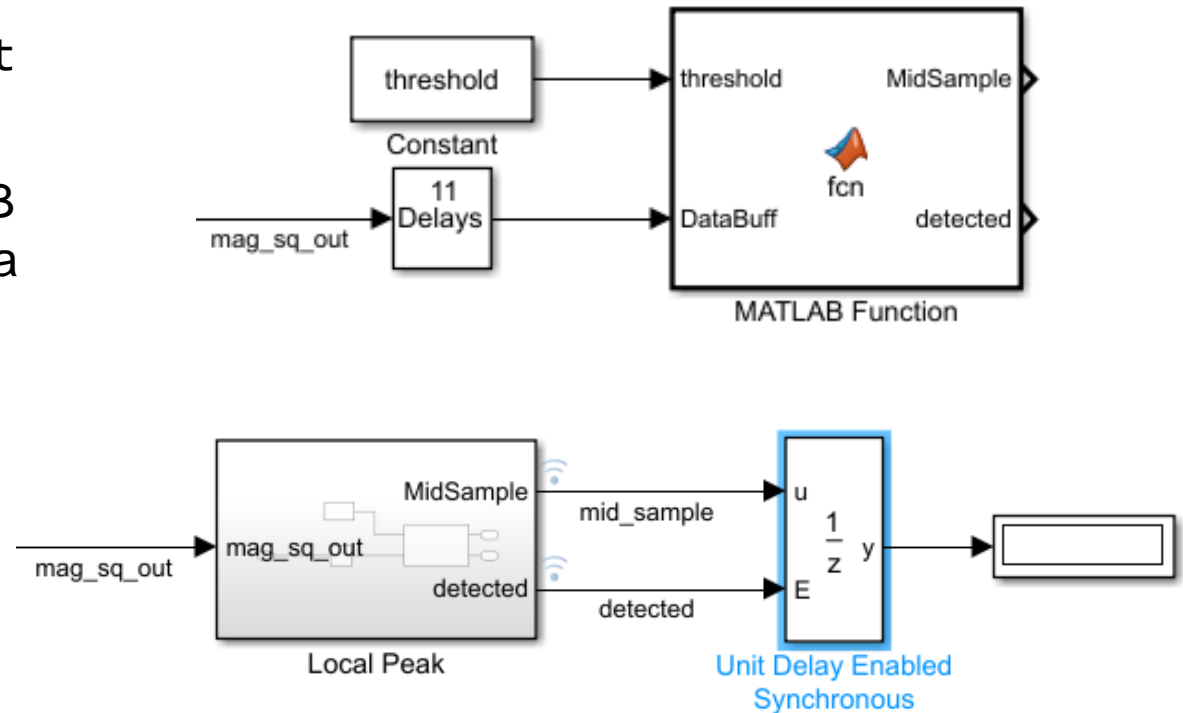
The Property Inspector on the right shows the 'WindowLen' parameter with the following settings:

- Scope: Parameter
- Size: -1
- Type: Inherit: Same as Simulink
- Advanced: ☐ Variable size, ☐ Tunable
- Complexity: Inherited

The Symbols pane at the bottom shows the 'WindowLen' parameter selected.

Step 1.3: Hardware-friendly peak finder (local peak)

4. Navigate back to the top-level model. Add a **Constant** block and enter **threshold** for Constant value.
5. Connect the constant, tapped delay and MATLAB function blocks as shown. Group the 3 blocks in a subsystem named **Local Peak**.
6. Connect Local Peak to a **Unit Delay Enabled Synchronous** (UDES) block; log and name the connecting signals **mid_sample** and **detected** as shown.
7. Finally, connect the UDES block to a **Display** block. The UDES block will keep the detected peak value on display at the end of the simulation.
8. Save the model.

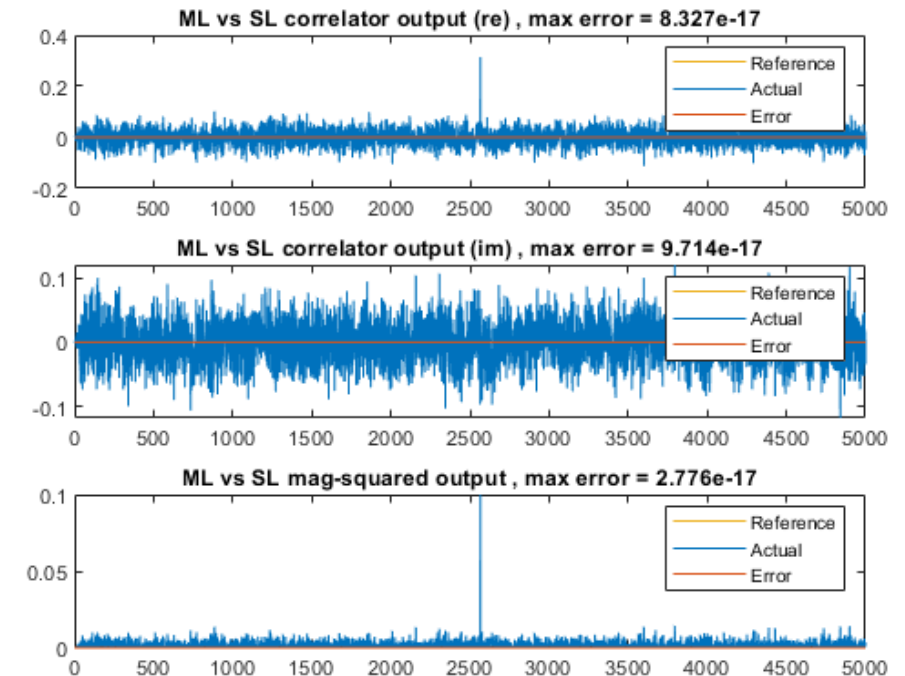


Step 1.4: Compare model to MATLAB reference

Run **pulse_detector_v1_tb.mlx** to simulate the model, and compare the Simulink outputs to the MATLAB reference.

- Maximum error for the correlator, magnitude-squared and peak value should be in the range of floating-point eps (e^{-16}).
- Peak location is randomized for each run.
- The Simulink model implements a *detected* output instead of an index for the peak location, as the algorithm is often used to determine the beginning of a data frame, where a detected signal is sufficient.

Maximum error for ML vs SL correlator output (re) out of 5000 values
 8.326673e-17 (absolute), 2.648455e-14 (percentage)
 Maximum error for ML vs SL correlator output (im) out of 5000 values
 9.714451e-17 (absolute), 8.099696e-14 (percentage)
 Maximum error for ML vs SL mag-squared output out of 5000 values
 2.775558e-17 (absolute), 2.772557e-14 (percentage)

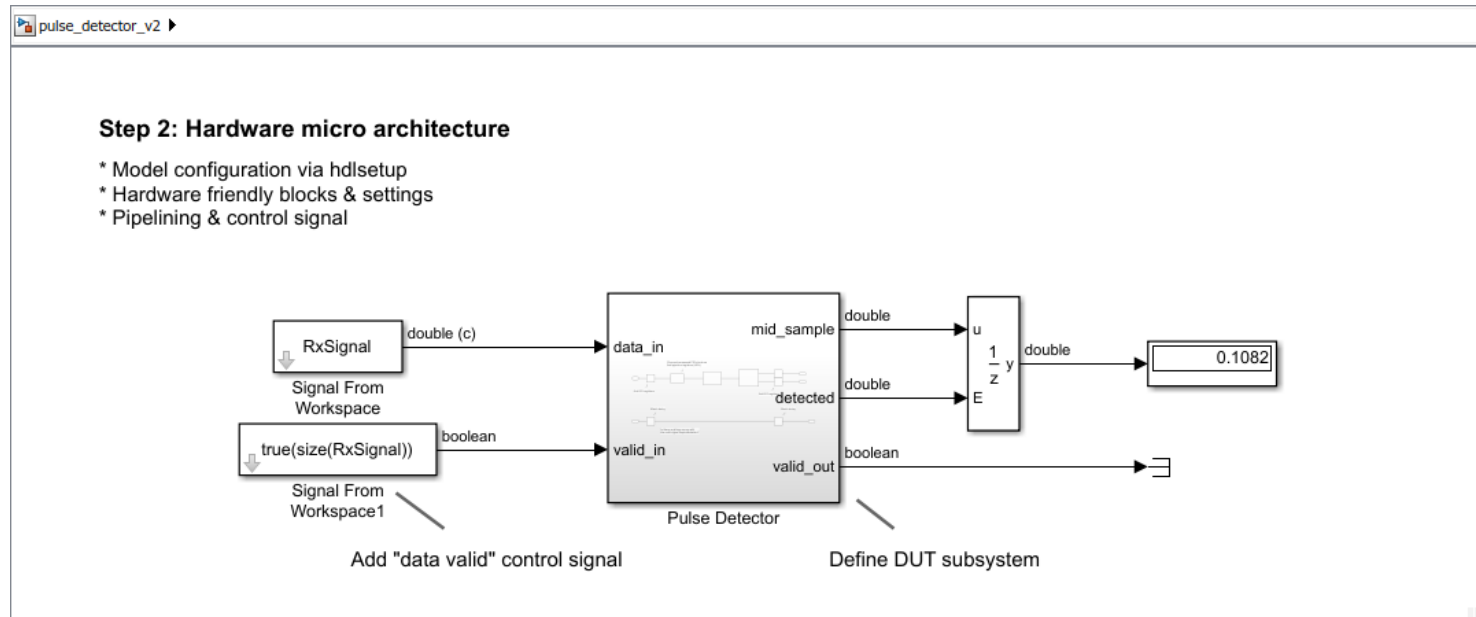


Peak location = 2566, magnitude = 3.164e-01 using global max
 Peak location = 2566, mag-squared = 1.001e-01 using local max
 Peak mag-squared from Simulink = 1.001e-01, error = 2.776e-17

Step 2: Hardware micro architecture

In this step, you will:

- Prepare the model for HDL code generation
- Add data valid control signal
- Use hardware-efficient blocks and pipeline the data path
- Compare the Simulink architecture model to the MATLAB golden reference



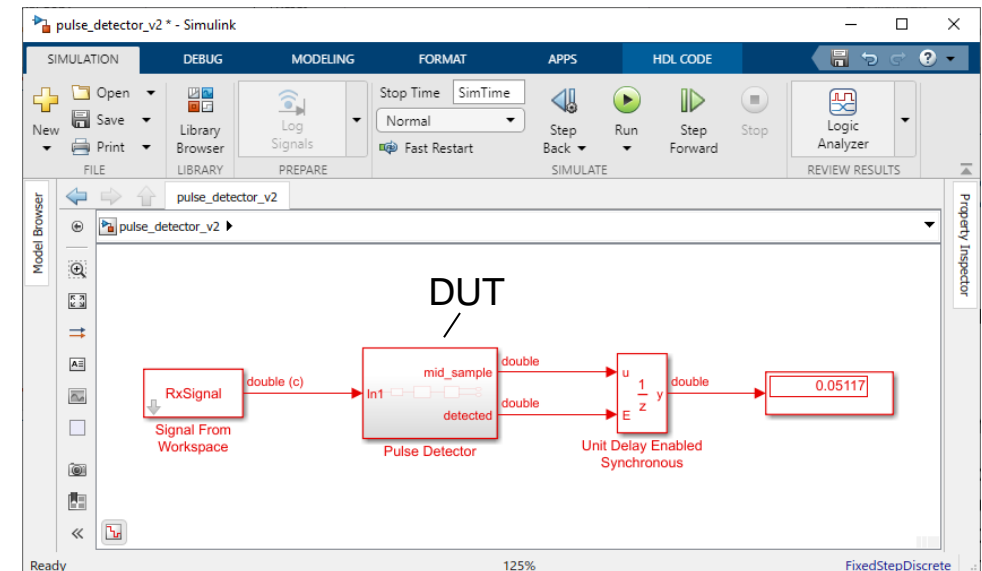
Step 2.1: HDL model configurations

1. Save the Simulink model as **pulse_detector_v2.slx**.
2. Run the MATLAB command **hdlsetup('pulse_detector_v2')**. This will configure the model settings to be compatible with HDL code generation.
3. Group the filter block, the *Compute Power* and *Local Peak* subsystems into a top-level subsystem named **Pulse Detector**. This top-level subsystem will be referred to as the **DUT** (Design Under Test) – i.e. the portion of the model that will generate HDL.

Note: **hdlsetup** enables sample time color display for the model. The next time you update/simulate the model, blocks will appear red as they operate at the fastest sample rate.

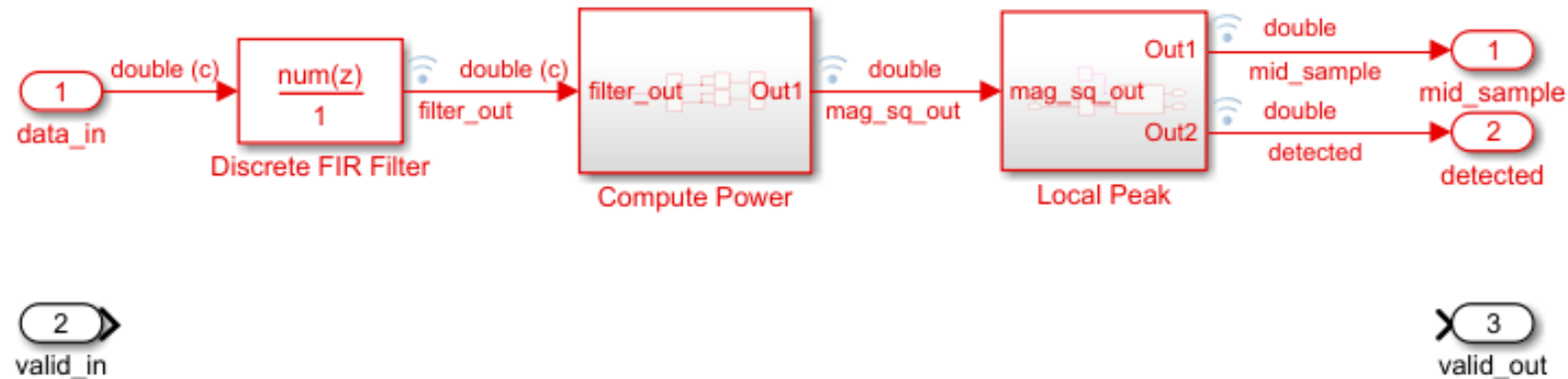
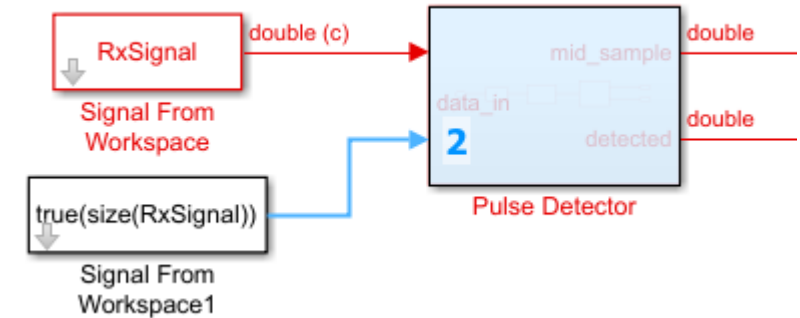
Command Window

```
>> hdlsetup('pulse_detector_v2')
### AlgebraicLoopMsg value is set from 'warning' to 'error' (revert).
### BlockReduction value is set from 'on' to 'off' (revert).
### ConditionallyExecuteInputs value is set from 'on' to 'off' (revert).
### DefaultParameterBehavior value is set from 'Tunable' to 'Inlined' (revert).
### InheritOutputTypeSmallerThanSingle value is set from 'off' to 'on' (revert).
### ProdHWDeviceType value is set from 'Intel->x86-64 (Windows64)' to 'ASIC/FPGA-'.
### SingleTaskRateTransMsg value is set from 'none' to 'error' (revert).
### Solver value is set from 'VariableStepAuto' to 'FixedStepDiscrete' (revert).
### The listed configuration parameter values are modified as a part of hdlsetup.
```



Step 2.2: Implement data valid interface

1. Add a data valid input using a **Signal From Workspace** block, and enter `true(size(RxSignal))` for Signal1. This enables the design to interface with a non-continuous data source, although the example uses continuous input data for simplicity.
2. Connect the block to the DUT subsystem as a second input.
3. Inside the DUT subsystem, name the first input port `data_in`, and the new input port `valid_in`.
4. Add a new **Output** port and name it `valid_out`.



Step 2.3: HDL optimized FIR filter

1. Replace the current FIR filter with a **Discrete FIR Filter** block from the **DSP HDL Toolbox** library. This block offers systolic filter architectures and pipeline register placements that are designed to use FPGA DSP resources efficiently. It also provides control signals for common data interfaces.
2. Again, enter **CorrFilter** for Coefficients, name the data output signal **filter_out**, and log the signal.
3. Connect the *valid_in* port to the FIR valid input, and the FIR valid output to the *valid_out* port. Log the FIR valid out as **filter_valid**.

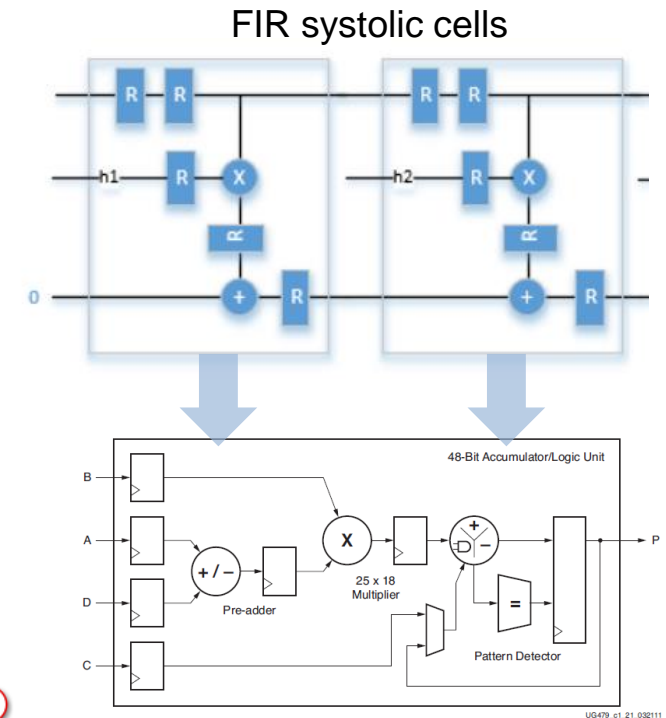
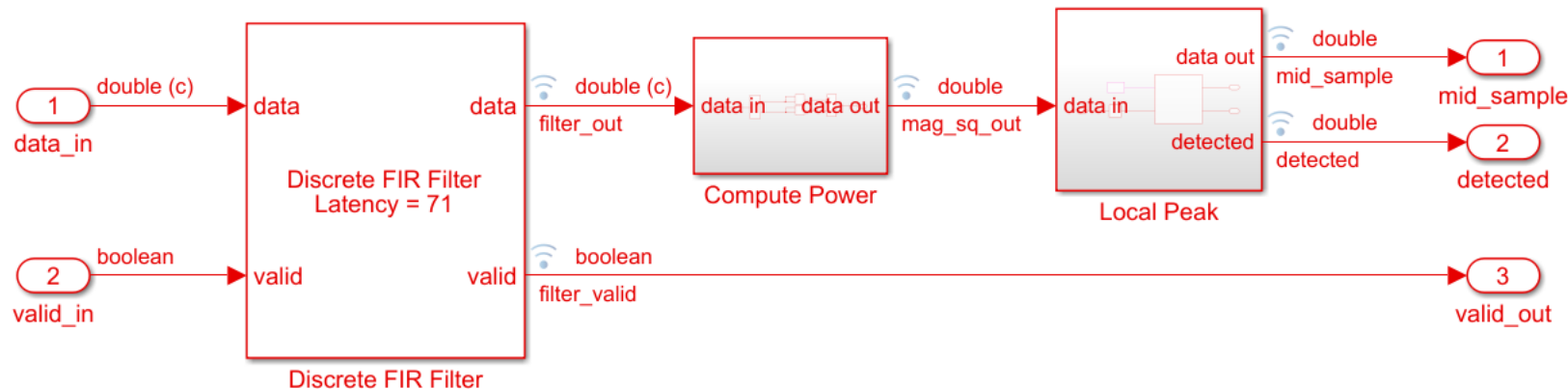
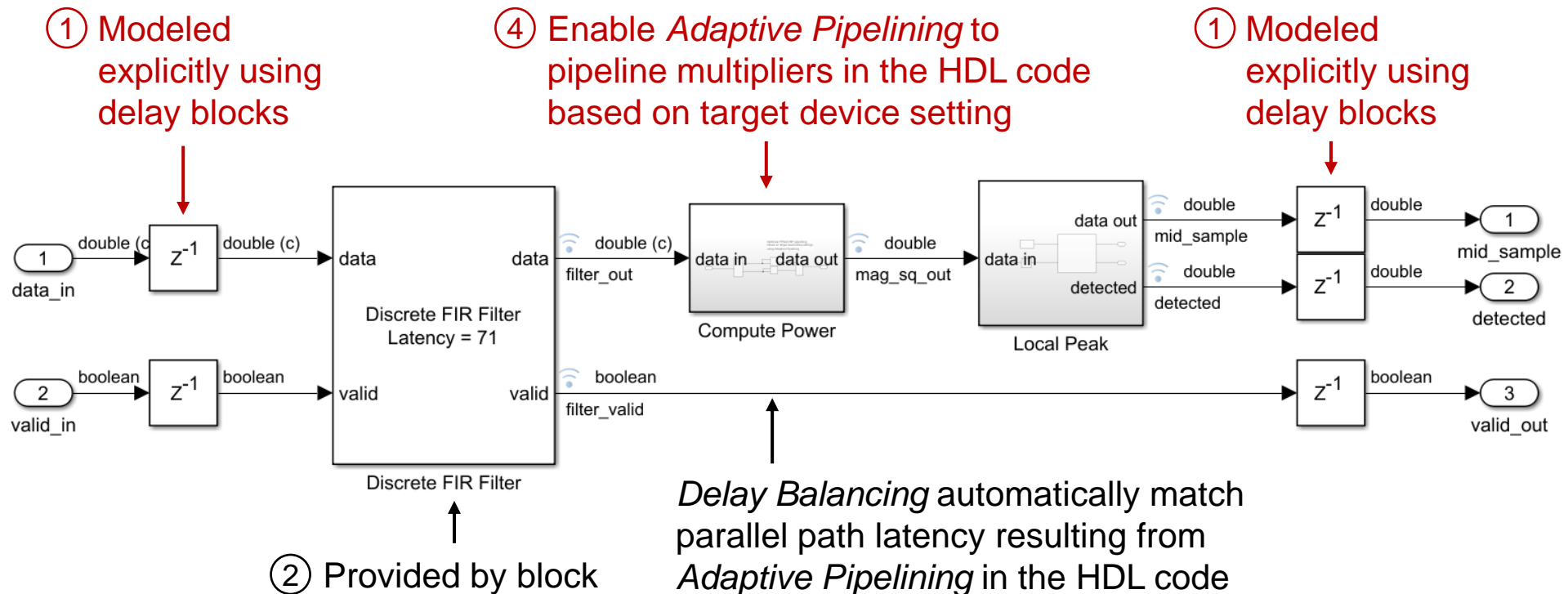


Figure 1-1: Basic DSP48E1 Slice Functionality

Step 2.4: Insert pipeline registers

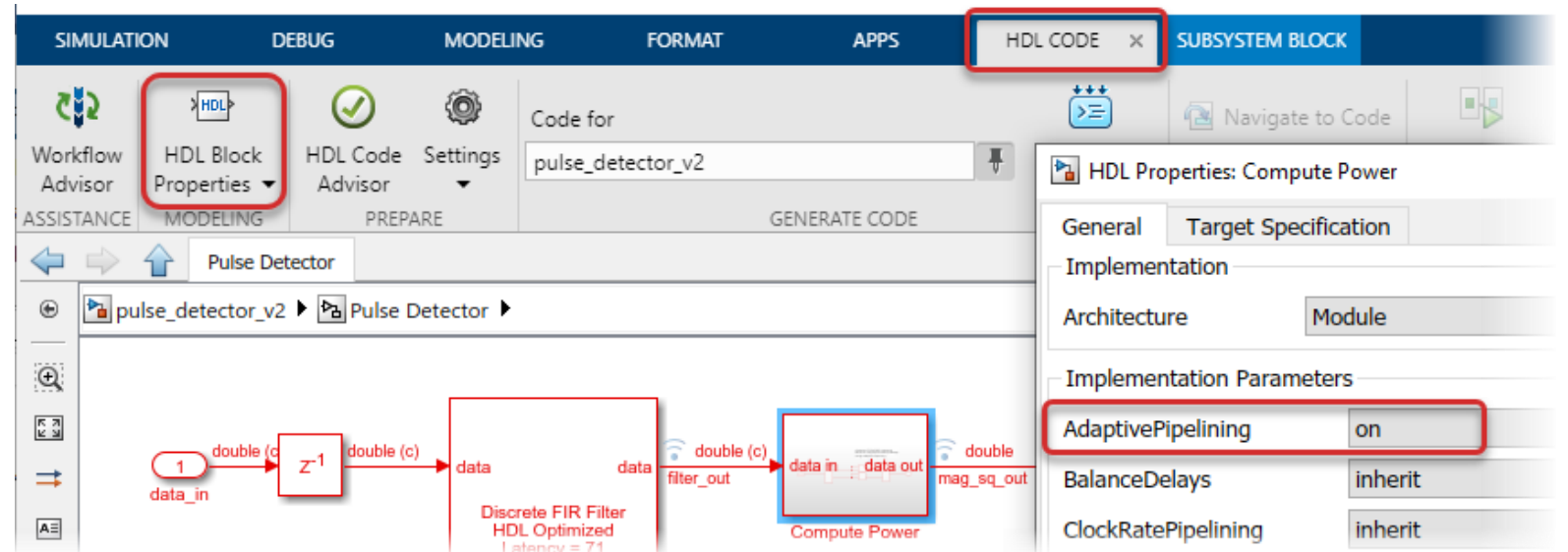
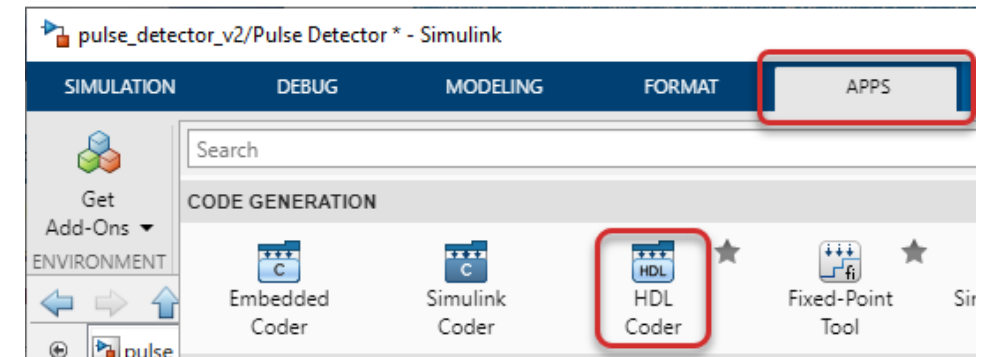
1. Pipeline the data input & output using **Delay** blocks as shown. Add matching delays to the valid signal path.
2. The HDL optimized FIR filter already contains pipeline registers. No action is required.

Pipelining options:



Step 2.4: Insert pipeline registers

3. Open the **HDL Code** Toolstrip under Apps > Code Generation > HDL Coder.
4. Select the *Compute Power* subsystem and open its **HDL Block Properties** dialog using the **HDL Code** Toolstrip. Set AdaptivePipelining to on, then click **OK** to close the HDL properties dialog.

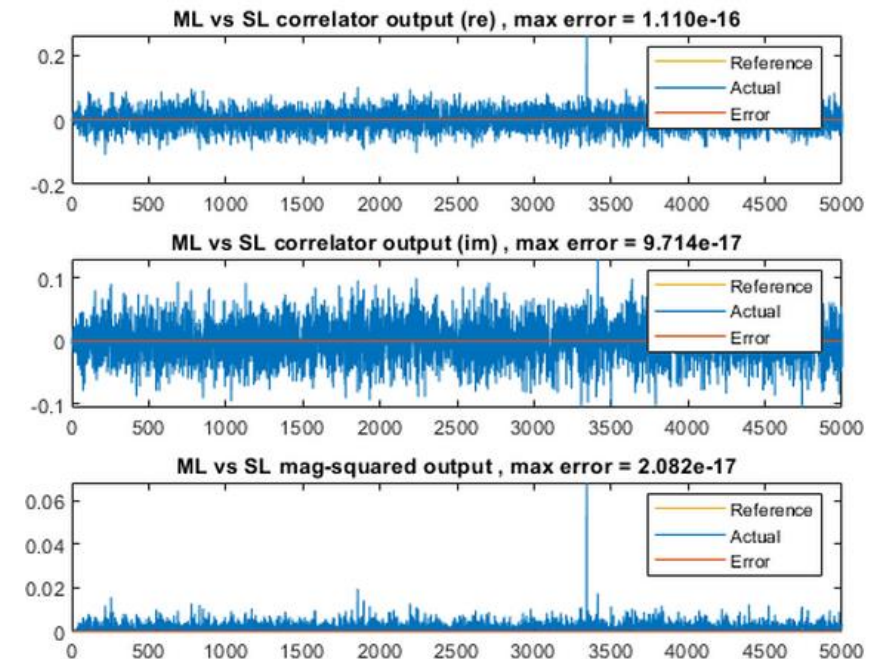


Step 2.5: Compare architecture model to MATLAB reference

1. In the top-level model, terminate the DUT output port *valid_out* by connecting it to a **Terminator** block. Save the model.
2. Run **pulse_detector_v2_tb.mlx** to simulate the model, and compare the Simulink outputs to the MATLAB reference.
 - This test bench uses the new *filter_valid* signal to qualify the logged filter & magnitude-squared outputs:

```
% Correlation filter output
FilterOutSL = getLogged(slout,'filter_out');
FilterValid = getLogged(slout,'filter_valid');
FilterOutSL = FilterOutSL(FilterValid);
```

- Maximum error for all outputs should be similar to that of step 1.



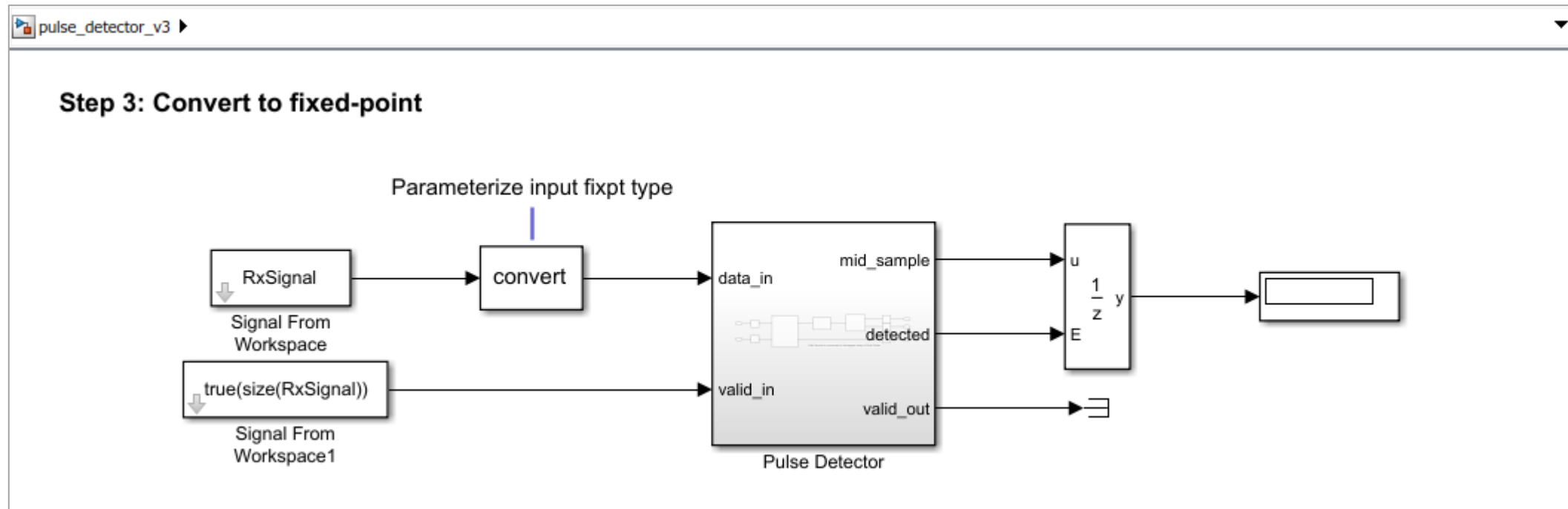
Question: What's wrong with the valid signal implementation?

Answer: The valid signal should also be connected to the sliding window buffer, to prevent invalid samples from entering the delay line. The simulation is only correct in this example because valid_in is always high.

Step 3: Fixed-point conversion

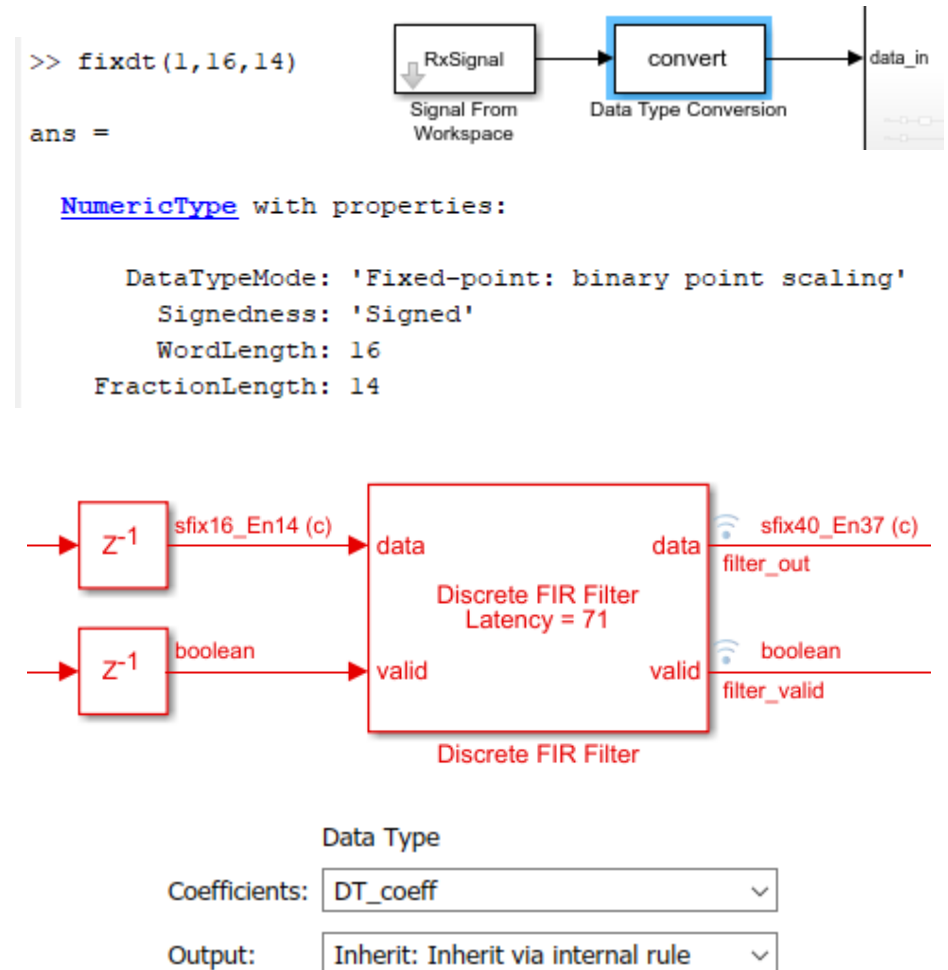
In this step, you will:

- Convert the model to fixed-point
- Compare the Simulink fixed-point model to the MATLAB golden reference



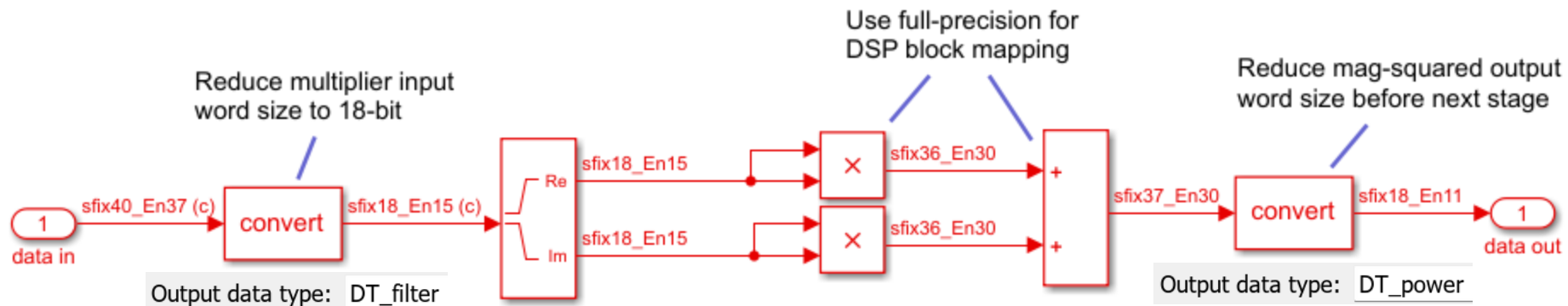
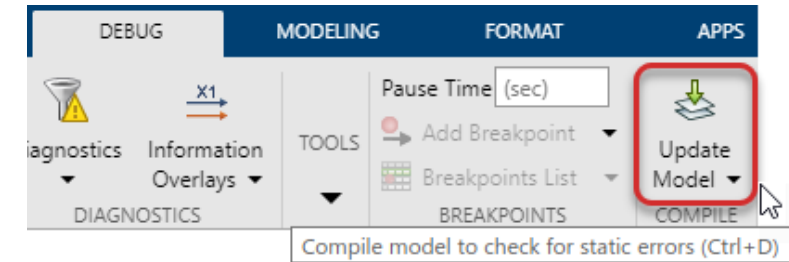
Step 3.1: Define input and filter fixed-point data types

1. Save the Simulink model as **pulse_detector_v3.slx**.
2. At the top-level model, add a **Data Type Conversion** block at the output of *RxSignal*. Set Output data type to **DT_input**, which is defined as `fixdt(1,16,14)` in the test bench script to fully represent -1 to 1.
3. Inside the DUT, set Coefficients Data Type on the FIR filter block to **DT_coeff**, which is defined as `fixdt(1,18)`. Fraction length of a constant can be automatically determined when it is left unspecified.
4. The filter is set up to perform multiply & add using full-precision fixed-point. Run **pulse_detector_v3_tb.mlx** to update the filter output data type (error is expected as the model is partially converted to fixed-point).



Step 3.2: Define magnitude-squared data types

1. In the *Compute Power* subsystem, add a **Data Type Conversion** block after the input port; set Output data type to **DT_filter**. This reduces the data word length to 18-bit while maintaining the integer range.
2. Update the model to examine the data types through the subsystem (error is still okay).
3. Reduce the final adder output to **DT_power** using another **Data Type Conversion** block, and update the model once more (error is still okay).



Tip: 18-bit inputs and full-precision fixed-point allow multiply-add operations (including those within the FIR filter in the previous step) to be implemented using DSP blocks in most FPGAs.

Step 3.3: Define peak picker data types

1. In the *Local Peak* subsystem, add a **Data Type Duplicate** block. Connect one port to the threshold constant block output, and another to the tapped delay block output.
2. Set Output data type of the threshold constant to **Inherit via back propagation**.

These 2 steps allow the threshold constant to take on the same data type used by the input data.

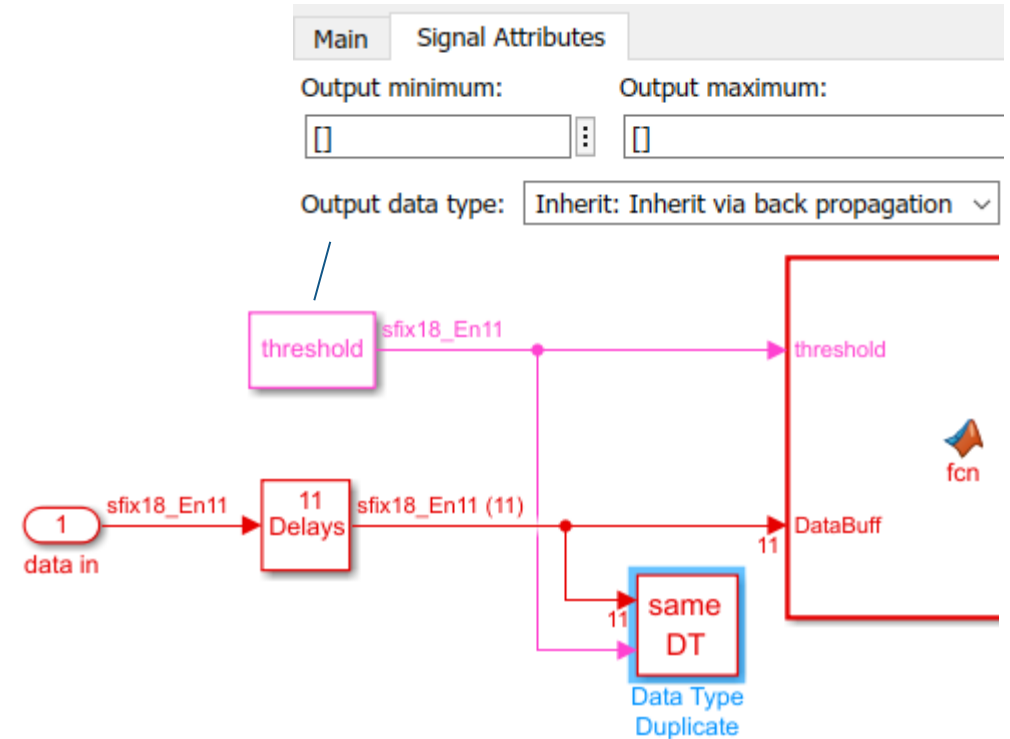
3. In the MATLAB function block, change the *detected* value to true/false.

```

11 - if all(CompareOut <= 0) && (MidSample > threshold)
12 -     detected = true;
13 - else
14 -     detected = false;
15 - end

```

4. Update and save the model. It should be error-free at this point.



Parameter precision loss occurred for 'Value' of '[pulse_detector_v3/Pulse_Detector/Local_Peak/Constant](#)'. The original value of the parameter, 0.03, cannot be represented exactly using the run-time data type sfix18_En11. The value is quantized to 0.02978515625. Quantization error occurred with an absolute difference of 0.00021484374999999989 and a relative difference of 0.716145833333333%.

Suggested Actions

- To disable this warning or error for all parameters in the model, set the 'Detect precision loss' option to 'none'.
- Inspect details in the Parameter Quantization Advisor.

Apply

Open

Component: Simulink | Category: Block warning

This warning message can be safely ignored or suppressed.

ⓘ Suppress

Step 3.4: Compare fixed-point model to MATLAB reference

Run **pulse_detector_v3_tb.mlx** to simulate the model, and compare the Simulink fixed-point outputs to the MATLAB floating-point reference.

- Note the increase in error due to quantization.
- You may switch between fixed-point and floating-point using the following flag in the test bench.

```

2  % Simulate model in fixed-point or floating-point
3  fxpt_mode = ☒;
4  if fxpt_mode % fixed-point
5      DT_input = fixdt(1,16,14);
6      DT_filter = fixdt(1,18,15);
7      DT_power = fixdt(1,18,11);
8  else % floating-point
9      DT_input = 'double';
10     DT_filter = 'double';
11     DT_power = 'double';
12 end
13 DT_coeff = fixdt(1,18); % coeff is treated as double

```

```

Maximum error for ML vs SL correlator output (re) out of 5000 values
8.713091e-06 (absolute), 4.352322e-03 (percentage)
Maximum error for ML vs SL correlator output (im) out of 5000 values
8.120594e-06 (absolute), 8.318296e-03 (percentage)
Maximum error for ML vs SL mag-squared output out of 5000 values
4.907380e-04 (absolute), 1.224467e+00 (percentage)

```

```

Peak location = 1268, magnitude = 2.002e-01 using global max
Peak location = 1268, mag-squared = 4.008e-02 using local max
Peak mag-squared from Simulink = 4.004e-02, error = 3.862e-05

```

Tip: Doing hardware architecture design before fixed-point conversion prevents quantization noise from obscuring design errors.

Step 4: HDL code generation & synthesis

In this step, you will:

- Check the model for HDL compatibility
- Generate HDL code and reports
- Synthesize the generated design using Xilinx Vivado

```

96
97 Product1_out1 <= Complex_to_Real_Imag_out2 * Complex_to_Real_Imag_out2;
98
99 PipelineRegister1_process : PROCESS (clk)
100 BEGIN
101   IF clk'EVENT AND clk = '1' THEN
102     IF reset = '1' THEN
103       Product1_out1_1 <= to_signed(0, 36);
104     ELSIF enb = '1' THEN
105       Product1_out1_1 <= Product1_out1;
106     END IF;
107   END IF;
108 END PROCESS PipelineRegister1_process;
109
110
111 Add_add_cast <= resize(Product_out1_1, 37);
112 Add_add_cast_1 <= resize(Product1_out1_1, 37);
113 Add_out1 <= Add_add_cast + Add_add_cast_1;
114
115 Data_Type_Conversion_out1 <= Add_out1(36 DOWNTO 19);
116
117 data_out <= std_logic_vector(Data_Type_Conversion_out1);
118
119 END rtl;
120
  
```

HDL Workflow Advisor - pulse_detector_v4/Pulse Detector

File Edit Run Help

Find:

HDL Workflow Advisor

- 1. Set Target
 - ✓ 1.1. Set Target Device and Synthesis Tool
 - ✓ 1.2. Set Target Frequency
- 2. Prepare Model For HDL Code Generation
 - ✓ 2.1. Check Model Settings
- 3. HDL Code Generation
 - ✓ 3.1. Set HDL Options
 - ✓ 3.2. Generate RTL Code and Testbench
- 4. FPGA Synthesis and Analysis
 - ✓ 4.1. Create Project
 - ✓ 4.2. Perform Synthesis and P/R
 - ✓ 4.2.1. Run Synthesis
 - 4.2.2. Run Implementation
 - 4.3. Annotate Model with Synthesis Result

4.2.1. Run Synthesis

Analysis

Run logic synthesis for specified FPGA device

Input Parameters

☐ Skip pre-route timing analysis

Run This Task

Result: ✓ Passed

Passed Synthesis

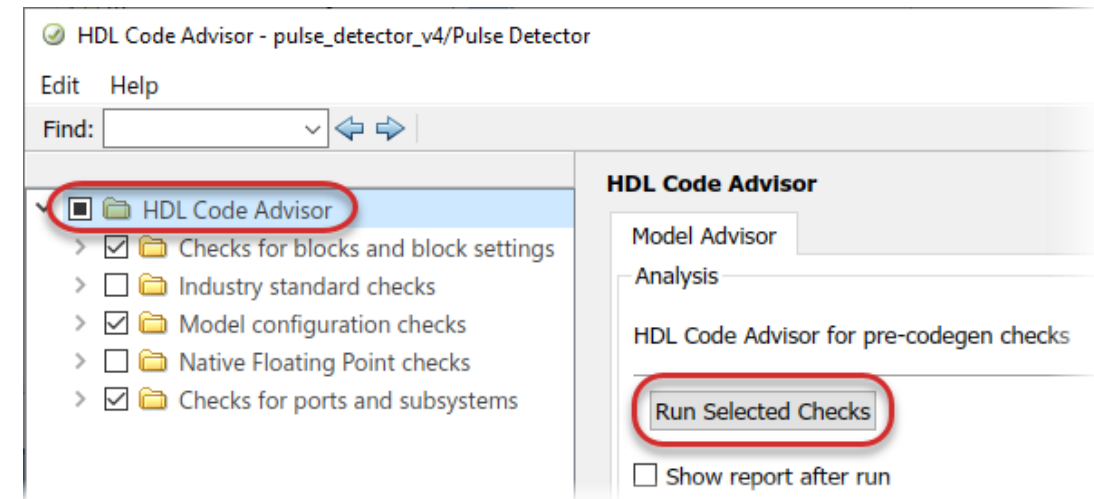
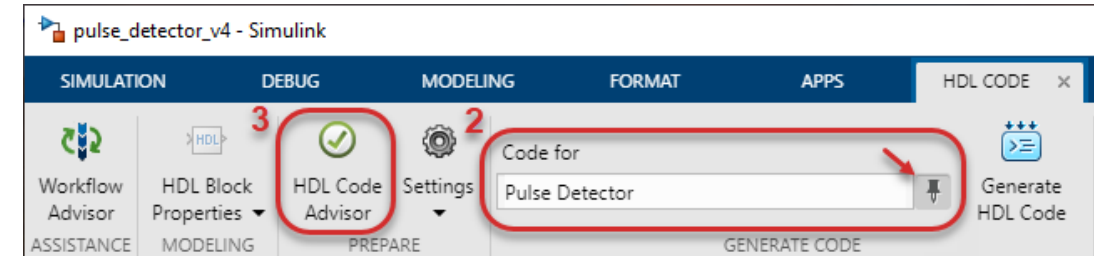
Parsed resource report file: [Pulse_Detector_utilization_synth.rpt](#)

Resource summary

Resource	Usage	Available	Utilization (%)
Slice LUTs	393	171900	0.23
Slice Registers	4523	343800	1.32
DSPs	194	900	21.56
Block RAM Tile	0	500	0.00
URAM	0	0	

Step 4.1: Check model for HDL compatibility

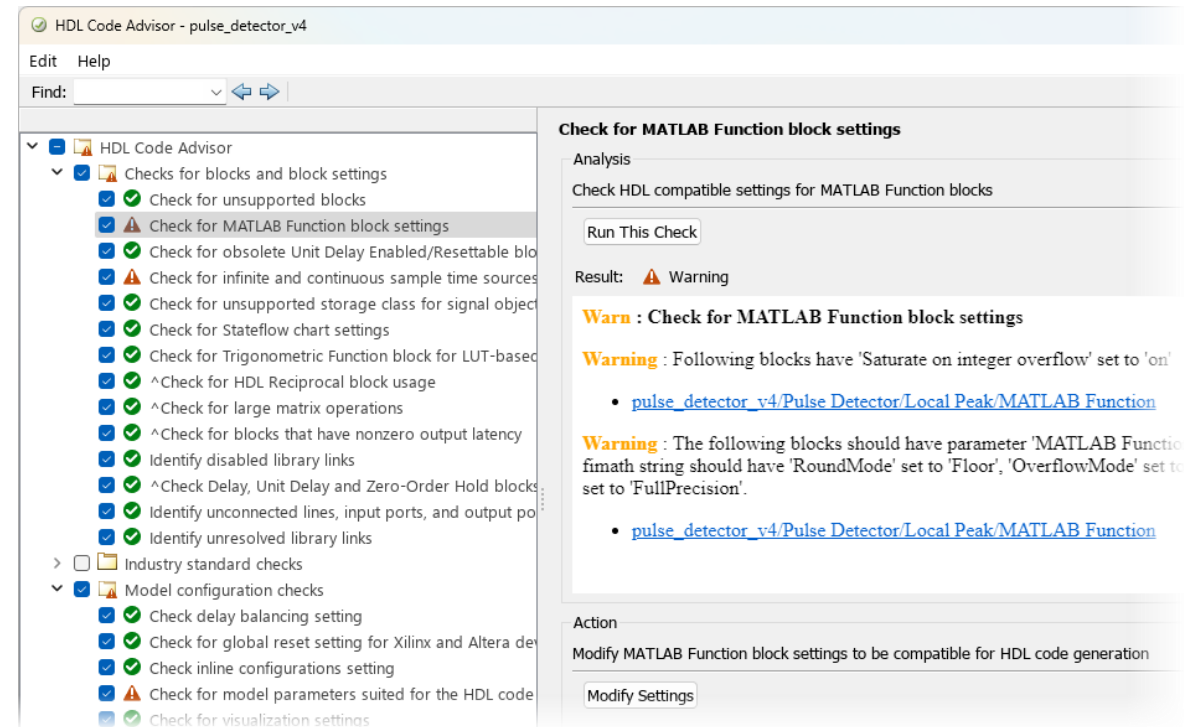
1. Save the Simulink model as **pulse_detector_v4.slx**.
2. Set the *Pulse Detector* subsystem as DUT (HDL Code Toolstrip > unpin > click on subsystem > pin).
3. Check HDL Compatibility for the DUT subsystem using **HDL Code Advisor**. Besides incompatibility, the tool also checks for settings that may result in inefficient hardware. In many cases, a shortcut is provided to modify those settings.
4. De-select the groups **Industry standard checks** and **Native Floating Point checks** – they are not applicable for this example. Highlight the top folder named **HDL Code Advisor**, then click **Run Selected Checks**.



Step 4.1: Check model for HDL compatibility

5. HDL Code Advisor identifies 3 warnings that are explained below. For this exercise, you may ignore the warnings and close the UI.

- **Check for MATLAB Function block settings** reports the use of saturation and rounding logic, which consumes extra hardware resources. If your design works with floor rounding and wrap on overflow, you may click Modify Settings to apply them automatically.
- **Check for infinite and continuous sample time sources** reports the use of *inf* sample time in the model, which may inhibit some optimization features. If that is the case, you may click Modify Settings to replace all such instances with back propagation (-1).
- **Check for model parameters suited for HDL code generation** reports the Simulink diagnostics for unconnected port / line are set to none. Turning on the diagnostics may help identify code generation issues related to unconnected signals.



Step 4.2: Generate HDL code and reports

1. In MATLAB, run the following command to add Xilinx Vivado 2022.1 to the system path:

```
hdlsetuptoolpath('ToolName','Xilinx Vivado','ToolPath','C:\Xilinx\Vivado\2022.1\bin');
```

2. Launch **HDL Workflow Advisor** for the DUT subsystem (HDL Code Toolstrip > Workflow Advisor).

1.1: Synthesis tool: Tool version:
Family: Device:
Package: Speed:

3. Configure the target settings as shown on the right in step 1. Click **Apply** at each step to save the changes.

1.2: Target Frequency (MHz):

4. Open **HDL Code Generation Settings...** in step 3.1.

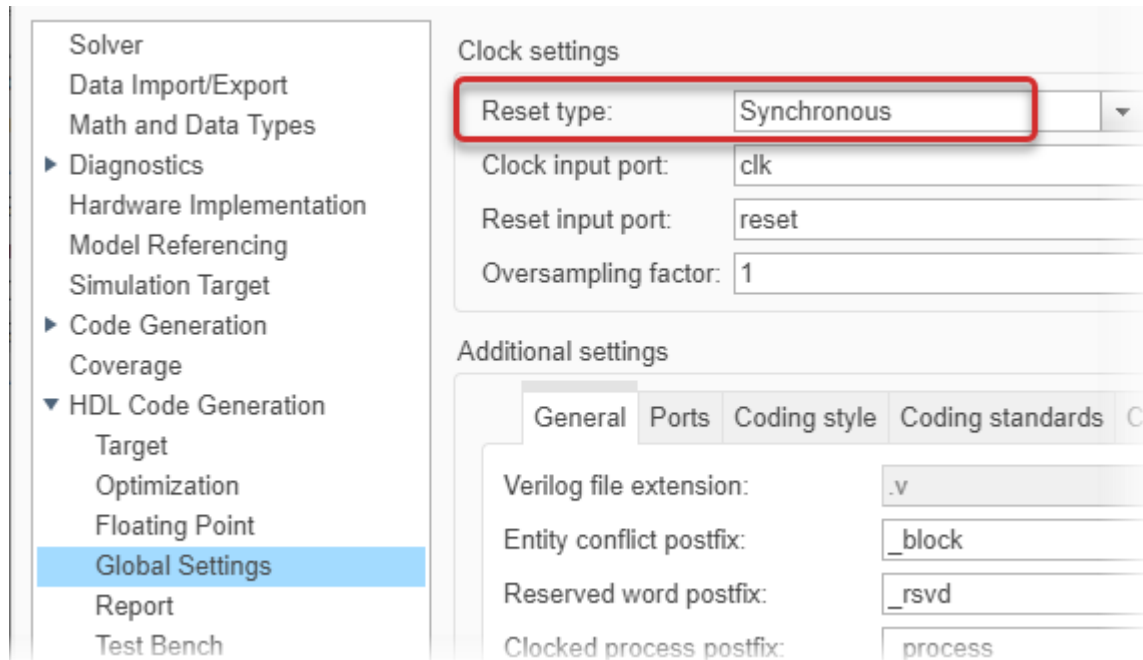
The screenshot shows the HDL Workflow Advisor interface. On the left, a tree view shows the workflow steps: 1. Set Target, 2. Prepare Model For HDL Code Generation, 3. HDL Code Generation, and 4. FPGA Synthesis and Analysis. Under step 3, '3.1. Set HDL Options' is selected. On the right, the '3.1. Set HDL Options' panel is displayed. It has sections for 'Analysis' and 'Input Parameters'. Under 'Input Parameters', the 'HDL Code Generation Settings...' button is highlighted with a red rectangle. Below this, there is a 'Run This Task' button and a 'Result:' field showing 'Not Run'.

Step 4.2: Generate HDL code and reports

5. Configure the following HDL settings, then click OK to close the dialog.

Tip: Choose the appropriate global reset type for your FPGA target to ensure multipliers and pre/post adders are mapped to DSP blocks.

HDL Code Generation > Global Settings



Solver
Data Import/Export
Math and Data Types
▶ Diagnostics
Hardware Implementation
Model Referencing
Simulation Target
▶ Code Generation
Coverage
▼ HDL Code Generation
Target
Optimization
Floating Point
Global Settings
Report
Test Bench

Clock settings

Reset type: Synchronous

Clock input port: clk

Reset input port: reset

Oversampling factor: 1

Additional settings

General Ports Coding style Coding standards

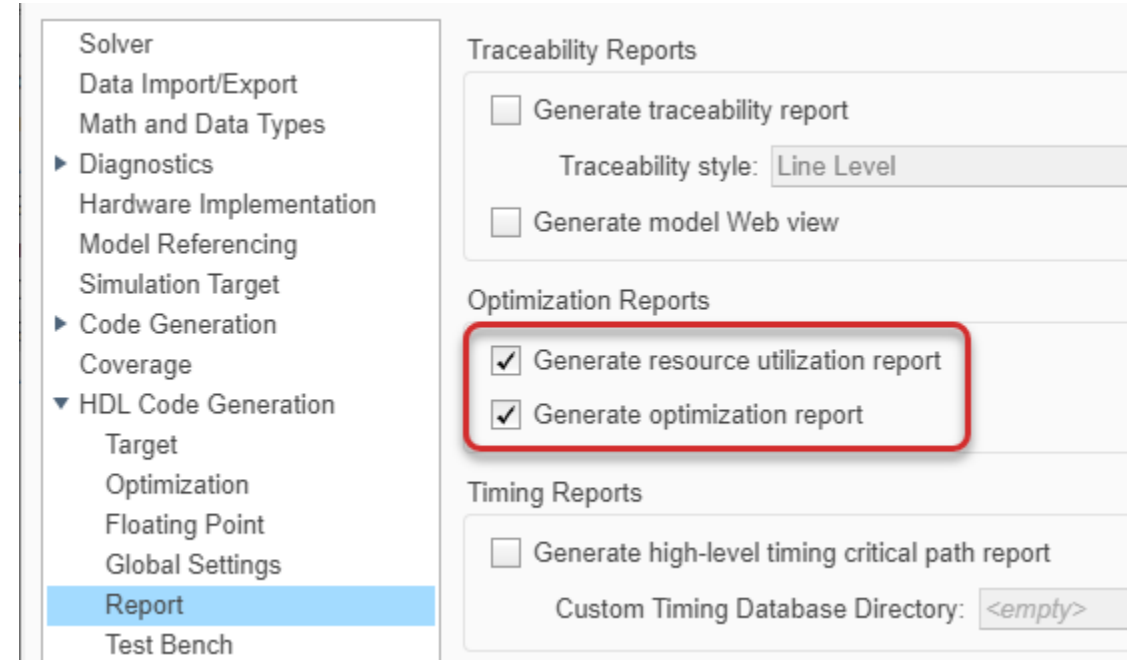
Verilog file extension: .v

Entity conflict postfix: _block

Reserved word postfix: _rsvd

Clocked process postfix: _process

HDL Code Generation > Report



Solver
Data Import/Export
Math and Data Types
▶ Diagnostics
Hardware Implementation
Model Referencing
Simulation Target
▶ Code Generation
Coverage
▼ HDL Code Generation
Target
Optimization
Floating Point
Global Settings
Report
Test Bench

Traceability Reports

☐ Generate traceability report

Traceability style: Line Level

☐ Generate model Web view

Optimization Reports

☒ Generate resource utilization report

☒ Generate optimization report

Timing Reports

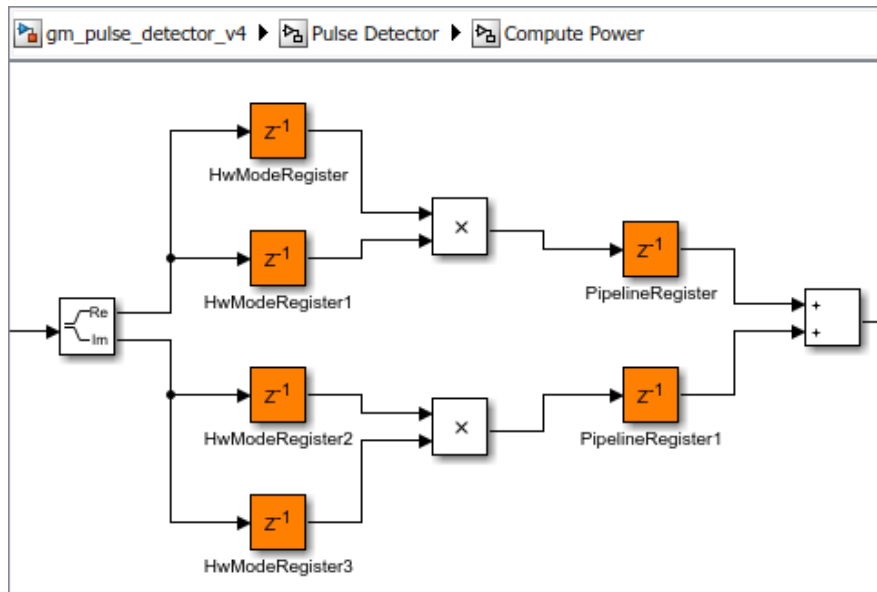
☐ Generate high-level timing critical path report

Custom Timing Database Directory: <empty>

6. Back in HDL Workflow Advisor, run through steps 1 to 3 (right-click on step 3.2 > **Run to Selected Task**).

Step 4.2: Generate HDL code and reports

7. Review the results of *Adaptive Pipelining* and *Delay Balancing* in the generated optimization report. Open the **generated model** using the provided link to visualize the added latency.
8. Review resource usage in the high-level resource report.



Code Generation Report

Find: Match Case

Contents

- [Summary](#)
- [Clock Summary](#)
- [Code Interface Report](#)
- [Timing And Area Report](#)
- [High-level Resource Report](#)
- [Optimization Report](#)
- [Frame to Sample](#)
- [Distributed Pipelining](#)
- [Streaming and Sharing](#)
- [Delay Balancing](#)
- [Adaptive Pipelining](#)**
- [Hierarchy Flattening](#)
- [Target Code Generation](#)
- [Code Reuse](#)

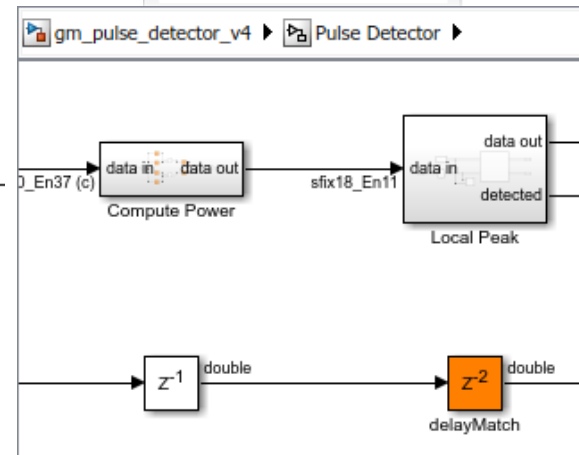
Adaptive Pipelining Report for pulse_detector_v4

Subsystem: [Compute Power](#)

Block Name	Number of pipelines inserted	Notes
Product	2	
Product1	2	

Generated Model

Generated model after the transformation: [gm_pulse_detector_v4](#)



Note: The generated model is bit-true & cycle-accurate to the generated HDL. It is used to verify the generated code.

Step 4.3: Synthesis the generated design

1. Run step 4.1 to create a Xilinx Vivado project. You may open the project using the provided link and continue synthesis in Vivado, especially if you expect it to take a long time.
2. Run step 4.2.1 to synthesize the design without launching Xilinx Vivado. MATLAB is blocked while synthesis is run in the background.

HDL Workflow Advisor - pulse_detector_v4/Pulse Detector

File Edit Run Help

Find:

4.1. Create Project

Analysis

Create synthesis tool project

Input Parameters

Project folder:

Synthesis objective:

Additional source files:

Additional project creation Tcl files:

Result: ☒ Passed

Create new Xilinx Vivado 2022.1 project [hdl_prj\vivado_prj\Pulse_Detector_vivado.xpr](#)

4.2.1. Run Synthesis

Analysis

Run logic synthesis for specified FPGA device

Input Parameters

☐ Skip pre-route timing analysis

Result: ☒ Passed

Passed Synthesis

Parsed resource report file: [Pulse_Detector_utilization_synth.rpt](#).

Resource summary			
Resource	Usage	Available	Utilization (%)
Slice LUTs	393	171900	0.23
Slice Registers	4521	343800	1.32
DSPs	194	900	21.56
Block RAM Tile	0	500	0.00
URAM	0	0	

Parsed timing report file: [timing_post_map.rpt](#).

Timing summary	
	Value
Requirement	5 ns (200 MHz)
Data Path Delay	3.769 ns
Slack	1.211 ns
Clock Frequency	263.92 MHz

Summary

This completes the tutorial. Compare your work to the solution models in the folder **/pulse_detector/solution**.

For more information:

- Visit our [FPGA and SoC design website](#)
- Explore MathWorks Training on [HDL code generation](#) and [FPGA signal processing](#)
- Contact us on [File Exchange](#) for additional questions