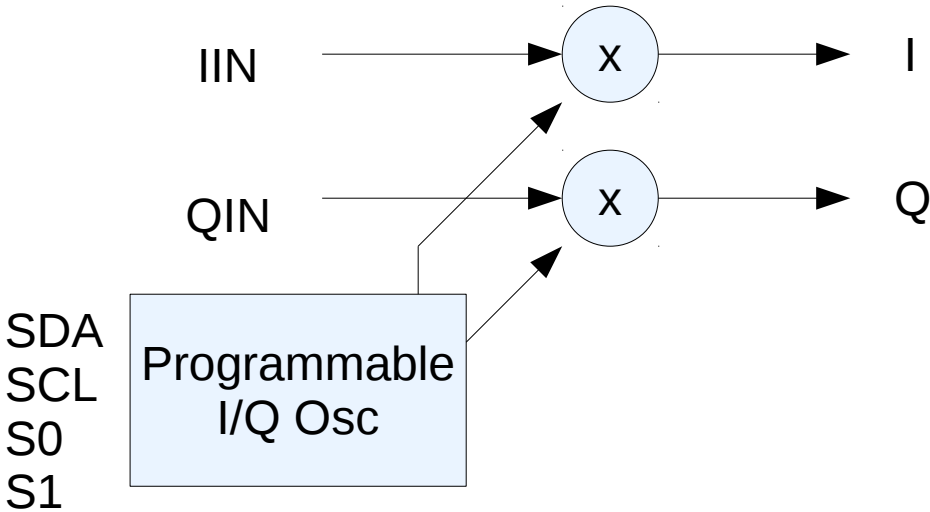




Simulating a Quadrature (I / Q) Mixer Design With Schematic Mobile and WaveformViewer

How to run this design example.



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Abstract

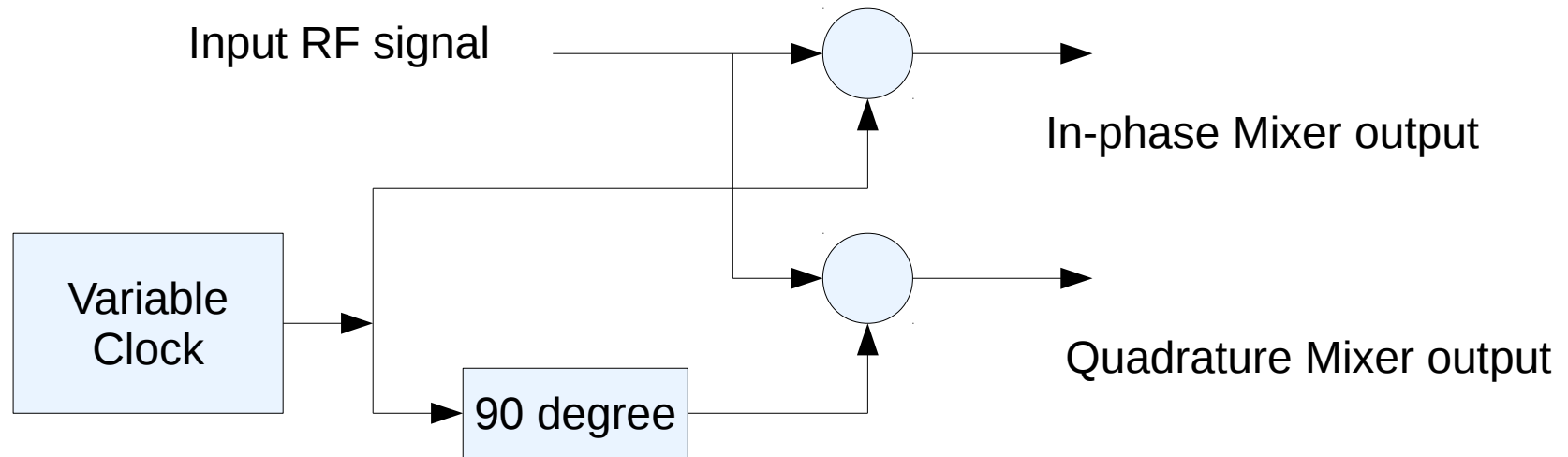
This presentation describes how to run the simulation demonstration of a Quadrature (I/Q) Mixer using eightolives Schematic Mobile and WaveformViewer.

The schematic is opened in eightolives' Schematic Mobile and then the menu command “View Waveforms” opens the design in WaveformViewer.

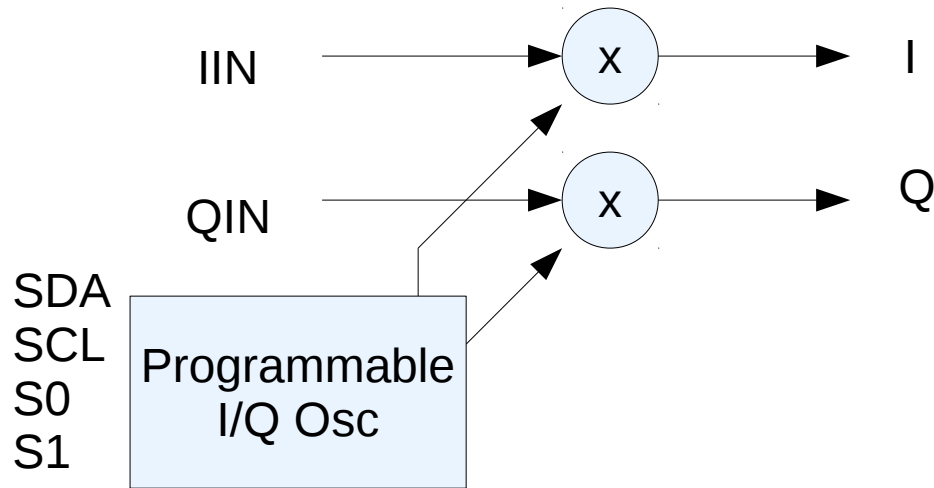
The circuit is usable as part of a Software Defined Receiver (SDR) design. The example shows the intended digital clocking waveforms and sampled outputs.

Background

- A Quadrature Mixer is a building block for radios. Sampling radio signals with two waveforms 90 degrees out of phase allows further processing elements to eliminate unwanted mixer products.



Circuit Overview



- The mixer consists of 2 – 4 to 1 differential analog selectors that are controlled by a low-jitter programmable clock oscillator feeding a programmable clock divider chain.
- D flip-flop chains allow use of three frequency ranges covering 10 Khz to 40 MHz
- No input or output filtering is included

- Key components

- Silicon Labs SI-570 Programmable XO
- T.I. TS3A5017
- Linear Tech LT3007 linear voltage regulator

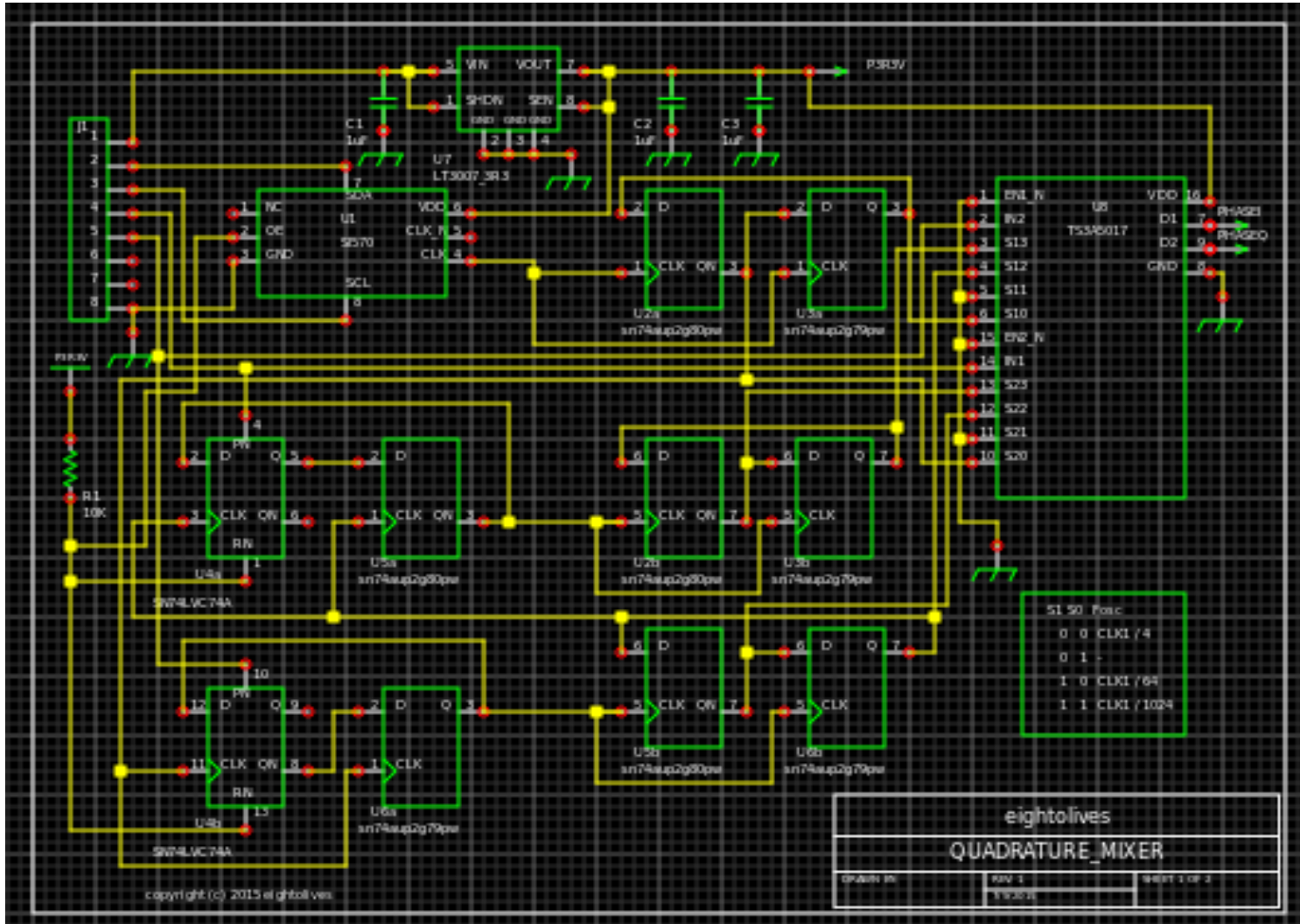
Specifications

- Input Power: 5 VDC
- Analog in/out: 0 – 3V
- Mixer osc ranges

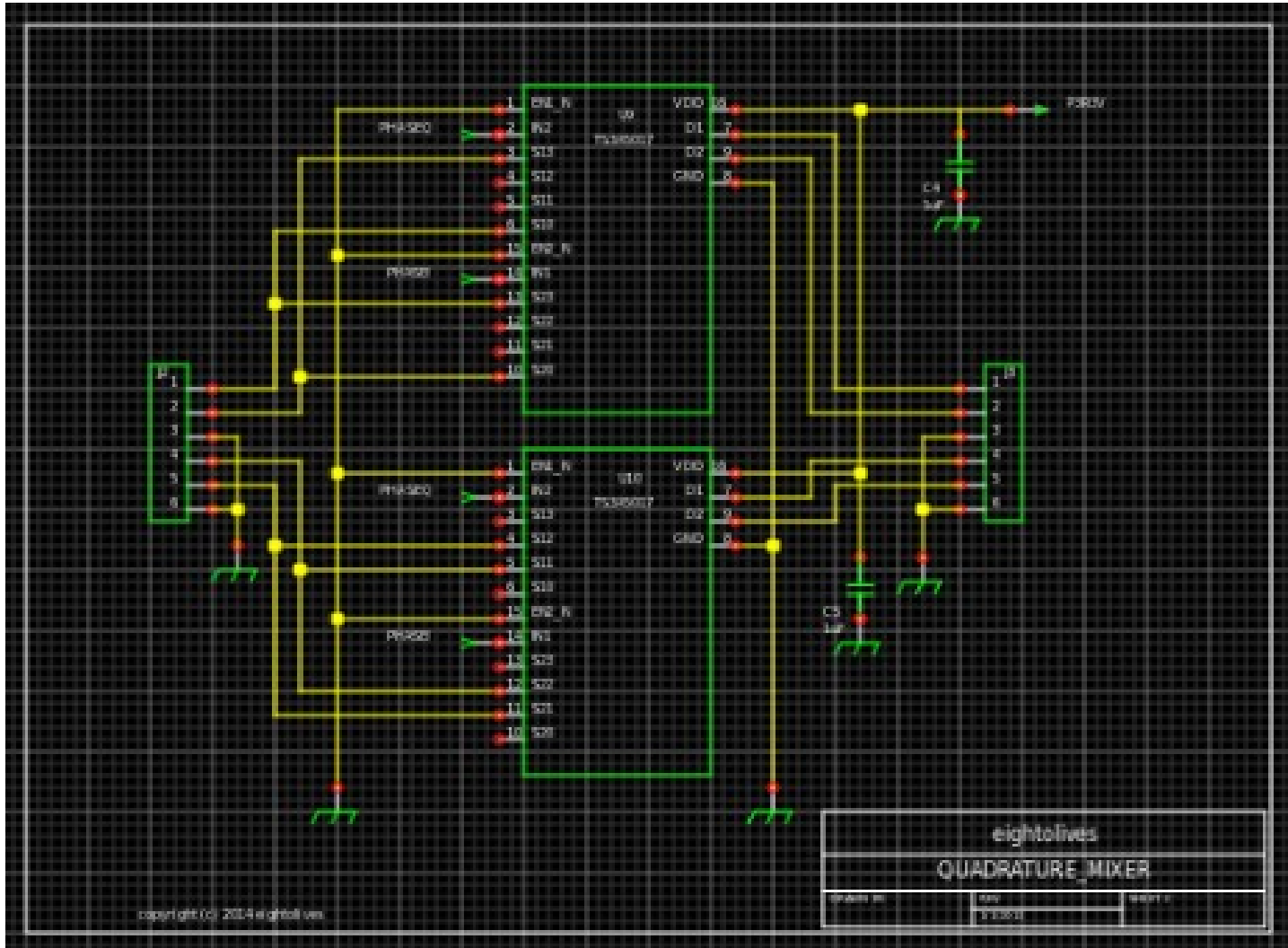
S1, S0		Fmixmin	Fminmax
(Si 570)		10 MHz	160 MHz
0, 0	/4	2.5 MHz	40 MHz
1, 0	/64	156 KHz	2.5 MHz
1, 1	/1024	10 KHz	156 KHz

- Input signals
 - IIN_P, IIN_N (0 – 3 V)
 - QIN_P, QIN_N (0 - 3V)
 - SDA, SCL (I2C serial)
 - S1, S1 (LVTTTL)
- Output Signals
 - I_P, I_N (0 - 3V)
 - Q_P, Q_N (0 - 3 V)

Sheet 1: Clock Generation



Sheet 2: Switching Mixers



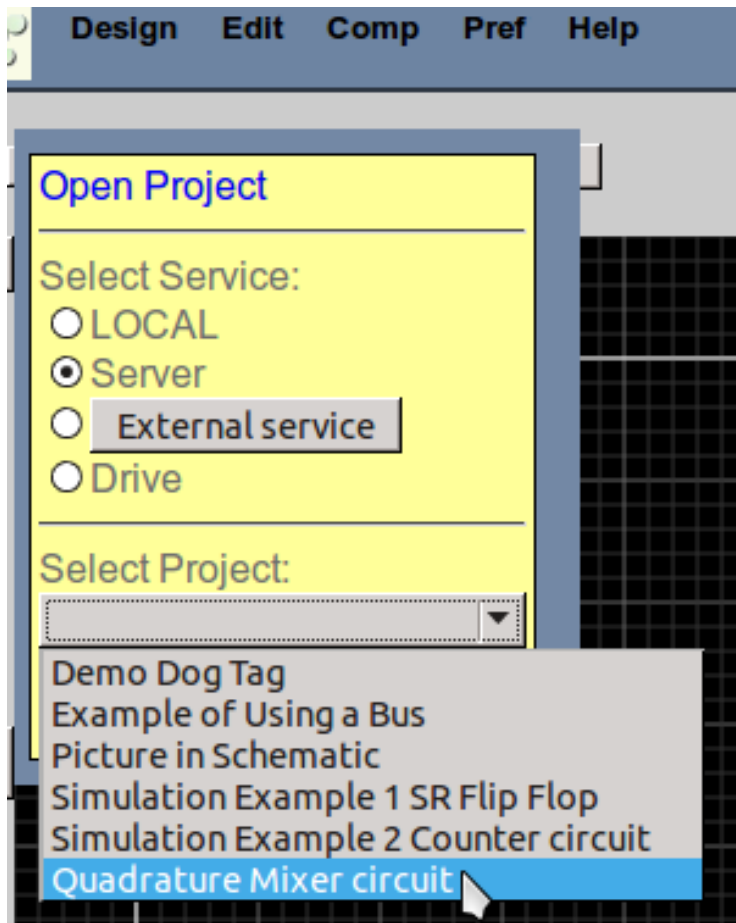
First, start Schematic Mobile

- Schematic Mobile is tested with Firefox, Safari and Chrome web browsers
- You can open it from:
 - Eightolives Home: <http://www.eightolives.com>
 - Eightolives' QuickApps menu
 - <http://www.eightolives.com/docs/Mobile/navigate/jstools.htm>
 - Directly:
 - <http://www.eightolives.com/docs/Schematic/SchematicM.htm>

Next, click the Design menu, select Open Project

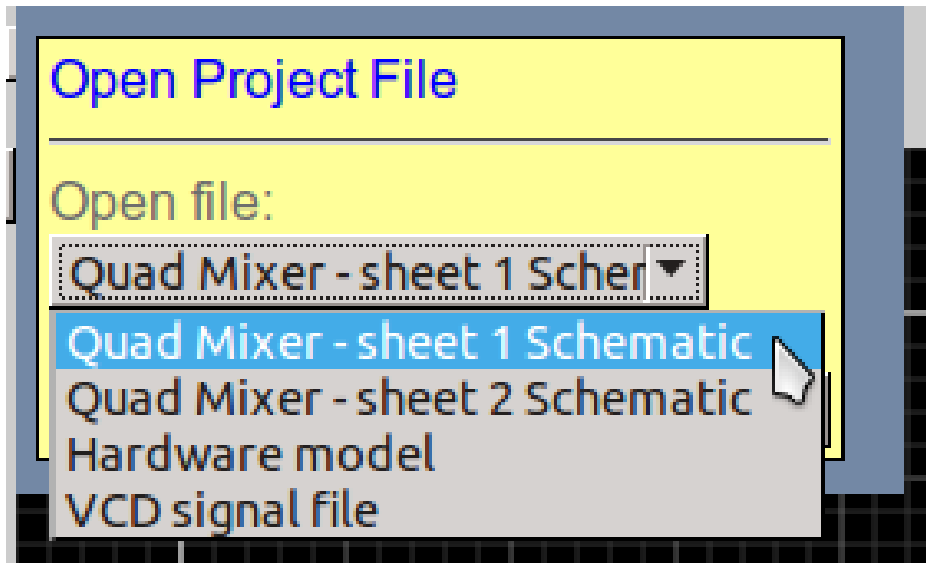
The screenshot shows the 'eightolives Schematic' application running in a Mozilla Firefox browser. The browser address bar shows the URL `www.eightolives.com/docs/Schematic/SchematicM.htm`. The application's menu bar includes 'Design', 'Edit', 'Comp', 'Pref', and 'Help'. The 'Design' menu is currently open, displaying a list of options: 'Open Project', 'Open Project File', 'Save Project', 'New Sheet', 'Open File (FS)', 'Upload File', 'Delete Sheet 1', 'Fix Refdes', 'Update Nets', 'Check Design', 'Generate BOM', 'Generate Netlist', 'Save Sheet (FS)', 'Save Sheet Local', 'Save Sheet Preview', 'Email Sheet', 'View Waveforms', 'Print Preview', and 'Close'. The 'Open Project' option is highlighted in yellow. The main workspace is a dark grid with a schematic diagram. The diagram includes a red text label 'eightolives Schematic Mobile' and 'Development version', a green circle labeled 'Q? NPN', and a green rectangle labeled 'U?'. The status bar at the bottom shows 'X = 500 mils; Y = 8500 mils'. A JavaScript console message at the bottom left reads `javascript:menu('Design')`. The page number '9' is visible in the bottom right corner.

Select “Server” service



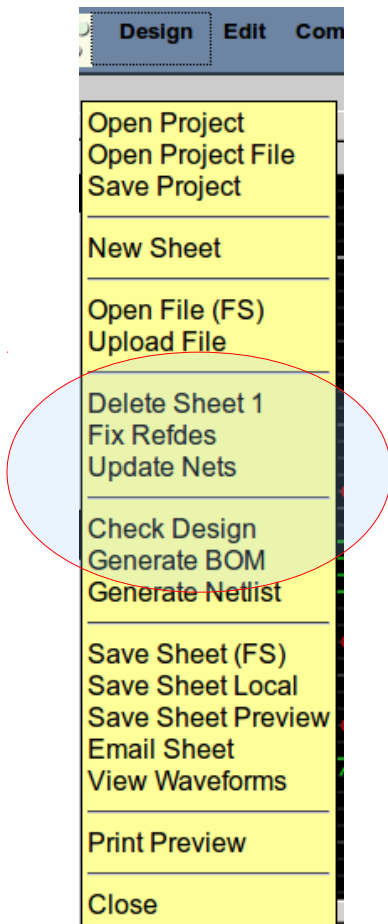
- Then from the Select Project drop-down window select “Quadrature Mixer circuit”
- Then click the Select button.

Next, select Design > Open Project File



- Select sheet 1 then click the Open button
- Wait for the sheet to load then open sheet 2
- When you load a sheet, the original, empty sheet 1 is retained so the new sheets appear as sheet 2 and 3

Clean up and checks



- Using the Design Menu, click “Delete Sheet 1” to delete the empty original sheet
- Click “Fix Refdes” to check and correct any refdes issues
- Click “Update Nets” to check all net connections
- Click “Check Design” to perform checks and see results in the Report Window at the bottom of the page (or also in a popup window in some browsers)

The Check Design Report

Check Design 5/6/15

Net Checks:

Nets OK

Check Sheet 5/6/15

QUADRATURE_MIXER

1: SHEET 1 OF 2

Comment: U1-1 NC has no connected signal
Warning: U1-5 CLK_N has no connected signal
Warning: J1-6 P6 has no connected signal
Warning: J1-7 P7 has no connected signal
Warning: U4a-6 QN has no connected signal
Warning: U4b-9 Q has no connected signal

Check Sheet 1 OK
5 warnings.

Check Sheet 5/6/15

QUADRATURE_MIXER

2: SHEET 2

Warning: U9-4 S12 has no connected signal
Warning: U9-5 S11 has no connected signal
Warning: U9-12 S22 has no connected signal
Warning: U9-11 S21 has no connected signal
Warning: U10-3 S13 has no connected signal
Warning: U10-6 S10 has no connected signal
Warning: U10-13 S23 has no connected signal
Warning: U10-10 S20 has no connected signal

Check Sheet 2 OK
8 warnings.

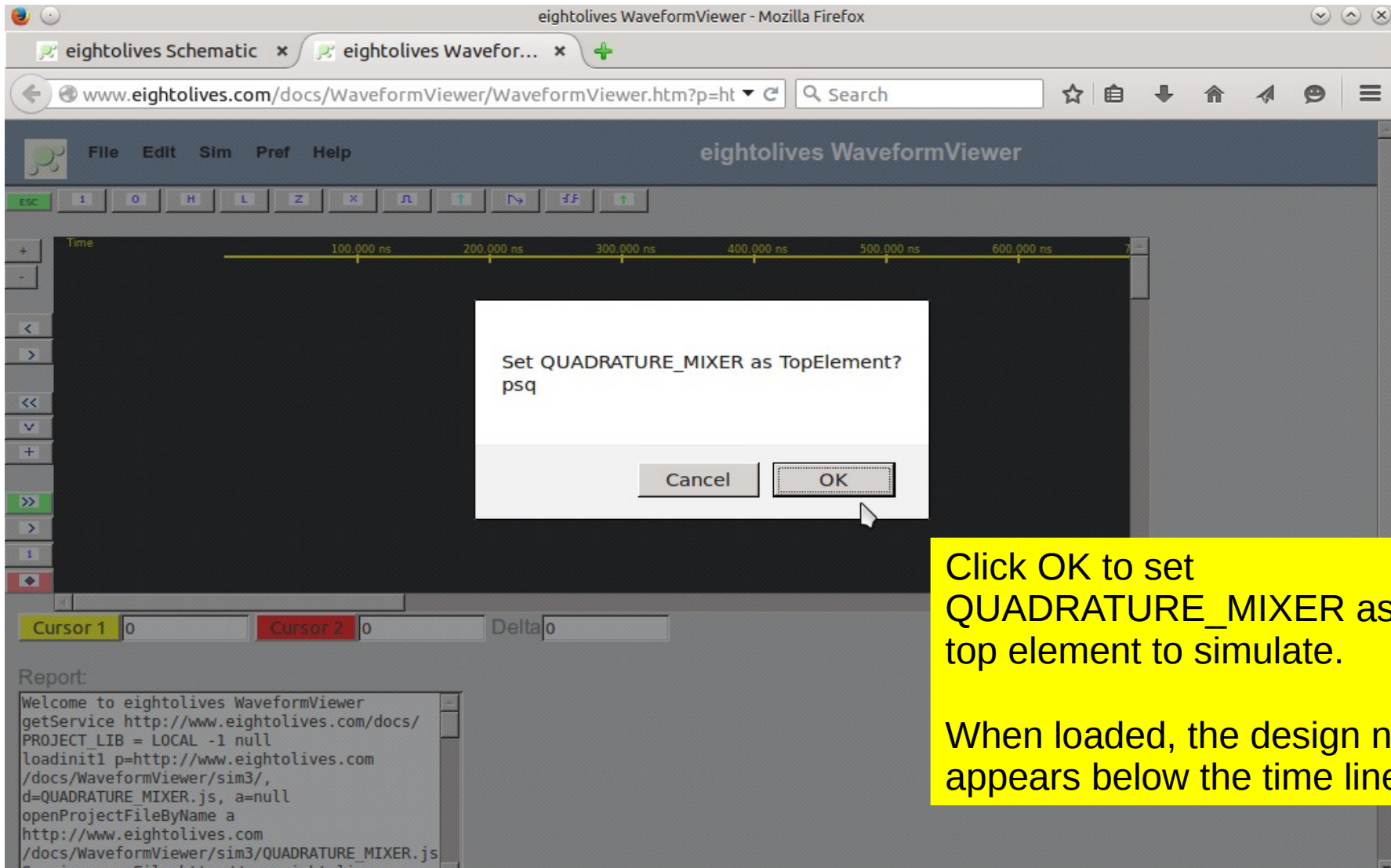
Check Design OK
13 warnings.

- No errors are reported
- The reported warnings are for pins that have no connections.
- Since it reflects the designer's intent, we continue on.

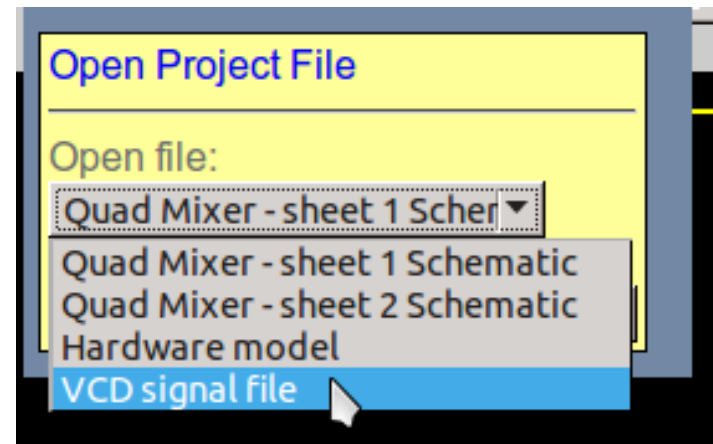
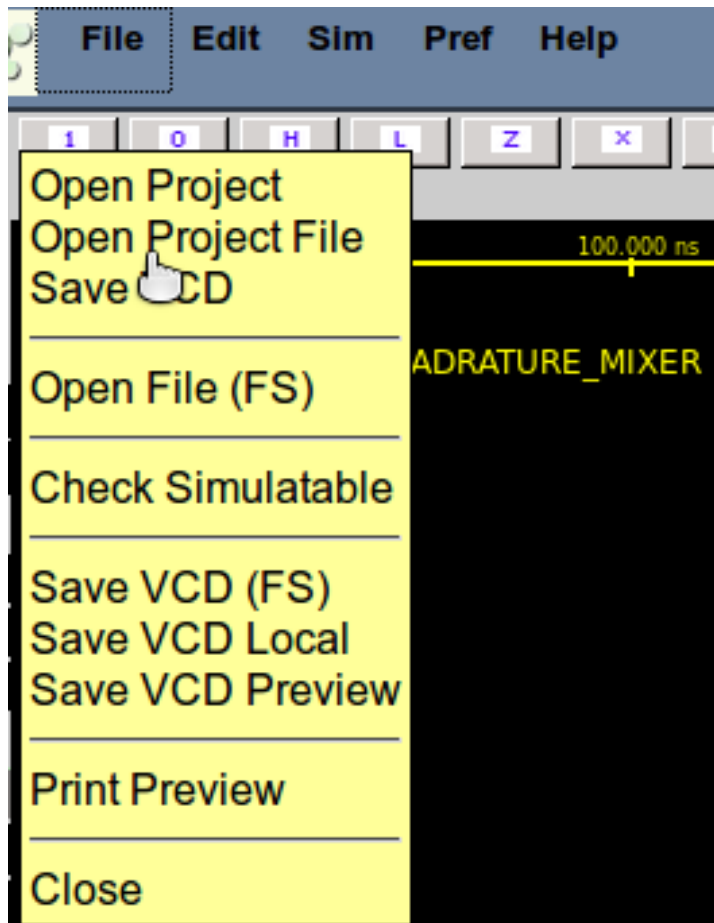
To start WaveformViewer

- For this demonstration, it is easiest to click Schematic Mobile's Design > View Waveforms menu option
- You will be prompted to save the eightolives' Hardware Model of the design, QUADRATURE_MIXER.js
 - Click OK

WaveformViewer will start



Click File > Open Project File



- Select the VCD (Value Change Dump) file entry and click the Open button. This loads a set of signals to monitor and sets predefined stimulus on the inputs.

WaveformViewer with VCD file loaded

Left Side Buttons

- Zoom In
- Zoom Out
- Pan Left
- Pan Right
- Restart
- Load VCD File
- Add to Sim Queue
- Run
- Run For
- Single Step
- Stop

The screenshot shows the eightolives WaveformViewer application running in a Mozilla Firefox browser. The browser tabs include 'eightolives Schematic' and 'eightolives Wavefor...'. The address bar shows the URL 'www.eightolives.com/docs/WaveformViewer/WaveformViewer.htm?p=ht'. The application has a menu bar with 'File', 'Edit', 'Sim', 'Pref', and 'Help'. Below the menu is a toolbar with icons for 'ESC', 'I', 'O', 'H', 'L', 'Z', 'X', 'JL', '↑', '↵', 'ff', and '↑'. The main display area shows a waveform for 'QUADRATURE_MIXER' with signals Q_N, Q_P, QIN_N, QIN_P, S0, S1, SCL, SDA, and VPWR. The time axis is marked from 0 to 700,000 ns. Below the waveform are two cursor fields: 'Cursor 1' and 'Cursor 2', both set to 0, and a 'Delta' field set to 0. A 'Report' window at the bottom contains the following text:

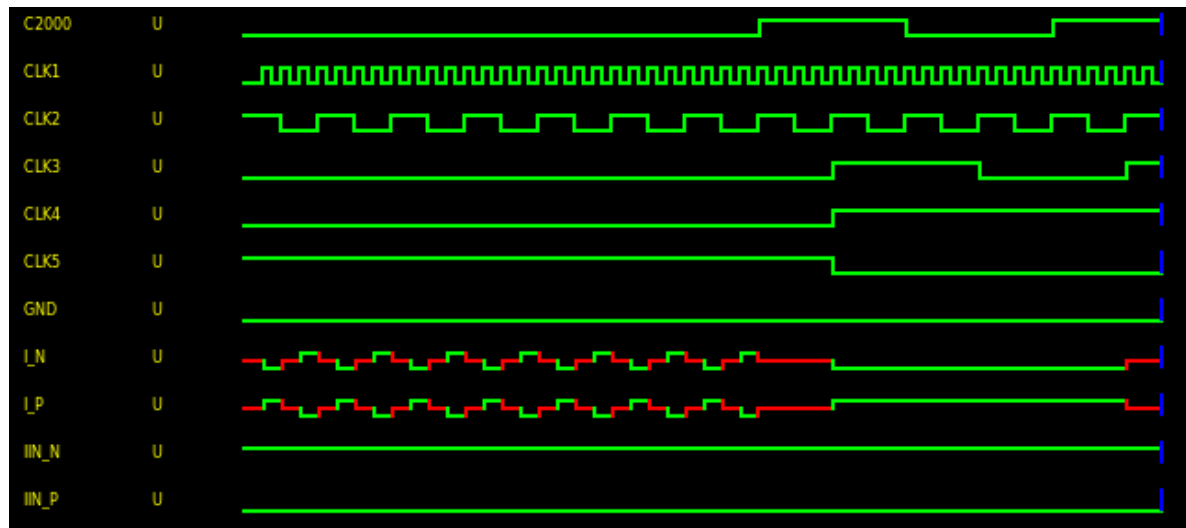
```
Report:
Welcome to eightolives WaveformViewer
getService http://www.eightolives.com/docs/
PROJECT_LIB = LOCAL -1 null
loadinit1 p=http://www.eightolives.com
/docs/WaveformViewer/sim3/,
d=QUADRATURE_MIXER.js, a=null
openProjectFileByName a
http://www.eightolives.com
/docs/WaveformViewer/sim3/QUADRATURE_MIXER.js
Service openFile http://www.eightolives.com
```

About the Stimulus

- The provided stimulus file puts fixed (DC) logic values on the I and Q differential inputs.
- The VPWR input is pulsed low at the beginning since some simulation models use power being low as a condition to reset (for simulation only)
- The S1 and S0 divider control lines start at 0,0 and later changed to 1,0 and then 1,1 to demonstrate the three operating ranges. The full sim requires about 150 us of sim time. This sim is not self-terminating and will run to Max Sim Time.
- The default Max Sim Time is 5 us so that preference will need to be modified to view all three ranges.

Run the Sim

- Click the “+” button to add the stimulus to the sim queue
- Click the green “>>” button to run the sim.
- The sim will stop at the default Max Sim Time of 5 us



The blue cursor shows the end of the sim.

I_P and I_N outputs show the mixing of the “DC” inputs with the mixing frequency.

Setting S1 to '1' at 2.8 us causes the frequency range to change.

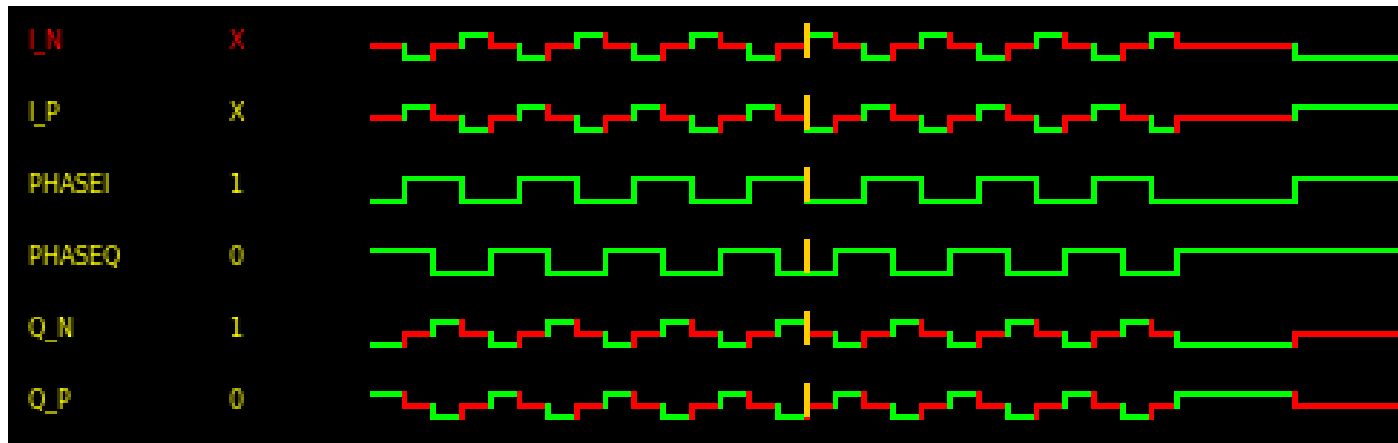
Set Max Sim Time to 150 us

- From the Preferences menu select “set Max Sim Time” and enter 150 us in the dialog box.
- Restart the simulation using the Restart sequence shown in the next slide.
- Notice that the simulation proceeds in “chunks” of 1 us of sim time

To rerun a simulation

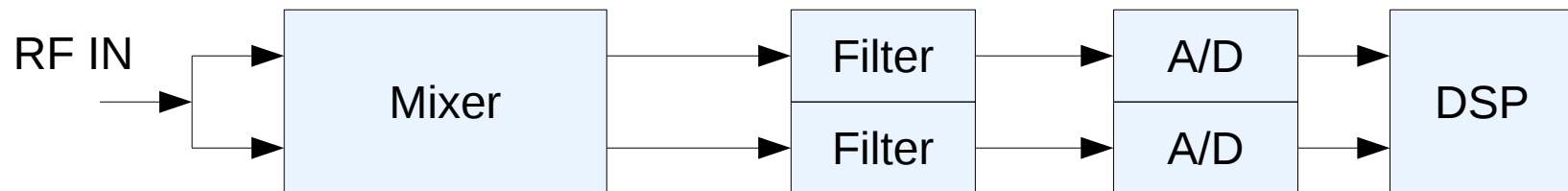
- Click the Restart button (“<<”)
- Click the Load VCD button (“v”) if you want to reload the last VCD stimulus file
- Edit the waveform stimulus if you wish
- Click the (“+”) button to add the stimulus to the simulation queue
- Click the Run button (“>>”)
 - Click the Run For button (“>”) for a specific run time

What the Mixer Does



- PHASEI is similar to a sine wave and PHASEQ is similar to a cosine wave with respect to phase
- Note that the I and Q outputs sample the mixed input values out of phase based on the PHASEI and PHASEQ values

- In an SDR receiver application, the outputs would typically be filtered and then further processed by analog circuits or converted to digital signals and be processed digitally



Results

- The simulation shows that the clocks for the 3 frequency bands have the correct phase relation.
- It shows the mixer outputs behaving as expected.

About Chunk Time

- Browsers execute Javascript in a single thread.
- In order to be responsive to user input and avoid browser timeouts, a long simulation run is divided into smaller chunks separated by a Pause Time.
 - WaveformViewer's default chunk is 1 us of sim time
 - The default PauseTime between chunks is 1000 ms (1 sec)
 - Both items can be changed via Preferences > Set Sim Chunk Timing
- If a chunk takes too long to execute (> 10 sec), the browser may report a non-responsive script which you may continue or halt.

Alternate way to start this sim

- You can also do this sim directly from WaveformViewer
 - <http://www.eightolives.com/docs/WaveformViewer/WaveformViewer.htm>
 - Or from the eightolives QuickApps menu
- File > Open Project, select Server service and then select the Quadrature Mixer project
- File > Open Project File and select the Hardware Model to open

For more information

- Check tutorials at: <http://www.eightolives.com>
 - Using Schematic Mobile
 - Using WaveformViewer
 - eightolives Hardware Model API (version 2)