525.787
MMIC Design
C Band Mixer

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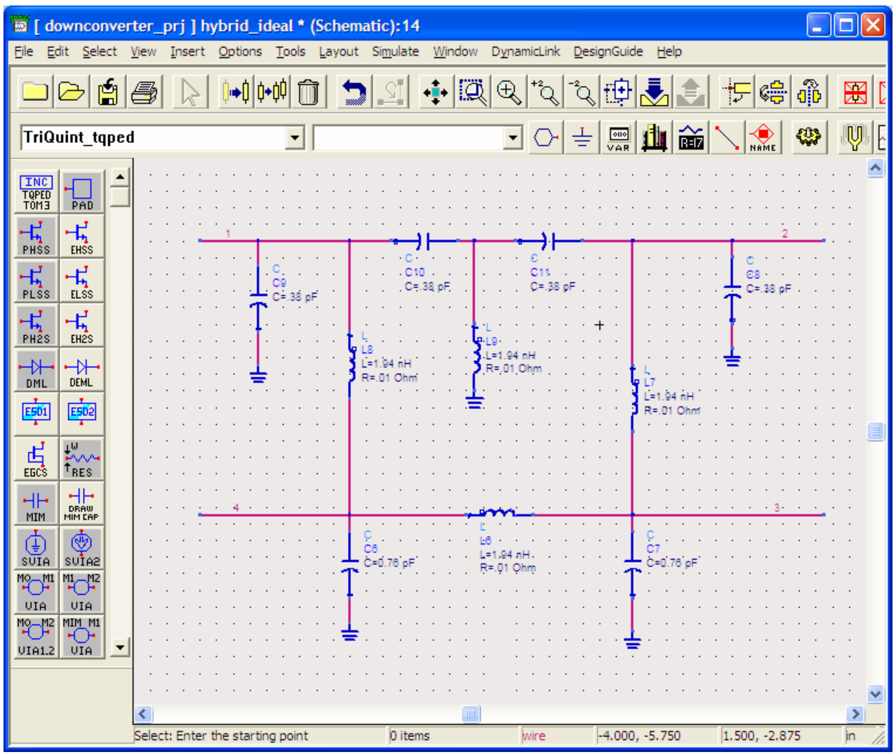
Abstract:
The purpose of this design was to create a up/downconverting mixer that operates using a 2.8GHz LO. Various designs were considered, and a lumped element equivalent retrace mixer, using depletion-mode FETs as diodes was decided upon. Performance for 5.7GHz RF input, and 100 MHz IF input, are shown.

Discussion of Design.

The mixer used is based on a lumped-element implementation of a racrace mixer, a form of 180 degree hybrid coupler. This design was chosen because of it's relative ease to implement, and because these mixers usually have low conversion losses. The limitations of the TriQuint library was also a factor in this – most double-balanced or active mixers require balun transformers, which the TriQuint library does not provide. The figure below shows the ratrace hybrid using ideal lumped elements, tuned to 5.8GHz.



Port 2, in this model, will be the LO input, while port 4 will be the RF input/output. Because of it's relatively low frequencies, the IF Input/output can theoretically be at any point in the hybrid, however, it was found that port 1 offered slightly better performance. In order to improve isolation and conversion loss, simple highpass filters (3dB point 2.5GHz) were added to the LO and RF ports, and a lowpass filter (same 3dB point) to the IF port.

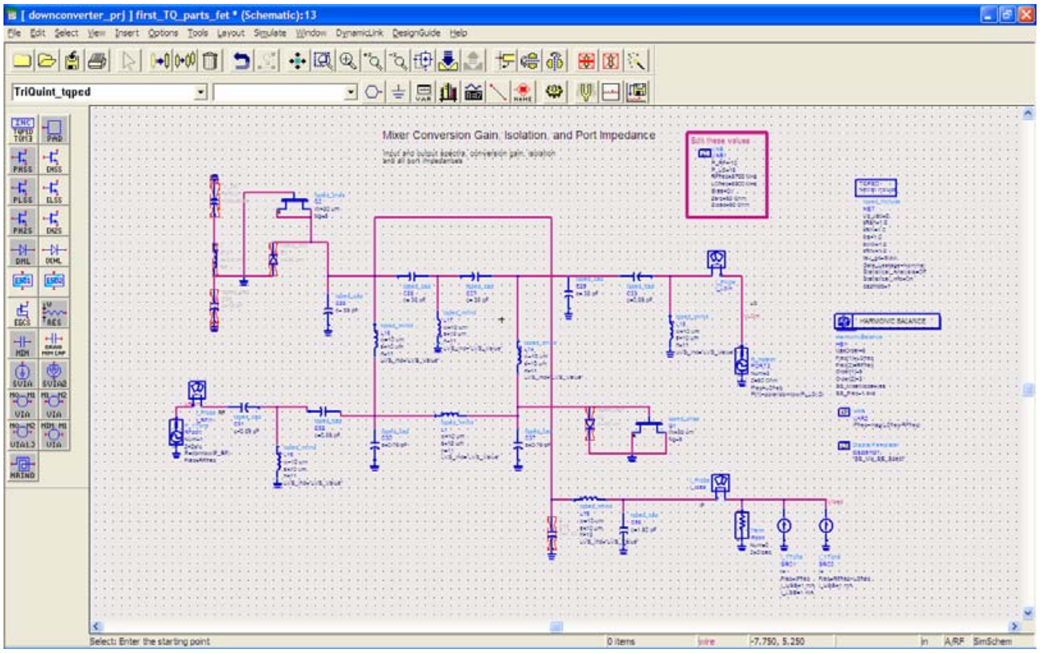
In order to complete the mixer, two nonlinear components must be added to the design – one to port 1 above, and one, in an opposite orientation, to port 3. The initial design used two overlap diodes, which are included in the TriQuint set. However, these devices require a very well controlled bias voltage – it was found that, depending on the diodes' physical characteristics, a 1.3-1.4 input was ideal, and deviations of as little a s0.1 volts had a large effect on conversion loss. An effective design, therefore, would require not only an additional input pad, but also a resistor network to minimize deviation. Furthermore, even when the diode widths were tuned, the maximum predicted conversion loss was 18 dB, which is far below the 6-9 dB goal for this design.

A second approach is to use two FETS, with source and drain tied together, to act as a type of diode. In this design, two depletion-mode FETs, each with gate width of 30 um and 5 fingers, are used. This was found to give optimal conversion loss. It was also found no input voltage was needed – the circuit gives best performance at 0 volt input. However, to compensate for this, a high LO drive is needed for the circuit to function – a table of downconversion performance vs. LO drive is given below.

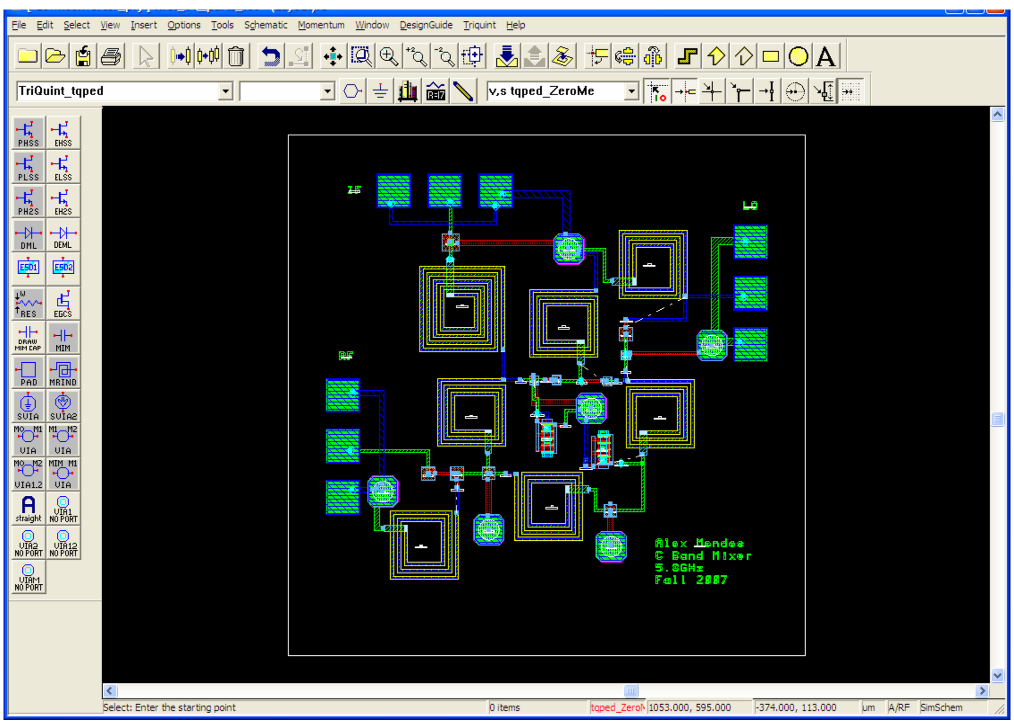
RF Power (dBm)	**Downconversion Loss (dB)**
+10	17.4
+11	10.4
+12	7.1
+13	6.1
+14	5.8
+15	5.6
+16	5.5

Table of downconversion loss (5.8GHz LO, 5,7GHz -10dBm RF)

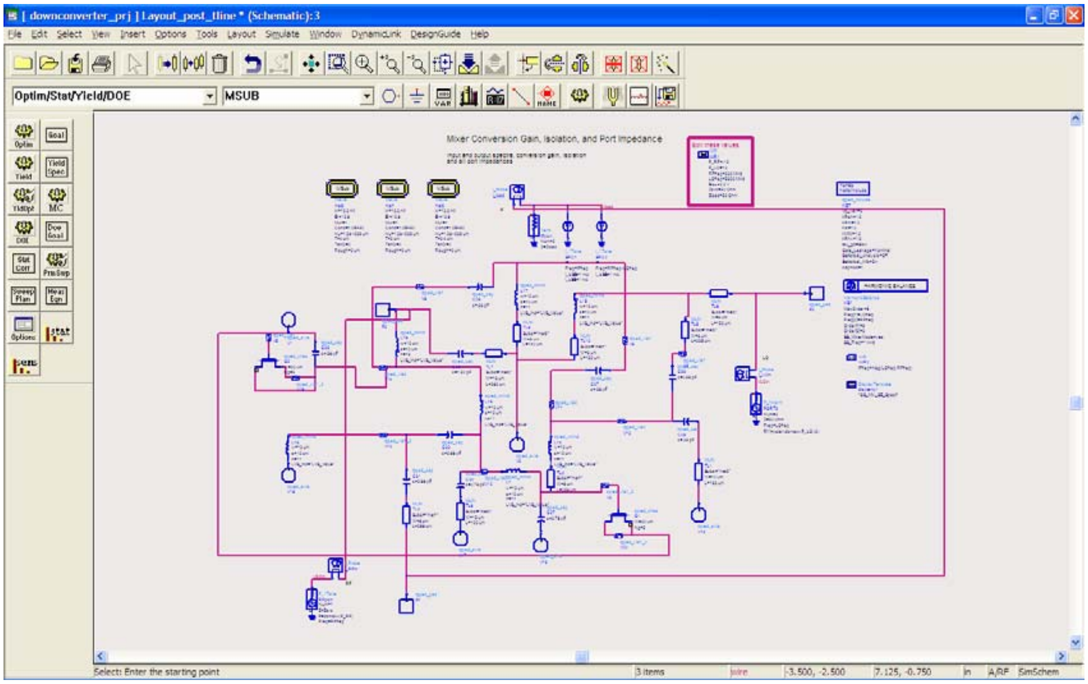
From this, it appears that a +13dBm drive LO is needed for best performance, while roughly +11dBm of LO power is needed to meet the design goals.



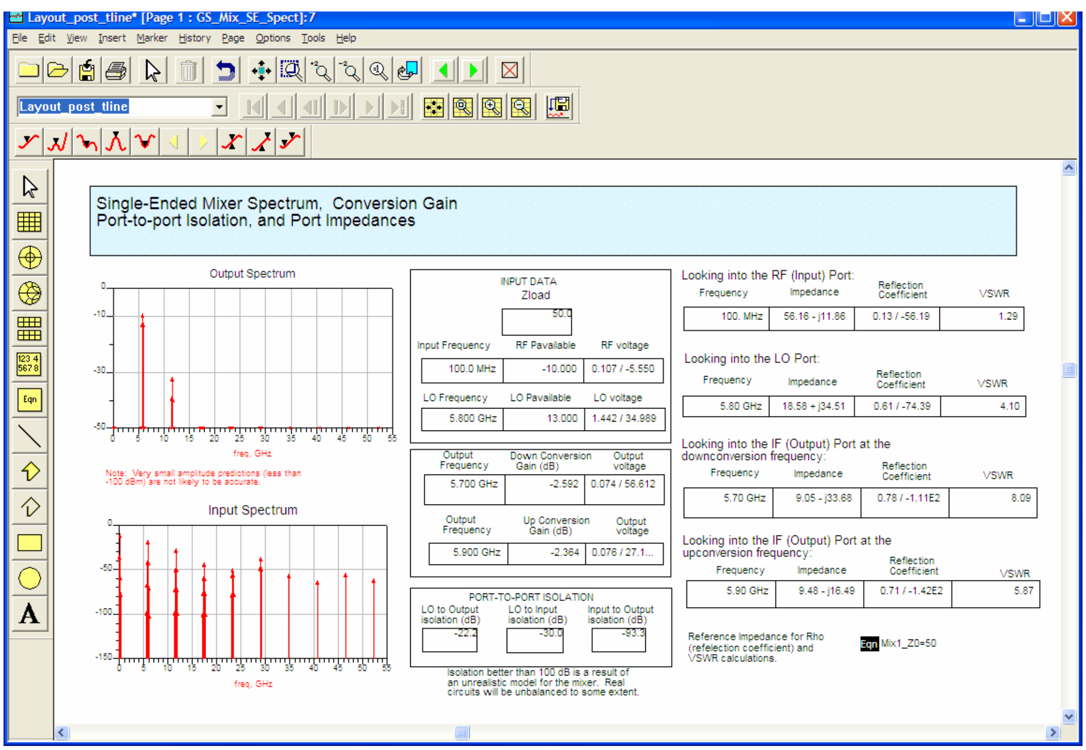
An ideal schematic of the ratrace mixer. This layout includes filtering on each input and output, as discussed above.



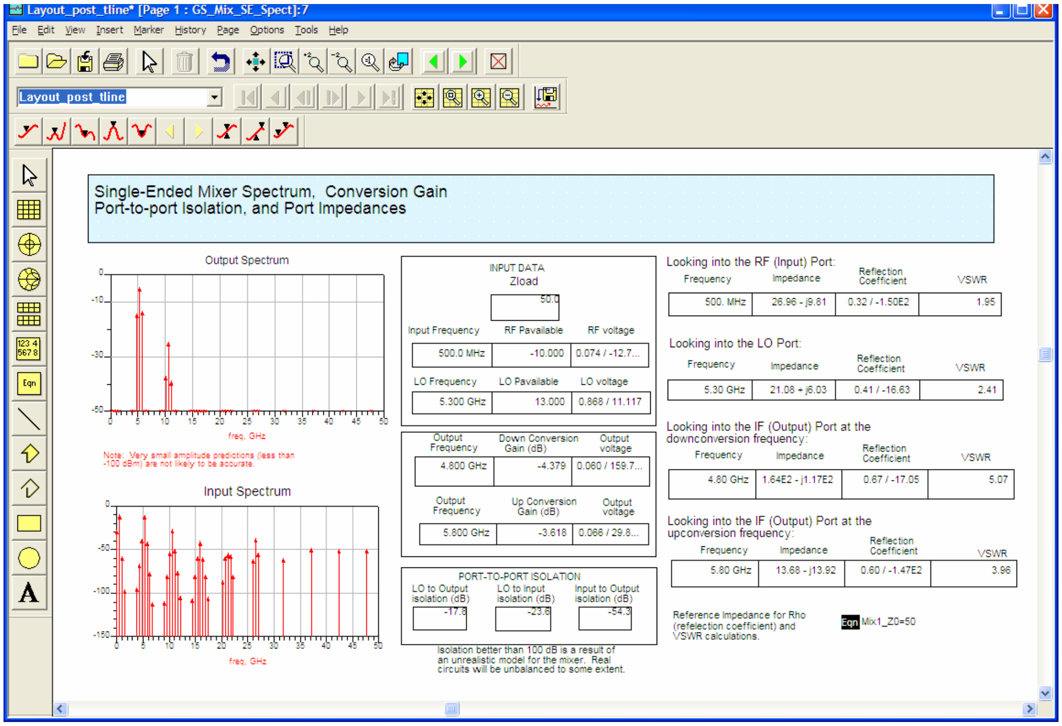
Layout of the mixer. While most components are connected using short traces, note that The RF input, as well as a few traces to ground vias show long traces. These are included in simulation results, however, these lengths were found to have little effect on the design performance



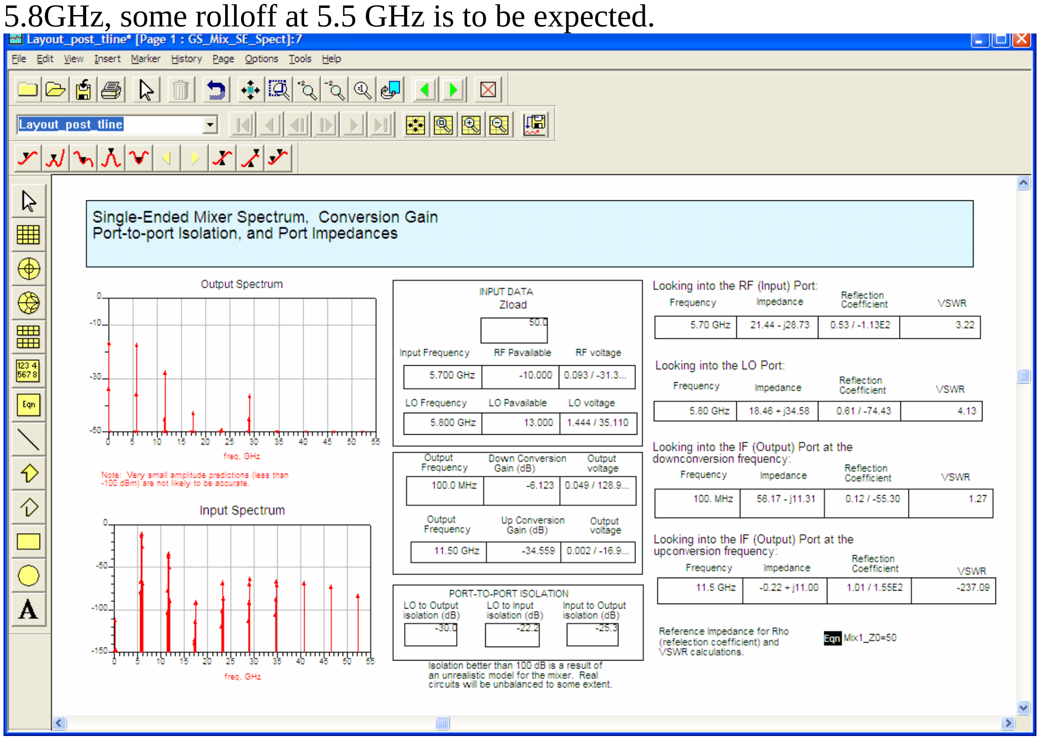
Schematic used for final simulation. Longer traces were added into the schematic, but short traces are ignored. Unlike the previous picture, this shows the schematic configured for upconversion simulation.



Upconversion results. IF = 100MHz, -10dBm, LO = 5.7GHz, 13dBm. The conversion loss here is better than expected at -2.6dB, however, the relatively high LO leakage may make this design impractical.



Upconversion, IF = 300MHz, LO = 5.5GHz. Note that the conversion loss is now 4.4dB. Because the filters added to the various inputs should not have an effect, this must be due to the nature of the circuit itself. Since the Ratrace was optimized for 5.8GHz, some rolloff at 5.5 GHz is to be expected.



Downconversion, 5.7GHz RF, 5.8GHz LO. Despite including basic filters, the LO and RF frequencies are still present on the IF output – however, as these are far from the IF frequency, they can be easily filtered out externally.

Test plans:

Test Equipment:

2 Frequency Generators, 0.1-6 GHz minimum.
1 Spectrum Analyzer, 0.1-6 GHz minimum frequency
3 test probes

Test 1: Downconversion

Equipment setup:

Calibrate all necessary equipment, measure and record cable losses, etc.
Set LO Generator to 5.8 GHz, +13 dBm (or maximum) output power
Set RF Generator to 5.7 GHz, -10 dBm output power
Turn off generator power outputs and connect all devices to the correct inputs
Turn on LO, followed by RF.

Measurements

RF Frequency sweep:
Vary RF input from 5.7 GHz to 6.2 GHz, record IF power and frequency.

RF Power Sweep

Set RF input to 5.7 GHZ
Vary RF Power from -10 to +10 dBm. Record output power and conversion loss

LO Power Sweep

Set RF Power to -10dBm, 5.7GHz
Vary LO input power and record output power and conversion loss

Test 2: Upconversion

Measurements

RF Frequency sweep:
Vary RF input from 0.1GHz to 0.5 GHz, record IF power and frequency.

RF Power Sweep

Set RF input to 0.3 GHZ
Vary RF Power from -10 to +10 dBm. Record output power and conversion loss

LO Power Sweep

Set RF Power to -10dBm, 5.7GHz
Vary LO input power and record output power and conversion loss