TEST RESULTS of STUDENT MMIC DESIGNS

The Johns Hopkins University EE 787 10/94

MMIC DESIGN EE 787
FALL 1993
STUDENT PROJECTS

ACTIVE INDUCTOR       D. COGHLAN
LOW NOISE AMPLIFIER    K. BONTZOS
BALANCED MIXER         M. DYE

WITH SUPPORT FROM:
HP/EESOF
TRIQUINT
This brief report documents the experimental test results obtained by students in the Johns Hopkins University MMIC Design course EE 787 on the chips they designed in the fall of 1993 and which were fabricated by TriQuint Semiconductor in the spring and summer of 1994. These projects represent the work of 3 students over a period of about 8 weeks and include an active inductor, an LNA, and an improved balanced diode mixer. The LNA and mixer are intended to be used in the down converter for a C-Band receiver on the next Amateur Radio satellite (AMSAT). The active inductor would be useful as a high Q tuned circuit in a voltage controlled oscillator. All layouts were generated in ACADEMY 3.5 using the TriQuint SMART Library and analyzed with LIBRA. The resulting Calma files were unstreamed in ICED and checked using ICED’s DRC.

When tested in July and August of 1994 on a Cascade probe station, these projects were found to be functional but did not perform exactly as simulated 8 months earlier. The measured mixer performance was the closest to predictions, with conversion loss better than simulated by 2.4 dB. The active inductor performance can be closely simulated with lower transistor current or a smaller gate width. The LNA performance was marred by an error in the design submission which caused the output matching network to not be connected to the FET collector. The small gap in the connection to the matching network probably occurred during correction of numerous design rule violations in ICED. Fortunately, the collector was also connected directly to a bond pad to permit use of an external output matching network. Resimulation of the circuit with this "error" introduced and the output taken at the collector bond pad agreed somewhat with the measurements.

Since these students have graduated and the CAD software has undergone a major revision, it is not feasible to pursue the differences between measurement and simulation of these circuits.
→ X denotes airbridges broken for testing.
Plot showing measured results versus resimulated "fit" to data. Fit was made by reducing the 2x20 um FETs to 2x13 um FETs in order to match the results.

**Key:**
- ZINACT (RE) Real part of Z11 as Resimulated.
- ZINMS (RE) Real part of Z11 as Measured.
- QM Calculated "Q" as Measured.
- Q Calculated "Q" as Resimulated.
Plot showing measured results versus resimulated "fit" to data. Fit was made by reducing the 2x20 um FETs to 2x13 um FETs in order to match the results.

Key:
- ZINACT (IM) Imaginary part of Z11 as Resimulated.
- PASIND (IM Z11) Imaginary part of a 20 nH inductor.
- ZINMS (IM) Imaginary part of Z11 as Measured.
Plot showing measured results versus resimulated "fit" to data. Fit was made by reducing the 2x20 um FETs to 2x13 um FETs in order to match the results.

**Key:**
- S11 Actind: S11 of active inductor as Resimulated.
- S22 Actind: S22 of active inductor as Resimulated.
- S11 AIX6: S11 of Measured inductor (6 broken airbrg).
- S22 AIX6: S22 of Measured inductor (6 broken airbrg).
Plot showing measured results versus resimulated "fit" to data. Fit was made by reducing the 2x20 um FETs to 2x13 um FETs in order to match the results.

**Key:**
- **MU1** Input Stability Function as Resimulated.
- **MU2** Output Stability Function as Resimulated.
- **MS1** Input Stability Function as Measured.
- **MS2** Output Stability Function as Measured.
Plot showing measured results versus resimulated "fit" to data. Fit was made by reducing the drain current of the FETs to 6% IDSS versus the original 20% IDSS in order to match the results. Since the model is not valid below 15% IDSS it is hard to know what "6%" really represents.

**Key:**
- ZINACT (RE) Real part of Z11 as Resimulated.
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- **MS1**: Input Stability Function as Measured.
- **MS2**: Output Stability Function as Measured.
Plot showing measured results versus the original circuit adjusted according to the six airbridges broken for the test. The original design expected all airbridges to be broken!

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**Key:**
- MU1: Input Stability Function as Resimulated.
- MU2: Output Stability Function as Resimulated.
- MS1: Input Stability Function as Measured.
- MS2: Output Stability Function as Measured.
Plot showing measured results of the Amplifier versus the original simulated and the resimulated circuit with a bypassed output matching circuit.

**Key:**
- **RL_LNA** S21 (dB) of the Original Amp.
- **LNA_MS** S21 (dB) of the Resimulated Amp (No OMN).
- **LNAFOMES** S21 (dB) of the Measured Amp.
Plot showing measured results of the Amplifier versus the original simulated and the resimulated circuit with a bypassed output matching circuit.

**Key:**
- RL_LNA: $S11$ (dB) of the Original Amp.
- LNA_MS: $S11$ (dB) of the Resimulated Amp (No OMN).
- LNAFOMES: $S11$ (dB) of the Measured Amp.
Plot showing measured results of the Amplifier versus the original simulated and the resimulated circuit with a bypassed output matching circuit.

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- RL_LNA $S_{12}$ (dB) of the Original Amp.
- LNA_MS $S_{12}$ (dB) of the Resimulated Amp (No OMN).
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Plot showing measured results of the Amplifier versus the original simulated and the resimulated circuit with a bypassed output matching circuit.

**Key:**
- **RL_LNA**  S22 (dB) of the Original Amp.
- **LNA_MS**  S22 (dB) of the Resimulated Amp (No OMN).
- **LNAFOMES**  S22 (dB) of the Measured Amp.
### Table 3.1 New MMIC Mixer Compliance Matrix

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Goal</th>
<th>Predicted</th>
<th>Meas</th>
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<tbody>
<tr>
<td>RF FREQ</td>
<td>5654 MHZ</td>
<td>-</td>
<td>5654 MHZ</td>
<td>5654 MHZ</td>
</tr>
<tr>
<td>LO FREQ</td>
<td>6400 MHZ</td>
<td>-</td>
<td>6400 MHZ</td>
<td>6400 MHZ</td>
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<tr>
<td>IF FREQ</td>
<td>746 MHZ</td>
<td>-</td>
<td>746 MHZ</td>
<td>746 MHZ</td>
</tr>
<tr>
<td>BANDWTH</td>
<td>&gt;1000 MHZ</td>
<td>-</td>
<td>Yes</td>
<td>IF: 1570 Hz</td>
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<tr>
<td>L TO R</td>
<td>10+16 DB</td>
<td>33 DB</td>
<td>&gt;10 DB</td>
<td>7.1 dB</td>
</tr>
<tr>
<td>R TO L</td>
<td>10+16 DB</td>
<td>25 DB</td>
<td>25 DB</td>
<td>23 dB</td>
</tr>
<tr>
<td>CONV L</td>
<td>15+6 DB</td>
<td>9.5 DB</td>
<td>23 dB</td>
<td>22 dB</td>
</tr>
<tr>
<td>SUPPLY</td>
<td>+5 V</td>
<td>+5 V</td>
<td>+5 V</td>
<td>+5 V</td>
</tr>
<tr>
<td>RF VSWR</td>
<td>2.5:1</td>
<td>1.3:1</td>
<td>7.1 dB</td>
<td></td>
</tr>
<tr>
<td>LO VSWR</td>
<td>2.5:1</td>
<td>1.3:1</td>
<td>7.1 dB</td>
<td></td>
</tr>
<tr>
<td>IF VSWR</td>
<td>?</td>
<td>?</td>
<td>&lt;2.5:1</td>
<td></td>
</tr>
<tr>
<td>L TO I</td>
<td>46 DB</td>
<td>37 dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R TO I</td>
<td>23 DB</td>
<td>22 dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LO PWR</td>
<td>+10 DB</td>
<td>+10 dB</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3.6** Conversion Loss vs LO Drive

**Return Loss LO vs**

**Return Loss RF vs**