MMIC Design and Technology

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Lecture 1 Overview
Class Intro

- MMIC
  - Monolithic Microwave Integrated Circuit

- MMIC Design and Technology
- Project based class
- Hands on Collaborative Engineering
Course Objective

• Design a MMIC chipset for a microwave transceiver.
• Learn about MMIC devices, components, and their design and fabrication
• Learn MMIC CAD Techniques
• Utilize RF system design skills
• Experience Collaborative Engineering
Syllabus

Review of Field & Wave, Microwave
Passive Microwave Devices
Active III-V Devices
Amplifier Design
Oscillator Design
Mixers and Non-Linear Circuits
Switches, Attenuators and Phase Shifters
CAD Software
Layout Techniques
Simulation and Verification

Lecture 1 Overview
## Grading

- **Midterm** 5/2/1387 20%
- **Final** 3/4/1387 30%
- **Project** 15/4/1387 40%
  - Home Works 5%
  - Design Requirement Report 5%
  - Schematic Design Report 5%
  - Simulation Report 5%
  - Layout Review Report 5%
  - Post Layout Simulations 5%
  - Final Report 10%
- **Presentations** 10%

**Lecture 1 Overview**
Text

• Microwave Solid State Circuit Design
  Second Edition
  Inder Bahl and Parkash Bharita
  2003 Wiley-Intersience

Website: ee.sharif.edu/~mmic

Lecture 1 Overview
Software

- Microwave Office by Applied Wave Research will be the primary design software used.
- Microwave Office will be available on a server during second part of the course.
- Agilent ADS may be available as an alternate.

www.appwave.com
Helpful Prerequisite Knowledge

- Electromagnetics
- Field and Wave
- RFIC
- Familiarity with RF Systems
- Microwave Measurements
- Microwave Devices and components
- Microwave Circuits
2-20 GHz Wideband AGC Amplifier

Key Features and Performance
- 0.5 um MESFET Technology
- 9 dB Nominal Gain
- 3.5 dB NF Typical Midband
- 17.5 dBm Nominal Pout @ P1dB
- Bias 5-8V @ 60 mA
- Dimensions 3.4 x 2.0 x 0.1 mm

Primary Applications
- Wideband Gain Block / LN Amplifier
- X-Ku Point to Point Radio
- IF & LO Buffer Applications

Letcture 1 Overview
### MMIC or MHIC

#### Lecture 1 Overview

<table>
<thead>
<tr>
<th><strong>MMICs</strong></th>
<th><strong>Hybrid MICs</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheap in large quantities; especially economical for complex circuits</td>
<td>Simple circuits can be cheaper; automatic assembly is possible</td>
</tr>
<tr>
<td>Very good reproducibility</td>
<td>Poor reproducibility due to device placement and bond-wires</td>
</tr>
<tr>
<td>Small and light</td>
<td>Compact multilayer substrates with embedded passives now available</td>
</tr>
<tr>
<td>Reliable</td>
<td>Hybrids are mostly ‘glued’ together and so reliability suffers</td>
</tr>
<tr>
<td>Less parasitics – more bandwidth and higher frequencies</td>
<td>The best transistors are always available for LNAs and PAs</td>
</tr>
<tr>
<td>Space is at a premium; the circuit must be made as small as possible</td>
<td>Substrate is cheap, which allows microstrip to be used abundantly</td>
</tr>
<tr>
<td>Very limited choice of component</td>
<td>A vast selection of devices and components is available</td>
</tr>
<tr>
<td>Long turn around time (3 months)</td>
<td>Can be very fast (1 week), making multiple iterations possible</td>
</tr>
<tr>
<td>Very expensive to start up</td>
<td>Very little capital equipment is required</td>
</tr>
</tbody>
</table>
Yield

Table 1.2 Chip cost against size

<table>
<thead>
<tr>
<th>Chip size (mm²)</th>
<th>Typical yield (%)</th>
<th>Working circuits per 6&quot; wafer</th>
<th>Bare chip cost ($) at $5k per wafer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 × 1</td>
<td>80</td>
<td>12800</td>
<td>0.4</td>
</tr>
<tr>
<td>2 × 2</td>
<td>70</td>
<td>2800</td>
<td>1.8</td>
</tr>
<tr>
<td>5 × 5</td>
<td>45</td>
<td>288</td>
<td>17</td>
</tr>
<tr>
<td>7 × 7</td>
<td>30</td>
<td>98</td>
<td>51</td>
</tr>
<tr>
<td>10 × 10</td>
<td>20</td>
<td>32</td>
<td>156</td>
</tr>
</tbody>
</table>

Lecture 1 Overview
Engineering Development Process

Specification

- Requirements Definition
- Preliminary Electrical Review
- Layout Review
- Final Electrical Review
- Project Presentations

MMIC Chipset Design

Lecture 1 Overview
MMIC Product Development Process

Customer or Market Requirement

MMIC Design → Wafer/Chip Fabrication Foundry Processes → Test

Assembly Test and Package

Iteration (s)

Product

Lecture 1 Overview
MMIC Production Process

Production Process

TriQuint SEMICONDUCTOR
GaAs MESFET Foundry Service

Features
- 0.6 μm Gate Length MESFET Process
- 4 Active Devices:
  - Power & Gain D-FETs
  - E-FET
  - Schottky-Barrier Diodes
- High Density Interconnects:
  - 2 Global and 1 local
  - 6 μm total thickness
- High-Q Passives
- Bulk & Thin Film Resistors
- High Value Capacitors
- Dielectric Encapsulated Metals
- Planarized Surface; simplified plastic packaging
- Substrate Vias Available
- Volume Production Process
- Validated Models and Design Support

Lecture 1 Overview
Active devices

- See also Figure 2.27 of text.
Passives

Letecture 1 Overview
Interconnects

- Interconnects are transmission lines
- Geometry is important
- May require Electromagnetic Solution
Lecture 1 Overview
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