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Notes on the Design and Fabrication of Custom RFICs and MMICs

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While there are powerful tools and great service available for RFIC and MMIC development, getting started is not always as easy as it seems

When I began working on this tutorial article, I had hoped to be able to list a few key issues and recommendations that would help an engineer begin the first efforts toward developing a custom RFIC or MMIC. As I gathered information an researched the topic, it became apparent that a few simple guidelines were insufficient!

There is now the ability to readily design, simulate and verify a design that will be implemented on Si, GaAs, GaN or other typical RF/microwave materials. There are many design aids, model packages, process design kits (PDKs) and other tools to support the designer's efforts. Semiconductor foundries and design tool vendors have more customer support and training available than at any time in the past.

These things should make it easier to create an RFIC or MMIC, but there is a hidden factor—the number of designers wanting to develop these products has grown, which means that engineers with less experience are now involved. In past years, only the best engineers were involved in this part of RF/microwave design, and they understood the challenges of such an undertaking.

In addition, competitive factors make it necessary to use integrated circuits to reduce size and cost, improve reliability and consistent performance, and achieve performance that is only achievable with devices having such small dimensions.

With these things in mind, the simplest recommendations I can offer are:

- Be prepared to spend the necessary time and effort as you work your way up the learning curve;
- Assign experienced designers and/or the most highly talented younger engineers to such a project; or
- Use the services of an outside consultant or design house.

RFIC and MMIC Design Resources

The major providers of EDA tools supporting RFIC and MMIC development are Agilent Technologies, AWR and Cadence. Along with other companies, additional tools are available for design verification for the selected foundry and the chosen process. These software tools make it possible to design a circuit that will be fabricated on a semiconductor substrate in a manner nearly the same as a circuit designed for FR-4, microwave laminate, alumina or other RF/microwave substrate material.

Making the transition from the circuit design to a design compatible with the materials science and fabrication processes for a semiconductor wafer is more complex, and will be unfamiliar to most RF/microwave designers. There are many significant differences between laminate and semiconductor structure and fabrication techniques!

In many cases, the selected foundry can provide assistance with the semiconductor part of the design. Independent design firms also have experience with the issues involved. Another tutorial-level recommendation is for any engineer new to chip-level design begin his/her study process by learning as much as possible about the unique constraints that a semiconductor process places on typical RF/microwave circuit design.

Atmel Corporation	Northrop Grumman (Velocium)
Cree, Inc.	NXP Semiconductor
austriamicrosystems	OMMIC
Bookham Technology	Peregrine Semiconductor
DuPont	Raytheon RF Components
Gallium Arsenide Enabling Technology Centre	RFMD
Global Communication Semiconductors, Inc.	Semiconductor Manufacturing International Corp. (SMIC)
HRL Laboratories	STMicroelectronics
IBM Semiconductor Solutions	Taiwan Semiconductor Manufacturing Company (TSMC)
IHP Microelectronics	TowerJazz
Infineon Technologies	TriQuint Semiconductor
Knowledge*on Semiconductor	United Microelectronics Corporation (UMC)
MagnaChip Semiconductor	United Monolithic Semiconductors (UMS)
Maxim Integrated Products	WIN Semiconductors Corporation
Northrop Grumman Electronic Systems	X-FAB Semiconductor Foundries

Table 1 · Foundries offering Si, GaAs, GaN and other RF/microwave processes.

Foundry Services

Table 1 is list of major companies that offer foundry services, supported through cooperation with major RF/microwave EDA tool providers. These foundries typically offer significant customer support, either directly or in cooperation with independent design firms. For example, TriQuint Semiconductor identifies these firms as being "familiar with TriQuint's process technologies and design tools"—

- CMDS Inc. (Westford, MA)
- IMST (Kamp-Lintfort, Germany)
- Plextek (Essex, UK)
- RF Integration (Boston, MA)
- Roke Manor Research Limited (Romsey, UK)

TriQuint's foundry information brochure lists the support services it provides for customers:

- Quick Turn Prototyping
- Device Samples
- Design Tool Libraries
- Data Sheets
- Design Handbooks
- Training Classes
- Real Time Applications Engineering
- Dedicated Sales and Customer Service
- 24/7 Automated Layout Verification
- Online Order Status Portal
- Die Sort Services
- Quality Programs
- Reliability Studies
- Failure Analysis Capabilities
- On-Wafer DC and RF Probe
- Export Management and Expertise

Other foundries will provide a range of services including all or part of the above list.

Choosing the Process

Once an engineer has gained some familiarity with various tools, foundries and processes, the choice of a specific process for a device must be made. Many circuits have performance and cost specifications that will clearly match the abilities of a particular process, especially silicon (CMOS, BiCMOS and SiGe) and gallium arsenide (GaAs HBT, pHEMT or FETs). High performance, mm-wave frequencies, or other special characteristics may require GaN, InGaP, AlGaAs, InGaP, InP or SiC processes, or perhaps a process intended for integrated passive devices.

The choice of a particular foundry is more like a classic vendor selection procedure—a decision will depend on the required support services, cost, scheduling and compatibility with the user's preferred design tools. Geography may be a factor when significant travel will be involved.

Summary

Implementing a design using a semiconductor process has substantial differences from RF/microwave design on traditional PCBs and other microwave substrates. When pursuing the first RFIC/MMIC development project, an engineer (and the employer) should be prepared to make the necessary investment in money and time.

The time spent researching and evaluating EDA tools, foundry services, and consultants will usually reveal the best path to follow. As conversations with representatives of these suppliers proceed, you will see that they are well-prepared to deal with inexperienced customers, in response to growing number of OEMs striving for chip-level designs to replace board-level designs.