

The analog integration race that helped fuel the wireless revolution

As seen by a designer in the midst of it, in the early 2000's

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Foreground

- **This is a personal account of what I think is an exciting story**
 - Of how our team inside Texas Instruments (TI) helped fuel the analog integration revolution of the early 2000's
 - And how, after a few years and many billions of chips sold, TI decided to get out of the handheld wireless market

- **Note:**

For those not in the IC design field, Texas Instruments (TI) maybe known for its laptops (a few years back) and calculators

But more than 90% of this 15-billion-dollar and 30-thousand-employees company, is dedicated to the design and fabrication of Integrated Circuits, and today TI is the leading supplier of Analog IC's in the world

Personal Introduction

- **A short recount of my life after PII**
 - After getting my Master's at PII, I went back to Colombia
 - Shortly after, I got a Research Assistantship in Ohio, and got a Master's degree (MSEE) from Wright State University
 - Went back to Colombia, as a professor at Universidad del Valle
 - Got another Research Assistantship, this time from Texas A&M University, to work on my PhD degree
 - After 3 years at Texas A&M, in 1995 I got a job at Texas Instruments, in Dallas, Texas, and have been with them ever since
 - 5 years designing High performance Audio chips
 - 10 years leading teams to design Analog modules for wireless applications
 - 6 years leading teams to design Analog modules for Microcontrollers

Wireless handheld systems before 2000

- **The wireless revolution was well into effect before 2000, with companies like Motorola, Ericsson and Nokia leading the charge**
 - Each cell phone had multiple chips and moderate processing capabilities



Motorola Star-Tac



Nokia 5110



Nokia 8210

- **But users wanted smaller phones**
 - And manufacturers needed to cover 2G, 2.5G and later on 3G standards, while at the same time they had to reduce phone form factors

The push for integration

- **Initially the push was to integrate digital, analog and RF separately**
 - More integration of functions, but each into separate types of IC's
- **Before 2000 Texas Instruments was already selling chips to the big cell phone manufacturers**
 - Application processor chips, digital modem chips and analog + power management chips



Ericsson T68



Nokia 6110



Sanyo SCP 5300

The challenge

- **At that time, most experts thought it didn't make sense to integrate analog into digital, deep-sub-micron CMOS processes**
 - Low voltages, expensive process, high Yield requirements, aggressive area scaling, digital noise, rapid migration to new process nodes – all were listed as disadvantages for analog design
 - Consensus in ISSCC* around year 2000 was that it would NOT be cost-efficient to integrate analog modules
- **A manager in our organization got tired of all the talk about analog integration**
 - And told three of us to “Just Do It”... and we started a team that got known since (inside TI) as “JDI”

* ISSCC: International Solid State Circuits Conference (IEEE Solid State circuits Society)

Humble beginnings

- **We started by designing a sigma delta ADC and a current DAC in 130nm and putting them in a test chip**
 - We added a “noise generator” and substrate noise test structures with different guard rings and layout methods
- **We ended up creating a new methodology to integrate analog modules (“IP’s”) in the same chip with large and noisy digital systems**
 - Methodology included process, design, verification, layout and manufacturing techniques
 - It also included what we called “digitally assisted analog design”: we added multiple digital compensation, trimming and calibration techniques

* IP: Intellectual Property – Modules handed out to others for integration are sometimes called “IP’s”

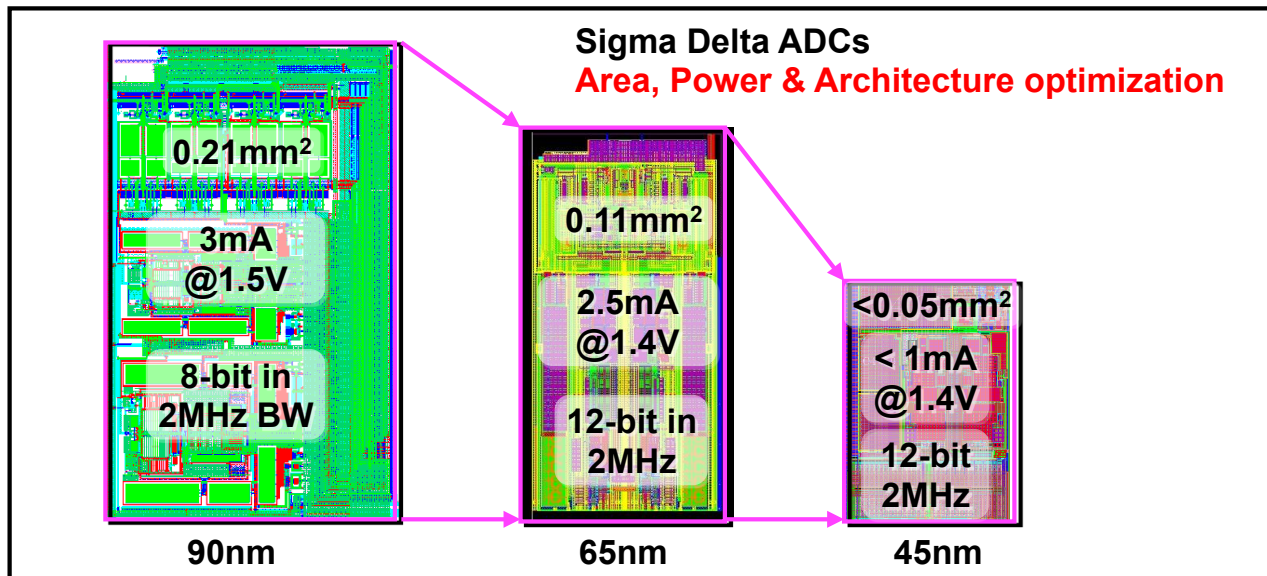
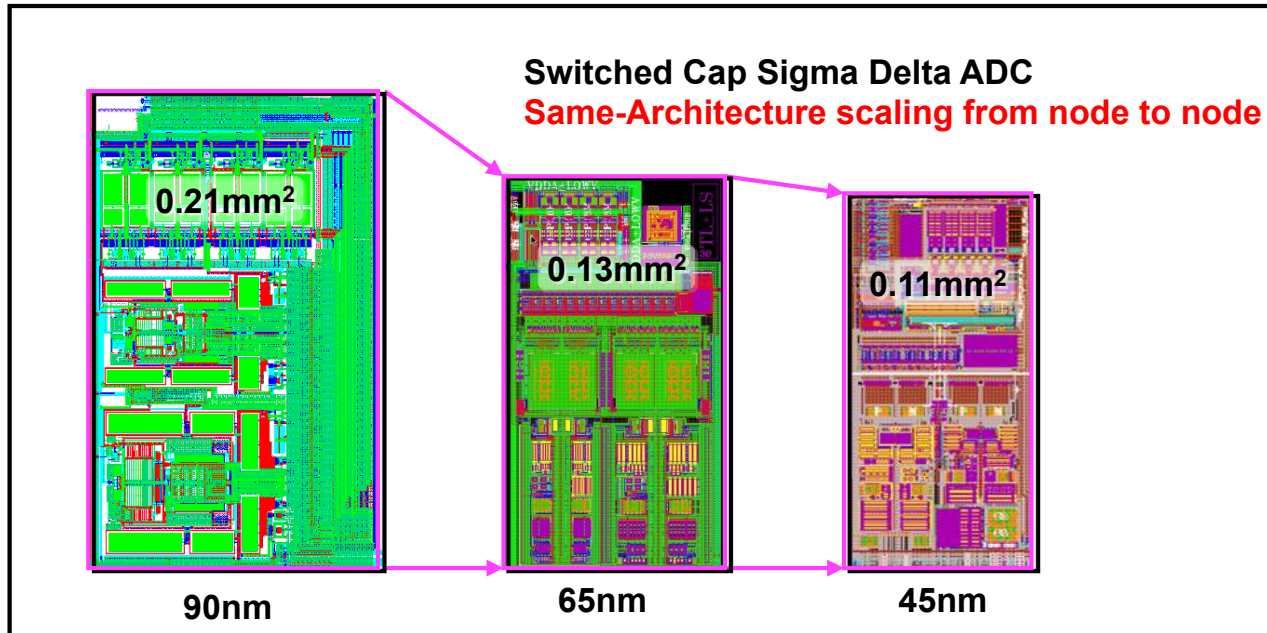
A competitive advantage

- **We worked closely with our CMOS process development teams to develop better components**
 - TI had its own CMOS process fabrication facilities at the time
 - We developed better components for analog design, without adding new masks or additional cost to the process
- **With all of these methodologies together:**
 - We convinced our customers to go with analog integration
 - Being one of the first on the market we had a competitive advantage that lasted for a few years
 - Around that time, another team at TI started RF integration on the same SoC's
- **In 2002 we published our first results in ISSCC**
 - And the race for integration started

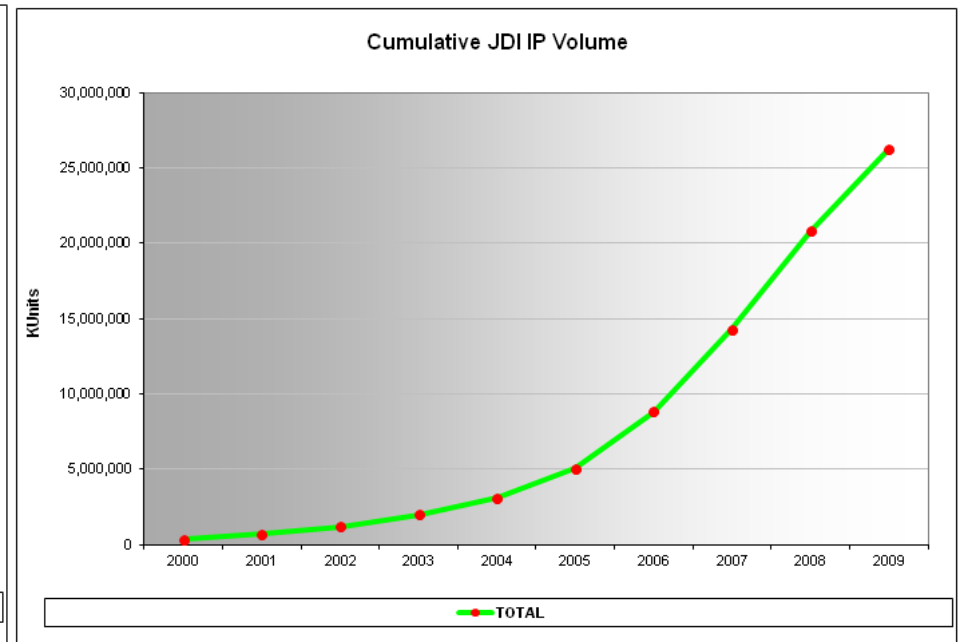
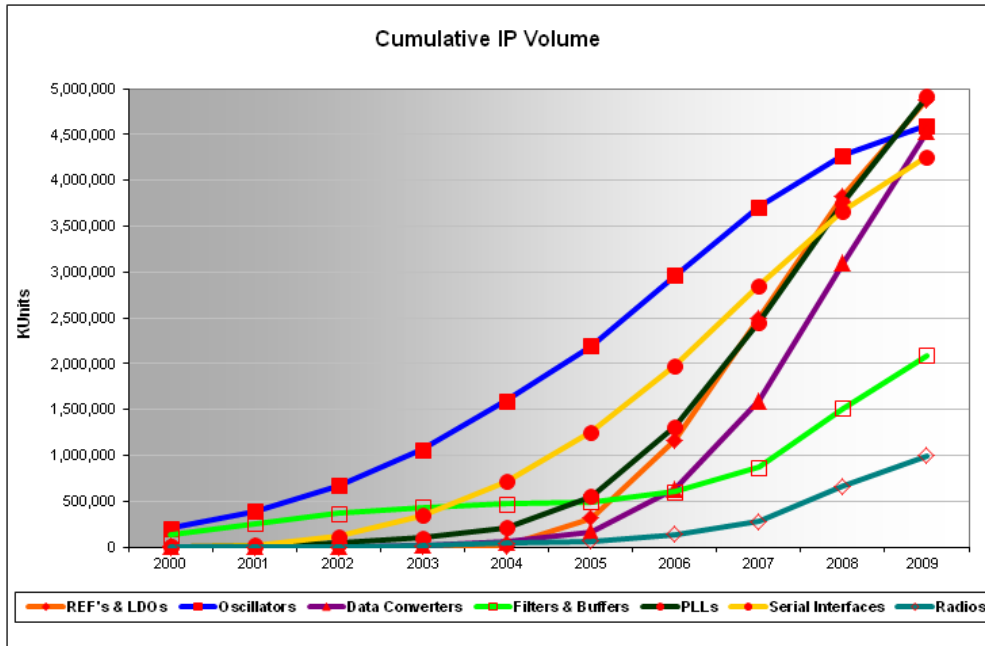
Results

- **All of this ended up in several extremely successful years for our team and for TI wireless**
 - Our team grew from 3 to more than 400 worldwide in about 4 years
 - We integrated every type of analog and RF module into our parts
- **Our team was kind of an “IP development house” inside of TI**
 - We kept going at full speed for several years, moving through 130, 90, 65, 45 and 28 nm processes
 - A similar IP development house would sell for > \$1Billion
- **But we were not the only ones**
 - TI became a market leader of highly integrated IC’s for handhelds for several years
 - But everyone wanted a slice of the pie

Analog Area shrink was a must



Final Results



- Total number of Analog modules produced by our team ~ 30 Billion (American billions) up to 2010
- They went into about 5 Billion devices, at about 6 analog modules per part
- Average Yield of Analog modules, well over 97%, and in most cases over 99%



Nokia 1100



BlackBerry Pearl



Motorola Razor



Nokia 6630

End of the race – for us

- **Shrinking margins in the wireless market**
 - Due to increased competition and commoditized products and IPs
 - TI decided the shrinking margins were not worth the cost to keep developing advanced CMOS processes
- **Final decision was to re-focus on higher margin markets**
 - We moved away from the modem and application processor cellular markets around 2010
 - Luckily TI got out of it before companies like Nokia, Ericson, Blackberry and Motorola crashed
- **But the race goes on – with different players**

Concluding remarks

- **It was fun while it lasted**
 - Running at full speed all the time
 - Developing the most advanced processes in the world
 - Developing new methodologies and architectures
 - Building a world class team, that is now scattered through TI and many other companies
- **Our analog and RF teams got more than 300 patents and dozens of papers published during these years**
- **In my new team we keep working on analog integration for Micro Controllers**
 - Still fun, but now we go at a more reasonable pace 😊
- **Thanks for your attention – Questions?**