Enabling Analog Integration

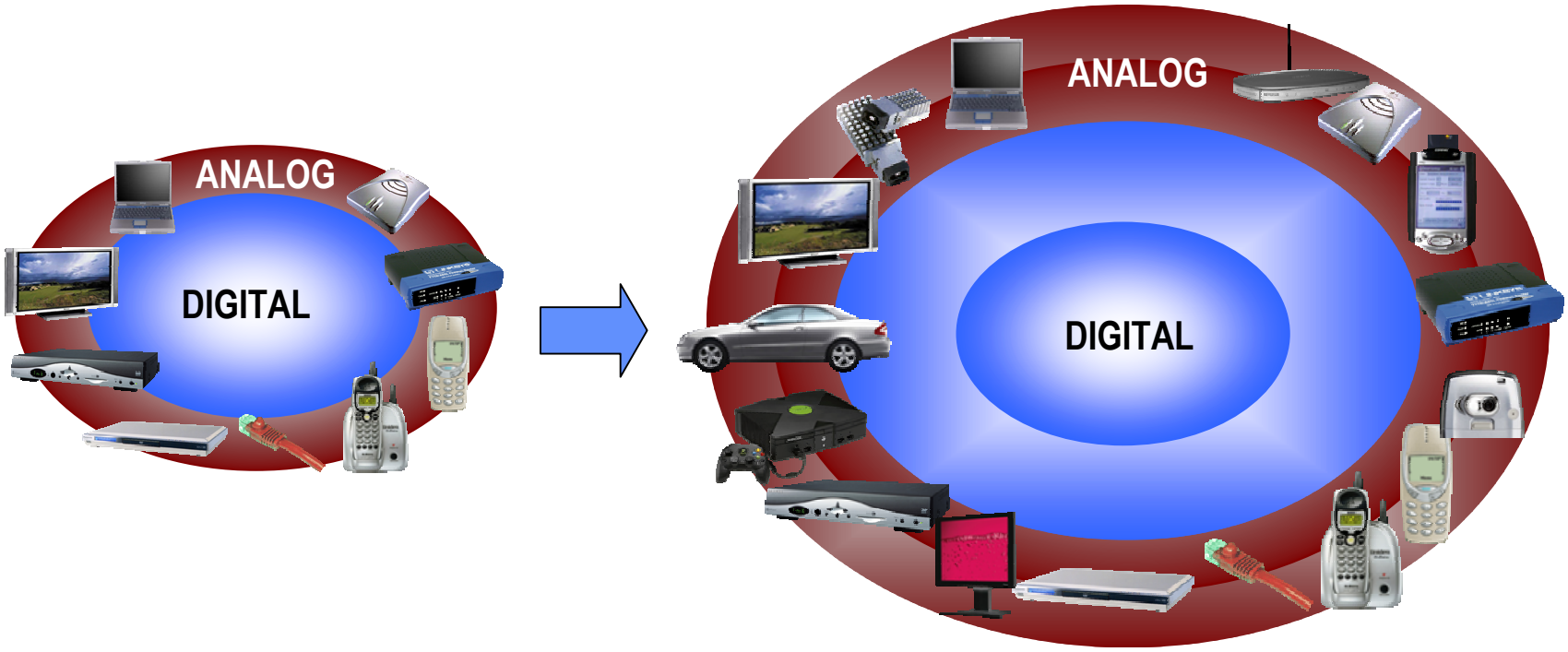
Paul Kempf

Overview

- **The New Analog**
  - Analog in New Markets
  - Opportunity in Integrated Analog/RF
  - Outsourcing Trends in Analog

- **Enabling Functional Integration**
  - Technology Requirements
  - Requirement for Analog / RF Foundry

Digital Integration Drives More Analog Interfaces



Analog Modem

Analog Modem
Ethernet (DSL / Cable)

Analog Modem
Ethernet (DSL / Cable)
WLAN 802.11b

Analog Modem
Ethernet (DSL / Cable)
WLAN 802.11a/b/g
Bluetooth
WiMax, UWB …

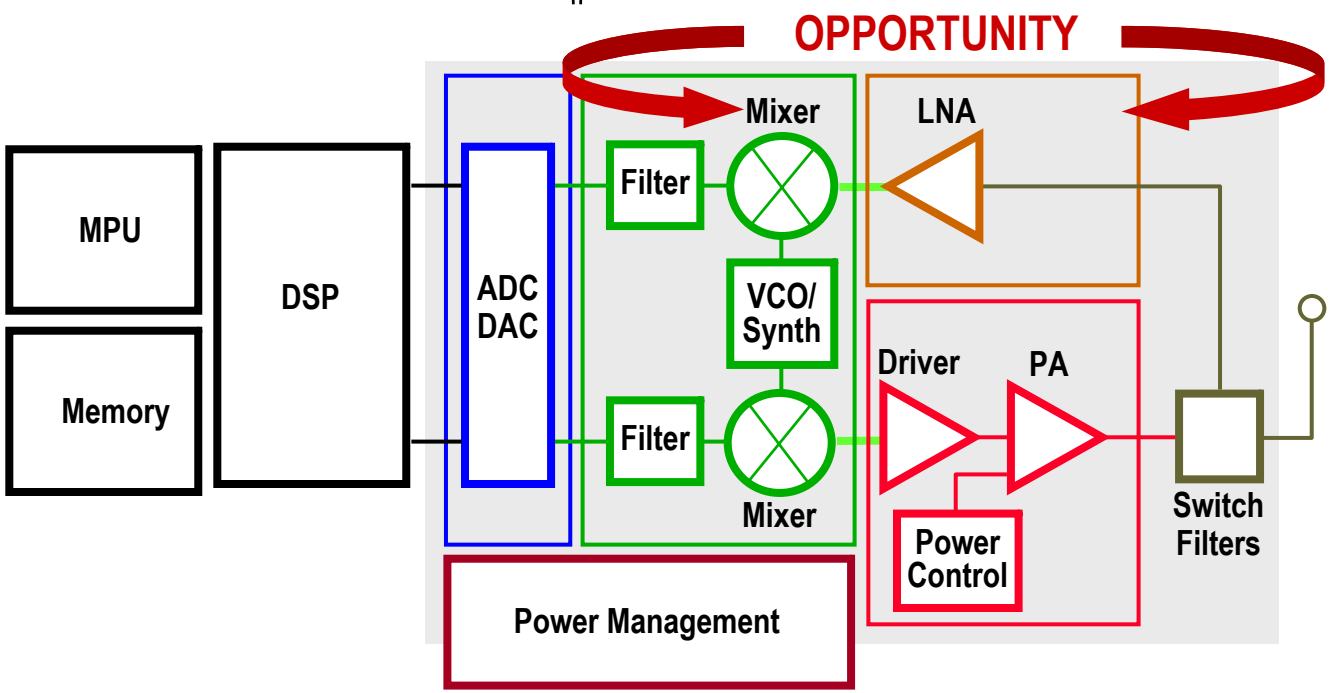
Integrated Functions for Added Value

Digital Integration

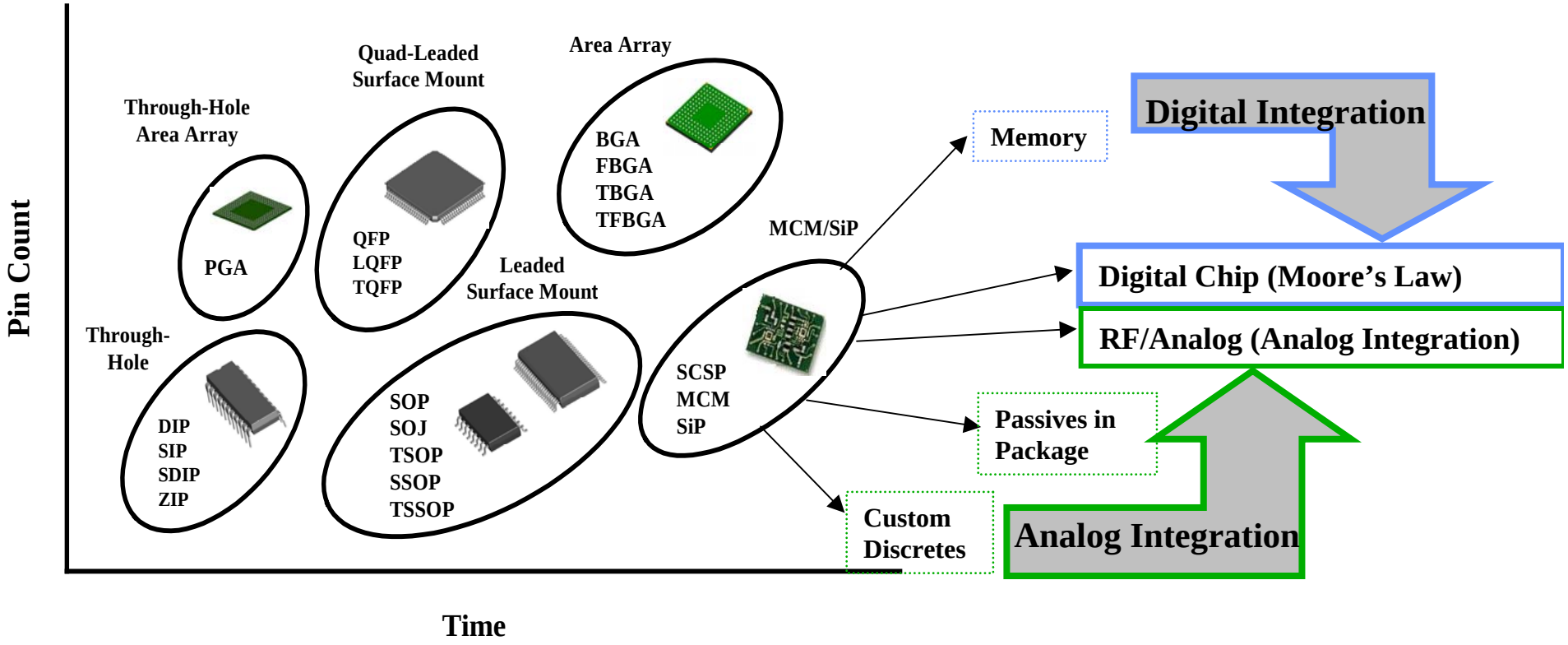
- CMOS process scaling enable high gate counts for digital SoC

Analog Integration

- Limited by available technology
- Analog sub-systems have emerged

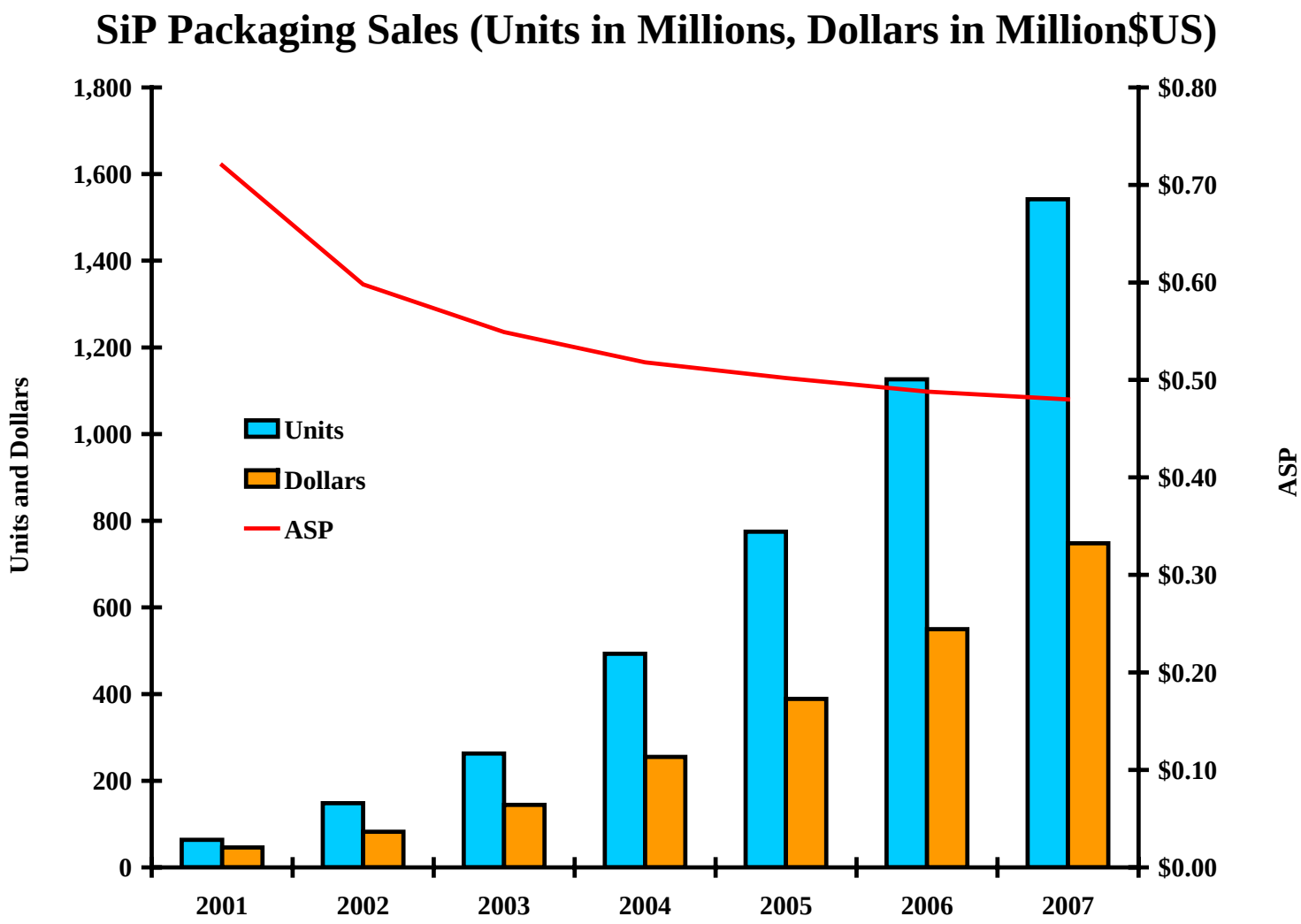


System in a Package (SiP) Progress



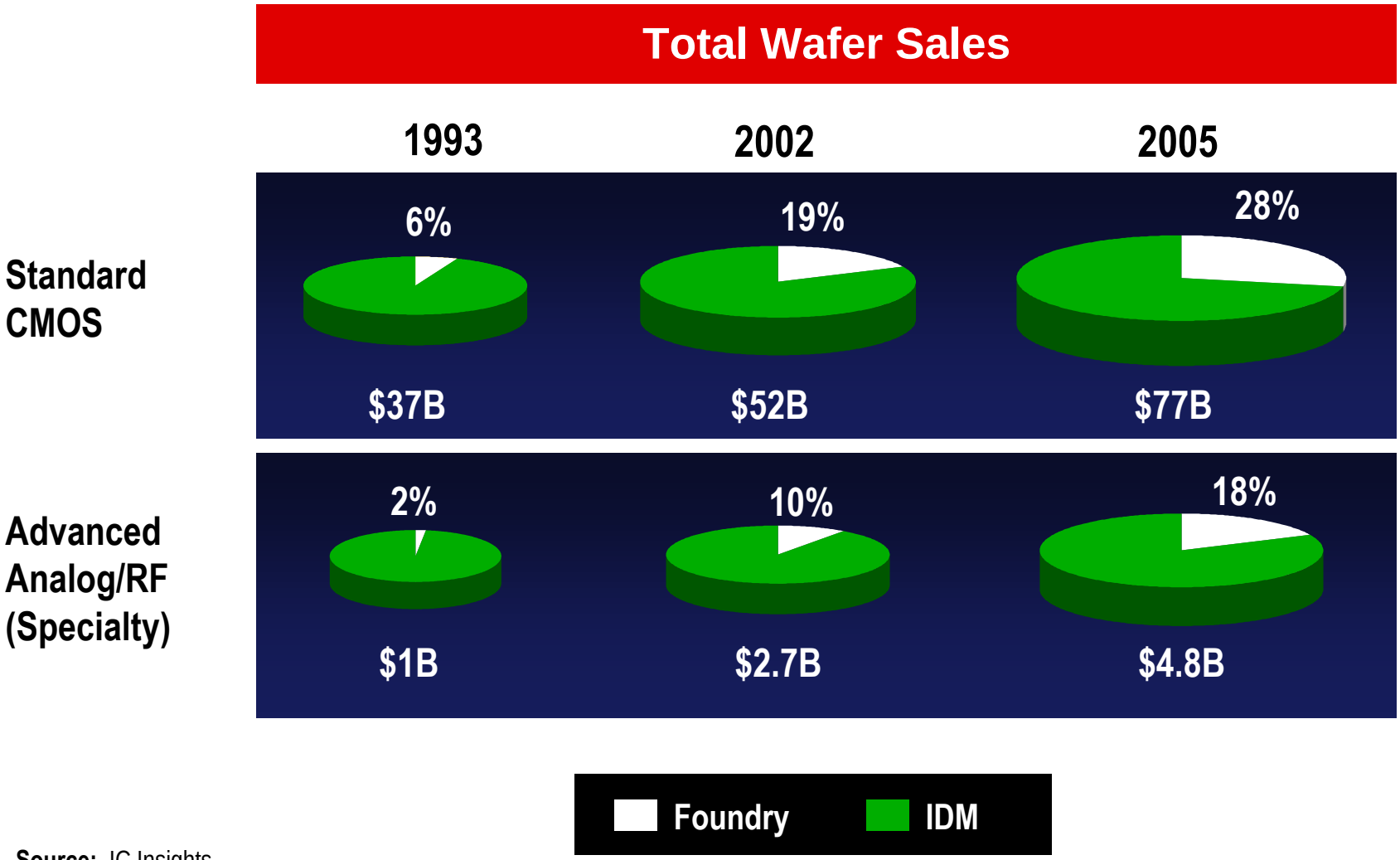
Source: Semico

SiP Growth as the Leading Indicator



Source: Semico

Outsourcing to Reduce Cost

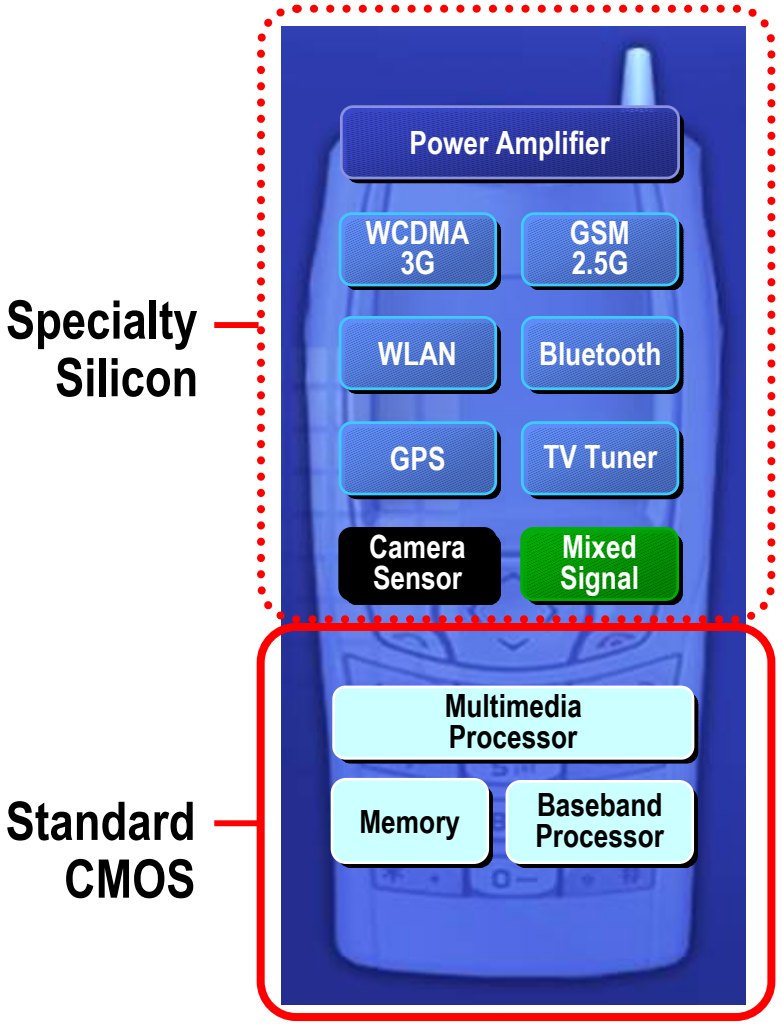


Source: IC Insights

Analog/RF Functions Increasing

Cell Phone Example

- Multi-band ‘world’ phones
- Computing/communications convergence
- Expanding features
- Greater need for integration



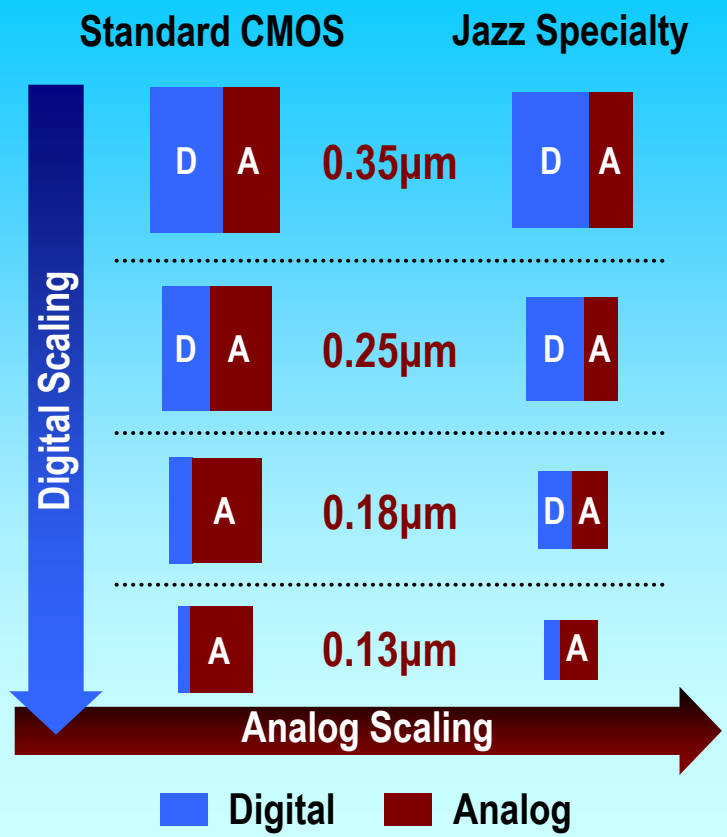
Analog/RF functions increasing in multiple consumer, wireless applications

Performance/Cost Optimization

The Advantages of Focusing on Analog/RF Processes

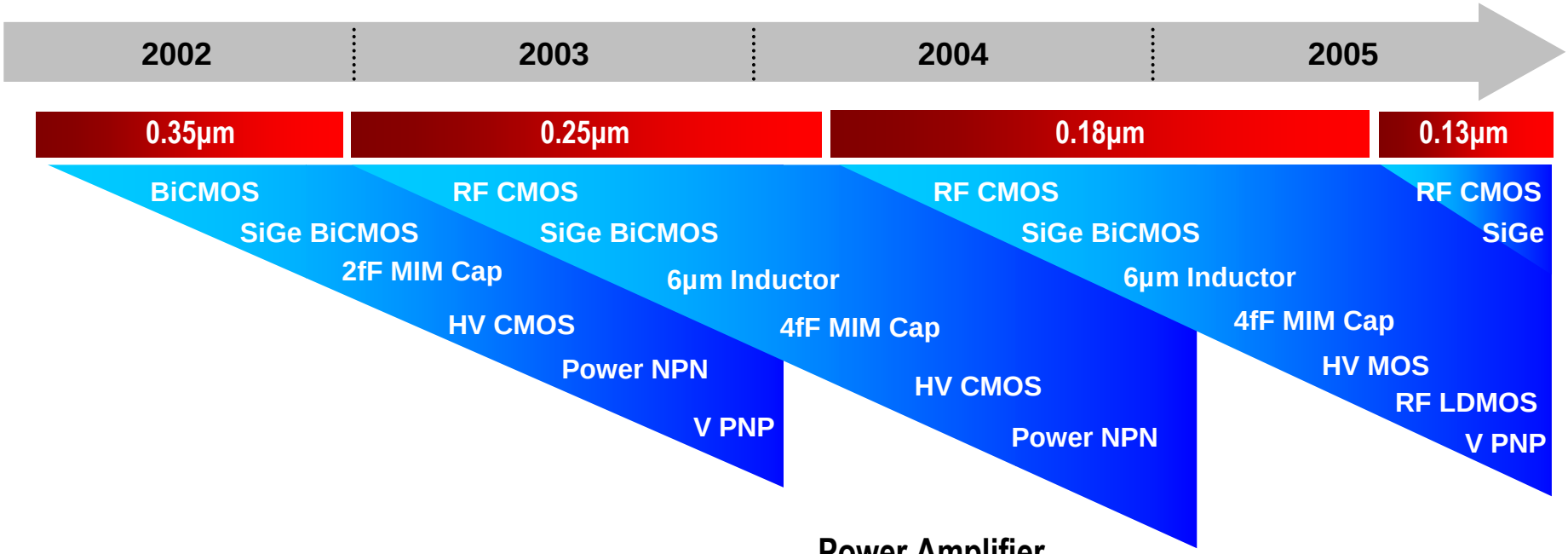
- Smaller size
- Lower cost
- More features
- Predictable performance

Addressing Both Digital and Analog Scaling

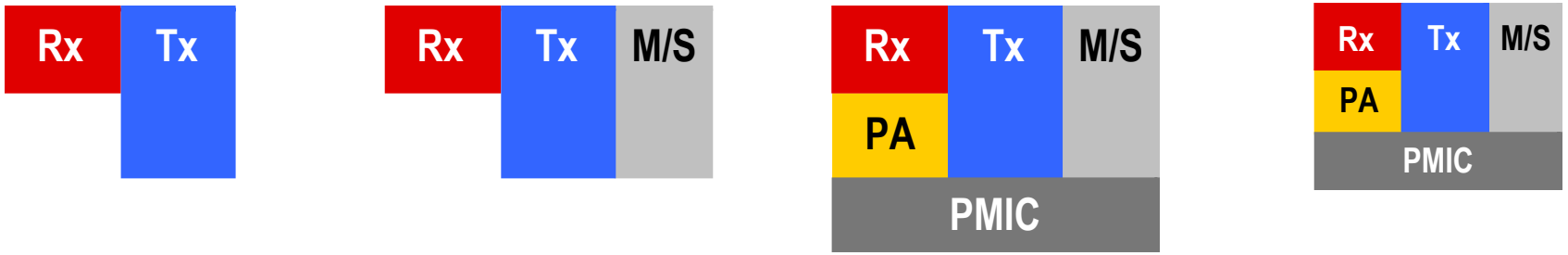


Modular Technology Enables Analog Sub-System Integration

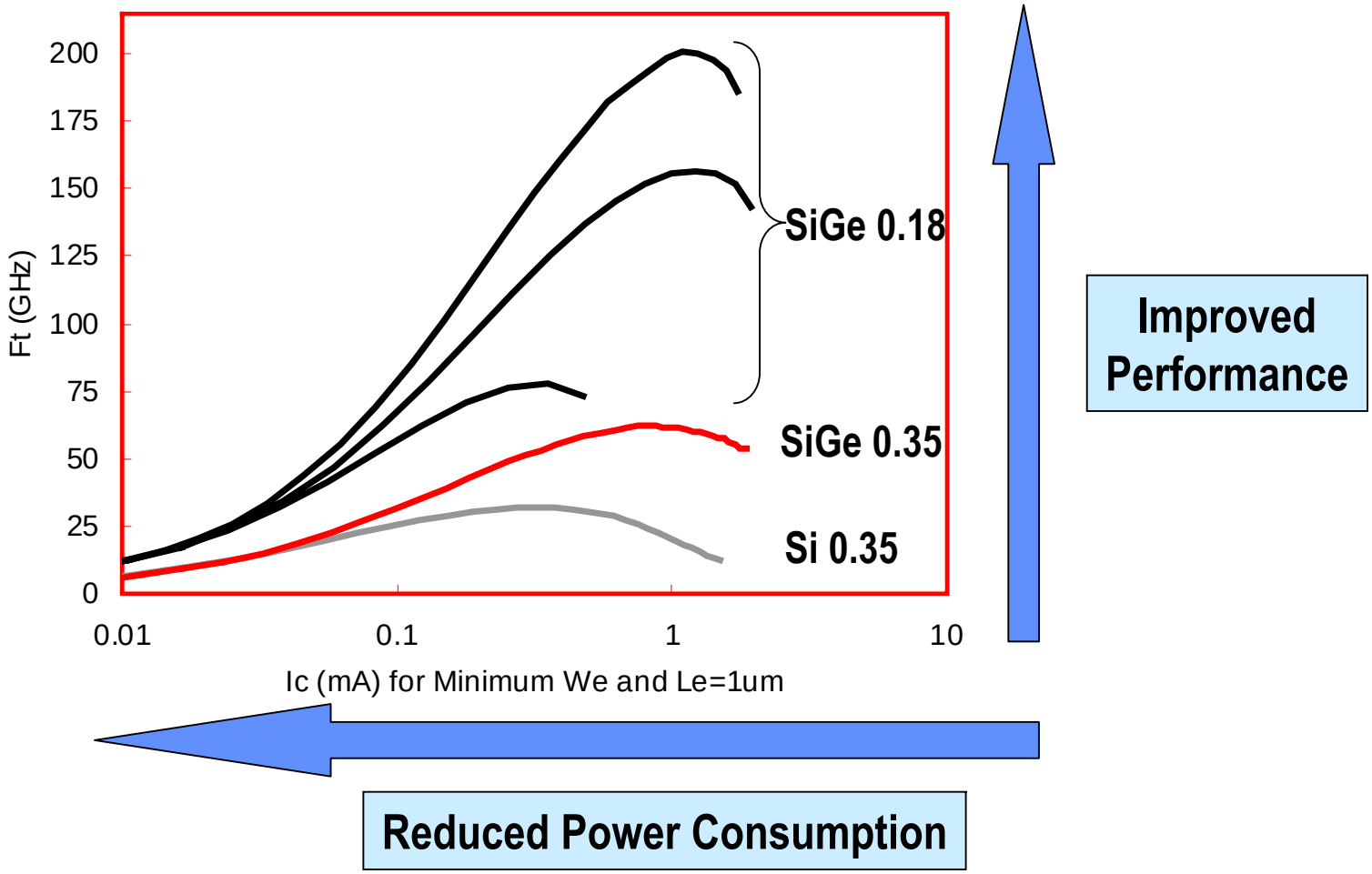
Innovation Manufactured



Direct Conversion Radio + Low-Noise SiGe LNA Data Converters + Power Amplifier Power Management Digital Control + Functional Scaling

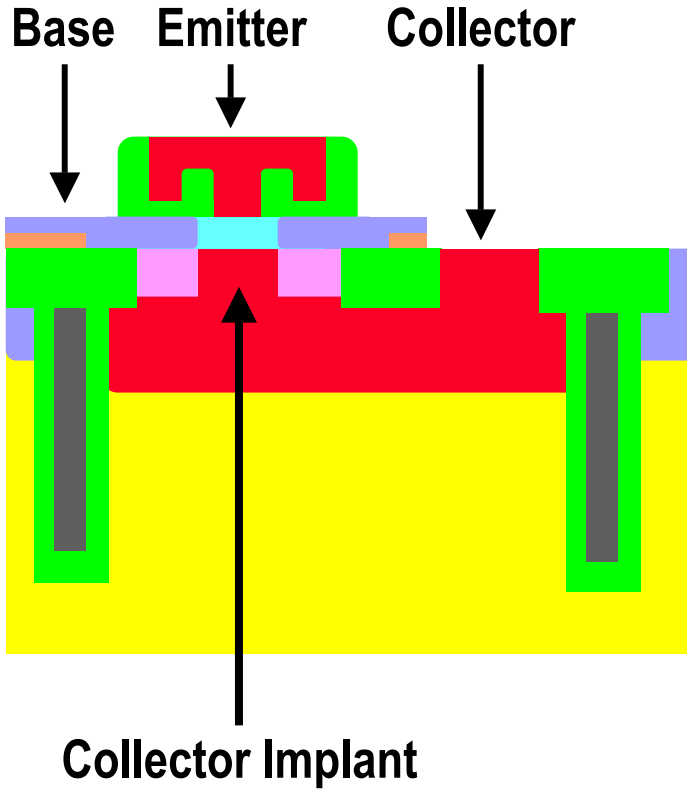


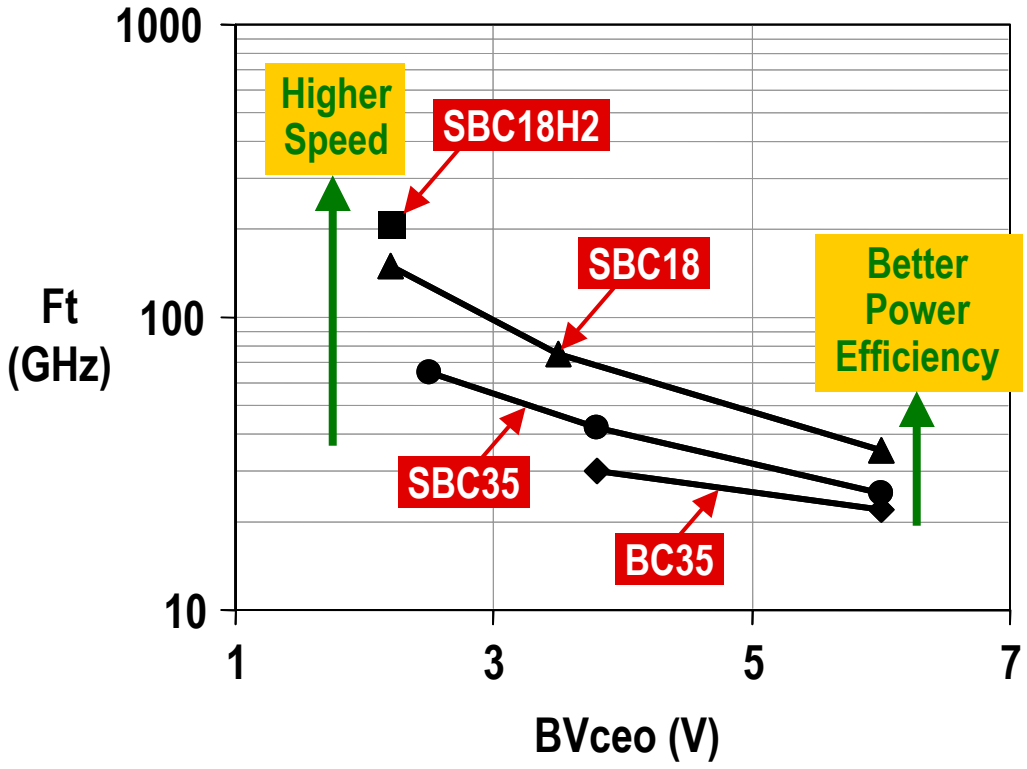
Example: Bipolar Modules



Analog technology can also provide performance/power consumption advantage

Power Amplifier Integration in SiGe BiCMOS

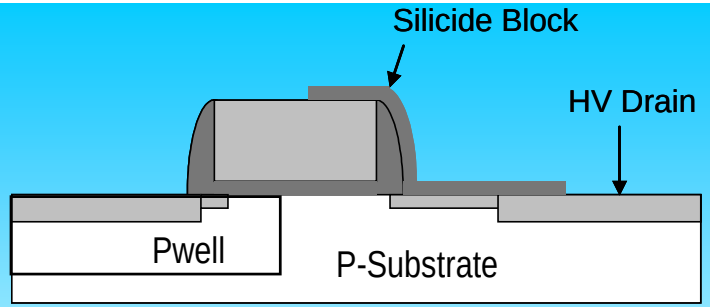




Power Integration in 0.18μm CMOS

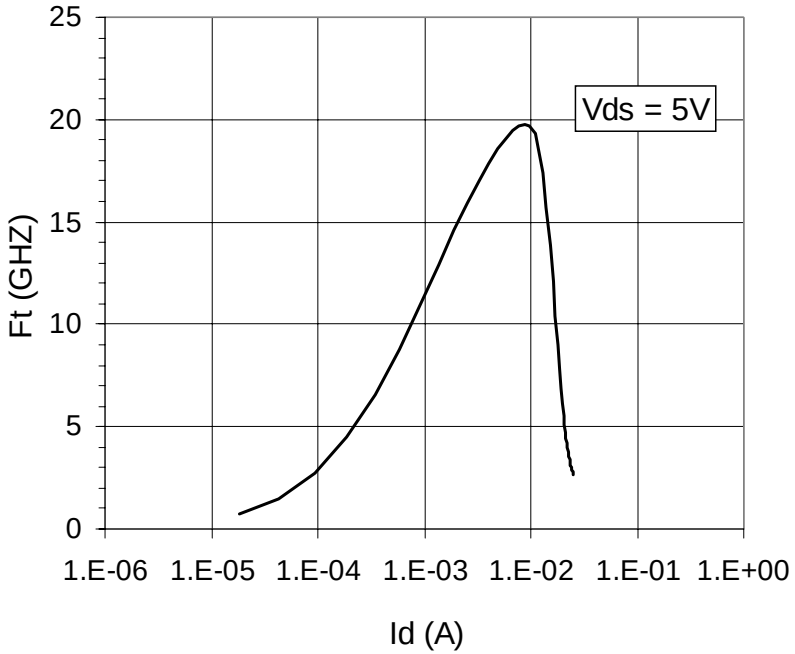
Innovation Manufactured

RF LDMOS

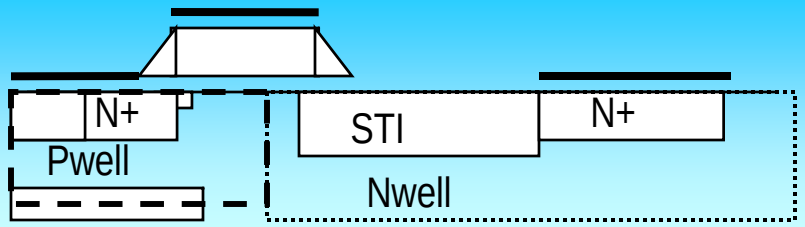


High Performance

- **Ft** **20GHz**
- **Ron** **< 4 Ohm-mm**
- **BVdss** **> 15V**



Extended Drain MOS

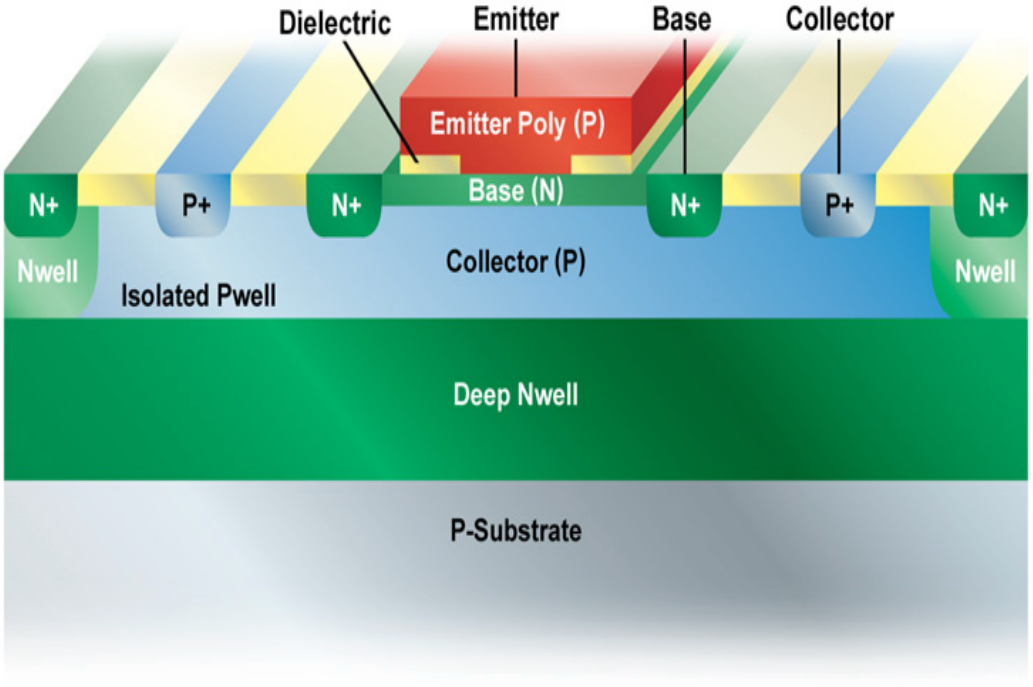


Power Management Options

- **Vgs** **1.8 3.3 5 12**
- **Vds** **1.8 3.3 5 12 20 40**

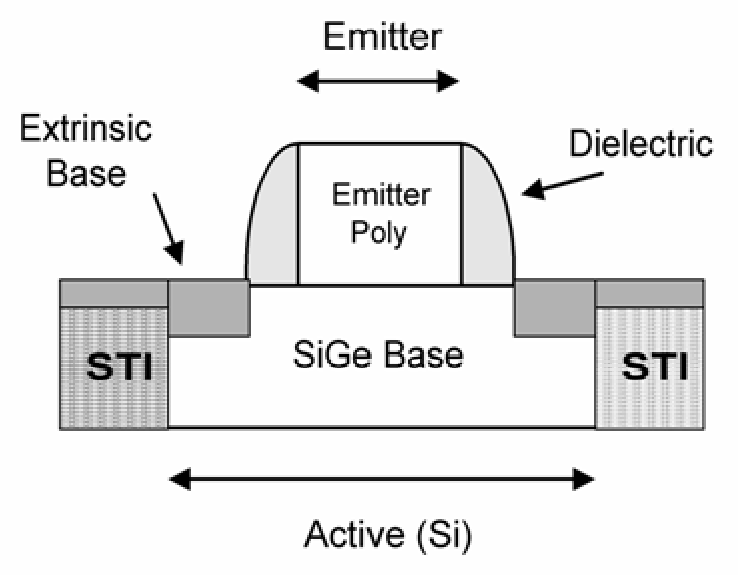
Vertical PNP Integration

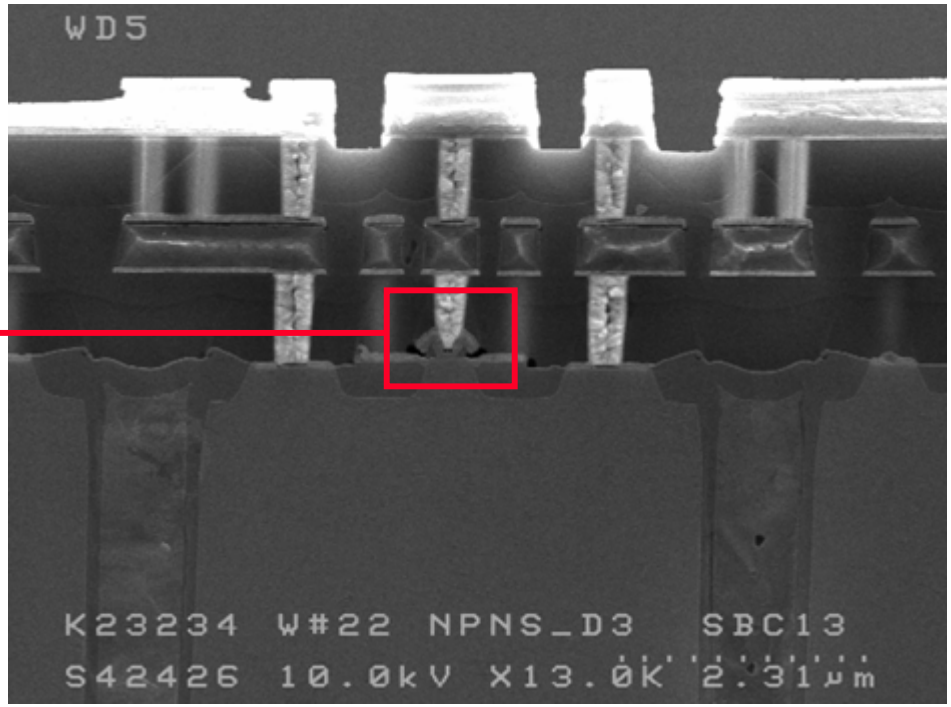
- Push/Pull Amplifiers
- Hard Disk Drive (HDD) Pre-Amp and Driver ICs
- High-Performance Data Converters



	0.35µm VPNP	0.18µm VPNP	
Peak Beta	50	50	
Ft (Vce = -5V)	15	17	GHz
BVceo	-7	-7	V

Ultra-High Performance: 200GHz SiGe BiCMOS



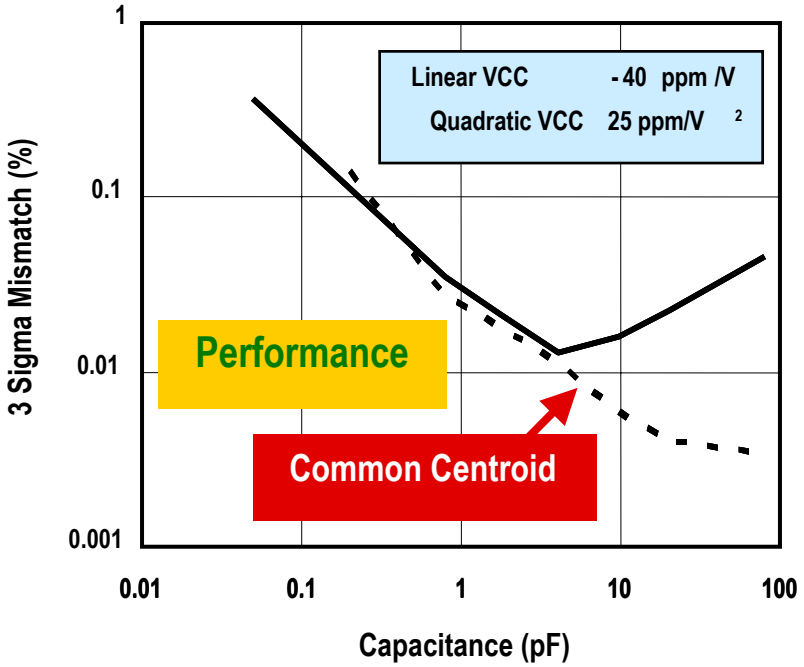


- 200/200GHz Ft and Fmax
- Shallow and Deep Trench Isolation
- SiGe epitaxial base (vertical scaling)
- Self-aligned emitter integration (lateral scaling)

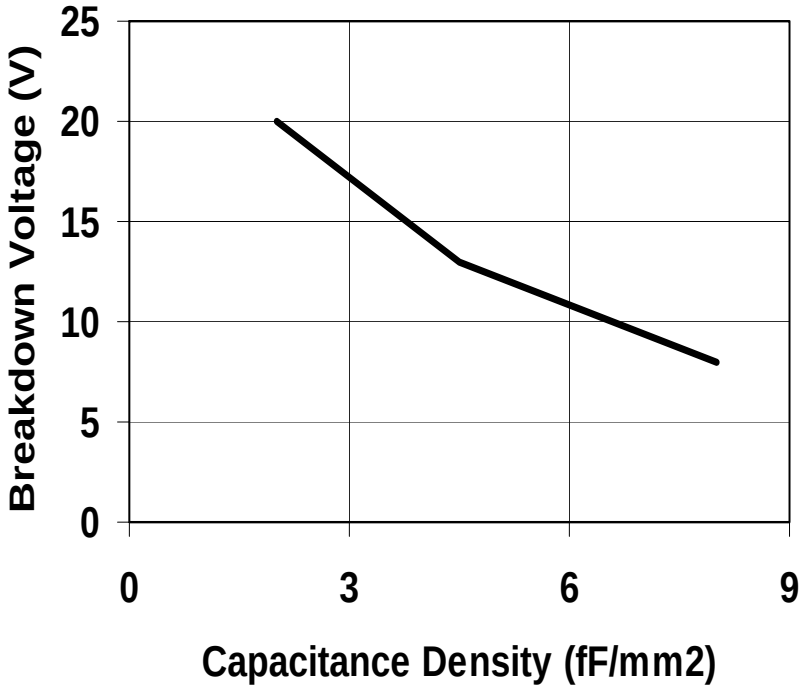
Scaling Linear Capacitors

Innovation Manufactured

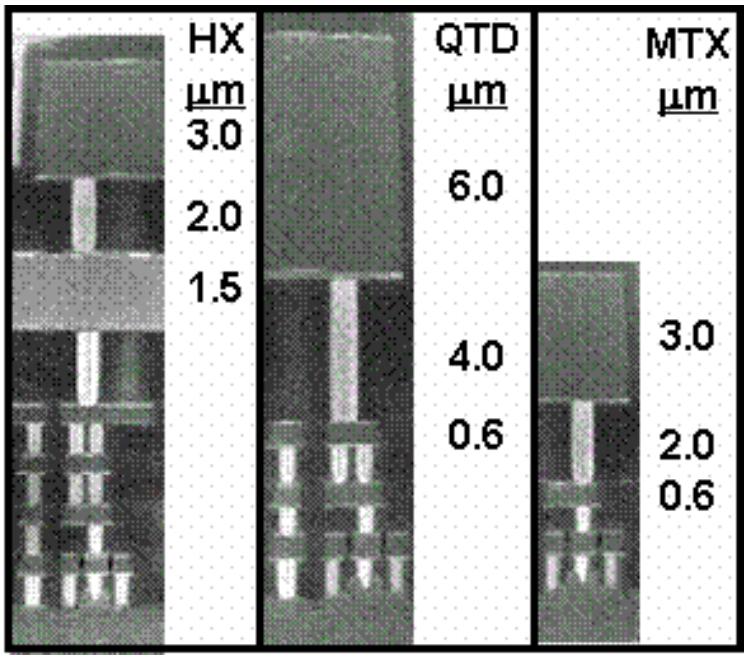
2fF/μm² MIM Capacitor

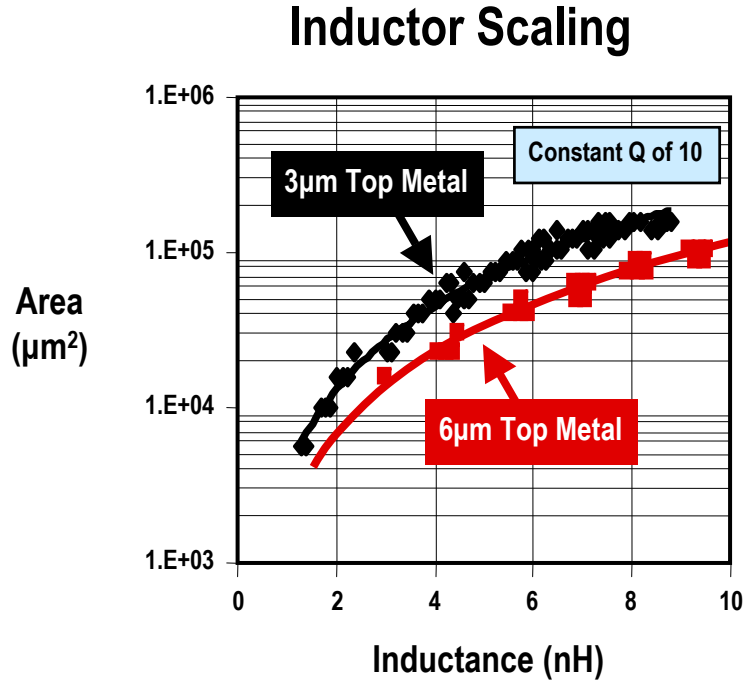


4.5-8 fF/μm² High K MIM



Integrated Inductors





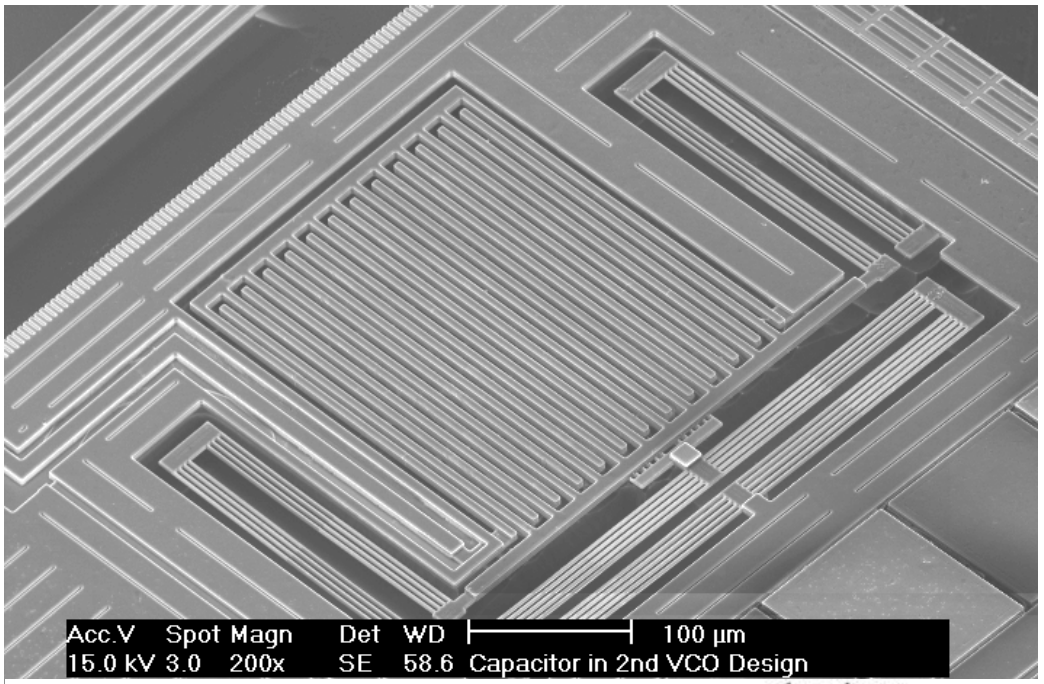
Thick metal to improve Q or reduce inductor area

Integrated MEMS

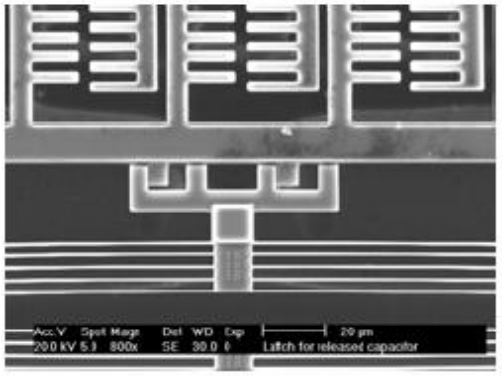
Innovation Manufactured

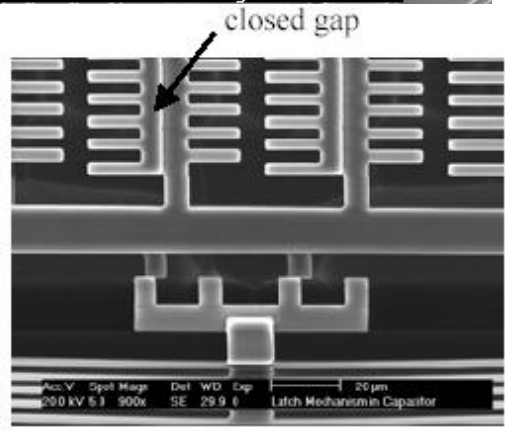
MEMS Circuits

- Tunable capacitor
- RF Filter
- Reconfigurable VCO
- RF Switch



Example: Tunable capacitor in VCO design courtesy Carnegie Mellon University





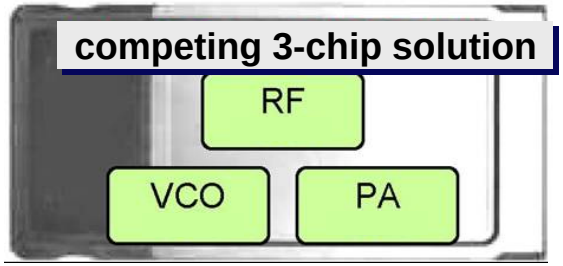
Example: RF/Analog SoC Products

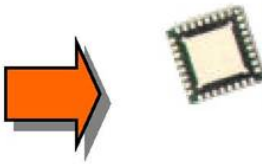
Innovation Manufactured

Single Chip TV Tuner – The World's First with Integrated Tuner + DeMod

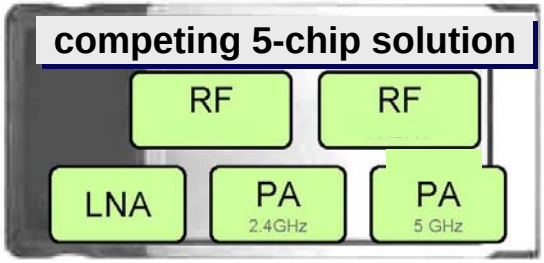
Single chip SoC
RF to Baseband IC
Tuner and DeMod Integration

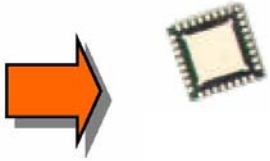
Single Chip WLAN RF Solution – The World's Most Integrated





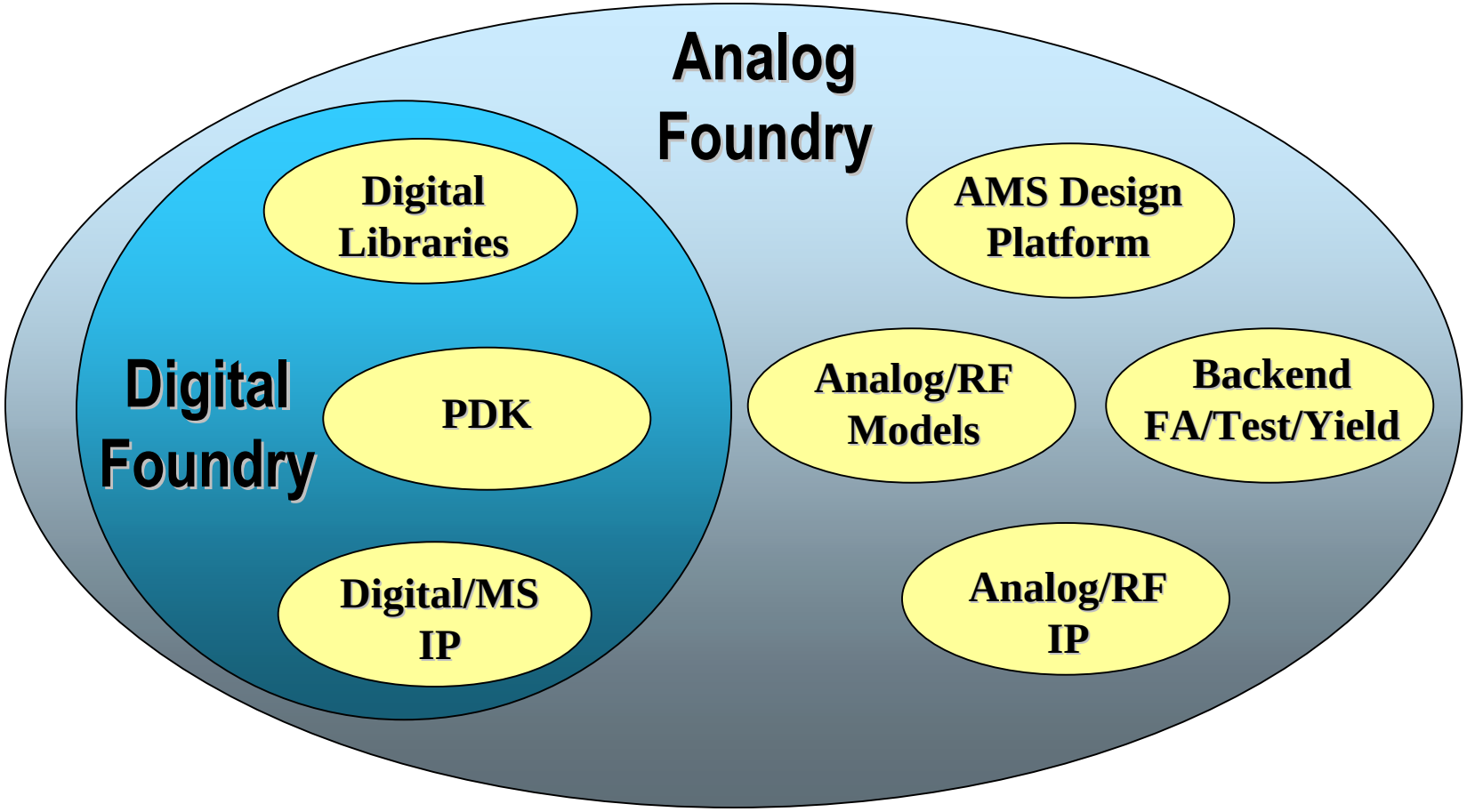
Single chip 802.11b/g
Transceiver, VCO
PA integration





Single chip 802.11a/b/g
Transceiver, LNA, VCO
PA integration

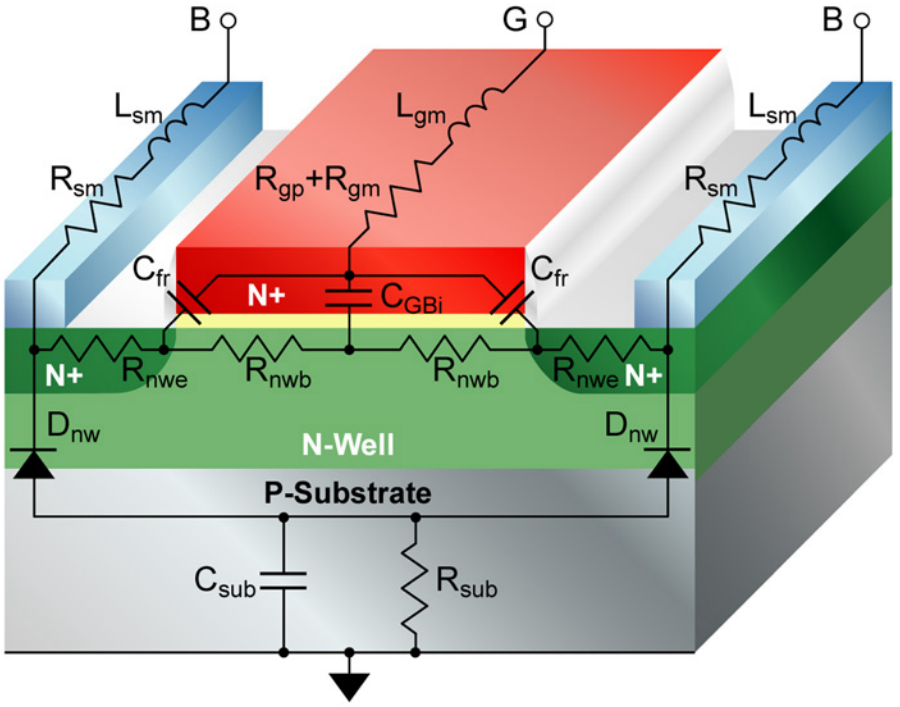
Analog Foundry: Design Support

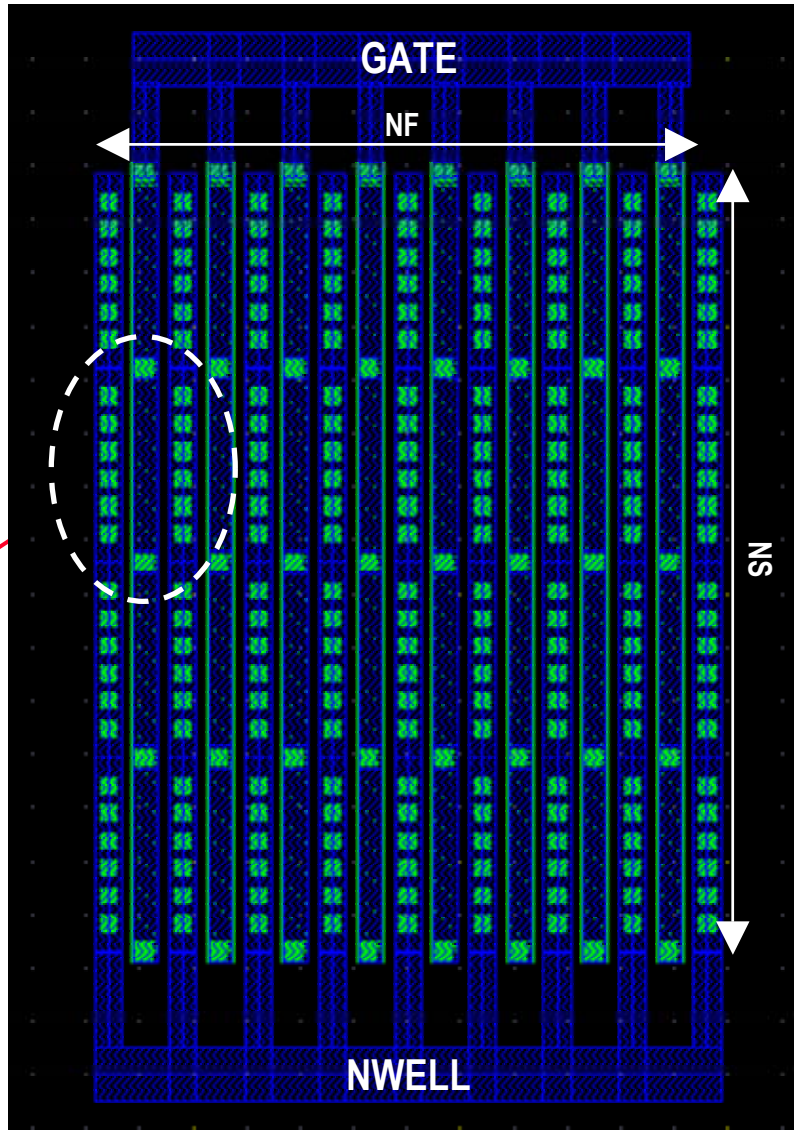


Higher level of investment in design support required in an Analog Foundry

Scalable Models

- Physical scalable models for all devices to ensure accurate simulation
- Design flexibility for optimum performance

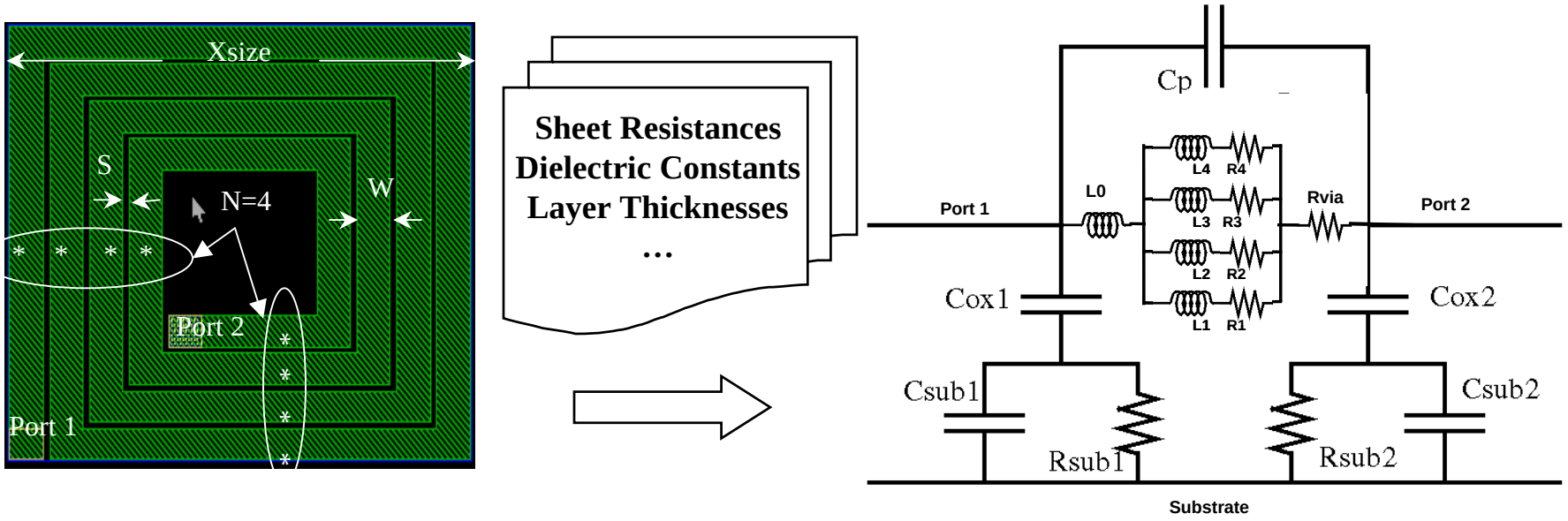




Scalable RF Inductor Model

Innovation Manufactured

Layout Input + **Technology Parameters** = **RF Circuit Model**



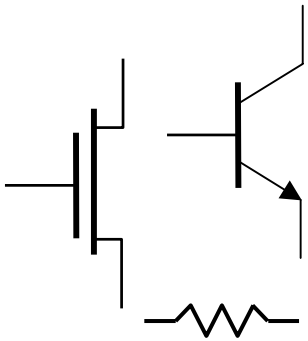
Scalable model enables optimization of inductor area/performance

Statistical Modeling Infrastructure

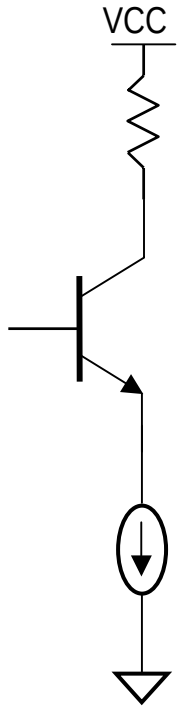
Implication of Process Variation → Product Yield

Process Parameters
(e.g., Tox, Doping, CD)
p^f

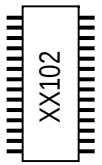
Device Parameters
(e.g., Idsat, Vth, Beta, Ft)



Circuit Performance
(e.g., Gain, NF)



Product Performance
(Yield, Sales)



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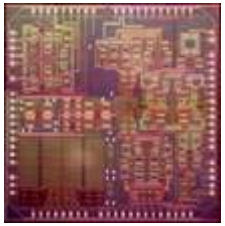
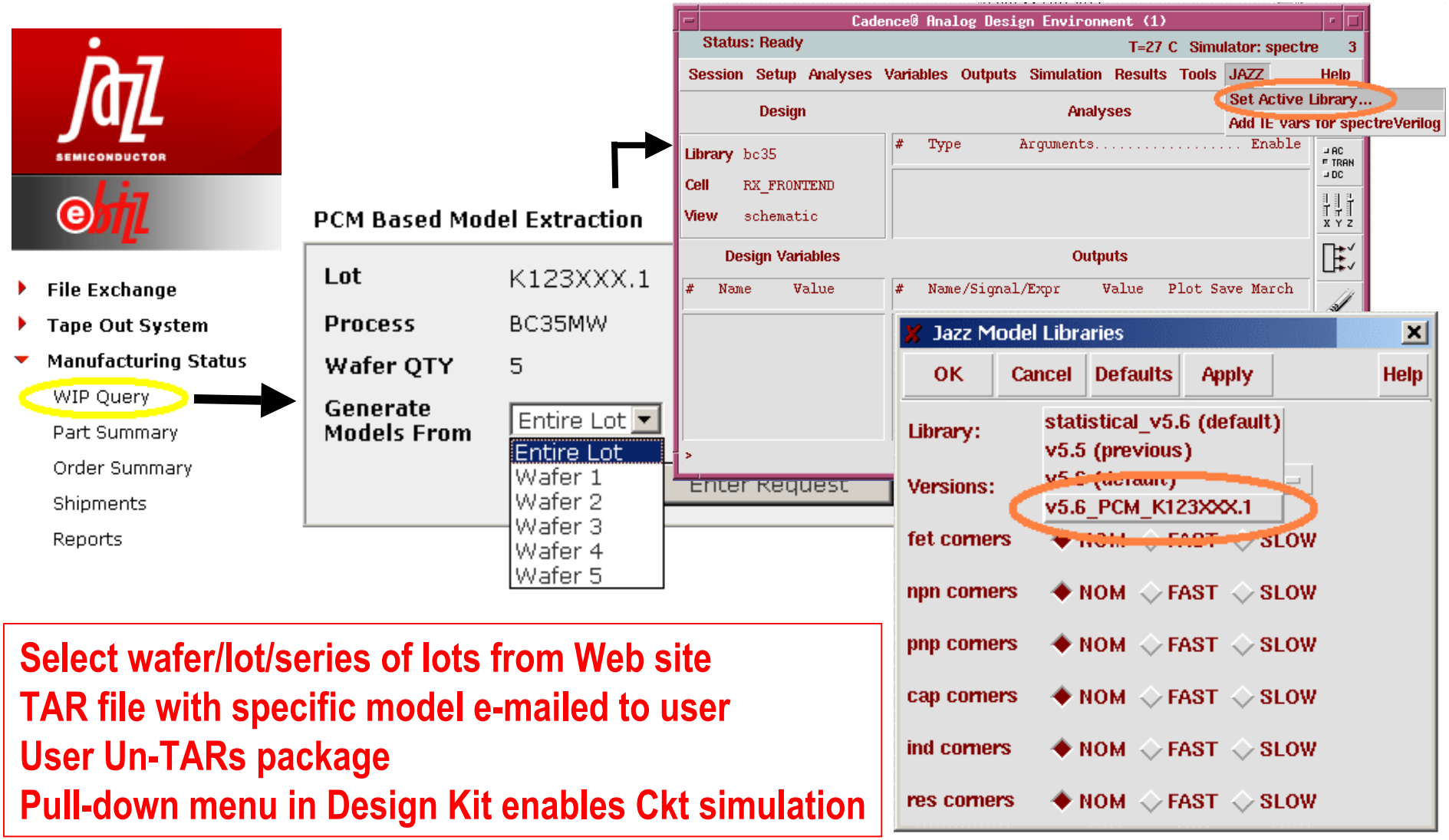
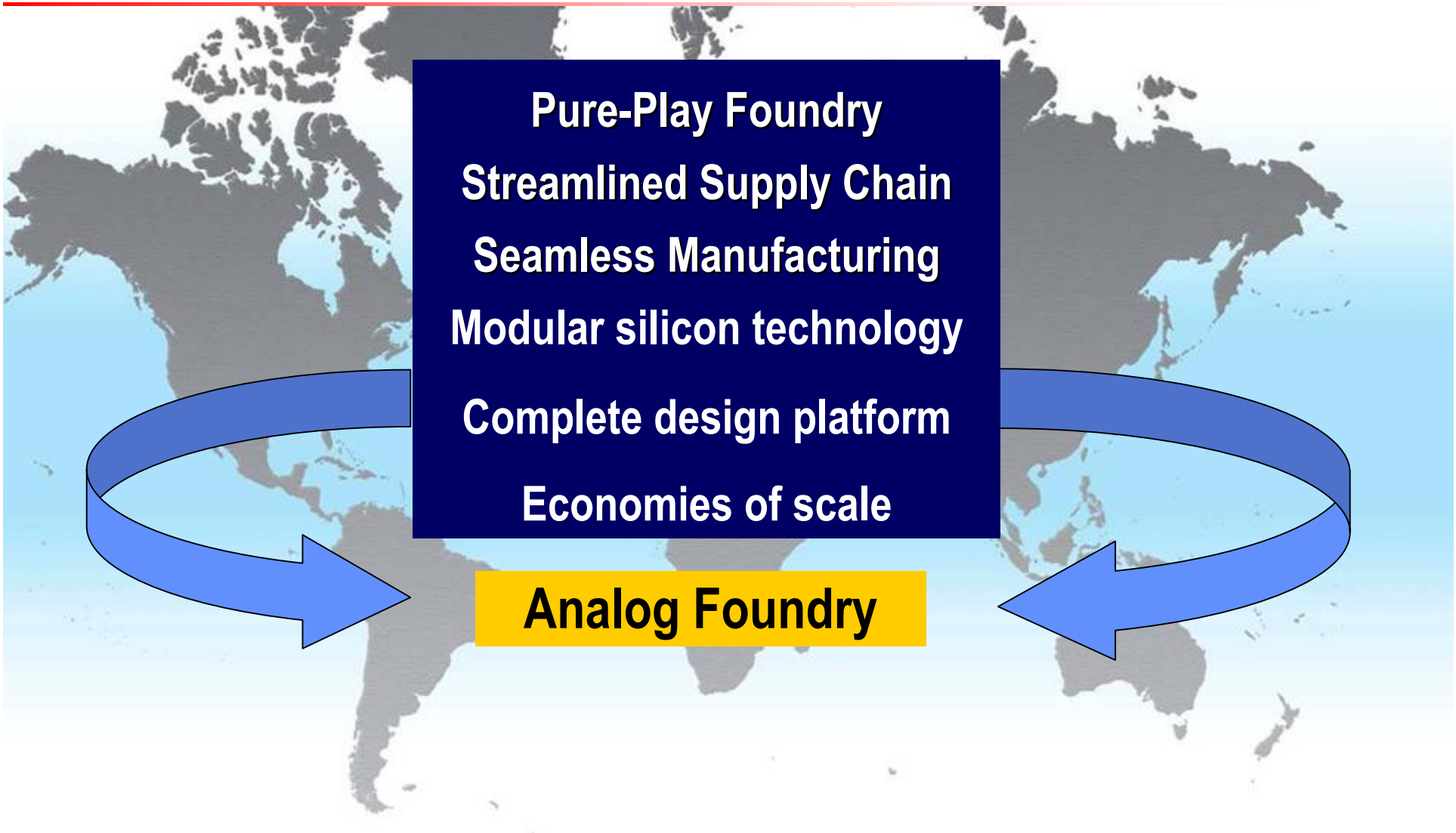


Wafer / Lot / Fab Specific Models



Select wafer/lot/series of lots from Web site
TAR file with specific model e-mailed to user
User Un-TARs package
Pull-down menu in Design Kit enables Ckt simulation

Enabling Functional Integration



Innovation Manufactured

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Thank You