



SEMICONDUCTOR

Enabling Analog Integration

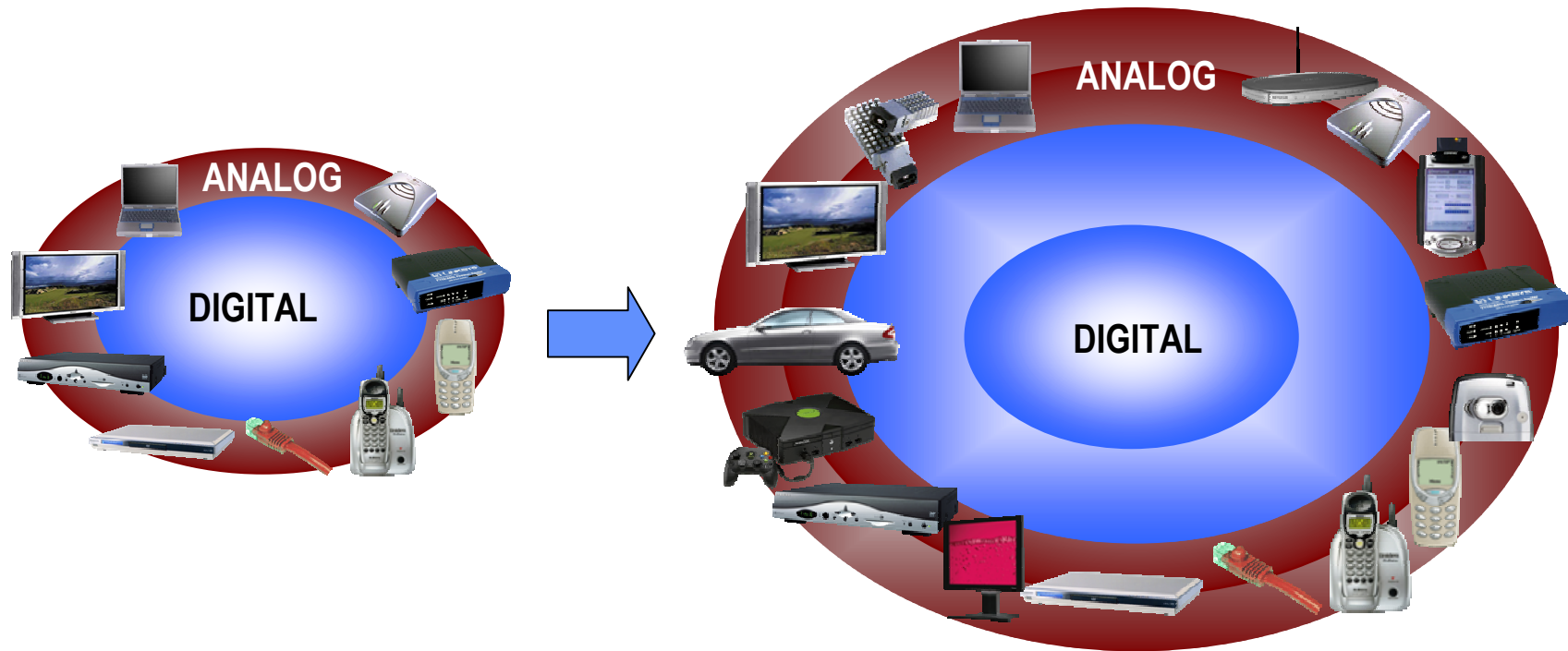
Paul Kempf

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

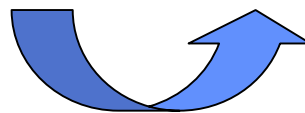
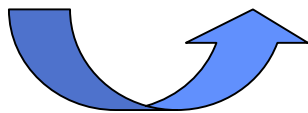
Analog Modem

Ethernet (DSL / Cable)

WLAN 802.11a/b/g

Bluetooth

WiMax, UWB ...



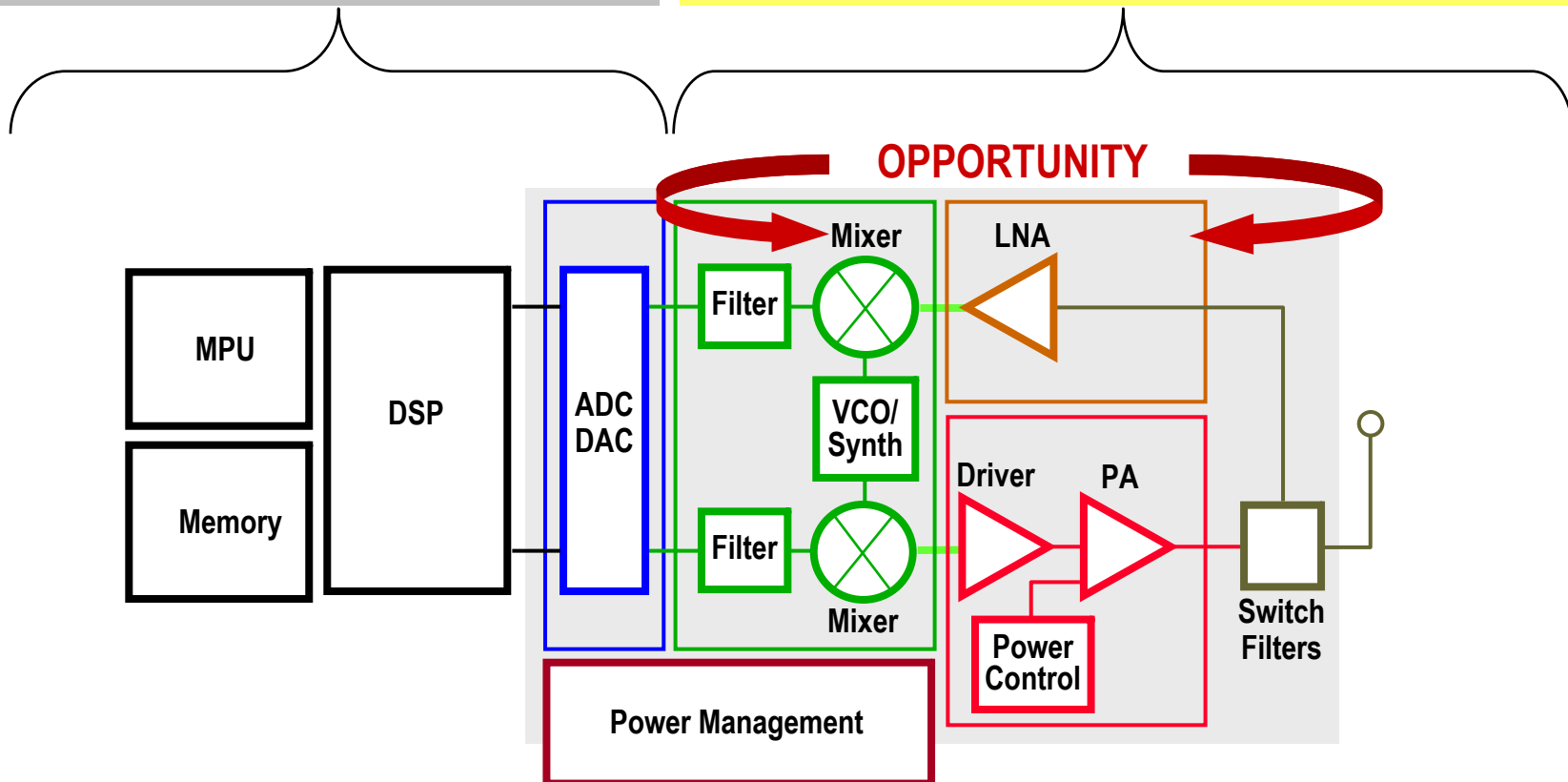
Integrated Functions for Added Value

Digital Integration

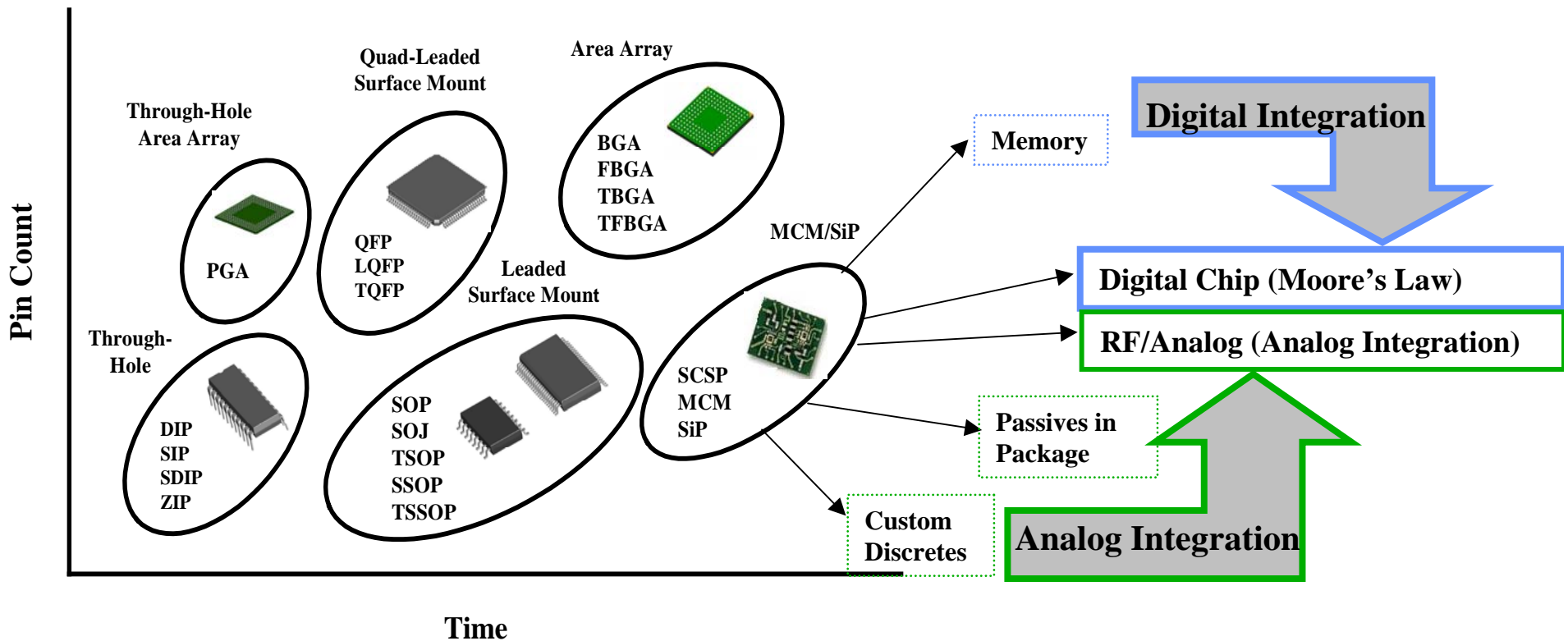
- CMOS process scaling enable high gate counts for digital SoC

Analog Integration

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



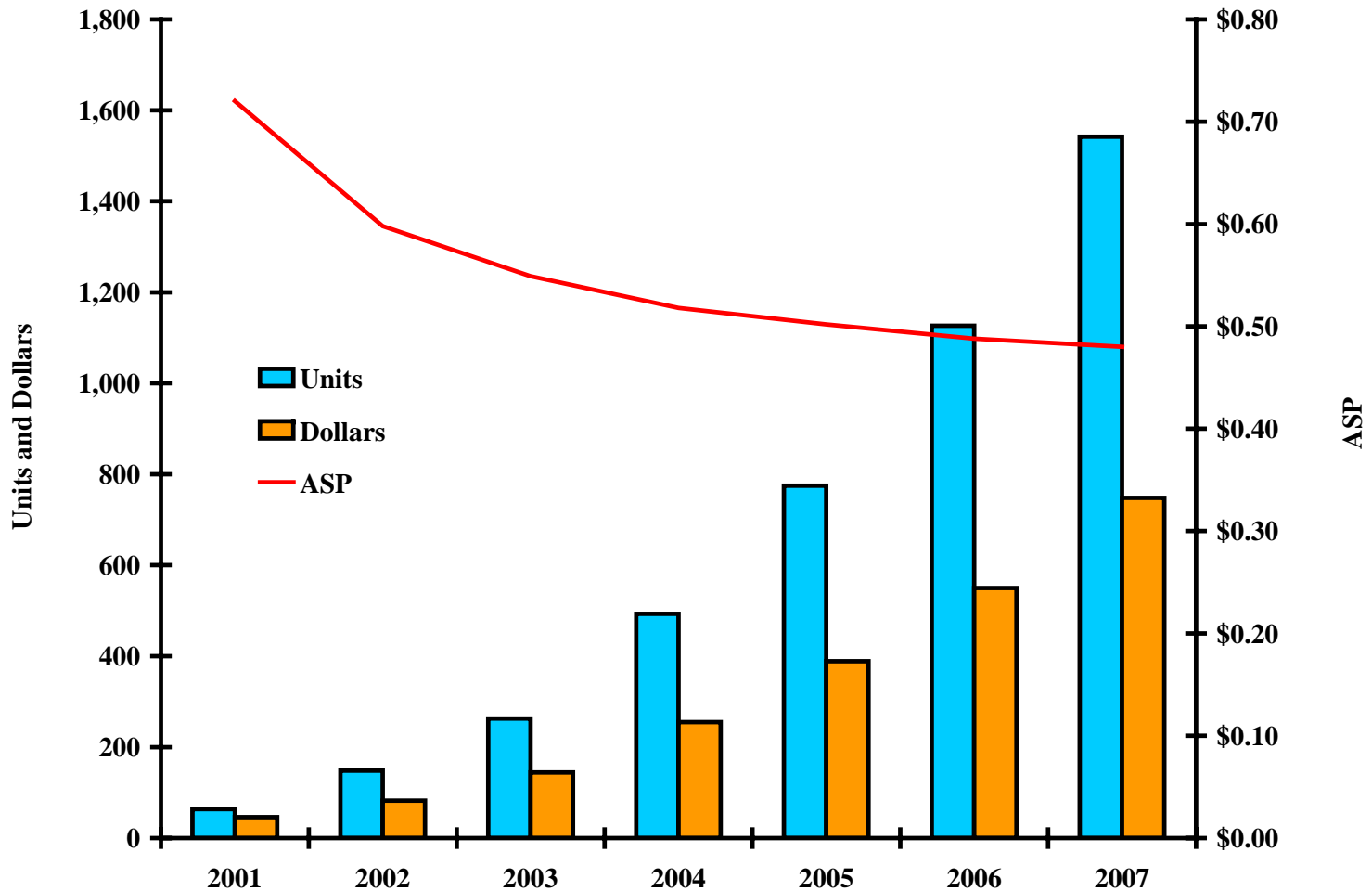
System in a Package (SiP) Progress



Source: Semico

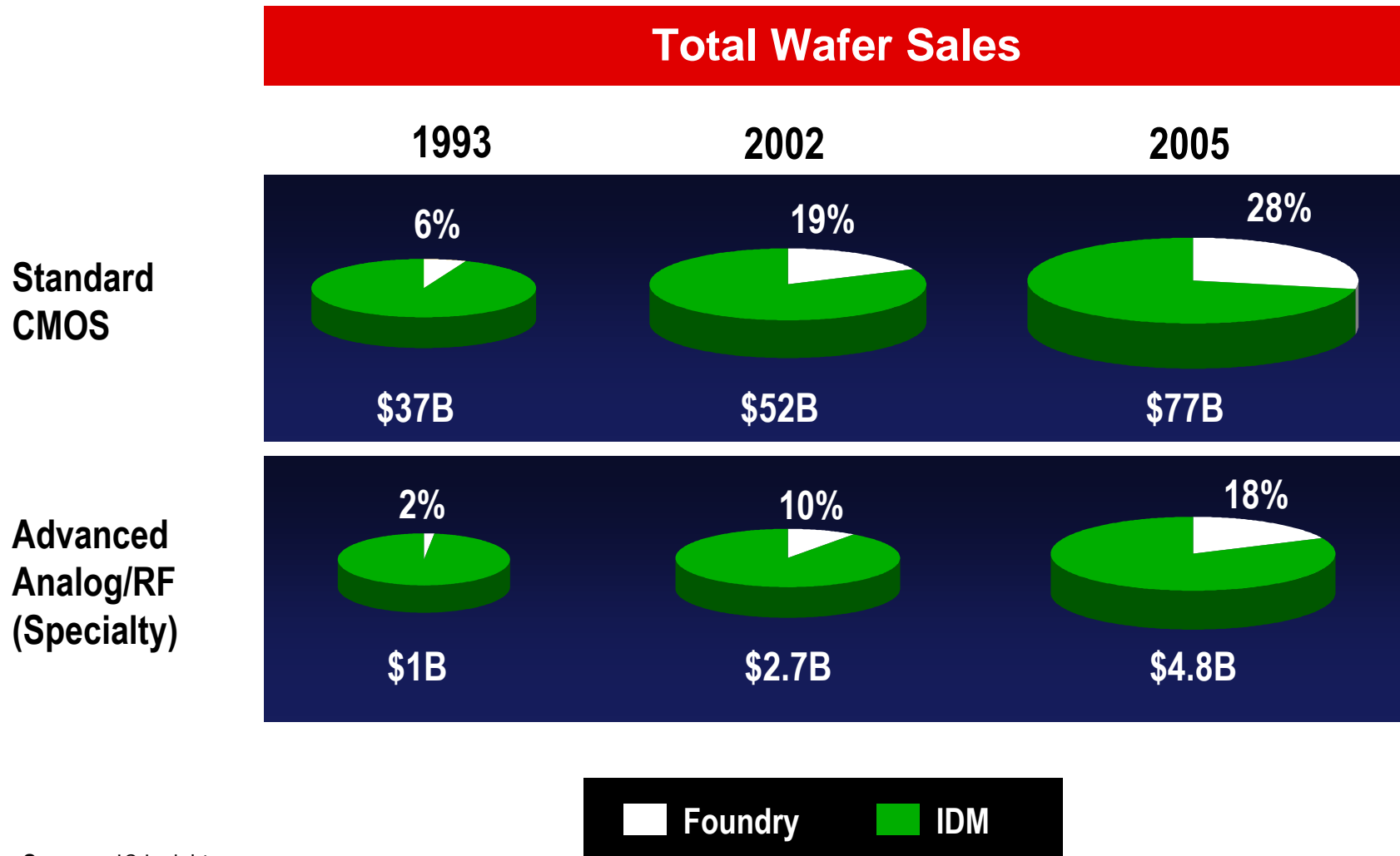
SiP Growth as the Leading Indicator

SiP Packaging Sales (Units in Millions, Dollars in Million\$US)



Source: Semico

Outsourcing to Reduce Cost



Source: IC Insights

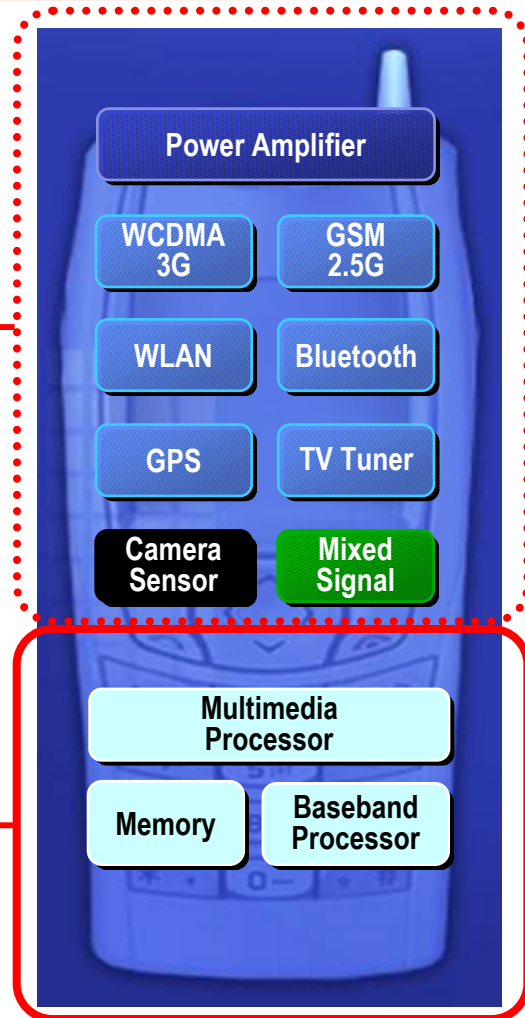
Analog/RF Functions Increasing

Cell Phone Example

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

Specialty
Silicon

Standard
CMOS



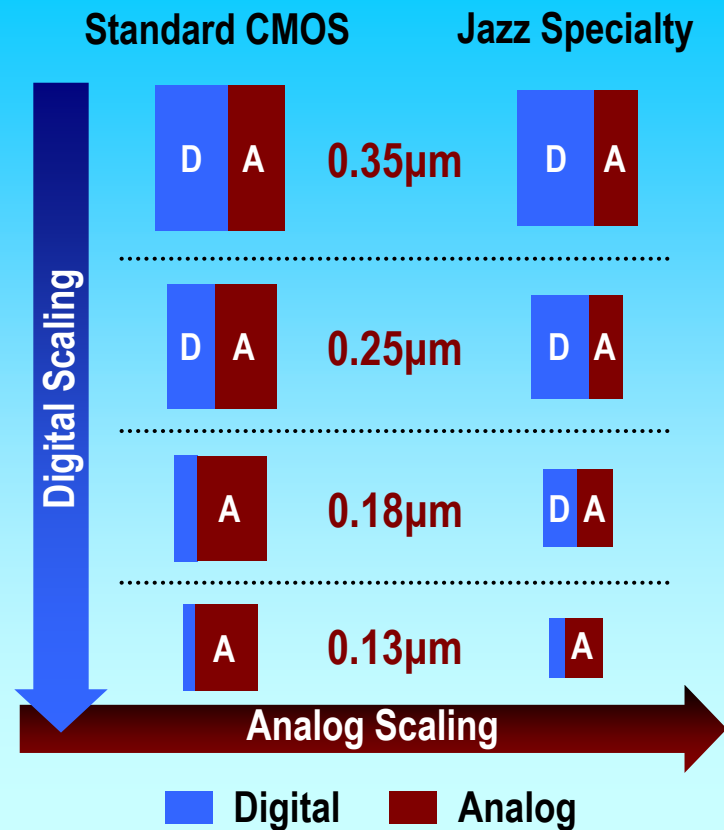
Analog/RF functions increasing in multiple consumer, wireless applications

Performance/Cost Optimization

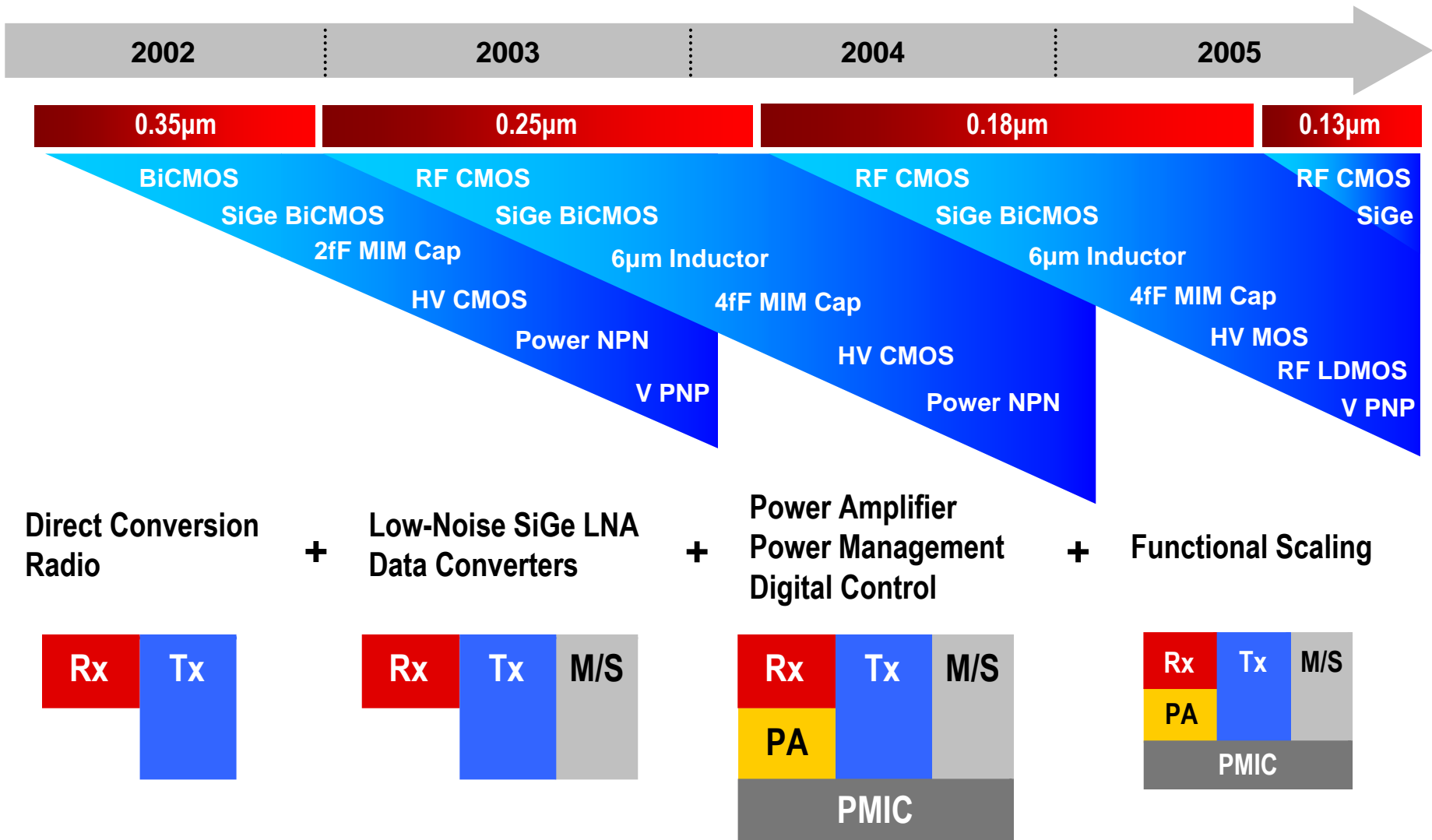
The Advantages of Focusing on Analog/RF Processes

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

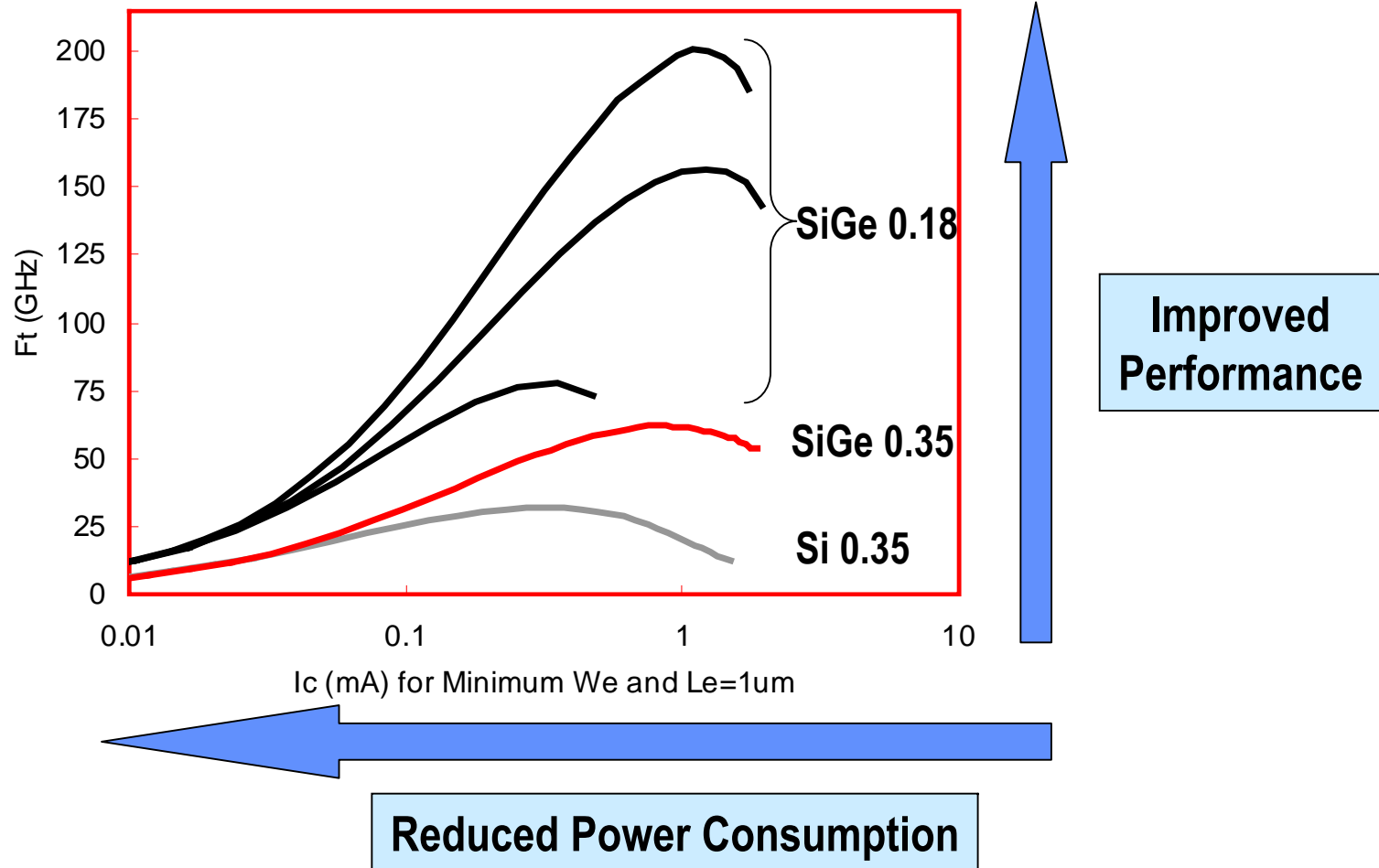
Addressing Both Digital and Analog Scaling



Modular Technology Enables Analog Sub-System Integration

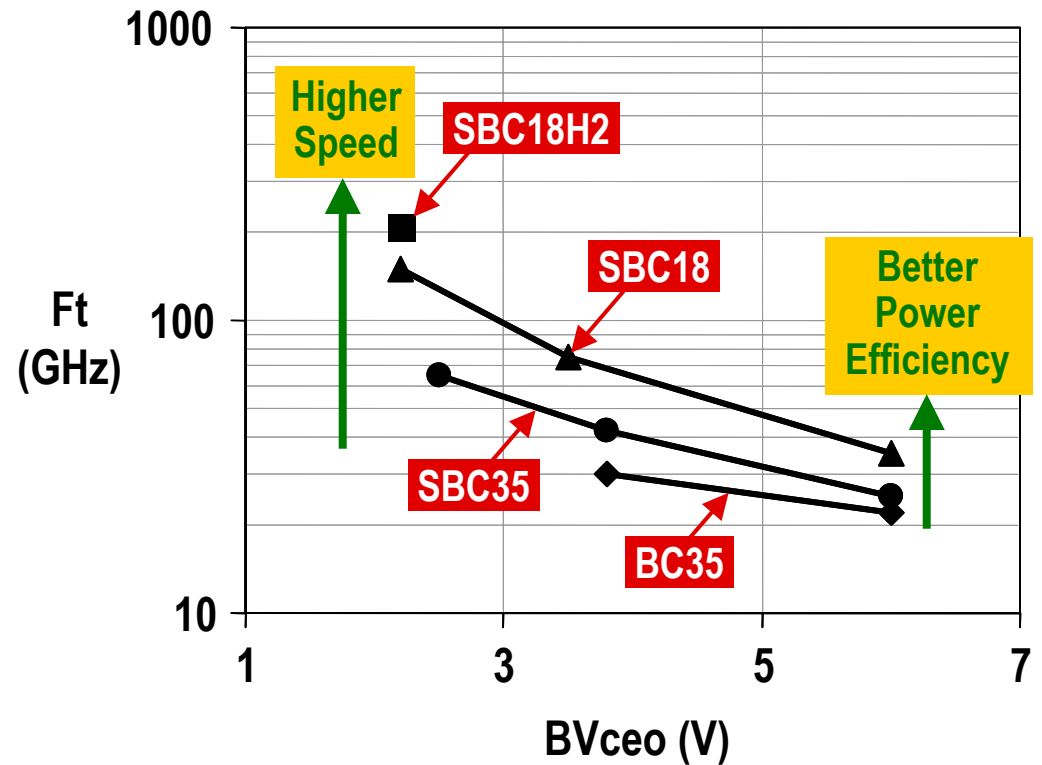
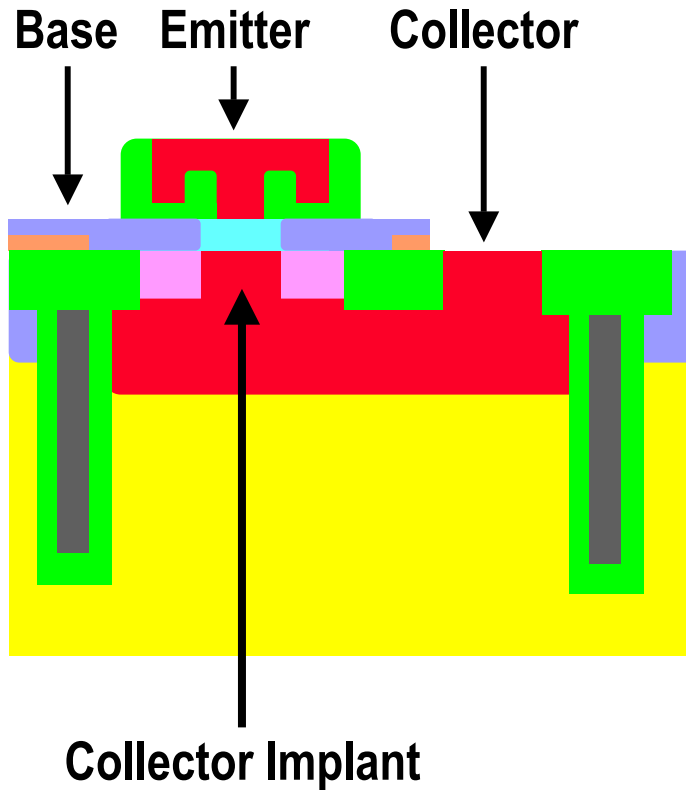


Example: Bipolar Modules



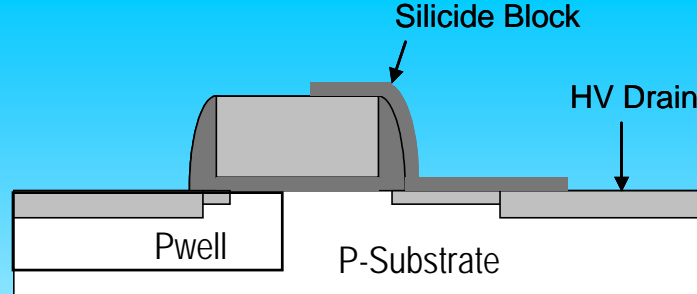
Analog technology can also provide performance/power consumption advantage

Power Amplifier Integration in SiGe BiCMOS



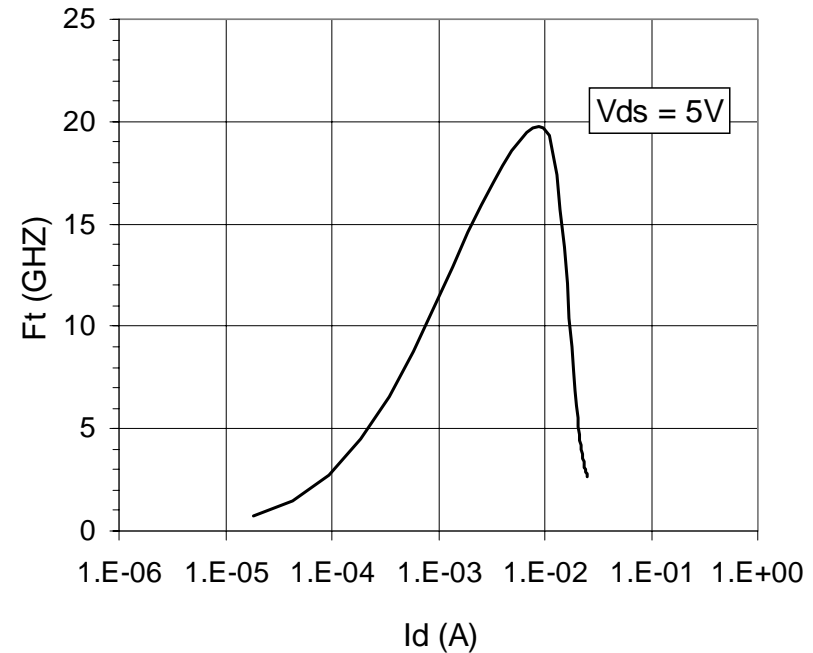
Power Integration in 0.18 μm CMOS

RF LDMOS

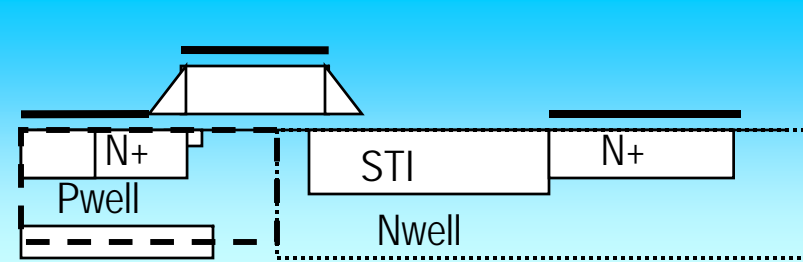


High Performance

- F_t **20GHz**
- R_{on} **< 4 Ohm-mm**
- BV_{dss} **> 15V**



Extended Drain MOS

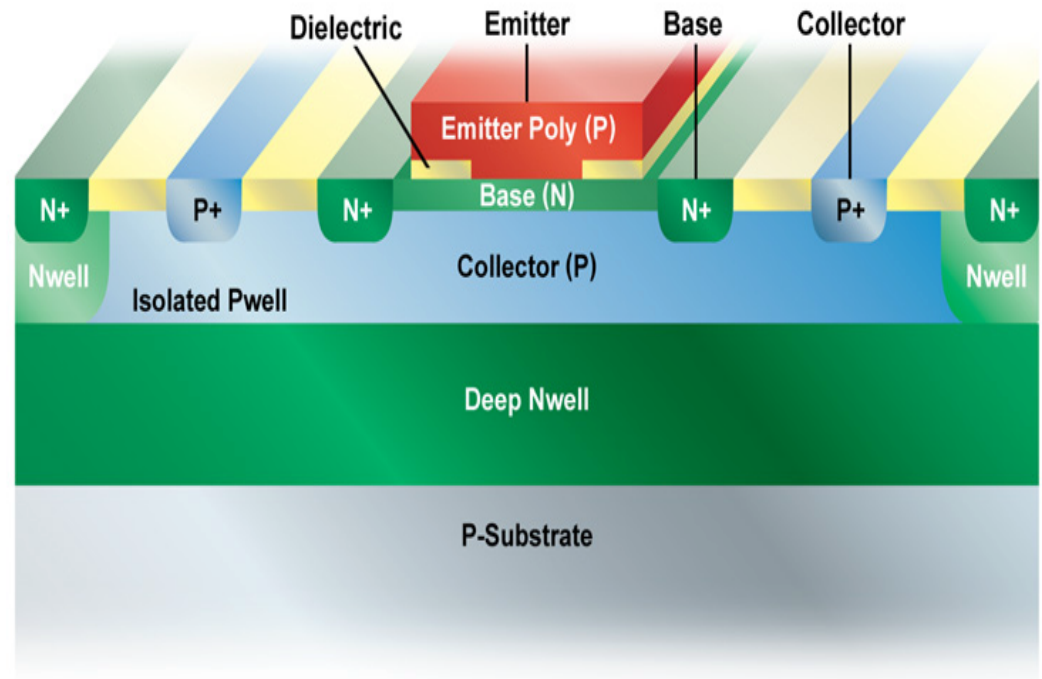


Power Management Options

- V_{gs} **1.8 3.3 5 12**
- V_{ds} **1.8 3.3 5 12 20 40**

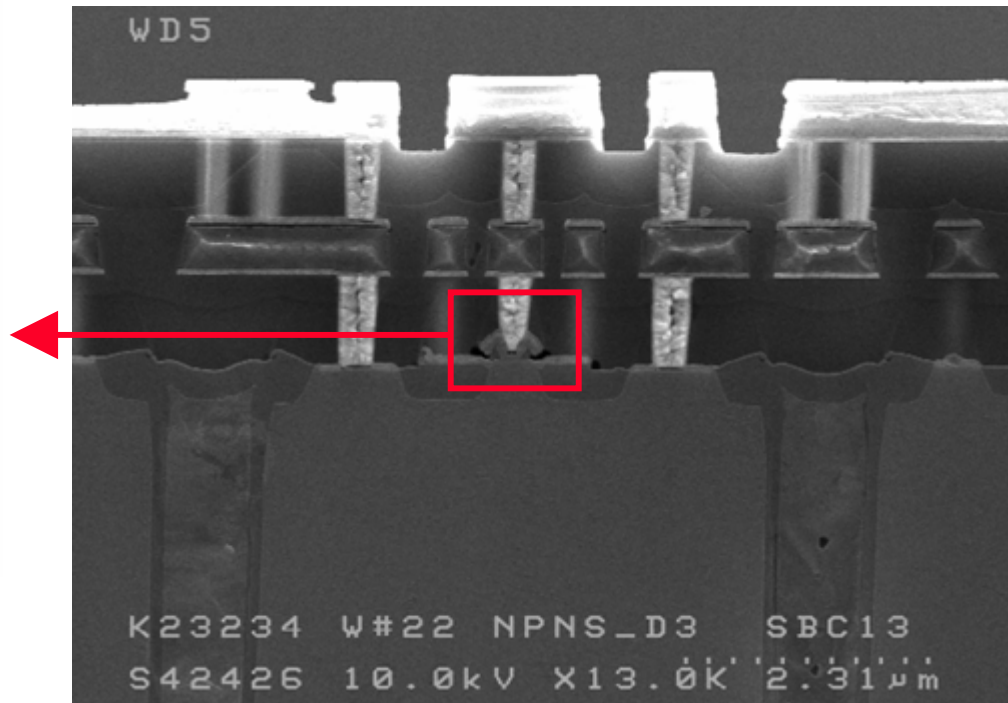
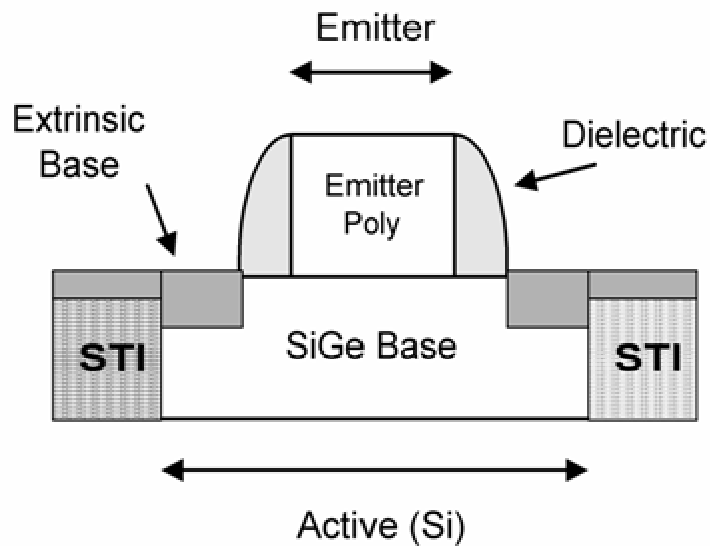
Vertical PNP Integration

- 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

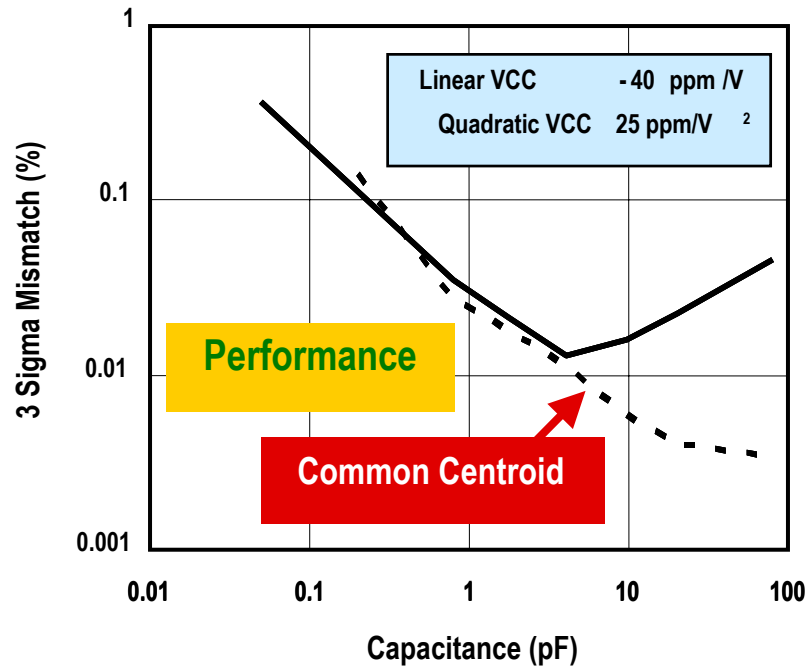
Ultra-High Performance: 200GHz SiGe BiCMOS



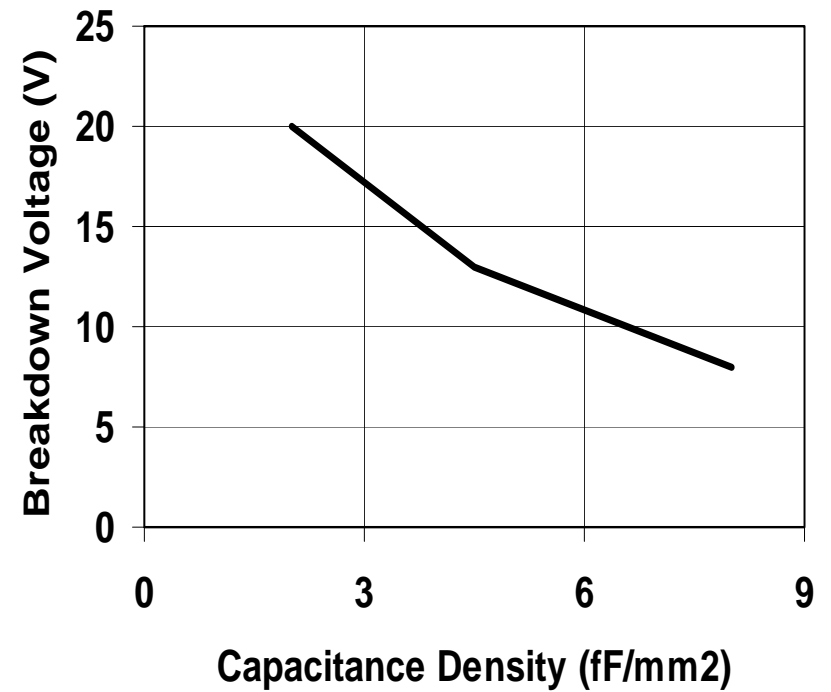
- 200/200GHz Ft and Fmax
- Shallow and Deep Trench Isolation
- SiGe epitaxial base (vertical scaling)
- Self-aligned emitter integration (lateral scaling)

Scaling Linear Capacitors

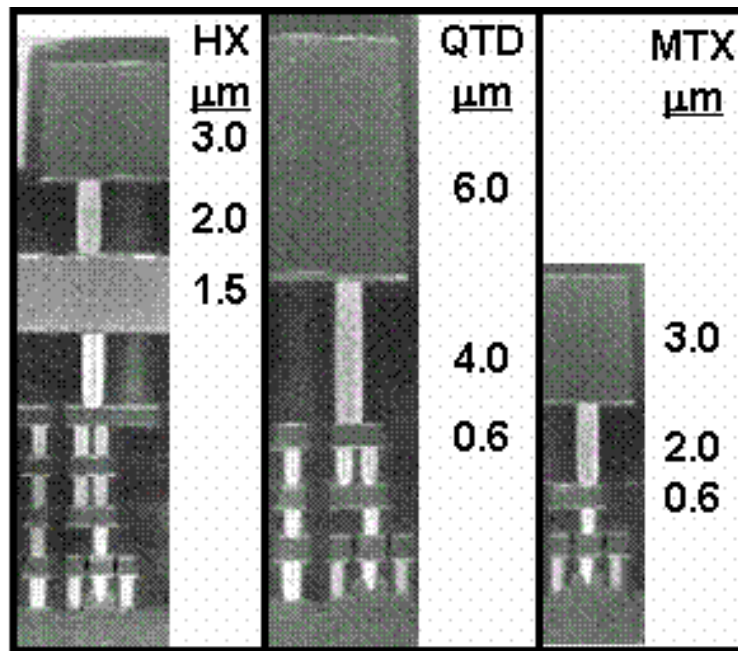
2fF/μm² MIM Capacitor



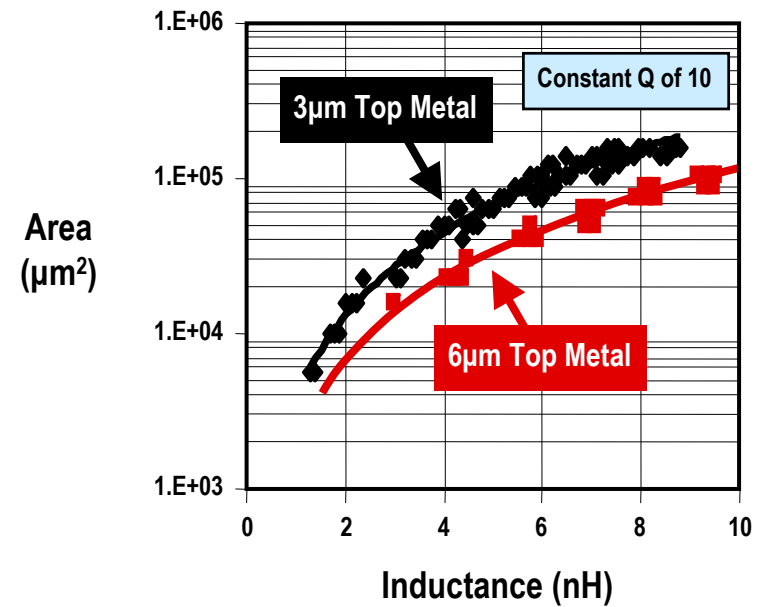
4.5-8 fF/μm² High K MIM



Integrated Inductors



Inductor Scaling



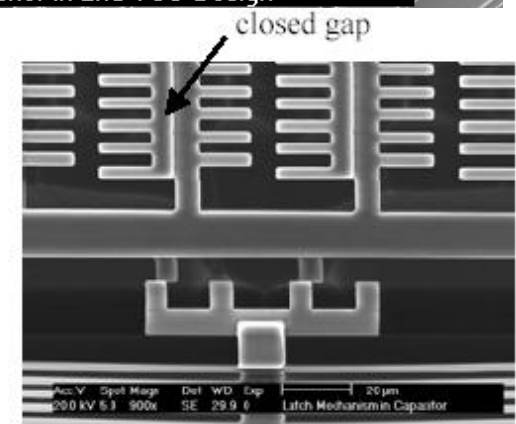
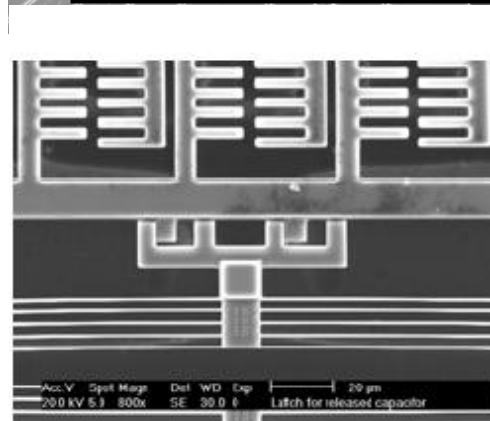
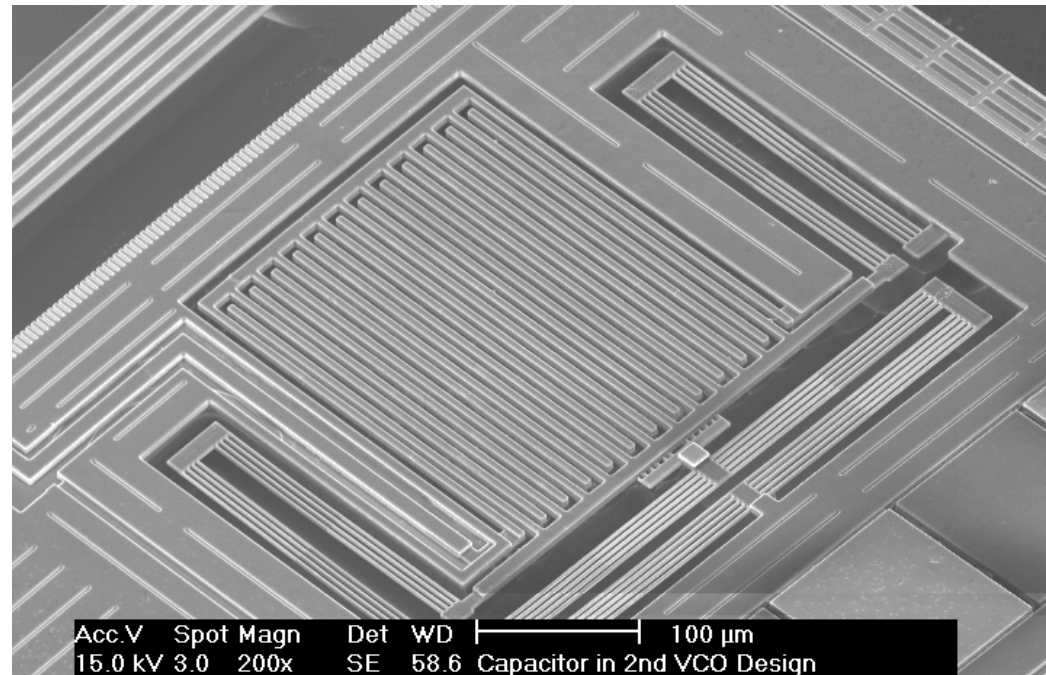
Thick metal to improve Q or reduce inductor area

Integrated MEMS

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

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

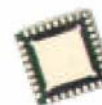


Single chip SoC
RF to Baseband IC
Tuner and DeMod Integration

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

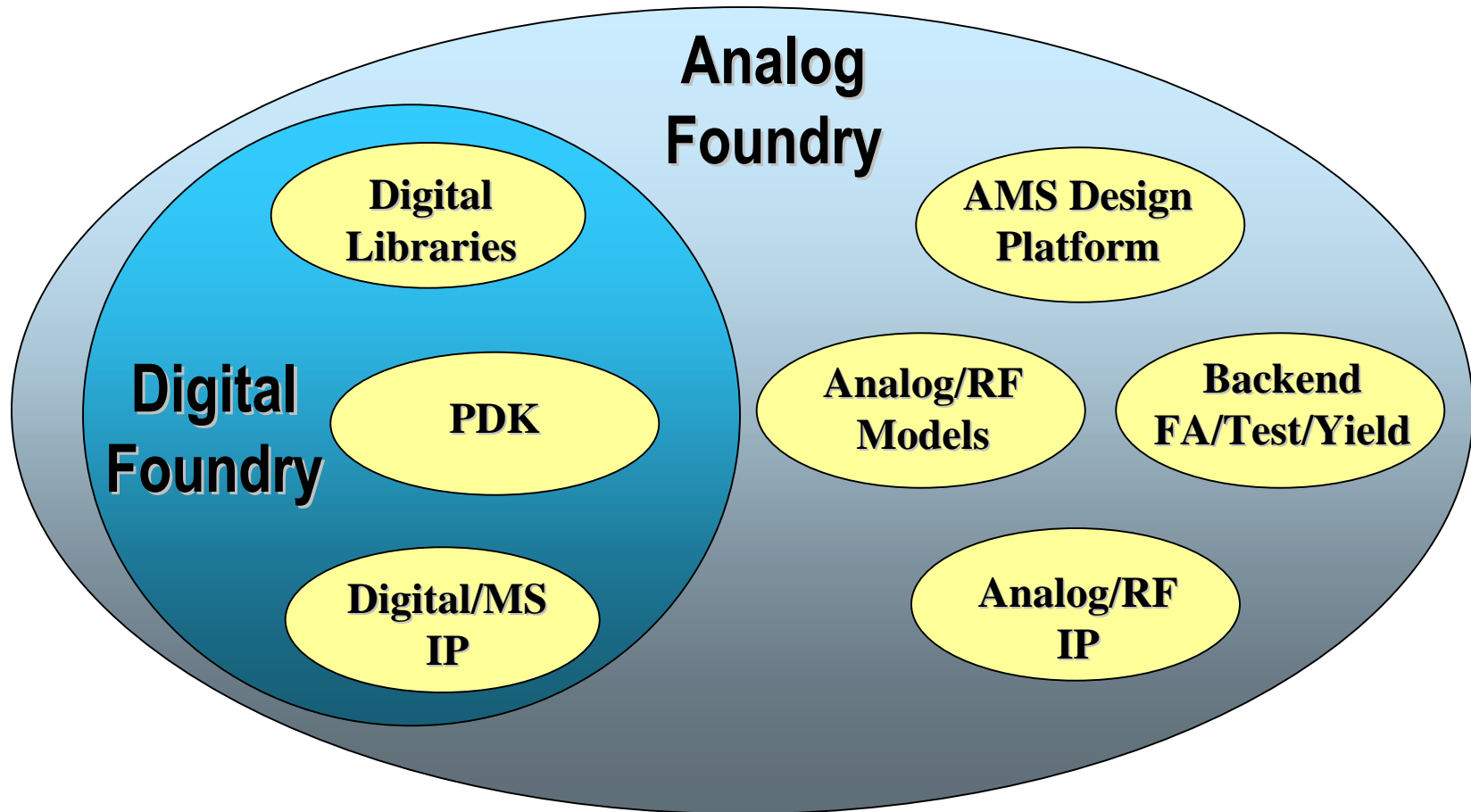


Single chip 802.11b/g
Transceiver, VCO
PA integration



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

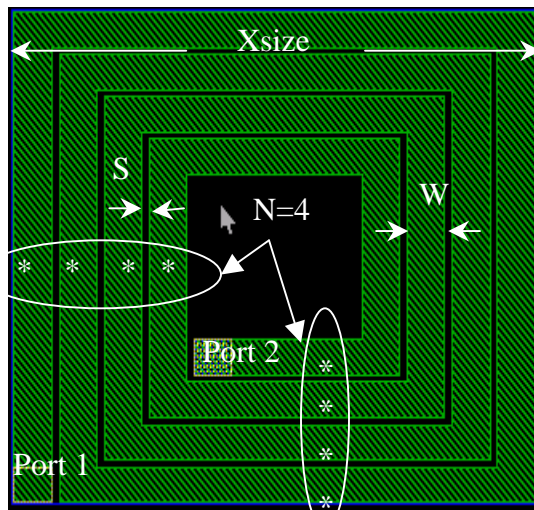
Analog Foundry: Design Support



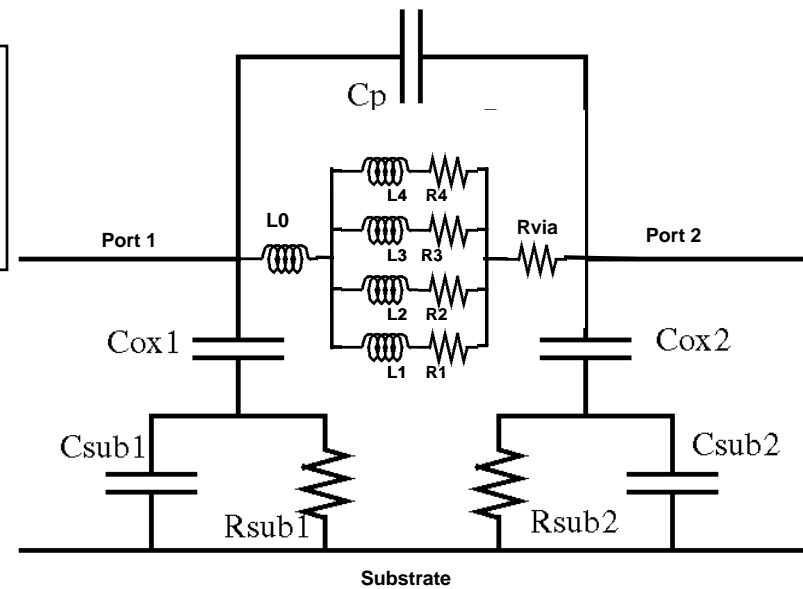
Higher level of investment in design support required in an Analog Foundry

Scalable RF Inductor Model

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



Sheet Resistances
Dielectric Constants
Layer Thicknesses
...



Scalable model enables optimization of inductor area/performance

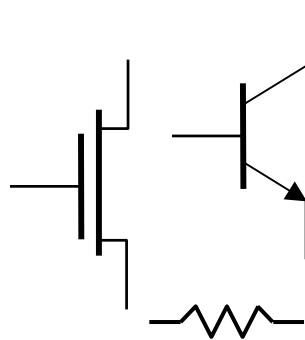
Statistical Modeling Infrastructure

Implication of Process Variation → Product Yield

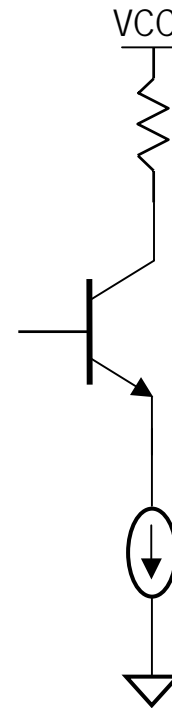
Process Parameters
(e.g., T_{ox} , Doping, CD)
 p^f



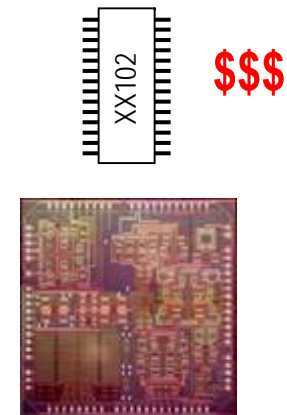
Device Parameters
(e.g., I_{dsat} , V_{th} , Beta, F_t)



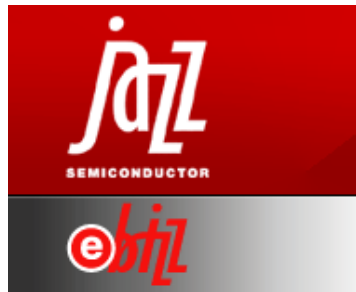
Circuit Performance
(e.g., Gain, NF)



Product Performance
(Yield, Sales)



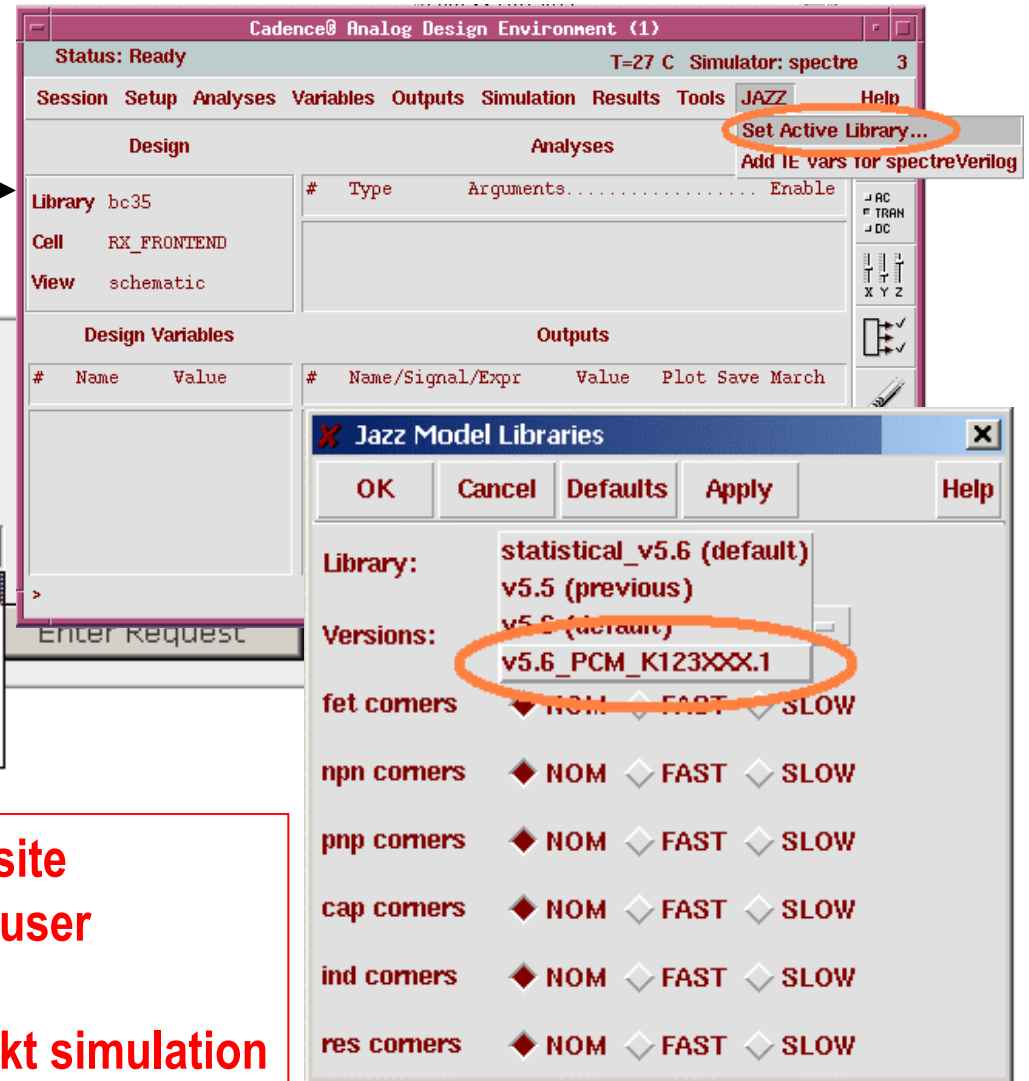
Wafer / Lot / Fab Specific Models



- ▶ File Exchange
- ▶ Tape Out System
- ▼ Manufacturing Status
 - WIP Query
 - Part Summary
 - Order Summary
 - Shipments
 - Reports

PCM Based Model Extraction

Lot	K123XXX.1
Process	BC35MW
Wafer QTY	5
Generate Models From	Entire Lot Entire Lot Wafer 1 Wafer 2 Wafer 3 Wafer 4 Wafer 5



The screenshot shows the Cadence Analog Design Environment (ADE) interface. The main window displays design parameters for a project named 'bc35'. The 'Library' is set to 'bc35', the 'Cell' is 'RX_FRONTEND', and the 'View' is 'schematic'. The 'Design Variables' table is empty. The 'Outputs' table is also empty. A 'Jazz Model Libraries' dialog box is open, showing a list of libraries and versions. The 'Library' field is set to 'statistical_v5.6 (default)'. The 'Versions' list includes 'v5.5 (previous)', 'v5.6 (default)', and 'v5.6_PCM_K123XXX.1', which is highlighted with a red circle. Below the versions, there are radio buttons for different corner models: 'fet comers', 'npn comers', 'pnp comers', 'cap comers', 'ind comers', and 'res comers'. Each corner model has three radio buttons for 'NOM', 'FAST', and 'SLOW'.

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

A world map in a light blue and grey color scheme serves as the background. In the center, there is a dark blue rectangular box containing white text. Below this box is a yellow rectangular box containing black text. Two large, blue, curved arrows originate from the sides of the dark blue box and point towards the yellow box, suggesting a flow or integration between the two concepts.

Pure-Play Foundry
Streamlined Supply Chain
Seamless Manufacturing
Modular silicon technology
Complete design platform
Economies of scale

Analog Foundry

Jazz Semiconductor



For more information visit:

www.jazzsemi.com

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info@jazzsemi.com

Thank You