Power Management Challenges

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ISSCC, Feb. 2001, Keynote

Patrick P. Gelsinger
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"Ten years from now, microprocessors will run at 10GHz to 30GHz and be capable of processing 1 trillion operations per second -- about the same number of calculations that the world's fastest supercomputer can perform now.

"Unfortunately, if nothing changes these chips will produce as much heat, for their proportional size, as a nuclear reactor. . . ."

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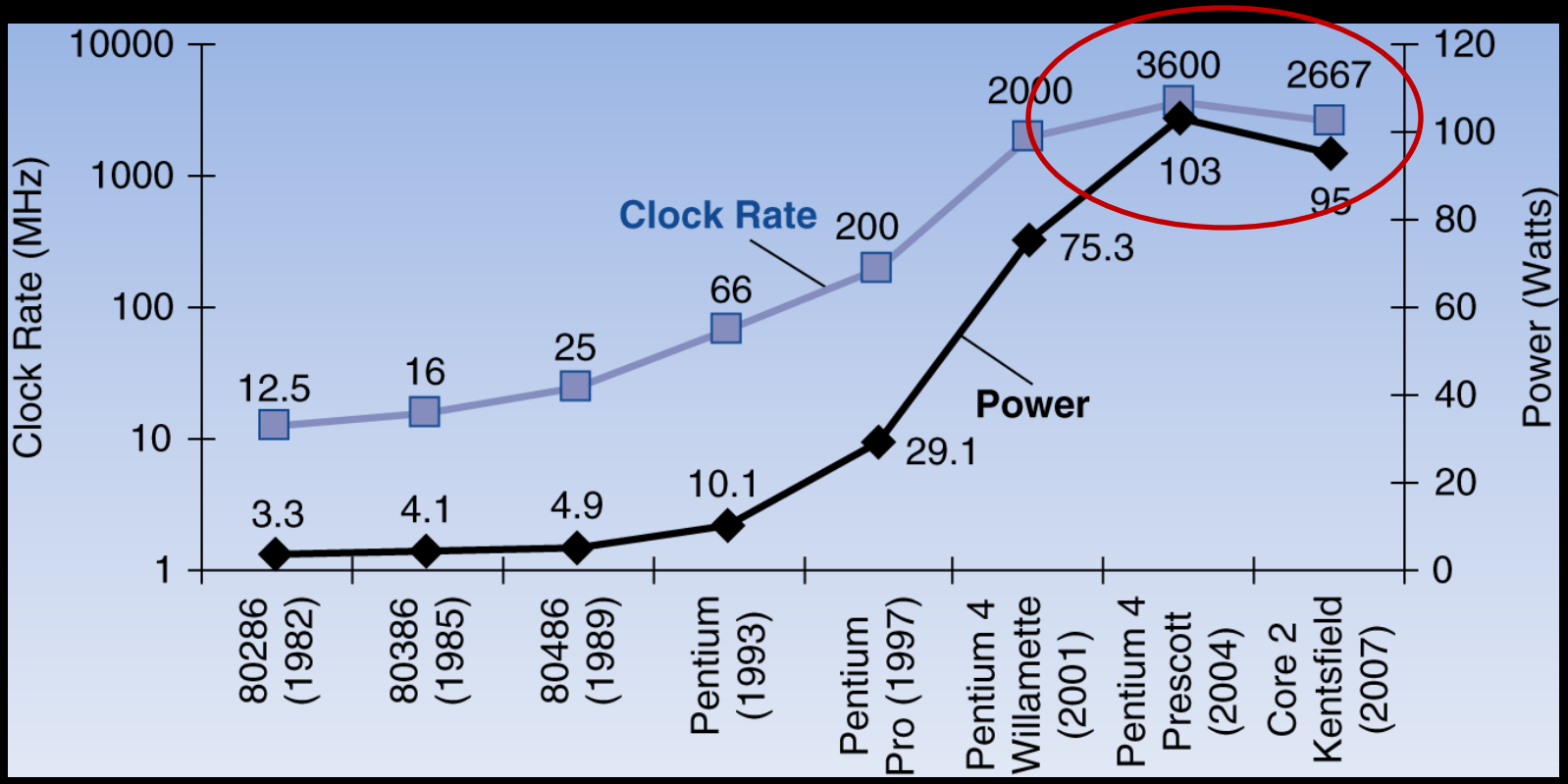
Power Trends



D. Patterson and J. Hennessey
Computer Organization

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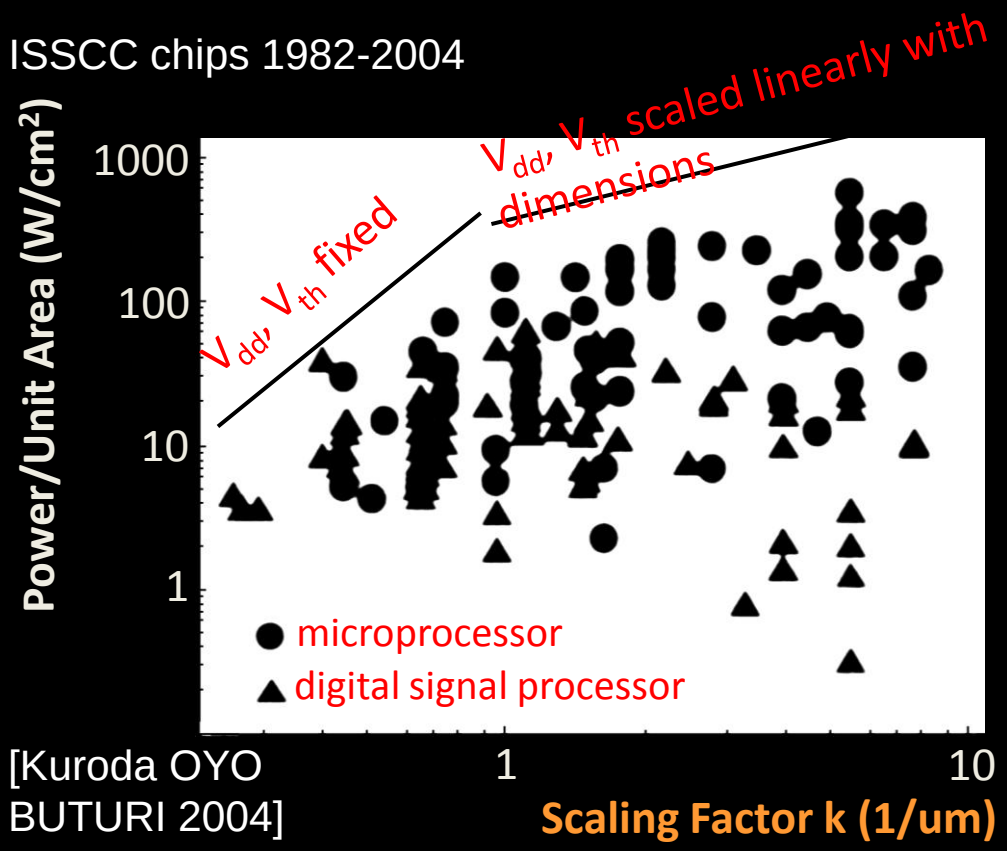
Increasing Power Density

- As device dimensions (W, L, Tox) scaled down by a factor k, for high performance
- V_{dd} and V_{th} fixed → power/unit area $\propto k^3$
- V_{dd} and V_{th} scaled down linearly → power/unit area $\propto k^{0.7}$



Chinnery and Keutzer, DAC 2005

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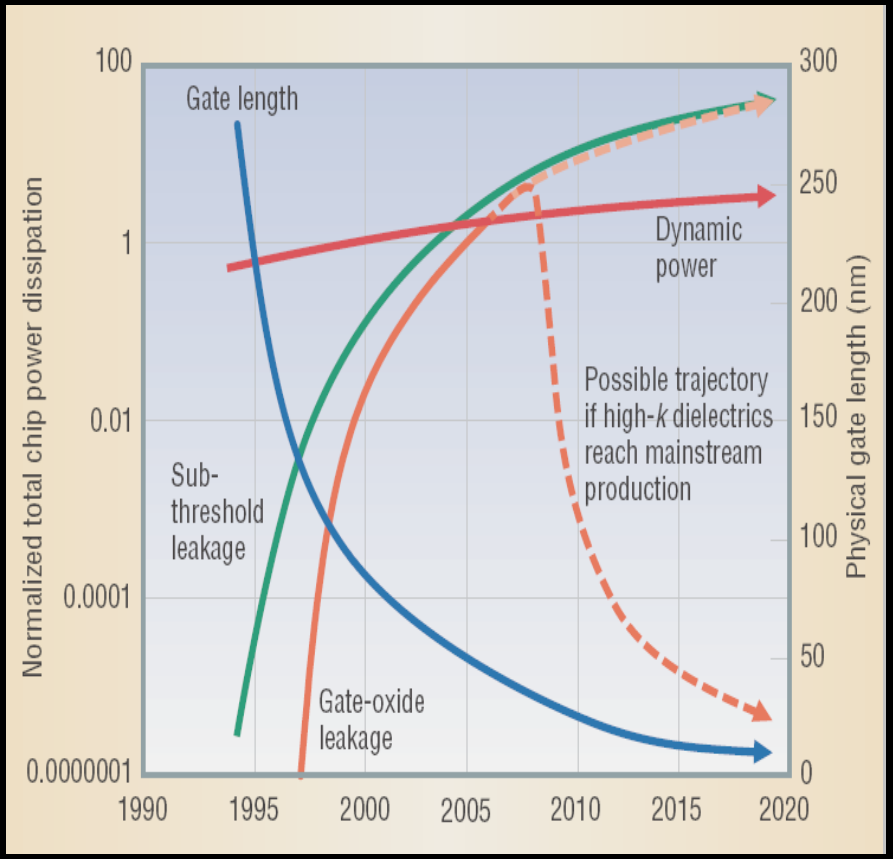
Power Trends

- Power: Dynamic , Leakage
- Dynamic: Activity, Frequency, Capacitance, Supply Voltage (V)
- Dynamic Power α V^2
- Leakage : Sub-threshold , Gate-Tunneling
- Leakage Power α V, e^{-Vt}
- Manage: Dynamic, Active Leakage, Standby Leakage



Power Trends, IEEE D&T, 2003

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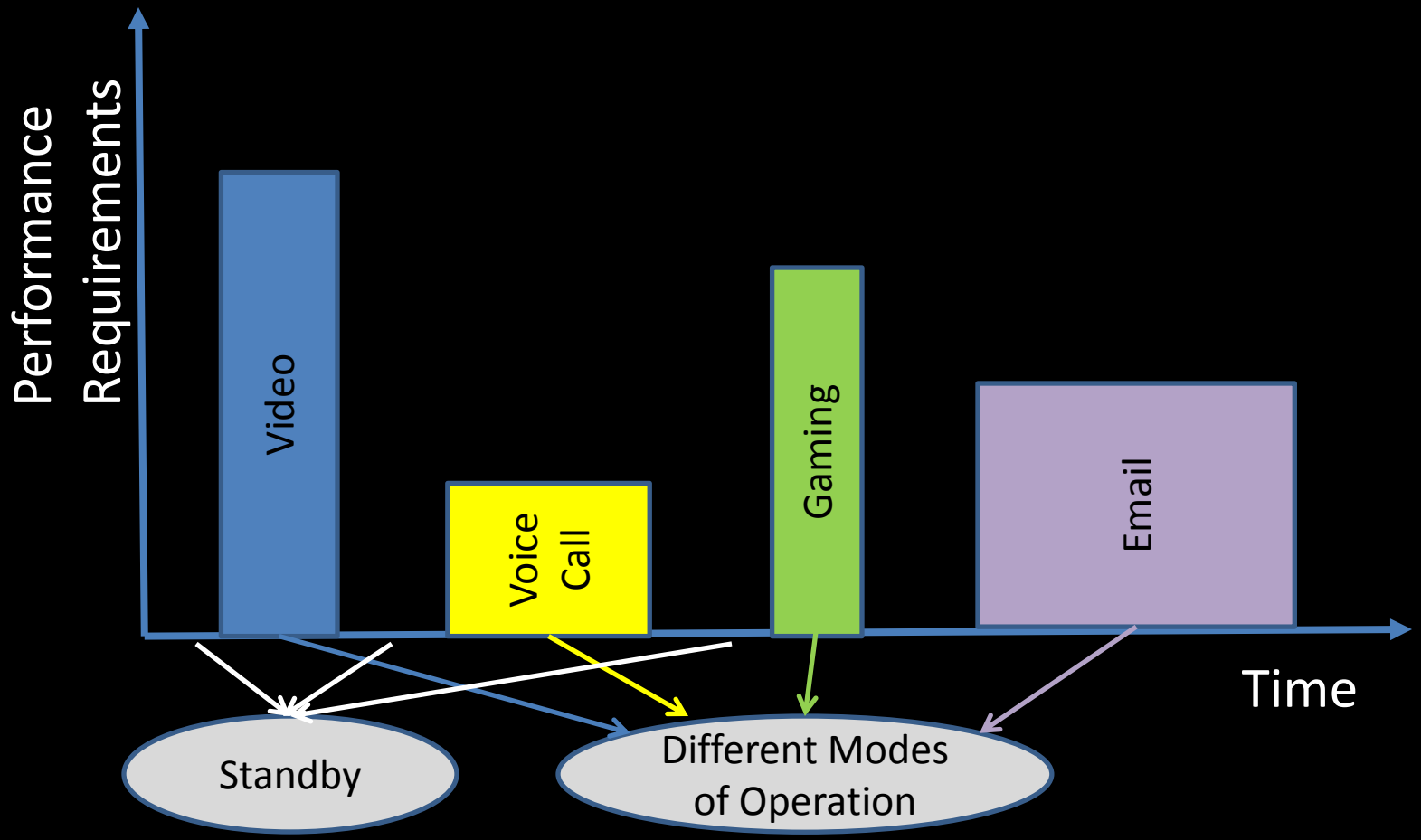
Power Consumption in a Mobile Phone



Voltage is the key variable to manage power in all modes

Power Types Targeted

Technique			Power Being Managed		
			Standby Leakage	Active Leakage	Dynamic
Power Gating	PG				
Retention with PG	RPG				
Multiple Supply Voltages	MSV				
Dynamic Voltage Scaling	DVS				
Adaptive Voltage Scaling	AVS				
Multi-Threshold CMOS	MTCMOS				
Adaptive Body-Biasing	ABB				

Primary

Secondary

Verification Impact

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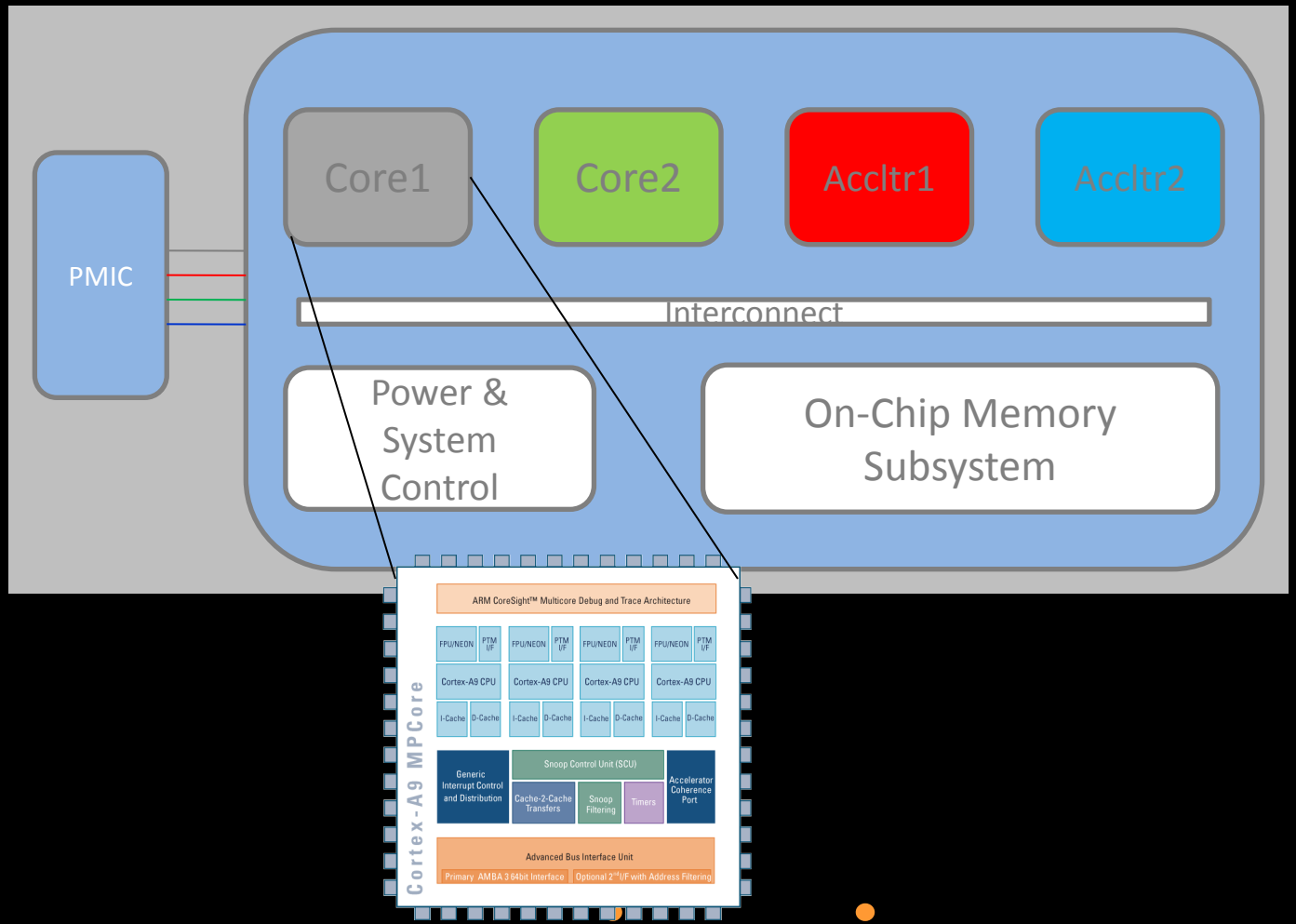
Typical Power Managed SoCs



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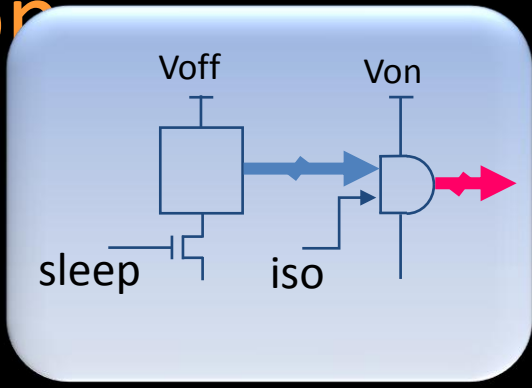
Infineon Baseband Processor – ISSCC06

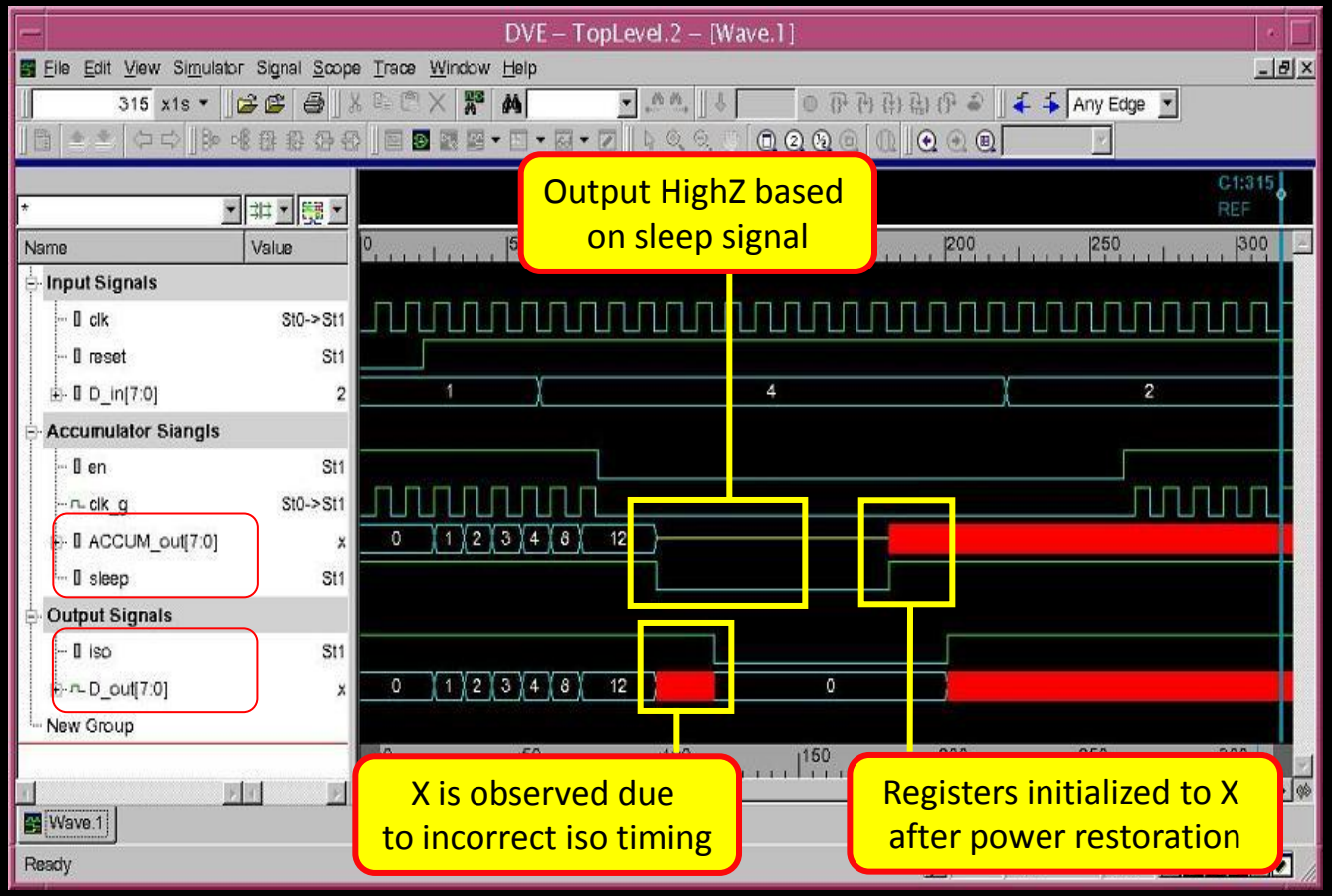
Application	Settings	ARM926 MHzX26	DSP MHzX26	Combo*	Peripheral Bus 1	Peripheral Bus 2	Analog	Standby Domain
GSM Voice	6.60-AMR	f1	f2	On	Off	Off	On	On
GSM Voice	6.60AMR+Handsfree	f1	f2a	Off	Off	Off	Off	On
GSM Idle	Sleep Mode	0	0	On	Off	Off	On	On
GSM Idle	Paging	f1	f1	On	Off	Off	On	On
Data Down.	HSDPA 3.6Mbps	f4	0	On	On	Off	Off	On
Data Down.	UMTS PS 384 kbps	f2	0	On	On	Off	Off	On
Data Down.	E-GPRS	f2	f3	On	On	Off	On	On
Video Enc.	MPEG-4 20fps QVGA	f5	f2	On	On	On	On	On
Video Tel.	MPEG-4 15fps QCIF	f3	f2b	On	On	On	On	On
Music Repl.	MP3	f1	f1	On	Off	Off	On	On
Music Repl.	MP3 + Paging	f2	f1	On	Off	Off	On	On

Challenge: Power Verification

Incorrect Isolation Sequence

Synopsys VCS





Intended Behavior

1. Gate the clk
2. Assert iso to 0
3. Assert sleep to 0

Actual Behavior

1. Gate the clk
2. Assert sleep to 0
3. Assert iso to 0

Control signal sequence error is discovered due to X propagation

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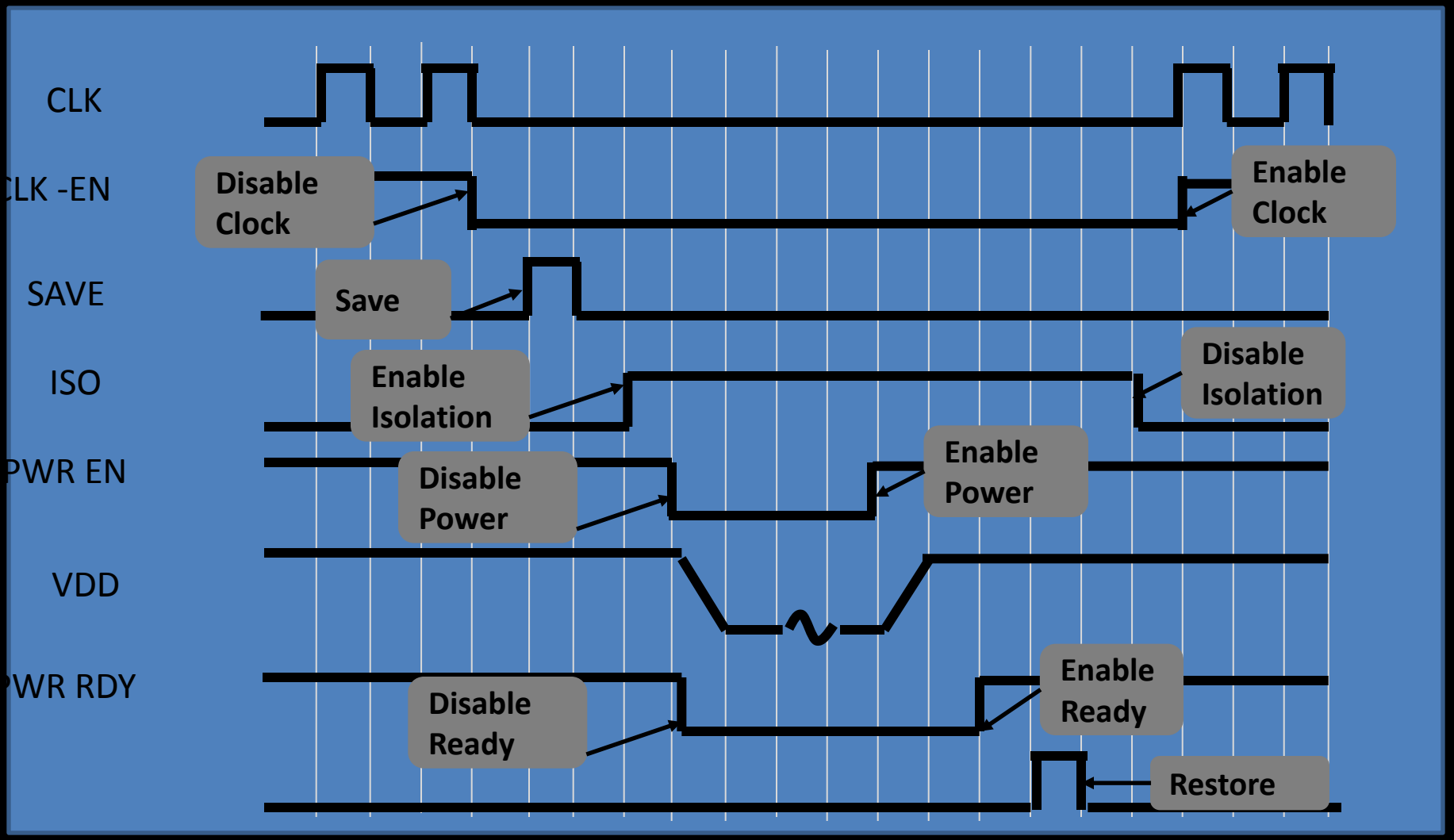
Power Verification



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ITRS Process Technology Roadmap

Planar Bulk CMOS

Year	2009	2010	2011	2012	2013	2014	2015	2016
Physical Lgate	32	29	27	24	22	20	18	17
Supply Vdd	1	0.97	0.93	0.9	0.87	0.84	0.81	0.78
Threshold Vt,sat	0.29	0.29	0.29	0.29	0.29	0.29	0.3	0.3

UTB FD

MG i.e., FinFETs

Challenge: Power Management Techniques

- Active Power: Voltage Scaling and Multi-Vt
- Limited/Reduced performance from fixed Vt, and doubling number of transistors per node
- Power density becomes a bigger issue
- Variability makes leakage management difficult [i.e., 20% of chips with higher leakage]

Challenge: Power Modeling

- System-level modeling is key to optimization
- System-level modeling is difficult
  - Power dependent on physical knowledge
- Regular structures help (FPGAs)
- More efficient utilization of existing PM techniques requires system-level design/ visualization
- Hardware/Software partitioning, Low Power Software

Low Power Software Development

- Power gains due to parallelization much better than performance gains: assumes voltage scaling – power corollary to Amdahl's Law
- Parallel software is a challenge
  - Amdahl's Law [Sky is falling!]
  - Programming has its own challenges
- Parallel software is the key to low power software
  - Slow and steady wins the (LP) race
  - Parallel software with voltage scaling controls

Summary

- Doubling of the cores per generation becomes an issue given limited voltage scaling
- Power management techniques challenged in scaling scenario
- Power modeling remains a challenge
- Low Power Software is a key to power management going forward