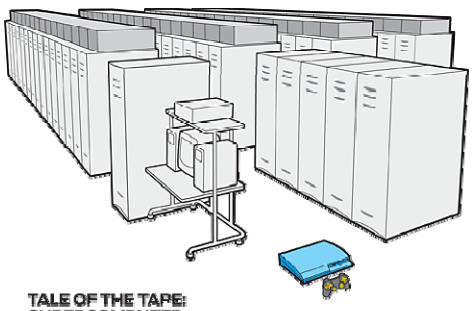
Computer Chips are Getting faster Every Year, Right?

Nader Bagherzadeh
EECS
UCI



TALE OF THE TAPE: SUPERCOMPUTER VS. GAME CONSOLE

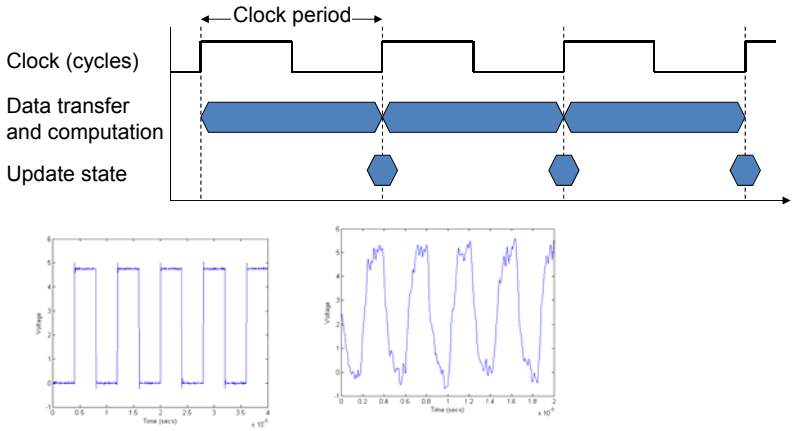
	SANDIA LAB'S ASCI RED	SONY PLAYSTATION 3
DATE OF ORIGIN	1997	2006
PEAK PERFORMANCE	1.8 teraflops	1.8 teraflops*
PHYSICAL SIZE	150 square meters	0.08 square meter
POWER CONSUMPTION	800 000 watts	<200 watts

* For GPU, CPU adds another 0.2 teraflops.

2

CPU Clocking (Synchronous)

- Operation of digital hardware governed by a constant-rate clock



3

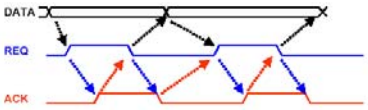
Auto Manufacturing Assembly Line by Henry Ford in 1913

Pipelining is Temporal Parallelism! What does it Improve?

4

Why Not a Clock Free Design (Asynchronous)

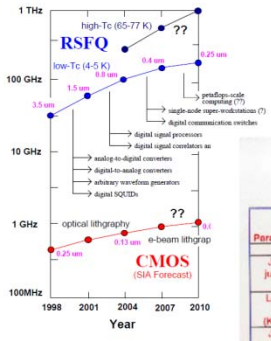
- Not as efficient when it comes to performance
- Our design tools are better suited for the synchronous design
- Will be lower power than synchronous, why?



4 phase

5

RSFQ Roadmap (VLSI Circuit Clock Frequency)



February 16, 1999 Petaflops II - HTMT Architecture

Stony Brook

RSFQ TECHNOLOGY ROADMAP

Technology / Parameters	HYPRES upgrade	SUNY upgrade	VLSI (shunted)	VLSI (unshunted)
Year	1998	2001	2004	2007
Josephson junction size (μm)	3.5	1.5	0.8	0.5
Logic circuit density (Kgates/cm²)	10	30	100	1,000
Josephson current density (kA/cm²)	1	6.5	20	50
Specific capacitance (aF/μm²)	45	60	67	75
I_cR_n product (mV)	0.3	0.6	1.0	1.5
SFQ pulse duration τ (ps)	4	2	1.2	0.8
Clock frequency f_{max} (GHz)	150	300	500	700
Speed of LSI circuits (GHz)	30	60	100	150
Average power (μW/gate)	0.03	0.06	0.1	0.15
Cost per junction (millicents)	100	30	10	1

999

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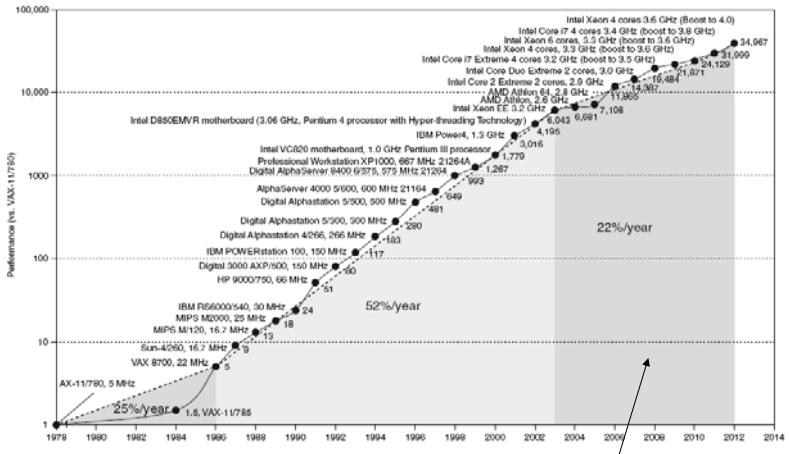
Uniprocessor Performance

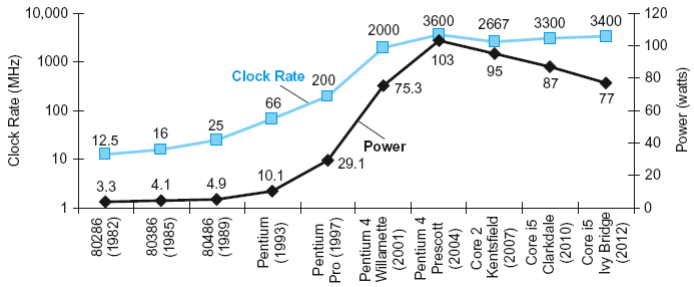
§1.8 The Sea Change: The Switch to Multiprocessors



Constrained by power, instruction-level parallelism, memory latency

Power Trends

§1.7 The Power Wall

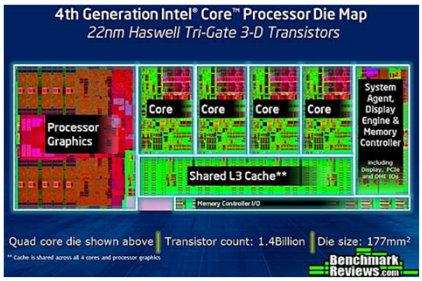


- In CMOS IC technology

$$\text{Power} = \text{Capacitive load} \times \text{Voltage}^2 \times \text{Frequency}$$

Need More Cores, Because Single Cores Reached Their Thermal Limits …

- Single cores reached their limits
  - **Power** consumption (die is too hot, **hotter than a nuclear power plant!)**
  - Reliability
  - Design complexity



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Application Processor in Devices: Comparison

TECHINSIGHTS

	Blackberry Z10	HTC One X+	Apple iPhone 5	Nokia Lumia 928	Samsung Galaxy S4	Apple iPad 4	Microsoft Surface Pro
	Phone	Phone	Phone	Phone	Phone	Tablet	Tablet
Processor	Qualcomm MSM8960	Nvidia Tegra 3	Apple A6	Qualcomm Snapdragon S4	Exynos 5410	Apple A6X	Intel i5-3317U Ivy Bridge
Number of Cores	2	4	2	2	8	2	2
Number of GPU Cores	?		3		3	4	
Baseband Integrated	Yes	Yes	No		No	No	-
Package Connection to DRAM	POP 2 GB LPDDR2	POP 1 GB	POP 1 GB LPDDR2	POP LPDDR2	POP LPDDR3	PUP 512 MB LPDDR2	PUP 512 MB LPDDR3
Cost	$25.12	$30.89	$33.20	$25.12	$ 37.80	$39.54	$40.64

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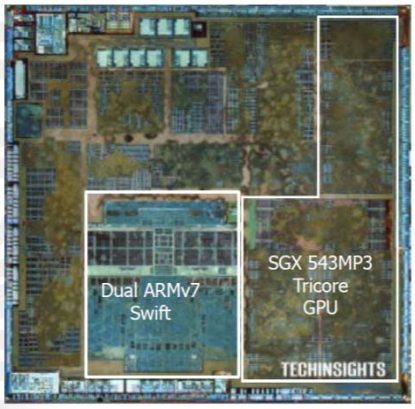
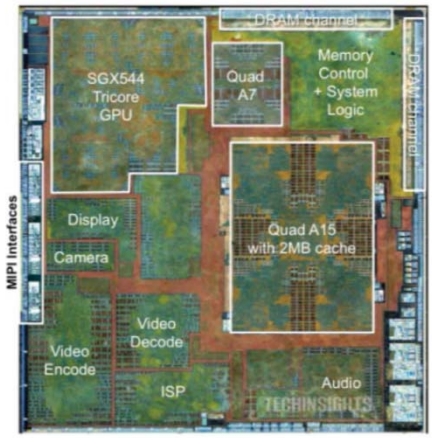
Bare Die View

TECHINSIGHTS



Apple A6
32 nm HKMG



Exynos 5410 "Octa"
28 nm HKMG

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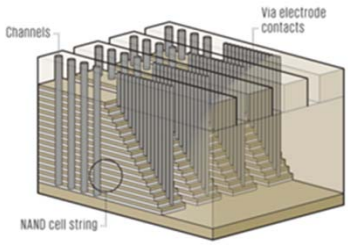
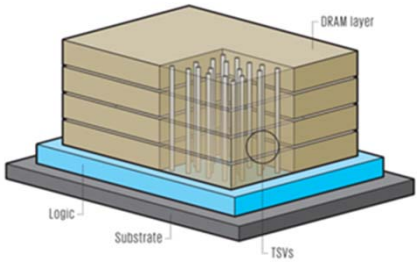
3D MEMORY

3-D NAND



HYBRID MEMORY CUBE



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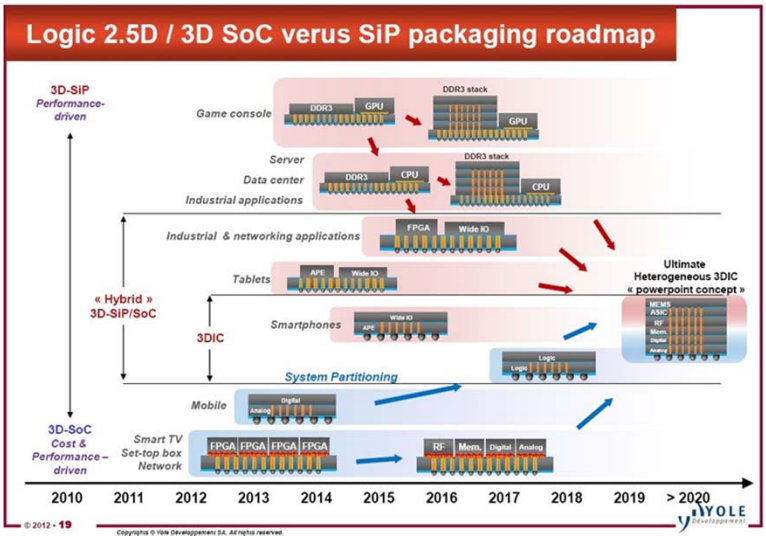
3D Future



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Conclusions

- By the time you graduate there will be great opportunities in:
  - Multicore software development (tools)
  - 3D Chips (memory, processors, mixed, etc…)
  - Reliability issues
  - Security
  - Smart systems (appliances, sensors, grid, automobiles, etc…)

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Sample Program of Study — Computer Engineering

Freshman		
Fall	**Winter**	**Spring**
MATH 2A	MATH 2B	MATH 2D
EECS 12	I&C SCI 6D	PHYSICS 7D
General Education	PHYSICS 7C- 7LC	PHYSICS 7LD
General Education	General Education	EECS 1
		EECS 20
		EECS 31
Sophomore		
Fall	**Winter**	**Spring**
MATH 3A	MATH 3D	EECS 40
PHYSICS 7E	EECS 22L	EECS 50
EECS 22	EECS 55	EECS 70B
EECS 31L	EECS 70A	EECS 70LB
	EECS 70LA	General Education
Junior		
Fall	**Winter**	**Spring**
EECS 112	EECS 112L	EECS 111
EECS 114	EECS 150	EECS 113
EECS 145	EECS 170B	EECS 118
EECS 170A	EECS 170LB	General Education
EECS 170LA	General Education	
Senior		
Fall	**Winter**	**Spring**
EECS 119	EECS 129B	Technical Elective

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Sample Program of Study — Computer Science and Engineering

Freshman		
Fall	**Winter**	**Spring**
MATH 2A	MATH 2B	MATH 2D
CSE 41	CSE 42	CSE 43
General Education	PHYSICS 7C- 7LC	PHYSICS 7D- 7LD
General Education	General Education	CSE 31
Sophomore		
Fall	**Winter**	**Spring**
MATH 3A	MATH 3D	I&C SCI 6B
I&C SCI 6D	CSE 46	CSE 50
CSE 45C	CSE 70A	CSE 90
CSE 31L	Science Elective	General Education
Junior		
Fall	**Winter**	**Spring**
IN4MATX 43	STATS 67	CSE 142
CSE 112	CSE 132L	COMPSCI 143A
CSE 132	CSE 141	CSE 145A- 145B
CSE 161	General Education	
Senior		
Fall	**Winter**	**Spring**
CSE 135A	CSE 135B	CSE 181CW
CSE 181A	CSE 181B	Technical Elective
EECS 148	Technical Elective	Science Elective
General Education	General Education	General Education
	General Education	

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Jobs

- Mobile anything
- Social Networking and Search Engines
- Advanced IC Designs
- Multicore Programming
- Computer Games

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