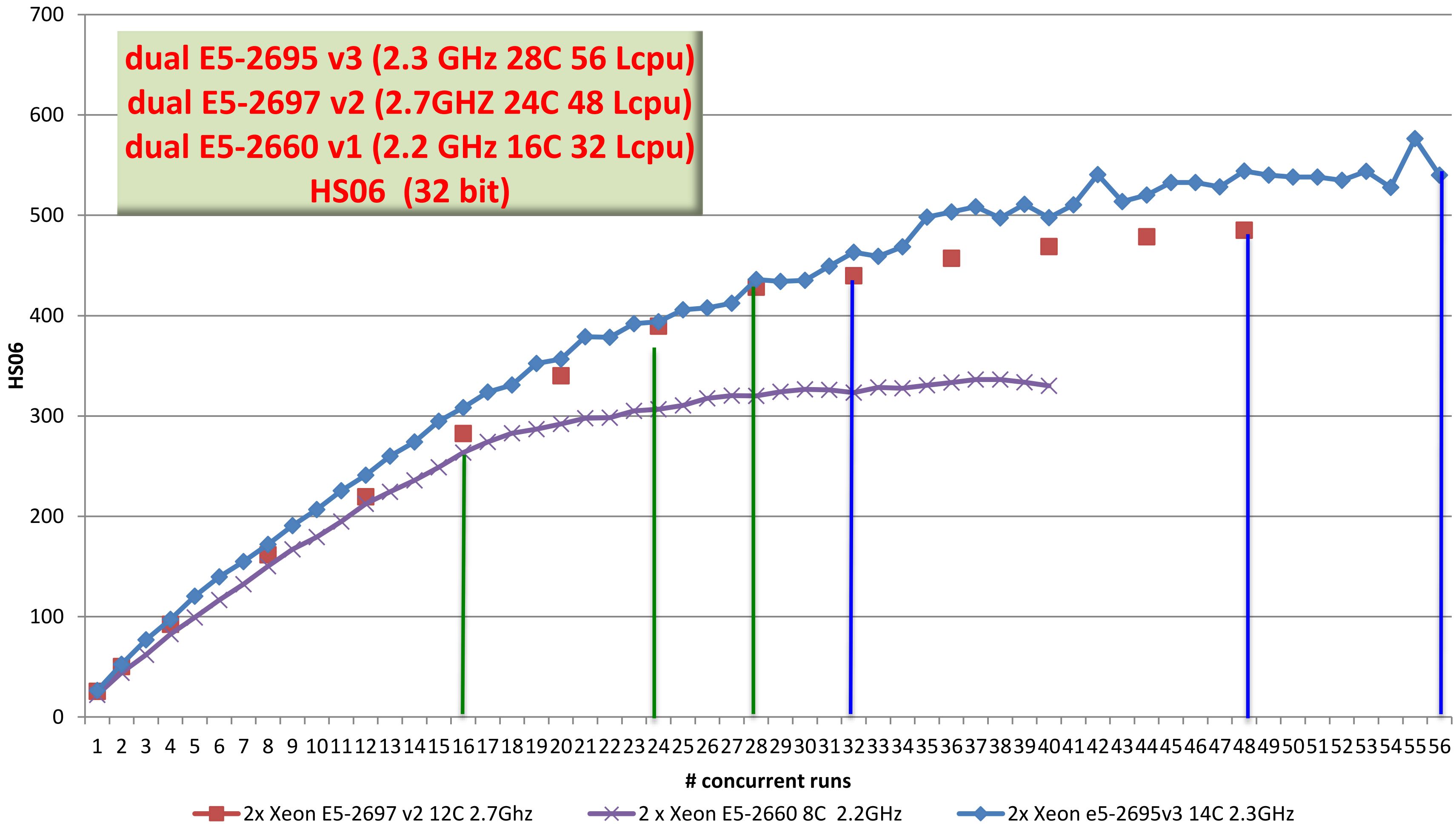
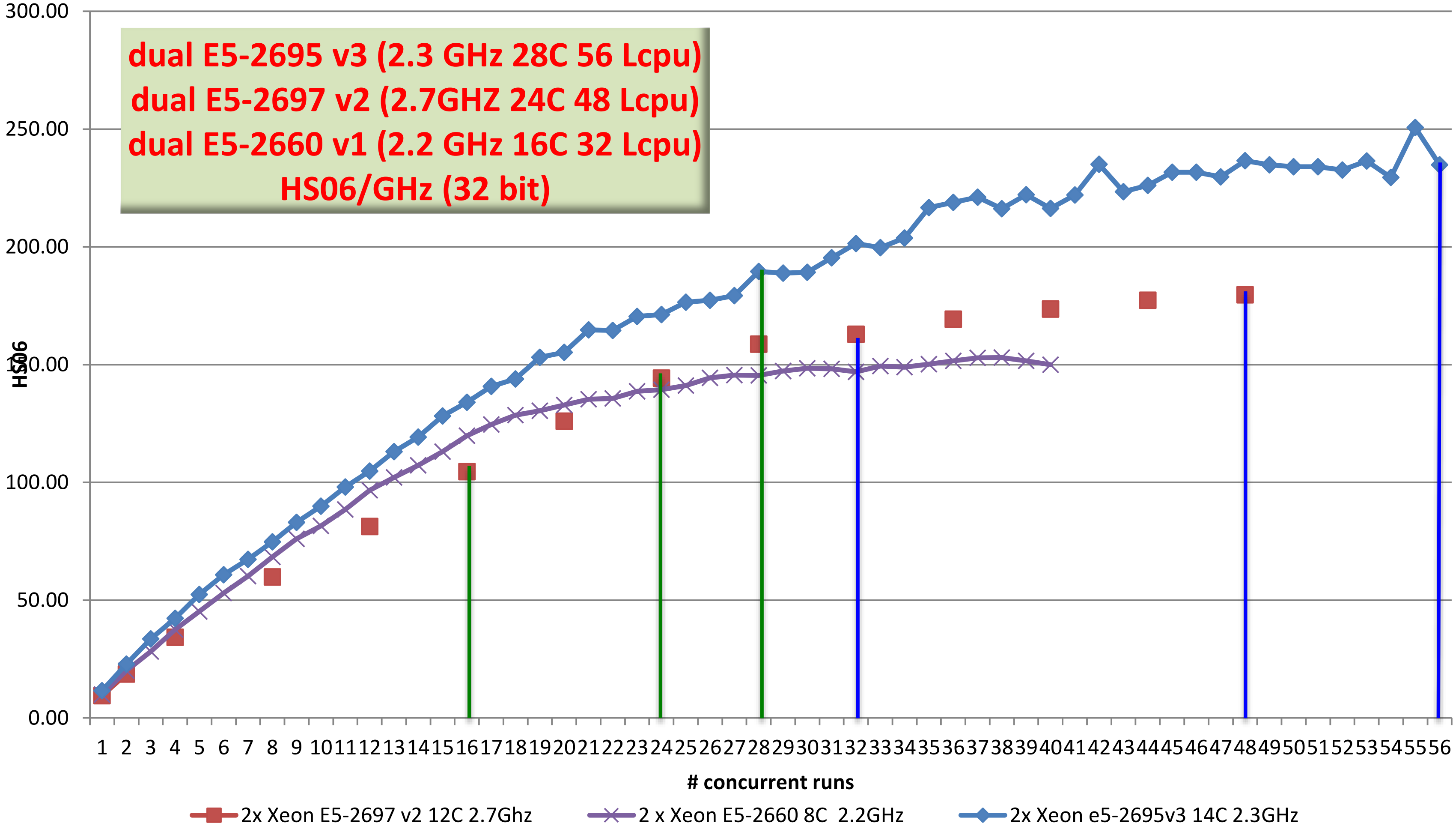
Low Power processors in HEP

Michele Michelotto – INFN Padova

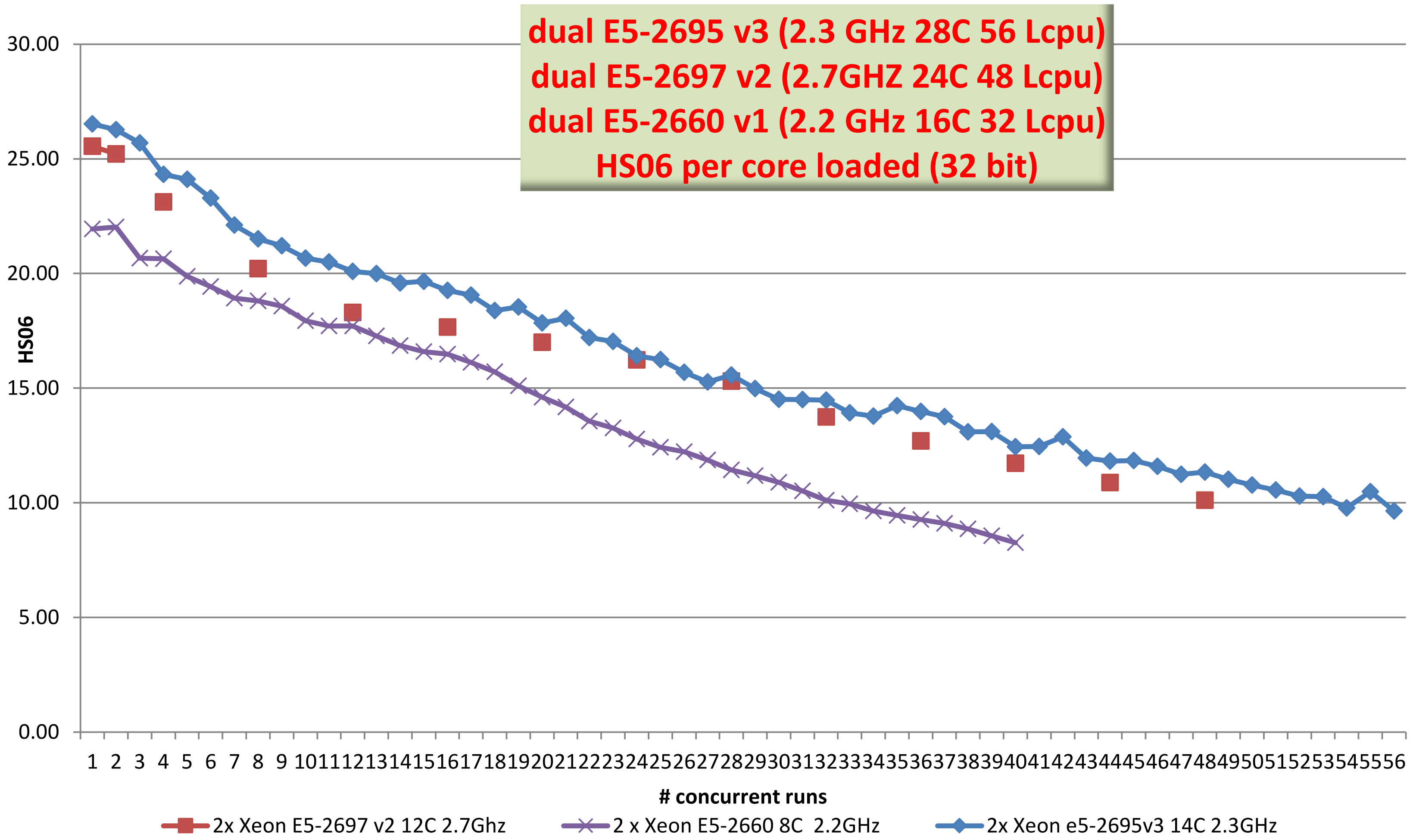
Intel Xeon v5 compare (V1, V2, V3) 32 bit



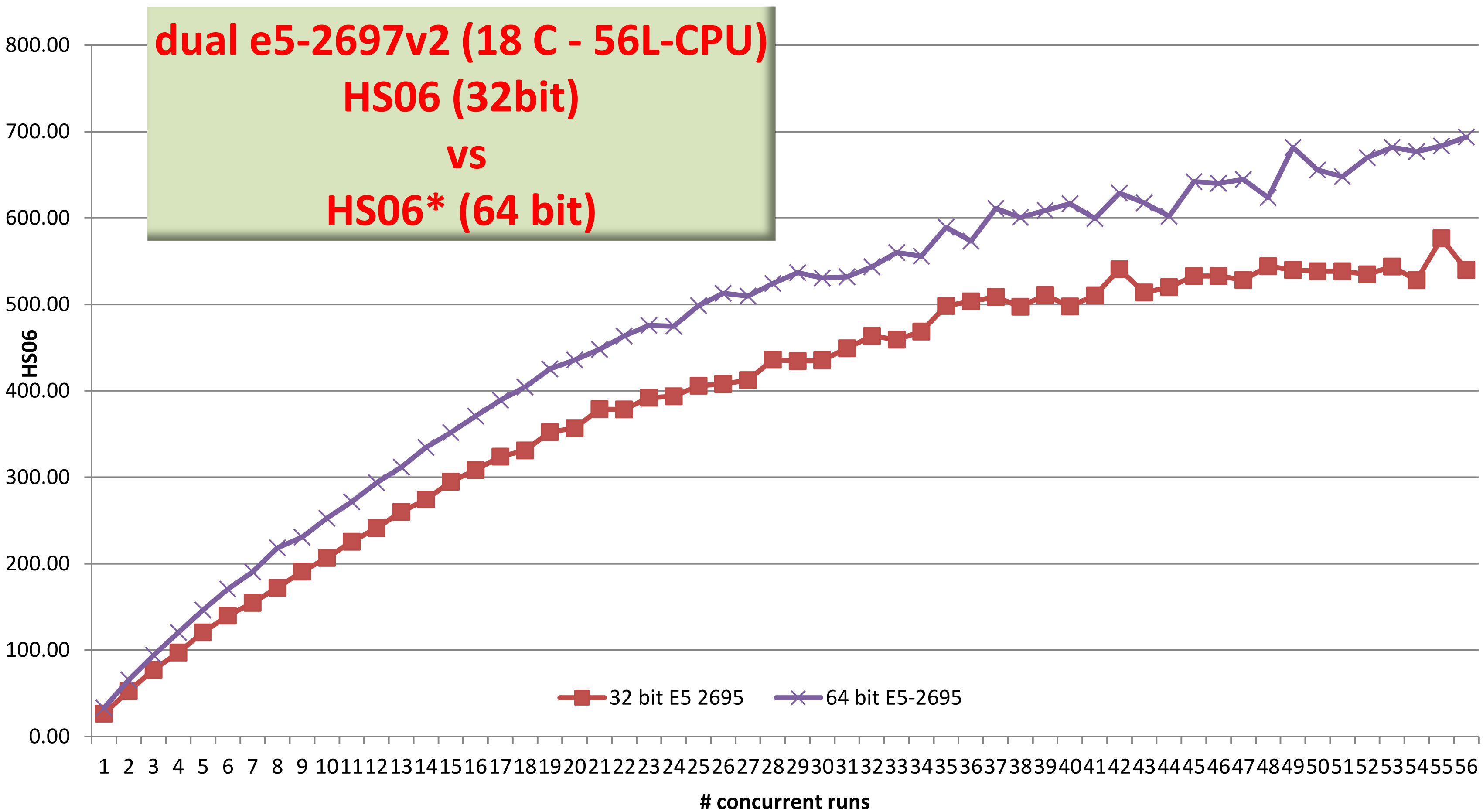
Intel Xeon v5 compare (V1, V2, V3) clock normalized (HS06/GHz)



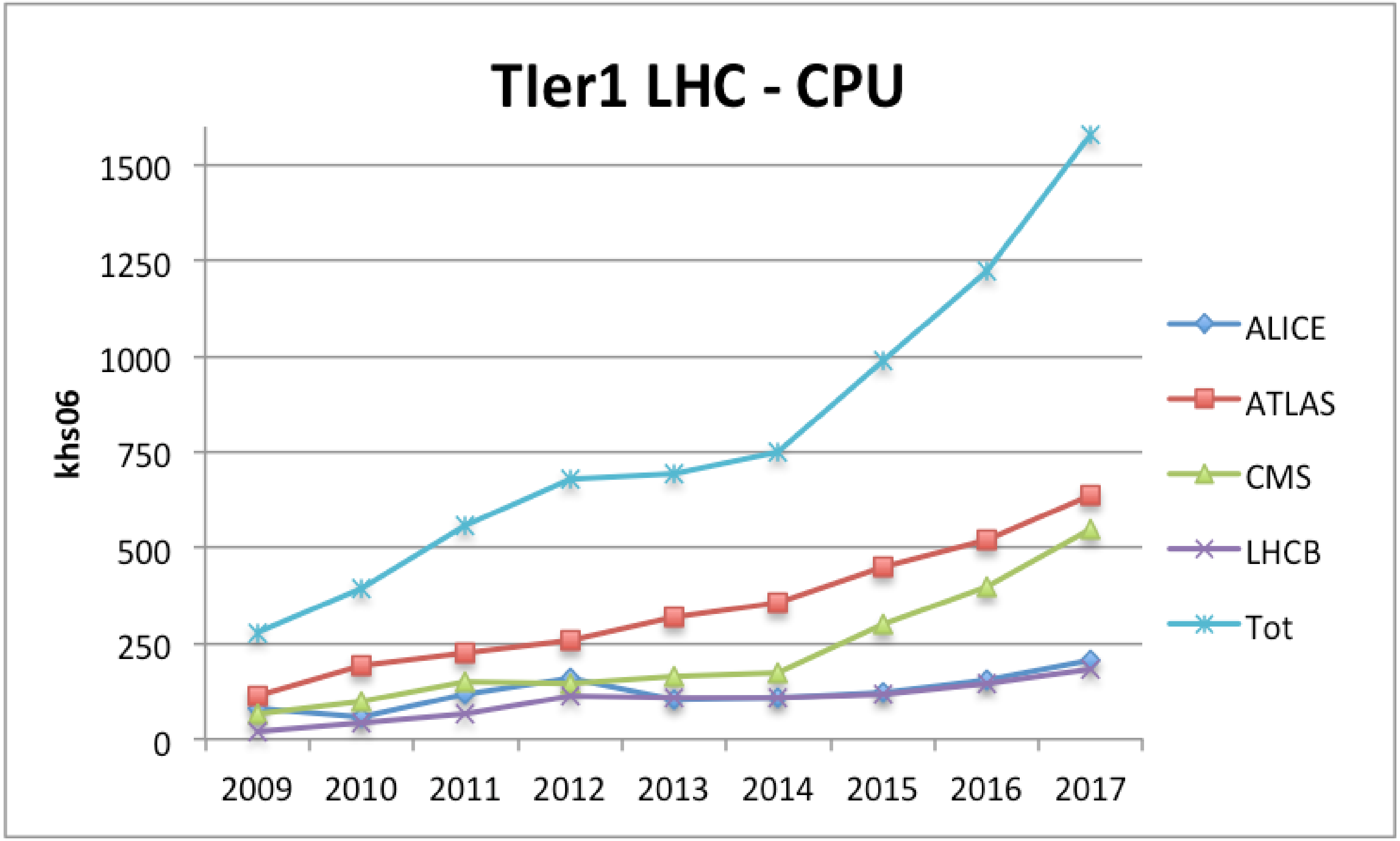
How many HS06 I get from a new job when N-1 core are loaded?



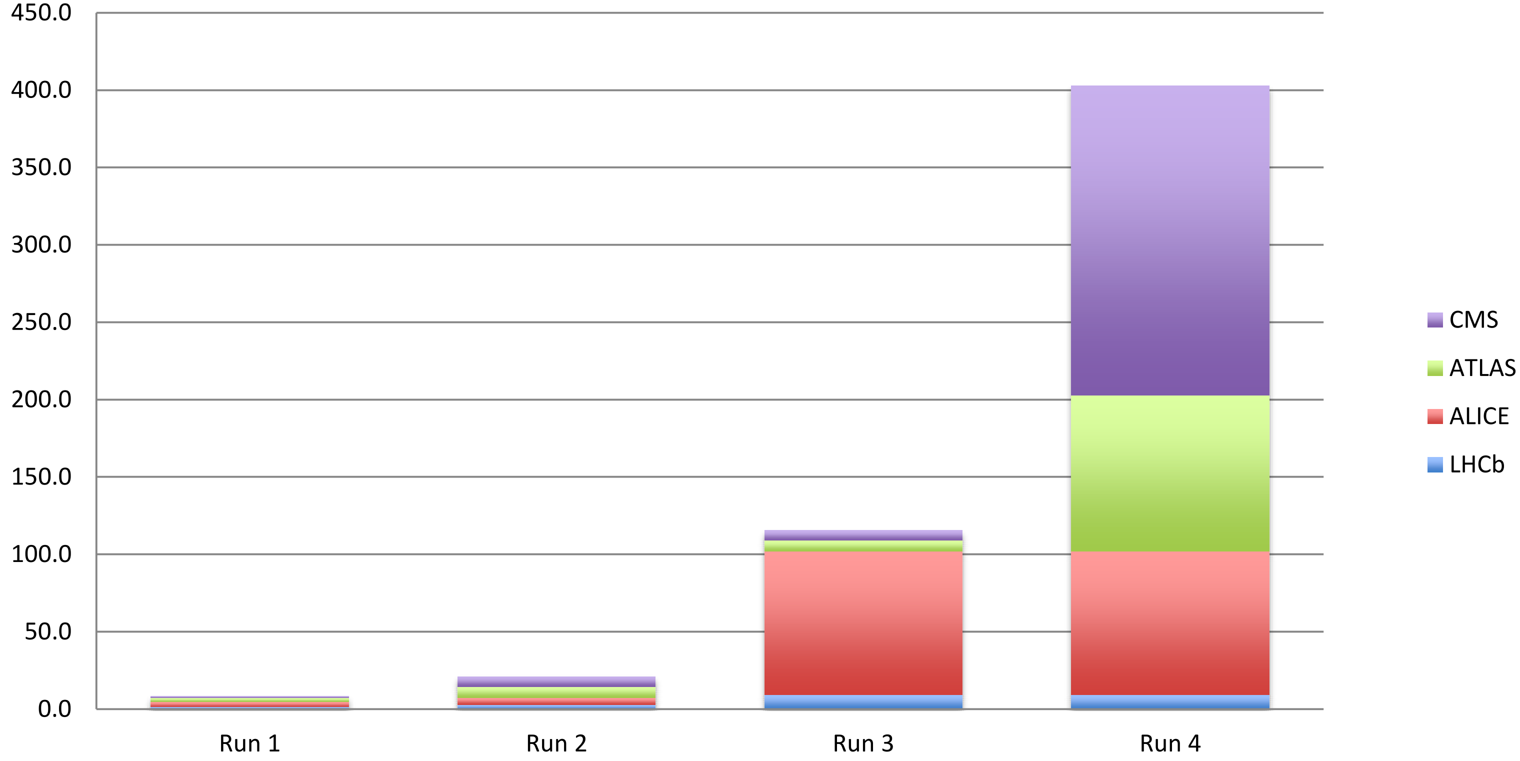
HS06 vs HS06 compiled at 64 bit



CPU requested LHC on all Tier1

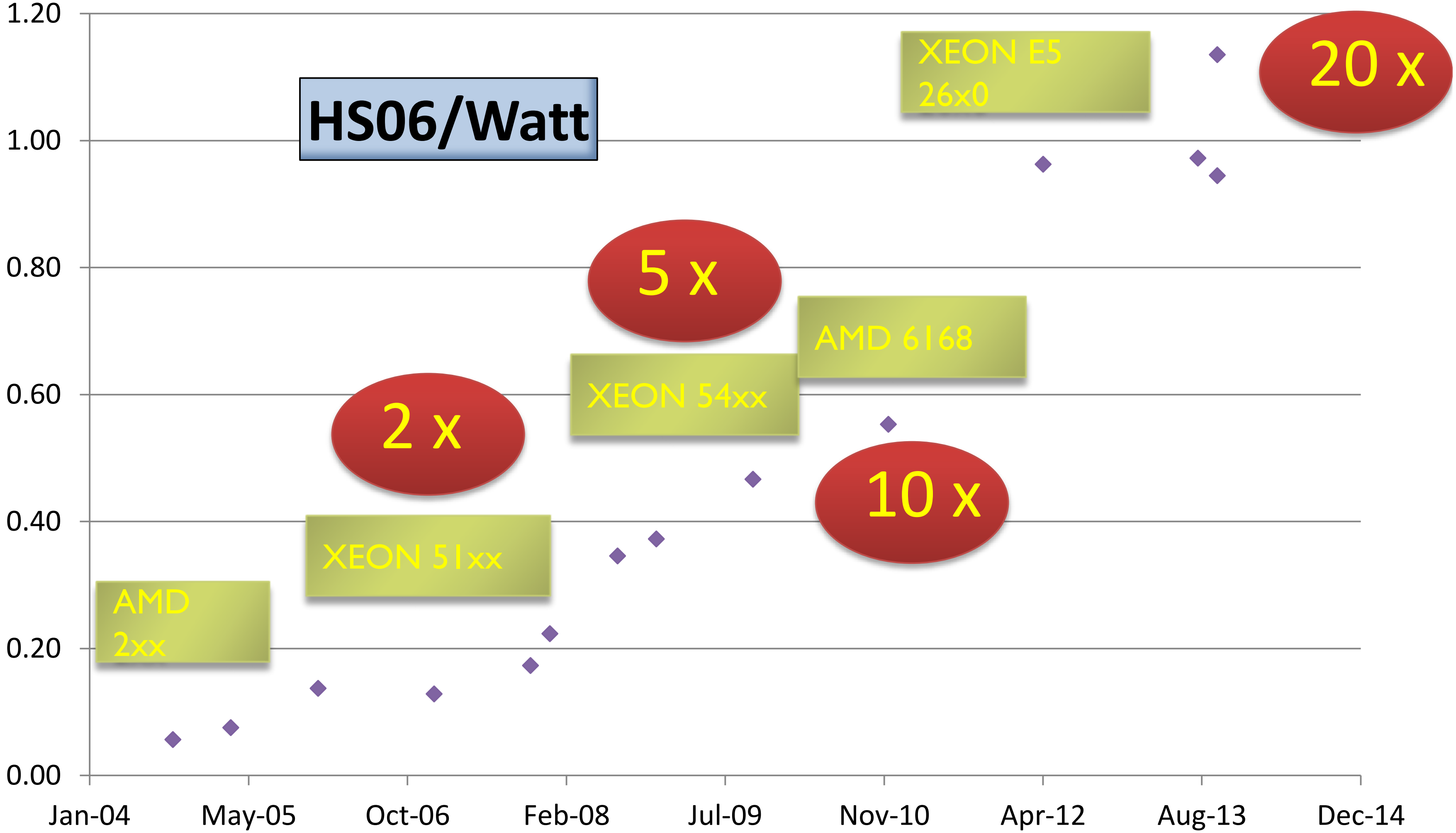


LHC data forecast



	years	Luminosity	Integr. Lum.	Pileup
run2	2015-2018	1.5 10^{34} $cm^{-2}s^{-1}$	150 fb^{-1}	40
Long shutdown 2	2019-2020			
run3	2021-2023	2.5 10^{34} $cm^{-2}s^{-1}$	300 fb^{-1}	60
long shutdown 2	2024-2025			
run4	2026-2029	5.0 10^{34} $cm^{-2}s^{-1}$	1000 fb^{-1}	140-200

Historical Trend (data from M.Alef)



Courtesy of Peter Elmer, Princeton Univ.

Type	Cores	Power	Events/min /core	Events/min /Watt
Exynos4412 Prime @ 1.704GHz	4	4W?	1.14	1.14
Xeon L5520 @ 2.27GHz	2x4	120W?	3.50	0.23
Xeon E5-2630L @ 2.0GHz	2x6	190W?	3.33	0.21

What drives the market?

- Videogames
  - High level GPUs
- Smartphones / Tablet
  - Low consumption CPUs, low cost (50$ each vs 1000$ for a Xeon)

- In both cases, expect many cores CPUs, O(1000) if you include GPU cores

Nvidia GTX Titan
4500 Gflops
250 W
(~1000$)

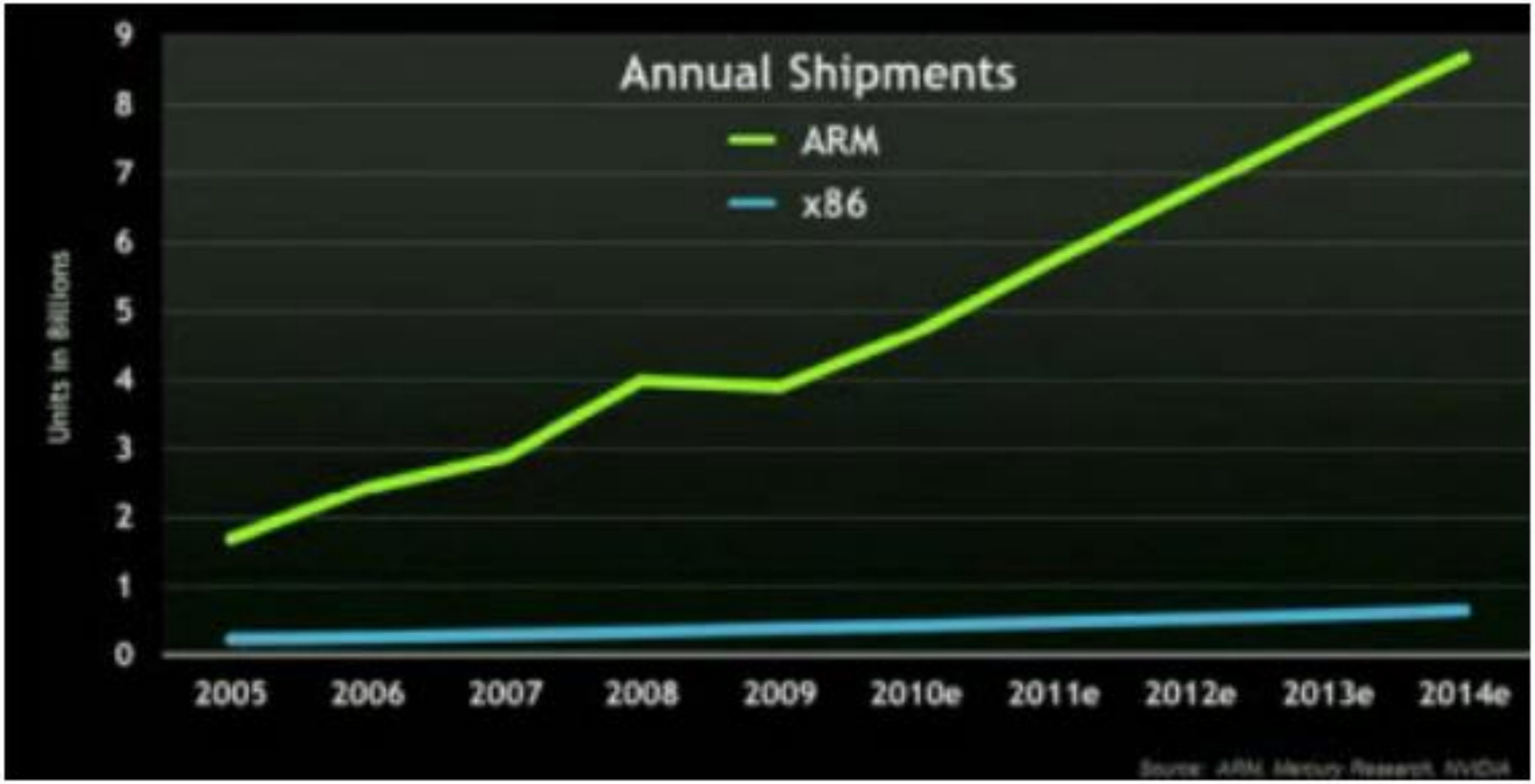
Tegra K1
365 Gflops
5 W (includes also 2 ARMv8 cores)
($50?)

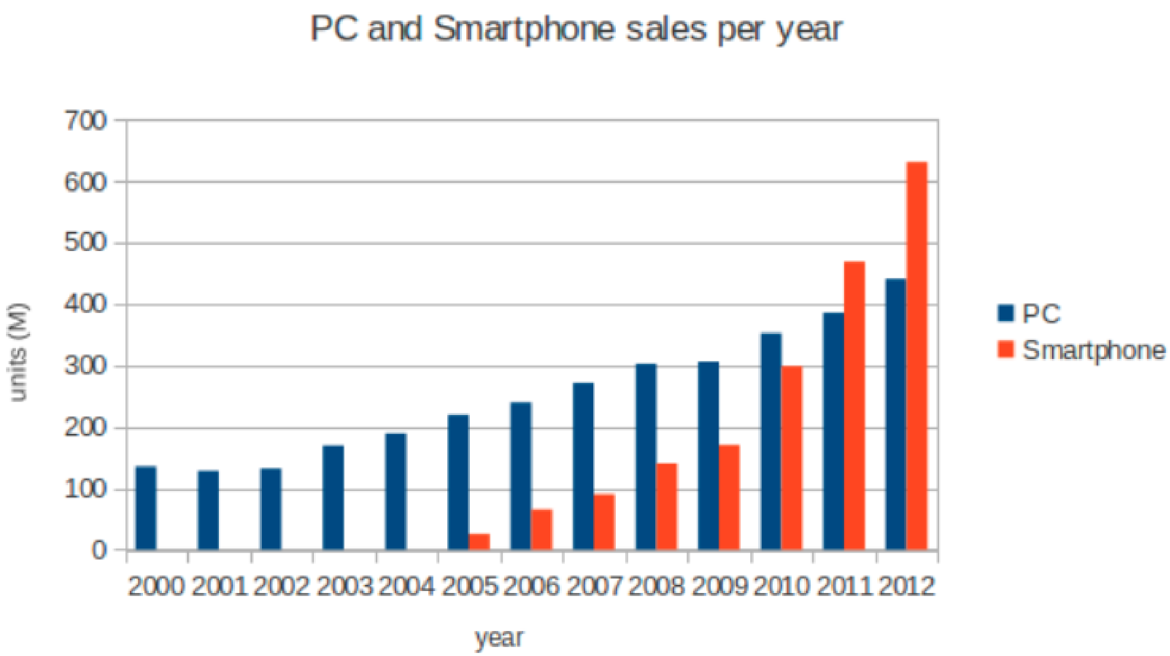
Xeon E5-4650L
1000 Gflops
115W
2000$

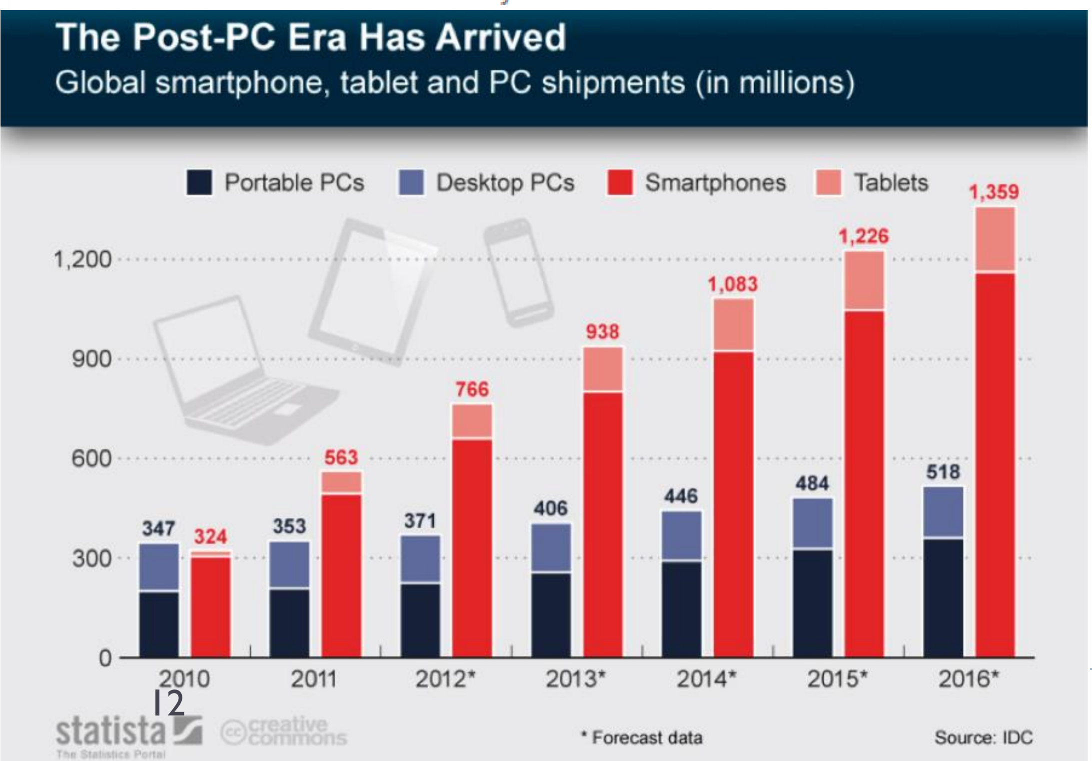
Shipment

ARM: Smarphone, Tablet, Cars, Home Media
X86: Personal computer, notebook

Billions !!!



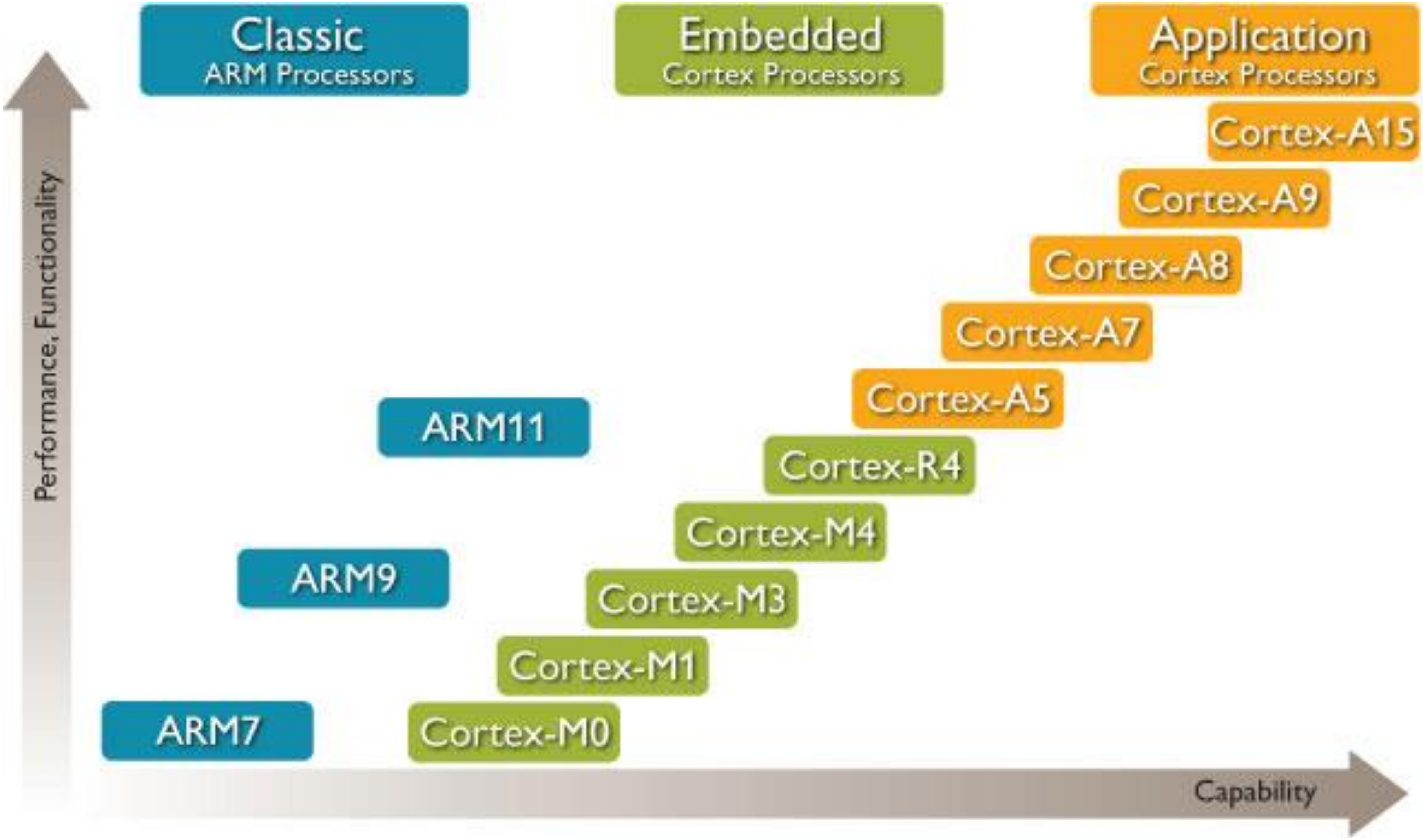




	Units shipped 2012 → 2013
Simple Phones	750 → 900
Smartphones	722 → 1000
Tablets	128 → 210
Notebooks	202 → 200
Desktops	148 → 142
Server	**10 → 9.5**
HPC	0.1 → 0.1

HEP!

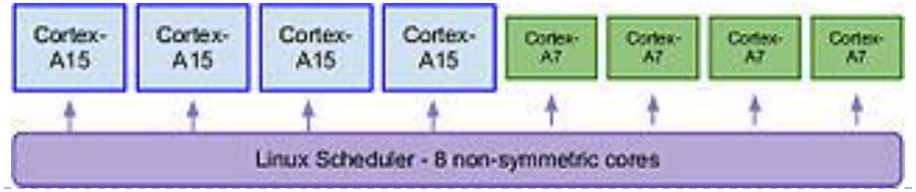
ARM introduction



The ARM Cortex A Series

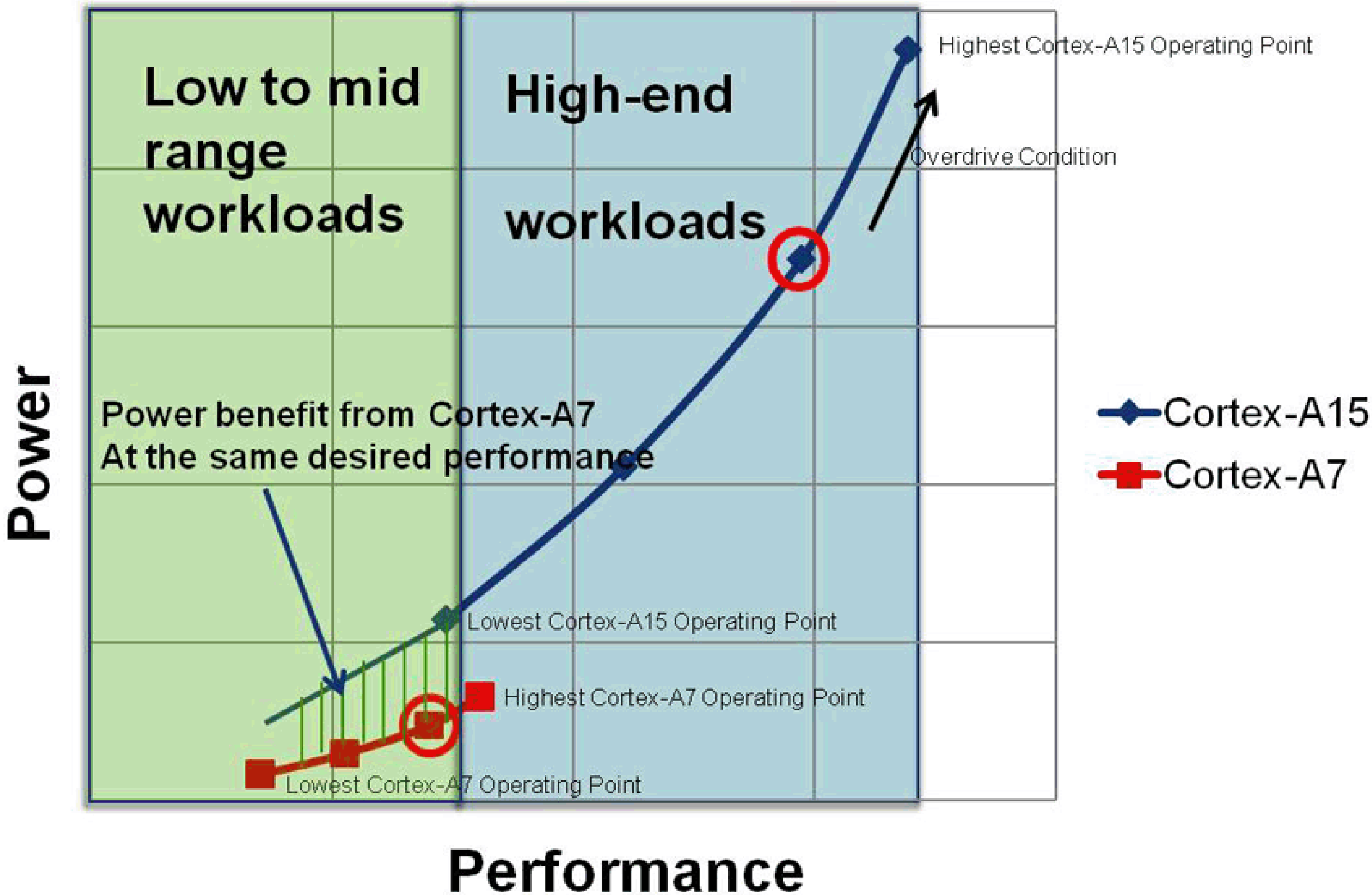
MODEL	Architecture	Process	out of order	Core	Cache L1	Cache L2	Dmips/MHz
		nm		min-max			
A5	Arm v7 32 bit	n.d.	no	1-4	4-64	n.d.	1.57
A7	Arm v7 32 bit	40-28	no	1-8	8-64	up to 1 MB	1.9
A8	Arm v7 32 bit	45-65	no	1	32+32	256-512 KB	2
A9	Arm v7 32 bit	28-65	yes	1-4	32+32	up to 1 MB	2.5
A12	Arm v7 32 bit	n.d.	yes	1-4	32+32	up to 8 MB	3
A15	**Arm v7 32 bit**	**28-32**	**yes**	**2-8**	**32+32**	**up to 8 MB**	**3.5 - 4.0**
A17	Arm v7 32 bit	28	yes	4	32+32	up to 8 MB	4
A53	Arm v8 64 bit	28	no	1-4	8-64 + 8-64	128 KB - 2MB	n.d.
A57	**Arm v8 64 bit**	**28-20**	**yes**	**1-4**	**48+32**	**512 KB - 2MB**	**n.d.**

Odroid XU



- Exynos5 Octa Cortex A15 1.6 Quadcore and A7 Quadcore CPUs
- 2GByte LPDDR3 RAM
- $169
- Fedora 18, armV7, gcc4.8, ODROID kernel

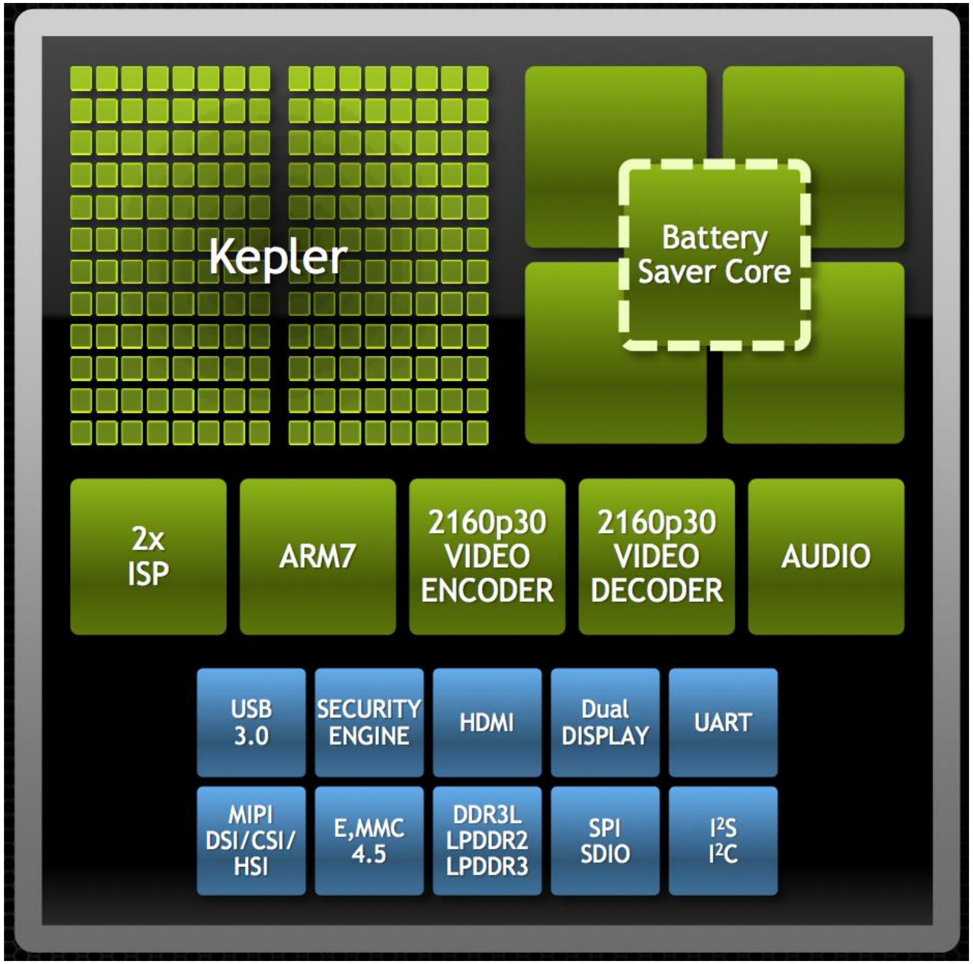
The big LITTLE architecture



Jetson Tegra K1

- Nvidia Tegra K1 SOC
  - Kepler GPU with 192 CUDA cores (unused in my tests)
  - 4+1 quad core A15 cpu
  - 2200 MHz
- 2GB x 16
- Linux Ubuntu/Linaro 4.8.2-19

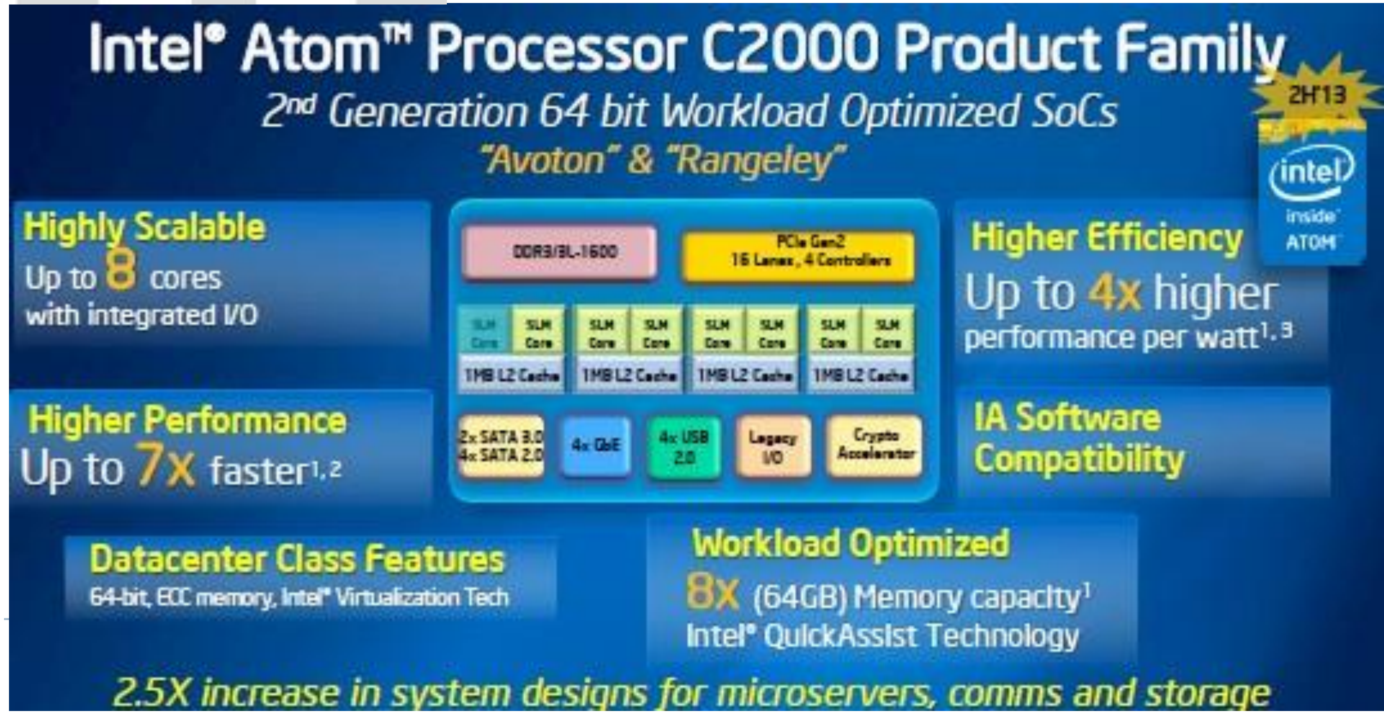
Nvidia Tegra K1 Building Blocks



Intel Atom Server

Processor	Power	Frequency (Boost™)	Cores	Memory Channels	DIMMs per Channel	Memory Type	Memory Speed	Max. Memory Capacity	Max. PCIe Lanes	PCIe* Controllers	Ports
Intel® Atom™ Processor C2750	20W	2.4 GHz (2.6 GHz)	8	2	2	ECC DDR3/L	1600 MHz	64 GB	16	4 PCIe* 2.0	4 x 2.5 GbE 2 x SATA 3 4 x SATA 2 4 x USB 2
Intel® Atom™ Processor C2730	12W	1.7 GHz (2.0 GHz)	8	2	2	ECC DDR3/L	1600 MHz	32 GB	8	2 PCIe 2.0	2 x 2.5 GbE 2 x SATA 3 4 x USB 2
Intel® Atom™ Processor C2550	14W	2.4 GHz (2.6 GHz)	4	2	2	ECC DDR3/L	1600 MHz	64 GB	16	4 PCIe 2.0	4 x 2.5 GbE 2 x SATA 3 4 x SATA 2 4 x USB 2
Intel® Atom™ Processor C2530	9W	1.7 GHz (2.0 GHz)	4	2	2	ECC DDR3/L	1333 MHz	32 GB	8	2 PCIe 2.0	2 x 2.5 GbE 2 x SATA 3 4 x USB 2
Intel® Atom™ Processor C2350	6W	1.7 GHz (2.0 GHz)	2	1	2	ECC DDR3/L	1333 MHz	16 GB	4	1 PCIe 2.0	4 x 2.5 GbE 2 x SATA 3 4 x USB 2

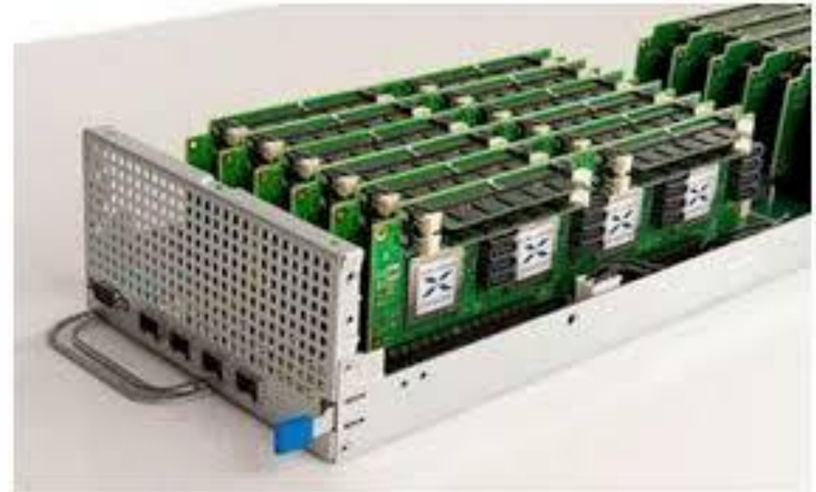
- Not a SOC but a low power architecture
- X86-64

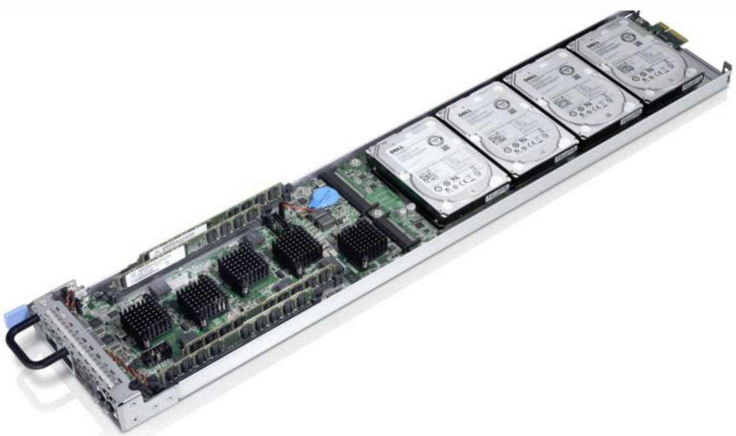


Server based on Intel server

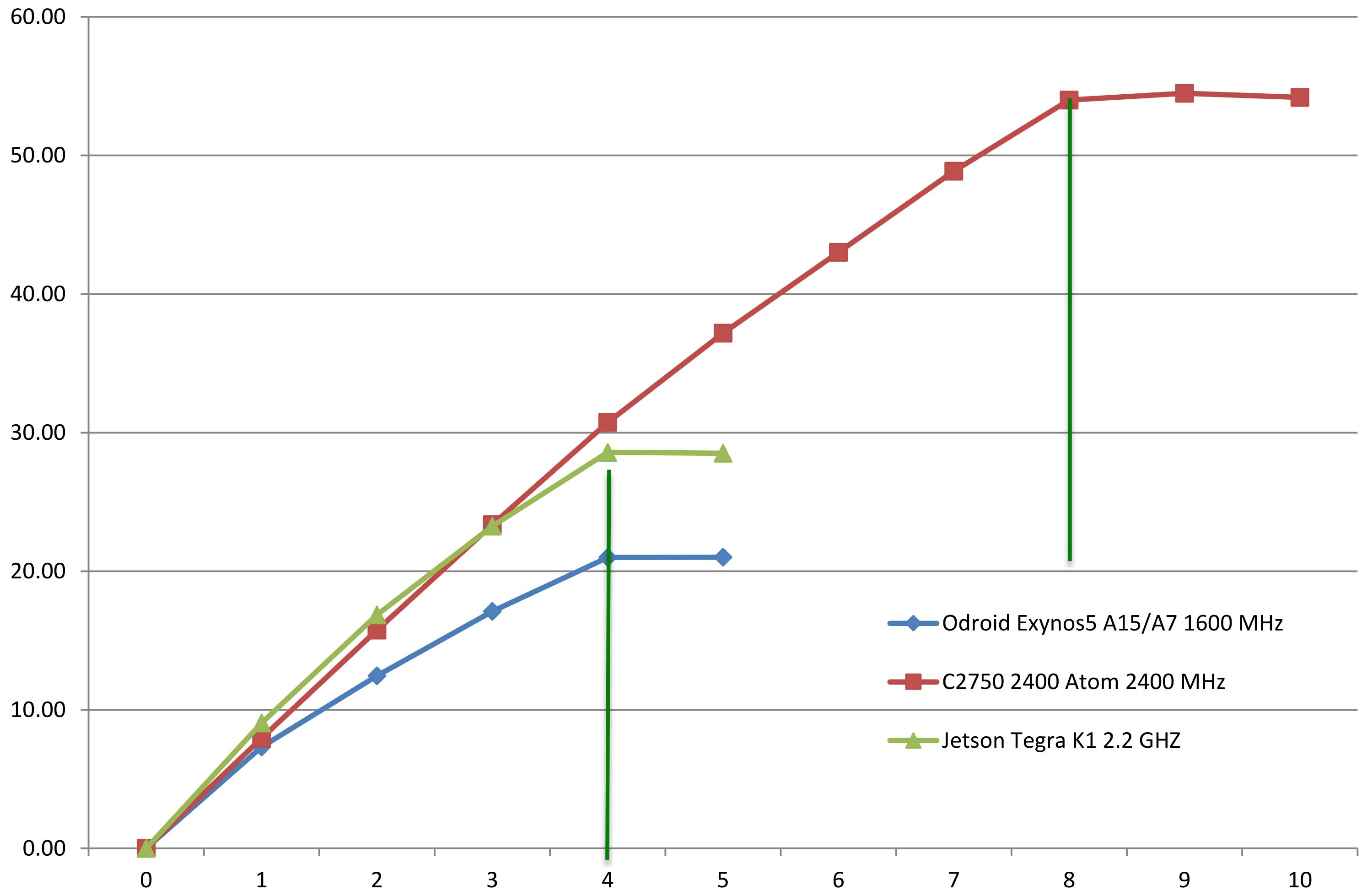
- Atom server in 2U rack mount chassis
- Each card has 8core Avoton computer node and up to 32GB
- 92 host is this prototype

ARM server for HTC

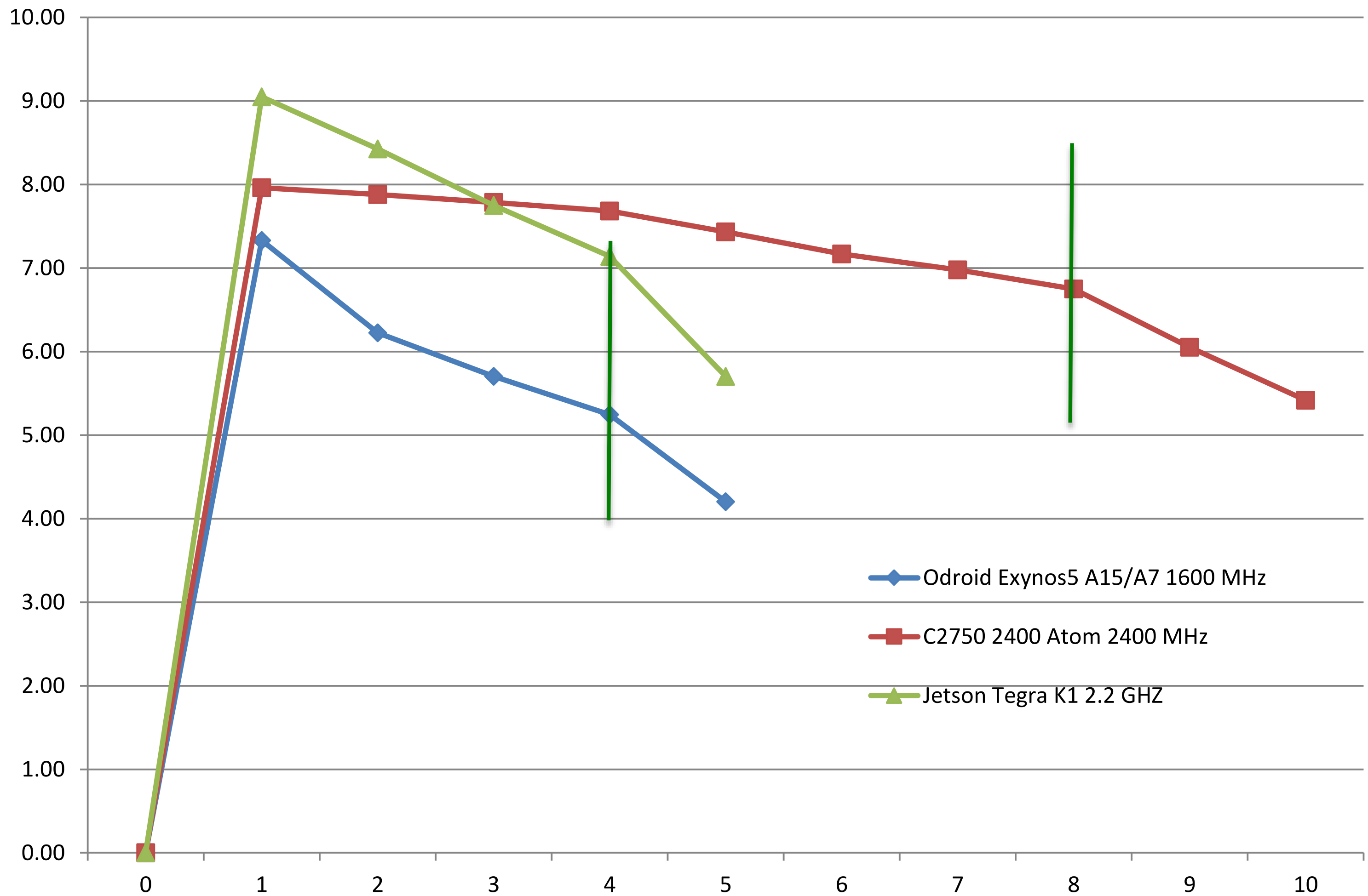




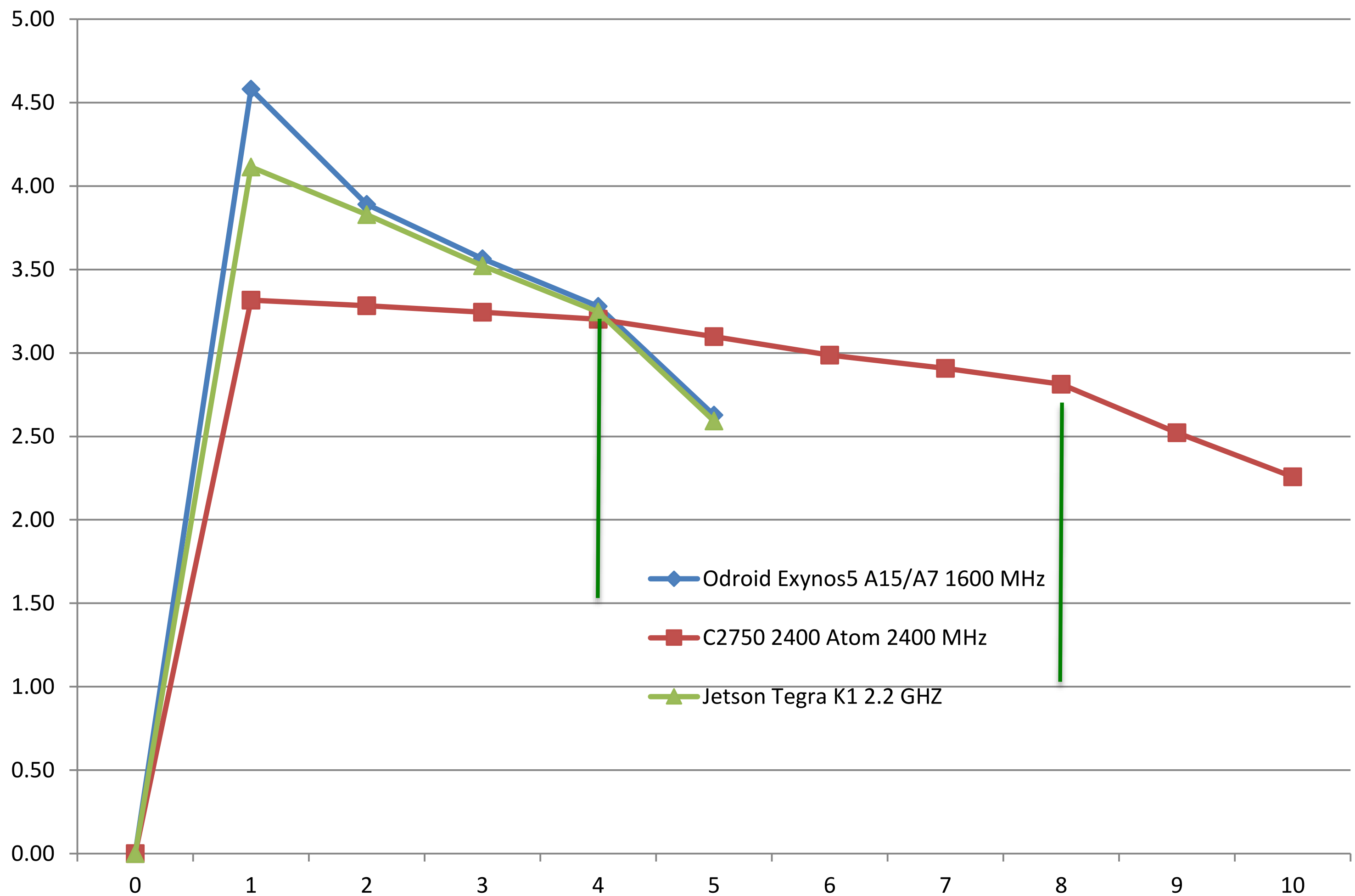
HS06 on Exynos5, TegraK1 and Atom C2750



HS06 on Exynos5, TegraK1 and Atom C2750 – Per core loaded



HS06 on Exynos5, TegraK1 and Atom C2750 – Per core loaded and per clock

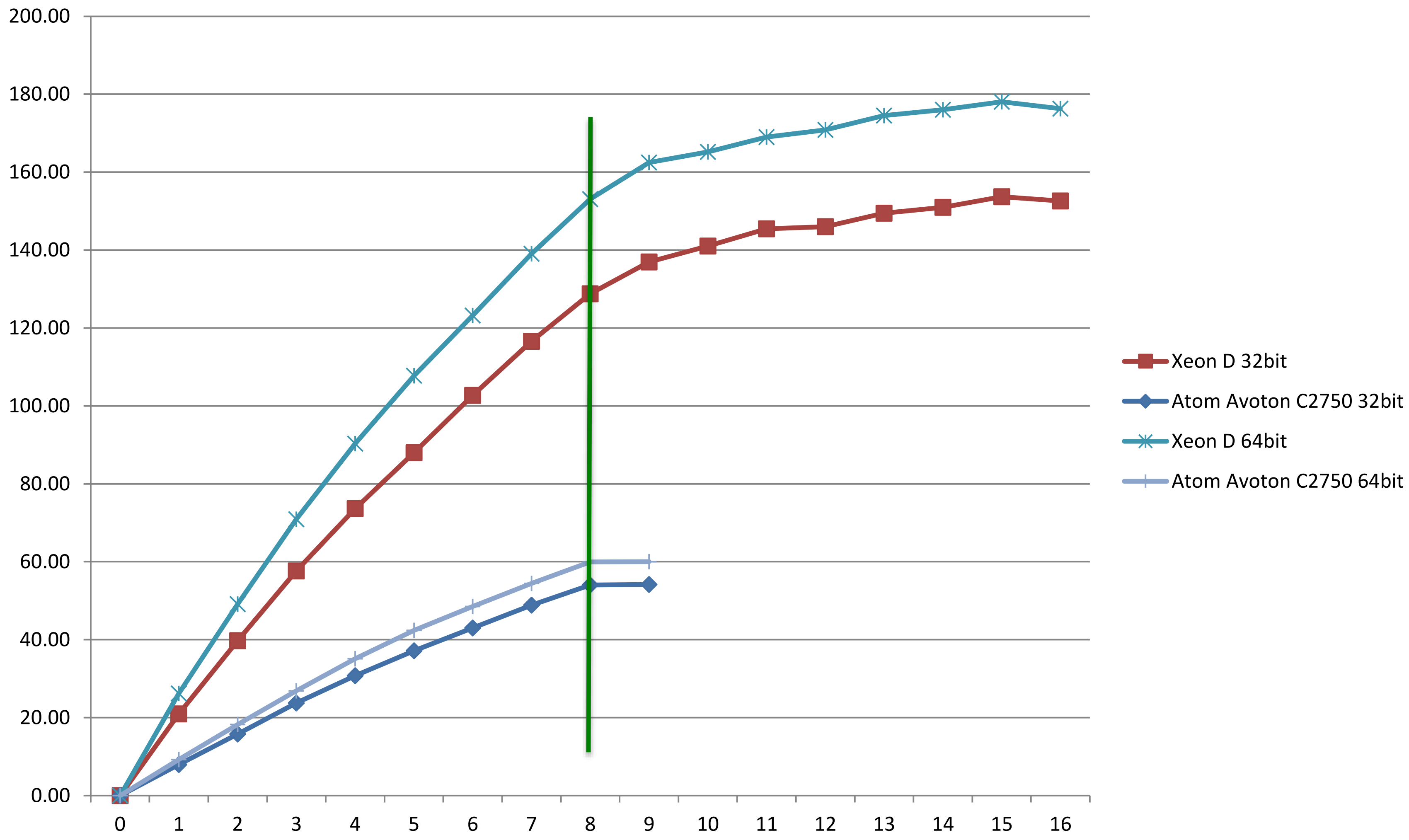


Xeon D Broadwell SoC

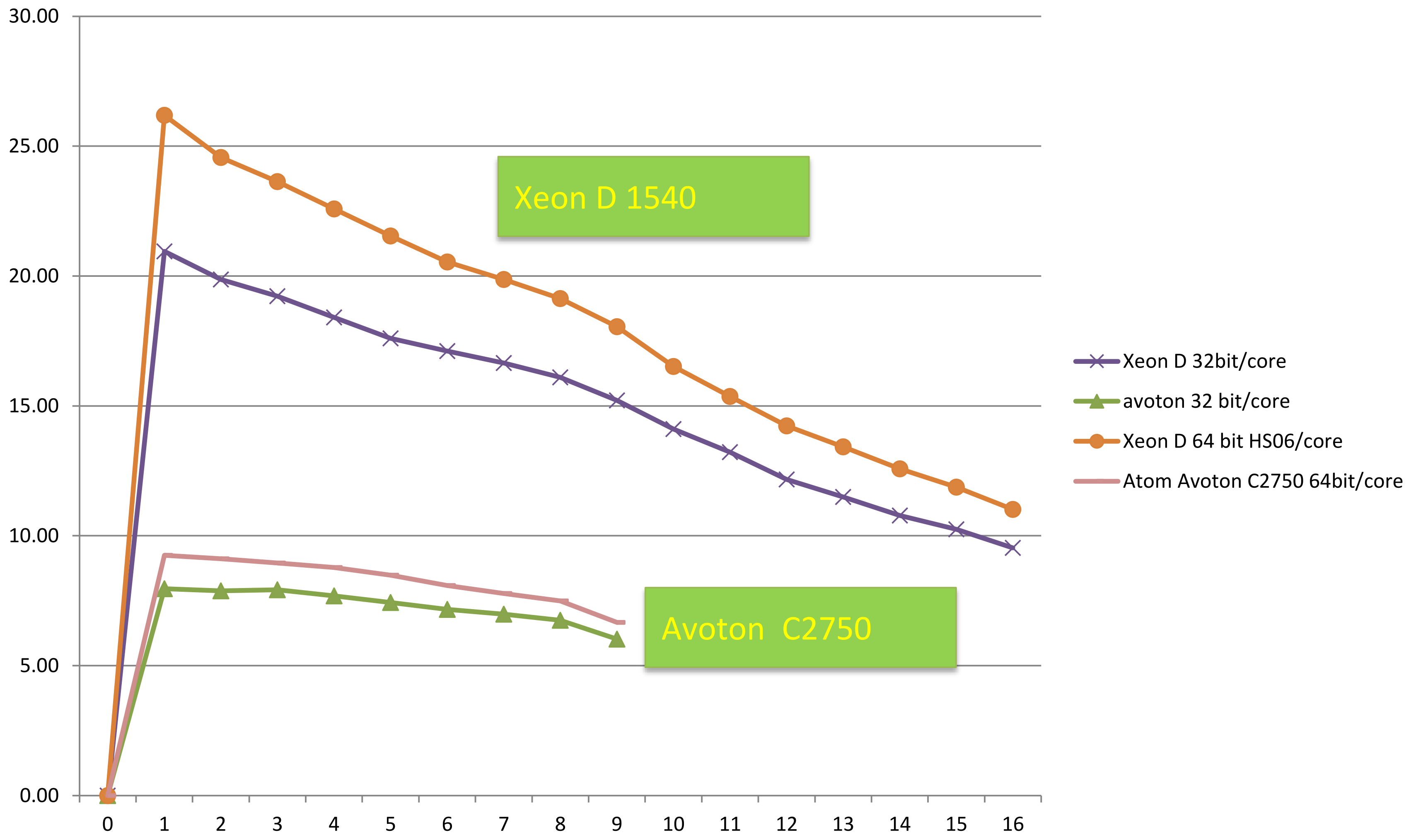
New Intel Xeon D-1500 Series Processors (to be updated)

Launch	Intel Xeon D Model	Cache (MB)	# of Cores	# of Threads	Processor Base (GHz)	Max Turbo (GHz)	TDP	RCP	Cores * Base GHz	Threads * Base GHz
Q1 2015	D-1540	12	8	16	2	2.6	45	$581	16	32
	D-1520	6	4	8	2.2	2.6	45	$199	8.8	17.6
Q4 2015	D-1518	6	4	8	2.2	2.2	35	$234	8.8	17.6
	D-1521	6	4	8	2.4	2.7	45		9.6	19.2
	D-1527	6	4	8	2.2	2.7	35	$259	8.8	17.6
	D-1528	9	6	12	1.9	2.5	35	$389	11.4	22.8
	D-1531	9	6	12	2.2	2.7	45		13.2	26.4
	D-1537	12	8	16	1.7	2.3	35	$571	13.6	27.2
	D-1541	12	8	16	2.1	2.7	45	$581	16.8	33.6
	D-1548	12	8	16	2	2.6	45	$675	16	32
Q1 2016 (Feb)	D-1557	18	12	24	1.5		45		18	36
	D-1567	18	12	24	2.3		65		27.6	55.2
	D-1571	24	16	32	1.3		45	$1,222	20.8	41.6
	D-1577	24	16	32	1.3		45		20.8	41.6
	D-1581								0	0
	D-1587	24	16	32	1.7		65		27.2	54.4

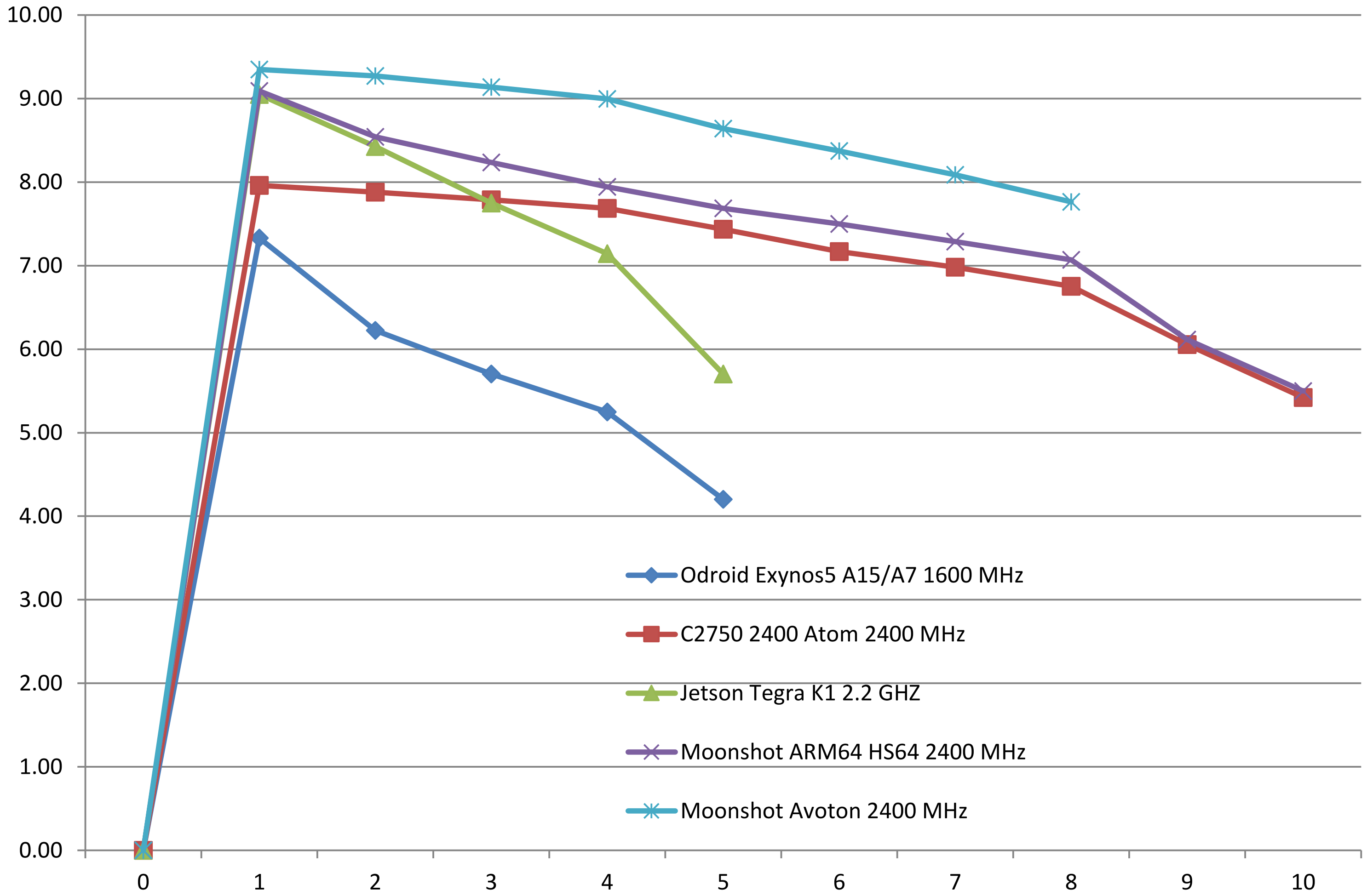
Xeon D vs Avoton



Xeon D vs Avoton per core

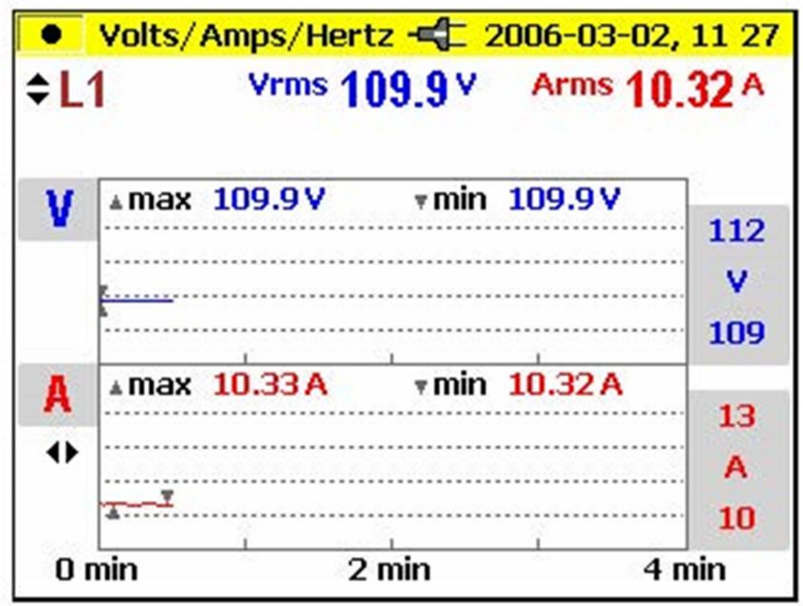


Performance per core

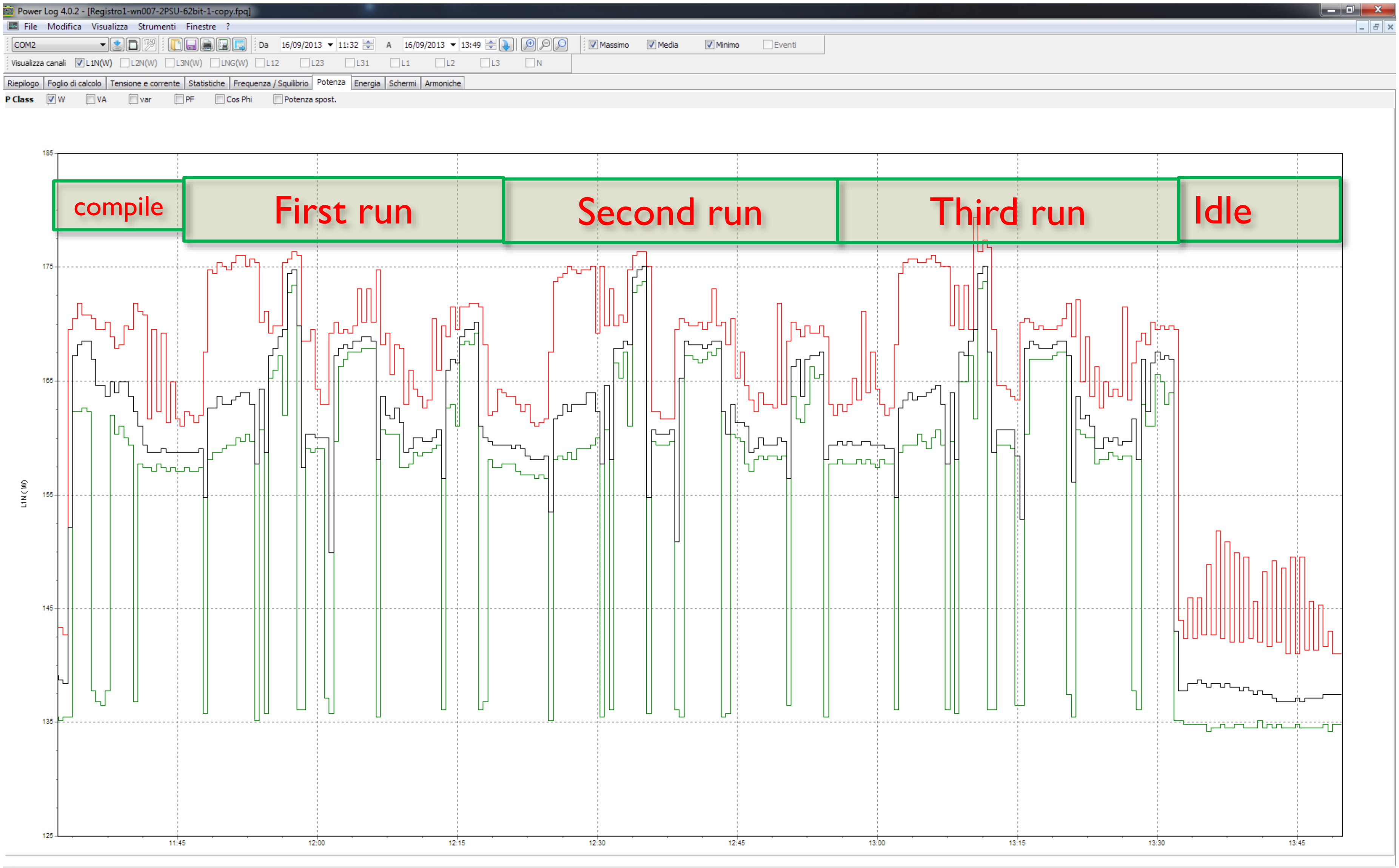


Measurements of power consumption

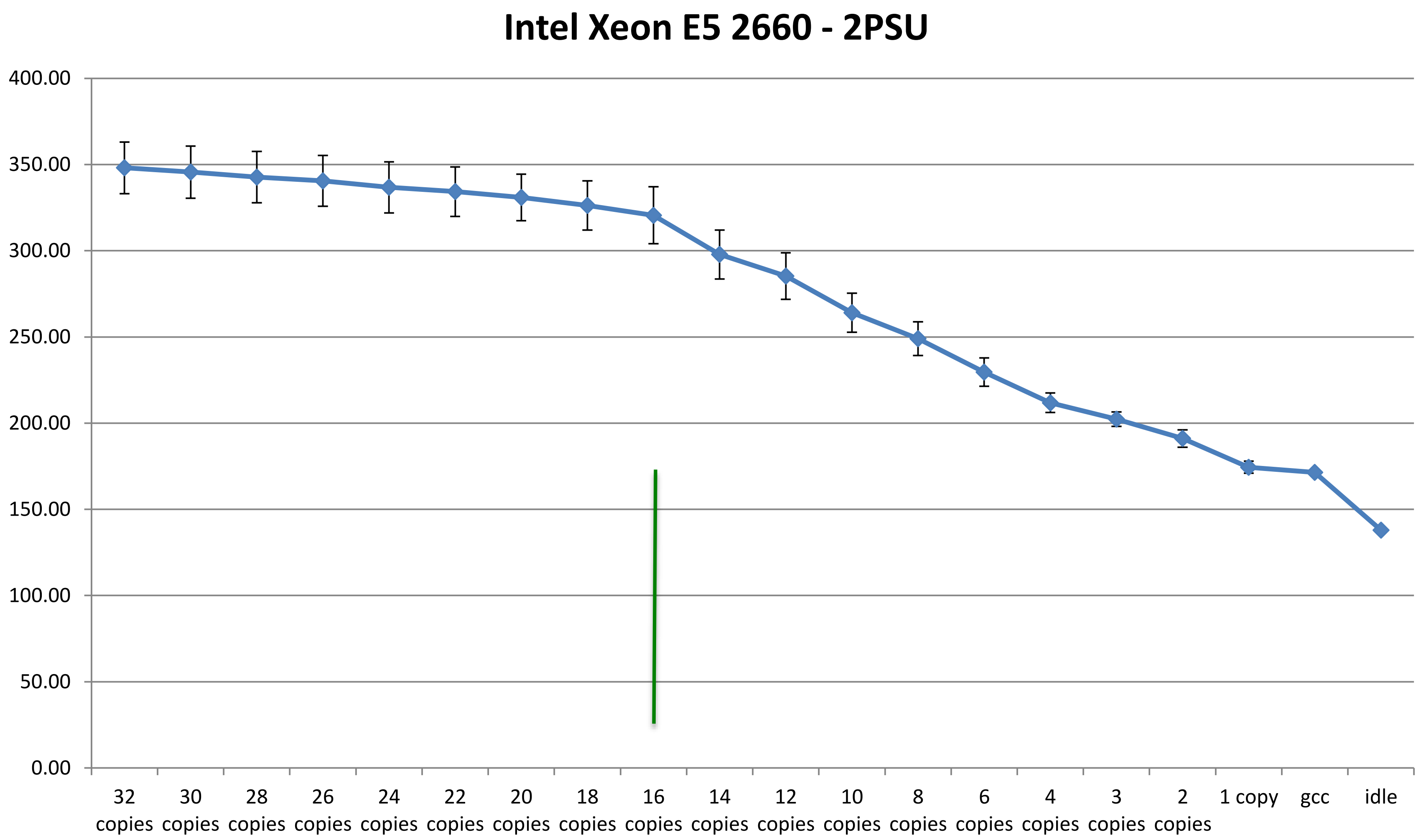
- Measurements of voltage, amperage and power consumption
- The power logger
- Measurements setup



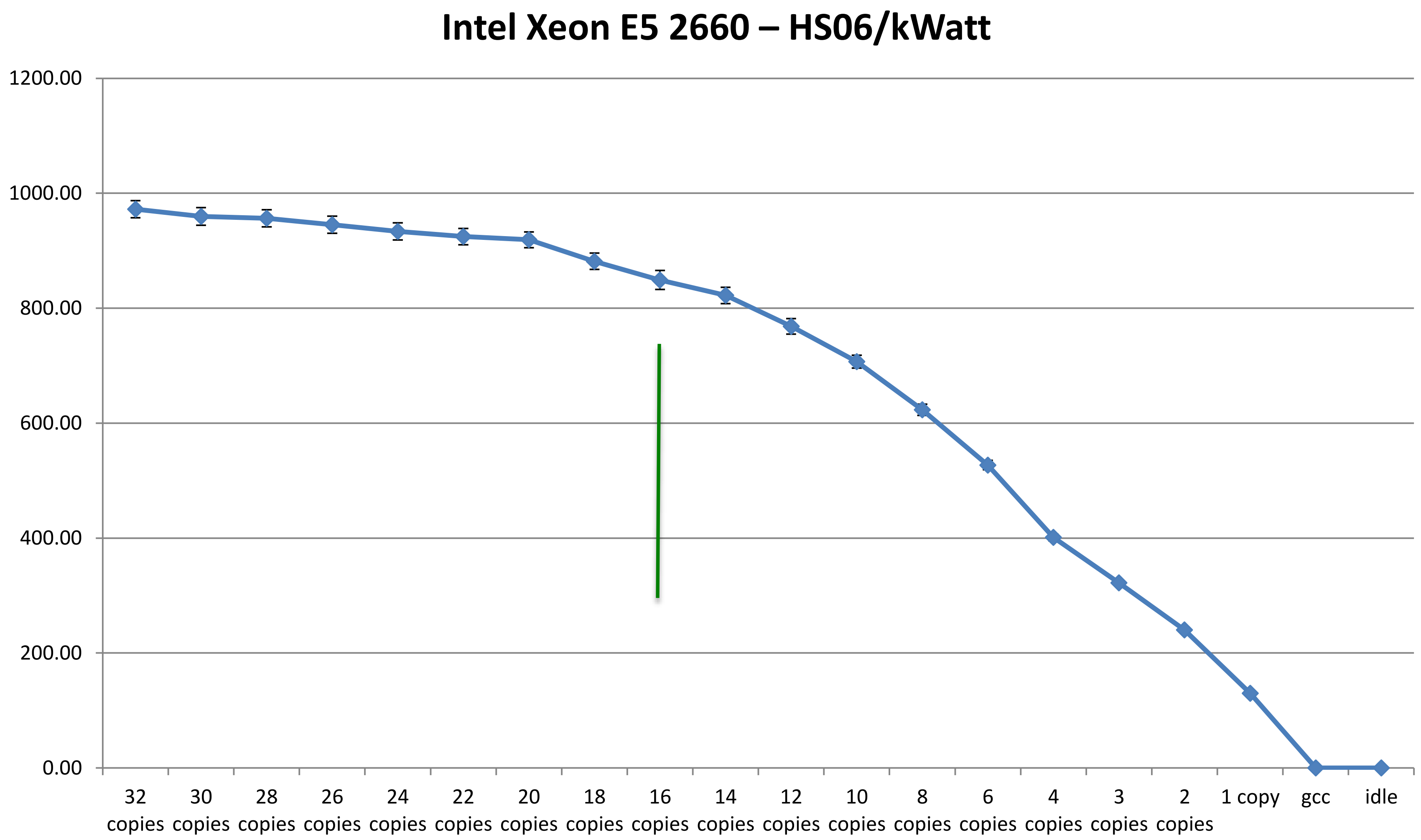
Power logger sw



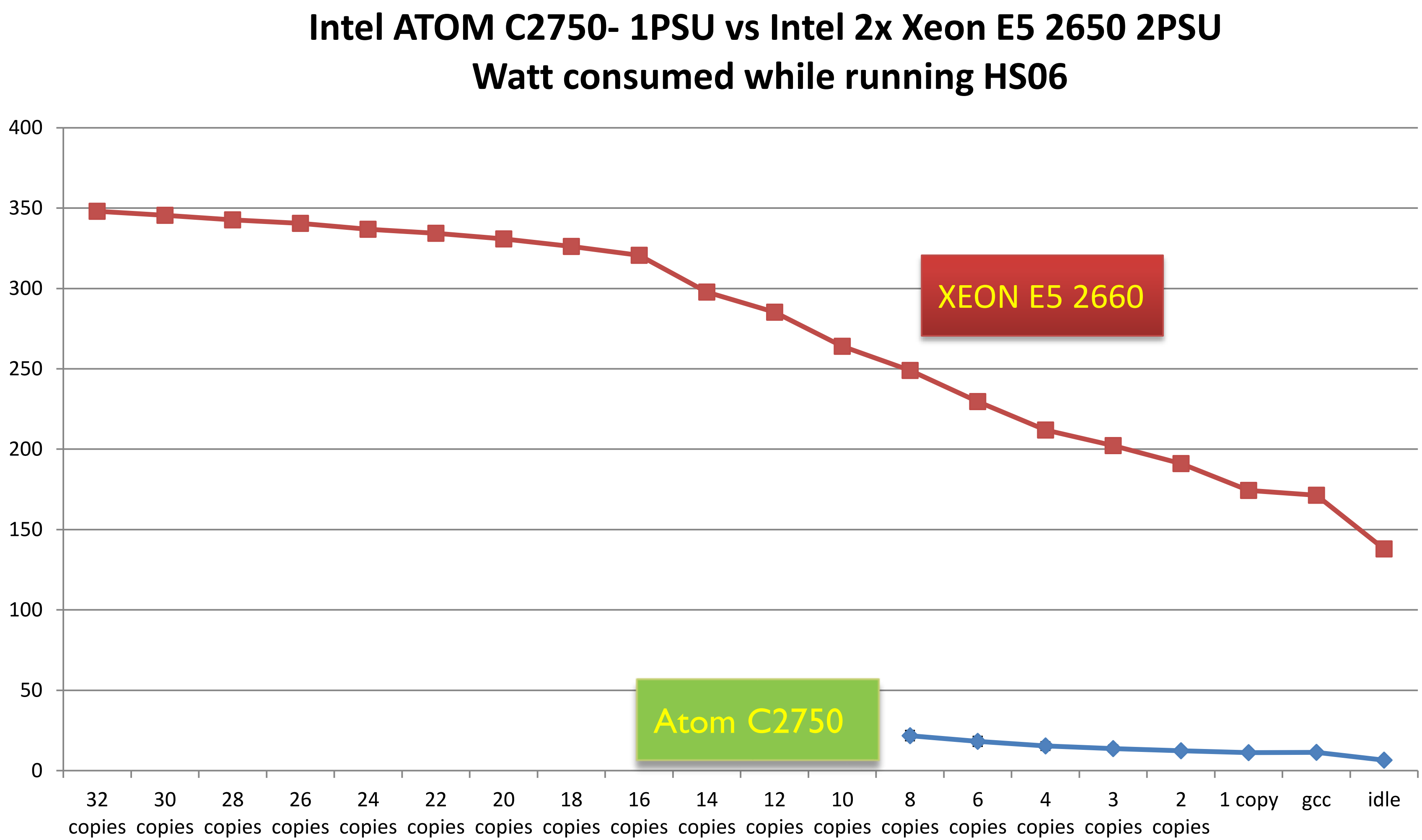
Power consumption (Watt) on Intel Xeon E5 2660



Efficiency HS06/Watt



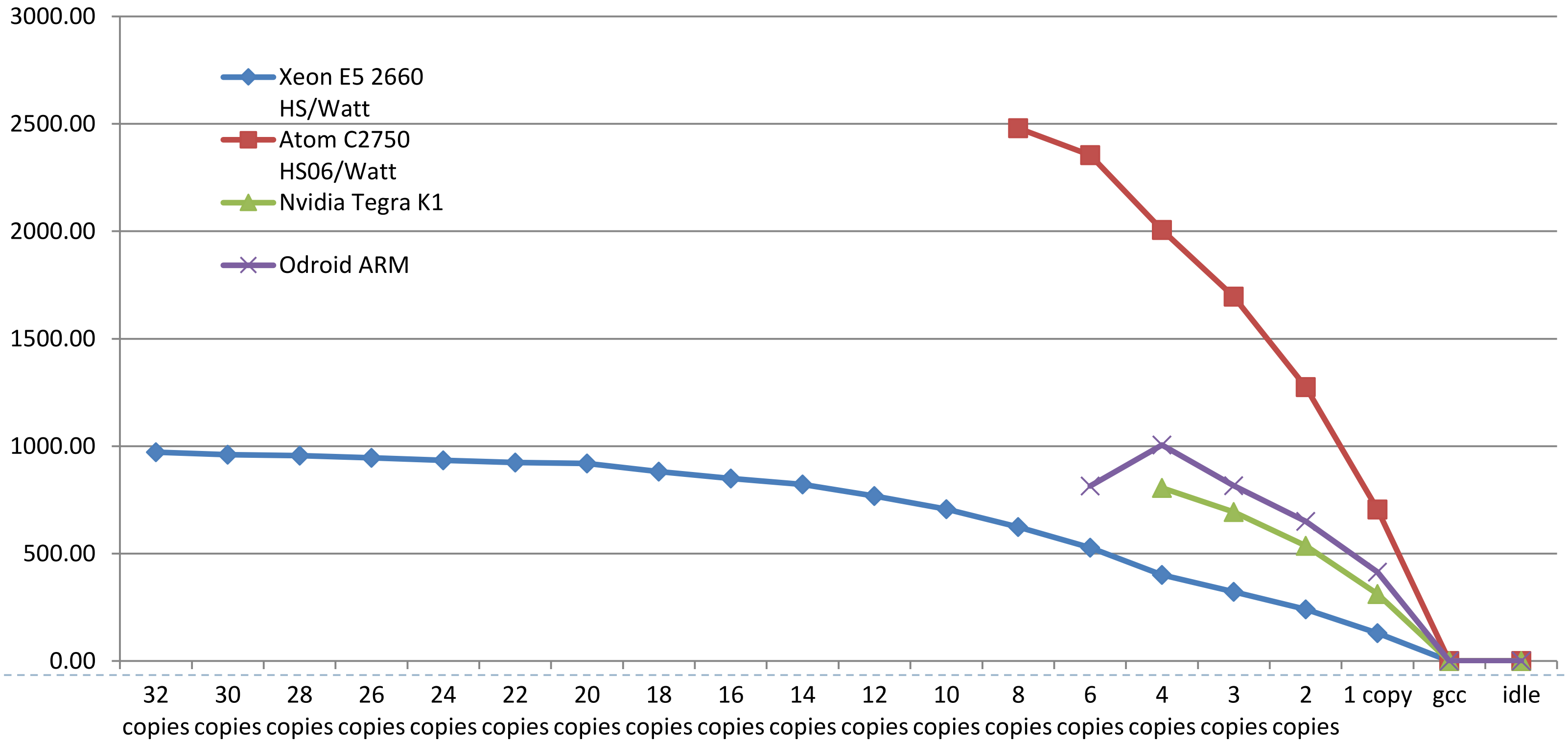
Power consumed on Intel ATOM C2750 vs XEON E5



Power Efficiency HS06/Watt
Intel ATOM C2750 vs XEON E5

HS06/Watt on ARM vs Intel

- I measured also the Tegra and Odroid dev kit
  - Efficiency less than Intel Atom but with cheap PSU, 20W consumed while 5W rumored
  - Waiting for next generation of ARM at 64bit



AMD A1100 – A57 ARM

"SEATTLE" SOC OVERVIEW

Power Efficient Cores
- Up to Eight ARM Cortex-A57 cores
- Up to 4MB shared L2 cache total

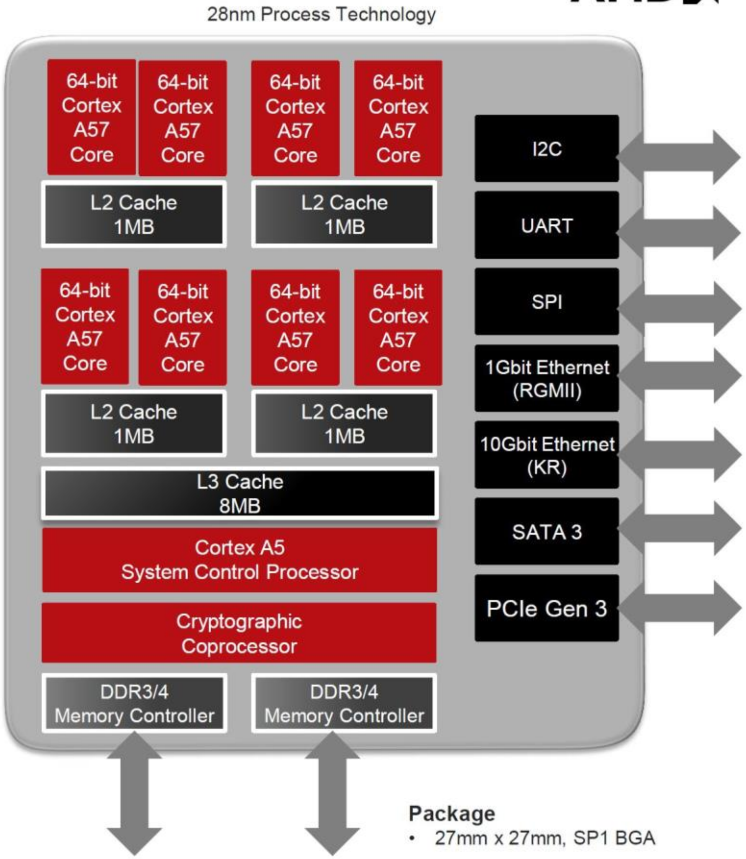
Cache Coherent Network
- Full cache coherency
- 8MB L3 cache
- SMMU: I/O address mapping and protection

High Performance, Flexible Memory
- Two 64-bit DDR3/4 channels with ECC
- Two DIMMs/channel up to 1866Mhz
- SODIMM, UDIMM, RDIMM support
- Up to 128GB per CPU

Highly Integrated I/O
- 8x SATA 3 (6Gb/s) ports
- Two 10GBASE-KR Ethernet ports
- 8 lanes PCI-Express® Gen 3, supports x8, x4, x2

System Control Processor
- TrustZone® technology for enhanced security
- Dedicated 1GbE system management port (RGMII)
- SPI, UART, I2C interfaces

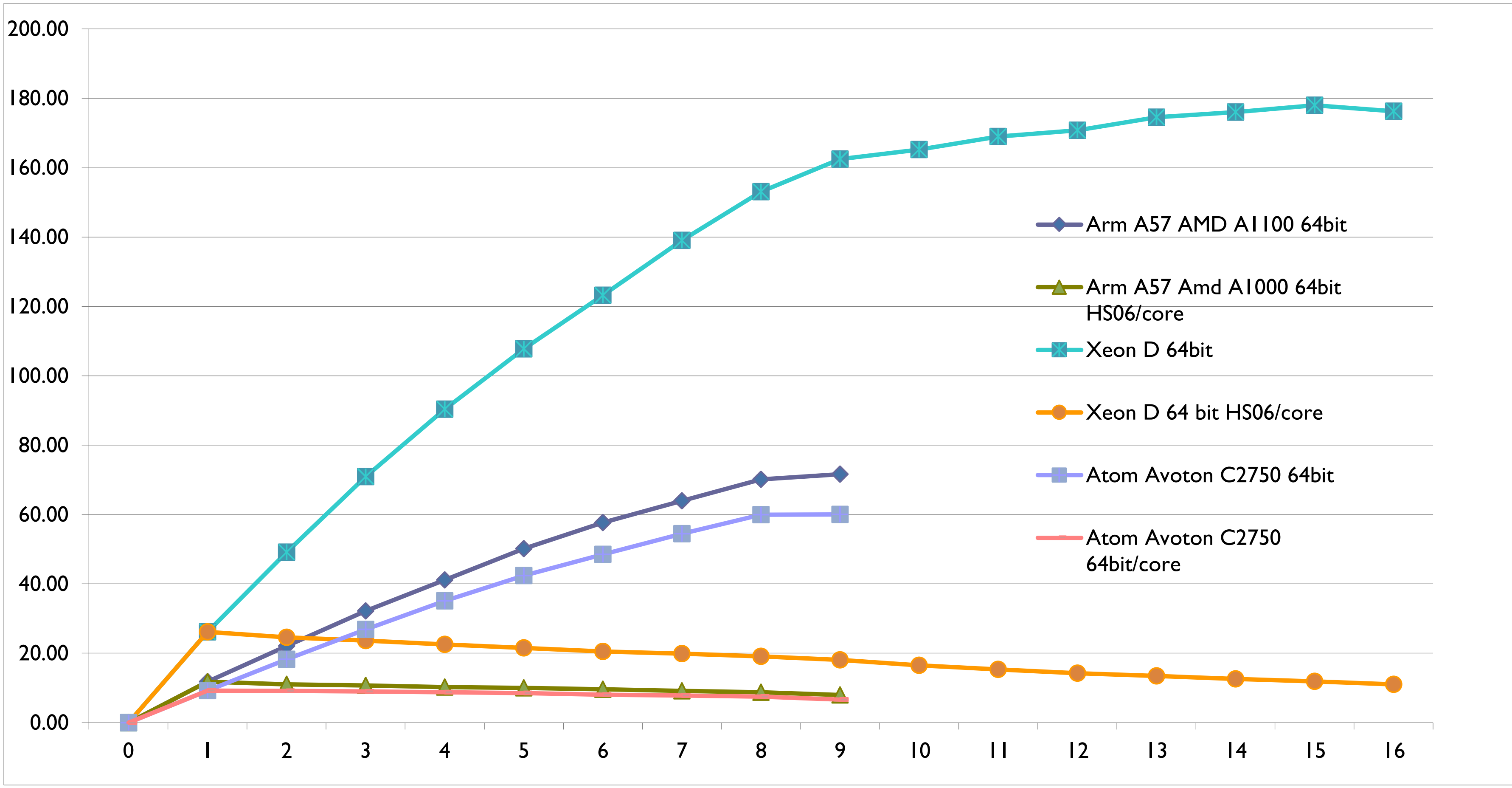
Cryptographic Coprocessor
- Separate Cryptographic algorithm engine for offloading encryption, decryption, compression, decompression computations



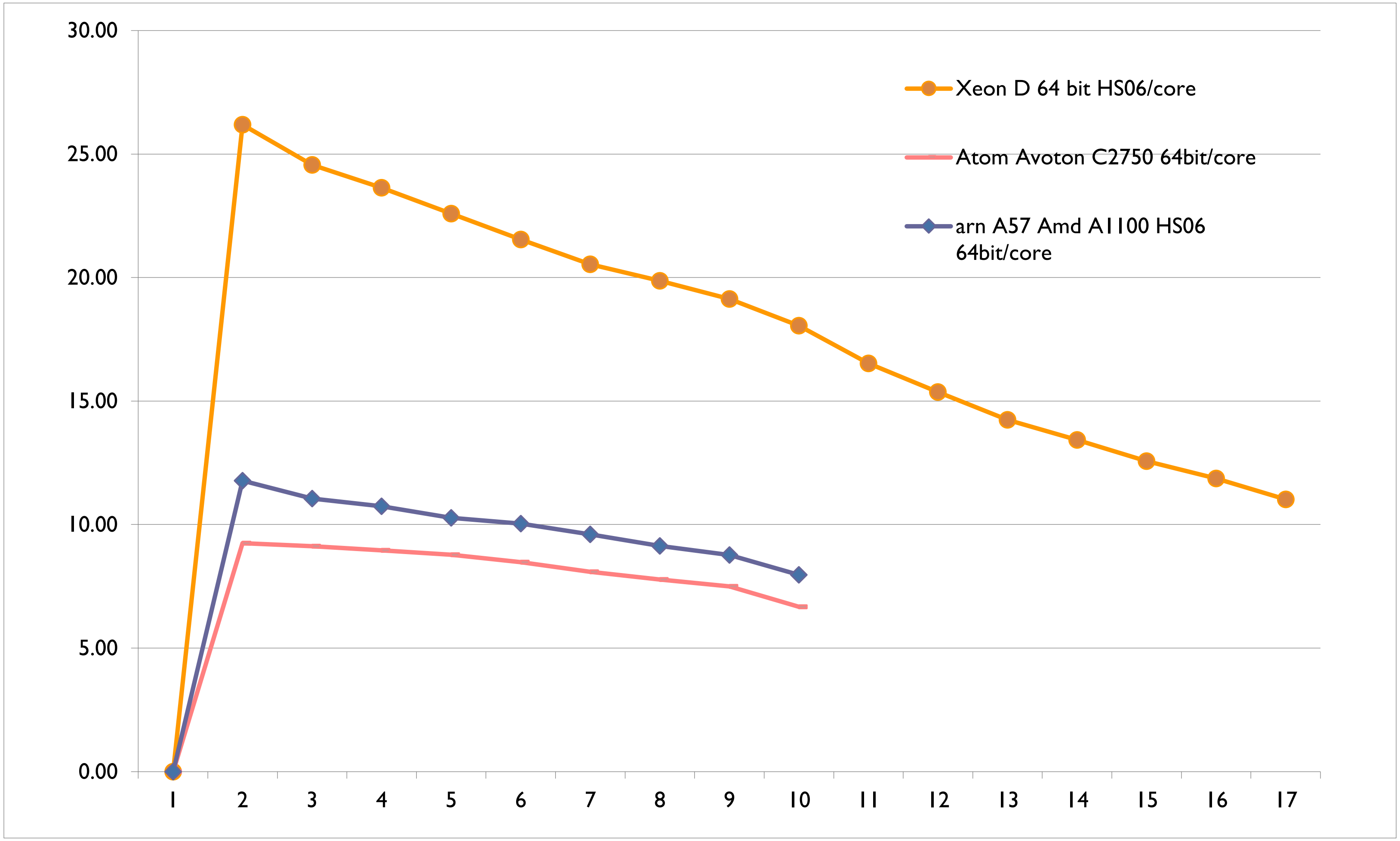
Package
- 27mm x 27mm, SP1 BGA

3 | AMD "SEATTLE" | HOT CHIPS 26 | 11 AUGUST 2014

HS06 – XeonD, Avoton, Amd A1100

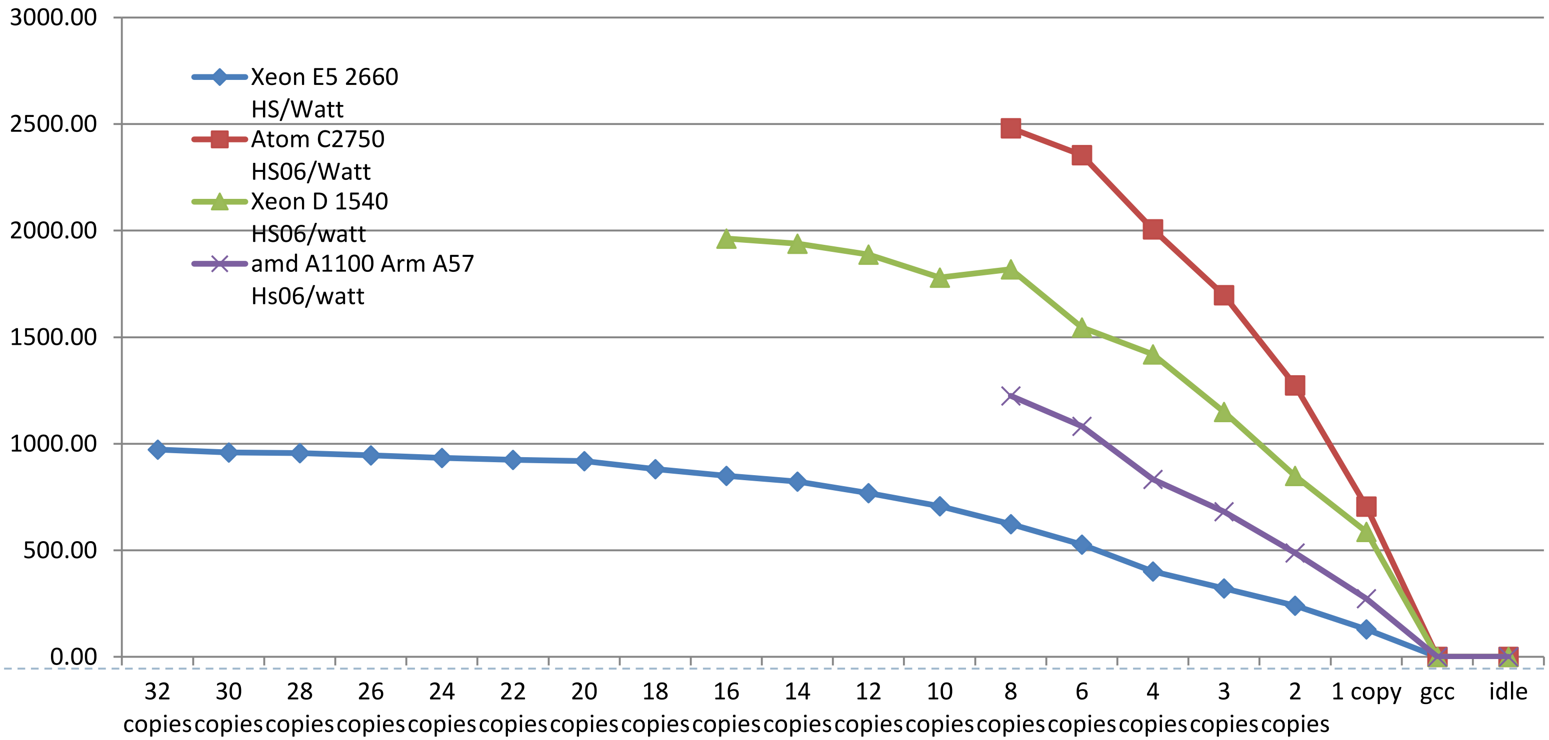


Per core loaded

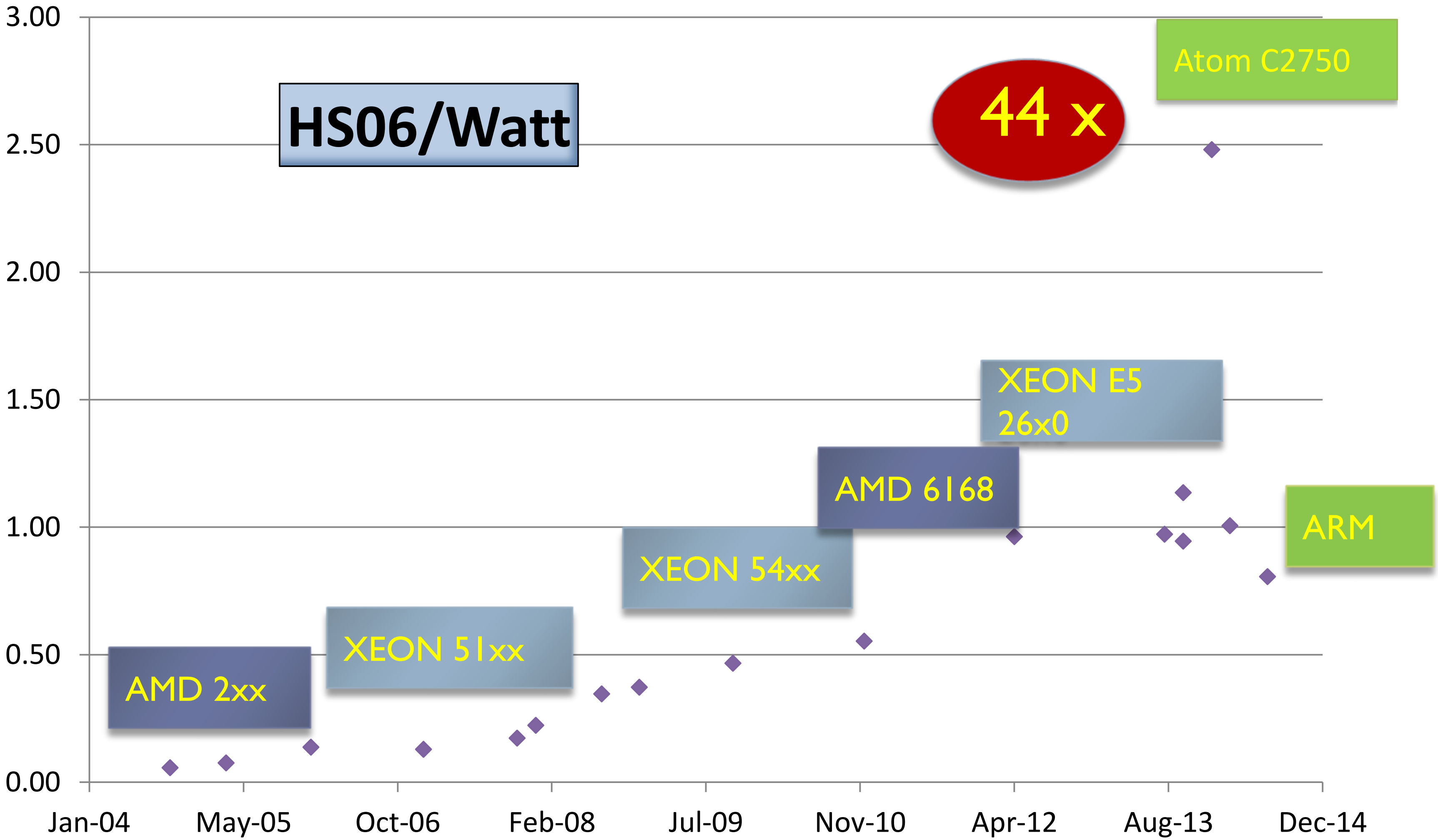


HS06/Watt on A57 and Xeon D

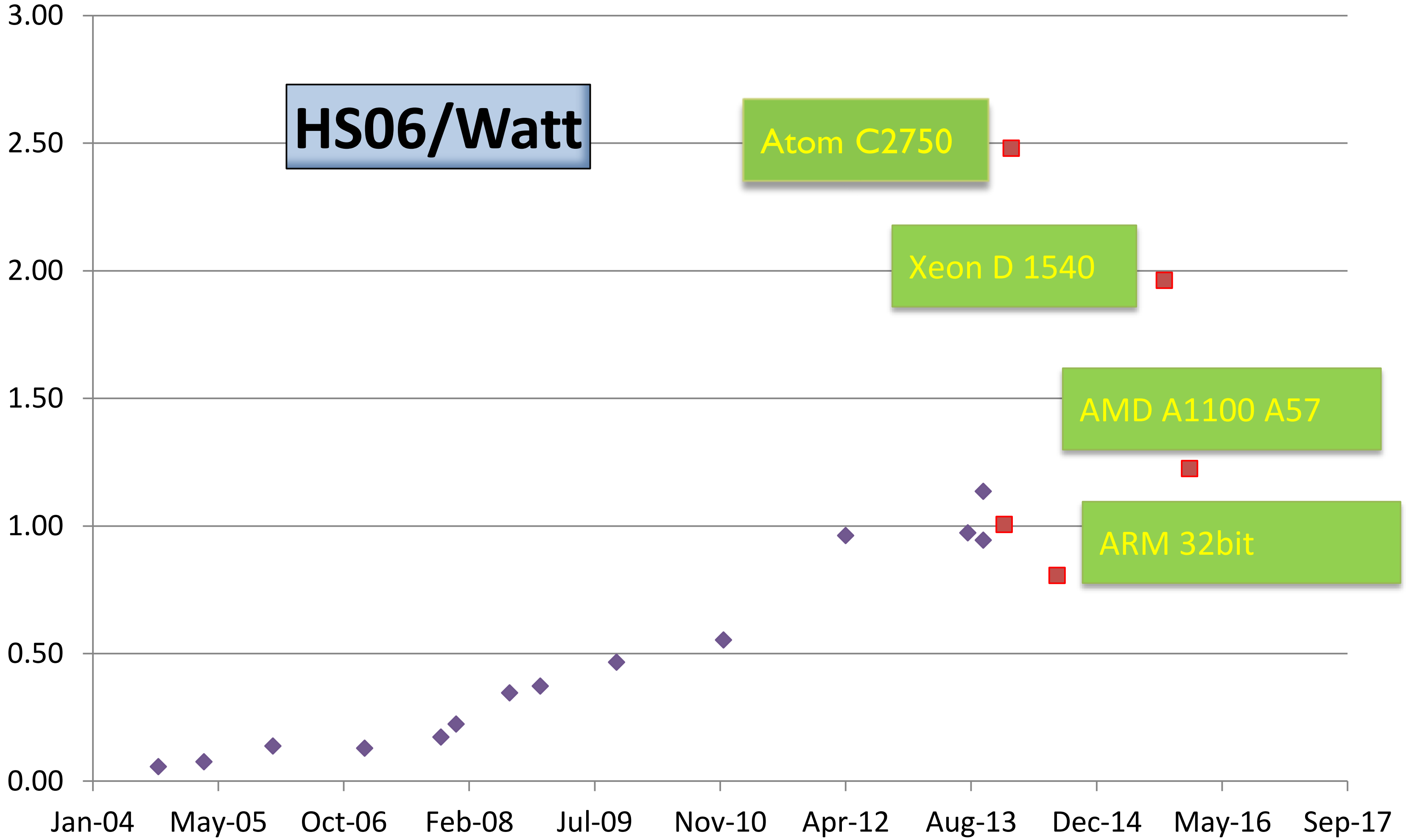
- Xeon D perform as expected
- Amd A1100 – A57 has good performances but disappointing power consumption. Not yet production grade configuration. Power supply issues?



Historical Trend with SoC



HS06/Watt x86-64 vs LowPower



Power consumption AMD A1100

AMD OPTERON A1100 SKUs

AMD

Model Number	OPN	TDP	Core Count	L2 Cache	L3 Cache	CPU Clock GHz	Max DDR3 Rate	Max DDR4 Rate	Temp Range (Tdie Max)	ECC
A1170	OA1170AQD8NAD	32W	8	4M	8MB	2.0	1600	1866	0C – 80C	Yes
A1150	OA1150AQD8NAD	32W	8	4M	8MB	1.7	1600	1866	0C – 80C	Yes
A1120	OA1120ARD4NAD	25W	4	2M	8MB	1.7	1600	1866	0C – 80C	Yes

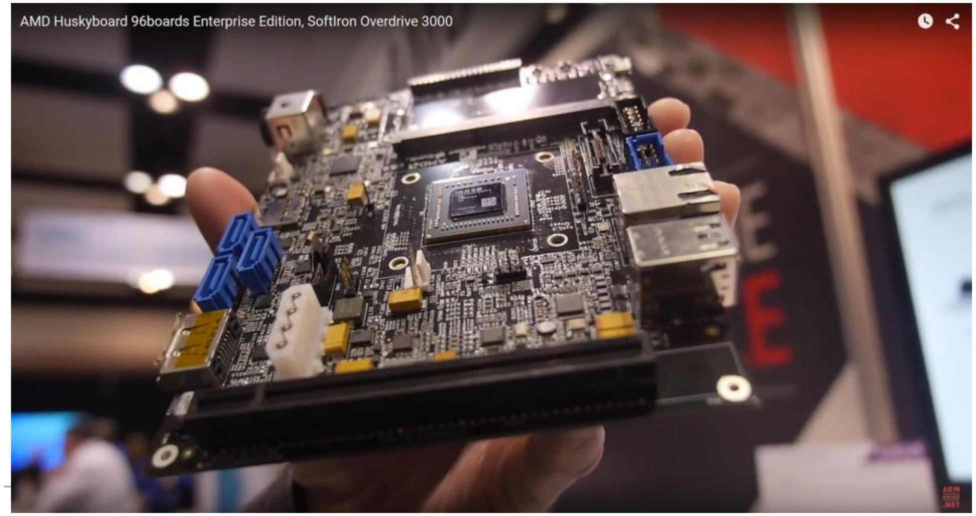
All information provided for reference only and subject to change. Always refer to latest AMD's technical documentation for support details.

Base frequency with TDP = 15W; Base frequency is higher when TDP > 15W

9 | AMD OPTERON A1100 | JANUARY, 2016 | UNDER EMBARGO UNTIL JANUARY 14, 2016 @ 9:00 AM EASTERN U.S. TIME

AMD Opteron A1100 vs. X2150

	CPU Core Configuration	CPU Frequency	SPECint_rate Estimate	SPECint per Core	Estimated TDP
AMD Opteron A1100	8 x ARM Cortex A57	>= 2GHz	80	10	25W
AMD Opteron X2150	4 x AMD Jaguar	1.9GHz	28.1	7	22W



Conclusion

- SoC processor can give us at least a 2x increase in HS06/Watt in HS06 and probably in HEP code
- The number of core/processor is very small. So special high density (proprietary) chassis are needed
- ARM64 look interesting but more evaluation is necessary
- Intel is leading in term of HS06/Watt


TIME FOR QUESTIONS