## ΕΠΛ 605: Προχωρημένη Αρχιτεκτονική Υπολογιστών

**Voltage - Frequency Tuning** 

## Voltage – frequency - power relation

Operating voltage	Cortex-A57 frequency
0.8V Underdrive	600MHz
0.9V Nominal	900MHz
1.0V Overdrive	1.15GHz

Source [arm.com] Cortex-A57 is an ARM CPU found in smartphones

- Higher CPU operating voltage allows higher operating frequency
- But of-course pushing voltage as high as possible for higher frequencies is not realistic because of thermal/power constrains

#### **CPUpower = Voltage<sup>2</sup>** Frequency \* Capacitance

### Hardware heterogeneity

• Same chips are not actually the same

👜 CPU-Z			-		-			
CPU Caches Processor Name	s   Mainboa	rd   Mem Intel Cor	ory SPD	Graphics	Bench	About		
Code Name	Haswe	II-E/EP	Max TDP	140.0 W	(ir	ntel2		
Package	Socket 2011LGA							
Technology	22 nm	Core V	/oltage 1	L.301 V	CO	RE 17		
Specification	on Intel(R) Core(TM) i7-5820K CPU @ 3.30GHz							
Family	6	Model F Ster			oing	2		
Ext. Family	6	Ext. Model 3F Revi			sion	MO		
Instructions MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, EM64T, VT-x, AES, AVX, AVX2, FMA3								
Clocks (Core #	≠0)	_	Cache -					
Core Speed	4398.97	MHz	L1 Data	6 x 32 KBy	tes	8-way		
Multiplier	x 44.0 ( 12	2-34)	L1 Inst.	6 x 32 KBy	tes	8-way		
Bus Speed	99.98 M	ИНz	Level 2	6 x 256 KBy	tes	8-way		
Rated FSB			Level 3	15 MByte	s	20-way		
Selection Processor #1  Cores 6 Threads 12								
CPU-Z	/er. 1.75.0.	x64	Tools 🔻	Validate		Close		



• Two chips of the same model (i7-5820K) one achieves 4.4GHz at 1.3V and the other 4.8GHz

## Heterogeneity among same products is a result of product binning

- Variations among chips of the same model exist due to the product binning
  - Intel/AMD cannot manufacture 1000 different products for each possible variation. Maybe they can sell 5-10 different CPU products, hence, some chips within the same product bin are faster than others



### Exploiting Hardware heterogeneity

- Motivation: Make the most out of each chip
- Three approaches:
  - F<sub>MAX (max frequency)</sub> testing: for a given voltage find the maximum working frequency
  - Overclocking: testing higher voltages and higher frequencies. The limit is the thermal and power consumption
  - Undervolting (V<sub>MIN (minimum voltage)</sub> testing): for a given frequency find the minimum working voltage

## V<sub>MIN</sub> Test







### V<sub>MIN</sub> testing results on X-Gene2 chips (Uniserver project work)



We can lower the voltage on chips #1 and #2 to save power

# Tools that allow modifying voltage and frequency

• UEFI/BIOS

My Favorites Main <u>Ai Tweaker</u> Advanced	Monitor	Boot Tool Exit	Hardware Monito
Pertormance Bias		Auto	CPU
DRAM Timing Control			Frequency Temperatur 3600 MHz 41°C
> DIGI+ VRM			APU Freg Ratio
VDDCR CPU Voltage	1.450V	Manual 👻	100.0 MHz 36x
VDDCR CPU Voltage Override		1.37500	Core Voltage 1.340 V
VDDCR SOC Voltage	1.062V	Manual 👻	
VDDCR SOC Voltage Override		1.20000	Memory
GFX core voltage	₽ A	1.20000	Frequency Voltage 2133 MHz 1.200 V
DRAM Voltage	1.200V	1.35000	Capacity
1.05V SB Voltage	1.050V	Auto	
2.5V SB Voltage	2.500V	Auto	Voltage
VDDP Voltage	0.900V	Auto	+12V +5V 12.033 V 4.986 V
Min = 1.2V Max = 1.80V Standard = 1.2V Increment = 0.005V +/- : Raise/Reduce			+3.3V 3.313 V

# Tools that allow modifying voltage and frequency

Motherboard software tools
e.g. ASUS A-Tuning
Even comes with auto
overclocking feature

III Operation Mode	To	ols OC Tweaker	System Info Li	ve Update	Tech Service	Settings
C Tweaker						
	✓ Custom	Save Profile Load	Profile Hot Key		Syste	em Info
Clock			1	A	CPU Freq.	3616.74 MH
BCLK/PCIE Frequency	100.47 MHz		٠		Cache Freq.	3415.81 M
CPU Ratio	× 16.0		*		DRAIT TEQ.	1007.00 11
CPU Cache Ratio	x 34.0		*			
GT Frequency	1200 MHz	- 🕸	+			
Voltage					<b>_</b>	
CPU Input Voltage (Offset)	-0.230 V		+			
CPU Vcore Voltage Mode	Adaptive Mode	Override Mode				
Vcore Adaptive Voltage	1.200 V		÷			
		Au	to apply when program starts		Apply	Cancel
Description						
Configurations for oversleskips	the sustam					

## Tools that allow modifying voltage and frequency

• MSI Afterburner for GPUs



## Intel Extreme Tuning Utility (IETU)

(intel® Extrem	ne Tuning Utility				Stop Monite	ors 🎫 Monitorina 🔒	Settings 2 Help	
System Information	Graphics							
Advanced Tuning						Core Default	Proposed 🔺 📤	
All Controls	Processor Graphics Voltage Mode	Processor Graphics Vo	bltage	© Deta	ault Refe	rence Clock 100.000 MHz	2 100.000 MHz 3 100 GHz	
Core	Adaptive Static Processor Graphics Voltage Offset 0 0,000 V	Processor Graphics Ic	cMax	0 34.00	0 A Intel® Turbo Boost	Technology Enable	Enable	
Cache					Turbo Boost Short	Power Max 31.250 W	25.000 W	
<ul> <li>Graphics</li> </ul>	Processor Graphics Media Voltage Mode 🕕	Processor Graphics M	edia Voltage	③ Defa	Turbo Boost Short F ault Turbo Boost Power	Power Max Enable Time Win 28.000 Secor	Enable nd:28.000 Second:	
Other	Adaptive Static				Core Vo	ltage Mode Adaptive Core Voltage Default	Adaptive Default	
Stress Test	Processor Graphics Media Voltage Offset 0.000 V	Processor Graphics U	nslice IccMax	© 34.00	0 A Core Vo Processor (	Itage Offset 0.000 V Core IccMax 35.000 A	0.000 V 35.000 A	
Benchmarking					AVX	Ratio Offset 0.000 x	0.000 x	
Profiles					2 /	Active Cores 31.000 x	31.000 x	
App-Profile Pairing						Cache Default	Proposed ^	
					Cache Vo Ca	ltage Mode Adaptive che Voltage Default	Adaptive Default	
					Cache Vo Ca	Itage Offset 0.000 V ache IccMax 35.000 A	0.000 V 35.000 A	
						Graphics Default	Proposed 🔺	
					Processor Graphics	Voltage M Adaptive	Adaptive	
					Processor Graphics	Processor Graphics Voltage Denault Denault Processor Graphics Voltage O 0.000 V 0.000 V		
					Processor Grad		34.000 A	
					Apply		Save	
Deless Transaction		٩					ع	
39 °C			CPU Utilization	Memory Utilization 3465 MB	Package Temperature 39 °C	Max Core Frequency 1.63 GHz		
CPU Utilization			Processor Cache Frequency	Processor Graphics Freque	Active Core Count	Thermal Throttling		
Max Core Frequency	~~~~^^~~^^~~~~~~~~~~~~~~~~~~~~~~~~~~~~		1.40 GHz	449 MHz	0	No		
			Power Limit Throttling	Current Limit Throttling	Motherboard VR Thermal			
	man har a martine the the		No	No	No	2 W		
	S	Minutes				KOLEROO	KCHECK	

Allows modifying CPU, Cache and on-board GPU voltage and frequency for Intel CPUs

### Live demonstration of IETU