

# 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

$$\text{CPUpower} = \text{Voltage}^2 * \text{Frequency} * \text{Capacitance}$$

# Hardware heterogeneity

- Same chips are not actually the same

CPU-Z Ver. 1.75.0.x64

Processor			
Name	Intel Core i7 5820K		
Code Name	Haswell-E/EP	Max TDP	140.0 W
Package	Socket 2011 LGA		
Technology	22 nm	Core Voltage	1.301 V
Specification			
Intel(R) Core(TM) i7-5820K CPU @ 3.30GHz			
Family	6	Model	F
Ext. Family	6	Ext. Model	3F
Stepping	2	Revision	M0
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 KBytes 8-way
Multiplier	x 44.0 ( 12 - 34 )	L1 Inst.	6 x 32 KBytes 8-way
Bus Speed	99.98 MHz	Level 2	6 x 256 KBytes 8-way
Rated FSB		Level 3	15 MBytes 20-way

Selection: Processor #1 | Cores: 6 | Threads: 12

CPU-Z Ver. 1.73.0.x64

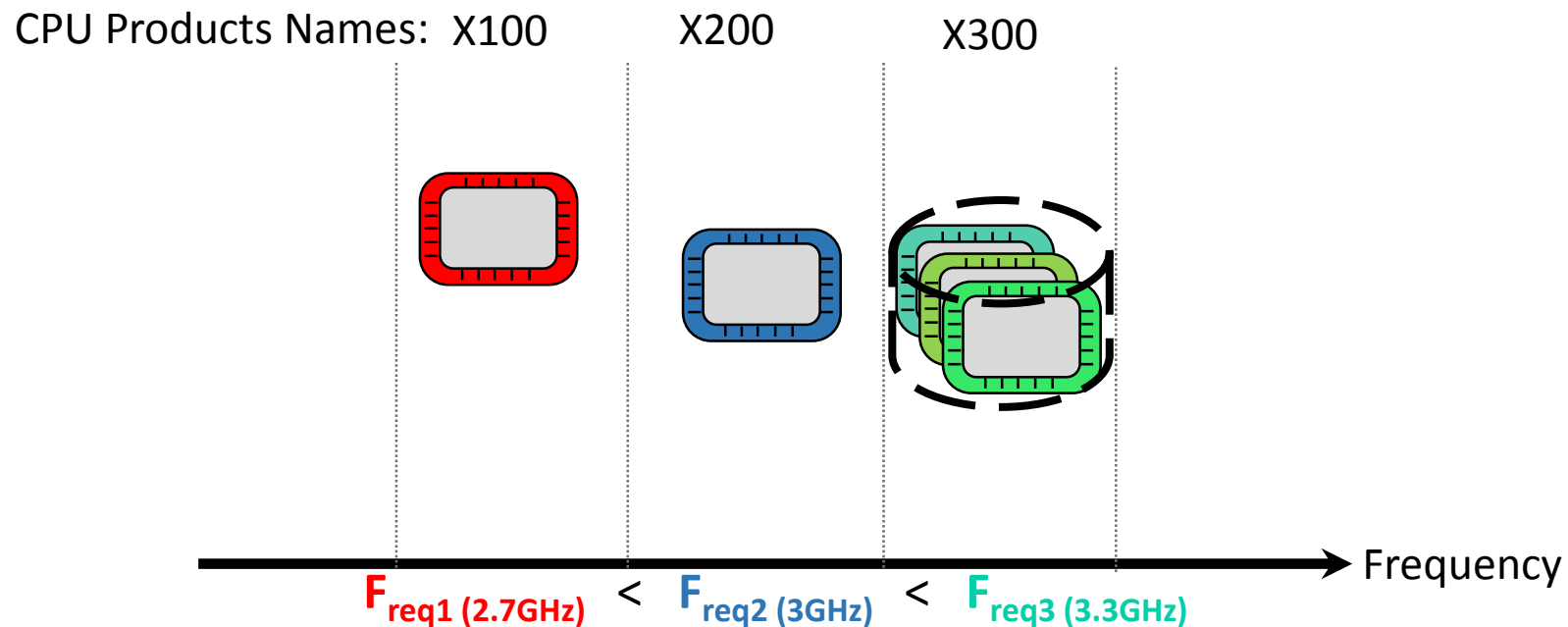
Processor			
Name	Intel Core i7 5820K		
Code Name	Haswell-E/EP	Max TDP	140.0 W
Package	Socket 2011 LGA		
Technology	22 nm	Core Voltage	1.304 V
Specification			
Intel(R) Core(TM) i7-5820K CPU @ 3.30GHz			
Family	6	Model	F
Ext. Family	6	Ext. Model	3F
Stepping	2	Revision	M0
Instructions			
MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, EM64T, VT-x, AES, AVX, AVX2, FMA3			
Clocks (Core #0)		Cache	
Core Speed	4798.88 MHz	L1 Data	6 x 32 KBytes 8-way
Multiplier	x 48.0 ( 12 - 34 )	L1 Inst.	6 x 32 KBytes 8-way
Bus Speed	99.98 MHz	Level 2	6 x 256 KBytes 8-way
Rated FSB		Level 3	15 MBytes 20-way

Selection: Processor #1 | Cores: 6 | Threads: 12

- 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

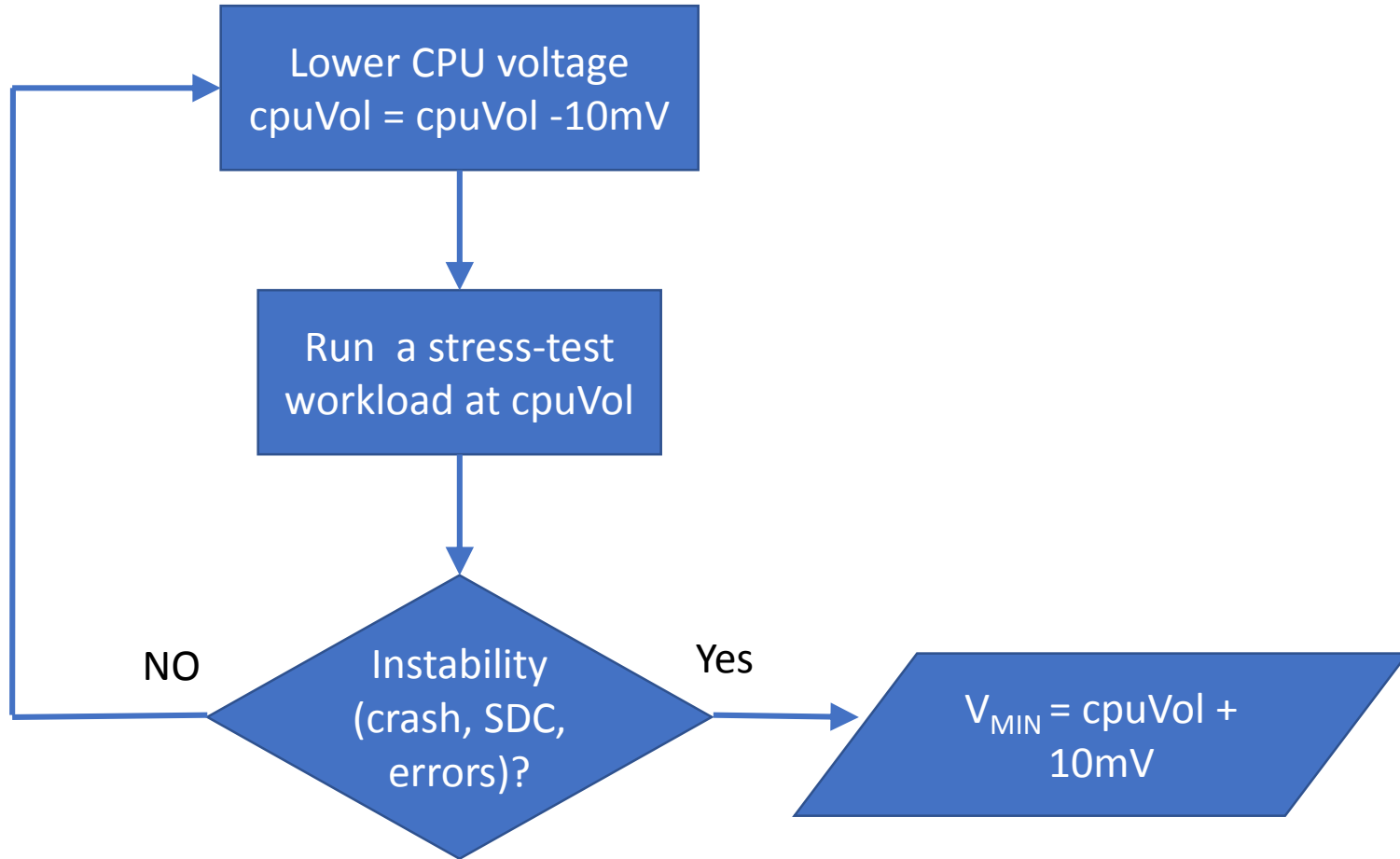
- Variations among chips of the same model exist due to the product binning
  - Intel/AMD cannot manufacture 1000 different products for each possible variation. Maybe they can sell 5-10 different CPU products, hence, some chips within the same product bin are faster than others



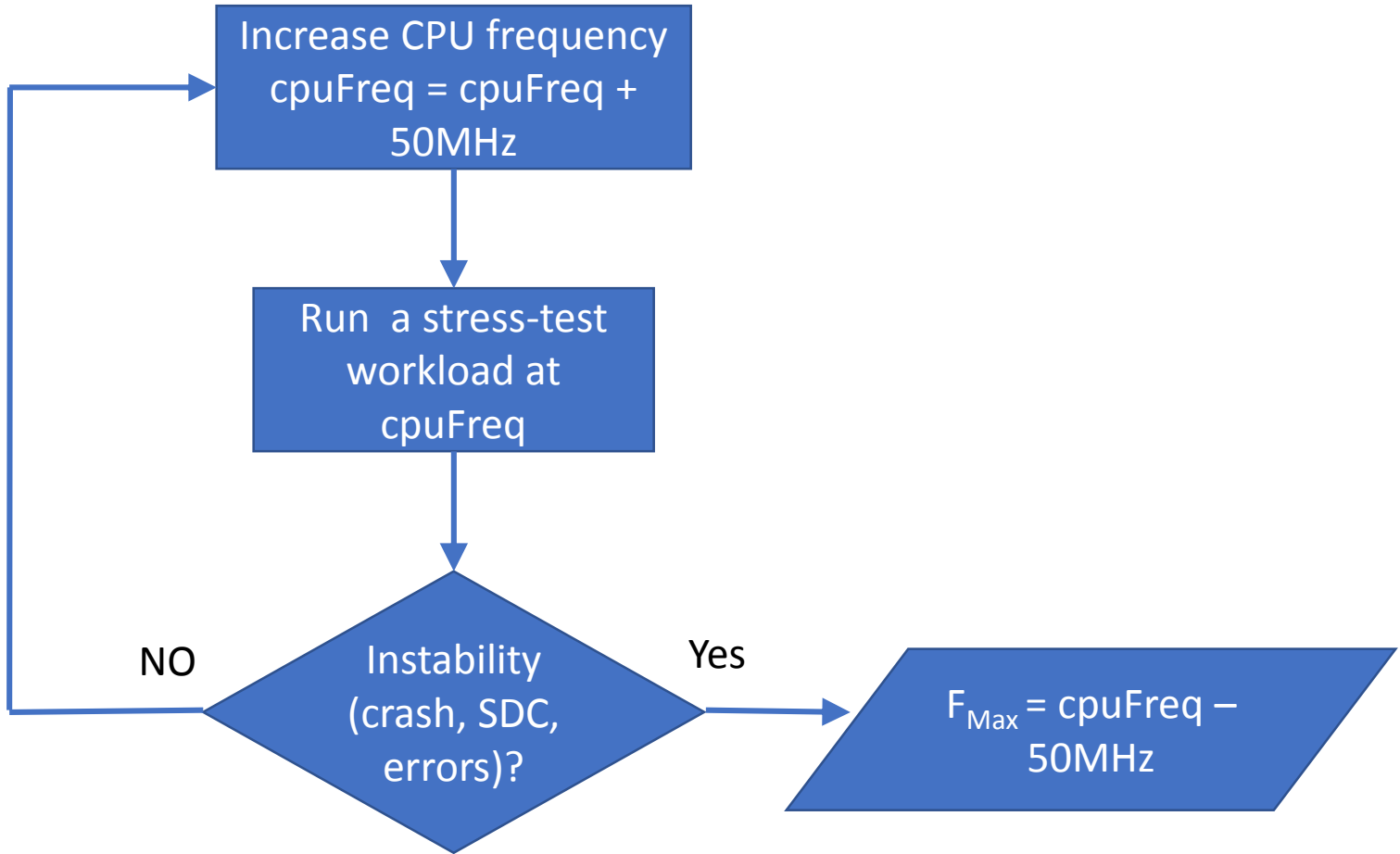
# Exploiting Hardware heterogeneity

- Motivation: Make the most out of each chip
- Three approaches:
  - $F_{MAX}$  (max frequency) 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 ( $V_{MIN}$  (minimum voltage) testing): for a given frequency find the minimum working voltage

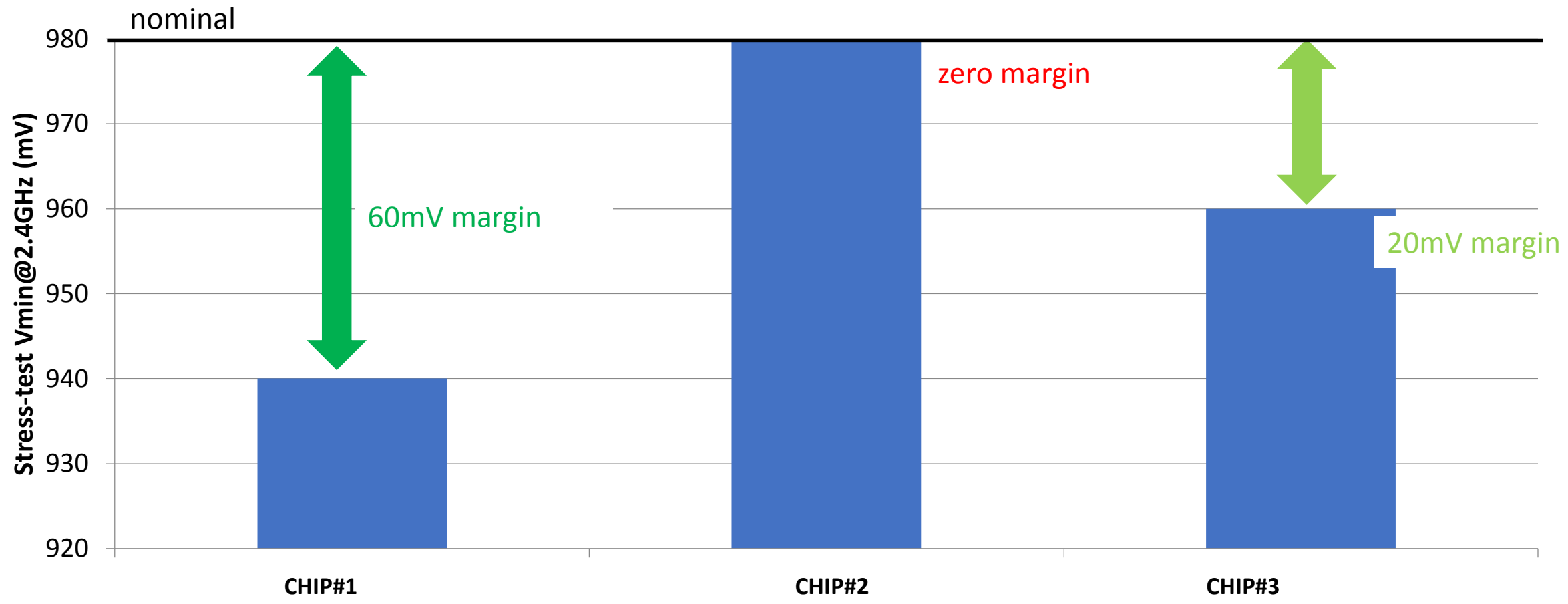
# $V_{\text{MIN}}$ Test



# F<sub>MAX</sub> Test



# $V_{\text{MIN}}$ testing results on X-Gene2 chips (Uniserver project work)

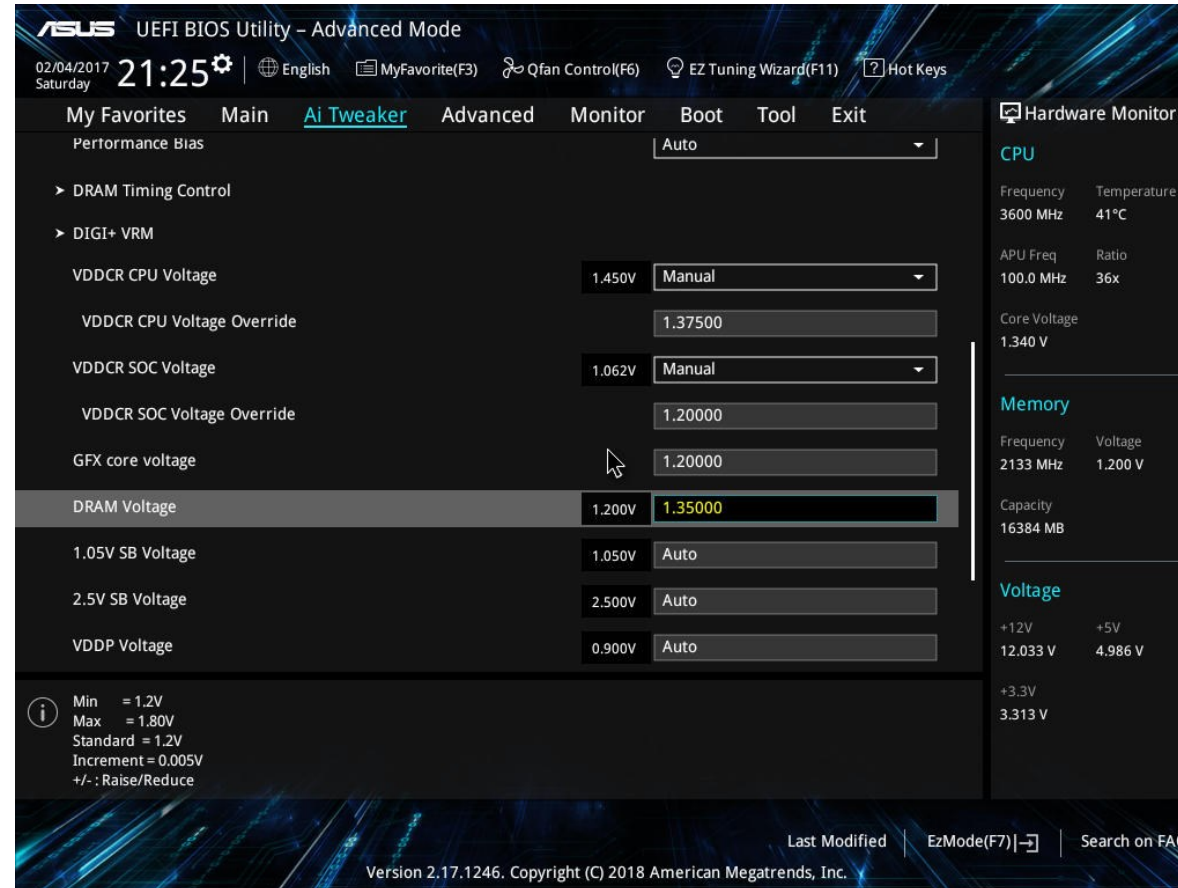


We can lower the voltage on chips #1 and #2 to save power



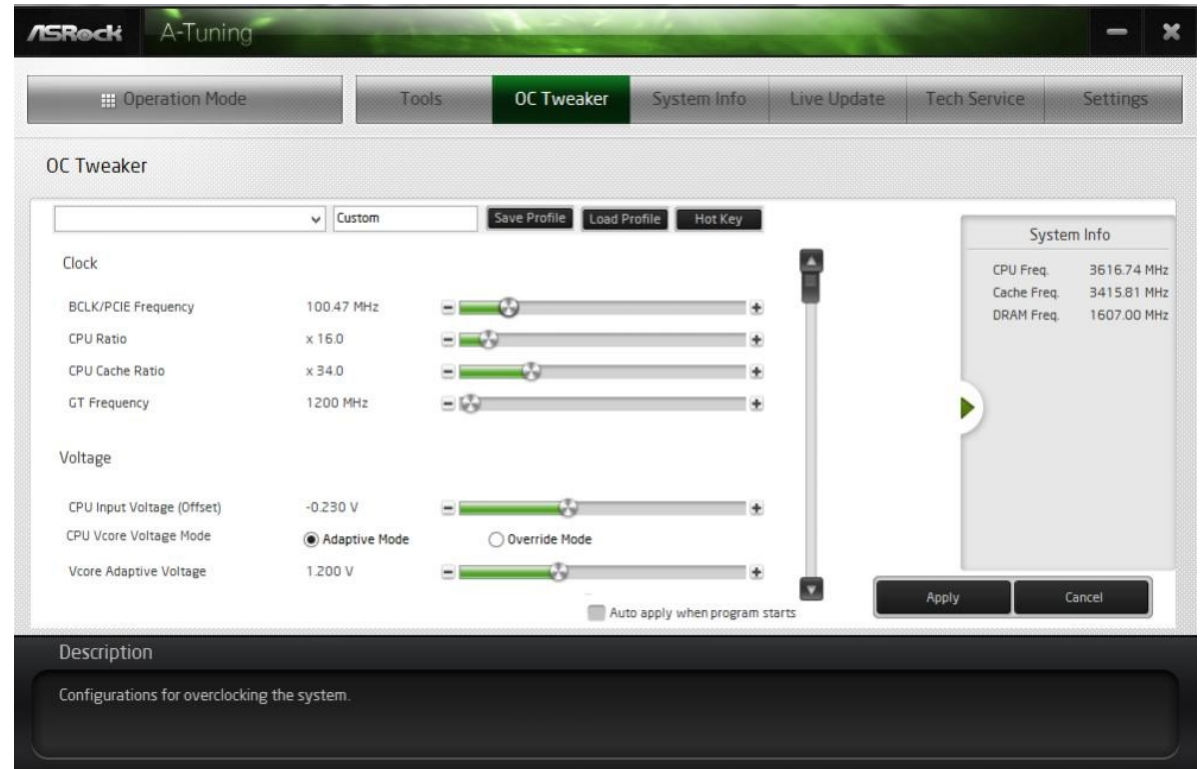
# Tools that allow modifying voltage and frequency

- UEFI/BIOS



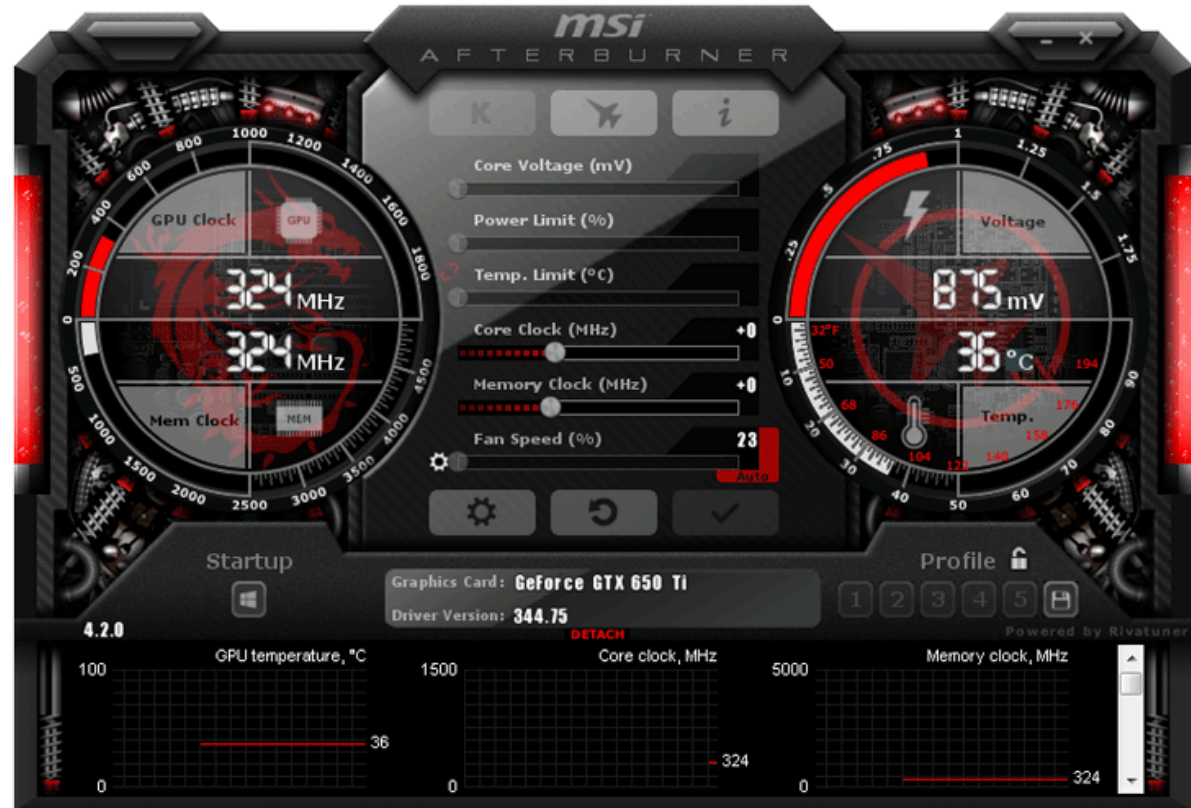
# Tools that allow modifying voltage and frequency

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



# Tools that allow modifying voltage and frequency

- MSI Afterburner for GPUs



# Intel Extreme Tuning Utility (IETU)

The screenshot displays the Intel Extreme Tuning Utility (IETU) interface. The main window is titled "Intel® Extreme Tuning Utility" and includes a menu bar with "Stop Monitors", "Monitoring", "Settings", and "Help". The interface is divided into several sections:

- System Information:** A sidebar on the left with options like "Advanced Tuning", "All Controls", "Core", "Cache", "Graphics", "Other", "Stress Test", "Benchmarking", "Profiles", and "App-Profile Pairing".
- Graphics:** A central panel with various settings for Processor Graphics Voltage, Processor Graphics Voltage Offset (highlighted with a red box), Processor Graphics Voltage Mode (Adaptive/Static), Processor Graphics IccMax, Processor Graphics Media Voltage, Processor Graphics Media Voltage Mode, Processor Graphics Media Voltage Offset, and Processor Graphics Unsliced IccMax.
- Core/Cache/Graphics Summary:** A table on the right comparing Default and Proposed values for various parameters. The "Core" section includes Reference Clock, Max Turbo Boost CPU Speed, Intel Turbo Boost Technology, Turbo Boost Power Max, Turbo Boost Short Power Max, and Turbo Boost Power Time Window. The "Cache" section includes Cache Voltage Mode, Cache Voltage, Cache Voltage Offset, and Cache IccMax. The "Graphics" section includes Processor Graphics Voltage Mode, Processor Graphics Voltage, Processor Graphics Voltage Offset, and Processor Graphics IccMax.
- Monitoring:** A bottom section with a graph showing Package Temperature (39°C), CPU Utilization (15%), and Max Core Frequency (1.63 GHz) over a 5-minute period. It also displays real-time statistics for CPU Utilization (12%), Memory Utilization (3465 MB), Processor Cache Frequency (1.40 GHz), Processor Graphics Frequency (449 MHz), Package Temperature (39°C), Active Core Count (0), Power Limit Throttling (No), Current Limit Throttling (No), Motherboard VR Thermal (No), and Max Core Frequency (1.63 GHz).

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

# Live demonstration of IETU