

Overclocking Unlocked Intel® Core™ Processors for High Performance Gaming and Content Creation

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Agenda

- **Overclocking Theory and Trends**
- **High-end Desktop Overclocking Architecture**
- **Overclocking Design Tips**
- **Desktop and Mobile Overclocking Architecture**
- **Harnessing Overclocking**
- **Summary**

Risk Reminder



WARNING: Altering clock frequency and/or voltage may: (i) reduce system stability and useful life of the system and processor; (ii) cause the processor and other system components to fail; (iii) cause reductions in system performance; (iv) cause additional heat or other damage; and (v) affect system data integrity. Intel has not tested, and does not warranty, the operation of the processor beyond its specifications. Intel assumes no responsibility that the processor, including if used with altered clock frequencies and/or voltages, will be fit for any particular purpose. For more information, visit:

<http://www.intel.com/consumer/game/gaming-power.htm>

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Defining Overclocking

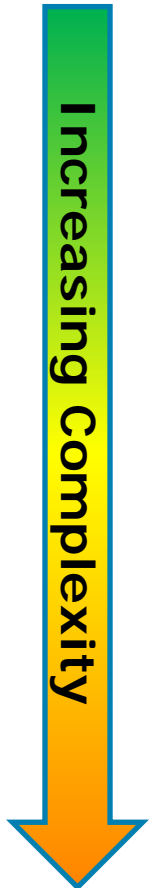
- **What is Overclocking (OC)?**
 - The process of increasing clock rates beyond specification
- **Why Overclock?**
 - Increase performance for compute intensive tasks, e.g., transcode, gaming, rendering
 - Compete, Promote, Socialize
- **How is this done?**
 - Obtain a motherboard optimized for Intel® unlocked processors
 - Change unlocked ratios or platform clock frequency
 - Increase voltage on relevant interfaces
 - Improve cooling on overclocked/overvoltaged components

Overclocking Theory

General Principles

The Rule: Maximize frequency, minimize voltage/current and maximize heat dissipation to meet personal stability requirements

What	Benefits	How
Processor Cores	Rendering, Music, Photo and Video editing, Transcode, Gaming Physics, AI, Compute Intensive	<ul style="list-style-type: none">✓ Increase Power Limits and Max Current✓ Raise Core voltage✓ Increase active Core ratios
Processor Integrated Graphics (pGfx) †	Gaming frame rates, Media Transcode	<ul style="list-style-type: none">✓ Increase Power Limits and Max Current✓ Raise pGfx voltage✓ Raise pGfx max ratio
Memory	Processor Graphics performance, Sound engineering, Photo and Video editing	<ul style="list-style-type: none">✓ Increase memory ratio✓ Raise memory IO voltage✓ Change timings✓ Increase system agent voltage
Platform Base Clock	All of the above	<ul style="list-style-type: none">✓ Increase all domain voltages✓ Reduce weakest domain frequency via ratios



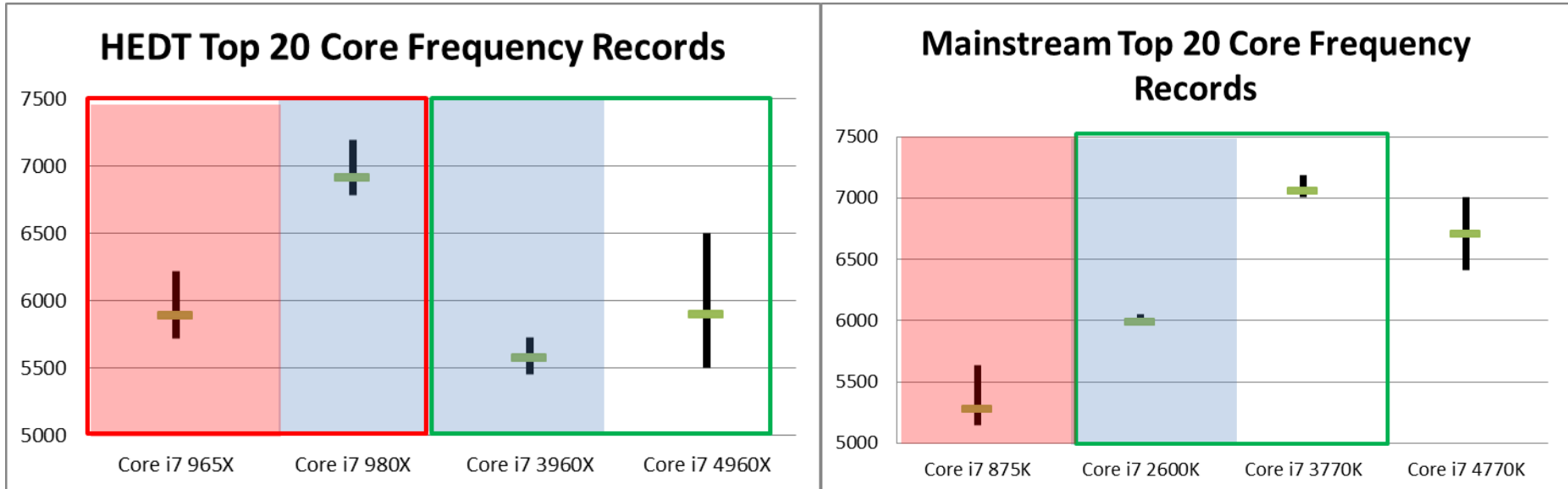
† pGfx utilizes Intel® Iris™ Pro., Intel® Iris , or Intel® HD Graphics

Observed Frequency Trends in OC

Q: How much OC can I expect from my CPU?

A: There are many factors

- Every CPU is designed to meet nominal requirements with intentional guardband – not specifically for OC
- Overclocking is the act of tapping into the intentional guardband + design conservatism + Si process conservatism
- This changes with each CPU process stepping, architecture change and overall design targets



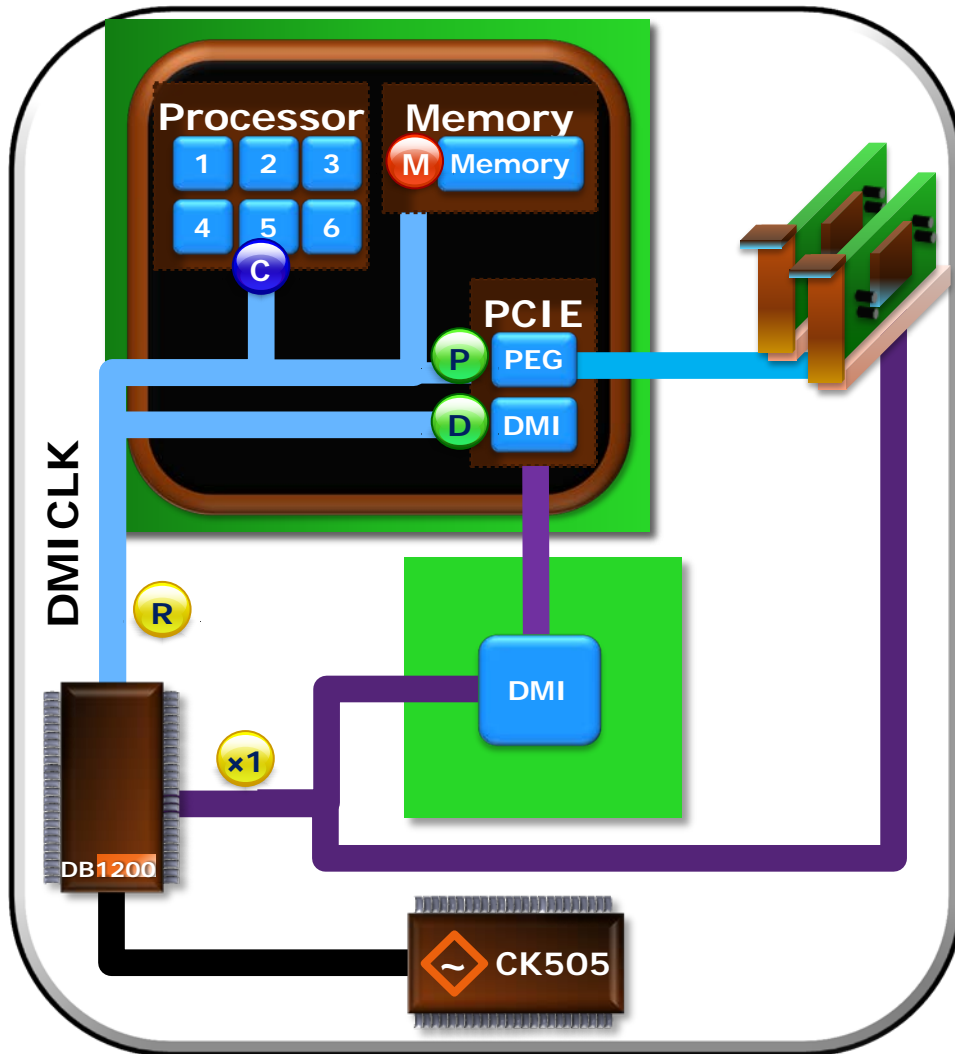
HEDT = High End Desktop. Today this includes Socket LGA2011.

This data was collected from overclocking forums and should be considered approximate for illustrative purposes only.

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Intel® Core™ i7 Desktop Processors Based on Socket LGA2011 with Intel® X79 Express Chipset

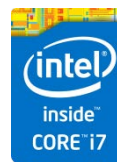


- C** • Core Frequency
 - Unlocked Intel® Turbo Boost Technology limits†
 - Unlocked core ratios up to 63 in 100MHz increments†
 - Programmable voltage offset
- M** • Memory Ratio
 - Unlocked memory controller
 - Granularity in 266MHz steps
 - Ratios supported up to 2400Hz
- R** • DMICLK (aka BCLK)
 - Fine Grain range $\pm 5-7\%$
 - BCLK ratios = 1.0, 1.25, 1.67
- P** **D** • PEG and DMI Ratios
 - PEG/DMI ratios = 80/50, 64/40, 48/30
 - Ratio option must reflect selected BCLK coarse ratio

Example : Core Freq x 1.25 **R** requires PEG/DMI ratios **P** **D** at 64/40 x 1.25 **R** to keep at 8 GHz/5 GHz nominal

Intel® Core™ i7 Desktop Processors Based on Socket LGA2011 with Intel® X79 Express Chipset

Feature Overview



SKU	i7-4960X	i7-4930K	i7-4820K
Cores/Cache	6/15M	6/12M	4/10M
Turbo Ratio Overrides (100MHz Steps) [†]	Up to 63	Up to 63	Up to 63
PL1, PL2, Tau, ICCMax Overrides	✓	✓	✓
Real-time Core Overclocking (in OS)	Yes	Yes	Yes
DDR Frequency Overrides (266MHz Steps)	Up to 2400	Up to 2400	Up to 2400
DDR Timing Overrides	✓	✓	✓
Coarse BCLK Ratios supported with PEG, DMI ratios	Enhanced Ratio Support (1.0, 1.25, 1.67)	Enhanced Ratio Support (1.0, 1.25, 1.67)	Enhanced Ratio Support (1.0, 1.25, 1.67)

[†] Memory ratio not fuse limited, but support above 2400 via ratio not guaranteed. Use BCLK for higher frequencies.

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Overclocking Design Tips

What board designers consider for unlocked Processors



COLLABORATION

Work closely with Intel to understand the platform architecture and gauge hardware requirements. This helps to define customized overclocking options for different segments.

POWER DESIGN

Ensuring that onboard power delivery circuitry is capable of exceeding processor power requirements under extreme loading conditions.

CIRCUITRY DESIGN

Tuning of trace layouts and platform microcode to extend overclocking headroom for CPU and DRAM.

CUSTOM SETUP

Utilize customized hardware to mitigate platform overclocking obstacles.

PRODUCT DEVELOPMENT

Develop software and hardware solutions to provide automated overclocking features.

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Overclocking Design Tips

How enthusiast board/system designs influence overclockability

- **High Quality Components**

- Long-life solid polymer & MLCC Capacitors
- High current MOSFETs
- Low DCR inductors
- Advanced digital buck controllers
- More copper in power plane

- **Efficient Cooling Through Layout Design**

- **Careful Analysis of Signal Integrity:**

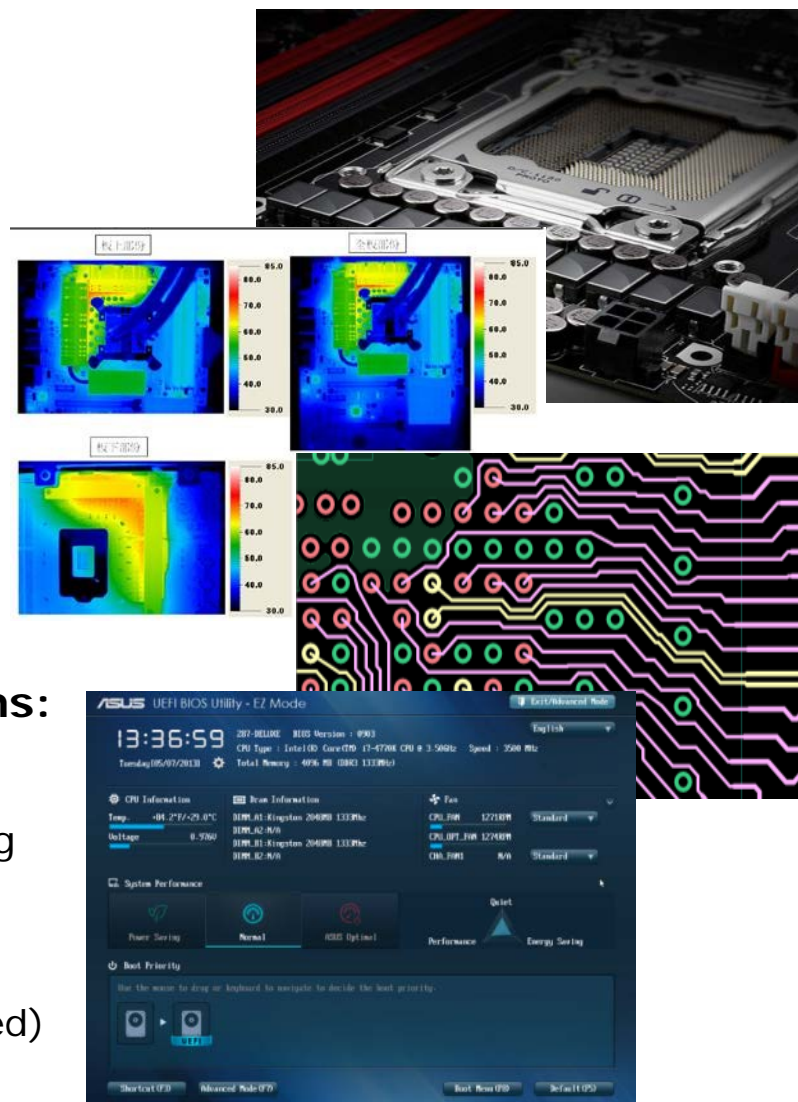
- Tight control of trace impedance on PCB, more layers, shorter lengths & length matching
- Tuning of MRC to improve signal margins and memory compatibility

- **Dedicated hardware and software solutions:**

- Hardware and software features that allow real-time changes to overclocking parameters and improve system stability for smooth overclocking experience

- **Intuitive UEFI**

- Intuitive layout with customizable menus, overclocking profiles (presets and user configured) and extensive auto-rules for all parameters
- OC recovery with low-level UEFI flashing capabilities

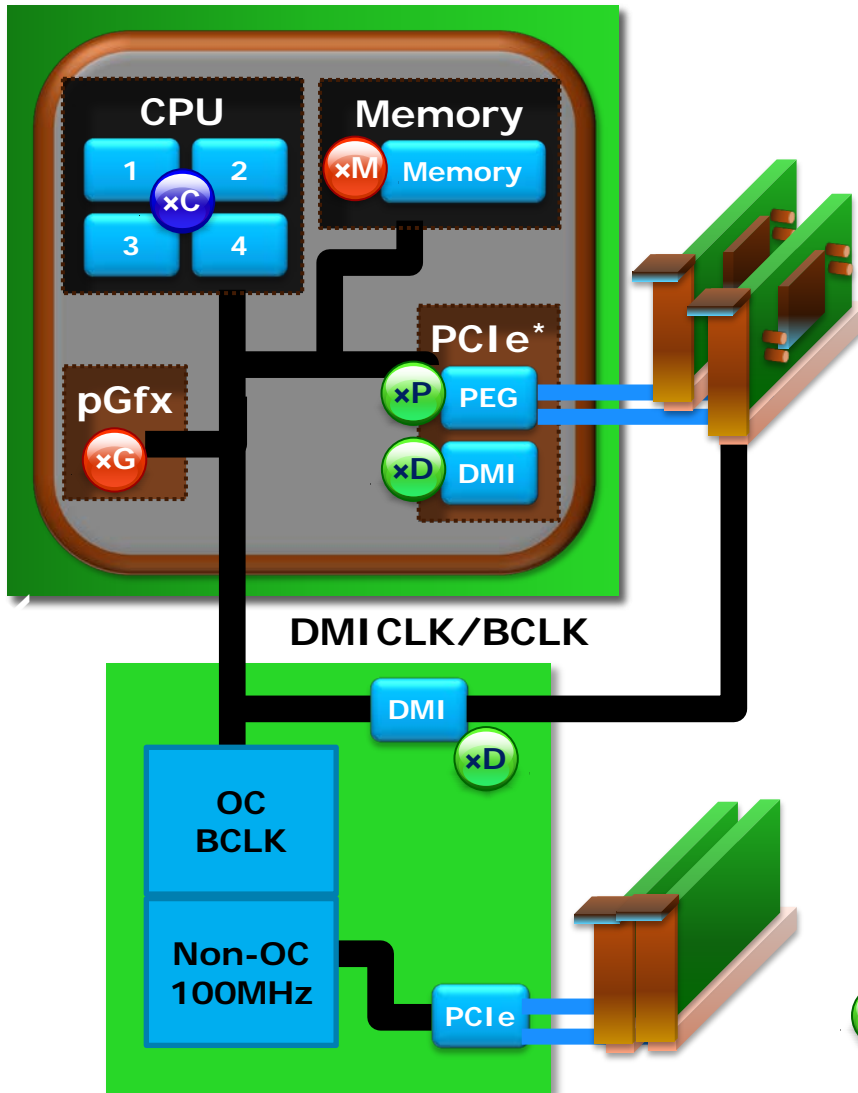


**Live Demo:
Optimization of Core, Memory and
BCLK to achieve visibly better
performance experience on
content creation with a Intel®
Core™ i7-4960X Extreme Edition
Processor**

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Next Generation Intel Haswell Microarchitecture

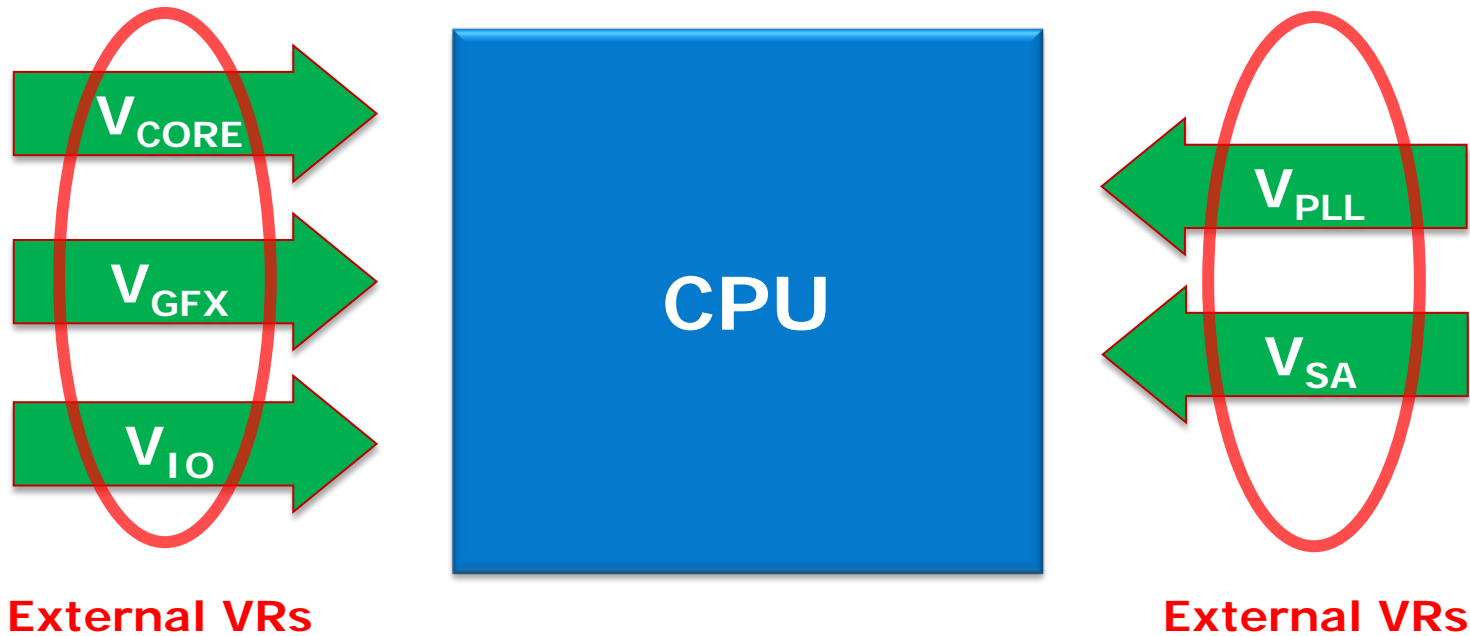


- **xC** • Core Frequency
 - Unlocked Intel® Turbo Boost Technology limits[†]
 - Unlocked core ratios up to 80 in 100MHz increments[†]
 - Programmable voltage via iVR
- **xG** • Graphics Frequency (pGfx)
 - Unlocked Intel® HD Graphics limits[†]
 - Unlocked graphics ratios up to 60 in 50MHz increments
 - Programmable voltage via iVR
- **xM** • Memory Ratio
 - Unlocked memory controller
 - Options for 200 and 266MHz steps[†]
 - Logical ratios up to 2933MHz[†]
 - DMICLK (aka BCLK)
 - Unlocked PCH clock controller (1MHz increments upwards of 200MHz)[†]
- **xP** ● **xD** • PEG and DMI Ratios
 - Variable ratios (must reflect selected BCLK frequency)[†]

PCIe = PCI Express*

[†] Only some processors enable part or all of these features.

OC VR Design on Legacy Platforms

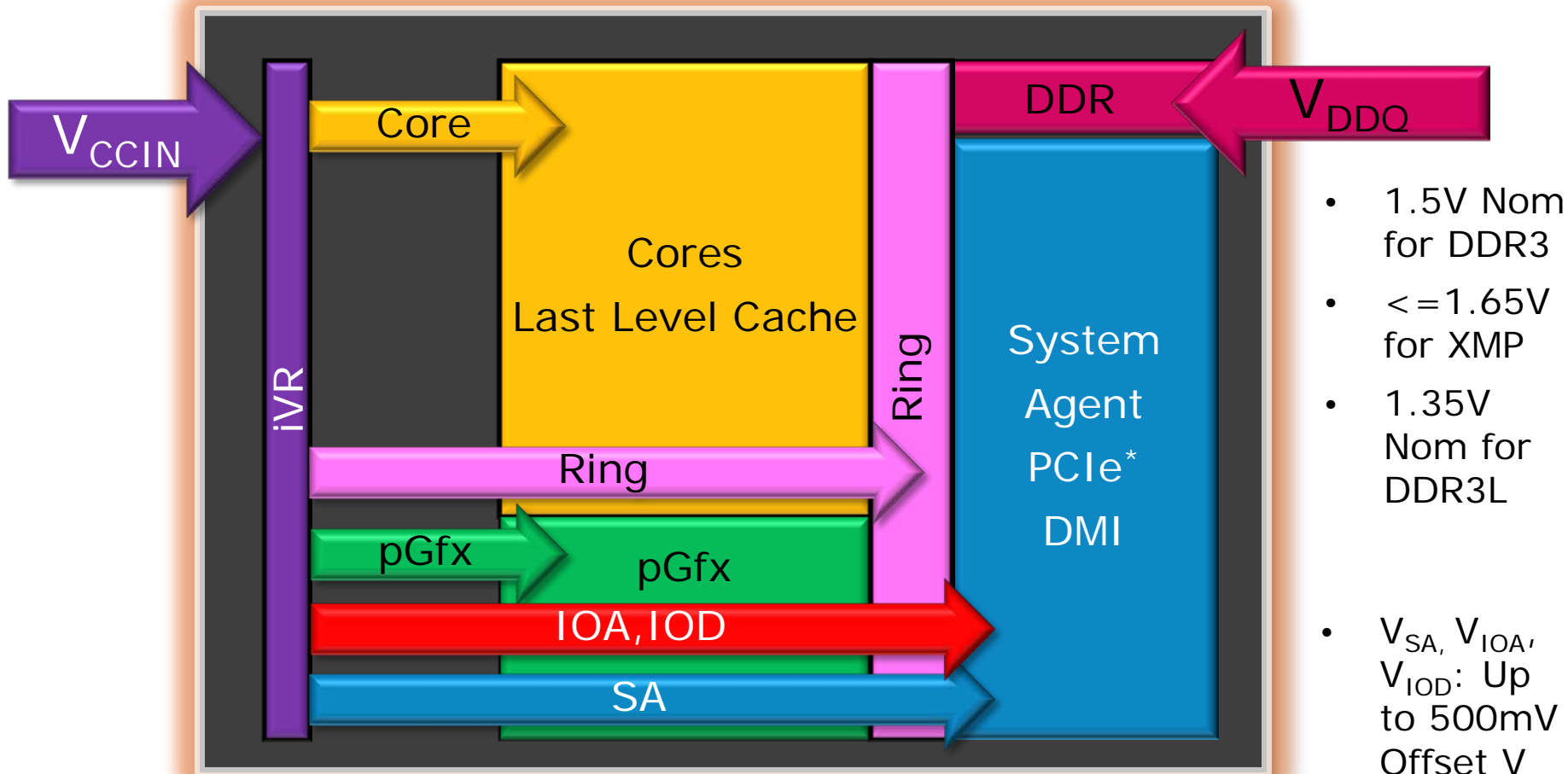


- In current generation platforms, CPU VRs are on the motherboard
- Often, a separate VR exists for each rail to the CPU
- Voltage margining is accomplished using platform VRs

4th Generation Intel® Core™ processor changes this dramatically with integrated voltage regulation

Next Generation Intel Haswell Microarchitecture

Voltage Planes for Performance Tuning



- V_{CCIN} : SVID 1.8V Nom up to 2.3V+, static V up to 3.04V
- V_{CORE} : dynamic additional V, static V up to 2.0 V
- V_{RING} : dynamic additional V, static V up to 2.0 V
- V_{GT} : dynamic additional V, static V up to 2.0 V

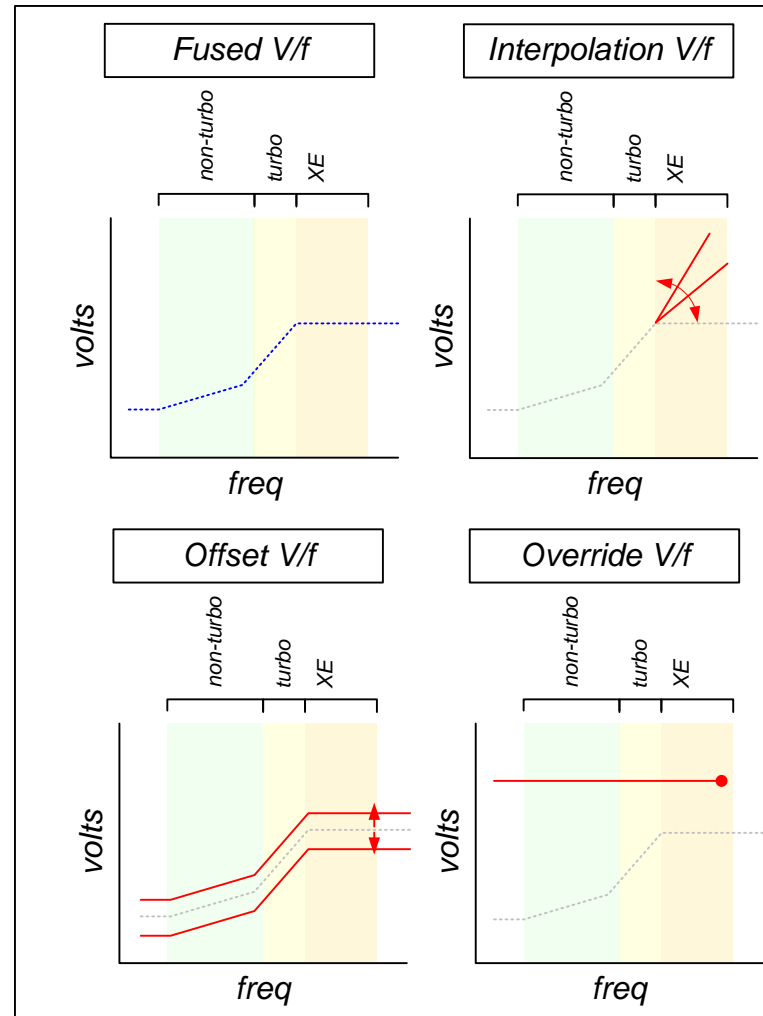
- 1.5V Nom for DDR3
- $\leq 1.65V$ for XMP
- 1.35V Nom for DDR3L
- V_{SA}, V_{IOA}, V_{IOD} : Up to 500mV Offset V from nominal

Next Generation Intel Haswell Microarchitecture

Voltage Override Modes

- Default V/f curve (SVID operation)

- Positive / Negative offset applied to the entire curve. Important for mainstream overclocking.



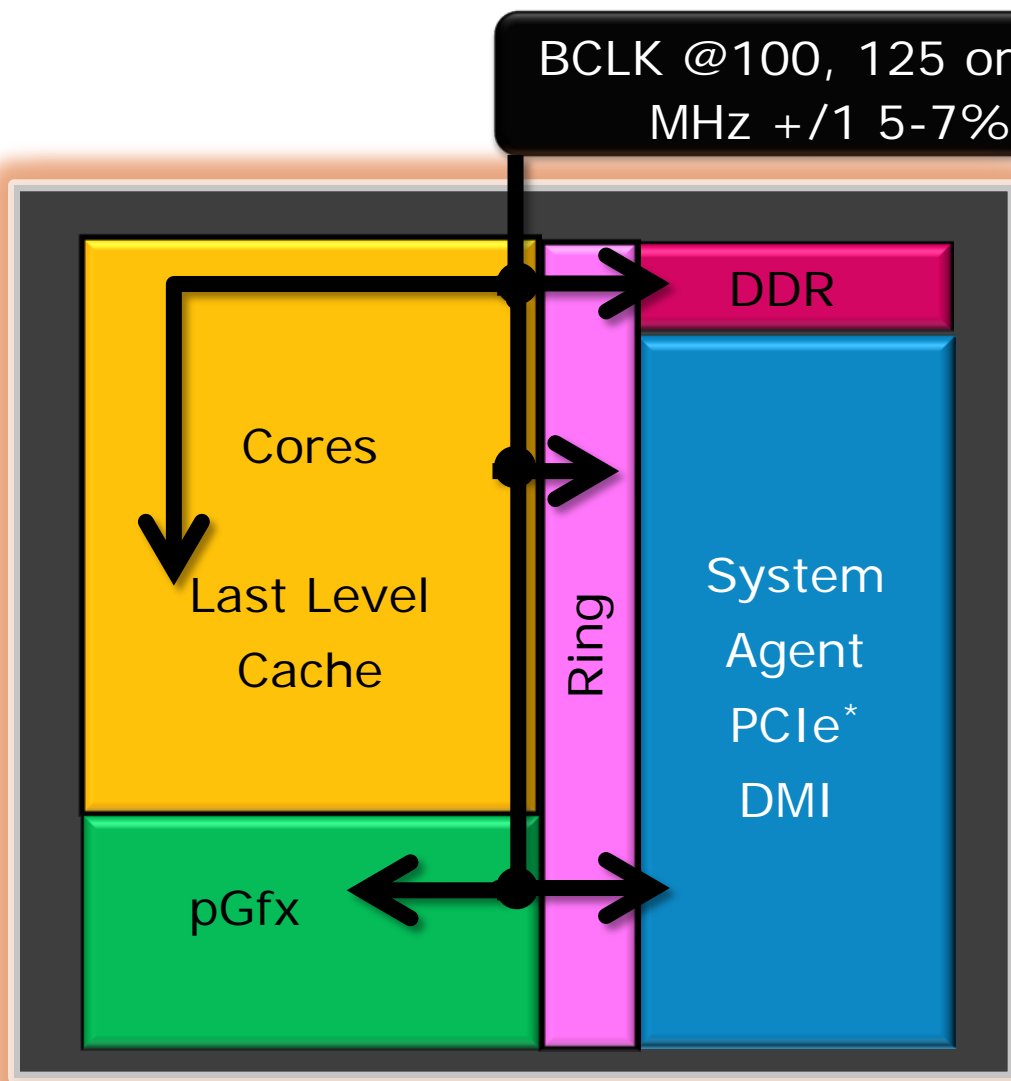
- Interpolation (adaptive) in the overclocking region

- Override applied to the entire curve. Important for extreme OC.

iVR provides flexibility consistent with all margining modes generally supported by current generation external VR designs

Next Generation Intel Haswell Microarchitecture

Clock Tree



- Single BCLK input comes from PCH in <1MHz steps
- Acceptable input to CPU limited by PIC Express* (PCIe) and DMI PLL interface:
 $100\text{MHz} \times \pm 5-7\%$ PEG/DMI @ 5:5
 $125\text{MHz} \times \pm 5-7\%$ PEG/DMI @ 5:4
 $167\text{MHz} \times \pm 5-7\%$ PEG/DMI @ 5:3
- Frequency Relationships
 $f(\text{GT}) = \text{BCLK} / 2 * \text{GT Ratio}$
 $f(\text{Core}) = \text{BCLK} * \text{Core Ratio}$
 $f(\text{Ring}) = \text{BCLK} * \text{Ring Ratio}$
 $f(\text{DDR}) = \text{BCLK} * 1.33 * \text{DDR Ratio}$
-Or-
 $f(\text{DDR}) = \text{BCLK} * 1.00 * \text{DDR Ratio}$

Enhanced BCLK Capabilities

Key Differences Between Generations

	Intel® Core™ i7 processors on LGA2011	3 rd Gen Intel Core processors on LGA1155	Next Gen Intel Haswell Microarchitecture
Coarse Adjustment	BCLK multipliers {1.0,1.25,1.67} input to CPU CPU adjusts PEG/DMI ratios {5:5,5:4,5:3} based on BCLK multi	None	Select CPU PEG/DMI ratios of {5:5,5:4,5:3} depending on what clock frequency you request from PCH
Fine	External clock device output adjustment \pm 5-7% over nominal 100MHz	PCH output adjustment \pm 5-7% over nominal 100MHz	PCH output \pm 5-7% around frequency points 100MHz, 125MHz, 167MHz
Range Peak Observed †	168 MHz (non-continuous)	116.95 MHz	>167 MHz (non-continuous)

4th Generation Intel Core processors deliver BCLK overclocking experience consistent with current generation high-end platforms based on LGA2011

† This data was collected from overclocking forums and should be considered approximate for illustrative purposes only.

Next Generation Intel Haswell Microarchitecture

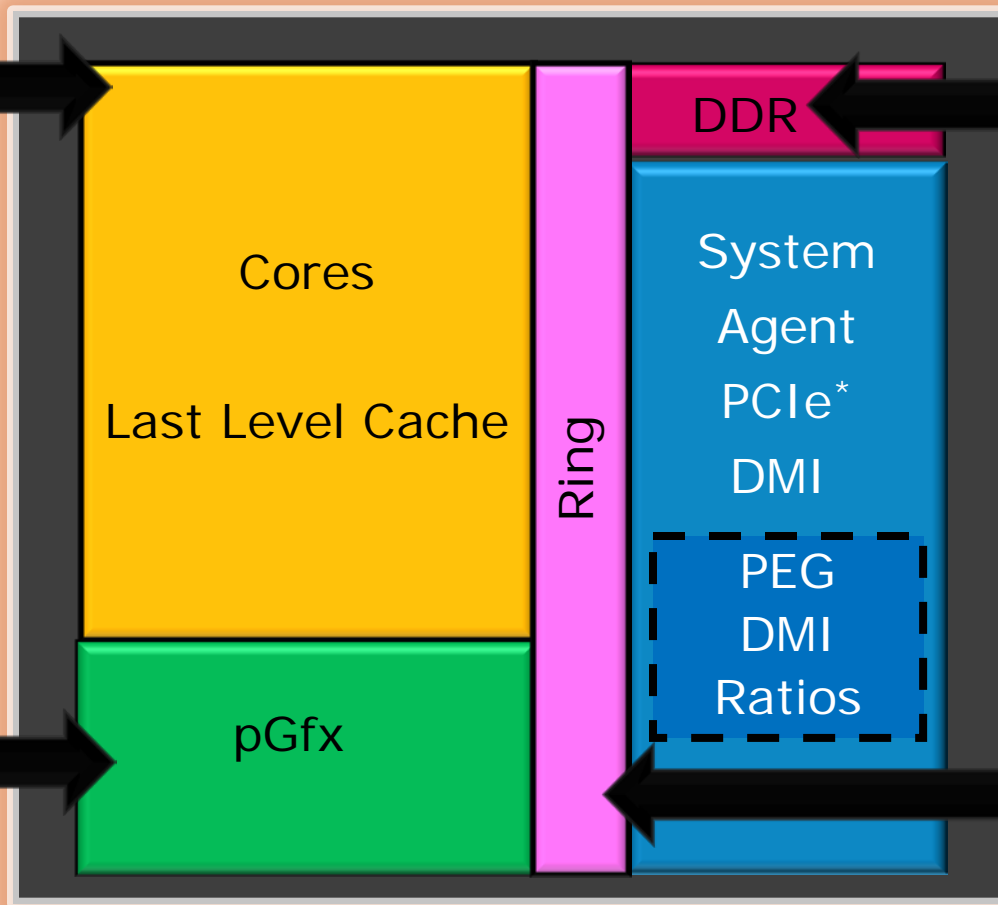
Available Performance Tuning Ratios

Core Turbo Ratios[†]

- Core ratios up to 80
- Unlocked Turbo Limits
- Current Limit Override
- Graphics ratios up to 60

pGfx Ratios[†]

PEG, DMI Ratios



DDR Ratios

- 266MHz Steps up to 2933MHz
- 200MHz steps up to 2800MHz
- Timing Overrides
- Manual or can be automated through XMP 1.3

Ring Ratios[†]

- Ring Ratios up to 80
- Ring Ratio typically \leq Core or GT

- BIOS sets based on requested BCLK f
- 100MHz: 80/50 (PEG/DMI Ratios)
- 125MHz: 64/40
- 167MHz: 48/30

[†] = Changeable at OS Level

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Desktop: 4th Generation Intel® Core™ i7/i5 Processors Based on Socket LGA 1150

 Intel® Z87 Express Chipset

 Intel H87 Express Chipset

Unlocked "K"



†Others

Turbo Ratio Overrides	✓	
DDR Frequency Overrides	✓	✓
Fine BCLK Overrides	✓ ¹	✓ ¹
Coarse BCLK Ratios	✓ ²	
iVR Overvoltage	✓	✓
PL1, PL2, Tau, ICCMax Overrides	✓	✓
DDR Timing Overrides	✓	✓
pGfx Ratio Overrides	✓	✓

Unlocked Processors:

Intel® Core™ i7 Processors
4770K

Intel Core i5 Processors
4670K

† This includes Intel Core i3, Intel® Pentium™, and Intel® Celeron™

¹ Actual Fine BCLK frequency adjustments will be limited. ~5%

² Coarse BCLK Ratios (1.0, 1.25, 1.67) are unlocked with K SKU processors only

Note: Actual overclocking results will vary and capabilities are subject to change.





- Turbo ratios and power, pGfx Ratios, iVR voltages are updateable real-time in OS
- Fine BCLK, DDR timings are changeable real-time over very small range
- Larger changes can be made with reset. BCLK range highly limited.
- DDR Frequency requires reset

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Mobile: 4th Generation Intel® Core™ Processor Overclocking†

Summary:

- Core overclocking on select Intel® Core™ i7 SKUs
- Graphics and memory overclocking on all Intel Core i7 and Core i5 based -H, -M, and -U series processors

		Turbo Ratio Overrides	iVR Over-voltage	BCLK Coarse ⁽¹⁾	BCLK Fine ⁽¹⁾	DDR Ratio & Timing Overrides	Processor Gfx Ratio Overrides
 	-H and -M Series	i7-4930MX	Unlimited	Yes	Yes	Yes	Yes
	i7-4900MQ	6 bins	Yes	Yes	Yes	Yes	Yes
	i7-4950HQ	6 bins	Yes	No	Yes	Yes	Yes
	i7-4800MQ	4 bins	Yes	Yes	Yes	Yes	Yes
	i7-4850HQ	4 bins	Yes	No	Yes	Yes	Yes
	i7-4702MQ	2 bins	Yes	Yes	Yes	Yes	Yes
	i7-4700MQ	2 bins	Yes	Yes	Yes	Yes	Yes
	i7-4750HQ	2 bins	Yes	No	Yes	Yes	Yes
	i5	None	No	No	Yes	Yes	Yes
	i3	None	No	No	No	No	No
 	-U Series	i7-4600U	4 bins	Yes	No	No	Yes
	i7-4650U	4 bins	Yes	No	No	Yes	Yes
	i7-4558U	4 bins	Yes	No	No	Yes	Yes
	i5	None	No	No	No	Yes	Yes
	i3	None	No	No	No	No	No
-Y Series	All	None	No	No	No	No	No

¹ Requires Intel HM87 or QM87 chipsets and results will vary.

† Actual overclocking results will vary and capabilities are subject to change.

**Live Demo:
Mobile Overclocking using the
Intel® Core™ i7-4950HQ processor
in the Clevo W740SU Notebook**

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Intel® Extreme Memory Profile (Intel® XMP)

- Expansion of the standard DDR3 memory specification. Enables speeds, latencies outside of JEDEC Specification.
 - Easy, robust, overclocking solution designed to take advantage of the unlocked capability of Intel® Core™ Processors
 - Predefined and tested Intel XMP profiles can be loaded via BIOS or a specific operating system-level tuning application
- Intel® XMP compliant DIMMs available
 - Supports all Intel Core i7, i5 Processors †
 - Corsair*, G.Skil*, Kingston*, Patriot*, Crucial* and others
 - XMP Ready: Module has been programmed with an uncertified profile **GOOD**
 - XMP Certified: Module has passed supplier test and submission process for specific CPU and motherboard **BEST**
 - Certifications posted at:

CPU-Z Version 1.61.3.x64

	JEDEC #4	JEDEC #5	JEDEC #6	XMP-2134
Frequency	685 MHz	761 MHz	838 MHz	1067 MHz
CAS# Latency	9.0	10.0	11.0	11.0
RAS# to CAS#	9	10	11	11
RAS# Precharge	9	10	11	11
tRAS	24	27	30	30
tRC	33	37	41	50
Command Rate				1T
Voltage	1.50 V	1.50 V	1.50 V	1.500 V

System boots with highest supported JEDEC defined parameters by default

Select XMP profile via enabled BIOS or tuning app and profile and reset



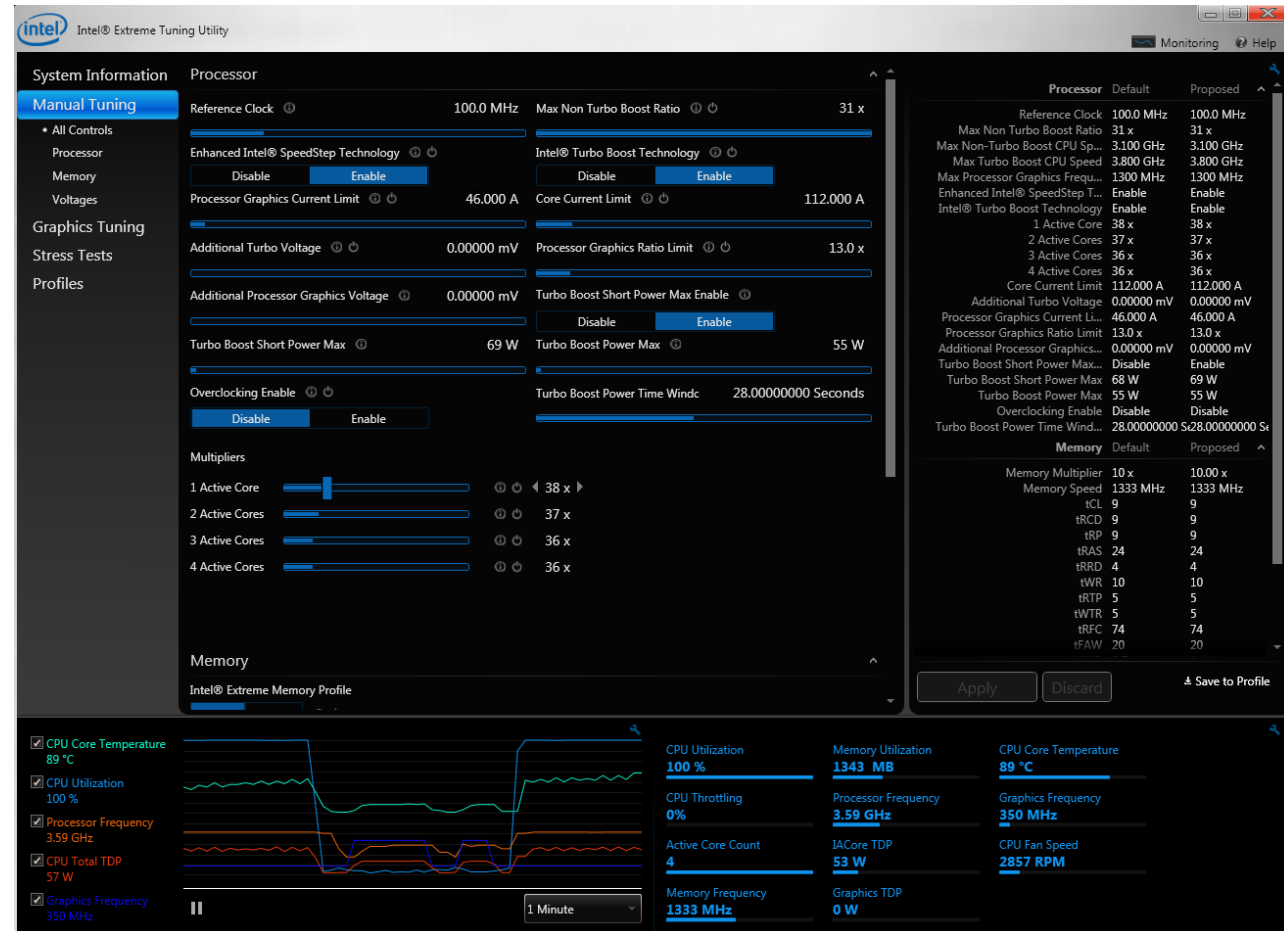
<http://www.intel.com/consumer/game/extreme-memory.htm>

†CPU must support unlocked memory multiplier and be paired with correct chipset. Intel XMP is overclocking

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Intel® Extreme Tuning Utility (Intel® XTU)

- Simple-to-use Windows* application
- Exposes CPU and PCH knobs for performance tuning by user
- Real-time adjustment of key settings without rebooting¹
- Version 4.2 now available for download from Intel or other motherboard suppliers[†]



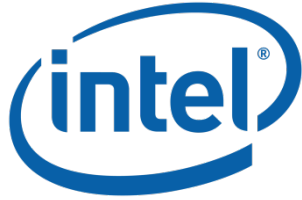
<http://www.intel.com/go/xtu>

[†]Motherboard BIOS must be configured correctly to work with XTU. Contact your motherboard supplier for more information.

¹ Available select 3rd and 4th Generation Intel® Core™ Processor SKUs.

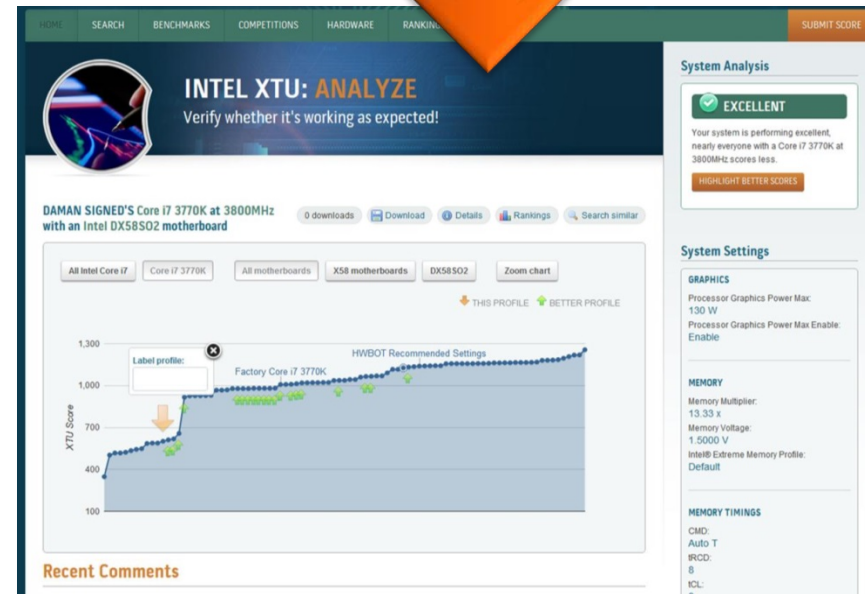
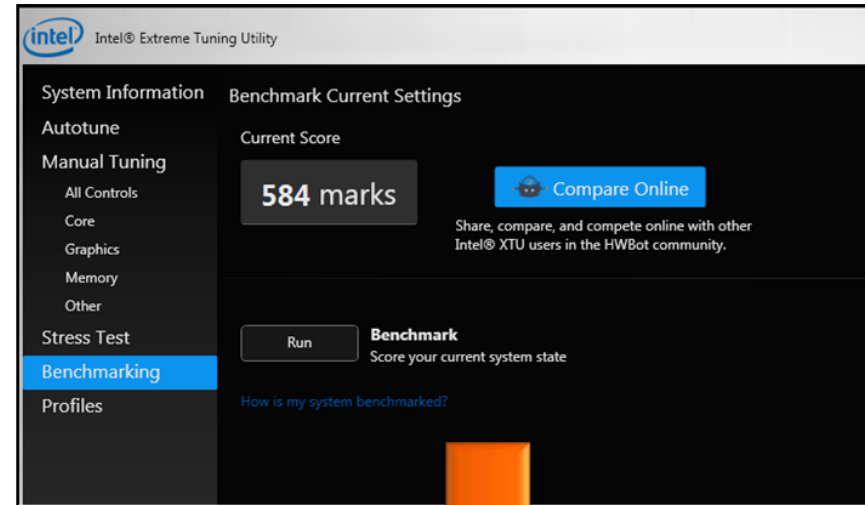
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Intel® XTU and HWBot.org*



Combined Features

- Upload/Download overclocking settings reliably
- Export/Import XTU overclocking settings
- Compare benchmark scores and configurations with others
- Link other benchmark scores to XTU profiles
- Compete with others for higher scores
- Integrated with existing social networks: Facebook* and Twitter*



**Live Demo:
Intel® Extreme Tuning Utility
v4.2 with AppTune Beta
Feature using a Intel® Core™
i7-4770K Processor**

**Live Demo:
SSD Overclocking Technology**

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Summary

- Intel® Core™ i7 Processors based on Socket LGA2011 offer Core, DDR and BCLK overclocking experience on processors with the highest core count and memory capacity
- Desktop and Mobile 4th Generation Intel Core processors offer select SKUs with unlocked core, memory and graphics ratios
- Real-time overclocking offers an improved user experience for content creation and gaming users
- The AppTune beta feature, in Intel® Extreme Tuning Utility v4.2, is an exciting new way to tune system performance dynamically and uniquely for each specific application
- Intel has not tested, and does not warranty, the operation of the processor beyond its specifications
- For designers wanting to develop overclocking platforms, documentation is available under NDA that details all tuning knobs. Contact your Intel field representative.

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- Overspeed Protection Removed Warning: Altering clock frequency and/or voltage may (i) reduce system stability and useful life of the system and processor; (ii) cause the processor and other system components to fail; (iii) cause reductions in system performance; (iv) cause additional heat or other damage; and (v) affect system data integrity. Intel has not tested, and does not warranty, the operation of the processor beyond its specifications.
- Processor Numbering Notice: Intel processor numbers are not a measure of performance. Processor numbers differentiate features within each processor family, not across different processor families: Go to: [Learn About Intel® Processor Numbers](#)
- Intel® Turbo Boost Technology requires a system with Intel Turbo Boost Technology. Intel Turbo Boost Technology and Intel Turbo Boost Technology 2.0 are only available on select Intel® processors. Consult your PC manufacturer. Performance varies depending on hardware, software, and system configuration. For more information, visit <http://www.intel.com/go/turbo>.

Risk Factors

The above statements and any others in this document that refer to plans and expectations for the third quarter, the year and the future are forward-looking statements that involve a number of risks and uncertainties. Words such as “anticipates,” “expects,” “intends,” “plans,” “believes,” “seeks,” “estimates,” “may,” “will,” “should” and their variations identify forward-looking statements. Statements that refer to or are based on projections, uncertain events or assumptions also identify forward-looking statements. Many factors could affect Intel’s actual results, and variances from Intel’s current expectations regarding such factors could cause actual results to differ materially from those expressed in these forward-looking statements. Intel presently considers the following to be the important factors that could cause actual results to differ materially from the company’s expectations. Demand could be different from Intel’s expectations due to factors including changes in business and economic conditions; customer acceptance of Intel’s and competitors’ products; supply constraints and other disruptions affecting customers; changes in customer order patterns including order cancellations; and changes in the level of inventory at customers. Uncertainty in global economic and financial conditions poses a risk that consumers and businesses may defer purchases in response to negative financial events, which could negatively affect product demand and other related matters. Intel operates in intensely competitive industries that are characterized by a high percentage of costs that are fixed or difficult to reduce in the short term and product demand that is highly variable and difficult to forecast. Revenue and the gross margin percentage are affected by the timing of Intel product introductions and the demand for and market acceptance of Intel’s products; actions taken by Intel’s competitors, including product offerings and introductions, marketing programs and pricing pressures and Intel’s response to such actions; and Intel’s ability to respond quickly to technological developments and to incorporate new features into its products. The gross margin percentage could vary significantly from expectations based on capacity utilization; variations in inventory valuation, including variations related to the timing of qualifying products for sale; changes in revenue levels; segment product mix; the timing and execution of the manufacturing ramp and associated costs; start-up costs; excess or obsolete inventory; changes in unit costs; defects or disruptions in the supply of materials or resources; product manufacturing quality/yields; and impairments of long-lived assets, including manufacturing, assembly/test and intangible assets. Intel’s results could be affected by adverse economic, social, political and physical/infrastructure conditions in countries where Intel, its customers or its suppliers operate, including military conflict and other security risks, natural disasters, infrastructure disruptions, health concerns and fluctuations in currency exchange rates. Expenses, particularly certain marketing and compensation expenses, as well as restructuring and asset impairment charges, vary depending on the level of demand for Intel’s products and the level of revenue and profits. Intel’s results could be affected by the timing of closing of acquisitions and divestitures. Intel’s results could be affected by adverse effects associated with product defects and errata (deviations from published specifications), and by litigation or regulatory matters involving intellectual property, stockholder, consumer, antitrust, disclosure and other issues, such as the litigation and regulatory matters described in Intel’s SEC reports. An unfavorable ruling could include monetary damages or an injunction prohibiting Intel from manufacturing or selling one or more products, precluding particular business practices, impacting Intel’s ability to design its products, or requiring other remedies such as compulsory licensing of intellectual property. A detailed discussion of these and other factors that could affect Intel’s results is included in Intel’s SEC filings, including the company’s most recent reports on Form 10-Q, Form 10-K and earnings release.

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