Intel's Core 2 family - TOCK lines
Kaby Lake to Coffee Lake

Dezső Sima

Vers. 3.1

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Contents (1)

Contents (2)

7. The Kaby Lake line

- 7.1 Introduction to the Kaby Lake line
- 7.2 Major enhancements of the Kaby Lake line
- 7.3 Major innovation of the Kaby Lake line: The Optane memory
- 7.4 Kaby Lake-based processor lines

7.1 Introduction to the Kaby Lake line

7.1 Introduction to the Kaby Lake line

- The 7th generation Kaby Lake line is actually a Skylake refresh line (Tock line) manufactured on 14 nm technology.
- Note that Intel designates it as a new generation in contrast to the Devil's Cannon models that were similar optimizations then of the Haswell (4. generation) line.

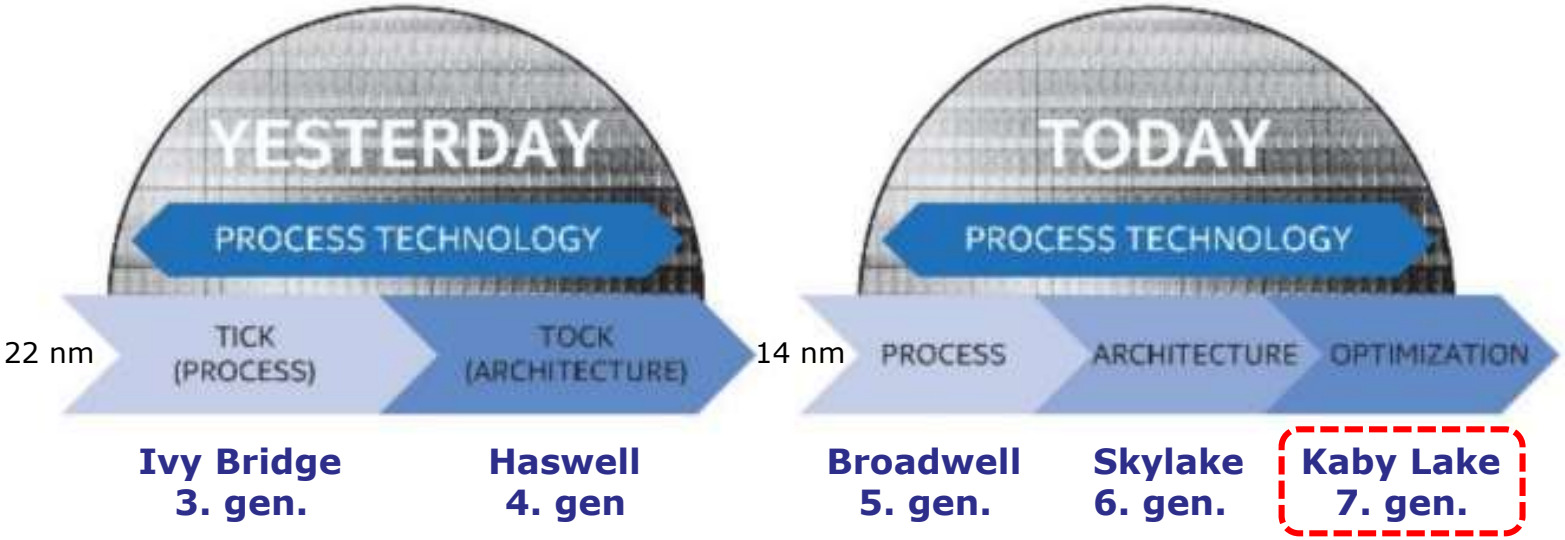


Figure: Enhancing the Tick-Tock model with an optimization phase [225]

- It is important to note that with the 14 nm technology the cadence of Intel's technology transitions slowed down to about 2.5 years, as Kranich, Intel's CEO stated at Intel's Q2 2015 Investor's conference call (07/2015). [228]:

  The last two technology transitions have signaled that our cadence today is closer to 2.5 years than two."
- Kaby Lake launched: in 08/2016 (U and Y platforms) and in 01/2017 (H and S platforms).
- Desktop chips use the the same socket type (LGA1151) as the preceeding Skylake chips.

*

The 7th generation Kaby Lake line -1

1. gen.				2. gen.	3. gen.	4. gen.	5. gen.
Core 2 New Microarch. 65 nm	Penryn New Process 45 nm	Nehalem New Microarch. 45 nm	West-mere New Process 32 nm	Sandy Bridge New Microarch. 32 nm	Ivy Bridge New Process 22 nm	Haswell New Microarchi. 22 nm	Broad-well New Process 14 nm
TOCK	*TICK*	*TOCK*	*TICK*	*TOCK*	*TICK*	*TOCK*	*TICK*
(2006)	*(2007)*	*(2008)*	*(2010)*	*(2011)*	*(2012)*	*(2013)*	*(2014)*

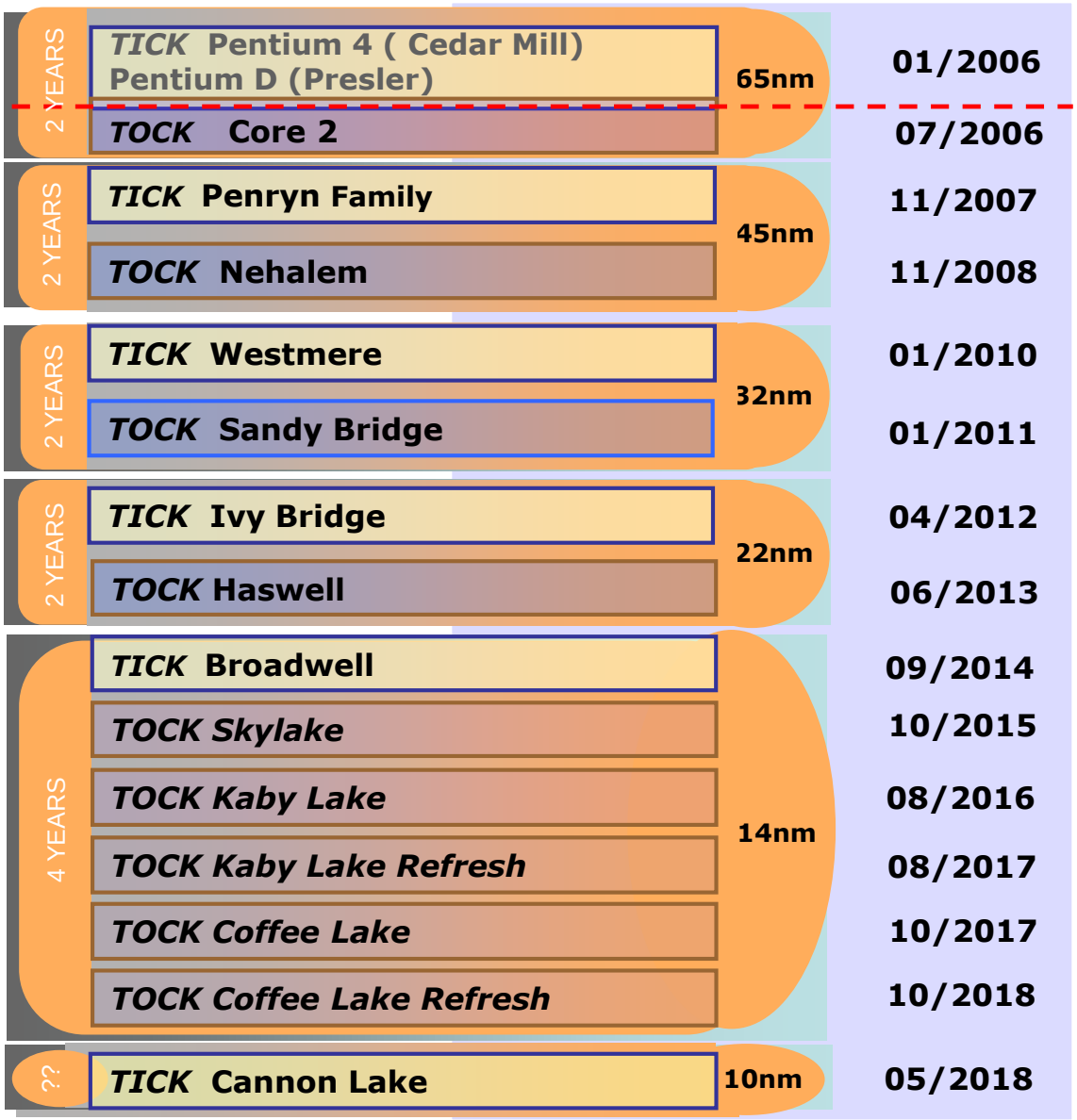
6. gen.	7. gen.	8. gen.[1]	9. gen.
Skylake New Microarch. 14 nm	Kaby Lake New Microarch. 14 nm	Kaby Lake R KL G-series Coffee Lake Cannon Lake 14/10 nm	Coffee Lake R New Mocroarch. 14 nm
TOCK	*TOCK*	*TOCK*	*TOCK*
(2015)	*(2016)*	*(2017/18)*	*(2018)*

[1]Astonishingly, the 8th generation encompasses four processor lines, as follows:

- Kaby Lake Refresh
- Kaby Lake G with AMD Vega graphics
- Coffee Lake (all 14 nm) and the
- 10 nm Cannon Lake designs [218].

R: Refresh

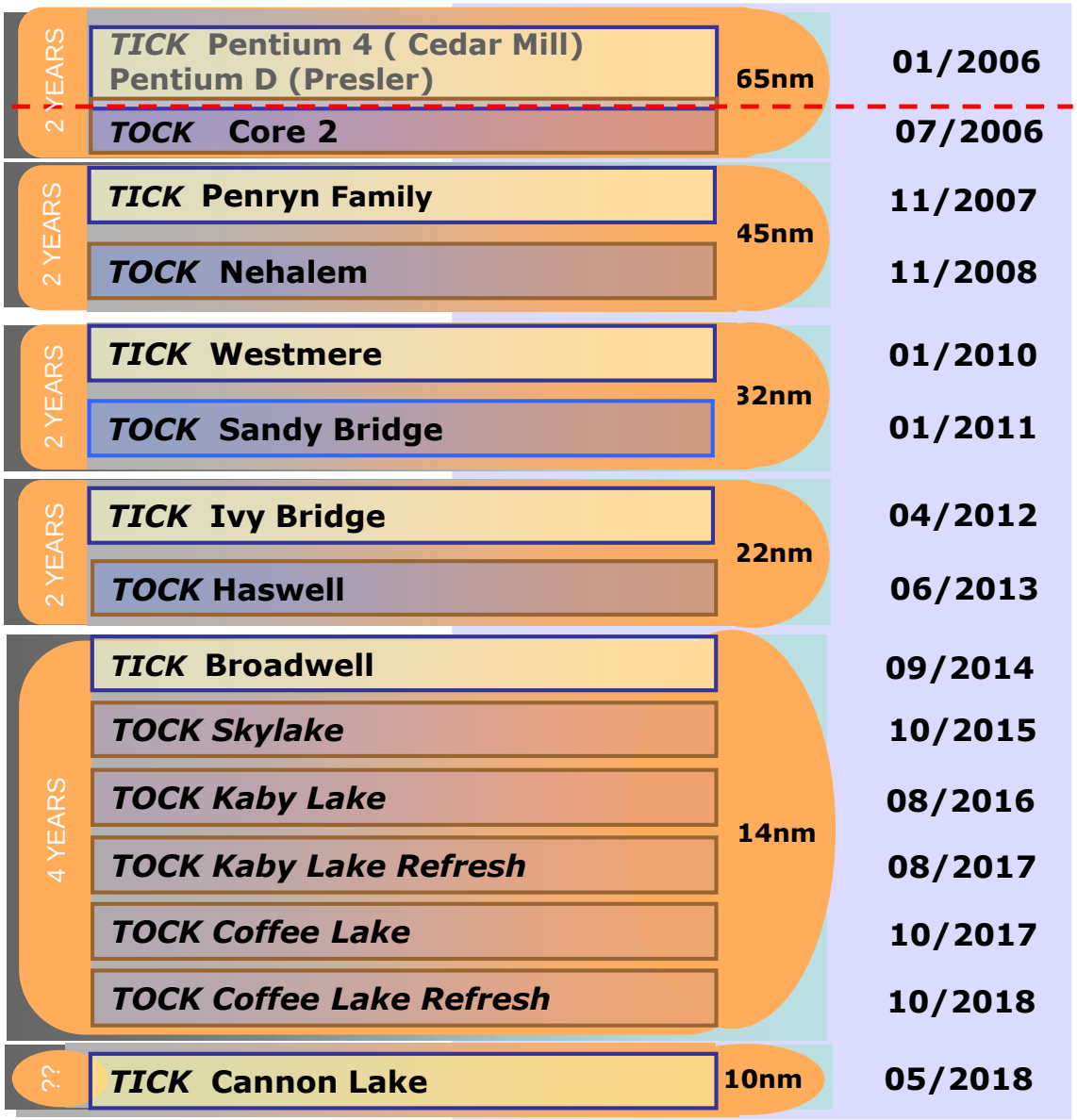
The 7th generation Kaby Lake line -2 (based on [3])



Key new features of the ISA and the microarchitecture

- **New microarch.: 4-wide core, 128-bit SIMD FX/FP EUs, shared L2 , no HT**
- **New microarch.: 4 cores, integr. MC, QPI, private L2, (inclusive) L3, HT**
- **In package integrated GPU**
- **New microarch.: 256-bit (FP) AVX, ring bus, integrated GPU**
- **New microarch.: 256-bit (FX) AVX2, L4 cache (discrete eDRAM), TSX**
- **Shared Virtual Memory**
- **New microarch.: 5-wide core, ISP, Memory Side L4 cache, no FIVR**
- **Optane memory, in KBL G series: in package integr. CPU, GPU, HBM2**
- **6C, (PCHs of S-series DTs support: USB G2, integr. conn., Optane 2)**
- **8C**
- **AVX512**

The 7th generation Kaby Lake line -3 (based on [3])



Key new features of the power management

- **Clock gating, PECI, Platform Thermal Control by 3. party controller**
- **EDAT**
- **Integrated Power Gates, PCU, Turbo Boost**
- **Turbo Boost 2.0**
- **FIVR**
- **2. gen. FIVR**
- **Speed Shift Technology, Duty Cycle control, No FIVR except Skylake X**
- **Speed Shift Technology v2**
- **In H-series: TVB (Thermal Velocity Boost)**
- **STIM**

7.2 Major enhancements of the Kaby Lake line

- 7.2.1 Use of an optimized 14 nm process, termed the 14 nm+ process
- 7.2.2 Enhanced Speed Shift technology (termed v2)

7.2.1 Use of an optimized 14 nm process, termed the 14 nm+ process [225]

- Kaby Lake processors have the same IPC scores as the previous Skylake models, as benchmark figures at the same clock rate demonstrate (see the Figure below).

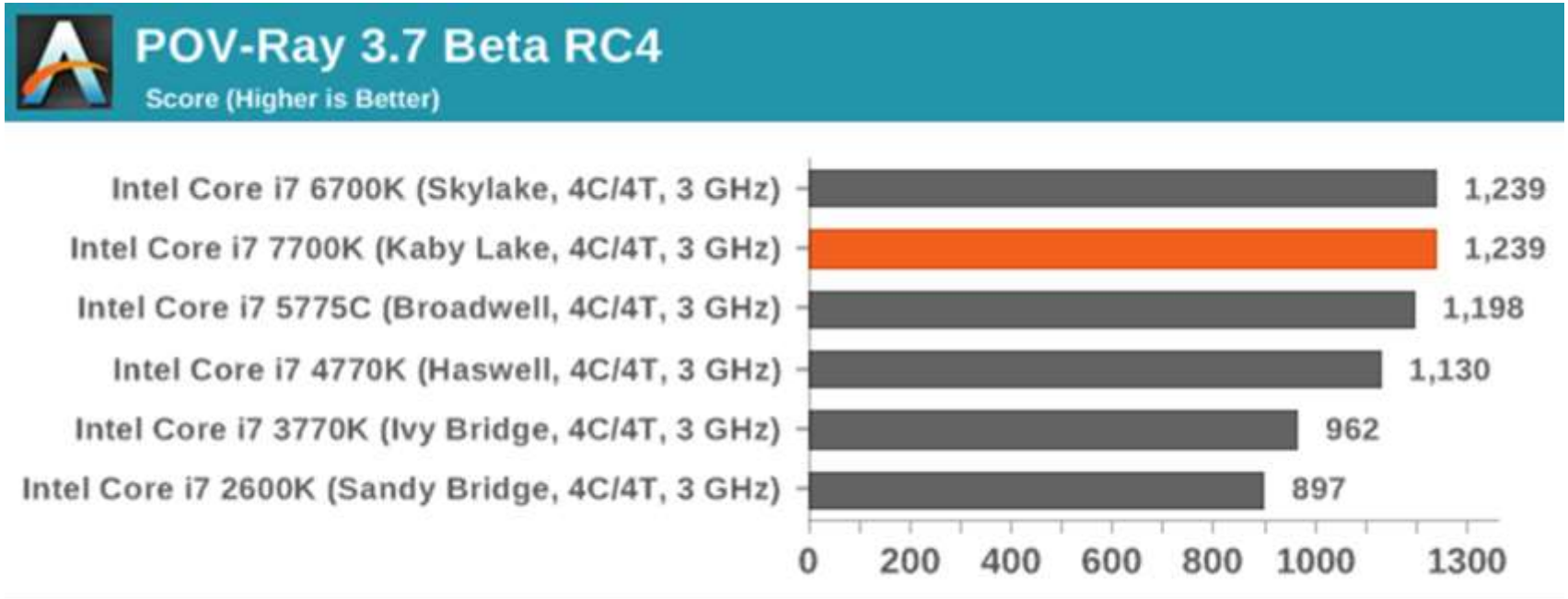


Figure: Benchmark results of subsequent Core 2 generations at the same clock rate [225]

- The new 14nm+ process has a higher power efficiency, i.e.
  - same frequency at lower power, or
  - higher frequency at same power

7.2.2 Enhanced Speed Shift technology (v2)

The Speed Shift technology has been introduced in the Skylake line, as indicated below.

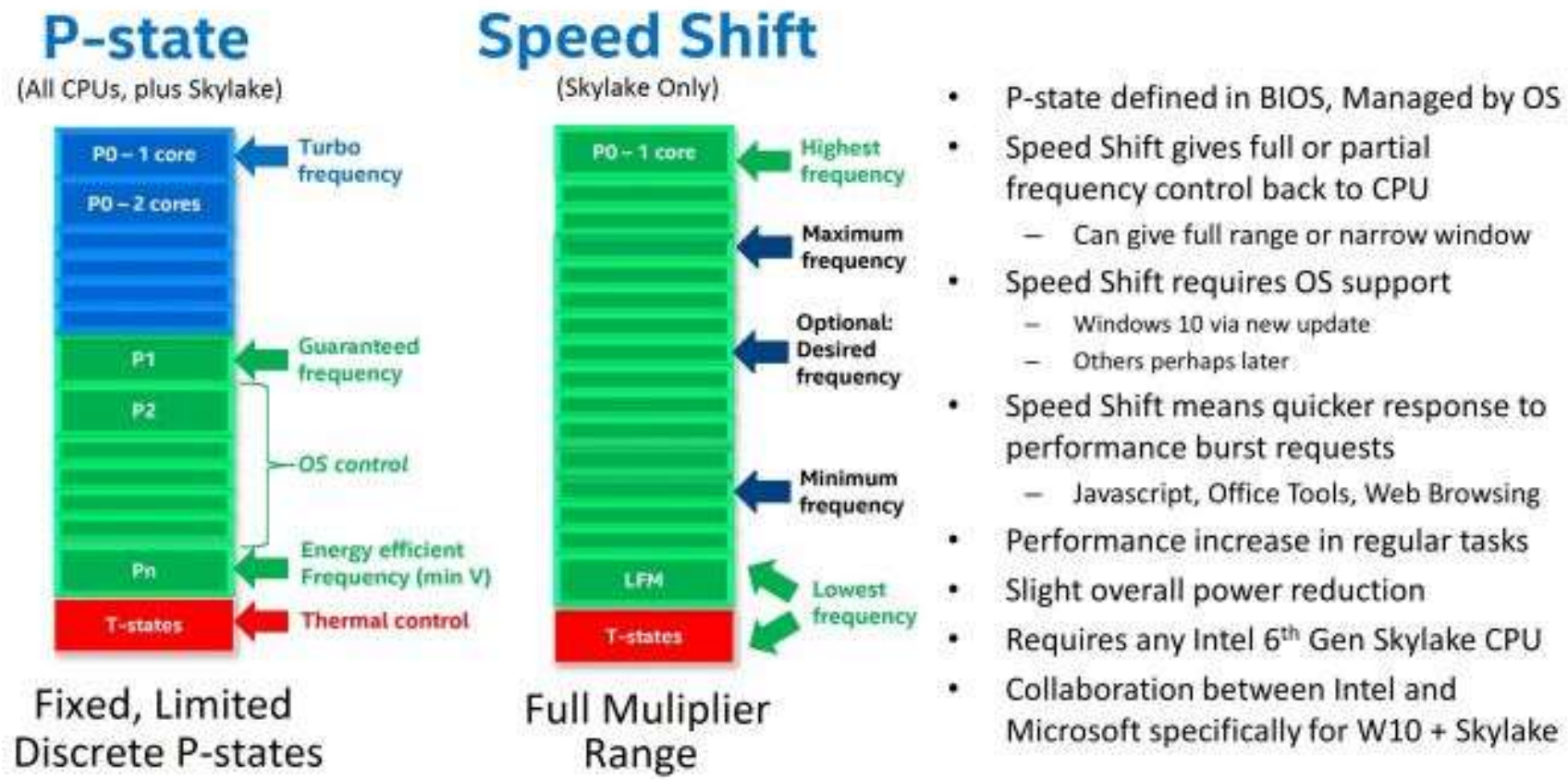


Figure: Main features of the Speed Shift technology vs. the Enhanced SpeedStep technology [225]

7.2.2 Enhanced Speed Shift technology (v2) (2)

Benefit of the Speed Shift technology v2 [225]

- Speed Shift v2 results in faster frequency transitions, as the Figure below shows.

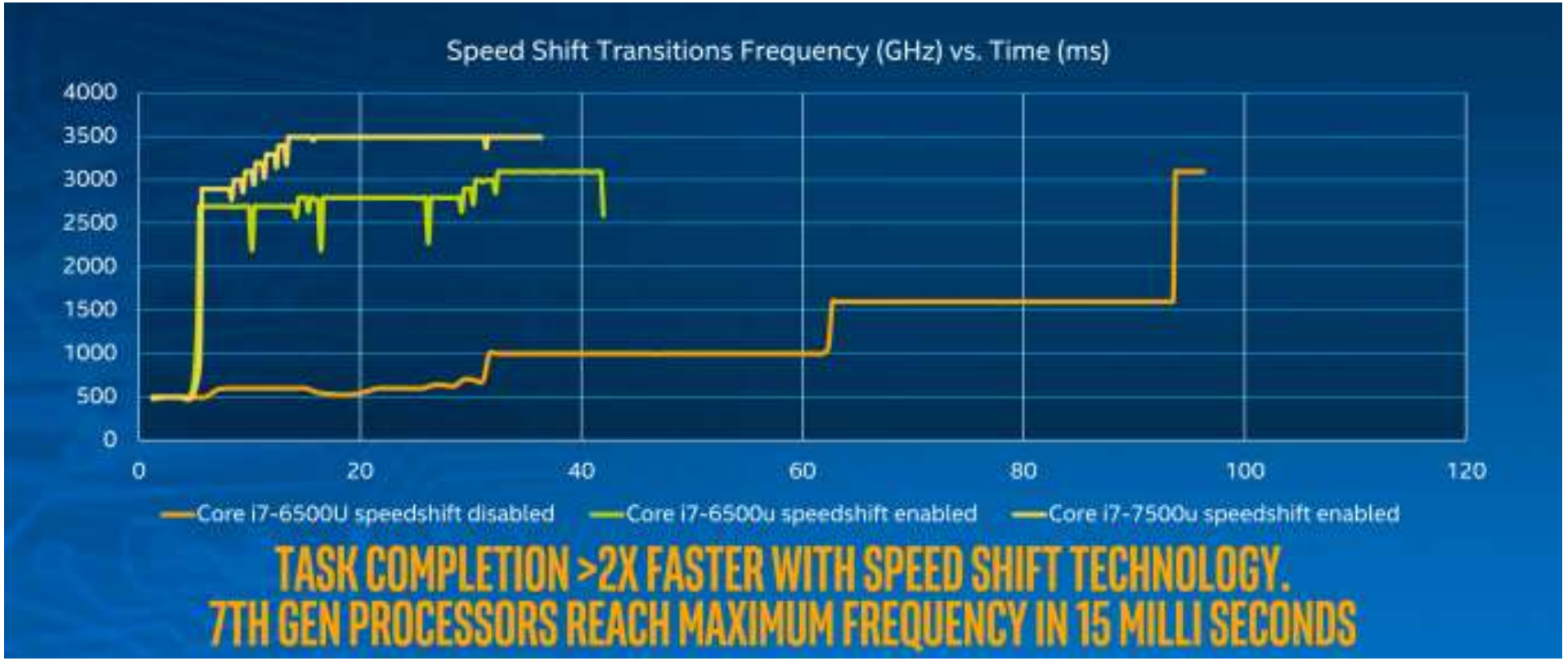


Figure: Achieving the max. clock frequency with and without the Speed Shift technology while contrasting both versions of this technology

- Faster frequency transitions result in reducing task completion, as also indicated in the Figure.

*

7.3 Major innovation of the Kaby Lake line: The Optane memory

7.3 Major innovation of the Kaby Lake line: The Optane memory -1

- Optane memory is an innovation related to the PCH.
- It is nonvolatile (nem-felejtő) memory typically used as a cache of a HDD drive.
- The Optane memory has a typical size of 16 or 32 GB.
- It is mounted on an M.2 card that is attached via 2 to 4 PCIe lanes (see the Figure below).
- Its use needs the Rapid Storage Technology driver (Release 15.5 or later).

Figure: Optane memory installed on a mainboard [229]

*

The M.2 interface standard

- It is an interface specification for internally mounted expansion cards and associated connectors from PCI-SIG, its 1. version was issued in 2013.
- It replaces the mSATA standard while providing different module widths and lengths, as seen below.
- The M.2 standard is particularly suited for small devices, like thin laptops or tablets.

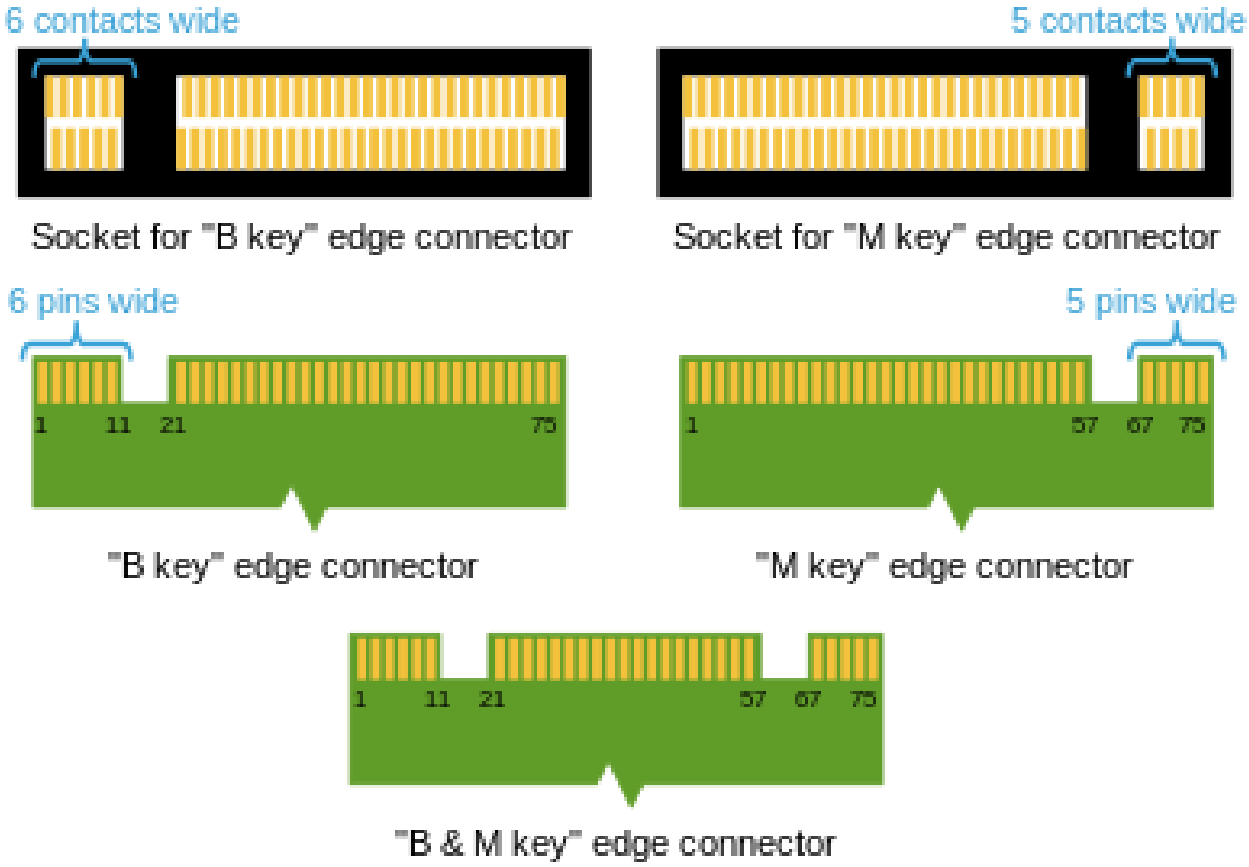


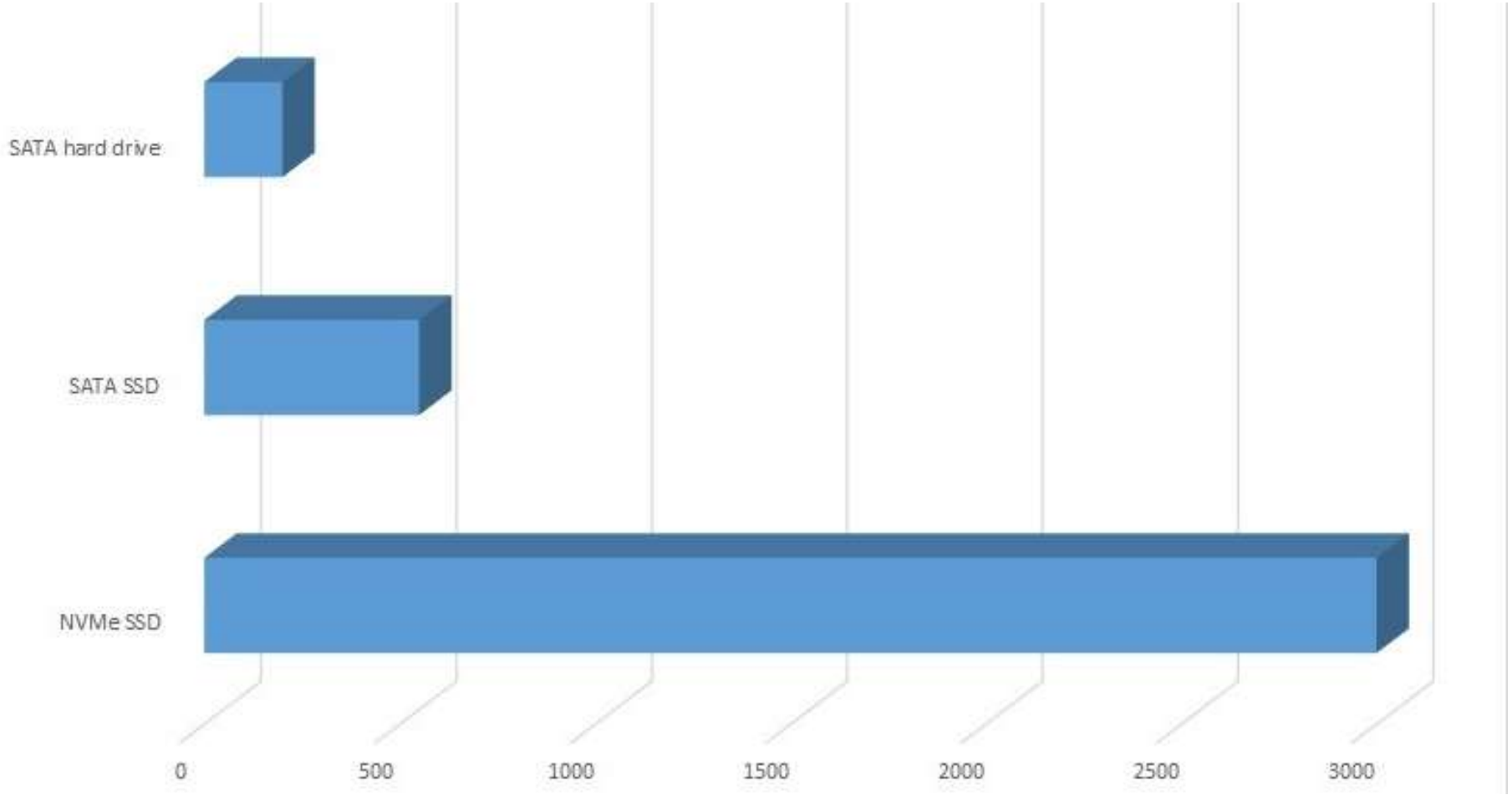
Figure: M.2 sockets and edge connectors [238]

M.2 card examples contrasted with mSATA (miniSATA) [290]

NVMe: Non-Volatile Memory express

7.3 Major innovation of the Kaby Lake line (4)

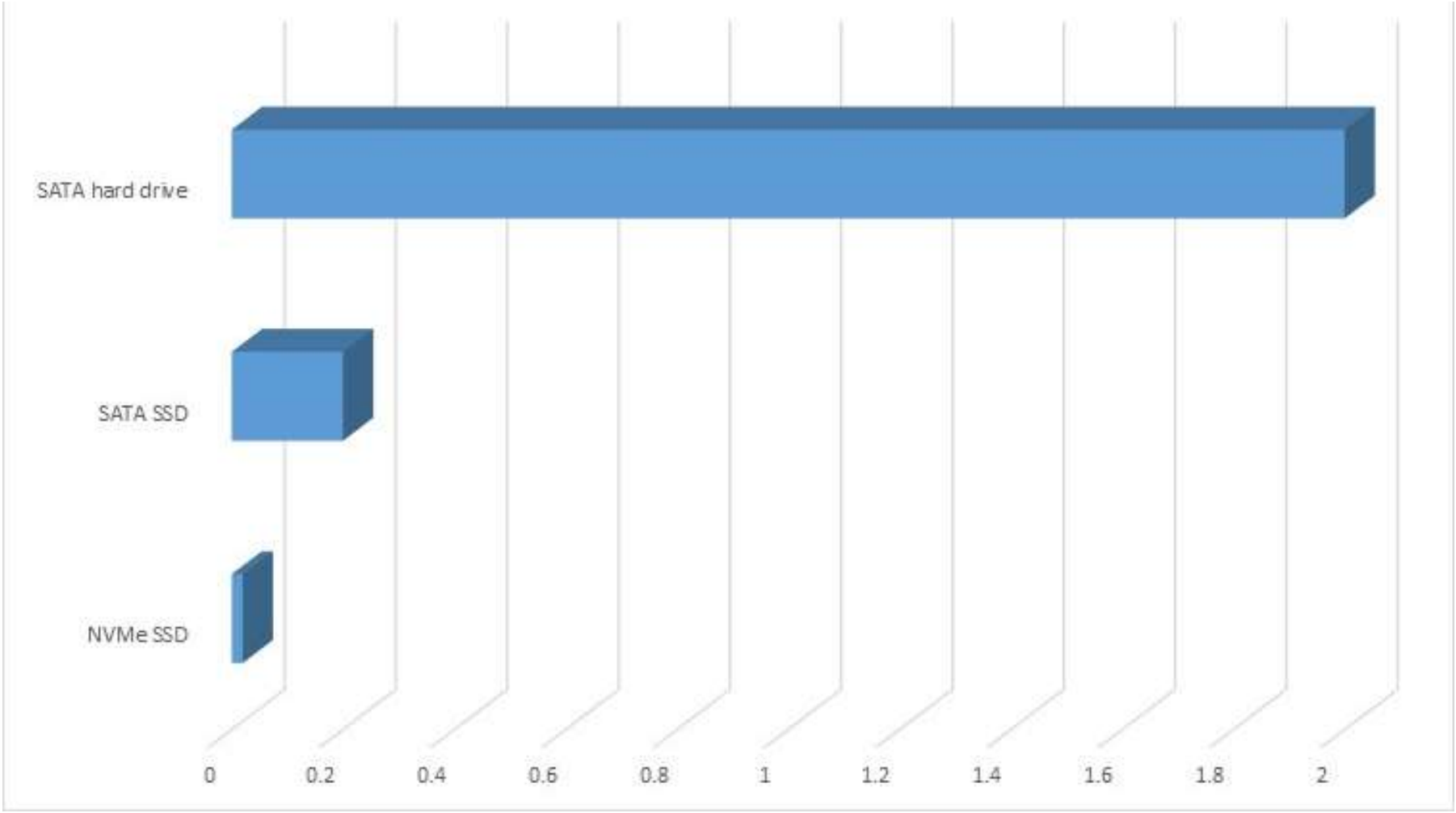
Sustained throughput of SATA hard rive, SATA SSD and NvMe SSD [MB/s] [291]



HDD = 200MB/s, SATA SSD = 550MB/s, NVMe SSD = 3GB/s.

7.3 Major innovation of the Kaby Lake line (5)

Seek time of SATA hard rive, SATA SSD and NvMe SSD [ms] [291]



HD = 2-5 ms seek, SATA SSD = 0.2 ms seek, NVMe SSD = 0.02 ms seek.

7.3 Major innovation of the Kaby Lake line (6)

Example for dual M.2 sockets mounted on a motherboard [230]

7.3 Major innovation of the Kaby Lake line (7)

Optane memory -2

- It is based on the 3D XPoint memory technology, announced by Intel and Micron in 2016.
- 3D Xpoint (Cross-Point) memory is a high-density, stackable, bit-level addressable matrix of non-volatile memory, as indicated below.
- It provides more endurability than SSD devices.
- First devices with Optane memory has been introduced in 1H 2017.

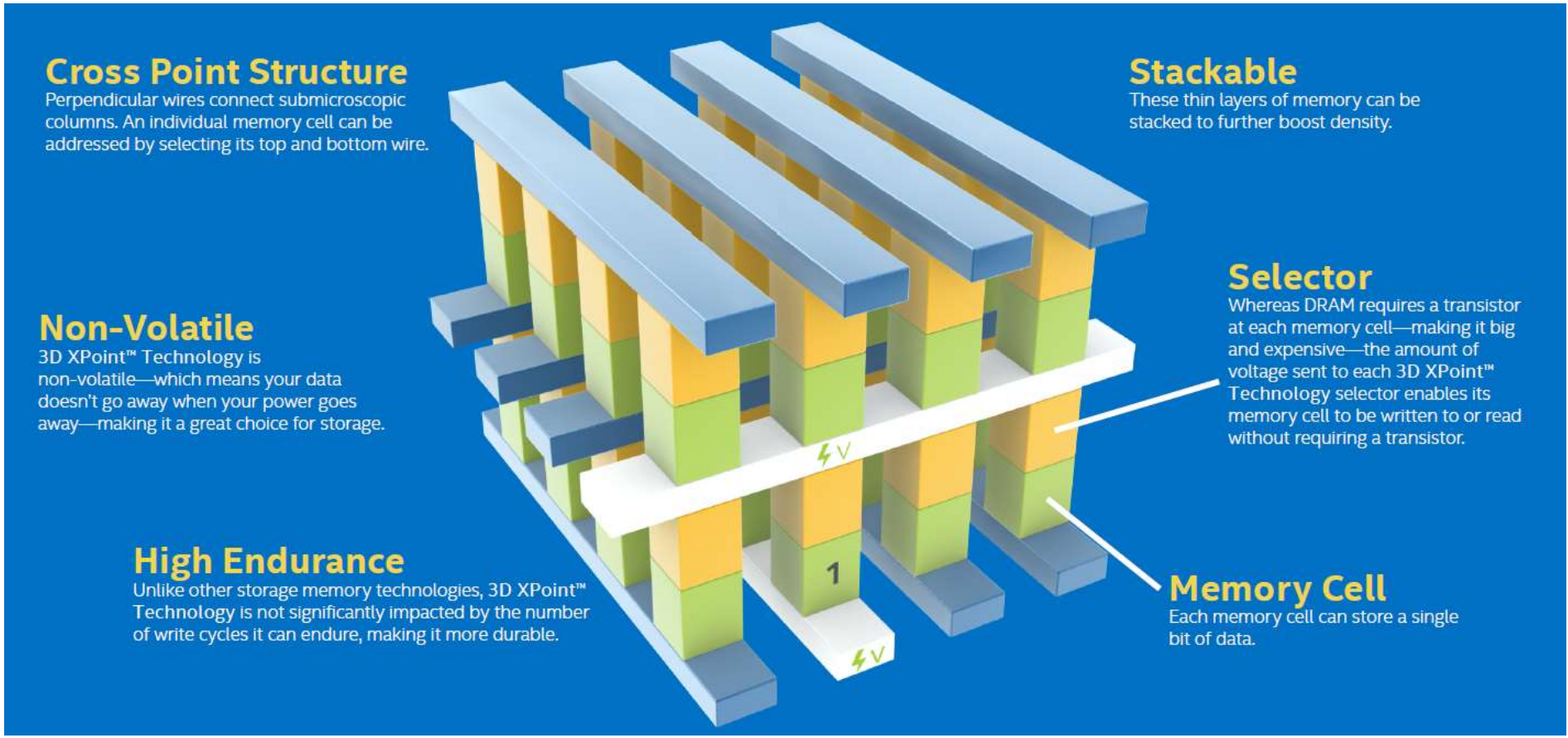


Figure: 3D XPoint memory [225]

7.3 Major innovation of the Kaby Lake line (8)

Main requirements for using Optane memory modules [229]

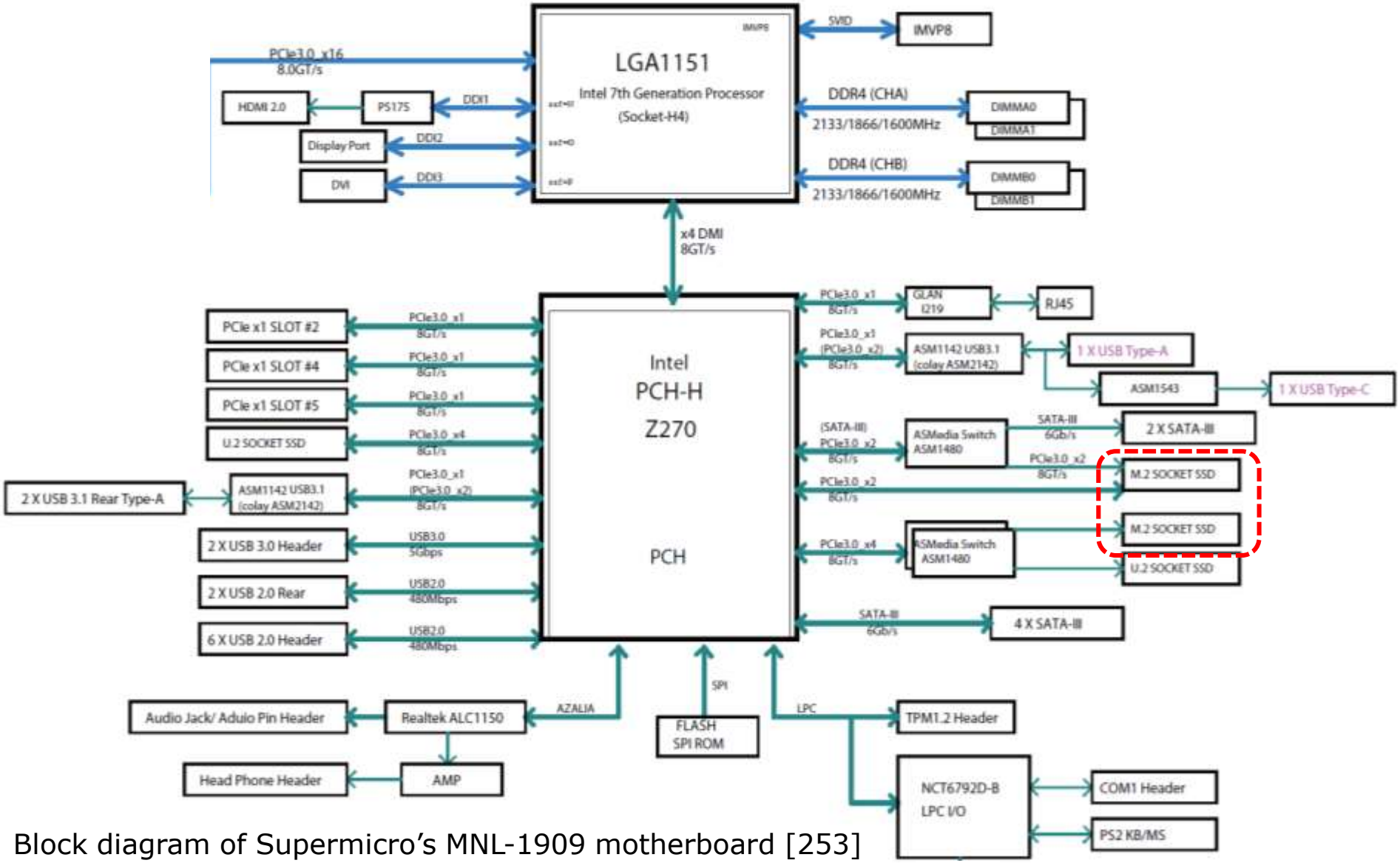
- 7th generation (Kaby Lake) processor with an Intel 200 series chipset (except the X299),
- an M.2 type socket on a PCIe 3.0 interface connected via 2 or 4 lanes,
- 64-bit Windows 10 OS,
- Rapid Storage Technology (RST) driver 15.5 or later
- appropriate system firmware (BIOS).

Note that the Optane memory, as introduced along with the 7th generation (Kaby Lake) processors is designated as the 1. generation Optane memory and it supports only a single HD drive.

Platforms with both a HD and SSD drive will be supported by the 2. generation Optane memory introduced along with the 8th generation (Coffee Lake) processors.

HD (Hard Drive): Merevlemez

Attaching two M.2 connectors to a Kaby Lake S-series DT processor



Block diagram of Supermicro's MNL-1909 motherboard [253]

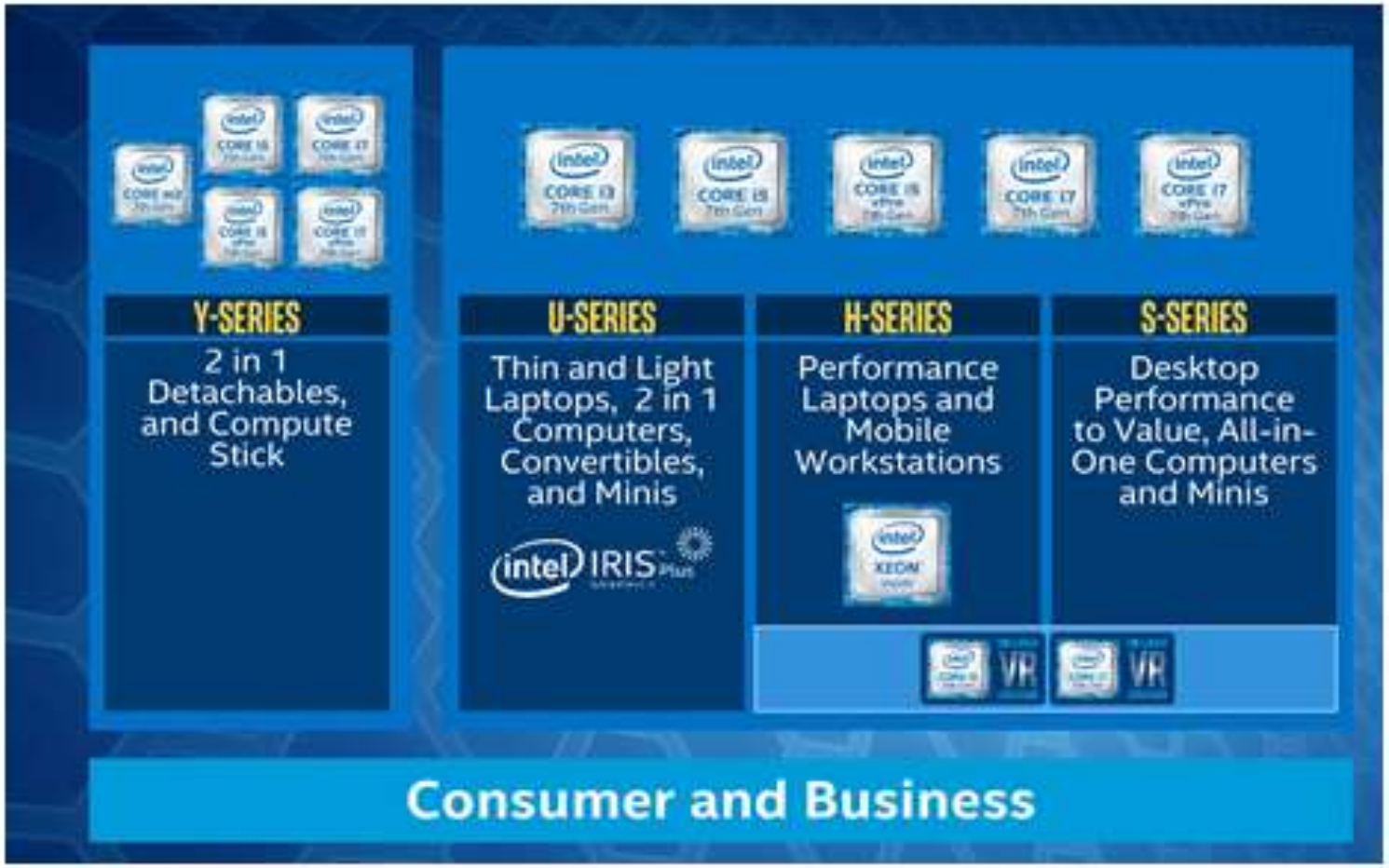
7.4 Kaby Lake-based processor lines

- 7.4.1 Overview of the Kaby Lake processor line
- 7.4.2 Example 1: The mobile Kaby Lake Y and U-series
- 7.4.3 Example 2: The 8th generation mobile Kaby Lake G-series
- 7.4.4 Example 3: The enthusiast mobile Kaby Lake X-series

Only Section 7.4.3 will be discussed.

7.4.1 Overview of the Kaby Lake processor line

7.4.1 Targeted market segments of the main Kaby Lake series [225]



7.4.1 Overview of the Kaby Lake processor line (2)

Key features of main Kaby Lake series [225]

	Mobiles				Desktops
Variant	**KBL-Y/Core m3 (BGA 1515)**	**KBL-U (BGA1356)**	**KBL-H (BGA1440)**	**KBL-G (BGA2270)**	**KBL-S (T/E/K/X) (LGA1151)**
Cores/Threads	2	2	2/4	4/8	2/4
Graphic Configurations	GT2	GT2/GT3e	GT2	AMD design	GT2
eDRAM	N/A	N/A / 64 MB	N/A	HBM2	N/A
SOC Design	Yes	Yes	No, 200-series PCH	No HM175 PCH	No, 200-series PCH
TDP	4.5W	15W / 28W	35W / 45W	100W (Package)	35W/51W/60W/ 65W/91W

Subclasses of the Mobile series

Y series: Mobile processors wih a very low TDP (4.5 W)
m3: Extreme low clock frequency models of the Y-series (1.0/1.1 GHz)
U-series: Mainline processors with a TDP of 15 or 28 W
H-series: High performance mobiles with a TDP of 35 or 45 W
of time, and at a level beyond that of the home PC user environment
G-series: High performance mobile with AMD Radeon RX Vega M GH graphics and HBM2 memory

7.4.1 Overview of the Kaby Lake processor line (3)

Subclasses of the desktop S-series

No suffix: Mainstream CPUs

T-series: Low power CPUs with lower TDP

E-series: Embedded series, Intel CPU will provide support for the product for a longer period of time, and at a level beyond that of the home PC user environment

X-series: Extreme performance desktops

Microserver series

E3-series: Microservers

Further tags used to designate models of the Kaby Lake lines

K-tag: Multiplier-unlocked CPU that can be overclocked

Q-tag: Quad core model

7.4.1 Overview of the Kaby Lake processor line (4)

Overview of the Kaby Lake (7th Gen) processor series

Mobiles (M/Y/U and H-series) (SoC designs)

4.5 W Core M and Y-series (SoC designs, BGA1515)

Core i7-7Y75, 2C+HD 615, HT, 8/2016
Core i5-7Y5x, 2C+HD 615, HT, 8/2016 and 1/2017
Core m3-7Y3x, 2C+HD 615, HT, 8/2016 and 7/2017

15 W U-series (SoC designs, BGA1356)

Core i7-76x0U/75x0U, 2C+HD 620/640/650, HT, 8/2016 and 1/2017
Core i5-73x0U/72x0U, 2C+HD 620/640/650, HT, 8/2016 and 1/2017
Core i3-71xxU, 2C+HD 620/650, HT, 8/2016 and 7/2017

28 W U-series (SoC designs, BGA1356)

Core i7-7567U, 2C+HD 650, HT, 1/2017
Core i5-7287U/7267U, 2C+HD 650, HT, 1/2017
Core i3-7167U, 2C+HD 650, HT, 1/2017

35 W H-series (2-chip designs, 200-series PCH, BGA1440)

Core i3-7100H, 2C+HD 630, HT, 1/2017

45 W H-series (2-chip designs, 200-series PCH, BGA1440)

Core i7-7920HQ/7820HQ/7820HK/7700HQ, 4C+HD 630, HT, 1/2017
Core i5-7440HQ/,7300HQ 4C+HD 630, HT, 1/2017

7.4.1 Overview of the Kaby Lake processor line (5)

Enthusiast mobiles (G-series) (2-chip designs, HM175 chipset)

- 100 W (in package integrated AMD Vega graphics and HBM2, BGA2270)
  - *Core i7-8809G/8709G/8706G/8705G/8305G, 4C+HD 630+AMD Vega M GH/GL + HBM2, HT 1/2018*

7.4.1 Overview of the Kaby Lake processor line (6)

Desktops (S-series) (2-chip designs, 200-series chipset)

35 W T-tagged (LGA1151)

Core i7-7700T 4C+HD 630, HT, 1/2017
Core i5-7600T/7500T/7400T, 4C+HD 630, HT, 1/2015
Core i3-7300T/7100T/7101TE, 2C+HD 630, HT, 1/2017

51 W untagged (LGA 1151)

Core i3-7100/7300/7320, 2C+HD 630, HT, 1/2017

65 W untagged series (LGA1151)

Core i7-7700, 4C+HD 630, HT, 1/2017
Core i5-7600/7500/7400 4C+HD 630, HT, 1/2017
Core i3-7350K (60 W), 2C+HD 630, HT, 1/2017

91 W K-tagged, unlocked (LGA1151), (needs the Z270 chipset due to unlocking)

Core i7-7700K, 4C+HD630, HT, 1/2017
Core i5-7600K, 4C+HD630, HT, 1/2017

Enthusiast desktops (X-series) (2-chip designs, model 299 chipset)

112 W X-series, unlocked (LGA2066)

Core i7-7740X, 4C, (no integrated graphics), HT, 7/2017
Core i5-7640X, 4C (no integrated graphics), no HT, 7/2017

7.4.1 Overview of the Kaby Lake processor line (7)

Microservers (E3 v6-series)

25 W E3 v6-series (BGA 1440)

Xeon E3-1505L v6, 4C+HD P630, HT, 1/2017

45 W E3 v6-series (BGA 1440)

Xeon E3-1505M/1535M v6, 4C+HD P630, HT, 1/2017

72 W E3 v6-series (LGA 1151)

Xeon E3-12x0 v6, 4C, HT, 1/2017

73 W E3 v6-series (LGA 1151)

Xeon E3-12x5 v6, 4C+HD P630, HT, 1/2017

7.4.2 Example 1: The mobile Kaby Lake Y and U-series

7.4.2 Example 1: The mobile Kaby Lake Y and U-series [225]

Main features of the mobile Kaby Lake Y and U-series

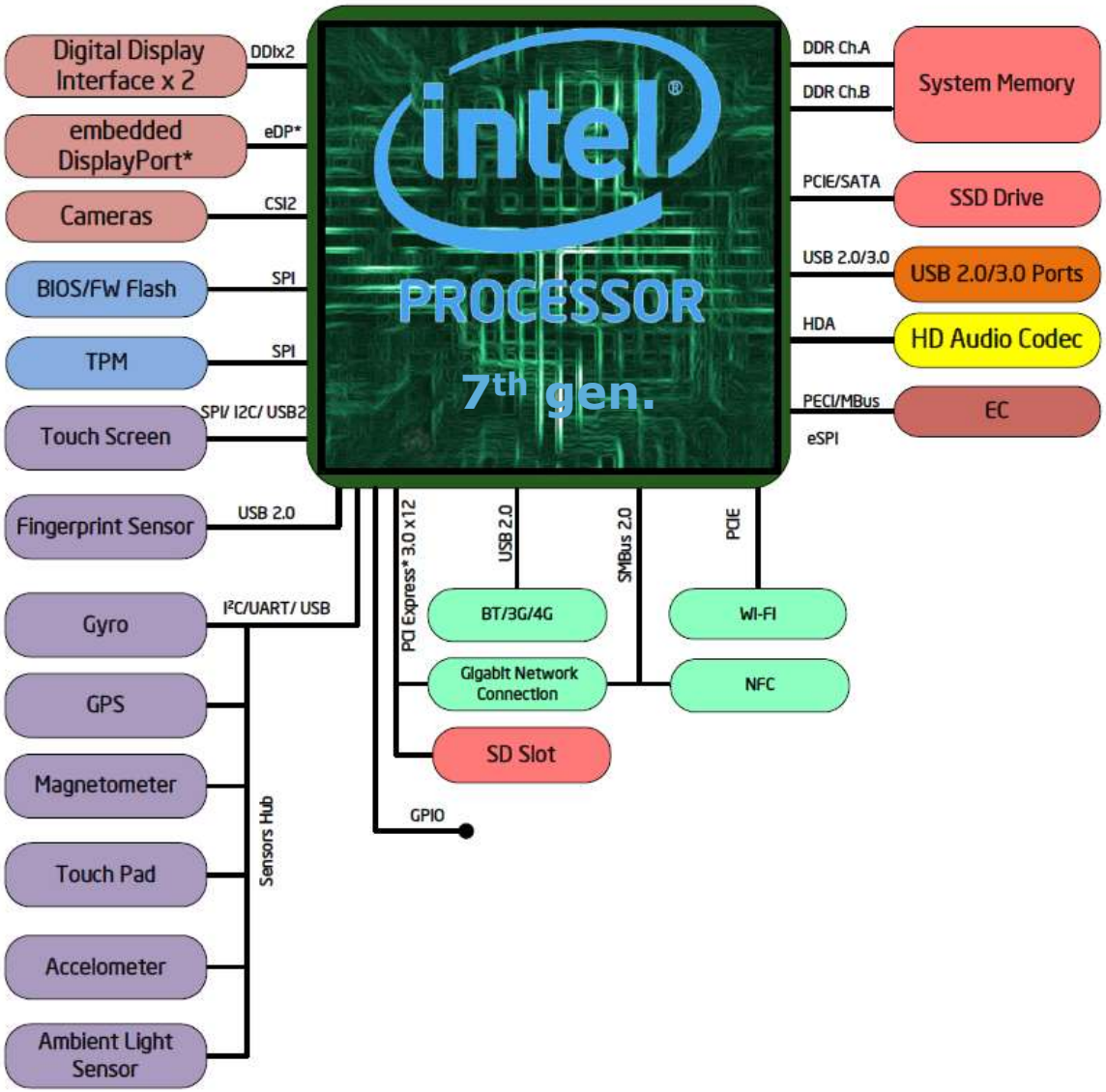
	Intel Kaby Lake Y and U SKUs						
	Cores/ Threads	Base/ Turbo	IGP	L3	eDRAM	TDP	Cost
			Y-Series				
i7-7Y75	2/4	1.3/3.6	HD 615	4 MB	-	4.5 W	$353
i5-7Y57	2/4	1.2/3.3	HD 615	4 MB	-	4.5 W	$253
i5-7Y54	2/4	1.2/3.2	HD 615	4 MB	-	4.5 W	$253
m3-7Y30	2/4	1.0/2.0	HD 615	4 MB	-	4.5 W	$253
			U-Series				
i7-7660U	2/4	2.5/4.0	Iris Plus 640	4 MB	64 MB	15 W	$373
i7-7600U	2/4	2.8/3.9	HD 620	4 MB	-	15 W	$353
i7-7567U	2/4	3.5/4.0	Iris Plus 650	4 MB	64 MB	28 W	$373
i7-7560U	2/4	2.4/3.8	Iris Plus 640	4 MB	64 MB	15 W	$373
i7-7500U	2/4	2.7/3.5	HD 620	4 MB	-	15 W	$353
i5-7360U	2/4	2.3/3.6	Iris Plus 640	4 MB	64 MB	15 W	$273
i5-7300U	2/4	2.6/3.5	HD 620	3 MB	-	15 W	$253
i5-7200U	2/4	2.5/3.1	HD 620	3 MB	-	15 W	$253
i5-7287U	2/4	3.3/3.7	Iris Plus 650	4 MB	64 MB	28 W	$273
i5-7267U	2/4	3.1/3.5	Iris Plus 650	4 MB	64 MB	28 W	$273
i5-7260U	2/4	2.2/3.4	Iris Plus 640	4 MB	64 MB	15 W	$273
i3-7167U	2/4	2.8	Iris Plus 650	3 MB	64 MB	28 W	$273
i3-7100U	2/4	2.4	HD 620	3 MB	-	15 W	$253

7.4.2 Example 1: The mobile Kaby Lake Y and U-series (2)

Main features of Intel's 10th generation graphics included in the Kaby Lake line [174]

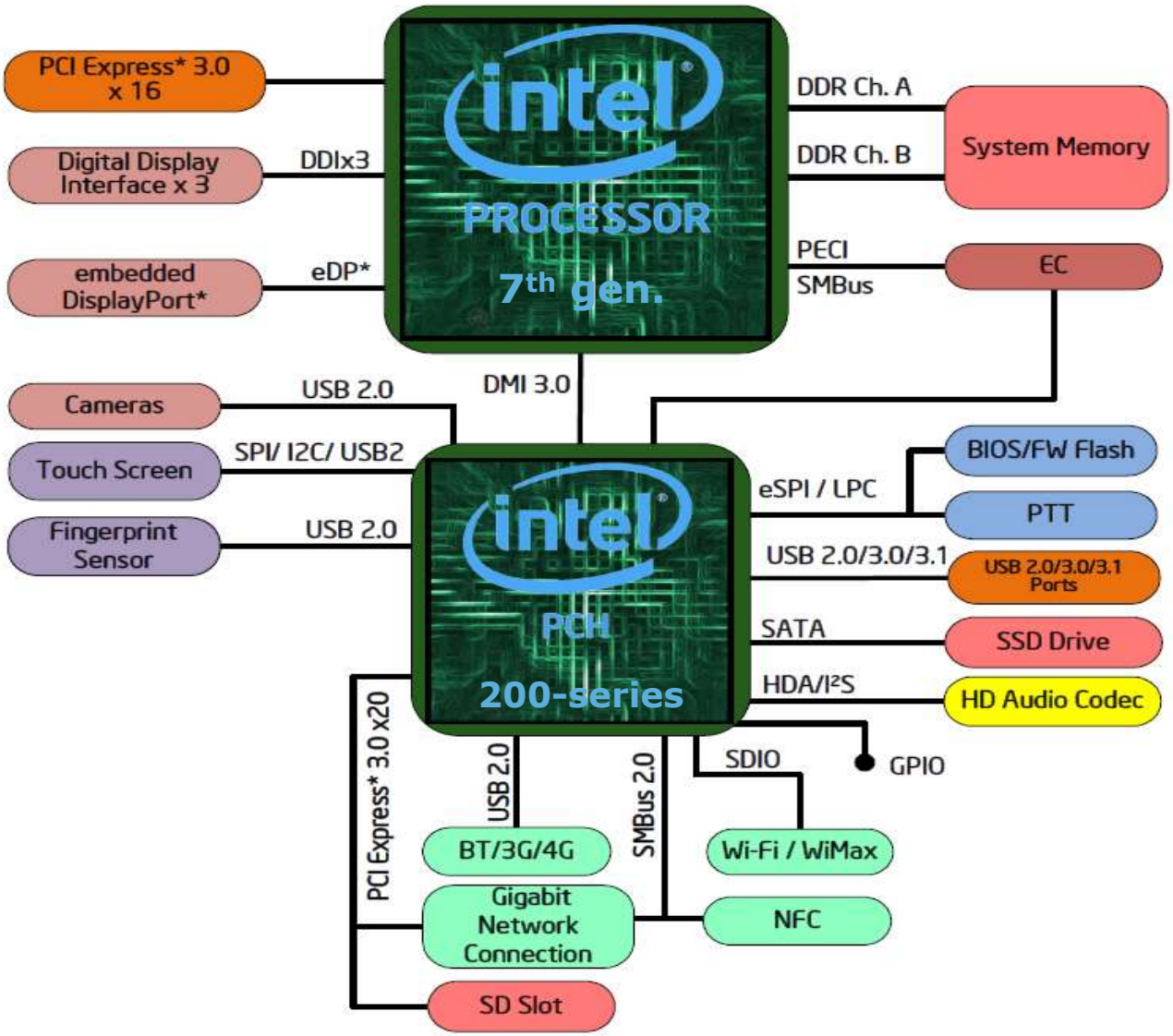
Market segment	Model number	Tier	Execution units	eDRAM (MB)	Base clock (MHz)	Boost clock (MHz)	GFLOPS	Used in
Consumer	HD Graphics 610	GT1	12	-	300–350	900–1100	≈ 200	Desktop Celeron, Desktop Pentium G45**, i3-7101
	HD Graphics 615	GT2	24	–	300	900–1050	345.6 – 403.2	m3-7Y30, i5-7Y54, i7-7Y75
	HD Graphics 620					1000–1050	384 – 403.2	i3-7100U, i5-7200U, i5-7300U, i7-7500U, i7-7600U
	HD Graphics 630				350	1000–1150	384 – 441.6	Desktop Pentium G46**, i3, i5 and i7, and Laptop H-series i3, i5 and i7
	Iris Plus Graphics 640	GT3e	48	64	300	950–1050	729.6 – 806.4	i5-7260U, i5-7360U, i7-7560U, i7-7660U
	Iris Plus Graphics 650					1050–1150	806.4 – 883.2	i3-7167U, i5-7267U, i5-7287U, i7-7567U

The Y/m and U-series platform [231]



7.4.2 Example 1: The mobile Kaby Lake Y and U-series (4)

By contrast The mobile H-series and desktop S-series platforms [232], [233]



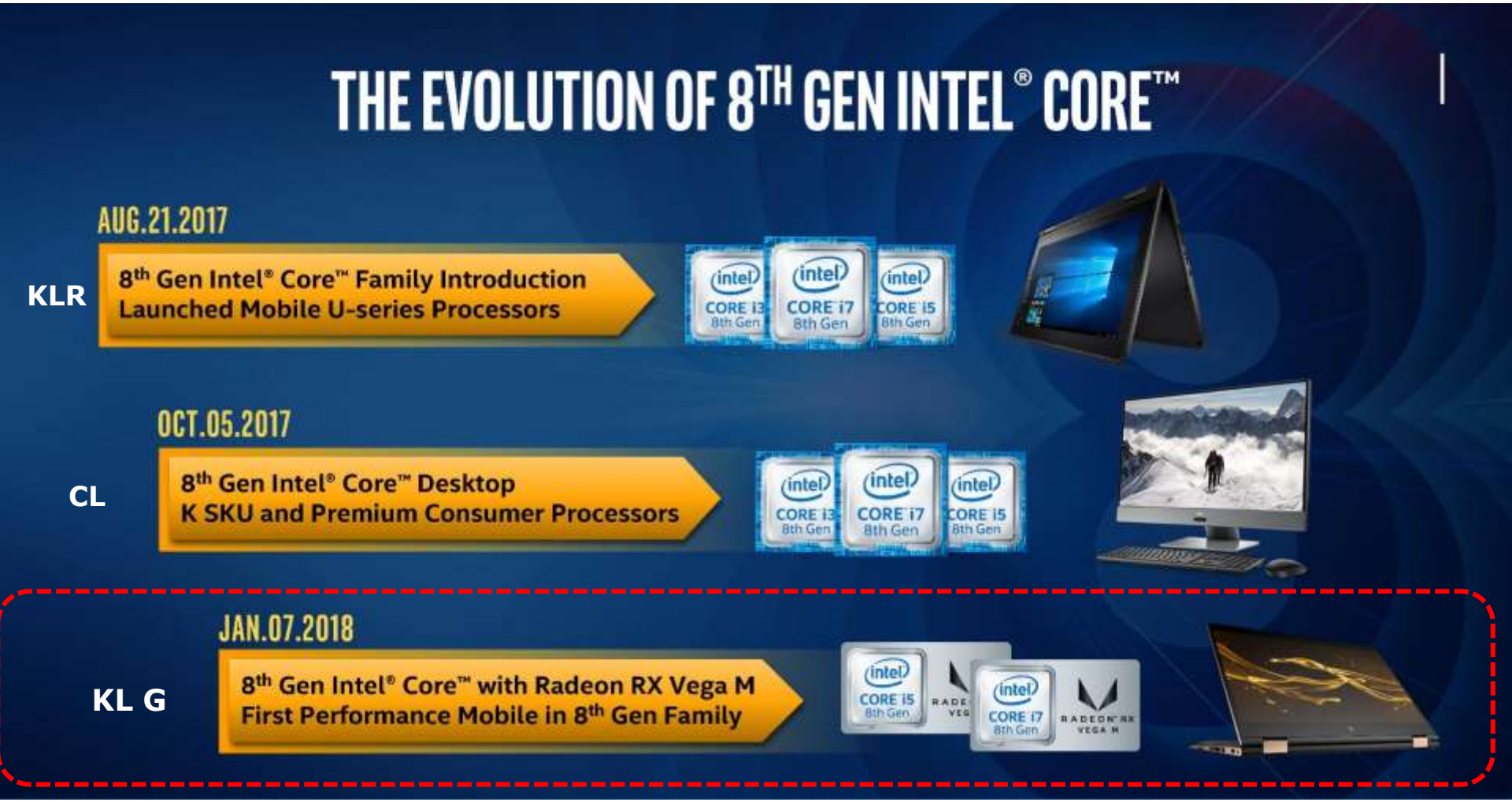
7.4.2 Example 1: The mobile Kaby Lake Y and U-series (5)

Main features of the Intel 200-series chipsets of the mobile H and desktop S series [225]

Intel 200-series Chipsets								
	Z270	H270	B250	Q270	Q250	HM175	QM175	CM238
DMI	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
PCIe 3.0 Lanes	24	20	12	24	14	16	16	20
SATA 6 Gbps Ports	6	6	6	6	6	4	4	8
USB 3.0 Ports	>= 10	8	6	>= 10	8	>= 8	>= 8	>= 10
Total USB 2/3	14	14	12	14	14	14	14	14
PCIe Config	x16 x8/x8 x8/x4/x4	x16	x16	x16 x8/x8 x8/x4/x4	x16	x16 x8/x8 x8/x4/x4		
Overclocking	Yes	No						
vPro	No	No	No	Yes	No	No	Yes	Yes
Intel Manageability	No	No	No	Yes	Yes	No	Yes	Yes

7.4.3 Example 2: The 8th generation mobile Kaby Lake G-series

7.4.3 Example 2: The 8th generation Kaby Lake G-series mobile processors -1 [253]



KLR: Kaby Lake Refresh CL: Coffee Lake KL G: Kaby Lake G

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7.4.3 Example 2: The 8th generation Kaby Lake G-series mobile processors (1b)

The 8th generation of the Core 2 family

1. gen.				2. gen.	3. gen.	4. gen.	5. gen.
Core 2 New Microarch. 65 nm	Penryn New Process 45 nm	Nehalem New Microarch. 45 nm	West-mere New Process 32 nm	Sandy Bridge New Microarch. 32 nm	Ivy Bridge New Process 22 nm	Haswell New Microarchi. 22 nm	Broad-well New Process 14 nm
TOCK	***TICK***	***TOCK***	***TICK***	***TOCK***	***TICK***	***TOCK***	***TICK***
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Skylake New Microarch. 14 nm	Kaby Lake New Microarch. 14 nm	Kaby Lake R KL G-series Coffee Lake Cannon Lake 14/10 nm	Coffee Lake R New Mocroarch. 14 nm
TOCK	***TOCK***	***TOCK***	***TOCK***
(2015)	*(2016)*	*(2017/18)*	*(2018)*

[1]Astonishingly, the 8th generation encompasses four processor lines, as follows:

- Kaby Lake Refresh
- Kaby Lake G with AMD Vega graphics
- Coffee Lake (all 14 nm) and the
- 10 nm Cannon Lake designs [218].

7.4.3 Example 2: The 8th generation Kaby Lake G-series mobile processors (2)

The Kaby Lake G-series mobile processors -2 [254]

- Initial details were released in 11/2017.
- Released in 01/2018
- It is marked as 8. generation processors.

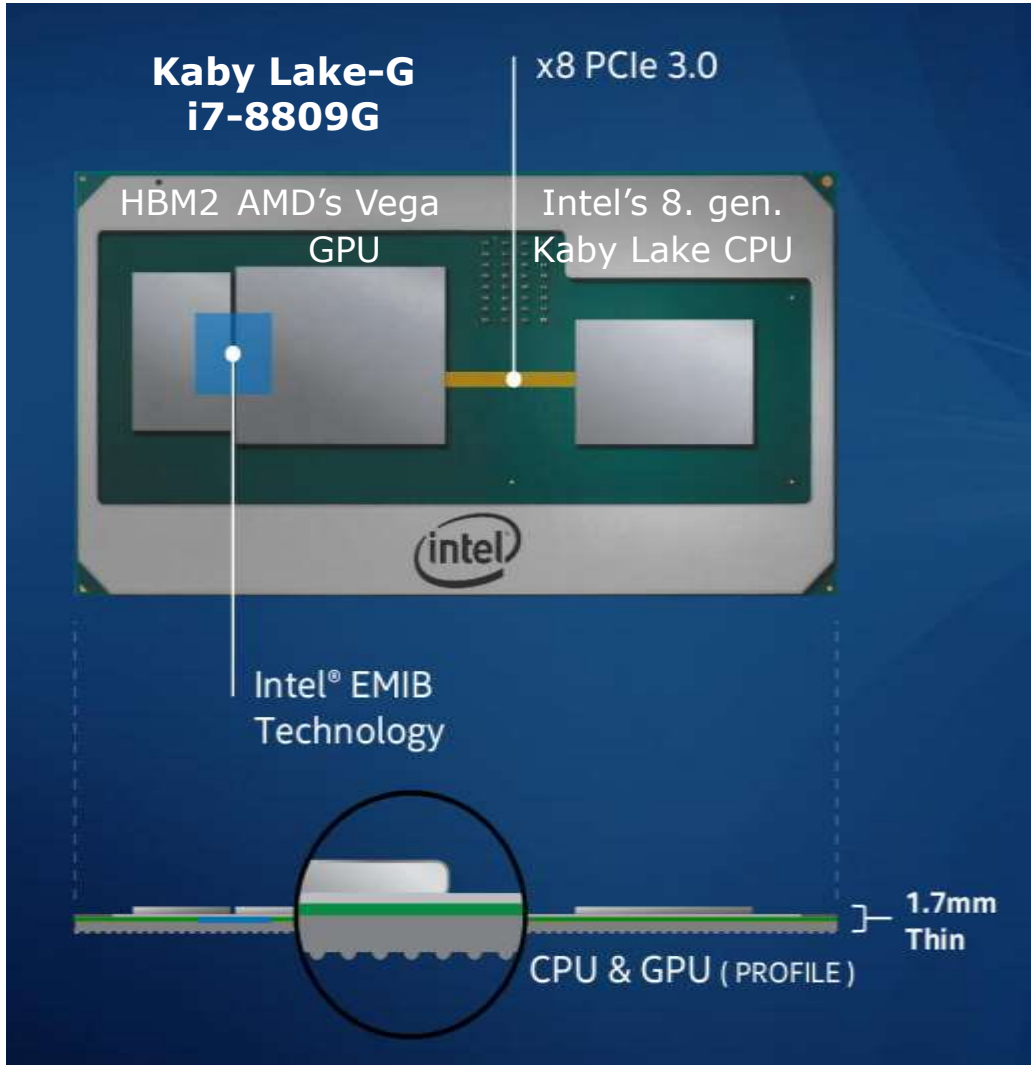
The Kaby Lake-G line integrates

- a Kaby Lake CPU
- an AMD graphics unit (Radeon RX Vega M GH or GL)
- along with a 4 GB HBM2 VRAM,

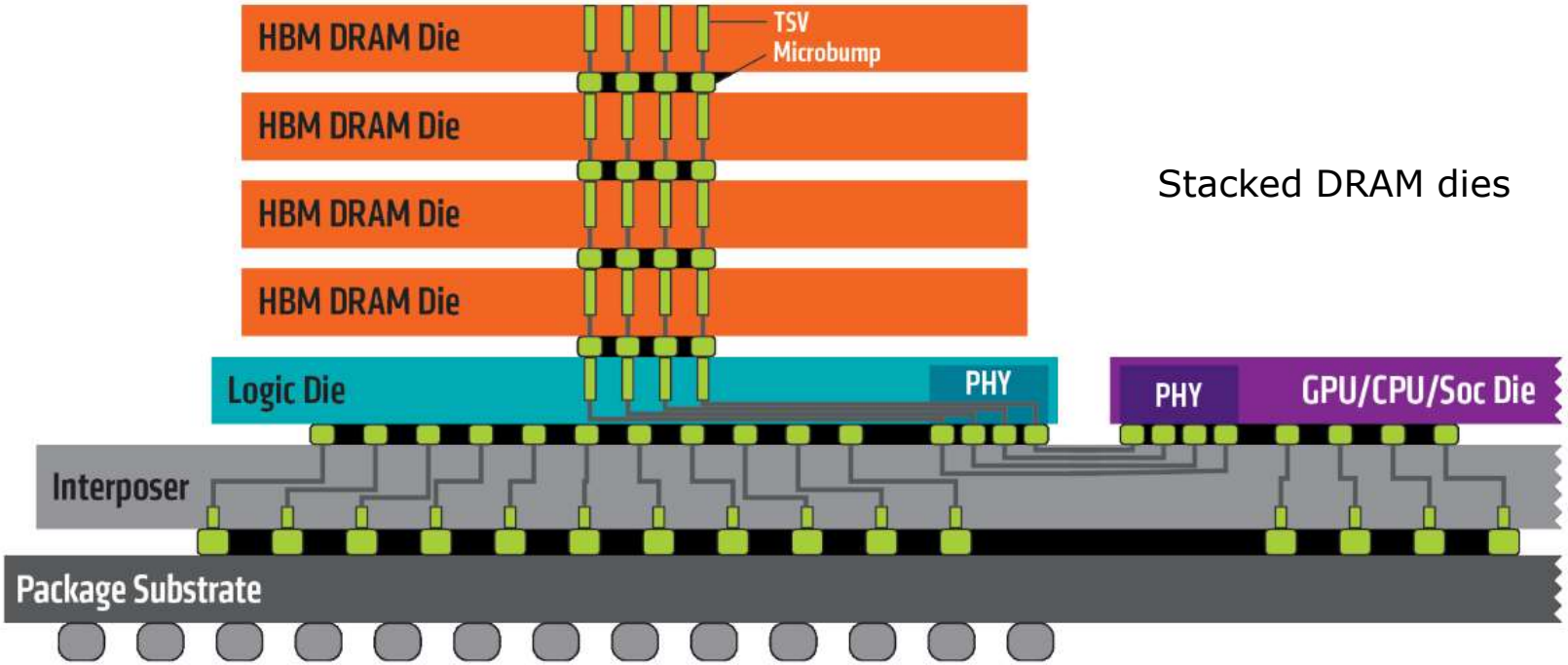
into an MCM package.

The GPU is interconnected to the CPU by an x8 PCI 3.0 lane whereas the GPU is interconnected with the HBM2 memory via Intel's EMIB (Embedded Multi-Die Interconnect Bridge) technology, as the Figure shows.

BGA2270
31 x 58 mm



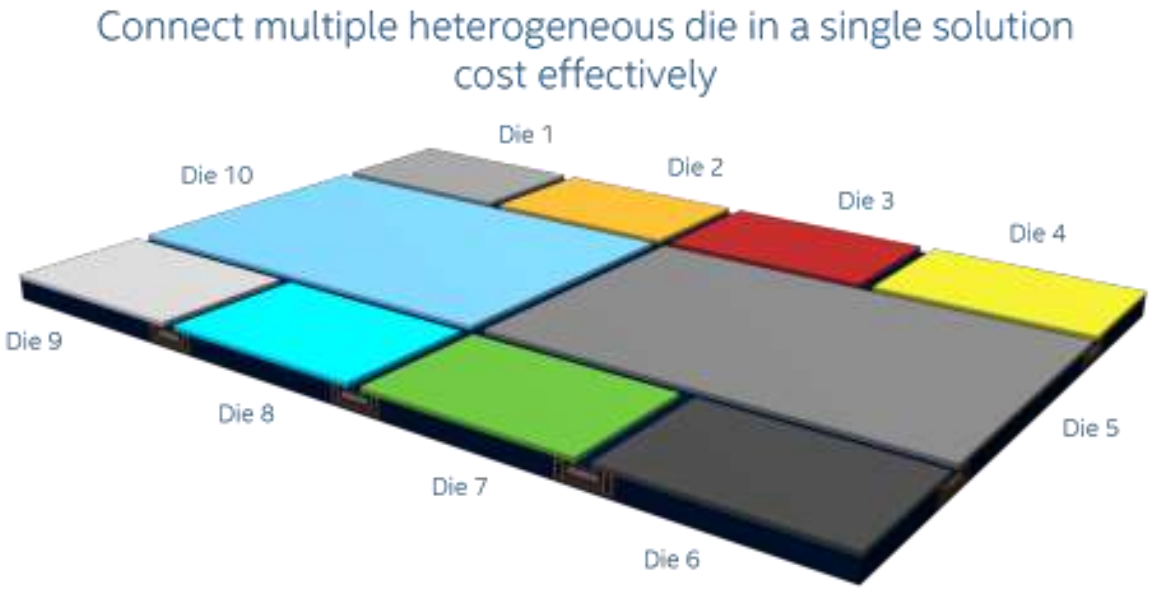
Principle of the HBM2 (High Bandwidth Memory) [292]

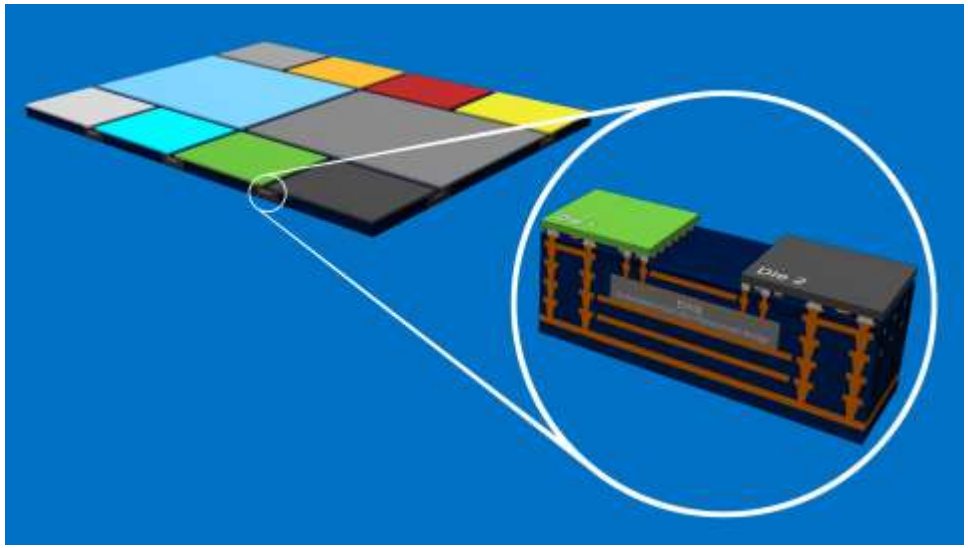


Stacked DRAM dies

7.4.3 Example 2: The 8th generation Kaby Lake G-series mobile processors (2c)

Intel's concept for interconnecting multiple dies through EMIB [274]





EMIB: Embedded Multi-Die Interconnect Bridge

*

7.4.3 Example 2: The 8th generation Kaby Lake G-series mobile processors (3)

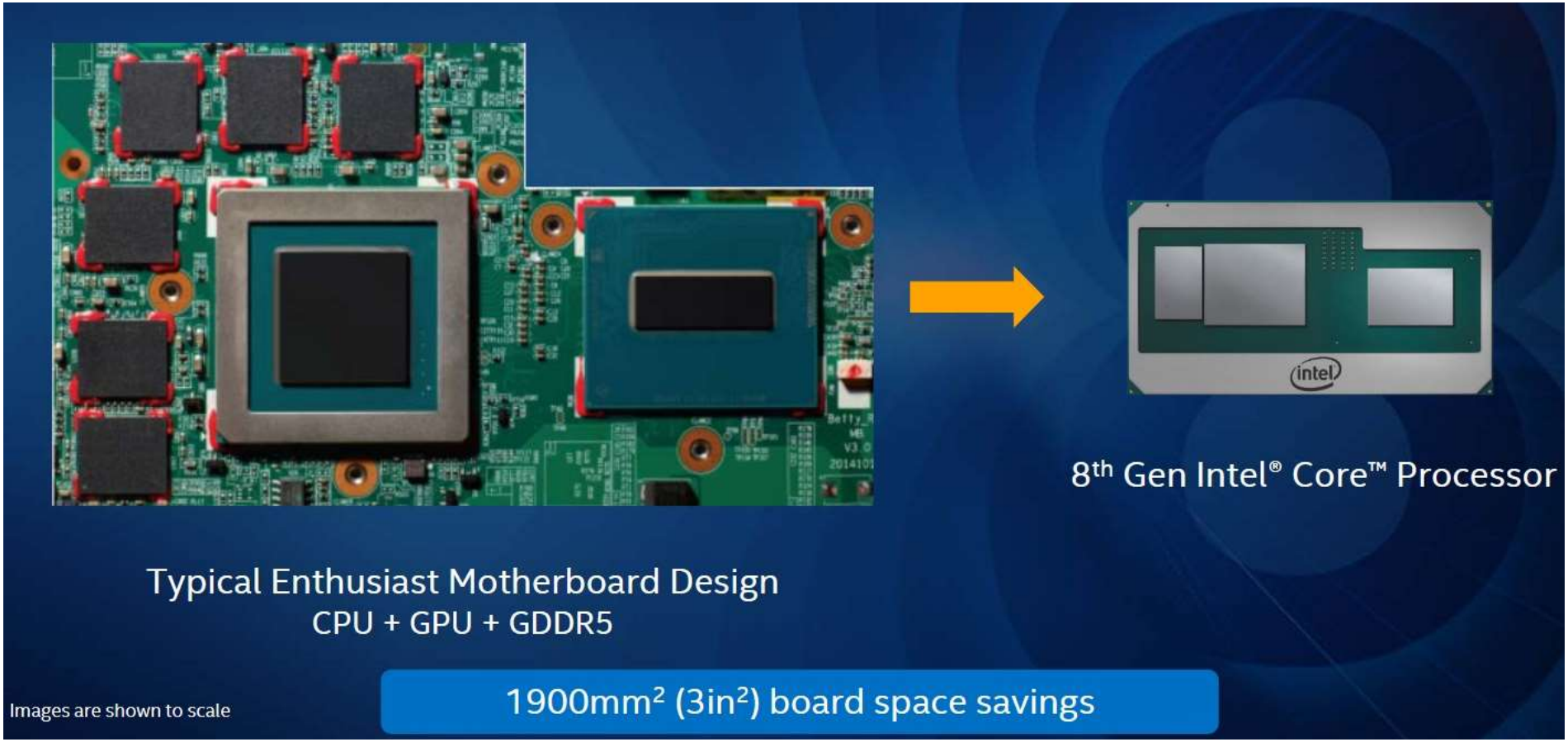
The Kaby Lake G-series mobile processors -3 [254]

- We note that AMD's Vega GPU has a considerable higher performance than Intel's integrated HD Graphics 630.

*

7.4.3 Example 2: The 8th generation Kaby Lake G-series mobile processors (4)

Additional benefit of the integrated CPU/GPU/HBM2 solution – less board space [255]



7.4.3 Example 2: The 8th generation Kaby Lake G-series mobile processors (5)

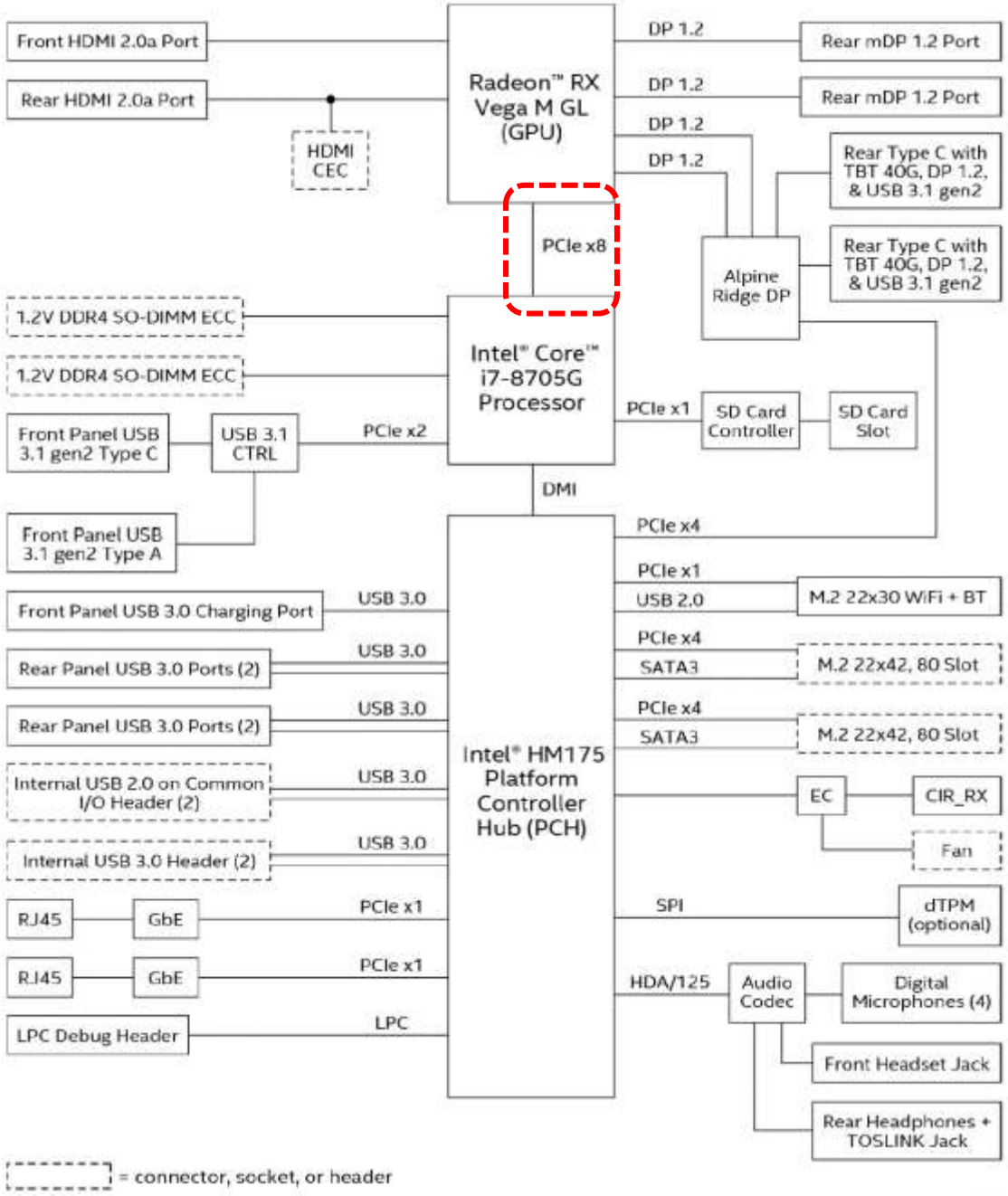
Main features of the Kaby Lake G-series mobile processors [255]

Model	Base/Turbo frequencyl	Cores/ Threads	L3 cache	TDP	AMD Radeon RX pGPU	HD Graphics IGP típusa
i7-8809G	3,1/4,2 GHz	4/8	8 MB	100 W	Vega M GH	630
i7-8709G	3,1/4,1 GHz	4/8	8 MB	100 W	Vega M GH	630
i7-8706G	3,1/4,1 GHz	4/8	8 MB	65 W	Vega M GL	630
i7-8705G	3,1/4,1 GHz	4/8	8 MB	65 W	Vega M GL	630
i5-8305G	2,8/3,8 GHz	4/8	6 MB	65 W	Vega M GL	630

The Vega M GH has about 10% higher performance than the Vega M GL.

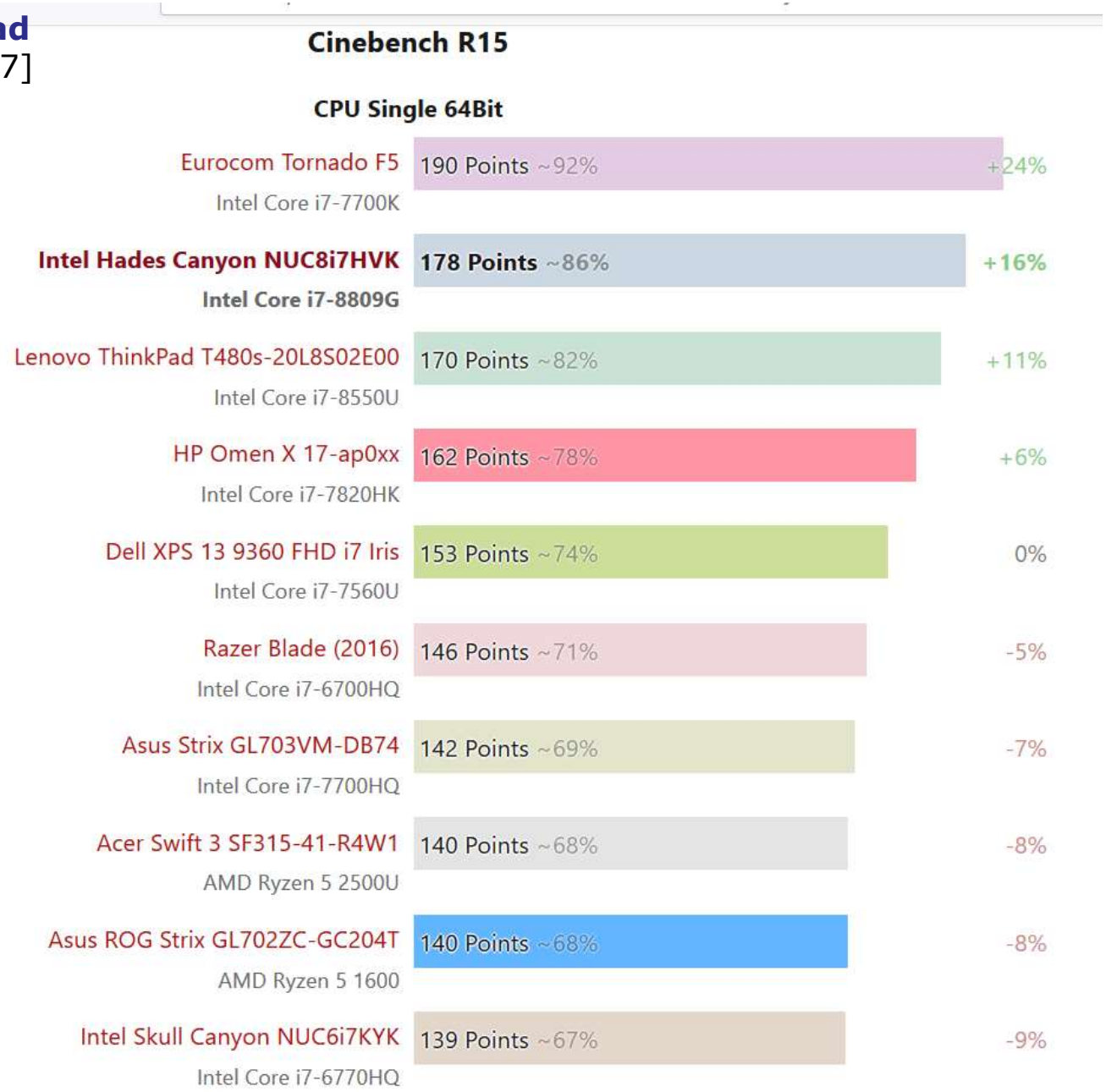
7.4.3 Example 2: The 8th generation Kaby Lake G-series mobile processors (6)

Block diagram of a Kaby Lake-G based platform (Intel's NUC8i7HN kit) [256]



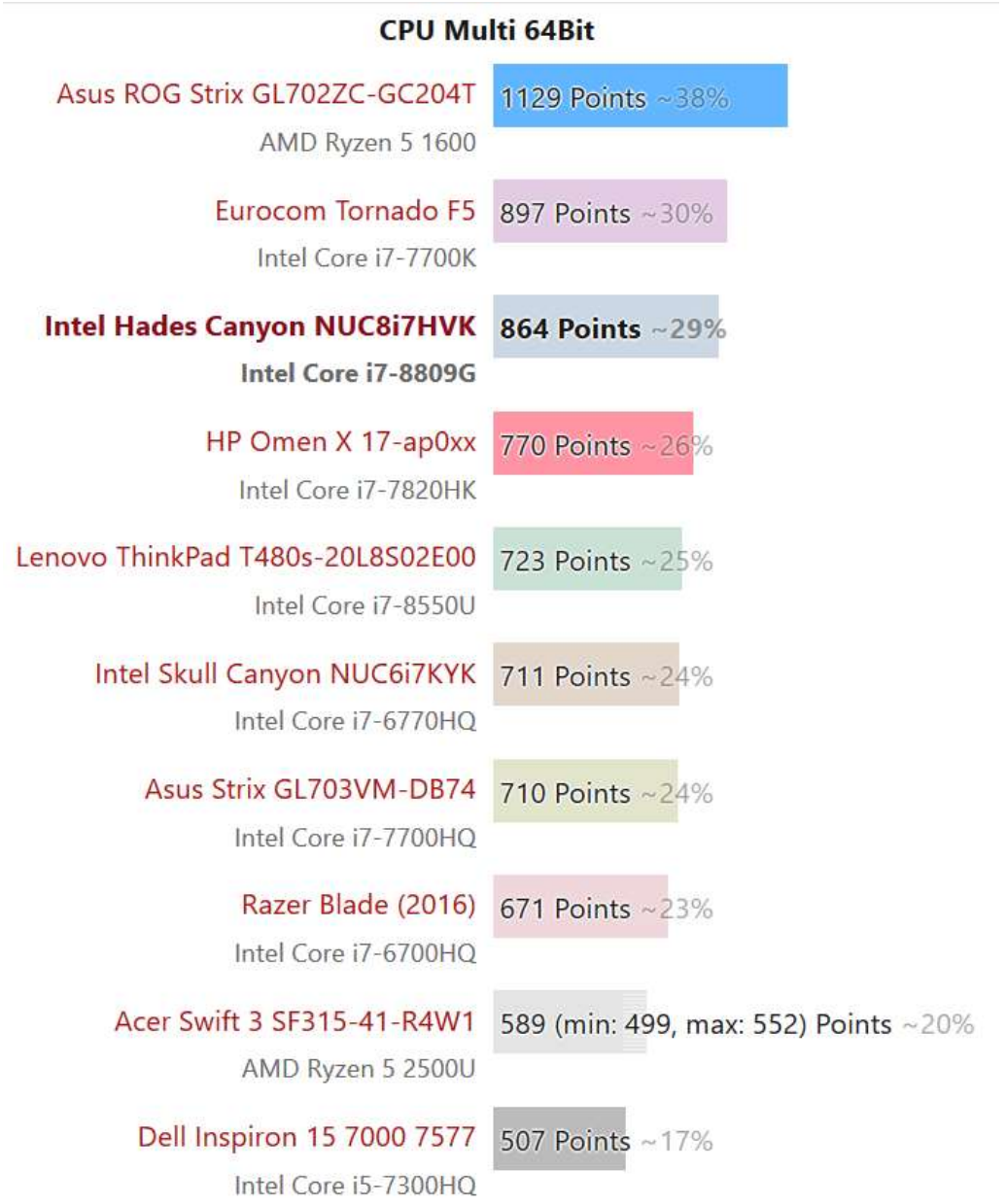
7.4.3 Example 2: The 8th generation Kaby Lake G-series mobile processors (7)

Cinebench R15 single thread benchmark comparison [257]



7.4.3 Example 2: The 8th generation Kaby Lake G-series mobile processors (8)

Cinebench R15 multi-thread benchmark comparison [257]



7.4.3 Example 2: The 8th generation mobile Kaby Lake G-series (9)

Remark

- Cinebench is a real-world cross platform test suite that evaluates computer's performance capabilities.
- It is based on MAXON's animation software Cinema 4D, which is used extensively by studios and production houses worldwide for 3D content creation.
- It is often used to assess graphics capabilities of processors.

*

7.4.4 Example 3: The enthusiast mobile Kaby Lake X-series

7.4.4 Example 3: The enthusiast mobile Kaby Lake X-series -1 [258]

- Announced in 05/2017
- Launched in 07/2017
- The X-series includes the highest performance models of the Kaby lake line.
- It has only two models (i7-7740X and i5-7640X), as seen below.

Note

The designation of these models is mobile X-series in order to emphasize the vast difference to the "ordinary" X-series used for HEDs, as the Table below shows.

Processor	Techn.	Date of intro.	Max. no. of cores	Platform topology	Highest mem./ speed	PCIe lanes	No. of mem. channels	PCH	Processor socket
Skylake-X	14 nm	6/2017	18C	On-die MC	DDR4-2666	44 PCI-3.0 on the die	4	X299 (Basin Falls)	LGA-2066
Kaby-Lake-X			4C			**16**			

Table: Main features of the HED oriented Skylake-X and the enthusiast mobile oriented Kaby Lake X-series

7.4.4 Example 3: The enthusiast mobile Kaby Lake X-series (2)

Main features of the enthusiast mobile Kaby Lake X-series -1 [258]

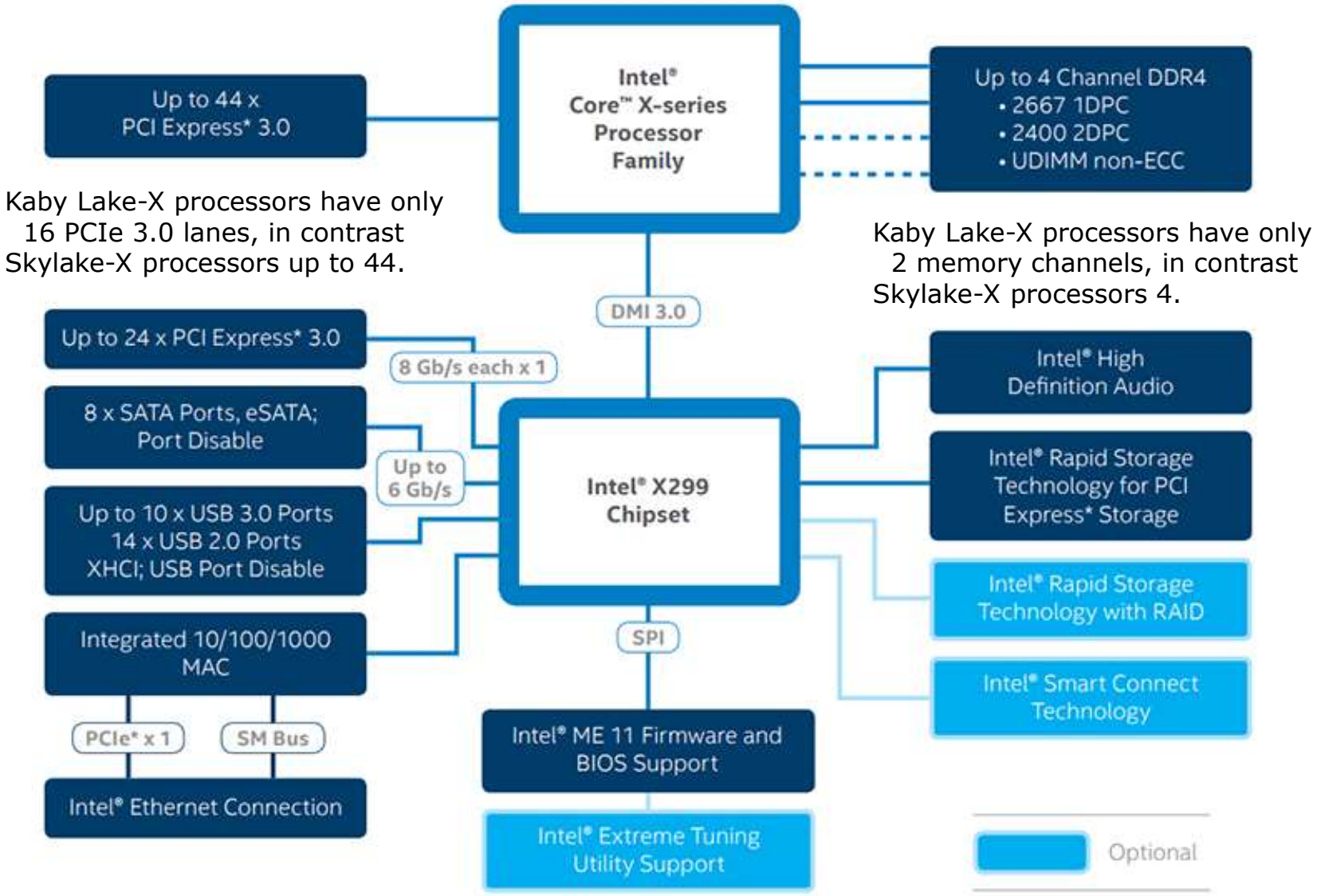
Intel Kaby Lake Processors				
	Core i7		Core i5	
	Core i7-7740X	Core i7-7700K	**Core i5-7640X**	Core i5-7600K
Socket	**LGA2066**	LGA1151	**LGA2066**	LGA1151
Cores/Threads	4/8	4/8	4/4	4/4
Base Frequency	4.3 GHz	4.2 GHz	4.0 GHz	3.8 GHz
Turbo Frequency	4.5 GHz	4.5 GHz	4.2 GHz	4.2 GHz
TDP	112 W	91 W	112 W	91 W
L2 Cache	256 KB/core			
L3 Cache	8 MB		6 MB	
DRAM Channels	2			
DRAM Support	DDR4-2666	DDR4-2400	DDR4-2666	DDR4-2400
Graphics	None	HD 620	None	HD 620
Price (MSRP)	$350		$250	
Price (7/21)	$349	$309	$248	$239
Launched	July 2017	Jan 2017	July 2017	Jan 2017

Main features of the Kaby Lake X-series models -2 [258]

Note the main differences between the enthusiast mobile Kaby Lake-X and desktop H-series models in the Table above:

- higher clock rates (e.g. 4.3 GHz base clock rate for the i7_7740X vs. 4.2 GHz for the i7-7700K)
- higher TDP (112 W vs. 91 W)
- higher memory rates (up to DDR4-2666 for the Kaby Lake-X series vs. up to DDR4-2400 for the Kaby Lake-H series)
- no integrated graphics
- LGA2066 socket vs. the LGA1151
- Higher prices

The Basin Falls platform with the X299 chipset [259]



Optional liquid cooling solution for Kaby Lake-X models [258]

INTEL® LIQUID COOLING TS13X

HIGH-PERFORMANCE THERMAL SOLUTION FOR ENTHUSIASTS

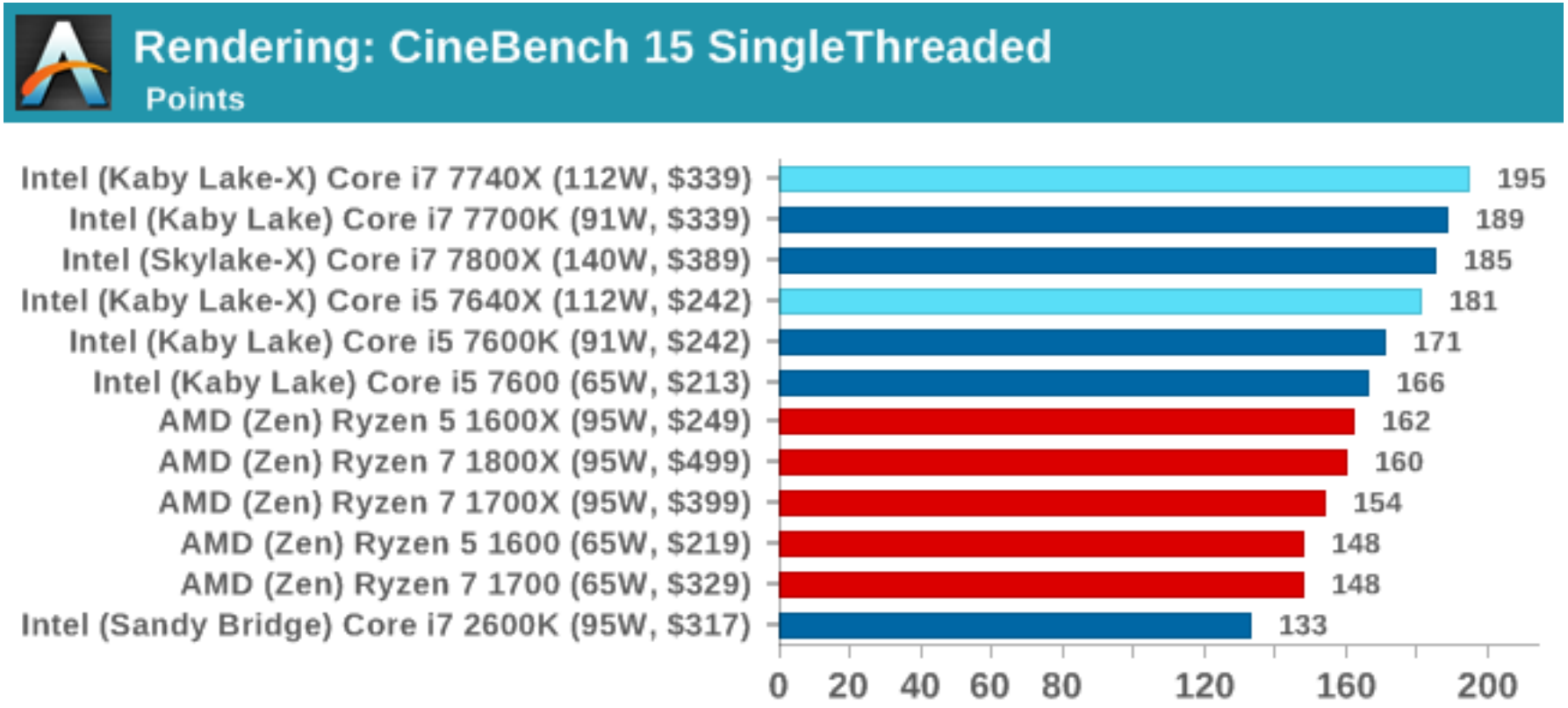
Separate boxed SKU available from distribution and at retail

Fan speed	800–2,200 RPM (four-wire PWM)
Fan dimensions	120 mm x 120 mm x 25 mm
Fan CFM	73.84 CFM
Unit noise level	21 dBA @ 800 RPM 35 dBA @ 2,200 RPM
Radiator dimensions	150 mm x 118 mm x 37 mm
Pump Z height	31 mm
Total thermal solution weight	820 grams
Cooling liquid	Propylene glycol
Thermal interface material	Dow Corning* TC-1996

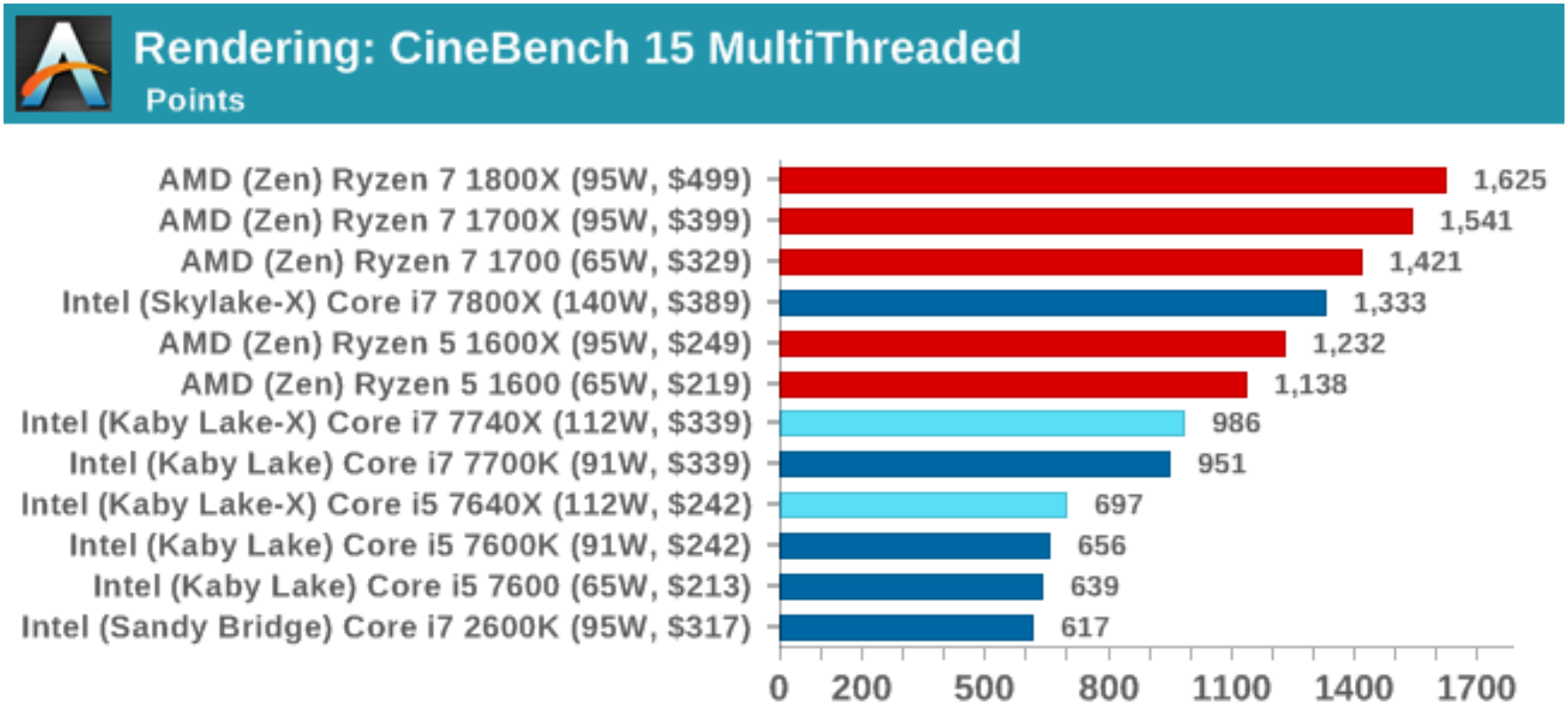
Compatible with socket 2011/1366/115X
Estimated retail pricing $85–$100

intel

Cinebench R15 single threaded benchmark comparison [258]



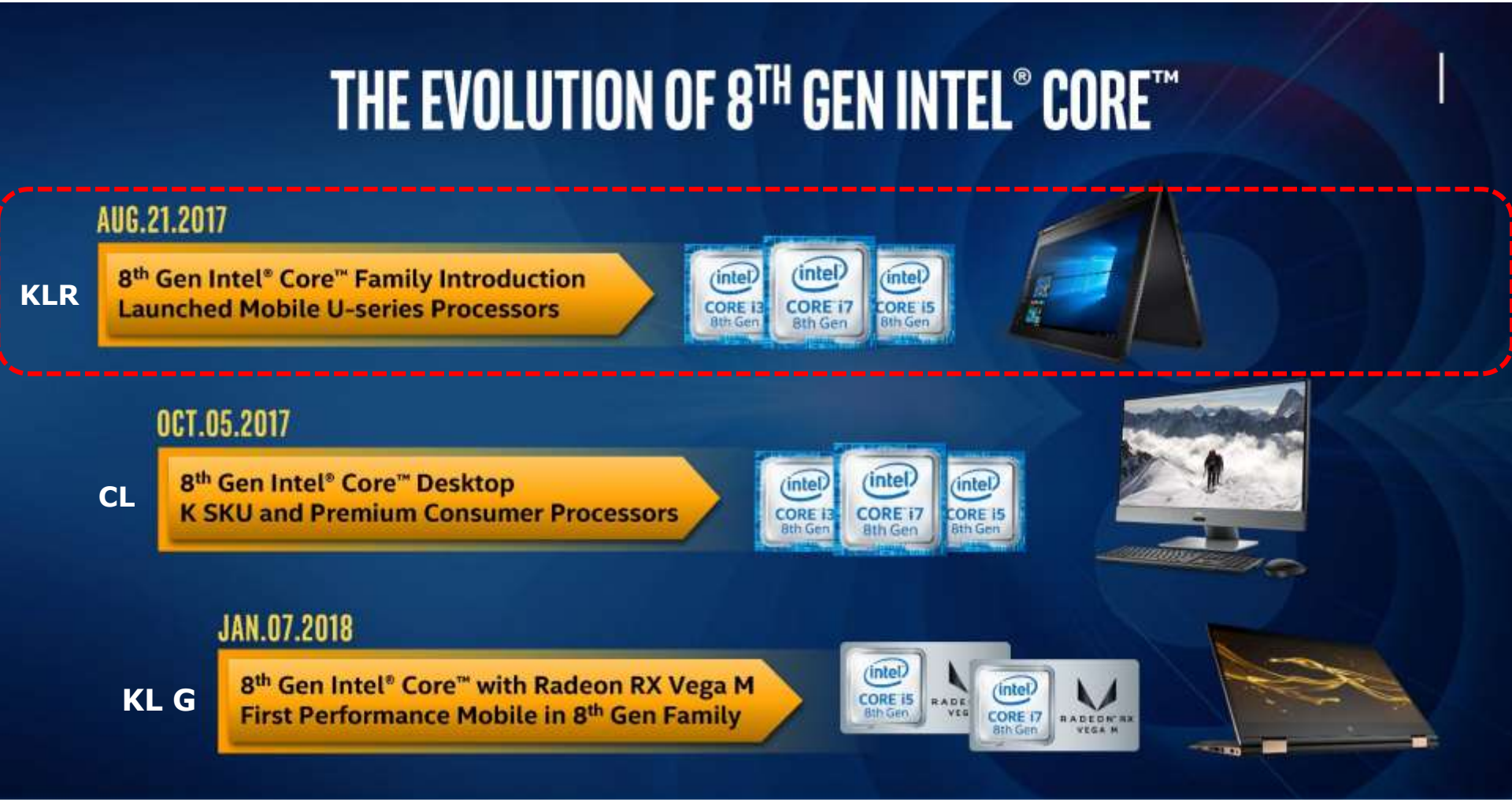
Cinebench R15 multi threaded benchmark comparison [258]



8. The Kaby Lake Refresh line

It will not be discussed.

8. The Kaby Lake Refresh line -1 [253]



KLR: Kaby Lake Refresh CL: Coffee Lake KL G: Kaby Lake G

*

The Kaby Lake Refresh line -2

- It is the second refreshment of the Skylake line (as seen in the Figure below.

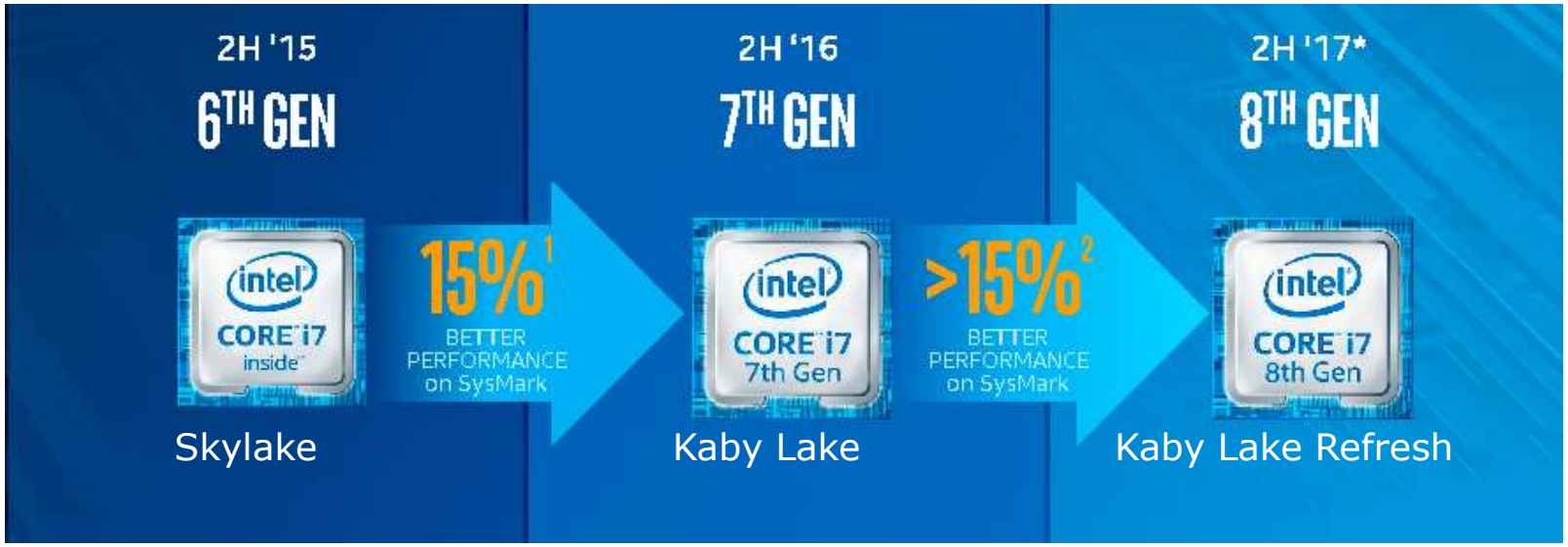


Figure: The 8th generation Kaby Lake Refresh line [235]

- Intel dubs it as belonging to the 8th generation Core architecture.

Here we note that the 8th generation does not only include the Kaby lake refresh line, which is based on the enhanced 14 nm process (designated as 14 nm+), but also contains models of

- the Kaby Lake G series with AMD Vega graphics (based on a 14 nm+) process,
- the Coffee Lake line (based on the 14 nm++ process and
- the Cannon Lake line (based on the 14 nm++ process),

as indicated in the next Figure.

*

The Kaby Lake Refresh line -3

1. gen.				2. gen.	3. gen.	4. gen.	5. gen.
Core 2 New Microarch. 65 nm	Penryn New Process 45 nm	Nehalem New Microarch. 45 nm	West-mere New Process 32 nm	Sandy Bridge New Microarch. 32 nm	Ivy Bridge New Process 22 nm	Haswell New Microarchi. 22 nm	Broad-well New Process 14 nm
TOCK	***TICK***	***TOCK***	***TICK***	***TOCK***	***TICK***	***TOCK***	***TICK***
(2006)	*(2007)*	*(2008)*	*(2010)*	*(2011)*	*(2012)*	*(2013)*	*(2014)*

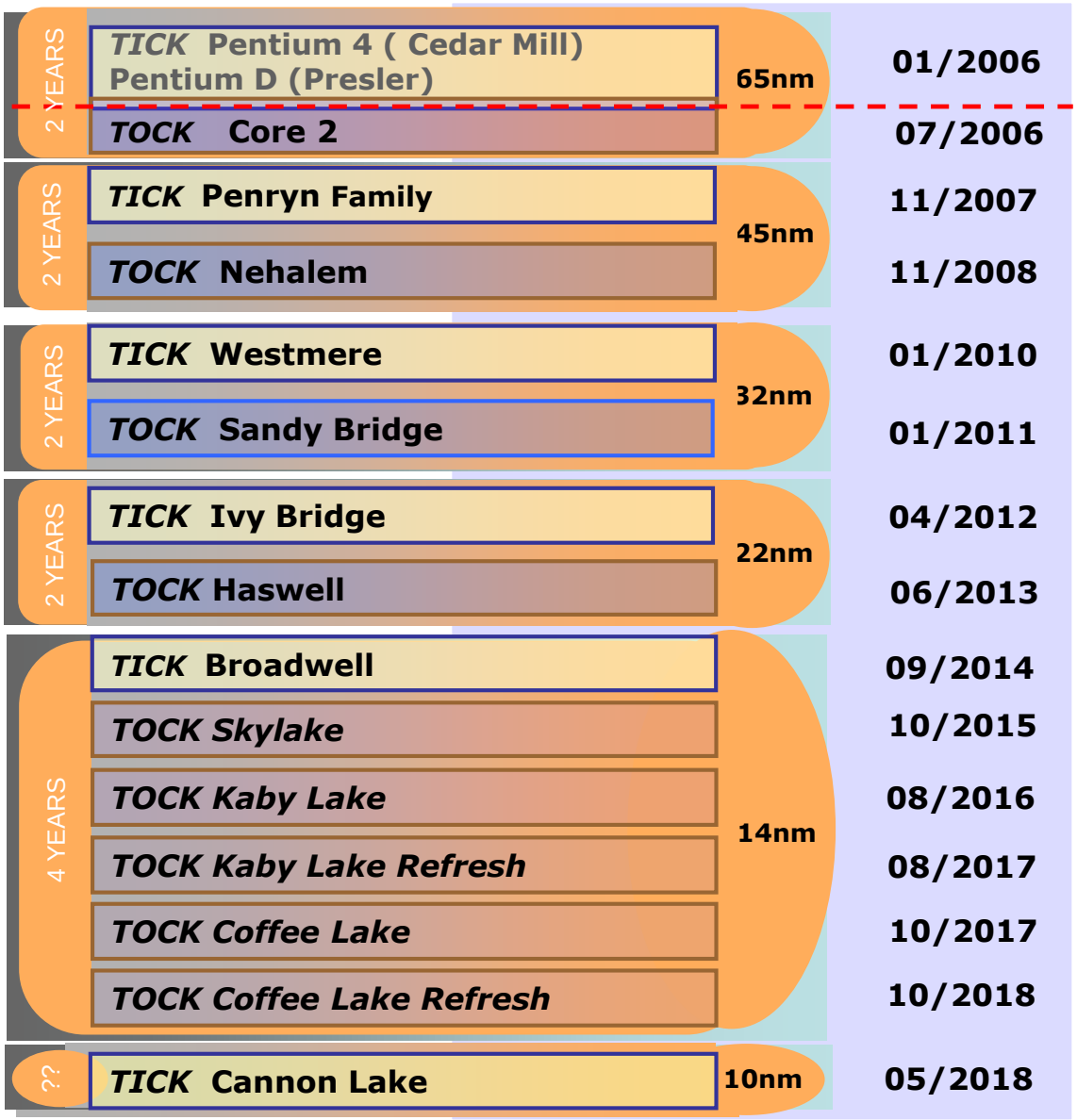
6. gen.	7. gen.	8. gen.[1]	9. gen.
Skylake New Microarch. 14 nm	Kaby Lake New Microarch. 14 nm	Kaby Lake R KL G-series Coffee Lake Cannon Lake 14/10 nm	Coffee Lake R New Mocroarch. 14 nm
TOCK	***TOCK***	***TOCK***	***TOCK***
(2015)	*(2016)*	*(2017/18)*	*(2018)*

[1]Astonishingly, the 8th generation encompasses four processor lines, as follows:

- Kaby Lake Refresh
- Kaby Lake G with AMD Vega graphics
- Coffee Lake (all 14 nm) and the
- 10 nm Cannon Lake designs [218].

8. The Kaby Lake Refresh line (4)

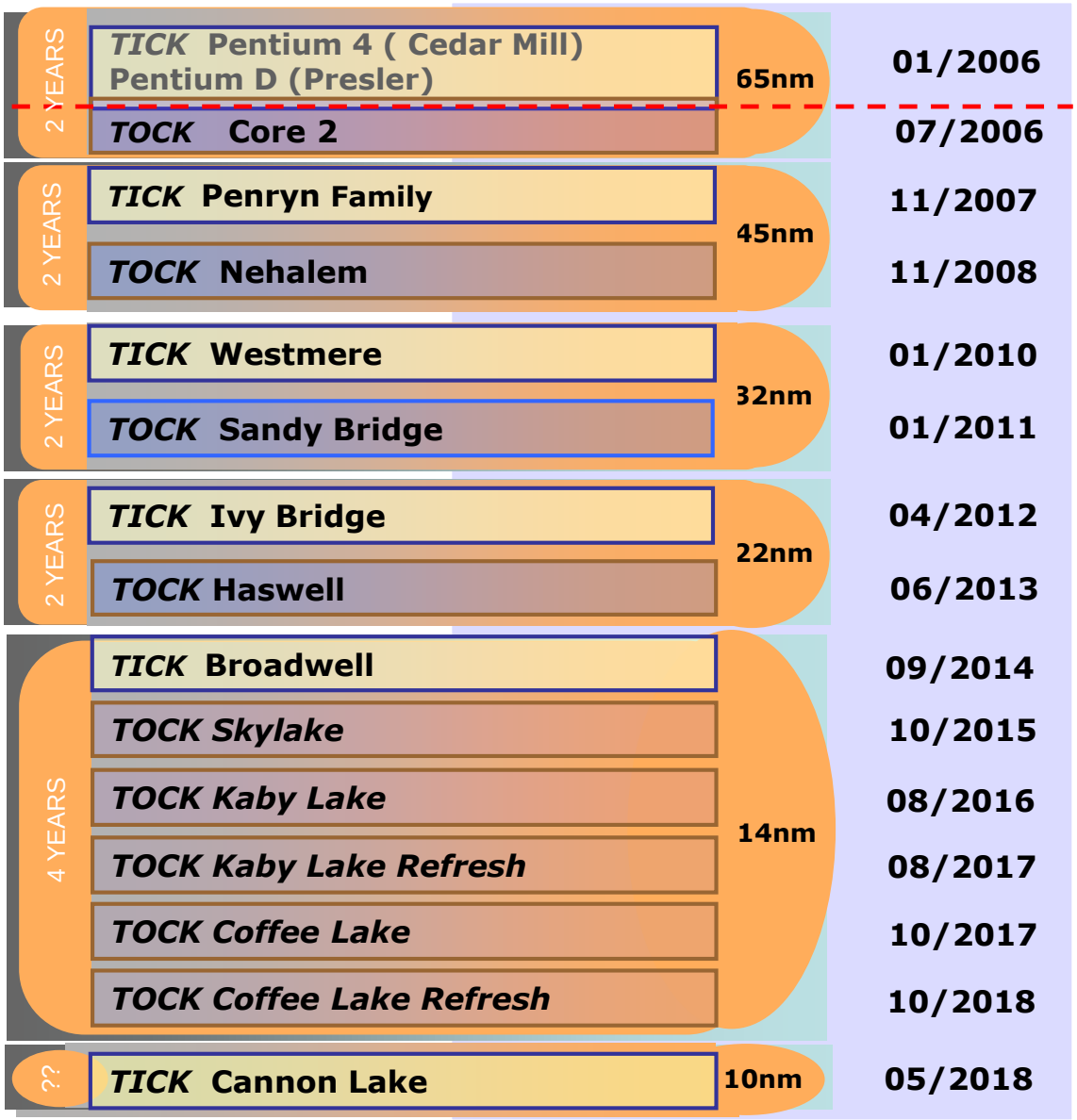
The Kaby Lake Refresh line -4 (based on [3])



Key new features of the ISA and the microarchitecture

- **New microarch.: 4-wide core, 128-bit SIMD FX/FP EUs, shared L2 , no HT**
- **New microarch.: 4 cores, integr. MC, QPI, private L2, (inclusive) L3, HT**
- **In package integrated GPU**
- **New microarch.: 256-bit (FP) AVX, ring bus, integrated GPU**
- **New microarch.: 256-bit (FX) AVX2, L4 cache (discrete eDRAM), TSX**
- **Shared Virtual Memory**
- **New microarch.: 5-wide core, ISP, Memory Side L4 cache, no FIVR**
- **Optane memory, in KBL G series: in package integr. CPU, GPU, HBM2**
- **6C, (PCHs of S-series DTs support: USB G2, integr. conn., Optane 2)**
- **8C**
- **AVX512**

The Kaby Lake Refresh line -5 (based on [3])



Key new features of the power management

- **Clock gating, PECI, Platform Thermal Control by 3. party controller**
- **EDAT**
- **Integrated Power Gates, PCU, Turbo Boost**
- **Turbo Boost 2.0**
- **FIVR**
- **2. gen. FIVR**
- **Speed Shift Technology, Duty Cycle control, No FIVR except Skylake X**
- **Speed Shift Technology v2**
- **In H-series: TVB (Thermal Velocity Boost)**
- **STIM**

8. The Kaby Lake Refresh line (6)

The 8th generation of Intel's Core 2 family [260]

Intel's Core Architecture Cadence (8/20)			
Core Generation	Microarchitecture	Process Node	Release Year
2nd	Sandy Bridge	32nm	2011
3rd	Ivy Bridge	22nm	2012
4th	Haswell	22nm	2013
5th	Broadwell	14nm	2014
6th	Skylake	14nm	2015
7th	Kaby Lake	14nm+	2016
8th	Kaby Lake Refresh Coffee Lake Kaby Lake G Cannon Lake	14nm+ 14nm++ 14 nm+ 10nm	2017 2017 2018 2018
9th	Ice Lake? ...	10nm+	2018?

*

The Kaby Lake Refresh line -5

- It was introduced in 8/2017.
- In incorporates U series 15 W mobile processors.

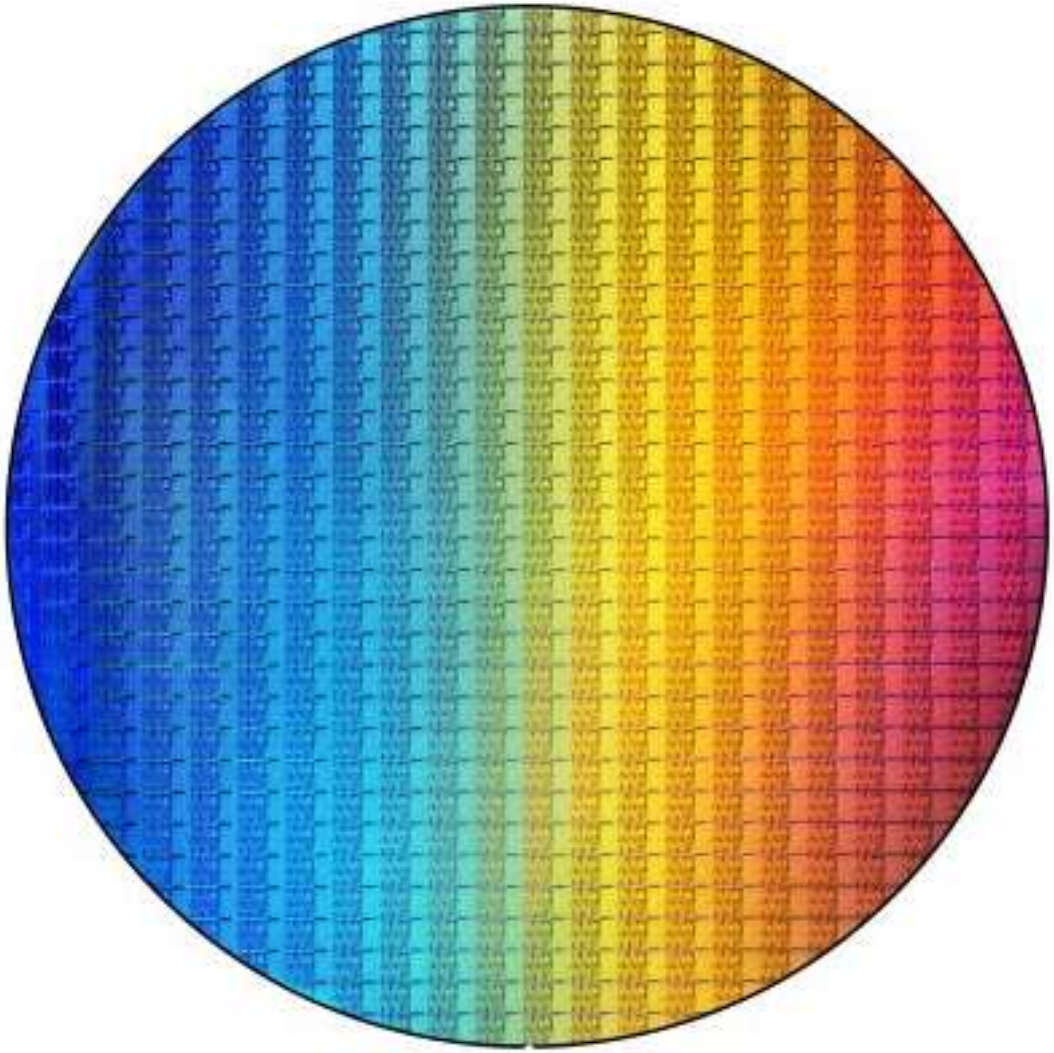
8. The Kaby Lake Refresh line (8)

Main features of Intel's Kaby Lake Refresh U line 15 W mobile processors [237]

7th Generation (Kaby Lake)					8th Generation (Kaby Lake Refresh)				
	Cores	Freq + Turbo	L3	Price		Cores	Freq + Turbo	L3	Price
i7-7660U	2/4	2.5/4.0 GHz	4 MB	$415	**i7-8650U**	4/8	1.9/4.2 GHz	8 MB	$409
i7-7560U		2.4/3.8 GHz		$415	**i7-8550U**		1.8/4.0 GHz		$409
i5-7360U	2/4	2.3/3.6 GHz	3 MB	$304	**i5-8350U**	4/8	1.7/3.6 GHz	6 MB	$297
i5-7260U		2.2/3.4 GHz		$304	**i5-8250U**		1.6/3.4 GHz		$297

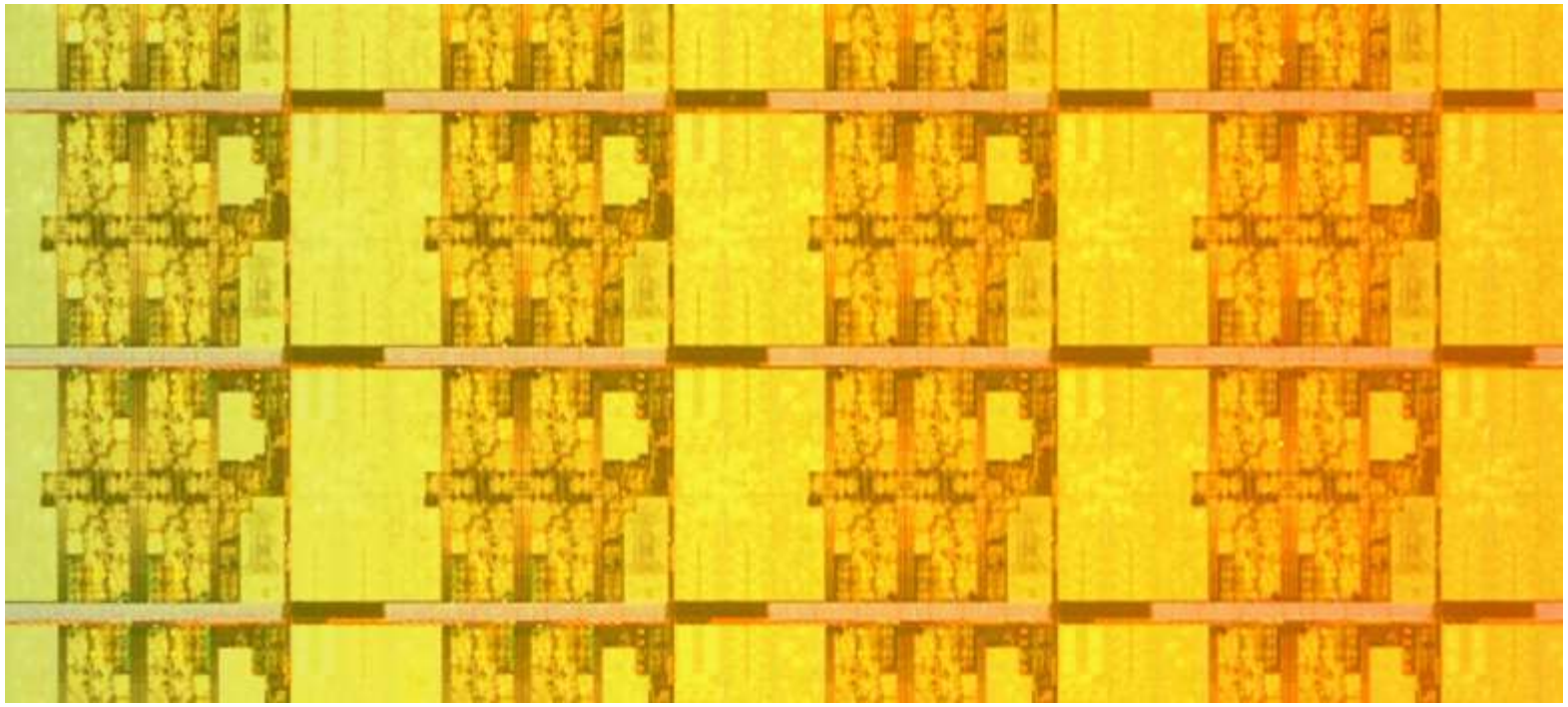
The Kaby Lake refresh models are 4+2 silicon designs, they include 4 cores and GT2 level integrated graphics, whereas the previous generation Kaby Lake U series models were 2+2 designs.

Wafer with Kaby Lake Refresh U-series processors [237]

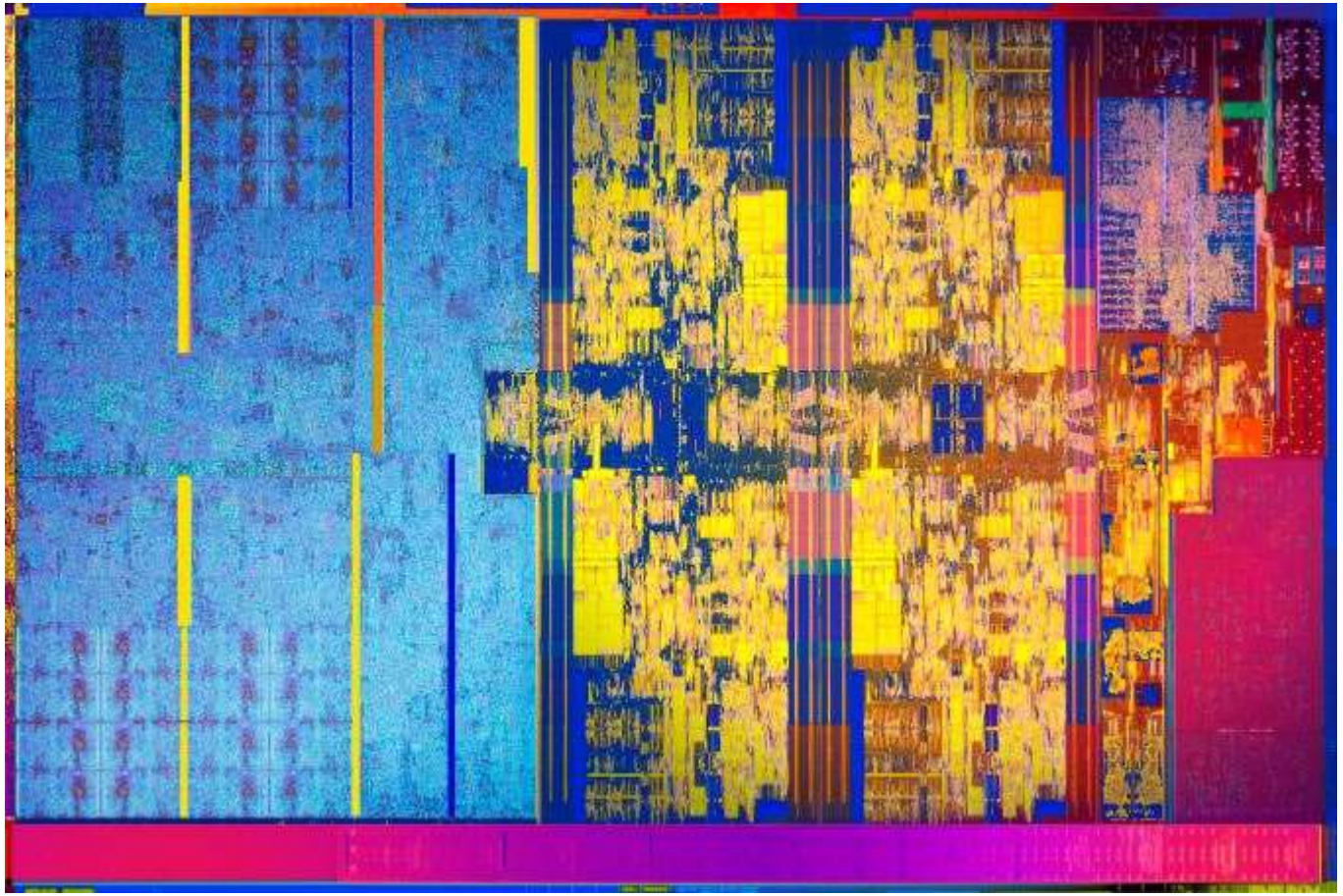


The wafer is assumed to have a 14” diameter and including about 480 dies [237].

Enlarged part of the wafer with U-series processors (4 cores) [237]



Die photograph of a Kaby Lake Refresh U-series processor [237]



The die size is about 124 mm^2.

9. The Coffee Lake line

- 9.1 Introduction to the Coffee Lake line
- 9.2 Example 1: The first gen. up to 6-core Coffee Lake S-series DT line
- 9.3 Example 2: The second gen. up to 6-core Coffee Lake S-series DT line
- 9.4 Example 3 : The Coffee Lake H-series mobile line
- 9.5 Example 4: The Coffee Lake U-series mobile line with Iris Plus graphics
- 9.6 Example 5: The Coffee Lake Y- and U-series mobile lines

Only Sections 9.1 to 9.3 will be discussed.

9.1 Introduction to the Coffee Lake line

9.1 Introduction to the Coffee Lake line

1. gen.				2. gen.	3. gen.	4. gen.	5. gen.
Core 2 New Microarch. 65 nm	Penryn New Process 45 nm	Nehalem New Microarch. 45 nm	West-mere New Process 32 nm	Sandy Bridge New Microarch. 32 nm	Ivy Bridge New Process 22 nm	Haswell New Microarchi. 22 nm	Broad-well New Process 14 nm
TOCK	***TICK***	***TOCK***	***TICK***	***TOCK***	***TICK***	***TOCK***	***TICK***
(2006)	*(2007)*	*(2008)*	*(2010)*	*(2011)*	*(2012)*	*(2013)*	*(2014)*

6. gen.	7. gen.	8. gen.[1]	9. gen.
Skylake New Microarch. 14 nm	Kaby Lake New Microarch. 14 nm	Kaby Lake R KL G-series Coffee Lake Cannon Lake 14/10 nm	Coffee Lake R New Mocroarch. 14 nm
TOCK	***TOCK***	***TOCK***	***TOCK***
(2015)	*(2016)*	*(2017/18)*	*(2018)*

[1]Astonishingly, the 8th generation encompasses four processor lines, as follows:

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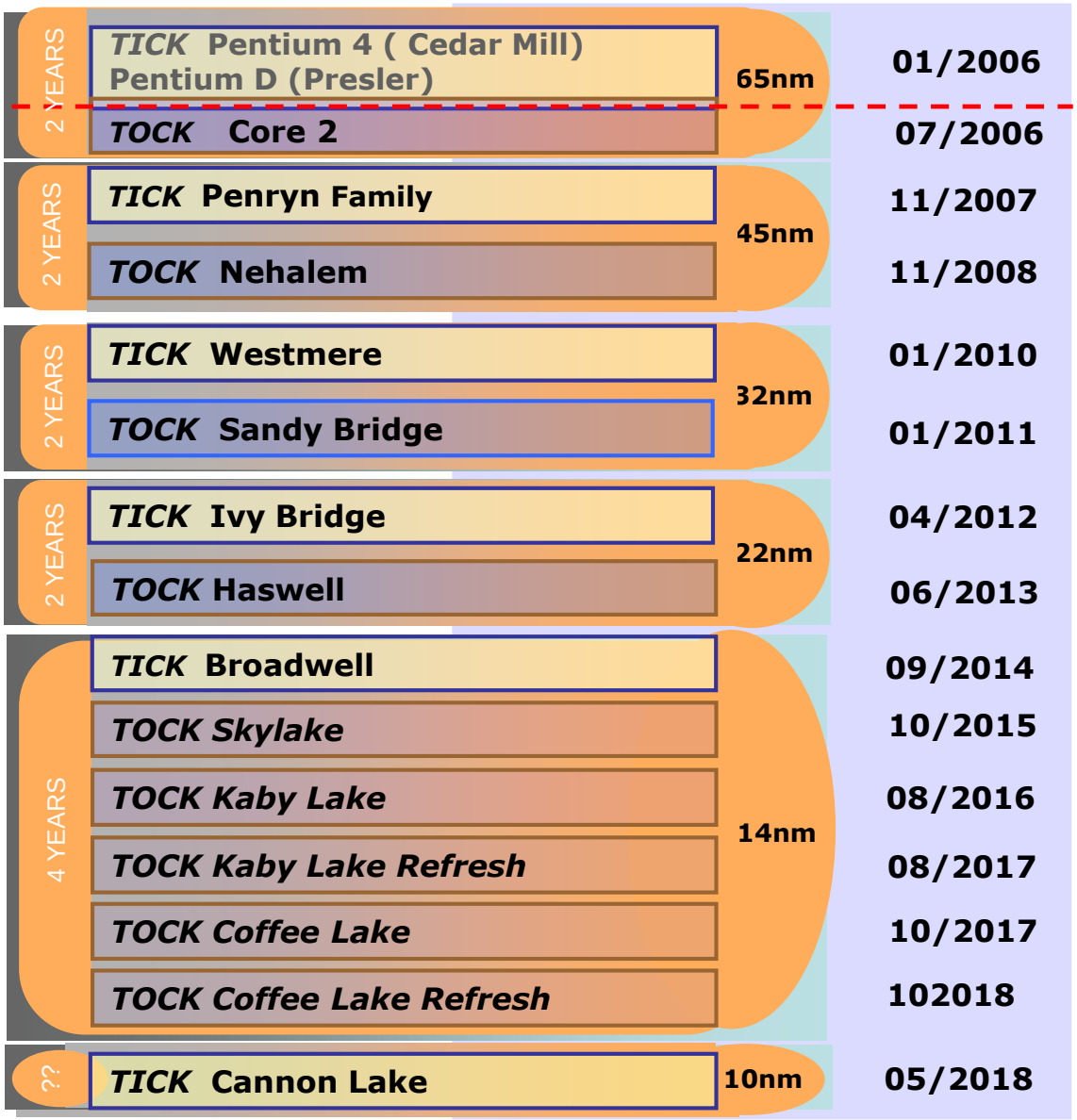
- Kaby Lake G with AMD Vega graphics
- Coffee Lake (all 14 nm) and the
- 10 nm Cannon Lake designs [218].

The Coffee Lake line -1 (based on [3])



Key new features of the ISA and the microarchitecture

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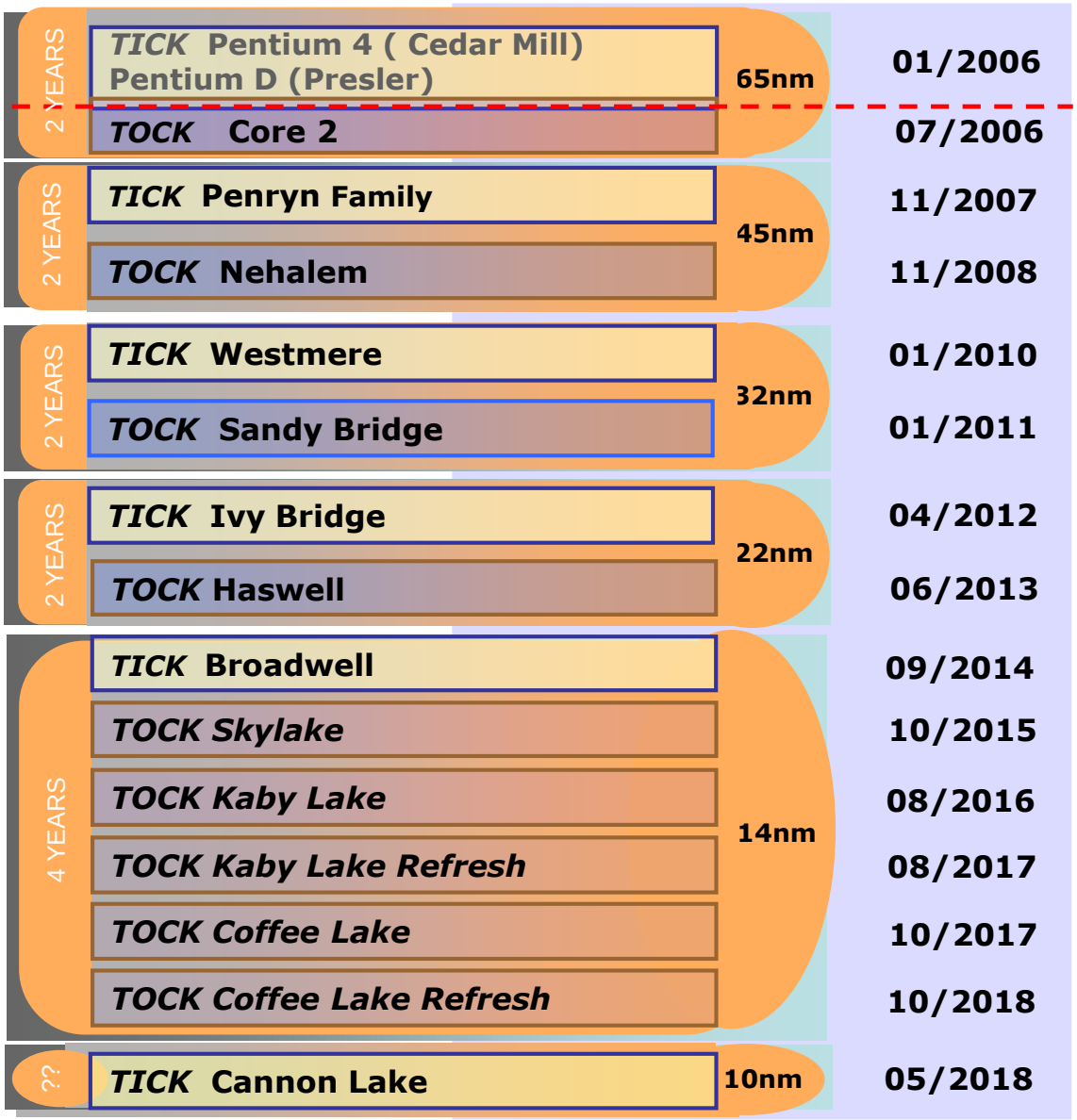
- **In package integrated GPU**
- **New microarch.: 256-bit (FP) AVX, ring bus, integrated GPU**
- **New microarch.: 256-bit (FX) AVX2, L4 cache (discrete eDRAM), TSX**
- **Shared Virtual Memory**
- **New microarch.: 5-wide core, ISP, Memory Side L4 cache, no FIVR**
- **Optane memory, in KBL G series: in package integr. CPU, GPU, HBM2**
- **6C, (PCHs of S-series DTs support: USB G2, integr. conn., Optane 2)**
- **8C**
- **AVX512**

The Coffee Lake line -2 (based on [3])



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- **Integrated Power Gates, PCU, Turbo Boost**
- **Turbo Boost 2.0**
- **FIVR**
- **2. gen. FIVR**
- **Speed Shift Technology, Duty Cycle control, No FIVR, except Skylake X**
- **Speed Shift Technology v2**
- **In H-series: TVB (Thermal Velocity Boost)**
- **STIM**

The Coffee Lake line -3 [253]

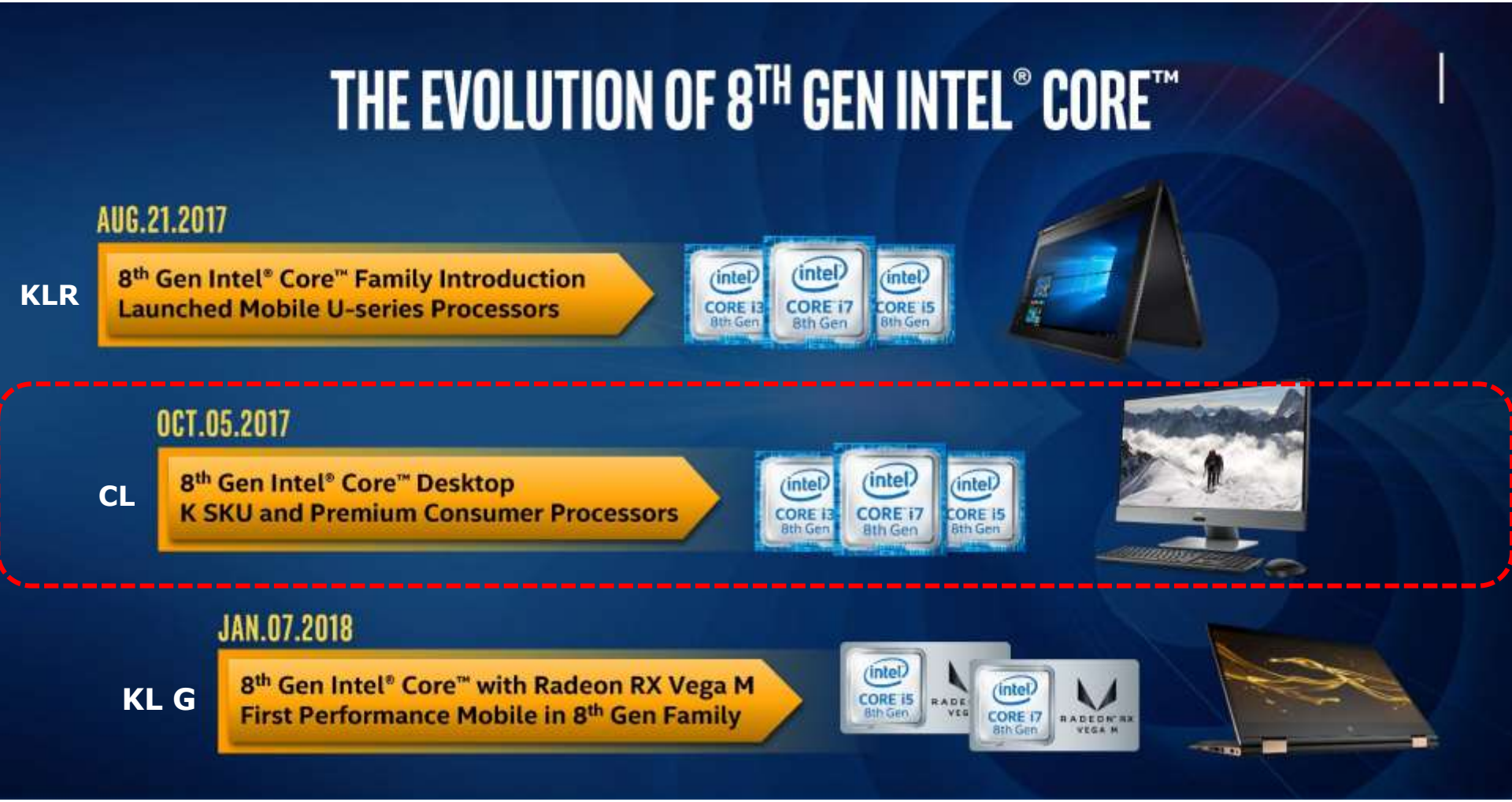
Models of the Coffee Lake line were launched in three waves until now (11/2018):

in 10/2017	• S-series desktop line and
in 04/2018	• U-series mobile line
	• H-series performance mobile line
	• S-series desktop line,
	• M-series mobile Xeon line
	• 300-series PCHs as well as
in 08/2018	• Y-series mobile line (Amber Lake models) and
	• U-series mobile line (Whiskey Lake models)

as the subsequent Figures indicate.

The Coffee Lake line -4 [253]

The 1. wave of Coffee Lake processors (10/2017)



KLR: Kaby Lake Refresh CL: Coffee Lake KL G: Kaby Lake G

The Coffee Lake line -5 [253]

The 2. wave of Coffee Lake processors (4/2018)

The Coffee Lake line -6 []

The 3. wave of Coffee Lake processors (8/2018)

KLR: Kaby Lake Refresh CL: Coffee Lake KL G: Kaby Lake G

9.1 Introduction to the Coffee Lake line (8)

Key features of the Coffee Lake lines [261]

	Mobiles					Desktops
Variant	**Y-series (BGA1515)**	**U-series (BGA1528)**	**U-series (BGA1528)**	**H-series (BGA1440)**	**M-series Xeon (BGA1440)**	**S-series) (LGA1151)**
Cores/ Threads	2/4	2/4, 4/8	2/4, 4/8	4/8, 6/12	4/8, 6/12	4/4, 6/6, 6/12
Graphic configuration	GT2	GT2	GT3e	GT2	GT2	GT2
eDRAM	No	No	128 MB	No	No	No
SOC design	Yes	Yes	Yes	No, with PCH	No, with PCH	No, with PCH
TDP	5W	15W	28W	45W	45W	35W/62W/65W
Launched	08/2018	08/2018	04/2018	04/2018	04/2018	10/2017 04/2018

9.1 Introduction to the Coffee Lake line (9)

Overview of the Coffee Lake (8th Gen) processor lines -1

Mobiles (SoC)

5 W Y-series (SoC, BGA1515) Amber Lake-Y Series (No Optane support)

Core i7-8500Y, 2C+HD615, HT, 8/2018
Core i5-8200Y, 2C+HD615, HT, 8/2018
Core m3-8100Y, 2C+HD615, HT, 8/2018

15 W U-series (SoC) BGA1528) Wiskey Lake-U series (Optane supported)

Core i7-8565U, 4C+UHD 620, HT, 8/2018
Core i5-8265U, 4C+UHD 620, HT, 8/2018
Core i3-8145U 2C+UHD 620, HT, 8/2018

Overview of the Coffee Lake (8th Gen) processor lines -2

Mobiles, Optane supported)

28 W U-series (SoC, BGA1528)

Core i7-8559U, 4C+Iris Plus Graphics 655HD, HT, 4/2018
Core i5-8269U/8259U, 4C+Iris Plus Graphics 655HD, HT, 4/2018
Core i3-8109U, 2C+Iris Plus Graphics 655HD, HT, 4/2018

45 W H-series (Two-chip designs, 300-series mobile chipset, BGA1440)

Core i9-8950HK, 6C+UHD 630, HT, 4/2018
Core i7-8850H/8750H, 6C+UHD 630, HT, 4/2018
Core i5-8400H/,8300H 4C+UHD 630, HT, 4/2018

Mobile Xeon-E (Two-chip designs, CM246 PCH, Optane supported, ECC supported)

45 W M-series (BGA1440, 300-series chipset)

Xeon E2176M/E2186M 6C+UHD P630, HT, 4/2018

9.1 Introduction to the Coffee Lake line (11)

Overview of the Coffee Lake (8th Gen) processor lines -3

Desktops (S-series) (2-chip designs, LGA1151, 300-series desktop PCHs, overclocking in K-tagged (i.e. unlocked) models with the Z370 PCH, Optane supported)

35 W T-tagged (low-power)

Core i7-8770T 6C+UHD 630, HT, 4/2018
Core i5-8600T/8500T/8400T 6C+UHD 630, no HT, 4/2018
Core i3-8300T/8100T 4C+UHD 630, no HT, 4/2018

62 W untagged

Core i3-8300, 4C+UHD 630, no HT, 4/2018

65 W untagged

Core i7-8700, 6C+UHD 630, HT, 10/2017
Core i5-8400 6C+UHD 630, no HT, 10/2017
Core i5-8600/8500 6C+UHD 630, no HT, 4/2018
Core i3-8100 4C+UHD 630, no HT, 10/2017

91 W K-tagged (unlocked)

Core i3-8350K, 4C+UHD630, no HT, 10/2017

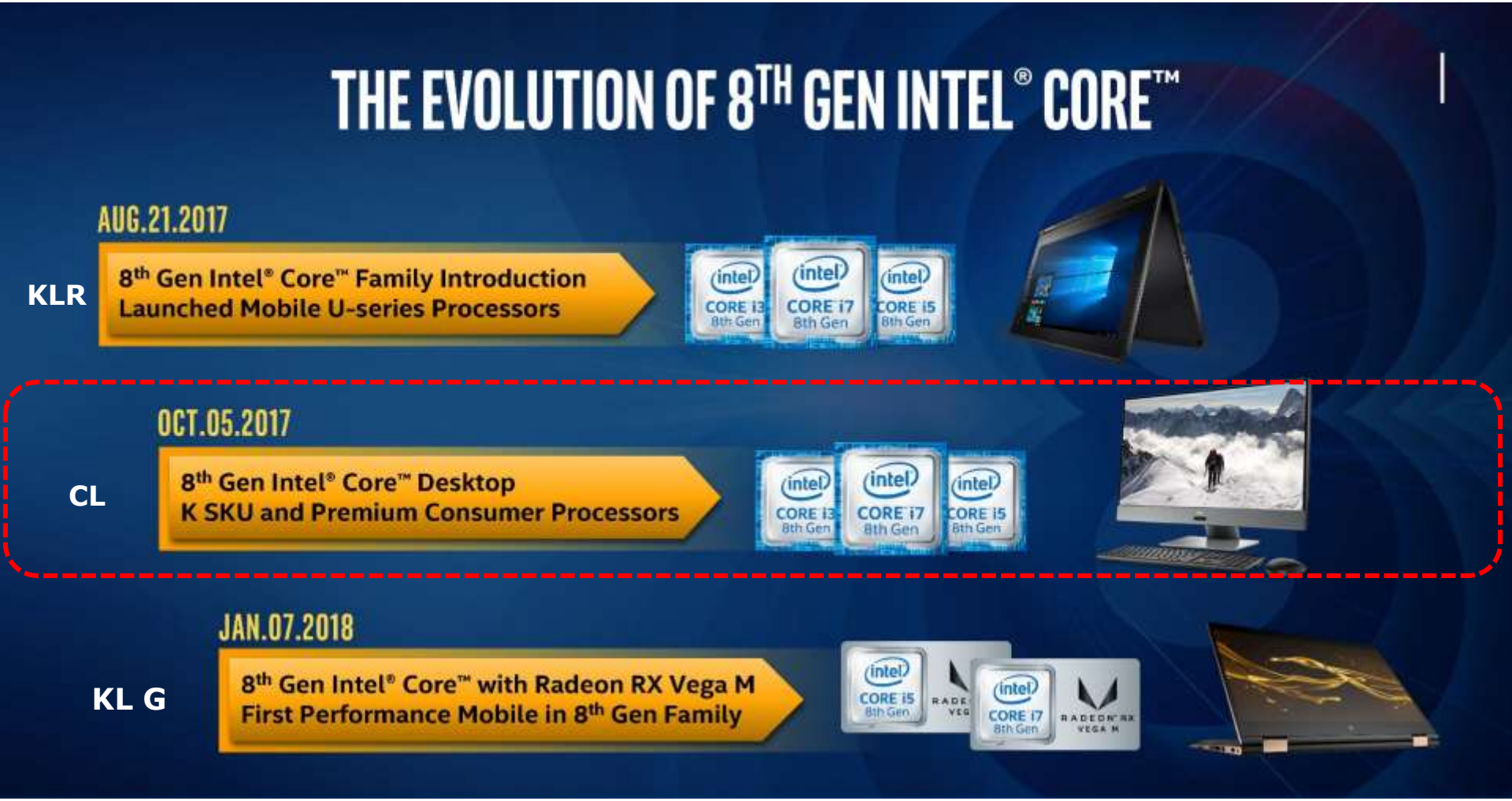
95 W K-tagged (unlocked)

Core i7-8700K, 6C+UHD630, HT, 10/2017
Core i5-8600K, 6C+UHD630, no HT, 10/2017

9.2 Example 1: The first gen. up to 6-core Coffee Lake S-series DT line

9.2 Example 1: The first gen. up to 6-core Coffee Lake S-series DT line [253]

Launched in 10/2017 as the first wave of Coffee Lake processors.



KLR: Kaby Lake Refresh CL: Coffee Lake KL G: Kaby Lake G

Main features of the first gen. up to 6-core Coffee Lake S-series DT line [260]

Launched in 10/2017

Intel 8th Generation 'Coffee Lake' Desktop Processors						
	i7-8700K	i7-8700	i5-8600K	i5-8400	i3-8350K	i3-8100
Cores	6C / 12T		6C / 6T		4C / 4T	
Base Frequency	3.7 GHz	3.2 GHz	3.6 GHz	2.8 GHz	4.0 GHz	3.6 GHz
Turbo Boost 2.0	4.7 GHz	4.6 GHz	4.3 GHz	4.0 GHz	-	-
L3 Cache	12 MB		9 MB		8 MB	6 MB
DRAM Support	DDR4-2666				DDR4-2400	
Integrated Graphics	GT2: 24 EUs			GT2: 23 EUs		
IGP Base Freq	350 MHz			350 MHz		
IGP Turbo	1.20 GHz		1.15 GHz	1.05 GHz	1.15 GHz	1.10 GHz
PCIe Lanes (CPU)	16			16		
PCIe Lanes (Z370)	< 24			< 24		
TDP	95 W	65 W	95 W	65 W	91 W	65 W
Price (tray)	$359	$303	$257	$182	$168	$117
Price (Newegg) Sale until 10/12	$380	$315	$260	$190	$180	$120
Price (Amazon)	$N/A	$N/A	$N/A	$N/A	$N/A	$N/A

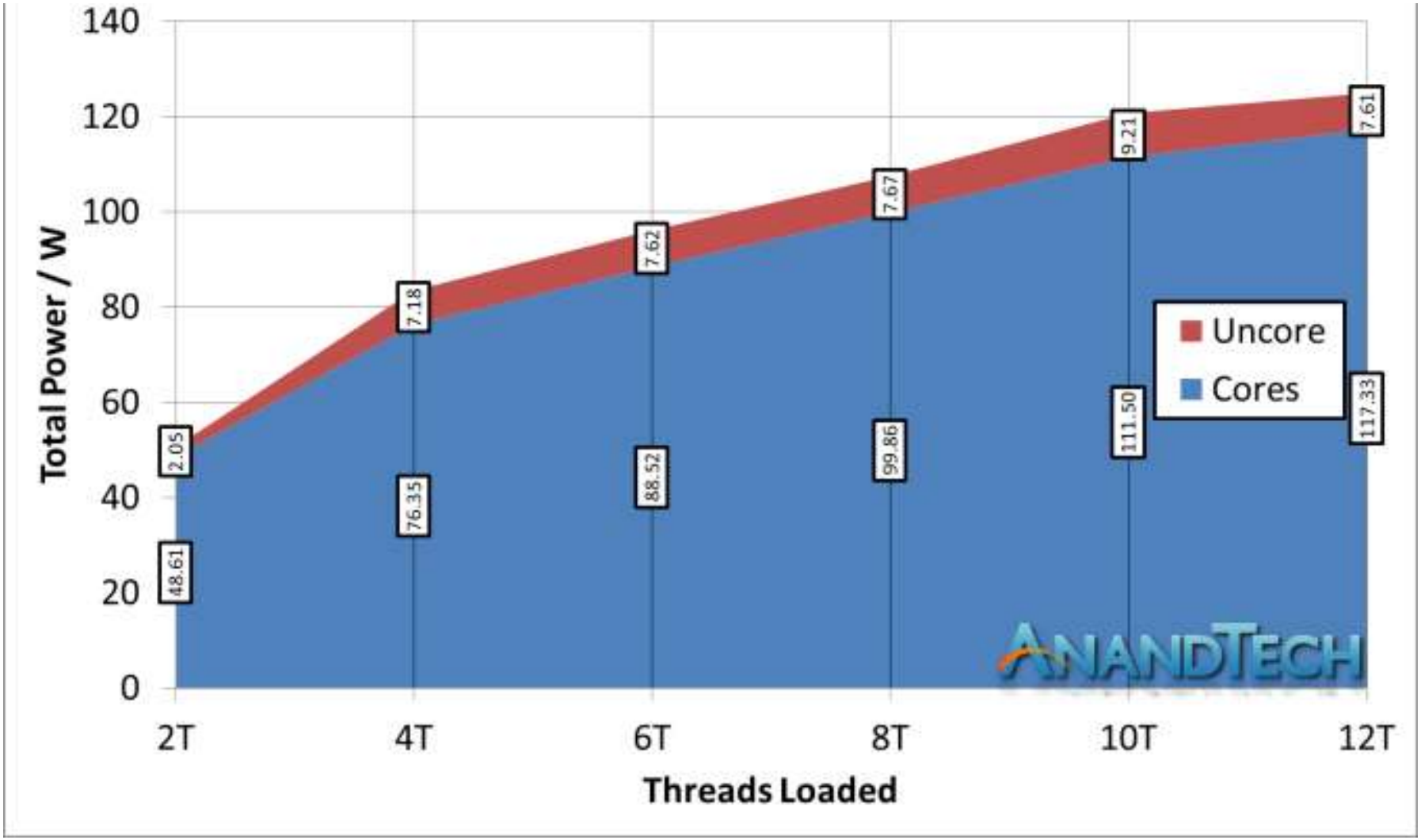
Comparing the Kaby Lake i7 K-tagged and the Coffee Lake i7 K-tagged models -1 [260]

Kaby Lake i7-K vs Coffee Lake i7-K		
i7-7700K (14 nm+)		i7-8700K (14 nm++)
4C / 8T	**Cores**	6C / 12T
4.2 GHz	**Base Frequency**	3.7 GHz
4.5 GHz	**Turbo Boost 2.0**	4.7 GHz
8 MB	**L3 Cache**	12 MB
DDR4-2400	**DRAM Support**	DDR4-2666
GT2: 24 EUs	**Integrated Graphics**	GT2: 24 EUs
350 MHz	**IGP Base Freq**	350 MHz
1.15 GHz	**IGP Turbo**	1.20 GHz
16	**PCIe Lanes (CPU)**	16
< 24	**PCIe Lanes (Chipset)**	< 24
95W	**TDP**	95 W
$339	**Price (tray)**	$359
$340	**Price (Newegg)**	$380
$351	**Price (Amazon)**	$N/A

Comparing the Kaby Lake i7 K-tagged and the Coffee Lake i7 K-tagged models -2 [260]

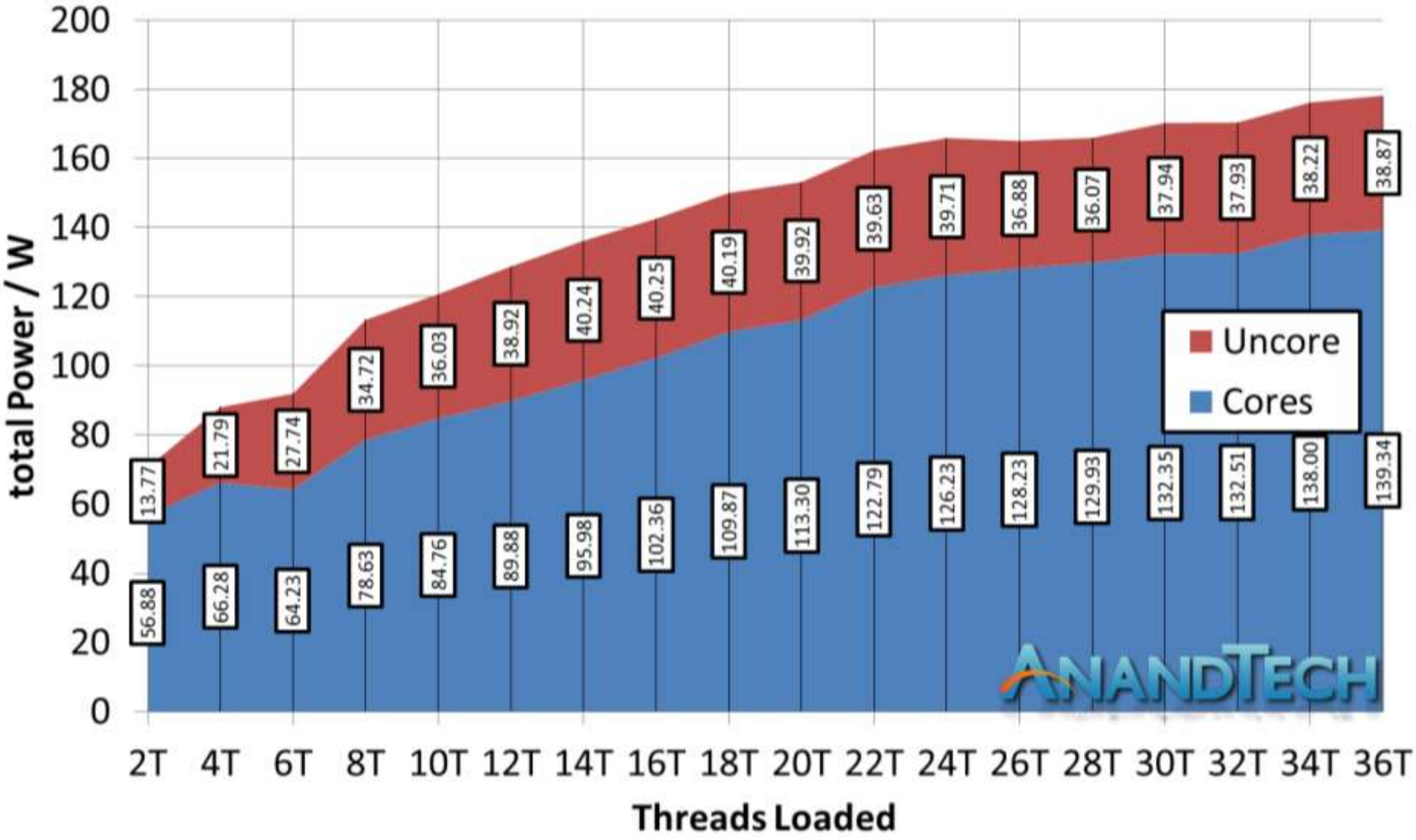
- Note that the introduced Coffee Lake DT models are Intel's first 6-core DT processors.
- Presumably, this move is triggered by AMD's introduction of 8-core Ryzen DT models.

Power distribution between "uncore" and cores in the i7-8700K with ring bus, depending on loading [275]

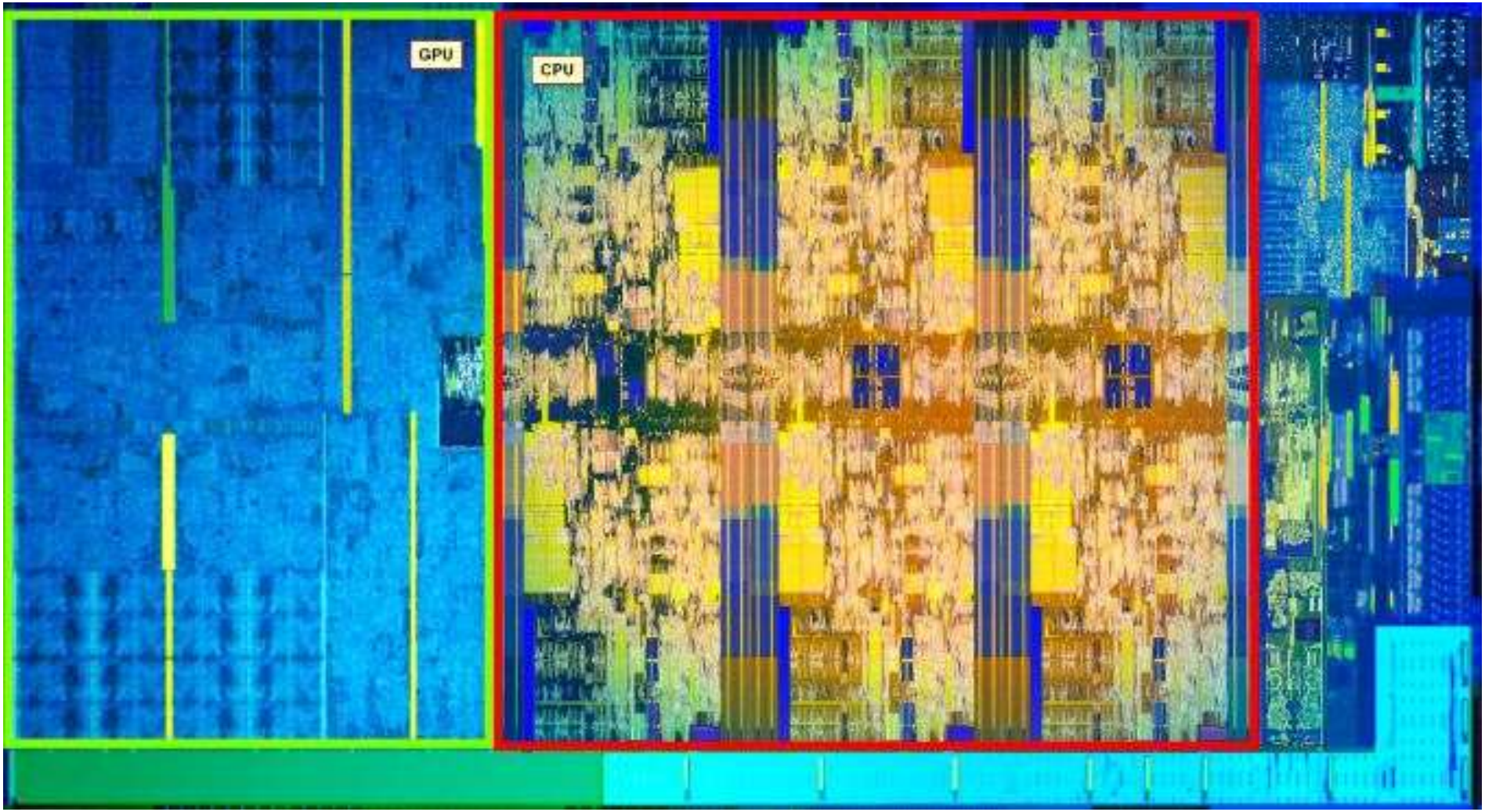


9.2 Example 1: The first gen. up to 6-core Coffee Lake S-series DT line (4c)

By contrast: Power distribution between the "uncore" and cores in the i9-7980XE (based on the Skylake-X core with 2D mesh), depending on loading [275]



Die photograph of a 6-core Coffee Lake desktop processor [260]



Per-core (non-AVX) turbo frequencies of first wave Coffee Lake DT processors [260]

Intel 8th Gen Coffee Lake Non-AVX Turbo Frequencies											
AnandTech	Cores	Thrds	LLC	TDP	Base	1	2	3	4	5	6
Core i7 8700K	6	12	12	95	3.70	4.7	4.6	4.5	4.4	4.4	4.3
Core i7 8700	6	12	12	65	3.20	4.6	4.5	4.4	4.3	4.3	4.3
Core i5 8600K	6	6	9	95	3.60	4.3	4.2	4.2	4.2	4.1	4.1
Core i5 8400	6	6	9	65	2.80	4.0	3.9	3.9	3.9	3.8	3.8
Core i3 8350K	4	4	8	91	4.00	4.0	4.0	4.0	4.0		
Core i3 8100	4	4	6	65	3.60	3.6	3.6	3.6	3.6		

We note that turbo frequency data were not provided by Intel by measured by the reviewer [260], i.e. these values may vary individually in the processors.

Socketing of Coffee Lake DT processors -1

Both the Kaby Lake and the Coffee Lake DT processors make use of the LGA1151 socket, nevertheless, the pin-outs of both sockets differ from each other, i.e. they are not socket compatible, as shown in the Figure below.

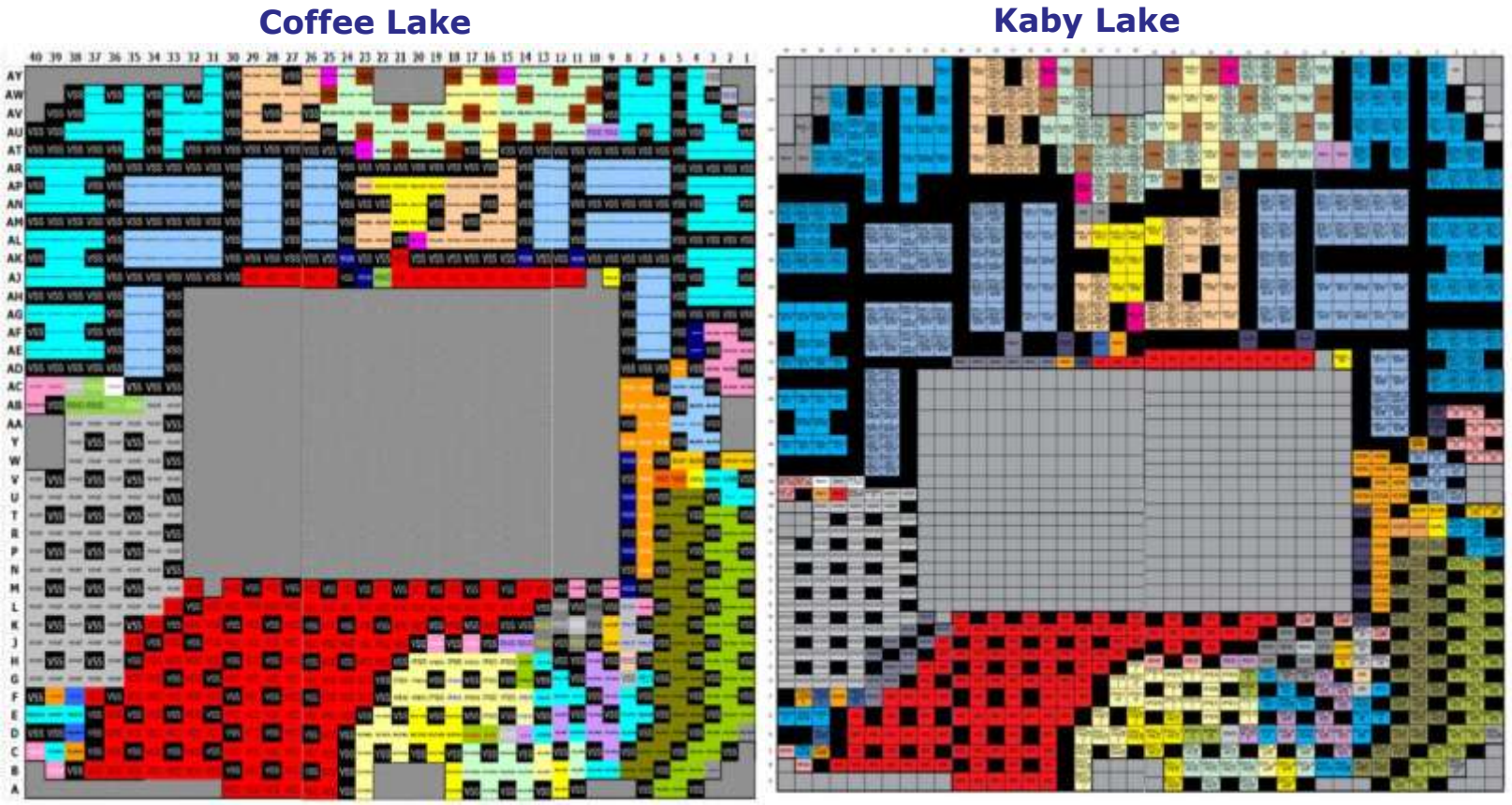


Figure: Pin-out differences of the LGA1151 sockets of the Coffee Lake and Kaby Lake DT processors [260]

Socketing of Coffee Lake DT processors [260] **-2**

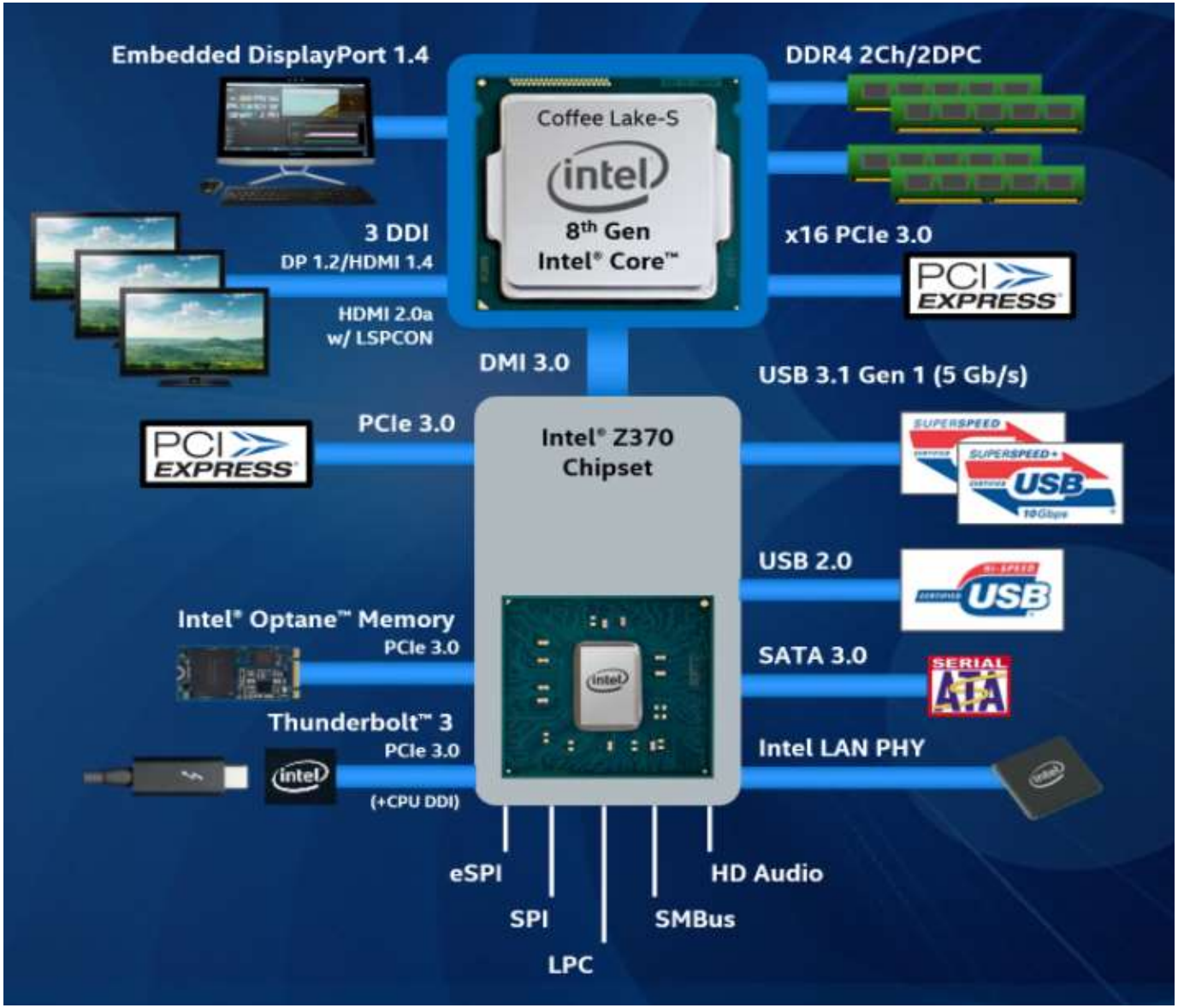
The main difference in socketing is that in the Coffee Lake socket from the until now reserved (RSVD) pins

- 18 are converted to red colored power (VSS) and
- 14 to grey colored ground (VSS) pins.

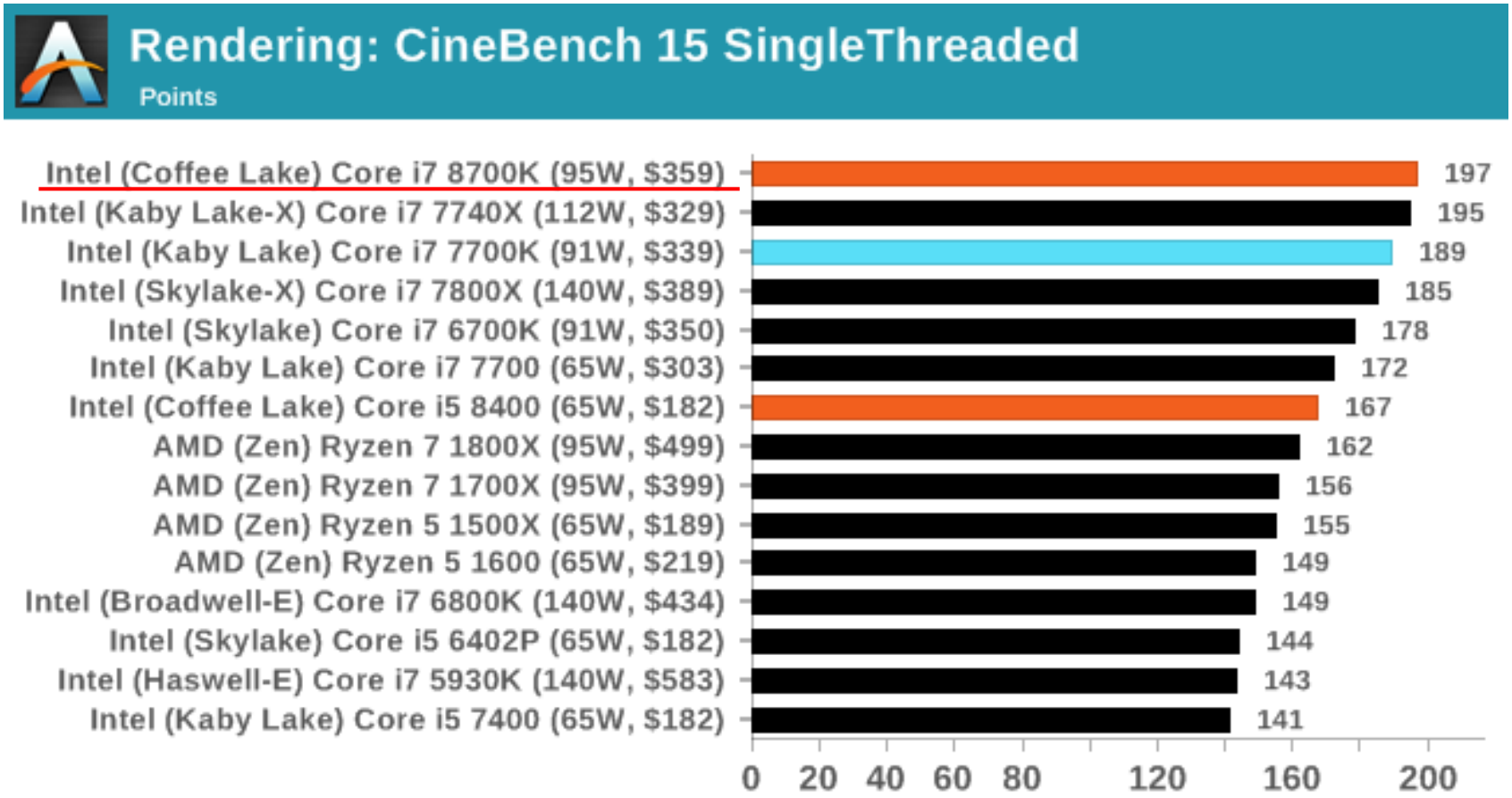
Coffee Lake DT platform [260]

It is supported by the Z370 chipset.

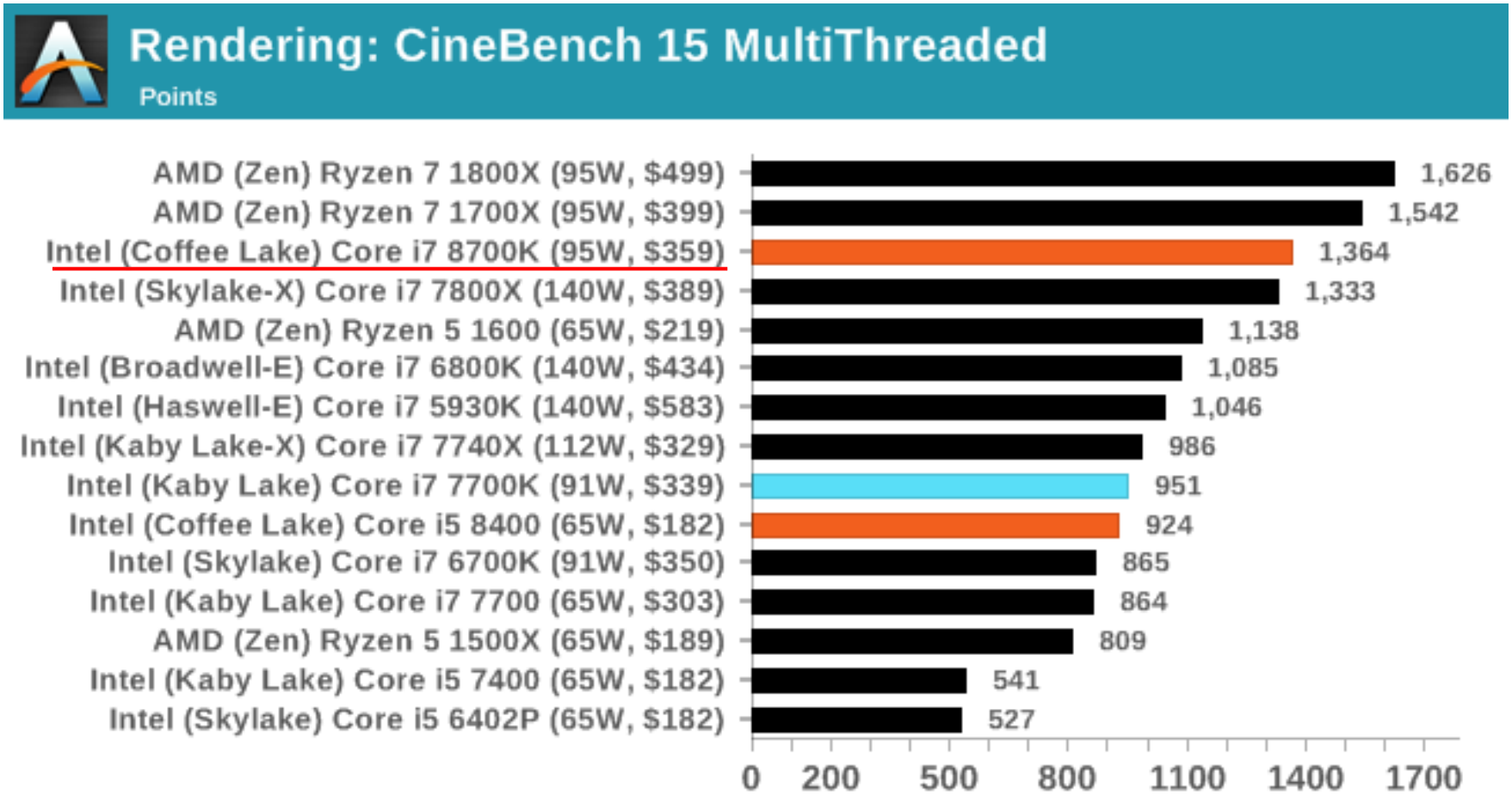
The Z370 is functionally almost equivalent with the Z270 chipset of the Kaby Lake DT series but the Z270 can't be used for the Cannon Lake DT platform.



Cinebench R15 single threaded benchmark results - comparison [260]



Cinebench R15 multi threaded benchmark results - comparison [260]



It is worth noting that the Coffee Lake i7-8700K has only about 3 % higher single threaded performance than the Kaby Lake i7-7700K but provides about 45 % higher multi-threaded performance due to its higher core count (6 vs. 4).

Remark [260]

It is interesting to note that the high-end Core i7-8700K (of the Coffee Lake line) essentially kills the related Kaby Lake-X i7-7740K model since the former provides for less price more cores and performance.

This move can probably be explained again by Intel’s intention to encounter AMD’s Ryzen introductions by lowering their prices.

9.3 Example 2: The second gen. up to 6-core Coffee Lake S-series DT line

9.3 Example 2: The second gen. up to 6-core Coffee Lake S-series DT line [253]

Launched in 04/2018

CL: Coffee Lake

*

9.3 Example 2: The second gen. up to 6-core Coffee Lake S-series DT line (2)

Main features of the second gen. up to 6-core Coffee Lake S-series DT line [253]

		Cores	TDP	Freq	L3	vPro	DRAM DDR4	iGPU	iGPU Turbo
Core i7-8700T*	**$303**	6 / 12	35 W	2.4 / 4.0	12 MB	Yes	2666	24 EUs	1200
Core i5-8600*	**$213**	6 / 6	65 W	3.1 / 4.3	9 MB	Yes	2666	24 EUs	1150
Core i5-8500*	**$192**	6 / 6	65 W	3.0 / 4.1	9 MB	Yes	2666	24 EUs	1100
Core i5-8500T*	**$192**	6 / 6	35 W	2.1 / 3.5	9 MB	Yes	2666	24 EUs	1100
Core i5-8400T*	**$192**	6 / 6	35 W	1.7 / 3.3	9 MB	No	2666	24 EUs	1050
Core i3-8300*	**$138**	4 / 4	65 W	3.7	8 MB	No	2400	23 EUs	1150
Core i3-8300T*	**$138**	4 / 4	35 W	3.2	8 MB	No	2400	23 EUs	1100
Core i3-8100T*	**$117**	4 / 4	35 W	3.1	6 MB	No	2400	23 EUs	1100

Note that higher numbered models support vPro technology (for enhanced business use)

9.3 Example 2: The second gen. up to 6-core Coffee Lake S-series DT line (3)

New DT chipset with enhancements vs. the previous Z370 [253]

Intel 8th Gen desktop chipsets (PCH)					
	Z370	H370	Q370	B360	H310
Launch	Oct '17	Apr '18	Apr '18	Apr '18	Apr '18
Market	Consumer -	Consumer Corporate	- Corporate	Consumer Corporate	Consumer -
ME Firmware	11	12	12	12	12
HSIO Lanes	30	30	30	24	14
Total USB	14	14	14	12	10
Max USB 3.1 G2	-	**4**	**6**	**4**	0
Max USB 3.1 G1	**10**	**10**	8	6	4
SATA 6 Gbps	**6**	**6**	**6**	**6**	4
PCH PCIe 3.0 Lanes	**24**	20	**24**	12	-
PCH PCIe 2.0 Lanes	-	-	-	-	6
Max RST PCIe Storage	**3**	2	**3**	1	0
Supports Optane	**Y**	**Y**	**Y**	**Y**	N
Integrated 802.11ac	N	**Y**	**Y**	**Y**	**Y**
Intel Smart Sound	**Y**	**Y**	**Y**	**Y**	N
Intel vPro	N	N	**Y**	N	N
TDP	6 W	6 W	6 W	6 W	6 W

RST: Rapid Storage technology (Software RAID) HSIO: High-Speed IO ME: Management Engine

9.3 Example 2: The second gen. up to 6-core Coffee Lake S-series DT line (4)

Enhancements of the new 8th gen. DT chipsets

a) USB Gen. 2 support
b) Integrated connectivity
c) Enhanced Optane support

*

9.3 Example 2: The second gen. up to 6-core Coffee Lake S-series DT line (5)

a) USB Gen2 support [262]

Evolution of the USB standard

USB 1.0 (1996) Transfer rates of up to 1.5 MB/s

USB 2.0 (2000) Transfer rates of up to 60 MB/s

USB 3.0 (2008) SuperSpeed transfer rate of up to 625 MB/s

The USB 3.0 specification recommends that the Standard-A USB receptacle have a blue insert.

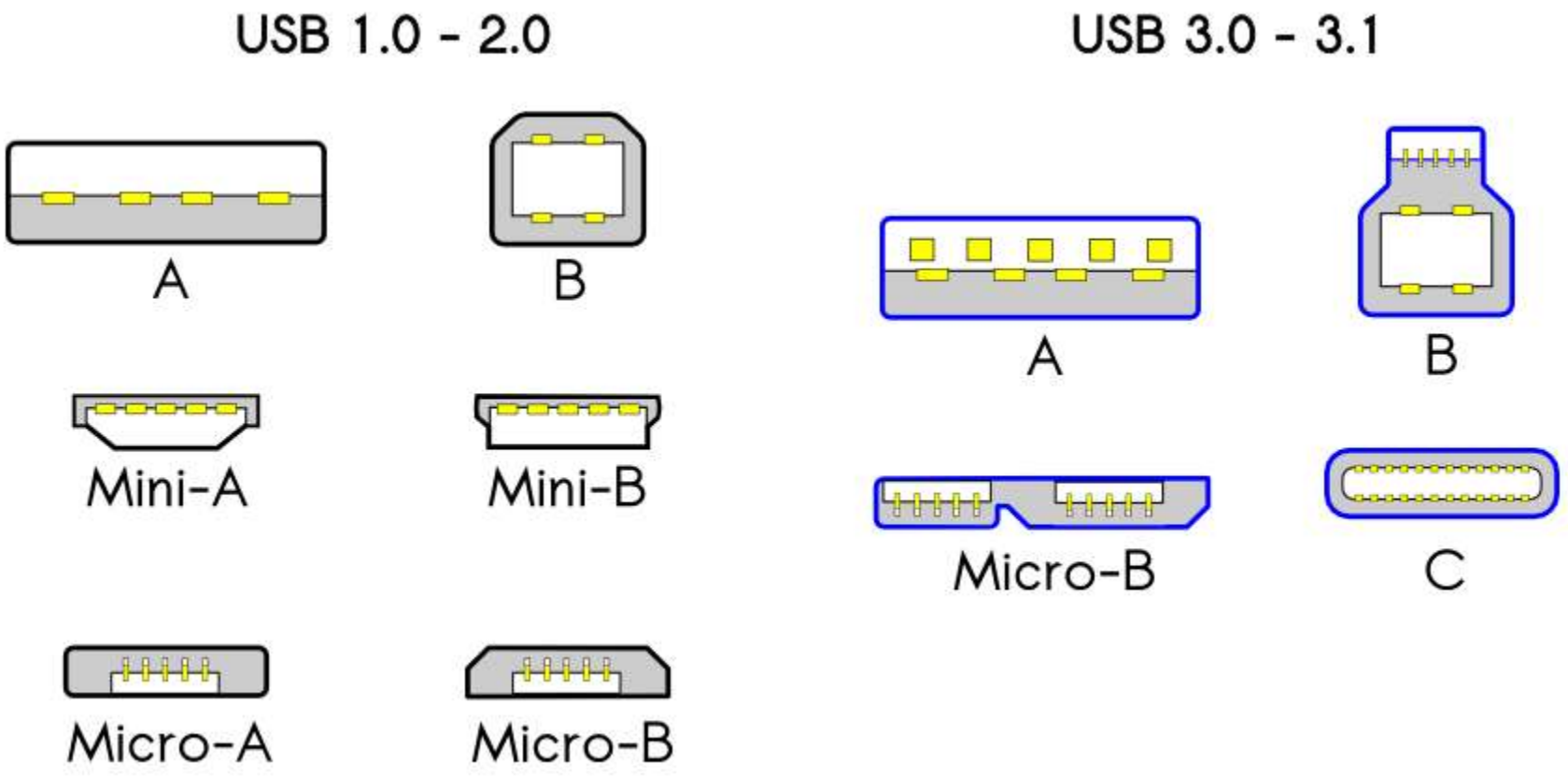
USB 3.1 (2013) has two alternatives:

- USB 3.1 Gen. 1 and
- USB 3.1 Gen 2 with the SuperSpeed+ transfer rate of up to 1.25 GB/s.

USB 3.2 (2017) Two new SuperSpeed+ transfer modes with transfer rates of 1.25 and 2.5 GB/s over USB-C connectors.

*

USB connectors [263]



The USB 3.0 connector [262]

- The SuperSpeed transfer rate of the USB 3.0 standard is based on the SuperSpeed bus that incorporates two new serial point-to-point data lanes (for full duplex transfer) and a Ground line, as shown in the Figure below.
- Consequently, the USB standard needs new connectors (see the Figure before).

Figure: Front view of a Standard-A USB 3.0 connector, showing its front row of four pins for the USB 1.x/2.0 backward compatibility, and a second row of five pins for the new USB 3.0 connectivity (above).
The plastic insert is in the USB 3.0 standard blue color.

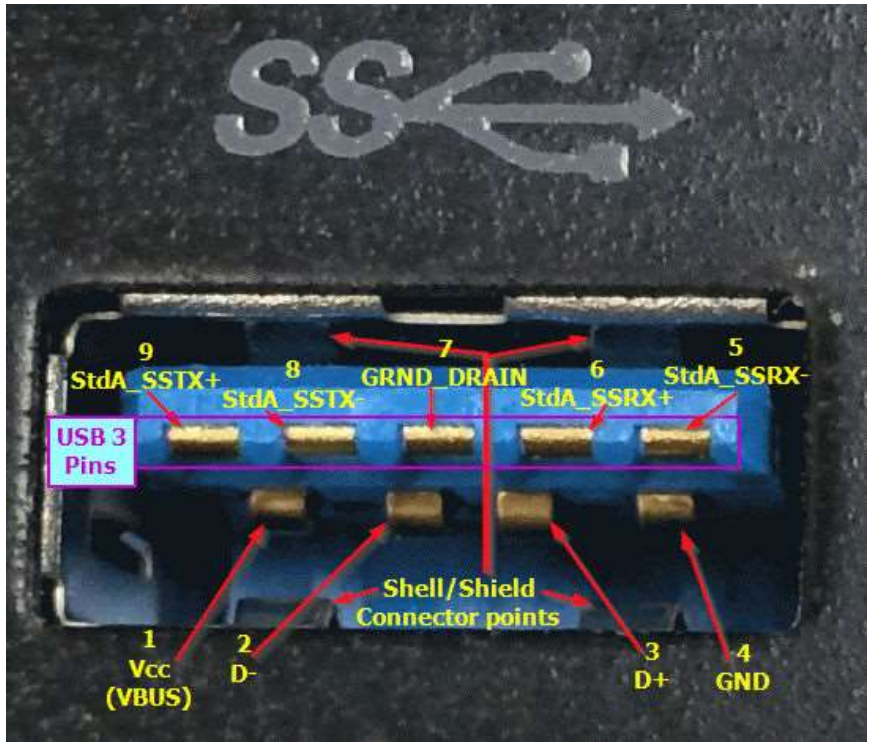


Figure: Pins of a standard USB 3.0 connector

*

9.3 Example 2: The second gen. up to 6-core Coffee Lake S-series DT line (8)

b) Integrated connectivity support

Intel's Integrated connectivity relates to partially integrating 802.11ac Wi-Fi, BT and RF blocks onto the PCH, as detailed later in this section.

*

Introduction to the IEEE 802.11ac Wi-Fi standards

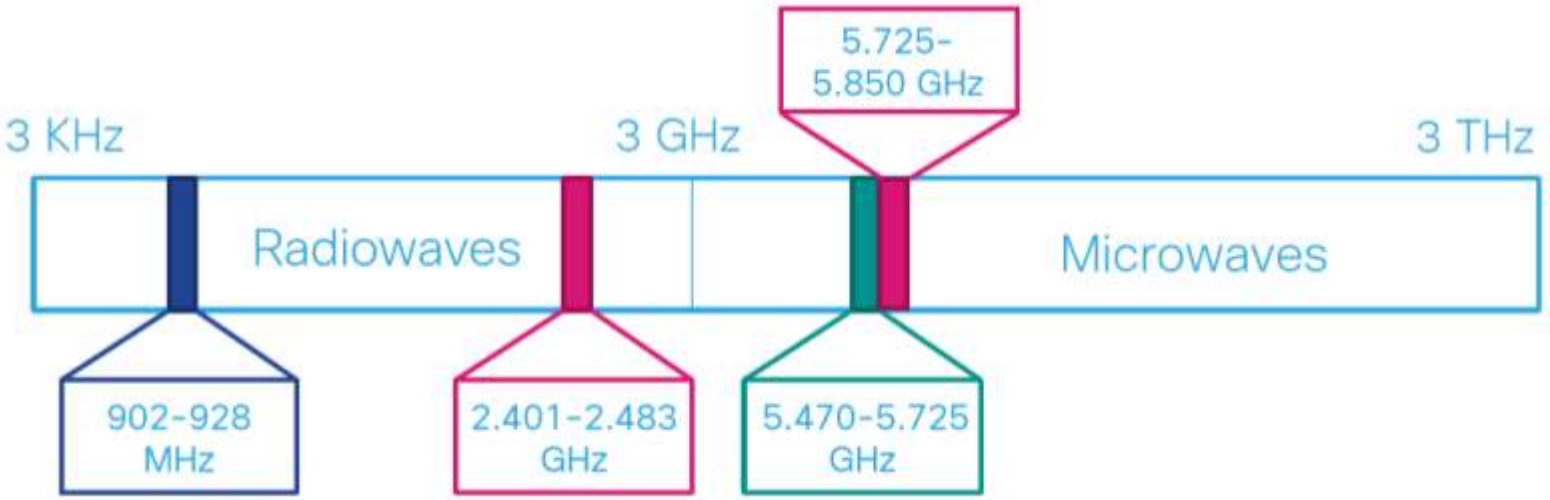
Key features of the IEEE 802.11 WiFi standards (Based on [264])

Standard	Approved in	Frequency band	Bandwidth	MIMO technology	Data rate (up to)
11.b	1999	2.4 GHz	22 MHz	no	11 Mb/s
11.a	1999	5 GHz	20 MHz	no	54 Mb/s
11.g	2002	2.4 GHz	20 GHz	no	54 Mb/s
11.n	2007	2.4 GHz/ 5 GHz	20 MHz	MIMO up to 4 streams	288.8 Mb/s
			40 MHz		600 Mb/s
11.ac	2013	5 GHz	20 MHz	MIMO up to 8 streams	346.8 Mb/s
			40 MHz		800 Mb/s
			80 MHz		1733.2 Mb/s
			160 MHz		3466.8 Mb/s

MIMO: Multiple-Input Multiple-Output (többszörös átviteli csatorna)

*

Frequency bands used for WiFi [265]



*

Principle of the MIMO technology

- MIMO (Multiple-Input Multiple-Output) was introduced in the IEEE 801.11n WiFi amendment in order to significantly raise data rate.
- It assumes multiple antennas both at the transmitter and the receiver and supports multiple communication channels for transmitting multiple data streams simultaneously, e.g. 2 data streams, as the Figure below shows.
- In the MIMO technology the transmitter splits the data stream to be transmitted into sub-streams, these will be in transmitted in parallel over available channels and then merged in the receiver, as indicated in the Figure.

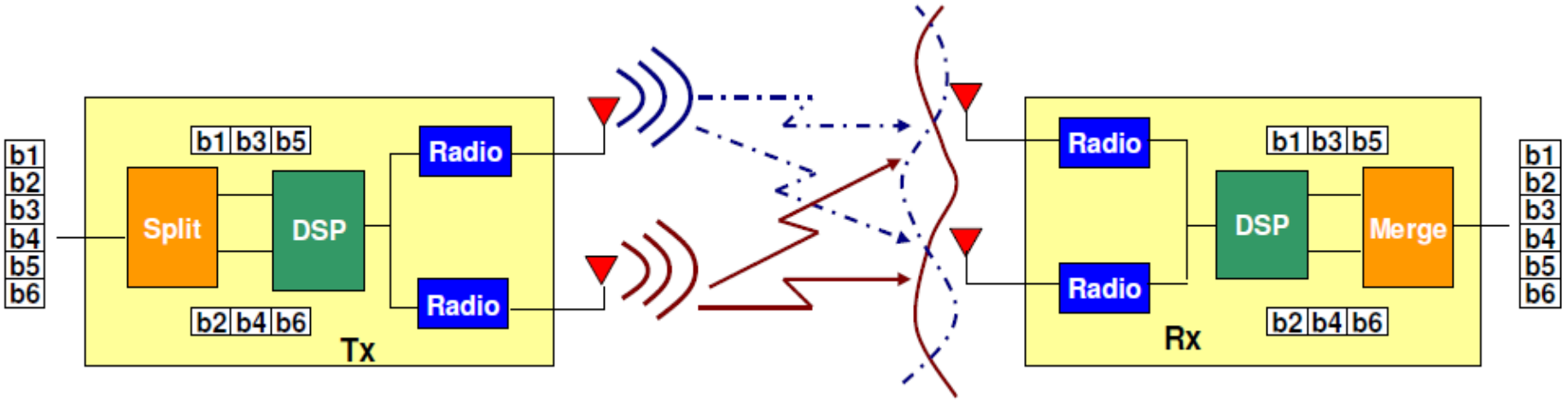


Figure: Principle of the MIMO technology [266]

- The 801.11n supports up to 4 whereas the 801.11ac up to 8 parallel data streams.
- In actual implementations the number of available transmitter and receiver antennas (channels) is usually given in the form of nTmR or nxm, e.g. 2T2R or 2x2.

*

Intel's Integrated connectivity (CNVi) -1

- Traditionally, there is a Wi-Fi/BT/RF module that is placed differently to the processor, e.g. on an M.2 card or as a chip mounted onto the mainboard.
- With "Integrated connectivity" Intel partially integrates the Wi-Fi/BT/RF module onto the PCH.
- In this kind of implementation" Intel places expensive functional blocks of the Wi-Fi/BT/RF module, such as the logic, MAC (Multiplier-Accumulator) and memory onto the PCH, into a block called Pulsar, whereas other parts of the module, like the PHY (Physical layer) and RF remain on a companion RF module (CRF), dubbed Jefferson Peak, as seen below.
- The CRF module is implemented on an M.2 card and is interconnected with the PCH via an Intel proprietary bus, called the CNVio interface, as shown below.

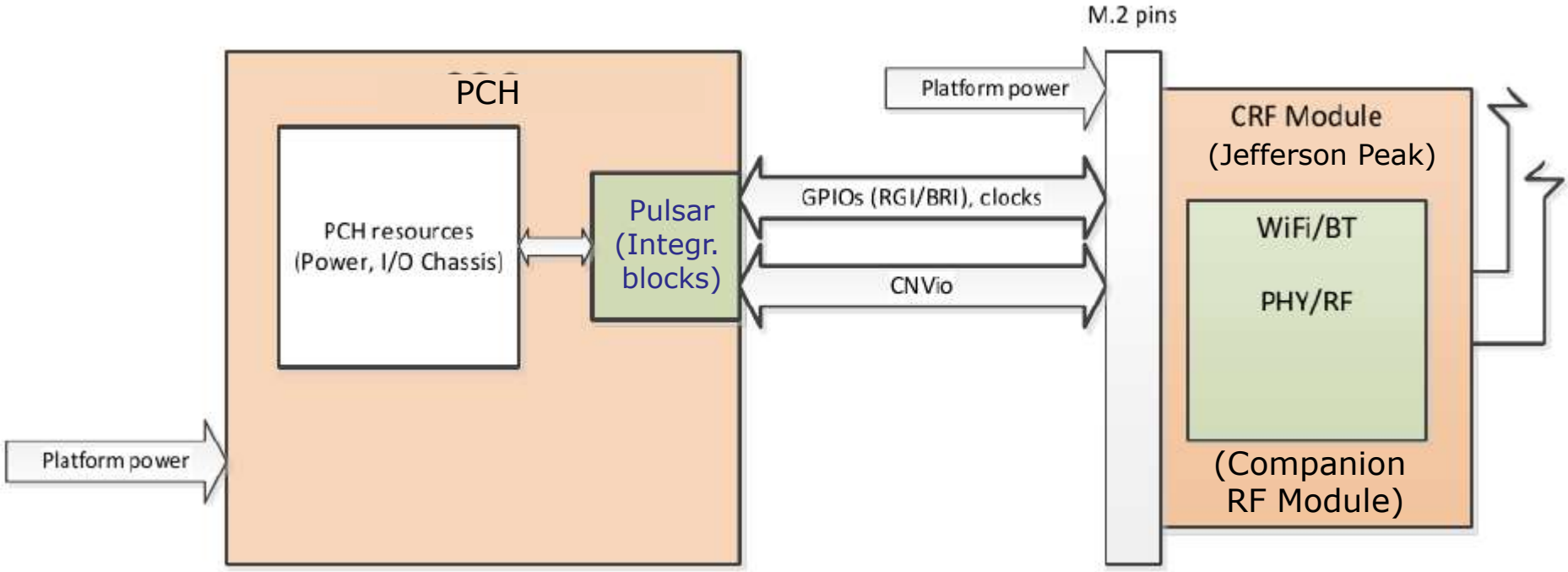
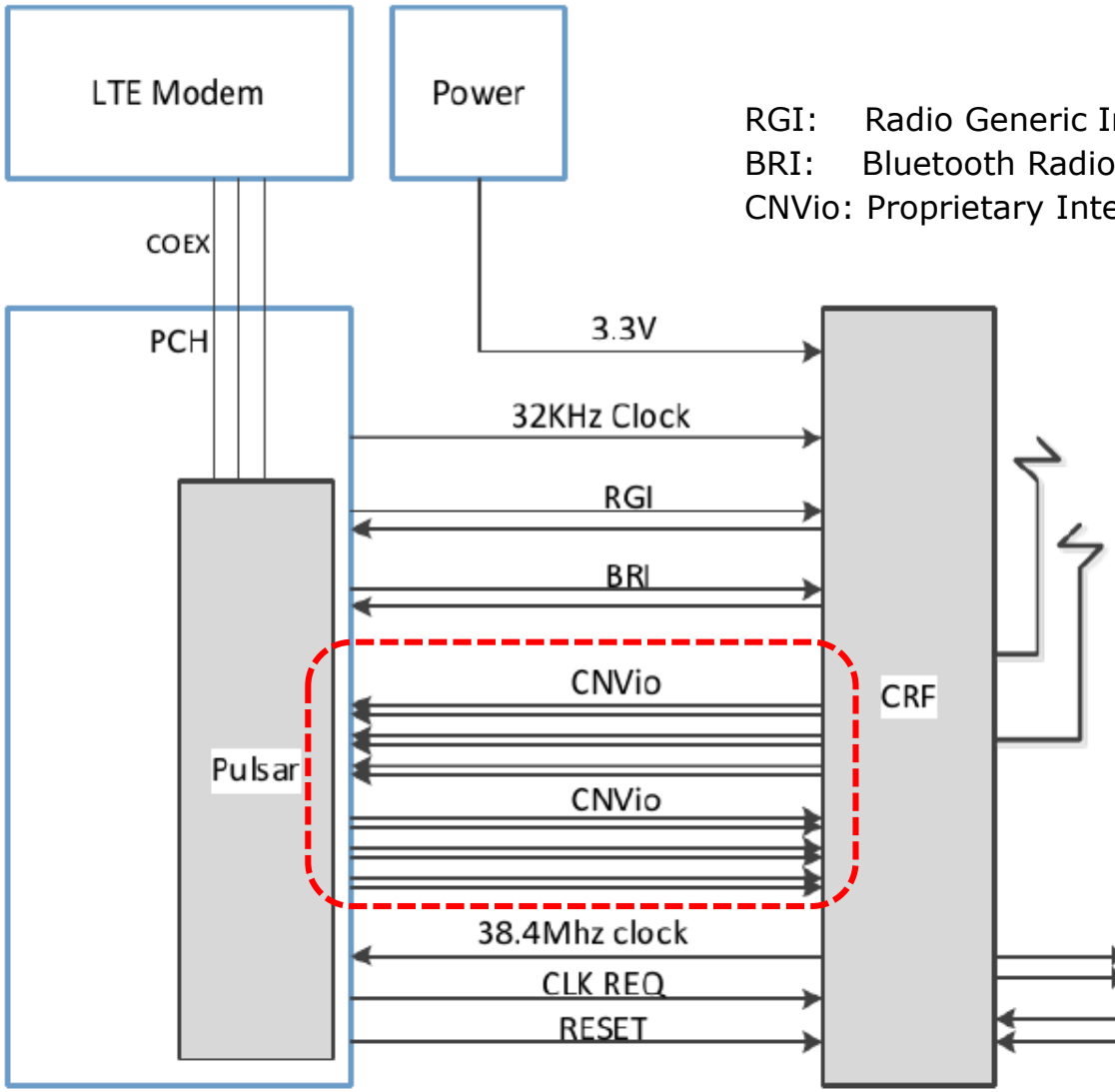


Figure: Intel's 2T2R 802.11ac implementation called Integrated connectivity (CNVi) [267]*

Interfacing the Companion RF module (CRF) to the PCH [267]



RGI: Radio Generic Interface, between CRF and Pulsar
BRI: Bluetooth Radio Interface, between CRF and Pulsar
CNVio: Proprietary Intel interface between CRF and Pulsar

The Intel proprietary CNVio bus has two data lanes and one clock for each direction.

Both data and clock signals are differential, 100 Ω signals.

Total number of the signals is 12 (6 pairs, 3 per direction).

Intel's Integrated connectivity (CNVi) -2 [253]

- Integrated connectivity is supported by the 300 series PCHs of the Coffee Lake line, both by the DT and mobile PCH models. (except the earlier (10/2017) launched Z370 PCH).
- As part of their Integrated connectivity technology Intel provides a number of CRF modules, including
  - the AC-9560 (2T2R module, the only vPro enabled CRF),
  - The AC-9462 (a 1T1R module), and
  - The AC-9461 (a low-end 1T1R module).

  All three CRFs are supported by Linux, Chrome OS, and Windows 10.

9.3 Example 2: The second gen. up to 6-core Coffee Lake S-series DT line (15)

Intel's Integrated connectivity implementation of 2T2R 802.11ac Wi-Fi [253]

- This feature supports 160 MHz channel bandwidth and yields data rates up to 1733 Mb/s.
- According to Intel this speed is 12x faster than 1T1R 802.11n support provided by low cost WiFi solutions and twice as much as most 2T2R solutions available on the market.
- We note that 2T2R support needs the AC9650 CRF, other models listed above do not implement it (only the 1T1R mode with lower data rates).
- Due to its additional costs (of about 15 $) only a few motherboards enable the Integrated connectivity feature.

9.3 Example 2: The second gen. up to 6-core Coffee Lake S-series DT line (16)

Remark 1

Actually Intel introduced Integrated connectivity already in 12/2017 in their low power oriented Atom line (in the Gemini SOC platform with Goldmont Plus cores in the low cost Pentium and Celeron models).

Remark 2

It can be presumed that Integrated connectivity aims at increasing Intel's revenue, since with it the Wi-Fi/BT/RF modules have to be bought from Intel as well.

*

c) Enhanced Optane support

- The 1. gen. Optane memory was introduced along with the Kaby Lake processor line in 2017.

  In the 1. generation a single HD Boot drive was assumed and the Octane memory served as a cache of it.

Recap

- The Optane memory is nonvolatile memory typically used as a cache of a HDD drive.
- It is based on the 3D XPoint memory technology, announced by Intel and Micron in 2016.
- It has a typical size of 16 or 32 GB.
- It is mounted on an M.2 card that is attached via 2 to 4 PCIe lanes (see the Figure below).
- Its use needs the Rapid Storage Technology driver (appropriate no.).

c) Enhanced Optane support

- By contrast, the 2. gen., introduced along with the Coffee Lake line in 2018 assumes a fast SSD Boot drive and a large HD data drive.

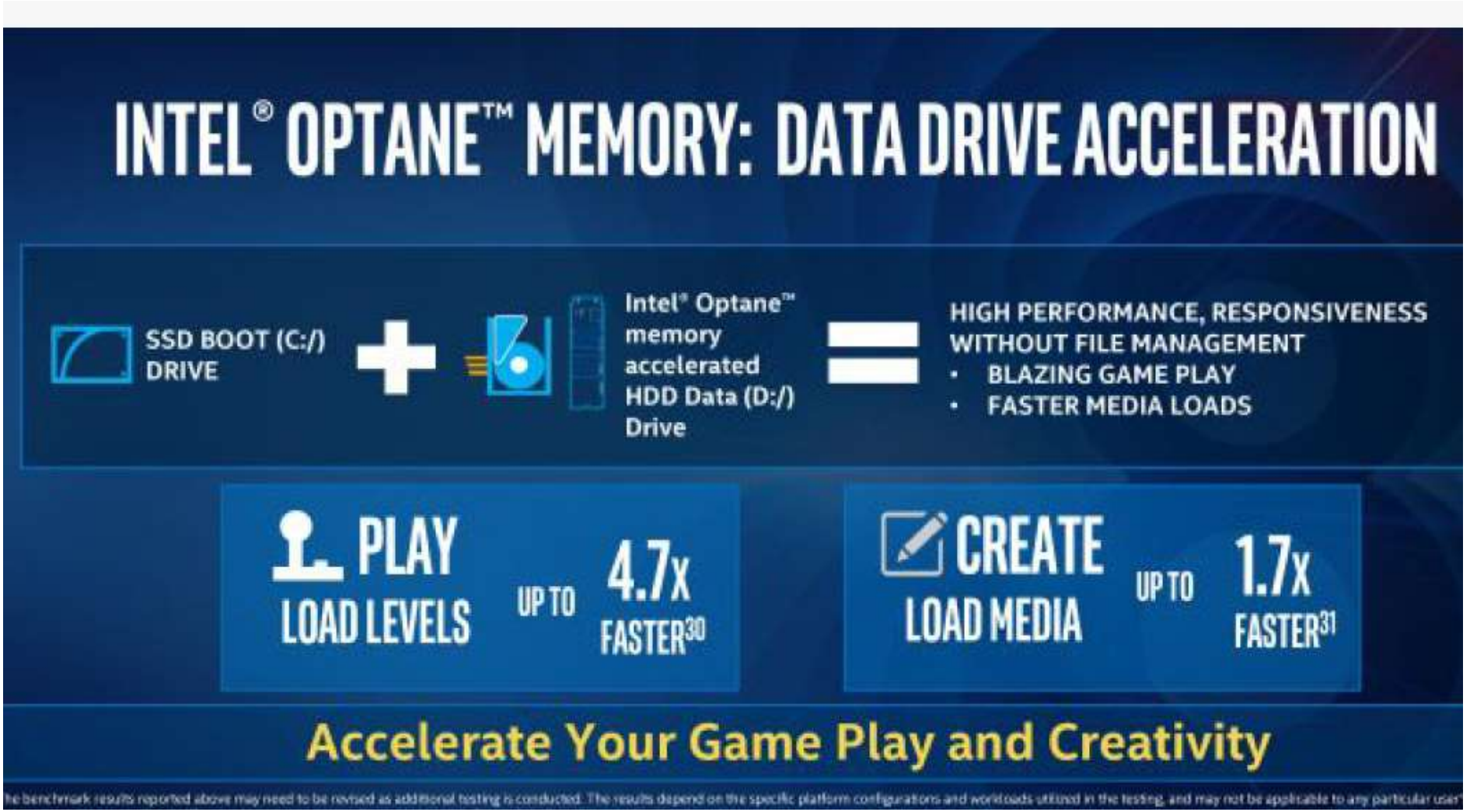
  In this case the Optane memory serves as a cache of the data drive (see the Table below).

	1. generation	2. generation
Storage system assumed	HD Boot drive and Optane memory	Fast SSD Boot drive, a large HD data drive and Optane memory
Principle of operation	Optane memory serves as a cache of the Boot drive (HD)	Optane memory serves as cache of the large HD data drive
Processor support	7. Generation (Kaby Lake)	8. Generation (Coffee Lake)
PCH support	200-series PCH or later	300-series PCH
Intro	2017	2018
Driver	RST 15.5 or later	RST 16.02 or later
OS	Windows 10 64-bit	Windows 10 64-bit

Table: Key features of the 1. and 2. generation Optane memory

*

Benefits of using the 2. generation Optane memory [253]



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Introducing the Core i9+, Core i7+, Core i5+ branding

- The "+" tag in the processor designation refers to" supported by Optane technology".
- It was introduced along with the 8. generation (Coffee Lake line).
- The new branding has a dark blue colored logo, as seen below.

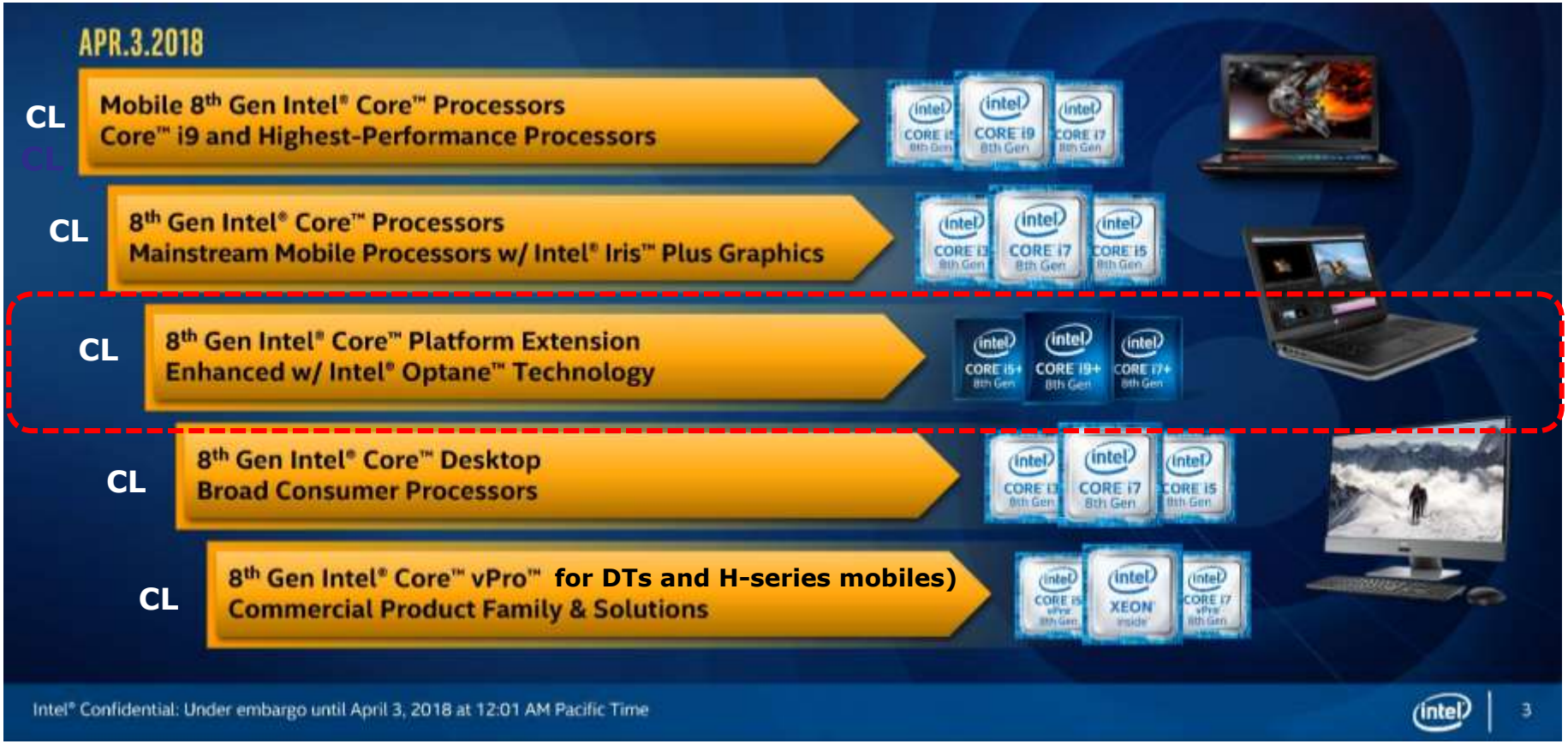

Figure: Introducing dark blue colored logo for Optane supported "+" tagged processors [253]

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9.4 Example 3: The Coffee Lake H-series mobile line

9.4 Example 3 : The Coffee Lake H-series mobile line [253]

CL: Coffee Lake

9.4 Example 3 : The Coffee Lake H-series mobile line (2)

Main features of the flagship H-series mobile Coffee Lake processor (Core i9-8950HK) vs. the flagship H-series Kaby Lake processor (Core i7-7820HK) [253]

	Core i9-8950HK	Core i7-7820HK
Generation	Coffee Lake-H	Kaby Lake-H
Launch	April 2018	January 2017
TDP	45 W	45 W
Cores	**6C / 12T**	4C/8T
Base Frequency	2.9 GHz	2.9 GHz
Turbo Frequency	**4.6 GHz**	3.9 GHz
Thermal Velocity Boost	+200 MHz	---
iGPU	UHD 630	HD 630
iGPU Base/Turbo	350 / **1200 MHz**	350 / 1100 MHz
DRAM Support	**DDR4-2666**	DDR4-2400
Optane Support	Yes	No
Tray Price	**$583**	$378

9.4 Example 3 : The Coffee Lake H-series mobile line (3)

Overview of the H-series mobile Coffee Lake line

45 W H-series (Two-chip designs, BGA1440, 300-series mobile chipset)

Core i9-8950HK, 6C+UHD 630, HT, 4/2018
Core i7-8850H/8750H, 6C+UHD 630, HT, 4/2018
Core i5-8400H/,8300H 4C+UHD 630, HT, 4/2018

9.4 Example 3 : The Coffee Lake H-series mobile line (4)

Innovative feature introduced in the Core i9-8950HK – Thermal Velocity Boost (TVB) [253]

TVB is a means to raise Turbo Boost frequencies given in specifications further on by 100 or 200 MHz.

Principle of TVB

If the temperature of the CPU is less than a certain limit (53^0C)

- single core turbo frequency will be raised by 200 MHz and
- multi-core turbo frequency by 100 MHz.

Obviously, TVB will be more likely applicable in OEM designs with efficient cooling.

We note here that due to the complex manufacturing process, parameters of individual processors have a variation, so certain processors may be more inclined to allow activating TVB than others.

Actually, the Turbo Boost values indicated by Intel already are the increased values assuming the use of TVB, this however is a questionable praxis since the usability of TVB can not be guaranteed in all cases.

Presumable, in connection with this, Intel declines to specify per-core turbo frequencies by saying

'Intel specifies only base and single-core turbo frequencies for its processors and no longer discloses turbo frequencies beyond this level of detail, as it is proprietary to Intel.'

9.4 Example 3 : The Coffee Lake H-series mobile line (5)

Remark

Intel's Thermal Velocity Boost (TVB) technology is similar to AMD's XFR (eXtended Frequency Range) technology introduced in the Ryzen desktop line in 03/2017.

XFR provides an automated overclocking over the max. Turbo Boost frequency if there is a premium cooler system and the operating conditions of the processor (e.g. temperature data) allow it.

In contrast to Intel, however AMD lists separately the max turbo and the XFR frequencies.

9.4 Example 3 : The Coffee Lake H-series mobile line (6)

Main features of the further H-series mobile Coffee Lake models [253]

		Cores	Base Freq	Turbo Freq	L3	vPro	DRAM DDR4	iGPU	iGPU Turbo
Core i7-8850H	**$395**	6 / 12	2.6	4.3	9 MB	Yes	2666	24 EUs	1150
Core i7-8750H	**$395**	6 / 12	2.2	4.2	9 MB	No	2666	24 EUs	1100
Core-i5-8400H	**$250**	4 / 8	2.5	4.2	8 MB	Yes	2666	24 EUs	1100
Core i5-8300H	**$250**	4 / 8	2.3	4.0	8 MB	No	2666	23 EUs	100

9.4 Example 3 : The Coffee Lake H-series mobile line (7)

Main features of the mobile Coffee Lake PCHs [253]

Intel 8th Gen Mobile Chipsets (PCH)			
	HM370	QM370	QMS380
Launch	Apr '18	Apr '18	Apr '18
Market	Consumer -	- Corporate	- Corporate
ME Firmware	12	12	12
HSIO Lanes	25	30	30
Total USB	14	14	6
Max USB 3.1 G2	4	**6**	0
Max USB 3.1 G1	8	**10**	6
SATA 6 Gbps	**4**	**4**	**4**
PCH PCIe 3.0 Lanes	16	**20**	8
Supports Optane	**Y**	**Y**	**Y**
Integrated 802.11ac	**Y**	**Y**	**Y**
Intel Smart Sound	**Y**	**Y**	**Y**
Intel vPro	N	**Y**	**Y**
TDP	3 W	3 W	2.4 W
Price	$49	$49	N/A

9.5 Example 4: The Coffee Lake U-series mobile line with Iris Plus graphics

9.5 Example 4: The Coffee Lake U-series mobile line with Iris Plus graphics [253]

Launched in 04/2018

CL: Coffee Lake

9.5 Example 4: The Coffee Lake U-series mobile line with Iris Plus graphics (2)

Main features of the Coffee Lake U-series mobile line with Iris Plus graphics [253]

Launched: 04/2018

NEW 8TH GEN INTEL® CORE™ MOBILE PROCESSORS

Processor number	Base clock speed (GHz)	Intel® Turbo Boost Technology 2.0 maximum single core turbo frequency (GHz)	Cores/ Threads	Thermal Design Power	Intel® Smart Cache	Memory support	Intel® Optane™ Memory Support[22]
Intel® Core™ i7-8559U	2.7	4.5	4/8	28	8 MB	Two channels DDR4-2400[23]	√
Intel® Core™ i5-8269U	2.6	4.2	4/8	28	6 MB	Two channels DDR4-2400[23]	√
Intel® Core™ i5-8259U	2.3	3.8	4/8	28	6 MB	Two channels DDR4-2400[23]	√
Intel® Core™ i3-8109U	3.0	3.6	2/4	28	4 MB	Two channels DDR4-2400[23]	√

9.5 Example 4: The Coffee Lake U-series mobile line with Iris Plus graphics (3)

Comparing graphics performance of the Coffee Lake U-series and Kaby Lake G-series including AMD Radeon RX Vega M GH graphics [269]

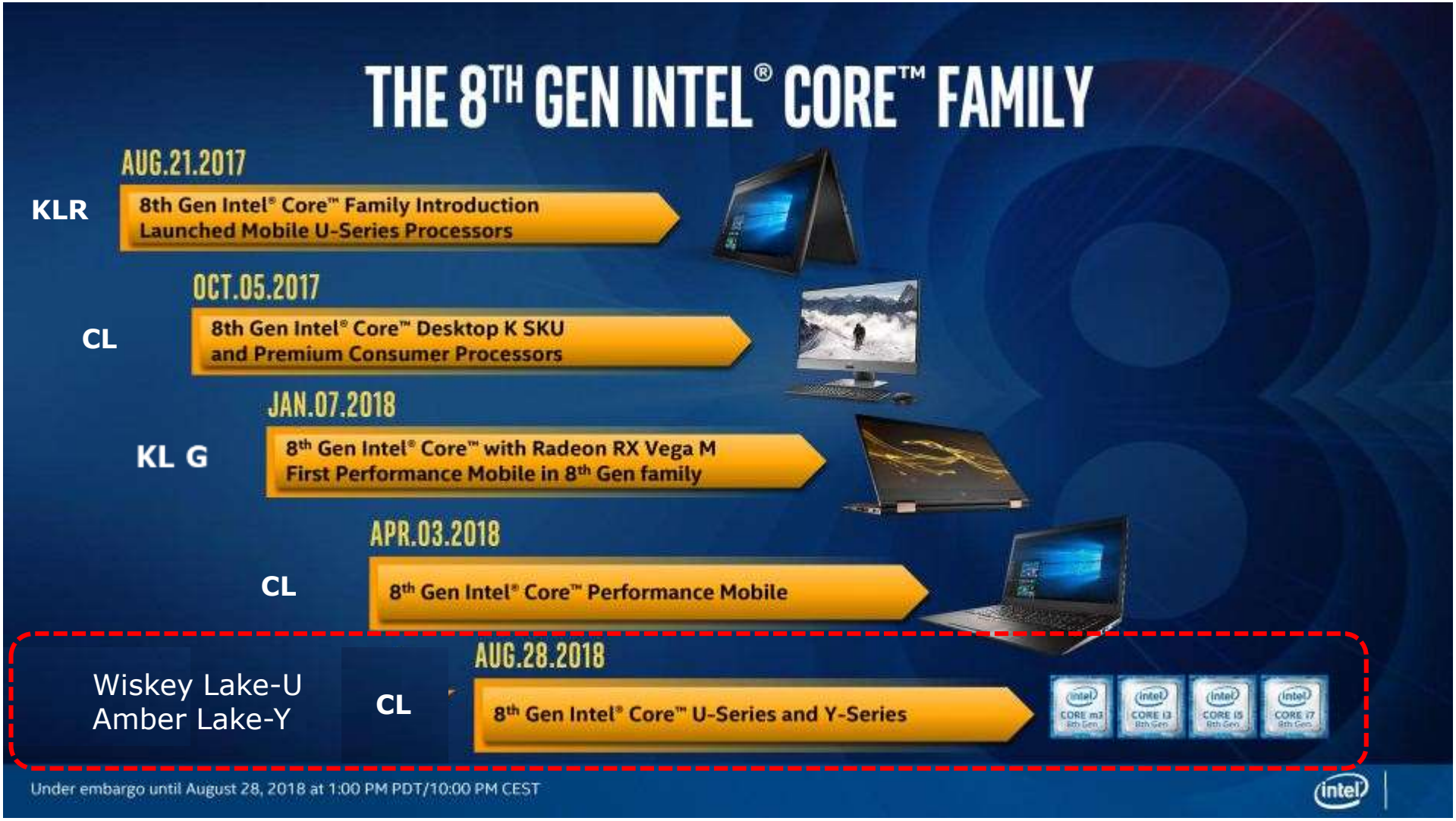
- The Coffee Lake U-series models make use of Intel's Iris Plus Graphics 655.
- Compared with this graphics AMD's Radeon RX Vega M GH graphics of the Kaby Lake G-series achieves much higher performance, as benchmark results show:

  Average Benchmarks Intel Iris Plus Graphics 655 → 100%
  Average Benchmarks AMD Radeon RX Vega M GH → 207%

9.6 Example 5: The Coffee Lake Y- and U-series mobile lines

9.6 Example 5: The Coffee Lake Y- and U-series mobile lines [294]

Launched: 08/2018



KLR: Kaby Lake Refresh CL: Coffee Lake KL G: Kaby Lake G

9.6 Example 5: The Coffee Lake Y- and U-series mobile lines (2)

Main features of the Coffee Lake Y series (Amber Lake) and U-series (Whiskey Lake) mobile lines [294]

Intel Whiskey Lake-U and Amber Lake-Y								
AnandTech	Cores	Base MHz	Turbo MHz	L3 Cache	TDP PL1	cTDP Up	cTDP Down	Cost
Whiskey Lake-U								
i7-8565U	4C/8T	1800	4600	8 MB	15W	25W @ 2.0GHz	10W @ 800MHz	$409
i5-8265U	4C/8T	1600	3900	6 MB	15W	25W @ 1.8GHz	10W @ 800MHz	$297
i3-8145U	2C/4T	2100	3900	4 MB	15W	25W @ 2.3GHz	10W @ 800MHz	$281
Amber Lake-Y								
i7-8500Y	2C/4T	1500	4200	4 MB	5W	7W @ 1.6GHz	3.5W @ 600MHz	$393
i5-8200Y	2C/4T	1300	3900	4 MB	5W	7W @ 1.6GHz	3.5W @ 600MHz	$291
m3-8100Y	2C/4T	1100	3400	4 MB	5W	8W @ 1.6GHz	4.5W @ 600MHz	$281

10. The Coffee Lake Refresh line

- 10.1 Introduction to the Coffee Lake Refresh line
- 10.2 The Coffee Lake Refresh line

10.1 Introduction to the Coffee Lake Refresh line

10.1 The 9th generation Coffee Lake Refresh line -1

1. gen.				2. gen.	3. gen.	4. gen.	5. gen.
Core 2 New Microarch. 65 nm	Penryn New Process 45 nm	Nehalem New Microarch. 45 nm	West-mere New Process 32 nm	Sandy Bridge New Microarch. 32 nm	Ivy Bridge New Process 22 nm	Haswell New Microarchi. 22 nm	Broad-well New Process 14 nm
TOCK	*TICK*	*TOCK*	*TICK*	*TOCK*	*TICK*	*TOCK*	*TICK*
(2006)	*(2007)*	*(2008)*	*(2010)*	*(2011)*	*(2012)*	*(2013)*	*(2014)*

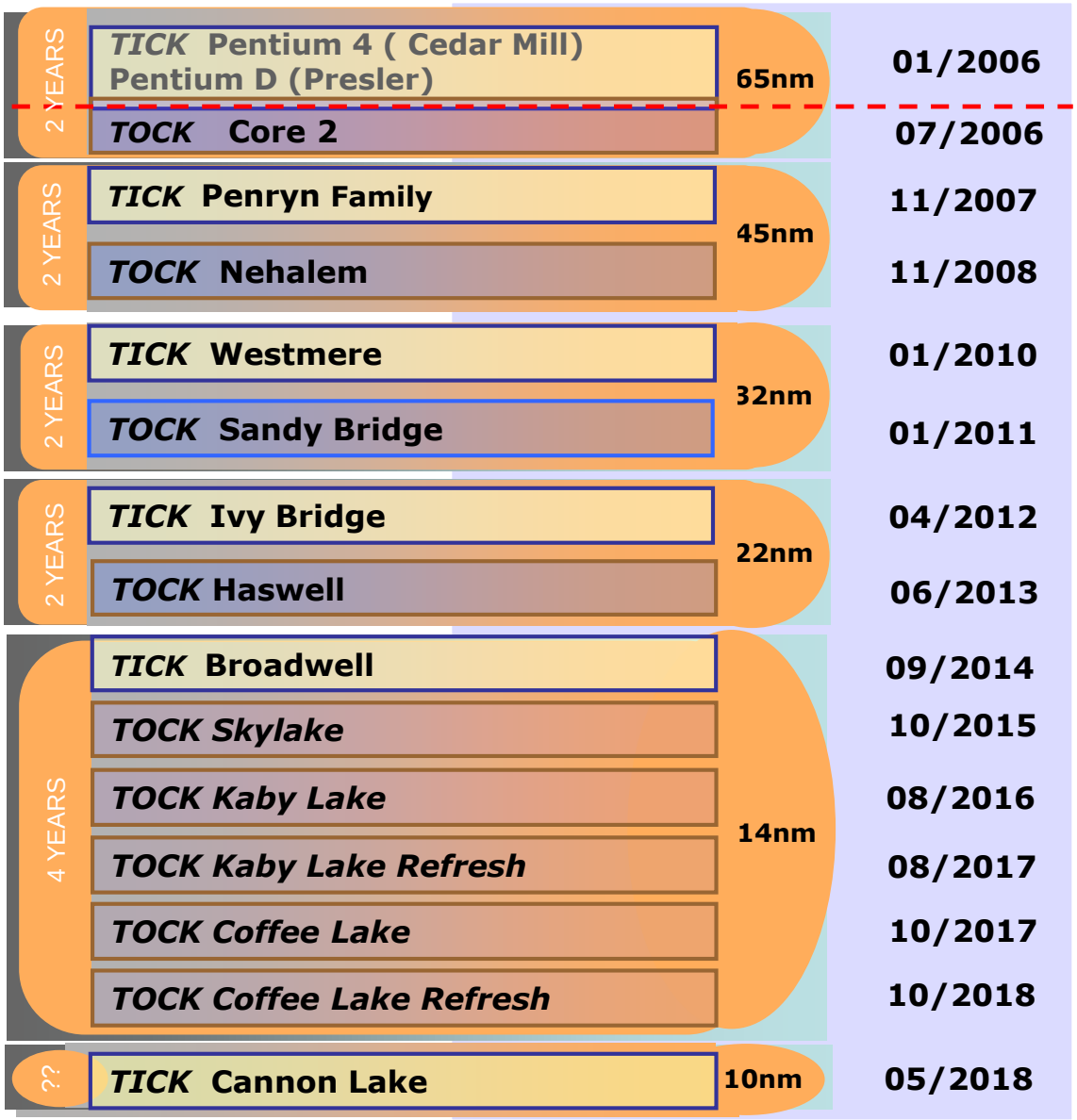
6. gen.	7. gen.	8. gen.[1]	9. gen.
Skylake New Microarch. 14 nm	Kaby Lake New Microarch. 14 nm	Kaby Lake R KL KL G-series Coffee Lake Cannon Lake 14/10 nm	Coffee Lake R New Mocroarch. 14 nm
TOCK	*TOCK*	*TOCK*	*TOCK*
(2015)	*(2016)*	*(2017/18)*	*(2018)*

[1]The 8th generation encompasses the lines

- Kaby Lake Refresh
- Kaby Lake G with AMD Vega graphics
- Coffee Lake (all 14 nm) and the
- 10 nm Cannon Lake [218].

R: Refresh

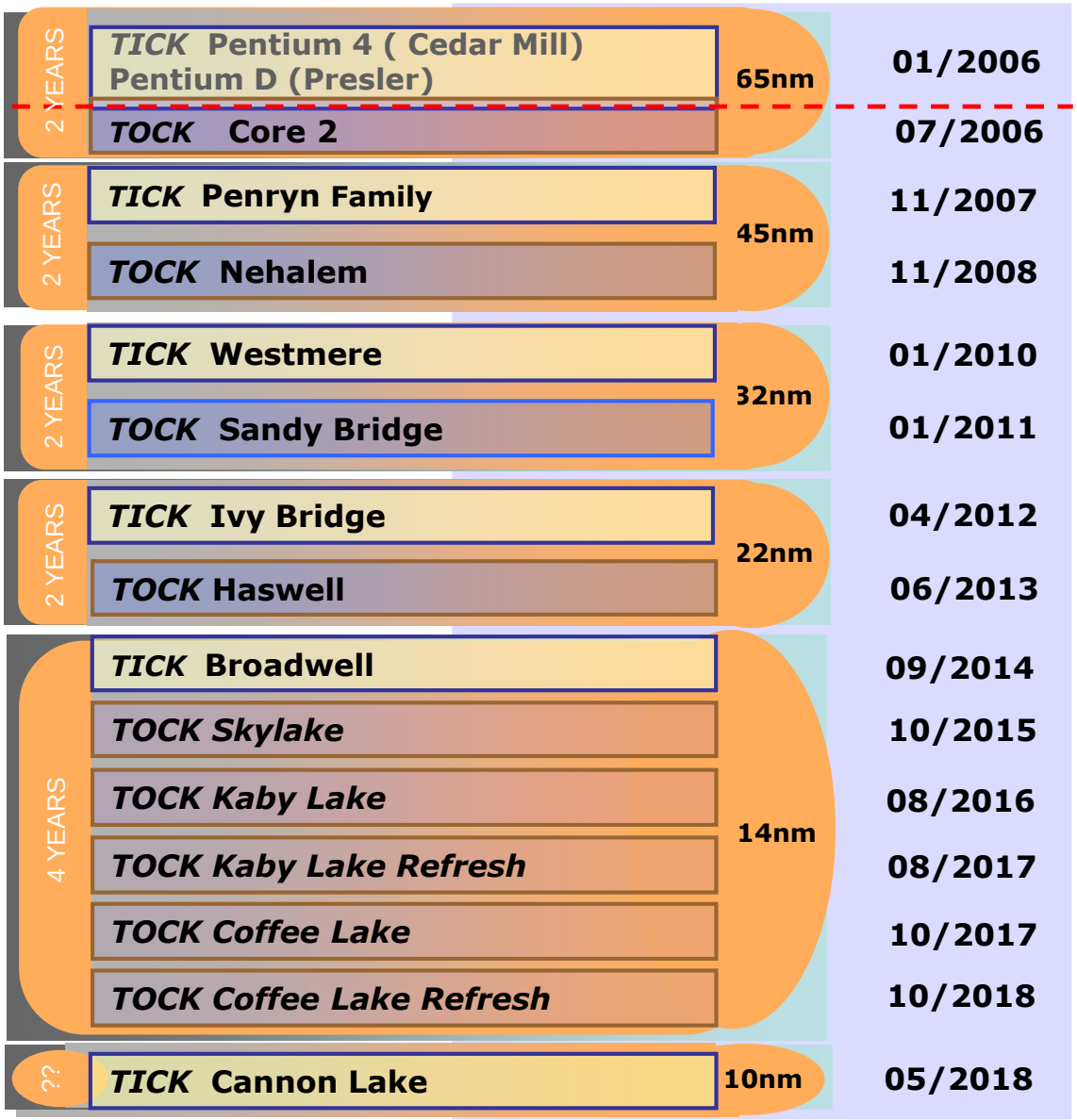
The 9th generation Coffee Lake Refresh -2 (based on [3])



Key new features of the ISA and the microarchitecture

- **New microarch.: 4-wide core, 128-bit SIMD FX/FP EUs, shared L2 , no HT**
- **New microarch.: 4 cores, integr. MC, QPI, private L2, (inclusive) L3, HT**
- **In package integrated GPU**
- **New microarch.: 256-bit (FP) AVX, ring bus, integrated GPU**
- **New microarch.: 256-bit (FX) AVX2, L4 cache (discrete eDRAM), TSX**
- **Shared Virtual Memory**
- **New microarch.: 5-wide core, ISP, Memory Side L4 cache, no FIVR**
- **Optane memory, in KBL G series: in package integr. CPU, GPU, HBM2**
- **6C, (PCHs of S-series DTs support: USB G2, integr. conn., Optane 2)**
- **8C**
- **AVX512**

The 9th generation Coffee Lake Refresh line -3 (based on [3])



Key new features of the power management

- **Clock gating, PECI, Platform Thermal Control by 3. party controller**
- **EDAT**
- **Integrated Power Gates, PCU, Turbo Boost**
- **Turbo Boost 2.0**
- **FIVR**
- **2. gen. FIVR**
- **Speed Shift Technology, Duty Cycle control, No FIVR except Skylake X**
- **Speed Shift Technology v2**
- **In H-series: TVB (Thermal Velocity Boost)**
- **STIM**

10.2 The Coffee Lake Refresh line

10.2 The Coffee Lake Refresh line

- Launched 10/2018.
- They are called Intel's 9th generation processor line.
- They are Intel's first 8-core client processors, introduced to encounter AMD's 8-core Ryzen models.
- At introduction models of this line became the highest performance client processors.
- Only the i9 model (supports hyperthreading, the i7/i5-models not.
- All three models introduced employ STIM (Solder Thermal Interface Material) that provides an increased thermal conductivity between the CPU die and the integrated heat spreader (HIS), to be discussed later in this Section).

10.2 The Coffee Lake Refresh line (2)

Main features of the Coffee Lake Refresh S-series DT models vs. the Coffee Lake S-series models [295]

		Cores	TDP	Freq	L3	L3 Per Core	DRAM DDR4	iGPU	iGPU Turbo	STIM
Intel 9th gen. models										
Core i9-9900K	$488*	8 / 16	95 W	3.6 / 5.0	16 MB	2.0 MB	2666	GT2	1200	Yes
Core i7-9700K	$374*	8 / 8	95 W	3.6 / 4.9	12 MB	1.5 MB	2666	GT2	1200	Yes
Core i5-9600K	$262*	6 / 6	95 W	3.7 / 4.6	9 MB	1.5 MB	2666	GT2	1150	Yes
Intel 8th gen. models										
Core i7-8086K	$425	6 / 12	95 W	4.0 / 5.0	12 MB	2 MB	2666	24 EUs	1200	No
Core i7-8700K	$359	6 / 12	95 W	3.7 / 4.7	12 MB	2 MB	2666	24 EUs	1200	No
Core i5-8600K	$258	6 / 6	95 W	3.6 / 4.3	9 MB	1.5 MB	2666	24 EUs	1150	No
Core i3-8350K	$179	4 / 4	91 W	4.0	8 MB	2 MB	2400	24 EUs	1150	No
Pentium G5600	$93	2 / 4	54 W	3.9	4 MB	2 MB	2400	24 EUs	1100	No

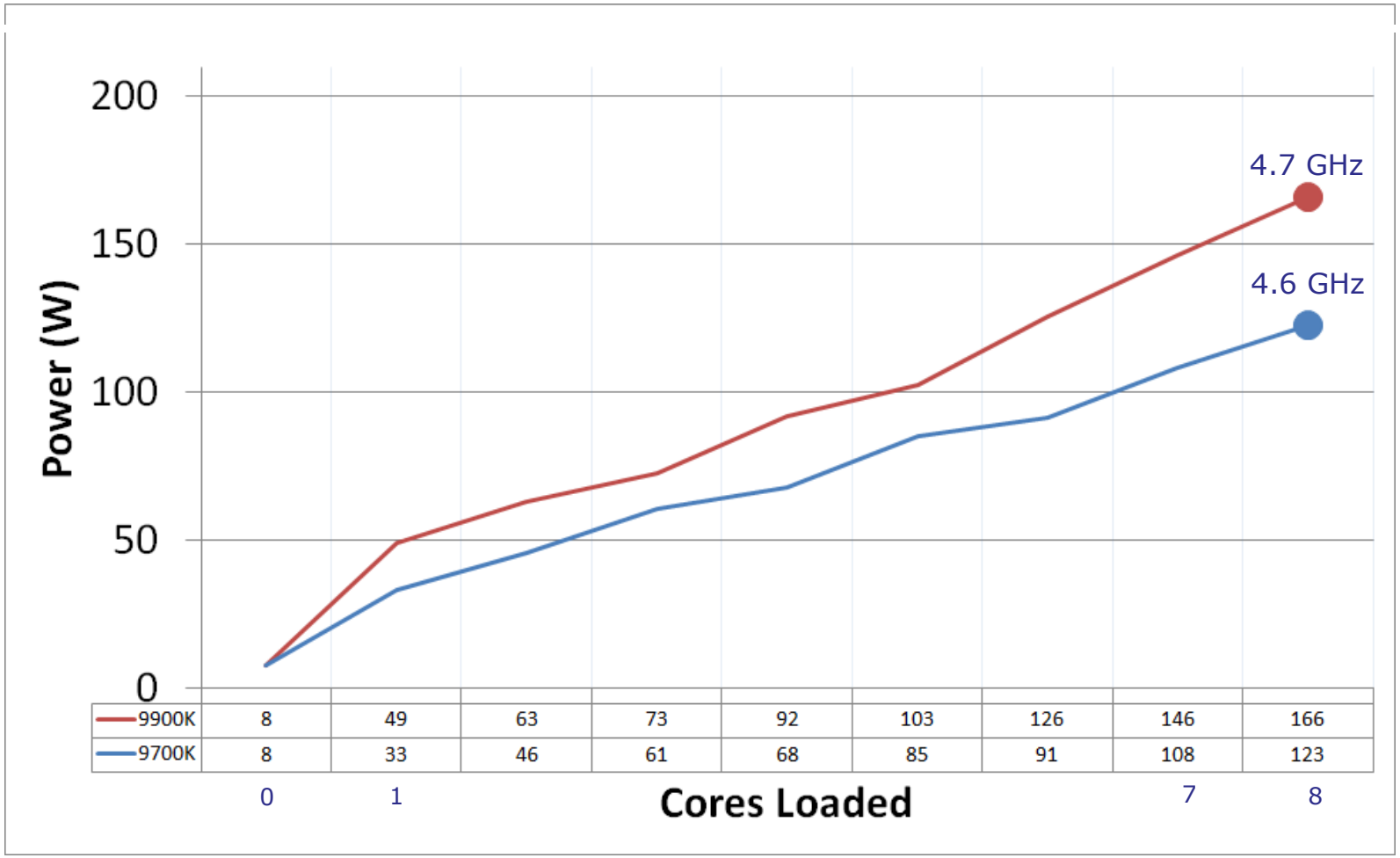
10.2 The Coffee Lake Refresh line (3)

Turbo frequencies of the Coffee Lake Refresh S-series DT models []

Intel 9th Gen Coffee Lake Refresh Non-AVX Turbo Frequencies														
AnandTech	Cores	Thrds	LLC	TDP	Base	1	2	3	4	5	6	7	8	Cost $
Core i9 9900K	8	16	16	95	3.60	5.0	5.0	4.8	4.8	4.7	4.7	4.7	4.7	$ 488.00
Core i7 9700K	8	8	12	95	3.60	4.9	4.8	4.7	4.7	4.6	4.6	4.6	4.6	$ 374.00
Core i5 9600K	6	6	9	95	3.70	4.6	4.5	4.4	4.4	4.3	4.3			$ 262.00

10.2 The Coffee Lake Refresh line (3b)

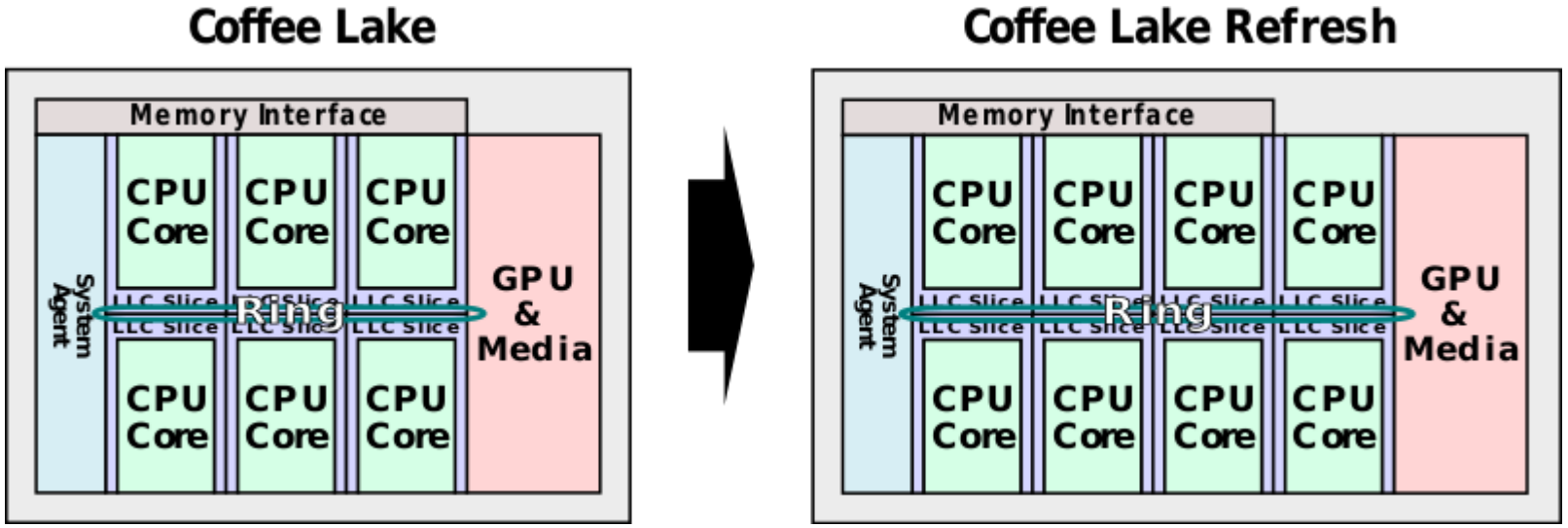
Package power draw of the 9th gen. processors 9800K and 9700K while running the active cores at the max. turbo frequency [295]



Note that the TDP values of both processors are 95 W and 65 W respectively, while the cores are running at 3.6 GHz.

10.2 The Coffee Lake Refresh line (4)

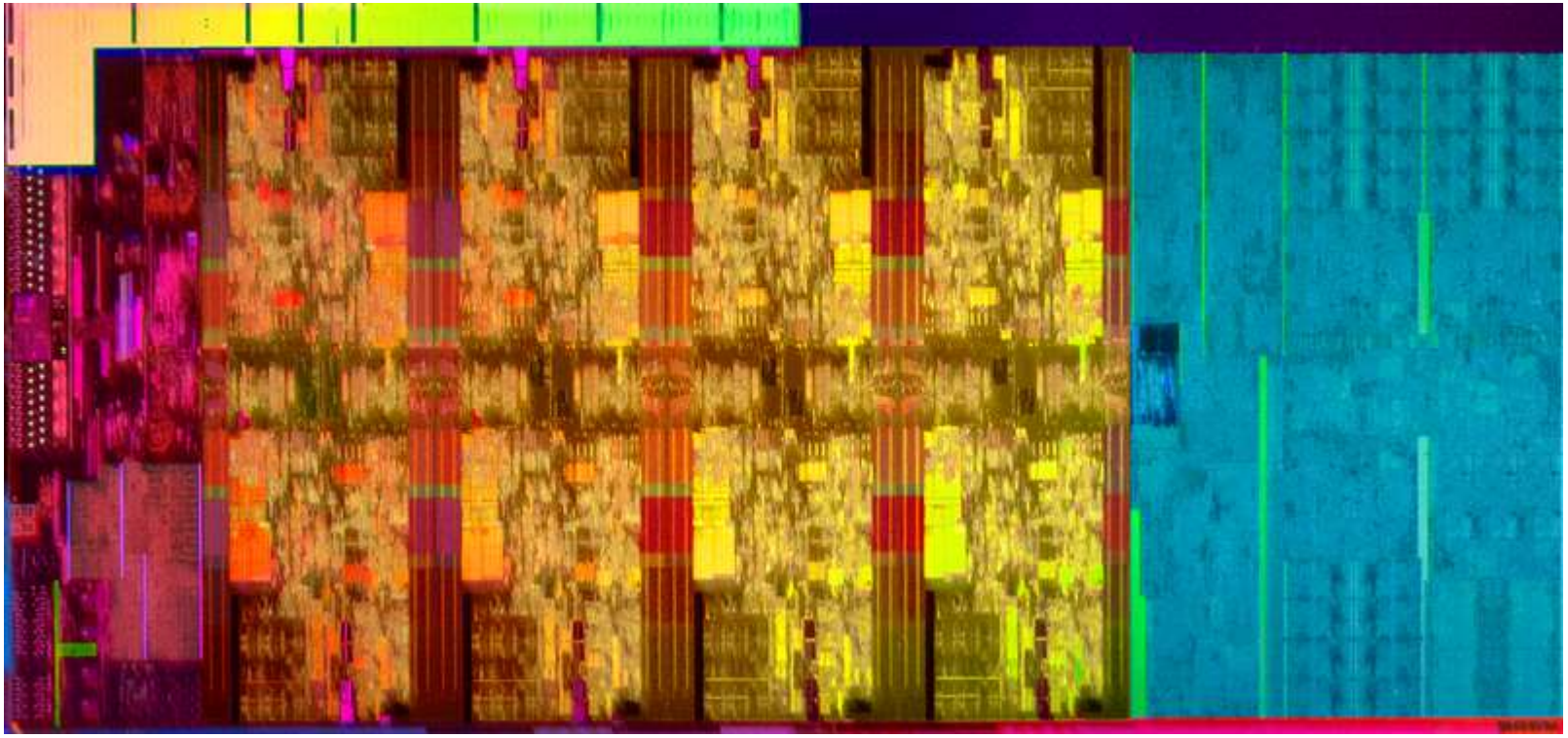
Contrasting the basic layout of the up to 6-core 8th generation Coffee Lake and the up to 8-core 9th generation Coffee Lake Refresh series []



https://en.wikichip.org/wiki/File:coffee_lake-coffee_lake_refresh_overview_change.svg

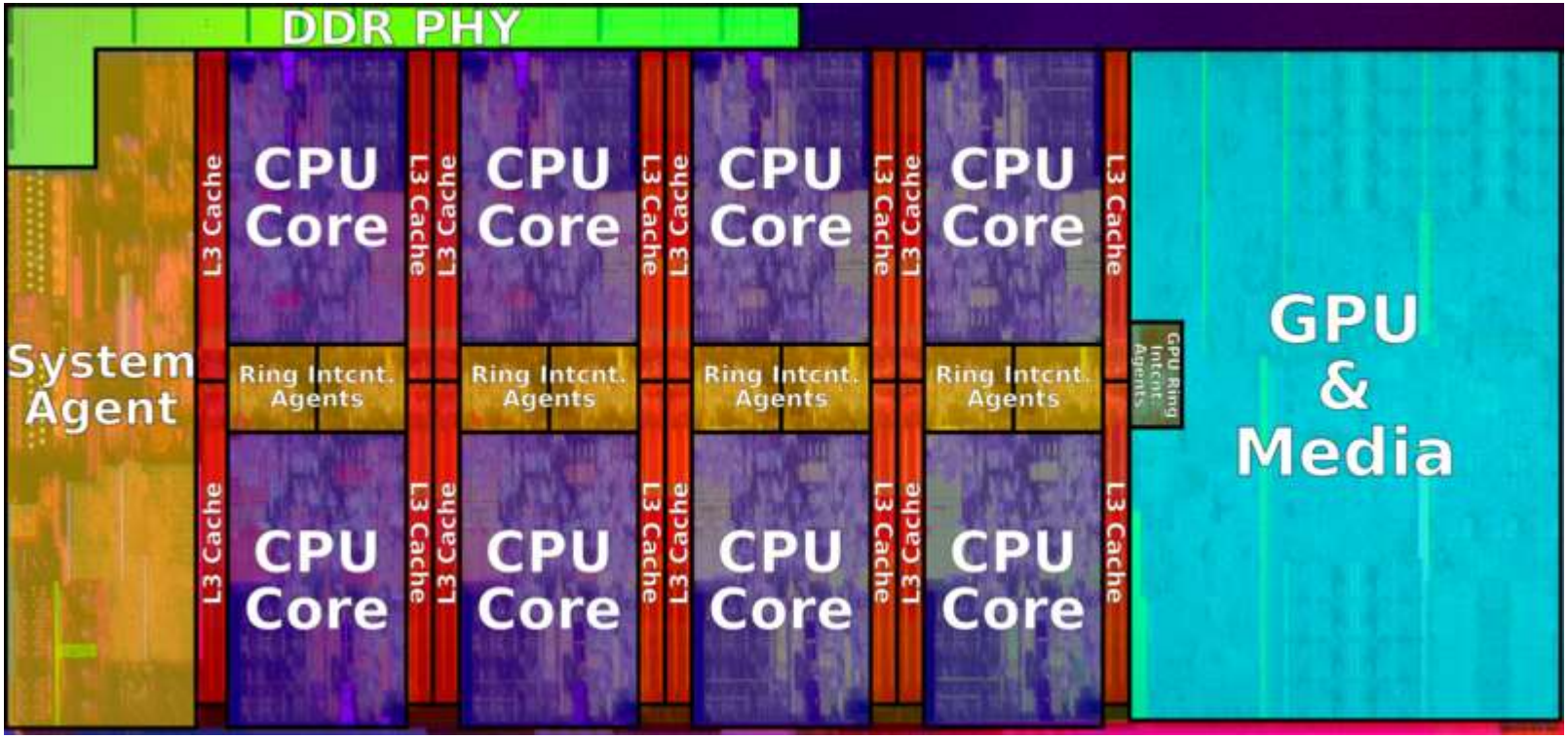
10.2 The Coffee Lake Refresh line (5)

Die micrograph of an 8-core 9th generation Coffee Lake Refresh processor []



https://en.wikichip.org/wiki/intel/microarchitectures/coffee_lake

Die layout of an 8-core 9th generation Coffee Lake Refresh processor [6]



https://en.wikichip.org/wiki/intel/microarchitectures/coffee_lake

Addressing Spectre and Meltdown by Intel [295]

Addressing Spectre and Meltdown by Intel							
AnandTech			SKX-R 3175X	CFL-R	Cascade Lake	Whiskey Lake	Amber Lake
Spectre	Variant 1	Bounds Check Bypass	OS/VMM	OS/VMM	OS/VMM	OS/VMM	OS/VMM
Spectre	Variant 2	Branch Target Injection	Firmware + OS	Firmware + OS	Hardware + OS	Firmware + OS	Firmware + OS
Meltdown	Variant 3	Rogue Data Cache Load	Firmware	**Hardware**	Hardware	Hardware	Firmware
Meltdown	Variant 3a	Rogue System Register Read	Firmware	Firmware	Firmware	Firmware	Firmware
	Variant 4	Speculative Store Bypass	Firmware + OS	Firmware + OS	Firmware + OS	Firmware + OS	Firmware + OS
	Variant 5	L1 Terminal Fault	Firmware	**Hardware**	Hardware	Hardware	Firmware

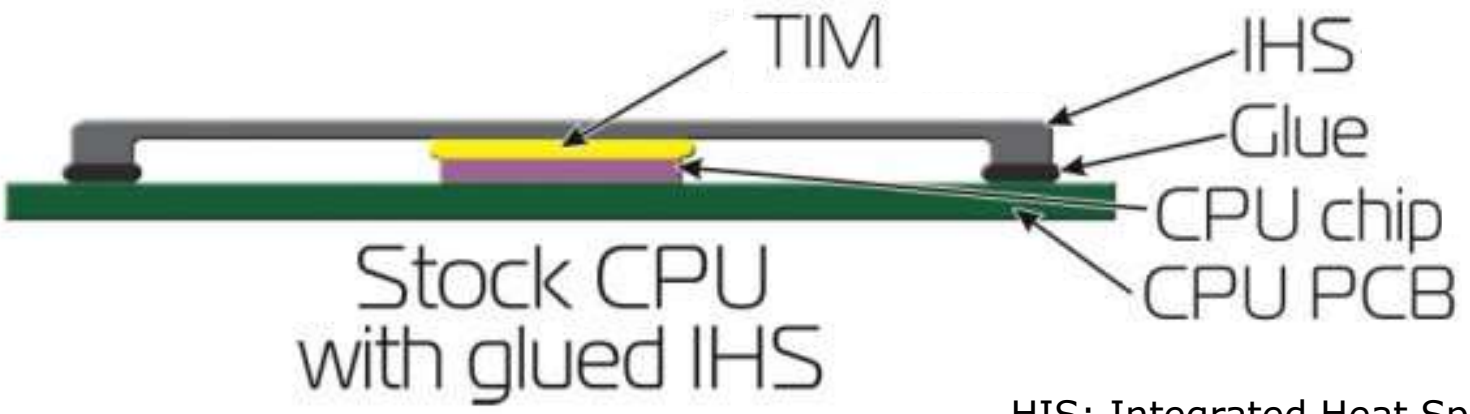
CFL-R: Coffee Lake Refresh SKX-R: Skylake-X Refresh

The Thermal Interface Material (TIM) and Solder Thermal Interface Material []

- In a processor package there is a layer between the CPU die and the headspreader, often implemented as an Integrated head Spreader (HIS).

This layer is made up of a Thermal Interface Material (TIM) (see Figure).

The task of the TIM is to transfer the heat away from the processor die to the headspreader and eventually to the processor cooler.



HIS: Integrated Heat Spreader
TIM: Thermal Interface Material

Figure: The Thermal Interface Material (TIM) between the IHS (Integrated heat Spreader and the processor die []

The Thermal Interface may be implemented

either as a layer of cheap thermal paste or as a more costly indium-tin soldering.

Delidding The AMD Ryzen 5 2400G APU: How To Guide and Results
by Gavin Bonshor on May 10, 2018 8:00 AM EST

10.2 The Coffee Lake Refresh line (9)

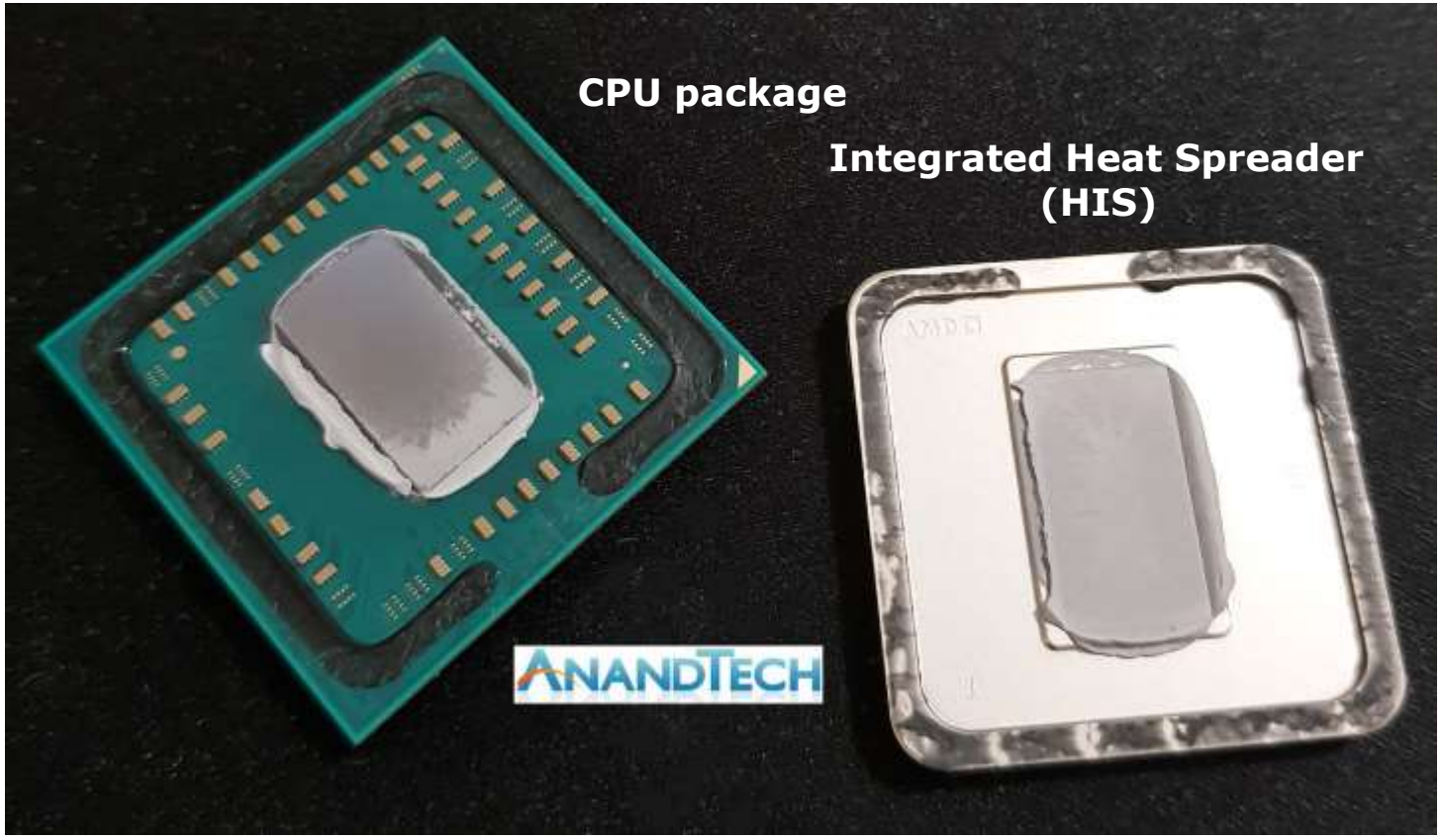
Benefits and drawbacks of the main implementation options of TIM

Type of TIM	Benefit	Drawback
Paste	• Lower cost • Longevity	• Worse heat conductivity
Soldered (Bonded)	• Better heat conductivity This results in larger power headroom and better overclocking capability	• Higher cost • Shorter lifecycle

Note that the more costly soldered (bonded) interface provide a better heat conductivity and thus results in a larger power headroom that may be converted into higher clock frequency.

On the other hand, a soldered (bonded) thermal interface has a shorter lifecycle since the soldered implementation results in higher thermal shocks during usage (in thermal cycles) than the pasted one.

Pasted (glued) CPU package and integrated heat Spreader (HIS) after separation []



The Figure shows the gray glue that holds the IHS to the CPU package.

Delidding The AMD Ryzen 5 2400G APU: How To Guide and Results
by Gavin Bonshor on May 10, 2018 8:00 AM EST

10.2 The Coffee Lake Refresh line (11)

Use of a pasted or soldered (bonded) heat conducting layer between the CPU die and the integrated heat spreader in Intel's and AMD's processor sockets []

Thermal Interface							
Intel		Celeron	Pentium	Core i3	Core i5	Core i7/i9	HEDT
Sandy Bridge	**LGA1155**	Paste	Paste	Paste	Bonded	Bonded	Bonded
Ivy Bridge	**LGA1155**	Paste	Paste	Paste	Paste	Paste	Bonded
Haswell / DK	**LGA1150**	Paste	Paste	Paste	Paste	Paste	Bonded
Broadwell	**LGA1150**	Paste	Paste	Paste	Paste	Paste	Bonded
Skylake	**LGA1151**	Paste	Paste	Paste	Paste	Paste	Paste
Kaby Lake	**LGA1151**	Paste	Paste	Paste	Paste	Paste	-
Coffee Lake	**1151 v2**	Paste	Paste	Paste	Paste	Paste	-
CFL-R	**1151 v2**	?	?	?	K models: Bonded		-
AMD							
Zambezi	**AM3+**	Bonded		**Carrizo**	**AM4**	Bonded	
Vishera	**AM3+**	Bonded		**Bristol R**	**AM4**	Bonded	
Llano	**FM1**	Paste		**Summit R**	**AM4**	Bonded	
Trinity	**FM2**	Paste		**Raven R**	**AM4**	Paste	
Richland	**FM2**	Paste		**Pinnacle**	**AM4**	Bonded	
Kaveri	**FM2+**	Paste / Bonded*		**TR**	**TR4**	Bonded	
Carrizo	**FM2+**	Paste		**TR2**	**TR4**	Bonded	
Kabini	**AM1**	Paste					

*Some Kaveri Refresh models were bonded

https://www.anandtech.com/print/13400/intel-9th-gen-core-i9-9900k-i7-9700k-i5-9600k-review

Use of STIM (Solder Thermal Interface Material) in Intel's 9th generation Coffee Lake Refresh S line []

All three models introduced in the Coffee lake Refresh S series make use of STIM that is Solder-based Thermal interface Material to improve heat conductivity between the CPU die and the integrated heat spreader (HIS), as indicated below.

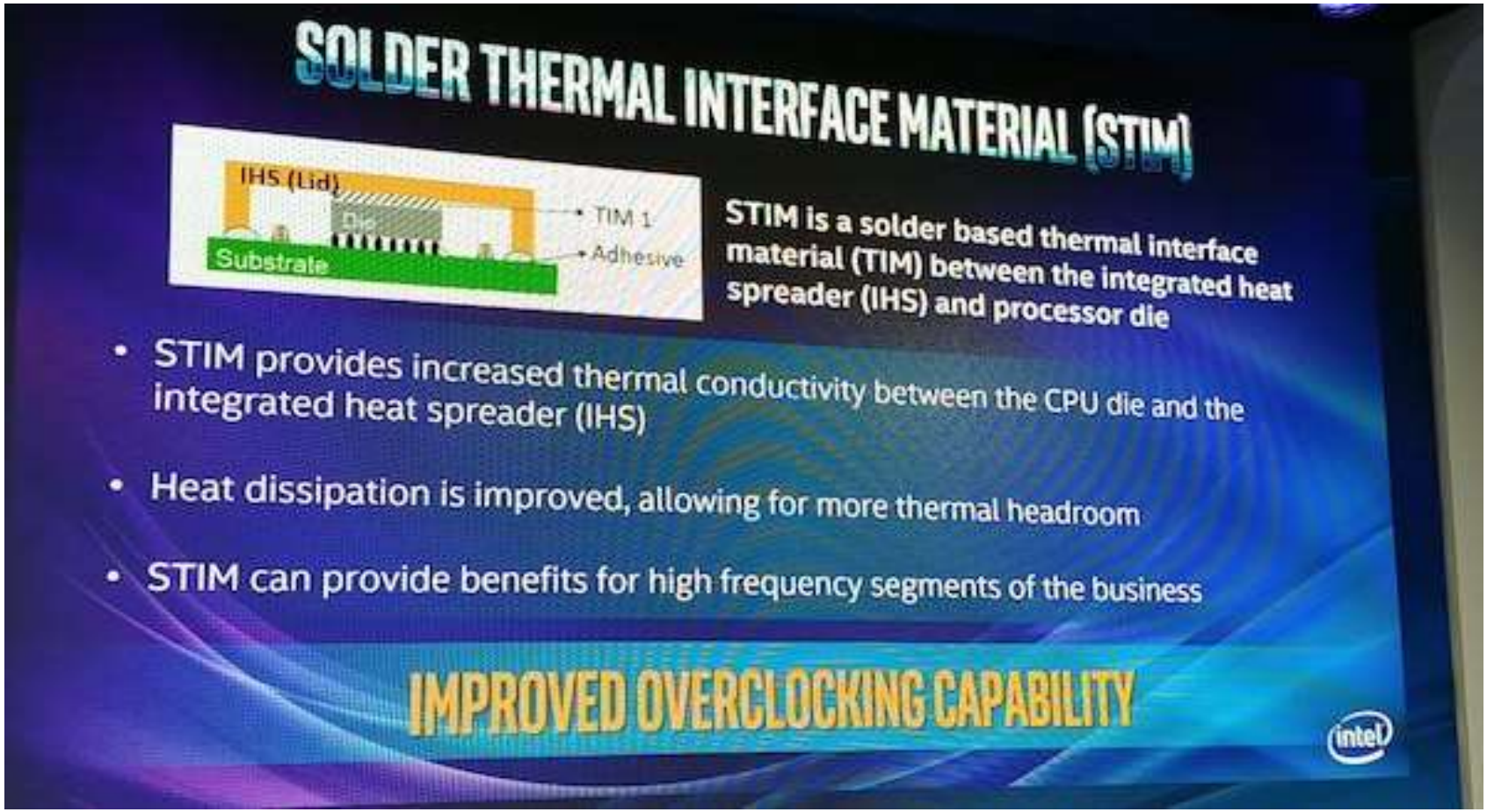
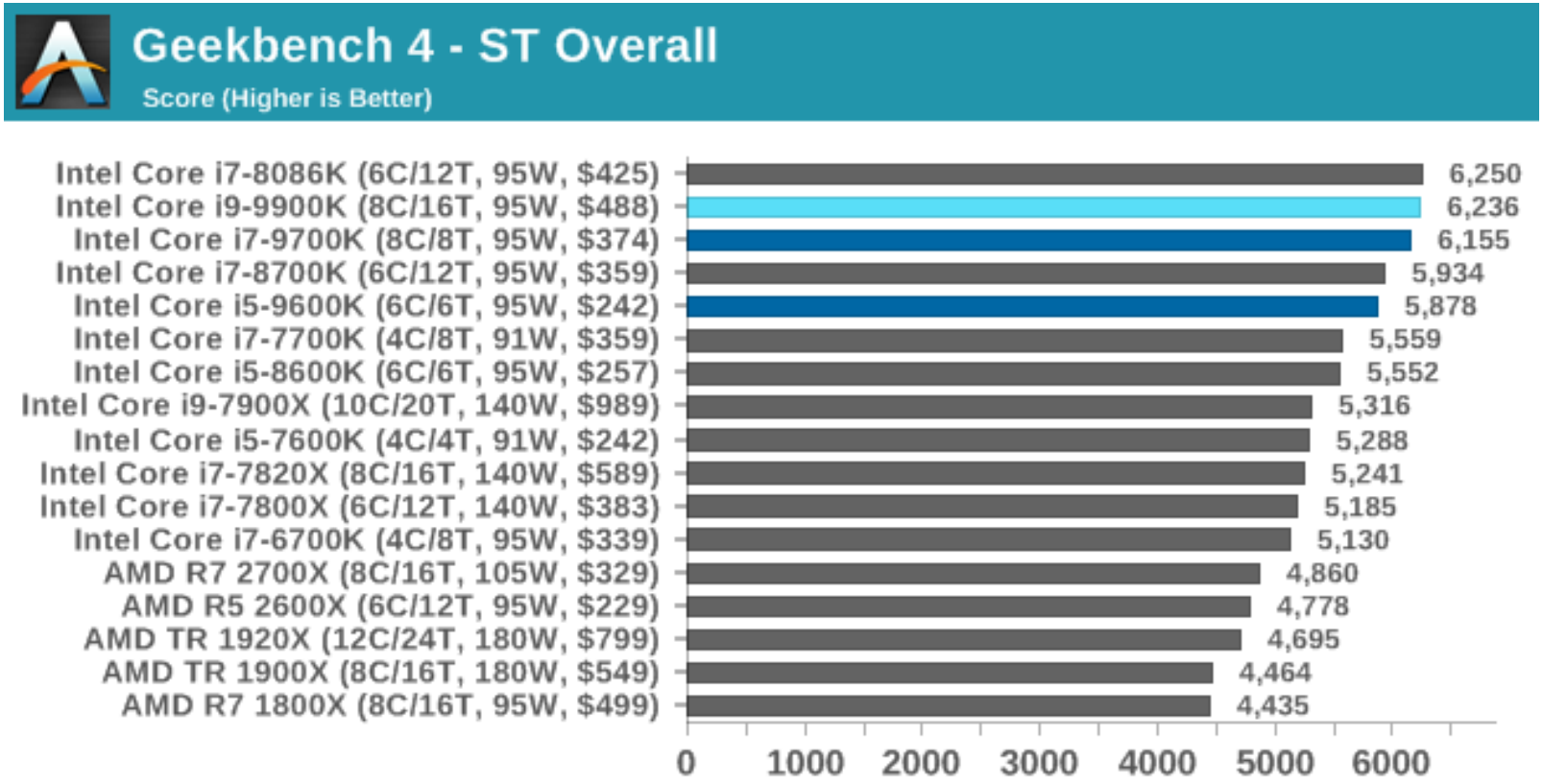


Figure: Introduction of STIM in the Coffee Lake Refresh S series to improve heat conductivity [295]

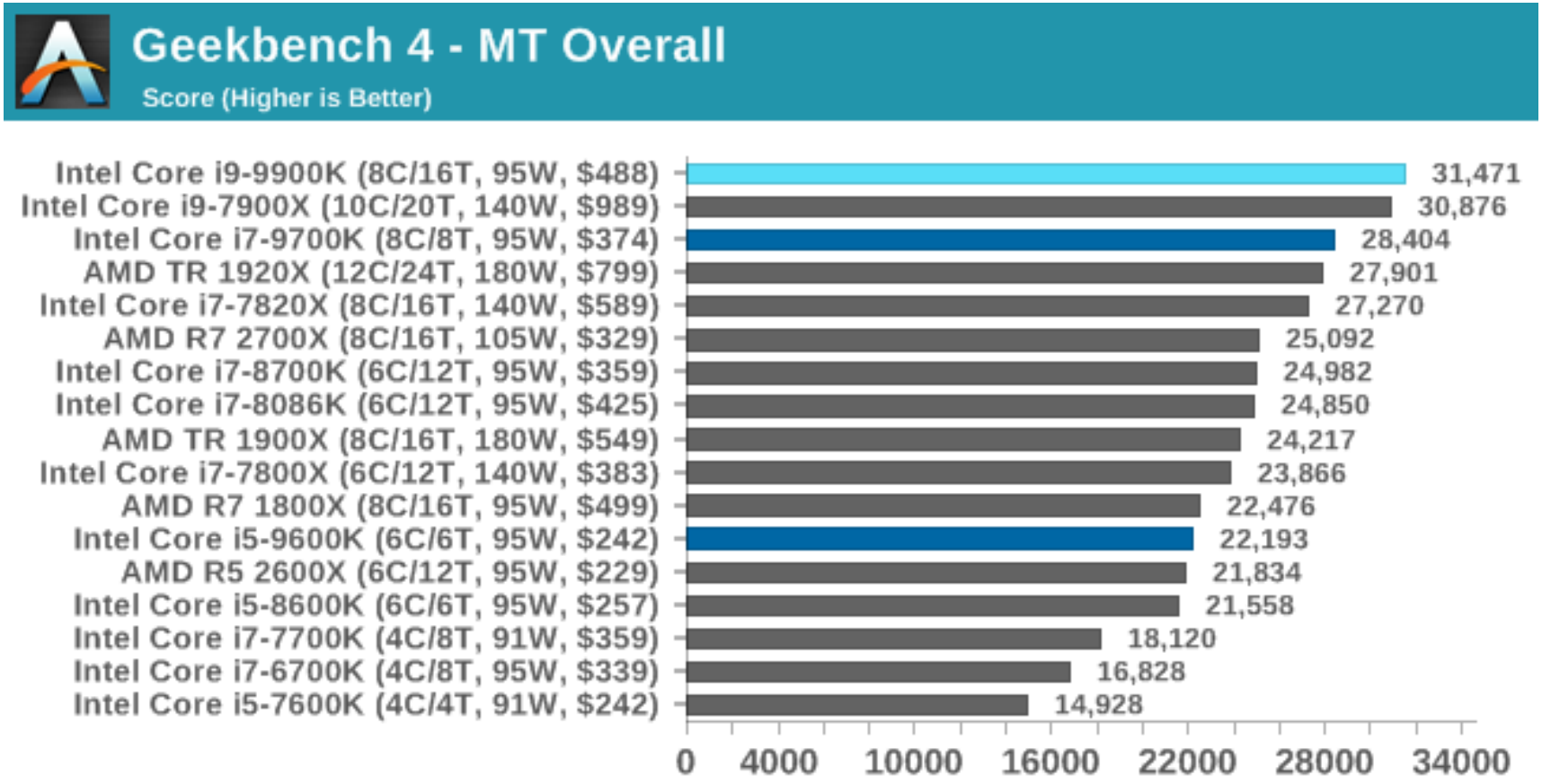
Single core Geekbench results of DT processors []



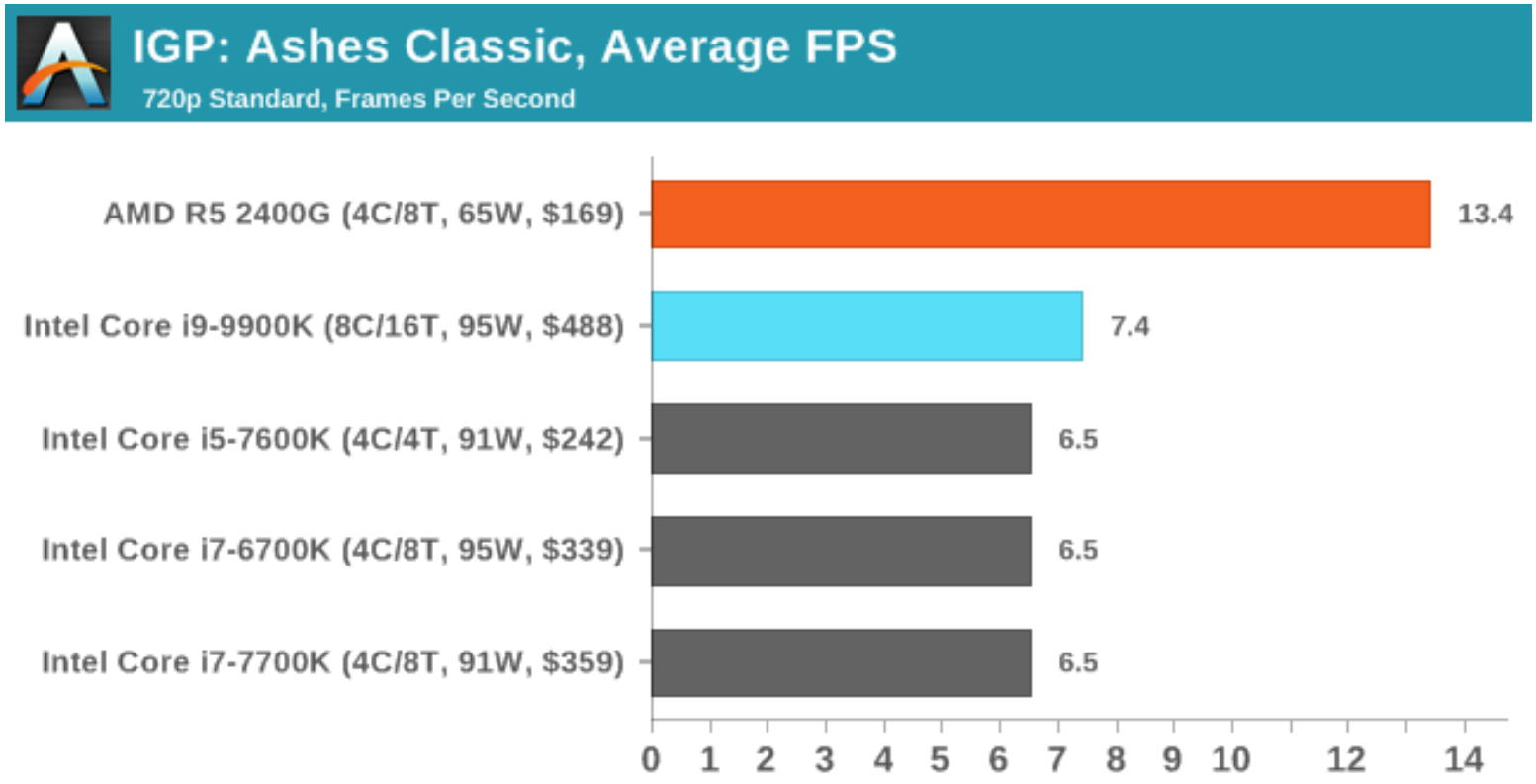
Remark []

- Geekbench is a cross-platform processor benchmark that simulate real-world scenarios while running worklads.
- It has a scoring system that separates single-core and multi-core performance.
- The current version is Geekbench 4, that provides scores calculated against a baseline score of 4000, which represents the performance of an Intel Core i7-6600U running at 2.60 GHz.

Multi-core Geekbench results of DT processors []



Graphics performance of integrated graphics (IGP) []



11. The Cannon Lake line

- 11.1 Introduction to the Cannon Lake line
- 11.2 The Cannon Lake line

(TICK line, nevertheless discussed from technological point of view)

11.1 Introduction to the Cannon Lake line

11.1 Introduction to the Cannon Lake line -1

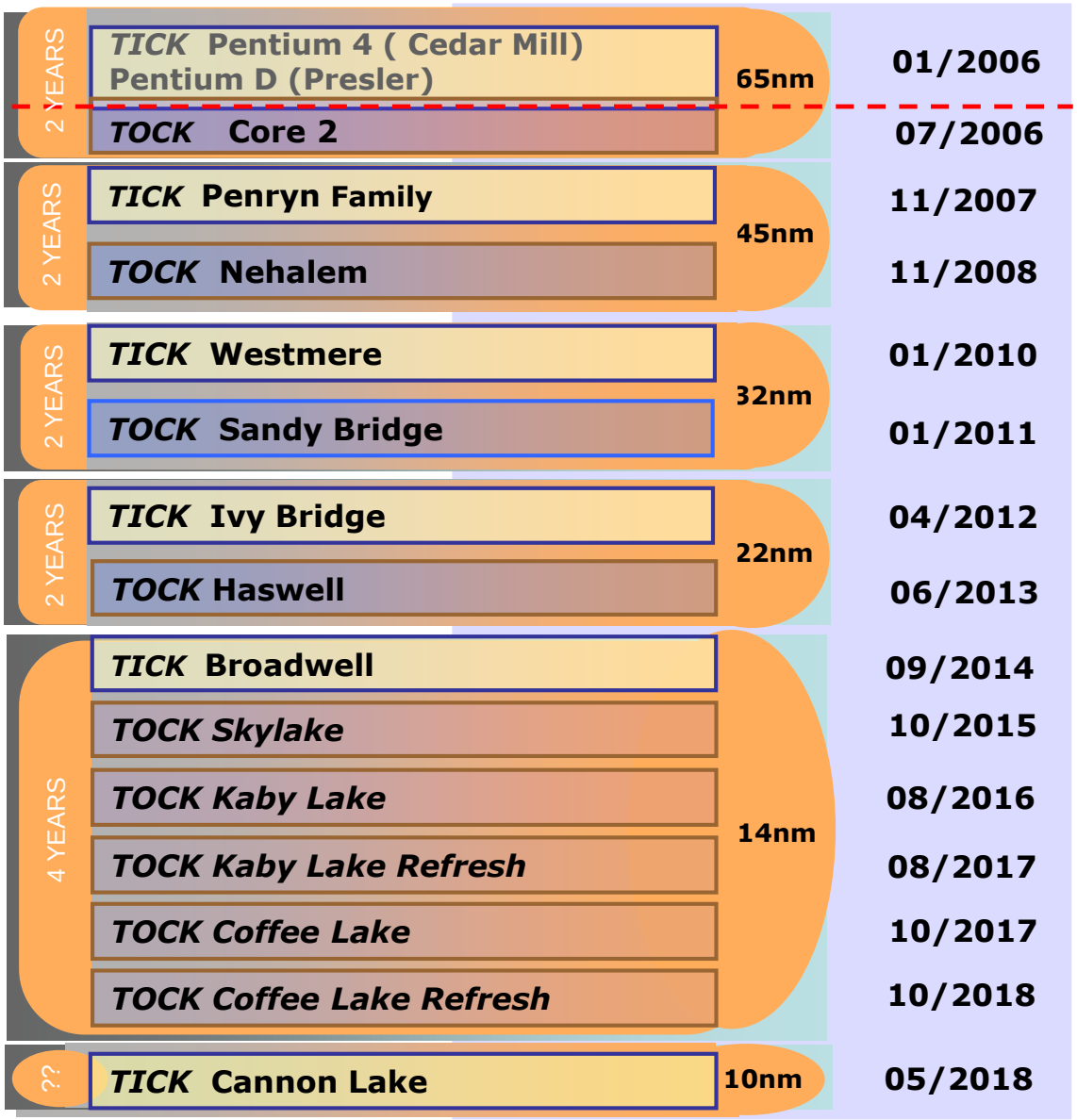
1. gen.				2. gen.	3. gen.	4. gen.	5. gen.
Core 2 New Microarch. 65 nm	Penryn New Process 45 nm	Nehalem New Microarch. 45 nm	West-mere New Process 32 nm	Sandy Bridge New Microarch. 32 nm	Ivy Bridge New Process 22 nm	Haswell New Microarchi. 22 nm	Broad-well New Process 14 nm
TOCK	***TICK***	***TOCK***	***TICK***	***TOCK***	***TICK***	***TOCK***	***TICK***
(2006)	*(2007)*	*(2008)*	*(2010)*	*(2011)*	*(2012)*	*(2013)*	*(2014)*

6. gen.	7. gen.	8. gen.[1]	9. gen.
Skylake New Microarch. 14 nm	Kaby Lake New Microarch. 14 nm	Kaby Lake R KL G-series Coffee Lake Cannon Lake 14/10 nm	Coffee Lake R New Mocroarch. 14 nm
TOCK	***TOCK***	***TOCK***	***TOCK***
(2015)	*(2016)*	*(2017/18)*	*(2018)*

[1]Astonishingly, the 8th generation encompasses four processor lines, as follows:

- Kaby Lake Refresh
- Kaby Lake G with AMD Vega graphics
- Coffee Lake (all 14 nm) and
- 10 nm Cannon Lake designs [218].

Introduction to the Cannon Lake line -2 (based on [3])



Key new features of the ISA and the microarchitecture

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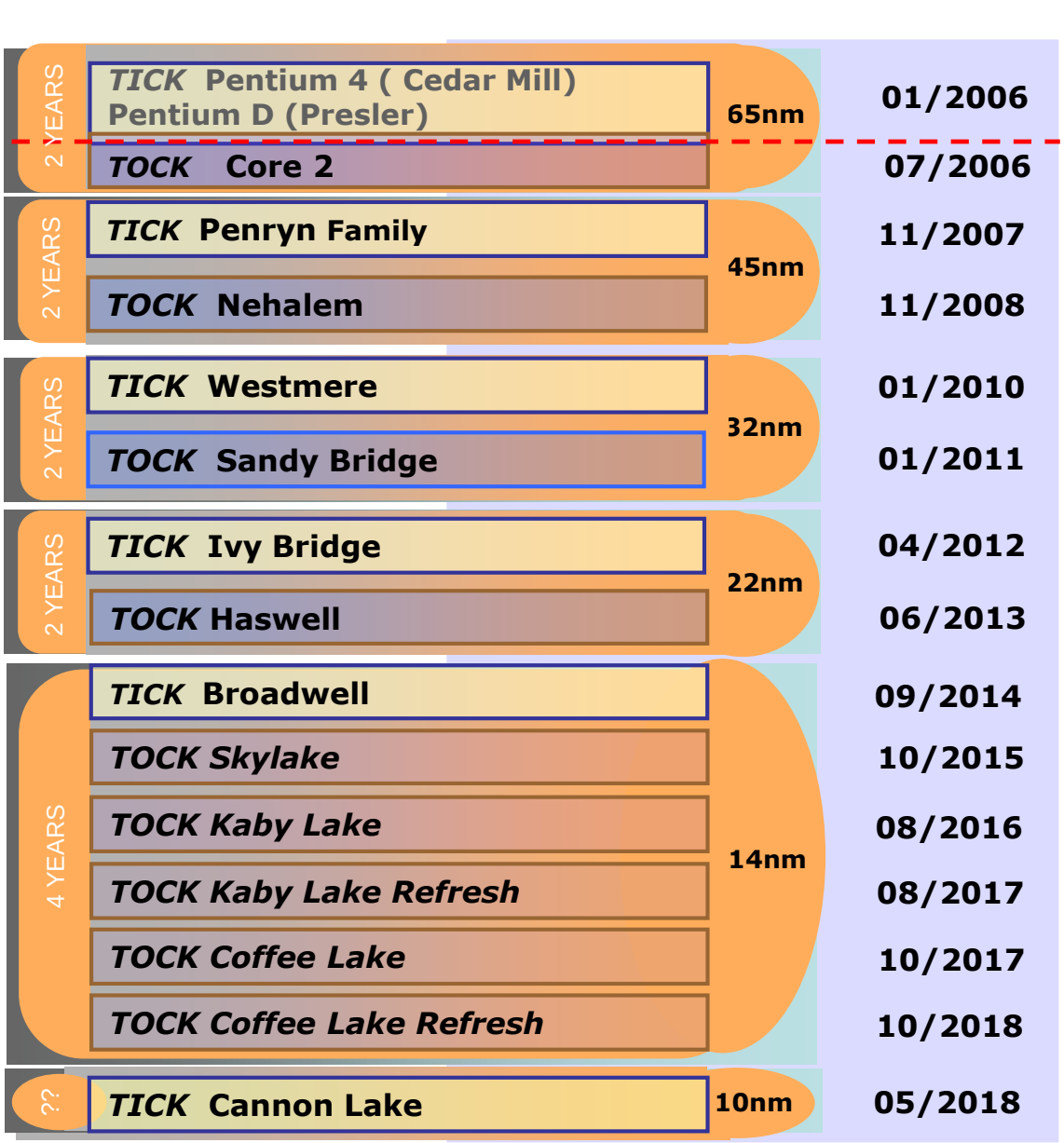
- In package integrated GPU
- New microarch.: 256-bit (FP) AVX, ring bus, integrated GPU
- New microarch.: 256-bit (FX) AVX2, L4 cache (discrete eDRAM), TSX
- Shared Virtual Memory
- New microarch.: 5-wide core, ISP, Memory Side L4 cache, no FIVR
- Optane memory, in KBL G series: in package integr. CPU, GPU, HBM2
- 6C, (PCHs of S-series DTs support: USB G2, integr. conn., Optane 2)
- 8C
- AVX512

Introduction to the Cannon Lake line -3 (based on [3])



Key new features of the power management

- Clock gating, PECI, Platform Thermal Control by 3. party controller
- EDAT
- Integrated Power Gates, PCU, Turbo Boost
- Turbo Boost 2.0
- FIVR
- 2. gen. FIVR
- Speed Shift Technology, Duty Cycle control, No FIVR except Skylake X
- Speed Shift Technology v2
- In H-series: TVB (Thermal Velocity Boost)
- STIM

11.2 The Cannon Lake line

11.2 The Cannon Lake line

Intel's technology roadmap published in 5/2011 [82]

- As a technology roadmap from 5/2011 indicates, at that time the company planned to have the 14 nm technology in 2013 and the 10 nm technology in 2015 based on a 2 year cadence for a new technology node (see the Table below)

Intel Technology Roadmap

Process Name	P1266	P1268	P1270	P1272	P1274
Lithography	45 nm	32 nm	22 nm	14 nm	10 nm
1st Production	2007	2009	2011	2013	2015

Intel's technology roadmap from 05/2011 [82]

- By contrast, Intel started production of their 14 nm Haswell line of processors in 2014 and began small volume production of 10 nm unambitious 2-core Cannon Lake parts in 2018, whereas volume production slipped to 2019.
- The first 10 nm model, launched in 5/2018 is the Core i3-8121.

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11.2 The Cannon Lake line (2)

Remark [270]

Concerning the delay of introducing the 10 nm technology Intel's CEO Brian Krzanich said during the company's April 26 2018 earnings call with financial analysts:

"We are shipping [10-nm chips] in low volume and yields are improving, but the rate of improvement is slower than we anticipated. As a result, volume production is moving from the second half of 2018 into 2019. We didn't say first or second half, but we'll do it as quickly as we can based on the yield.

We understand the yield issues and have defined improvements for them, but they will take time to implement and qualify."

11.2 The Cannon Lake line (3)

Main features of the Cannon Lake Core i3-8121U vs. the previous Kaby Lake i3-8130U -1 [271]

Intel Core i3-8121U		Intel Core i3-8130U
2.20 GHz	Frequency	**2.20 GHz**
3.20 GHz	Turbo (1 Core)	**3.40 GHz**
2.70 GHz	Turbo (All Cores)	**2.80 GHz**
2	Cores	**2**
Yes	Hyperthreading	**Yes**
4 MB	Cache	**4 MB**
No	GPU	**Intel UHD Graphics 620**
Cannon Lake	Architecture	**Coffee Lake**
DDR4-2400 SO-DIMM	Memory	**DDR4-2400 SO-DIMM**
2	Memory channels	**2**
No	ECC	**Yes**
3.0	PCIe version	**3.0**
16	PCIe lanes	**12**
10nm	Technology	**14nm**
BGA 1356	Socket	**BGA 1356**
15W	TDP	**15W**
Yes	AVX-512	**No**
Yes	AES-NI	**Yes**
VT-x, VT-x EPT, VT-d	Virtualization	**VT-x, VT-x EPT, Vt-d**
Q2/2018	Release date	**Q1/2018**

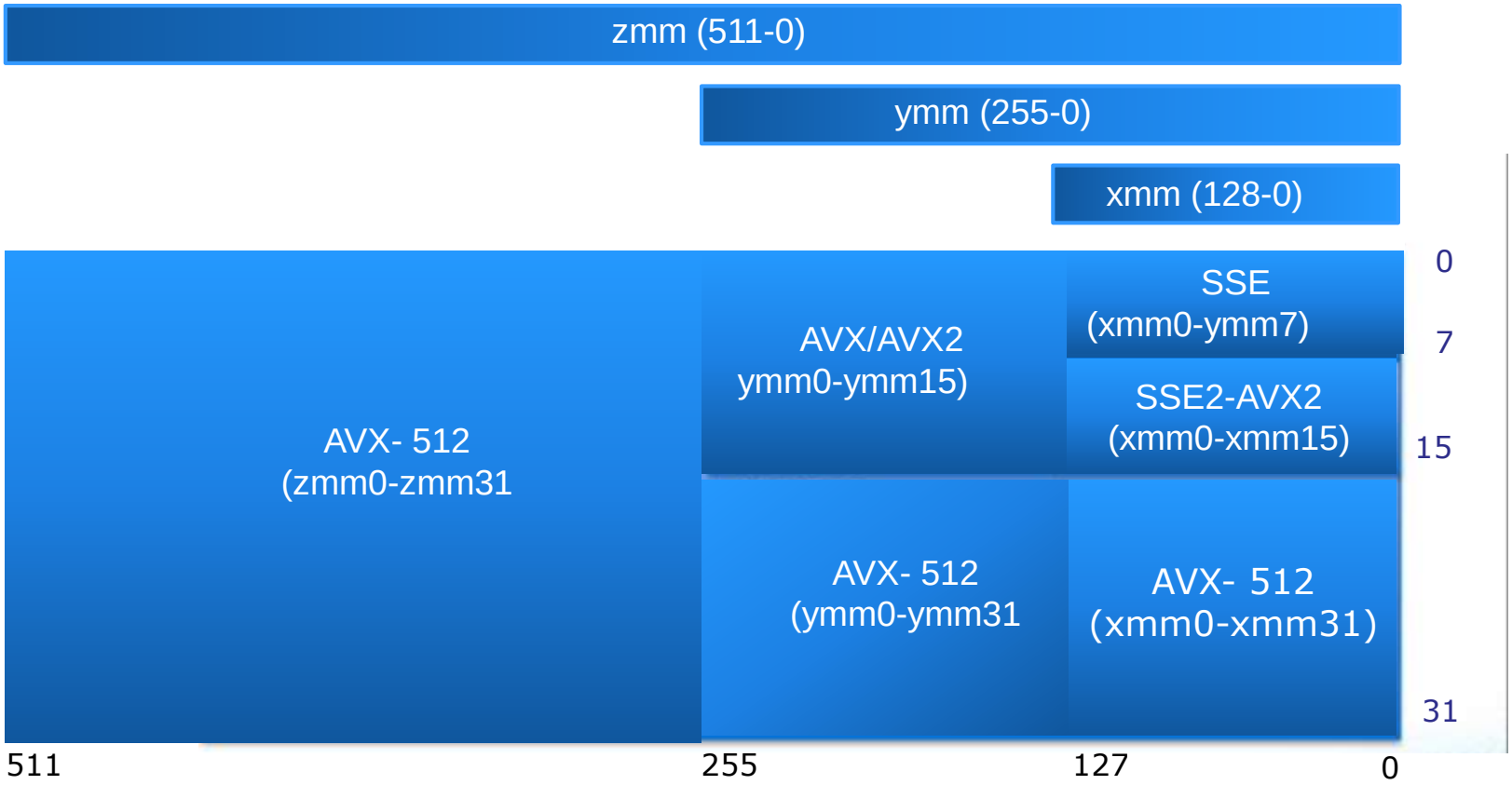
Note that the 10 nm Cannon Lake part is dubbed as a gen. 8 part.

11.2 The Cannon Lake line (4)

Main features of the Cannon Lake Core i3-8121U vs. the previous Kaby Lake i3-8130U -2 [271]

- As the comparison shows the Cannon Lake i3-8121U model has no GPU and does not show convincing benefits over the previous Kaby Lake i3-8130U model.
- The main noteworthy enhancement of the i3-8121U vs. the previous i3-8130U is that it supports AVX 512 whereas the previous processor does not.
- As industry sources reported, this model appeared already in the Lenovo IdeaPad 330 laptop in 5/2018.

Register spaces of the AVX-512 and preceding ISA extensions [293]



- The AVX-512 ISA extension supports 512-bit wide SIMD registers (zmm0-zmm31).
- The lower 256-bits of the zmm registers are aliased to the respective 256-bit ymm registers and the lower 128-bit are aliased to the respective 128-bit xmm registers.
- In 64-bit mode the AVX-512 ISA extension provides 32 xmm, ymm and zmm SIMD registers (xmm0-xmm31, ymm0-ymm31 and zmm0-zmm31).
- In 32-bit mode the number of available vector registers is still 8.

11.2 The Cannon Lake line (6)

Support of AVX-512 in Intel's processor lines [272]

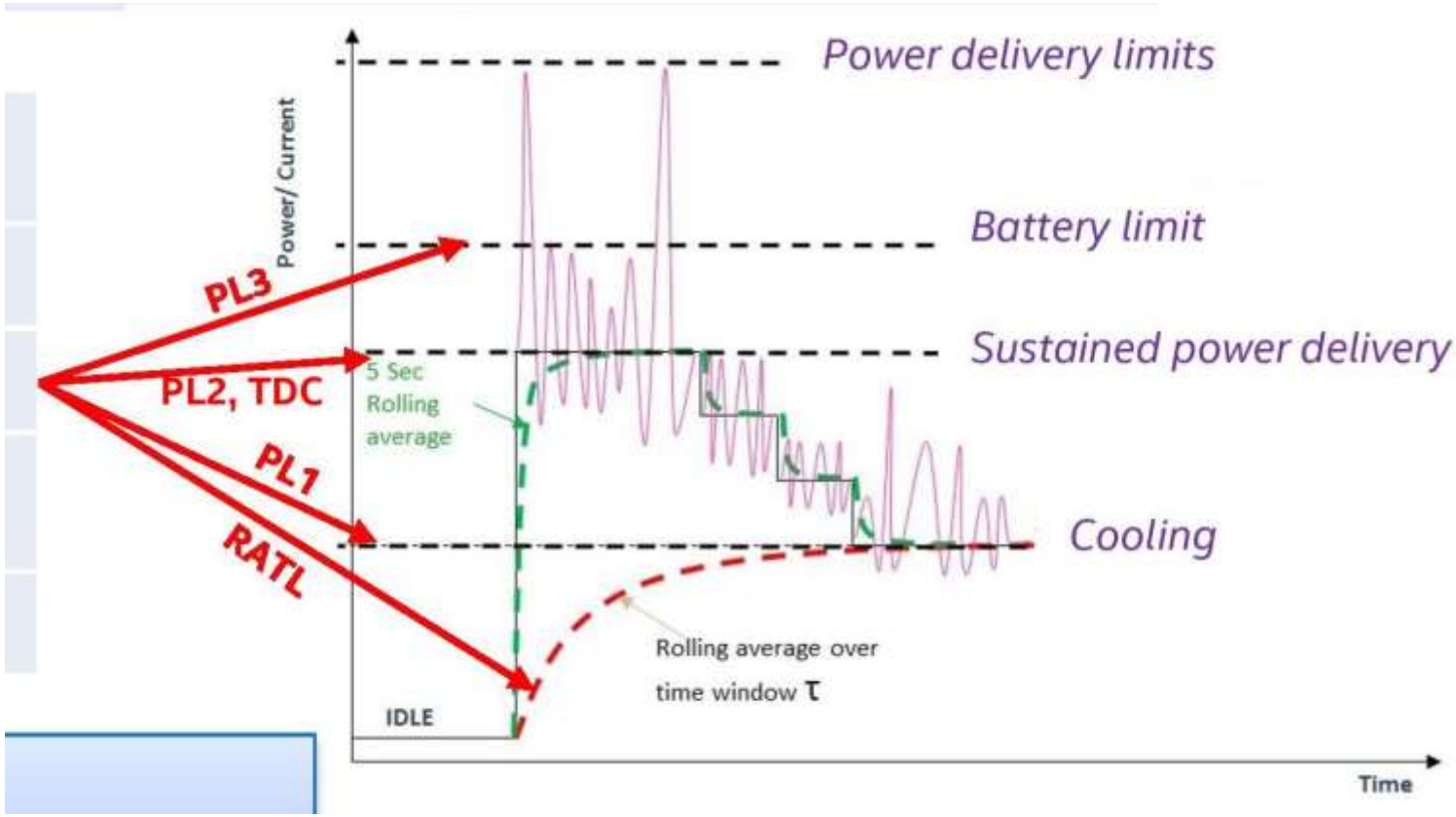
AVX-512 Support Propagation by Various Intel CPUs				
	Xeon, Core X	General	Xeon Phi	
Skylake-SP	AVX512BW AVX512DQ AVX512VL	AVX512F AVX512CD	AVX512ER AVX512PF	**Knights Landing**
Cannon Lake	AVX512VBMI AVX512IFMA			
Ice Lake	AVX512_VNNI AVX512_VBMI2 AVX512_BITALG AVX512+VAES AVX512+GFNI AVX512+VPCLMULQDQ	AVX512_VPOPCNTDQ	AVX512_4FMAPS AVX512_4VNNIW	**Knights Mill**

Source: Intel Architecture Instruction Set Extensions and Future Features Programming Reference (pages 12 and 13)

11.2 The Cannon Lake line (7)

300-Series PCHs, supported CPU models and application areas [273]

Intel's 300-Series and 240-Series PCHs			
Chipset SKU	Silicon PCH	Supported CPUs	Application
Z390	Cannon Point-H (CNP-H)	Cannon Lake Coffee Lake-S	Enthusiast Desktops
H370			Desktops
H310			
Q370			
Q360			
B360			
C246			Workstations
CM246		Cannon Lake Coffee Lake-H	Mobile Workstations
QM370			High-End Laptops
HM370			
X399		Skylake-X	High-End Desktops
9th Gen Core Platform I/O Controller	Cannon Point-LP (CNP-LP)	Cannon Point-U	Low-Power Laptop



The Intel 9th Gen Review: Core i9-9900K, Core i7-9700K and Core i5-9600K Tested
by Ian Cutress on October 19, 2018 9:00 AM EST

Here we have four horizontal lines from bottom to top: cooling limit (PL1), sustained power delivery (PL2),
battery limit (PL3), and power delivery limit.
The bottom line, the cooling limit, is effectively the TDP value. Here the power (and frequency) is limited by
the cooling at hand. It is the lowest sustainable frequency for the cooling, so for the most part TDP = PL1.
This is our '95W' value.
The PL2 value, or sustained power delivery, is what amounts to the turbo. This is the maximum sustainable
power that the processor can take until we start to hit thermal issues. When a chip goes into a turbo mode,
sometimes briefly, this is the part that is relied upon. The value of PL2 can be set by the system manufacturer,
however Intel has its own recommended PL2 values.
In this case, for the new 9 Generation Core processors, Intel has set the PL2 value to 210W. This is
essentially the power required to hit the peak turbo on all cores, such as 4.7 GHz on the eight-core Core i9-
9900K. So users can completely forget the 95W TDP when it comes to cooling. If a user wants those peak
frequencies, it's time to invest in something capable and serious.

The Intel 9th Gen Review: Core i9-9900K, Core i7-9700K and Core i5-9600K Tested
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