Skylake (microarchitecture)

Skylake[7][8] is the codename used by Intel for a processor microarchitecture which was launched in August 2015[9] succeeding the Broadwell microarchitecture.[10] Skylake is a microarchitecture redesign using the same 14 nm manufacturing process technology[11] as its predecessor Broadwell, serving as a "tock" in Intel's "tick-tock" manufacturing and design model. According to Intel, the redesign brings greater CPU and GPU performance and reduced power consumption. It has been succeeded by Kaby Lake.

Skylake is the last Intel platform on which Windows earlier than Windows 10 will be officially supported by Microsoft.[12]

1 Development history

Skylake's development, as with processors such as Banias, Dothan, Conroe, Sandy Bridge and Ivy Bridge, was primarily undertaken by Intel Israel [13] at its engineering research center in Haifa, Israel. The Haifa development team worked on the project for four years, and faced many challenges: "But by re-writing the microarchitecture and developing new concepts such as the Speed Shift Technology, we created a processor for 4.5 W to 45 W mobile devices, and up to 91 W for desktop devices."[14] The Skylake processors will be used to power a wide range of devices, from smartphones and tablets, all the way to desktops.[15] "Because of Skylake's features, companies will be able to release laptop PCs that are half as thick and half as heavy as those from five years ago," according to Intel.[16]

In September 2014, Intel announced the Skylake microarchitecture at the Intel Developer Forum in San Francisco, and that volume shipments of Skylake CPUs were scheduled for the second half of 2015. Also, the Skylake development platform was announced to be available in Q1 2015. During the announcement, Intel also demonstrated two computers with desktop and mobile Skylake prototypes: the first was a desktop testbed system, running the latest version of 3DMark, while the second computer was a fully functional laptop, playing 4K video.[17]

An initial batch of Skylake CPU models (6600K and 6700K) was announced for immediate availability during the Gamescom on August 5, 2015,[1] unusually soon after the release of its predecessor, Broadwell, which had suffered from launch delays.[18] Intel acknowledged in 2014 that moving from 22 nm (Haswell) to 14 nm (Broadwell) had been its most difficult process to develop yet, causing Broadwell's planned launch to slip by several months;[19] yet, the 14 nm production was back on track and in full production as of Q3 2014.[20] Industry observers had initially believed that the issues impacting Broadwell would also cause Skylake to slip to 2016, but Intel was able to bring forward Skylake's release and shorten Broadwell's release cycle instead.[21][22] As a result, the Broadwell architecture had an unusually short run.[21]

2 Overclocking of unsupported processors

Officially Intel supported overclocking of only the "K" versions of Skylake processors. However, it was later discovered that other "non-K" chips could be overclocked by modifying the base clock value – a process made feasible by the base clock only applying to the CPU, RAM, and integrated graphics on Skylake. Through beta UEFI firmware updates, some motherboard vendors, such as ASRock (which prominently promoted it under the name "Sky OC") allowed the base clock to be modified in this manner.[23][24]

In February 2016, however, an ASRock firmware update removed the feature. On February 9, 2016, Intel announced that it would no longer allow such overclocking of non-K processors, and that it had issued a CPU microcode update which removes the function.[25][26][27] In April 2016 ASRock started selling motherboards which allow overclocking of unsupported CPUs using an external clock generator.[28][29]

3 Operating system support

While Skylake and Kaby Lake CPUs are fully *compatible* with most existing x86/x86-64 operating systems, full *support* for all CPU features may vary depending on OS.[30]

In January 2016, Microsoft announced that it would end support of Windows 7 and Windows 8.1 on Skylake processors effective July 17, 2017; after this date, only the "most critical" updates for the two operating systems would be released for Skylake users if they have been judged not to affect the reliability of the OS on older hardware, and Windows 10 would be the only Microsoft Windows platform officially supported on Skylake, as

well as all future Intel CPU microarchitectures beginning with Skylake's successor Kaby Lake. Terry Myerson stated that Microsoft had to make a "large investment" in order to reliably support Skylake on older versions of Windows, and that future generations of processors would require further investments. Microsoft also stated that due to the age of the platform, it would be "challenging" for newer hardware, firmware, and device driver combinations to properly run under Windows 7.[31][32]

On March 18, 2016, in response to criticism over the move, primarily from enterprise customers, Microsoft announced revisions to the support policy, changing the cutoff for support and non-critical updates to July 17, 2018 and stating that Skylake users would receive all critical security updates for Windows 7 and 8.1 through the end of extended support.[33][34]

On August 11, 2016, Microsoft announced a further reprieve for users of Windows 7 and 8.x, giving support to the former until January 14, 2020, and to the latter until January 2023.[35][36]

As of Linux kernel version 4.5, Skylake mobile products are not fully supported, missing support for some Low-Power Idle States. Because of that, long term reliability can be reduced.[37]

As of OpenBSD version 6.1, Skylake is not supported, missing support for video acceleration amongst other things.[38]

4 Features

Like its predecessor, Broadwell, Skylake is available in four variants, identified by the suffixes "S" (*SKL-S*), "H" (*SKL-H*), "U" (*SKL-U*), and "Y" (*SKL-Y*). SKL-S contains an overclockable "K" variant with unlocked multipliers.[39] The H, U and Y variants are manufactured in ball grid array (BGA) packaging, while the S variant is manufactured in land grid array (LGA) packaging using a new socket, LGA 1151.[40] Skylake is used in conjunction with Intel 100 Series chipsets, also known as *Sunrise Point*.[41]

The major changes between the Haswell and Skylake architectures include the removal of the fully integrated voltage regulator (FIVR) introduced with Haswell.[42] On the variants that will use a discrete Platform Controller Hub (PCH), Direct Media Interface (DMI) 2.0 is replaced by DMI 3.0, which allows speeds of up to 8 GT/s.

Skylake's U and Y variants support one DIMM slot per channel, while H and S variants support two DIMM slots per channel.[40] Skylake's launch and sales lifespan occur at the same time as the ongoing SDRAM market transition, with DDR3 SDRAM memory gradually being replaced by DDR4 memory. Rather than working exclusively with DDR4, the Skylake microarchitecture remains backward compatible by interoperating with both types of memory. Accompanying the microarchitecture's support for both memory standards, a new SO-DIMM type capable of carrying either DDR3 or DDR4 memory chips, called UniDIMM, was also announced.[43]

Skylake's few P variants have a reduced on-die graphics unit (12 exections units enabled instead of 24 execution units) over their direct counterparts, see the table below. In contrast, with Ivy Bridge CPUs the P suffix was used for CPUs with completely disabled on-die video chipset.

Other enhancements include Thunderbolt 3.0, SATA Express, Iris Pro graphics with Direct3D feature level 12_1 with up to 128 MB of L4 eDRAM cache on certain SKUs.[44] The Skylake line of processors retires VGA support,[45] while supporting up to five monitors connected via HDMI 1.4, DisplayPort 1.2 or Embedded DisplayPort (eDP) interfaces.[46] HDMI 2.0 (4K@60 Hz) is only supported on motherboards equipped with Intel's Alpine Ridge Thunderbolt controller.[47]

The Skylake instruction set changes include Intel MPX (Memory Protection Extensions) and Intel SGX (Software Guard Extensions). Future Xeon variants will also have Advanced Vector Extensions 3.2 ("AVX-512F").[3][4]

Skylake-based laptops may use wireless technology called Rezence for charging, and other wireless technologies for communication with peripherals. Many major PC vendors have agreed to use this technology in Skylake-based laptops, which should be released by the end of 2015.[48]

The integrated GPU of Skylake's S variant supports on Windows DirectX 12 Feature Level 12_1, OpenGL 4.4 (OpenGL 4.5 on Linux[49]) and OpenCL 2.0 standards, as well as some modern hardware video encoding/decoding formats such as VP9 (GPU accelerated decode only), VP8 and HEVC (hardware accelerated 8-bit encode/decode and GPU accelerated 10-bit decode).[50][51]

Intel also released unlocked (capable of overclocking) mobile Skylake CPUs.[52]

Unlike previous generations, Skylake-based Xeon E3 no longer works with a desktop chipset that supports the same socket, and requires either the C232 or the C236 chipset to operate.

5 Architecture

- Improved front-end, deeper out-of-order buffers, improved execution units, more execution units (third vector integer ALU(VALU)) for five ALUs in total, more load/store bandwidth, improved hyper-threading (wider retirement), speedup of AES-GCM and AES-CBC by 17% and 33% accordingly.[53][54]

- 14 nm manufacturing process[55]
- LGA 1151 socket for desktop processors
- 100 Series chipset (Sunrise Point)[56]
- Thermal design power (TDP) up to 95 W (LGA 1151)[57]
- Support for both DDR3L SDRAM and DDR4 SDRAM in mainstream variants, using custom UniDIMM SO-DIMM form factor[58][59][60] with up to 64 GB of RAM on LGA 1151 variants. Usual DDR3 memory is also supported by certain motherboard vendors even though Intel doesn't officially support it.[61][62]
- Support for 16 PCI Express 3.0 lanes from CPU, 20 PCI Express 3.0 lanes from PCH (LGA 1151)
- Support for Thunderbolt 3 (Alpine Ridge)[63]
- 64 to 128 MB L4 eDRAM cache on certain SKUs
- Up to four cores as the default mainstream configuration[58]
- AVX-512: F, CDI, VL, BW, and DQ for some future Xeon variants, but not Xeon E3[3]
- Intel MPX (Memory Protection Extensions)
- Intel SGX (Software Guard Extensions)
- Intel Speed Shift[64]
- Skylake's integrated Gen9 GPU supports Direct3D 12 at the feature level 12_1[7][65][66]
- Full fixed function HEVC Main/8bit encoding/decoding acceleration. Hybrid/Partial HEVC Main10/10bit decoding acceleration. JPEG encoding acceleration for resolutions up to 16,000×16,000 pixels. Partial VP9 encoding/decoding acceleration.[67]

6 Configurations

Skylake processors are produced in four main families: Y, U, H and S. Multiple configurations are available within each family:[40]

7 List of Skylake processors

7.1 Desktop processors

Common features of the desktop Skylake CPUs:

- LGA 1151 socket, except for Skylake-**R** CPUs which feature socket FCBGA1440[68]
- DMI 3.0 and PCIe 3.0 interfaces
- Dual channel memory support in the following configurations: DDR3L-1600 1.35 V (32GiB maximum) or DDR4-2133 1.2 V (64GiB maximum). DDR3 is unofficially supported through some motherboard vendors[69][70][71]
- 16 PCI-E 3.0 lanes
- The Core-branded processors support the AVX2 instruction set. The Celeron and Pentium-branded ones support only SSE4.1/4.2.
- 350 MHz base graphics clock rate

7.2 Mobile processors

See also "Server, Mobile" below for mobile workstation processors.

7.3 Server processors

E3 series server chips all consist of System Bus 9 GT/s, max. memory bandwidth of 34.1 GB/s dual channel memory. Unlike its predecessor, the Skylake Xeon CPUs require either a C232 or a C236 chipset to operate.

8 See also

- List of Intel CPU microarchitectures

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