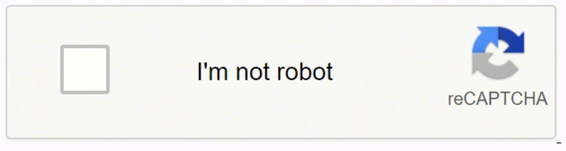

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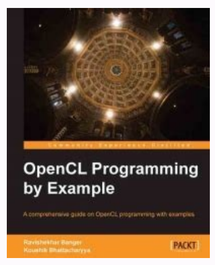

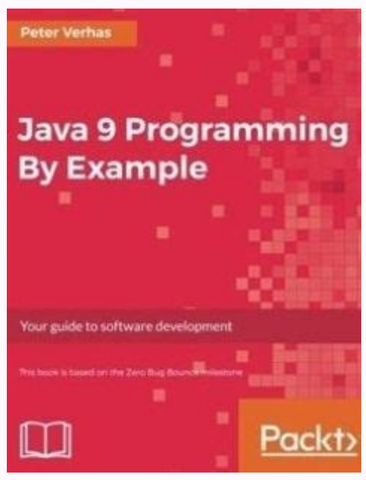

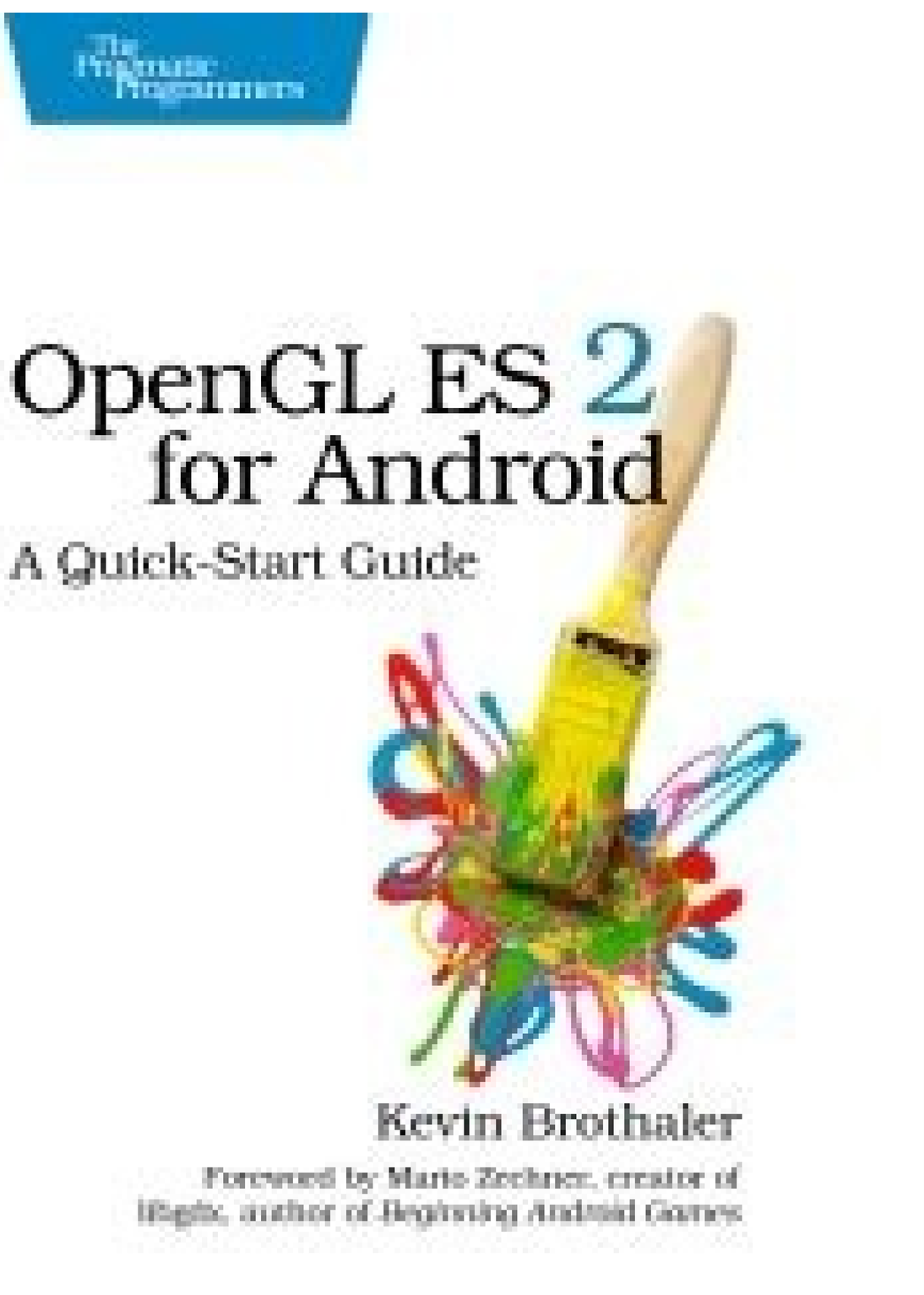

^ Trevett, Neil (April 2016). ibm.com. June 9, 2008. FreeBSD. Retrieved December 23, 2015. For example, the z/OS operating system takes this approach, requiring program code to reside in 31-bit address spaces (the high order bit is not used in address calculation on the underlying hardware platform) while data objects can optionally reside in 64-bit regions. When these architectures were devised, 4 GiB of memory was so far beyond the typical amounts (4 MiB) in installations, that this was considered to be enough headroom for addressing. Machine learning has been suggested to solve this problem: Grewe and O'Boyle describe a system of support-vector machines trained on compile-time features of program that can decide the device partitioning problem statically, without actually running the programs to measure their performance.[185] In a comparison of actual graphic cards of AMD RDNA 2 and Nvidia RTX Series there is an undecided result by OpenCL-Tests. Archived from the original on October 31, 2013. ^ "Cray-1 Computer System Hardware Reference Manual" (PDF). Retrieved Jun 24, 2020. "Intel's Beignet OpenCL Is Still Slowly Baking". By the mid-1990s, HAL Computer Systems, Sun Microsystems, IBM, Silicon Graphics, and Hewlett Packard had developed 64-bit architectures for their workstation and server systems. "The OpenCL C++ 1.0 Specification" (PDF). This opens up a smooth transition path to C++ functionality for the OpenCL kernel code developers as they can continue using familiar programming flow and even tools as well as leverage existing extensions and libraries available for OpenCL C. ^ "AMD64 Programmer's Manual Volume 2: System Programming" (PDF). ISBN 978-1-4799-1010-6. A processor that can hold all values and variables in registers can loop through them with no need to move data between registers and memory for each iteration. C code should prefer (u)intptr_t instead of long when casting pointers into integer objects. 01.org. Retrieved October 8, 2013. (October 2021) (Learn how and when to remove this template message) OpenCL APIOriginal author(s)Apple Inc.Developer(s)Khronos GroupInitial releaseAugust 28, 2009; 12 years ago (2009-08-28)Stable release3.0[1] / September 30, 2020; 19 months ago (2020-09-30) Written inC with C++ bindingsOperating systemAndroid (vendor dependent),[2] FreeBSD,[3] Linux, macOS (via Pocl), WindowsPlatformARMv7, ARMv8,[4] Cell, IA-32, Power, x86-64TypeHeterogeneous computing APILicenseOpenCL specification licenseWebsitewww.khronos.org/opencl/ OpenCL C/C++ and C++ for OpenCLParadigmImperative (procedural), structured, (C++ only) object-oriented, generic programmingFamilyCStable releaseOpenCL C++ 1.0 revision V2.2-11[5] OpenCL C 3.0 revision V3.0.7[6] C++ for OpenCL 1.0 revision 2[7] / March 31, 2021; 13 months ago (2021-03-31) Typing disciplineStatic, weak, manifest, nominalImplementation languageImplementation specificFilename extensions.cl .clcppWebsitewww.khronos.org/openclMajor implementationsAMD, Gallium Compute, IBM, Intel NEO, Intel SDK, Texas Instruments, Nvidia, POCL, ArmInfluenced byC99, CUDA, C++14, C++17 OpenCL (Open Computing Language) is a framework for writing programs that execute across heterogeneous platforms consisting of central processing units (CPUs), graphics processing units (GPUs), digital signal processors (DSPs), field-programmable gate arrays (FPGAs) and other processors or hardware accelerators. MIPS Technologies, Inc. Archived from the original (PDF) on July 26, 2020. Retrieved April 27, 2020. This allowed those Macs to support 64-bit processes while still supporting 32-bit device drivers; although not 64-bit drivers and performance advantages that can come with them. releases.llvm.org. Retrieved May 9, 2015. The disadvantage of the LP64 model is that storing a long into an int truncates. Retrieved October 30, 2009. This is a problem, as memory mapping, if properly implemented by the OS, is one of the most efficient disk-to-memory methods. Proc. Another consideration is the data model used for device drivers. ^ "WebCL Latest Spec". Some operating systems reserve portions of process address space for OS use, effectively reducing the total address space available for mapping memory for user programs. ^ "VIA Unveils Details of Next-Generation Isaiah Processor Core". For instance, 32-bit Windows reserves 1 or 2 GiB (depending on the settings) of the total address space for the kernel, which leaves only 3 or 2 GiB (respectively) of the address space available for user mode. Computing in Science & Engineering. AMD decided to support OpenCL instead of the now deprecated Close to Metal in its Stream framework.[44][45] RapidMind announced their adoption of OpenCL underneath their development platform to support GPUs from multiple vendors with one interface.[46] On December 9, 2008, Nvidia announced its intention to add full support for the OpenCL 1.0 specification to its GPU Computing Toolkit.[47] On October 30, 2009, IBM released its first OpenCL implementation as a part of the XL compilers.[48] Acceleration of calculations with factor to 1000 are possible with OpenCL in graphic cards against normal CPU.[49] Some important features of next Version of OpenCL are optional in 1.0 like double- or half-precision operations.[50] OpenCL 1.1 OpenCL 1.1 was ratified by the Khronos Group on June 14, 2010[51] and adds significant functionality for enhanced parallel programming flexibility, functionality, and performance including: New data types including 3-component vectors and additional image formats; Handling commands from multiple host threads and processing buffers across multiple devices; Operations on regions of a buffer including read, write and copy of 1D, 2D, or 3D rectangular regions; Enhanced use of events to drive and control command execution; Additional OpenCL built-in C functions such as integer clamp, shuffle, and asynchronous strided copies; Improved OpenGL interoperability through efficient sharing of images and buffers by linking OpenCL and OpenGL events. ^ "ILP32 for AArch64 Whitepaper". ^ "Imagination Technologies launches advanced, highly-efficient POWERVR SGX543MP multi-processor graphics IP family". Enhanced image support (optional): 1.2 adds support for 1D images and 1D/2D image arrays. Archived from the original on April 5, 2009. ^ "Apple devices in 2018". ^ "Khronos Releases OpenCL 2.1 Provisional Specification for Public Review". ^ "OpenCL - Open Computing Language Bindings". Archived from the original on December 2, 2009. Retrieved 30 November 2010. Retrieved August 14, 2008. AtariAge. Intel Software. Retrieved September 13, 2010. www.phoronix.com. This creates the potential to harness GPU and multi-core CPU parallel processing from a Web browser.[132][133] March 31, 2011: IBM released a fully conformant version of OpenCL 1.1.[4][134] April 25, 2011: IBM released OpenCL Common Runtime v0.1 for Linux on x86 Architecture.[135] May 4, 2011: Nokia Research releases an open source WebCL extension for the Firefox web browser, providing a JavaScript binding to OpenCL.[136] July 1, 2011: Samsung Electronics releases an open source prototype implementation of WebCL for WebKit, providing a JavaScript binding to OpenCL.[137] August 8, 2011: AMD released the OpenCL-driven AMD Accelerated Parallel Processing (APP) Software Development Kit (SDK) v2.5, replacing the ATI Stream SDK as technology and concept.[138] December 12, 2011: AMD released AMD APP SDK v2.6[139] which contains a preview of OpenCL 1.2. February 27, 2012: The Portland Group released the PGI OpenCL compiler for multi-core ARM CPUs.[140] April 17, 2012: Khronos released a WebCL working draft.[141] May 6, 2013: Altera released the Altera SDK for OpenCL, version 13.0.[142] It is conformant to OpenCL 1.0.[143] November 18, 2013: Khronos announced that the specification for OpenCL 2.0 had been finalized.[144] March 19, 2014: Khronos releases the WebCL 1.0 specification.[145][146] August 29, 2014: Intel releases HD Graphics 5300 driver that supports OpenCL 2.0.[147] September 25, 2014: AMD releases Catalyst 14.41 RC1, which includes an OpenCL 2.0 driver.[148] January 14, 2015: Xilinx Inc. Uses the new Khronos SPIR-V 1.1 intermediate language which fully supports the OpenCL C++ kernel language. December 8, 2008. Retrieved February 24, 2016. The range of integer values that can be stored in 64 bits depends on the integer representation used. 32-bit applications are no longer compatible. Archived from the original on 2007-10-11. "Pushing the Limits of Windows: Physical Memory". Google Docs. ^ "Taking Radeon ROCm 2.0 OpenCL For A Benchmarking Test Drive - Phoronix". In response, MIPS and DEC developed 64-bit microprocessor architectures, initially for high-end workstation and server machines. Lecture Notes in Computer Science. W.; et al. woachk, security researcher. OpenCL is based on the C programming language and has been proposed as an open standard. ^ Mark Russinovich (2008-07-21). S2CID 9905244. ^ "Khronos Announces OpenCL 2.1: C++ Comes to OpenCL". Open standard for programming heterogenous computing systems, such as CPUs or GPUs Not to be confused with OpenGL. ^ "OpenCL Demo, AMD CPU". ^ "Intel OpenCL SDK – Release Notes". Archived from the original on August 1, 2014. ^ "Intel 64 and IA-32 Architectures Software Developer's Manual Volume 3A: System Programming Guide, Part 1" (PDF). ARM Holdings. OpenCL Next may integrate extensions such as Vulkan / OpenCL Interop, Scratch-Pad Memory Management, Extended Subgroups, SPIR-V 1.4 ingestion and SPIR-V Extended debug info. 1983 Elxsi launches the Elxsi 6400 parallel minisupercomputer. 2006-11-01. High-end printers, network equipment, and industrial computers, also used 64-bit microprocessors, such as the Quantum Effect Devices R5000.[citation needed] 64-bit computing started to trickle down to the personal computer desktop from 2003 onward, when some models in Apple's Macintosh lines switched to PowerPC 970 processors (termed G5 by Apple), and Advanced Micro Devices (AMD) released its first 64-bit x86-64 processor. ^ "Radeon ROCm 3.10 Released with Data Center Tool Improvements, New APIs - Phoronix". OpenCL C language OpenCL C[20] is a C99-based language dialect adapted to fit the device model in OpenCL. Pros and cons A common misconception is that 64-bit architectures are no better than 32-bit architectures unless the computer has more than 4 GiB of random-access memory.[34] This is not entirely true: Some operating systems and certain hardware configurations limit the physical memory space to 3 GiB on IA-32 systems, due to much of the 3–4 GiB region being reserved for hardware addressing; see 3 GiB barrier; 64-bit architectures can address far more than 4 GiB. doi:10.1145/1165754.1165766. doi:10.1145/3203217.3203244. Retrieved June 24, 2014. Retrieved 2007-05-03. ^ "D binding for OpenCL". Phoronix. alphaWorks. ^ "mesa/mesa - The Mesa 3D Graphics Library". PR Newswire. Retrieved October 23, 2009. ^ "Welcome to Wikis". Archived from the original on September 17, 2014. Building on Clang and LLVM.[103] With version 1.0 OpenCL 1.2 was nearly fully implemented along with some 2.x features.[104] Version 1.2 is with LLVM/CLANG 6.0, 7.0 and Full OpenCL 1.2 support with all closed tickets in Milestone 1.2.[104][105] OpenCL 2.0 is nearly full implemented.[106] Version 1.3 Supports Mac OS X.[107] Version 1.4 includes support for LLVM 8.0 and 9.0.[108] Version 1.5 implements LLVM/Clang 10 support.[109] Version 1.6 implements LLVM/Clang 11 support and CUDA Acceleration.[110] Actual targets are complete OpenCL 2.x, OpenCL 3.0 and improvement of performance. "Live Update: WWDC 2009 Keynote". 2001 Intel ships its IA-64 processor line, after repeated delays in getting to market. June 3, 2020: AMD announced RocM 3.5 with OpenCL 2.2 support.[158] September 30, 2020: Khronos announced that the specifications for OpenCL 3.0 had been finalized (CTS also available). ^ "OpenCL Demo, Nvidia GPU". ^ "AMD and Havok demo OpenCL accelerated physics". Archived from the original (PDF) on March 19, 2012. ^ "OpenCL Development Kit for Linux on Power". ^ "Khronos Releases OpenCL 1.2 Specification". Retrieved February 10, 2014. In most processors, only integer or address-registers can be used to address data in memory; the other types of registers cannot. Retrieved August 6, 2009. ^ Peter Seebach (2006). ^ "Archived copy". Retrieved August 8, 2017. SIGGRAPH2008. AMD showed a CPU-accelerated OpenCL demo explaining the scalability of OpenCL on one or more cores while Nvidia showed a GPU-accelerated demo.[119][120] March 16, 2009: at the 4th Multicore Expo, Imagination Technologies announced the PowerVR SGX543MP, the first GPU of this company to feature OpenCL support.[121] March 26, 2009: at GDC 2009, AMD and Havok demonstrated the first working implementation for OpenCL accelerating Havok Cloth on AMD Radeon HD 4000 series GPU.[122] April 20, 2009: Nvidia announced the release of its OpenCL driver and SDK to developers participating in its OpenCL Early Access Program.[123] August 5, 2009: AMD unveiled the first development tools for its OpenCL platform as part of its ATI Stream SDK v2.0 Beta Program.[124] August 28, 2009: Apple released Mac OS X Snow Leopard, which contains a full implementation of OpenCL.[125] September 28, 2009: Nvidia released its own OpenCL drivers and SDK implementation. Retrieved April 28, 2015. April 25, 2005. Applications such as multi-tasking, stress testing, and clustering – for high-performance computing (HPC) – may be more suited to a 64-bit architecture when deployed appropriately. __kernel void matvec(__global const float *A, __global const float *x, uint ncols, __global float *y) { size_t i = get_global_id(0); // Global id, used as the row index __global float const *a = &A[i*ncols]; // Pointer to the i'th row float sum = 0.f; // Accumulator for dot product for (size_t j = 0; j < ncols; j++) { sum += a[j] * x[j]; } y[i] = sum; } The kernel function matvec computes, in each invocation, the dot product of a single row of a matrix A and a vector x: $y_i = a_{i,:} \cdot x = \sum_j a_{i,j} x_j$ {\displaystyle $y_{i}=a_{i,:}\cdot x=\sum _{j}a_{i,j}x_{j}$} . ^ a b "NVIDIA is Now OpenCL 3.0 Conformant". March 14, 2019. ^ a b "Cray C/C++ Reference Manual". Depending on the language features used in such kernel sources it can also be executed on devices supporting earlier OpenCL versions or OpenCL 3.0. Aside from OpenCL drivers kernels written in C++ for OpenCL can be compiled for execution on Vulkan devices using clspv[38] compiler and clvk[39] runtime layer just the same way as OpenCL C kernels. doi:10.1109/ICPP.2011.45. 8 Broadwell + Gen. "PA-8000 Combines Complexity and Speed". Some supercomputer architectures of the 1970s and 1980s, such as the Cray-1,[3] used registers up to 64 bits wide, and supported 64-bit integer arithmetic, although they did not support 64-bit addressing. In many programming environments for C and C-derived languages on 64-bit machines, int variables are still 32 bits wide, but long integers and pointers are 64 bits wide. "Microsoft nixes Windows XP for Itanium". ^ Henry Spencer. Intel maintains that its Itanium chips would remain its only 64-bit processors. arXiv:1005.2581v3 [cs.PF]. August 20, 2019. June 9, 2015. The 1024 length FFT is decomposed into // calls to a radix 16 function, another radix 16 function and then a radix 4 function __kernel void fft1D_1024 (__global float2 *in, __global float2 *out, __local float *sMemx, __local float *sMemy) { int tid = get_local_id(0); int blockIdx = get_group_id(0) * 1024 + tid; float2 data[16]; // starting index of data to/from global memory in = in + blockIdx; out = out + blockIdx; globalLoads(data, in, 64); // coalesced global reads fftRadix16Pass(data); // in-place radix-16 pass twiddleFactorMul(data, tid, 1024, 0); // local shuffle using local memory localShuffle(data, sMemx, sMemy, tid, (((tid & 15) * 65) + (tid >> 4))); fftRadix16Pass(data); // in-place radix-16 pass twiddleFactorMul(data, tid, 64, 4); // twiddle factor multiplication localShuffle(data, sMemx, sMemy, tid, (((tid >> 4) * 64) + (tid & 15))); // four radix-4 function calls fftRadix4Pass(data); // radix-4 function number 1 fftRadix4Pass(data + 4); // radix-4 function number 2 fftRadix4Pass(data + 8); // radix-4 function number 3 fftRadix4Pass(data + 12); // radix-4 function number 4 // coalesced global writes globalStores(data, out, 64); })" A full, open source implementation of an OpenCL FFT can be found on Apple's website.[24] C++ for OpenCL language In 2020, Khronos announced[25] the transition to the community driven C++ for OpenCL programming language[26] that provides features from C++17 in combination with the traditional OpenCL C features. OpenCL 1.2 functionality has become a mandatory baseline, while all OpenCL 2.x and OpenCL 3.0 features were made optional. Older machines that are unable to run the 64-bit kernel run the 32-bit kernel, but, as with earlier releases, can still run 64-bit applications; Lion does not support machines with 32-bit processors. March 13, 2015. Archived from the original on November 1, 2009. To unlock the hardware potential, the device runtime uses a push-based task dispatching strategy and the performance of the kernel atomics is improved significantly. ^ Richard L. "Is your X code ready for 64-bit?". doi:10.1109/38.31467. doi:10.1007/s10766-014-0320-y. ^ Gianelli, Silvia E. Support for hardware made before early 2007, was problematic for open-source platforms,[citation needed] due to the relatively small number of users. Architectural implications Processor registers are typically divided into several groups: integer, floating-point, single instruction, multiple data (SIMD), control, and often special registers for address arithmetic which may have various uses and names such as address, index, or base registers. W. They also showed two demos. Int'l Conf. P. Retrieved August 11, 2011. Retrieved December 7, 2009. "Exploring 64-bit development on POWER5: How portable is your code, really?". ^ "A Nice Overview Of The ROCm Linux Compute Stack - Phoronix". AMD Developer Central. ^ "ATI Stream Software Development Kit (SDK) v2.0 Beta Program". ISBN 0-02-935671-7. Oracle. O'Connell; S. ^ "i860 Processor Family Programmer's Reference Manual" (PDF). ^ "Radeon RX 6800 Series Has Excellent ROCm-Based OpenCL Performance on Linux". (2011). POCL A portable implementation supporting CPUs and some GPUs (via CUDA and HSA). Intel ships updated versions of its Xeon and Pentium 4 processor families supporting the new 64-bit instruction set. Retrieved 2010-11-19. November 10, 2008. Example: computing the FFT This example will load a fast Fourier transform (FFT) implementation and execute it. May 16, 2017. doi:10.1109/MuCoCoS.2013.6633603. 1998-01-20. Retrieved April 18, 2021.{{cite web}}: CS1 maint: url-status (link) ^ a b c Aaftab Munshi, ed. For example, although the x86/x87 architecture has instructions able to load and store 64-bit (and 32-bit) floating-point values in memory, the internal floating point data and register format is 80 bits wide, while the general-purpose registers are 32 bits wide. Nvidia. February 7, 2018. Archived from the original on August 4, 2011. ^ bare URL PDF] ^ bare URL PDF] ^ "Using Semaphore and Memory Sharing Extensions for Vulkan Interop with NVIDIA OpenCL". Each vendor must implement each OpenCL call in their driver.[72] The Apple,[73] Nvidia,[74] ROCm, RapidMind[75] and Gallium3D[76] implementations of OpenCL are all based on the LLVM Compiler technology and use the Clang compiler as their frontend. April 6, 2021: Nvidia supports OpenCL 3.0 for Ampere. Unsourced material may be challenged and removed. Archived from the original on January 17, 2021. 4 (8): 85–94. The 32-bit versions of libraries have been removed by Apple in macOS Catalina (10.15). It was released on November 16, 2015.[55] It introduced the OpenCL C++ kernel language, based on a subset of C++14, while maintaining support for the preexisting OpenCL C kernel language. May 14, 2018. Apple submitted this initial proposal to the Khronos Group. February 2009. ^ "Intel OpenCL 2.0 Driver". www.khronos.org. ^ "Welcome to AMD ROCm™ Platform — ROCm Documentation 1.0.0 documentation". AMD. ^ "WebCL 1.0 Press Release". ^ "01.org Intel Open Source - Compute Runtime". Retrieved March 28, 2009. ^ "Android Devices With OpenCL support". 1992 Digital Equipment Corporation (DEC) introduces the pure 64-bit Alpha architecture which was born from the PRISM project.[11] 1994 Intel announces plans for the 64-bit IA-64 architecture (jointly developed with Hewlett-Packard) as a successor to its 32-bit IA-32 processors. August 1998. Consistency between the various levels in the hierarchy is relaxed, and only enforced by explicit synchronization constructs, notably barriers. ^ a b Fang, Jianbin; Varbanescu, Ana Lucia; Sips, Henk (2011). This is useful for reserving areas of the device to reduce latency for time-critical tasks. Linux and most other Unix-like operating systems, and the C and C++ toolchains for them, have supported 64-bit processors for many years. ^ "OpenCL ICD Specification". Ottawa Linux Symposium 2001. There are also systems with 64-bit processors using an ILP32 data model, with the addition of 64-bit long long integers; this is also used on many platforms with 32-bit processors. ^ Larabel, Michael (April 16, 2013). The latest is the Fujitsu Supernova, which emulates the original environment on 64-bit Intel processors. ^ Gall, T.; Pitney, G. auto res = num1 * num2; // Every work-item writes 2 consecutive items to the output buffer. Retrieved August 20, 2019. LP64 Interface". If a processor can keep only two or three values or variables in registers, it would need to move some values between memory and registers to be able to process variables d and e also; this is a process that takes many CPU cycles. ^ Tompson, Jonathan; Schlachter, Kristofer (2012). Due to the rich variety of C++ language features, applications written in C++ for OpenCL can express complex functionality more conveniently than applications written in OpenCL C and in particular generic programming paradigm from C++ is very attractive to the library developers. December 10, 2008. ^ a b "OpenCL 2.2 Maintenance Update Released". NEO An implementation by Intel for Gen. ^ "beignet - Beignet OpenCL Library for Intel Ivy Bridge and newer GPUs". Retrieved March 17, 2017. With no further qualification, a 64-bit computer architecture generally has integer and addressing processor registers that are 64 bits wide, allowing direct support for 64-bit data types and addresses. pp. 89–90. Kendall Square Research deliver their first KSR1 supercomputer, based on a proprietary 64-bit RISC processor architecture running OSF/1. The size of these registers therefore normally limits the amount of directly addressable memory, even if there are registers, such as floating-point registers, that are wider. [113] Shamrock A Port of Mesa Clover for ARM with full support of OpenCL 1.2,[114] [115] no actual development for 2.0. FreeOCL A CPU focused implementation of OpenCL 1.2 that implements an external compiler to create a more reliable platform,[116] no actual development. S2CID 225784. Bibcode:2010CSE....12c..66S. complex_t operator*(const complex_t &other) const { return {m_re * other.m_re - m_im * other.m_im, m_re * other.m_im + m_im * other.m_re}; } T get_re() const { return m_re; } T get_im() const { return m_im; } }; // A helper function to compute multiplication over complex numbers read from // the input buffer and to store the computed result into the output buffer. Retrieved April 18, 2021.{{cite web}}: CS1 maint: url-status (link) ^ "Mali SDK Supporting Compilation of Kernels in C++ for OpenCL". Retrieved June 9, 2008. 43 (5): 752–785. Updates to the OpenCL API include: Additional subgroup functionality Copying of kernel objects and states Low-latency device timer queries Ingestion of SPIR-V code by runtime Execution priority hints for queues Zero-sized dispatches from host AMD, ARM, Intel, HPC, and YetiWare have declared support for OpenCL 2.1.[56][57] OpenCL 2.2 OpenCL 2.2 brings the OpenCL C++ kernel language into the core specification for significantly enhanced parallel programming productivity.[58][59][60] It was released on May 16, 2017.[61] Maintenance Update released in May 2018 with bugfixes.[62] The OpenCL C++ kernel language is a static subset of the C++14 standard and includes classes, templates, lambda expressions, function overloads and many other constructs for generic and meta-programming. It is possible to run any OpenCL kernel on any conformant implementation. doi:10.1016/j.parco.2011.09.001. However, not all 64-bit instruction sets support full 64-bit virtual memory addresses; x86-64 and ARMv8, for example, support only 48 bits of virtual address, with the remaining 16 bits of the virtual address required to be all 0's or all 1's, and several 64-bit instruction sets support fewer than 64 bits of physical memory address. Warner Books. This language allows to leverage a rich variety of language features from standard C++ while preserving backward compatibility to OpenCL C. OpenCL specifies programming languages (based on C99, C++14 and C++17) for programming these devices and application programming interfaces (APIs) to control the platform and execute programs on the compute devices. This problem is solved by having the OS take the memory restrictions of the device into account when generating requests to drivers for DMA, or by using an input–output memory management unit (IOMMU). "The OpenCL C Specification Version: 3.0 Document Revision: V3.0.7" (PDF). ^ "A description of the differences between 32-bit versions of Windows Vista and 64-bit versions of Windows Vista". Xilinx. March 3, 2015. 1977. 64-bit drivers were not provided for many older devices, which could consequently not be used in 64-bit systems. ^ Grewe, Dominik; O'Boyle, Michael F. ^ "IBM releases OpenCL Development Kit for Linux on Power v0.3 – OpenCL 1.1 conformant release available". Microsoft releases Windows 11 on October 5, which only supports 64-bit systems, dropping support for IA-32 systems. A 64-bit processor may have backward compatibility, allowing it to run 32-bit application software for the 32-bit version of its instruction set, and may also support running 32-bit operating systems for the 32-bit version of its instruction set. "Khronos Announcements and Panel Discussion" (PDF).{{cite web}}: CS1 maint: url-status (link) ^ Stulova, Anastasia; Hickey, Neil; van Haastregt, Sven; Antognini, Marco; Petit, Kevin (April 27, 2020). W7 Forums. A 64-bit register can hold any of 264 (over 18 quintillion or 1.8×1019) different values. Archived from the original on February 18, 2015. Retrieved October 15, 2013. "NVIDIA enables OpenCL 2.0 beta-support". Intel® SDK for OpenCL™ Applications 2016, R3". ^ "zuzuf/freeocl". December 2020. On April 30, Microsoft releases Windows XP Professional x64 Edition and Windows Server 2003 x64 Edition for AMD64 and EM64T processors.[24] 2006 Microsoft releases Windows Vista, including a 64-bit version for AMD64/EM64T processors that retains 32-bit compatibility. ^ "Apple entry on LLVM Users page". August 26, 2015. 64-bit microcomputers are computers in which 64-bit microprocessors are the norm. ^ "Apple Previews Mac OS X Snow Leopard to Developers" (Press release). This source-based distribution model, with an emphasis on frequent releases, makes availability of application software for those operating systems less of an issue. OpenCL 2.2 also includes features for enhanced optimization of generated code: applications can provide the value of specialization constant at SPIR-V compilation time, a new query can detect non-trivial constructors and destructors of program scope global objects, and user callbacks can be set at program release time. ^ "AMD does reverse GPGPU, announces OpenCL SDK for x86". ^ "clinfo by Simon Leblanc". 2017 Apple releases iOS 11, supporting only machines with AArch64 processors. Devices may or may not share memory with the host CPU.[13] The host API provides handles on device memory buffers and functions to transfer data back and forth between host and devices. Retrieved December 4, 2016. ^ "PoCL home page". Retrieved June 16, 2013. November 16, 2015: Khronos announced that the specification for OpenCL 2.1 had been finalized.[152] April 18, 2016: Khronos announced that the specification for OpenCL 2.2 had been provisionally finalized.[59] November 3, 2016 Intel support for Gen7+ of OpenCL 2.1 in SDK 2016 r3.[153] February 17, 2017: Nvidia begins evaluation support of OpenCL 2.0 with driver 378.66.[154][155][156] May 16, 2017: Khronos announced that the specification for OpenCL 2.2 had been finalized with SPIR-V 1.2.[157] May 14, 2018: Khronos announced Maintenance Update for OpenCL 2.2 with Bugfix and unified headers.[62] April 27, 2020: Khronos announced provisional Version of OpenCL 3.0. June 1, 2020: Intel Neo Runtime with OpenCL 3.0 for new Tiger Lake. ^ "OpenCL Overview". Pipe storage is a new device-side type in OpenCL 2.2 that is useful for FPGA implementations by making connectivity size and type known at compile time, enabling efficient device-scope communication between kernels. ^ "Using the ILP64 Interface vs. ^ "OpenCL-CTS/Test_conformance at main · KhronosGroup/OpenCL-CTS". The lengths and precision of all the built-in types, such as char, short, int, long, float, and double, and the types that can be used as array indices, are specified by the standard and are not dependent on the underlying architecture. Munich, Germany: Association for Computing Machinery: 1–2. OpenCL provides a standard interface for parallel computing using task- and data-based parallelism. IWOCL. Possible performance increases from the use of Nvidia CUDA or OptiX were not tested.[186] See also Advanced Simulation Library AMD FireStream BrookGPU C++ AMP Close to Metal CUDA DirectCompute GPGPU HIP Larrabee Lib Sh List of OpenCL applications OpenACC OpenGL OpenHMPP OpenMP Metal RenderScript SequenceL SIMD SYCL Vulkan WebCL References ^ "Khronos OpenCL Registry". Sandy Bridge will integrate Intel's newest graphics chip technology directly onto the central processing unit.[131] November 15, 2010: Wolfram Research released Mathematica 8 with OpenCLLink package. Please help improve it to make it understandable to non-experts, without removing the technical details. August 6, 2008. "Mac OS X 10.6 Snow Leopard: the Ars Technica review". "NVIDIA beta-support for OpenCL 2.0 works on Linux too". Bibcode:2016arXiv161107083J. Retrieved October 14, 2009. ZiiLABS. MOCL An OpenCL implementation based on POCL by the NUDT researchers for Matrix-2000 was released in 2018. Digital Technical Journal. OpenCL is an open standard maintained by the non-profit technology consortium Khronos Group. Therefore, the total number of addresses to memory is often determined by the width of these registers. Mac OS X 10.6 "Snow Leopard" had both 32- and 64-bit kernels, and, on most Macs, used the 32-bit kernel even on 64-bit processors. 2013 IEEE 6th International Workshop on Multi-/Many-core Computing Systems (MuCoCoS). LLP64 16 32 32 64 64 Microsoft Windows (x86-64 and IA-64) using Visual C++; and MinGW LP64 16 32 64 64 64 Most Unix and Unix-like systems, e.g., Solaris, Linux, BSD, macOS. __kernel void compute_sp(__global float *in, __global float *out) { compute_helper(in, out); } #ifdef cl_khr_fp16 // This kernel is used for complex-number multiplication in half precision when // it is supported by the device. MESA Gallium Compute An implementation of OpenCL (actual 1.1 incomplete, mostly done AMD Radeon GCN) for a number of platforms is maintained as part of the Gallium Compute Project, [77] which builds on the work of the Mesa project to support multiple platforms. ^ "AMD Opens the Throttle on APU Performance with Updated OpenCL Software Development". ^ a b c "OpenCL 1.2 Specification" (PDF). March 31, 2021. October 13, 2009: AMD released the fourth beta of the ATI Stream SDK 2.0, which provides a complete OpenCL implementation on both R700/R800 GPUs and SSE3 capable CPUs. The SDK is available for both Linux and Windows.[126] November 26, 2009: Nvidia released drivers for OpenCL 1.0 (rev 48). template void compute_helper(__global T *in, __global T *out) { auto idx = get_global_id(0); // Every work-item uses 4 consecutive items from the input buffer // - two for each complex number. Retrieved November 15, 2012. doi:10.1147/rd.404.0495. ^ "RadeonOpenCompute/ROCm: ROCm - Open Source Platform for HPC and Ultrascale GPU Computing". Retrieved January 2, 2017. The language semantics is described in the documentation published in the releases of OpenCL-Docs[27] repository hosted by the Khronos Group but it is currently not ratified by the Khronos Group. ^ F. Loading... Retrieved 2011-01-09. Microsoft also releases Windows Server 2008 R2, which is the first 64-bit only server operating system. pp. Retrieved 9 March 2017. On April 29, Apple releases Mac OS X 10.4 "Tiger" which provides limited support for 64-bit command-line applications on machines with PowerPC 970 processors; later versions for Intel-based Macs supported 64-bit command-line applications on Macs with EM64T processors. Java programs that run on a 64-bit Java virtual machine have access to a larger address space.[33] Speed is not the only factor to consider in comparing 32-bit and 64-bit processors. ^ "FreeBSD Graphics/OpenCL". Retrieved April 28, 2021. IBM Corporation. "My Life and Free Software". "Xilinx SDAccel Development Environment for OpenCL, C, and C++, Achieves Khronos Conformance". "More Criticism Comes Towards Intel's Beignet OpenCL". 2003 Apple releases its Mac OS X 10.3 "Panther" operating system which adds support for native 64-bit integer arithmetic on PowerPC 970 processors.[22] Several Linux distributions release with support for AMD64. ^ Joe Heinrich (1994). To extend this into a full matrix–vector multiplication, the OpenCL runtime maps the kernel over the rows of the matrix. New York University Media Research Lab. A single kernel execution

can run on all or many of the PEs in parallel. However, a CPU might have external data buses or address buses with different sizes from the registers, even larger (the 32-bit Pentium had a 64-bit data bus, for instance).[2] The term may also refer to the size of low-level data types, such as 64-bit floating-point arithmetic numbers. On June 16, 2008, the Khronos Compute Working Group was formed[40] with representatives from CPU, GPU, embedded-processor, and software companies. "An Introduction to the OpenCL Programming Model" (PDF). Retrieved October 14, 2014. ^ Szuppe, Jakub (March 6, 2017). Datacenterworks.com. "PowerPC AS A10 64-bit RISC microprocessor". ^ "compute-runtime". May 4, 2011. Archived from the original on 18 June 2013. The ability to force IEEE 754 compliance for single-precision floating-point math: OpenCL by default allows the single-precision versions of the division, reciprocal, and square root operation to be less accurate than the correctly rounded values that IEEE 754 requires.[53] If the programmer passes the "-cl-fp32-correctly-rounded-divide-sqrt" command line argument to the compiler, these three operations will be computed to IEEE 754 requirements if the OpenCL implementation supports this, and will fail to compile if the OpenCL implementation does not support computing these operations to their correctly-rounded values as defined by the IEEE 754 specification.[53] This ability is supplemented by the ability to query the OpenCL implementation to determine if it can perform these operations to IEEE 754 accuracy.[53] OpenCL 2.0 On November 18, 2013, the Khronos Group announced the ratification and public release of the finalized OpenCL 2.0 specification.[54] Updates and additions to OpenCL 2.0 include: Shared virtual memory Nested parallelism Generic address space Images (optional, include 3D-Image) C11 atomics Pipes Android installable client driver extension half precision extended with optional cl_khr_fp16 extension cl_double: double precision IEEE 754 (optional) OpenCL 2.1 The ratification and release of the OpenCL 2.1 provisional specification was announced on March 3, 2015 at the Game Developer Conference in San Francisco. Many applications and libraries for those platforms are open-source software, written in C and C++, so that if they are 64-bit-safe, they can be compiled into 64-bit versions. International Computers Limited launches the ICL 2900 Series with 32-bit, 64-bit, and 128-bit two's complement integers; 64-bit and 128-bit floating point; 32-bit, 64-bit, and 128-bit packed decimal and a 128-bit accumulator register. Vasily Volkov and Brian Kazian, UC Berkeley CS258 project report. November 18, 2013. Mac OS X 10.7 "Lion" ran with a 64-bit kernel on more Macs, and OS X 10.8 "Mountain Lion" and later macOS releases only have a 64-bit kernel. ^ "Intel Compute-Runtime 20.43.18277 Brings Alder Lake Support". MOCL: An Efficient OpenCL Implementation for the Matrix-2000 Architecture (PDF). 2021 Google releases Android 12, dropping support for 32-bit applications. ^ Mashey, John (October 2006). ^ "Khronos Releases OpenCL 2.1 and SPIR-V 1.0 Specifications for Heterogeneous Parallel Programming". August 26, 2015: AMD released AMD APP SDK v3.0[151] which contains full support of OpenCL 2.0 and sample coding. Retrieved September 11, 2015. www.operating-system.org. Retrieved September 10, 2015. Retrieved August 6, 2009. [permanent dead link] ^ Moren, Dan; Snell, Jason (June 8, 2009). History Many computer instruction sets are designed so that a single integer register can store the memory address to any location in the computer's physical or virtual memory. Retrieved January 9, 2014. "pocl: A Performance-Portable OpenCL Implementation". portablecl.org. ^ Bishop, J. It is common in 64-bit RISC machines,[citation needed] explored in x86 as x32 ABI, and has recently been used in the Apple Watch Series 4 and 5.[48][49] 64-bit data models Data model short(integer) int long(integer) long long pointers,size_t Sample operating systems ILP32 16 32 32 64 32 x32 and arm64ilp32 ABIs on Linux systems; MIPS N32 ABI. Archived from the original (PDF) on November 11, 2011. However, not all instruction sets, and not all processors implementing those instruction sets, support a full 64-bit virtual or physical address space. pp. 216–225. Furthermore, the OpenGL sharing extensions now allow for OpenGL 1D textures and 1D/2D texture arrays to be used to create OpenCL images. Another alternative is the LLP64 model, which maintains compatibility with 32-bit code by leaving both int and long as 32-bit.[47][43] LL refers to the long long integer type, which is at least 64 bits on all platforms, including 32-bit environments. Archived from the original on December 5, 2020. ^ "AMD Drives Adoption of Industry Standards in GPGPU Software Development" (Press release). In order to open the OpenCL programming model to other languages or to protect the kernel source from inspection, the Standard Portable Intermediate Representation (SPIR)[17] can be used as a target-independent way to ship kernels between a front-end compiler and the OpenCL back-end. POCL 1.6 is with manual optimization at the same level of Intel compute runtime.[111] Version 1.7 implements LLVM/Clang 12 support and some new OpenCL 3.0 features.[112] Version 1.8 implements LLVM/Clang 13 support. NEO provides OpenCL 2.1 support on Core platforms and OpenCL 1.2 on Atom platforms.[90] Actual in 2020 also Graphic Gen 11 Ice Lake and Gen 12 Tiger Lake are supported. ^ Dolbeau, Romain; Bodin, François; de Verdière, Guillaume Colin (September 7, 2013). (March 6, 2014). "OpenCL: a parallel programming standard for heterogeneous computing systems". The x86-64 architecture (as of 2016[update]) allows 48 bits for virtual memory and, for any given processor, up to 52 bits for physical memory.[26][27] These limits allow memory sizes of 256 TiB (256 × 10244 bytes) and 4 PiB (4 × 10245 bytes), respectively. 1994 Support for the R8000 processor is added by Silicon Graphics to the IRIX operating system in release 6.0. 1995 DEC releases OpenVMS 7.0, the first full 64-bit version of OpenVMS for Alpha. For 64-bit images in computer graphics, see Deep color. People interested by C++ kernels but not by SYCL single-source programming style can use C++ features with compute kernel sources written in "C++ for OpenCL" language.[19] Memory hierarchy OpenCL defines a four-level memory hierarchy for the compute device:[13] global memory: shared by all processing elements, but has high access latency (__global); read-only memory: smaller, low latency, writable by the host CPU but not the compute devices (__constant); local memory: shared by a group of processing elements (__local); per-element private memory (registers; __private). Marketed as a "64-Bit Microprocessor", it had essentially a 32-bit architecture, enhanced with a 3D graphics unit capable of 64-bit integer operations.[8] 1993 Atari introduces the Atari Jaguar video game console, which includes some 64-bit wide data paths in its architecture.[9] 64-bit address timeline 1991 MIPS Computer Systems produces the first 64-bit microprocessor, the R4000, which implements the MIPS III architecture, the third revision of its MIPS architecture.[10] The CPU is used in SGI graphics workstations starting with the IRIS Crimson. ^ Howes, Lee (November 11, 2015). ^ "Khronos Releases OpenCL 2.2 With SPIR-V 1.2". p. 475. Archived from the original on September 6, 2011. August 5, 2009. External links 64-bit Transition Guide, Mac Developer Library Karpov, Andrey. Archived from the original on June 20, 2008. "UltraSparc Unleashes SPARC Performance". New Basic Development is done by Red Hat with SPIR-V also for Clover.[80][81] New Target is modular OpenCL 3.0 with full support of OpenCL 1.2. Actual state is available in Mesamatrix. In contrast, the 64-bit Alpha family uses a 64-bit floating-point data and register format, and 64-bit integer registers. First 64-bit Linux distribution for the Alpha architecture is released.[20] 1996 Support for the R4x00 processors in 64-bit mode is added by Silicon Graphics to the IRIX operating system in release 6.2. 1998 Sun releases Solaris 7, with full 64-bit UltraSPARC support. This article may be too technical for most readers to understand. October 20, 2009. "PyCUDA and PyOpenCL: A scripting-based approach to GPU run-time code generation". January 21, 2014. Apple releases Mac OS X 10.6, "Snow Leopard", which ships with a 64-bit kernel for AMD64/Intel64 processors, although only certain recent models of Apple computers will run the 64-bit kernel by default. November 30, 2015. The translation software is all that must be rewritten to move the full OS and all software to a new platform, as when IBM transitioned the native instruction set for AS/400 from the older 32/48-bit IMPI to the newer 64-bit PowerPC-AS, codenamed Amazon. This has the same effect as changing all the values to a. "Khronos and OpenCL Overview EVS Workshop May19" (PDF). Technet.microsoft.com. Windows when using Cygwin; z/OS ILP64 16 64 64 64 64 HAL Computer Systems port of Solaris to the SPARC64 SILP64 64 64 64 64 64 Classic UNICOS[45][46] (versus UNICOS/mp, etc.) Many 64-bit platforms today use an LP64 model (including Solaris, AIX, HP-UX, Linux, macOS, BSD, and IBM z/OS). ^ Chappell, Geoff (2009-01-27). The Elxsi architecture has 64-bit data registers but a 32-bit address space. Altera.com. New OpenCL 3.0 is available for Alder Lake, Tiger Lake to Broadwell with Version 20.41+. A compiled Java program can run on a 32- or 64-bit Java virtual machine with no modification. Retrieved April 18, 2021.{{cite web}}: CS1 maint: url-status (link) ^ "OpenCL-Guide, Programming OpenCL Kernels". ^ dead link] ^ "Radeon ROCm 3.5 Released with New Features but Still No Navi Support - Phoronix". April 12, 2021. How a compute device is subdivided into compute units and PEs is up to the vendor; a compute unit can be thought of as a "core", but the notion of core is hard to define across all the types of devices supported by OpenCL (or even within the category of "CPUs"),[11]:49–50 and the number of compute units may not correspond to the number of cores claimed in vendors' marketing literature (which may actually be counting SIMD lanes).[12] In addition to its C-like programming language, OpenCL defines an application programming interface (API) that allows programs running on the host to launch kernels on the compute devices and manage device memory, which is (at least conceptually) separate from host memory. freedesktop.org. public: complex_t(T re, T im): m_re{re}, m_im{im} {}; // Define operator for complex-number multiplication. Alpha 21264 supported user-configurable 43 or 48 bits of virtual memory address space (8 TiB or 256 TiB) and 44 bits of physical memory address space (16 TiB). 40 (4): 495–505. Amd.com. MacWorld.com. The implementation is shown below.[22] The code asks the OpenCL library for the first available graphics card, creates memory buffers for reading and writing (from the perspective of the graphics card), JIT-compiles the FFT-kernel and then finally asynchronously runs the kernel. p. 5. Heterogeneous Computing with OpenCL: Revised OpenCL 1.2 Edition. The Matrix-2000 architecture is designed to replace the Intel Xeon Phi accelerators of the TianHe-2 supercomputer. ^ "ARMv8 Technology Preview" (PDF). Advanced Micro Devices. ACM Queue. Retrieved April 18, 2021.{{cite web}}: CS1 maint: url-status (link) ^ "cl_ext_cxx_for_opencl". Compiler Construction. This increases the memory requirements of a given process and can have implications for efficient processor cache use. ^ "Nvidia Releases OpenCL Driver". Retrieved October 24, 2016. Retrieved 2020-06-05. ^ Larabel, Michael (January 10, 2013). ARMdevices.net. Limits of processors This section needs additional citations for verification. Archived from the original on July 9, 2015. ^ ^ Jääskeläinen, Pekka; Sánchez de La Lama, Carlos; Schnetter, Erik; Raiskila, Kalle; Takala, Jarmo; Berg, Heikki (2016). IBM Journal of Research and Development. ^ "UEFI_on_Dell BizClient_Platforms" (PDF). It has a 64-bit kernel that only supports 64-bit applications. ^ "OpenCL on FFT". June 16, 2008. Sun Microsystems, Inc. The following is a matrix–vector multiplication algorithm in OpenCL C. The IBM System/360 of the 1960s was an early 32-bit computer; it had 32-bit integer registers, although it only used the low order 24 bits of a word for addresses, resulting in a 16 MiB (16 × 10242 bytes) address space. Kernels can be called to use specialised or non-programmable aspects of underlying hardware. ^ "Intel Brings Beignet To Android For OpenCL Compute - Phoronix". IBM. ^ "About Intel OpenCL SDK 1.1". Some 64-bit programs, such as encoders, decoders and encryption software, can benefit greatly from 64-bit registers,[citation needed] while the performance of other programs, such as 3D graphics-oriented ones, remains unaffected when switching from a 32-bit to a 64-bit environment.[citation needed] Some 64-bit architectures, such as x86-64 and AArch64, support more general-purpose registers than their 32-bit counterparts (although this is not due specifically to the word length). The specification retains the OpenCL C language and deprecates the OpenCL C++ Kernel Language, replacing it with the C++ for OpenCL language[19] based on a Clang/LLVM compiler which implements a subset of C++17 and SPIR-V intermediate code.[63][64][65] Version 3.0.7 of C++ for OpenCL with some Khronos openCL extensions were presented at IWOCL 21.[66] Actual is 3.0.11 with some new extensions and corrections. During the 1990s, several low-cost 64-bit microprocessors were used in consumer electronics and embedded applications. Proceedings of the International Workshop on OpenCL. 2005 On January 4, Microsoft discontinues Windows XP 64-Bit Edition, as no PCs with IA-64 processors had been available since the previous September, and announces that it is developing x86-64 versions of Windows to replace it.[23] On January 31, Sun releases Solaris 10 with support for AMD64 and EM64T processors. 2011 International Conference on Parallel Processing. ^ a b c d e "Conformant Products". Retrieved October 1, 2009. ^ Grimes, Jack; Kohn, Les; Bharadhwaj, Rajeev (July–August 1989). Retrieved July 6, 2015. However, in modern designs, these functions are often performed by more general purpose integer registers. 64-bit operating system timeline 1985 Cray releases UNICOS, the first 64-bit implementation of the Unix operating system.[19] 1993 DEC releases the 64-bit DEC OSF/1 AXP Unix-like operating system (later renamed Tru64 UNIX) for its systems based on the Alpha architecture. Apple. This model reduces code size and the size of data structures containing pointers, at the cost of a much smaller address space, a good choice for some embedded systems. Retrieved June 23, 2015. Functions executed on an OpenCL device are called "kernels".[10]:17 A single compute device typically consists of several compute units, which in turn comprise multiple processing elements (PEs). "A Comprehensive Performance Comparison of CUDA and OpenCL". Retrieved October 27, 2009. April 13, 2015. GitHub. Table 9-1. November 16, 2009. Digital Equipment Corporation. Microsoft Windows uses an LLP64 model. November 15, 2011. November 7, 2013. ^ "OpenCL" (PDF). doi:10.1145/3388333.3388647. ^ Andi Kleen. Intel released Core 2 Duo as the first mainstream x86-64 processor for its mobile, desktop, and workstation line. Programs in the OpenCL language are intended to be compiled at run-time, so that OpenCL-using applications are portable between implementations for various host devices.[13] The OpenCL standard defines host APIs for C and C++; third-party APIs exist for other programming languages and platforms such as Python,[14] Java, Perl,[15] D[16] and .NET.[11]:15 An implementation of the OpenCL standard consists of a library that implements the API for C and C++, and an OpenCL C compiler for the compute device(s) targeted. PMID 21037981. 1996 Nintendo introduces the Nintendo 64 video game console, built around a low-cost variant of the MIPS R4000. p. 120. Archived from the original on January 9, 2014. ^ "Radeon ROCm 2.0 Officially Out With OpenCL 2.0 Support, TensorFlow 1.12, Vega 48-bit VA - Phoronix". out[idx * 2] = res.get_re(); out[idx * 2 + 1] = res.get_im(); } // This kernel is used for complex-number multiplication in single precision. C++ for OpenCL sources can be compiled by OpenCL drivers that support cl_ext_cxx_for_opencl extension.[33] Arm has announced support for this extension in December 2020.[34] However, due to increasing complexity of the algorithms accelerated on OpenCL devices, it is expected that more applications will compile C++ for OpenCL kernels offline using stand alone compilers such as Clang[35] into executable binary format or portable binary format e.g. SPIR-V.[36] Such an executable can be loaded during the OpenCL applications execution using a dedicated OpenCL API.[37] Binaries compiled from sources in C++ for OpenCL 1.0 can be executed on OpenCL 2.0 conformant devices. ^ "Opencl Standard - an overview | ScienceDirect Topics". 9 hardware released in 2018.[89] This driver replaces Beignet implementation for supported platforms (not older 6.gen to Haswell). December 2016. March 21, 2019. Ars Technica. ^ "Status". Retrieved 17 October 2017. ^ "i860 64-Bit Microprocessor". July 21, 2013. This programming framework is built on top of LLVM v5.0 and reuses some code pieces from POCL as well. ^ a b "Introduction to OpenCL Programming 201005" (PDF). ^ "Abstract Data Models - Windows applications". Please help improve this article by adding citations to reliable sources. ^ "Khronos Group Releases OpenCL 3.0". Archived from the original on December 15, 2009. For the cryptographic library initially known as OpenCL, see Botan (programming library). 8 (15). Software availability x86-based 64-bit systems sometimes lack equivalents of software that is written for 32-bit architectures. T m_im; // Imaginary component. 4-2. Archived from the original on 26 November 2010. OpenCL 3.0 The OpenCL 3.0 specification was released on September 30, 2020 after being in preview since April 2020. In Mesa 22.2 experimental implementation will be available with openCL 3.0-support and image extension implementation for programs like Darktable.[82] BEIGNET An implementation by Intel for its Ivy Bridge + hardware was released in 2013.[83] This software from Intel's China Team, has attracted criticism from developers at AMD and Red Hat,[84] as well as Michael Larabel of Phoronix.[85] Actual Version 1.3.2 support OpenCL 1.2 complete (Ivy Bridge and higher) and OpenCL 2.0 optional for Skylake and newer.[86][87] support for Android has been added to Beignet.,[88] actual development targets: only support for 1.2 and 2.0, road to OpenCL 2.1, 2.2, 3.0 is gone to NEO. Retrieved June 18, 2008. Parallel Programming. Retrieved April 18, 2021.{{cite web}}: CS1 maint: url-status (link) ^ a b "The C++ for OpenCL 1.0 Programming Language Documentation". AMD64 (EM64T) architecture Retrieved from " This framework has been deployed on the TH-2A system and is readily available to the public.[117] Some of the software will next ported to improve POCL.[104] VC4CL An OpenCL 1.2 implementation for the VideoCore IV (BCM2763) processor used in the Raspberry Pi before its model 4.[118] Vendor implementations Timeline of vendor implementations June, 2008: During Apple's WWDC conference an early beta of Mac OS X Snow Leopard was made available to the participants, it included the first beta implementation of OpenCL, about 6 months before the final version 1.0 specification was ratified late 2008. September 2016. Retrieved December 13, 2018. 2007 Apple releases Mac OS X 10.5 "Leopard", which fully supports 64-bit applications on machines with PowerPC 970 or EM64T processors. ^ "AMD APP SDK 3.0 Released". 1976 Cray Research delivers the first Cray-1 supercomputer, which is based on a 64-bit word architecture and will form the basis for later Cray vector supercomputers. September 2020. On the host side, the clEnqueueNDRangeKernel function does this; it takes as arguments the kernel to execute, its arguments, and a number of work-items, corresponding to the number of rows in the matrix A. April 26, 2020. The other demo was a N-body simulation running on the GPU of a Mac Pro, a data parallel task. Github.com. announces SDAccel development environment for OpenCL, C, and C++, achieves Khronos Conformance.[149] April 13, 2015: Nvidia releases WHQL driver v350.12, which includes OpenCL 1.2 support for GPUs based on Kepler or later architectures.[150] Driver 340+ support OpenCL 1.1 for Tesla and Fermi. May 30, 2018. Similarly, the 48-bit virtual address space was designed to provide 65,536 (216) times the 32-bit limit of 4 GiB (4 × 10243 bytes), allowing room for later expansion and incurring no overhead of translating full 64-bit addresses. ^ "KhronosGroup/OpenCL-CTL: The OpenCL Conformance Tests". // A is a row-major matrix, meaning the (i,j) element is at A[i*ncols+j]. ^ "Intel discloses new Sandy Bridge technical details". The architecture has survived through a succession of ICL and Fujitsu machines. Imagination Technologies. It includes now optional OpenCL 2.0, 2.1 Features complete and some of 2.2. ROCm Created as part of AMD's GPUOpen, ROCm (Radeon Open Compute) is an open source Linux project built on OpenCL 1.2 with language support for 2.0. The system is compatible with all modern AMD CPUs and APUs (actual partly GFX 7, GFX 8 and 9), as well as Intel Gen7.5+ CPUs (only with PCI 3.0).[91][92] With version 1.9 support is in some points extended experimental to Hardware with PCIe 2.0 and without atomics. Retrieved July 19, 2019. Archived from the original on October 22, 2020. Cray Research systems data type mapping. Showstopper! The Breakneck Race to Create Windows NT and the Next Generation at Microsoft. A 1998 to 1999 launch date was targeted. IBM releases the A10 and A30 microprocessors, the first 64-bit PowerPC AS processors.[13] IBM also releases a 64-bit AS/400 system upgrade, which can convert the operating system, database and applications. D4-1723, D4-1724, D4-1731. March 19, 2014. geoffchappell.com. ^ Gwennap, Linley (14 November 1994). Retrieved April 18, 2021.{{cite web}}: CS1 maint: url-status (link) ^ "OpenCL-Guide, Offline Compilation of OpenCL Kernel Sources". Forums.amd.com. ^ Stefan Berka. ^ "Khronos Finalizes OpenCL 2.0 Specification for Heterogeneous Computing". ^ Lincoln Spector (August 12, 2013). Archived from the original on 5 April 2009. ^ Trevett, Neil (April 28, 2020). Not every device needs to implement each level of this hierarchy in hardware. On systems with 64-bit processors, both the 32- and 64-bit macOS kernels can run 32-bit user-mode code, and all versions of macOS up to macOS Mojave (10.14) include 32-bit versions of libraries that 32-bit applications would use, so 32-bit user-mode software for macOS will run on those systems. March 14, 2019 – via GitHub. "Licensed Memory in 32-Bit Windows Vista". Examples include video encoding/decoding and digital signal processors. ^ "What's new? Retrieved November 11, 2008. "OpenCL – A State of the Union" (PDF). 2001 Linux becomes the first OS kernel to fully support x86-64 (on a simulator, as no x86-64 processors had been released yet).[21] 2001 Microsoft releases Windows XP 64-Bit Edition for the Itanium's IA-64 architecture; it could run 32-bit applications through an execution layer. On 64-bit hardware with x86-64 architecture (AMD64), most 32-bit operating systems and applications can run with no compatibility issues. ^ Trevett, Neil (May 23, 2019). 64-bit data timeline 1961 IBM delivers the IBM 7030 Stretch supercomputer, which uses 64-bit data words and 32- or 64-bit instruction words. "LCA14-412: GPGPU on ARM SoC" (PDF). Equally, for DX11, seamless sharing between OpenCL and DX11 surfaces is enabled. Retrieved 2009-04-05. www.ibm.com. dri.freedesktop.org. March 19, 2009. Linux Journal. ^ "The Khronos Group Releases OpenCL 1.0 Specification" (Press release). Retrieved August 18, 2018. "From CUDA to OpenCL: Towards a performance-portable solution for multi-platform GPU programming". ^ a b Gaster, Benedict; Howes, Lee; Kaeli, David R.; Mistry, Perhaad; Schaa, Dana (2012). This leads to a significant speed increase for tight loops since the processor does not have to fetch data from the cache or main memory if the data can fit in the available registers. An overview of actual work is done on XDC2018.[93][94] ROCm Version 2.0 supports Full OpenCL 2.0, but some errors and limitations are on the todo list.[95][96] Version 3.3 is improving in details.[97] Version 3.5 does support OpenCL 2.2.[98] Version 3.10 was with improvements and new APIs.[99] Announced at SC20 is ROCm 4.0 with support of AMD Compute Card Instinct MI 100.[100] Actual documentation of 5.1.1 and before is available at github.[101][102] OpenCL 3.0 is available. "POWER3: The next generation of PowerPC processors". ^ "Nvidia entry on LLVM Users page". Retrieved April 18, 2021.{{cite web}}: CS1 maint: url-status (link) ^ "Clang 9, Language Extensions, OpenCL". ^ "Gallium Clover With SPIR-V & NIR Opening Up New Compute Options Inside Mesa - Phoronix". Drivers make up the majority of the operating system code in most modern operating systems[citation needed] (although many may not be loaded when the operating system is running). This is not necessarily true on 64-bit machines.[39][40][41] Mixing data types in programming languages such as C and its descendants such as C++ and Objective-C may thus work on 32-bit implementations but not on 64-bit implementations. 8 (13). CiteSeerX 10.1.1.193.7712. Retrieved December 10, 2009. The IMPI instruction set was quite different from even 32-bit PowerPC, so this transition was even bigger than moving a given instruction set from 32 to 64 bits. Retrieved December 10, 2008. // Multiplies A*x, leaving the result in y. February 17, 2017. doi:10.1007/978-3-642-19861-8_16. ^ A Survey of CPU-GPU Heterogeneous Computing Techniques, ACM Computing Surveys, 2015. Retrieved May 4, 2012. Most applications bundled with Mac OS X 10.6 are now also 64-bit.[22] 2011 Apple releases Mac OS X 10.7, "Lion", which runs the 64-bit kernel by default on supported machines. The standard OpenCL header is used by the consumer application; calls to each function are then proxied by the OpenCL runtime to the appropriate driver using the ICD. May 2008. Archived from the original on March 2, 2016. Runs on any OpenCL 2.0-capable hardware (only a driver update is required). However, most 32-bit applications will work well. 9 (4): 85–94. "A Static Task Partitioning Approach for Heterogeneous Systems Using OpenCL". ^ "OpenCL and the AMD APP SDK". OpenCL kernel language The programming language that is used to write compute kernels is called kernel language. June 17, 2015. According to an Apple press release:[43] Snow Leopard further extends support for modern hardware with Open Computing Language (OpenCL), which lets any application tap into the vast gigaflops of GPU computing power previously available only to graphics applications. ^ "NVIDIA 378.66 drivers for Windows offer OpenCL 2.0 evaluation support". ^ "Inside Native Applications". ^ a b c "C++ for OpenCL, OpenCL-Guide". "Samsung's WebCL Prototype for WebKit". Memory buffers reside in specific levels of the memory hierarchy, and pointers are annotated with the region qualifiers __global, __local, __constant, and __private, reflecting this. www.pcper.com. Nvidia improves with Khronos Vulkan Interop with semaphores and memory sharing.[67] Roadmap The International Workshop on OpenCL (IWOCL) held by the Khronos Group When releasing OpenCL 2.2, the Khronos Group announced that OpenCL would converge where possible with Vulkan to enable OpenCL software deployment flexibility over both APIs.[68][69] This has been now demonstrated by Adobe's Premiere Rush using the clspv[38] open source compiler to compile significant amounts of OpenCL C kernel code to run on a Vulkan runtime for deployment on Android.[70] OpenCL has a forward looking roadmap independent of Vulkan, with 'OpenCL Next' under development and targeting release in 2020. On the other hand, converting a pointer to a long will “work” in LP64. intel.com. z/OS XL C/C++ Programming Guide. (2014). September 2019. Parallel Computing. Archived from the original on July 17, 2011. pp. 1–6. ISBN 978-1-4577-1336-1. ^ "clinfo by Oblomov". ^ Joris Evers (5 January 2005). ^ "NEO GitHub README". ^ "AMD Backs OpenCL, Microsoft DirectX 11". Computerworld. ^ "GitHub - RadeonOpenCompute/ROCm at roc-3.5.0". Retrieved May 15, 2017. Now branded Itanium and targeting high-end servers, sales fail to meet expectations. More recently Khronos Group has ratified SYCL,[18] a higher-level programming model for OpenCL as a single-source eDSL based on pure C++17 to improve programming productivity. metacpan.org. ^ "Release 349 Graphics Drivers for Windows, Version 350.12" (PDF). Microprocessor Report. 2019 Apple releases macOS 10.15 "Catalina", dropping support for 32-bit Intel applications. template class complex_t { T m_re; // Real component. The result from the transform is not read in this example. December 10, 2008: AMD and Nvidia held the first public OpenCL demonstration, a 75-minute presentation at SIGGRAPH Asia 2008. Archived from the original on August 6, 2020. ^ "Xilinx SDAccel development environment for OpenCL, C, and C++, achieves Khronos Conformance - khronos.org news". ^ "Beignet". See also Computer memory References ^ a b "ARM Launches Cortex-A50 Series, the World's Most Energy-Efficient 64-bit Processors" (Press release). Retrieved August 29, 2009. March 26, 2009. Retrieved 2011-02-19. 64 bits is a word size that defines certain classes of computer architecture, buses, memory, and CPUs and, by extension, the software that runs on them. Retrieved April 18, 2021.{{cite web}}: CS1 maint: url-status (link) ^ "Release of Documentation of C++ for OpenCL kernel language, version 1.0, revision 1 · KhronosGroup/OpenCL-Docs". NEC. Retrieved June 29, 2021. Memory-mapped files are becoming more difficult to implement in 32-bit architectures as files of over 4 GiB become more common; such large files cannot be memory-mapped easily to 32-bit architectures, as only part of the file can be mapped into the address space at a time, and to access such a file by memory mapping, the parts mapped must be swapped into and out of the address space as needed. Formerly this was known as CLOVER.,[78] actual development: mostly support for running incomplete framework with actual LLVM and CLANG, some new features like fp16 in 17.3,[79] Target complete OpenCL 1.0, 1.1 and 1.2 for AMD and Nvidia. A 32-bit processor is incompatible with 64-bit software. Archived from the original (PDF) on May 16, 2011. A notable exception to this trend were mainframes from IBM, which then used 32-bit data and 31-bit address sizes; the IBM mainframes did not include 64-bit processors until 2000. on Compiler Construction. Retrieved September 12, 2019. 2003 AMD introduces its Opteron and Athlon 64 processor lines, based on its AMD64 architecture which is the first x86-based 64-bit processor architecture. ^ Klöckner, Andreas; Pinto, Nicolas; Lee, Yunsup; Catanzaro, Bryan; Ivanov, Paul; Fasih, Ahmed (2012). Morgan Kaufmann. ^ a b c "pocl home page". ^ "AMD Launches Arcturus as the Instinct MI100, Radeon ROCm 4.0 - Phoronix". Retrieved September 26, 2012. 1995 Sun launches a 64-bit SPARC processor, the UltraSPARC.[12] Fujitsu-owned HAL Computer Systems launches workstations based on a 64-bit CPU, HAL's independently designed first-generation SPARC64. However, drivers and other kernel mode software, more so older versions, may be incompatible with PAE; this has been cited as the reason for 32-bit versions of Microsoft Windows being limited to 4 GiB of physical RAM[35] (although the validity of this explanation has been disputed[36]). ^ bare URL PDF] ^ "Mesa's "Rusticl" Implementation Now Manages to Handle Darktable OpenCL". Khronos Group. Retrieved April 18, 2021. Microsoft. ^ "Zack Rusin's blog post about the Gallium3D OpenCL implementation". 2014 Google announces the Nexus 9 tablet, the first Android device to run on the 64-bit Tegra K1 chip. ^ a b "Khronos Releases OpenCL 2.2 Provisional Specification with OpenCL C++ Kernel Language for Parallel Programming". Traditionally OpenCL C was used to program the accelerators in OpenCL standard, later C++ for OpenCL kernel language was developed that inherited all functionality from OpenCL C but allowed to use C++ features in the kernel sources. October 6, 2018. ^ "WebCL related stories". Kilgard, Mark J. ^ "Breaking: OpenCL Merging Roadmap into Vulkan | PC Perspective". (January 2010) (Learn how and when to remove this template message) In principle, a 64-bit microprocessor can address 16 EiB (16 × 10246 = 264 = 18,446,744,073,709,551,616 bytes, or about 18.4 exabytes) of memory. ^ "Product Support". Archived from the original on June 3, 2001. AMD publicly discloses its set of 64-bit extensions to IA-32, called x86-64 (later branded AMD64). ArrayFire. 2012 Microsoft releases Windows 8 which supports UEFI Class 3 (UEFI without CSM) and Secure Boot.[25] 2013 Apple releases iOS 7, which, on machines with AArch64 processors, has a 64-bit kernel that supports 64-bit applications. ^ "About". While the larger address space of 64-bit architectures makes working with large data sets in applications such as digital video, scientific computing, and large databases easier, there has been considerable debate on whether they or their 32-bit compatibility modes will be faster than comparably priced 32-bit systems for other tasks. Existing implementations have been shown to be competitive when kernel code is properly tuned, though, and auto-tuning has been suggested as a solution to the performance portability problem,[180] yielding "acceptable levels of performance" in experimental linear algebra kernels.[181] Portability of an entire application containing multiple kernels with differing behaviors was also studied, and shows that portability only required limited tradeoffs.[182] A study at Delft University from 2011 that compared CUDA programs and their straightforward translation into OpenCL C found CUDA to outperform OpenCL by at most 30% on the Nvidia implementation. As an example, a driver for a 32-bit PCI device asking the device to DMA data into upper areas of a 64-bit machine's memory could not satisfy requests from the operating system to load data from the device to memory above the 4 gibibyte barrier, because the pointers for those addresses would not fit into the DMA registers of the device. Sites (1992). arXiv:1611.07083. S2CID 18928397. ^ Pentium Processor User's Manual Volume 1: Pentium Processor Data Book (PDF). Retrieved 2017-03-09. In the 64-bit version, all Windows applications and components are 64-bit, although many also have their 32-bit versions included for compatibility with plug-ins. AnandTech. Contributions C++ for OpenCL is an open language developed by the community of contributors listed in its documentation.[31] New contributions to the language semantic definition or open source tooling support are accepted from anyone interested as soon as they are aligned with the main design philosophy and they are reviewed and approved by the experienced contributors.[19] History OpenCL was initially developed by Apple Inc., which holds trademark rights, and refined into an initial proposal in collaboration with technical teams at AMD, IBM, Qualcomm, Intel, and Nvidia. (January 14, 2015). Maintaining a partial 32-bit model is one way to handle this, and is in general reasonably effective. ^ "Rapidmind entry on LLVM Users page". Retrieved November 16, 2015. Khronos OpenCL Working Group. ^ "HPCWire: RapidMind Embraces Open Source and Standards Projects". VIA Technologies announces the Isaiah 64-bit processor.[16] 2006 Sony, IBM, and Toshiba begin manufacturing the 64-bit Cell processor for use in the PlayStation 3, servers, workstations, and other appliances. The C++ for OpenCL language is not documented in a stand-alone document and it is based on the specification of C++ and OpenCL C. ^ "Issues · KhronosGroup/OpenCL-CTS". October 30, 2009. 1974 Control Data Corporation launches the CDC Star-100 vector supercomputer, which uses a 64-bit word architecture (prior CDC systems were based on a 60-bit architecture). ^ Szuppe, Jakub (February 22, 2017). ^ "Nvidia Releases OpenCL Driver To Developers". MacWorld. ^ a b KhronosGroup/OpenCL-Docs, The Khronos Group, April 16, 2021, retrieved April 18, 2021 ^ "Clang release 9 documentation, OpenCL support". These are not problems which affect fully standard-compliant code, but code is often written with implicit assumptions about the widths of data types. found that "The OpenCL kernel's performance is between about 13% and 63% slower, and the end-to-end time is between about 16% and 67% slower" than CUDA's performance.[183] The fact that OpenCL allows workloads to be shared by CPU and GPU, executing the same programs, means that programmers can exploit both by dividing work among the devices.[184] This leads to the problem of deciding how to partition the work, because the relative speeds of operations differ among the devices. 4.29 billion addresses were considered an appropriate size to work with for another important reason: 4.29 billion integers are enough to assign unique references to most entities in applications like databases. MicroDesign Resources. ^ "Clover Status Update" (PDF). Most 32-bit application software can run on a 64-bit operating system in a compatibility mode, also termed an emulation mode, e.g., Microsoft WoW64 Technology for IA-64 and AMD64. ^ "The Story of Thud and Blunder". ^ "HSA support implementation status as of 2016-05-17 — Portable Computing Language (pocl) 1.3-pre documentation". pocl. ^ Du, Peng; Weber, Rick; Luszczek, Piotr; Tomov, Stanimire; Peterson, Gregory; Dongarra, Jack (2012). Retrieved 2009-09-06. p. ^ "Fitting FFT onto G80 Architecture" (PDF). Retrieved December 3, 2020.{{cite web}}: CS1 maint: archived copy as title (link) ^ bare URL PDF] ^ "PoCL home page". ^ "Power ISA Version 3.0". Nearly all applications bundled with Mac OS X 10.7 are now also 64-bit, including iTunes. 38 (8): 391–407. 64-bit applications 32-bit vs 64-bit A change from a 32-bit to a 64-bit architecture is a fundamental alteration, as most operating systems must be extensively modified to take advantage of the new architecture, because that software has to manage the actual memory addressing hardware.[31] Other software must also be ported to use the new abilities; older 32-bit software may be supported either by virtue of the 64-bit instruction set being a superset of the 32-bit instruction set, so that processors that support the 64-bit instruction set can also run code for the 32-bit instruction set, or through software emulation, or by the actual implementation of a 32-bit processor core within the 64-bit processor, as with some Itanium processors from Intel, which included an IA-32 processor core to run 32-bit x86 applications. community.arm.com. pp. 286–305. Versions of the VR4300 processor are widely used in consumer and office automation applications, including the popular Nintendo 64TM video game and advanced laser printers such as the recently announced, award-winning Hewlett-Packard LaserJet 4000 printer family. Built-in kernels: custom devices that contain specific unique functionality are now integrated more closely into the OpenCL framework. OpenCL library functions can now use the C++ language to provide increased safety and reduced undefined behavior while accessing features such as atomics, iterators, images, samplers, pipes, and device queue built-in types and address spaces. March 14, 2014. Alpha 21064 supported 43 bits of virtual memory address space (8 TiB) and 34 bits of physical memory address space (16 GiB). October 16, 2020: Intel announced with Neo 20.41 support for OpenCL 3.0 (includes mostly of optional OpenCL 2.x). A 32-bit address register meant that 232 addresses, or 4 GiB of random-access memory (RAM), could be referenced. RustiCL is a new implementation for Gallium compute with Rust instead of C for better code. Int'l J. ^ KamathK, Sharath. The first official release of this document describing C++ for OpenCL version 1.0 has been published in December 2020.[30] C++ for OpenCL 1.0 contains features from C++17 and it is backward compatible with OpenCL C 2.0. A work in progress draft of its documentation can be found on the Khronos website.[31] Features C++ for OpenCL supports most of the features (sy

clSetKernelArg(kernel, 2, sizeof(float)*(local_work_size[0] + 1) * 16, NULL); clSetKernelArg(kernel, 3, sizeof(float)*(local_work_size[0] + 1) * 16, NULL); // create N-D range object with work-item dimensions and execute kernel size_t global_work_size[1] = { 256 }; global_work_size[0] = NUM_ENTRIES; local_work_size[0] = 64; //Nvidia: 192 or 256 clEnqueueNDRangeKernel(queue, kernel, 1, NULL, global_work_size, local_work_size, 0, NULL, NULL); } The actual calculation inside file "fft1D_1024_kernel_src.cl" (based on Fitting FFT onto the G80 Architecture):[23] R"(// This kernel computes FFT of length 1024. 1991. "The OpenCL Specification Version: 2.1 Document Revision: 23" (PDF). 38 (3): 157–174. ^ "OpenCL". Retrieved June 12, 2009. From the software perspective, 64-bit computing means the use of machine code with 64-bit virtual memory addresses. April 20, 2009. ^ Larabel, Michael (December 24, 2013). ^ Zhang, Peng; Fang, Jianbin; Yang, Canqun; Tang, Tao; Huang, Chun; Wang, Zheng (2018). FreeBSD releases with support for AMD64. External links Official website Official website for WebCL International Workshop on OpenCL Archived January 26, 2021, at the Wayback Machine (IWOCL) sponsored by The Khronos Group Retrieved from " 2Computer architecture bit width "64-bit" redirects here. The performance differences could mostly be attributed to differences in the programming model (especially the memory model) and to NVIDIA's compiler optimizations for CUDA compared to those for OpenCL.[180] Another study at D-Wave Systems Inc. PMC 2964860. "Unicos Operating System". August 14, 2008. "The Intel i860 64-Bit Processor: A General-Purpose CPU with 3D Graphics Capabilities". October 27, 2009: S3 released their first product supporting native OpenCL 1.0 – the Chrome 5400E embedded graphics processor.[127] December 10, 2009: VIA released their first product supporting OpenCL 1.0 – ChromotionHD 2.0 video processor included in VN1000 chipset.[128] December 21, 2009: AMD released the production version of the ATI Stream SDK 2.0,[129] which provides OpenCL 1.0 support for R800 GPUs and beta support for R700 GPUs. June 1, 2010: ZiiLABS released details of their first OpenCL implementation for the ZMS processor for handheld, embedded and digital home products.[130] June 30, 2010: IBM released a fully conformant version of OpenCL 1.0.[4] September 13, 2010: Intel released details of their first OpenCL implementation for the Sandy Bridge chip architecture. Archived from the original on October 16, 2013. Amazon Web Services. OpenCL Lounge. ^ "Announcing OpenCL Development Kit for Linux on Power v0.3". YouTube. Retrieved April 27, 2009. S2CID 38831149. "The Long Road to 64 Bits". The researchers noted that their comparison could be made fairer by applying manual optimizations to the OpenCL programs, in which case there was "no reason for OpenCL to obtain worse performance than CUDA". Image supports are here in the focus of development. ^ Gwennap, Linley (3 October 1994). HPCWire. ^ Sochacki, Bartosz (July 19, 2019). However, IA-32 processors from the Pentium Pro onward allow a 36-bit physical memory address space, using Physical Address Extension (PAE), which gives a 64 GiB physical address range, of which up to 62 GiB may be used by main memory; operating systems that support PAE may not be limited to 4 GiB of physical memory, even on IA-32 processors. Vulkan and OpenCL 2.1 share SPIR-V as an intermediate representation allowing high-level language front-ends to share a common compilation target. 2000 IBM releases z/OS, a 64-bit operating system descended from MVS, for the new zSeries 64-bit mainframes; 64-bit Linux on z Systems follows the CPU release almost immediately. ^ "ILP32 and LP64 data models and data type sizes".

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