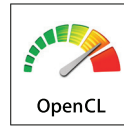


OpenCL (Open Computing Language) is a multi-vendor open standard for general-purpose parallel programming of heterogeneous systems that include CPUs, GPUs, and other processors. OpenCL provides a uniform programming environment for software developers to write efficient, portable code for high-performance compute servers, desktop computer systems, and handheld devices. Specifications and online reference available at www.khronos.org/opencvl.



KHRONOS
GROUP

[n.n.n] and purple text: sections and text in the OpenCL API Spec.
[n.n.n] and green text: sections and text in the OpenCL C Spec.
[n.n.n] and blue text: sections and text in the OpenCL Extension Spec.

OpenCL API Reference

The OpenCL Platform Layer

The OpenCL platform layer implements platform-specific features that allow applications to query OpenCL devices, device configuration information, and to create OpenCL contexts using one or more devices. **Items in blue apply when the appropriate extension is supported.**

Querying Platform Info & Devices [4.1-2] [9.16.9]

`cl_int` **clGetPlatformIDs** (`cl_uint num_entries,`
`cl_platform_id *platforms,` `cl_uint *num_platforms`)

`cl_int` **clCldGetPlatformIDsKHR** (`cl_uint num_entries,`
`cl_platform_id *platforms,` `cl_uint *num_platforms`)

`cl_int` **clGetPlatformInfo** (`cl_platform_id platform,`
`cl_platform_info param_name,`
`size_t param_value_size,` `void *param_value,`
`size_t *param_value_size_ret`)

param_name: CL_PLATFORM_{PROFILE, VERSION},
 CL_PLATFORM_{NAME, VENDOR, EXTENSIONS},
 CL_PLATFORM_ICD_SUFFIX_KHR [Table 4.1]

`cl_int` **clGetDeviceIDs** (`cl_platform_id platform,`
`cl_device_type device_type,` `cl_uint num_entries,`
`cl_device_id *devices,` `cl_uint *num_devices`)

device_type: [Table 4.2]

CL_DEVICE_TYPE_{ACCELERATOR, ALL, CPU},
 CL_DEVICE_TYPE_{CUSTOM, DEFAULT, GPU}

`cl_int` **clGetDeviceInfo** (`cl_device_id device,`
`cl_device_info param_name,`
`size_t param_value_size,` `void *param_value,`
`size_t *param_value_size_ret`)

param_name: [Table 4.3]

CL_DEVICE_ADDRESS_BITS, CL_DEVICE_AVAILABLE,
 CL_DEVICE_BUILT_IN_KERNELS,
 CL_DEVICE_COMPILER_AVAILABLE,
 CL_DEVICE_{DOUBLE, HALF, SINGLE}_FP_CONFIG,
 CL_DEVICE_ENDIAN_LITTLE, CL_DEVICE_EXTENSIONS,
 CL_DEVICE_ERROR_CORRECTION_SUPPORT,
 CL_DEVICE_EXECUTION_CAPABILITIES,
 CL_DEVICE_GLOBAL_MEM_CACHE_{SIZE, TYPE},
 CL_DEVICE_GLOBAL_MEM_{CACHELINE_SIZE, SIZE},
 CL_DEVICE_GLOBAL_VARIABLE_PREFERRED_TOTAL_SIZE,
 CL_DEVICE_PREFERRED_{PLATFORM, LOCAL,
 GLOBAL}_ATOMIC_ALIGNMENT,
 CL_DEVICE_GLOBAL_VARIABLE_SHARING,
 CL_DEVICE_HOST_UNIFIED_MEMORY,
 CL_DEVICE_IMAGE_MAX_{ARRAY, BUFFER}_SIZE,
 CL_DEVICE_IMAGE_SUPPORT,
 CL_DEVICE_IMAGE2D_MAX_{WIDTH, HEIGHT},
 CL_DEVICE_IMAGE3D_MAX_{WIDTH, HEIGHT, DEPTH},
 CL_DEVICE_IMAGE_BASE_ADDRESS_ALIGNMENT,
 CL_DEVICE_IMAGE_PITCH_ALIGNMENT,
 CL_DEVICE_LINKER_AVAILABLE,
 CL_DEVICE_LOCAL_MEM_{TYPE, SIZE},
 CL_DEVICE_MAX_READ_IMAGE_ARGS,
 CL_DEVICE_MAX_WRITE_IMAGE_ARGS,
 CL_DEVICE_MAX_{CLOCK_FREQUENCY, PIPE_ARGS},
 CL_DEVICE_MAX_{COMPUTE_UNITS, SAMPLERS},
 CL_DEVICE_MAX_CONSTANT_{ARGS, BUFFER_SIZE},
 CL_DEVICE_MAX_{MEM_ALLOC, PARAMETER}_SIZE,
 CL_DEVICE_MAX_GLOBAL_VARIABLE_SIZE,
 CL_DEVICE_MAX_ON_DEVICE_{QUEUES, EVENTS},
 CL_DEVICE_MAX_WORK_GROUP_SIZE,
 CL_DEVICE_MAX_WORK_ITEM_{DIMENSIONS, SIZES},
 CL_DEVICE_MEM_BASE_ADDR_ALIGN,
 CL_DEVICE_NAME,
 CL_DEVICE_NATIVE_VECTOR_WIDTH_{CHAR, INT},
 CL_DEVICE_NATIVE_VECTOR_WIDTH_{LONG, SHORT},
 CL_DEVICE_NATIVE_VECTOR_WIDTH_{DOUBLE, HALF},
 CL_DEVICE_NATIVE_VECTOR_WIDTH_FLOAT,
 CL_DEVICE_{OPENCL_C_VERSION, PARENT_DEVICE},
 CL_DEVICE_PARTITION_AFFINITY_DOMAIN,
 CL_DEVICE_PARTITION_MAX_SUB_DEVICES,
 CL_DEVICE_PARTITION_{PROPERTIES, TYPE},
 CL_DEVICE_PIPE_MAX_ACTIVE_RESERVATIONS,
 CL_DEVICE_PIPE_MAX_PACKET_SIZE,

CL_DEVICE_{PLATFORM, PRINTF_BUFFER_SIZE},
 CL_DEVICE_PREFERRED_VECTOR_WIDTH_{CHAR, INT},
 CL_DEVICE_PREFERRED_VECTOR_WIDTH_DOUBLE,
 CL_DEVICE_PREFERRED_VECTOR_WIDTH_HALF,
 CL_DEVICE_PREFERRED_VECTOR_WIDTH_LONG,
 CL_DEVICE_PREFERRED_VECTOR_WIDTH_SHORT,
 CL_DEVICE_PREFERRED_VECTOR_WIDTH_FLOAT,
 CL_DEVICE_PREFERRED_INTEROP_USER_SYNC,
 CL_DEVICE_PROFILE,
 CL_DEVICE_PROFILING_TIMER_RESOLUTION,
 CL_DEVICE_SPIR_VERSIONS,
 CL_DEVICE_QUEUE_ON_DEVICE_PROPERTIES,
 CL_DEVICE_QUEUE_ON_HOST_PROPERTIES,
 CL_DEVICE_QUEUE_ON_DEVICE_MAX_SIZE,
 CL_DEVICE_QUEUE_ON_DEVICE_PREFERRED_SIZE,
 CL_DEVICE_{REFERENCE_COUNT, VENDOR_ID},
 CL_DEVICE_SVM_CAPABILITIES,
 CL_DEVICE_TERMINATE_CAPABILITY_KHR,
 CL_DEVICE_{TYPE, VENDOR},
 CL_{DEVICE, DRIVER}_VERSION

Partitioning a Device [4.3]

`cl_int` **clCreateSubDevices** (`cl_device_id in_device,`
`const cl_device_partition_property *properties,`
`cl_uint num_devices,` `cl_device_id *out_devices,`
`cl_uint *num_devices_ret`)

properties: CL_DEVICE_PARTITION_EQUALLY,
 CL_DEVICE_PARTITION_BY_COUNTS,
 CL_DEVICE_PARTITION_BY_AFFINITY_DOMAIN

`cl_int` **clRetainDevice** (`cl_device_id device`)

`cl_int` **clReleaseDevice** (`cl_device_id device`)

Contexts [4.4]

`cl_context` **clCreateContext** (
`const cl_context_properties *properties,`
`cl_uint num_devices,` `const cl_device_id *devices,`
`void (CL_CALLBACK *pfn_notify)`
`(const char *errinfo,` `const void *private_info,`
`size_t cb,` `void *user_data),`
`void *user_data,` `cl_int *errcode_ret`)

The OpenCL Runtime

API calls that manage OpenCL objects such as command-queues, memory objects, program objects, kernel objects for __kernel functions in a program and calls that allow you to enqueue commands to a command-queue such as executing a kernel, reading, or writing a memory object.

Command Queues [5.1]

`cl_command_queue`
clCreateCommandQueueWithProperties (
`cl_context context,` `cl_device_id device,`
`const cl_command_queue_properties *properties,`
`cl_int *errcode_ret`)

properties: [Table 5.1] CL_QUEUE_SIZE,
 CL_QUEUE_PROPERTIES (bitfield which may be set to an OR of CL_QUEUE_* where * may be: OUT_OF_ORDER_EXEC_MODE_ENABLE, PROFILING_ENABLE, ON_DEVICE[_DEFAULT])

`cl_int` **clRetainCommandQueue** (
`cl_command_queue command_queue`)

`cl_int` **clReleaseCommandQueue** (
`cl_command_queue command_queue`)

`cl_int` **clGetCommandQueueInfo** (
`cl_command_queue command_queue,`
`cl_command_queue_info param_name,`
`size_t param_value_size,` `void *param_value,`
`size_t *param_value_size_ret`)

param_name: [Table 5.2] CL_QUEUE_CONTEXT,
 CL_QUEUE_DEVICE, CL_QUEUE_SIZE,
 CL_QUEUE_REFERENCE_COUNT,
 CL_QUEUE_PROPERTIES

properties: [Table 4.5]

NULL or CL_CONTEXT_PLATFORM,
 CL_CONTEXT_INTEROP_USER_SYNC,
 CL_CONTEXT_{D3D10, D3D11}_DEVICE_KHR,
 CL_CONTEXT_ADAPTER_{D3D9, D3D9EX}_KHR,
 CL_CONTEXT_ADAPTER_DXVA_KHR,
 CL_CONTEXT_MEMORY_INITIALIZE_KHR,
 CL_CONTEXT_TERMINATE_KHR,
 CL_GL_CONTEXT_KHR, CL_CGL_SHAREGROUP_KHR,
 CL_{EGL, GLX}_DISPLAY_KHR, CL_WGL_HDC_KHR

`cl_context` **clCreateContextFromType** (
`const cl_context_properties *properties,`
`cl_device_type device_type,`
`void (CL_CALLBACK *pfn_notify)`
`(const char *errinfo,` `const void *private_info,`
`size_t cb,` `void *user_data),`
`void *user_data,` `cl_int *errcode_ret`)

properties: See **clCreateContext**
device_type: See **clGetDeviceIDs**

`cl_int` **clRetainContext** (`cl_context context`)

`cl_int` **clReleaseContext** (`cl_context context`)

`cl_int` **clGetContextInfo** (`cl_context context,`
`cl_context_info param_name,`
`size_t param_value_size,` `void *param_value,`
`size_t *param_value_size_ret`)

param_name: CL_CONTEXT_REFERENCE_COUNT,
 CL_CONTEXT_{DEVICES, NUM_DEVICES,
 PROPERTIES}, CL_CONTEXT_{D3D10, D3D11}_
 PREFER_SHARED_RESOURCES_KHR [Table 4.6]

`cl_int` **clTerminateContextKHR** (`cl_context context`)

Get CL Extension Function Pointers [9.2]

`void*` **clGetExtensionFunctionAddressForPlatform** (
`cl_platform_id platform,` `const char *funcname`)

Buffer Objects

Elements are stored sequentially and accessed using a pointer by a kernel executing on a device.

Create Buffer Objects [5.2.1]

`cl_mem` **clCreateBuffer** (`cl_context context,`
`cl_mem_flags flags,` `size_t size,` `void *host_ptr,`
`cl_int *errcode_ret`)

flags: [Table 5.3] CL_MEM_READ_WRITE,
 CL_MEM_{WRITE, READ}_ONLY,
 CL_MEM_HOST_NO_ACCESS,
 CL_MEM_HOST_{READ, WRITE}_ONLY,
 CL_MEM_{USE, ALLOC, COPY}_HOST_PTR

`cl_mem` **clCreateSubBuffer** (`cl_mem buffer,`
`cl_mem_flags flags,`
`cl_buffer_create_type buffer_create_type,`
`const void *buffer_create_info,` `cl_int *errcode_ret`)

flags: See **clCreateBuffer**

buffer_create_type: CL_BUFFER_CREATE_TYPE_REGION

Read, Write, Copy Buffer Objects [5.2.2]

`cl_int` **clEnqueueReadBuffer** (
`cl_command_queue command_queue,`
`cl_mem buffer,`
`cl_bool blocking_read,` `size_t offset,` `size_t size,`
`void *ptr,` `cl_uint num_events_in_wait_list,`
`const cl_event *event_wait_list,` `cl_event *event`)

`cl_int` **clEnqueueReadBufferRect** (
`cl_command_queue command_queue,`
`cl_mem buffer,` `cl_bool blocking_read,`
`const size_t *buffer_origin,` `const size_t *host_origin,`
`const size_t *region,` `size_t buffer_row_pitch,`
`size_t buffer_slice_pitch,` `size_t host_row_pitch,`
`size_t host_slice_pitch,` `void *ptr,`
`cl_uint num_events_in_wait_list,`
`const cl_event *event_wait_list,` `cl_event *event`)

(Continued on next page >)

Buffer Objects (continued)

```
cl_int clEnqueueWriteBuffer (
    cl_command_queue command_queue, cl_mem buffer, cl_bool blocking_write,
    size_t offset, size_t size, const void *ptr, cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

```
cl_int clEnqueueWriteBufferRect (
    cl_command_queue command_queue, cl_mem buffer, cl_bool blocking_write,
    const size_t *buffer_origin, const size_t *host_origin, const size_t *region,
    size_t buffer_row_pitch, size_t buffer_slice_pitch, size_t host_row_pitch,
    size_t host_slice_pitch, const void *ptr, cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

```
cl_int clEnqueueFillBuffer (
    cl_command_queue command_queue, cl_mem buffer, const void *pattern,
    size_t pattern_size, size_t offset, size_t size, cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

```
cl_int clEnqueueCopyBuffer (
    cl_command_queue command_queue, cl_mem src_buffer, cl_mem dst_buffer,
    size_t src_offset, size_t dst_offset, size_t size, cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

```
cl_int clEnqueueCopyBufferRect (
    cl_command_queue command_queue, cl_mem src_buffer, cl_mem dst_buffer,
    const size_t *src_origin, const size_t *dst_origin, const size_t *region,
    size_t src_row_pitch, size_t src_slice_pitch, size_t dst_row_pitch,
    size_t dst_slice_pitch, cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

Map Buffer Objects [5.2.4]

```
void * clEnqueueMapBuffer (
    cl_command_queue command_queue, cl_mem buffer, cl_bool blocking_map,
    cl_map_flags map_flags, size_t offset, size_t size,
    cl_uint num_events_in_wait_list, const cl_event *event_wait_list,
    cl_event *event, cl_int *errcode_ret)
```

map_flags: CL_MAP_READ, CL_MAP_WRITE, CL_MAP_WRITE_INVALIDATE_REGION

Conversions and Type Casting Examples [6.2]

```
T a = (T)b; // Scalar to scalar, _rte to nearest even
           // or scalar to vector _rtz toward zero
T a = convert_T(b); _rtp toward + infinity
T a = convert_T_R(b); _rtn toward - infinity
T a = as_T(b);
T a = convert_T_sat_R(b);
R: one of the following rounding modes:
```

Memory Objects

A memory object is a handle to a reference counted region of global memory. Includes Buffer Objects, Image Objects, and Pipe Objects. **Items in blue apply when the appropriate extension is supported.**

Memory Objects [5.5.1, 5.5.2]

```
cl_int clRetainMemObject (cl_mem memobj)
```

```
cl_int clReleaseMemObject (cl_mem memobj)
```

```
cl_int clSetMemObjectDestructorCallback (cl_mem memobj,
    void (CL_CALLBACK *pfn_notify)
    (cl_mem memobj, void *user_data),
    void *user_data)
```

```
cl_int clEnqueueUnmapMemObject (cl_command_queue command_queue,
    cl_mem memobj, void *mapped_ptr, cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

Migrate Memory Objects [5.5.4]

```
cl_int clEnqueueMigrateMemObjects (cl_command_queue command_queue,
    cl_uint num_mem_objects, const cl_mem *mem_objects,
    cl_mem_migration_flags flags, cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

flags: CL_MIGRATE_MEM_OBJECT_HOST, CL_MIGRATE_MEM_OBJECT_CONTENT_UNDEFINED

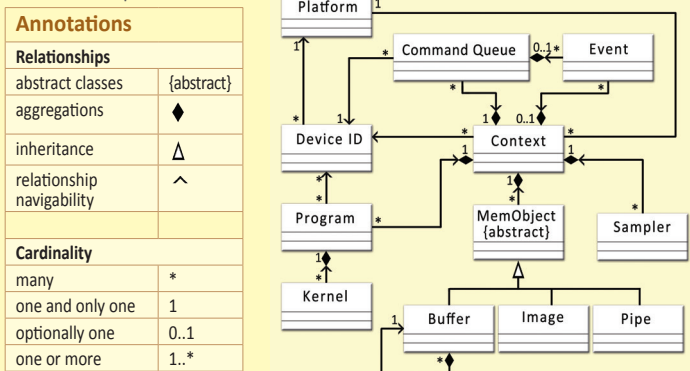
Query Memory Object [5.5.5]

```
cl_int clGetMemObjectInfo (cl_mem memobj, cl_mem_info param_name,
    size_t param_value_size, void *param_value, size_t *param_value_size_ret)
```

param_name: CL_MEM_TYPE, CL_MEM_FLAGS, CL_MEM_SIZE, CL_MEM_HOST_PTR, CL_MEM_OFFSET, CL_MEM_MAP_REFERENCE_COUNT, CL_MEM_ASSOCIATED_MEMOBJECT, CL_MEM_CONTEXT, CL_MEM_USES_SVM_POINTER, CL_MEM_D3D10_RESOURCE_KHR, CL_MEM_D3D11_RESOURCE_KHR, CL_MEM_DX9_MEDIA_ADAPTER_TYPE, CL_MEM_SURFACE_INFO_KHR [Table 5.12]

OpenCL Class Diagram

The figure below describes the OpenCL specification as a class diagram using the Unified Modeling Language¹ (UML) notation. The diagram shows both nodes and edges which are classes and their relationships. As a simplification it shows only classes, and no attributes or operations.



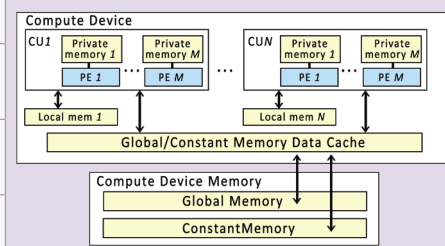
¹ Unified Modeling Language (<http://www.uml.org/>) is a trademark of Object Management Group (OMG).

OpenCL Device Architecture Diagram

The table below shows memory regions with allocation and memory access capabilities. R=Read, W=Write

	Host	Kernel
Global	Dynamic allocation R/W access	No allocation R/W access
Constant	Dynamic allocation R/W access	Static allocation R-only access
Local	Dynamic allocation No access	Static allocation R/W access
Private	No allocation No access	Static allocation R/W access

This conceptual OpenCL device architecture diagram shows processing elements (PE), compute units (CU), and devices. The host is not shown.



Pipes

A pipe is a memory object that stores data organized as a FIFO. Pipe objects can only be accessed using built-in functions that read from and write to a pipe. Pipe objects are not accessible from the host.

Create Pipe Objects [5.4.1]

```
cl_mem clCreatePipe (cl_context context, cl_mem_flags flags, cl_uint pipe_packet_size,
    cl_uint pipe_max_packets, const cl_pipe_properties *properties, cl_int *errcode_ret)
```

flags: 0 or CL_MEM_READ_WRITE, CL_MEM_READ_WRITE_ONLY, CL_MEM_HOST_NO_ACCESS

Pipe Object Queries [5.4.2]

```
cl_int clGetPipeInfo (cl_mem pipe, cl_pipe_info param_name, size_t param_value_size,
    void *param_value, size_t *param_value_size_ret)
```

param_name: CL_PIPE_PACKET_SIZE, CL_PIPE_MAX_PACKETS

Shared Virtual Memory

Shared Virtual Memory (SVM) allows the host and kernels executing on devices to directly share complex, pointer-containing data structures such as trees and linked lists.

SVM Sharing Granularity [5.6.1]

```
void * clSVMAlloc (cl_context context, cl_svm_mem_flags flags, size_t size,
    unsigned int alignment)
```

flags: [Table 5.13] CL_MEM_READ_WRITE, CL_MEM_WRITE_READ_ONLY, CL_MEM_SVM_FINE_GRAIN_BUFFER, CL_MEM_SVM_ATOMICS

```
void clSVMFree (cl_context context, void *svm_pointer)
```

Enqueuing SVM Operations [5.6.2]

```
cl_int clEnqueueSVMFree (
    cl_command_queue command_queue,
    cl_uint num_svm_pointers, void *svm_pointers[],
    void (CL_CALLBACK *pfn_free_func)
    (cl_command_queue command_queue,
    cl_uint num_svm_pointers,
    void *svm_pointers[], void *user_data),
    void *user_data, cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

(Continued on next page >)

Shared Virtual Memory (continued)

```
cl_int clEnqueueSVMMemcpy (
    cl_command_queue command_queue,
    cl_bool blocking_copy, void *dst_ptr,
    const void *src_ptr, size_t size,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)

cl_int clEnqueueSVMMemFill (
    cl_command_queue command_queue,
    void *svm_ptr, const void *pattern,
    size_t pattern_size, size_t size,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)

cl_int clEnqueueSVMMap (
    cl_command_queue command_queue,
    cl_bool blocking_map, cl_map_flags map_flags,
    void *svm_ptr, size_t size,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)

cl_int clEnqueueSVMUnmap (
    cl_command_queue command_queue,
    void *svm_ptr, cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

Kernel Objects

A kernel is a function declared in a program, identified by the `__kernel` qualifier. A kernel object encapsulates the specific `__kernel` function and the argument values to be used when executing it. **Items in blue apply when the appropriate extension is supported.**

Create Kernel Objects [5.9.1]

```
cl_kernel clCreateKernel (cl_program program,
    const char *kernel_name, cl_int *errcode_ret)

cl_int clCreateKernelsInProgram (cl_program program,
    cl_uint num_kernels, cl_kernel *kernels,
    cl_uint *num_kernels_ret)

cl_int clRetainKernel (cl_kernel kernel)
cl_int clReleaseKernel (cl_kernel kernel)
```

Kernel Arguments and Queries [5.9.2, 5.9.3]

```
cl_int clSetKernelArg (cl_kernel kernel,
    cl_uint arg_index, size_t arg_size,
    const void *arg_value)

cl_int clSetKernelArgSVMPointer (cl_kernel kernel,
    cl_uint arg_index, const void *arg_value)

cl_int clSetKernelExecInfo (cl_kernel kernel,
    cl_kernel_exec_info param_name,
    size_t param_value_size, const void *param_value)
param_name: CL_KERNEL_EXEC_INFO_SVM_PTRS,
             CL_KERNEL_EXEC_INFO_SVM_FINE_GRAIN_SYSTEM

cl_int clGetKernelInfo (cl_kernel kernel,
    cl_kernel_info param_name,
    size_t param_value_size, void *param_value,
    size_t *param_value_size_ret)
param_name: [Table 5.19]
             CL_KERNEL_FUNCTION_NAME,
             CL_KERNEL_NUM_ARGS,
             CL_KERNEL_REFERENCE_COUNT,
             CL_KERNEL_{ATTRIBUTES, CONTEXT, PROGRAM}

cl_int clGetKernelWorkGroupInfo (cl_kernel kernel,
    cl_device_id device,
    cl_kernel_work_group_info param_name,
    size_t param_value_size, void *param_value,
    size_t *param_value_size_ret)
param_name: CL_KERNEL_GLOBAL_WORK_SIZE,
             CL_KERNEL_{COMPILE}_WORK_GROUP_SIZE,
             CL_KERNEL_{LOCAL, PRIVATE}_MEM_SIZE,
             CL_KERNEL_PREFERRED_WORK_GROUP_SIZE_
             MULTIPLE [Table 5.20]

cl_int clGetKernelArgInfo (cl_kernel kernel,
    cl_uint arg_idx, cl_kernel_arg_info param_name,
    size_t param_value_size, void *param_value,
    size_t *param_value_size_ret)
param_name: CL_KERNEL_ARG_{ACCESS, ADDRESS}_QUALIFIER,
             CL_KERNEL_ARG_NAME,
             CL_KERNEL_ARG_TYPE_{NAME, QUALIFIER} [Table 5.21]
```

Program Objects

An OpenCL program consists of a set of kernels that are identified as functions declared with the `__kernel` qualifier in the program source.

Create Program Objects [5.8.1]

```
cl_program clCreateProgramWithSource (
    cl_context context, cl_uint count,
    const char **strings, const size_t *lengths,
    cl_int *errcode_ret)

cl_program clCreateProgramWithBinary (
    cl_context context, cl_uint num_devices,
    const cl_device_id *device_list, const size_t *lengths,
    const unsigned char **binaries,
    cl_int *binary_status, cl_int *errcode_ret)

cl_program clCreateProgramWithBuiltInKernels (
    cl_context context, cl_uint num_devices,
    const cl_device_id *device_list,
    const char *kernel_names, cl_int *errcode_ret)

cl_int clRetainProgram (cl_program program)
cl_int clReleaseProgram (cl_program program)
```

Building Program Executables [5.8.2]

```
cl_int clBuildProgram (cl_program program,
    cl_uint num_devices, const cl_device_id *device_list,
    const char *options, void (CL_CALLBACK *pfn_notify)
    (cl_program program, void *user_data),
    void *user_data)
```

Separate Compilation and Linking [5.8.3]

```
cl_int clCompileProgram (cl_program program,
    cl_uint num_devices, const cl_device_id *device_list,
    const char *options, cl_uint num_input_headers,
    const cl_program *input_headers,
    const char **header_include_names,
    void (CL_CALLBACK *pfn_notify)
    (cl_program program, void *user_data),
    void *user_data)
```

cl_int clGetKernelSubGroupInfoKHR

```
(cl_kernel kernel, cl_device_id device,
    cl_kernel_sub_group_info param_name,
    size_t input_value_size, const void *input_value,
    size_t param_value_size, void *param_value,
    size_t *param_value_size_ret)
```

param_name:
CL_KERNEL_MAX_SUB_GROUP_SIZE_FOR_NDRANGE,
CL_KERNEL_SUB_GROUP_COUNT_FOR_NDRANGE

Execute Kernels [5.10]

```
cl_int clEnqueueNDRangeKernel (
    cl_command_queue command_queue,
    cl_kernel kernel, cl_uint work_dim,
    const size_t *global_work_offset,
    const size_t *global_work_size,
    const size_t *local_work_size,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)

cl_int clEnqueueNativeKernel (
    cl_command_queue command_queue,
    void (CL_CALLBACK *user_func)(void *), void *args,
    size_t cb_args, cl_uint num_mem_objects,
    const cl_mem *mem_list, const void **args_mem_loc,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

Flush and Finish [5.15]

```
cl_int clFlush (cl_command_queue command_queue)
cl_int clFinish (cl_command_queue command_queue)
```

Event Objects

Event objects can be used to refer to a kernel execution command, and read, write, map and copy commands on memory objects or user events.

Event Objects [5.11]

```
cl_event clCreateUserEvent (cl_context context,
    cl_int *errcode_ret)
```

```
cl_program clLinkProgram (cl_context context,
    cl_uint num_devices, const cl_device_id *device_list,
    const char *options, cl_uint num_input_programs,
    const cl_program *input_programs,
    void (CL_CALLBACK *pfn_notify)
    (cl_program program, void *user_data),
    void *user_data, cl_int *errcode_ret)
```

Unload the OpenCL Compiler [5.8.6]

```
cl_int clUnloadPlatformCompiler (
    cl_platform_id platform)
```

Query Program Objects [5.8.7]

```
cl_int clGetProgramInfo (cl_program program,
    cl_program_info param_name,
    size_t param_value_size, void *param_value,
    size_t *param_value_size_ret)
param_name: [Table 5.16]
             CL_PROGRAM_REFERENCE_COUNT,
             CL_PROGRAM_{CONTEXT, NUM_DEVICES, DEVICES},
             CL_PROGRAM_{SOURCE, BINARY_SIZES, BINARIES},
             CL_PROGRAM_{NUM_KERNELS, KERNEL_NAMES}

cl_int clGetProgramBuildInfo (
    cl_program program, cl_device_id device,
    cl_program_build_info param_name,
    size_t param_value_size, void *param_value,
    size_t *param_value_size_ret)
param_name: [Table 5.17]
             CL_PROGRAM_BINARY_TYPE,
             CL_PROGRAM_BUILD_{STATUS, OPTIONS, LOG},
             CL_PROGRAM_BUILD_GLOBAL_VARIABLE_TOTAL_SIZE
```

Compiler Options [5.8.4]

SPIR options require the `cl_khr_spir` extension.

Preprocessor: (-D processed in order for `clBuildProgram` or `clCompileProgram`)

-D name -D name=definition -I dir

Math intrinsics:

-cl-single-precision-constant
-cl-denorms-are-zero
-cl-fp32-correctly-rounded-divide-sqrt

Optimization options:

-cl-opt-disable -cl-mad-enable
-cl-no-signed-zeros -cl-finite-math-only
-cl-unsafe-math-optimizations -cl-fast-relaxed-math
-cl-uniform-work-group-size

Warning request/suppress:

-w -Werror

Control OpenCL C language version:

-cl-std=CL1.1 // OpenCL 1.1 specification
-cl-std=CL1.2 // OpenCL 1.2 specification
-cl-std=CL2.0 // OpenCL 2.0 specification

Query kernel argument information:

-cl-kernel-arg-info

Debugging options:

-g // generate additional errors for built-in
// functions that allow you to enqueue
// commands on a device

SPIR binary options:

-x spir // indicate that binary is in SPIR format
-spir-std=x // x is SPIR spec version, e.g.: 1.2

Linker Options [5.8.5]**Library linking options:**

-create-library -enable-link-options

Program linking options:

-cl-denorms-are-zero -cl-no-signed-zeroes
-cl-finite-math-only -cl-fast-relaxed-math
-cl-unsafe-math-optimizations

```
cl_int clSetUserEventStatus (cl_event event,
    cl_int execution_status)
```

```
cl_int clWaitForEvents (cl_uint num_events,
    const cl_event *event_list)
```

```
cl_int clGetEventInfo (cl_event event,
    cl_event_info param_name, size_t param_value_size,
    void *param_value, size_t *param_value_size_ret)
param_name: CL_EVENT_COMMAND_{QUEUE, TYPE},
             CL_EVENT_{CONTEXT, REFERENCE_COUNT},
             CL_EVENT_COMMAND_EXECUTION_STATUS [Table 5.22]
```

```
cl_int clRetainEvent (cl_event event)
```

(Continued on next page >)

Event Objects (continued)

```
cl_int clReleaseEvent (cl_event event)
cl_int clSetEventCallback (cl_event event,
cl_int command_exec_callback_type,
void (CL_CALLBACK *pfn_event_notify)
(cl_event event, cl_int event_command_exec_status,
void *user_data), void *user_data)
```

Markers, Barriers, Waiting for Events [5.12]

```
cl_int clEnqueueMarkerWithWaitList (
cl_command_queue command_queue,
cl_uint num_events_in_wait_list,
const cl_event *event_wait_list, cl_event *event)
cl_int clEnqueueBarrierWithWaitList (
cl_command_queue command_queue,
cl_uint num_events_in_wait_list,
const cl_event *event_wait_list, cl_event *event)
```

Profiling Operations [5.14]

```
cl_int clGetEventProfilingInfo (cl_event event,
cl_profiling_info_param_name,
size_t param_value_size, void *param_value,
size_t *param_value_size_ret)
param_name: [Table 5.23]
CL_PROFILING_COMMAND_QUEUED, CL_PROFILING_
COMMAND_COMPLETE,
CL_PROFILING_COMMAND_{SUBMIT, START, END}
```

OpenCL C Language Reference

Supported Data Types

The optional double scalar and vector types are supported if CL_DEVICE_DOUBLE_FP_CONFIG is not zero.

Built-in Scalar Data Types [6.1.1]

Table with 3 columns: OpenCL Type, API Type, Description. Lists types like bool, char, short, int, float, double, half, size_t, ptrdiff_t, intptr_t, uintptr_t, void.

Built-in Vector Data Types [6.1.2]

Table with 3 columns: OpenCL Type, API Type, Description. Lists vector types like charn, uchar, shortn, ushortn, intn, uintn, longn, ulongn, floatn, doublen, halfn.

Other Built-in Data Types [6.1.3]

The OPTIONAL types shown below are only defined if CL_DEVICE_IMAGE_SUPPORT is CL_TRUE. API type for application shown in italics where applicable. Items in blue require the cl_khr_gl_msaa_sharing extension.

Table with 3 columns: OpenCL Type, API Type, Description. Lists image types like image2d, image3d, image2d_array, image1d, image1d_buffer.

Table with 3 columns: OpenCL Type, API Type, Description. Lists sampler and queue types like image1d_array_t, image2d, image2d_array, sampler_t, queue_t, ndranger_t, clk_event_t, reserve_id_t, event_t, cl_mem_fence_flags.

Reserved Data Types [6.1.4]

Table with 2 columns: OpenCL Type, Description. Lists reserved types like booln, halfn, quad, complex half, complex float, complex double, complex quad, floatnxm, doublenxm.

Vector Component Addressing [6.1.7]

Vector Components

Table showing vector component addressing for float2, float3, float4, float8, float16 across 16 indices.

Vector Addressing Equivalences

Numeric indices are preceded by the letter s or S, e.g.: s1. Swizzling, duplication, and nesting are allowed, e.g.: v.yx, v.xx, v.lo.x

Table showing vector addressing equivalences for float2, float3, float4, float8, float16.

*When using .lo or .hi with a 3-component vector, the .w component is undefined.

Preprocessor Directives & Macros [6.10]

Table of preprocessor directives and macros including #pragma OPENCL FP_CONTRACT, __FILE__, __func__, __LINE__, __OPENCL_VERSION__, __CL_VERSION__, __CL_VERSION_1_0, __CL_VERSION_1_1, __CL_VERSION_1_2, __CL_VERSION_2_0, __OPENCL_C_VERSION__, __ENDIAN_LITTLE__, __IMAGE_SUPPORT__, __FAST_RELAXED_MATH__, FP_FAST_FMA, FP_FAST_FMAF, FP_FAST_FMA_HALF, __kernel_exec, __kernel_attribute__, __attribute__.

Operators and Qualifiers

Operators [6.3]

These operators behave similarly as in C99 except operands may include vector types when possible:

Table of operators: +, ++, >, &&, comma; -, ==, <, ||, op=; *, !=, >=, ?:, sizeof; %, &, <=, >>, sizeof; /, ~, |, <<, =; --, ^, !, =.

Address Space Qualifiers [6.5]

```
__global, global __local, local
__constant, constant __private, private
```

Function Qualifiers [6.7]

```
__kernel, kernel
__attribute__((vec_type_hint(type)))
//type defaults to int
__attribute__((work_group_size_hint(X, Y, Z)))
__attribute__((reqd_work_group_size(X, Y, Z)))
```

Blocks [6.12]

A result value type with a list of parameter types, similar to a function type. In this example:

- 1. The ^ declares variable "myBlock" is a Block.
2. The return type for the Block "myBlock" is int.
3. myBlock takes a single argument of type int.
4. The argument is named "num."
5. Multiplier captured from block's environment.

```
int (^myBlock)(int) =
^(int num) {return num * multiplier;};
```

Work-Item Built-in Functions [6.13.1]

Query the number of dimensions, global and local work size specified to clEnqueueNDRangeKernel, and global and local identifier of each work-item when this kernel is executed on a device. Sub-groups require the cl_khr_subgroups extension.

Table of work-item built-in functions: uint get_work_dim(), size_t get_global_size(), size_t get_global_id(), size_t get_local_size().

(Continued on next page >)

Work-Item Functions (continued)

size_t get_enqueued_local_size (uint dimindx)	Number of local work-items
size_t get_local_id (uint dimindx)	Local work-item ID
size_t get_num_groups (uint dimindx)	Number of work-groups
size_t get_group_id (uint dimindx)	Work-group ID
size_t get_global_offset (uint dimindx)	Global offset

size_t get_global_linear_id ()	Work-items 1-dimensional global ID
size_t get_local_linear_id ()	Work-items 1-dimensional local ID
uint get_sub_group_size ()	Number of work-items in the subgroup
uint get_max_sub_group_size ()	Maximum size of a subgroup
uint get_num_sub_groups ()	Number of subgroups
uint get_enqueued_num_sub_groups ()	
uint get_sub_group_id ()	Sub-group ID
uint get_sub_group_local_id ()	Unique work-item ID

Attribute Qualifiers [6.11]

Use to specify special attributes of enum, struct and union types.

__attribute__((aligned(n)))
 __attribute__((aligned))
 __attribute__((packed))
 __attribute__((endian(host)))
 __attribute__((endian(device)))
 __attribute__((endian))

Use to specify special attributes of variables or structure fields.

__attribute__((aligned(alignment)))
 __attribute__((nosvm))

Use to specify basic blocks and control-flow-statements.

__attribute__((attr1)) {...}

Use to specify that a loop (for, while and do loops) can be unrolled. (Must appear immediately before the loop to be affected.)

__attribute__((opencl_unroll_hint(n)))
 __attribute__((opencl_unroll_hint))

Math Built-in Functions [6.13.2] [9.4.2]

Ts is type float, optionally double, or half if the cl_khr_fp16 extension is enabled. Tn is the vector form of Ts, where n is 2, 3, 4, 8, or 16. T is Ts and Tn.

HN indicates that half and native variants are available using only the float or floatn types by prepending "half_" or "native_" to the function name. Prototypes shown in brown text are available in half_ and native_ forms only using the float or floatn types.

T acos (T)	Arc cosine
T acosh (T)	Inverse hyperbolic cosine
T acospi (T x)	acos (x) / π
T asin (T)	Arc sine
T asinh (T)	Inverse hyperbolic sine
T asinpi (T x)	asin (x) / π
T atan (T y_over_x)	Arc tangent
T atan2 (T y, T x)	Arc tangent of y / x
T atanh (T)	Hyperbolic arc tangent
T atanpi (T x)	atan (x) / π
T atan2pi (T x, T y)	atan2 (y, x) / π
T cbrt (T)	Cube root
T ceil (T)	Round to integer toward + infinity
T copysign (T x, T y)	x with sign changed to sign of y
T cos (T) HN	Cosine
T cosh (T)	Hyperbolic cosine
T cospi (T x)	cos (π x)
T half_divide (T x, T y)	x / y (T may only be float or floatn)
T native_divide (T x, T y)	
T erfc (T)	Complementary error function
T erf (T)	Calculates error function of T
T exp (T x) HN	Exponential base e
T exp2 (T) HN	Exponential base 2
T exp10 (T) HN	Exponential base 10

T expm1 (T x)	e ^x - 1.0
T fabs (T)	Absolute value
T fdim (T x, T y)	Positive difference between x and y
T floor (T)	Round to integer toward infinity
T fma (T a, T b, T c)	Multiply and add, then round
T fmax (T x, T y)	Return y if x < y, otherwise it returns x
Tn fmax (Tn x, Tn y)	
T fmin (T x, T y)	Return y if y < x, otherwise it returns x
Tn fmin (Tn x, Tn y)	
T fmod (T x, T y)	Modulus. Returns x - y * trunc (x/y)
T fract (T x, T *iptr)	Fractional value in x
Ts frexp (T x, int *exp)	Extract mantissa and exponent
Tn frexp (T x, intn *exp)	
T hypot (T x, T y)	Square root of x ² + y ²
int[n] ilogb (T x)	Return exponent as an integer value
Ts ldexp (T x, int n)	x * 2 ⁿ
Tn ldexp (T x, intn n)	
T lgamma (T x)	Log gamma function
Ts lgamma_r (T x, int *signp)	
Tn lgamma_r (Tn x, intn *signp)	
T log (T) HN	Natural logarithm
T log2 (T) HN	Base 2 logarithm
T log10 (T) HN	Base 10 logarithm
T log1p (T x)	ln (1.0 + x)
T logb (T x)	Exponent of x
T mad (T a, T b, T c)	Approximates a * b + c
T maxmag (T x, T y)	Maximum magnitude of x and y
T minmag (T x, T y)	Minimum magnitude of x and y
T modf (T x, T *iptr)	Decompose floating-point number
float[n] nan (uint[n] nancode)	Quiet NaN (Return is scalar when nancode is scalar)
half[n] nan (ushort[n] nancode)	
double[n] nan (ulong[n] nancode)	

T nextafter (T x, T y)	Next representable floating-point value after x in the direction of y
T pow (T x, T y)	Compute x to the power of y
Ts pown (T x, int y)	Compute x ^y , where y is an integer
Tn pown (T x, intn y)	
T power (T x, T y) HN	Compute x ^y , where x is >= 0
T half_recip (T x)	1 / x (T may only be float or floatn)
T native_recip (T x)	
T remainder (T x, T y)	Floating point remainder
Ts remquo (T x, T y, int *quo)	Remainder and quotient
Tn remquo (Tn x, Tn y, intn *quo)	
T rint (T)	Round to nearest even integer
Ts rootn (T x, int y)	Compute x to the power of 1/y
Tn rootn (T x, intn y)	
T round (T x)	Integral value nearest to x rounding
T rsqrt (T) HN	Inverse square root
T sin (T) HN	Sine
T sincos (T x, T *cosval)	Sine and cosine of x
T sinh (T)	Hyperbolic sine
T sinpi (T x)	sin (π x)
T sqrt (T) HN	Square root
T tan (T) HN	Tangent
T tanh (T)	Hyperbolic tangent
T tanpi (T x)	tan (π x)
T tgamma (T)	Gamma function
T trunc (T)	Round to integer toward zero

Math Constants [6.13.2] [9.4.2]

The values of the following symbolic constants are single-precision float.

MAXFLOAT	Value of maximum non-infinite single-precision floating-point number
HUGE_VALF	Positive float expression, evaluates to +infinity
HUGE_VAL	Positive double expression, evals. to +infinity OPTIONAL
INFINITY	Constant float expression, positive or unsigned infinity
NAN	Constant float expression, quiet NaN

When double precision is supported, macros ending in _F are available in type double by removing _F from the macro name, and in type half when the cl_khr_fp16 extension is enabled by replacing _F with _H.

M_E_F	Value of e
M_LOG2E_F	Value of log ₂ e
M_LOG10E_F	Value of log ₁₀ e
M_LN2_F	Value of log ₂ 2
M_LN10_F	Value of log ₁₀ 10
M_PI_F	Value of π
M_PI_2_F	Value of π / 2
M_PI_4_F	Value of π / 4
M_1_PI_F	Value of 1 / π
M_2_PI_F	Value of 2 / π
M_2_SQRTPI_F	Value of 2 / √π
M_SQRT2_F	Value of √2
M_SQRT1_2_F	Value of 1 / √2

Integer Built-in Functions [6.13.3]

T is type char, charn, uchar, uchar_n, short, shortn, ushort, ushortn, int, intn, uint, uintn, long, longn, ulong, or ulongn, where n is 2, 3, 4, 8, or 16. Tu is the unsigned version of T. Tsc is the scalar version of T.

Tu abs (T x)	x
Tu abs_diff (T x, T y)	x - y without modulo overflow
T add_sat (T x, T y)	x + y and saturates the result
T hadd (T x, T y)	(x + y) >> 1 without mod. overflow
T rhadd (T x, T y)	(x + y + 1) >> 1
T clamp (T x, T min, T max)	min(max(x, minval), maxval)
T clamp (T x, Tsc min, Tsc max)	
T clz (T x)	number of leading 0-bits in x
T ctz (T x)	number of trailing 0-bits in x
T mad_hi (T a, T b, T c)	mul_hi(a, b) + c
T mad_sat (T a, T b, T c)	a * b + c and saturates the result
T max (T x, T y)	y if x < y, otherwise it returns x
Tn max (T x, Tsc y)	
T min (T x, T y)	y if y < x, otherwise it returns x
Tn min (T x, Tsc y)	
T mul_hi (T x, T y)	high half of the product of x and y
T rotate (T v, T i)	result[indx] = v[indx] << i[indx]
T sub_sat (T x, T y)	x - y and saturates the result
T popcount (T x)	Number of non-zero bits in x

For upsample, return type is scalar when the parameters are scalar.

short[n] upsample (char[n] hi, uchar[n] lo)	result[i] = ((short)hi[i] << 8) lo[i]
ushort[n] upsample (uchar[n] hi, uchar[n] lo)	result[i] = ((ushort)hi[i] << 8) lo[i]

int[n] upsample (short[n] hi, ushort[n] lo)	result[i] = ((int)hi[i] << 16) lo[i]
uint[n] upsample (ushort[n] hi, ushort[n] lo)	result[i] = ((uint)hi[i] << 16) lo[i]
long[n] upsample (int[n] hi, uint[n] lo)	result[i] = ((long)hi[i] << 32) lo[i]
ulong[n] upsample (uint[n] hi, uint[n] lo)	result[i] = ((ulong)hi[i] << 32) lo[i]

The following fast integer functions optimize the performance of kernels. In these functions, T is type int, uint, intn or intn, where n is 2, 3, 4, 8, or 16.

T mad24 (T x, T y, T z)	Multiply 24-bit integer values x, y, add 32-bit int. result to 32-bit integer z
T mul24 (T x, T y)	Multiply 24-bit integer values x and y

Common Built-in Functions [6.13.4] [9.4.3]

These functions operate component-wise and use round to nearest even rounding mode. Ts is type float, optionally double, or half if cl_khr_fp16 is enabled. Tn is the vector form of Ts, where n is 2, 3, 4, 8, or 16. T is Ts and Tn.

T clamp (T x, T min, T max)	Clamp x to range given by min, max
Tn clamp (Tn x, Tsc min, Tsc max)	
T degrees (T radians)	radians to degrees
T max (T x, T y)	Max of x and y
Tn max (Tn x, Tn y)	
T min (T x, T y)	Min of x and y
Tn min (Tn x, Tn y)	

(Continued on next page >)

Common Functions (continued)

<i>T mix</i> (<i>T x</i> , <i>T y</i> , <i>T a</i>)	Linear blend of <i>x</i> and <i>y</i>
<i>Tn mix</i> (<i>Tn x</i> , <i>Tn y</i> , <i>Ts a</i>)	
<i>T radians</i> (<i>T degrees</i>)	<i>degrees</i> to radians
<i>T step</i> (<i>T edge</i> , <i>T x</i>)	0.0 if <i>x</i> < <i>edge</i> , else 1.0
<i>Tn step</i> (<i>Ts edge</i> , <i>Tn x</i>)	
<i>T smoothstep</i> (<i>T edge0</i> , <i>T edge1</i> , <i>T x</i>)	Step and interpolate
<i>T smoothstep</i> (<i>Ts edge0</i> , <i>Ts edge1</i> , <i>T x</i>)	
<i>T sign</i> (<i>T x</i>)	Sign of <i>x</i>

Geometric Built-in Functions [6.13.5] [9.4.4]

Ts is scalar type float, optionally double, or half if the **half extension** is enabled. *T* is *Ts* and the 2-, 3-, or 4-component vector forms of *Ts*.

float[3,4] cross (float[3,4] <i>p0</i> , float[3,4] <i>p1</i>)	Cross product
double[3,4] cross (double[3,4] <i>p0</i> , double[3,4] <i>p1</i>)	
half[3,4] cross (half[3,4] <i>p0</i> , half[3,4] <i>p1</i>)	
<i>Ts distance</i> (<i>T p0</i> , <i>T p1</i>)	Vector distance
<i>Ts dot</i> (<i>T p0</i> , <i>T p1</i>)	Dot product

<i>Ts length</i> (<i>T p</i>)	Vector length
<i>T normalize</i> (<i>T p</i>)	Normal vector length 1
float fast_distance (float <i>p0</i> , float <i>p1</i>)	Vector distance
float fast_distance (floatn <i>p0</i> , floatn <i>p1</i>)	
float fast_length (float <i>p</i>)	Vector length
float fast_length (floatn <i>p</i>)	
float fast_normalize (float <i>p</i>)	Normal vector length 1
floatn fast_normalize (floatn <i>p</i>)	

Relational Built-in Functions [6.13.6]

These functions can be used with built-in scalar or vector types as arguments and return a scalar or vector integer result. *T* is type float, floatn, char, charn, uchar, uchar, short, shortn, ushort, ushortn, int, intrn, uint, uintn, long, longn, ulong, ulongn, or optionally double or doublen. *Ti* is type char, charn, short, shortn, int, intrn, long, or longn. *Tu* is type uchar, uchar, ushort, ushortn, uint, uintn, long, or ulongn. *n* is 2, 3, 4, 8, or 16. **half** and **halfn** types require the **cl_khr_fp16** extension.

int isequal (float <i>x</i> , float <i>y</i>)	Compare of <i>x == y</i>
intrn isequal (floatn <i>x</i> , floatn <i>y</i>)	
int isequal (double <i>x</i> , double <i>y</i>)	
longn isequal (doublen <i>x</i> , doublen <i>y</i>)	
int isequal (half <i>x</i> , half <i>y</i>)	Compare of <i>x != y</i>
shortn isequal (halfn <i>x</i> , halfn <i>y</i>)	
int isnotequal (float <i>x</i> , float <i>y</i>)	
intrn isnotequal (floatn <i>x</i> , floatn <i>y</i>)	
int isnotequal (double <i>x</i> , double <i>y</i>)	Compare of <i>x > y</i>
longn isnotequal (doublen <i>x</i> , doublen <i>y</i>)	
int isnotequal (half <i>x</i> , half <i>y</i>)	
shortn isnotequal (halfn <i>x</i> , halfn <i>y</i>)	
int isgreater (float <i>x</i> , float <i>y</i>)	Compare of <i>x >= y</i>
intrn isgreater (floatn <i>x</i> , floatn <i>y</i>)	
int isgreater (double <i>x</i> , double <i>y</i>)	
longn isgreater (doublen <i>x</i> , doublen <i>y</i>)	
int isgreater (half <i>x</i> , half <i>y</i>)	Compare of <i>x >= y</i>
shortn isgreater (halfn <i>x</i> , halfn <i>y</i>)	
int isgreaterequal (float <i>x</i> , float <i>y</i>)	
intrn isgreaterequal (floatn <i>x</i> , floatn <i>y</i>)	
int isgreaterequal (double <i>x</i> , double <i>y</i>)	Compare of <i>x >= y</i>
longn isgreaterequal (doublen <i>x</i> , doublen <i>y</i>)	
int isgreaterequal (half <i>x</i> , half <i>y</i>)	
shortn isgreaterequal (halfn <i>x</i> , halfn <i>y</i>)	

int isless (float <i>x</i> , float <i>y</i>)	Compare of <i>x < y</i>
intrn isless (floatn <i>x</i> , floatn <i>y</i>)	
int isless (double <i>x</i> , double <i>y</i>)	
longn isless (doublen <i>x</i> , doublen <i>y</i>)	
int isless (half <i>x</i> , half <i>y</i>)	Compare of <i>x < y</i>
shortn isless (halfn <i>x</i> , halfn <i>y</i>)	
int islessequal (float <i>x</i> , float <i>y</i>)	
intrn islessequal (floatn <i>x</i> , floatn <i>y</i>)	
int islessequal (double <i>x</i> , double <i>y</i>)	Compare of <i>x <= y</i>
longn islessequal (doublen <i>x</i> , doublen <i>y</i>)	
int islessequal (half <i>x</i> , half <i>y</i>)	
shortn islessequal (halfn <i>x</i> , halfn <i>y</i>)	
int islessgreater (float <i>x</i> , float <i>y</i>)	Compare of <i>(x < y) (x > y)</i>
intrn islessgreater (floatn <i>x</i> , floatn <i>y</i>)	
int islessgreater (double <i>x</i> , double <i>y</i>)	
longn islessgreater (doublen <i>x</i> , doublen <i>y</i>)	
int islessgreater (half <i>x</i> , half <i>y</i>)	Test for finite value
shortn islessgreater (halfn <i>x</i> , halfn <i>y</i>)	
int isfinite (float)	
intrn isfinite (floatn)	
int isfinite (double)	Test for finite value
longn isfinite (doublen)	
int isfinite (half)	
shortn isfinite (halfn)	
int isinf (float)	Test for + or - infinity
intrn isinf (floatn)	
int isinf (double)	
longn isinf (doublen)	
int isinf (half)	Test for a NaN
shortn isinf (halfn)	
int isnan (float)	
intrn isnan (floatn)	

int isnan (double)	Test for a NaN
longn isnan (doublen)	
int isnan (half)	
shortn isnan (halfn)	
int isnormal (float)	Test for a normal value
intrn isnormal (floatn)	
int isnormal (double)	
longn isnormal (doublen)	
int isnormal (half)	Test for a normal value
shortn isnormal (halfn)	
int isordered (float <i>x</i> , float <i>y</i>)	
intrn isordered (floatn <i>x</i> , floatn <i>y</i>)	
int isordered (double <i>x</i> , double <i>y</i>)	Test if arguments are ordered
longn isordered (doublen <i>x</i> , doublen <i>y</i>)	
int isordered (half <i>x</i> , half <i>y</i>)	
shortn isordered (halfn <i>x</i> , halfn <i>y</i>)	
int isunordered (float <i>x</i> , float <i>y</i>)	Test if arguments are unordered
intrn isunordered (floatn <i>x</i> , floatn <i>y</i>)	
int isunordered (double <i>x</i> , double <i>y</i>)	
longn isunordered (doublen <i>x</i> , doublen <i>y</i>)	
int isunordered (half <i>x</i> , half <i>y</i>)	Test for sign bit
shortn isunordered (halfn <i>x</i> , halfn <i>y</i>)	
int signbit (float)	
intrn signbit (floatn)	
int signbit (double)	Test for sign bit
longn signbit (doublen)	
int signbit (half)	
shortn signbit (halfn)	
int any (<i>Ti x</i>)	1 if MSB in component of <i>x</i> is set; else 0
int all (<i>Ti x</i>)	1 if MSB in all components of <i>x</i> are set; else 0

Vector Data Load/Store [6.13.7] [9.4.6]

T is type char, uchar, short, ushort, int, uint, long, ulong, or float, optionally double, or half if the **cl_khr_fp16** extension is enabled. *Tn* refers to the vector form of type *T*, where *n* is 2, 3, 4, 8, or 16. *R* defaults to current rounding mode, or is one of the rounding modes listed in 6.2.3.2.

<i>Tn vload</i> (<i>size_t offset</i> , const [constant] <i>T *p</i>)	Read vector data from address (<i>p</i> + (<i>offset</i> * <i>n</i>))
void vstoren (<i>Tn data</i> , <i>size_t offset</i> , <i>T *p</i>)	Write vector data to address (<i>p</i> + (<i>offset</i> * <i>n</i>))
float vload_half (<i>size_t offset</i> , const [constant] half * <i>p</i>)	Read a half from address (<i>p</i> + <i>offset</i>)
floatn vload_halfn (<i>size_t offset</i> , const [constant] half * <i>p</i>)	Read a halfn from address (<i>p</i> + (<i>offset</i> * <i>n</i>))
void vstore_half (float <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	Write a half to address (<i>p</i> + <i>offset</i>)
void vstore_half_R (float <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	
void vstore_half (double <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	
void vstore_half_R (double <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	

void vstore_half_R (double <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	Write a half to address (<i>p</i> + <i>offset</i>)
void vstore_halfn (floatn <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	Write a half vector to address (<i>p</i> + (<i>offset</i> * <i>n</i>))
void vstore_halfn_R (floatn <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	
void vstore_halfn (doublen <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	
void vstore_halfn_R (doublen <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	
floatn vloada_halfn (<i>size_t offset</i> , const [constant] half * <i>p</i>)	Read half vector data from (<i>p</i> + (<i>offset</i> * <i>n</i>)). For half3, read from (<i>p</i> + (<i>offset</i> * 4)).
void vstorea_halfn (floatn <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	Write half vector data to (<i>p</i> + (<i>offset</i> * <i>n</i>)). For half3, write to (<i>p</i> + (<i>offset</i> * 4)).
void vstorea_halfn_R (floatn <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	
void vstorea_halfn (doublen <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	
void vstorea_halfn_R (doublen <i>data</i> , <i>size_t offset</i> , half * <i>p</i>)	

<i>T bitsselect</i> (<i>T a</i> , <i>T b</i> , <i>T c</i>)	Each bit of result is corresponding bit of <i>a</i> if corresponding bit of <i>c</i> is 0
half bitsselect (half <i>a</i> , half <i>b</i> , half <i>c</i>)	
halfn bitsselect (halfn <i>a</i> , halfn <i>b</i> , halfn <i>c</i>)	
<i>T select</i> (<i>T a</i> , <i>T b</i> , <i>Ti c</i>)	For each component of a vector type, result[i] = if MSB of <i>c</i> [i] is set ? <i>b</i> [i] : <i>a</i> [i] For scalar type, result = <i>c</i> ? <i>b</i> : <i>a</i>
<i>T select</i> (<i>T a</i> , <i>T b</i> , <i>Tu c</i>)	
halfn select (halfn <i>a</i> , halfn <i>b</i> , shortn <i>c</i>)	
half select (half <i>a</i> , half <i>b</i> , short <i>c</i>)	
halfn select (halfn <i>a</i> , halfn <i>b</i> , ushortn <i>c</i>)	
half select (half <i>a</i> , half <i>b</i> , ushort <i>c</i>)	

Synchronization & Memory Fence Functions [6.13.8]

flags argument is the memory address space, set to a 0 or an OR'd combination of CLK_X_MEM_FENCE where *X* may be LOCAL, GLOBAL, or IMAGE. Memory fence functions provide ordering between memory operations of a work-item. **Sub-groups require the cl_khr_subgroups extension.**

void work_group_barrier (cl_mem_fence_flags <i>flags</i> [, memory_scope <i>scope</i>])	Work-items in a work-group must execute this before any can continue
void atomic_work_item_fence (cl_mem_fence_flags <i>flags</i> [, memory_scope <i>scope</i>])	Orders loads and stores of a work-item executing a kernel
void sub_group_barrier (cl_mem_fence_flags <i>flags</i> [, memory_scope <i>scope</i>])	Work-items in a sub-group must execute this before any can continue

Async Copies and Prefetch [6.13.10] [9.4.7]

T is type char, charn, uchar, uchar, short, shortn, ushort, ushortn, int, intrn, uint, uintn, long, longn, ulong, ulongn, float, floatn, optionally double or doublen, or half or halfn if the **cl_khr_fp16** extension is enabled.

event_t async_work_group_copy (__local <i>T *dst</i> , const __global <i>T *src</i> , <i>size_t num_gentypes</i> , event_t <i>event</i>)	Copies <i>num_gentypes</i> <i>T</i> elements from <i>src</i> to <i>dst</i>
event_t async_work_group_copy (__global <i>T *dst</i> , const __local <i>T *src</i> , <i>size_t num_gentypes</i> , event_t <i>event</i>)	
event_t async_work_group_strided_copy (__local <i>T *dst</i> , const __global <i>T *src</i> , <i>size_t num_gentypes</i> , <i>size_t src_stride</i> , event_t <i>event</i>)	Copies <i>num_gentypes</i> <i>T</i> elements from <i>src</i> to <i>dst</i>
event_t async_work_group_strided_copy (__global <i>T *dst</i> , const __local <i>T *src</i> , <i>size_t num_gentypes</i> , <i>size_t dst_stride</i> , event_t <i>event</i>)	
void wait_group_events (int <i>num_events</i> , event_t * <i>event_list</i>)	Wait for async_work_group_copy to complete
void prefetch (const __global <i>T *p</i> , <i>size_t num_gentypes</i>)	Prefetch <i>num_gentypes</i> * sizeof(<i>T</i>) bytes into global cache

Atomic Functions [6.13.11]

OpenCL C implements a subset of the C11 atomics (see 7.17 of the C11 spec.) and synchronization operations.

Atomic Functions

In the following definitions, **A** refers to one of the atomic_* types. **C** refers to its corresponding non-atomic type. **M** refers to the type of the other argument for arithmetic operations. For atomic integer types, **M** is **C**. For atomic pointer types, **M** is ptrdiff_t. The type atomic_* is a 32-bit integer. [atomic_long](#) and [atomic_ulong](#) require extension [cl_khr_int64_base_atomics](#) or [cl_khr_int64_extended_atomics](#). The atomic_double type requires double precision support. The default scope is work_group for local atomics and all_svm_devices for global atomics.

See the table under Atomic Types and Enum Constants for information about parameter types memory_order, memory_scope, and memory_flag.

void atomic_init(volatile A *obj, C value)	Initializes the atomic object pointed to by obj to the value value.
void atomic_work_item_fence(cl_mem_fence_flags flags, memory_order_order, memory_scope_scope)	Effects based on value of order. flags must be CLK_{GLOBAL, LOCAL, IMAGE}. MEM_FENCE or a combination of these.
void atomic_store(volatile A *object, C desired)	Atomically replace the value pointed to by object with the value of desired. Memory is affected according to the value of order.
void atomic_store_explicit(volatile A *object, C desired, memory_order_order[, memory_scope_scope])	
C atomic_load(volatile A *object)	Atomically returns the value pointed to by object. Memory is affected according to the value of order.
C atomic_load_explicit(volatile A *object, memory_order_order[, memory_scope_scope])	
C atomic_exchange(volatile A *object, C desired)	Atomically replace the value pointed to by object with desired. Memory is affected according to the value of order.
C atomic_exchange_explicit(volatile A *object, C desired, memory_order_order[, memory_scope_scope])	
bool atomic_compare_exchange_strong(volatile A *object, C *expected, C desired)	Atomically compares the value pointed to by object for equality with that in expected, and if true, replaces the value pointed to by object with desired, and if false, updates the value in expected with the value pointed to by object.
bool atomic_compare_exchange_strong_explicit(volatile A *object, C *expected, C desired, memory_order_success, memory_order_failure[, memory_scope_scope])	
bool atomic_compare_exchange_weak(volatile A *object, C *expected, C desired)	Further, if the comparison is true, memory is affected according to the value of success, and if the comparison is false, memory is affected according to the value of failure. These operations are atomic read-modify-write operations.
bool atomic_compare_exchange_weak_explicit(volatile A *object, C *expected, C desired, memory_order_success, memory_order_failure[, memory_scope_scope])	
C atomic_fetch_<key>(volatile A *object, M operand)	Atomically replaces the value pointed to by object with the result of the computation applied to the value pointed to by object and the given operand. Memory is affected according to the value of order. <key> is to be defined.
C atomic_fetch_<key>_explicit(volatile A *object, M operand, memory_order_order[, memory_scope_scope])	
bool atomic_flag_test_and_set(volatile atomic_flag *object)	Atomically sets the value pointed to by object to true. Memory is affected according to the value of order. Returns atomically, the value of the object immediately before the effects.
bool atomic_flag_test_and_set_explicit(volatile atomic_flag *object, memory_order_order[, memory_scope_scope])	
void atomic_flag_clear(volatile atomic_flag *object)	Atomically sets the value pointed to by object to false. The order argument shall not be memory_order_acquire nor memory_order_acq_rel. Memory is affected according to the value of order.
void atomic_flag_clear_explicit(volatile atomic_flag *object, memory_order_order[, memory_scope_scope])	

Values for key for atomic_fetch* functions

key	op	computation	key	op	computation	key	op	computation
add	+	addition	or		bitwise inclusive or	and	&	bitwise and
sub	-	subtraction	xor	^	bitwise exclusive or	min	min	compute min
						max	max	compute max

Atomic Types and Enum Constants

Parameter Type	Values	Description
memory_order	memory_order_relaxed memory_order_release memory_order_seq_cst memory_order_acquire memory_order_acq_rel	Enum which identifies memory ordering constraints.
memory_scope	memory_scope_work_item memory_scope_work_group memory_scope_sub_group memory_scope_device (default for functions that do not take a memory_scope argument) memory_scope_all_svm_devices	Enum which identifies scope of memory ordering constraints. memory_scope_sub_group requires the cl_khr_subgroups extension.

Atomic integer and floating-point types

† indicates types supported by a limited subset of atomic operations
‡ indicates size depends on whether implemented on 64-bit or 32-bit architecture.
§ indicates types supported only if both 64-bit extensions are supported.

atomic_int	atomic_long §	atomic_float †	atomic_intptr_t ‡§	atomic_size_t ‡§
atomic_uint	atomic_ulong §	atomic_double †§	atomic_uintptr_t ‡§	atomic_ptrdiff_t ‡§
atomic_flag				

Atomic Macros

#define ATOMIC_VAR_INIT(C value)	Expands to a token sequence to initialize an atomic object of a type that is initialization-compatible with value.
#define ATOMIC_FLAG_INIT	Initialize an atomic_flag to the clear state.

64-bit Atomics [9.3]

The cl_khr_int64_base_atomics extension enables 64-bit versions of the following functions: atom_add, atom_sub, atom_inc, atom_dec, atom_xchg, atom_cmpxchg

The cl_khr_int64_extended_atomics extension enables 64-bit versions of the following functions: atom_min, atom_max, atom_and, atom_or, atom_xor

Address Space Qualifier Functions [6.13.9]

T refers to any of the built-in data types supported by OpenCL C or a user-defined type.

[const] global T * to_global([const] T *ptr)	global address space
[const] local T * to_local([const] T *ptr)	local address space
[const] private T * to_private([const] T *ptr)	private address space
[const] cl_mem_fence_flags get_fence([const] T *ptr)	Memory fence value: CLK_GLOBAL_MEM_FENCE, CLK_LOCAL_MEM_FENCE

printf Function [6.13.13]

Writes output to an implementation-defined stream.

```
int printf (constant char * restrict format, ...)
```

printf output synchronization

When the event associated with a particular kernel invocation completes, the output of applicable printf calls is flushed to the implementation-defined output stream.

printf format string

The format string follows C99 conventions and supports an optional vector specifier:

```
%[flags][width][.precision][vector][length] conversion
```

Examples:

The following examples show the use of the vector specifier in the printf format string.

```
float4 f = (float4){1.0f, 2.0f, 3.0f, 4.0f};
printf("f4 = %2.2v4f\n", f);
Output: f4 = 1.00,2.00,3.00,4.00
```

```
uchar4 uc = (uchar4){0xFA, 0xFB, 0xFC, 0xFD};
printf("uc = %#v4x\n", uc);
Output: uc = 0xfa,0xfb,0xfc,0xfd
```

```
uint2 ui = (uint2){0x12345678, 0x87654321};
printf("unsigned short value = (%#v2hx)\n", ui);
Output: unsigned short value = (0x5678,0x4321)
```

Workgroup Functions [6.13.15][9.17.3.4]

T is type int, uint, long, ulong, or float, optionally double, or half if the cl_khr_fp16 extension is supported. Sub-groups require the cl_khr_subgroups extension. Double and vector types require double precision support.

Returns a non-zero value if predicate evaluates to non-zero for all or any workitems in the work-group or sub-group.

```
int work_group_all (int predicate)
int work_group_any (int predicate)
int sub_group_all (int predicate)
int sub_group_any (int predicate)
```

Broadcast the value of a to all work-items in the work-group or sub_group. local_id must be the same value for all workitems in the work-group. n may be 2 or 3.

```
T work_group_broadcast (T a, size_t local_id)
T work_group_broadcast (T a, size_t local_id_x, size_t local_id_y)
T work_group_broadcast (T a, size_t local_id_x, size_t local_id_y, size_t local_id_z)
T sub_group_broadcast (T x, uint sub_group_local_id)
```

Return result of reduction operation specified by <op> for all values of x specified by workitems in work-group or sub_group. <op> may be min, max, or add.

```
T work_group_reduce_<op> (T x)
T sub_group_reduce_<op> (T x)
```

Do an exclusive or inclusive scan operation specified by <op> of all values specified by work-items in the work-group or sub-group. The scan results are returned for each work-item. <op> may be min, max, or add.

```
T work_group_scan_exclusive_<op> (T x)
T work_group_scan_inclusive_<op> (T x)
T sub_group_scan_exclusive_<op> (T x)
T sub_group_scan_inclusive_<op> (T x)
```

Pipe Built-in Functions [6.13.16.2-4]

T represents the built-in OpenCL C scalar or vector integer or floating-point data types or any user defined type built from these scalar and vector data types. **Half scalar and vector types require the `cl_khr_fp16` extension. Sub-groups require the `cl_khr_subgroups` extension.** Double or vector double types require double precision support. The macro `CLK_NULL_RESERVE_ID` refers to an invalid reservation ID.

<code>int read_pipe (pipe T p, T *ptr)</code>	Read packet from <i>p</i> into <i>ptr</i> .	<code>reserve_id_t reserve_read_pipe (pipe T p, uint num_packets)</code>	Reserve <i>num_packets</i> entries for reading from or writing to <i>p</i> .
<code>int read_pipe (pipe T p, reserve_id_t reserve_id, uint index, T *ptr)</code>	Read packet from reserved area of the pipe <i>reserve_id</i> and <i>index</i> into <i>ptr</i> .	<code>reserve_id_t reserve_write_pipe (pipe T p, uint num_packets)</code>	
<code>int write_pipe (pipe T p, const T *ptr)</code>	Write packet specified by <i>ptr</i> to <i>p</i> .	<code>void commit_read_pipe (pipe T p, reserve_id_t reserve_id)</code>	Indicates that all reads and writes to <i>num_packets</i> associated with reservation <i>reserve_id</i> are completed.
<code>int write_pipe (pipe T p, reserve_id_t reserve_id, uint index, const T *ptr)</code>	Write packet specified by <i>ptr</i> to reserved area <i>reserve_id</i> and <i>index</i> .	<code>void commit_write_pipe (pipe T p, reserve_id_t reserve_id)</code>	
<code>bool is_valid_reserve_id (reserve_id_t reserve_id)</code>	Return true if <i>reserve_id</i> is a valid reservation ID and false otherwise.	<code>uint get_pipe_max_packets (pipe T p)</code>	Returns maximum number of packets specified when <i>p</i> was created.
		<code>uint get_pipe_num_packets (pipe T p)</code>	Returns the number of available entries in <i>p</i> .

<code>void work_group_commit_read_pipe (pipe T p, reserve_id_t reserve_id)</code> <code>void work_group_commit_write_pipe (pipe T p, reserve_id_t reserve_id)</code> <code>void sub_group_commit_read_pipe (pipe T p, reserve_id_t reserve_id)</code> <code>void sub_group_commit_write_pipe (pipe T p, reserve_id_t reserve_id)</code>	Indicates that all reads and writes to <i>num_packets</i> associated with reservation <i>reserve_id</i> are completed.
<code>reserve_id_t work_group_reserve_read_pipe (pipe T p, uint num_packets)</code> <code>reserve_id_t work_group_reserve_write_pipe (pipe T p, uint num_packets)</code> <code>reserve_id_t sub_group_reserve_read_pipe (pipe T p, uint num_packets)</code> <code>reserve_id_t sub_group_reserve_write_pipe (pipe T p, uint num_packets)</code>	Reserve <i>num_packets</i> entries for reading from or writing to <i>p</i> . Returns a valid reservation ID if the reservation is successful.

Enqueuing and Kernel Query Built-in Functions [6.13.17] [9.17.3.6]

A kernel may enqueue code represented by Block syntax, and control execution order with event dependencies including user events and markers. There are several advantages to using the Block syntax: it is more compact; it does not require a `cl_kernel` object; and enqueuing can be done as a single semantic step. **Sub-groups require the `cl_khr_subgroups` extension.** The macro `CLK_NULL_EVENT` refers to an invalid device event. The macro `CLK_NULL_QUEUE` refers to an invalid device queue.

<code>int enqueue_kernel (queue_t queue, kernel_enqueue_flags_t flags, const ndrange_t ndrange, void (^block)(void))</code>	Allows a work-item to enqueue a block for execution to <i>queue</i> .
<code>int enqueue_kernel (queue_t queue, kernel_enqueue_flags_t flags, const ndrange_t ndrange, uint num_events_in_wait_list, const clk_event_t *event_wait_list, clk_event_t *event_ret, void (^block)(void))</code>	Work-items can enqueue multiple blocks to a device queue(s). <i>flags</i> may be one of <code>CLK_ENQUEUE_FLAGS_{NO_WAIT, WAIT_KERNEL, WAIT_WORK_GROUP}</code>
<code>int enqueue_kernel (queue_t queue, kernel_enqueue_flags_t flags, const ndrange_t ndrange, void (^block)(local void *, ...), uint size0, ...)</code>	
<code>int enqueue_kernel (queue_t queue, kernel_enqueue_flags_t flags, const ndrange_t ndrange, uint num_events_in_wait_list, const clk_event_t *event_wait_list, clk_event_t *event_ret, void (^block)(local void *, ...), uint size0, ...)</code>	
<code>uint get_kernel_work_group_size (void (^block)(void))</code> <code>uint get_kernel_work_group_size (void (^block)(local void *, ...))</code>	Query the maximum work-group size that can be used to execute a block.
<code>uint get_kernel_preferred_work_group_size_multiple (void (^block)(void))</code> <code>uint get_kernel_preferred_work_group_size_multiple (void (^block)(local void *, ...))</code>	Returns the preferred multiple of work-group size for launch.
<code>int enqueue_marker (queue_t queue, uint num_events_in_wait_list, const clk_event_t *event_wait_list, clk_event_t *event_ret)</code>	Enqueue a marker command to <i>queue</i> .
<code>uint get_kernel_sub_group_count_for_ndrange (const ndrange_t ndrange, void (^block)(void))</code> <code>uint get_kernel_sub_group_count_for_ndrange (const ndrange_t ndrange, void (^block)(local void *, ...))</code>	Returns number of subgroups in each workgroup of the dispatch.
<code>uint get_kernel_max_sub_group_size_for_ndrange (const ndrange_t ndrange, void (^block)(void))</code> <code>uint get_kernel_max_sub_group_size_for_ndrange (const ndrange_t ndrange, void (^block)(local void *, ...))</code>	Returns the maximum sub-group size for a block.

Miscellaneous Vector Functions [6.13.12]

Tm and *Tn* are type charn, uchar, shortn, ushortn, intrn, uintn, longn, ulongn, floatn, optionally doublen, or halfn if the `cl_khr_fp16` extension is supported, where *n* is 2,4,8, or 16 except in `vec_step` it may also be 3. *TUn* is uchar, ushortn, uintn, or ulongn.

<code>int vec_step (Tn a)</code> <code>int vec_step (typename)</code>	Takes a built-in scalar or vector data type argument. Returns 1 for scalar, 4 for 3-component vector, else number of elements in the specified type.
<code>Tn shuffle (Tm x, TUn mask)</code> <code>Tn shuffle2 (Tm x, Tm y, TUn mask)</code>	Construct permutation of elements from one or two input vectors, return a vector with same element type as input and length that is the same as the shuffle mask.

Event Built-in Functions [6.13.17.8]

T is type `int`, `uint`, `long`, `ulong`, or `float`, optionally `double`, or half if the `cl_khr_fp16` extension is enabled.

<code>void retain_event (clk_event_t event)</code>	Increments event reference count.
<code>void release_event (clk_event_t event)</code>	Decrements event reference count.
<code>clk_event_t create_user_event ()</code>	Create a user event.
<code>bool is_valid_event (clk_event_t event)</code>	True for valid event.
<code>void set_user_event_status (clk_event_t event, int status)</code>	Sets the execution status of a user event. <i>status</i> : <code>CL_COMPLETE</code> or a negative error value.
<code>void capture_event_profiling_info (clk_event_t event, clk_profiling_info name, global void *value)</code>	Captures profiling information for command associated with <i>event</i> in <i>value</i> .

Helper Built-in Functions [6.13.17.9]

<code>queue_t get_default_queue (void)</code>	Default queue or <code>CLK_NULL_QUEUE</code>
<code>ndrange_t ndrange_1D (size_t global_work_size)</code> <code>ndrange_t ndrange_1D (size_t global_work_size, size_t local_work_size)</code> <code>ndrange_t ndrange_1D (size_t global_work_offset, size_t global_work_size, size_t local_work_size)</code>	Builds a 1D ND-range descriptor.
<code>ndrange_t ndrange_nD (const size_t global_work_size[n])</code> <code>ndrange_t ndrange_nD (size_t global_work_size, const size_t local_work_size[n])</code> <code>ndrange_t ndrange_nD (const size_t global_work_offset, const size_t global_work_size, const size_t local_work_size[n])</code>	Builds a 2D or 3D ND-range descriptor. <i>n</i> may be 2 or 3.

OpenCL Image Processing Reference

A subset of the OpenCL API and C Language specifications pertaining to image processing and graphics

Image Objects

Items in blue apply when the appropriate extension is supported.

Create Image Objects [5.3.1]

`cl_mem clCreateImage (cl_context context, cl_mem_flags flags, const cl_image_format *image_format, const cl_image_desc *image_desc, void *host_ptr, cl_int *errcode_ret)`
flags: See `clCreateBuffer`

Query List of Supported Image Formats [5.3.2]

`cl_int clGetSupportedImageFormats (cl_context context, cl_mem_flags flags, cl_mem_object_type image_type, cl_uint num_entries, cl_image_format *image_formats, cl_uint *num_image_formats)`
flags: See `clCreateBuffer`
image_type: `CL_MEM_OBJECT_IMAGE{1D, 2D, 3D}`, `CL_MEM_OBJECT_IMAGE1D_BUFFER`, `CL_MEM_OBJECT_IMAGE{1D, 2D}_ARRAY`

Read, Write, Copy, Fill Image Objects [5.3.4]

`cl_int clEnqueueReadImage (cl_command_queue command_queue, cl_mem image, cl_bool blocking_read, const size_t *origin, const size_t *region, size_t row_pitch, size_t slice_pitch, void *ptr, cl_uint num_events_in_wait_list, const cl_event *event_wait_list, cl_event *event)`
`cl_int clEnqueueWriteImage (cl_command_queue command_queue, cl_mem image, cl_bool blocking_write, const size_t *origin, const size_t *region, size_t input_row_pitch, size_t input_slice_pitch, const void *ptr, cl_uint num_events_in_wait_list, const cl_event *event_wait_list, cl_event *event)`
`cl_int clEnqueueFillImage (cl_command_queue command_queue, cl_mem image, const void *fill_color, const size_t *origin, const size_t *region, cl_uint num_events_in_wait_list, const cl_event *event_wait_list, cl_event *event)`

`cl_int clEnqueueCopyImage (cl_command_queue command_queue, cl_mem src_image, cl_mem dst_image, const size_t *src_origin, const size_t *dst_origin, const size_t *region, cl_uint num_events_in_wait_list, const cl_event *event_wait_list, cl_event *event)`

Copy Between Image, Buffer Objects [5.3.5]

`cl_int clEnqueueCopyImageToBuffer (cl_command_queue command_queue, cl_mem src_image, cl_mem dst_buffer, const size_t *src_origin, const size_t *region, size_t dst_offset, cl_uint num_events_in_wait_list, const cl_event *event_wait_list, cl_event *event)`
`cl_int clEnqueueCopyBufferToImage (cl_command_queue command_queue, cl_mem src_buffer, cl_mem dst_image, size_t src_offset, const size_t *dst_origin, const size_t *region, cl_uint num_events_in_wait_list, const cl_event *event_wait_list, cl_event *event)`

(Continued on next page >)

Image Objects (continued)

Map and Unmap Image Objects [5.3.6]

```
void * clEnqueueMapImage (
    cl_command_queue command_queue,
    cl_mem image, cl_bool blocking_map,
    cl_map_flags map_flags, const size_t *origin,
    const size_t *region, size_t *image_row_pitch,
    size_t *image_slice_pitch,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event,
    cl_int *errcode_ret)
```

```
map_flags: CL_MAP_READ, CL_MAP_WRITE,
            CL_MAP_WRITE_INVALIDATE_REGION
```

Query Image Objects [5.3.7]

```
cl_int clGetImageInfo (cl_mem image,
    cl_image_info param_name, size_t param_value_size,
    void *param_value, size_t *param_value_size_ret)
param_name: [Table 5.9] CL_IMAGE_FORMAT, CL_IMAGE_BUFFER,
            CL_IMAGE_ARRAY_ELEMENT_SIZE, CL_IMAGE_ROW_SLICE_PITCH,
            CL_IMAGE_HEIGHT_WIDTH_DEPTH, CL_IMAGE_NUM_SAMPLES_MIP_LEVELS,
            CL_IMAGE_DX9_MEDIA_PLANE_KHR, CL_IMAGE_D3D10_D3D11_SUBRESOURCE_KHR
```

Also see [clGetMemObjectInfo](#) [5.4.5]

Image Formats [5.3.1.1]

Supported image formats: `image_channel_order` with `image_channel_data_type`.

Built-in support: [Table 5.8]

```
CL_R (read + write): CL_HALF_FLOAT, CL_FLOAT,
                    CL_UNORM_INT8, CL_UNORM_INT16,
                    CL_SNORM_INT8, CL_SNORM_INT16,
                    CL_SIGNED_INT8, CL_SIGNED_INT16,
                    CL_UNSIGNED_INT8, CL_UNSIGNED_INT16
```

```
CL_DEPTH (read + write): CL_FLOAT, CL_UNORM_INT16
```

```
CL_DEPTH_STENCIL (read only): CL_FLOAT,
                               CL_UNORM_INT24
(Requires the extension cl_khr_gl_depth_images)
```

```
CL_RG (read + write): CL_HALF_FLOAT, CL_FLOAT,
                    CL_UNORM_INT8, CL_UNORM_INT16,
                    CL_SNORM_INT8, CL_SNORM_INT16,
                    CL_SIGNED_INT8, CL_SIGNED_INT16,
                    CL_UNSIGNED_INT8, CL_UNSIGNED_INT16
```

```
CL_RGBA (read + write): CL_HALF_FLOAT, CL_FLOAT,
                    CL_UNORM_INT8, CL_UNORM_INT16,
                    CL_SNORM_INT8, CL_SNORM_INT16,
                    CL_SIGNED_INT8, CL_SIGNED_INT16,
                    CL_UNSIGNED_INT8, CL_UNSIGNED_INT16
```

```
CL_BGRA (read + write): CL_UNORM_INT8
```

```
CL_sRGBA (read only): CL_UNORM_INT8
(Requires the extension cl_khr_srgb_image_writes)
```

Optional support: [Table 5.6]

```
CL_R, CL_A: CL_HALF_FLOAT, CL_FLOAT, CL_UNORM_INT8, CL_UNORM_INT16,
            CL_SIGNED_INT8, CL_SIGNED_INT16, CL_UNSIGNED_INT8, CL_UNSIGNED_INT16,
            CL_SNORM_INT8, CL_SNORM_INT16
```

```
CL_INTENSITY: CL_HALF_FLOAT, CL_FLOAT,
              CL_UNORM_INT8, CL_UNORM_INT16, CL_SNORM_INT8, CL_SNORM_INT16
```

```
CL_DEPTH_STENCIL: Only used if extension cl_khr_gl_depth_images is enabled and
                  channel data type = CL_UNORM_INT24 or CL_FLOAT
```

```
CL_LUMINANCE: CL_UNORM_INT8, CL_UNORM_INT16, CL_HALF_FLOAT,
              CL_FLOAT, CL_SNORM_INT8, CL_SNORM_INT16
```

```
CL_RG, CL_RA: CL_HALF_FLOAT, CL_FLOAT,
              CL_UNORM_INT8, CL_UNORM_INT16, CL_SIGNED_INT8, CL_SIGNED_INT16,
              CL_UNSIGNED_INT8, CL_UNSIGNED_INT16, CL_SNORM_INT8, CL_SNORM_INT16
```

```
CL_RGB: CL_UNORM_SHORT_555, CL_UNORM_SHORT_565,
        CL_UNORM_INT101010
```

```
CL_ARGB: CL_UNORM_INT8, CL_SIGNED_INT8, CL_UNSIGNED_INT8, CL_SNORM_INT8
```

```
CL_BGRA: CL_{SIGNED, UNSIGNED}_INT8, CL_SNORM_INT8
```

Image Read and Write Functions [6.13.14]

The built-in functions defined in this section can only be used with image memory objects created with `clCreateImage`. `sampler` specifies the addressing and filtering mode to use. Writing to sRGB images from a kernel requires the `cl_khr_srgb_image_writes` extension. `read_imageh` and `write_imageh` require the `cl_khr_fp16` extension. MSAA images require the `cl_khr_gl_msaa_sharing` extension, and image 3D writes require the extension `cl_khr_3d_image_writes`.

Read and write functions for 1D images

Read an element from a 1D image, or write a color value to a location in a 1D image.

```
float4 read_imagef (image1d_t image, sampler_t sampler,
                  {int, float} coord)
```

```
float4 read_imagef (image1d_t image, int coord)
```

```
float4 read_imagef (image1d_array_t image, sampler_t sampler,
                  {int2, float4} coord)
```

```
float4 read_imagef (image1d_array_t image, int2 coord)
```

```
float4 read_imagef (image1d_buffer_t image, int coord)
```

```
int4 read_imagei (image1d_t image, sampler_t sampler,
                  {int, float} coord)
```

```
int4 read_imagei (image1d_t image, int coord)
```

```
int4 read_imagei (image1d_array_t image, sampler_t sampler,
                  {int2, float2} coord)
```

```
int4 read_imagei (image1d_array_t image, int2 coord)
```

```
int4 read_imagei (image1d_buffer_t image, int coord)
```

```
uint4 read_imageui (image1d_t image, sampler_t sampler,
                   {int, float} coord)
```

```
uint4 read_imageui (image1d_t image, int coord)
```

```
uint4 read_imageui (image1d_array_t image, sampler_t sampler,
                   {int2, float2} coord)
```

```
uint4 read_imageui (image1d_array_t image, int2 coord)
```

```
uint4 read_imageui (image1d_buffer_t image, int coord)
```

```
half4 read_imageh (image1d_t image, sampler_t sampler,
                  {int, float} coord)
```

```
half4 read_imageh (image1d_t image, int coord)
```

```
half4 read_imageh (image1d_array_t image, sampler_t sampler,
                  {int2, float4} coord)
```

```
half4 read_imageh (image1d_array_t image, int2 coord)
```

```
half4 read_imageh (image1d_buffer_t image, int coord)
```

```
void write_imagef (image1d_t image, int coord, float4 color)
```

```
void write_imagef (image1d_array_t image, int2 coord,
                  float4 color)
```

```
void write_imagef (image1d_buffer_t image, int coord,
                  float4 color)
```

```
void write_imagei (image1d_t image, int coord, int4 color)
```

```
void write_imagei (image1d_array_t image, int2 coord,
                  int4 color)
```

```
void write_imagei (image1d_buffer_t image, int coord,
                  int4 color)
```

```
void write_imageh (image1d_t image, int coord, half4 color)
```

```
void write_imageh (image1d_array_t image, int2 coord,
                  half4 color)
```

```
void write_imageh (image1d_buffer_t image, int coord,
                  half4 color)
```

```
void write_imageui (image1d_t image, int coord, uint4 color)
```

```
void write_imageui (image1d_array_t image, int2 coord,
                  uint4 color)
```

```
void write_imageui (image1d_buffer_t image, int coord,
                  uint4 color)
```

Read and write functions for 2D images

Read an element from a 2D image, or write a color value to a location in a 2D image.

```
float4 read_imagef (image2d_t image, sampler_t sampler,
                  {int2, float2} coord)
```

```
float4 read_imagef (image2d_t image, int2 coord)
```

```
float4 read_imagef (image2d_array_t image, sampler_t sampler,
                  {int4, float4} coord)
```

```
float4 read_imagef (image2d_array_t image, int4 coord)
```

```
float read_imagef (image2d_depth_t image, sampler_t sampler,
                  {int2, float2} coord)
```

```
float read_imagef (image2d_array_depth_t image, sampler_t sampler,
                  {int4, float4} coord)
```

```
float read_imagef (image2d_depth_t image, int2 coord)
```

```
float read_imagef (image2d_array_depth_t image, int4 coord)
```

```
int4 read_imagei (image2d_t image, sampler_t sampler,
                  {int2, float2} coord)
```

```
int4 read_imagei (image2d_t image, int2 coord)
```

```
int4 read_imagei (image2d_array_t image, sampler_t sampler,
                  {int4, float4} coord)
```

```
int4 read_imagei (image2d_array_t image, int4 coord)
```

```
uint4 read_imageui (image2d_t image, sampler_t sampler,
                   {int2, float2} coord)
```

```
uint4 read_imageui (image2d_t image, int2 coord)
```

```
uint4 read_imageui (image2d_array_t image, sampler_t sampler,
                   {int4, float4} coord)
```

```
uint4 read_imageui (image2d_array_t image, int4 coord)
```

Read and write functions for 2D images (continued)

```
half4 read_imageh (image2d_t image, sampler_t sampler,
                  {int2, float2} coord)
```

```
half4 read_imageh (image2d_t image, int2 coord)
```

```
half4 read_imageh (image2d_array_t image, sampler_t sampler,
                  {int4, float4} coord)
```

```
half4 read_imageh (image2d_array_t image, int4 coord)
```

```
void write_imagef (image2d_t image, int2 coord, float4 color)
```

```
void write_imagef (image2d_array_t image, int4 coord,
                  float4 color)
```

```
void write_imagef (image2d_depth_t image, int2 coord, int lod,
                  float depth)
```

```
void write_imagef (image2d_array_depth_t image, int4 coord,
                  int lod, float depth)
```

```
void write_imagei (image2d_t image, int2 coord, int4 color)
```

```
void write_imagei (image2d_array_t image, int4 coord,
                  int4 color)
```

```
void write_imageui (image2d_t image, int2 coord, uint4 color)
```

```
void write_imageui (image2d_array_t image, int4 coord,
                  uint4 color)
```

```
void write_imageh (image2d_t image, int2 coord, half4 color)
```

```
void write_imageh (image2d_array_t image, int4 coord,
                  half4 color)
```

Read and write functions for 3D images

Read an element from a 3D image, or write a color value to a location in a 3D image. Writing to 3D images requires the `cl_khr_3d_image_writes` extension.

```
float4 read_imagef (image3d_t image, sampler_t sampler,
                  {int4, float4} coord)
```

```
float4 read_imagef (image3d_t image, int4 coord)
```

```
int4 read_imagei (image3d_t image, sampler_t sampler,
                  {int4, float4} coord)
```

```
int4 read_imagei (image3d_t image, int4 coord)
```

```
uint4 read_imageui (image3d_t image, sampler_t sampler,
                   {int4, float4} coord)
```

```
uint4 read_imageui (image3d_t image, int4 coord)
```

```
half4 read_imageh (image3d_t image, sampler_t sampler,
                  {int4, float4} coord)
```

```
half4 read_imageh (image3d_t image, int4 coord)
```

```
void write_imagef (image3d_t image, int4 coord, float4 color)
```

```
void write_imagei (image3d_t image, int4 coord, int4 color)
```

```
void write_imageui (image3d_t image, int4 coord, uint4 color)
```

```
void write_imageh (image3d_t image, int4 coord, half4 color)
```

(Continued on next page >)

Image Read and Write (continued)

Extended mipmap read and write functions [9.18.2.1]
These functions require the `cl_khr_mipmap_image` and `cl_khr_mipmap_image_writes` extensions.

```
float read_imagef (image2d_ [depth_]t image,
                  sampler_t sampler, float2 coord, float lod)
int4 read_imagei (image2d_t image, sampler_t sampler,
                 float2 coord, float lod)
uint4 read_imageui (image2d_t image, sampler_t sampler,
                   float2 coord, float lod)

float read_imagef (image2d_ [depth_]t image,
                  sampler_t sampler, float2 coord, float2 gradient_x,
                  float2 gradient_y)
int4 read_imagei (image2d_t image, sampler_t sampler,
                 float2 coord, float2 gradient_x, float2 gradient_y)
uint4 read_imageui (image2d_t image, sampler_t sampler,
                   float2 coord, float2 gradient_x, float2 gradient_y)

float4 read_imagef (image1d_t image, sampler_t sampler,
                  float coord, float lod)
int4 read_imagei (image1d_t image, sampler_t sampler,
                 float coord, float lod)
uint4 read_imageui (image1d_t image, sampler_t sampler,
                   float coord, float lod)

float4 read_imagef (image1d_t image, sampler_t sampler,
                  float coord, float gradient_x, float gradient_y)
int4 read_imagei (image1d_t image, sampler_t sampler,
                 float coord, float gradient_x, float gradient_y)
uint4 read_imageui (image1d_t image, sampler_t sampler,
                   float coord, float gradient_x, float gradient_y)

float4 read_imagef (image3d_t image, sampler_t sampler,
                  float4 coord, float lod)
int4 read_imagei (image3d_t image, sampler_t sampler,
                 float4 coord, float lod)
uint4 read_imageui (image3d_t image, sampler_t sampler,
                   float4 coord, float lod)

float4 read_imagef (image3d_t image, sampler_t sampler,
                  float4 coord, float4 gradient_x, float4 gradient_y)
int4 read_imagei (image3d_t image, sampler_t sampler,
                 float4 coord, float4 gradient_x, float4 gradient_y)
uint4 read_imageui (image3d_t image, sampler_t sampler,
                   float4 coord, float4 gradient_x, float4 gradient_y)

float4 read_imagef (image1d_array_t image, sampler_t sampler,
                  float2 coord, float lod)
int4 read_imagei (image1d_array_t image, sampler_t sampler,
                 float2 coord, float lod)
uint4 read_imageui (image1d_array_t image, sampler_t sampler,
                   float2 coord, float lod)

float4 read_imagef (image1d_array_t image, sampler_t sampler,
                  float2 coord, float gradient_x, float gradient_y)
int4 read_imagei (image1d_array_t image, sampler_t sampler,
                 float2 coord, float gradient_x, float gradient_y)
uint4 read_imageui (image1d_array_t image, sampler_t sampler,
                   float2 coord, float gradient_x, float gradient_y)
```

Sampler Objects [5.7]

Items in blue require the `cl_khr_mipmap_image` extension.

```
cl_sampler clCreateSamplerWithProperties
( cl_context context,
  const cl_sampler_properties *sampler_properties,
  cl_int *errcode_ret)

sampler_properties: [Table 5.14]
CL_SAMPLER_NORMALIZED_COORDS,
CL_SAMPLER_ADDRESSING_MODE,
CL_SAMPLER_MIP_FILTER_MODE,
CL_SAMPLER_LOD_{MIN, MAX}

cl_int clRetainSampler (cl_sampler sampler)
cl_int clReleaseSampler (cl_sampler sampler)

cl_int clGetSamplerInfo (cl_sampler sampler,
                        cl_sampler_info param_name,
                        size_t param_value_size, void *param_value,
                        size_t *param_value_size_ret)

param_name: CL_SAMPLER_REFERENCE_COUNT,
CL_SAMPLER_CONTEXT, CL_SAMPLER_FILTER_MODE,
CL_SAMPLER_ADDRESSING_MODE,
CL_SAMPLER_NORMALIZED_COORDS [Table 5.15]
```

```
int4 read_imagei (image1d_array_t image, sampler_t sampler,
                 float2 coord, float gradient_x, float gradient_y)
uint4 read_imageui (image1d_array_t image, sampler_t sampler,
                   float2 coord, float gradient_x, float gradient_y)

float read_imagef (image2d_array_ [depth_]t image,
                  sampler_t sampler, float4 coord, float lod)
int4 read_imagei (image2d_array_t image, sampler_t sampler,
                 float4 coord, float lod)
uint4 read_imageui (image2d_array_t image,
                   sampler_t sampler, float4 coord, float lod)

float read_imagef (image2d_array_ [depth_]t image,
                  sampler_t sampler, float4 coord, float2 gradient_x,
                  float2 gradient_y)
int4 read_imagei (image2d_array_t image, sampler_t sampler,
                 float4 coord, float2 gradient_x, float2 gradient_y)
uint4 read_imageui (image2d_array_t image, sampler_t
                   sampler, float4 coord, float2 gradient_x, float2 gradient_y)

void write_imagef (image2d_ [depth_]t image, int2 coord,
                  int lod, float4 color)
void write_imagei (image2d_t image, int2 coord, int lod,
                  int4 color)
void write_imageui (image2d_t image, int2 coord, int lod,
                   uint4 color)

void write_imagef (image1d_t image, int coord, int lod, float4 color)
void write_imagei (image1d_t image, int coord, int lod, int4 color)
void write_imageui (image1d_t image, int coord, int lod, uint4 color)

void write_imagef (image1d_array_t image, int2 coord, int lod,
                  float4 color)
void write_imagei (image1d_array_t image, int2 coord, int lod,
                  int4 color)
void write_imageui (image1d_array_t image, int2 coord, int lod,
                   uint4 color)

void write_imagef (image2d_array_ [depth_]t image, int4 coord,
                  int lod, float4 color)
void write_imagei (image2d_array_t image, int4 coord, int lod,
                  int4 color)
void write_imageui (image2d_array_t image, int4 coord, int lod,
                   uint4 color)

void write_imagef (image3d_t image, int4 coord, int lod,
                  float4 color)
void write_imagei (image3d_t image, int4 coord, int lod,
                  int4 color)
void write_imageui (image3d_t image, int4 coord, int lod,
                   uint4 color)
```

Extended multi-sample image read functions [9.12.3]

The extension `cl_khr_gl_msaa_sharing` adds the following built-in functions.

```
float read_imagef (image2d_msaa_depth_t image,
                  int2 coord, int sample)
float read_imagef (image2d_array_depth_msaa_t image,
                  int4 coord, int sample)

float4 read_image{f, i, ui} (image2d_msaa_t image,
                             int2 coord, int sample)
float4 read_image{f, i, ui} (image2d_array_msaa_t image,
                             int4 coord, int sample)
```

Sampler Declaration Fields [6.13.14.1]

The sampler can be passed as an argument to the kernel using `clSetKernelArg`, or can be declared in the outermost scope of kernel functions, or it can be a constant variable of type `sampler_t` declared in the program source.

```
const sampler_t <sampler-name> =
<normalized-mode> | <address-mode> | <filter-mode>

normalized-mode:
CLK_NORMALIZED_COORDS_{TRUE, FALSE}

address-mode:
CLK_ADDRESS_{REPEAT, CLAMP, NONE},
CLK_ADDRESS_{CLAMP_TO_EDGE},
CLK_ADDRESS_{MIRRORED_REPEAT}

filter-mode: CLK_FILTER_NEAREST, CLK_FILTER_LINEAR
```

Image Query Functions [6.13.14.5] [9.12]

The MSAA forms require the extension `cl_khr_gl_msaa_sharing`. Mipmap requires the extension `cl_khr_mipmap_image`.

Query image width, height, and depth in pixels

```
int get_image_width (image{1,2,3}d_t image)
int get_image_width (image1d_buffer_t image)
int get_image_width (image{1,2}d_array_t image)
int get_image_width (image2d_ [array_]depth_t image)
int get_image_width (image2d_ [array_]msaa_t image)
int get_image_width (image2d_ [array_]msaa_depth_t
                    image)

int get_image_height (image{2,3}d_t image)
int get_image_height (image2d_array_t image)
int get_image_height (image2d_ [array_]depth_t image)
int get_image_height (image2d_ [array_]msaa_t image)
int get_image_height (image2d_ [array_]msaa_depth_t
                    image)

int get_image_depth (image3d_t image)
```

Query image array size

```
size_t get_image_array_size (image1d_array_t image)
size_t get_image_array_size (image2d_array_t image)
size_t get_image_array_size (image2d_array_depth_t image)
size_t get_image_array_size (
    image2d_array_msaa_depth_t image)
```

Query image dimensions

```
int2 get_image_dim (image2d_t image)
int2 get_image_dim (image2d_array_t image)
int4 get_image_dim (image3d_t image)
int2 get_image_dim (image2d_ [array_]depth_t image)
int2 get_image_dim (image2d_ [array_]msaa_t image)
int2 get_image_dim (image2d_ [array_]msaa_depth_t image)
```

Query image Channel data type and order

```
int get_image_channel_data_type (image{1,2,3}d_t image)
int get_image_channel_data_type (image1d_buffer_t image)
int get_image_channel_data_type (image{1,2}d_array_t image)
int get_image_channel_data_type
(image2d_ [array_]depth_t image)
int get_image_channel_data_type (
    image2d_ [array_]msaa_t image)
int get_image_channel_data_type (
    image2d_ [array_]msaa_depth_t image)

int get_image_channel_order (image{1,2,3}d_t image)
int get_image_channel_order (image1d_buffer_t image)
int get_image_channel_order (image{1,2}d_array_t image)
int get_image_channel_order
(image2d_ [array_]depth_t image)
int get_image_channel_order (image2d_ [array_]msaa_t image)
int get_image_channel_order (
    image2d_ [array_]msaa_depth_t image)
```

Extended query functions [9.18.2.1]

These functions require the `cl_khr_mipmap_image` extension.

```
int get_image_num_mip_levels (image1d_t image)
int get_image_num_mip_levels (image2d_ [depth_]t image)
int get_image_num_mip_levels (image3d_t image)
int get_image_num_mip_levels (image1d_array_t image)
int get_image_num_mip_levels (
    image2d_array_ [depth_]t image)

int get_image_num_samples (
    image2d_ [array_]msaa_t image)
int get_image_num_samples (
    image2d_ [array_]msaa_depth_t image)
```

Access Qualifiers [6.6]

Apply to 2D and 3D image types to declare if the image memory object is being read or written by a kernel.

```
__read_only, read_only
__write_only, write_only
```

A C++ wrapper is available for developing OpenCL applications in C++.

See www.khronos.org/registry/cl/

OpenCL Extensions Reference

Using OpenCL Extensions [9]

The following extensions extend the OpenCL API. Extensions shown in *italics* provide core features.

To control an extension: #pragma OPENCL EXTENSION *extension_name* : {enable | disable}

To test if an extension is supported: `clGetPlatformInfo()` or `clGetDeviceInfo()`

To get the address of the extension function: `clGetExtensionFunctionAddressForPlatform()`

<code>cl_apple_gl_sharing</code> (see <code>cl_khr_gl_sharing</code>)
<code>cl_khr_3d_image_writes</code>
<code>cl_khr_byte_addressable_store</code>

OpenGL Sharing [9.5 - 9.7]

These functions require the `cl_khr_gl_sharing` or `cl_apple_gl_sharing` extension.

CL Context > GL Context, Sharegroup [9.5.5]

```
cl_int clGetGLContextInfoKHR (
    const cl_context_properties *properties,
    cl_gl_context_info param_name,
    size_t param_value_size, void *param_value,
    size_t *param_value_size_ret)
```

param_name: CL_DEVICES_FOR_GL_CONTEXT_KHR, CL_CURRENT_DEVICE_FOR_GL_CONTEXT_KHR

CL Buffer Objects > GL Buffer Objects [9.6.2]

```
cl_mem clCreateFromGLBuffer (cl_context context,
    cl_mem_flags flags, GLuint bufobj, cl_int *errcode_ret)
    flags: CL_MEM_{READ_ONLY, WRITE_ONLY, READ_WRITE}
```

CL Image Objects > GL Textures [9.6.3]

```
cl_mem clCreateFromGLTexture (cl_context context,
    cl_mem_flags flags, GLenum texture_target,
    GLint miplevel, GLuint texture, cl_int *errcode_ret)
    flags: See clCreateFromGLBuffer
```

texture_target: GL_TEXTURE_{1D, 2D}[_ARRAY], GL_TEXTURE_{3D, BUFFER, RECTANGLE}, GL_TEXTURE_CUBE_MAP_POSITIVE_{X, Y, Z}, GL_TEXTURE_CUBE_MAP_NEGATIVE_{X, Y, Z}, GL_TEXTURE_2D_MULTISAMPLE[_ARRAY] (Requires extension `cl_khr_gl_msaa_sharing`)

DX9 Media Surface Sharing [9.9]

These functions require the extension `cl_khr_dx9_media_sharing`. The associated header file is `cl_dx9_media_sharing.h`.

```
cl_int clGetDeviceIDsFromDX9MediaAdapterKHR (
    cl_platform_id platform, cl_uint num_media_adapters,
    cl_dx9_media_adapter_type_khr *media_adapters_type,
    void *media_adapters,
    cl_dx9_media_adapter_set_khr media_adapter_set,
    cl_uint num_entries, cl_device_id *devices,
    cl_int *num_devices)
```

media_adapter_type: CL_ADAPTER_{D3D9, D3D9EX, DXVA}_KHR

media_adapter_set: CL_{ALL, PREFERRED}_DEVICES_FOR_DX9_MEDIA_ADAPTER_KHR

```
cl_mem clCreateFromDX9MediaSurfaceKHR (
    cl_context context, cl_mem_flags flags,
    cl_dx9_media_adapter_type_khr adapter_type,
    void *surface_info, cl_uint plane, cl_int *errcode_ret)
    flags: See clCreateFromGLBuffer
```

adapter_type: CL_ADAPTER_{D3D9, D3D9EX, DXVA}_KHR

```
cl_int clEnqueue(Acquire, Release)DX9MediaSurfacesKHR(
    cl_command_queue command_queue,
    cl_uint num_objects, const cl_mem *mem_objects,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

EGL Interoperability [9.19, 9.20]

Create CL Image Objects from EGL [9.19]

These functions require the extension `cl_khr_egl_image`.

```
cl_mem clCreateFromEGLImageKHR (
    cl_context context, CLEGLDisplayKHR display,
    CLEGLImageKHR image, cl_mem_flags flags,
    const cl_egl_image_properties_khr *properties,
    cl_int *errcode_ret)
```

<code>cl_khr_context_abort</code>
<code>cl_khr_d3d10_sharing</code>
<code>cl_khr_d3d11_sharing</code>
<code>cl_khr_depth_images</code>
<code>cl_khr_dx9_media_sharing</code>
<code>cl_khr_egl_event</code>
<code>cl_khr_egl_image</code>
<code>cl_khr_fp16</code>
<code>cl_khr_fp64</code>
<code>cl_khr_gl_depth_images</code>
<code>cl_khr_gl_event</code>
<code>cl_khr_gl_msaa_sharing</code>
<code>cl_khr_gl_sharing</code>
<code>cl_khr_global_int32_base_atomics - atomic_*</code>

<code>cl_khr_global_int32_extended_atomics - atomic_*</code>
<code>cl_khr_icd</code>
<code>cl_khr_image2d_from_buffer</code>
<code>cl_khr_initialize_memory</code>
<code>cl_khr_int64_base_atomics - atom_*</code>
<code>cl_khr_int64_extended_atomics - atom_*</code>
<code>cl_khr_local_int32_base_atomics - atomic_*</code>
<code>cl_khr_local_int32_extended_atomics - atomic_*</code>
<code>cl_khr_mipmap_image</code>
<code>cl_khr_mipmap_image_writes</code>
<code>cl_khr_srgb_image_writes</code>
<code>cl_khr_spir</code>
<code>cl_khr_subgroups</code>
<code>cl_khr_terminate_context</code>

CL Image Objects > GL Renderbuffers [9.6.4]

```
cl_mem clCreateFromGLRenderbuffer (
    cl_context context, cl_mem_flags flags,
    GLuint renderbuffer, cl_int *errcode_ret)
```

flags: See `clCreateFromGLBuffer`

Query Information [9.6.5]

```
cl_int clGetGLObjectInfo (cl_mem memobj,
    cl_gl_object_type *gl_object_type,
    GLuint *gl_object_name)
```

**gl_object_type* returns: CL_GL_OBJECT_TEXTURE_BUFFER, CL_GL_OBJECT_TEXTURE_{1D, 2D, 3D}, CL_GL_OBJECT_TEXTURE_{1D, 2D}_ARRAY, CL_GL_OBJECT_{BUFFER, RENDERBUFFER}

```
cl_int clGetGLTextureInfo (cl_mem memobj,
    cl_gl_texture_info param_name,
    size_t param_value_size, void *param_value,
    size_t *param_value_size_ret)
```

param_name: CL_GL_{TEXTURE_TARGET, MIPMAP_LEVEL}, CL_GL_NUM_SAMPLES (Requires extension `cl_khr_gl_msaa_sharing`)

Share Objects [9.6.6]

```
cl_int clEnqueue(Acquire, Release)GLObjects (
    cl_command_queue command_queue,
    cl_uint num_objects, const cl_mem *mem_objects,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

CL Event Objects > GL Sync Objects [9.7.4]

```
cl_event clCreateEventFromGLsyncKHR (
    cl_context context, GLsync sync,
    cl_int *errcode_ret)
```

Requires the `cl_khr_gl_event` extension.

Direct3D 11 Sharing [9.10.7.3 - 9.10.7.6]

These functions require the `cl_khr_d3d11_sharing` extension. Associated header file is `cl_d3d11.h`.

```
cl_int clGetDeviceIDsFromD3D11KHR (
    cl_platform_id platform,
    cl_d3d11_device_source_khr d3d_device_source,
    void *d3d_object,
    cl_d3d11_device_set_khr d3d_device_set,
    cl_uint num_entries, cl_device_id *devices,
    cl_uint *num_devices)
```

d3d_device_source: CL_D3D11_DEVICE_KHR, CL_D3D11_DXGI_ADAPTER_KHR

d3d_device_set: CL_ALL_DEVICES_FOR_D3D11_KHR, CL_PREFERRED_DEVICES_FOR_D3D11_KHR

```
cl_mem clCreateFromD3D11BufferKHR (
    cl_context context, cl_mem_flags flags,
    ID3D11Buffer *resource, cl_int *errcode_ret)
```

flags: See `clCreateFromGLBuffer`

Direct3D 10 Sharing [9.8.7]

These functions require the `cl_khr_d3d10_sharing` extension. The associated header file is `cl_d3d10.h`.

```
cl_int clGetDeviceIDsFromD3D10KHR (
    cl_platform_id platform,
    cl_d3d10_device_source_khr d3d_device_source,
    void *d3d_object,
    cl_d3d10_device_set_khr d3d_device_set,
    cl_uint num_entries, cl_device_id *devices,
    cl_uint *num_devices)
```

d3d_device_source:

CL_D3D10_{DEVICE, DXGI_ADAPTER}_KHR

d3d_device_set:

CL_{ALL, PREFERRED}_DEVICES_FOR_D3D10_KHR

```
cl_mem clCreateFromD3D10BufferKHR (
    cl_context context, cl_mem_flags flags,
    ID3D10Buffer *resource, cl_int *errcode_ret)
    flags: See clCreateFromGLBuffer
```

```
cl_mem clCreateFromD3D10Texture2DKHR (
    cl_context context, cl_mem_flags flags,
    ID3D10Texture2D *resource, UINT subresource,
    cl_int *errcode_ret)
```

flags: See `clCreateFromD3D10BufferKHR`

```
cl_mem clCreateFromD3D10Texture3DKHR (
    cl_context context, cl_mem_flags flags,
    ID3D10Texture3D *resource, UINT subresource,
    cl_int *errcode_ret)
```

flags: See `clCreateFromGLBuffer`

```
cl_int clEnqueue(Acquire, Release)D3D10ObjectsKHR (
    cl_command_queue command_queue,
    cl_uint num_objects, const cl_mem *mem_objects,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

```
cl_mem clCreateFromD3D11Texture3DKHR (
    cl_context context, cl_mem_flags flags,
    ID3D11Texture3D *resource, UINT subresource,
    cl_int *errcode_ret)
```

flags: See `clCreateFromGLBuffer`

```
cl_mem clCreateFromD3D11Texture2DKHR (
    cl_context context, cl_mem_flags flags,
    ID3D11Texture2D *resource,
    UINT subresource, cl_int *errcode_ret)
```

flags: See `clCreateFromGLBuffer`

```
cl_int clEnqueue(Acquire, Release)D3D11ObjectsKHR (
    cl_command_queue command_queue,
    cl_uint num_objects, const cl_mem *mem_objects,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

Create CL Event Objects from EGL [9.20]

This function requires the extension `cl_khr_egl_event`.

```
cl_event clCreateEventFromEGLsyncKHR (
    cl_context context, CLEGLSyncKHR sync,
    CLEGLDisplayKHR display, cl_int *errcode_ret)
```

```
cl_int clEnqueue(Acquire, Release)EGLObjectsKHR (
    cl_command_queue command_queue,
    cl_uint num_objects, const cl_mem *mem_objects,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list,
    cl_event *event)
```

OpenCL Reference Card Index

The following index shows each item included on this card along with the page on which it is described. The color of the row in the table below is the color of the box to which you should refer.

A		clEnqueueNDRangeKernel	3	clRetainProgram	3	Memory Fence Functions	6
Access Qualifiers	10	clEnqueueReadBuffer	1	clRetainSampler	10	Memory Objects	2
Address Space Qualifier Functions	7	clEnqueueReadBufferRect	1	clSetEventCallback	4	Migrate Memory Objects	2
Aligned attribute qualifiers	5	clEnqueueReadImage	8	clSetKernelArg	3	O	
Async Copies and Prefetch	6	clEnqueueReleaseD3D10ObjectsKHR	11	clSetKernelArgSVMPointer	3	OpenCL Class Diagram	2
Atomic Functions	7	clEnqueueReleaseD3D11ObjectsKHR	11	clSetKernelExecInfo	3	OpenCL Extensions	11
Attribute Qualifiers	5	clEnqueueReleaseDX9MediaSurfacesKHR	11	clSetMemObjectDestructorCallback	2	OpenGL Sharing	11
B		clEnqueueReleaseEGLOObjectsKHR	11	clSetUserEventStatus	3	Operators	4
Barriers	4	clEnqueueReleaseGLOObjects	11	clSVMAlloc	2	Optimization options	3
Blocks	4	clEnqueueSVM[Un]Map	3	clSVMFree	2	P	
Buffer Objects	1-2	clEnqueueSVMFree	2	clTerminateContextKHR	1	Partitioning a Device	1
C		clEnqueueSVMMem[cpy, Fill]	3	clUnloadPlatformCompiler	3	Pipe Built-in Functions	8
cl_KHR	11	clEnqueueUnmapMemObject	2	clWaitForEvents	3	Pipes	2
clBuildProgram	3	clEnqueueWriteBuffer	2	Command Queues	1	Prefetch	6
clCompileProgram	3	clEnqueueWriteBufferRect	2	Common Built-in Functions	5-6	Preprocessor	3
clCreateBuffer	1	clEnqueueWriteImage	8	Compiler Options	3	Preprocessor Directives & Macros	4
clCreateCommandQueueWithProperties	1	clFinish	3	const_sampler_t	10	printf Function	7
clCreateContext	1	clFlush	3	Contexts	1	Profiling Operations	4
clCreateContextFromType	1	clGetCommandQueueInfo	1	Conversions and Type Casting	2	Program linking options	3
clCreateEventFromEGLsyncKHR	11	clGetContextInfo	1	Copy Between Image, Buffer Objects	8	Program Objects	3
clCreateEventFromGLsyncKHR	11	clGetDeviceIDs	1	D		Q	
clCreateFromD3D10BufferKHR	11	clGetDeviceIDsFromD3D10KHR	11	Data Types	4	Qualifiers	4
clCreateFromD3D10Texture2DKHR	11	clGetDeviceIDsFromD3D11KHR	11	Debugging options	3	Query Image Objects	9
clCreateFromD3D10Texture3DKHR	11	clGetDeviceIDsFromDX9MediaAdapterKHR	11	Device Architecture Diagram	2	Query Image Functions	10
clCreateFromD3D11BufferKHR	11	clGetDeviceInfo	1	Direct3D 10 Sharing	11	Query List of Supported Image Formats	8
clCreateFromD3D11Texture2DKHR	11	clGetEventInfo	3	Direct3D 11 Sharing	11	Query Memory Object	2
clCreateFromD3D11Texture3DKHR	11	clGetEventProfilingInfo	4	DX9 Media Surface Sharing	11	Query Program Objects	3
clCreateFromDX9MediaSurfaceKHR	11	clGetExtensionFunctionAddressForPlatform	1	E - F		Querying Platform Info & Devices	1
clCreateFromEGLImageKHR	11	clGetGLContextInfoKHR	11	EGL Interoperability	11	R	
clCreateFromGLBuffer	11	clGetGLObjectInfo	11	Enqueing & Kernel Query Built-in Functions	8	Read, Write, Copy Buffer Objects	1-2
clCreateFromGLRenderbuffer	11	clGetGLTextureInfo	11	Event Built-in Functions	8	Read, Write, Copy, Fill Image Objects	8
clCreateFromGLTexture	11	clGetKernelArgInfo	3	Event Objects	3	Read and Write Image Objects	9-10
clCreatelImage	8	clGetKernelInfo	3	Execute Kernels	3	Relational Built-in Functions	6
clCreateKernel	3	clGetKernelSubGroupInfoKHR	3	Extension Function Pointers	1	S - T	
clCreateKernelsInProgram	3	clGetKernelWorkGroupInfo	3	Extensions	11	Sampler Objects, Declaration Fields	10
clCreatePipe	2	clGetMemObjectInfo	2	Fence Functions	6	Scalar Data Types	4
clCreateProgramWithBinary	3	clGetMemObjectInfo	9	G - H		Separate Compilation and Linking	3
clCreateProgramWithBuiltInKernels	3	clGetPipeInfo	2	Geometric Built-in Functions	6	Share Objects	11
clCreateProgramWithSource	3	clGetPlatformIDs	1	Helper Built-in Functions	8	Shared Virtual Memory	2-3
clCreateSamplerWithProperties	10	clGetPlatformInfo	1	I		SPIR compiler options	3
clCreateSubBuffer	1	clGetProgramBuildInfo	3	Image Formats	9	Supported Data Types	4
clCreateSubDevices	1	clGetProgramInfo	3	Image Objects	8-9	SVM Sharing Granularity	2
clCreateUserEvent	3	clGetProgramInfo	3	Image Query Functions	10	Synchronization & Memory Fence Functions	6
clEnqueueAcquireD3D10ObjectsKHR	11	clGetSamplerInfo	10	Image Read and Write Functions	9-10	Type Casting Examples	2
clEnqueueAcquireD3D11ObjectsKHR	11	clGetSupportedImageFormats	8	Integer Built-in Functions	5	Types	4
clEnqueueAcquireDX9MediaSurfacesKHR	11	clIcdGetPlatformIDsKHR	1	K		U - V	
clEnqueueAcquireEGLOObjectsKHR	11	clLinkProgram	3	Kernel Arguments and Queries	3	Unload the OpenCL Compiler	3
clEnqueueAcquireGLOObjects	11	clReleaseCommandQueue	1	Kernel Objects	3	Unroll attribute qualifiers	5
clEnqueueBarrierWithWaitList	4	clReleaseContext	1	Kernel Query Built-in Functions	8	Vector Component Addressing	4
clEnqueueCopyBuffer	2	clReleaseDevice	1	L		Vector Data Load/Store	6
clEnqueueCopyBufferToImage	8	clReleaseEvent	4	Library linking options	3	Vector Functions	8
clEnqueueCopyImage	8	clReleaseKernel	3	Linker Options	3	Vector Data Types	4
clEnqueueCopyImageToBuffer	8	clReleaseMemObject	2	M		Version	3
clEnqueueCopyImageToBuffer	8	clReleaseProgram	3	Map and Unmap Image Objects	9	W	
clEnqueueFillBuffer	2	clReleaseSampler	10	Map Buffer Objects	2	Waiting for Events	3
clEnqueueFillImage	8	clRetainCommandQueue	1	Markers, Barriers, Waiting for Events	4	Warning request/suppress	3
clEnqueueMapBuffer	2	clRetainContext	1	Math Built-in Functions	5	Workgroup Functions	7
clEnqueueMapImage	9	clRetainDevice	1	Math Constants	5	Work-Item Built-in Functions	4-5
clEnqueueMarkerWithWaitList	4	clRetainEvent	3				
clEnqueueMigrateMemObjects	2	clRetainKernel	3				
clEnqueueNativeKernel	3	clRetainMemObject	2				



The Khronos Group is an industry consortium creating open standards for the authoring and acceleration of parallel computing, graphics and dynamic media on a wide variety of platforms and devices. See www.khronos.org to learn more about the Khronos Group.

OpenCL is a trademark of Apple Inc. and is used under license by Khronos.