

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.

[n.n.n] refers to the section in the OpenCL Specification.

[n.n.n] refers to the section in the OpenCL Extension Specification

Text shown in purple is as per the OpenCL Extension Specification.

Specifications are available at www.khronos.org/opencv.

The OpenCL Runtime

Command Queues [5.1]

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

properties: CL_QUEUE_PROFILING_ENABLE,
CL_QUEUE_OUT_OF_ORDER_EXEC_MODE_ENABLE

```
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: CL_QUEUE_CONTEXT,
CL_QUEUE_DEVICE,
CL_QUEUE_REFERENCE_COUNT,
CL_QUEUE_PROPERTIES

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.

Querying Platform Info and Devices [4.1, 4.2]

```
cl_int clGetPlatformIDs (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, CL_PLATFORM_VERSION,
CL_PLATFORM_NAME, CL_PLATFORM_VENDOR, CL_PLATFORM_EXTENSIONS

```
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: CL_DEVICE_TYPE_ACCELERATOR, CL_DEVICE_TYPE_CPU,
CL_DEVICE_TYPE_CUSTOM, CL_DEVICE_TYPE_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:

CL_DEVICE_NAME, CL_DEVICE_VENDOR, CL_DEVICE_PROFILE, CL_DEVICE_TYPE,
CL_DEVICE_NATIVE_VECTOR_WIDTH_CHAR, CL_DEVICE_NATIVE_VECTOR_WIDTH_INT,
CL_DEVICE_NATIVE_VECTOR_WIDTH_LONG, CL_DEVICE_NATIVE_VECTOR_WIDTH_SHORT,
CL_DEVICE_NATIVE_VECTOR_WIDTH_DOUBLE, CL_DEVICE_NATIVE_VECTOR_WIDTH_HALF,
CL_DEVICE_NATIVE_VECTOR_WIDTH_FLOAT, CL_DEVICE_PREFERRED_VECTOR_WIDTH_CHAR,
CL_DEVICE_PREFERRED_VECTOR_WIDTH_INT, CL_DEVICE_PREFERRED_VECTOR_WIDTH_LONG,
CL_DEVICE_PREFERRED_VECTOR_WIDTH_SHORT, CL_DEVICE_PREFERRED_VECTOR_WIDTH_DOUBLE,
CL_DEVICE_PREFERRED_VECTOR_WIDTH_HALF, CL_DEVICE_PREFERRED_VECTOR_WIDTH_FLOAT,
CL_DEVICE_PREFERRED_INTEROP_USER_SYNC, CL_DEVICE_ADDRESS_BITS, CL_DEVICE_AVAILABLE,
CL_DEVICE_BUILT_IN_KERNELS, CL_DEVICE_COMPILER_AVAILABLE, CL_DEVICE_DOUBLE_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, CL_DEVICE_GLOBAL_MEM_CACHE_TYPE,
CL_DEVICE_GLOBAL_MEM_CACHELINE_SIZE, 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_LOCAL_MEM_SIZE, CL_DEVICE_MAX_READ_WRITE_IMAGE_ARGS, CL_DEVICE_MAX_CLOCK_FREQUENCY,
CL_DEVICE_MAX_COMPUTE_UNITS, CL_DEVICE_MAX_CONSTANT_ARGS_BUFFER_SIZE, CL_DEVICE_MAX_MEM_ALLOC_PARAMETER_SIZE,
CL_DEVICE_MAX_SAMPLERS, CL_DEVICE_MAX_WORK_GROUP_SIZE, CL_DEVICE_MAX_WORK_ITEM_DIMENSIONS_SIZES,
CL_DEVICE_MEM_BASE_ADDR_ALIGN, CL_DEVICE_OPENCL_C_VERSION, CL_DEVICE_PARENT_DEVICE, CL_DEVICE_PARTITION_AFFINITY_DOMAIN,
CL_DEVICE_PARTITION_MAX_SUB_DEVICES, CL_DEVICE_PARTITION_PROPERTIES, CL_DEVICE_PLATFORM, CL_DEVICE_PRINTF_BUFFER_SIZE,
CL_DEVICE_PROFILING_TIMER_RESOLUTION, CL_DEVICE_QUEUE_PROPERTIES, CL_DEVICE_REFERENCE_COUNT, CL_DEVICE_VENDOR_ID, 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

(Affinity domains may be: CL_DEVICE_AFFINITY_DOMAIN_NUMA, CL_DEVICE_AFFINITY_DOMAIN_L4_L3_L2_L1_CACHE, CL_DEVICE_AFFINITY_DOMAIN_NEXT_PARTITIONABLE)

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

Buffer Objects

Elements of a buffer object are stored sequentially and accessed using a pointer by a kernel executing on a device. Data is stored in the same format as it is accessed by the kernel.

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: 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, CL_MEM_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: same as for 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)
```

```
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)
```

properties: NULL or CL_CONTEXT_PLATFORM, CL_CONTEXT_INTEROP_USER_SYNC, CL_CONTEXT_D3D10_D3D11_DEVICE_KHR, CL_CONTEXT_ADAPTER_D3D9_D3D9EX_DXVA1_KHR, CL_GL_CONTEXT_KHR, CL_CGL_SHAREGROUP_KHR, CL_EGL_KHR, CL_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

```
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, CL_CONTEXT_PROPERTIES, CL_CONTEXT_D3D10_PREFER_SHARED_RESOURCES_KHR, CL_CONTEXT_D3D11_PREFER_SHARED_RESOURCES_KHR

Get CL Extension Function Pointers [9.2]

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

```
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_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 [5.2.3]

```
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

Memory Objects [5.4.1, 5.4.2]

```
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 [5.4.4]

```
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 [5.4.5]

```
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_MAP_REFERENCE_COUNT, CL_MEM_OFFSET, CL_MEM_CONTEXT, CL_MEM_ASSOCIATED_MEMOBJECT, CL_MEM_D3D10_D3D11_RESOURCE_KHR, CL_MEM_DX9_MEDIA_ADAPTER_TYPE_KHR, CL_MEM_DX9_MEDIA_SURFACE_INFO_KHR

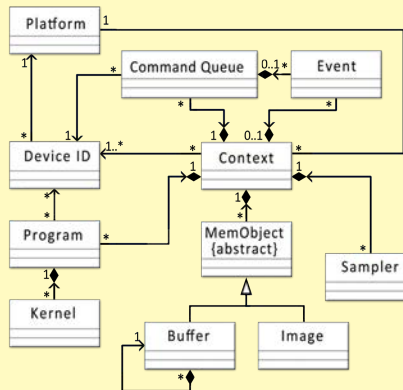
OpenCL Class Diagram [2.1]

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.

Annotations

| Relationships | |
|---------------------------|------------|
| abstract classes | {abstract} |
| aggregations | ◆ |
| inheritance | △ |
| relationship navigability | ^ |

| Cardinality | |
|------------------|------|
| many | * |
| one and only one | 1 |
| optionally one | 0..1 |
| one or more | 1..* |



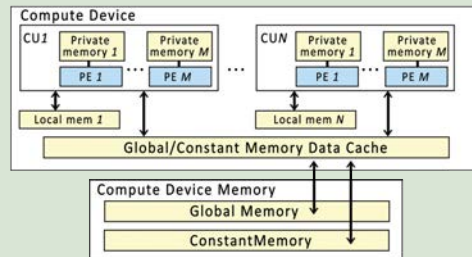
¹ Unified Modeling Language (<http://www.uml.org/>) is a trademark of Object Management Group (OMG).

OpenCL Device Architecture Diagram [3.3]

The table below shows memory regions with allocation and memory access capabilities.

| | Global | Constant | Local | Private |
|--------|---|---|--|--|
| Host | Dynamic allocation Read/Write access | Dynamic allocation Read/Write access | Dynamic allocation No access | No allocation No access |
| Kernel | No allocation Read/Write access | Static allocation Read-only access | Static allocation Read/Write access | Static allocation Read/Write access |

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



Program Objects

Create Program Objects [5.6.1]

```
cl_program clCreateProgramWithSource (
    cl_context context, cl_uint num_devices, 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 [5.6.2]

```
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 [5.6.3]

```
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)
```

Kernel and Event Objects

Create Kernel Objects [5.7.1]

```
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 [5.7.2, 5.7.3]

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

```
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: 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
```

```
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 [5.6.6]

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

Query Program Objects [5.6.7]

```
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: CL_PROGRAM_REFERENCE_COUNT,
    CL_PROGRAM_CONTEXT_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: CL_PROGRAM_BINARY_TYPE,
    CL_PROGRAM_BUILD_STATUS_OPTIONS_LOG)
```

Compiler Options [5.6.4]

```
Preprocessor: (-D processed in order listed in
    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
```

```
cl_int clGetKernelArgInfo (cl_kernel kernel,
    cl_uint arg_index, 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_TYPE_QUALIFIER,
    CL_KERNEL_ARG_NAME, CL_KERNEL_ARG_TYPE_NAME
```

Execute Kernels [5.8]

```
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 clEnqueueTask (
    cl_command_queue command_queue,
    cl_kernel kernel, 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 (*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)
```

Event Objects [5.9]

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

Optimization options:

```
-cl-opt-disable -cl-mad-enable
-cl-no-signed-zeros -cl-finite-math-only
-cl-unsafe-math-optimizations -cl-fast-relaxed-math
```

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.
```

Query kernel argument information:

```
-cl-kernel-arg-info
```

Linker Options [5.6.5]

| | |
|---------------------------------|---------------------------------|
| Library linking options: | Program linking options: |
| -create-library | -cl-denorms-are-zero |
| -enable-link-options | -cl-no-signed-zeros |
| | -cl-unsafe-math-optimizations |
| | -cl-finite-math-only |
| | -cl-fast-relaxed-math |

```
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
```

```
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, and Waiting for Events [5.10]

```
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 [5.12]

```
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: CL_PROFILING_COMMAND_QUEUED,
    CL_PROFILING_COMMAND_SUBMIT_START_END)
```

Flush and Finish [5.13]

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


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]

| OpenCL Type | API Type | Description |
|------------------------|--------------------|--------------------------------|
| bool | -- | true (1) or false (0) |
| char | cl_char | 8-bit signed |
| unsigned char, uchar | cl_uchar | 8-bit unsigned |
| short | cl_short | 16-bit signed |
| unsigned short, ushort | cl_ushort | 16-bit unsigned |
| int | cl_int | 32-bit signed |
| unsigned int, uint | cl_uint | 32-bit unsigned |
| long | cl_long | 64-bit signed |
| unsigned long, ulong | cl_ulong | 64-bit unsigned |
| float | cl_float | 32-bit float |
| double | OPTIONAL cl_double | 64-bit. IEEE 754 |
| half | cl_half | 16-bit float (storage only) |
| size_t | -- | 32- or 64-bit unsigned integer |
| ptrdiff_t | -- | 32- or 64-bit signed integer |
| intptr_t | -- | 32- or 64-bit signed integer |
| uintptr_t | -- | 32- or 64-bit unsigned integer |
| void | void | void |

Built-in Vector Data Types [6.1.2]

| OpenCL Type | API Type | Description |
|---------------------|---------------------------------|-----------------|
| char _n | cl_char _n | 8-bit signed |
| uchar _n | cl_uchar _n | 8-bit unsigned |
| short _n | cl_short _n | 16-bit signed |
| ushort _n | cl_ushort _n | 16-bit unsigned |
| int _n | cl_int _n | 32-bit signed |
| uint _n | cl_uint _n | 32-bit unsigned |
| long _n | cl_long _n | 64-bit signed |
| ulong _n | cl_ulong _n | 64-bit unsigned |
| float _n | cl_float _n | 32-bit float |
| double _n | OPTIONAL cl_double _n | 64-bit float |

Other Built-in Data Types [6.1.3]

The optional types listed here other than event_t are only defined if CL_DEVICE_IMAGE_SUPPORT is CL_TRUE.

| OpenCL Type | Description |
|------------------|--------------------------|
| image2d_t | OPTIONAL 2D image handle |
| image3d_t | OPTIONAL 3D image handle |
| image2d_array_t | OPTIONAL 2D image array |
| image1d_t | OPTIONAL 1D image handle |
| image1d_buffer_t | OPTIONAL 1D image buffer |
| image1d_array_t | OPTIONAL 1D image array |
| sampler_t | OPTIONAL sampler handle |
| event_t | event handle |

Reserved Data Types [6.1.4]

| OpenCL Type | Description |
|--|--------------------------------------|
| bool _n | boolean vector |
| half _n | 16-bit, vector |
| quad, quad _n | 128-bit float, vector |
| complex half, complex half _n imaginary half, imaginary half _n | 16-bit complex, vector |
| complex float, complex float _n imaginary float, imaginary float _n | 32-bit complex, vector |
| complex double, complex double _n imaginary double, imaginary double _n | 64-bit complex, vector |
| complex quad, complex quad _n imaginary quad, imaginary quad _n | 128-bit complex, vector |
| float _n x _m | $n \times m$ matrix of 32-bit floats |
| double _n x _m | $n \times m$ matrix of 64-bit floats |

Preprocessor Directives & Macros [6.10]

| | |
|--------------------------------|--|
| #pragma OPENCL FP_CONTRACT | on-off-switch on-off-switch: ON, OFF, DEFAULT |
| #pragma OPENCL EXTENSION | extensionname : behavior |
| #pragma OPENCL EXTENSION all : | behavior |
| __FILE__ | Current source file |
| __func__ | Current function name |

Vector Component Addressing [6.1.7]

Vector Components

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|------------|-----------|-----------|-----------|-----------|------|------|------|------|------|------|------------|------------|------------|------------|------------|------------|
| float2 v; | v.x, v.s0 | v.y, v.s1 | | | | | | | | | | | | | | |
| float3 v; | v.x, v.s0 | v.y, v.s1 | v.z, v.s2 | | | | | | | | | | | | | |
| float4 v; | v.x, v.s0 | v.y, v.s1 | v.z, v.s2 | v.w, v.s3 | | | | | | | | | | | | |
| float8 v; | v.s0 | v.s1 | v.s2 | v.s3 | v.s4 | v.s5 | v.s6 | v.s7 | | | | | | | | |
| float16 v; | v.s0 | v.s1 | v.s2 | v.s3 | v.s4 | v.s5 | v.s6 | v.s7 | v.s8 | v.s9 | v.sa, v.sA | v.sb, v.sB | v.sc, v.sC | v.sd, v.sD | v.se, v.sE | v.sF, v.sF |

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

| | v.lo | v.hi | v.odd | v.even | | v.lo | v.hi | v.odd | v.even |
|---------|-------------|-------------|-------------|-------------|---------|-------------|-------------|-------------|-------------|
| float2 | v.x, v.s0 | v.y, v.s1 | v.y, v.s1 | v.x, v.s0 | float8 | v.s0123 | v.s4567 | v.s1357 | v.s0246 |
| float3* | v.s01, v.xy | v.s23, v.zw | v.s13, v.yw | v.s02, v.xz | float16 | v.s01234567 | v.s89abcdef | v.s13579bdf | v.s02468ace |
| float4 | v.s01, v.xy | v.s23, v.zw | v.s13, v.yw | v.s02, v.xz | | | | | |

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

Operators and Qualifiers

Operators [6.3]

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

+ - * % / -- ++ == != &
~ ^ > < >= <= | ! && ||
?: >> << = , op= 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)))

Specify Type Attributes [6.11.1]

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))

Math Constants [6.12.2] [9.5.2]

The values of the following symbolic constants are type float, accurate within the precision of a single precision floating-point number.

| | |
|-----------|---|
| 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 is supported, macros ending in _F are available in type double by removing _F from the macro name, and in type half when the half 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 |
| M_LN10_F | Value of log 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 [6.12.3]

T is type char, charn, uchar, uchar_n, short, shortn, ushort, ushortn, int, intr, 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 (Tx) | x |
| Tu abs_diff (Tx, Ty) | x - y without modulo overflow |
| T add_sat (Tx, Ty) | x + y and saturates the result |
| T hadd (Tx, Ty) | (x + y) >> 1 without mod. overflow |
| Th radd (Tx, Ty) | (x + y + 1) >> 1 |
| T clamp (Tx, T min, T max) | min(max(x, minval), maxval) |
| T clamp (Tx, Tsc min, Tsc max) | min(max(x, minval), maxval) |
| T clz (Tx) | number of leading 0-bits in x |
| T mad_hi (Ta, Tb, Tc) | mul_hi(a, b) + c |
| T mad_sat (Ta, Tb, Tc) | a * b + c and saturates the result |
| T max (Tx, Ty) | y if x < y, otherwise it returns x |
| T max (Tx, Tsc y) | y if x < y, otherwise it returns x |
| T min (Tx, Ty) | y if y < x, otherwise it returns x |
| T min (Tx, Tsc y) | y if y < x, otherwise it returns x |
| T mul_hi (Tx, Ty) | high half of the product of x and y |
| T rotate (Tv, Ti) | result[indx] = v[indx] << i[indx] |

| | |
|--------------------|--------------------------------|
| T sub_sat (Tx, Ty) | x - y and saturates the result |
| T popcount (Tx) | 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, intr or intrn, where n is 2, 3, 4, 8, or 16.

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

| | |
|----------------------|------------------------------------|
| __LINE__ | Integer line number |
| __OPENCL_VERSION__ | Integer version number, e.g: 120 |
| __CL_VERSION_1_0 | Substitutes integer 100 for 1.0 |
| __CL_VERSION_1_1 | Substitutes integer 110 for 1.1 |
| __CL_VERSION_1_2 | Substitutes integer 120 for 1.2 |
| __OPENCL_C_VERSION__ | Sub. integer for OpenCL C version. |
| __ENDIAN_LITTLE__ | 1 if device is little endian |
| __IMAGE_SUPPORT__ | 1 if images are supported |

| | |
|---|---|
| __FAST_RELAXED_MATH__ | 1 if -cl-fast-relaxed-math optimization option is specified |
| FP_FAST_FMA | Defined if double fma is fast |
| FP_FAST_FMAF | Defined if float fma is fast |
| FP_FAST_FMA_HALF | Defined if half fma is fast |
| __kernel_exec(X, typen) | Same as: |
| __kernel_attribute__((work_group_size_hint(X, 1, 1))) | |
| __attribute__((vec_type_hint(typen))) | |

Math Built-in Functions [6.12.2] [9.5.2]

Ts is type float, optionally double, or half if the **half extension** is enabled. *Tn* is the vector form of *Ts*, where *n* is 2, 3, 4, 8, or 16. *T* is *Ts* and *Tn*. *Q* is qualifier `__global`, `__local`, or `__private`. **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.

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

| | |
|--|--|
| <i>T</i> exp10 (<i>T</i>) | HN Exponential base 10 |
| <i>T</i> expm1 (<i>T x</i>) | e ^{<i>x</i>} - 1.0 |
| <i>T</i> fabs (<i>T</i>) | Absolute value |
| <i>T</i> fdim (<i>T x, T y</i>) | Positive difference between <i>x</i> and <i>y</i> |
| <i>T</i> floor (<i>T</i>) | Round to integer toward - infinity |
| <i>T</i> fma (<i>T a, T b, T c</i>) | Multiply and add, then round |
| <i>T</i> fmax (<i>T x, T y</i>) | Return <i>y</i> if <i>x</i> < <i>y</i> , otherwise it returns <i>x</i> |
| <i>Tn</i> fmax (<i>Tn x, Ts y</i>) | |
| <i>T</i> fmin (<i>T x, T y</i>) | Return <i>y</i> if <i>y</i> < <i>x</i> , otherwise it returns <i>x</i> |
| <i>Tn</i> fmin (<i>Tn x, Ts y</i>) | |
| <i>T</i> fmod (<i>T x, T y</i>) | Modulus. Returns <i>x</i> - <i>y</i> * trunc (<i>x</i> / <i>y</i>) |
| <i>T</i> fract (<i>T x, Q T *iptr</i>) | Fractional value in <i>x</i> |
| <i>Ts</i> frexp (<i>T x, Q int *exp</i>) | Extract mantissa and exponent |
| <i>Tn</i> frexp (<i>T x, Q intrn *exp</i>) | |
| <i>T</i> hypot (<i>T x, T y</i>) | Square root of <i>x</i> ² + <i>y</i> ² |
| int[<i>n</i>] ilogb (<i>T x</i>) | Return exponent as an integer value |
| <i>Ts</i> ldexp (<i>T x, int n</i>) | <i>x</i> * 2 ^{<i>n</i>} |
| <i>Tn</i> ldexp (<i>T x, intrn n</i>) | |
| <i>T</i> lgamma (<i>T x</i>) | |
| <i>Ts</i> lgamma_r (<i>T x, Q int *signp</i>) | Log gamma function |
| <i>Tn</i> lgamma_r (<i>T x, Q intrn *signp</i>) | |
| <i>T</i> log (<i>T</i>) | HN Natural logarithm |
| <i>T</i> log2 (<i>T</i>) | HN Base 2 logarithm |
| <i>T</i> log10 (<i>T</i>) | HN Base 10 logarithm |
| <i>T</i> log1p (<i>T x</i>) | ln (1.0 + <i>x</i>) |
| <i>T</i> logb (<i>T x</i>) | Exponent of <i>x</i> |
| <i>T</i> mad (<i>T a, T b, T c</i>) | Approximates <i>a</i> * <i>b</i> + <i>c</i> |
| <i>T</i> maxmag (<i>T x, T y</i>) | Maximum magnitude of <i>x</i> and <i>y</i> |
| <i>T</i> minmag (<i>T x, T y</i>) | Minimum magnitude of <i>x</i> and <i>y</i> |

| | |
|---|---|
| <i>T</i> modf (<i>T x, Q T *iptr</i>) | Decompose floating-point number |
| float[<i>n</i>] nan (uint[<i>n</i>] <i>nancode</i>) | Quiet NaN |
| half[<i>n</i>] nan (ushort[<i>n</i>] <i>nancode</i>) | (Return is scalar when <i>nancode</i> is scalar) |
| double[<i>n</i>] nan (ulong[<i>n</i>] <i>nancode</i>) | |
| <i>T</i> nextafter (<i>T x, T y</i>) | Next representable floating-point value after <i>x</i> in the direction of <i>y</i> |
| <i>T</i> pow (<i>T x, T y</i>) | Compute <i>x</i> to the power of <i>y</i> |
| <i>Ts</i> pow (<i>T x, int y</i>) | Compute <i>x</i> ^{<i>y</i>} , where <i>y</i> is an integer |
| <i>Tn</i> pow (<i>T x, intrn y</i>) | |
| <i>T</i> powr (<i>T x, T y</i>) | HN Compute <i>x</i> ^{<i>y</i>} , where <i>x</i> is >= 0 |
| <i>T</i> half_recip (<i>T x</i>) | 1 / <i>x</i> (<i>T</i> may only be float or floatn) |
| <i>T</i> native_recip (<i>T x</i>) | |
| <i>T</i> remainder (<i>T x, T y</i>) | Floating point remainder |
| <i>Ts</i> remquo (<i>T x, T y, Q int *quo</i>) | Remainder and quotient |
| <i>Tn</i> remquo (<i>T x, T y, Q intrn *quo</i>) | |
| <i>T</i> rint (<i>T</i>) | Round to nearest even integer |
| <i>Ts</i> rootn (<i>T x, int y</i>) | Compute <i>x</i> to the power of 1/ <i>y</i> |
| <i>Tn</i> rootn (<i>T x, intrn y</i>) | |
| <i>T</i> round (<i>T x</i>) | Integral value nearest to <i>x</i> rounding |
| <i>T</i> rsqrt (<i>T</i>) | HN Inverse square root |
| <i>T</i> sin (<i>T</i>) | HN Sine |
| <i>T</i> sincos (<i>T x, Q T *cosval</i>) | Sine and cosine of <i>x</i> |
| <i>T</i> sinh (<i>T</i>) | Hyperbolic sine |
| <i>T</i> sinpi (<i>T x</i>) | sin (π <i>x</i>) |
| <i>T</i> sqrt (<i>T</i>) | HN Square root |
| <i>T</i> tan (<i>T</i>) | HN Tangent |
| <i>T</i> tanh (<i>T</i>) | Hyperbolic tangent |
| <i>T</i> tanpi (<i>T x</i>) | tan (π <i>x</i>) |
| <i>T</i> tgamma (<i>T</i>) | Gamma function |
| <i>T</i> trunc (<i>T</i>) | Round to integer toward zero |

Geometric Built-in Functions [6.12.5] [9.5.4]

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</i> distance (<i>T p0, T p1</i>) | Vector distance |
| <i>Ts</i> dot (<i>T p0, T p1</i>) | Dot product |
| <i>Ts</i> length (<i>T p</i>) | Vector length |
| <i>T</i> normalize (<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>) | |

Vector Data Load/Store [6.12.7] [9.5.6]

T is type char, uchar, short, ushort, int, uint, long, ulong, or float, optionally double, or half if the **half extension** is enabled. *Tn* refers to the vector form of type *T*, where *n* is 2, 3, 4, 8, or 16. *Q* is an Address Space Qualifier listed in 6.5 unless otherwise noted. When red, *Q* cannot be `__constant`. *R* defaults to the current rounding mode, or is one of the Rounding Modes listed in 6.2.3.2.

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

| | |
|--|---|
| void vstore_half_R (double <i>data</i> , size_t <i>offset</i> , <i>Q half *p</i>) | Write a half to address (<i>p</i> + <i>offset</i>) |
| void vstore_halfn (floatn <i>data</i> , size_t <i>offset</i> , <i>Q half *p</i>) | |
| void vstore_halfn_R (floatn <i>data</i> , size_t <i>offset</i> , <i>Q half *p</i>) | Write a half vector to address (<i>p</i> + (<i>offset</i> * <i>n</i>)) |
| void vstore_halfn_R (doublen <i>data</i> , size_t <i>offset</i> , <i>Q half *p</i>) | |
| floatn vloada_halfn (size_t <i>offset</i> , const <i>Q half *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> , size_t <i>offset</i> , <i>Q half *p</i>) | |
| void vstorea_halfn_R (floatn <i>data</i> , size_t <i>offset</i> , <i>Q half *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 (doublen <i>data</i> , size_t <i>offset</i> , <i>Q half *p</i>) | |

Async Copies and Prefetch Functions [6.12.10] [9.5.7]

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

| | |
|---|---|
| event_t async_work_group_copy (__local <i>T *dst</i> , const __global <i>T *src</i> , size_t <i>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> , size_t <i>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> , size_t <i>num_gentypes</i> , size_t <i>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> , size_t <i>num_gentypes</i> , size_t <i>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 events that identify the async_work_group_copy operations to complete |
| void prefetch (const __global <i>T *p</i> , size_t <i>num_gentypes</i>) | Prefetch <i>num_gentypes</i> * sizeof(<i>T</i>) bytes into the global cache |

Work-Item Built-in Functions [6.12.1]

These functions query the number of dimensions, the global and local work size specified to `clEnqueueNDRangeKernel`, and the global and local identifier of each work-item when this kernel is executed on a device. *D* is the dimension index.

| | |
|--|-----------------------------|
| uint get_work_dim () | Number of dimensions in use |
| size_t get_global_size (uint <i>D</i>) | Number of global work-items |
| size_t get_global_id (uint <i>D</i>) | Global work-item ID value |
| size_t get_local_size (uint <i>D</i>) | Number of local work-items |
| size_t get_local_id (uint <i>D</i>) | Local work-item ID |
| size_t get_num_groups (uint <i>D</i>) | Number of work-groups |
| size_t get_group_id (uint <i>D</i>) | Returns the work-group ID |
| size_t get_global_offset (uint <i>D</i>) | Returns global offset |

Common Built-in Functions [6.12.4] [9.5.3]

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

| | |
|--|--|
| <i>T clamp</i> (<i>T x</i> , <i>T min</i> , <i>T max</i>) <i>Tn clamp</i> (<i>Tn x</i> , <i>Ts min</i> , <i>Ts max</i>) | Clamp <i>x</i> to range given by <i>min</i> , <i>max</i> |
| <i>T degrees</i> (<i>T radians</i>) | <i>radians</i> to <i>degrees</i> |
| <i>T max</i> (<i>T x</i> , <i>T y</i>) <i>Tn max</i> (<i>Tn x</i> , <i>Ts y</i>) | Max of <i>x</i> and <i>y</i> |

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

Relational Built-in Functions [6.12.6]

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, float*n*, char, char*n*, uchar, uchar*n*, short, short*n*, ushort, ushort*n*, int, int*n*, uint, uint*n*, long, long*n*, ulong, ulong*n*, or optionally double or double*n*. *Ti* is type char, char*n*, short, short*n*, int, int*n*, long, or long*n*. *Tu* is type uchar, uchar*n*, ushort, ushort*n*, uint, uint*n*, ulong, or ulong*n*. *n* is 2, 3, 4, 8, or 16. Optional extension enables half and half*n* types.

| | |
|--|---|
| int <i>isequal</i> (float <i>x</i> , float <i>y</i>) int <i>n</i> <i>isequal</i> (float <i>n</i> <i>x</i> , float <i>n</i> <i>y</i>) int <i>isequal</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isequal</i> (double <i>n</i> <i>x</i> , double <i>n</i> <i>y</i>) int <i>isequal</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isequal</i> (half <i>n</i> <i>x</i> , half <i>n</i> <i>y</i>) | Compare of <i>x</i> == <i>y</i> |
| int <i>isnotequal</i> (float <i>x</i> , float <i>y</i>) int <i>n</i> <i>isnotequal</i> (float <i>n</i> <i>x</i> , float <i>n</i> <i>y</i>) int <i>isnotequal</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isnotequal</i> (double <i>n</i> <i>x</i> , double <i>n</i> <i>y</i>) int <i>isnotequal</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isnotequal</i> (half <i>n</i> <i>x</i> , half <i>n</i> <i>y</i>) | Compare of <i>x</i> != <i>y</i> |
| int <i>isgreater</i> (float <i>x</i> , float <i>y</i>) int <i>n</i> <i>isgreater</i> (float <i>n</i> <i>x</i> , float <i>n</i> <i>y</i>) int <i>isgreater</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isgreater</i> (double <i>n</i> <i>x</i> , double <i>n</i> <i>y</i>) int <i>isgreater</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isgreater</i> (half <i>n</i> <i>x</i> , half <i>n</i> <i>y</i>) | Compare of <i>x</i> > <i>y</i> |
| int <i>isgreaterequal</i> (float <i>x</i> , float <i>y</i>) int <i>n</i> <i>isgreaterequal</i> (float <i>n</i> <i>x</i> , float <i>n</i> <i>y</i>) int <i>isgreaterequal</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isgreaterequal</i> (double <i>n</i> <i>x</i> , double <i>n</i> <i>y</i>) int <i>isgreaterequal</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isgreaterequal</i> (half <i>n</i> <i>x</i> , half <i>n</i> <i>y</i>) | Compare of <i>x</i> >= <i>y</i> |
| int <i>isless</i> (float <i>x</i> , float <i>y</i>) int <i>n</i> <i>isless</i> (float <i>n</i> <i>x</i> , float <i>n</i> <i>y</i>) int <i>isless</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isless</i> (double <i>n</i> <i>x</i> , double <i>n</i> <i>y</i>) int <i>isless</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isless</i> (half <i>n</i> <i>x</i> , half <i>n</i> <i>y</i>) | Compare of <i>x</i> < <i>y</i> |
| int <i>islessequal</i> (float <i>x</i> , float <i>y</i>) int <i>n</i> <i>islessequal</i> (float <i>n</i> <i>x</i> , float <i>n</i> <i>y</i>) int <i>islessequal</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>islessequal</i> (double <i>n</i> <i>x</i> , double <i>n</i> <i>y</i>) int <i>islessequal</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>islessequal</i> (half <i>n</i> <i>x</i> , half <i>n</i> <i>y</i>) | Compare of <i>x</i> <= <i>y</i> |
| int <i>islessgreater</i> (float <i>x</i> , float <i>y</i>) int <i>n</i> <i>islessgreater</i> (float <i>n</i> <i>x</i> , float <i>n</i> <i>y</i>) int <i>islessgreater</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>islessgreater</i> (double <i>n</i> <i>x</i> , double <i>n</i> <i>y</i>) int <i>islessgreater</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>islessgreater</i> (half <i>n</i> <i>x</i> , half <i>n</i> <i>y</i>) | Compare of (<i>x</i> < <i>y</i>) (<i>x</i> > <i>y</i>) |
| int <i>isfinite</i> (float) int <i>n</i> <i>isfinite</i> (float <i>n</i>) int <i>isfinite</i> (double) long <i>n</i> <i>isfinite</i> (double <i>n</i>) int <i>isfinite</i> (half) short <i>n</i> <i>isfinite</i> (half <i>n</i>) | Test for finite value |

| | |
|--|--|
| int <i>isinf</i> (float) int <i>n</i> <i>isinf</i> (float <i>n</i>) int <i>isinf</i> (double) long <i>n</i> <i>isinf</i> (double <i>n</i>) int <i>isinf</i> (half) short <i>n</i> <i>isinf</i> (half <i>n</i>) | Test for + or - infinity |
| int <i>isnan</i> (float) int <i>n</i> <i>isnan</i> (float <i>n</i>) int <i>isnan</i> (double) long <i>n</i> <i>isnan</i> (double <i>n</i>) int <i>isnan</i> (half) short <i>n</i> <i>isnan</i> (half <i>n</i>) | Test for a NaN |
| int <i>isnormal</i> (float) int <i>n</i> <i>isnormal</i> (float <i>n</i>) int <i>isnormal</i> (double) long <i>n</i> <i>isnormal</i> (double <i>n</i>) | Test for a normal value |
| long <i>n</i> <i>isnormal</i> (double <i>n</i>) int <i>isnormal</i> (half) short <i>n</i> <i>isnormal</i> (half <i>n</i>) | Test for a normal value |
| int <i>isordered</i> (float <i>x</i> , float <i>y</i>) int <i>n</i> <i>isordered</i> (float <i>n</i> <i>x</i> , float <i>n</i> <i>y</i>) int <i>isordered</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isordered</i> (double <i>n</i> <i>x</i> , double <i>n</i> <i>y</i>) int <i>isordered</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isordered</i> (half <i>n</i> <i>x</i> , half <i>n</i> <i>y</i>) | Test if arguments are ordered |
| int <i>isunordered</i> (float <i>x</i> , float <i>y</i>) int <i>n</i> <i>isunordered</i> (float <i>n</i> <i>x</i> , float <i>n</i> <i>y</i>) int <i>isunordered</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isunordered</i> (double <i>n</i> <i>x</i> , double <i>n</i> <i>y</i>) int <i>isunordered</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isunordered</i> (half <i>n</i> <i>x</i> , half <i>n</i> <i>y</i>) | Test if arguments are unordered |
| int <i>signbit</i> (float) int <i>n</i> <i>signbit</i> (float <i>n</i>) int <i>signbit</i> (double) long <i>n</i> <i>signbit</i> (double <i>n</i>) int <i>signbit</i> (half) short <i>n</i> <i>signbit</i> (half <i>n</i>) | Test for sign bit |
| int <i>any</i> (<i>Ti x</i>) | 1 if MSB in component of <i>x</i> is set; else 0 |
| int <i>all</i> (<i>Ti x</i>) | 1 if MSB in all components of <i>x</i> are set; else 0 |
| <i>T</i> <i>bitselect</i> (<i>T a</i> , <i>T b</i> , <i>T c</i>) half <i>bitselect</i> (half <i>a</i> , half <i>b</i> , half <i>c</i>) half <i>n</i> <i>bitselect</i> (half <i>n</i> <i>a</i> , half <i>n</i> <i>b</i> , half <i>n</i> <i>c</i>) | Each bit of result is corresponding bit of <i>a</i> if corresponding bit of <i>c</i> is 0 |
| <i>T</i> <i>select</i> (<i>T a</i> , <i>T b</i> , <i>Ti c</i>) <i>T</i> <i>select</i> (<i>T a</i> , <i>T b</i> , <i>Tu c</i>) half <i>n</i> <i>select</i> (half <i>n</i> <i>a</i> , half <i>n</i> <i>b</i> , short <i>n</i> <i>c</i>) half <i>select</i> (half <i>a</i> , half <i>b</i> , short <i>c</i>) half <i>n</i> <i>select</i> (half <i>n</i> <i>a</i> , half <i>n</i> <i>b</i> , ushort <i>n</i> <i>c</i>) half <i>select</i> (half <i>a</i> , half <i>b</i> , ushort <i>c</i>) | For each component of a vector type, result[<i>i</i>] = if MSB of <i>c</i> [<i>i</i>] is set ? <i>b</i> [<i>i</i>] : <i>a</i> [<i>i</i>] For scalar type, result = <i>c</i> ? <i>b</i> : <i>a</i> |

Atomic Functions [6.12.11] [9.3]

These functions provide atomic operations on 32-bit signed and unsigned integers and single precision floating-point to locations in `__global` or `__local` memory. *T* is type int or unsigned int. *T* may also be type float for `atomic_xchg`, and type long or ulong for extended 64-bit atomic functions. *Q* is volatile `__global` or volatile `__local`.

| | |
|--|---|
| <i>T</i> <i>atomic_add</i> (<i>Q T *p</i> , <i>T val</i>) | Read, add, and store |
| <i>T</i> <i>atomic_sub</i> (<i>Q T *p</i> , <i>T val</i>) | Read, subtract, and store |
| <i>T</i> <i>atomic_xchg</i> (<i>Q T *p</i> , <i>T val</i>) | Read, swap, and store |
| <i>T</i> <i>atomic_inc</i> (<i>Q T *p</i>) | Read, increment, and store |
| <i>T</i> <i>atomic_dec</i> (<i>Q T *p</i>) | Read, decrement, and store |
| <i>T</i> <i>atomic_cmpxchg</i> (<i>Q T *p</i> , <i>T cmp</i> , <i>T val</i>) | Read, store (* <i>p</i> == <i>cmp</i>) ? <i>val</i> : * <i>p</i> |
| <i>T</i> <i>atomic_min</i> (<i>Q T *p</i> , <i>T val</i>) | Read, store min(* <i>p</i> , <i>val</i>) |
| <i>T</i> <i>atomic_max</i> (<i>Q T *p</i> , <i>T val</i>) | Read, store max(* <i>p</i> , <i>val</i>) |
| <i>T</i> <i>atomic_and</i> (<i>Q T *p</i> , <i>T val</i>) | Read, store (* <i>p</i> & <i>val</i>) |
| <i>T</i> <i>atomic_or</i> (<i>Q T *p</i> , <i>T val</i>) | Read, store (* <i>p</i> <i>val</i>) |
| <i>T</i> <i>atomic_xor</i> (<i>Q T *p</i> , <i>T val</i>) | Read, store (* <i>p</i> ^ <i>val</i>) |

Optional extensions enable forms of these functions using the `atom_` prefix that implement atomic operations on 64-bit signed and unsigned integers. To use any of these forms, include the following in the OpenCL program source:

```
#pragma OPENCL EXTENSION extension-name : enable

Use cl_khr_int64_base_atomics for extension-name to enable 64-bit versions of the following functions:
    atom_add      atom_sub      atom_inc
    atom_dec      atom_xchg     atom_cmpxchg

Use cl_khr_int64_extended_atomics for extension-name to enable 64-bit versions of the following functions:
    atom_min      atom_max      atom_and
    atom_or       atom_xor
```

Conversions and Type Casting Examples [6.2]

```
T a = (T)b; // Scalar to scalar, or scalar to vector
T a = convert_T(b);      T a = convert_T_R(b);
T a = as_T(b);          T a = convert_T_sat_R(b);

R can be one of the following rounding modes:
    _rte to nearest even    _rtp toward + infinity
    _rtz toward zero       _rtn toward - infinity
```

Synchronization and Explicit Memory Fence Functions [6.12.8, 6.12.9]

flags argument is the memory address space, set to a combination of `CLK_LOCAL_MEM_FENCE` and `CLK_GLOBAL_MEM_FENCE`. Explicit memory fence functions provide ordering between memory operations of a work-item.

| | |
|---|--|
| void <i>barrier</i> (<i>cl_mem_fence_flags flags</i>) | Work-items in a work-group must execute this before any can continue |
| void <i>mem_fence</i> (<i>cl_mem_fence_flags flags</i>) | Orders loads and stores of a work-item executing a kernel |
| void <i>read_mem_fence</i> (<i>cl_mem_fence_flags flags</i>) | Orders memory loads |
| void <i>write_mem_fence</i> (<i>cl_mem_fence_flags flags</i>) | Orders memory stores |

Miscellaneous Vector Functions [6.12.12]

Tm and *Tn* are type char*n*, uchar*n*, short*n*, ushort*n*, int*n*, uint*n*, long*n*, ulong*n*, float*n*, optionally double*n*, or half*n* if the half extension is enabled, where *n* is 2,4,8, or 16 except in `vec_step` it may also be 3. *TUn* is uchar*n*, ushort*n*, uint*n*, or ulong*n*.

| | |
|--|---|
| int <i>vec_step</i> (<i>Tn a</i>) int <i>vec_step</i> (<i>typename</i>) | Takes a built-in scalar or vector data type argument, returns an integer showing number of elements in the scalar or vector. Returns 1 for scalar, 4 for 3-component vector, else number of elements in the specified type. |
| <i>Tn</i> <i>shuffle</i> (<i>Tm x</i> , <i>TUn mask</i>) | 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. |
| <i>Tn</i> <i>shuffle2</i> (<i>Tm x</i> , <i>Tm y</i> , <i>TUn mask</i>) | |

printf Function [6.12.13]

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)
```


OpenCL Image Processing: Following is a subset of the OpenCL specification that pertains to image processing and graphics.

Image Objects

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:
CL_MEM_READ_WRITE,
CL_MEM_(WRITE, READ)_ONLY,
CL_MEM_HOST_(WRITE, READ)_ONLY,
CL_MEM_HOST_NO_ACCESS,
CL_MEM_(USE, ALLOC, COPY)_HOST_PTR
```

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 clCreateImage
image_type: CL_MEM_OBJECT_IMAGE(1D, 2D, 3D),
            CL_MEM_OBJECT_IMAGE1D_BUFFER,
            CL_MEM_OBJECT_IMAGE(1D, 2D)_ARRAY
```

Read, Write, Copy Image Objects [5.3.3]

```
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 [5.3.4]

```
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)
```

Map and Unmap Image Objects [5.3.5]

```
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)
```

Also see [clGetMemObjectInfo \[5.4.5\]](#)

Query Image Objects [5.3.6]

```
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: CL_IMAGE_{ARRAY, ELEMENT}_SIZE,
            CL_IMAGE_{ROW, SLICE}_PITCH,
            CL_IMAGE_{FORMAT, BUFFER, HEIGHT, WIDTH, DEPTH},
            CL_IMAGE_NUM_{SAMPLES, MIP_LEVELS},
            CL_IMAGE_DX9_MEDIA_PLANE_KHR,
            CL_IMAGE_{D3D10, D3D11}_SUBRESOURCE_KHR
```

Image Formats [5.3.1.1, 9.5]

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

Built-in support: [\[Table 5.8\]](#)

```
CL_RGBA: CL_HALF_FLOAT, CL_FLOAT, CL_UNORM_INT(8,16),
          CL_SIGNED_INT(8,16,32), CL_UNSIGNED_INT(8,16,32)
```

```
CL_BGRA: CL_UNORM_INT8
```

Optional support: [\[Table 5.6\]](#)

```
CL_R, CL_A: CL_HALF_FLOAT, CL_FLOAT, CL_UNORM_INT(8,16),
            CL_SIGNED_INT(8,16,32), CL_UNSIGNED_INT(8,16,32),
            CL_SNORM_INT(8,16)
```

```
CL_INTENSITY: CL_HALF_FLOAT, CL_FLOAT, CL_UNORM_INT(8,16),
              CL_SNORM_INT(8,16)
```

```
CL_LUMINANCE: CL_UNORM_INT(8,16), CL_HALF_FLOAT,
              CL_FLOAT, CL_SNORM_INT(8,16)
```

```
CL_RG, CL_RA: CL_HALF_FLOAT, CL_FLOAT, CL_UNORM_INT(8,16),
              CL_SIGNED_INT(8,16,32), CL_UNSIGNED_INT(8,16,32),
              CL_SNORM_INT(8,16)
```

```
CL_RGB: CL_UNORM_SHORT_{555,565}, CL_UNORM_INT_101010
```

```
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 Built-in Functions

[6.12.14] [9.4, 9.5.8]

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. To enable the `read_imageh` and `write_imageh` forms, enable the extension `cl_khr_fp16`. To enable the type `image3d_t` in functions `write_imagef`, `write_imagef_i`, `ui`, `h`), enable 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)
```

Read and write functions for 1D images (continued)

```
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)
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)
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)
```

Read and write functions for 2D images (continued)

```
void write_imagef (image2d_t image, int2 coord, float4 color)
void write_imagef (image2d_array_t image, int4 coord,
                  float4 color)
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.

```
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)
```

Use this pragma to enable writes to type `image3d_t`:

```
#pragma OPENCL EXTENSION cl_khr_3d_image_writes : enable
```

```
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)
```

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
```

OpenCL Image Processing (continued): Following is a subset of the OpenCL specification that pertains to image processing and graphics.

Sampler Objects [5.5]

```
cl_sampler clCreateSampler (
    cl_context context, cl_bool normalized_coords,
    cl_addressing_mode addressing_mode,
    cl_filter_mode filter_mode, cl_int *errcode_ret)
    addressing_mode: CL_ADDRESS_MIRRORED_REPEAT,
    CL_ADDRESS_CLAMP_TO_EDGE, CL_ADDRESS_NONE
    filter_mode: CL_FILTER_NEAREST, LINEAR)
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, FILTER_MODE,
    CL_SAMPLER_ADDRESSING_MODE,
    CL_SAMPLER_NORMALIZED_COORDS
```

Sampler Declaration Fields [6.12.14.1]

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, MIRRORING_REPEAT}
filter-mode: CLK_FILTER_NEAREST, CLK_FILTER_LINEAR
```

Direct3D 10 Sharing [9.9]

Provide interoperability between OpenCL and Direct3D 10. If supported, `cl_khr_d3d10_sharing` will be present in `CL_PLATFORM_EXTENSIONS` or `CL_DEVICE_EXTENSIONS`.

```
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_int *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: CL_MEM_{READ, WRITE}_ONLY, CL_MEM_READ_WRITE
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 clCreateFromD3D10BufferKHR
cl_int clEnqueueAcquireD3D10ObjectsKHR (
    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_int clEnqueueReleaseD3D10ObjectsKHR (
    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)
```

Direct3D 11 Sharing [9.11]

Provide interoperability between OpenCL and Direct3D 11. If supported, `cl_khr_d3d11_sharing` will be present in `CL_PLATFORM_EXTENSIONS` or `CL_DEVICE_EXTENSIONS`.

```
cl_mem clCreateFromD3D11Texture2DKHR (
    cl_context context, cl_mem_flags flags,
    ID3D11Texture2D *resource,
    UINT subresource, cl_int *errcode_ret)
    flags: CL_MEM_{READ, WRITE}_ONLY, CL_MEM_READ_WRITE
```

Image Query Functions [6.12.14.5]

Query image width, height, and depth in pixels

```
int get_image_width (image1,2,3d_t image)
int get_image_width (image1d_buffer_t image)
int get_image_width (image1,2d_array_t image)
```

```
int get_image_height (image2,3d_t image)
int get_image_height (image2d_array_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)
```

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)
```

Query image Channel data type and order

```
int get_image_channel_data_type (image1,2,3d_t image)
int get_image_channel_data_type (image1d_buffer_t image)
int get_image_channel_data_type (image1,2d_array_t image)
```

```
int get_image_channel_order (image1,2,3d_t image)
int get_image_channel_order (image1d_buffer_t image)
int get_image_channel_order (image1,2d_array_t image)
```

OpenGL Sharing

Functions available if `cl_khr_gl_sharing` or `cl_apple_gl_sharing` is supported. Creating OpenCL memory objects from OpenGL objects using `clCreateFromGLBuffer`, `clCreateFromGLTexture`, and `clCreateFromGLRenderbuffer` ensure the OpenGL object will not be deleted while the corresponding OpenCL memory object exists.

CL Buffer Objects > GL Buffer Objects [9.7.2]

```
cl_mem clCreateFromGLBuffer (cl_context context,
    cl_mem_flags flags, GLuint bufobj, cl_int *errcode_ret)
    flags: CL_MEM_{READ, WRITE}_ONLY, CL_MEM_READ_WRITE
```

CL Image Objects > GL Textures [9.7.3]

```
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}
```

CL Image Objects > GL Renderbuffers [9.7.4]

```
cl_mem clCreateFromGLRenderbuffer (
    cl_context context, cl_mem_flags flags,
    GLuint renderbuffer, cl_int *errcode_ret)
    flags: CL_MEM_{READ, WRITE}_ONLY, CL_MEM_READ_WRITE
```

Query Information [9.7.5]

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

DX9 Media Surface Sharing [9.10]

These functions allow applications to use media surfaces as OpenCL memory objects. If this extension is supported, `cl_khr_dx9_media_sharing` will be present in `CL_PLATFORM_EXTENSIONS` or `CL_DEVICE_EXTENSIONS`.

```
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_DEVICES_FOR_DXP_MEDIA_ADAPTER_KHR,
    CL_PREFERRED_DEVICES_FOR_DX9_MEDIA_ADAPTER_KHR
```

```
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_int *num_devices)
```

```
d3d_device_source: CL_D3D11_DEVICE_KHR,
    CL_D3D11_DXGI_ADAPTER_KHR
d3d_device_set: CL_PREFERRED_DEVICES_FOR_D3D11_KHR,
    CL_ALL_DEVICES_FOR_D3D11_KHR
```

```
cl_mem clCreateFromD3D11BufferKHR (
    cl_context context, cl_mem_flags flags,
    ID3D11Buffer *resource, cl_int *errcode_ret)
    flags: CL_MEM_{READ, WRITE}_ONLY, CL_MEM_READ_WRITE
```

*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}
```

Share Objects [9.7.6]

```
cl_int clEnqueueAcquireGLObjects (
    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_int clEnqueueReleaseGLObjects (
    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 [9.8.2]

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

CL Context > GL Context, Sharegroup [9.6.5]

```
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_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: CL_MEM_{READ, WRITE}_ONLY, CL_MEM_READ_WRITE
    adapter_type: CL_ADAPTER_{D3D9, D3D9EX, DXVA}_KHR
```

```
cl_int clEnqueueAcquireDX9MediaSurfacesKHR (
    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_int clEnqueueReleaseDX9MediaSurfacesKHR (
    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: CL_MEM_{READ, WRITE}_ONLY, CL_MEM_READ_WRITE
```

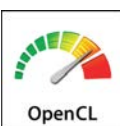
```
cl_int clEnqueueAcquireD3D11ObjectsKHR (
    cl_command_queue command_queue,
    cl_uint num_objects, const cl_mem *mem_objects,
    cl_uint num_events_in_wait_list,
    const cl_event *event_wait_list, cl_event *event)
```

```
cl_int clEnqueueReleaseD3D11ObjectsKHR (
    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)
```

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