

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_CACHELINE_SIZE,
    CL_DEVICE_GLOBAL_MEM_SIZE, CL_DEVICE_HOST_UNIFIED_MEMORY, CL_DEVICE_IMAGE_MAX_ARRAY_BUFFER_SIZE,
    CL_DEVICE_IMAGE_SUPPORT, CL_DEVICE_IMAGE2D_MAX_WIDTH, CL_DEVICE_IMAGE2D_MAX_HEIGHT,
    CL_DEVICE_IMAGE3D_MAX_WIDTH, CL_DEVICE_IMAGE3D_MAX_HEIGHT, CL_DEVICE_IMAGE3D_MAX_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, CL_DEVICE_MAX_CONSTANT_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, 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_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_ONLY,
        CL_MEM_HOST_NO_ACCESS,
        CL_MEM_HOST_READ_WRITE_ONLY,
        CL_MEM_USE_ALLOC_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_DXVA_KHR,
            CL_GL_CONTEXT_KHR, CL_CGL_SHAREGROUP_KHR,
            CL_EGL_KHR, CL_GLX_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_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 [5.2.3]

```
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
```

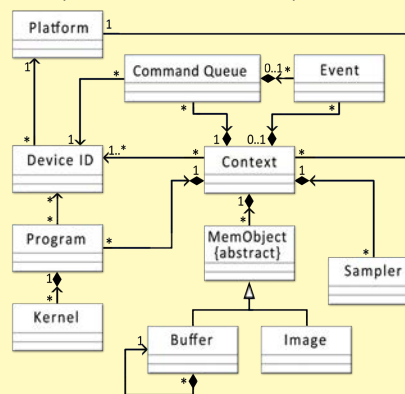
OpenCL Class Diagram [2.1]

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..*



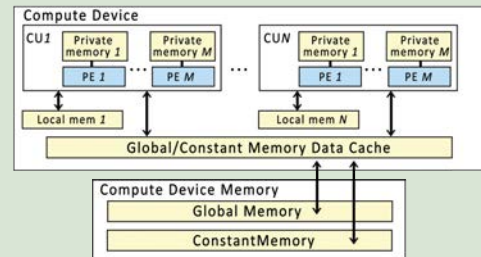
¹ Unified Modeling Language (<http://www.uml.org/>) is a trademark of Object Management Group (OMG).

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)
```

```
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, 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: 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

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 clSetEventStatus (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)
```

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

```
cl_int clReleaseEvent (cl_event event)
```

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)
```

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_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)
```


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 × _m	<i>n</i> × <i>m</i> matrix of 32-bit floats
double _n × _m	<i>n</i> × <i>m</i> matrix of 64-bit floats

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, short_n, ushort, ushort_n, int, int_n, uint, uint_n, long, long_n, ulong, or ulong_n, 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) T clamp (T x, Tsc min, Tsc max)	min(max(x, minval), maxval)
T clz (T x)	number of leading 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) T max (T x, Tsc y)	y if x < y, otherwise it returns x
T min (T x, T y)	y if y < x, otherwise it returns x
T min (T x, Tsc y)	y if y < x, otherwise it returns x
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] << [iindx]

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, int_n or int_n, 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 int. z
T mul24 (T x, T y)	Multiply 24-bit integer values x and y

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

__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]

T_s is type float, optionally double, or half if the **half extension** is enabled. T_n is the vector form of T_s , where n is 2, 3, 4, 8, or 16. T is T_s and T_n . Q is qualifier `__global`, `__local`, or `__private`. **HN** indicates that half and native variants are available using only the float or float $_n$ 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 float $_n$ types.

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

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

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

Geometric Built-in Functions [6.12.5] [9.5.4]

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

$\text{float}\{3,4\} \text{ cross}$ ($\text{float}\{3,4\} p0, \text{float}\{3,4\} p1$) $\text{double}\{3,4\} \text{ cross}$ ($\text{double}\{3,4\} p0, \text{double}\{3,4\} p1$) $\text{half}\{3,4\} \text{ cross}$ ($\text{half}\{3,4\} p0, \text{half}\{3,4\} p1$)	Cross product
$T_s \text{ distance}$ ($T p0, T p1$)	Vector distance
$T_s \text{ dot}$ ($T p0, T p1$)	Dot product
$T_s \text{ length}$ ($T p$)	Vector length
$T \text{ normalize}$ ($T p$)	Normal vector length 1
$\text{float fast_distance}$ ($\text{float } p0, \text{float } p1$) $\text{float fast_distance}$ ($\text{floatn } p0, \text{floatn } p1$)	Vector distance
float fast_length ($\text{float } p$) float fast_length ($\text{floatn } p$)	Vector length
$\text{float fast_normalize}$ ($\text{float } p$) $\text{floatn fast_normalize}$ ($\text{floatn } p$)	Normal vector length 1

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. T_n 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.

$T_n \text{ vloadn}$ (size_t offset , $\text{const } Q T * p$)	Read vector data from address ($p + (\text{offset} * n)$)
void vstoren ($T_n \text{ data}$, size_t offset , $Q T * p$)	Write vector data to address ($p + (\text{offset} * n)$)
float vload_half (size_t offset , $\text{const } Q \text{ half} * p$)	Read a half from address ($p + \text{offset}$)
$\text{floatn vload_halfn}$ (size_t offset , $\text{const } Q \text{ half} * p$)	Read a half $_n$ from address ($p + (\text{offset} * n)$)
void vstore_half (float data , size_t offset , $Q \text{ half} * p$) $\text{void vstore_half}_R$ (float data , size_t offset , $Q \text{ half} * p$) void vstore_half (double data , size_t offset , $Q \text{ half} * p$)	Write a half to address ($p + \text{offset}$)

$\text{void vstore_half}_R$ (double data , size_t offset , $Q \text{ half} * p$)	Write a half to address ($p + \text{offset}$)
void vstore_halfn (floatn data , size_t offset , $Q \text{ half} * p$) $\text{void vstore_halfn}_R$ (floatn data , size_t offset , $Q \text{ half} * p$) void vstore_halfn (doublen data , size_t offset , $Q \text{ half} * p$) $\text{void vstore_halfn}_R$ (doublen data , size_t offset , $Q \text{ half} * p$)	Write a half vector to address ($p + (\text{offset} * n)$)
$\text{floatn vloada_halfn}$ (size_t offset , $\text{const } Q \text{ half} * p$)	Read half vector data from ($p + (\text{offset} * n)$). For half3, read from ($p + (\text{offset} * 4)$).
$\text{void vstorea_halfn}$ (floatn data , size_t offset , $Q \text{ half} * p$) $\text{void vstorea_halfn}_R$ (floatn data , size_t offset , $Q \text{ half} * p$) $\text{void vstorea_halfn}$ (doublen data , size_t offset , $Q \text{ half} * p$) $\text{void vstorea_halfn}_R$ (doublen data , size_t offset , $Q \text{ half} * p$)	Write half vector data to ($p + (\text{offset} * n)$). For half3, write to ($p + (\text{offset} * 4)$).

Async Copies and Prefetch Functions [6.12.10] [9.5.7]

T is type char, charn, uchar, uchar $_n$, short, shortn, ushort, ushort $_n$, int, intrn, uint, uint $_n$, long, long $_n$, ulong, ulong $_n$, float, float $_n$, optionally double or double $_n$, or half or half $_n$ if the **half extension** is enabled.

$\text{event_t async_work_group_copy}$ ($\text{__local } T * \text{dst}$, $\text{const __global } T * \text{src}$, $\text{size_t num_gentypes}$, event_t event)	Copies num_gentypes T elements from src to dst
$\text{event_t async_work_group_copy}$ ($\text{__global } T * \text{dst}$, $\text{const __local } T * \text{src}$, $\text{size_t num_gentypes}$, event_t event)	
$\text{event_t async_work_group_strided_copy}$ ($\text{__local } T * \text{dst}$, $\text{const __global } T * \text{src}$, $\text{size_t num_gentypes}$, size_t src_stride , event_t event)	Copies num_gentypes T elements from src to dst
$\text{event_t async_work_group_strided_copy}$ ($\text{__global } T * \text{dst}$, $\text{const __local } T * \text{src}$, $\text{size_t num_gentypes}$, size_t dst_stride , event_t event)	
$\text{void wait_group_events}$ (int num_events , $\text{event_t} * \text{event_list}$)	Wait for events that identify the async_work_group_copy operations to complete
void prefetch ($\text{const __global } T * p$, $\text{size_t num_gentypes}$)	Prefetch $\text{num_gentypes} * \text{sizeof}(T)$ 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 (int)	Number of dimensions in use
$\text{size_t get_global_size}$ ($\text{uint } D$)	Number of global work-items
$\text{size_t get_global_id}$ ($\text{uint } D$)	Global work-item ID value
$\text{size_t get_local_size}$ ($\text{uint } D$)	Number of local work-items
$\text{size_t get_local_id}$ ($\text{uint } D$)	Local work-item ID
$\text{size_t get_num_groups}$ ($\text{uint } D$)	Number of work-groups
$\text{size_t get_group_id}$ ($\text{uint } D$)	Returns the work-group ID
$\text{size_t get_global_offset}$ ($\text{uint } D$)	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>T 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 x</i> , float <i>n y</i>) int <i>isequal</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isequal</i> (double <i>n x</i> , double <i>n y</i>) int <i>isequal</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isequal</i> (half <i>n x</i> , half <i>n 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 x</i> , float <i>n y</i>) int <i>isnotequal</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isnotequal</i> (double <i>n x</i> , double <i>n y</i>) int <i>isnotequal</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isnotequal</i> (half <i>n x</i> , half <i>n 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 x</i> , float <i>n y</i>) int <i>isgreater</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isgreater</i> (double <i>n x</i> , double <i>n y</i>) int <i>isgreater</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isgreater</i> (half <i>n x</i> , half <i>n 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 x</i> , float <i>n y</i>) int <i>isgreaterequal</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isgreaterequal</i> (double <i>n x</i> , double <i>n y</i>) int <i>isgreaterequal</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isgreaterequal</i> (half <i>n x</i> , half <i>n 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 x</i> , float <i>n y</i>) int <i>isless</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isless</i> (double <i>n x</i> , double <i>n y</i>) int <i>isless</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isless</i> (half <i>n x</i> , half <i>n 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 x</i> , float <i>n y</i>) int <i>islessequal</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>islessequal</i> (double <i>n x</i> , double <i>n y</i>) int <i>islessequal</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>islessequal</i> (half <i>n x</i> , half <i>n 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 x</i> , float <i>n y</i>) int <i>islessgreater</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>islessgreater</i> (double <i>n x</i> , double <i>n y</i>) int <i>islessgreater</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>islessgreater</i> (half <i>n x</i> , half <i>n 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>) int <i>isnormal</i> (half) short <i>n</i> <i>isnormal</i> (half <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 x</i> , float <i>n y</i>) int <i>isordered</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isordered</i> (double <i>n x</i> , double <i>n y</i>) int <i>isordered</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isordered</i> (half <i>n x</i> , half <i>n 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 x</i> , float <i>n y</i>) int <i>isunordered</i> (double <i>x</i> , double <i>y</i>) long <i>n</i> <i>isunordered</i> (double <i>n x</i> , double <i>n y</i>) int <i>isunordered</i> (half <i>x</i> , half <i>y</i>) short <i>n</i> <i>isunordered</i> (half <i>n x</i> , half <i>n 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 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 a</i> , half <i>n b</i> , half <i>n c</i>)	Each bit of result is corresponding bit of <i>a</i> if corresponding bit of <i>c</i> is 0
<i>T select</i> (<i>T a</i> , <i>T b</i> , <i>Ti c</i>) <i>T select</i> (<i>T a</i> , <i>T b</i> , <i>Tu c</i>) half <i>n</i> <i>select</i> (half <i>n a</i> , half <i>n b</i> , short <i>n 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 a</i> , half <i>n b</i> , ushort <i>n 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] = if MSB of c[i] is set ? b[i] : a[i] For scalar type, result = c ? b : a

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

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 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 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_ONLY,
    CL_MEM_HOST_WRITE_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_IMAGE1D, 2D, 3D,
    CL_MEM_OBJECT_IMAGE1D_BUFFER,
    CL_MEM_OBJECT_IMAGE1D_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)

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)

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.

Build-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, 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`, `read_imagef`, `write_imageh`, `read_imageh`, 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, CL_FILTER_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, CL_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, MIRRORED_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_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: 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 (image1d_t image)
int get_image_width (image1d_buffer_t image)
int get_image_width (image1d_array_t image)
int get_image_height (image2d_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 (image1d_t image)
int get_image_channel_data_type (image1d_buffer_t image)
int get_image_channel_data_type (image1d_array_t image)
int get_image_channel_order (image1d_t image)
int get_image_channel_order (image1d_buffer_t image)
int get_image_channel_order (image1d_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_DX9_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_uint *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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