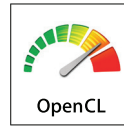


**OpenCL (Open Computing Language)** is a multi-vendor open standard for general-purpose parallel programming of heterogeneous systems that include CPUs, GPUs, and other processors. OpenCL provides a uniform programming environment for software developers to write efficient, portable code for high-performance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



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

## OpenCL API Reference

### The OpenCL Platform Layer

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

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

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

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

`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)`

*param\_name*: CL\_PLATFORM {PROFILE, VERSION},  
CL\_PLATFORM {NAME, VENDOR, EXTENSIONS},  
CL\_PLATFORM\_ICD\_SUFFIX\_KHR [Table 4.1]

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

*device\_type*: [Table 4.2]

CL\_DEVICE\_TYPE {ACCELERATOR, ALL, CPU},  
CL\_DEVICE\_TYPE {CUSTOM, DEFAULT, GPU}

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

*param\_name*: [Table 4.3]

CL\_DEVICE\_ADDRESS\_BITS, CL\_DEVICE\_AVAILABLE,  
CL\_DEVICE\_BUILT\_IN\_KERNELS,  
CL\_DEVICE\_COMPILER\_AVAILABLE,  
CL\_DEVICE {DOUBLE, HALF, SINGLE} FP\_CONFIG,  
CL\_DEVICE\_ENDIAN\_LITTLE, CL\_DEVICE\_EXTENSIONS,  
CL\_DEVICE\_ERROR\_CORRECTION\_SUPPORT,  
CL\_DEVICE\_EXECUTION\_CAPABILITIES,  
CL\_DEVICE\_GLOBAL\_MEM\_CACHE\_SIZE, CL\_DEVICE\_GLOBAL\_MEM\_CACHELINE\_SIZE, CL\_DEVICE\_GLOBAL\_VARIABLE\_PREFERRED\_TOTAL\_SIZE,  
CL\_DEVICE\_PREFERRED\_PLATFORM, LOCAL, GLOBAL, ATOMIC\_ALIGNMENT,  
CL\_DEVICE\_GLOBAL\_VARIABLE\_SHARING,  
CL\_DEVICE\_HOST\_UNIFIED\_MEMORY,  
CL\_DEVICE\_IMAGE\_MAX\_ARRAY\_BUFFER\_SIZE,  
CL\_DEVICE\_IMAGE\_SUPPORT,  
CL\_DEVICE\_IMAGE2D\_MAX {WIDTH, HEIGHT},  
CL\_DEVICE\_IMAGE3D\_MAX {WIDTH, HEIGHT, DEPTH},  
CL\_DEVICE\_IMAGE\_BASE\_ADDRESS\_ALIGNMENT,  
CL\_DEVICE\_IMAGE\_PITCH\_ALIGNMENT,  
CL\_DEVICE\_LINKER\_AVAILABLE,  
CL\_DEVICE\_LOCAL\_MEM {TYPE, SIZE},  
CL\_DEVICE\_MAX\_READ\_IMAGE\_ARGS,  
CL\_DEVICE\_MAX\_WRITE\_IMAGE\_ARGS,  
CL\_DEVICE\_MAX {CLOCK\_FREQUENCY, PIPE\_ARGS},  
CL\_DEVICE\_MAX {COMPUTE\_UNITS, SAMPLERS},  
CL\_DEVICE\_MAX\_CONSTANT\_ARGS\_BUFFER\_SIZE,  
CL\_DEVICE\_MAX {MEM\_ALLOC, PARAMETER} SIZE,  
CL\_DEVICE\_MAX\_GLOBAL\_VARIABLE\_SIZE,  
CL\_DEVICE\_MAX\_ON\_DEVICE {QUEUES, EVENTS},  
CL\_DEVICE\_MAX\_WORK\_GROUP\_SIZE,  
CL\_DEVICE\_MAX\_WORK\_ITEM {DIMENSIONS, SIZES},  
CL\_DEVICE\_MEM\_BASE\_ADDR\_ALIGN,  
CL\_DEVICE\_NAME,  
CL\_DEVICE\_NATIVE\_VECTOR\_WIDTH {CHAR, INT},  
CL\_DEVICE\_NATIVE\_VECTOR\_WIDTH {LONG, SHORT},  
CL\_DEVICE\_NATIVE\_VECTOR\_WIDTH {DOUBLE, HALF},  
CL\_DEVICE\_NATIVE\_VECTOR\_WIDTH\_FLOAT,  
CL\_DEVICE {OPENCL\_C\_VERSION, PARENT\_DEVICE},  
CL\_DEVICE\_PARTITION\_AFFINITY\_DOMAIN,  
CL\_DEVICE\_PARTITION\_MAX\_SUB\_DEVICES,  
CL\_DEVICE\_PARTITION {PROPERTIES, TYPE},  
CL\_DEVICE\_PIPE\_MAX\_ACTIVE\_RESERVATIONS,  
CL\_DEVICE\_PIPE\_MAX\_PACKET\_SIZE,

CL\_DEVICE {PLATFORM, PRINTF\_BUFFER\_SIZE},  
CL\_DEVICE\_PREFERRED\_VECTOR\_WIDTH {CHAR, INT},  
CL\_DEVICE\_PREFERRED\_VECTOR\_WIDTH\_DOUBLE,  
CL\_DEVICE\_PREFERRED\_VECTOR\_WIDTH\_HALF,  
CL\_DEVICE\_PREFERRED\_VECTOR\_WIDTH\_LONG,  
CL\_DEVICE\_PREFERRED\_VECTOR\_WIDTH\_SHORT,  
CL\_DEVICE\_PREFERRED\_VECTOR\_WIDTH\_FLOAT,  
CL\_DEVICE\_PREFERRED\_INTEROP\_USER\_SYNC,  
CL\_DEVICE\_PROFILE,  
CL\_DEVICE\_PROFILING\_TIMER\_RESOLUTION,  
CL\_DEVICE\_SPIR\_VERSIONS,  
CL\_DEVICE\_QUEUE\_ON\_DEVICE\_PROPERTIES,  
CL\_DEVICE\_QUEUE\_ON\_HOST\_PROPERTIES,  
CL\_DEVICE\_QUEUE\_ON\_DEVICE\_MAX\_SIZE,  
CL\_DEVICE\_QUEUE\_ON\_DEVICE\_PREFERRED\_SIZE,  
CL\_DEVICE {REFERENCE\_COUNT, VENDOR\_ID},  
CL\_DEVICE\_SVM\_CAPABILITIES,  
CL\_DEVICE\_TERMINATE\_CAPABILITY\_KHR,  
CL\_DEVICE {TYPE, VENDOR},  
CL\_DEVICE {DRIVER} VERSION

#### Partitioning a Device [4.3]

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

*properties*: CL\_DEVICE\_PARTITION\_EQUALLY,  
CL\_DEVICE\_PARTITION\_BY\_COUNTS,  
CL\_DEVICE\_PARTITION\_BY\_AFFINITY\_DOMAIN

`cl_int clRetainDevice (cl_device_id device)`

`cl_int clReleaseDevice (cl_device_id device)`

#### Contexts [4.4]

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

*properties*: [Table 4.5]

NULL or CL\_CONTEXT\_PLATFORM,  
CL\_CONTEXT\_INTEROP\_USER\_SYNC,  
CL\_CONTEXT {D3D10, D3D11}\_DEVICE\_KHR,  
CL\_CONTEXT\_ADAPTER {D3D9, D3D9EX}\_KHR,  
CL\_CONTEXT\_ADAPTER\_DXVA\_KHR,  
CL\_CONTEXT\_MEMORY\_INITIALIZE\_KHR,  
CL\_CONTEXT\_TERMINATE\_KHR,  
CL\_GL\_CONTEXT\_KHR, CL\_CGL\_SHAREGROUP\_KHR,  
CL {EGL, GLX}\_DISPLAY\_KHR, CL\_WGL\_HDC\_KHR

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

*properties*: See `clCreateContext`

*device\_type*: See `clGetDeviceIDs`

`cl_int clRetainContext (cl_context context)`

`cl_int clReleaseContext (cl_context context)`

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

*param\_name*: CL\_CONTEXT\_REFERENCE\_COUNT,  
CL\_CONTEXT {DEVICES, NUM\_DEVICES, PROPERTIES}, CL\_CONTEXT {D3D10, D3D11}\_PREFER\_SHARED\_RESOURCES\_KHR [Table 4.6]

`cl_int clTerminateContextKHR (cl_context context)`

#### Get CL Extension Function Pointers [9.2]

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

### Buffer Objects

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

#### Create Buffer Objects [5.2.1]

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

*flags*: [Table 5.3] CL\_MEM\_READ\_WRITE,  
CL\_MEM {WRITE, READ}\_ONLY,  
CL\_MEM\_HOST\_NO\_ACCESS,  
CL\_MEM\_HOST {READ, WRITE}\_ONLY,  
CL\_MEM {USE, ALLOC, COPY}\_HOST\_PTR

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

*flags*: See `clCreateBuffer`

*buffer\_create\_type*: CL\_BUFFER\_CREATE\_TYPE\_REGION

#### Read, Write, Copy Buffer Objects [5.2.2]

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

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

(Continued on next page >)

### The OpenCL Runtime

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

#### Command Queues [5.1]

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

*properties*: [Table 5.1] CL\_QUEUE\_SIZE,  
CL\_QUEUE\_PROPERTIES (bitfield which may be set to an OR of CL\_QUEUE\_\* where \* may be: OUT\_OF\_ORDER\_EXEC\_MODE\_ENABLE, PROFILING\_ENABLE, ON\_DEVICE [DEFAULT])

`cl_int clRetainCommandQueue (cl_command_queue command_queue)`

`cl_int clReleaseCommandQueue (cl_command_queue command_queue)`

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

*param\_name*: [Table 5.2] CL\_QUEUE\_CONTEXT,  
CL\_QUEUE\_DEVICE, CL\_QUEUE\_SIZE,  
CL\_QUEUE\_REFERENCE\_COUNT,  
CL\_QUEUE\_PROPERTIES

## Buffer Objects (continued)

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

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

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

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

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

## Map Buffer Objects [5.2.4]

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

map\_flags: CL\_MAP\_READ, CL\_MAP\_WRITE, CL\_MAP\_WRITE\_INVALIDATE\_REGION

## Conversions and Type Casting Examples [6.2]

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

## Memory Objects

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

## Memory Objects [5.5.1, 5.5.2]

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

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

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

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

## Migrate Memory Objects [5.5.4]

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

flags: CL\_MIGRATE\_MEM\_OBJECT\_HOST,  
CL\_MIGRATE\_MEM\_OBJECT\_CONTENT\_UNDEFINED

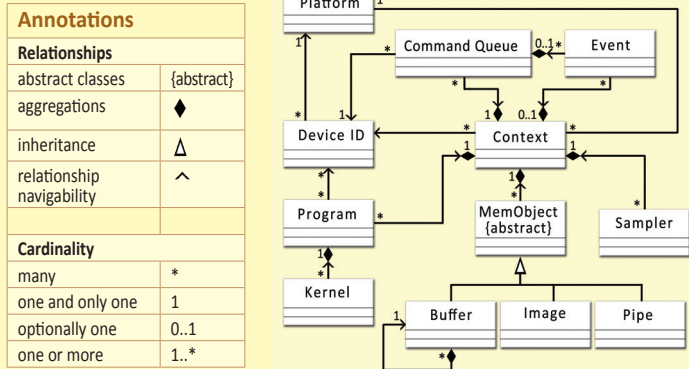
## Query Memory Object [5.5.5]

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

param\_name: CL\_MEM\_TYPE, CL\_MEM\_FLAGS, CL\_MEM\_SIZE, CL\_MEM\_HOST\_PTR, CL\_MEM\_OFFSET,  
CL\_MEM\_MAP, CL\_MEM\_REFERENCE\_COUNT, CL\_MEM\_ASSOCIATED\_MEMOBJECT,  
CL\_MEM\_CONTEXT, CL\_MEM\_USES\_SVM\_POINTER,  
CL\_MEM\_D3D10\_D3D11\_RESOURCE\_KHR,  
CL\_MEM\_DX9\_MEDIA\_ADAPTER\_TYPE\_SURFACE\_INFO\_KHR [Table 5.12]

## OpenCL Class Diagram

The figure below describes the OpenCL specification as a class diagram using the Unified Modeling Language<sup>1</sup> (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.



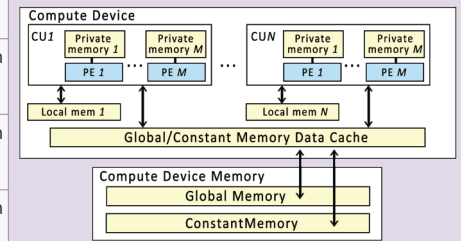
<sup>1</sup> Unified Modeling Language (<http://www.uml.org/>) is a trademark of Object Management Group (OMG).

## OpenCL Device Architecture Diagram

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

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

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



## Pipes

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

## Create Pipe Objects [5.4.1]

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

flags:

0 or CL\_MEM\_READ\_WRITE, CL\_MEM\_READ\_WRITE\_ONLY,  
CL\_MEM\_HOST\_NO\_ACCESS

## Pipe Object Queries [5.4.2]

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

param\_name:

CL\_PIPE\_PACKET\_SIZE, CL\_PIPE\_MAX\_PACKETS

## Shared Virtual Memory

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

## SVM Sharing Granularity [5.6.1]

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

flags: [Table 5.13]

CL\_MEM\_READ\_WRITE, CL\_MEM\_READ\_WRITE\_ONLY,  
CL\_MEM\_SVM\_FINE\_GRAIN\_BUFFER, CL\_MEM\_SVM\_ATOMICS

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

## Enqueuing SVM Operations [5.6.2]

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

(Continued on next page >)



## Shared Virtual Memory (continued)

```

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

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

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

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

```

## Kernel Objects

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

## Create Kernel Objects [5.9.1]

```

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

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

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

```

## Kernel Arguments and Queries [5.9.2, 5.9.3]

```

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

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

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

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

cl_int clGetKernelWorkGroupInfo (cl_kernel kernel,
    cl_device_id device,
    cl_kernel_work_group_info param_name,
    size_t param_value_size, void *param_value,
    size_t *param_value_size_ret)
param_name: CL_KERNEL_GLOBAL_WORK_SIZE,
             CL_KERNEL_COMPILE_WORK_GROUP_SIZE,
             CL_KERNEL_LOCAL_MEM_SIZE,
             CL_KERNEL_PREFERRED_WORK_GROUP_SIZE_MULTIPLE [Table 5.20]

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

```

## Program Objects

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

## Create Program Objects [5.8.1]

```

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

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

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

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

```

## Building Program Executables [5.8.2]

```

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

```

## Separate Compilation and Linking [5.8.3]

```

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

```

## cl\_int clGetKernelSubGroupInfoKHR

```

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

```

param\_name:  
CL\_KERNEL\_MAX\_SUB\_GROUP\_SIZE\_FOR\_NDRANGE,  
CL\_KERNEL\_SUB\_GROUP\_COUNT\_FOR\_NDRANGE

## Execute Kernels [5.10]

```

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

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

```

## Flush and Finish [5.15]

```

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

```

## Event Objects

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

## Event Objects [5.11]

```

cl_event clCreateUserEvent (cl_context context,
    cl_int *errcode_ret)

```

```

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

```

## Unload the OpenCL Compiler [5.8.6]

```

cl_int clUnloadPlatformCompiler (
    cl_platform_id platform)

```

## Query Program Objects [5.8.7]

```

cl_int clGetProgramInfo (cl_program program,
    cl_program_info param_name,
    size_t param_value_size, void *param_value,
    size_t *param_value_size_ret)
param_name: [Table 5.16]
             CL_PROGRAM_REFERENCE_COUNT,
             CL_PROGRAM_CONTEXT, NUM_DEVICES, DEVICES,
             CL_PROGRAM_SOURCE, BINARY_SIZES, BINARIES,
             CL_PROGRAM_NUM_KERNELS, KERNEL_NAMES}

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

```

## Compiler Options [5.8.4]

SPIR options require the `cl_khr_spir` extension.

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

-D name -D name=definition -I dir

## Math intrinsics:

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

## Optimization options:

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

## Warning request/suppress:

-w -Werror

## Control OpenCL C language version:

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

## Query kernel argument information:

-cl-kernel-arg-info

## Debugging options:

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

## SPIR binary options:

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

## Linker Options [5.8.5]

## Library linking options:

-create-library -enable-link-options

## Program linking options:

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

```

cl_int clSetUserEventStatus (cl_event event,
    cl_int execution_status)

```

```

cl_int clWaitForEvents (cl_uint num_events,
    const cl_event *event_list)

```

```

cl_int clGetEventInfo (cl_event event,
    cl_event_info param_name, size_t param_value_size,
    void *param_value, size_t *param_value_size_ret)
param_name: CL_EVENT_COMMAND_QUEUE, TYPE,
             CL_EVENT_CONTEXT, REFERENCE_COUNT,
             CL_EVENT_COMMAND_EXECUTION_STATUS [Table 5.22]

```

```

cl_int clRetainEvent (cl_event event)

```

(Continued on next page >)

## Event Objects (continued)

`cl_int clReleaseEvent (cl_event event)`

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

## Markers, Barriers, Waiting for Events [5.12]

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

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

## Profiling Operations [5.14]

`cl_int clGetEventProfilingInfo (cl_event event,  
cl_profiling_info param_name,  
size_t param_value_size, void *param_value,  
size_t *param_value_size_ret)`

*param\_name:* [Table 5.23]  
CL\_PROFILING\_COMMAND\_QUEUED, CL\_PROFILING\_COMMAND\_COMPLETE,  
CL\_PROFILING\_COMMAND\_{SUBMIT, START, END}

## OpenCL C Language Reference

## Supported Data Types

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

## Built-in Scalar Data Types [6.1.1]

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 <i>OPTIONAL</i>	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
charn	cl_charn	8-bit signed
ucharn	cl_ucharn	8-bit unsigned
shortn	cl_shortn	16-bit signed
ushortn	cl_ushortn	16-bit unsigned
intn	cl_intn	32-bit signed
uintn	cl_uintn	32-bit unsigned
longn	cl_longn	64-bit signed
ulongn	cl_ulongn	64-bit unsigned
floatn	cl_floatn	32-bit float
doublen <i>OPTIONAL</i>	cl_doublen	64-bit float
halfn	Requires the <code>cl_khr_fp16</code> extension	

## Other Built-in Data Types [6.1.3]

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

OpenCL Type	Description
image2d <i>[msaa]_t</i> <i>OPTIONAL</i>	2D image handle
image3d <i>t</i> <i>OPTIONAL</i>	3D image handle
image2d_array <i>[msaa]_t</i> <i>OPTIONAL</i>	2D image array
image1d <i>t</i> <i>OPTIONAL</i>	1D image handle
image1d_buffer <i>t</i> <i>OPTIONAL</i>	1D image buffer

image1d_array <i>t</i> <i>OPTIONAL</i>	1D image array
image2d <i>[msaa]_depth_t</i> <i>OPTIONAL</i>	2D depth image
image2d_array <i>[msaa]_depth_t</i> <i>OPTIONAL</i>	2D depth image array
sampler <i>t</i> <i>OPTIONAL</i>	sampler handle
queue <i>t</i>	
ndrange <i>t</i>	
clk_event <i>t</i>	
reserve_id <i>t</i>	
event <i>t</i>	event handle
cl_mem_fence_flags	

## Reserved Data Types [6.1.4]

OpenCL Type	Description
booln	boolean vector
halfn	16-bit, vector
quad, quadn	128-bit float, vector
complex half, complex halfn	16-bit complex, vector
imaginary half, imaginary halfn	
complex float, complex floatn	32-bit complex, vector
imaginary float, imaginary floatn	
complex double, complex doublen	64-bit complex, vector
imaginary double, imaginary doublen	
complex quad, complex quadn	128-bit complex, vector
imaginary quad, imaginary quadn	
floatn $\times$ m	$n \times m$ matrix of 32-bit floats
doublen $\times$ m	$n \times m$ 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
float2	v.x, v.s0	v.y, v.s1	v.y, v.s1	v.x, v.s0
float3*	v.s01, v.xy	v.s23, v.zw	v.s13, v.yw	v.s02, v.xz
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 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)))`

## Blocks [6.12]

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

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

```

② ① ③
int (^myBlock)(int) =
  ^ (int num) {return num * multiplier;
  };
                                ④ ⑤

```

## Preprocessor Directives &amp; Macros [6.10]

#pragma OPENCL FP_CONTRACT <i>on-off-switch</i> <i>on-off-switch: ON, OFF, DEFAULT</i>	
__FILE__	Current source file
__func__	Current function name
__LINE__	Integer line number
__OPENCL_VERSION__	Integer version number, e.g: 200
__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
__CL_VERSION_2_0	Substitutes integer 200 for 2.0
__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
CL_DEVICE_MAX_GLOBAL_VARIABLE_SIZE	Max size in bytes for a program scope or static function variable
FP_FAST_FMA	Defined if double <b>fma</b> is fast
FP_FAST_FMAF	Defined if float <b>fma</b> is fast
FP_FAST_FMA_HALF	Defined if half <b>fma</b> is fast
__kernel_exec(X, typen)	Same as:
__kernel__attribute__((work_group_size_hint(X, 1, 1)))	
__attribute__((vec_type_hint(typen)))	

## Work-Item Built-in Functions [6.13.1]

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

uint get_work_dim ()	Number of dimensions in use
size_t get_global_size (uint dimindx)	Number of global work-items
size_t get_global_id (uint dimindx)	Global work-item ID value
size_t get_local_size (uint dimindx)	Number of local work-items if kernel executed with uniform work-group size

(Continued on next page >)

## Work-Item Functions (continued)

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

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

## Attribute Qualifiers [6.11]

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

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

Use to specify special attributes of variables or structure fields.

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

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

```
__attribute__((attr1)) {...}
```

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

```
__attribute__((opengl_unroll_hint(n)))
__attribute__((opengl_unroll_hint))
```

## Math Built-in Functions [6.13.2] [9.4.2]

$T_s$  is type float, optionally double, or half if the `cl_khr_fp16` 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  $T_n$ .

**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.

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

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

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

## Math Constants [6.13.2] [9.4.2]

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

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

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

<code>M_E_F</code>	Value of $e$
<code>M_LOG2E_F</code>	Value of $\log_2 e$
<code>M_LOG10E_F</code>	Value of $\log_{10} e$
<code>M_LN2_F</code>	Value of $\log_e 2$
<code>M_LN10_F</code>	Value of $\log_{10} e$
<code>M_PI_F</code>	Value of $\pi$
<code>M_PI_2_F</code>	Value of $\pi / 2$
<code>M_PI_4_F</code>	Value of $\pi / 4$
<code>M_1_PI_F</code>	Value of $1 / \pi$
<code>M_2_PI_F</code>	Value of $2 / \pi$
<code>M_2_SQRTPI_F</code>	Value of $2 / \sqrt{\pi}$
<code>M_SQRT2_F</code>	Value of $\sqrt{2}$
<code>M_SQRT1_2_F</code>	Value of $1 / \sqrt{2}$

## Integer Built-in Functions [6.13.3]

$T$  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.  $T_u$  is the unsigned version of  $T$ .  $T_{sc}$  is the scalar version of  $T$ .

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

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

<code>short[n] upsample (char[n] hi, uchar[n] lo)</code>	$\text{result}[i] = ((\text{short})hi[i] << 8)   lo[i]$
<code>ushort[n] upsample (uchar[n] hi, uchar[n] lo)</code>	$\text{result}[i] = ((\text{ushort})hi[i] << 8)   lo[i]$

<code>int[n] upsample (short[n] hi, ushort[n] lo)</code>	$\text{result}[i] = ((\text{int})hi[i] << 16)   lo[i]$
<code>uint[n] upsample (ushort[n] hi, ushort[n] lo)</code>	$\text{result}[i] = ((\text{uint})hi[i] << 16)   lo[i]$
<code>long[n] upsample (int[n] hi, uint[n] lo)</code>	$\text{result}[i] = ((\text{long})hi[i] << 32)   lo[i]$
<code>ulong[n] upsample (uint[n] hi, uint[n] lo)</code>	$\text{result}[i] = ((\text{ulong})hi[i] << 32)   lo[i]$

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.

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

## Common Built-in Functions [6.13.4] [9.4.3]

These functions operate component-wise and use round to nearest even rounding mode.  $T_s$  is type float, optionally double, or half if `cl_khr_fp16` 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  $T_n$ .

<code>T clamp (T x, T min, T max)</code>	Clamp $x$ to range given by $min, max$
<code>Tn clamp (Tn x, Tsc min, Tsc max)</code>	
<code>T degrees (T radians)</code>	radians to degrees
<code>T max (T x, T y)</code>	Max of $x$ and $y$
<code>Tn max (Tn x, Ts y)</code>	
<code>T min (T x, T y)</code>	Min of $x$ and $y$
<code>Tn min (Tn x, Ts y)</code>	

(Continued on next page >)



## Common Functions (continued)

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

## Geometric Built-in Functions [6.13.5] [9.4.4]

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

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

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

## Relational Built-in Functions [6.13.6]

These functions can be used with built-in scalar or vector types as arguments and return a scalar or vector integer result. *T* is type float, floatn, char, charn, uchar, uchar, short, shortn, ushort, ushortn, int, intrn, uint, uintn, long, longn, ulong, ulongn, or optionally double or doublen. *Ti* is type char, charn, short, shortn, int, intrn, long, or longn. *Tu* is type uchar, uchar, ushort, ushortn, uint, uintn, ulong, or ulongn. *n* is 2, 3, 4, 8, or 16. **half** and **halfn** types require the **cl\_khr\_fp16** extension.

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

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

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

## Vector Data Load/Store [6.13.7] [9.4.6]

*T* is type char, uchar, short, ushort, int, uint, long, ulong, or float, optionally double, or half if the **cl\_khr\_fp16** extension is enabled. *Tn* refers to the vector form of type *T*, where *n* is 2, 3, 4, 8, or 16. *R* defaults to current rounding mode, or is one of the rounding modes listed in 6.2.3.2.

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

<b>void vstore_half_R</b> ( <b>doublen data</b> , <b>size_t offset</b> , <b>half *p</b> )	Write a half to address ( <i>p</i> + <i>offset</i> )
<b>void vstore_halfn</b> ( <b>floatn data</b> , <b>size_t offset</b> , <b>half *p</b> )	Write a half vector to address ( <i>p</i> + ( <i>offset</i> * <i>n</i> ))
<b>void vstore_halfn_R</b> ( <b>floatn data</b> , <b>size_t offset</b> , <b>half *p</b> )	
<b>void vstore_halfn</b> ( <b>doublen data</b> , <b>size_t offset</b> , <b>half *p</b> )	
<b>void vstore_halfn_R</b> ( <b>doublen data</b> , <b>size_t offset</b> , <b>half *p</b> )	
<b>floatn vloada_halfn</b> ( <b>size_t offset</b> , <b>const [constant] half *p</b> )	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)).
<b>void vstorea_halfn</b> ( <b>floatn data</b> , <b>size_t offset</b> , <b>half *p</b> )	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)).
<b>void vstorea_halfn_R</b> ( <b>floatn data</b> , <b>size_t offset</b> , <b>half *p</b> )	
<b>void vstorea_halfn</b> ( <b>doublen data</b> , <b>size_t offset</b> , <b>half *p</b> )	
<b>void vstorea_halfn_R</b> ( <b>doublen data</b> , <b>size_t offset</b> , <b>half *p</b> )	

## Synchronization &amp; Memory Fence Functions [6.13.8]

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

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

## Async Copies and Prefetch [6.13.10] [9.4.7]

*T* is type char, charn, uchar, uchar, short, shortn, ushort, ushortn, int, intrn, uint, uintn, long, longn, ulong, ulongn, float, floatn, optionally double or doublen, or half or halfn if the **cl\_khr\_fp16** extension is enabled.

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

**Atomic Functions** [6.13.11]

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

**Atomic Functions**

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

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

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

**Atomic Types and Enum Constants**

Parameter Type	Values	Description
<code>memory_order</code>	<code>memory_order_relaxed</code> <code>memory_order_acquire</code> <code>memory_order_release</code> <code>memory_order_seq_cst</code>	Enum which identifies memory ordering constraints.
<code>memory_scope</code>	<code>memory_scope_work_item</code> <code>memory_scope_work_group</code> <code>memory_scope_sub_group</code> <code>memory_scope_device</code> (default for functions that do not take a <code>memory_scope</code> argument) <code>memory_scope_all_svm_devices</code>	Enum which identifies scope of memory ordering constraints. <code>memory_scope_sub_group</code> requires the <code>cl_khr_subgroups</code> extension.
<code>atomic_flag</code>	32-bit int representing a lock-free, primitive atomic flag; and several atomic analogs of integer types.	

**Atomic integer and floating-point types**

<code>atomic_int</code>	<code>atomic_long</code>	<code>atomic_float</code>	<code>atomic_intptr_t</code>	<code>atomic_size_t</code>
<code>atomic_uint</code>	<code>atomic_ulong</code>	<code>atomic_double</code>	<code>atomic_uintptr_t</code>	<code>atomic_ptrdiff_t</code>

**Atomic Macros**

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

**64-bit Atomics** [9.3]

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

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

**Address Space Qualifier Functions** [6.13.9]

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

<code>global T * to_global(T *ptr)</code> <code>const global T * to_global(const T *ptr)</code>	global address space
<code>local T * to_local(T *ptr)</code> <code>const local T * to_local(const T *ptr)</code>	local address space
<code>private T * to_private(T *ptr)</code> <code>const private T * to_private(const T *ptr)</code>	private address space
<code>cl_mem_fence_flags get_fence(T *ptr)</code> <code>const cl_mem_fence_flags get_fence(const T *ptr)</code>	Memory fence value: <code>CLK_GLOBAL_MEM_FENCE</code> , <code>CLK_LOCAL_MEM_FENCE</code>

**printf Function** [6.13.13]

Writes output to an implementation-defined stream.

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

**printf output synchronization**

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

**printf format string**

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

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

**Examples:**

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

```
float4 f = (float4)(1.0f, 2.0f, 3.0f, 4.0f);
printf("f4 = %2.2v4f\n", f);
```

Output: f4 = 1.00,2.00,3.00,4.00

```
uchar4 uc = (uchar4)(0xFA, 0xFB, 0xFC, 0xFD);
printf("uc = %#v4x\n", uc);
```

Output: uc = 0xfa,0xfb,0xfc,0xfd

```
uint2 ui = (uint2)(0x12345678, 0x87654321);
printf("unsigned short value = (%#v2hx)\n", ui);
```

Output: unsigned short value = (0x5678,0x4321)

**Workgroup Functions** [6.13.15] [9.17.3.4]

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

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

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

Broadcast the value of *a* to all work-items in the work-group or sub-group. *local\_id* must be the same value for all workitems in the work-group. *n* may be 2 or 3.

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

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

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

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

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



**Pipe Built-in Functions** [6.13.16.2-4]

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

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

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

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

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

**Miscellaneous Vector Functions** [6.13.12]

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

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

**Event Built-in Functions** [6.13.17.8]

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

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

**Helper Built-in Functions** [6.13.17.9]

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

**OpenCL Image Processing Reference**

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

**Image Objects**

Items in blue apply when the appropriate extension is supported.

**Create Image Objects** [5.3.1]

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

*flags*: See `clCreateBuffer`

**Query List of Supported Image Formats** [5.3.2]

`cl_int clGetSupportedImageFormats (cl_context context, cl_mem_flags flags, cl_mem_object_type image_type, cl_uint num_entries, cl_image_format *image_formats, cl_uint *num_image_formats)`

*flags*: See `clCreateBuffer`

*image\_type*: `CL_MEM_OBJECT_IMAGE{1D, 2D, 3D}`, `CL_MEM_OBJECT_IMAGE1D_BUFFER`, `CL_MEM_OBJECT_IMAGE{1D, 2D}_ARRAY`

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

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

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

`cl_int clEnqueueFillImage (cl_command_queue command_queue, cl_mem image, const void *fill_color, const size_t *origin, const size_t *region, cl_uint num_events_in_wait_list, const cl_event *event_wait_list, cl_event *event)`

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

**Copy Between Image, Buffer Objects** [5.3.5]

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

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

(Continued on next page >)



## Image Objects (continued)

## Map and Unmap Image Objects [5.3.6]

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

map_flags: CL_MAP_READ, CL_MAP_WRITE,
            CL_MAP_WRITE_INVALIDATE_REGION
```

## Query Image Objects [5.3.7]

```
cl_int clGetImageInfo (cl_mem image,
    cl_image_info param_name, size_t param_value_size,
    void *param_value, size_t *param_value_size_ret)

param_name: [Table 5.9] CL_IMAGE_FORMAT, CL_IMAGE_BUFFER,
CL_IMAGE_ARRAY_ELEMENT_SIZE,
CL_IMAGE_ROW_SLICE_PITCH,
CL_IMAGE_HEIGHT_WIDTH_DEPTH,
CL_IMAGE_NUM_SAMPLES_MIP_LEVELS,
CL_IMAGE_DX9_MEDIA_PLANE_KHR,
CL_IMAGE_D3D10_D3D11_SUBRESOURCE_KHR
```

Also see `clGetMemObjectInfo` [5.4.5]

## Image Formats [5.3.1.1]

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

Built-in support: [Table 5.8]

**CL\_R (read + write):** CL\_HALF\_FLOAT, CL\_FLOAT, CL\_UNORM\_INT8, CL\_SNORM\_INT8, CL\_SIGNED\_INT8, CL\_UNSIGNED\_INT8, CL\_SIGNED\_INT16, CL\_UNSIGNED\_INT16

**CL\_DEPTH (read + write):** CL\_FLOAT, CL\_UNORM\_INT16

**CL\_DEPTH\_STENCIL (read only):** CL\_FLOAT, CL\_UNORM\_INT24  
(Requires the extension `cl_khr_gl_depth_images`)

**CL\_RG (read + write):** CL\_HALF\_FLOAT, CL\_FLOAT, CL\_UNORM\_INT8, CL\_SNORM\_INT8, CL\_SIGNED\_INT8, CL\_UNSIGNED\_INT8, CL\_SIGNED\_INT16, CL\_UNSIGNED\_INT16

**CL\_RGBA (read + write):** CL\_HALF\_FLOAT, CL\_FLOAT, CL\_UNORM\_INT8, CL\_SNORM\_INT8, CL\_SIGNED\_INT8, CL\_UNSIGNED\_INT8, CL\_SIGNED\_INT16, CL\_UNSIGNED\_INT16

**CL\_BGRA (read + write):** CL\_UNORM\_INT8

**CL\_sRGBA (read only):** CL\_UNORM\_INT8  
(Requires the extension `cl_khr_srgb_image_writes`)

Optional support: [Table 5.6]

**CL\_R, CL\_A:** CL\_HALF\_FLOAT, CL\_FLOAT, CL\_UNORM\_INT8, CL\_SIGNED\_INT8, CL\_UNSIGNED\_INT8, CL\_SIGNED\_INT16, CL\_UNSIGNED\_INT16, CL\_SNORM\_INT8, CL\_UNSIGNED\_INT16

**CL\_INTENSITY:** CL\_HALF\_FLOAT, CL\_FLOAT, CL\_UNORM\_INT8, CL\_SIGNED\_INT8, CL\_UNSIGNED\_INT8, CL\_SNORM\_INT8

**CL\_DEPTH\_STENCIL:** Only used if extension `cl_khr_gl_depth_images` is enabled and channel data type = CL\_UNORM\_INT24 or CL\_FLOAT

**CL\_LUMINANCE:** CL\_UNORM\_INT8, CL\_HALF\_FLOAT, CL\_FLOAT, CL\_SNORM\_INT8

**CL\_RG, CL\_RA:** CL\_HALF\_FLOAT, CL\_FLOAT, CL\_UNORM\_INT8, CL\_SIGNED\_INT8, CL\_UNSIGNED\_INT8, CL\_SIGNED\_INT16, CL\_UNSIGNED\_INT16, CL\_SNORM\_INT8

**CL\_RGB:** CL\_UNORM\_SHORT\_555, CL\_UNSIGNED\_SHORT\_555, CL\_UNORM\_INT101010

**CL\_ARGB:** CL\_UNORM\_INT8, CL\_SIGNED\_INT8, CL\_UNSIGNED\_INT8, CL\_SNORM\_INT8

**CL\_BGRA:** CL\_SIGNED\_INT8, CL\_UNSIGNED\_INT8, CL\_SNORM\_INT8

## Image Read and Write Functions [6.13.14]

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

## Read and write functions for 1D images

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

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

float4 read_imagef (image1d_t image, int coord)

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

float4 read_imagef (image1d_array_t image, int2 coord)

float4 read_imagef (image1d_buffer_t image, int coord)

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

int4 read_imagei (image1d_t image, int coord)

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

int4 read_imagei (image1d_array_t image, int2 coord)

int4 read_imagei (image1d_buffer_t image, int coord)

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

uint4 read_imageui (image1d_t image, int coord)

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

uint4 read_imageui (image1d_array_t image, int2 coord)

uint4 read_imageui (image1d_buffer_t image, int coord)

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

half4 read_imageh (image1d_t image, int coord)

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

half4 read_imageh (image1d_array_t image, int2 coord)

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

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

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

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

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

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

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

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

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

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

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

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

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

## Read and write functions for 2D images

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

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

float4 read_imagef (image2d_t image, int2 coord)

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

float4 read_imagef (image2d_array_t image, int4 coord)

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

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

float read_imagef (image2d_depth_t image, int2 coord)

float read_imagef (image2d_array_depth_t image, int4 coord)

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

int4 read_imagei (image2d_t image, int2 coord)

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

int4 read_imagei (image2d_array_t image, int4 coord)

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

uint4 read_imageui (image2d_t image, int2 coord)

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

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

## Read and write functions for 2D images (continued)

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

`half4 read_imageh (image2d_t image, int2 coord)`

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

`half4 read_imageh (image2d_array_t image, int4 coord)`

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

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

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

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

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

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

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

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

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

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

## Read and write functions for 3D images

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

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

`float4 read_imagef (image3d_t image, int4 coord)`

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

`int4 read_imagei (image3d_t image, int4 coord)`

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

`uint4 read_imageui (image3d_t image, int4 coord)`

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

`half4 read_imageh (image3d_t image, int4 coord)`

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

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

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

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

(Continued on next page >)

## Image Read and Write (continued)

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

```
float read_imagef (image2d_ [depth_]t image,
                  sampler_t sampler, float2 coord, float lod)

int4 read_imagei (image2d_t image, sampler_t sampler,
                  float2 coord, float lod)

uint4 read_imageui (image2d_t image, sampler_t sampler,
                    float2 coord, float lod)

float read_imagef (image2d_ [depth_]t image,
                  sampler_t sampler, float2 coord, float2 gradient_x,
                  float2 gradient_y)

int4 read_imagei (image2d_t image, sampler_t sampler,
                  float2 coord, float2 gradient_x, float2 gradient_y)

uint4 read_imageui (image2d_t image, sampler_t sampler,
                    float2 coord, float2 gradient_x, float2 gradient_y)

float4 read_imagef (image1d_t image, sampler_t sampler,
                    float coord, float lod)

int4 read_imagei (image1d_t image, sampler_t sampler,
                    float coord, float lod)

uint4 read_imageui (image1d_t image, sampler_t sampler,
                    float coord, float lod)

float4 read_imagef (image1d_t image, sampler_t sampler,
                    float coord, float gradient_x, float gradient_y)

int4 read_imagei (image1d_t image, sampler_t sampler,
                    float coord, float gradient_x, float gradient_y)

uint4 read_imageui (image1d_t image, sampler_t sampler,
                    float coord, float gradient_x, float gradient_y)

float4 read_imagef (image3d_t image, sampler_t sampler,
                    float4 coord, float lod)

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

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

float4 read_imagef (image3d_t image, sampler_t sampler,
                    float4 coord, float4 gradient_x, float4 gradient_y)

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

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

float4 read_imagef (image1d_array_t image, sampler_t sampler,
                    float2 coord, float lod)

int4 read_imagei (image1d_array_t image, sampler_t sampler,
                    float2 coord, float lod)

uint4 read_imageui (image1d_array_t image, sampler_t sampler,
                    float2 coord, float lod)

float4 read_imagef (image1d_array_t image, sampler_t sampler,
                    float2 coord, float gradient_x, float gradient_y)
```

## Sampler Objects [5.7]

Items in blue require the `cl_khr_mipmap_image` extension.

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

sampler_properties: [Table 5.14]
    CL_SAMPLER_NORMALIZED_COORDS,
    CL_SAMPLER_{ADDRESSING, FILTER}_MODE,
    CL_SAMPLER_MIP_FILTER_MODE,
    CL_SAMPLER_LOD_{MIN, MAX}

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

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

param_name: CL_SAMPLER_REFERENCE_COUNT,
            CL_SAMPLER_{CONTEXT, FILTER_MODE},
            CL_SAMPLER_ADDRESSING_MODE,
            CL_SAMPLER_NORMALIZED_COORDS [Table 5.15]
```

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

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

float read_imagef (image2d_array_ [depth_]t image,
                  sampler_t sampler, float4 coord, float lod)

int4 read_imagei (image2d_array_t image, sampler_t sampler,
                  float4 coord, float lod)

uint4 read_imageui (image2d_array_t image,
                    sampler_t sampler, float4 coord, float lod)

float read_imagef (image2d_array_ [depth_]t image,
                  sampler_t sampler, float4 coord, float2 gradient_x,
                  float2 gradient_y)

int4 read_imagei (image2d_array_t image, sampler_t sampler,
                  float4 coord, float2 gradient_x, float2 gradient_y)

uint4 read_imageui (image2d_array_t image, sampler_t
                    sampler, float4 coord, float2 gradient_x, float2 gradient_y)

void write_imagef (image2d_ [depth_]t image, int2 coord,
                  int lod, float4 color)

void write_imagei (image2d_t image, int2 coord, int lod,
                  int4 color)

void write_imageui (image2d_t image, int2 coord, int lod,
                   uint4 color)

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

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

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

void write_imagef (image1d_array_t image, int2 coord, int lod,
                  float4 color)

void write_imagei (image1d_array_t image, int2 coord, int lod,
                  int4 color)

void write_imageui (image1d_array_t image, int2 coord, int lod,
                   uint4 color)

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

void write_imagei (image2d_array_t image, int4 coord, int lod,
                  int4 color)

void write_imageui (image2d_array_t image, int4 coord, int lod,
                   uint4 color)

void write_imagef (image3d_t image, int4 coord, int lod,
                  float4 color)

void write_imagei (image3d_t image, int4 coord, int lod,
                  int4 color)

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

**Extended multi-sample image read functions** [9.12.3]  
The extension `cl_khr_gl_msaa_sharing` adds the following built-in functions.

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

float read_imagef (image2d_array_depth_msaa_t image,
                  int4 coord, int sample)

float4 read_imagef (image2d_msaa_t image,
                   int2 coord, int sample)

float4 read_imagef (image2d_array_msaa_t image,
                   int4 coord, int sample)
```

## Sampler Declaration Fields [6.13.14.1]

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

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

normalized-mode:
    CLK_NORMALIZED_COORDS_{TRUE, FALSE}

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

filter-mode: CLK_FILTER_NEAREST, CLK_FILTER_LINEAR
```

## Image Query Functions [6.13.14.5] [9.12]

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

### Query image width, height, and depth in pixels

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

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

int get_image_depth (image3d_t image)
```

### Query image array size

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

### Query image dimensions

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

### Query image Channel data type and order

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

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

### Extended query functions [9.18.2.1]

These functions require the `cl_khr_mipmap_image` extension.

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

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

## Access Qualifiers [6.6]

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

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

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

See [www.khronos.org/registry/cl/](http://www.khronos.org/registry/cl/)



## OpenCL Extensions Reference

## Using OpenCL Extensions [9]

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

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

To test if an extension is supported:

`clGetPlatformInfo()` or `clGetDeviceInfo()`

To get the address of the extension function:

`clGetExtensionFunctionAddressForPlatform()`

```
cl_apple_gl_sharing (see cl_khr_gl_sharing)
cl_khr_3d_image_writes
cl_khr_byte_addressable_store
```

## OpenGL Sharing [9.5 - 9.7]

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

## CL Context &gt; GL Context, Sharegroup [9.5.5]

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

param\_name: CL\_DEVICES\_FOR\_GL\_CONTEXT\_KHR, CL\_CURRENT\_DEVICE\_FOR\_GL\_CONTEXT\_KHR

## CL Buffer Objects &gt; GL Buffer Objects [9.6.2]

```
cl_mem clCreateFromGLBuffer (cl_context context,
    cl_mem_flags flags, GLuint bufobj, cl_int *errcode_ret)
flags: CL_MEM_READ_ONLY, WRITE_ONLY, READ_WRITE
```

## CL Image Objects &gt; GL Textures [9.6.3]

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

flags: See `clCreateFromGLBuffer`

texture\_target: GL\_TEXTURE\_{1D, 2D}[\_ARRAY], GL\_TEXTURE\_{3D, BUFFER, RECTANGLE}, GL\_TEXTURE\_CUBE\_MAP\_POSITIVE\_{X, Y, Z}, GL\_TEXTURE\_CUBE\_MAP\_NEGATIVE\_{X, Y, Z}, GL\_TEXTURE\_2D\_MULTISAMPLE[\_ARRAY] (Requires extension `cl_khr_gl_msaa_sharing`)

## DX9 Media Surface Sharing [9.9]

These functions require the extension

`cl_khr_dx9_media_sharing`. The associated header file is `cl_dx9_media_sharing.h`.

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

media\_adapter\_type: CL\_ADAPTER\_{D3D9, D3D9EX, DXVA}\_KHR

media\_adapter\_set: CL\_{ALL, PREFERRED}\_DEVICES\_FOR\_DX9\_MEDIA\_ADAPTER\_KHR

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

flags: See `clCreateFromGLBuffer`

adapter\_type: CL\_ADAPTER\_{D3D9, D3D9EX, DXVA}\_KHR

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

## EGL Interoperability [9.19, 9.20]

## Create CL Image Objects from EGL [9.19]

These functions require the extension `cl_khr_egl_image`.

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

```
cl_khr_context_abort
cl_khr_d3d10_sharing
cl_khr_d3d11_sharing
cl_khr_depth_images
cl_khr_dx9_media_sharing
cl_khr_egl_event
cl_khr_egl_image
cl_khr_fp16
cl_khr_fp64
cl_khr_gl_depth_images
cl_khr_gl_event
cl_khr_gl_msaa_sharing
cl_khr_gl_sharing
cl_khr_global_int32_base_atomics - atomic_*( )
```

```
cl_khr_global_int32_extended_atomics - atomic_*( )
cl_khr_icd
cl_khr_image2d_from_buffer
cl_khr_initialize_memory
cl_khr_int64_base_atomics - atom_*( )
cl_khr_int64_extended_atomics - atom_*( )
cl_khr_local_int32_base_atomics - atomic_*( )
cl_khr_local_int32_extended_atomics - atomic_*( )
cl_khr_mipmap_image
cl_khr_mipmap_image_writes
cl_khr_srgb_image_writes
cl_khr_spir
cl_khr_subgroups
cl_khr_terminate_context
```

## CL Image Objects &gt; GL Renderbuffers [9.6.4]

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

flags: See `clCreateFromGLBuffer`

## Query Information [9.6.5]

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

\*gl\_object\_type returns:

CL\_GL\_OBJECT\_TEXTURE\_BUFFER,  
CL\_GL\_OBJECT\_TEXTURE\_{1D, 2D, 3D},  
CL\_GL\_OBJECT\_TEXTURE\_{1D, 2D}\_ARRAY,  
CL\_GL\_OBJECT\_{BUFFER, RENDERBUFFER}

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

param\_name:

CL\_GL\_{TEXTURE\_TARGET, MIPMAP\_LEVEL},  
CL\_GL\_NUM\_SAMPLES (Requires extension  
`cl_khr_gl_msaa_sharing`)

## Share Objects [9.6.6]

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

## CL Event Objects &gt; GL Sync Objects [9.7.4]

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

Requires the `cl_khr_gl_event` extension.

## Direct3D 11 Sharing [9.10.7.3 - 9.10.7.6]

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

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

d3d\_device\_source: CL\_D3D11\_DEVICE\_KHR, CL\_D3D11\_DXGI\_ADAPTER\_KHR

d3d\_device\_set: CL\_ALL\_DEVICES\_FOR\_D3D11\_KHR, CL\_PREFERRED\_DEVICES\_FOR\_D3D11\_KHR

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

flags: See `clCreateFromGLBuffer`

## Direct3D 10 Sharing [9.8.7]

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

```
cl_int clGetDeviceIDsFromD3D10KHR (
    cl_platform_id platform,
    cl_d3d10_device_source_khr d3d_device_source,
    void *d3d_object,
    cl_d3d10_device_set_khr d3d_device_set,
    cl_uint num_entries, cl_device_id *devices,
    cl_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: See `clCreateFromGLBuffer`

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

flags: See `clCreateFromD3D10BufferKHR`

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

flags: See `clCreateFromGLBuffer`

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

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

flags: See `clCreateFromGLBuffer`

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

flags: See `clCreateFromGLBuffer`

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

## Create CL Event Objects from EGL [9.20]

This function requires the extension `cl_khr_egl_event`.

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

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