GNU Offloading and Multi Processing Runtime Library

The GNU OpenMP and OpenACC Implementation
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1 Enabling OpenMP

To activate the OpenMP extensions for C/C++ and Fortran, the compile-time flag `-fopenmp` must be specified. For C and C++, this enables the handling of the OpenMP directives using `#pragma omp` and the `[[omp::directive(...)]]`, `[[omp::sequence(...)]]`, and `[[omp::decl(...)]]` attributes. For Fortran, it enables for free source form the `!$omp` sentinel for directives and the `!$` conditional compilation sentinel and for fixed source form the `c$omp`, `*$omp` and `!$omp` sentinels for directives and the `c$`, `*$` and `!$` conditional compilation sentinels. The flag also arranges for automatic linking of the OpenMP runtime library (Chapter 3 [Runtime Library Routines], page 11).

The `-fopenmp-simd` flag can be used to enable a subset of OpenMP directives that do not require the linking of either the OpenMP runtime library or the POSIX threads library.

A complete description of all OpenMP directives may be found in the OpenMP Application Program Interface (https://www.openmp.org) manuals. See also Chapter 2 [OpenMP Implementation Status], page 3.
2 OpenMP Implementation Status

The _OPENMP preprocessor macro and Fortran's openmp_version parameter, provided by omp_lib.h and the omp_lib module, have the value 201511 (i.e. OpenMP 4.5).

2.1 OpenMP 4.5

The OpenMP 4.5 specification is fully supported.

2.2 OpenMP 5.0

New features listed in Appendix B of the OpenMP specification

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<thead>
<tr>
<th>Description</th>
<th>Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Array shaping</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Array sections with non-unit strides in C and C++</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Iterators</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>metadirective directive</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>declare variant directive</td>
<td>P</td>
<td>simd traits not handled correctly</td>
</tr>
<tr>
<td>target-offload-var ICV and OMP_TARGET_OFFLOAD env variable</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Nested-parallel changes to max-active-levels-var ICV requires directive</td>
<td>Y</td>
<td>See also Chapter 12 [Offload-Target Specifics], page 99,</td>
</tr>
<tr>
<td>teams construct outside an enclosing target region</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Non-rectangular loop nests</td>
<td>P</td>
<td>Full support for C/C++, partial for Fortran (PR110735 (<a href="https://gcc.gnu.org/PR110735">https://gcc.gnu.org/PR110735</a>))</td>
</tr>
<tr>
<td>!= as relational-op in canonical loop form for C/C++</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>nonmonotonic as default loop schedule modifier for worksharing-loop constructs</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Collapse of associated loops that are imperfectly nested loops</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Clauses if, nontemporal and order(concurrent) in simd construct</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>atomic constructs in simd</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>loop construct</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>order(concurrent) clause</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>scan directive and in_scan modifier for the reduction clause</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>in_reduction clause on task constructs</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>in_reduction clause on target constructs</td>
<td>P</td>
<td>nowait only stub</td>
</tr>
<tr>
<td>task_reduction clause with taskgroup</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>
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Other new OpenMP 5.0 features

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<thead>
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<th>Description</th>
<th>Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supporting C++’s range-based for loop</td>
<td>Y</td>
<td></td>
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</table>

2.3 OpenMP 5.1

New features listed in Appendix B of the OpenMP specification

<table>
<thead>
<tr>
<th>Description</th>
<th>Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>OpenMP directive as C++ attribute specifiers</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><code>omp_all_memory</code> reserved locator</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><code>target_device</code> trait in OpenMP Context</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td><code>target_device</code> selector set in context selectors</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>C/C++’s <code>declare variant</code> directive: elision support of preprocessed code</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td><code>declare variant</code>: new clauses <code>adjust_args</code> and <code>append_args</code></td>
<td>N</td>
<td></td>
</tr>
<tr>
<td><code>dispatch</code> construct</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>device-specific ICV settings with environment variables</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><code>assume</code> and <code>assumes</code> directives</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><code>nothing</code> directive</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><code>error</code> directive</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><code>masked</code> construct</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><code>scope</code> directive</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Loop transformation constructs</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><code>strict</code> modifier in the <code>grainsize</code> and <code>num_tasks</code> clauses of the <code>taskloop</code> construct</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td><code>align</code> clause in <code>allocate</code> directive</td>
<td>P</td>
<td>Only C and Fortran (and not for static variables)</td>
</tr>
</tbody>
</table>

| `align` modifier in `allocate` clause    | Y      |          |
| `thread_limit` clause to `target` construct | Y |          |
| `has_device_addr` clause to `target` construct | Y |          |
| Iterators in `target update` motion clauses and `map` clauses | N |          |
| Indirect calls to the device version of a procedure or function in `target` regions | Y |          |
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Other new OpenMP 5.1 features

<table>
<thead>
<tr>
<th>Description</th>
<th>Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support of strictly structured blocks in Fortran</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Support of structured block sequences in C/C++</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>unconstrained and reproducible modifiers on order clause</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Support begin/end declare target syntax in C/C++</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Pointer predetermined firstprivate getting initialized to address of matching mapped list item per 5.1, Sect. 2.21.7.2</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>
For Fortran, diagnose placing declarative before/between USE, IMPORT, and IMPLICIT as invalid
Optional comma between directive and clause in the #pragma form
indirect clause in declare target
device_type(nohost)/device_type(host) for variables
present modifier to the map, to and from clauses

2.4 OpenMP 5.2

New features listed in Appendix B of the OpenMP specification

<table>
<thead>
<tr>
<th>Description</th>
<th>Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>omp_in_explicit_task routine and explicit-task-var ICV</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>omp/ompx/omx sentinels and omp_/ompx_ namespaces</td>
<td>N/A</td>
<td>warning for ompx/omx sentinels¹</td>
</tr>
<tr>
<td>Clauses on end directive can be on directive</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>destroy clause with destroy-var argument on depobj</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Deprecation of no-argument destroy clause on depobj</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>linear clause syntax changes and step modifier</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Deprecation of minus operator for reductions</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Deprecation of separating map modifiers without comma</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>declare mapper with iterator and present modifiers</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>If a matching mapped list item is not found in the data environment, the pointer retains its original value</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>New enter clause as alias for to on declare target directive</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Deprecation of to clause on declare target directive</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Extended list of directives permitted in Fortran pure procedures</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>New allocators directive for Fortran</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Deprecation of allocate directive for Fortran allocatables/pointers</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Optional paired end directive with dispatch</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>New memspace and traits modifiers for uses_allocators</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Deprecation of traits array following the allocator_handle expression in uses_allocators</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

¹ The omx sentinel as C/C++ pragma and C++ attributes are warned for with -Wunknown- pragmas (implied by -Wall) and -Wattributes (enabled by default), respectively; for Fortran free-source code, there is a warning enabled by default and, for fixed-source code, the omx sentinel is warned for with -Wsurprising (enabled by -Wall). Unknown clauses are always rejected with an error.
New otherwise clause as alias for default on metadirectives N
Deprecation of default clause on metadirectives N
Deprecation of delimited form of declare target N
Reproducible semantics changed for order(concurrent) N
allocate and firstprivate clauses on scope Y
ompt_callback_work N
Default map-type for the map clause in target Y
enter/exit data
New doacross clause as alias for depend with source/sink modifier Y
Deprecation of depend with source/sink modifier N
omp_cur_iteration keyword Y

Other new OpenMP 5.2 features

<table>
<thead>
<tr>
<th>Description</th>
<th>Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Fortran, optional comma between directive and clause</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Conforming device numbers and omp_initial_device and omp_invalid_device enum/PARAMETER</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Initial value of default-device-var ICV with OMP_TARGET_OFFLOAD=mandatory</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>all as implicit-behavior for defaultmap</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>interop_types in any position of the modifier list for the init clause of the interop construct</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Invoke virtual member functions of C++ objects created on the host device on other devices</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>iterator and mapper as map-type modifier in declare mappter</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

2.5 OpenMP Technical Report 12

Technical Report (TR) 12 is the second preview for OpenMP 6.0.

New features listed in Appendix B of the OpenMP specification

| Features deprecated in versions 5.2, 5.1 and 5.0 were removed | N/A | Backward compatibility |
| Full support for C23 was added | P | |
| Full support for C++23 was added | P | |
| _ALL suffix to the device-scope environment variables | P | Host device number wrongly accepted |

num_threads now accepts a list N
Supporting increments with abstract names in OMP_PLACES N
Extension of `OMP_DEFAULTDEVICE` and new `OMPAVAILABLE_DEVICES` environment vars

New `OMP_THREADSRESERVE` environment variable

The `decl` attribute was added to the C++ attribute syntax

The OpenMP directive syntax was extended to include C 23 attribute specifiers

All inarguable clauses take now an optional Boolean argument

For Fortran, `locator list` can be also function reference with data pointer result

Concept of `assumed-size arrays` in C and C++

`directive-name-modifier` accepted in all clauses

For Fortran, atomic with BLOCK construct and, for C/C++, with unlimited curly braces supported

For Fortran, atomic compare with storing the comparison result

New `looprange` clause

Ref-count change for `use_device_ptr/use_device_addr`

Support for inductions

Implicit reduction identifiers of C++ classes

Change of the `map-type` property from `ultimate` to `default`

`self` modifier to `map` and `self` as `defaultmap` argument

Mapping of `assumed-size arrays` in C, C++ and Fortran

`groupprivate` directive

`local` clause to `declare target` directive

`part_size` allocator trait

`pin_device, preferred_device` and `target_access` allocator traits

`access` allocator trait changes

Extension of `interop` operation of `append_args`, allowing all modifiers of the `init` clause

`Interop` clause to `dispatch`

`message` and `severity` clauses to `parallel` directive

`self` clause to `requires` directive

`no_openmp_constructs` assumptions clause

`reverse` loop-transformation construct

`interchange` loop-transformation construct

`fuse` loop-transformation construct

`apply` code to loop-transforming constructs

`omp curr_progress_width` identifier

`safesync` clause to the `parallel` construct

`omp get max_progress_width` runtime routine
**strict** modifier keyword to **num_threads** 
atomic permitted in a construct with order(concurrent)
**workdistribute** directive for Fortran

Renamed just after TR12; added in TR12 as **coexecute**

Fortran DO CONCURRENT as associated loop in a loop construct
**threadset** clause in task-generating constructs
**nowait** clause with reverse-offload **target** directives
Boolean argument to **nowait** and **nogroup** may be non-constant

**memscope** clause to atomic and flush
**omp_is_free_agent** and **omp_ancestor_is_free_agent** routines
**omp_target_memset** and **omp_target_memset_rect_async** routines
Routines for obtaining memory spaces/allocators for shared/device memory

**omp_get_memspace_num_resources** routine
**omp_get_submemspace** routine
**ompt_target_data_transfer** and **ompt_**
target_data_transfer_async values in
**ompt_target_data_op_t** enum
**ompt_get_buffer_limits** OMPT routine

**Other new TR 12 features**
Canonical loop nest enclosed in (multiple) curly braces (C/C++) or **BLOCK** constructs (Fortran)
Relaxed Fortran restrictions to the **aligned** clause
Mapping lambda captures
New **omp_pause_stop_tool** constant for **omp_pause_resource**
3 OpenMP Runtime Library Routines

The runtime routines described here are defined by Section 18 of the OpenMP specification in version 5.2.

3.1 Thread Team Routines

Routines controlling threads in the current contention group. They have C linkage and do not throw exceptions.

3.1.1 omp_set_num_threads – Set upper team size limit

Description:
Specifies the number of threads used by default in subsequent parallel sections, if those do not specify a num_threads clause. The argument of omp_set_num_threads shall be a positive integer.

C/C++:
Prototype: void omp_set_num_threads(int num_threads);

Fortran:
Interface: subroutine omp_set_num_threads(num_threads)
integer, intent(in) :: num_threads

See also: Section 4.12 [OMP_NUM_THREADS], page 54, Section 3.1.2 [omp_get_num_threads], page 11, Section 3.1.3 [omp_get_max_threads], page 12,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.1.

3.1.2 omp_get_num_threads – Size of the active team

Description:
Returns the number of threads in the current team. In a sequential section of the program omp_get_num_threads returns 1.

The default team size may be initialized at startup by the OMP_NUM_THREADS environment variable. At runtime, the size of the current team may be set either by the NUM_THREADS clause or by omp_set_num_threads. If none of the above were used to define a specific value and OMP_DYNAMIC is disabled, one thread per CPU online is used.

C/C++:
Prototype: int omp_get_num_threads(void);

Fortran:
Interface: integer function omp_get_num_threads()

See also: Section 3.1.3 [omp_get_max_threads], page 12, Section 3.1.1 [omp_set_num_threads], page 11, Section 4.12 [OMP_NUM_THREADS], page 54,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.2.
3.1.3 omp_get_max_threads – Maximum number of threads of parallel region

Description:
Return the maximum number of threads used for the current parallel region that does not use the clause num_threads.

C/C++:
Prototype: int omp_get_max_threads(void);

Fortran:
Interface: integer function omp_get_max_threads()

See also: Section 3.1.1 [omp_set_num_threads], page 11, Section 3.1.6 [omp_set_dynamic], page 13, Section 3.3.6 [omp_get_thread_limit], page 20,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.3.

3.1.4 omp_get_thread_num – Current thread ID

Description:
Returns a unique thread identification number within the current team. In a sequential parts of the program, omp_get_thread_num always returns 0. In parallel regions the return value varies from 0 to omp_get_num_threads-1 inclusive. The return value of the primary thread of a team is always 0.

C/C++:
Prototype: int omp_get_thread_num(void);

Fortran:
Interface: integer function omp_get_thread_num()

See also: Section 3.1.2 [omp_get_num_threads], page 11, Section 3.1.18 [omp_get_ancestor_thread_num], page 17,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.4.

3.1.5 omp_in_parallel – Whether a parallel region is active

Description:
This function returns true if currently running in parallel, false otherwise. Here, true and false represent their language-specific counterparts.

C/C++:
Prototype: int omp_in_parallel(void);

Fortran:
Interface: logical function omp_in_parallel()

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.6.
3.1.6 omp_set_dynamic – Enable/disable dynamic teams

**Description:**
Enable or disable the dynamic adjustment of the number of threads within a team. The function takes the language-specific equivalent of true and false, where true enables dynamic adjustment of team sizes and false disables it.

**C/C++:**

**Prototype:**

```c
void omp_set_dynamic(int dynamic_threads);
```

**Fortran:**

**Interface:**

```fortran
subroutine omp_set_dynamic(dynamic_threads)
    logical, intent(in) :: dynamic_threads
end subroutine
```

**See also:** Section 4.7 [OMP_DYNAMIC], page 52, Section 3.1.7 [omp_get_dynamic], page 13,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.7.

3.1.7 omp_get_dynamic – Dynamic teams setting

**Description:**
This function returns true if enabled, false otherwise. Here, true and false represent their language-specific counterparts. The dynamic team setting may be initialized at startup by the OMP_DYNAMIC environment variable or at runtime using omp_set_dynamic. If undefined, dynamic adjustment is disabled by default.

**C/C++:**

**Prototype:**

```c
int omp_get_dynamic(void);
```

**Fortran:**

**Interface:**

```fortran
logical function omp_get_dynamic()
```

**See also:** Section 3.1.6 [omp_set_dynamic], page 13, Section 4.7 [OMP_DYNAMIC], page 52,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.8.

3.1.8 omp_get_cancellation – Whether cancellation support is enabled

**Description:**
This function returns true if cancellation is activated, false otherwise. Here, true and false represent their language-specific counterparts. Unless OMP_CANCELLATION is set true, cancellations are deactivated.

**C/C++:**

**Prototype:**

```c
int omp_get_cancellation(void);
```

**Fortran:**

**Interface:**

```fortran
logical function omp_get_cancellation()
```

**See also:** Section 4.3 [OMP_CANCELLATION], page 51,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.9.
3.1.9 omp_set_nested – Enable/disable nested parallel regions

Description:
Enable or disable nested parallel regions, i.e., whether team members are allowed to create new teams. The function takes the language-specific equivalent of true and false, where true enables dynamic adjustment of team sizes and false disables it.

Enabling nested parallel regions also sets the maximum number of active nested regions to the maximum supported. Disabling nested parallel regions sets the maximum number of active nested regions to one.

Note that the omp_set_nested API routine was deprecated in the OpenMP specification 5.2 in favor of omp_set_max_active_levels.

C/C++:
Prototype: void omp_set_nested(int nested);

Fortran:
Interface: subroutine omp_set_nested(nested)
logical, intent(in) :: nested

See also: Section 3.1.10 [omp_get_nested], page 14, Section 3.1.15 [omp_set_max_active_levels], page 16, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53, Section 4.10 [OMP_NESTED], page 53,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.10.

3.1.10 omp_get_nested – Nested parallel regions

Description:
This function returns true if nested parallel regions are enabled, false otherwise. Here, true and false represent their language-specific counterparts.

The state of nested parallel regions at startup depends on several environment variables. If OMP_MAX_ACTIVE_LEVELS is defined and is set to greater than one, then nested parallel regions will be enabled. If not defined, then the value of the OMP_NESTED environment variable will be followed if defined. If neither are defined, then if either OMP_NUM_THREADS or OMP_PROC_BIND are defined with a list of more than one value, then nested parallel regions are enabled. If none of these are defined, then nested parallel regions are disabled by default.

Nested parallel regions can be enabled or disabled at runtime using omp_set_nested, or by setting the maximum number of nested regions with omp_set_max_active_levels to one to disable, or above one to enable.

Note that the omp_get_nested API routine was deprecated in the OpenMP specification 5.2 in favor of omp_get_max_active_levels.

C/C++:
Prototype: int omp_get_nested(void);

Fortran:
Interface: logical function omp_get_nested()
See also: Section 3.1.16 [omp_get_max_active_levels], page 17, Section 3.1.9 [omp_set_nested], page 14, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53, Section 4.10 [OMP_NESTED], page 53.

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.11.

3.1.11 omp_set_schedule – Set the runtime scheduling method

Description:
Sets the runtime scheduling method. The kind argument can have the value omp_sched_static, omp_sched_dynamic, omp_sched_guided or omp_sched_auto. Except for omp_sched_auto, the chunk size is set to the value of chunk_size if positive, or to the default value if zero or negative. For omp_sched_auto the chunk_size argument is ignored.

C/C++

Prototype: void omp_set_schedule(omp_sched_t kind, int chunk_size);

Fortran:

Interface: subroutine omp_set_schedule(kind, chunk_size)
            integer(kind=omp_sched_kind) kind
            integer chunk_size

See also: Section 3.1.12 [omp_get_schedule], page 15, Section 4.16 [OMP_SCHEDULE], page 56.

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.12.

3.1.12 omp_get_schedule – Obtain the runtime scheduling method

Description:
Obtain the runtime scheduling method. The kind argument is set to omp_sched_static, omp_sched_dynamic, omp_sched_guided or omp_sched_auto. The second argument, chunk_size, is set to the chunk size.

C/C++

Prototype: void omp_get_schedule(omp_sched_t *kind, int *chunk_size);

Fortran:

Interface: subroutine omp_get_schedule(kind, chunk_size)
            integer(kind=omp_sched_kind) kind
            integer chunk_size

See also: Section 3.1.11 [omp_set_schedule], page 15, Section 4.16 [OMP_SCHEDULE], page 56.

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.13.
3.1.13 **omp_get_teams_thread_limit** – Maximum number of threads imposed by teams

*Description:*

Return the maximum number of threads that are able to participate in each team created by a teams construct.

*C/C++:

Prototype: `int omp_get_teams_thread_limit(void);`

*Fortran:

Interface: `integer function omp_get_teams_thread_limit()`

*See also:* Section 3.3.5 [omp_set_teams_thread_limit], page 20, Section 4.18 [OMP_TEAMS_THREAD_LIMIT], page 57,

*Reference:* OpenMP specification v5.1 (https://www.openmp.org), Section 3.4.6.

3.1.14 **omp_get_supported_active_levels** – Maximum number of active regions supported

*Description:*

This function returns the maximum number of nested, active parallel regions supported by this implementation.

*C/C++

Prototype: `int omp_get_supported_active_levels(void);`

*Fortran:

Interface: `integer function omp_get_supported_active_levels()`

*See also:* Section 3.1.16 [omp_get_max_active_levels], page 17, Section 3.1.15 [omp_set_max_active_levels], page 16,

*Reference:* OpenMP specification v5.0 (https://www.openmp.org), Section 3.2.15.

3.1.15 **omp_set_max_active_levels** – Limits the number of active parallel regions

*Description:*

This function limits the maximum allowed number of nested, active parallel regions. `max_levels` must be less or equal to the value returned by **omp_get_supported_active_levels**.

*C/C++

Prototype: `void omp_set_max_active_levels(int max_levels);`

*Fortran:

Interface: `subroutine omp_set_max_active_levels(max_levels)`

integer max_levels

*See also:* Section 3.1.16 [omp_get_max_active_levels], page 17, Section 3.1.20 [omp_get_active_level], page 18, Section 3.1.14 [omp_get_supported_active_levels], page 16,

*Reference:* OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.15.
3.1.16 `omp_get_max_active_levels` – Current maximum number of active regions

**Description:**
This function obtains the maximum allowed number of nested, active parallel regions.

**C/C++**

**Prototype:**
```
int omp_get_max_active_levels(void);
```

**Fortran**

**Interface:**
```
integer function omp_get_max_active_levels()
```

**See also:** Section 3.1.15 [omp_set_max_active_levels], page 16, Section 3.1.20 [omp_get_active_level], page 18,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.16.

3.1.17 `omp_get_level` – Obtain the current nesting level

**Description:**
This function returns the nesting level for the parallel blocks, which enclose the calling call.

**C/C++**

**Prototype:**
```
int omp_get_level(void);
```

**Fortran**

**Interface:**
```
integer function omp_level()
```

**See also:** Section 3.1.20 [omp_get_active_level], page 18,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.17.

3.1.18 `omp_get_ancestor_thread_num` – Ancestor thread ID

**Description:**
This function returns the thread identification number for the given nesting level of the current thread. For values of `level` outside zero to `omp_get_level` -1 is returned; if `level` is `omp_get_level` the result is identical to `omp_get_thread_num`.

**C/C++**

**Prototype:**
```
int omp_get_ancestor_thread_num(int level);
```

**Fortran**

**Interface:**
```
integer function omp_get_ancestor_thread_num(level)
   integer level
```

**See also:** Section 3.1.17 [omp_get_level], page 17, Section 3.1.4 [omp_get_thread_num], page 12, Section 3.1.19 [omp_get_team_size], page 18,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.18.
3.1.19 omp_get_team_size – Number of threads in a team

Description:
This function returns the number of threads in a thread team to which either the current thread or its ancestor belongs. For values of level outside zero to omp_get_level, -1 is returned; if level is zero, 1 is returned, and for omp_get_level, the result is identical to omp_get_num_threads.

C/C++:
Prototype: int omp_get_team_size(int level);

Fortran:
Interface: integer function omp_get_team_size(level)
           integer level

See also: Section 3.1.2 [omp_get_num_threads], page 11, Section 3.1.17 [omp_get_level], page 17, Section 3.1.18 [omp_get_ancestor_thread_num], page 17,
Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.19.

3.1.20 omp_get_active_level – Number of parallel regions

Description:
This function returns the nesting level for the active parallel blocks, which enclose the calling call.

C/C++
Prototype: int omp_get_active_level(void);

Fortran:
Interface: integer function omp_get_active_level()

See also: Section 3.1.17 [omp_get_level], page 17, Section 3.1.16 [omp_get_max_active_levels], page 17, Section 3.1.15 [omp_set_max_active_levels], page 16,
Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.20.

3.2 Thread Affinity Routines

Routines controlling and accessing thread-affinity policies. They have C linkage and do not throw exceptions.

3.2.1 omp_get_proc_bind – Whether threads may be moved between CPUs

Description:
This function returns the currently active thread affinity policy, which is set via OMP_PROC_BIND. Possible values are omp_proc_bind_false, omp_proc_bind_true, omp_proc_bind_primary, omp_proc_bind_master, omp_proc_bind_close and omp_proc_bind_spread, where omp_proc_bind_master is an alias for omp_proc_bind_primary.

C/C++:
Prototype: omp_proc_bind_t omp_get_proc_bind(void);
Chapter 3: OpenMP Runtime Library Routines

Fortran:

Interface: integer(kind=omp_proc_bind_kind) function omp_get_proc_bind()

See also: Section 4.13 [OMP_PROC_BIND], page 54, Section 4.14 [OMP_PLACES], page 55, Section 4.21 [GOMP_CPU_AFFINITY], page 58.

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.22.

3.3 Teams Region Routines

Routines controlling the league of teams that are executed in a teams region. They have C linkage and do not throw exceptions.

3.3.1 omp_get_num_teams – Number of teams

Description:
Returns the number of teams in the current team region.

C/C++:
Prototype: int omp_get_num_teams(void);

Fortran:
Interface: integer function omp_get_num_teams()

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.32.

3.3.2 omp_get_team_num – Get team number

Description:
Returns the team number of the calling thread.

C/C++:
Prototype: int omp_get_team_num(void);

Fortran:
Interface: integer function omp_get_team_num()

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.33.

3.3.3 omp_set_num_teams – Set upper teams limit for teams construct

Description:
Specifies the upper bound for number of teams created by the teams construct which does not specify a num_teams clause. The argument of omp_set_num_teams shall be a positive integer.

C/C++:
Prototype: void omp_set_num_teams(int num_teams);

Fortran:
Interface: subroutine omp_set_num_teams(num_teams)
integer, intent(in) :: num_teams
See also: Section 4.11 [OMP_NUM_TEAMS], page 54, Section 3.3.1 [omp_get_num_teams], page 19, Section 3.3.4 [omp_get_max_teams], page 20,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.4.3.

3.3.4 omp_get_max_teams – Maximum number of teams of teams region

Description:
Return the maximum number of teams used for the teams region that does not use the clause num_teams.

C/C++:
Prototype: int omp_get_max_teams(void);

Fortran:
Interface: integer function omp_get_max_teams()

See also: Section 3.3.3 [omp_set_num_teams], page 19, Section 3.3.1 [omp_get_num_teams], page 19,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.4.4.

3.3.5 omp_set_teams_thread_limit – Set upper thread limit for teams construct

Description:
Specifies the upper bound for number of threads that are available for each team created by the teams construct which does not specify a thread_limit clause.
The argument of omp_set_teams_thread_limit shall be a positive integer.

C/C++:
Prototype: void omp_set_teams_thread_limit(int thread_limit);

Fortran:
Interface: subroutine omp_set_teams_thread_limit(thread_limit)
integer, intent(in) :: thread_limit

See also: Section 4.18 [OMP_TEAMS_THREAD_LIMIT], page 57, Section 3.1.13 [omp_get_teams_thread_limit], page 16, Section 3.3.6 [omp_get_thread_limit], page 20,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.4.5.

3.3.6 omp_get_thread_limit – Maximum number of threads

Description:
Return the maximum number of threads of the program.

C/C++:
Prototype: int omp_get_thread_limit(void);
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Fortran:

Interface: integer function omp_get_thread_limit()

See also: Section 3.1.3 [omp_get_max_threads], page 12, Section 4.19 [OMP_THREADLIMIT], page 57,


3.4 Tasking Routines

Routines relating to explicit tasks. They have C linkage and do not throw exceptions.

3.4.1 omp_get_max_task_priority – Maximum priority value that can be set for tasks.

Description:

This function obtains the maximum allowed priority number for tasks.

C/C++

Prototype: int omp_get_max_task_priority(void);

Fortran:

Interface: integer function omp_get_max_task_priority()

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.29.

3.4.2 omp_in_explicit_task – Whether a given task is an explicit task

Description:

The function returns the explicit-task-vars ICV; it returns true when the encountering task was generated by a task-generating construct such as target, task or taskloop. Otherwise, the encountering task is in an implicit task region such as generated by the implicit or explicit parallel region and omp_in_explicit_task returns false.

C/C++

Prototype: int omp_in_explicit_task(void);

Fortran:

Interface: logical function omp_in_explicit_task()

Reference: OpenMP specification v5.2 (https://www.openmp.org), Section 18.5.2.

3.4.3 omp_in_final – Whether in final or included task region

Description:

This function returns true if currently running in a final or included task region, false otherwise. Here, true and false represent their language-specific counterparts.

C/C++:

Prototype: int omp_in_final(void);
Fortran:

Interface:  logical function omp_in_final()

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.21.

3.5 Resource Relinquishing Routines

Routines releasing resources used by the OpenMP runtime. They have C linkage and do not throw exceptions.

3.5.1 omp_pause_resource – Release OpenMP resources on a device

Description:
Free resources used by the OpenMP program and the runtime library on and for the device specified by device_num; on success, zero is returned and non-zero otherwise.

The value of device_num must be a conforming device number. The routine may not be called from within any explicit region and all explicit threads that do not bind to the implicit parallel region have finalized execution.

C/C++:

Prototype:  int omp_pause_resource(omp_pause_resource_t kind, int device_num);

Fortran:

Interface:  integer function omp_pause_resource(kind, device_num)
            integer (kind=omp_pause_resource_kind) kind
            integer device_num

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 3.2.43.

3.5.2 omp_pause_resource_all – Release OpenMP resources on all devices

Description:
Free resources used by the OpenMP program and the runtime library on all devices, including the host. On success, zero is returned and non-zero otherwise.

The routine may not be called from within any explicit region and all explicit threads that do not bind to the implicit parallel region have finalized execution.

C/C++:

Prototype:  int omp_pause_resource(omp_pause_resource_t kind);

Fortran:

Interface:  integer function omp_pause_resource(kind)
            integer (kind=omp_pause_resource_kind) kind

See also:  Section 3.5.1 [omp_pause_resource], page 22,

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 3.2.44.


3.6 Device Information Routines

Routines related to devices available to an OpenMP program. They have C linkage and do not throw exceptions.

3.6.1 omp_get_num_procs – Number of processors online

Description:
Returns the number of processors online on that device.

C/C++:
Prototype: int omp_get_num_procs(void);

Fortran:
Interface: integer function omp_get_num_procs()

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.5.

3.6.2 omp_set_default_device – Set the default device for target regions

Description:
Set the default device for target regions without device clause. The argument shall be a nonnegative device number.

C/C++:
Prototype: void omp_set_default_device(int device_num);

Fortran:
Interface: subroutine omp_set_default_device(device_num)
 integer device_num

See also: Section 4.6 [OMP_DEFAULT_DEVICE], page 52, Section 3.6.3 [omp_get_default_device], page 23,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.29.

3.6.3 omp_get_default_device – Get the default device for target regions

Description:
Get the default device for target regions without device clause.

C/C++:
Prototype: int omp_get_default_device(void);

Fortran:
Interface: integer function omp_get_default_device()

See also: Section 4.6 [OMP_DEFAULT_DEVICE], page 52, Section 3.6.2 [omp_set_default_device], page 23,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.30.
3.6.4 omp_get_num_devices – Number of target devices

Description:
Returns the number of target devices.

C/C++:
Prototype: int omp_get_num_devices(void);

Fortran:
Interface: integer function omp_get_num_devices()

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.31.

3.6.5 omp_get_device_num – Return device number of current device

Description:
This function returns a device number that represents the device that the current thread is executing on. For OpenMP 5.0, this must be equal to the value returned by the omp_get_initial_device function when called from the host.

C/C++
Prototype: int omp_get_device_num(void);

Fortran:
Interface: integer function omp_get_device_num()

See also: Section 3.6.7 [omp_get_initial_device], page 24,
Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 3.2.37.

3.6.6 omp_is_initial_device – Whether executing on the host device

Description:
This function returns true if currently running on the host device, false otherwise. Here, true and false represent their language-specific counterparts.

C/C++:
Prototype: int omp_is_initial_device(void);

Fortran:
Interface: logical function omp_is_initial_device()

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.2.34.

3.6.7 omp_get_initial_device – Return device number of initial device

Description:
This function returns a device number that represents the host device. For OpenMP 5.1, this must be equal to the value returned by the omp_get_num_devices function.
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3.7 Device Memory Routines

Routines related to memory allocation and managing corresponding pointers on devices. They have C linkage and do not throw exceptions.

3.7.1 omp_target_alloc — Allocate device memory

Description:
This routine allocates size bytes of memory in the device environment associated with the device number device_num. If successful, a device pointer is returned, otherwise a null pointer.

In GCC, when the device is the host or the device shares memory with the host, the memory is allocated on the host; in that case, when size is zero, either NULL or a unique pointer value that can later be successfully passed to omp_target_free is returned. When the allocation is not performed on the host, a null pointer is returned when size is zero; in that case, additionally a diagnostic might be printed to standard error (stderr).

Running this routine in a target region except on the initial device is not supported.

C/C++
Prototype: void *omp_target_alloc(size_t size, int device_num)

Fortran
Interface: type(c_ptr) function omp_target_alloc(size, device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int, c_size_t
integer(c_size_t), value :: size
integer(c_int), value :: device_num

See also: Section 3.7.2 [omp_target_free], page 25, Section 3.7.9 [omp_target_associate_ptr], page 32,
Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.8.1

3.7.2 omp_target_free — Free device memory

Description:
This routine frees memory allocated by the omp_target_alloc routine. The device_ptr argument must be either a null pointer or a device pointer returned
by `omp_target_alloc` for the specified `device_num`. The device number `device_num` must be a conforming device number.

Running this routine in a `target` region except on the initial device is not supported.

\[ C/C++ \]

**Prototype:**

```c
void omp_target_free(void *device_ptr, int device_num)
```

\[ Fortran \]

**Interface:**

```fortran
subroutine omp_target_free(device_ptr, device_num)
bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int
type(c_ptr), value :: device_ptr
integer(c_int), value :: device_num
```

\[ See also: \] Section 3.7.1 [omp_target_alloc], page 25, Section 3.7.10 [omp_target_disassociate_ptr], page 33,

\[ Reference: \] OpenMP specification v5.1 (https://www.openmp.org), Section 3.8.2

### 3.7.3 `omp_target_is_present` – Check whether storage is mapped

**Description:**

This routine tests whether storage, identified by the host pointer `ptr` is mapped to the device specified by `device_num`. If so, it returns a nonzero value and otherwise zero.

In GCC, this includes self mapping such that `omp_target_is_present` returns `true` when `device_num` specifies the host or when the host and the device share memory. If `ptr` is a null pointer, `true` is returned and if `device_num` is an invalid device number, `false` is returned.

If those conditions do not apply, `true` is returned if the association has been established by an explicit or implicit `map` clause, the `declare target` directive or a call to the `omp_target_associate_ptr` routine.

Running this routine in a `target` region except on the initial device is not supported.

\[ C/C++ \]

**Prototype:**

```c
int omp_target_is_present(const void *ptr, int device_num)
```

\[ Fortran \]

**Interface:**

```fortran
integer(c_int) function omp_target_is_present(ptr, &
device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int
type(c_ptr), value :: ptr
integer(c_int), value :: device_num
```

\[ See also: \] Section 3.7.9 [omp_target_associate_ptr], page 32,
3.7.4 omp_target_is_accessible – Check whether memory is device accessible

**Description:**
This routine tests whether memory, starting at the address given by `ptr` and extending `size` bytes, is accessibly on the device specified by `device_num`. If so, it returns a nonzero value and otherwise zero.

The address given by `ptr` is interpreted to be in the address space of the device and `size` must be positive.

Note that GCC’s current implementation assumes that `ptr` is a valid host pointer. Therefore, all addresses given by `ptr` are assumed to be accessible on the initial device. And, to err on the safe side, this memory is only available on a non-host device that can access all host memory ([uniform] shared memory access).

Running this routine in a target region except on the initial device is not supported.

**C/C++**

**Prototype:**
```
int omp_target_is_accessible(const void *ptr, size_t size, int device_num)
```

**Fortran**

**Interface:**
```
integer(c_int) function omp_target_is_accessible(ptr, &
    size, device_num) bind(C)
    use, intrinsic :: iso_c_binding, only: c_ptr, c_size_t, c_int
    type(c_ptr), value :: ptr
    integer(c_size_t), value :: size
    integer(c_int), value :: device_num
```

**See also:** Section 3.7.9 [omp_target_associate_ptr], page 32,

**Reference:** OpenMP specification v5.1 (https://www.openmp.org), Section 3.8.4

3.7.5 omp_target_memcpy – Copy data between devices

**Description:**
This routine copies `length` of bytes of data from the device identified by device number `src_device_num` to device `dst_device_num`. The data is copied from the source device from the address provided by `src`, shifted by the offset of `src_offset` bytes, to the destination device’s `dst` address shifted by `dst_offset`. The routine returns zero on success and non-zero otherwise.

Running this routine in a target region except on the initial device is not supported.
C/C++

Prototype:

```
int omp_target_memcpy(void *dst,
const void *src,
size_t length,
size_t dst_offset,
size_t src_offset,
int dst_device_num,
int src_device_num)
```

Fortran:

Interface:

```
integer(c_int) function omp_target_memcpy( &
dst, src, length, dst_offset, src_offset, &
dst_device_num, src_device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: dst, src
integer(c_size_t), value :: length, dst_offset,
src_offset
integer(c_int), value :: dst_device_num, src_device_num
```

See also: Section 3.7.6 [omp_target_memcpy_async], page 28, Section 3.7.7 [omp_target_memcpy_rect], page 29,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.8.5

3.7.6 omp_target_memcpy_async — Copy data between devices asynchronously

Description:

This routine copies asynchronously length of bytes of data from the device identified by device number src_device_num to device dst_device_num. The data is copied from the source device from the address provided by src, shifted by the offset of src_offset bytes, to the destination device’s dst address shifted by dst_offset. Task dependence is expressed by passing an array of depend objects to depobj_list, where the number of array elements is passed as depobj_count; if the count is zero, the depobj_list argument is ignored. The routine returns zero if the copying process has successfully been started and non-zero otherwise.

Running this routine in a target region except on the initial device is not supported.

C/C++

Prototype:

```
int omp_target_memcpy_async(void *dst,
const void *src,
size_t length,
size_t dst_offset,
size_t src_offset,
int dst_device_num,
int src_device_num,
```
int depobj_count,
omp_depend_t *depobj_list)

Fortran:

Interface:

integer(c_int) function omp_target_memcpy_async(&
dst, src, length, dst_offset, src_offset, &
dst_device_num, src_device_num, &
depobj_count, depobj_list) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: dst, src
integer(c_size_t), value :: length, dst_offset,
src_offset
integer(c_int), value :: dst_device_num, src_
device_num, depobj_count
integer(omp_depend_kind), optional :: depobj_
list(*)

See also: Section 3.7.5 [omp target memcpy], page 27, Section 3.7.8
[omp target memcpy rect async], page 30,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.8.7

3.7.7 omp_target_memcpy_rect – Copy a subvolume of data between
devices

Description:

This routine copies a subvolume of data from the device identified by device
number src.device_num to device dst.device_num. The array has num dims
dimensions and each array element has a size of element size bytes. The vol-
ume array specifies how many elements per dimension are copied. The full
sizes of the destination and source arrays are given by the dst.dimensions and
src.dimensions arguments, respectively. The offset per dimension to the first
element to be copied is given by the dst_offset and src_offset arguments. The
routine returns zero on success and non-zero otherwise.

The OpenMP specification only requires that num dims up to three is sup-
ported. In order to find implementation-specific maximally supported number
of dimensions, the routine returns this value when invoked with a null pointer
to both the dst and src arguments. As GCC supports arbitrary dimensions, it
returns INT_MAX.

The device-number arguments must be conforming device numbers, the src
and dst must be either both null pointers or all of the following must be ful-
filled: element size and num dims must be positive and the volume, offset and
dimension arrays must have at least num dims dimensions.

Running this routine in a target region is not supported except on the initial
device.

C/C++

Prototype:

int omp_target_memcpy_rect(void *dst,
const void *src,
size_t element_size,
int num_dims,
const size_t *volume,
const size_t *dst_offset,
const size_t *src_offset,
const size_t *dst_dimensions,
const size_t *src_dimensions,
int dst_device_num,
int src_device_num)

Fortran:

Interface: integer(c_int) function omp_target_memcpy_rect( &
dst, src, element_size, num_dims, volume, &
dst_offset, src_offset, dst_dimensions, &
src_dimensions, dst_device_num, src_device_num)
bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: dst, src
integer(c_size_t), value :: element_size,
dst_offset, src_offset
integer(c_size_t), value :: volume, dst_dimensions,
src_dimensions
integer(c_int), value :: num_dims, dst_device_num,
src_device_num

See also: Section 3.7.8 [omp_target_memcpy_rect_async], page 30, Section 3.7.5
[omp_target_memcpy], page 27,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.8.6

3.7.8 omp_target_memcpy_rect_async – Copy a subvolume of data
between devices asynchronously

Description:
This routine copies asynchronously a subvolume of data from the device identified by device number src_device_num to device dst_device_num. The array has num_dims dimensions and each array element has a size of element_size bytes. The volume array specifies how many elements per dimension are copied. The full sizes of the destination and source arrays are given by the dst_dimensions and src_dimensions arguments, respectively. The offset per dimension to the first element to be copied is given by the dst_offset and src_offset arguments. Task dependence is expressed by passing an array of depend objects to depobj_list, where the number of array elements is passed as depobj_count; if the count is zero, the depobj_list argument is ignored. The routine returns zero on success and non-zero otherwise.

The OpenMP specification only requires that num_dims up to three is supported. In order to find implementation-specific maximally supported number
of dimensions, the routine returns this value when invoked with a null pointer to both the dst and src arguments. As GCC supports arbitrary dimensions, it returns INT_MAX.

The device-number arguments must be conforming device numbers, the src and dst must be either both null pointers or all of the following must be fulfilled: element_size and num_dims must be positive and the volume, offset and dimension arrays must have at least num_dims dimensions.

Running this routine in a target region is not supported except on the initial device.

C/C++

Prototype: int omp_target_memcpy_rect_async(void *dst,
const void *src,
size_t element_size,
int num_dims,
const size_t *volume,
const size_t *dst_offset,
const size_t *src_offset,
const size_t *dst_dimensions,
const size_t *src_dimensions,
int dst_device_num,
int src_device_num,
int depobj_count,
omp_depend_t *depobj_list)

Fortran:

Interface: integer(c_int) function omp_target_memcpy_rect_async( &
dst, src, element_size, num_dims, volume, &
dst_offset, src_offset, dst_dimensions, &
src_dimensions, dst_device_num, src_device_num, &
depobj_count, depobj_list) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr,
c_size_t, c_int
type(c_ptr), value :: dst, src
integer(c_size_t), value :: element_size,
dst_offset, src_offset
integer(c_size_t), value :: volume, dst_dimensions,
src_dimensions
integer(c_int), value :: num_dims, dst_device_num,
src_device_num
integer(c_int), value :: depobj_count
integer(omp_depend_kind), optional :: : depobj_list(*)

See also: Section 3.7.7 [omp_target_memcpy_rect], page 29, Section 3.7.6 [omp_target_memcpy_async], page 28,
3.7.9 omp_target_associate_ptr – Associate a device pointer with a host pointer

Description:
This routine associates storage on the host with storage on a device identified by device_num. The device pointer is usually obtained by calling omp_target_alloc or by other means (but not by using the map clauses or the declare target directive). The host pointer should point to memory that has a storage size of at least size.

The device_offset parameter specifies the offset into device_ptr that is used as the base address for the device side of the mapping; the storage size should be at least device_offset plus size.

After the association, the host pointer can be used in a map clause and in the to and from clauses of the target update directive to transfer data between the associated pointers. The reference count of such associated storage is infinite. The association can be removed by calling omp_target_disassociate_ptr which should be done before the lifetime of either storage ends.

The routine returns nonzero (EINVAL) when the device_num invalid, for when the initial device or the associated device shares memory with the host. omp_target_associate_ptr returns zero if host_ptr points into already associated storage that is fully inside of a previously associated memory. Otherwise, if the association was successful zero is returned; if none of the cases above apply, nonzero (EINVAL) is returned.

The omp_target_is_present routine can be used to test whether associated storage for a device pointer exists.

Running this routine in a target region except on the initial device is not supported.

C/C++

Prototype:
int omp_target_associate_ptr(const void *host_ptr,
const void *device_ptr,
size_t size,
size_t device_offset,
int device_num)

Fortran:

Interface:
integer(c_int) function omp_target_associate_ptr(host_ptr, &
device_ptr, size, device_offset, device_num)
bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int,
c_size_t
type(c_ptr), value :: host_ptr, device_ptr
integer(c_size_t), value :: size, device_offset
integer(c_int), value :: device_num

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.8.8
See also: Section 3.7.10 [omp_target_disassociate_ptr], page 33, Section 3.7.3 [omp_target_is_present], page 26, Section 3.7.1 [omp_target_alloc], page 25,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.8.9

3.7.10 omp_target_disassociate_ptr – Remove device–host pointer association

Description:
This routine removes the storage association established by calling omp_targetassociate_ptr and sets the reference count to zero, even if omp_targetassociate_ptr was invoked multiple times for host pointer ptr. If applicable, the device memory needs to be freed by the user.

If an associated device storage location for the device_num was found and has infinite reference count, the association is removed and zero is returned. In all other cases, nonzero (EINVAL) is returned and no other action is taken.

Note that passing a host pointer where the association to the device pointer was established with the declare target directive yields undefined behavior.

Running this routine in a target region except on the initial device is not supported.

C/C++

Prototype:
int omp_target_disassociate_ptr(const void *ptr, int device_num)

Fortran:

Interface:
integer(c_int) function omp_target_disassociate_ptr(ptr, &device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int
type(c_ptr), value :: ptr
type(c_int), value :: device_num

See also: Section 3.7.9 [omp_target_associate_ptr], page 32,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.8.10

3.7.11 omp_get_mapped_ptr – Return device pointer to a host pointer

Description:
If the device number is refers to the initial device or to a device with memory accessible from the host (shared memory), the omp_get_mapped_ptr routines returns the value of the passed ptr. Otherwise, if associated storage to the passed host pointer ptr exists on device associated with device_num, it returns that pointer. In all other cases and in cases of an error, a null pointer is returned.

The association of storage location is established either via an explicit or implicit map clause, the declare target directive or the omp_target_associate_ptr routine.
Running this routine in a target region except on the initial device is not supported.

**C/C++**

**Prototype:**

```c
void *omp_get_mapped_ptr(const void *ptr, int device_num);
```

**Fortran**

**Interface:**

```fortran
type(c_ptr) function omp_get_mapped_ptr(ptr, device_num) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_int
type(c_ptr), value :: ptr
integer(c_int), value :: device_num
```

**See also:** Section 3.7.9 [omp_target_associate_ptr], page 32,

**Reference:** OpenMP specification v5.1 (https://www.openmp.org), Section 3.8.11

### 3.8 Lock Routines

Initialize, set, test, unset and destroy simple and nested locks. The routines have C linkage and do not throw exceptions.

#### 3.8.1 omp_init_lock — Initialize simple lock

**Description:**

Initialize a simple lock. After initialization, the lock is in an unlocked state.

**C/C++:**

**Prototype:**

```c
void omp_init_lock(omp_lock_t *lock);
```

**Fortran:**

**Interface:**

```fortran
subroutine omp_init_lock(svar)
integer(omp_lock_kind), intent(out) :: svar
```

**See also:** Section 3.8.3 [omp_destroy_lock], page 35,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.3.1.

#### 3.8.2 omp_init_nest_lock — Initialize nested lock

**Description:**

Initialize a nested lock. After initialization, the lock is in an unlocked state and the nesting count is set to zero.

**C/C++:**

**Prototype:**

```c
void omp_init_nest_lock(omp_nest_lock_t *lock);
```

**Fortran:**

**Interface:**

```fortran
subroutine omp_init_nest_lock(nvar)
integer(omp_nest_lock_kind), intent(out) :: nvar
```

**See also:** Section 3.8.4 [omp_destroy_nest_lock], page 35,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.3.1.
3.8.3 omp_destroy_lock – Destroy simple lock

**Description:**
Destroy a simple lock. In order to be destroyed, a simple lock must be in the unlocked state.

**C/C++:**

**Prototype:**

```c
void omp_destroy_lock(omp_lock_t *lock);
```

**Fortran:**

**Interface:**

```fortran
subroutine omp_destroy_lock(svar)
   integer(omp_lock_kind), intent(inout) :: svar
```

**See also:** Section 3.8.1 [omp_init_lock], page 34,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.3.3.

3.8.4 omp_destroy_nest_lock – Destroy nested lock

**Description:**
Destroy a nested lock. In order to be destroyed, a nested lock must be in the unlocked state and its nesting count must equal zero.

**C/C++:**

**Prototype:**

```c
void omp_destroy_nest_lock(omp_nest_lock_t *);
```

**Fortran:**

**Interface:**

```fortran
subroutine omp_destroy_nest_lock(nvar)
   integer(omp_nest_lock_kind), intent(inout) :: nvar
```

**See also:** Section 3.8.1 [omp_init_lock], page 34,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.3.3.

3.8.5 omp_set_lock – Wait for and set simple lock

**Description:**
Before setting a simple lock, the lock variable must be initialized by omp_init_lock. The calling thread is blocked until the lock is available. If the lock is already held by the current thread, a deadlock occurs.

**C/C++:**

**Prototype:**

```c
void omp_set_lock(omp_lock_t *lock);
```

**Fortran:**

**Interface:**

```fortran
subroutine omp_set_lock(svar)
   integer(omp_lock_kind), intent(inout) :: svar
```

**See also:** Section 3.8.1 [omp_init_lock], page 34, Section 3.8.9 [omp_test_lock], page 37, Section 3.8.7 [omp_unset_lock], page 36,

**Reference:** OpenMP specification v4.5 (https://www.openmp.org), Section 3.3.4.
3.8.6 omp_set_nest_lock – Wait for and set nested lock

Description:
Before setting a nested lock, the lock variable must be initialized by `omp_init_nest_lock`. The calling thread is blocked until the lock is available. If the lock is already held by the current thread, the nesting count for the lock is incremented.

C/C++:

Prototype: `void omp_set_nest_lock(omp_nest_lock_t *lock);`

Fortran:

Interface: `subroutine omp_set_nest_lock(nvar)`
`integer(omp_nest_lock_kind), intent(inout) :: nvar`

See also: Section 3.8.2 [omp_init_nest_lock], page 34, Section 3.8.8 [omp_unset_nest_lock], page 36,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.3.4.

3.8.7 omp_unset_lock – Unset simple lock

Description:
A simple lock about to be unset must have been locked by `omp_set_lock` or `omp_test_lock` before. In addition, the lock must be held by the thread calling `omp_unset_lock`. Then, the lock becomes unlocked. If one or more threads attempted to set the lock before, one of them is chosen to, again, set the lock to itself.

C/C++:

Prototype: `void omp_unset_lock(omp_lock_t *lock);`

Fortran:

Interface: `subroutine omp_unset_lock(svar)`
`integer(omp_lock_kind), intent(inout) :: svar`

See also: Section 3.8.5 [omp_set_lock], page 35, Section 3.8.9 [omp_test_lock], page 37,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.3.5.

3.8.8 omp_unset_nest_lock – Unset nested lock

Description:
A nested lock about to be unset must have been locked by `omp_set_nested_lock` or `omp_test_nested_lock` before. In addition, the lock must be held by the thread calling `omp_unset_nest_lock`. If the nesting count drops to zero, the lock becomes unlocked. If one or more threads attempted to set the lock before, one of them is chosen to, again, set the lock to itself.

C/C++:

Prototype: `void omp_unset_nest_lock(omp_nest_lock_t *lock);`
**3.9 Timing Routines**

Portable, thread-based, wall clock timer. The routines have C linkage and do not throw exceptions.
3.9.1 omp_get_wtick – Get timer precision

Description:

Gets the timer precision, i.e., the number of seconds between two successive clock ticks.

C/C++:

Prototype:    double omp_get_wtick(void);

Fortran:

Interface:    double precision function omp_get_wtick()

See also: Section 3.9.2 [omp_get_wtime], page 38,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.4.2.

3.9.2 omp_get_wtime – Elapsed wall clock time

Description:

Elapsed wall clock time in seconds. The time is measured per thread, no guarantee can be made that two distinct threads measure the same time. Time is measured from some "time in the past", which is an arbitrary time guaranteed not to change during the execution of the program.

C/C++:

Prototype:    double omp_get_wtime(void);

Fortran:

Interface:    double precision function omp_get_wtime()

See also: Section 3.9.1 [omp_get_wtick], page 38,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 3.4.1.

3.10 Event Routine

Support for event objects. The routine has C linkage and do not throw exceptions.

3.10.1 omp_fulfill_event – Fulfill and destroy an OpenMP event

Description:

Fulfill the event associated with the event handle argument. Currently, it is only used to fulfill events generated by detach clauses on task constructs - the effect of fulfilling the event is to allow the task to complete.

The result of calling omp_fulfill_event with an event handle other than that generated by a detach clause is undefined. Calling it with an event handle that has already been fulfilled is also undefined.

C/C++:

Prototype:    void omp_fulfill_event(omp_event_handle_t event);

Fortran:

Interface:    subroutine omp_fulfill_event(event)

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 3.5.1.
3.11 Memory Management Routines

Routines to manage and allocate memory on the current device. They have C linkage and do not throw exceptions.

3.11.1 omp_init_allocator – Create an allocator

Description:
Create an allocator that uses the specified memory space and has the specified traits; if an allocator that fulfills the requirements cannot be created, omp_null_allocator is returned.

The predefined memory spaces and available traits can be found at Section 4.1 [OMP_ALLOCATOR], page 49, where the trait names have to be prefixed by omp_atk_ (e.g. omp_atk_pinned) and the named trait values by omp_atv_ (e.g. omp_atv_true); additionally, omp_atv_default may be used as trait value to specify that the default value should be used.

C/C++:
Prototype: omp_allocator_handle_t omp_init_allocator(
omp_memspace_handle_t memspace,
int ntraits,
const omp_alloctrait_t traits[]);

Fortran:
Interface: function omp_init_allocator(memspace, ntraits, traits)
integer (omp_allocator_handle_kind) :: omp_init_allocator
integer (omp_memspace_handle_kind), intent(in) :: memspace
integer, intent(in) :: ntraits
type (omp_alloctrait), intent(in) :: traits(*)

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.2 [omp_destroy_allocator], page 39,
Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 3.7.2

3.11.2 omp_destroy_allocator – Destroy an allocator

Description:
Releases all resources used by a memory allocator, which must not represent a predefined memory allocator. Accessing memory after its allocator has been destroyed has unspecified behavior. Passing omp_null_allocator to the routine is permitted but has no effect.

C/C++:
Prototype: void omp_destroy_allocator (omp_allocator_handle_t allocator);

Fortran:
subroutine omp_destroy_allocator(allocator)
integer (omp_allocator_handle_kind), intent(in) ::
    allocator

See also: Section 3.11.1 [omp_init_allocator], page 39,

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 3.7.3

3.11.3 omp_set_default_allocator – Set the default allocator

Description:
Sets the default allocator that is used when no allocator has been specified in
the allocate or allocator clause or if an OpenMP memory routine is invoked
with the omp_null_allocator allocator.

C/C++:
Prototype: void omp_set_default_allocator(omp_allocator_
handle_t allocator);

Fortran:
Interface: subroutine omp_set_default_allocator(allocator)
integer (omp_allocator_handle_kind), intent(in) ::
    allocator

See also: Section 3.11.4 [omp_get_default_allocator], page 40, Section 3.11.1
[omp_init_allocator], page 39, Section 4.1 [OMP_ALLOCATOR], page 49,
Section 11.3 [Memory allocation], page 95,

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 3.7.4

3.11.4 omp_get_default_allocator – Get the default allocator

Description:
The routine returns the default allocator that is used when no allocator has
been specified in the allocate or allocator clause or if an OpenMP memory
routine is invoked with the omp_null_allocator allocator.

C/C++:
Prototype: omp_allocator_handle_t omp_get_default_
allocator();

Fortran:
Interface: function omp_get_default_allocator()
integer (omp_allocator_handle_kind) :: omp_get_
default_allocator

See also: Section 3.11.3 [omp_set_default_allocator], page 40, Section 4.1
[OMP_ALLOCATOR], page 49,

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 3.7.5
3.11.5 omp_alloc – Memory allocation with an allocator

Description:
Allocate memory with the specified allocator, which can either be a predefined allocator, an allocator handle or omp_null_allocator. If the allocators is omp_null_allocator, the allocator specified by the def-allocator-var ICV is used. size must be a nonnegative number denoting the number of bytes to be allocated; if size is zero, omp_alloc will return a null pointer. If successful, a pointer to the allocated memory is returned, otherwise the fallback trait of the allocator determines the behavior. The content of the allocated memory is unspecified.

In target regions, either the dynamic_allocators clause must appear on a requires directive in the same compilation unit – or the allocator argument may only be a constant expression with the value of one of the predefined allocators and may not be omp_null_allocator.
Memory allocated by omp_alloc must be freed using omp_free.

C:
Prototype: void* omp_alloc(size_t size, omp_allocator_handle_t allocator)

C++:
Prototype: void* omp_alloc(size_t size, omp_allocator_handle_t allocator=omp_null_allocator)

Fortran:
Interface: type(c_ptr) function omp_alloc(size, allocator)
bind(C)
use, intrinsic :: iso_c_binding, only : c_ptr,
c_size_t
integer (c_size_t), value :: size
integer (omp_allocator_handle_kind), value :: allocator

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.3 [omp_set_default_allocator], page 40, Section 3.11.7 [omp_free], page 42, Section 3.11.1 [omp_init_allocator], page 39,

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 3.7.6

3.11.6 omp_aligned_alloc – Memory allocation with an allocator and alignment

Description:
Allocate memory with the specified allocator, which can either be a predefined allocator, an allocator handle or omp_null_allocator. If the allocators is omp_null_allocator, the allocator specified by the def-allocator-var ICV is used. alignment must be a positive power of two and size must be a nonnegative number that is a multiple of the alignment and denotes the number of bytes
to be allocated; if size is zero, \texttt{omp\_aligned\_alloc} will return a null pointer. The alignment will be at least the maximal value required by \texttt{alignment} trait of the allocator and the value of the passed \texttt{alignment} argument. If successful, a pointer to the allocated memory is returned, otherwise the \texttt{fallback} trait of the allocator determines the behavior. The content of the allocated memory is unspecified.

In target regions, either the \texttt{dynamic\_allocators} clause must appear on a \texttt{requires} directive in the same compilation unit – or the \texttt{allocator} argument may only be a constant expression with the value of one of the predefined allocators and may not be \texttt{omp\_null\_allocator}.

Memory allocated by \texttt{omp\_aligned\_alloc} must be freed using \texttt{omp\_free}.

\textbf{C:}

\textit{Prototype:}

\begin{verbatim}
void* omp_aligned_alloc(size_t alignment, size_t size, omp_allocator_handle_t allocator)
\end{verbatim}

\textbf{C++:}

\textit{Prototype:}

\begin{verbatim}
void* omp_aligned_alloc(size_t alignment, size_t size, omp_allocator_handle_t allocator=omp_null_allocator)
\end{verbatim}

\textbf{Fortran:}

\textit{Interface:}

\begin{verbatim}
type(c_ptr) function omp_aligned_alloc(alignment, size, allocator) bind(C)
use, intrinsic :: iso_c_binding, only : c_ptr, c_size_t
integer (c_size_t), value :: alignment, size
integer (omp_allocator_handle_kind), value :: allocator
\end{verbatim}

\textit{See also:} Section 4.1 [OMP\_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.3 [omp\_set\_default\_allocator], page 40, Section 3.11.7 [omp\_free], page 42, Section 3.11.1 [omp\_init\_allocator], page 39,

\textit{Reference:} OpenMP specification v5.1 (https://www.openmp.org), Section 3.13.6

\textbf{3.11.7 \texttt{omp\_free} – Freeing memory allocated with OpenMP routines}

\textit{Description:}

The \texttt{omp\_free} routine deallocates memory previously allocated by an OpenMP memory-management routine. The \texttt{ptr} argument must point to such memory or be a null pointer; if it is a null pointer, no operation is performed. If specified, the \texttt{allocator} argument must be either the memory allocator that was used for the allocation or \texttt{omp\_null\_allocator}; if it is \texttt{omp\_null\_allocator}, the implementation will determine the value automatically.

Calling \texttt{omp\_free} invokes undefined behavior if the memory was already deallocated or when the used allocator has already been destroyed.
3.11.8 `omp_calloc` — Allocate nullified memory with an allocator

**Description:**

Allocate zero-initialized memory with the specified allocator, which can either be a predefined allocator, an allocator handle or `omp_null_allocator`. If the allocators is `omp_null_allocator`, the allocator specified by the `def-allocator-var` ICV is used. The to-be allocated memory is for an array with `nmemb` elements, each having a size of `size` bytes. Both `nmemb` and `size` must be nonnegative numbers; if either of them is zero, `omp_calloc` will return a null pointer. If successful, a pointer to the zero-initialized allocated memory is returned, otherwise the fallback trait of the allocator determines the behavior. In `target` regions, either the `dynamic_allocators` clause must appear on a `requires` directive in the same compilation unit – or the `allocator` argument may only be a constant expression with the value of one of the predefined allocators and may not be `omp_null_allocator`.

Memory allocated by `omp_calloc` must be freed using `omp_free`.

**C:**

```c
Prototype: void* omp_calloc(size_t nmemb, size_t size,
omp_allocator_handle_t allocator)
```

**C++:**

```c
Prototype: void* omp_calloc(size_t nmemb, size_t size,
omp_allocator_handle_t allocator=omp_null_allocator)
```

**Fortran:**

```fortran
subroutine omp_calloc(ptr, allocator) bind(C)
use, intrinsic :: iso_c_binding, only : c_ptr
type (c_ptr), value :: ptr
integer (omp_allocator_handle_kind), value :: allocator
```

**See also:** Section 3.11.5 [omp_alloc], page 41, Section 3.11.6 [omp_aligned_alloc], page 41, Section 3.11.8 [omp_calloc], page 43, Section 3.11.9 [omp_aligned_calloc], page 44, Section 3.11.10 [omp_realloc], page 45,

**Reference:** OpenMP specification v5.0 (https://www.openmp.org), Section 3.7.7
Interface: type(c_ptr) function omp_aligned_calloc(nmemb, size, allocator) bind(C)

use, intrinsic :: iso_c_binding, only: c_ptr, c_size_t
integer (c_size_t), value :: nmemb, size
integer (omp_allocator_handle_kind), value :: allocator

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.3 [omp_set_default_allocator], page 40, Section 3.11.7 [omp_free], page 42, Section 3.11.1 [omp_init_allocator], page 39,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.13.8

3.11.9 omp_aligned_calloc – Allocate aligned nullified memory with an allocator

Description:
Allocate zero-initialized memory with the specified allocator, which can either be a predefined allocator, an allocator handle or omp_null_allocator. If the allocators is omp_null_allocator, the allocator specified by the def_allocator-var ICV is used. The to-be allocated memory is for an array with nmemb elements, each having a size of size bytes. Both nmemb and size must be non-negative numbers; if either of them is zero, omp_aligned_calloc will return a null pointer. alignment must be a positive power of two and size must be a multiple of the alignment; the alignment will be at least the maximal value required by alignment trait of the allocator and the value of the passed alignment argument. If successful, a pointer to the zero-initialized allocated memory is returned, otherwise the fallback trait of the allocator determines the behavior.

In target regions, either the dynamic_allocators clause must appear on a requires directive in the same compilation unit – or the allocator argument may only be a constant expression with the value of one of the predefined allocators and may not be omp_null_allocator. Memory allocated by omp_aligned_calloc must be freed using omp_free.

C:
Prototype: void* omp_aligned_calloc(size_t nmemb, size_t size, omp_allocator_handle_t allocator)

C++:
Prototype: void* omp_aligned_calloc(size_t nmemb, size_t size, omp_allocator_handle_t allocator=omp_null_allocator)

Fortran:
Interface: type(c_ptr) function omp_aligned_calloc(nmemb, size, allocator) bind(C)
use, intrinsic :: iso_c_binding, only: c_ptr, c_size_t
integer (c_size_t), value :: nmemb, size
integer (omp_allocator_handle_kind), value ::
allocator

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.3 [omp_set_default_allocator], page 40, Section 3.11.7 [omp_free], page 42, Section 3.11.1 [omp_init_allocator], page 39,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.13.8

3.11.10 omp_realloc – Reallocate memory allocated with OpenMP routines

Description:
The omp_realloc routine deallocates memory to which ptr points to and allocates new memory with the specified allocator argument; the new memory will have the content of the old memory up to the minimum of the old size and the new size, otherwise the content of the returned memory is unspecified. If the new allocator is the same as the old one, the routine tries to resize the existing memory allocation, returning the same address as ptr if successful. ptr must point to memory allocated by an OpenMP memory-management routine.

The allocator and free_allocator arguments must be a predefined allocator, an allocator handle or omp_null_allocator. If free_allocator is omp_null_allocator, the implementation automatically determines the allocator used for the allocation of ptr. If allocator is omp_null_allocator and ptr is not a null pointer, the same allocator as free_allocator is used and when ptr is a null pointer the allocator specified by the def_allocator_var ICV is used.

The size must be a nonnegative number denoting the number of bytes to be allocated; if size is zero, omp_realloc will return free the memory and return a null pointer. When size is nonzero: if successful, a pointer to the allocated memory is returned, otherwise the fallback trait of the allocator determines the behavior.

In target regions, either the dynamic_allocators clause must appear on a requires directive in the same compilation unit – or the free_allocator and allocator arguments may only be a constant expression with the value of one of the predefined allocators and may not be omp_null_allocator.

Memory allocated by omp_realloc must be freed using omp_free. Calling omp_free invokes undefined behavior if the memory was already deallocated or when the used allocator has already been destroyed.

C:

Prototype:     void* omp_realloc(void *ptr, size_t size,
omp_allocator_handle_t allocator,
omp_allocator_handle_t free_allocator)

C++:

Prototype:     void* omp_realloc(void *ptr, size_t size,
omp_allocator_handle_t allocator=omp_null_allocator,
omp_allocator_handle_t free_allocator=omp_null_allocator)

Fortran:

Interface: type(c_ptr) function omp_realloc(ptr, size, allocator, free_allocator) bind(C)
use, intrinsic :: iso_c_binding, only : c_ptr, c_size_t
type(C_ptr), value :: ptr
integer (c_size_t), value :: size
integer (omp_allocator_handle_kind), value :: allocator, free_allocator

See also: Section 4.1 [OMP_ALLOCATOR], page 49, Section 11.3 [Memory allocation], page 95, Section 3.11.3 [omp_set_default_allocator], page 40, Section 3.11.7 [omp_free], page 42, Section 3.11.1 [omp_init_allocator], page 39,

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 3.7.9

3.12 Environment Display Routine

Routine to display the OpenMP version number and the initial value of ICVs. It has C linkage and does not throw exceptions.

3.12.1 omp_display_env – print the initial ICV values

Description:

Each time this routine is invoked, the OpenMP version number and initial value of internal control variables (ICVs) is printed on stderr. The displayed values are those at startup after evaluating the environment variables; later calls to API routines or clauses used in enclosing constructs do not affect the output.

If the verbose argument is false, only the OpenMP version and standard OpenMP ICVs are shown; if it is true, additionally, the GCC-specific ICVs are shown.

The output consists of multiple lines and starts with ‘OPENMP DISPLAY ENVIRONMENT BEGIN’ followed by the name-value lines and ends with ‘OPENMP DISPLAY ENVIRONMENT END’. The name is followed by an equal sign and the value is enclosed in single quotes.

The first line has as name either ‘_OPENMP’ or ‘openmp_version’ and shows as value the supported OpenMP version number (4-digit year, 2-digit month) of the implementation, matching the value of the _OPENMP macro and, in Fortran, the named constant openmp_version.

In each of the succeeding lines, the name matches the environment-variable name of an ICV and shows its value. Those line are might be prefixed by pair of brackets and a space, where the brackets enclose a comma-separated list of devices to which the ICV-value combination applies to; the value can either be a numeric device number or an abstract name denoting all devices (all), the initial host device (host) or all devices but the host (device). Note that the
same ICV might be printed multiple times for multiple devices, even if all have the same value.
The effect when invoked from within a target region is unspecified.

C/C++:

Prototype: \[ \text{void omp\_display\_env(int verbose)} \]

Fortran:

Interface: \( \text{subroutine omp\_display\_env(vebose)} \)
\[
\text{logical, intent(in)} :: \text{verbose}
\]

Example: Note that the GCC-specific ICVs, such as the shown GOMP\_SPINCOUNT, are only printed when \text{verbose} set to \text{true}.

\[
\text{OPENMP DISPLAY ENVIRONMENT BEGIN}
\_\text{OPENMP} = '201511'
[host] \text{OMP\_DYNAMIC} = 'FALSE'
[host] \text{OMP\_NESTED} = 'FALSE'
[all] \text{OMP\_CANCELLATION} = 'FALSE'
...
[host] \text{GOMP\_SPINCOUNT} = '300000'
\text{OPENMP DISPLAY ENVIRONMENT END}
\]

See also: Section 4.5 [OMP\_DISPLAY\_ENV], page 52, Chapter 4 [Environment Variables], page 49, Section 11.1 [Implementation-defined ICV Initialization], page 95,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 3.15
4 OpenMP Environment Variables

The environment variables which beginning with OMP_ are defined by section 4 of the OpenMP specification in version 4.5 or in a later version of the specification, while those beginning with GOMP_ are GNU extensions. Most OMP_ environment variables have an associated internal control variable (ICV).

For any OpenMP environment variable that sets an ICV and is neither OMP_DEFAULT_DEVICE nor has global ICV scope, associated device-specific environment variables exist. For them, the environment variable without suffix affects the host. The suffix _DEV_ followed by a non-negative device number less that the number of available devices sets the ICV for the corresponding device. The suffix _DEV_ sets the ICV of all non-host devices for which a device-specific corresponding environment variable has not been set while the _ALL_ suffix sets the ICV of all host and non-host devices for which a more specific corresponding environment variable is not set.

4.1 OMP_ALLOCATOR – Set the default allocator

ICV: def-allocator-var
Scope: data environment
Description:
Sets the default allocator that is used when no allocator has been specified in the allocate or allocator clause or if an OpenMP memory routine is invoked with the omp_null_allocator allocator. If unset, omp_default_mem_alloc is used.

The value can either be a predefined allocator or a predefined memory space or a predefined memory space followed by a colon and a comma-separated list of memory trait and value pairs, separated by =.

Note: The corresponding device environment variables are currently not supported. Therefore, the non-host def-allocator-var ICVs are always initialized to omp_default_mem_alloc. However, on all devices, the omp_set_default_allocator API routine can be used to change value.

Predefined allocators

omp_default_mem_alloc
omp_large_cap_mem_alloc
omp_const_mem_alloc
omp_high_bw_mem_alloc
omp_low_lat_mem_alloc
omp_cgroup_mem_alloc
omp_pteam_mem_alloc
omp_thread_mem_alloc

Associated predefined memory spaces

omp_default_mem_space
omp_large_cap_mem_space
omp_const_mem_space
omp_high_bw_mem_space
omp_low_lat_mem_space
omp_low_lat_mem_space (implementation defined)
omp_low_lat_mem_space (implementation defined)
omp_low_lat_mem_space (implementation defined)
The predefined allocators use the default values for the traits, as listed below. Except that the last three allocators have the access trait set to cgroup, pteam, and thread, respectively.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Allowed values</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>sync_hint</td>
<td>contended, uncontended, serialized, private</td>
<td>contended</td>
</tr>
<tr>
<td>alignment</td>
<td>Positive integer being a power of two</td>
<td>1 byte</td>
</tr>
<tr>
<td>access</td>
<td>all, cgroup, pteam, thread</td>
<td>all</td>
</tr>
<tr>
<td>pool_size</td>
<td>Positive integer</td>
<td>See Section 11.3</td>
</tr>
<tr>
<td>fallback</td>
<td>default_mem_fb, null_fb, abort_fb, allocator_fb</td>
<td>See below</td>
</tr>
<tr>
<td>fb_data</td>
<td>unsupported as it needs an allocator handle</td>
<td>(none)</td>
</tr>
<tr>
<td>pinned</td>
<td>true, false</td>
<td>false</td>
</tr>
<tr>
<td>partition</td>
<td>environment, nearest, environment, blocked, interleaved</td>
<td></td>
</tr>
</tbody>
</table>

For the fallback trait, the default value is null_fb for the omp_default_mem_alloc allocator and any allocator that is associated with device memory; for all other allocators, it is default_mem_fb by default.

Examples:

```
OMP_ALLOCATOR=omp_high_bw_mem_alloc
OMP_ALLOCATOR=omp_large_cap_mem_space
OMP_ALLOCATOR=omp_low_lat_mem_space:pinned=true,partition=nearest
```

See also: Section 11.3 [Memory allocation], page 95, Section 3.11.4 [omp_get_default_allocator], page 40, Section 3.11.3 [omp_set_default_allocator], page 40, Chapter 12 [Offload-Target Specifics], page 99,

Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 6.21

### 4.2 OMP_AFFINITY_FORMAT – Set the format string used for affinity display

**ICV:** affinity-format-var

**Scope:** device

**Description:**
Sets the format string used when displaying OpenMP thread affinity information. Special values are output using % followed by an optional size specification and then either the single-character field type or its long name enclosed in curly braces; using %% displays a literal percent. The size specification consists of an optional 0. or . followed by a positive integer, specifying the minimal width of the output. With 0. and numerical values, the output is padded with zeros on the left; with ., the output is padded by spaces on the left; otherwise, the output is padded by spaces on the right. If unset, the value is “level %L thread %i affinity %A”.
Supported field types are:

- **t** team_num value returned by `omp_get_team_num`
- **T** num_teams value returned by `omp_get_num_teams`
- **L** nesting_level value returned by `omp_get_level`
- **n** thread_num value returned by `omp_get_thread_num`
- **N** num_threads value returned by `omp_get_num_threads`
- **a** ancestor_thread_num value returned by `omp_get_ancestor_thread_num(omp_get_level()-1)`
- **H** host name of the host that executes the thread
- **P** process_id process identifier
- **i** native_thread_id native thread identifier
- **A** thread_affinity comma separated list of integer values or ranges, representing the processors on which a process might execute, subject to affinity mechanisms

For instance, after setting

```
OMP_AFFINITY_FORMAT="%0.2a!%n!%.4L!%N;%.2t;%{team_num};%{num_teams};%A"
```

with either `OMP_DISPLAY_AFFINITY` being set or when calling `omp_display_affinity` with NULL or an empty string, the program might display the following:

```
00!0! 1!4; 0;01;0;1;0-11
00!3! 1!4; 0;01;0;1;0-11
00!2! 1!4; 0;01;0;1;0-11
00!1! 1!4; 0;01;0;1;0-11
```

See also: Section 4.4 [OMP_DISPLAY_AFFINITY], page 51,

Reference: OpenMP specification v5.0 ([https://www.openmp.org](https://www.openmp.org)), Section 6.14

### 4.3 OMP_CANCELLATION – Set whether cancellation is activated

**ICV:** cancel-var  
**Scope:** global  
**Description:**  
If set to TRUE, the cancellation is activated. If set to FALSE or if unset, cancellation is disabled and the cancel construct is ignored.

See also: Section 3.1.8 [omp_get_cancellation], page 13,

Reference: OpenMP specification v4.5 ([https://www.openmp.org](https://www.openmp.org)), Section 4.11

### 4.4 OMP_DISPLAY_AFFINITY – Display thread affinity information

**ICV:** display-affinity-var  
**Scope:** global  
**Description:**  
If set to FALSE or if unset, affinity displaying is disabled. If set to TRUE, the runtime displays affinity information about OpenMP threads in a parallel region upon entering the region and every time any change occurs.
See also: Section 4.2 [OMP_AFFINITY_FORMAT], page 50,
Reference: OpenMP specification v5.0 (https://www.openmp.org), Section 6.13

4.5 OMP_DISPLAY_ENV – Show OpenMP version and environment variables

ICV: none
Scope: not applicable
Description:
If set to TRUE, the runtime displays the same information to stderr as shown by the omp_display_env routine invoked with verbose argument set to false. If set to VERBOSE, the same information is shown as invoking the routine with verbose set to true. If unset or set to FALSE, this information is not shown. The result for any other value is unspecified.

See also: Section 3.12.1 [omp_display_env], page 46,
Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.12

4.6 OMP_DEFAULTDEVICE – Set the device used in target regions

ICV: default-device-var
Scope: data environment
Description:
Set to choose the device which is used in a target region, unless the value is overridden by omp_set_default_device or by a device clause. The value shall be the nonnegative device number. If no device with the given device number exists, the code is executed on the host. If unset, OMP_TARGET_OFFLOAD is mandatory and no non-host devices are available, it is set to omp_invalid_device. Otherwise, if unset, device number 0 is used.

See also: Section 3.6.3 [omp_get_default_device], page 23, Section 3.6.2 [omp_set_default_device], page 23, Section 4.17 [OMP_TARGET_OFFLOAD], page 56,
Reference: OpenMP specification v5.2 (https://www.openmp.org), Section 21.2.7

4.7 OMP_DYNAMIC – Dynamic adjustment of threads

ICV: dyn-var
Scope: global
Description:
Enable or disable the dynamic adjustment of the number of threads within a team. The value of this environment variable shall be TRUE or FALSE. If undefined, dynamic adjustment is disabled by default.

See also: Section 3.1.6 [omp_set_dynamic], page 13,
Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.3
4.8 OMP_MAX_ACTIVE_LEVELS – Set the maximum number of nested parallel regions

ICV: max-active-levels-var  
Scope: data environment  
Description: Specifies the initial value for the maximum number of nested parallel regions. The value of this variable shall be a positive integer. If undefined, then if OMP_NESTED is defined and set to true, or if OMP_NUM_THREADS or OMP_PROC_BIND are defined and set to a list with more than one item, the maximum number of nested parallel regions is initialized to the largest number supported, otherwise it is set to one.

See also: Section 3.1.15 [omp_set_max_active_levels], page 16, Section 4.10 [OMP_NESTED], page 53, Section 4.13 [OMP_PROC_BIND], page 54, Section 4.12 [OMP_NUM_THREADS], page 54,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.9

4.9 OMP_MAX_TASK_PRIORITY – Set the maximum priority number that can be set for a task.

ICV: max-task-priority-var  
Scope: global  
Description: Specifies the initial value for the maximum priority value that can be set for a task. The value of this variable shall be a non-negative integer, and zero is allowed. If undefined, the default priority is 0.

See also: Section 3.4.1 [omp_get_max_task_priority], page 21,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.14

4.10 OMP_NESTED – Nested parallel regions

ICV: max-active-levels-var  
Scope: data environment  
Description: Enable or disable nested parallel regions, i.e., whether team members are allowed to create new teams. The value of this environment variable shall be TRUE or FALSE. If set to TRUE, the number of maximum active nested regions supported is by default set to the maximum supported, otherwise it is set to one. If OMP_MAX_ACTIVE_LEVELS is defined, its setting overrides this setting. If both are undefined, nested parallel regions are enabled if OMP_NUM_THREADS or OMP_PROC_BINDS are defined to a list with more than one item, otherwise they are disabled by default.

Note that the OMP_NESTED environment variable was deprecated in the OpenMP specification 5.2 in favor of OMP_MAX_ACTIVE_LEVELS.

See also: Section 3.1.15 [omp_set_max_active_levels], page 16, Section 3.1.9 [omp_set_nested], page 14, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53,
**4.11 OMP_NUM_TEAMS** – Specifies the number of teams to use by teams region

*ICV: nteams-var*

*Scope: device*

*Description:*

Specifies the upper bound for number of teams to use in teams regions without explicit `num_teams` clause. The value of this variable shall be a positive integer. If undefined it defaults to 0 which means implementation defined upper bound.

*See also: Section 3.3.3 [omp_set_num_teams], page 19, Reference: OpenMP specification v5.1 ([https://www.openmp.org](https://www.openmp.org)), Section 6.23*

**4.12 OMP_NUM_THREADS** – Specifies the number of threads to use

*ICV: nthreads-var*

*Scope: data environment*

*Description:*

Specifies the default number of threads to use in parallel regions. The value of this variable shall be a comma-separated list of positive integers; the value specifies the number of threads to use for the corresponding nested level. Specifying more than one item in the list automatically enables nesting by default. If undefined one thread per CPU is used.

When a list with more than value is specified, it also affects the `max-active-levels-var` ICV as described in Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53.

*See also: Section 3.1.1 [omp_set_num_threads], page 11, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53, Reference: OpenMP specification v4.5 ([https://www.openmp.org](https://www.openmp.org)), Section 4.2*

**4.13 OMP_PROC_BIND** – Whether threads may be moved between CPUs

*ICV: bind-var*

*Scope: data environment*

*Description:*

Specifies whether threads may be moved between processors. If set to TRUE, OpenMP threads should not be moved; if set to FALSE they may be moved. Alternatively, a comma separated list with the values PRIMARY, MASTER, CLOSE and SPREAD can be used to specify the thread affinity policy for the corresponding nesting level. With PRIMARY and MASTER the worker threads are in the same place partition as the primary thread. With CLOSE those are kept close to the primary thread in contiguous place partitions. And with SPREAD a sparse
distribution across the place partitions is used. Specifying more than one item in the list automatically enables nesting by default.

When a list is specified, it also affects the `max-active-levels-var` ICV as described in Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53.

When undefined, OMP_PROC_BIND defaults to TRUE when OMP_PLACES or GOMP_CPU_AFFINITY is set and FALSE otherwise.

See also: Section 3.2.1 [omp_get_proc_bind], page 18, Section 4.21 [GOMP_CPU_AFFINITY], page 58, Section 4.14 [OMP_PLACES], page 55, Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.4

4.14 OMP_PLACES — Specifies on which CPUs the threads should be placed

ICV: place-partition-var

Scope: implicit tasks

Description:
The thread placement can be either specified using an abstract name or by an explicit list of the places. The abstract names `threads`, `cores`, `sockets`, `ll_caches` and `numa_domains` can be optionally followed by a positive number in parentheses, which denotes the how many places shall be created. With `threads` each place corresponds to a single hardware thread; `cores` to a single core with the corresponding number of hardware threads; with `sockets` the place corresponds to a single socket; with `ll_caches` to a set of cores that shares the last level cache on the device; and `numa_domains` to a set of cores for which their closest memory on the device is the same memory and at a similar distance from the cores. The resulting placement can be shown by setting the OMP_DISPLAY_ENV environment variable.

Alternatively, the placement can be specified explicitly as comma-separated list of places. A place is specified by set of nonnegative numbers in curly braces, denoting the hardware threads. The curly braces can be omitted when only a single number has been specified. The hardware threads belonging to a place can either be specified as comma-separated list of nonnegative thread numbers or using an interval. Multiple places can also be either specified by a comma-separated list of places or by an interval. To specify an interval, a colon followed by the count is placed after the hardware thread number or the place. Optionally, the length can be followed by a colon and the stride number – otherwise a unit stride is assumed. Placing an exclamation mark (!) directly before a curly brace or numbers inside the curly braces (excluding intervals) excludes those hardware threads.

For instance, the following specifies the same places list: "\{0,1,2\}, \{3,4,6\}, \{7,8,9\}, \{10,11,12\}"; "\{0:3\}, \{3:3\}, \{7:3\}, \{10:3\}"; and "\{0:2:4:3\}"

If OMP_PLACES and GOMP_CPU_AFFINITY are unset and OMP_PROC_BIND is either unset or false, threads may be moved between CPUs following no placement policy.
4.15 OMP_STACKSIZE – Set default thread stack size

ICV: stacksize-var
Scope: device
Description:
Set the default thread stack size in kilobytes, unless the number is suffixed by B, K, M or G, in which case the size is, respectively, in bytes, kilobytes, megabytes or gigabytes. This is different from pthread_attr_setstacksize which gets the number of bytes as an argument. If the stack size cannot be set due to system constraints, an error is reported and the initial stack size is left unchanged. If undefined, the stack size is system dependent.

See also: Section 4.23 [GOMP_STACKSIZE], page 58,
Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.7

4.16 OMP_SCHEDULE – How threads are scheduled

ICV: run-sched-var
Scope: data environment
Description:
Allows to specify schedule type and chunk size. The value of the variable shall have the form: type[,chunk] where type is one of static, dynamic, guided or auto The optional chunk size shall be a positive integer. If undefined, dynamic scheduling and a chunk size of 1 is used.

See also: Section 3.1.11 [omp_set_schedule], page 15,
Reference: OpenMP specification v4.5 (https://www.openmp.org), Sections 2.7.1.1 and 4.1

4.17 OMP_TARGET_OFFLOAD – Controls offloading behavior

ICV: target-offload-var
Scope: global
Description:
Specifies the behavior with regard to offloading code to a device. This variable can be set to one of three values - MANDATORY, DISABLED or DEFAULT.
If set to MANDATORY, the program terminates with an error if any device construct or device memory routine uses a device that is unavailable or not supported by the implementation, or uses a non-conforming device number. If set to DISABLED, then offloading is disabled and all code runs on the host. If set to DEFAULT, the program tries offloading to the device first, then falls back to running code on the host if it cannot.
If undefined, then the program behaves as if DEFAULT was set.

Note: Even with MANDATORY, no run-time termination is performed when the device number in a device clause or argument to a device memory routine is for host, which includes using the device number in the default-device-var ICV. However, the initial value of the default-device-var ICV is affected by MANDATORY.

See also: Section 4.6 [OMP_DEFAULT_DEVICE], page 52,

Reference: OpenMP specification v5.2 (https://www.openmp.org), Section 21.2.8

4.18 OMP_TEAMS_THREAD_LIMIT – Set the maximum number of threads imposed by teams

ICV: teams-thread-limit-var
Scope: device
Description:
Specifies an upper bound for the number of threads to use by each contention group created by a teams construct without explicit thread_limit clause. The value of this variable shall be a positive integer. If undefined, the value of 0 is used which stands for an implementation defined upper limit.

See also: Section 4.19 [OMP_THREAD_LIMIT], page 57, Section 3.3.5 [omp_set_teams_thread_limit], page 20,

Reference: OpenMP specification v5.1 (https://www.openmp.org), Section 6.24

4.19 OMP_THREAD_LIMIT – Set the maximum number of threads

ICV: thread-limit-var
Scope: data environment
Description:
Specifies the number of threads to use for the whole program. The value of this variable shall be a positive integer. If undefined, the number of threads is not limited.

See also: Section 4.12 [OMP_NUM_THREADS], page 54, Section 3.3.6 [omp_set_thread_limit], page 20,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.10

4.20 OMP_WAIT_POLICY – How waiting threads are handled

Description:
Specifies whether waiting threads should be active or passive. If the value is PASSIVE, waiting threads should not consume CPU power while waiting; while the value is ACTIVE specifies that they should. If undefined, threads wait actively for a short time before waiting passively.

See also: Section 4.24 [GOMP_SPINCOUNT], page 59,

Reference: OpenMP specification v4.5 (https://www.openmp.org), Section 4.8
4.21 GOMP_CPU_AFFINITY – Bind threads to specific CPUs

Description:
Binds threads to specific CPUs. The variable should contain a space-separated or comma-separated list of CPUs. This list may contain different kinds of entries: either single CPU numbers in any order, a range of CPUs (M-N) or a range with some stride (M-N:S). CPU numbers are zero based. For example, 
\[
GOMP_CPU_AFFINITY='0 3 1-2 4-15:2'
\]
binds the initial thread to CPU 0, the second to CPU 3, the third to CPU 1, the fourth to CPU 2, the fifth to CPU 4, the sixth through tenth to CPUs 6, 8, 10, 12, and 14 respectively and then starts assigning back from the beginning of the list. 
\[
GOMP_CPU_AFFINITY=0
\]
binds all threads to CPU 0.
There is no libgomp library routine to determine whether a CPU affinity specification is in effect. As a workaround, language-specific library functions, e.g., `getenv` in C or `GET_ENVIRONMENT_VARIABLE` in Fortran, may be used to query the setting of the `GOMP_CPU_AFFINITY` environment variable. A defined CPU affinity on startup cannot be changed or disabled during the runtime of the application.
If both `GOMP_CPU_AFFINITY` and `OMP_PROC_BIND` are set, `OMP_PROC_BIND` has a higher precedence. If neither has been set and `OMP_PROC_BIND` is unset, or when `OMP_PROC_BIND` is set to `FALSE`, the host system handles the assignment of threads to CPUs.

See also: Section 4.14 [OMP PLACES], page 55, Section 4.13 [OMP PROC BIND], page 54,

4.22 GOMP_DEBUG – Enable debugging output

Description:
Enable debugging output. The variable should be set to 0 (disabled, also the default if not set), or 1 (enabled).
If enabled, some debugging output is printed during execution. This is currently not specified in more detail, and subject to change.

4.23 GOMP_STACKSIZE – Set default thread stack size

Description:
Set the default thread stack size in kilobytes. This is different from `pthread_attr_setstacksize` which gets the number of bytes as an argument. If the stack size cannot be set due to system constraints, an error is reported and the initial stack size is left unchanged. If undefined, the stack size is system dependent.

See also: Section 4.15 [OMP STACKSIZE], page 56,

4.24 GOMP_SPINCOUNT – Set the busy-wait spin count

Description:
Determines how long a thread waits actively with consuming CPU power before waiting passively without consuming CPU power. The value may be either INFINITE, INFINITY to always wait actively or an integer which gives the number of spins of the busy-wait loop. The integer may optionally be followed by the following suffixes acting as multiplication factors: k (kilo, thousand), M (mega, million), G (giga, billion), or T (tera, trillion). If undefined, 0 is used when OMP_WAIT_POLICY is PASSIVE, 300,000 is used when OMP_WAIT_POLICY is undefined and 30 billion is used when OMP_WAIT_POLICY is ACTIVE. If there are more OpenMP threads than available CPUs, 1000 and 100 spins are used for OMP_WAIT_POLICY being ACTIVE or undefined, respectively; unless the GOMP_SPINCOUNT is lower or OMP_WAIT_POLICY is PASSIVE.

See also: Section 4.20 [OMP_WAIT_POLICY], page 57,

4.25 GOMP_RTEMS_THREAD_POOLS – Set the RTEMS specific thread pools

Description:
This environment variable is only used on the RTEMS real-time operating system. It determines the scheduler instance specific thread pools. The format for GOMP_RTEMS_THREAD_POOLS is a list of optional <thread-pool-count>[$<priority>]@<scheduler-name> configurations separated by : where:

- <thread-pool-count> is the thread pool count for this scheduler instance.
- $<priority> is an optional priority for the worker threads of a thread pool according to pthread_setschedparam. In case a priority value is omitted, then a worker thread inherits the priority of the OpenMP primary thread that created it. The priority of the worker thread is not changed after creation, even if a new OpenMP primary thread using the worker has a different priority.
- @<scheduler-name> is the scheduler instance name according to the RTEMS application configuration.

In case no thread pool configuration is specified for a scheduler instance, then each OpenMP primary thread of this scheduler instance uses its own dynamically allocated thread pool. To limit the worker thread count of the thread pools, each OpenMP primary thread must call omp_set_num_threads.

Example: Lets suppose we have three scheduler instances IO, WRK0, and WRK1 with GOMP_RTEMS_THREAD_POOLS set to "10WRK0:3$4@WRK1". Then there are no thread pool restrictions for scheduler instance IO. In the scheduler instance WRK0 there is one thread pool available. Since no priority is specified for this scheduler instance, the worker thread inherits the priority of the OpenMP primary thread that created it. In the scheduler instance WRK1 there are three thread pools available and their worker threads run at priority four.
5 Enabling OpenACC

To activate the OpenACC extensions for C/C++ and Fortran, the compile-time flag
-fopenacc must be specified. This enables the OpenACC directive ‘#pragma acc’ in
C/C++ and, in Fortran, the ‘!$acc’ sentinel in free source form and the ‘c$acc’, ‘*$acc’
and ‘!$acc’ sentinels in fixed source form. The flag also arranges for automatic linking
of the OpenACC runtime library (Chapter 6 [OpenACC Runtime Library Routines],
page 63).

See https://gcc.gnu.org/wiki/OpenACC for more information.

A complete description of all OpenACC directives accepted may be found in the
OpenACC (https://www.openacc.org) Application Programming Interface manual,
version 2.6.
6 OpenACC Runtime Library Routines

The runtime routines described here are defined by section 3 of the OpenACC specifications in version 2.6. They have C linkage, and do not throw exceptions. Generally, they are available only for the host, with the exception of acc_on_device, which is available for both the host and the acceleration device.

6.1 acc_get_num_devices – Get number of devices for given device type

Description
This function returns a value indicating the number of devices available for the device type specified in devicetype.

C/C++:
Prototype: int acc_get_num_devices(acc_device_t devicetype);

Fortran:
Interface: integer function acc_get_num_devices(devicetype)
integer(kind=acc_device_kind) devicetype

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.1.

6.2 acc_set_device_type – Set type of device accelerator to use.

Description
This function indicates to the runtime library which device type, specified in devicetype, to use when executing a parallel or kernels region.

C/C++:
Prototype: acc_set_device_type(acc_device_t devicetype);

Fortran:
Interface: subroutine acc_set_device_type(devicetype)
integer(kind=acc_device_kind) devicetype

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.2.

6.3 acc_get_device_type – Get type of device accelerator to be used.

Description
This function returns what device type will be used when executing a parallel or kernels region.

This function returns acc_device_none if acc_get_device_type is called from acc_ev_device_init_start, acc_ev_device_init_end callbacks of the OpenACC Profiling Interface (Chapter 10 [OpenACC Profiling Interface], page 89), that is, if the device is currently being initialized.
C/C++:
Prototype: acc_device_t acc_get_device_type(void);

Fortran:
Interface: function acc_get_device_type(void)
integer(kind=acc_device_kind) acc_get_device_type

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.3.

6.4 acc_set_device_num—Set device number to use.

Description
This function will indicate to the runtime which device number, specified by devicenum, associated with the specified device type devicetype.

C/C++:
Prototype: acc_set_device_num(int devicenum, acc_device_t devicetype);

Fortran:
Interface: subroutine acc_set_device_num(devicenum, devicetype)
integer devicenum
integer(kind=acc_device_kind) devicetype

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.4.

6.5 acc_get_device_num—Get device number to be used.

Description
This function returns which device number associated with the specified device type devicetype, will be used when executing a parallel or kernels region.

C/C++:
Prototype: int acc_get_device_num(acc_device_t devicetype);

Fortran:
Interface: function acc_get_device_num(devicetype)
integer(kind=acc_device_kind) devicetype
integer acc_get_device_num

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.5.

6.6 acc_get_property—Get device property.

Description
These routines return the value of the specified property for the device being queried according to devicenum and devicetype. Integer-valued and string-valued properties are returned by acc_get_property and acc_get_property_string respectively. The Fortran acc_get_property_string subroutine returns the string retrieved in its fourth argument while the remaining entry points are functions, which pass the return value as their result.
Note for Fortran, only: the OpenACC technical committee corrected and, hence, modified the interface introduced in OpenACC 2.6. The kind-value parameter acc_device_property has been renamed to acc_device_property_kind for consistency and the return type of the acc_get_property function is now a c_size_t integer instead of a acc_device_property integer. The parameter acc_device_property is still provided, but might be removed in a future version of GCC.

C/C++:

Prototype:  
\[
\text{size_t acc_get_property(int devicenum, acc_device_t devicetype, acc_device_property_t property)};
\]

Prototype:  
\[
\text{const char *acc_get_property_string(int devicenum, acc_device_t devicetype, acc_device_property_t property)};
\]

Fortran:

Interface:  
\[
\text{function acc_get_property(devicenum, devicetype, property)}
\]

Interface:  
\[
\text{subroutine acc_get_property_string(devicenum, devicetype, property, string)}
\]

use ISO_C_Binding, only: c_size_t

integer devicenum

integer(kind=acc_device_kind) devicetype

integer(kind=acc_device_property_kind) property

integer(kind=c_size_t) acc_get_property

character(*) string

Reference:  
OpenACC specification v2.6 (https://www.openacc.org), section 3.2.6.

6.7 acc_async_test — Test for completion of a specific asynchronous operation.

Description

This function tests for completion of the asynchronous operation specified in arg. In C/C++, a non-zero value is returned to indicate the specified asynchronous operation has completed while Fortran returns true. If the asynchronous operation has not completed, C/C++ returns zero and Fortran returns false.

C/C++:

Prototype:  
\[
\text{int acc_async_test(int arg)};
\]

Fortran:

Interface:  
\[
\text{function acc_async_test(arg)}
\]

integer(kind=acc_handle_kind) arg

logical acc_async_test

Reference:  
OpenACC specification v2.6 (https://www.openacc.org), section 3.2.9.
6.8 acc_async_test_all – Tests for completion of all asynchronous operations.

Description
This function tests for completion of all asynchronous operations. In C/C++, a non-zero value is returned to indicate all asynchronous operations have completed while Fortran returns true. If any asynchronous operation has not completed, C/C++ returns zero and Fortran returns false.

C/C++:
Prototype: int acc_async_test_all(void);

Fortran:
Interface: function acc_async_test()
   logical acc_get_device_num

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.10.

6.9 acc_wait – Wait for completion of a specific asynchronous operation.

Description
This function waits for completion of the asynchronous operation specified in arg.

C/C++:
Prototype: acc_wait(arg);
Prototype (OpenACC 1.0 compatibility):
Prototype (acc_async_wait(arg);

Fortran:
Interface: subroutine acc_wait(arg)
   integer(acc_handle_kind) arg
   subroutine acc_async_wait(arg)
   integer(acc_handle_kind) arg

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.11.

6.10 acc_wait_all – Waits for completion of all asynchronous operations.

Description
This function waits for the completion of all asynchronous operations.

C/C++:
Prototype: acc_wait_all(void);
Prototype (OpenACC 1.0 compatibility):
Prototype (acc_async_wait_all(void);
6.11 acc_wait_all_async – Wait for completion of all asynchronous operations.

**Description**

This function enqueues a wait operation on the queue `async` for any and all asynchronous operations that have been previously enqueued on any queue.

**C/C++**

Prototype: `acc_wait_all_async(int async);`

**Fortran**

Interface: 

```fortran
subroutine acc_wait_all_async(async)
integer(acc_handle_kind) async
end subroutine acc_wait_all_async
```

**Reference:** OpenACC specification v2.6 (https://www.openacc.org), section 3.2.14.

6.12 acc_wait_async – Wait for completion of asynchronous operations.

**Description**

This function enqueues a wait operation on queue `async` for any and all asynchronous operations enqueued on queue `arg`.

**C/C++**

Prototype: `acc_wait_async(int arg, int async);`

**Fortran**

Interface: 

```fortran
subroutine acc_wait_async(arg, async)
integer(acc_handle_kind) arg, async
end subroutine acc_wait_async
```

**Reference:** OpenACC specification v2.6 (https://www.openacc.org), section 3.2.12.

6.13 acc_init – Initialize runtime for a specific device type.

**Description**

This function initializes the runtime for the device type specified in `devicetype`.

**C/C++**

Prototype: `acc_init(acc_device_t devicetype);`

**Fortran**

Interface: 

```fortran
subroutine acc_init(devicetype)
integer(acc_device_kind) devicetype
end subroutine acc_init
```

**Reference:** OpenACC specification v2.6 (https://www.openacc.org), section 3.2.7.
6.14 acc_shutdown – Shuts down the runtime for a specific device type.

Description
This function shuts down the runtime for the device type specified in devicetype.

C/C++:
Prototype: acc_shutdown(acc_device_t devicetype);

Fortran:
Interface: subroutine acc_shutdown(devicetype)
integer(acc_device_kind) devicetype

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.8.

6.15 acc_on_device – Whether executing on a particular device

Description:
This function returns whether the program is executing on a particular device specified in devicetype. In C/C++ a non-zero value is returned to indicate the device is executing on the specified device type. In Fortran, true is returned. If the program is not executing on the specified device type C/C++ returns zero, while Fortran returns false.

C/C++:
Prototype: acc_on_device(acc_device_t devicetype);

Fortran:
Interface: function acc_on_device(devicetype)
integer(acc_device_kind) devicetype
logical acc_on_device

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.17.

6.16 acc_malloc – Allocate device memory.

Description
This function allocates bytes bytes of device memory. It returns the device address of the allocated memory.

C/C++:
Prototype: d_void* acc_malloc(size_t bytes);

Fortran:
Interface: type(c_ptr) function acc_malloc(bytes)
integer(c_size_t), value :: bytes

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.18.
openacc specification v3.3 (https://www.openacc.org), section 3.2.16.
6.17 acc_free – Free device memory.

Description
Free previously allocated device memory at the device address data_dev.

C/C++:
Prototype:    void acc_free(d_void *data_dev);

Fortran:
Interface:    subroutine acc_free(data_dev)
              type(c_ptr), value :: data_dev

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.19.
openacc specification v3.3 (https://www.openacc.org), section 3.2.17.

6.18 acc_copyin – Allocate device memory and copy host memory to it.

Description
In C/C++, this function allocates len bytes of device memory and maps it to the specified host address in a. The device address of the newly allocated device memory is returned.

In Fortran, two (2) forms are supported. In the first form, a specifies a contiguous array section. The second form a specifies a variable or array element and len specifies the length in bytes.

C/C++:
Prototype:    void *acc_copyin(h_void *a, size_t len);
Prototype:    void *acc_copyin_async(h_void *a, size_t len, int async);

Fortran:
Interface:    subroutine acc_copyin(a)
              type, dimension(:, :, ...) :: a
Interface:    subroutine acc_copyin(a, len)
              type, dimension(:, :, ...) :: a
              integer len
Interface:    subroutine acc_copyin_async(a, async)
              type, dimension(:, :, ...) :: a
              integer(acc_handle_kind) :: async
Interface:    subroutine acc_copyin_async(a, len, async)
              type, dimension(:, :, ...) :: a
              integer len
              integer(acc_handle_kind) :: async

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.20.
6.19 acc_present_or_copyin — If the data is not present on
the device, allocate device memory and copy from host
memory.

Description
This function tests if the host data specified by \texttt{a} and of length \texttt{len} is present
or not. If it is not present, device memory is allocated and the host memory
copied. The device address of the newly allocated device memory is returned.

In Fortran, two (2) forms are supported. In the first form, \texttt{a} specifies a con-
tiguous array section. The second form \texttt{a} specifies a variable or array element
and \texttt{len} specifies the length in bytes.

Note that \texttt{acc_present_or_copyin} and \texttt{acc_pcopyin} exist for backward com-
patibility with OpenACC 2.0; use Section 6.18 [acc_copyin], page 69, instead.

\textbf{C/C++:}

\textit{Prototype:}\hspace{1cm} void *acc_present_or_copyin(h_void *a, size_t len);
\textit{Prototype:}\hspace{1cm} void *acc_pcopyin(h_void *a, size_t len);

\textbf{Fortran:}

\textit{Interface:}\hspace{1cm} subroutine acc_present_or_copyin(a)
  type, dimension(:,:) ... :: a
\textit{Interface:}\hspace{1cm} subroutine acc_present_or_copyin(a, len)
  type, dimension(:,:) ... :: a
  integer len
\textit{Interface:}\hspace{1cm} subroutine acc_pcopyin(a)
  type, dimension(:,:) ... :: a
\textit{Interface:}\hspace{1cm} subroutine acc_pcopyin(a, len)
  type, dimension(:,:) ... :: a
  integer len

\textbf{Reference:} OpenACC specification v2.6 (https://www.openacc.org), section 3.2.20.

6.20 acc_create — Allocate device memory and map it to
host memory.

Description
This function allocates device memory and maps it to host memory specified by
the host address \texttt{a} with a length of \texttt{len} bytes. In C/C++, the function returns
the device address of the allocated device memory.

In Fortran, two (2) forms are supported. In the first form, \texttt{a} specifies a con-
tiguous array section. The second form \texttt{a} specifies a variable or array element
and \texttt{len} specifies the length in bytes.

\textbf{C/C++:}

\textit{Prototype:}\hspace{1cm} void *acc_create(h_void *a, size_t len);
\textit{Prototype:}\hspace{1cm} void *acc_create_async(h_void *a, size_t len, int
async);

\textbf{Fortran:}

\textit{Interface:}\hspace{1cm} subroutine acc_create(a)
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6.21 acc_present_or_create – If the data is not present on the device, allocate device memory and map it to host memory.

Description
This function tests if the host data specified by a and of length len is present or not. If it is not present, device memory is allocated and mapped to host memory. In C/C++, the device address of the newly allocated device memory is returned.

In Fortran, two (2) forms are supported. In the first form, a specifies a contiguous array section. The second form a specifies a variable or array element and len specifies the length in bytes.

Note that acc_present_or_create and acc_pcreate exist for backward compatibility with OpenACC 2.0; use Section 6.20 [acc_create], page 70, instead.

C/C++:

Prototype: void *acc_present_or_create(h_void *a, size_t len)
Prototype: void *acc_pcreate(h_void *a, size_t len)

Fortran:

Interface: subroutine acc_present_or_create(a)
            type, dimension(:[,:]...) :: a
Interface: subroutine acc_present_or_create(a, len)
            type, dimension(:[,:]...) :: a
            integer len
Interface: subroutine acc_pcreate(a)
            type, dimension(:[,:]...) :: a
Interface: subroutine acc_pcreate(a, len)
            type, dimension(:[,:]...) :: a
            integer len

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.21.
6.22 acc_copyout – Copy device memory to host memory.

Description
This function copies mapped device memory to host memory which is specified by host address a for a length len bytes in C/C++.

In Fortran, two (2) forms are supported. In the first form, a specifies a contiguous array section. The second form a specifies a variable or array element and len specifies the length in bytes.

C/C++:

Prototype: acc_copyout(h_void *a, size_t len);
Prototype: acc_copyout_async(h_void *a, size_t len, int async);
Prototype: acc_copyout_finalize(h_void *a, size_t len);
Prototype: acc_copyout_finalize_async(h_void *a, size_t len, int async);

Fortran:

Interface: subroutine acc_copyout(a)
           type, dimension(:,:,:...) :: a
Interface: subroutine acc_copyout(a, len)
           type, dimension(:,:,:...) :: a
           integer len
Interface: subroutine acc_copyout_async(a, async)
           type, dimension(:,:,:...) :: a
           integer(acc_handle_kind) :: async
Interface: subroutine acc_copyout_async(a, len, async)
           type, dimension(:,:,:...) :: a
           integer len
           integer(acc_handle_kind) :: async
Interface: subroutine acc_copyout_finalize(a)
           type, dimension(:,:,:...) :: a
Interface: subroutine acc_copyout_finalize(a, len)
           type, dimension(:,:,:...) :: a
           integer len
Interface: subroutine acc_copyout_finalize_async(a, async)
           type, dimension(:,:,:...) :: a
           integer(acc_handle_kind) :: async
Interface: subroutine acc_copyout_finalize_async(a, len, async)
           type, dimension(:,:,:...) :: a
           integer len
           integer(acc_handle_kind) :: async

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.22.
6.23 acc_delete – Free device memory.

Description
This function frees previously allocated device memory specified by the device address \( a \) and the length of \( len \) bytes.

In Fortran, two (2) forms are supported. In the first form, \( a \) specifies a contiguous array section. The second form \( a \) specifies a variable or array element and \( len \) specifies the length in bytes.

C/C++:

Prototype: acc_delete(h_void *a, size_t len);
Prototype: acc_delete_async(h_void *a, size_t len, int async);
Prototype: acc_delete_finalize(h_void *a, size_t len);
Prototype: acc_delete_finalize_async(h_void *a, size_t len, int async);

Fortran:

Interface: subroutine acc_delete(a)
type, dimension(:,:,:,:) :: a
Interface: subroutine acc_delete(a, len)
type, dimension(:,:,:,:) :: a
integer len
Interface: subroutine acc_delete_async(a, async)
type, dimension(:,:,:,:) :: a
integer(acc_handle_kind) :: async
Interface: subroutine acc_delete_async(a, len, async)
type, dimension(:,:,:,:) :: a
integer len
integer(acc_handle_kind) :: async
Interface: subroutine acc_delete_finalize(a)
type, dimension(:,:,:,:) :: a
Interface: subroutine acc_delete_finalize(a, len)
type, dimension(:,:,:,:) :: a
integer len
Interface: subroutine acc_delete_async_finalize(a, async)
type, dimension(:,:,:,:) :: a
integer(acc_handle_kind) :: async
Interface: subroutine acc_delete_async_finalize(a, len, async)
type, dimension(:,:,:,:) :: a
integer len
integer(acc_handle_kind) :: async

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.23.
6.24 acc_update_device – Update device memory from mapped host memory.

Description
This function updates the device copy from the previously mapped host memory. The host memory is specified with the host address \( a \) and a length of \( \text{len} \) bytes.

In Fortran, two (2) forms are supported. In the first form, \( a \) specifies a contiguous array section. The second form \( a \) specifies a variable or array element and \( \text{len} \) specifies the length in bytes.

C/C++:

Prototype: acc_update_device(h_void *a, size_t len);
Prototype: acc_update_device(h_void *a, size_t len, async);

Fortran:

Interface: subroutine acc_update_device(a)
            type, dimension(:,:,\ldots) :: a
Interface: subroutine acc_update_device(a, len)
            type, dimension(:,:,\ldots) :: a
            integer len
Interface: subroutine acc_update_device_async(a, async)
            type, dimension(:,:,\ldots) :: a
            integer(acc_handle_kind) :: async
Interface: subroutine acc_update_device_async(a, len, async)
            type, dimension(:,:,\ldots) :: a
            integer len
            integer(acc_handle_kind) :: async

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.24.

6.25 acc_update_self – Update host memory from mapped device memory.

Description
This function updates the host copy from the previously mapped device memory. The host memory is specified with the host address \( a \) and a length of \( \text{len} \) bytes.

In Fortran, two (2) forms are supported. In the first form, \( a \) specifies a contiguous array section. The second form \( a \) specifies a variable or array element and \( \text{len} \) specifies the length in bytes.

C/C++:

Prototype: acc_update_self(h_void *a, size_t len);
Prototype: acc_update_self_async(h_void *a, size_t len, int async);

Fortran:

Interface: subroutine acc_update_self(a)
            type, dimension(:,:,\ldots) :: a
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6.26 acc_map_data – Map previously allocated device memory to host memory.

Description
This function maps previously allocated device and host memory. The device memory is specified with the device address `data_dev`. The host memory is specified with the host address `data_arg` and a length of `bytes`.

C/C++:

Prototype:
```c
void acc_map_data(h_void *data_arg, d_void *data_dev, size_t bytes);
```

Fortran:

Interface:
```fortran
subroutine acc_map_data(data_arg, data_dev, bytes)
  type(*), dimension(*) :: data_arg
  type(c_ptr), value :: data_dev
  integer(c_size_t), value :: bytes
```

Reference:

6.27 acc_unmap_data – Unmap device memory from host memory.

Description
This function unmaps previously mapped device and host memory. The latter specified by `data_arg`.

C/C++:

Prototype:
```c
void acc_unmap_data(h_void *data_arg);
```

Fortran:

Interface:
```fortran
subroutine acc_unmap_data(data_arg)
  type(*), dimension(*) :: data_arg
```

Reference:
OpenACC specification v2.6 (https://www.openacc.org), section 3.2.27. OpenACC specification v3.3 (https://www.openacc.org), section 3.2.22.
6.28 acc_deviceptr – Get device pointer associated with specific host address.

**Description**
This function returns the device address that has been mapped to the host address specified by `data_arg`.

C/C++:

**Prototype:**
```c
void *acc_deviceptr(h_void *data_arg);
```

Fortran:

**Interface:**
```fortran
type(c_ptr) function acc_deviceptr(data_arg)
    type(*), dimension(*) :: data_arg
```

**Reference:**
OpenACC specification v2.6 ([https://www.openacc.org](https://www.openacc.org)), section 3.2.28.
OpenACC specification v3.3 ([https://www.openacc.org](https://www.openacc.org)), section 3.2.23.

6.29 acc_hostptr – Get host pointer associated with specific device address.

**Description**
This function returns the host address that has been mapped to the device address specified by `data_dev`.

C/C++:

**Prototype:**
```c
void *acc_hostptr(d_void *data_dev);
```

Fortran:

**Interface:**
```fortran
type(c_ptr) function acc_hostptr(data_dev)
    type(c_ptr), value :: data_dev
```

**Reference:**
OpenACC specification v2.6 ([https://www.openacc.org](https://www.openacc.org)), section 3.2.29.
OpenACC specification v3.3 ([https://www.openacc.org](https://www.openacc.org)), section 3.2.24.

6.30 acc_is_present – Indicate whether host variable / array is present on device.

**Description**
This function indicates whether the specified host address in `a` and a length of `len` bytes is present on the device. In C/C++, a non-zero value is returned to indicate the presence of the mapped memory on the device. A zero is returned to indicate the memory is not mapped on the device.

In Fortran, two (2) forms are supported. In the first form, `a` specifies a contiguous array section. The second form `a` specifies a variable or array element and `len` specifies the length in bytes. If the host memory is mapped to device memory, then a `true` is returned. Otherwise, a `false` is returned to indicate the mapped memory is not present.

C/C++:

**Prototype:**
```c
int acc_is_present(h_void *a, size_t len);
```
Fortran:

Interface: function acc_is_present(a)
  type, dimension(:[,,:]...) :: a
  logical acc_is_present

Interface: function acc_is_present(a, len)
  type, dimension(:[,,:]...) :: a
  integer len
  logical acc_is_present

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.30.

6.31 acc_memcpy_to_device – Copy host memory to device memory.

Description
This function copies host memory specified by host address of data_host_src
to device memory specified by the device address data_dev_dest for a length of
bytes bytes.

C/C++:

Prototype: void acc_memcpy_to_device(d_void* data_dev_dest,
h_void* data_host_src, size_t bytes);
Prototype: void acc_memcpy_to_device_async(d_void* data_dev_dest,
h_void* data_host_src, size_t bytes, int async_arg);

Fortran:

Interface: subroutine acc_memcpy_to_device(data_dev_dest, &
data_host_src, bytes)
Interface: subroutine acc_memcpy_to_device_async(data_dev_dest, &
data_host_src, bytes, async_arg)
  type(c_ptr), value :: data_dev_dest
  type(*), dimension(*) :: data_host_src
  integer(c_size_t), value :: bytes
  integer(acc_handle_kind), value :: async_arg

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.31

6.32 acc_memcpy_from_device – Copy device memory to host memory.

Description
This function copies device memory specified by device address of data_dev_src
to host memory specified by the host address data_host_dest for a length of
bytes bytes.

C/C++:
Prototype: void acc_memcpy_from_device(h_void* data_host_dest, d_void* data_dev_src, size_t bytes);
Prototype: void acc_memcpy_from_device_async(h_void* data_host_dest, d_void* data_dev_src, size_t bytes, int async_arg);

Fortran:

Interface: subroutine acc_memcpy_from_device(data_host_dest, & data_dev_src, bytes)
Interface: subroutine acc_memcpy_from_device_async(data_host_dest, & data_dev_src, bytes, async_arg)
type(*), dimension(*) :: data_host_dest
type(c_ptr), value :: data_dev_src
integer(c_size_t), value :: bytes
integer(acc_handle_kind), value :: async_arg

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.32.
OpenACC specification v3.3 (https://www.openacc.org), section 3.2.27.

6.33 acc_attach – Let device pointer point to device-pointer target.

Description
This function updates a pointer on the device from pointing to a host-pointer address to pointing to the corresponding device data.

C/C++:

Prototype: void acc_attach(h_void **ptr_addr);
Prototype: void acc_attach_async(h_void **ptr_addr, int async);

Reference: OpenACC specification v2.6 (https://www.openacc.org), section 3.2.34.

6.34 acc_detach – Let device pointer point to host-pointer target.

Description
This function updates a pointer on the device from pointing to a device-pointer address to pointing to the corresponding host data.

C/C++:

Prototype: void acc_detach(h_void **ptr_addr);
Prototype: void acc_detach_async(h_void **ptr_addr, int async);
Prototype: void acc_detach_finalize(h_void **ptr_addr);
6.35 acc_get_current_cuda_device – Get CUDA device handle.

Description
This function returns the CUDA device handle. This handle is the same as used by the CUDA Runtime or Driver API's.

C/C++:
Prototype: void *acc_get_current_cuda_device(void);
Reference: OpenACC specification v2.6 (https://www.openacc.org), section A.2.1.1.

6.36 acc_get_current_cuda_context – Get CUDA context handle.

Description
This function returns the CUDA context handle. This handle is the same as used by the CUDA Runtime or Driver API's.

C/C++:
Prototype: void *acc_get_current_cuda_context(void);
Reference: OpenACC specification v2.6 (https://www.openacc.org), section A.2.1.2.

6.37 acc_get_cuda_stream – Get CUDA stream handle.

Description
This function returns the CUDA stream handle for the queue async. This handle is the same as used by the CUDA Runtime or Driver API's.

C/C++:
Prototype: void *acc_get_cuda_stream(int async);
Reference: OpenACC specification v2.6 (https://www.openacc.org), section A.2.1.3.

6.38 acc_set_cuda_stream – Set CUDA stream handle.

Description
This function associates the stream handle specified by stream with the queue async.
This cannot be used to change the stream handle associated with acc_async_sync.
The return value is not specified.

C/C++:
Prototype: int acc_set_cuda_stream(int async, void *stream);
Reference: OpenACC specification v2.6 (https://www.openacc.org), section A.2.1.4.

**Description:**
This function registers callbacks.

**C/C++:**

**Prototype:**

```c
void acc_prof_register (acc_event_t, acc_prof_callback, acc_register_t);
```

**See also:** Chapter 10 [OpenACC Profiling Interface], page 89,

**Reference:** OpenACC specification v2.6 (https://www.openacc.org), section 5.3.

6.40 acc_prof_unregister – Unregister callbacks.

**Description:**
This function unregisters callbacks.

**C/C++:**

**Prototype:**

```c
void acc_prof_unregister (acc_event_t, acc_prof_callback, acc_register_t);
```

**See also:** Chapter 10 [OpenACC Profiling Interface], page 89,

**Reference:** OpenACC specification v2.6 (https://www.openacc.org), section 5.3.

6.41 acc_prof_lookup – Obtain inquiry functions.

**Description:**
Function to obtain inquiry functions.

**C/C++:**

**Prototype:**

```c
acc_query_fn acc_prof_lookup (const char *);
```

**See also:** Chapter 10 [OpenACC Profiling Interface], page 89,

**Reference:** OpenACC specification v2.6 (https://www.openacc.org), section 5.3.

6.42 acc_register_library – Library registration.

**Description:**
Function for library registration.

**C/C++:**

**Prototype:**

```c
void acc_register_library (acc_prof_reg, acc_prof_reg, acc_prof_lookup_func);
```

**See also:** Chapter 10 [OpenACC Profiling Interface], page 89, Section 7.3 [ACC_PROFLIB], page 81,

**Reference:** OpenACC specification v2.6 (https://www.openacc.org), section 5.3.
7 OpenACC Environment Variables

The variables ACC\_DEVICE\_TYPE and ACC\_DEVICE\_NUM are defined by section 4 of the OpenACC specification in version 2.0. The variable ACC\_PROFLIB is defined by section 4 of the OpenACC specification in version 2.6.

7.1 ACC\_DEVICE\_TYPE

*Description:*
Control the default device type to use when executing compute regions. If unset, the code can be run on any device type, favoring a non-host device type. Supported values in GCC (if compiled in) are
- host
- nvidia
- radeon

*Reference:* OpenACC specification v2.6 (https://www.openacc.org), section 4.1.

7.2 ACC\_DEVICE\_NUM

*Description:*
Control which device, identified by device number, is the default device. The value must be a nonnegative integer less than the number of devices. If unset, device number zero is used.

*Reference:* OpenACC specification v2.6 (https://www.openacc.org), section 4.2.

7.3 ACC\_PROFLIB

*Description:*
Semicolon-separated list of dynamic libraries that are loaded as profiling libraries. Each library must provide at least the acc\_register\_library routine. Each library file is found as described by the documentation of dlopen of your operating system.

*See also:* Section 6.42 [acc\_register\_library], page 80, Chapter 10 [OpenACC Profiling Interface], page 89,

*Reference:* OpenACC specification v2.6 (https://www.openacc.org), section 4.3.
8 NVIDIA CUDA Streams Usage

This applies to the nvptx plugin only.

The library provides elements that perform asynchronous movement of data and asynchronous operation of computing constructs. This asynchronous functionality is implemented by making use of CUDA streams\(^1\).

The primary means by that the asynchronous functionality is accessed is through the use of those OpenACC directives which make use of the **async** and **wait** clauses. When the **async** clause is first used with a directive, it creates a CUDA stream. If an **async-argument** is used with the **async** clause, then the stream is associated with the specified **async-argument**.

Following the creation of an association between a CUDA stream and the **async-argument** of an **async** clause, both the **wait** clause and the **wait** directive can be used. When either the clause or directive is used after stream creation, it creates a rendezvous point whereby execution waits until all operations associated with the **async-argument**, that is, stream, have completed.

Normally, the management of the streams that are created as a result of using the **async** clause, is done without any intervention by the caller. This implies the association between the **async-argument** and the CUDA stream is maintained for the lifetime of the program. However, this association can be changed through the use of the library function `acc_set_cuda_stream`. When the function `acc_set_cuda_stream` is called, the CUDA stream that was originally associated with the **async** clause is destroyed. Caution should be taken when changing the association as subsequent references to the **async-argument** refer to a different CUDA stream.

---

\(^1\) See "Stream Management" in "CUDA Driver API", TRM-06703-001, Version 5.5, for additional information
9 OpenACC Library Interoperability

9.1 Introduction
The OpenACC library uses the CUDA Driver API, and may interact with programs that use the Runtime library directly, or another library based on the Runtime library, e.g., CUBLAS\(^1\). This chapter describes the use cases and what changes are required in order to use both the OpenACC library and the CUBLAS and Runtime libraries within a program.

9.2 First invocation: NVIDIA CUBLAS library API
In this first use case (see below), a function in the CUBLAS library is called prior to any of the functions in the OpenACC library. More specifically, the function `cublasCreate()`. When invoked, the function initializes the library and allocates the hardware resources on the host and the device on behalf of the caller. Once the initialization and allocation has completed, a handle is returned to the caller. The OpenACC library also requires initialization and allocation of hardware resources. Since the CUBLAS library has already allocated the hardware resources for the device, all that is left to do is to initialize the OpenACC library and acquire the hardware resources on the host.

Prior to calling the OpenACC function that initializes the library and allocate the host hardware resources, you need to acquire the device number that was allocated during the call to `cublasCreate()`. The invoking of the runtime library function `cudaGetDevice()` accomplishes this. Once acquired, the device number is passed along with the device type as parameters to the OpenACC library function `acc_set_device_num()`.

Once the call to `acc_set_device_num()` has completed, the OpenACC library uses the context that was created during the call to `cublasCreate()`. In other words, both libraries share the same context.

```c
/* Create the handle */
s = cublasCreate(&h);
if (s != CUBLAS_STATUS_SUCCESS)
{
    fprintf(stderr, "cublasCreate failed %d\n", s);
    exit(EXIT_FAILURE);
}

/* Get the device number */
e = cudaGetDevice(&dev);
if (e != cudaSuccess)
{
    fprintf(stderr, "cudaGetDevice failed %d\n", e);
    exit(EXIT_FAILURE);
}

/* Initialize OpenACC library and use device 'dev' */
acc_set_device_num(dev, acc_device_nvidia);
```

Use Case 1

---

1 See section 2.26, “Interactions with the CUDA Driver API” in "CUDA Runtime API", Version 5.5, and section 2.27, "VDPAU Interoperability", in "CUDA Driver API", TRM-06703-001, Version 5.5, for additional information on library interoperability.
9.3 First invocation: OpenACC library API

In this second use case (see below), a function in the OpenACC library is called prior to any of the functions in the CUBLAS library. More specifically, the function `acc_set_device_num()`.

In the use case presented here, the function `acc_set_device_num()` is used to both initialize the OpenACC library and allocate the hardware resources on the host and the device. In the call to the function, the call parameters specify which device to use and what device type to use, i.e., `acc_device_nvidia`. It should be noted that this is but one method to initialize the OpenACC library and allocate the appropriate hardware resources. Other methods are available through the use of environment variables and these is discussed in the next section.

Once the call to `acc_set_device_num()` has completed, other OpenACC functions can be called as seen with multiple calls being made to `acc_copyin()`. In addition, calls can be made to functions in the CUBLAS library. In the use case a call to `cublasCreate()` is made subsequent to the calls to `acc_copyin()`. As seen in the previous use case, a call to `cublasCreate()` initializes the CUBLAS library and allocates the hardware resources on the host and the device. However, since the device has already been allocated, `cublasCreate()` only initializes the CUBLAS library and allocates the appropriate hardware resources on the host. The context that was created as part of the OpenACC initialization is shared with the CUBLAS library, similarly to the first use case.

```c
dev = 0;

acc_set_device_num(dev, acc_device_nvidia);

/* Copy the first set to the device */
d_X = acc_copyin(&h_X[0], N * sizeof (float));
if (d_X == NULL)
{
    fprintf(stderr, "copyin error h_X\n");
    exit(EXIT_FAILURE);
}

/* Copy the second set to the device */
d_Y = acc_copyin(&h_Y[0], N * sizeof (float));
if (d_Y == NULL)
{
    fprintf(stderr, "copyin error h_Y\n");
    exit(EXIT_FAILURE);
}

/* Create the handle */
s = cublasCreate(&h);
if (s != CUBLAS_STATUS_SUCCESS)
{
    fprintf(stderr, "cublasCreate failed %d\n", s);
    exit(EXIT_FAILURE);
}

/* Perform saxpy using CUBLAS library function */
s = cublasSaxpy(h, N, &alpha, d_X, 1, d_Y, 1);
if (s != CUBLAS_STATUS_SUCCESS)
{
```
fprintf(stderr, "cublasSaxpy failed %d\n", s);
exit(EXIT_FAILURE);
}

/* Copy the results from the device */
acc_memcpy_from_device(&h_Y1[0], d_Y, N * sizeof (float));

Use Case 2

9.4 OpenACC library and environment variables

There are two environment variables associated with the OpenACC library that may be used to control the device type and device number: ACC_DEVICE_TYPE and ACC_DEVICE_NUM, respectively. These two environment variables can be used as an alternative to calling acc_set_device_num(). As seen in the second use case, the device type and device number were specified using acc_set_device_num(). If however, the aforementioned environment variables were set, then the call to acc_set_device_num() would not be required.

The use of the environment variables is only relevant when an OpenACC function is called prior to a call to cudaCreate(). If cudaCreate() is called prior to a call to an OpenACC function, then you must call acc_set_device_num().

---

2 More complete information about ACC_DEVICE_TYPE and ACC_DEVICE_NUM can be found in sections 4.1 and 4.2 of the OpenACC (https://www.openacc.org) Application Programming Interface”, Version 2.6.
10 OpenACC Profiling Interface

10.1 Implementation Status and Implementation-Defined Behavior

We’re implementing the OpenACC Profiling Interface as defined by the OpenACC 2.6 specification. We’re clarifying some aspects here as implementation-defined behavior, while they’re still under discussion within the OpenACC Technical Committee.

This implementation is tuned to keep the performance impact as low as possible for the (very common) case that the Profiling Interface is not enabled. This is relevant, as the Profiling Interface affects all the hot code paths (in the target code, not in the offloaded code). Users of the OpenACC Profiling Interface can be expected to understand that performance is impacted to some degree once the Profiling Interface is enabled: for example, because of the runtime (libgomp) calling into a third-party library for every event that has been registered.

We’re not yet accounting for the fact that OpenACC events may occur during event processing. We just handle one case specially, as required by CUDA 9.0 nvprof, that acc_get_device_type (Section 6.3 [acc_get_device_type], page 63) may be called from acc_ev_device_init_start, acc_ev_device_init_end callbacks.

We’re not yet implementing initialization via a acc_register_library function that is either statically linked in, or dynamically via LD_PRELOAD. Initialization via acc_register_library functions dynamically loaded via the ACC_PROFLIB environment variable does work, as does directly calling acc_prof_register, acc_prof_unregister, acc_prof_lookup.

As currently there are no inquiry functions defined, calls to acc_prof_lookup always returns NULL.

There aren’t separate start, stop events defined for the event types acc_ev_create, acc_ev_delete, acc_ev_alloc, acc_ev_free. It’s not clear if these should be triggered before or after the actual device-specific call is made. We trigger them after.

Remarks about data provided to callbacks:

acc_prof_info.event_type
It’s not clear if for nested event callbacks (for example, acc_ev_enqueue_launch_start as part of a parent compute construct), this should be set for the nested event (acc_ev_enqueue_launch_start), or if the value of the parent construct should remain (acc_ev_compute_construct_start). In this implementation, the value generally corresponds to the innermost nested event type.

acc_prof_info.device_type
- For acc_ev_compute_construct_start, and in presence of an if clause with false argument, this still refers to the offloading device type. It’s not clear if that’s the expected behavior.
- Complementary to the item before, for acc_ev_compute_construct_end, this is set to acc_device_host in presence of an if clause with false argument. It’s not clear if that’s the expected behavior.
acc_prof_info.thread_id
   Always -1; not yet implemented.

acc_prof_info.async
   • Not yet implemented correctly for acc_ev_compute_construct_start.
   • In a compute construct, for host-fallback execution/acc_device_host it always is acc_async_sync. It is unclear if that is the expected behavior.
   • For acc_ev_device_init_start and acc_ev_device_init_end, it will always be acc_async_sync. It is unclear if that is the expected behavior.

acc_prof_info.async_queue
   There is no limited number of asynchronous queues in libgomp. This always has the same value as acc_prof_info.async.

acc_prof_info.src_file
   Always NULL; not yet implemented.

acc_prof_info.func_name
   Always NULL; not yet implemented.

acc_prof_info.line_no
   Always -1; not yet implemented.

acc_prof_info.end_line_no
   Always -1; not yet implemented.

acc_prof_info.func_line_no
   Always -1; not yet implemented.

acc_prof_info.func_end_line_no
   Always -1; not yet implemented.

acc_event_info.event_type, acc_event_info.*.event_type
   Relating to acc_prof_info.event_type discussed above, in this implementation, this will always be the same value as acc_prof_info.event_type.

acc_event_info.*.parent_construct
   • Will be acc_construct_parallel for all OpenACC compute constructs as well as many OpenACC Runtime API calls; should be the one matching the actual construct, or acc_construct_runtime_api, respectively.
   • Will be acc_construct_enter_data or acc_construct_exit_data when processing variable mappings specified in OpenACC declare directives; should be acc_construct_declare.
   • For implicit acc_ev_device_init_start, acc_ev_device_init_end, and explicit as well as implicit acc_ev_alloc, acc_ev_free, acc_ev_enqueue_upload_start, acc_ev_enqueue_upload_end, acc_ev_enqueue_download_start, and acc_ev_enqueue_download_end, will be acc_construct_parallel; should reflect the real parent construct.

acc_event_info.*.implicit
   For acc_ev_alloc, acc_ev_free, acc_ev_enqueue_upload_start, acc_ev_enqueue_upload_end, acc_ev_enqueue_download_start, and
acc_ev_enqueue_download_end, this currently will be 1 also for explicit usage.

acc_event_info.data_event.var_name
Always NULL; not yet implemented.

acc_event_info.data_event.host_ptr
For acc_ev_alloc, and acc_ev_free, this is always NULL.

typedef union acc_api_info
... as printed in 5.2.3. Third Argument: API-Specific Information. This should obviously be typedef struct acc_api_info.

acc_api_info.device_api
Possibly not yet implemented correctly for acc_ev_compute_construct_start, acc_ev_device_init_start, acc_ev_device_init_end: will always be acc_device_api_none for these event types. For acc_ev_enter_data_start, it will be acc_device_api_none in some cases.

acc_api_info.device_type
Always the same as acc_prof_info.device_type.

acc_api_info.vendor
Always -1; not yet implemented.

acc_api_info.device_handle
Always NULL; not yet implemented.

acc_api_info.context_handle
Always NULL; not yet implemented.

acc_api_info.async_handle
Always NULL; not yet implemented.

Remarks about certain event types:

acc_ev_device_init_start, acc_ev_device_init_end
• When a compute construct triggers implicit acc_ev_device_init_start and acc_ev_device_init_end events, they currently aren’t nested within the corresponding acc_ev_compute_construct_start and acc_ev_compute_construct_end, but they’re currently observed before acc_ev_compute_construct_start. It’s not clear what to do: the standard asks us provide a lot of details to the acc_ev_compute_construct_start callback, without (implicitly) initializing a device before?
• Callbacks for these event types will not be invoked for calls to the acc_set_device_type and acc_set_device_num functions. It’s not clear if they should be.

acc_ev_enter_data_start, acc_ev_enter_data_end, acc_ev_exit_data_start, acc_ev_exit_data_end
• Callbacks for these event types will also be invoked for OpenACC host_data constructs. It’s not clear if they should be.
Callbacks for these event types will also be invoked when processing variable mappings specified in OpenACC `declare` directives. It’s not clear if they should be.

Callbacks for the following event types will be invoked, but dispatch and information provided therein has not yet been thoroughly reviewed:

- `acc_ev_alloc`
- `acc_ev_free`
- `acc_ev_update_start`, `acc_ev_update_end`
- `acc_ev_enqueue_upload_start`, `acc_ev_enqueue_upload_end`
- `acc_ev_enqueue_download_start`, `acc_ev_enqueue_download_end`

During device initialization, and finalization, respectively, callbacks for the following event types will not yet be invoked:

- `acc_ev_alloc`
- `acc_ev_free`

Callbacks for the following event types have not yet been implemented, so currently won’t be invoked:

- `acc_ev_device_shutdown_start`, `acc_ev_device_shutdown_end`
- `acc_ev_runtime_shutdown`
- `acc_ev_create`, `acc_ev_delete`
- `acc_ev_wait_start`, `acc_ev_wait_end`

For the following runtime library functions, not all expected callbacks will be invoked (mostly concerning implicit device initialization):

- `acc_get_num_devices`
- `acc_set_device_type`
- `acc_get_device_type`
- `acc_set_device_num`
- `acc_get_device_num`
- `acc_init`
- `acc_shutdown`

Aside from implicit device initialization, for the following runtime library functions, no callbacks will be invoked for shared-memory offloading devices (it’s not clear if they should be):

- `acc_malloc`
- `acc_free`
- `acc_copyin`, `acc_present_or_copyin`, `acc_copyin_async`
- `acc_create`, `acc_present_or_create`, `acc_create_async`
- `acc_copyout`, `acc_copyout_async`, `acc_copyout_finalize`, `acc_copyout_finalize_async`
- `acc_delete`, `acc_delete_async`, `acc_delete_finalize`, `acc_delete_finalize_async`
- `acc_update_device`, `acc_update_device_async`
- `acc_update_self`, `acc_update_self_async`
- `acc_map_data`, `acc_unmap_data`
- `acc_memcpy_to_device`, `acc_memcpy_to_device_async`
- `acc_memcpy_from_device`, `acc_memcpy_from_device_async`
11 OpenMP-Implementation Specifics

11.1 Implementation-defined ICV Initialization

affinity-format-var See Section 4.2 [OMP_AFFINITY_FORMAT], page 50.
def-allocator-var See Section 4.1 [OMP_ALLOCATOR], page 49.
max-active-levels-var See Section 4.8 [OMP_MAX_ACTIVE_LEVELS], page 53.
dyn-var See Section 4.7 [OMP_DYNAMIC], page 52.
nthreads-var See Section 4.12 [OMP_NUM_THREADS], page 54.
num-devices-var Number of non-host devices found by GCC’s run-time library.
nnum-procs-var The number of CPU cores on the initial device, except that
affinity settings might lead to a smaller number. On non-host
devices, the value of the nthreads-var ICV.

place-partition-var See Section 4.14 [OMP_PLACES], page 55.
run-sched-var See Section 4.16 [OMP_SCHEDULE], page 56.
stacksize-var See Section 4.15 [OMP_STACKSIZE], page 56.
thread-limit-var See Section 4.18 [OMP_TEAMS_THREAD_LIMIT], page 57,
wait-policy-var See Section 4.20 [OMP_WAIT_POLICY], page 57, and Section
4.24 [GOMP_SPINCOUNT], page 59.

11.2 OpenMP Context Selectors

vendor is always gnu. References are to the GCC manual.

For the host compiler, kind always matches host; for the offloading architectures AMD
GCN and Nvidia PTX, kind always matches gpu. For the x86 family of computers, AMD
GCN and Nvidia PTX the following traits are supported in addition; while OpenMP is
supported on more architectures, GCC currently does not match any arch or isa traits for
those.

arch
x86, x86_64, i386, i486, i586, i686, ia32

isa
See -m... flags in “x86
Options” (without -m)
amdgcnc, gcn
See -march= in “AMD
GCN Options”
nvptx, nvptx64
See -march= in “Nvidia
PTX Options”

11.3 Memory allocation

The description below applies to:

• Explicit use of the OpenMP API routines, see Section 3.11 [Memory Management
  Routines], page 39.
• The allocate clause, except when the allocator modifier is a constant expression
  with value omp_default_mem_alloc and no align modifier has been specified. (In
  that case, the normal malloc allocation is used.)

---

1 Additionally, gfx803 is supported as an alias for fiji.
• Using the `allocate` directive for automatic/stack variables, except when the `allocator` clause is a constant expression with value `omp_default_mem_alloc` and no `align` clause has been specified. (In that case, the normal allocation is used: stack allocation and, sometimes for Fortran, also `malloc` [depending on flags such as `-fstack-arrays`].)

• Using the `allocate` directive for variable in static memory is currently not supported (compile time error).

• In Fortran, the `allocators` directive and the executable `allocate` directive for Fortran pointers and allocatables is supported, but requires that files containing those directives has to be compiled with `-fopenmp-allocators`. Additionally, all files that might explicitly or implicitly deallocate memory allocated that way must also be compiled with that option.

For the available predefined allocators and, as applicable, their associated predefined memory spaces and for the available traits and their default values, see Section 4.1 [OMP_ALLOCATOR], page 49. Predefined allocators without an associated memory space use the `omp_default_mem_space` memory space.

For the memory spaces, the following applies:

• `omp_default_mem_space` is supported

• `omp_const_mem_space` maps to `omp_default_mem_space`

• `omp_low_lat_mem_space` is only available on supported devices, and maps to `omp_default_mem_space` otherwise.

• `omp_large_cap_mem_space` maps to `omp_default_mem_space`, unless the memkind library is available

• `omp_high_bw_mem_space` maps to `omp_default_mem_space`, unless the memkind library is available

On Linux systems, where the memkind library ([https://github.com/memkind/memkind](https://github.com/memkind/memkind)) (libmemkind.so.0) is available at runtime, it is used when creating memory allocators requesting

• the memory space `omp_high_bw_mem_space`

• the memory space `omp_large_cap_mem_space`

• the `partition` trait interleaved; note that for `omp_large_cap_mem_space` the allocation will not be interleaved

On Linux systems, where the numa library ([https://github.com/numactl/numactl](https://github.com/numactl/numactl)) (libnuma.so.1) is available at runtime, it used when creating memory allocators requesting

• the `partition` trait nearest, except when both the libmemkind library is available and the memory space is either `omp_large_cap_mem_space` or `omp_high_bw_mem_space`

Note that the numa library will round up the allocation size to a multiple of the system page size; therefore, consider using it only with large data or by sharing allocations via the `pool_size` trait. Furthermore, the Linux kernel does not guarantee that an allocation will always be on the nearest NUMA node nor that after reallocation the same node will be used. Note additionally that, on Linux, the default setting of the memory placement policy is to use the current node; therefore, unless the memory placement policy has been
overridden, the \texttt{partition} trait \texttt{environment} (the default) will be effectively a \texttt{nearest} allocation.

Additional notes regarding the traits:

\begin{itemize}
  \item The \texttt{pinned} trait is supported on Linux hosts, but is subject to the OS \texttt{ulimit/rlimit} locked memory settings.
  \item The default for the \texttt{pool\_size} trait is no pool and for every (re)allocation the associated library routine is called, which might internally use a memory pool.
  \item For the \texttt{partition} trait, the partition part size will be the same as the requested size (i.e. \texttt{interleaved} or \texttt{blocked} has no effect), except for \texttt{interleaved} when the memkind library is available. Furthermore, for \texttt{nearest} and unless the numa library is available, the memory might not be on the same NUMA node as thread that allocated the memory; on Linux, this is in particular the case when the memory placement policy is set to preferred.
  \item The \texttt{access} trait has no effect such that memory is always accessible by all threads.
  \item The \texttt{sync\_hint} trait has no effect.
\end{itemize}

See also: Chapter 12 [Offload-Target Specifics], page 99,
12 Offload-Target Specifics

The following sections present notes on the offload-target specifics

12.1 AMD Radeon (GCN)

On the hardware side, there is the hierarchy (fine to coarse):

- work item (thread)
- wavefront
- work group
- compute unit (CU)

All OpenMP and OpenACC levels are used, i.e.

- OpenMP’s simd and OpenACC’s vector map to work items (thread)
- OpenMP’s threads (“parallel”) and OpenACC’s workers map to wavefronts
- OpenMP’s teams and OpenACC’s gang use a threadpool with the size of the number of teams or gangs, respectively.

The used sizes are

- Number of teams is the specified num_teams (OpenMP) or num_gangs (OpenACC) or otherwise the number of CU. It is limited by two times the number of CU.
- Number of wavefronts is 4 for gfx900 and 16 otherwise; num_threads (OpenMP) and num_workers (OpenACC) overrides this if smaller.
- The waveform has 102 scalars and 64 vectors
- Number of workitems is always 64
- The hardware permits maximally 40 workgroups/CU and 16 wavefronts/workgroup up to a limit of 40 wavefronts in total per CU.
- 80 scalars registers and 24 vector registers in non-kernel functions (the chosen procedure-calling API).
- For the kernel itself: as many as register pressure demands (number of teams and number of threads, scaled down if registers are exhausted)

The implementation remark:

- I/O within OpenMP target regions and OpenACC compute regions is supported using the C library printf functions and the Fortran print/write statements.
- Reverse offload regions (i.e. target regions with device(ancestor:1)) are processed serially per target region such that the next reverse offload region is only executed after the previous one returned.
- OpenMP code that has a requires directive with unified_shared_memory is only supported if all AMD GPUs have the HSA_AMD_SYSTEM_INFO_SVM_ACCESSIBLE_BY_DEFAULT property; for discrete GPUs, this may require setting the HSA_XNACK environment variable to ‘1’; for systems with both an APU and a discrete GPU that does not support XNACK, consider using ROCR_VISIBLE_DEVICES to enable only the APU. If not supported, all AMD GPU devices are removed from the list of available devices (“host fallback”).
• The available stack size can be changed using the `GCN_STACK_SIZE` environment variable; the default is 32 kiB per thread.
• Low-latency memory (omp_low_lat_mem_space) is supported when the the access trait is set to `cgroup`. The default pool size is automatically scaled to share the 64 kiB LDS memory between the number of teams configured to run on each compute-unit, but may be adjusted at runtime by setting environment variable `GOMP_GCN_LOWLAT_POOL=bytes`.
• `omp_low_lat_mem_alloc` cannot be used with true low-latency memory because the definition implies the `omp_atv_all` trait; main graphics memory is used instead.
• `omp_cgroup_mem_alloc`, `omp_pteam_mem_alloc`, and `omp_thread_mem_alloc`, all use low-latency memory as first preference, and fall back to main graphics memory when the low-latency pool is exhausted.

12.2 nvptx

On the hardware side, there is the hierarchy (fine to coarse):
• thread
• warp
• thread block
• streaming multiprocessor

All OpenMP and OpenACC levels are used, i.e.
• OpenMP’s simd and OpenACC’s vector map to threads
• OpenMP’s threads (“parallel”) and OpenACC’s workers map to warps
• OpenMP’s teams and OpenACC’s gang use a threadpool with the size of the number of teams or gangs, respectively.

The used sizes are
• The `warp_size` is always 32
• CUDA kernel launched: `dim={#teams,1,1}, blocks={#threads,warp_size,1}`.
• The number of teams is limited by the number of blocks the device can host simultaneously.

Additional information can be obtained by setting the environment variable to `GOMP_DEBUG=1` (very verbose; grep for `kernel.*launch` for launch parameters).

GCC generates generic PTX ISA code, which is just-in-time compiled by CUDA, which caches the JIT in the user’s directory (see CUDA documentation; can be tuned by the environment variables `CUDA_CACHE_{DISABLE,MAXSIZE,PATH}`).

Note: While PTX ISA is generic, the `-mptx=` and `-march=` commandline options still affect the used PTX ISA code and, thus, the requirements on CUDA version and hardware.

The implementation remark:
• I/O within OpenMP target regions and OpenACC compute regions is supported using the C library `printf` functions. Additionally, the Fortran `print/write` statements are supported within OpenMP target regions, but not yet within OpenACC compute regions.
• Compilation OpenMP code that contains requires reverse_offload requires at least 
-march=sm_35, compiling for -march=sm_30 is not supported.

• For code containing reverse offload (i.e. target regions with device(ancestor:1)),
there is a slight performance penalty for all target regions, consisting mostly of shut-
down delay Per device, reverse offload regions are processed serially such that the next
reverse offload region is only executed after the previous one returned.

• OpenMP code that has a requires directive with unified_shared_memory runs on
nvptx devices if and only if all of those support the pageableMemoryAccess prop-
erty;\(^1\) otherwise, all nvptx device are removed from the list of available devices (“host
fallback”).

• The default per-warp stack size is 128 kiB; see also -msoft-stack in the GCC manual.

• The OpenMP routines omp_target_memcpy_rect and omp_target_memcpy_rect_
async and the target update directive for non-contiguous list items will use the 2D
and 3D memory-copy functions of the CUDA library. Higher dimensions will call
those functions in a loop and are therefore supported.

• Low-latency memory (omp_low_lat_mem_space) is supported when the the access
trait is set to cgroup, the ISA is at least sm_53, and the PTX version is at least
4.1. The default pool size is 8 kiB per team, but may be adjusted at runtime by
setting environment variable GOMP_NVPTX_LOWLAT_POOL=bytes. The maximum value
is limited by the available hardware, and care should be taken that the selected pool
size does not unduly limit the number of teams that can run simultaneously.

• omp_low_lat_mem_alloc cannot be used with true low-latency memory because the
definition implies the omp_atv_all trait; main graphics memory is used instead.

• omp_cgroup_mem_alloc, omp_pteam_mem_alloc, and omp_thread_mem_alloc, all use
low-latency memory as first preference, and fall back to main graphics memory when
the low-latency pool is exhausted.

\(^1\) [https://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html#um-requirements](https://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html#um-requirements)
13 The libgomp ABI

The following sections present notes on the external ABI as presented by libgomp. Only maintainers should need them.

13.1 Implementing MASTER construct

```c
if (omp_get_thread_num () == 0)
  block
```

Alternately, we generate two copies of the parallel subfunction and only include this in the version run by the primary thread. Surely this is not worthwhile though...

13.2 Implementing CRITICAL construct

Without a specified name,

```c
void GOMP_critical_start (void);
void GOMP_critical_end (void);
```

so that we don’t get COPY relocations from libgomp to the main application.

With a specified name, use omp_set_lock and omp_unset_lock with name being transformed into a variable declared like

```c
omp_lock_t gomp_critical_user_<name> __attribute__((common))
```

Ideally the ABI would specify that all zero is a valid unlocked state, and so we wouldn’t need to initialize this at startup.

13.3 Implementing ATOMIC construct

The target should implement the `__sync` builtins.

Failing that we could add

```c
void GOMP_atomic_enter (void)
void GOMP_atomic_exit (void)
```

which reuses the regular lock code, but with yet another lock object private to the library.

13.4 Implementing FLUSH construct

Expands to the `__sync_synchronize` builtin.

13.5 Implementing BARRIER construct

```c
void GOMP_barrier (void)
```

13.6 Implementing THREADPRIVATE construct

In most cases we can map this directly to `__thread`. Except that OMP allows constructors for C++ objects. We can either refuse to support this (how often is it used?) or we can implement something akin to `.ctors`.

Even more ideally, this ctor feature is handled by extensions to the main pthreads library. Failing that, we can have a set of entry points to register ctor functions to be called.
13.7 Implementing PRIVATE clause

In association with a PARALLEL, or within the lexical extent of a PARALLEL block, the variable becomes a local variable in the parallel subfunction.

In association with FOR or SECTIONS blocks, create a new automatic variable within the current function. This preserves the semantic of new variable creation.

13.8 Implementing FIRSTPRIVATE LASTPRIVATE COPYIN and COPYPRIVATE clauses

This seems simple enough for PARALLEL blocks. Create a private struct for communicating between the parent and subfunction. In the parent, copy in values for scalar and "small" structs; copy in addresses for others TREE_ADDRESSABLE types. In the subfunction, copy the value into the local variable.

It is not clear what to do with bare FOR or SECTION blocks. The only thing I can figure is that we do something like:

```c
#pragma omp for firstprivate(x) lastprivate(y)
for (int i = 0; i < n; ++i)
body;
```

which becomes

```c
{
int x = x, y;
// for stuff
if (i == n)
y = y;
}
```

where the "x=x" and "y=y" assignments actually have different uids for the two variables, i.e. not something you could write directly in C. Presumably this only makes sense if the "outer" x and y are global variables.

COPYPRIVATE would work the same way, except the structure broadcast would have to happen via SINGLE machinery instead.

13.9 Implementing REDUCTION clause

The private struct mentioned in the previous section should have a pointer to an array of the type of the variable, indexed by the thread’s team_id. The thread stores its final value into the array, and after the barrier, the primary thread iterates over the array to collect the values.

13.10 Implementing PARALLEL construct

```c
#pragma omp parallel
{
body;
}
```

becomes

```c
void subfunction (void *data)
{
```
use data;
body;
}

setup data;
GOMP_parallel_start (subfunction, &data, num_threads);
subfunction (&data);
GOMP_parallel_end ()

void GOMP_parallel_start (void (*fn)(void *), void *data, unsigned num_threads)

The FN argument is the subfunction to be run in parallel.
The DATA argument is a pointer to a structure used to communicate data in and out
of the subfunction, as discussed above with respect to FIRSTPRIVATE et al.
The NUM_THREADS argument is 1 if an IF clause is present and false, or the value of
the NUM_THREADS clause, if present, or 0.
The function needs to create the appropriate number of threads and/or launch them
from the dock. It needs to create the team structure and assign team ids.
void GOMP_parallel_end (void)
Tears down the team and returns us to the previous omp_in_parallel() state.

13.11 Implementing FOR construct

#pragma omp parallel for
for (i = lb; i <= ub; i++)
  body;

becomes
void subfunction (void *data)
{
  long _s0, _e0;
  while (GOMP_loop_static_next (&_s0, &_e0))
  {
    long _e1 = _e0, i;
    for (i = _s0; i < _e1; i++)
      body;
  }
  GOMP_loop_end_nowait ();
}

GOMP_parallel_loop_static (subfunction, NULL, 0, lb, ub+1, 1, 0);
subfunction (NULL);
GOMP_parallel_end ();
#pragma omp for schedule(runtime)
for (i = 0; i < n; i++)
  body;

becomes
{
  long i, _s0, _e0;
  if (GOMP_loop_runtime_start (0, n, 1, &_s0, &_e0))
    do {
      long _e1 = _e0;
      for (i = _s0, i < _e0; i++)
        body;
    } while (GOMP_loop_runtime_next (&_s0, _&e0));
Note that while it looks like there is trickiness to propagating a non-constant STEP, there isn’t really. We’re explicitly allowed to evaluate it as many times as we want, and any variables involved should automatically be handled as PRIVATE or SHARED like any other variables. So the expression should remain evaluable in the subfunction. We can also pull it into a local variable if we like, but since it’s supposed to remain unchanged, we can also not if we like.

If we have SCHEDULE(STATIC), and no ORDERED, then we ought to be able to get away with no work-sharing context at all, since we can simply perform the arithmetic directly in each thread to divide up the iterations. Which would mean that we wouldn’t need to call any of these routines.

There are separate routines for handling loops with an ORDERED clause. Bookkeeping for that is non-trivial...

### 13.12 Implementing ORDERED construct

```c
void GOMP_ordered_start (void)
void GOMP_ordered_end (void)
```

### 13.13 Implementing SECTIONS construct

A block as

```c
#pragma omp sections
{
#pragma omp section
stmt1;
#pragma omp section
stmt2;
#pragma omp section
stmt3;
}
```

becomes

```c
for (i = GOMP_sections_start (3); i != 0; i = GOMP_sections_next ())
switch (i)
{
  case 1:
    stmt1;
    break;
  case 2:
    stmt2;
    break;
  case 3:
    stmt3;
    break;
}
GOMP_barrier ();
```

### 13.14 Implementing SINGLE construct

A block like

```c
#pragma omp single
```
{  
    body;  
}

becomes
if (GOMP_single_start ())
    body;
GOMP_barrier ();

while
    #pragma omp single copyprivate(x)
    body;

becomes
    datap = GOMP_single_copy_start ();
    if (datap == NULL)
        {
            body;
            data.x = x;
            GOMP_single_copy_end (&data);
        }
    else
        x = datap->x;
    GOMP_barrier ();

13.15 Implementing OpenACC’s PARALLEL construct
    void GOACC_parallel ()
14 Reporting Bugs

Bugs in the GNU Offloading and Multi Processing Runtime Library should be reported via Bugzilla (https://gcc.gnu.org/bugzilla/). Please add "openacc", or "openmp", or both to the keywords field in the bug report, as appropriate.
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Version 3, 29 June 2007

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