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Chapter 1.
MODULES

Here is a list of all modules:

‣ Half Precision Intrinsics
  ▪ Half Arithmetic Functions
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  ▪ Half Precision Conversion And Data Movement
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‣ Mathematical Functions
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‣ Single Precision Intrinsics
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‣ Integer Intrinsics
  ▪ Type Casting Intrinsics
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1.1. Half Precision Intrinsics

This section describes half precision intrinsic functions that are only supported in device code. To use these functions include the header file cuda_fp16.h in your program.

Half Arithmetic Functions

Half2 Arithmetic Functions
Half Comparison Functions

Half2 Comparison Functions

Half Precision Conversion And Data Movement

Half Math Functions

Half2 Math Functions

1.1.1. Half Arithmetic Functions

Half Precision Intrinsics

To use these functions include the header file cuda_fp16.h in your program.

__device__ __half __habs (const __half a)
Calculates the absolute value of input half number and returns the result.

Parameters
a
- half. Is only being read.

Returns
half

The absolute value of a.

Description
Calculates the absolute value of input half number and returns the result.

__device__ __half __hadd (const __half a, const __half b)
Performs half addition in round-to-nearest-even mode.

Parameters
a
- half. Is only being read.

b
- half. Is only being read.
Returns
half
  ▶ The sum of a and b.

Description
Performs half addition of inputs a and b, in round-to-nearest-even mode.
DEEPLEARN-SRM_REQ-94

__device__ __half __hadd_sat (const __half a, const __half b)
Performs half addition in round-to-nearest-even mode, with saturation to [0.0, 1.0].

Parameters
a
  - half. Is only being read.
b
  - half. Is only being read.

Returns
half
  ▶ The sum of a and b, with respect to saturation.

Description
Performs half add of inputs a and b, in round-to-nearest-even mode, and clamps the result to range [0.0, 1.0]. NaN results are flushed to +0.0.

__device__ __half __hdiv (const __half a, const __half b)
Performs half division in round-to-nearest-even mode.

Parameters
a
  - half. Is only being read.
b
  - half. Is only being read.

Returns
half
The result of dividing \(a\) by \(b\).

**Description**

Divides \(\text{half}\) input \(a\) by input \(b\) in round-to-nearest mode. DEEPLEARN-SRM_REQ-98

```c
__device__ __half __hfma (const __half a, const __half b, const __half c)
```

Performs \(\text{half}\) fused multiply-add in round-to-nearest-even mode.

**Parameters**

- \(a\)
  - \(\text{half}\). Is only being read.
- \(b\)
  - \(\text{half}\). Is only being read.
- \(c\)
  - \(\text{half}\). Is only being read.

**Returns**

- \(\text{half}\)
  - The result of fused multiply-add operation on \(a\), \(b\), and \(c\).

**Description**

Performs \(\text{half}\) multiply on inputs \(a\) and \(b\), then performs a \(\text{half}\) add of the result with \(c\), rounding the result once in round-to-nearest-even mode. DEEPLEARN-SRM_REQ-96

```c
__device__ __half __hfma_sat (const __half a, const __half b, const __half c)
```

Performs \(\text{half}\) fused multiply-add in round-to-nearest-even mode, with saturation to \([0.0, 1.0]\).

**Parameters**

- \(a\)
  - \(\text{half}\). Is only being read.
- \(b\)
  - \(\text{half}\). Is only being read.
- \(c\)
  - \(\text{half}\). Is only being read.
Returns
half
  ▶ The result of fused multiply-add operation on a, b, and c, with respect to saturation.

Description
Performs half multiply on inputs a and b, then performs a half add of the result with c, rounding the result once in round-to-nearest-even mode, and clamps the result to range [0.0, 1.0]. NaN results are flushed to +0.0.

__device__ __half __hmul (const __half a, const __half b)
Performs half multiplication in round-to-nearest-even mode.

Parameters
a
  - half. Is only being read.
b
  - half. Is only being read.

Returns
half
  ▶ The result of multiplying a and b.

Description
Performs half multiplication of inputs a and b, in round-to-nearest mode.
DEEPEARN-SRM_REQ-99

__device__ __half __hmul_sat (const __half a, const __half b)
Performs half multiplication in round-to-nearest-even mode, with saturation to [0.0, 1.0].

Parameters
a
  - half. Is only being read.
b
  - half. Is only being read.
Returns
half
  The result of multiplying $a$ and $b$, with respect to saturation.

Description
Performs half multiplication of inputs $a$ and $b$, in round-to-nearest mode, and clamps the result to range $[0.0, 1.0]$. NaN results are flushed to +0.0.

__device__ __half __hneg (const __half a)
Negates input half number and returns the result.

Parameters
a
  - half. Is only being read.

Returns
half
  minus
    a

Description
Negates input half number and returns the result. DEEPLEARN-SRM_REQ-100

__device__ __half __hsub (const __half a, const __half b)
Performs half subtraction in round-to-nearest-even mode.

Parameters
a
  - half. Is only being read.

b
  - half. Is only being read.

Returns
half
  The result of subtracting $b$ from $a$. 

www.nvidia.com
CUDA Math API
vRelease Version | 6
Description
Subtracts half input \( b \) from input \( a \) in round-to-nearest mode. DEEPLEARN-SRM_REQ-97

\[
\text{\_device\_\_half \_hsub\_sat (const \_half \_a, const \_half \_b)}
\]
Performs half subtraction in round-to-nearest-even mode, with saturation to \([0.0, 1.0]\).

Parameters
\( a \)
- half. Is only being read.
\( b \)
- half. Is only being read.

Returns
half
- The result of subtraction of \( b \) from \( a \), with respect to saturation.

Description
Subtracts half input \( b \) from input \( a \) in round-to-nearest mode, and clamps the result to range \([0.0, 1.0]\). NaN results are flushed to +0.0.

1.1.2. Half2 Arithmetic Functions
Half Precision Intrinsics
To use these functions include the header file \texttt{cuda_fp16.h} in your program.

\[
\text{\_device\_\_half2 \_h2div (const \_half2 \_a, const \_half2 \_b)}
\]
Performs half2 vector division in round-to-nearest-even mode.

Parameters
\( a \)
- half2. Is only being read.
\( b \)
- half2. Is only being read.

Returns
half2
- The
elementwise division of \( a \) with \( b \).

**Description**

Divides \( \text{half2} \) input vector \( a \) by input vector \( b \) in round-to-nearest mode.
DEEPLREARN-SRM_REQ-103

\[
\text{\_device\_ \_half2 \_\_habs2 (const \_\_half2 a)}
\]

Calculates the absolute value of both halves of the input \( \text{half2} \) number and returns the result.

**Parameters**

\( a \)
- \( \text{half2} \). Is only being read.

**Returns**

\( \text{half2} \)
- Returns
  \( a \) with the absolute value of both halves.

**Description**

Calculates the absolute value of both halves of the input \( \text{half2} \) number and returns the result.

\[
\text{\_device\_ \_half2 \_\_hadd2 (const \_\_half2 a, const \_\_half2 b)}
\]

Performs \( \text{half2} \) vector addition in round-to-nearest-even mode.

**Parameters**

\( a \)
- \( \text{half2} \). Is only being read.

\( b \)
- \( \text{half2} \). Is only being read.

**Returns**

\( \text{half2} \)
- The
  sum of vectors \( a \) and \( b \).
Description
Performs half2 vector add of inputs a and b, in round-to-nearest mode. DEEPLEARN-SRM_REQ-95

__device__ __half2 __hadd2_sat (const __half2 a, const __half2 b)
Performs half2 vector addition in round-to-nearest-even mode, with saturation to [0.0, 1.0].

Parameters
a
- half2. Is only being read.
b
- half2. Is only being read.

Returns
half2

• The
  sum of a and b, with respect to saturation.

Description
Performs half2 vector add of inputs a and b, in round-to-nearest mode, and clamps the results to range [0.0, 1.0]. NaN results are flushed to +0.0.

__device__ __half2 __hfma2 (const __half2 a, const __half2 b, const __half2 c)
Performs half2 vector fused multiply-add in round-to-nearest-even mode.

Parameters
a
- half2. Is only being read.
b
- half2. Is only being read.
c
- half2. Is only being read.

Returns
half2

• The
  result of elementwise fused multiply-add operation on vectors a, b, and c.
Description
Performs \texttt{half2} vector multiply on inputs \texttt{a} and \texttt{b}, then performs a \texttt{half2} vector add of the result with \texttt{c}, rounding the result once in round-to-nearest-even mode. DEEPLEARN-SRM_REQ-105

\begin{verbatim}
__device__ __half2 __hfma2_sat (const __half2 a, const __half2 b, const __half2 c)
Performs \texttt{half2} vector fused multiply-add in round-to-nearest-even mode, with saturation to \([0.0, 1.0]\).

Parameters
\begin{itemize}
\item \texttt{a} - \texttt{half2}. Is only being read.
\item \texttt{b} - \texttt{half2}. Is only being read.
\item \texttt{c} - \texttt{half2}. Is only being read.
\end{itemize}

Returns
\texttt{half2}
\begin{itemize}
\item The result of elementwise fused multiply-add operation on vectors \texttt{a}, \texttt{b}, and \texttt{c}, with respect to saturation.
\end{itemize}
\end{verbatim}

Description
Performs \texttt{half2} vector multiply on inputs \texttt{a} and \texttt{b}, then performs a \texttt{half2} vector add of the result with \texttt{c}, rounding the result once in round-to-nearest-even mode, and clamps the results to range \([0.0, 1.0]\). NaN results are flushed to +0.0.

\begin{verbatim}
__device__ __half2 __hmul2 (const __half2 a, const __half2 b)
Performs \texttt{half2} vector multiplication in round-to-nearest-even mode.

Parameters
\begin{itemize}
\item \texttt{a} - \texttt{half2}. Is only being read.
\item \texttt{b} - \texttt{half2}. Is only being read.
\end{itemize}
\end{verbatim}
Returns

half2
- The result of elementwise multiplying the vectors a and b.

Description

Performs half2 vector multiplication of inputs a and b, in round-to-nearest-even mode.
DEEPLYARN-SRM_REQ-102

__device__ __half2 __hmul2_sat (const __half2 a, const __half2 b)

Performs half2 vector multiplication in round-to-nearest-even mode, with saturation to [0.0, 1.0].

Parameters

a - half2. Is only being read.
b - half2. Is only being read.

Returns

half2
- The result of elementwise multiplication of vectors a and b, with respect to saturation.

Description

Performs half2 vector multiplication of inputs a and b, in round-to-nearest-even mode, and clamps the results to range [0.0, 1.0]. NaN results are flushed to +0.0.

__device__ __half2 __hneg2 (const __half2 a)

Negates both halves of the input half2 number and returns the result.

Parameters

a - half2. Is only being read.

Returns

half2
- Returns
a with both halves negated.

Description
Negates both halves of the input half2 number a and returns the result. DEEPLEARN-SRM_REQ-101

__device__ __half2 __hsub2 (const __half2 a, const __half2 b)
Performs half2 vector subtraction in round-to-nearest-even mode.

Parameters
a
- half2. Is only being read.
b
- half2. Is only being read.

Returns
half2
The subtraction of vector b from a.

Description
Subtracts half2 input vector b from input vector a in round-to-nearest-even mode. DEEPLEARN-SRM_REQ-104

__device__ __half2 __hsub2_sat (const __half2 a, const __half2 b)
Performs half2 vector subtraction in round-to-nearest-even mode, with saturation to [0.0, 1.0].

Parameters
a
- half2. Is only being read.
b
- half2. Is only being read.

Returns
half2
The subtraction of vector b from a, with respect to saturation.
Description
Subtracts `half2` input vector `b` from input vector `a` in round-to-nearest-even mode, and clamps the results to range `[0.0, 1.0]`. NaN results are flushed to +0.0.

1.1.3. Half Comparison Functions

Half Precision Intrinsics
To use these functions include the header file `cuda_fp16.h` in your program.

```c
__device__ bool __heq (const __half a, const __half b)
```
Performs half if-equal comparison.

Parameters
- `a` - `half`. Is only being read.
- `b` - `half`. Is only being read.

Returns
- `bool`

Description
Performs half if-equal comparison of inputs `a` and `b`. NaN inputs generate false results.

```c
__device__ bool __hequ (const __half a, const __half b)
```
Performs half unordered if-equal comparison.

Parameters
- `a` - `half`. Is only being read.
- `b` - `half`. Is only being read.

Returns
- `bool`

Description
Performs half unordered if-equal comparison of inputs `a` and `b`. NaN inputs generate false results.
boolean result of unordered if-equal comparison of \( a \) and \( b \).

**Description**

Performs half if-equal comparison of inputs \( a \) and \( b \). NaN inputs generate true results.

\[
\text{__device__ bool __hge (const __half a, const __half b)}
\]

Performs half greater-equal comparison.

**Parameters**

\( a \)
- half. Is only being read.

\( b \)
- half. Is only being read.

**Returns**

bool

- The boolean result of greater-equal comparison of \( a \) and \( b \).

**Description**

Performs half greater-equal comparison of inputs \( a \) and \( b \). NaN inputs generate false results.

\[
\text{__device__ bool __hgeu (const __half a, const __half b)}
\]

Performs half unordered greater-equal comparison.

**Parameters**

\( a \)
- half. Is only being read.

\( b \)
- half. Is only being read.

**Returns**

bool

- The boolean result of unordered greater-equal comparison of \( a \) and \( b \).
Description
Performs half greater-equal comparison of inputs \( a \) and \( b \). NaN inputs generate true results.

\[
\text{\_\_device\_ bool \_\_hgt (const \_half a, const \_half b)}
\]
Performs half greater-than comparison.

Parameters

\( a \)
- half. Is only being read.

\( b \)
- half. Is only being read.

Returns

bool
  - The boolean result of greater-than comparison of \( a \) and \( b \).

Description
Performs half greater-than comparison of inputs \( a \) and \( b \). NaN inputs generate false results.

\[
\text{\_\_device\_ bool \_\_hgtu (const \_half a, const \_half b)}
\]
Performs half unordered greater-than comparison.

Parameters

\( a \)
- half. Is only being read.

\( b \)
- half. Is only being read.

Returns

bool
  - The boolean result of unordered greater-than comparison of \( a \) and \( b \).
Description
Performs half greater-than comparison of inputs \(a\) and \(b\). NaN inputs generate true results.

\[\text{__device__ int __hisinf (const __half a)}\]
Checks if the input half number is infinite.

Parameters
\(a\)
- half. Is only being read.

Returns
int
-1
  iff \(a\) is equal to negative infinity,
1
  iff \(a\) is equal to positive infinity,
0
  otherwise.

Description
Checks if the input half number \(a\) is infinite.

\[\text{__device__ bool __hisnan (const __half a)}\]
Determine whether half argument is a NaN.

Parameters
\(a\)
- half. Is only being read.

Returns
bool
true
  iff argument is NaN.

Description
Determine whether half value \(a\) is a NaN.
__device__ bool __hle (const __half a, const __half b)
Performs half less-equal comparison.

Parameters

a
- half. Is only being read.

b
- half. Is only being read.

Returns

bool

The
boolean result of less-equal comparison of a and b.

Description

Performs half less-equal comparison of inputs a and b. NaN inputs generate false results.

__device__ bool __hleu (const __half a, const __half b)
Performs half unordered less-equal comparison.

Parameters

a
- half. Is only being read.

b
- half. Is only being read.

Returns

bool

The
boolean result of unordered less-equal comparison of a and b.

Description

Performs half less-equal comparison of inputs a and b. NaN inputs generate true results.
__device__ bool __hlt (const __half a, const __half b)
Performs \texttt{half} less-than comparison.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{a} - \texttt{half}. Is only being read.
  \item \texttt{b} - \texttt{half}. Is only being read.
\end{itemize}

\textbf{Returns}

\begin{itemize}
  \item \texttt{bool} - The boolean result of less-than comparison of \texttt{a} and \texttt{b}.
\end{itemize}

\textbf{Description}

Performs \texttt{half} less-than comparison of inputs \texttt{a} and \texttt{b}. NaN inputs generate false results.

__device__ bool __hltu (const __half a, const __half b)
Performs \texttt{half} unordered less-than comparison.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{a} - \texttt{half}. Is only being read.
  \item \texttt{b} - \texttt{half}. Is only being read.
\end{itemize}

\textbf{Returns}

\begin{itemize}
  \item \texttt{bool} - The boolean result of unordered less-than comparison of \texttt{a} and \texttt{b}.
\end{itemize}

\textbf{Description}

Performs \texttt{half} less-than comparison of inputs \texttt{a} and \texttt{b}. NaN inputs generate true results.
__device__ bool __hne (const __half a, const __half b)
Performs half not-equal comparison.

Parameters

a
- half. Is only being read.

b
- half. Is only being read.

Returns

bool

- The boolean result of not-equal comparison of \(a\) and \(b\).

Description

Performs half not-equal comparison of inputs \(a\) and \(b\). NaN inputs generate false results.

__device__ bool __hneu (const __half a, const __half b)
Performs half unordered not-equal comparison.

Parameters

a
- half. Is only being read.

b
- half. Is only being read.

Returns

bool

- The boolean result of unordered not-equal comparison of \(a\) and \(b\).

Description

Performs half not-equal comparison of inputs \(a\) and \(b\). NaN inputs generate true results.
1.1.4. Half2 Comparison Functions

Half Precision Intrinsics

To use these functions include the header file `cuda_fp16.h` in your program.

```c
__device__ bool __hbeq2 (const __half2 a, const __half2 b)
```

Performs half2 vector if-equal comparison, and returns boolean true iff both half results are true, boolean false otherwise.

**Parameters**

- **a**
  - half2. Is only being read.
- **b**
  - half2. Is only being read.

**Returns**

- `bool` if both half results of if-equal comparison of vectors `a` and `b` are true;
- `false` otherwise.

**Description**

Performs half2 vector if-equal comparison of inputs `a` and `b`. The bool result is set to true only if both half if-equal comparisons evaluate to true, or false otherwise. NaN inputs generate false results.

```c
__device__ bool __hbequ2 (const __half2 a, const __half2 b)
```

Performs half2 vector unordered if-equal comparison, and returns boolean true iff both half results are true, boolean false otherwise.

**Parameters**

- **a**
  - half2. Is only being read.
- **b**
  - half2. Is only being read.

**Returns**

- `bool`
trueif

both half results of unordered if-equal comparison of vectors a and b are true;
falseotherwise.

Description
Performs half2 vector if-equal comparison of inputs a and b. The bool result is set to true only if both half if-equal comparisons evaluate to true, or false otherwise. NaN inputs generate true results.

__device__ bool __hbge2 (const __half2 a, const __half2 b)
Performs half2 vector greater-equal comparison, and returns boolean true iff both half results are true, boolean false otherwise.

Parameters

a
- half2. Is only being read.

b
- half2. Is only being read.

Returns

bool
trueif

both half results of greater-equal comparison of vectors a and b are true;
falseotherwise.

Description
Performs half2 vector greater-equal comparison of inputs a and b. The bool result is set to true only if both half greater-equal comparisons evaluate to true, or false otherwise. NaN inputs generate false results.

__device__ bool __hbgeu2 (const __half2 a, const __half2 b)
Performs half2 vector unordered greater-equal comparison, and returns boolean true iff both half results are true, boolean false otherwise.

Parameters

a
- half2. Is only being read.

b
- half2. Is only being read.
**Returns**

`bool`

- `true` if both `half` results of unordered greater-equal comparison of vectors `a` and `b` are true;
- `false` otherwise.

**Description**

Performs `half2` vector greater-equal comparison of inputs `a` and `b`. The bool result is set to true only if both `half` greater-equal comparisons evaluate to true, or false otherwise. NaN inputs generate true results.

```c
__device__ bool __hbgt2 (const __half2 a, const __half2 b)
```

Performs `half2` vector greater-than comparison, and returns boolean true iff both `half` results are true, boolean false otherwise.

**Parameters**

- `a` - `half2`. Is only being read.
- `b` - `half2`. Is only being read.

**Returns**

`bool`

- `true` if both `half` results of greater-than comparison of vectors `a` and `b` are true;
- `false` otherwise.

**Description**

Performs `half2` vector greater-than comparison of inputs `a` and `b`. The bool result is set to true only if both `half` greater-than comparisons evaluate to true, or false otherwise. NaN inputs generate false results.
__device__ bool __hbgtu2 (const __half2 a, const __half2 b)
Performs half2 vector unordered greater-than comparison, and returns boolean true iff both half results are true, boolean false otherwise.

Parameters
a
  - half2. Is only being read.

b
  - half2. Is only being read.

Returns
bool
  ▶ true if both half results of unordered greater-than comparison of vectors a and b are true;
  ▶ false otherwise.

Description
Performs half2 vector greater-than comparison of inputs a and b. The bool result is set to true only if both half greater-than comparisons evaluate to true, or false otherwise. NaN inputs generate true results.

__device__ bool __hble2 (const __half2 a, const __half2 b)
Performs half2 vector less-equal comparison, and returns boolean true iff both half results are true, boolean false otherwise.

Parameters
a
  - half2. Is only being read.

b
  - half2. Is only being read.

Returns
bool
  ▶ true if both half results of less-equal comparison of vectors a and b are true;
  ▶ false otherwise.
Description
Performs `half2` vector less-equal comparison of inputs `a` and `b`. The bool result is set to true only if both `half` less-equal comparisons evaluate to true, or false otherwise. NaN inputs generate false results.

```c
__device__ bool __hbleu2 (const __half2 a, const __half2 b)
```
Performs `half2` vector unordered less-equal comparison, and returns boolean true iff both `half` results are true, boolean false otherwise.

Parameters
a
- `half2`. Is only being read.

b
- `half2`. Is only being read.

Returns
bool
  ▶ true if both `half` results of unordered less-equal comparison of vectors `a` and `b` are true;
  ▶ false otherwise.

Description
Performs `half2` vector less-equal comparison of inputs `a` and `b`. The bool result is set to true only if both `half` less-equal comparisons evaluate to true, or false otherwise. NaN inputs generate true results.

```c
__device__ bool __hblt2 (const __half2 a, const __half2 b)
```
Performs `half2` vector less-than comparison, and returns boolean true iff both `half` results are true, boolean false otherwise.

Parameters
a
- `half2`. Is only being read.

b
- `half2`. Is only being read.

Returns
bool
  ▶ true if
both \texttt{half} results of less-than comparison of vectors \(a\) and \(b\) are true;

\begin{itemize}
  \item false otherwise.
\end{itemize}

\textbf{Description}

Performs \texttt{half2} vector less-than comparison of inputs \(a\) and \(b\). The bool result is set to true only if both \texttt{half} less-than comparisons evaluate to true, or false otherwise. NaN inputs generate false results.

\texttt{\_device\_ bool \_\_hbltu2 (const \_\_half2 a, const \_\_half2 b)}

Performs \texttt{half2} vector unordered less-than comparison, and returns boolean true iff both \texttt{half} results are true, boolean false otherwise.

\textbf{Parameters}

\begin{itemize}
  \item \(a\) - \texttt{half2}. Is only being read.
  \item \(b\) - \texttt{half2}. Is only being read.
\end{itemize}

\textbf{Returns}

\begin{itemize}
  \item \texttt{bool}
  \begin{itemize}
    \item \texttt{true} if both \texttt{half} results of unordered less-than comparison of vectors \(a\) and \(b\) are true;
    \item false otherwise.
  \end{itemize}
\end{itemize}

\textbf{Description}

Performs \texttt{half2} vector less-than comparison of inputs \(a\) and \(b\). The bool result is set to true only if both \texttt{half} less-than comparisons evaluate to true, or false otherwise. NaN inputs generate true results.

\texttt{\_device\_ bool \_\_hbne2 (const \_\_half2 a, const \_\_half2 b)}

Performs \texttt{half2} vector not-equal comparison, and returns boolean true iff both \texttt{half} results are true, boolean false otherwise.

\textbf{Parameters}

\begin{itemize}
  \item \(a\) - \texttt{half2}. Is only being read.
  \item \(b\) - \texttt{half2}. Is only being read.
\end{itemize}
Returns

bool

▶ true if both half results of not-equal comparison of vectors \(a\) and \(b\) are true,
▶ false otherwise.

Description

Performs half2 vector not-equal comparison of inputs \(a\) and \(b\). The bool result is set to true only if both half not-equal comparisons evaluate to true, or false otherwise. NaN inputs generate false results.

__device__ bool __hbneu2 (const __half2 a, const __half2 b)

Performs half2 vector unordered not-equal comparison, and returns boolean true iff both half results are true, boolean false otherwise.

Parameters

\(a\)

- half2. Is only being read.

\(b\)

- half2. Is only being read.

Returns

bool

▶ true if both half results of unordered not-equal comparison of vectors \(a\) and \(b\) are true;
▶ false otherwise.

Description

Performs half2 vector not-equal comparison of inputs \(a\) and \(b\). The bool result is set to true only if both half not-equal comparisons evaluate to true, or false otherwise. NaN inputs generate true results.
`__device__ __half2 __heq2 (const __half2 a, const __half2 b)`
Performs half2 vector if-equal comparison.

**Parameters**

- **a**
  - half2. Is only being read.
- **b**
  - half2. Is only being read.

**Returns**

half2

- The vector result of if-equal comparison of vectors `a` and `b`.

**Description**

Performs half2 vector if-equal comparison of inputs `a` and `b`. The corresponding half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate false results.

`__device__ __half2 __hequ2 (const __half2 a, const __half2 b)`
Performs half2 vector unordered if-equal comparison.

**Parameters**

- **a**
  - half2. Is only being read.
- **b**
  - half2. Is only being read.

**Returns**

half2

- The vector result of unordered if-equal comparison of vectors `a` and `b`.

**Description**

Performs half2 vector if-equal comparison of inputs `a` and `b`. The corresponding half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate true results.
__device__ __half2 __hge2 (const __half2 a, const __half2 b)
Performs half2 vector greater-equal comparison.

Parameters
a
  - half2. Is only being read.
b
  - half2. Is only being read.

Returns
half2
  ▶ The
  
    vector result of greater-equal comparison of vectors a and b.

Description
Performs half2 vector greater-equal comparison of inputs a and b. The corresponding half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate false results.

__device__ __half2 __hgeu2 (const __half2 a, const __half2 b)
Performs half2 vector unordered greater-equal comparison.

Parameters
a
  - half2. Is only being read.
b
  - half2. Is only being read.

Returns
half2
  ▶ The
  
    half2 vector result of unordered greater-equal comparison of vectors a and b.

Description
Performs half2 vector greater-equal comparison of inputs a and b. The corresponding half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate true results.
__device__ __half2 __hgt2 (const __half2 a, const __half2 b)
Performs half2 vector greater-than comparison.

Parameters
a
  - half2. Is only being read.
b
  - half2. Is only being read.

Returns
half2
  ▶ The
    vector result of greater-than comparison of vectors a and b.

Description
Performs half2 vector greater-than comparison of inputs a and b. The corresponding
half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate false results.

__device__ __half2 __hgtu2 (const __half2 a, const __half2 b)
Performs half2 vector unordered greater-than comparison.

Parameters
a
  - half2. Is only being read.
b
  - half2. Is only being read.

Returns
half2
  ▶ The
    half2 vector result of unordered greater-than comparison of vectors a and b.

Description
Performs half2 vector greater-than comparison of inputs a and b. The corresponding
half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate true results.
__device__ __half2 __hisnan2 (const __half2 a)
Determine whether half2 argument is a NaN.

Parameters
a
- half2. Is only being read.

Returns
half2
- The half2 with the corresponding half results set to 1.0 for NaN, 0.0 otherwise.

Description
Determine whether each half of input half2 number a is a NaN.

__device__ __half2 __hle2 (const __half2 a, const __half2 b)
Performs half2 vector less-equal comparison.

Parameters
a
- half2. Is only being read.
b
- half2. Is only being read.

Returns
half2
- The half2 result of less-equal comparison of vectors a and b.

Description
Performs half2 vector less-equal comparison of inputs a and b. The corresponding half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate false results.
__device__ __half2 __hleu2 (const __half2 a, const __half2 b)
Performs half2 vector unordered less-equal comparison.

Parameters
a
  - half2. Is only being read.
b
  - half2. Is only being read.

Returns
half2
  ▶ The
    vector result of unordered less-equal comparison of vectors a and b.

Description
Performs half2 vector less-equal comparison of inputs a and b. The corresponding half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate true results.

__device__ __half2 __hlt2 (const __half2 a, const __half2 b)
Performs half2 vector less-than comparison.

Parameters
a
  - half2. Is only being read.
b
  - half2. Is only being read.

Returns
half2
  ▶ The
    half2 vector result of less-than comparison of vectors a and b.

Description
Performs half2 vector less-than comparison of inputs a and b. The corresponding half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate false results.
__device__ __half2 __hltu2 (const __half2 a, const __half2 b)
Performs half2 vector unordered less-than comparison.

Parameters
a
  - half2. Is only being read.
b
  - half2. Is only being read.

Returns
half2
  - The vector result of unordered less-than comparison of vectors a and b.

Description
Performs half2 vector less-than comparison of inputs a and b. The corresponding half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate true results.

__device__ __half2 __hne2 (const __half2 a, const __half2 b)
Performs half2 vector not-equal comparison.

Parameters
a
  - half2. Is only being read.
b
  - half2. Is only being read.

Returns
half2
  - The vector result of not-equal comparison of vectors a and b.

Description
Performs half2 vector not-equal comparison of inputs a and b. The corresponding half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate false results.
__device__ __half2 __hneu2 (const __half2 a, const __half2 b)
Performs half2 vector unordered not-equal comparison.

Parameters
a
- half2. Is only being read.
b
- half2. Is only being read.

Returns
half2
▷ The vector result of unordered not-equal comparison of vectors a and b.

Description
Performs half2 vector not-equal comparison of inputs a and b. The corresponding half results are set to 1.0 for true, or 0.0 for false. NaN inputs generate true results.

1.1.5. Half Precision Conversion And Data Movement

Half Precision Intrinsics
To use these functions include the header file cuda_fp16.h in your program.

__host____device__ __half2 __float22half2_rn (const float2 a)
Converts both components of float2 number to half precision in round-to-nearest-even mode and returns half2 with converted values.

Parameters
a
- float2. Is only being read.

Returns
half2
▷ The half2 which has corresponding halves equal to the converted float2 components.
Description
Converts both components of float2 to half precision in round-to-nearest mode and combines the results into one half2 number. Low 16 bits of the return value correspond to a.x and high 16 bits of the return value correspond to a.y.

__host__ __device__ __half__ __float2half (const float a)
Converts float number to half precision in round-to-nearest-even mode and returns half with converted value.

Parameters
a
- float. Is only being read.

Returns
half

Description
Converts float number a to half precision in round-to-nearest-even mode.

__host__ __device__ __half2__ __float2half2_rn (const float a)
Converts input to half precision in round-to-nearest-even mode and populates both halves of half2 with converted value.

Parameters
a
- float. Is only being read.

Returns
half2

Description
Converts input a to half precision in round-to-nearest-even mode and populates both halves of half2 with converted value.
__host__ __device__ __half __float2half_rd (const float a)
Converts float number to half precision in round-down mode and returns half with converted value.

Parameters
a
- float. Is only being read.

Returns
half

Description
Converts float number a to half precision in round-down mode.

__host__ __device__ __half __float2half_rn (const float a)
Converts float number to half precision in round-to-nearest-even mode and returns half with converted value.

Parameters
a
- float. Is only being read.

Returns
half

Description
Converts float number a to half precision in round-to-nearest-even mode.
__host__ __device__ __half __float2half_ru (const float a)
Converts float number to half precision in round-up mode and returns half with converted value.

Parameters
a
- float. Is only being read.

Returns
half

Description
Converts float number \( a \) to half precision in round-up mode.

__host__ __device__ __half __float2half_rz (const float a)
Converts float number to half precision in round-towards-zero mode and returns half with converted value.

Parameters
a
- float. Is only being read.

Returns
half

Description
Converts float number \( a \) to half precision in round-towards-zero mode.
__host__ __device__ __half2 __floats2half2_rn (const float a, const float b)
Converts both input floats to half precision in round-to-nearest-even mode and returns half2 with converted values.

**Parameters**

- **a**
  - float. Is only being read.
- **b**
  - float. Is only being read.

**Returns**

half2

- The half2 value with corresponding halves equal to the converted input floats.

**Description**

Converts both input floats to half precision in round-to-nearest-even mode and combines the results into one half2 number. Low 16 bits of the return value correspond to the input a, high 16 bits correspond to the input b.

__host__ __device__ float2 __half22float2 (const __half2 a)
Converts both halves of half2 to float2 and returns the result.

**Parameters**

- **a**
  - half2. Is only being read.

**Returns**

float2

- \p
  - a converted to float2.

**Description**

Converts both halves of half2 input a to float2 and returns the result.
__host__ __device__ float __half2float (const __half a)
Converting half number to float.

Parameters
a
- float. Is only being read.

Returns
float

}\p
   a converted to float.

Description
Converting half number \texttt{a} to float.

__device__ __half2 __half2half2 (const __half a)
Returns half2 with both halves equal to the input value.

Parameters
a
- half. Is only being read.

Returns
half2

\begin{itemize}
  \item The vector which has both its halves equal to the input \texttt{a}.
\end{itemize}

Description
Returns half2 number with both halves equal to the input \texttt{a} half number.

__device__ int __half2int_rd (__half h)
Convert a half to a signed integer in round-down mode.

Parameters
h
- half. Is only being read.
Returns

int

\p

h converted to a signed integer.

Description

Convert the half-precision floating point value \( h \) to a signed integer in round-down mode.

\[ \text{\texttt{\_\_device\_\_ int \_\_half2int\_rn (\_\_half h)}} \]

Convert a half to a signed integer in round-to-nearest-even mode.

Parameters

h

- half. Is only being read.

Returns

int

\p

h converted to a signed integer.

Description

Convert the half-precision floating point value \( h \) to a signed integer in round-to-nearest-even mode.

\[ \text{\texttt{\_\_device\_\_ int \_\_half2int\_ru (\_\_half h)}} \]

Convert a half to a signed integer in round-up mode.

Parameters

h

- half. Is only being read.

Returns

int

\p

h converted to a signed integer.
**Description**  
Convert the half-precision floating point value \( h \) to a signed integer in round-up mode.

\[
\text{__device__ int __half2int_rz (__half h)}
\]

Convert a half to a signed integer in round-towards-zero mode.

**Parameters**  
\( h \)  
- half. Is only being read.

**Returns**  
int  
- \( h \) converted to a signed integer.

**Description**  
Convert the half-precision floating point value \( h \) to a signed integer in round-towards-zero mode.

\[
\text{__device__ long long int __half2ll_rd (__half h)}
\]

Convert a half to a signed 64-bit integer in round-down mode.

**Parameters**  
\( h \)  
- half. Is only being read.

**Returns**  
long long int  
- \( h \) converted to a signed 64-bit integer.

**Description**  
Convert the half-precision floating point value \( h \) to a signed 64-bit integer in round-down mode.
__device__ long long int __half2ll_rn (__half h)
Convert a half to a signed 64-bit integer in round-to-nearest-even mode.

Parameters

h
- half. Is only being read.

Returns

long long int

\- \p
h converted to a signed 64-bit integer.

Description

Convert the half-precision floating point value \( h \) to a signed 64-bit integer in round-to-nearest-even mode.

__device__ long long int __half2ll_ru (__half h)
Convert a half to a signed 64-bit integer in round-up mode.

Parameters

h
- half. Is only being read.

Returns

long long int

\- \p
h converted to a signed 64-bit integer.

Description

Convert the half-precision floating point value \( h \) to a signed 64-bit integer in round-up mode.
__device__ long long int __half2ll_rz (__half h)
Convert a half to a signed 64-bit integer in round-towards-zero mode.

Parameters
h
- half. Is only being read.

Returns
long long int
  h converted to a signed 64-bit integer.

Description
Convert the half-precision floating point value h to a signed 64-bit integer in round-towards-zero mode.

__device__ short int __half2short_rd (__half h)
Convert a half to a signed short integer in round-down mode.

Parameters
h
- half. Is only being read.

Returns
short int
  h converted to a signed short integer.

Description
Convert the half-precision floating point value h to a signed short integer in round-down mode.
__device__ short int __half2short_rn (__half h)
Convert a half to a signed short integer in round-to-nearest-even mode.

Parameters
h
- half. Is only being read.

Returns
short int
\[ h \]
- h converted to a signed short integer.

Description
Convert the half-precision floating point value \( h \) to a signed short integer in round-to-nearest-even mode.

__device__ short int __half2short_ru (__half h)
Convert a half to a signed short integer in round-up mode.

Parameters
h
- half. Is only being read.

Returns
short int
\[ h \]
- h converted to a signed short integer.

Description
Convert the half-precision floating point value \( h \) to a signed short integer in round-up mode.
__device__ short int __half2short_rz (__half h)
Convert a half to a signed short integer in round-towards-zero mode.

Parameters

h
- half. Is only being read.

Returns

short int

\[
\text{h converted to a signed short integer.}
\]

Description

Convert the half-precision floating point value \( h \) to a signed short integer in round-towards-zero mode.

__device__ unsigned int __half2uint_rd (__half h)
Convert a half to an unsigned integer in round-down mode.

Parameters

h
- half. Is only being read.

Returns

unsigned int

\[
\text{h converted to an unsigned integer.}
\]

Description

Convert the half-precision floating point value \( h \) to an unsigned integer in round-down mode.
**__device__ unsigned int __half2uint_rn (__half h)**
Convert a half to an unsigned integer in round-to-nearest-even mode.

**Parameters**

h
- half. Is only being read.

**Returns**

unsigned int

- h converted to an unsigned integer.

**Description**

Convert the half-precision floating point value `h` to an unsigned integer in round-to-nearest-even mode.

**__device__ unsigned int __half2uint_ru (__half h)**
Convert a half to an unsigned integer in round-up mode.

**Parameters**

h
- half. Is only being read.

**Returns**

unsigned int

- h converted to an unsigned integer.

**Description**

Convert the half-precision floating point value `h` to an unsigned integer in round-up mode.
__device__ unsigned int __half2uint_rz (__half h)
Convert a half to an unsigned integer in round-towards-zero mode.

Parameters
h
- half. Is only being read.

Returns
unsigned int

h converted to an unsigned integer.

Description
Convert the half-precision floating point value h to an unsigned integer in round-towards-zero mode.

__device__ unsigned long long int __half2ull_rd (__half h)
Convert a half to an unsigned 64-bit integer in round-down mode.

Parameters
h
- half. Is only being read.

Returns
unsigned long long int

h converted to an unsigned 64-bit integer.

Description
Convert the half-precision floating point value h to an unsigned 64-bit integer in round-down mode.
__device__ unsigned long long int __half2ull_rn (__half h)
Convert a half to an unsigned 64-bit integer in round-to-nearest-even mode.

Parameters
h
- half. Is only being read.

Returns
unsigned long long int

h converted to an unsigned 64-bit integer.

Description
Convert the half-precision floating point value \( h \) to an unsigned 64-bit integer in round-to-nearest-even mode.

__device__ unsigned long long int __half2ull_ru (__half h)
Convert a half to an unsigned 64-bit integer in round-up mode.

Parameters
h
- half. Is only being read.

Returns
unsigned long long int

h converted to an unsigned 64-bit integer.

Description
Convert the half-precision floating point value \( h \) to an unsigned 64-bit integer in round-up mode.
__device__ unsigned long long int __half2ull_rz (__half h)
Convert a half to an unsigned 64-bit integer in round-towards-zero mode.

Parameters
h
- half. Is only being read.

Returns
unsigned long long int

\p
h converted to an unsigned 64-bit integer.

Description
Convert the half-precision floating point value \( h \) to an unsigned 64-bit integer in round-towards-zero mode.

__device__ unsigned short int __half2ushort_rd (__half h)
Convert a half to an unsigned short integer in round-down mode.

Parameters
h
- half. Is only being read.

Returns
unsigned short int

\p
h converted to an unsigned short integer.

Description
Convert the half-precision floating point value \( h \) to an unsigned short integer in round-down mode.
__device__ unsigned short int __half2ushort_rn (__half h)
Convert a half to an unsigned short integer in round-to-nearest-even mode.

Parameters

h
  - half. Is only being read.

Returns

unsigned short int
  \n  h converted to an unsigned short integer.

Description

Convert the half-precision floating point value \( h \) to an unsigned short integer in round-to-nearest-even mode.

__device__ unsigned short int __half2ushort_ru (__half h)
Convert a half to an unsigned short integer in round-up mode.

Parameters

h
  - half. Is only being read.

Returns

unsigned short int
  \n  h converted to an unsigned short integer.

Description

Convert the half-precision floating point value \( h \) to an unsigned short integer in round-up mode.
__device__ unsigned short int __half2ushort_rz (__half h)
Convert a half to an unsigned short integer in round-towards-zero mode.

Parameters
h
- half. Is only being read.

Returns
unsigned short int
‣ h converted to an unsigned short integer.

Description
Convert the half-precision floating point value \( h \) to an unsigned short integer in round-towards-zero mode.

__device__ short int __half_as_short (const __half h)
Reinterprets bits in a half as a signed short integer.

Parameters
h
- half. Is only being read.

Returns
short int
‣ The reinterpreted value.

Description
Reinterprets the bits in the half-precision floating point number \( h \) as a signed short integer.
__device__ unsigned short int __half_as_ushort (const __half h)
Reinterprets bits in a half as an unsigned short integer.

Parameters
h
- half. Is only being read.

Returns
unsigned short int
- The interpreted value.

Description
Reinterprets the bits in the half-precision floating point h as an unsigned short number.

__device__ __half2 __halves2half2 (const __half a, const __half b)
Combines two half numbers into one half2 number.

Parameters
a
- half. Is only being read.
b
- half. Is only being read.

Returns
half2
- The half2 with one half equal to a and the other to b.

Description
Combines two input half number a and b into one half2 number. Input a is stored in low 16 bits of the return value, input b is stored in high 16 bits of the return value.
__host__ __device__ float __high2float (const __half2 a)
Converts high 16 bits of half2 to float and returns the result.

Parameters
a
- half2. Is only being read.

Returns
float
  ▶ The
  high 16 bits of a converted to float.

Description
Converts high 16 bits of half2 input a to 32 bit floating point number and returns the result.

__device__ __half __high2half (const __half2 a)
Returns high 16 bits of half2 input.

Parameters
a
- half2. Is only being read.

Returns
half
  ▶ The
  high 16 bits of the input.

Description
Returns high 16 bits of half2 input a.

__device__ __half2 __high2half2 (const __half2 a)
Extracts high 16 bits from half2 input.

Parameters
a
- half2. Is only being read.
Returns
half2

- The high 16 bits of the input.

Description
Extracts high 16 bits from input and returns a new number which has both halves equal to the extracted bits.

\[ \text{__device__ __half2 __highs2half2 (const __half2 a, const __half2 b)} \]
Extracts high 16 bits from each of the two inputs and combines into one number.

Parameters
- \( a \) - half2. Is only being read.
- \( b \) - half2. Is only being read.

Returns
half2

- The high 16 bits of \( a \) and \( b \).

Description
Extracts high 16 bits from each of the two inputs and combines into one number. High 16 bits from input \( a \) is stored in low 16 bits of the return value, high 16 bits from input \( b \) is stored in high 16 bits of the return value.

\[ \text{__device__ __half __int2half_rd (int i)} \]
Convert a signed integer to a half in round-down mode.

Parameters
- \( i \) - int. Is only being read.

Returns
half
\p

i converted to half.

Description
Convert the signed integer value i to a half-precision floating point value in round-down mode.

__device__ __half __int2half_rn (int i)
Convert a signed integer to a half in round-to-nearest-even mode.

Parameters
i
- int. Is only being read.

Returns
half

\p
i converted to half.

Description
Convert the signed integer value i to a half-precision floating point value in round-to-nearest-even mode.

__device__ __half __int2half_ru (int i)
Convert a signed integer to a half in round-up mode.

Parameters
i
- int. Is only being read.

Returns
half

\p
i converted to half.

Description
Convert the signed integer value i to a half-precision floating point value in round-up mode.
__device__ __half __int2half_rz (int i)
Convert a signed integer to a half in round-towards-zero mode.

Parameters
i
  - int. Is only being read.

Returns
half
  
  i converted to half.

Description
Convert the signed integer value \( i \) to a half-precision floating point value in round-towards-zero mode.

__device__ __half __ll2half_rd (long long int i)
Convert a signed 64-bit integer to a half in round-down mode.

Parameters
i
  - long long int. Is only being read.

Returns
half
  
  i converted to half.

Description
Convert the signed 64-bit integer value \( i \) to a half-precision floating point value in round-down mode.
__device__ __half __ll2half_rn (long long int i)
Convert a signed 64-bit integer to a half in round-to-nearest-even mode.

Parameters
i
- long long int. Is only being read.

Returns
half
  \p
  i converted to half.

Description
Convert the signed 64-bit integer value \( i \) to a half-precision floating point value in round-to-nearest-even mode.

__device__ __half __ll2half_ru (long long int i)
Convert a signed 64-bit integer to a half in round-up mode.

Parameters
i
- long long int. Is only being read.

Returns
half
  \p
  i converted to half.

Description
Convert the signed 64-bit integer value \( i \) to a half-precision floating point value in round-up mode.
__device__ __half __ll2half_rz (long long int i)
Convert a signed 64-bit integer to a half in round-towards-zero mode.

Parameters
i
- long long int. Is only being read.

Returns
half
rieb
i converted to half.

Description
Convert the signed 64-bit integer value i to a half-precision floating point value in round-towards-zero mode.

__host____device__ float __low2float (const __half2 a)
Converts low 16 bits of half2 to float and returns the result.

Parameters
a
- half2. Is only being read.

Returns
float
rieb
The
low 16 bits of a converted to float.

Description
Converts low 16 bits of half2 input a to 32 bit floating point number and returns the result.
__device__ __half __low2half (const __half2 a)
Returns low 16 bits of half2 input.

Parameters

a
- half2. Is only being read.

Returns

half

Returns

half which contains low 16 bits of the input a.

Description

Returns low 16 bits of half2 input a.

__device__ __half2 __low2half2 (const __half2 a)
Extracts low 16 bits from half2 input.

Parameters

a
- half2. Is only being read.

Returns

half2

The

half2 with both halves equal to the low 16 bits of the input.

Description

Extracts low 16 bits from half2 input a and returns a new half2 number which has both halves equal to the extracted bits.

__device__ __half2 __lowhigh2highlow (const __half2 a)
Swaps both halves of the half2 input.

Parameters

a
- half2. Is only being read.
Returns
half2

\p

a with its halves being swapped.

Description
Swaps both halves of the half2 input and returns a new half2 number with swapped halves.

__device__ __half2 __lows2half2 (const __half2 a, const __half2 b)
Extracts low 16 bits from each of the two half2 inputs and combines into one half2 number.

Parameters
a
- half2. Is only being read.

b
- half2. Is only being read.

Returns
half2

\p

The

low 16 bits of a and of b.

Description
Extracts low 16 bits from each of the two half2 inputs and combines into one half2 number. Low 16 bits from input a is stored in low 16 bits of the return value, low 16 bits from input b is stored in high 16 bits of the return value.

__device__ __half __shfl_down_sync (unsigned mask, __half var, unsigned int delta, int width)
Exchange a variable between threads within a warp. Copy from a thread with higher ID relative to the caller.

Parameters
mask
- unsigned int. Is only being read.

var
- half. Is only being read.
```c
__device__ __half2 __shfl_down_sync (unsigned mask, __half2 var, unsigned int delta, int width)
```

Exchange a variable between threads within a warp. Copy from a thread with higher ID relative to the caller.

**Parameters**

- **mask**
  
  - unsigned int. Is only being read.

- **var**
  
  - half2. Is only being read.

- **delta**
  
  - int. Is only being read.

- **width**
  
  - int. Is only being read.

**Returns**

Returns the 4-byte word referenced by var from the source thread ID as half2. If the source thread ID is out of range or the source thread has exited, the calling thread's own var is returned.

**Description**

Calculates a source thread ID by adding delta to the caller's thread ID. The value of var held by the resulting thread ID is returned: this has the effect of shifting var down the warp by delta threads. If width is less than warpSize then each subsection of the warp behaves as a separate entity with a starting logical thread ID of 0. As for `__shfl_up_sync()`, the ID number of the source thread will not wrap around the value of width and so the upper delta threads will remain unchanged.

Calculates a source thread ID by adding delta to the caller's thread ID. The value of var held by the resulting thread ID is returned: this has the effect of shifting var down the warp by delta threads. If width is less than warpSize then each subsection of the warp behaves as a separate entity with a starting logical thread ID of 0. As for `__shfl_up_sync()`, the ID number of the source thread will not wrap around the value of width and so the upper delta threads will remain unchanged.
down the warp by delta threads. If width is less than warpSize then each subsection of
the warp behaves as a separate entity with a starting logical thread ID of 0. As for
__shfl_up_sync(), the ID number of the source thread will not wrap around the value of
width and so the upper delta threads will remain unchanged.

__device__ __half __shfl_sync (unsigned mask, __half var, int delta,
int width)
Exchange a variable between threads within a warp. Direct copy from indexed thread.

Parameters

mask
- unsigned int. Is only being read.

var
- half. Is only being read.

delta
- int. Is only being read.

width
- int. Is only being read.

Returns

Returns the 2-byte word referenced by var from the source thread ID as half. If the
source thread ID is out of range or the source thread has exited, the calling thread’s own
var is returned.

Description

Returns the value of var held by the thread whose ID is given by delta. If width is less
than warpSize then each subsection of the warp behaves as a separate entity with a
starting logical thread ID of 0. If delta is outside the range [0:width-1], the value returned
corresponds to the value of var held by the delta modulo width (i.e. within the same
subsection). width must have a value which is a power of 2; results are undefined if
width is not a power of 2, or is a number greater than warpSize.

__device__ __half2 __shfl_sync (unsigned mask, __half2 var, int
delta, int width)
Exchange a variable between threads within a warp. Direct copy from indexed thread.

Parameters

mask
- unsigned int. Is only being read.

var
- half2. Is only being read.
**delta**
- int. Is only being read.

**width**
- int. Is only being read.

**Returns**
Returns the 4-byte word referenced by var from the source thread ID as half2. If the source thread ID is out of range or the source thread has exited, the calling thread’s own var is returned.

**Description**
Returns the value of var held by the thread whose ID is given by delta. If width is less than warpSize then each subsection of the warp behaves as a separate entity with a starting logical thread ID of 0. If delta is outside the range [0:width-1], the value returned corresponds to the value of var held by the delta modulo width (i.e. within the same subsection). width must have a value which is a power of 2; results are undefined if width is not a power of 2, or is a number greater than warpSize.

```c
__device__ __half __shfl_up_sync (unsigned mask, __half var, unsigned int delta, int width)
```
Exchange a variable between threads within a warp. Copy from a thread with lower ID relative to the caller.

**Parameters**

**mask**
- unsigned int. Is only being read.

**var**
- half. Is only being read.

**delta**
- int. Is only being read.

**width**
- int. Is only being read.

**Returns**
Returns the 2-byte word referenced by var from the source thread ID as half. If the source thread ID is out of range or the source thread has exited, the calling thread’s own var is returned.

**Description**
Calculates a source thread ID by subtracting delta from the caller’s lane ID. The value of var held by the resulting lane ID is returned: in effect, var is shifted up the warp by
delta threads. If width is less than warpSize then each subsection of the warp behaves
as a separate entity with a starting logical thread ID of 0. The source thread index
will not wrap around the value of width, so effectively the lower delta threads will be
unchanged. width must have a value which is a power of 2; results are undefined if
width is not a power of 2, or is a number greater than warpSize.

__device__ __half2 __shfl_up_sync (unsigned mask, __half2 var,
unsigned int delta, int width)
Exchange a variable between threads within a warp. Copy from a thread with lower ID
relative to the caller.

Parameters

- mask
  - unsigned int. Is only being read.
- var
  - half2. Is only being read.
- delta
  - int. Is only being read.
- width
  - int. Is only being read.

Returns

Returns the 4-byte word referenced by var from the source thread ID as half2. If the
source thread ID is out of range or the source thread has exited, the calling thread's own
var is returned.

Description

Calculates a source thread ID by subtracting delta from the caller's lane ID. The value
of var held by the resulting lane ID is returned: in effect, var is shifted up the warp by
delta threads. If width is less than warpSize then each subsection of the warp behaves
as a separate entity with a starting logical thread ID of 0. The source thread index
will not wrap around the value of width, so effectively the lower delta threads will be
unchanged. width must have a value which is a power of 2; results are undefined if
width is not a power of 2, or is a number greater than warpSize.
__device__ __half __shfl_xor_sync (unsigned mask, __half var, int delta, int width)
Exchange a variable between threads within a warp. Copy from a thread based on bitwise XOR of own thread ID.

Parameters

mask
- unsigned int. Is only being read.

var
- half. Is only being read.

delta
- int. Is only being read.

width
- int. Is only being read.

Returns

Returns the 2-byte word referenced by var from the source thread ID as half. If the source thread ID is out of range or the source thread has exited, the calling thread’s own var is returned.

Description

Calculates a source thread ID by performing a bitwise XOR of the caller’s thread ID with mask: the value of var held by the resulting thread ID is returned. If width is less than warpSize then each group of width consecutive threads are able to access elements from earlier groups of threads, however if they attempt to access elements from later groups of threads their own value of var will be returned. This mode implements a butterfly addressing pattern such as is used in tree reduction and broadcast.

__device__ __half2 __shfl_xor_sync (unsigned mask, __half2 var, int delta, int width)
Exchange a variable between threads within a warp. Copy from a thread based on bitwise XOR of own thread ID.

Parameters

mask
- unsigned int. Is only being read.

var
- half2. Is only being read.

delta
- int. Is only being read.
width
- int. Is only being read.

Returns
Returns the 4-byte word referenced by var from the source thread ID as half2. If the source thread ID is out of range or the source thread has exited, the calling thread's own var is returned.

Description
Calculates a source thread ID by performing a bitwise XOR of the caller's thread ID with mask: the value of var held by the resulting thread ID is returned. If width is less than warpSize then each group of width consecutive threads are able to access elements from earlier groups of threads, however if they attempt to access elements from later groups of threads their own value of var will be returned. This mode implements a butterfly addressing pattern such as is used in tree reduction and broadcast.

__device__ __half __short2half_rd (short int i)
Convert a signed short integer to a half in round-down mode.

Parameters
i
- short int. Is only being read.

Returns
half

Description
Convert the signed short integer value i to a half-precision floating point value in round-down mode.

__device__ __half __short2half_rd (short int i)
Convert a signed short integer to a half in round-to-nearest-even mode.

Parameters
i
- short int. Is only being read.
Returns
half
  i converted to half.

Description
Convert the signed short integer value \( i \) to a half-precision floating point value in round-to-nearest-even mode.

__device__ __half __short2half_ru (short int i)
Convert a signed short integer to a half in round-up mode.

Parameters
i
  - short int. Is only being read.

Returns
half
  i converted to half.

Description
Convert the signed short integer value \( i \) to a half-precision floating point value in round-up mode.

__device__ __half __short2half_rz (short int i)
Convert a signed short integer to a half in round-towards-zero mode.

Parameters
i
  - short int. Is only being read.

Returns
half
  i converted to half.
Description
Convert the signed short integer value \( i \) to a half-precision floating point value in round-towards-zero mode.

\[
\text{__device__ __half __short\_as\_half (const short int i)}
\]
Reinterprets bits in a signed short integer as a half.

Parameters
\( i \)
- short int. Is only being read.

Returns
half
- The reinterpreted value.

Description
Reinterprets the bits in the signed short integer \( i \) as a half-precision floating point number.

\[
\text{__device__ __half __uint2half\_rd (unsigned int i)}
\]
Convert an unsigned integer to a half in round-down mode.

Parameters
\( i \)
- unsigned int. Is only being read.

Returns
half
- \( i \) converted to half.

Description
Convert the unsigned integer value \( i \) to a half-precision floating point value in round-down mode.
__device__ __half __uint2half_rn (unsigned int i)
Convert an unsigned integer to a half in round-to-nearest-even mode.

Parameters
i
- unsigned int. Is only being read.

Returns
half

\[ \text{i converted to half.} \]

Description
Convert the unsigned integer value \( i \) to a half-precision floating point value in round-to-nearest-even mode.

__device__ __half __uint2half_ru (unsigned int i)
Convert an unsigned integer to a half in round-up mode.

Parameters
i
- unsigned int. Is only being read.

Returns
half

\[ \text{i converted to half.} \]

Description
Convert the unsigned integer value \( i \) to a half-precision floating point value in round-up mode.
__device__ __half __uint2half_rz (unsigned int i)
Convert an unsigned integer to a half in round-towards-zero mode.

Parameters
i
- unsigned int. Is only being read.

Returns
half
    i converted to half.

Description
Convert the unsigned integer value \( i \) to a half-precision floating point value in round-towards-zero mode.

__device__ __half __ull2half_rd (unsigned long long int i)
Convert an unsigned 64-bit integer to a half in round-down mode.

Parameters
i
- unsigned long long int. Is only being read.

Returns
half
    i converted to half.

Description
Convert the unsigned 64-bit integer value \( i \) to a half-precision floating point value in round-down mode.
__device__ __half __ull2half_rn (unsigned long long int i)
Convert an unsigned 64-bit integer to a half in round-to-nearest-even mode.

Parameters

i
- unsigned long long int. Is only being read.

Returns

half

i converted to half.

Description

Convert the unsigned 64-bit integer value i to a half-precision floating point value in round-to-nearest-even mode.

__device__ __half __ull2half_ru (unsigned long long int i)
Convert an unsigned 64-bit integer to a half in round-up mode.

Parameters

i
- unsigned long long int. Is only being read.

Returns

half

i converted to half.

Description

Convert the unsigned 64-bit integer value i to a half-precision floating point value in round-up mode.
__device__ __half __ull2half_rz (unsigned long long int i)
Convert an unsigned 64-bit integer to a half in round-towards-zero mode.

Parameters
i
- unsigned long long int. Is only being read.

Returns
half

\p
  i converted to half.

Description
Convert the unsigned 64-bit integer value $i$ to a half-precision floating point value in round-towards-zero mode.

__device__ __half __ushort2half_rd (unsigned short int i)
Convert an unsigned short integer to a half in round-down mode.

Parameters
i
- unsigned short int. Is only being read.

Returns
half

\p
  i converted to half.

Description
Convert the unsigned short integer value $i$ to a half-precision floating point value in round-down mode.
__device__ __half __ushort2half_rn (unsigned short int i)
Convert an unsigned short integer to a half in round-to-nearest-even mode.

Parameters

i
- unsigned short int. Is only being read.

Returns

half
- i converted to half.

Description

Convert the unsigned short integer value \( i \) to a half-precision floating point value in round-to-nearest-even mode.

__device__ __half __ushort2half_ru (unsigned short int i)
Convert an unsigned short integer to a half in round-up mode.

Parameters

i
- unsigned short int. Is only being read.

Returns

half
- i converted to half.

Description

Convert the unsigned short integer value \( i \) to a half-precision floating point value in round-up mode.
__device__ __half __ushort2half_rz (unsigned short int i)
Convert an unsigned short integer to a half in round-towards-zero mode.

Parameters

i
- unsigned short int. Is only being read.

Returns

half

- i converted to half.

Description

Convert the unsigned short integer value i to a half-precision floating point value in round-towards-zero mode.

__device__ __half __ushort_as_half (const unsigned short int i)
Reinterprets bits in an unsigned short integer as a half.

Parameters

i
- unsigned short int. Is only being read.

Returns

half

- The reinterpreted value.

Description

Reinterprets the bits in the unsigned short integer i as a half-precision floating point number.

1.1.6. Half Math Functions

Half Precision Intrinsics

To use these functions include the header file cuda_fp16.h in your program.
__device__ __half hceil (const __half h)
Calculate ceiling of the input argument.

Parameters
h
- half. Is only being read.

Returns
half
- The smallest integer value not less than h.

Description
Compute the smallest integer value not less than h.

__device__ __half hcos (const __half a)
Calculates half cosine in round-to-nearest-even mode.

Parameters
a
- half. Is only being read.

Returns
half
- The cosine of a.

Description
Calculates half cosine of input a in round-to-nearest-even mode.

__device__ __half hexp (const __half a)
Calculates half natural exponential function in round-to-nearest mode.

Parameters
a
- half. Is only being read.
Returns
half
▶ The
natural exponential function on a.

Description
Calculates half natural exponential function of input a in round-to-nearest-even mode.

__device__ __half hexp10 (const __half a)
Calculates half decimal exponential function in round-to-nearest mode.

Parameters
a
- half. Is only being read.

Returns
half
▶ The
decimal exponential function on a.

Description
Calculates half decimal exponential function of input a in round-to-nearest-even mode.

__device__ __half hexp2 (const __half a)
Calculates half binary exponential function in round-to-nearest mode.

Parameters
a
- half. Is only being read.

Returns
half
▶ The
binary exponential function on a.

Description
Calculates half binary exponential function of input a in round-to-nearest-even mode.
__device__ __half hfloor (const __half h)
Calculate the largest integer less than or equal to h.

Parameters
h
- half. Is only being read.

Returns
half
- The
  largest integer value which is less than or equal to h.

Description
Calculate the largest integer value which is less than or equal to h.

__device__ __half hlog (const __half a)
Calculates half natural logarithm in round-to-nearest-even mode.

Parameters
a
- half. Is only being read.

Returns
half
- The
  natural logarithm of a.

Description
Calculates half natural logarithm of input a in round-to-nearest-even mode.

__device__ __half hlog10 (const __half a)
Calculates half decimal logarithm in round-to-nearest-even mode.

Parameters
a
- half. Is only being read.
**Returns**

half

- The decimal logarithm of \(a\).

**Description**

Calculates half decimal logarithm of input \(a\) in round-to-nearest-even mode.

```c
__device__ __half hlog2 (const __half a)
```

**Parameters**

\(a\)

- half. Is only being read.

**Returns**

half

- The binary logarithm of \(a\).

**Description**

Calculates half binary logarithm of input \(a\) in round-to-nearest-even mode.

```c
__device__ __half hrcp (const __half a)
```

**Parameters**

\(a\)

- half. Is only being read.

**Returns**

half

- The reciprocal of \(a\).

**Description**

Calculates half reciprocal of input \(a\) in round-to-nearest-even mode.
__device__ __half hrint (const __half h)
Round input to nearest integer value in half-precision floating point number.

Parameters

h
- half. Is only being read.

Returns

half

- The nearest integer to h.

Description

Round h to the nearest integer value in half-precision floating point format, with halfway cases rounded to the nearest even integer value.

__device__ __half hrsqrt (const __half a)
Calculates half reciprocal square root in round-to-nearest-even mode.

Parameters

a
- half. Is only being read.

Returns

half

- The reciprocal square root of a.

Description

Calculates half reciprocal square root of input a in round-to-nearest mode.

__device__ __half hsin (const __half a)
Calculates half sine in round-to-nearest-even mode.

Parameters

a
- half. Is only being read.
Returns
half
▶ The sine of a.

Description
Calculates half sine of input a in round-to-nearest-even mode.

__device__ __half hsqrt (const __half a)
Calculates half square root in round-to-nearest-even mode.

Parameters
a
- half. Is only being read.

Returns
half
▶ The square root of a.

Description
Calculates half square root of input a in round-to-nearest-even mode.

__device__ __half htrunc (const __half h)
Truncate input argument to the integral part.

Parameters
h
- half. Is only being read.

Returns
half
▶ The truncated integer value.

Description
Round h to the nearest integer value that does not exceed h in magnitude.
1.1.7. Half2 Math Functions

Half Precision Intrinsics

To use these functions include the header file cuda_fp16.h in your program.

__device__ __half2 h2ceil (const __half2 h)
Calculate half2 vector ceiling of the input argument.

Parameters

h
- half2. Is only being read.

Returns

half2
  The
  vector of smallest integers not less than h.

Description

For each component of vector h compute the smallest integer value not less than h.

__device__ __half2 h2cos (const __half2 a)
Calculates half2 vector cosine in round-to-nearest-even mode.

Parameters

a
- half2. Is only being read.

Returns

half2
  The
  elementwise cosine on vector a.

Description

Calculates half2 cosine of input vector a in round-to-nearest-even mode.
__device__ __half2 h2exp (const __half2 a)
Calculates half2 vector exponential function in round-to-nearest mode.

Parameters
a
- half2. Is only being read.

Returns
half2

Description
Calculates half2 exponential function of input vector a in round-to-nearest-even mode.

__device__ __half2 h2exp10 (const __half2 a)
Calculates half2 vector decimal exponential function in round-to-nearest-even mode.

Parameters
a
- half2. Is only being read.

Returns
half2

Description
Calculates half2 decimal exponential function of input vector a in round-to-nearest-even mode.

__device__ __half2 h2exp2 (const __half2 a)
Calculates half2 vector binary exponential function in round-to-nearest-even mode.

Parameters
a
- half2. Is only being read.
\textbf{Returns}

\texttt{half2}

- The elementwise binary exponential function on vector \texttt{a}.

\textbf{Description}

Calculates \texttt{half2} binary exponential function of input vector \texttt{a} in round-to-nearest-even mode.

\begin{verbatim}
__device__ __half2 h2floor (const __half2 h)
\end{verbatim}

Calculate the largest integer less than or equal to \texttt{h}.

\textbf{Parameters}

\texttt{h}

- \texttt{half2}. Is only being read.

\textbf{Returns}

\texttt{half2}

- The vector of largest integers which is less than or equal to \texttt{h}.

\textbf{Description}

For each component of vector \texttt{h} calculate the largest integer value which is less than or equal to \texttt{h}.

\begin{verbatim}
__device__ __half2 h2log (const __half2 a)
\end{verbatim}

Calculates \texttt{half2} vector natural logarithm in round-to-nearest-even mode.

\textbf{Parameters}

\texttt{a}

- \texttt{half2}. Is only being read.

\textbf{Returns}

\texttt{half2}

- The elementwise natural logarithm on vector \texttt{a}.
Description
Calculates half2 natural logarithm of input vector \( a \) in round-to-nearest-even mode.

```
__device__ __half2 h2log10 (const __half2 a)
```
Calculates half2 vector decimal logarithm in round-to-nearest-even mode.

Parameters
\( a \)
- half2. Is only being read.

Returns
half2
- The elementwise decimal logarithm on vector \( a \).

Description
Calculates half2 decimal logarithm of input vector \( a \) in round-to-nearest-even mode.

```
__device__ __half2 h2log2 (const __half2 a)
```
Calculates half2 vector binary logarithm in round-to-nearest-even mode.

Parameters
\( a \)
- half2. Is only being read.

Returns
half2
- The elementwise binary logarithm on vector \( a \).

Description
Calculates half2 binary logarithm of input vector \( a \) in round-to-nearest mode.
__device__ __half2 h2rcp (const __half2 a)
Calculates half2 vector reciprocal in round-to-nearest-even mode.

Parameters
a
- half2. Is only being read.

Returns
half2
- The elementwise reciprocal on vector a.

Description
Calculates half2 reciprocal of input vector a in round-to-nearest-even mode.

__device__ __half2 h2rint (const __half2 h)
Round input to nearest integer value in half-precision floating point number.

Parameters
h
- half2. Is only being read.

Returns
half2
- The vector of rounded integer values.

Description
Round each component of half2 vector h to the nearest integer value in half-precision floating point format, with halfway cases rounded to the nearest even integer value.

__device__ __half2 h2rsqrt (const __half2 a)
Calculates half2 vector reciprocal square root in round-to-nearest mode.

Parameters
a
- half2. Is only being read.
Returns
half2
  - The elementwise reciprocal square root on vector a.

Description
Calculates half2 reciprocal square root of input vector a in round-to-nearest-even mode.

_device_ __half2 h2sin (const __half2 a)
Calculates half2 vector sine in round-to-nearest-even mode.

Parameters
a
  - half2. Is only being read.

Returns
half2
  - The elementwise sine on vector a.

Description
Calculates half2 sine of input vector a in round-to-nearest-even mode.

_device_ __half2 h2sqrt (const __half2 a)
Calculates half2 vector square root in round-to-nearest-even mode.

Parameters
a
  - half2. Is only being read.

Returns
half2
  - The elementwise square root on vector a.
**Description**
Calculates  \( \text{half2} \) square root of input vector \( a \) in round-to-nearest mode.

```
__device__ __half2 h2trunc (const __half2 h)
```
Truncate \( \text{half2} \) vector input argument to the integral part.

**Parameters**
\( h \)
- \( \text{half2} \). Is only being read.

**Returns**
\( \text{half2} \)
- The truncated \( h \).

**Description**
Round each component of vector \( h \) to the nearest integer value that does not exceed \( h \) in magnitude.

### 1.2. Mathematical Functions

CUDA mathematical functions are always available in device code. Some functions are also available in host code as indicated.

Note that floating-point functions are overloaded for different argument types. For example, the \( \log() \) function has the following prototypes:

```
double log(double x);
float  log(float x);
float  logf(float  x);
```

### 1.3. Single Precision Mathematical Functions

This section describes single precision mathematical functions. To use these functions you do not need to include any additional header files in your program.
__device__ float acosf (float x)
Calculate the arc cosine of the input argument.

Returns
Result will be in radians, in the interval [0, \( \pi \)] for \( x \) inside [-1, +1].

- \( \text{acos}(1) \) returns +0.
- \( \text{acos}(x) \) returns NaN for \( x \) outside [-1, +1].

Description
Calculate the principal value of the arc cosine of the input argument \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float acoshf (float x)
Calculate the nonnegative arc hyperbolic cosine of the input argument.

Returns
Result will be in the interval [0, +\( \infty \)].

- \( \text{acosh}(1) \) returns 0.
- \( \text{acosh}(x) \) returns NaN for \( x \) in the interval \([-\infty, 1)\).

Description
Calculate the nonnegative arc hyperbolic cosine of the input argument \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float asinf (float x)
Calculate the arc sine of the input argument.

Returns
Result will be in radians, in the interval \([-\pi/2, +\pi/2]\) for \( x \) inside [-1, +1].

- \( \text{asinf}(0) \) returns +0.
- \( \text{asinf}(x) \) returns NaN for \( x \) outside [-1, +1].
Description
Calculate the principal value of the arc sine of the input argument x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float asinhf (float x)
Calculate the arc hyperbolic sine of the input argument.

Returns
-asinhf(0) returns 1.

Description
Calculate the arc hyperbolic sine of the input argument x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float atan2f (float y, float x)
Calculate the arc tangent of the ratio of first and second input arguments.

Returns
Result will be in radians, in the interval [-π, +π].
- atan2f(0, 1) returns +0.

Description
Calculate the principal value of the arc tangent of the ratio of first and second input arguments y / x. The quadrant of the result is determined by the signs of inputs y and x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
**__device__ float atanf (float x)**
Calculate the arc tangent of the input argument.

**Returns**
Result will be in radians, in the interval \([ -\pi/2 , +\pi/2 ] \).

- `atanf(0)` returns +0.

**Description**
Calculate the principal value of the arc tangent of the input argument `x`.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

**__device__ float atanhf (float x)**
Calculate the arc hyperbolic tangent of the input argument.

**Returns**

- `atanhf(\pm0)` returns ±0.
- `atanhf(\pm1)` returns ±∞.
- `atanhf(x)` returns NaN for `x` outside interval \([-1, 1]\).

**Description**
Calculate the arc hyperbolic tangent of the input argument `x`.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

**__device__ float cbrtf (float x)**
Calculate the cube root of the input argument.

**Returns**
Returns \(x^{1/3}\).

- `cbrtf(\pm0)` returns ±0.
- `cbrtf(\pm\infty)` returns ±∞.
Description
Calculate the cube root of \( x \), \( x^{1/3} \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

\texttt{__device__ float ceilf(float x)}

Calculate ceiling of the input argument.

Returns
Returns \([x] \) expressed as a floating-point number.

- \( \text{ceilf}(\pm 0) \) returns \( \pm 0 \).
- \( \text{ceilf}(\pm \infty) \) returns \( \pm \infty \).

Description
Compute the smallest integer value not less than \( x \).

\texttt{__device__ float copysignf(float x, float y)}

Create value with given magnitude, copying sign of second value.

Returns
Returns a value with the magnitude of \( x \) and the sign of \( y \).

Description
Create a floating-point value with the magnitude \( x \) and the sign of \( y \).

\texttt{__device__ float cosf(float x)}

Calculate the cosine of the input argument.

Returns

- \( \text{cosf}(0) \) returns 1.
- \( \text{cosf}(\pm \infty) \) returns NaN.

Description
Calculate the cosine of the input argument \( x \) (measured in radians).
__device__ float coshf (float x)
Calculate the hyperbolic cosine of the input argument.

Returns
- `coshf(0)` returns 1.
- `coshf(±∞)` returns NaN.

Description
Calculate the hyperbolic cosine of the input argument `x`.

__device__ float cospif (float x)
Calculate the cosine of the input argument `x` measured in radians.

Returns
- `cospif(±0)` returns 1.
- `cospif(±∞)` returns NaN.

Description
Calculate the cosine of `x` measured in radians, where `x` is the input argument.
__device__ float cyl_bessel_i0f (float x)
Calculate the value of the regular modified cylindrical Bessel function of order 0 for the input argument.

Returns
Returns the value of the regular modified cylindrical Bessel function of order 0.

Description
Calculate the value of the regular modified cylindrical Bessel function of order 0 for the input argument \( x \), \( I_0(x) \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float cyl_bessel_i1f (float x)
Calculate the value of the regular modified cylindrical Bessel function of order 1 for the input argument.

Returns
Returns the value of the regular modified cylindrical Bessel function of order 1.

Description
Calculate the value of the regular modified cylindrical Bessel function of order 1 for the input argument \( x \), \( I_1(x) \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float erfcf (float x)
Calculate the complementary error function of the input argument.

Returns
- \( \text{erfcf}( -\infty ) \) returns 2.
- \( \text{erfcf}( +\infty ) \) returns +0.
Description
Calculate the complementary error function of the input argument $x$, $1 - \text{erf}(x)$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float erfcinvf (float y)
Calculate the inverse complementary error function of the input argument.

Returns
- erfcinvf(0) returns $+\infty$.
- erfcinvf(2) returns $-\infty$.

Description
Calculate the inverse complementary error function of the input argument $y$, for $y$ in the interval $[0, 2]$. The inverse complementary error function find the value $x$ that satisfies the equation $y = \text{erfc}(x)$, for $0 \leq y \leq 2$, and $-\infty \leq x \leq \infty$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float erfcxf (float x)
Calculate the scaled complementary error function of the input argument.

Returns
- erfcx($-\infty$) returns $+\infty$
- erfcx($+\infty$) returns $+0$
- erfcx($x$) returns $+\infty$ if the correctly calculated value is outside the single floating point range.

Description
Calculate the scaled complementary error function of the input argument $x$, $e^{x^2} \cdot \text{erfc}(x)$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
__device__ float erff (float x)
Calculate the error function of the input argument.

Returns

\[ \begin{align*}
\text{erff}(\pm 0) & \text{ returns } \pm 0. \\
\text{erff}(\pm \infty) & \text{ returns } \pm 1.
\end{align*} \]

Description

Calculate the value of the error function for the input argument \( x \),
\[
\frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt.
\]

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float erfinvf (float y)
Calculate the inverse error function of the input argument.

Returns

\[ \begin{align*}
\text{erfinvf}(1) & \text{ returns } +\infty. \\
\text{erfinvf}(-1) & \text{ returns } -\infty.
\end{align*} \]

Description

Calculate the inverse error function of the input argument \( y \), for \( y \) in the interval \([-1, 1]\). The inverse error function finds the value \( x \) that satisfies the equation \( y = \text{erf}(x) \), for \( -1 \leq y \leq 1 \), and \( -\infty \leq x \leq \infty \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float exp10f (float x)
Calculate the base 10 exponential of the input argument.

Returns

Returns \( 10^x \).
Description
Calculate the base 10 exponential of the input argument \( x \).

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
- This function is affected by the --use_fast_math compiler flag. See the CUDA C++ Programming Guide, Appendix E.2, Table 8 for a complete list of functions affected.

__device__ float exp2f (float x)
Calculate the base 2 exponential of the input argument.

Returns
Returns \( 2^x \).

Description
Calculate the base 2 exponential of the input argument \( x \).

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float expf (float x)
Calculate the base \( e \) exponential of the input argument.

Returns
Returns \( e^x \).

Description
Calculate the base \( e \) exponential of the input argument \( x \), \( e^x \).

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
- This function is affected by the --use_fast_math compiler flag. See the CUDA C++ Programming Guide, Appendix E.2, Table 8 for a complete list of functions affected.
__device__ float expm1f (float x)
Calculate the base $e$ exponential of the input argument, minus 1.

Returns
Returns $e^x - 1$.

Description
Calculate the base $e$ exponential of the input argument $x$, minus 1.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float fabsf (float x)
Calculate the absolute value of its argument.

Returns
Returns the absolute value of its argument.

- $\text{fabs}(\pm \infty)$ returns $+\infty$.
- $\text{fabs}(\pm 0)$ returns 0.

Description
Calculate the absolute value of the input argument $x$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float fdimf (float x, float y)
Compute the positive difference between $x$ and $y$.

Returns
Returns the positive difference between $x$ and $y$.

- $\text{fdimf}(x, y)$ returns $x - y$ if $x > y$.
- $\text{fdimf}(x, y)$ returns $+0$ if $x \leq y$. 
Description
Compute the positive difference between \( x \) and \( y \). The positive difference is \( x - y \) when \( x > y \) and \( +0 \) otherwise.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float fdividef (float x, float y)
Divide two floating point values.

Returns
Returns \( x / y \).

Description
Compute \( x \) divided by \( y \). If \(--use_fast_math\) is specified, use \( __fdividef() \) for higher performance, otherwise use normal division.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

This function is affected by the \(--use_fast_math\) compiler flag. See the CUDA C++ Programming Guide, Appendix E.2, Table 8 for a complete list of functions affected.

__device__ float floorf (float x)
Calculate the largest integer less than or equal to \( x \).

Returns
Returns \( x \) expressed as a floating-point number.

- floorf( \( \pm \infty \) ) returns \( \pm \infty \).
- floorf( \( \pm 0 \) ) returns \( \pm 0 \).

Description
Calculate the largest integer value which is less than or equal to \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
__device__ float fmaf (float x, float y, float z)
Compute $x \times y + z$ as a single operation.

Returns
Returns the rounded value of $x \times y + z$ as a single operation.

- $\text{fmaf}(\pm \infty, \pm 0, z)$ returns NaN.
- $\text{fmaf}(\pm 0, \pm \infty, z)$ returns NaN.
- $\text{fmaf}(x, y, -\infty)$ returns NaN if $x \times y$ is an exact $+\infty$.
- $\text{fmaf}(x, y, +\infty)$ returns NaN if $x \times y$ is an exact $-\infty$.

Description
Compute the value of $x \times y + z$ as a single ternary operation. After computing the value to infinite precision, the value is rounded once.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float fmaxf (float x, float y)
Determine the maximum numeric value of the arguments.

Returns
Returns the maximum numeric values of the arguments $x$ and $y$.

- If both arguments are NaN, returns NaN.
- If one argument is NaN, returns the numeric argument.

Description
Determines the maximum numeric value of the arguments $x$ and $y$. Treats NaN arguments as missing data. If one argument is a NaN and the other is legitimate numeric value, the numeric value is chosen.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
__device__ float fminf (float x, float y)
Determine the minimum numeric value of the arguments.

Returns
Returns the minimum numeric values of the arguments \( x \) and \( y \).

- If both arguments are NaN, returns NaN.
- If one argument is NaN, returns the numeric argument.

Description
Determines the minimum numeric value of the arguments \( x \) and \( y \). Treats NaN arguments as missing data. If one argument is a NaN and the other is legitimate numeric value, the numeric value is chosen.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float fmodf (float x, float y)
Calculate the floating-point remainder of \( x / y \).

Returns
- Returns the floating point remainder of \( x / y \).
- \( \text{fmodf}( \pm 0, y) \) returns \( \pm 0 \) if \( y \) is not zero.
- \( \text{fmodf}(x, y) \) returns NaN and raised an invalid floating point exception if \( x \) is \( \pm \infty \) or \( y \) is zero.
- \( \text{fmodf}(x, y) \) returns zero if \( y \) is zero or the result would overflow.
- \( \text{fmodf}(x, \pm \infty) \) returns \( x \) if \( x \) is finite.
- \( \text{fmodf}(x, 0) \) returns NaN.

Description
Calculate the floating-point remainder of \( x / y \). The absolute value of the computed value is always less than \( y \)'s absolute value and will have the same sign as \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
__device__ float frexp (float x, int *nptr)
Extract mantissa and exponent of a floating-point value.

Returns

Returns the fractional component \( m \).

- frexp(0, nptr) returns 0 for the fractional component and zero for the integer component.
- frexp(±0, nptr) returns ±0 and stores zero in the location pointed to by nptr.
- frexp(±∞, nptr) returns ±∞ and stores an unspecified value in the location to which nptr points.
- frexp(NaN, y) returns a NaN and stores an unspecified value in the location to which nptr points.

Description

Decomposes the floating-point value \( x \) into a component \( m \) for the normalized fraction element and another term \( n \) for the exponent. The absolute value of \( m \) will be greater than or equal to 0.5 and less than 1.0 or it will be equal to 0; \( x = m \cdot 2^n \). The integer exponent \( n \) will be stored in the location to which nptr points.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float __CRTDECL hypotf (float x, float y)
Calculate the square root of the sum of squares of two arguments.

Returns

Returns the length of the hypotenuse \( \sqrt{x^2 + y^2} \). If the correct value would overflow, returns +\( \infty \). If the correct value would underflow, returns 0.

Description

Calculates the length of the hypotenuse of a right triangle whose two sides have lengths \( x \) and \( y \) without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
__device__ int ilogbf (float x)
Compute the unbiased integer exponent of the argument.

Returns
- If successful, returns the unbiased exponent of the argument.
- \( \text{ilogbf}(0) \) returns INT_MIN.
- \( \text{ilogbf}(\text{NaN}) \) returns NaN.
- \( \text{ilogbf}(x) \) returns INT_MAX if \( x \) is \( \infty \) or the correct value is greater than INT_MAX.
- \( \text{ilogbf}(x) \) returns INT_MIN if the correct value is less than INT_MIN.

Description
Calculates the unbiased integer exponent of the input argument \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ __RETURN_TYPE isfinite (float a)
Determine whether argument is finite.

Returns
- With Visual Studio 2013 host compiler: __RETURN_TYPE is 'bool'. Returns true if and only if \( a \) is a finite value.
- With other host compilers: __RETURN_TYPE is 'int'. Returns a nonzero value if and only if \( a \) is a finite value.

Description
Determine whether the floating-point value \( a \) is a finite value (zero, subnormal, or normal and not infinity or NaN).

__device__ __RETURN_TYPE isinf (float a)
Determine whether argument is infinite.

Returns
- With Visual Studio 2013 host compiler: __RETURN_TYPE is 'bool'. Returns true if and only if \( a \) is an infinite value.
- With other host compilers: __RETURN_TYPE is 'int'. Returns a nonzero value if and only if \( a \) is an infinite value.
Description
Determine whether the floating-point value \( a \) is an infinite value (positive or negative).

\[
\text{\texttt{\_device\_ \_RETURN\_TYPE isnan (float a)}}
\]
Determine whether argument is a NaN.

Returns
- With Visual Studio 2013 host compiler: \_RETURN\_TYPE is 'bool'. Returns true if and only if \( a \) is a NaN value.
- With other host compilers: \_RETURN\_TYPE is 'int'. Returns a nonzero value if and only if \( a \) is a NaN value.

Description
Determine whether the floating-point value \( a \) is a NaN.

\[
\text{\_device\_ float j0f (float x)}
\]
Calculate the value of the Bessel function of the first kind of order 0 for the input argument.

Returns
Returns the value of the Bessel function of the first kind of order 0.
- \( j_0f(\pm \infty) \) returns +0.
- \( j_0f(\text{NaN}) \) returns NaN.

Description
Calculate the value of the Bessel function of the first kind of order 0 for the input argument \( x \), \( j_0(x) \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

\[
\text{\_device\_ float j1f (float x)}
\]
Calculate the value of the Bessel function of the first kind of order 1 for the input argument.

Returns
Returns the value of the Bessel function of the first kind of order 1.
j1f( ±0 ) returns ±0.
• j1f( ±∞ ) returns +0.
• j1f(NaN) returns NaN.

Description
Calculate the value of the Bessel function of the first kind of order 1 for the input argument \( x \), \( J_1(x) \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float jnf (int n, float x)

Calculate the value of the Bessel function of the first kind of order \( n \) for the input argument.

Returns
Returns the value of the Bessel function of the first kind of order \( n \).

• jnf(\( n \), NaN) returns NaN.
• jnf(\( n \), x) returns NaN for \( n < 0 \).
• jnf(\( n \), +∞) returns +0.

Description
Calculate the value of the Bessel function of the first kind of order \( n \) for the input argument \( x \), \( J_n(x) \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float ldexpf (float x, int exp)

Calculate the value of \( x \cdot 2^{\text{exp}} \).

Returns
• ldexpf(\( x \)) returns ±∞ if the correctly calculated value is outside the single floating point range.

Description
Calculate the value of \( x \cdot 2^{\text{exp}} \) of the input arguments \( x \) and \( \text{exp} \).
For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float lgammaf (float x)

Calculate the natural logarithm of the absolute value of the gamma function of the input argument.

Returns

- lgammaf(1) returns +0.
- lgammaf(2) returns +0.
- lgammaf(x) returns $\pm \infty$ if the correctly calculated value is outside the single floating point range.
- lgammaf(x) returns $+\infty$ if $x \leq 0$ and $x$ is an integer.
- lgammaf( $-\infty$ ) returns $-\infty$.
- lgammaf( $+\infty$ ) returns $+\infty$.

Description

Calculate the natural logarithm of the absolute value of the gamma function of the input argument $x$, namely the value of $\log \int_0^\infty e^{-t}t^{x-1}dt$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ long long int llrintf (float x)

Round input to nearest integer value.

Returns

Returns rounded integer value.

Description

Round $x$ to the nearest integer value, with halfway cases rounded to the nearest even integer value. If the result is outside the range of the return type, the result is undefined.
__device__ long long int llroundf (float x)
Round to nearest integer value.

Returns
Returns rounded integer value.

Description
Round x to the nearest integer value, with halfway cases rounded away from zero. If the result is outside the range of the return type, the result is undefined.

This function may be slower than alternate rounding methods. See llrintf().

__device__ float log10f (float x)
Calculate the base 10 logarithm of the input argument.

Returns
‣ log10f( ±0 ) returns −∞.
‣ log10f(1) returns +0.
‣ log10f(x) returns NaN for x < 0.
‣ log10f( +∞ ) returns +∞.

Description
Calculate the base 10 logarithm of the input argument x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float log1pf (float x)
Calculate the value of $\log_e(1 + x)$.

Returns
‣ log1pf( ±0 ) returns −∞.
‣ log1pf(-1) returns +0.
‣ log1pf(x) returns NaN for x < -1.
‣ log1pf( +∞ ) returns +∞.
**Description**
Calculate the value of $\log_e(1 + x)$ of the input argument $x$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

**__device__ float log2f (float x)**
Calculate the base 2 logarithm of the input argument.

**Returns**
- $\log2f( \pm 0)$ returns $-\infty$.
- $\log2f(1)$ returns $+0$.
- $\log2f(x)$ returns NaN for $x < 0$.
- $\log2f( + \infty)$ returns $+\infty$.

**Description**
Calculate the base 2 logarithm of the input argument $x$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

**__device__ float logbf (float x)**
Calculate the floating point representation of the exponent of the input argument.

**Returns**
- $\logbf \pm 0$ returns $-\infty$
- $\logbf + \infty$ returns $+\infty$

**Description**
Calculate the floating point representation of the exponent of the input argument $x$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
__device__ float logf (float x)
Calculate the natural logarithm of the input argument.

Returns

- logf(±0) returns −∞.
- logf(1) returns +0.
- logf(x) returns NaN for x < 0.
- logf(+∞) returns +∞.

Description
Calculate the natural logarithm of the input argument x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ long int lrintf (float x)
Round input to nearest integer value.

Returns
Returns rounded integer value.

Description
Round x to the nearest integer value, with halfway cases rounded to the nearest even integer value. If the result is outside the range of the return type, the result is undefined.

__device__ long int lroundf (float x)
Round to nearest integer value.

Returns
Returns rounded integer value.

Description
Round x to the nearest integer value, with halfway cases rounded away from zero. If the result is outside the range of the return type, the result is undefined.

This function may be slower than alternate rounding methods. See lrintf().
__device__ float modff (float x, float *iptr)

Break down the input argument into fractional and integral parts.

Returns

- modff(±x, iptr) returns a result with the same sign as x.
- modff(±∞, iptr) returns ±0 and stores ±∞ in the object pointed to by iptr.
- modff(NaN, iptr) stores a NaN in the object pointed to by iptr and returns a NaN.

Description

Break down the argument x into fractional and integral parts. The integral part is stored in the argument iptr. Fractional and integral parts are given the same sign as the argument x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float nanf (const char *tagp)

Returns "Not a Number" value.

Returns

- nanf(tagp) returns NaN.

Description

Return a representation of a quiet NaN. Argument tagp selects one of the possible representations.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float nearbyintf (float x)

Round the input argument to the nearest integer.

Returns

- nearbyintf(±0) returns ±0.
- nearbyintf(±∞) returns ±∞.
### Description
Round argument $x$ to an integer value in single precision floating-point format.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

#### __device__ float `nextafterf`(float $x$, float $y$)
Return next representable single-precision floating-point value after argument.

**Returns**

- `nextafterf(\pm \infty, y)` returns $\pm \infty$.

#### Description
Calculate the next representable single-precision floating-point value following $x$ in the direction of $y$. For example, if $y$ is greater than $x$, `nextafterf()` returns the smallest representable number greater than $x$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

#### __device__ float `norm3df`(float $a$, float $b$, float $c$)
Calculate the square root of the sum of squares of three coordinates of the argument.

**Returns**

Returns the length of the 3D $\sqrt{p.x^2 + p.y^2 + p.z^2}$. If the correct value would overflow, returns $+\infty$. If the correct value would underflow, returns 0.

#### Description
Calculates the length of three dimensional vector $p$ in euclidean space without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
__device__ float norm4df (float a, float b, float c, float d)
Calculate the square root of the sum of squares of four coordinates of the argument.

Returns
Returns the length of the 4D vector \( \sqrt{a^2 + b^2 + c^2 + d^2} \). If the correct value would overflow, returns +\( \infty \). If the correct value would underflow, returns 0.

Description
Calculates the length of four dimensional vector \( \mathbf{p} \) in euclidean space without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float normcdff (float y)
Calculate the standard normal cumulative distribution function.

Returns
- \( \text{normcdff}(+\infty) \) returns 1
- \( \text{normcdff}(-\infty) \) returns +0

Description
Calculate the cumulative distribution function of the standard normal distribution for input argument \( y \), \( \Phi(y) \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float normcdfinvf (float y)
Calculate the inverse of the standard normal cumulative distribution function.

Returns
- \( \text{normcdfinvf}(0) \) returns \(-\infty\).
- \( \text{normcdfinvf}(1) \) returns +\( \infty \).
- \( \text{normcdfinvf}(\times) \) returns NaN if \( \times \) is not in the interval \([0,1]\).
Description
Calculate the inverse of the standard normal cumulative distribution function for input argument \( y \), \( \Phi^{-1}(y) \). The function is defined for input values in the interval \((0, 1)\).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float normf (int dim, const float *a)
Calculate the square root of the sum of squares of any number of coordinates.

Returns
Returns the length of the vector \( \sqrt{p_1^2 + p_2^2 + \ldots + p_{\text{dim}}^2} \). If the correct value would overflow, returns \(+\infty\). If the correct value would underflow, returns 0.

Description
Calculates the length of a vector \( p \), dimension of which is passed as an argument without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float powf (float x, float y)
Calculate the value of first argument to the power of second argument.

Returns
- \( \text{powf}(\pm 0, y) \) returns \( \pm \infty \) for \( y \) an integer less than 0.
- \( \text{powf}(\pm 0, y) \) returns \( 0 \) for \( y \) an odd integer greater than 0.
- \( \text{powf}(\pm 0, y) \) returns \( +0 \) for \( y > 0 \) and not and odd integer.
- \( \text{powf}(-1, \pm \infty) \) returns 1.
- \( \text{powf}(+1, y) \) returns 1 for any \( y \), even a NaN.
- \( \text{powf}(x, \pm 0) \) returns 1 for any \( x \), even a NaN.
- \( \text{powf}(x, y) \) returns a NaN for finite \( x < 0 \) and finite non-integer \( y \).
- \( \text{powf}(x, -\infty) \) returns \( +\infty \) for \( |x| < 1 \).
- \( \text{powf}(x, -\infty) \) returns \( +0 \) for \( |x| > 1 \).
- \( \text{powf}(x, +\infty) \) returns \( +0 \) for \( |x| < 1 \).
- \( \text{powf}(x, +\infty) \) returns \( +\infty \) for \( |x| > 1 \).
powf( -∞, y) returns -0 for y an odd integer less than 0.
powf( -∞, y) returns +0 for y < 0 and not an odd integer.
powf( -∞, y) returns -∞ for y an odd integer greater than 0.
powf( -∞, y) returns +∞ for y > 0 and not an odd integer.
powf( +∞, y) returns +0 for y < 0.
powf( +∞, y) returns +∞ for y > 0.

Description
Calculate the value of x to the power of y.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float rcbt f (float x)
Calculate reciprocal cube root function.

Returns
- rcbt( ±0 ) returns ±∞.
- rcbt( ±∞ ) returns ±0.

Description
Calculate reciprocal cube root function of x

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float remainderf (float x, float y)
Compute single-precision floating-point remainder.

Returns
- remainderf(x, 0) returns NaN.
- remainderf( ±∞ , y) returns NaN.
- remainderf(x, ±∞ ) returns x for finite x.
**Description**

Compute single-precision floating-point remainder \( r \) of dividing \( x \) by \( y \) for nonzero \( y \).

Thus \( r = x - ny \). The value \( n \) is the integer value nearest \( \frac{x}{y} \). In the case when \( |n - \frac{x}{y}| = \frac{1}{2} \), the even \( n \) value is chosen.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

```c
__device__ float remquof (float x, float y, int *quo)
```

Compute single-precision floating-point remainder and part of quotient.

**Returns**

Returns the remainder.

- \( \text{remquof}(x, 0, \text{quo}) \) returns NaN.
- \( \text{remquof}(\pm \infty, y, \text{quo}) \) returns NaN.
- \( \text{remquof}(x, \pm \infty, \text{quo}) \) returns \( x \).

**Description**

Compute a double-precision floating-point remainder in the same way as the \texttt{remainderf()} function. Argument \texttt{quo} returns part of quotient upon division of \( x \) by \( y \).

Value \texttt{quo} has the same sign as \( x \) and may not be the exact quotient but agrees with the exact quotient in the low order 3 bits.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

```c
__device__ float rhypotf (float x, float y)
```

Calculate one over the square root of the sum of squares of two arguments.

**Returns**

Returns one over the length of the hypotenuse \( \frac{1}{\sqrt{x^2 + y^2}} \). If the square root would overflow, returns 0. If the square root would underflow, returns \( +\infty \).
Description
Calculates one over the length of the hypotenuse of a right triangle whose two sides have lengths x and y without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float rintf (float x)
Round input to nearest integer value in floating-point.

Returns
Returns rounded integer value.

Description
Round x to the nearest integer value in floating-point format, with halfway cases rounded to the nearest even integer value.

__device__ float rnorm3df (float a, float b, float c)
Calculate one over the square root of the sum of squares of three coordinates of the argument.

Returns
Returns one over the length of the 3D vector \( \frac{1}{\sqrt{p.x^2 + p.y^2 + p.z^2}} \). If the square root would overflow, returns 0. If the square root would underflow, returns \( +\infty \).

Description
Calculates one over the length of three dimension vector \( \mathbf{p} \) in euclidean space without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
__device__ float rnorm4df (float a, float b, float c, float d)
Calculate one over the square root of the sum of squares of four coordinates of the argument.

Returns

Returns one over the length of the 3D vector $\frac{1}{\sqrt{p.x^2 + p.y^2 + p.z^2 + p.z^2}}$. If the square root would overflow, returns 0. If the square root would underflow, returns $+\infty$.

Description

Calculates one over the length of four dimension vector $p$ in euclidean space without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float rnormf (int dim, const float *a)
Calculate the reciprocal of square root of the sum of squares of any number of coordinates.

Returns

Returns one over the length of the vector $\frac{1}{\sqrt{p.1^2 + p.2^2 + ... + p.dim^2}}$. If the square root would overflow, returns 0. If the square root would underflow, returns $+\infty$.

Description

Calculates one over the length of vector $p$, dimension of which is passed as an argument, in euclidean space without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
__device__ float roundf (float x)
Round to nearest integer value in floating-point.

Returns
Returns rounded integer value.

Description
Round \( x \) to the nearest integer value in floating-point format, with halfway cases rounded away from zero.

This function may be slower than alternate rounding methods. See rintf().

__device__ float rsqrtf (float x)
Calculate the reciprocal of the square root of the input argument.

Returns
Returns \( \frac{1}{\sqrt{x}} \).

- rsqrtf( +\infty ) returns +0.
- rsqrtf( ±0 ) returns ±\infty.
- rsqrtf(\( x \)) returns NaN if \( x \) is less than 0.

Description
Calculate the reciprocal of the nonnegative square root of \( x \), \( \frac{1}{\sqrt{x}} \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float scalblnf (float x, long int n)
Scale floating-point input by integer power of two.

Returns
Returns \( x \times 2^n \).

- scalblnf( ±0 , \( n \)) returns ±0.
- scalblnf(\( x \), 0) returns \( x \).
scalblnf( ±∞, n) returns ±∞.

**Description**
Scale \( x \) by \( 2^n \) by efficient manipulation of the floating-point exponent.

**__device__ float scalbnf (float x, int n)**
Scale floating-point input by integer power of two.

**Returns**
Returns \( x \times 2^n \).

- scalbnf( ±0, n) returns ±0.
- scalbnf(\( x \), 0) returns \( x \).
- scalbnf( ±\( ∞ \), n) returns ±\( ∞ \).

**Description**
Scale \( x \) by \( 2^n \) by efficient manipulation of the floating-point exponent.

**__device__ __RETURN_TYPE signbit (float a)**
Return the sign bit of the input.

**Returns**
Reports the sign bit of all values including infinities, zeros, and NaNs.

- With Visual Studio 2013 host compiler: __RETURN_TYPE is 'bool'. Returns true if and only if \( a \) is negative.
- With other host compilers: __RETURN_TYPE is 'int'. Returns a nonzero value if and only if \( a \) is negative.

**Description**
Determine whether the floating-point value \( a \) is negative.

**__device__ void sincosf (float x, float *sptr, float *cptr)**
Calculate the sine and cosine of the first input argument.

**Returns**
- none
Description
Calculate the sine and cosine of the first input argument \( x \) (measured in radians). The results for sine and cosine are written into the second argument, \( 	ext{sptr} \), and, respectively, third argument, \( 	ext{cptr} \).

See also:
sinf() and cosf().

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

This function is affected by the --use_fast_math compiler flag. See the CUDA C++ Programming Guide, Appendix E.2, Table 8 for a complete list of functions affected.

\[
\text{__device__ void sincospif (float } x, \text{ float *sptr, float *cptr)}
\]
Calculate the sine and cosine of the first input argument \( x \times \pi \).

Returns
none

Description
Calculate the sine and cosine of the first input argument, \( x \) (measured in radians), \( x \times \pi \). The results for sine and cosine are written into the second argument, \( 	ext{sptr} \), and, respectively, third argument, \( 	ext{cptr} \).

See also:
sinfif() and csinfif().

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

\[
\text{__device__ float sinf (float } x)\]
Calculate the sine of the input argument.

Returns
sinf( \( \pm 0 \) ) returns \( \pm 0 \).
- \( \sinf( \pm \infty ) \) returns NaN.

**Description**

Calculate the sine of the input argument \( x \) (measured in radians).

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
- This function is affected by the `--use_fast_math` compiler flag. See the CUDA C++ Programming Guide, Appendix E.2, Table 8 for a complete list of functions affected.

___device___ float sinhf (float x)

Calculate the hyperbolic sine of the input argument.

**Returns**

- \( \sinhf( \pm 0 ) \) returns \( \pm 0 \).
- \( \sinhf( \pm \infty ) \) returns NaN.

**Description**

Calculate the hyperbolic sine of the input argument \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

___device___ float sinpif (float x)

Calculate the sine of the input argument \( x \) measured in radians.

**Returns**

- \( \sinpif( \pm 0 ) \) returns \( \pm 0 \).
- \( \sinpif( \pm \infty ) \) returns NaN.

**Description**

Calculate the sine of \( x \times \pi \) (measured in radians), where \( x \) is the input argument.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
__device__ float sqrtf (float x)
Calculate the square root of the input argument.

Returns

Returns $\sqrt{x}$.

- $\text{sqrtf}(\pm 0)$ returns $\pm 0$.
- $\text{sqrtf}(+\infty)$ returns $+\infty$.
- $\text{sqrtf}(x)$ returns NaN if $x$ is less than 0.

Description

Calculate the nonnegative square root of $x$, $\sqrt{x}$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float tanf (float x)
Calculate the tangent of the input argument.

Returns

- $\text{tanf}(\pm 0)$ returns $\pm 0$.
- $\text{tanf}(\pm \infty)$ returns NaN.

Description

Calculate the tangent of the input argument $x$ (measured in radians).

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
- This function is affected by the `--use_fast_math` compiler flag. See the CUDA C++ Programming Guide, Appendix E.2, Table 8 for a complete list of functions affected.
__device__ float tanhf (float x)
Calculate the hyperbolic tangent of the input argument.

Returns
- tanhf( ±0 ) returns ±0.

Description
Calculate the hyperbolic tangent of the input argument x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float tgammaf (float x)
Calculate the gamma function of the input argument.

Returns
- tgammaf( ±0 ) returns ±∞.
- tgammaf(2) returns +1.
- tgammaf(x) returns ±∞ if the correctly calculated value is outside the single floating point range.
- tgammaf(x) returns NaN if x < 0 and x is an integer.
- tgammaf( −∞ ) returns NaN.
- tgammaf( +∞ ) returns +∞.

Description
Calculate the gamma function of the input argument x, namely the value of \( \int_0^\infty e^{-t}t^{x-1}dt \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float truncf (float x)
Truncate input argument to the integral part.

Returns
Returns truncated integer value.
Description
Round \( x \) to the nearest integer value that does not exceed \( x \) in magnitude.

\_\texttt{device}\_\_ float \( y0f \) (float \( x \))
Calculate the value of the Bessel function of the second kind of order 0 for the input argument.

Returns
Returns the value of the Bessel function of the second kind of order 0.

- \( y0f(0) \) returns \(- \infty\).
- \( y0f(\infty) \) returns NaN for \( x < 0 \).
- \( y0f(- \infty) \) returns +0.
- \( y0f(\text{NaN}) \) returns NaN.

Description
Calculate the value of the Bessel function of the second kind of order 0 for the input argument \( x \), \( Y_0(x) \).

\_\texttt{device}\_\_ float \( y1f \) (float \( x \))
Calculate the value of the Bessel function of the second kind of order 1 for the input argument.

Returns
Returns the value of the Bessel function of the second kind of order 1.

- \( y1f(0) \) returns \(- \infty\).
- \( y1f(\infty) \) returns NaN for \( x < 0 \).
- \( y1f(+ \infty) \) returns +0.
- \( y1f(\text{NaN}) \) returns NaN.

Description
Calculate the value of the Bessel function of the second kind of order 1 for the input argument \( x \), \( Y_1(x) \).
__device__ float ynf (int n, float x)
Calculate the value of the Bessel function of the second kind of order \( n \) for the input argument.

Returns
Returns the value of the Bessel function of the second kind of order \( n \).

- \( \text{ynf}(n, x) \) returns NaN for \( n < 0 \).
- \( \text{ynf}(n, 0) \) returns \(-\infty\).
- \( \text{ynf}(n, x) \) returns NaN for \( x < 0 \).
- \( \text{ynf}(n, +\infty) \) returns +0.
- \( \text{ynf}(n, \text{NaN}) \) returns NaN.

Description
Calculate the value of the Bessel function of the second kind of order \( n \) for the input argument \( x \), \( Y_n(x) \).

1.4. Double Precision Mathematical Functions

This section describes double precision mathematical functions. To use these functions you do not need to include any additional header files in your program.

__device__ double acos (double x)
Calculate the arc cosine of the input argument.

Returns
Result will be in radians, in the interval \([0, \pi]\) for \( x \) inside \([-1, +1]\).

- \( \text{acos}(1) \) returns +0.
- \( \text{acos}(\text{NaN}) \) returns NaN for \( x \) outside \([-1, +1]\).
Description
Calculate the principal value of the arc cosine of the input argument \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

\[ \text{__device__ double acosh (double x)} \]
Calculate the nonnegative arc hyperbolic cosine of the input argument.

Returns
Result will be in the interval \([0, +\infty]\).

- \( \text{acosh}(1) \) returns 0.
- \( \text{acosh}(\times) \) returns NaN for \( \times \) in the interval \([-\infty, 1)\).

Description
Calculate the nonnegative arc hyperbolic cosine of the input argument \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

\[ \text{__device__ double asin (double x)} \]
Calculate the arc sine of the input argument.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

Returns
Result will be in radians, in the interval \([-\pi/2, +\pi/2]\) for \( x \) inside \([-1, +1]\).

- \( \text{asin}(0) \) returns +0.
- \( \text{asin}(\times) \) returns NaN for \( x \) outside \([-1, +1]\).

Description
Calculate the principal value of the arc sine of the input argument \( x \).
__device__ double asinh (double x)
Calculate the arc hyperbolic sine of the input argument.

Returns
- asinh(0) returns 1.

Description
Calculate the arc hyperbolic sine of the input argument x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double atan (double x)
Calculate the arc tangent of the input argument.

Returns
- Result will be in radians, in the interval [-\pi/2, +\pi/2].
- atan(0) returns +0.

Description
Calculate the principal value of the arc tangent of the input argument x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double atan2 (double y, double x)
Calculate the arc tangent of the ratio of first and second input arguments.

Returns
- Result will be in radians, in the interval [-\pi, +\pi].
- atan2(0, 1) returns +0.

Description
Calculate the principal value of the arc tangent of the ratio of first and second input arguments \( y / x \). The quadrant of the result is determined by the signs of inputs \( y \) and \( x \).
__device__ double atanh (double x)
Calculate the arc hyperbolic tangent of the input argument.

Returns
- atanh( ±0 ) returns ±0.
- atanh( ±1 ) returns ±∞.
- atanh(x) returns NaN for x outside interval [-1, 1].

Description
Calculate the arc hyperbolic tangent of the input argument x.

__device__ double cbrt (double x)
Calculate the cube root of the input argument.

Returns
Returns \( x^{1/3} \).
- cbrt( ±0 ) returns ±0.
- cbrt( ±∞ ) returns ±∞.

Description
Calculate the cube root of \( x \), \( x^{1/3} \).
__device__ __CUDA_MATH_CRTIMP double ceil (double x)
Calculate ceiling of the input argument.

Returns
Returns \([x]\) expressed as a floating-point number.

- \(\text{ceil}(\pm 0)\) returns \(\pm 0\).
- \(\text{ceil}(\pm \infty)\) returns \(\pm \infty\).

Description
Compute the smallest integer value not less than \(x\).

__device__ double copysign (double x, double y)
Create value with given magnitude, copying sign of second value.

Returns
Returns a value with the magnitude of \(x\) and the sign of \(y\).

Description
Create a floating-point value with the magnitude \(x\) and the sign of \(y\).

__device__ double cos (double x)
Calculate the cosine of the input argument.

Returns
- \(\cos(\pm 0)\) returns 1.
- \(\cos(\pm \infty)\) returns NaN.

Description
Calculate the cosine of the input argument \(x\) (measured in radians).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
__device__ double cosh (double x)
Calculate the hyperbolic cosine of the input argument.

Returns

- \(\cosh(0)\) returns 1.
- \(\cosh(\pm\infty)\) returns \(+\infty\).

Description
Calculate the hyperbolic cosine of the input argument \(x\).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double cospi (double x)
Calculate the cosine of the input argument \(x\pi\).

Returns

- \(\cospi(\pm0)\) returns 1.
- \(\cospi(\pm\infty)\) returns NaN.

Description
Calculate the cosine of \(x\pi\) (measured in radians), where \(x\) is the input argument.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ __CUDA_MATH_CRTIMP double cyl_bessel_i0 (double x)
Calculate the value of the regular modified cylindrical Bessel function of order 0 for the input argument.

Returns
Returns the value of the regular modified cylindrical Bessel function of order 0.
Description
Calculate the value of the regular modified cylindrical Bessel function of order 0 for the input argument \( x \), \( I_0(x) \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ __CUDA_MATH_CRTIMP double cyl_bessel_i1 (double x)
Calculate the value of the regular modified cylindrical Bessel function of order 1 for the input argument.

Returns
Returns the value of the regular modified cylindrical Bessel function of order 1.

Description
Calculate the value of the regular modified cylindrical Bessel function of order 1 for the input argument \( x \), \( I_1(x) \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double erf (double x)
Calculate the error function of the input argument.

Returns

- \( \text{erf}( \pm 0) \) returns \( \pm 0 \).
- \( \text{erf}( \pm \infty) \) returns \( \pm 1 \).

Description
Calculate the value of the error function for the input argument \( x \), \( \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt \).
__device__ double erfc (double x)
Calculate the complementary error function of the input argument.

Returns
- erfc( $-\infty$) returns 2.
- erfc( $+\infty$) returns +0.

Description
Calculate the complementary error function of the input argument $x$, $1 - \text{erf}(x)$.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double erfcinv (double y)
Calculate the inverse complementary error function of the input argument.

Returns
- erfcinv(0) returns +0.
- erfcinv(2) returns +0.

Description
Calculate the inverse complementary error function of the input argument $y$, for $y$ in the interval $[0, 2]$. The inverse complementary error function find the value $x$ that satisfies the equation $y = \text{erfc}(x)$, for $0 \leq y \leq 2$, and $-\infty \leq x \leq \infty$.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double erfcx (double x)
Calculate the scaled complementary error function of the input argument.

Returns
- erfcx( $-\infty$) returns $+\infty$
- erfcx( $+\infty$) returns +0
- erfcx($x$) returns $+\infty$ if the correctly calculated value is outside the double floating point range.
**Description**

Calculate the scaled complementary error function of the input argument \( x \), \( e^{x^2} \cdot \text{erfc}(x) \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

**__device__ double erfinv (double y)**

Calculate the inverse error function of the input argument.

**Returns**

- \( \text{erfinv}(1) \) returns \( +\infty \).
- \( \text{erfinv}(-1) \) returns \( -\infty \).

**Description**

Calculate the inverse error function of the input argument \( y \), for \( y \) in the interval \([-1, 1]\). The inverse error function finds the value \( x \) that satisfies the equation \( y = \text{erf}(x) \), for \(-1 \leq y \leq 1\), and \(-\infty \leq x \leq \infty\).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

**__device__ double exp (double x)**

Calculate the base \( e \) exponential of the input argument.

**Returns**

Returns \( e^x \).

**Description**

Calculate the base \( e \) exponential of the input argument \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
__device__ double exp10 (double x)
Calculate the base 10 exponential of the input argument.

Returns
Returns $10^x$.

Description
Calculate the base 10 exponential of the input argument $x$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double exp2 (double x)
Calculate the base 2 exponential of the input argument.

Returns
Returns $2^x$.

Description
Calculate the base 2 exponential of the input argument $x$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double expm1 (double x)
Calculate the base $e$ exponential of the input argument, minus 1.

Returns
Returns $e^x - 1$.

Description
Calculate the base $e$ exponential of the input argument $x$, minus 1.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
__device__ double fabs (double x)
Calculate the absolute value of the input argument.

Returns
Returns the absolute value of the input argument.

- fabs( ±∞ ) returns +∞.
- fabs( ±0 ) returns 0.

Description
Calculate the absolute value of the input argument \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double fdim (double x, double y)
Compute the positive difference between \( x \) and \( y \).

Returns
Returns the positive difference between \( x \) and \( y \).

- fdim( \( x \), \( y \) ) returns \( x - y \) if \( x > y \).
- fdim( \( x \), \( y \) ) returns +0 if \( x \leq y \).

Description
Compute the positive difference between \( x \) and \( y \). The positive difference is \( x - y \) when \( x > y \) and +0 otherwise.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ __CUDA_MATH_CRTIMP double floor (double x)
Calculate the largest integer less than or equal to \( x \).

Returns
Returns \( \lfloor x \rfloor \) expressed as a floating-point number.
floor(±∞) returns ±∞.
floor(±0) returns ±0.

**Description**
Calculates the largest integer value which is less than or equal to x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double fma (double x, double y, double z)
Compute \( x \times y + z \) as a single operation.

**Returns**
Returns the rounded value of \( x \times y + z \) as a single operation.

- fma(±∞, ±0, z) returns NaN.
- fma(±0, ±∞, z) returns NaN.
- fma(x, y, −∞) returns NaN if \( x \times y \) is an exact +∞.
- fma(x, y, +∞) returns NaN if \( x \times y \) is an exact −∞.

**Description**
Compute the value of \( x \times y + z \) as a single ternary operation. After computing the value to infinite precision, the value is rounded once.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double fmax (double, double)
Determine the maximum numeric value of the arguments.

**Returns**
Returns the maximum numeric values of the arguments x and y.

- If both arguments are NaN, returns NaN.
- If one argument is NaN, returns the numeric argument.
Description
Determines the maximum numeric value of the arguments \( x \) and \( y \). Treats NaN arguments as missing data. If one argument is a NaN and the other is legitimate numeric value, the numeric value is chosen.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double fmin (double \( x \), double \( y \))
Determine the minimum numeric value of the arguments.

Returns
Returns the minimum numeric values of the arguments \( x \) and \( y \).

- If both arguments are NaN, returns NaN.
- If one argument is NaN, returns the numeric argument.

Description
Determines the minimum numeric value of the arguments \( x \) and \( y \). Treats NaN arguments as missing data. If one argument is a NaN and the other is legitimate numeric value, the numeric value is chosen.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double fmod (double \( x \), double \( y \))
Calculate the floating-point remainder of \( x / y \).

Returns
- Returns the floating point remainder of \( x / y \).
- \( \text{fmod}(\pm 0, y) \) returns \( 0 \) if \( y \) is not zero.
- \( \text{fmod}(x, y) \) returns NaN and raised an invalid floating point exception if \( x \) is \( \pm \infty \) or \( y \) is zero.
- \( \text{fmod}(x, y) \) returns zero if \( y \) is zero or the result would overflow.
- \( \text{fmod}(x, \pm \infty) \) returns \( x \) if \( x \) is finite.
- \( \text{fmod}(x, 0) \) returns NaN.
Description

Calculate the floating-point remainder of \( x / y \). The absolute value of the computed value is always less than \( y \)'s absolute value and will have the same sign as \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

\[
\text{\_device\_ \_CUDA_MATH_CRTIMP double frexp (double x, int \*nptr)}
\]

Extract mantissa and exponent of a floating-point value.

Returns

Returns the fractional component \( m \).

- \( \text{frexp(0, nptr)} \) returns 0 for the fractional component and zero for the integer component.
- \( \text{frexp( ±0, nptr)} \) returns ±0 and stores zero in the location pointed to by \( nptr \).
- \( \text{frexp( ±∞, nptr)} \) returns ±∞ and stores an unspecified value in the location to which \( nptr \) points.
- \( \text{frexp(NaN, y)} \) returns a NaN and stores an unspecified value in the location to which \( nptr \) points.

Description

Decompose the floating-point value \( x \) into a component \( m \) for the normalized fraction element and another term \( n \) for the exponent. The absolute value of \( m \) will be greater than or equal to 0.5 and less than 1.0 or it will be equal to 0; \( x = m \cdot 2^n \). The integer exponent \( n \) will be stored in the location to which \( nptr \) points.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

\[
\text{\_device\_ACRTIMP double hypot (double x, double y)}
\]

Calculate the square root of the sum of squares of two arguments.

Returns

Returns the length of the hypotenuse \( \sqrt{x^2 + y^2} \). If the correct value would overflow, returns \( +\infty \). If the correct value would underflow, returns 0.
Description

Calculate the length of the hypotenuse of a right triangle whose two sides have lengths \( x \) and \( y \) without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ int ilogb (double x)

Compute the unbiased integer exponent of the argument.

Returns

- If successful, returns the unbiased exponent of the argument.
- ilogb(0) returns INT_MIN.
- ilogb(NaN) returns NaN.
- ilogb(\( x \)) returns INT_MAX if \( x \) is \( \infty \) or the correct value is greater than INT_MAX.
- ilogb(\( x \)) return INT_MIN if the correct value is less than INT_MIN.

Description

Calculates the unbiased integer exponent of the input argument \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ __RETURN_TYPE isfinite (double a)

Determine whether argument is finite.

Returns

- With Visual Studio 2013 host compiler: __RETURN_TYPE is 'bool'. Returns true if and only if \( a \) is a finite value.
- With other host compilers: __RETURN_TYPE is 'int'. Returns a nonzero value if and only if \( a \) is a finite value.

Description

Determine whether the floating-point value \( a \) is a finite value (zero, subnormal, or normal and not infinity or NaN).
__device__ __RETURN_TYPE isnan (double a)
Determine whether argument is a NaN.

Returns
- With Visual Studio 2013 host compiler: __RETURN_TYPE is 'bool'. Returns true if and only if a is a NaN value.
- With other host compilers: __RETURN_TYPE is 'int'. Returns a nonzero value if and only if a is a NaN value.

Description
Determine whether the floating-point value a is a NaN.

__device__ __CUDA_MATH_CRTIMP double j0 (double x)
Calculate the value of the Bessel function of the first kind of order 0 for the input argument.

Returns
Returns the value of the Bessel function of the first kind of order 0.

- j0( ±∞ ) returns +0.
- j0(NaN) returns NaN.

Description
Calculate the value of the Bessel function of the first kind of order 0 for the input argument x, j_0(x).
For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ __CUDA_MATH_CRTIMP double j1 (double x)
Calculate the value of the Bessel function of the first kind of order 1 for the input argument.

Returns
Returns the value of the Bessel function of the first kind of order 1.

- \( j_1(\pm 0) \) returns \( \pm 0 \).
- \( j_1(\pm \infty) \) returns +0.
- \( j_1(\text{NaN}) \) returns NaN.

Description
Calculate the value of the Bessel function of the first kind of order 1 for the input argument \( x, J_1(x) \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ __CUDA_MATH_CRTIMP double jn (int n, double x)
Calculate the value of the Bessel function of the first kind of order \( n \) for the input argument.

Returns
Returns the value of the Bessel function of the first kind of order \( n \).

- \( j_n(n, \text{NaN}) \) returns NaN.
- \( j_n(n, x) \) returns NaN for \( n < 0 \).
- \( j_n(n, +\infty) \) returns +0.

Description
Calculate the value of the Bessel function of the first kind of order \( n \) for the input argument \( x, J_n(x) \).
__device__ __CUDA_MATH_CRTIMP double ldexp (double x, int exp)
Calculate the value of $x \cdot 2^{\text{exp}}$.

**Returns**
- ldexp($x$) returns $\pm \infty$ if the correctly calculated value is outside the double floating point range.

**Description**
Calculate the value of $x \cdot 2^{\text{exp}}$ of the input arguments $x$ and $\text{exp}$.

__device__ double lgamma (double x)
Calculate the natural logarithm of the absolute value of the gamma function of the input argument.

**Returns**
- lgamma(1) returns +0.
- lgamma(2) returns +0.
- lgamma($x$) returns $\pm \infty$ if the correctly calculated value is outside the double floating point range.
- lgamma($x$) returns $+\infty$ if $x \leq 0$ and $x$ is an integer.
- lgamma($-\infty$) returns $-\infty$.
- lgamma($+\infty$) returns $+\infty$.

**Description**
Calculate the natural logarithm of the absolute value of the gamma function of the input argument $x$, namely the value of $\log_e \left| \int_0^{\infty} e^{-t} t^{x-1} dt \right|$. 
__device__ long long int llrint (double x)
Round input to nearest integer value.

Returns
Returns rounded integer value.

Description
Round $x$ to the nearest integer value, with halfway cases rounded to the nearest even integer value. If the result is outside the range of the return type, the result is undefined.

__device__ long long int llround (double x)
Round to nearest integer value.

Returns
Returns rounded integer value.

Description
Round $x$ to the nearest integer value, with halfway cases rounded away from zero. If the result is outside the range of the return type, the result is undefined.

This function may be slower than alternate rounding methods. See llrint().

__device__ double log (double x)
Calculate the base $e$ logarithm of the input argument.

Returns
- log( ±0 ) returns $-\infty$.
- log(1) returns +0.
- log($x$) returns NaN for $x < 0$.
- log( $+\infty$ ) returns $+\infty$

Description
Calculate the base $e$ logarithm of the input argument $x$. 
__device__ double log10 (double x)
Calculate the base 10 logarithm of the input argument.

Returns
- \( \log_{10}( \pm 0 ) \) returns \( -\infty \).
- \( \log_{10}(1) \) returns +0.
- \( \log_{10}(x) \) returns NaN for \( x < 0 \).
- \( \log_{10}( +\infty ) \) returns +\( \infty \).

Description
Calculate the base 10 logarithm of the input argument \( x \).

__device__ double log1p (double x)
Calculate the value of \( \log_{10}(1+x) \).

Returns
- \( \log_{10p}( \pm 0 ) \) returns \( -\infty \).
- \( \log_{10p}(-1) \) returns +0.
- \( \log_{10p}(x) \) returns NaN for \( x < -1 \).
- \( \log_{10p}( +\infty ) \) returns +\( \infty \).

Description
Calculate the value of \( \log_{10}(1+x) \) of the input argument \( x \).
__device__ double log2 (double x)
Calculate the base 2 logarithm of the input argument.

Returns
- log2( ±0 ) returns −∞.
- log2(1) returns +0.
- log2(∞) returns NaN for x < 0.
- log2( +∞ ) returns +∞.

Description
Calculate the base 2 logarithm of the input argument x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double logb (double x)
Calculate the floating point representation of the exponent of the input argument.

Returns
- logb ±0 returns −∞
- logb ±∞ returns +∞

Description
Calculate the floating point representation of the exponent of the input argument x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ long int lrint (double x)
Round input to nearest integer value.

Returns
Returns rounded integer value.
Description
Round $x$ to the nearest integer value, with halfway cases rounded to the nearest even integer value. If the result is outside the range of the return type, the result is undefined.

__device__ long int lround (double x)
Round to nearest integer value.

Returns
Returns rounded integer value.

Description
Round $x$ to the nearest integer value, with halfway cases rounded away from zero. If the result is outside the range of the return type, the result is undefined.

This function may be slower than alternate rounding methods. See lrint().

__device__ __CUDA_MATH_CRTIMP double modf (double x, double *iptr)
Break down the input argument into fractional and integral parts.

Returns
- modf(±x, iptr) returns a result with the same sign as $x$.
- modf(±∞, iptr) returns ±0 and stores ±∞ in the object pointed to by iptr.
- modf(NaN, iptr) stores a NaN in the object pointed to by iptr and returns a NaN.

Description
Break down the argument $x$ into fractional and integral parts. The integral part is stored in the argument iptr. Fractional and integral parts are given the same sign as the argument $x$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
**__device__** double nan (const char *tagp)

Returns "Not a Number" value.

**Returns**

- nan(tagp) returns NaN.

**Description**

Return a representation of a quiet NaN. Argument tagp selects one of the possible representations.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

**__device__** double nearbyint (double x)

Round the input argument to the nearest integer.

**Returns**

- nearbyint(±0) returns ±0.
- nearbyint(±∞) returns ±∞.

**Description**

Round argument x to an integer value in double precision floating-point format.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

**__device__** double nextafter (double x, double y)

Return next representable double-precision floating-point value after argument.

**Returns**

- nextafter(±∞, y) returns ±∞.

**Description**

Calculate the next representable double-precision floating-point value following x in the direction of y. For example, if y is greater than x, nextafter() returns the smallest representable number greater than x.
__device__ double norm (int dim, const double *t)
Calculate the square root of the sum of squares of any number of coordinates.

Returns
Returns the length of the dim-D vector √(p.1² + p.2² + ... + p.dim). If the correct value would overflow, returns +∞. If the correct value would underflow, returns 0. If two of the input arguments is 0, returns remaining argument.

Description
Calculate the length of a vector p, dimension of which is passed as an argument without undue overflow or underflow.

__device__ __CUDA_MATH_CRTIMP double norm3d (double a, double b, double c)
Calculate the square root of the sum of squares of three coordinates of the argument.

Returns
Returns the length of 3D vector √(p.x² + p.y² + p.z²). If the correct value would overflow, returns +∞. If the correct value would underflow, returns 0.

Description
Calculate the length of three dimensional vector p in euclidean space without undue overflow or underflow.
__device__ __CUDA_MATH_CRTIMP double norm4d (double a, double b, double c, double d)
Calculate the square root of the sum of squares of four coordinates of the argument.

Returns

Returns the length of 4D vector $\sqrt{a^2 + b^2 + c^2 + d^2}$. If the correct value would overflow, returns $+\infty$. If the correct value would underflow, returns 0.

Description

Calculate the length of four dimensional vector $p$ in euclidean space without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double normcdf (double y)
Calculate the standard normal cumulative distribution function.

Returns

- normcdf($+\infty$) returns 1
- normcdf($-\infty$) returns +0

Description

Calculate the cumulative distribution function of the standard normal distribution for input argument $y$, $\Phi(y)$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double normcdfinv (double y)
Calculate the inverse of the standard normal cumulative distribution function.

Returns

- normcdfinv(0) returns $-\infty$.
- normcdfinv(1) returns $+\infty$.
- normcdfinv($x$) returns NaN if $x$ is not in the interval [0,1].
Description
Calculate the inverse of the standard normal cumulative distribution function for input argument \( y \), \( \Phi^{-1}(y) \). The function is defined for input values in the interval (0, 1).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double pow (double x, double y)
Calculate the value of first argument to the power of second argument.

Returns
- \( \text{pow}(\pm 0, y) \) returns \( \pm \infty \) for \( y \) an integer less than 0.
- \( \text{pow}(\pm 0, y) \) returns \( 0 \) for \( y \) an odd integer greater than 0.
- \( \text{pow}(\pm 0, y) \) returns +0 for \( y > 0 \) and not and odd integer.
- \( \text{pow}(-1, \pm \infty) \) returns 1.
- \( \text{pow}(+1, y) \) returns 1 for any \( y \), even a NaN.
- \( \text{pow}(x, \pm 0) \) returns 1 for any \( x \), even a NaN.
- \( \text{pow}(x, y) \) returns a NaN for finite \( x < 0 \) and finite non-integer \( y \).
- \( \text{pow}(x, -\infty) \) returns +\( \infty \) for \( |x| < 1 \).
- \( \text{pow}(x, -\infty) \) returns +0 for \( |x| > 1 \).
- \( \text{pow}(x, +\infty) \) returns +0 for \( |x| < 1 \).
- \( \text{pow}(x, +\infty) \) returns +\( \infty \) for \( |x| > 1 \).
- \( \text{pow}(-\infty, y) \) returns -0 for \( y \) an odd integer less than 0.
- \( \text{pow}(-\infty, y) \) returns +0 for \( y < 0 \) and not an odd integer.
- \( \text{pow}(-\infty, y) \) returns -\( \infty \) for \( y \) an odd integer greater than 0.
- \( \text{pow}(-\infty, y) \) returns +\( \infty \) for \( y > 0 \) and not an odd integer.
- \( \text{pow}(+\infty, y) \) returns +0 for \( y < 0 \).
- \( \text{pow}(+\infty, y) \) returns +\( \infty \) for \( y > 0 \).

Description
Calculate the value of \( x \) to the power of \( y \)

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
__device__ double rcbrt (double x)

Calculate reciprocal cube root function.

Returns

- rcbrt(±0) returns ±∞.
- rcbrt(±∞) returns ±0.

Description

Calculate reciprocal cube root function of x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double remainder (double x, double y)

Compute double-precision floating-point remainder.

Returns

- remainder(x, 0) returns NaN.
- remainder(±∞, y) returns NaN.
- remainder(x, ±∞) returns x for finite x.

Description

Compute double-precision floating-point remainder r of dividing x by y for nonzero y. Thus r = x − ny. The value n is the integer value nearest \( \frac{x}{y} \). In the case when \( |n - \frac{x}{y}| = \frac{1}{2} \), the even n value is chosen.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double remquo (double x, double y, int *quo)

Compute double-precision floating-point remainder and part of quotient.

Returns

Returns the remainder.
remquo(x, 0, quo) returns NaN.
remquo(±∞, y, quo) returns NaN.
remquo(x, ±∞, quo) returns x.

Description
Compute a double-precision floating-point remainder in the same way as the remainder() function. Argument quo returns part of quotient upon division of x by y. Value quo has the same sign as \( \frac{x}{y} \) and may not be the exact quotient but agrees with the exact quotient in the low order 3 bits.

__device__ double rhypot (double x, double y)
Calculate one over the square root of the sum of squares of two arguments.

Returns
Returns one over the length of the hypotenuse \( \frac{1}{\sqrt{x^2 + y^2}} \). If the square root would overflow, returns 0. If the square root would underflow, returns +\( \infty \).

Description
Calculate one over the length of the hypotenuse of a right triangle whose two sides have lengths x and y without undue overflow or underflow.

__device__ double rint (double x)
Round to nearest integer value in floating-point.

Returns
Returns rounded integer value.

Description
Round x to the nearest integer value in floating-point format, with halfway cases rounded to the nearest even integer value.
__device__ double rnorm (int dim, const double *t)
Calculate the reciprocal of square root of the sum of squares of any number of coordinates.

**Returns**
Returns one over the length of the vector \( \frac{1}{\sqrt{p.1^2 + p.2^2 + \ldots + p \cdot \text{dim}^2}} \). If the square root would overflow, returns 0. If the square root would underflow, returns \( +\infty \).

**Description**
Calculates one over the length of vector \( p \), dimension of which is passed as an argument, in euclidean space without undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double rnorm3d (double a, double b, double c)
Calculate one over the square root of the sum of squares of three coordinates of the argument.

**Returns**
Returns one over the length of the 3D vector \( \frac{1}{\sqrt{p.x^2 + p.y^2 + p.z^2}} \). If the square root would overflow, returns 0. If the square root would underflow, returns \( +\infty \).

**Description**
Calculate one over the length of three dimensional vector \( p \) in euclidean space undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
__device__ double rnorm4d (double a, double b, double c, double d)
Calculate one over the square root of the sum of squares of four coordinates of the argument.

Returns
Returns one over the length of the 3D vector \( \frac{1}{\sqrt{p.x^2 + p.y^2 + p.z^2 + p.t^2}} \). If the square root would overflow, returns 0. If the square root would underflow, returns +\( \infty \).

Description
Calculate one over the length of four dimensional vector \( p \) in euclidean space undue overflow or underflow.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double round (double x)
Round to nearest integer value in floating-point.

Returns
Returns rounded integer value.

Description
Round \( x \) to the nearest integer value in floating-point format, with halfway cases rounded away from zero.

This function may be slower than alternate rounding methods. See \texttt{rint()}.

__device__ double rsqrt (double x)
Calculate the reciprocal of the square root of the input argument.

Returns
Returns \( 1/\sqrt{x} \).
\[ \text{rsqrt}(+\infty) \text{ returns } +0. \]
rsqrt(±0) returns ±∞.
rsqrt(±) returns NaN if x is less than 0.

Description
Calculate the reciprocal of the nonnegative square root of x, 1/√x.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double scalbln (double x, long int n)
Scale floating-point input by integer power of two.

Returns
Returns x * 2^n.

- scalbln(±0, n) returns ±0.
- scalbln(x, 0) returns x.
- scalbln(±∞, n) returns ±∞.

Description
Scale x by 2^n by efficient manipulation of the floating-point exponent.

__device__ double scalbn (double x, int n)
Scale floating-point input by integer power of two.

Returns
Returns x * 2^n.

- scalbn(±0, n) returns ±0.
- scalbn(x, 0) returns x.
- scalbn(±∞, n) returns ±∞.

Description
Scale x by 2^n by efficient manipulation of the floating-point exponent.
**__device__ __RETURN_TYPE signbit (double a)**

Return the sign bit of the input.

**Returns**

Reports the sign bit of all values including infinities, zeros, and NaNs.

- With Visual Studio 2013 host compiler: __RETURN_TYPE is 'bool'. Returns true if and only if a is negative.
- With other host compilers: __RETURN_TYPE is 'int'. Returns a nonzero value if and only if a is negative.

**Description**

Determine whether the floating-point value a is negative.

**__device__ double sin (double x)**

Calculate the sine of the input argument.

**Returns**

- sin(±0) returns ±0.
- sin(±∞) returns NaN.

**Description**

Calculate the sine of the input argument x (measured in radians).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

**__device__ void sincos (double x, double *sptr, double *cptr)**

Calculate the sine and cosine of the first input argument.

**Returns**

- none
Description
Calculate the sine and cosine of the first input argument \( x \) (measured in radians). The results for sine and cosine are written into the second argument, \( sptr \), and, respectively, third argument, \( cptr \).

See also:
sin() and cos().

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ void sincospi (double x, double *sptr, double *cptr)
Calculate the sine and cosine of the first input argument \( x \times \pi \).

Returns
none

Description
Calculate the sine and cosine of the first input argument, \( x \) (measured in radians), \( x \times \pi \). The results for sine and cosine are written into the second argument, \( sptr \), and, respectively, third argument, \( cptr \).

See also:
sinpi() and cospi().

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double sinh (double x)
Calculate the hyperbolic sine of the input argument.

Returns
\( \sinh( \pm 0 ) \) returns \( \pm 0 \).

Description
Calculate the hyperbolic sine of the input argument \( x \).
__device__ double sinpi (double x)

Calculate the sine of the input argument \( x \times \pi \).

**Returns**

- \( \sin pi(\pm 0) \) returns \( \pm 0 \).
- \( \sin pi(\pm \infty) \) returns NaN.

**Description**

Calculate the sine of \( x \times \pi \) (measured in radians), where \( x \) is the input argument.

__device__ double sqrt (double x)

Calculate the square root of the input argument.

**Returns**

Returns \( \sqrt{x} \).

- \( \sqrt{\pm 0} \) returns \( \pm 0 \).
- \( \sqrt{+ \infty} \) returns \( +\infty \).
- \( \sqrt{x} \) returns NaN if \( x \) is less than 0.

**Description**

Calculate the nonnegative square root of \( x, \sqrt{x} \).
__device__ double tan (double x)
Calculate the tangent of the input argument.

Returns
- \( \tan( \pm 0 ) \) returns \( \pm 0 \).
- \( \tan( \pm \infty ) \) returns NaN.

Description
Calculate the tangent of the input argument \( x \) (measured in radians).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double tanh (double x)
Calculate the hyperbolic tangent of the input argument.

Returns
- \( \tanh( \pm 0 ) \) returns \( \pm 0 \).

Description
Calculate the hyperbolic tangent of the input argument \( x \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double tgamma (double x)
Calculate the gamma function of the input argument.

Returns
- \( \text{tgamma}( \pm 0 ) \) returns \( \pm \infty \).
- \( \text{tgamma}(2) \) returns +1.
- \( \text{tgamma}(x) \) returns \( \pm \infty \) if the correctly calculated value is outside the double floating point range.
- \( \text{tgamma}(x) \) returns NaN if \( x < 0 \) and \( x \) is an integer.
- \( \text{tgamma}( - \infty ) \) returns NaN.
- \( \text{tgamma}( + \infty ) \) returns +\( \infty \).
Description

Calculate the gamma function of the input argument $x$, namely the value of $\int_0^\infty e^{-t}t^{x-1}dt$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double trunc (double x)

Truncate input argument to the integral part.

Returns

Returns truncated integer value.

Description

Round $x$ to the nearest integer value that does not exceed $x$ in magnitude.

__device__ __CUDA_MATH_CRTIMP double y0 (double x)

Calculate the value of the Bessel function of the second kind of order 0 for the input argument.

Returns

Returns the value of the Bessel function of the second kind of order 0.

- $y0(0)$ returns $-\infty$.
- $y0(x)$ returns NaN for $x < 0$.
- $y0(+\infty)$ returns +0.
- $y0(\text{NaN})$ returns NaN.

Description

Calculate the value of the Bessel function of the second kind of order 0 for the input argument $x$, $Y_0(x)$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
__device__ __CUDA_MATH_CRTIMP double y1 (double x)
Calculate the value of the Bessel function of the second kind of order 1 for the input argument.

Returns
Returns the value of the Bessel function of the second kind of order 1.

- y1(0) returns $-\infty$.
- y1($x$) returns NaN for $x < 0$.
- y1($+\infty$) returns $+0$.
- y1(NaN) returns NaN.

Description
Calculate the value of the Bessel function of the second kind of order 1 for the input argument $x$, $Y_1(x)$.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ __CUDA_MATH_CRTIMP double yn (int n, double x)
Calculate the value of the Bessel function of the second kind of order n for the input argument.

Returns
Returns the value of the Bessel function of the second kind of order n.

- yn(n, $x$) returns NaN for $n < 0$.
- yn(n, 0) returns $-\infty$.
- yn(n, $x$) returns NaN for $x < 0$.
- yn(n, $+\infty$) returns $+0$.
- yn(n, NaN) returns NaN.

Description
Calculate the value of the Bessel function of the second kind of order $n$ for the input argument $x$, $Y_n(x)$. 
1.5. Single Precision Intrinsics

This section describes single precision intrinsic functions that are only supported in device code. To use these functions you do not need to include any additional header files in your program.

__device__ float __cosf (float x)

Calculate the fast approximate cosine of the input argument.

Returns

Returns the approximate cosine of \( x \).

Description

Calculate the fast approximate cosine of the input argument \( x \), measured in radians.

__device__ float __exp10f (float x)

Calculate the fast approximate base 10 exponential of the input argument.

Returns

Returns an approximation to \( 10^x \).

Description

Calculate the fast approximate base 10 exponential of the input argument \( x \), \( 10^x \).
__device__ float __expf (float x)
Calculate the fast approximate base $e$ exponential of the input argument.

Returns
Returns an approximation to $e^x$.

Description
Calculate the fast approximate base $e$ exponential of the input argument $x$, $e^x$.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.2, Table 9.
- Most input and output values around denormal range are flushed to sign preserving 0.0.

__device__ float __fadd_rd (float x, float y)
Add two floating point values in round-down mode.

Returns
Returns $x + y$.

Description
Compute the sum of $x$ and $y$ in round-down (to negative infinity) mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
- This operation will never be merged into a single multiply-add instruction.

__device__ float __fadd_rn (float x, float y)
Add two floating point values in round-to-nearest-even mode.

Returns
Returns $x + y$.

Description
Compute the sum of $x$ and $y$ in round-to-nearest-even rounding mode.
__device__ float __fadd_ru (float x, float y)
Add two floating point values in round-up mode.

Returns
Returns \( x + y \).

Description
Compute the sum of \( x \) and \( y \) in round-up (to positive infinity) mode.

__device__ float __fadd_rz (float x, float y)
Add two floating point values in round-towards-zero mode.

Returns
Returns \( x + y \).

Description
Compute the sum of \( x \) and \( y \) in round-towards-zero mode.

__device__ float __fdiv_rd (float x, float y)
Divide two floating point values in round-down mode.

Returns
Returns \( x / y \).
Description
Divide two floating point values $x$ by $y$ in round-down (to negative infinity) mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float __fdiv_rn (float x, float y)
Divide two floating point values in round-to-nearest-even mode.

Returns
Returns $x / y$.

Description
Divide two floating point values $x$ by $y$ in round-to-nearest-even mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float __fdiv_ru (float x, float y)
Divide two floating point values in round-up mode.

Returns
Returns $x / y$.

Description
Divide two floating point values $x$ by $y$ in round-up (to positive infinity) mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float __fdiv_rz (float x, float y)
Divide two floating point values in round-towards-zero mode.

Returns
Returns $x / y$. 

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
Description
Divide two floating point values \( x \) by \( y \) in round-towards-zero mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

\[ \text{__device__ float __fdividef (float x, float y)} \]
Calculate the fast approximate division of the input arguments.

Returns
- Returns \( x \div y \).
- \( \text{__fdividef}(\infty, y) \) returns NaN for \( 2^{126} < y < 2^{128} \).
- \( \text{__fdividef}(x, y) \) returns 0 for \( 2^{126} < y < 2^{128} \) and \( x \neq \infty \).

Description
Calculate the fast approximate division of \( x \) by \( y \).

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.2, Table 9.

\[ \text{__device__ float __fmaf_rd (float x, float y, float z)} \]
Compute \( x \times y + z \) as a single operation, in round-down mode.

Returns
- Returns the rounded value of \( x \times y + z \) as a single operation.
- \( \text{fmaf}(\pm\infty, \pm0, z) \) returns NaN.
- \( \text{fmaf}(\pm0, \pm\infty, z) \) returns NaN.
- \( \text{fmaf}(x, y, -\infty) \) returns NaN if \( x \times y \) is an exact \( +\infty \).
- \( \text{fmaf}(x, y, +\infty) \) returns NaN if \( x \times y \) is an exact \( -\infty \).

Description
Computes the value of \( x \times y + z \) as a single ternary operation, rounding the result once in round-down (to negative infinity) mode.
__device__ float __fmaf_rn (float x, float y, float z)
Compute \(x \times y + z\) as a single operation, in round-to-nearest-even mode.

Returns

Returns the rounded value of \(x \times y + z\) as a single operation.

- \(\text{fmaf}(\pm \infty, \pm 0, z)\) returns NaN.
- \(\text{fmaf}(\pm 0, \pm \infty, z)\) returns NaN.
- \(\text{fmaf}(x, y, -\infty)\) returns NaN if \(x \times y\) is an exact \(+\infty\).
- \(\text{fmaf}(x, y, +\infty)\) returns NaN if \(x \times y\) is an exact \(-\infty\).

Description

Computes the value of \(x \times y + z\) as a single ternary operation, rounding the result once in round-to-nearest-even mode.

__device__ float __fmaf_ru (float x, float y, float z)
Compute \(x \times y + z\) as a single operation, in round-up mode.

Returns

Returns the rounded value of \(x \times y + z\) as a single operation.

- \(\text{fmaf}(\pm \infty, \pm 0, z)\) returns NaN.
- \(\text{fmaf}(\pm 0, \pm \infty, z)\) returns NaN.
- \(\text{fmaf}(x, y, -\infty)\) returns NaN if \(x \times y\) is an exact \(+\infty\).
- \(\text{fmaf}(x, y, +\infty)\) returns NaN if \(x \times y\) is an exact \(-\infty\).

Description

Computes the value of \(x \times y + z\) as a single ternary operation, rounding the result once in round-up (to positive infinity) mode.
__device__ float __fmaf_rz (float x, float y, float z)
Compute $x \times y + z$ as a single operation, in round-towards-zero mode.

Returns
Returns the rounded value of $x \times y + z$ as a single operation.

- $fmaf(\pm \infty, \pm 0, z)$ returns NaN.
- $fmaf(\pm 0, \pm \infty, z)$ returns NaN.
- $fmaf(x, y, -\infty)$ returns NaN if $x \times y$ is an exact $+\infty$.
- $fmaf(x, y, +\infty)$ returns NaN if $x \times y$ is an exact $-\infty$.

Description
Computes the value of $x \times y + z$ as a single ternary operation, rounding the result once in round-towards-zero mode.

__device__ float __fmul_rd (float x, float y)
Multiply two floating point values in round-down mode.

Returns
Returns $x \times y$.

Description
Compute the product of $x$ and $y$ in round-down (to negative infinity) mode.
__device__ float __fmul_rn (float x, float y)
Multiply two floating point values in round-to-nearest-even mode.

Returns
Returns \( x \cdot y \).

Description
Compute the product of \( x \) and \( y \) in round-to-nearest-even mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
- This operation will never be merged into a single multiply-add instruction.

__device__ float __fmul_ru (float x, float y)
Multiply two floating point values in round-up mode.

Returns
Returns \( x \cdot y \).

Description
Compute the product of \( x \) and \( y \) in round-up (to positive infinity) mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
- This operation will never be merged into a single multiply-add instruction.

__device__ float __fmul_rz (float x, float y)
Multiply two floating point values in round-towards-zero mode.

Returns
Returns \( x \cdot y \).

Description
Compute the product of \( x \) and \( y \) in round-towards-zero mode.
__device__ float __frcp_rd (float x)
Compute \( \frac{1}{x} \) in round-down mode.

**Returns**
Returns \( \frac{1}{x} \).

**Description**
Compute the reciprocal of \( x \) in round-down (to negative infinity) mode.

__device__ float __frcp_rn (float x)
Compute \( \frac{1}{x} \) in round-to-nearest-even mode.

**Returns**
Returns \( \frac{1}{x} \).

**Description**
Compute the reciprocal of \( x \) in round-to-nearest-even mode.

__device__ float __frcp_ru (float x)
Compute \( \frac{1}{x} \) in round-up mode.

**Returns**
Returns \( \frac{1}{x} \).
Description
Compute the reciprocal of $x$ in round-up (to positive infinity) mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float __frcp_rz (float x)
Compute $\frac{1}{x}$ in round-towards-zero mode.

Returns
Returns $\frac{1}{x}$.

Description
Compute the reciprocal of $x$ in round-towards-zero mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

__device__ float __frsqrt_rn (float x)
Compute $1/\sqrt{x}$ in round-to-nearest-even mode.

Returns
Returns $1/\sqrt{x}$.

Description
Compute the reciprocal square root of $x$ in round-to-nearest-even mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
\_\_device\_\_ float \_\_fsqrt\_rd (float x)

Compute $\sqrt{x}$ in round-down mode.

Returns

Returns $\sqrt{x}$.

Description

Compute the square root of $x$ in round-down (to negative infinity) mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

\_\_device\_\_ float \_\_fsqrt\_rn (float x)

Compute $\sqrt{x}$ in round-to-nearest-even mode.

Returns

Returns $\sqrt{x}$.

Description

Compute the square root of $x$ in round-to-nearest-even mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.

\_\_device\_\_ float \_\_fsqrt\_ru (float x)

Compute $\sqrt{x}$ in round-up mode.

Returns

Returns $\sqrt{x}$.

Description

Compute the square root of $x$ in round-up (to positive infinity) mode.
__device__ float __fsqrt_rz (float x)
Compute $\sqrt{x}$ in round-towards-zero mode.

Returns
Returns $\sqrt{x}$.

Description
Compute the square root of $x$ in round-towards-zero mode.

__device__ float __fsub_rd (float x, float y)
Subtract two floating point values in round-down mode.

Returns
Returns $x - y$.

Description
Compute the difference of $x$ and $y$ in round-down (to negative infinity) mode.

__device__ float __fsub_rn (float x, float y)
Subtract two floating point values in round-to-nearest-even mode.

Returns
Returns $x - y$. 
**Description**
Compute the difference of $x$ and $y$ in round-to-nearest-even rounding mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
- This operation will never be merged into a single multiply-add instruction.

```c
__device__ float __fsub_ru (float x, float y)
```

Subtract two floating point values in round-up mode.

**Returns**
Returns $x - y$.

**Description**
Compute the difference of $x$ and $y$ in round-up (to positive infinity) mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
- This operation will never be merged into a single multiply-add instruction.

```c
__device__ float __fsub_rz (float x, float y)
```

Subtract two floating point values in round-towards-zero mode.

**Returns**
Returns $x - y$.

**Description**
Compute the difference of $x$ and $y$ in round-towards-zero mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 6.
- This operation will never be merged into a single multiply-add instruction.
**__device__ float __log10f (float x)***

Calculate the fast approximate base 10 logarithm of the input argument.

**Returns**

Returns an approximation to \(\log_{10}(x)\).

**Description**

Calculate the fast approximate base 10 logarithm of the input argument \(x\).

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.2, Table 9.
- Most input and output values around denormal range are flushed to sign preserving 0.0.

**__device__ float __log2f (float x)***

Calculate the fast approximate base 2 logarithm of the input argument.

**Returns**

Returns an approximation to \(\log_{2}(x)\).

**Description**

Calculate the fast approximate base 2 logarithm of the input argument \(x\).

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.2, Table 9.
- Input and output in the denormal range is flushed to sign preserving 0.0.

**__device__ float __logf (float x)***

Calculate the fast approximate base \(e\) logarithm of the input argument.

**Returns**

Returns an approximation to \(\log_{e}(x)\).

**Description**

Calculate the fast approximate base \(e\) logarithm of the input argument \(x\).
__device__ float __powf (float x, float y)

Calculate the fast approximate of $x^y$.

**Returns**

Returns an approximation to $x^y$.

**Description**

Calculate the fast approximate of $x$, the first input argument, raised to the power of $y$, the second input argument, $x^y$.

---

__device__ float __saturatef (float x)

Clamp the input argument to $[+0.0, 1.0]$.

**Returns**

- __saturatef($x$) returns 0 if $x < 0$.
- __saturatef($x$) returns 1 if $x > 1$.
- __saturatef($x$) returns $x$ if $0 \leq x \leq 1$.
- __saturatef(NaN) returns 0.

**Description**

Clamp the input argument $x$ to be within the interval $[+0.0, 1.0]$.
__device__ void __sincosf (float x, float *sptr, float *cptr)
Calculate the fast approximate of sine and cosine of the first input argument.

Returns
‣ none

Description
Calculate the fast approximate of sine and cosine of the first input argument \( x \) (measured in radians). The results for sine and cosine are written into the second argument, \( sptr \), and, respectively, third argument, \( cptr \).

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.2, Table 9.
- Denorm input/output is flushed to sign preserving 0.0.

__device__ float __sinf (float x)
Calculate the fast approximate sine of the input argument.

Returns
Returns the approximate sine of \( x \).

Description
Calculate the fast approximate sine of the input argument \( x \), measured in radians.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.2, Table 9.
- Input and output in the denormal range is flushed to sign preserving 0.0.

__device__ float __tanf (float x)
Calculate the fast approximate tangent of the input argument.

Returns
Returns the approximate tangent of \( x \).
Description
Calculate the fast approximate tangent of the input argument \( x \), measured in radians.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.2, Table 9.
- The result is computed as the fast divide of \( \sinf() \) by \( \cosf() \). Denormal input and output are flushed to sign-preserving 0.0 at each step of the computation.

1.6. Double Precision Intrinsics

This section describes double precision intrinsic functions that are only supported in device code. To use these functions you do not need to include any additional header files in your program.

\texttt{__device__ double \_dadd\_rd (double x, double y)}
Add two floating point values in round-down mode.

\textbf{Returns}
Returns \( x + y \).

\textbf{Description}
Adds two floating point values \( x \) and \( y \) in round-down (to negative infinity) mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
- This operation will never be merged into a single multiply-add instruction.

\texttt{__device__ double \_dadd\_rn (double x, double y)}
Add two floating point values in round-to-nearest-even mode.

\textbf{Returns}
Returns \( x + y \).

\textbf{Description}
Adds two floating point values \( x \) and \( y \) in round-to-nearest-even mode.
void __device__ double __dadd_ru (double x, double y)

Add two floating point values in round-up mode.

Returns

Returns \( x + y \).

Description

Adds two floating point values \( x \) and \( y \) in round-up (to positive infinity) mode.

void __device__ double __dadd_rz (double x, double y)

Add two floating point values in round-towards-zero mode.

Returns

Returns \( x + y \).

Description

Adds two floating point values \( x \) and \( y \) in round-towards-zero mode.

void __device__ double __ddiv_rd (double x, double y)

Divide two floating point values in round-down mode.

Returns

Returns \( x / y \).
Description
Divides two floating point values $x$ by $y$ in round-down (to negative infinity) mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
- Requires compute capability $\geq 2.0$.

__device__ double __ddiv_rn (double x, double y)
Divide two floating point values in round-to-nearest-even mode.

Returns
Returns $x / y$.

Description
Divides two floating point values $x$ by $y$ in round-to-nearest-even mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
- Requires compute capability $\geq 2.0$.

__device__ double __ddiv_ru (double x, double y)
Divide two floating point values in round-up mode.

Returns
Returns $x / y$.

Description
Divides two floating point values $x$ by $y$ in round-up (to positive infinity) mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
- Requires compute capability $\geq 2.0$. 
__device__ double __ddiv_rz (double x, double y)
Divide two floating point values in round-towards-zero mode.

**Returns**
Returns \( x / y \).

**Description**
Divides two floating point values \( x \) by \( y \) in round-towards-zero mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
- Requires compute capability >= 2.0.

__device__ double __dmul_rd (double x, double y)
Multiply two floating point values in round-down mode.

**Returns**
Returns \( x \times y \).

**Description**
Multiplies two floating point values \( x \) and \( y \) in round-down (to negative infinity) mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
- This operation will never be merged into a single multiply-add instruction.

__device__ double __dmul_rn (double x, double y)
Multiply two floating point values in round-to-nearest-even mode.

**Returns**
Returns \( x \times y \).

**Description**
Multiplies two floating point values \( x \) and \( y \) in round-to-nearest-even mode.
__device__ double __dmul_ru (double x, double y)
Multiply two floating point values in round-up mode.

Returns
Returns \( x \times y \).

Description
Multiplies two floating point values \( x \) and \( y \) in round-up (to positive infinity) mode.

__device__ double __dmul_rz (double x, double y)
Multiply two floating point values in round-towards-zero mode.

Returns
Returns \( x \times y \).

Description
Multiplies two floating point values \( x \) and \( y \) in round-towards-zero mode.

__device__ double __drcp_rd (double x)
Compute \( \frac{1}{x} \) in round-down mode.

Returns
Returns \( \frac{1}{x} \).
Description
Compute the reciprocal of \( x \) in round-down (to negative infinity) mode.

\[
\text{\_device\_ double \_drcp\_rn (double x)}
\]
Compute \( \frac{1}{x} \) in round-to-nearest-even mode.

Returns
Returns \( \frac{1}{x} \).

Description
Compute the reciprocal of \( x \) in round-to-nearest-even mode.

\[
\text{\_device\_ double \_drcp\_ru (double x)}
\]
Compute \( \frac{1}{x} \) in round-up mode.

Returns
Returns \( \frac{1}{x} \).

Description
Compute the reciprocal of \( x \) in round-up (to positive infinity) mode.
__device__ double __drcp_rz (double x)
Compute $\frac{1}{x}$ in round-towards-zero mode.

Returns
Returns $\frac{1}{x}$.

Description
Compute the reciprocal of $x$ in round-towards-zero mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
- Requires compute capability $\geq 2.0$.

__device__ double __dsqrt_rd (double x)
Compute $\sqrt{x}$ in round-down mode.

Returns
Returns $\sqrt{x}$.

Description
Compute the square root of $x$ in round-down (to negative infinity) mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
- Requires compute capability $\geq 2.0$.

__device__ double __dsqrt_rn (double x)
Compute $\sqrt{x}$ in round-to-nearest-even mode.

Returns
Returns $\sqrt{x}$.

Description
Compute the square root of $x$ in round-to-nearest-even mode.
\textbf{__device__ double __dsqrt_ru (double x)}

Compute $\sqrt{x}$ in round-up mode.

\textbf{Returns}

Returns $\sqrt{x}$.

\textbf{Description}

Compute the square root of $x$ in round-up (to positive infinity) mode.

\textbf{__device__ double __dsqrt_rz (double x)}

Compute $\sqrt{x}$ in round-towards-zero mode.

\textbf{Returns}

Returns $\sqrt{x}$.

\textbf{Description}

Compute the square root of $x$ in round-towards-zero mode.
__device__ double __dsub_rd (double x, double y)
Subtract two floating point values in round-down mode.

Returns
Returns \( x - y \).

Description
Subtracts two floating point values \( x \) and \( y \) in round-down (to negative infinity) mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
- This operation will never be merged into a single multiply-add instruction.

__device__ double __dsub_rn (double x, double y)
Subtract two floating point values in round-to-nearest-even mode.

Returns
Returns \( x - y \).

Description
Subtracts two floating point values \( x \) and \( y \) in round-to-nearest-even mode.

- For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
- This operation will never be merged into a single multiply-add instruction.

__device__ double __dsub_ru (double x, double y)
Subtract two floating point values in round-up mode.

Returns
Returns \( x - y \).

Description
Subtracts two floating point values \( x \) and \( y \) in round-up (to positive infinity) mode.
__device__ double __dsub_rz (double x, double y)
Subtract two floating point values in round-towards-zero mode.

Returns
Returns `x - y`.

Description
Subtracts two floating point values `x` and `y` in round-towards-zero mode.

__device__ double __fma_rd (double x, double y, double z)
Compute `x × y + z` as a single operation in round-down mode.

Returns
Returns the rounded value of `x × y + z` as a single operation.

- `fmaf(±∞, 0, z)` returns NaN.
- `fmaf(0, ±∞, z)` returns NaN.
- `fmaf(x, y, −∞)` returns NaN if `x × y` is an exact `+∞`
- `fmaf(x, y, +∞)` returns NaN if `x × y` is an exact `−∞`

Description
Computes the value of `x × y + z` as a single ternary operation, rounding the result once in round-down (to negative infinity) mode.
__device__ double __fma_rn (double x, double y, double z)
Compute $x \times y + z$ as a single operation in round-to-nearest-even mode.

Returns
Returns the rounded value of $x \times y + z$ as a single operation.

- $\text{fma}(\pm \infty, \pm 0, z)$ returns NaN.
- $\text{fma}(\pm 0, \pm \infty, z)$ returns NaN.
- $\text{fma}(x, y, -\infty)$ returns NaN if $x \times y$ is an exact $+\infty$
- $\text{fma}(x, y, +\infty)$ returns NaN if $x \times y$ is an exact $-\infty$

Description
Computes the value of $x \times y + z$ as a single ternary operation, rounding the result once in round-to-nearest-even mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

__device__ double __fma_ru (double x, double y, double z)
Compute $x \times y + z$ as a single operation in round-up mode.

Returns
Returns the rounded value of $x \times y + z$ as a single operation.

- $\text{fma}(\pm \infty, \pm 0, z)$ returns NaN.
- $\text{fma}(\pm 0, \pm \infty, z)$ returns NaN.
- $\text{fma}(x, y, -\infty)$ returns NaN if $x \times y$ is an exact $+\infty$
- $\text{fma}(x, y, +\infty)$ returns NaN if $x \times y$ is an exact $-\infty$

Description
Computes the value of $x \times y + z$ as a single ternary operation, rounding the result once in round-up (to positive infinity) mode.

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.
__device__ double __fma_rz (double x, double y, double z)

Compute $x \times y + z$ as a single operation in round-towards-zero mode.

**Returns**

Returns the rounded value of $x \times y + z$ as a single operation.

- fmaf($\pm \infty$, $\pm 0$, $z$) returns NaN.
- fmaf($\pm 0$, $\pm \infty$, $z$) returns NaN.
- fmaf($x$, $y$, $-\infty$) returns NaN if $x \times y$ is an exact $+\infty$
- fmaf($x$, $y$, $+\infty$) returns NaN if $x \times y$ is an exact $-\infty$

**Description**

Computes the value of $x \times y + z$ as a single ternary operation, rounding the result once in round-towards-zero mode.

---

For accuracy information for this function see the CUDA C++ Programming Guide, Appendix E.1, Table 7.

### 1.7. Integer Intrinsics

This section describes integer intrinsic functions that are only supported in device code. To use these functions you do not need to include any additional header files in your program.

__device__ unsigned int __brev (unsigned int x)

Reverse the bit order of a 32 bit unsigned integer.

**Returns**

Returns the bit-reversed value of $x$. i.e. bit $N$ of the return value corresponds to bit $31-N$ of $x$.

**Description**

Reverses the bit order of the 32 bit unsigned integer $x$. 
**__device__ unsigned long long int __brevll (unsigned long long int x)**
Reverse the bit order of a 64 bit unsigned integer.

**Returns**
Returns the bit-reversed value of x. i.e. bit N of the return value corresponds to bit 63-N of x.

**Description**
Reverses the bit order of the 64 bit unsigned integer x.

**__device__ unsigned int __byte_perm (unsigned int x, unsigned int y, unsigned int s)**
Return selected bytes from two 32 bit unsigned integers.

**Returns**
The returned value r is computed to be: `result[n] := input[selector[n]]` where `result[n]` is the nth byte of r.

**Description**
`byte_perm(x,y,s)` returns a 32-bit integer consisting of four bytes from eight input bytes provided in the two input integers x and y, as specified by a selector, s.


**__device__ int __clz (int x)**
Return the number of consecutive high-order zero bits in a 32 bit integer.

**Returns**
Returns a value between 0 and 32 inclusive representing the number of zero bits.

**Description**
Count the number of consecutive leading zero bits, starting at the most significant bit (bit 31) of x.
__device__ int __clzll (long long int x)
Count the number of consecutive high-order zero bits in a 64 bit integer.

Returns
Returns a value between 0 and 64 inclusive representing the number of zero bits.

Description
Count the number of consecutive leading zero bits, starting at the most significant bit (bit 63) of x.

__device__ int __ffs (int x)
Find the position of the least significant bit set to 1 in a 32 bit integer.

Returns
Returns a value between 0 and 32 inclusive representing the position of the first bit set.

- __ffs(0) returns 0.

Description
Find the position of the first (least significant) bit set to 1 in x, where the least significant bit position is 1.

__device__ int __ffsll (long long int x)
Find the position of the least significant bit set to 1 in a 64 bit integer.

Returns
Returns a value between 0 and 64 inclusive representing the position of the first bit set.

- __ffsll(0) returns 0.

Description
Find the position of the first (least significant) bit set to 1 in x, where the least significant bit position is 1.
__device__ unsigned int __funnelshift_l (unsigned int lo, unsigned int hi, unsigned int shift)
Concatenate hi:lo, shift left by shift & 31 bits, return the most significant 32 bits.

Returns
Returns the most significant 32 bits of the shifted 64-bit value.

Description
Shift the 64-bit value formed by concatenating argument lo and hi left by the amount specified by the argument shift. Argument lo holds bits 31:0 and argument hi holds bits 63:32 of the 64-bit source value. The source is shifted left by the wrapped value of shift (shift & 31). The most significant 32-bits of the result are returned.

__device__ unsigned int __funnelshift_lc (unsigned int lo, unsigned int hi, unsigned int shift)
Concatenate hi:lo, shift left by min(shift, 32) bits, return the most significant 32 bits.

Returns
Returns the most significant 32 bits of the shifted 64-bit value.

Description
Shift the 64-bit value formed by concatenating argument lo and hi left by the amount specified by the argument shift. Argument lo holds bits 31:0 and argument hi holds bits 63:32 of the 64-bit source value. The source is shifted left by the clamped value of shift (min(shift, 32)). The most significant 32-bits of the result are returned.

__device__ unsigned int __funnelshift_r (unsigned int lo, unsigned int hi, unsigned int shift)
Concatenate hi:lo, shift right by shift & 31 bits, return the least significant 32 bits.

Returns
Returns the least significant 32 bits of the shifted 64-bit value.

Description
Shift the 64-bit value formed by concatenating argument lo and hi right by the amount specified by the argument shift. Argument lo holds bits 31:0 and argument hi holds bits 63:32 of the 64-bit source value. The source is shifted right by the wrapped value of shift (shift & 31). The least significant 32-bits of the result are returned.
__device__ unsigned int __funnelshift_rc (unsigned int lo, unsigned int hi, unsigned int shift)
Concatenate hi:lo, shift right by min(shift, 32) bits, return the least significant 32 bits.

Returns
Returns the least significant 32 bits of the shifted 64-bit value.

Description
Shift the 64-bit value formed by concatenating argument lo and hi right by the amount specified by the argument shift. Argument lo holds bits 31:0 and argument hi holds bits 63:32 of the 64-bit source value. The source is shifted right by the clamped value of shift (min(shift, 32)). The least significant 32-bits of the result are returned.

__device__ int __hadd (int, int)
Compute average of signed input arguments, avoiding overflow in the intermediate sum.

Returns
Returns a signed integer value representing the signed average value of the two inputs.

Description
Compute average of signed input arguments x and y as \((x + y) \gg 1\), avoiding overflow in the intermediate sum.

__device__ int __mul24 (int x, int y)
Calculate the least significant 32 bits of the product of the least significant 24 bits of two integers.

Returns
Returns the least significant 32 bits of the product \(x \times y\).

Description
Calculate the least significant 32 bits of the product of the least significant 24 bits of \(x\) and \(y\). The high order 8 bits of \(x\) and \(y\) are ignored.
__device__ long long int __mul64hi (long long int x, long long int y)
Calculate the most significant 64 bits of the product of the two 64 bit integers.

Returns
Returns the most significant 64 bits of the product \( x \times y \).

Description
Calculate the most significant 64 bits of the 128-bit product \( x \times y \), where \( x \) and \( y \) are 64-bit integers.

__device__ int __mulhi (int x, int y)
Calculate the most significant 32 bits of the product of the two 32 bit integers.

Returns
Returns the most significant 32 bits of the product \( x \times y \).

Description
Calculate the most significant 32 bits of the 64-bit product \( x \times y \), where \( x \) and \( y \) are 32-bit integers.

__device__ int __popc (unsigned int x)
Count the number of bits that are set to 1 in a 32 bit integer.

Returns
Returns a value between 0 and 32 inclusive representing the number of set bits.

Description
Count the number of bits that are set to 1 in \( x \).

__device__ int __popcll (unsigned long long int x)
Count the number of bits that are set to 1 in a 64 bit integer.

Returns
Returns a value between 0 and 64 inclusive representing the number of set bits.
Description
Count the number of bits that are set to 1 in \( x \).

```c
__device__ int __rhadd (int, int)
```
Compute rounded average of signed input arguments, avoiding overflow in the intermediate sum.

Returns
Returns a signed integer value representing the signed rounded average value of the two inputs.

Description
Compute average of signed input arguments \( x \) and \( y \) as \((x + y + 1) \gg 1\), avoiding overflow in the intermediate sum.

```c
__device__ unsigned int __sad (int x, int y, unsigned int z)
```
Calculate \( |x - y| + z \), the sum of absolute difference.

Returns
Returns \( |x - y| + z \).

Description
Calculate \( |x - y| + z \), the 32-bit sum of the third argument \( z \) plus and the absolute value of the difference between the first argument, \( x \), and second argument, \( y \).

Inputs \( x \) and \( y \) are signed 32-bit integers, input \( z \) is a 32-bit unsigned integer.

```c
__device__ unsigned int __uhadd (unsigned int, unsigned int)
```
Compute average of unsigned input arguments, avoiding overflow in the intermediate sum.

Returns
Returns an unsigned integer value representing the unsigned average value of the two inputs.
Description
Compute average of unsigned input arguments $x$ and $y$ as $(x + y) \gg 1$, avoiding
overflow in the intermediate sum.

__device__ unsigned int __umul24 (unsigned int x, unsigned int y)
Calculate the least significant 32 bits of the product of the least significant 24 bits of two
unsigned integers.

Returns
Returns the least significant 32 bits of the product $x \times y$.

Description
Calculate the least significant 32 bits of the product of the least significant 24 bits of $x$
and $y$. The high order 8 bits of $x$ and $y$ are ignored.

__device__ unsigned long long int __umul64hi (unsigned long long int x, unsigned long long int y)
Calculate the most significant 64 bits of the product of the two 64 unsigned bit integers.

Returns
Returns the most significant 64 bits of the product $x \times y$.

Description
Calculate the most significant 64 bits of the 128-bit product $x \times y$, where $x$ and $y$ are 64-
bit unsigned integers.

__device__ unsigned int __umulhi (unsigned int x, unsigned int y)
Calculate the most significant 32 bits of the product of the two 32 bit unsigned integers.

Returns
Returns the most significant 32 bits of the product $x \times y$.

Description
Calculate the most significant 32 bits of the 64-bit product $x \times y$, where $x$ and $y$ are 32-bit
unsigned integers.
__device__ unsigned int __urhadd (unsigned int, unsigned int)

Compute rounded average of unsigned input arguments, avoiding overflow in the intermediate sum.

**Returns**

Returns an unsigned integer value representing the unsigned rounded average value of the two inputs.

**Description**

Compute average of unsigned input arguments \( x \) and \( y \) as \( (x + y + 1) >> 1 \), avoiding overflow in the intermediate sum.

__device__ unsigned int __usad (unsigned int x, unsigned int y, unsigned int z)

Calculate \(|x - y| + z\), the sum of absolute difference.

**Returns**

Returns \(|x - y| + z\).

**Description**

Calculate \(|x - y| + z\), the 32-bit sum of the third argument \( z \) plus the absolute value of the difference between the first argument, \( x \), and second argument, \( y \).

Inputs \( x \), \( y \), and \( z \) are unsigned 32-bit integers.

### 1.8. Type Casting Intrinsics

This section describes type casting intrinsic functions that are only supported in device code. To use these functions you do not need to include any additional header files in your program.

__device__ float __double2float_rd (double x)

Convert a double to a float in round-down mode.

**Returns**

Returns converted value.
Description
Convert the double-precision floating point value \( x \) to a single-precision floating point value in round-down (to negative infinity) mode.

`__device__ float __double2float_rn (double x)`
Convert a double to a float in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to a single-precision floating point value in round-to-nearest-even mode.

`__device__ float __double2float_ru (double x)`
Convert a double to a float in round-up mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to a single-precision floating point value in round-up (to positive infinity) mode.

`__device__ float __double2float_rz (double x)`
Convert a double to a float in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to a single-precision floating point value in round-towards-zero mode.
__device__ int __double2hiint (double x)
Reinterpret high 32 bits in a double as a signed integer.

Returns
Returns reinterpreted value.

Description
Reinterpret the high 32 bits in the double-precision floating point value $x$ as a signed integer.

__device__ int __double2int_rd (double x)
Convert a double to a signed int in round-down mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value $x$ to a signed integer value in round-down (to negative infinity) mode.

__device__ int __double2int_rn (double x)
Convert a double to a signed int in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value $x$ to a signed integer value in round-to-nearest-even mode.

__device__ int __double2int_ru (double x)
Convert a double to a signed int in round-up mode.

Returns
Returns converted value.
Description
Convert the double-precision floating point value \( x \) to a signed integer value in round-up (to positive infinity) mode.

__device__ int __double2int_rz (double)
Convert a double to a signed int in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to a signed integer value in round-towards-zero mode.

__device__ long long int __double2ll_rd (double x)
Convert a double to a signed 64-bit int in round-down mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to a signed 64-bit integer value in round-down (to negative infinity) mode.

__device__ long long int __double2ll_rn (double x)
Convert a double to a signed 64-bit int in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to a signed 64-bit integer value in round-to-nearest-even mode.
__device__ long long int __double2ll_ru (double x)
Convert a double to a signed 64-bit int in round-up mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to a signed 64-bit integer value in round-up (to positive infinity) mode.

__device__ long long int __double2ll_rz (double)
Convert a double to a signed 64-bit int in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to a signed 64-bit integer value in round-towards-zero mode.

__device__ int __double2loint (double x)
Reinterpret low 32 bits in a double as a signed integer.

Returns
Returns reinterpreted value.

Description
Reinterpret the low 32 bits in the double-precision floating point value \( x \) as a signed integer.

__device__ unsigned int __double2uint_rd (double x)
Convert a double to an unsigned int in round-down mode.

Returns
Returns converted value.
Description
Convert the double-precision floating point value x to an unsigned integer value in round-down (to negative infinity) mode.

__device__ unsigned int __double2uint_rn (double x)
Convert a double to an unsigned int in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value x to an unsigned integer value in round-to-nearest-even mode.

__device__ unsigned int __double2uint_ru (double x)
Convert a double to an unsigned int in round-up mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value x to an unsigned integer value in round-up (to positive infinity) mode.

__device__ unsigned int __double2uint_rz (double)
Convert a double to an unsigned int in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value x to an unsigned integer value in round-towards-zero mode.
__device__ unsigned long long int __double2ull_rd (double x)
Convert a double to an unsigned 64-bit int in round-down mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to an unsigned 64-bit integer value in round-down (to negative infinity) mode.

__device__ unsigned long long int __double2ull_rn (double x)
Convert a double to an unsigned 64-bit int in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to an unsigned 64-bit integer value in round-to-nearest-even mode.

__device__ unsigned long long int __double2ull_ru (double x)
Convert a double to an unsigned 64-bit int in round-up mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value \( x \) to an unsigned 64-bit integer value in round-up (to positive infinity) mode.
__device__ unsigned long long int __double2ull_rz (double)
Convert a double to an unsigned 64-bit int in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the double-precision floating point value $x$ to an unsigned 64-bit integer value in round-towards-zero mode.

__device__ long long int __double_as_longlong (double $x$)
Reinterpret bits in a double as a 64-bit signed integer.

Returns
Returns reinterpreted value.

Description
Reinterpret the bits in the double-precision floating point value $x$ as a signed 64-bit integer.

__device__ int __float2int_rd (float $x$)
Convert a float to a signed integer in round-down mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value $x$ to a signed integer in round-down (to negative infinity) mode.

__device__ int __float2int_rn (float $x$)
Convert a float to a signed integer in round-to-nearest-even mode.

Returns
Returns converted value.
Description
Convert the single-precision floating point value \( x \) to a signed integer in round-to-nearest-even mode.

__device__ int __float2int_ru (float)
Convert a float to a signed integer in round-up mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value \( x \) to a signed integer in round-up (to positive infinity) mode.

__device__ int __float2int_rz (float x)
Convert a float to a signed integer in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value \( x \) to a signed integer in round-towards-zero mode.

__device__ long long int __float2ll_rd (float x)
Convert a float to a signed 64-bit integer in round-down mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value \( x \) to a signed 64-bit integer in round-down (to negative infinity) mode.
__device__ long long int __float2ll_rn (float x)
Convert a float to a signed 64-bit integer in round-to-nearest-even mode.

**Returns**
Returns converted value.

**Description**
Convert the single-precision floating point value \(x\) to a signed 64-bit integer in round-to-nearest-even mode.

__device__ long long int __float2ll_ru (float x)
Convert a float to a signed 64-bit integer in round-up mode.

**Returns**
Returns converted value.

**Description**
Convert the single-precision floating point value \(x\) to a signed 64-bit integer in round-up (to positive infinity) mode.

__device__ long long int __float2ll_rz (float x)
Convert a float to a signed 64-bit integer in round-towards-zero mode.

**Returns**
Returns converted value.

**Description**
Convert the single-precision floating point value \(x\) to a signed 64-bit integer in round-towards-zero mode.

__device__ unsigned int __float2uint_rd (float x)
Convert a float to an unsigned integer in round-down mode.

**Returns**
Returns converted value.
Description
Convert the single-precision floating point value \( x \) to an unsigned integer in round-down (to negative infinity) mode.

\[
\text{__device__ unsigned int __float2uint_rn (float x)}
\]
Convert a float to an unsigned integer in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value \( x \) to an unsigned integer in round-to-nearest-even mode.

\[
\text{__device__ unsigned int __float2uint_ru (float x)}
\]
Convert a float to an unsigned integer in round-up mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value \( x \) to an unsigned integer in round-up (to positive infinity) mode.

\[
\text{__device__ unsigned int __float2uint_rz (float x)}
\]
Convert a float to an unsigned integer in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value \( x \) to an unsigned integer in round-towards-zero mode.
__device__ unsigned long long int __float2ull_rd (float x)
Convert a float to an unsigned 64-bit integer in round-down mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value \( x \) to an unsigned 64-bit integer in round-down (to negative infinity) mode.

__device__ unsigned long long int __float2ull_rn (float x)
Convert a float to an unsigned 64-bit integer in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value \( x \) to an unsigned 64-bit integer in round-to-nearest-even mode.

__device__ unsigned long long int __float2ull_ru (float x)
Convert a float to an unsigned 64-bit integer in round-up mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value \( x \) to an unsigned 64-bit integer in round-up (to positive infinity) mode.
__device__ unsigned long long int __float2ull_rz (float x)
Convert a float to an unsigned 64-bit integer in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the single-precision floating point value \( x \) to an unsigned 64-bit integer in round-towards_zero mode.

__device__ int __float_as_int (float x)
Reinterpret bits in a float as a signed integer.

Returns
Returns reinterpreted value.

Description
Reinterpret the bits in the single-precision floating point value \( x \) as a signed integer.

__device__ unsigned int __float_as_uint (float x)
Reinterpret bits in a float as a unsigned integer.

Returns
Returns reinterpreted value.

Description
Reinterpret the bits in the single-precision floating point value \( x \) as a unsigned integer.

__device__ double __hiloint2double (int hi, int lo)
Reinterpret high and low 32-bit integer values as a double.

Returns
Returns reinterpreted value.
Description
Reinterpret the integer value of hi as the high 32 bits of a double-precision floating point value and the integer value of lo as the low 32 bits of the same double-precision floating point value.

__device__ double __int2double_rn (int x)
Convert a signed int to a double.

Returns
Returns converted value.

Description
Convert the signed integer value x to a double-precision floating point value.

__device__ float __int2float_rd (int x)
Convert a signed integer to a float in round-down mode.

Returns
Returns converted value.

Description
Convert the signed integer value x to a single-precision floating point value in round-down (to negative infinity) mode.

__device__ float __int2float_rn (int x)
Convert a signed integer to a float in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the signed integer value x to a single-precision floating point value in round-to-nearest-even mode.
__device__ float __int2float_ru (int x)
Convert a signed integer to a float in round-up mode.

Returns
Returns converted value.

Description
Convert the signed integer value $x$ to a single-precision floating point value in round-up (to positive infinity) mode.

__device__ float __int2float_rz (int x)
Convert a signed integer to a float in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the signed integer value $x$ to a single-precision floating point value in round-towards-zero mode.

__device__ float __int_as_float (int x)
Reinterpret bits in an integer as a float.

Returns
Returns reinterpreted value.

Description
Reinterpret the bits in the signed integer value $x$ as a single-precision floating point value.

__device__ double __ll2double_rd (long long int x)
Convert a signed 64-bit int to a double in round-down mode.

Returns
Returns converted value.
**Description**
Convert the signed 64-bit integer value \( x \) to a double-precision floating point value in round-down (to negative infinity) mode.

```c
__device__ double __ll2double_rn (long long int x)
```
Convert a signed 64-bit int to a double in round-to-nearest-even mode.

**Returns**
Returns converted value.

**Description**
Convert the signed 64-bit integer value \( x \) to a double-precision floating point value in round-to-nearest-even mode.

```c
__device__ double __ll2double_ru (long long int x)
```
Convert a signed 64-bit int to a double in round-up mode.

**Returns**
Returns converted value.

**Description**
Convert the signed 64-bit integer value \( x \) to a double-precision floating point value in round-up (to positive infinity) mode.

```c
__device__ double __ll2double_rz (long long int x)
```
Convert a signed 64-bit int to a double in round-towards-zero mode.

**Returns**
Returns converted value.

**Description**
Convert the signed 64-bit integer value \( x \) to a double-precision floating point value in round-towards-zero mode.
```c
__device__ float __ll2float_rd (long long int x)
Convert a signed integer to a float in round-down mode.

Returns
Returns converted value.

Description
Convert the signed integer value x to a single-precision floating point value in round-down (to negative infinity) mode.

__device__ float __ll2float_rn (long long int x)
Convert a signed 64-bit integer to a float in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the signed 64-bit integer value x to a single-precision floating point value in round-to-nearest-even mode.

__device__ float __ll2float_ru (long long int x)
Convert a signed integer to a float in round-up mode.

Returns
Returns converted value.

Description
Convert the signed integer value x to a single-precision floating point value in round-up (to positive infinity) mode.

__device__ float __ll2float_rz (long long int x)
Convert a signed integer to a float in round-towards-zero mode.

Returns
Returns converted value.
**Description**
Convert the signed integer value $x$ to a single-precision floating point value in round-towards-zero mode.

```c
__device__ double __longlong_as_double (long long int x)
```
Reinterpret bits in a 64-bit signed integer as a double.

**Returns**
Returns reinterpreted value.

**Description**
Reinterpret the bits in the 64-bit signed integer value $x$ as a double-precision floating point value.

```c
__device__ double __uint2double_rn (unsigned int x)
```
Convert an unsigned int to a double.

**Returns**
Returns converted value.

**Description**
Convert the unsigned integer value $x$ to a double-precision floating point value.

```c
__device__ float __uint2float_rd (unsigned int x)
```
Convert an unsigned integer to a float in round-down mode.

**Returns**
Returns converted value.

**Description**
Convert the unsigned integer value $x$ to a single-precision floating point value in round-down (to negative infinity) mode.
__device__ float __uint2float_rn (unsigned int x)
Convert an unsigned integer to a float in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the unsigned integer value \( x \) to a single-precision floating point value in round-to-nearest-even mode.

__device__ float __uint2float_ru (unsigned int x)
Convert an unsigned integer to a float in round-up mode.

Returns
Returns converted value.

Description
Convert the unsigned integer value \( x \) to a single-precision floating point value in round-up (to positive infinity) mode.

__device__ float __uint2float_rz (unsigned int x)
Convert an unsigned integer to a float in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the unsigned integer value \( x \) to a single-precision floating point value in round-towards-zero mode.

__device__ float __uint_as_float (unsigned int x)
Reinterpret bits in an unsigned integer as a float.

Returns
Returns reinterpreted value.
Description
Reinterpret the bits in the unsigned integer value \( x \) as a single-precision floating point value.

```c
__device__ double __ull2double_rd (unsigned long long int x)
```
Convert an unsigned 64-bit int to a double in round-down mode.

Returns
Returns converted value.

Description
Convert the unsigned 64-bit integer value \( x \) to a double-precision floating point value in round-down (to negative infinity) mode.

```c
__device__ double __ull2double_rn (unsigned long long int x)
```
Convert an unsigned 64-bit int to a double in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the unsigned 64-bit integer value \( x \) to a double-precision floating point value in round-to-nearest-even mode.

```c
__device__ double __ull2double_ru (unsigned long long int x)
```
Convert an unsigned 64-bit int to a double in round-up mode.

Returns
Returns converted value.

Description
Convert the unsigned 64-bit integer value \( x \) to a double-precision floating point value in round-up (to positive infinity) mode.
__device__ double __ull2double_rz (unsigned long long int x)
Convert an unsigned 64-bit int to a double in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the unsigned 64-bit integer value x to a double-precision floating point value in round-towards-zero mode.

__device__ float __ull2float_rd (unsigned long long int x)
Convert an unsigned integer to a float in round-down mode.

Returns
Returns converted value.

Description
Convert the unsigned integer value x to a single-precision floating point value in round-down (to negative infinity) mode.

__device__ float __ull2float_rn (unsigned long long int x)
Convert an unsigned integer to a float in round-to-nearest-even mode.

Returns
Returns converted value.

Description
Convert the unsigned integer value x to a single-precision floating point value in round-to-nearest-even mode.
__device__ float __ull2float_ru (unsigned long long int x)
Convert an unsigned integer to a float in round-up mode.

Returns
Returns converted value.

Description
Convert the unsigned integer value \( x \) to a single-precision floating point value in round-up (to positive infinity) mode.

__device__ float __ull2float_rz (unsigned long long int x)
Convert an unsigned integer to a float in round-towards-zero mode.

Returns
Returns converted value.

Description
Convert the unsigned integer value \( x \) to a single-precision floating point value in round-towards-zero mode.

1.9. SIMD Intrinsic

This section describes SIMD intrinsic functions that are only supported in device code. To use these functions you do not need to include any additional header files in your program.

__device__ unsigned int __vabs2 (unsigned int a)
Computes per-halfword absolute value.

Returns
Returns computed value.

Description
Splits 4 bytes of argument into 2 parts, each consisting of 2 bytes, then computes absolute value for each of parts. Result is stored as unsigned int and returned.
__device__ unsigned int __vabs4 (unsigned int a)
Computes per-byte absolute value.

Returns
Returns computed value.

Description
Splits argument by bytes. Computes absolute value of each byte. Result is stored as unsigned int.

__device__ unsigned int __vabsdiffs2 (unsigned int a, unsigned int b)
Computes per-halfword sum of absolute difference of signed integer.

Returns
Returns computed value.

Description
Splits 4 bytes of each into 2 parts, each consisting of 2 bytes. For corresponding parts function computes absolute difference. Result is stored as unsigned int and returned.

__device__ unsigned int __vabsdiffs4 (unsigned int a, unsigned int b)
Computes per-byte absolute difference of signed integer.

Returns
Returns computed value.

Description
Splits 4 bytes of each into 4 parts, each consisting of 1 byte. For corresponding parts function computes absolute difference. Result is stored as unsigned int and returned.
__device__ unsigned int __vabsdiffu2 (unsigned int a, unsigned int b)
Performs per-halfword absolute difference of unsigned integer computation: |a - b|.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function computes absolute difference. Result is stored as unsigned int and returned.

__device__ unsigned int __vabsdiffu4 (unsigned int a, unsigned int b)
Computes per-byte absolute difference of unsigned integer.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function computes absolute difference. Result is stored as unsigned int and returned.

__device__ unsigned int __vabsss2 (unsigned int a)
Computes per-halfword absolute value with signed saturation.

Returns
Returns computed value.

Description
Splits 4 bytes of argument into 2 parts, each consisting of 2 bytes, then computes absolute value with signed saturation for each of parts. Result is stored as unsigned int and returned.
__device__ unsigned int __vabsss4 (unsigned int a)
Computes per-byte absolute value with signed saturation.

Returns
Returns computed value.

Description
Splits 4 bytes of argument into 4 parts, each consisting of 1 byte, then computes absolute value with signed saturation for each of parts. Result is stored as unsigned int and returned.

__device__ unsigned int __vadd2 (unsigned int a, unsigned int b)
Performs per-halfword (un)signed addition, with wrap-around: \( a + b \).

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes, then performs unsigned addition on corresponding parts. Result is stored as unsigned int and returned.

__device__ unsigned int __vadd4 (unsigned int a, unsigned int b)
Performs per-byte (un)signed addition.

Returns
Returns computed value.

Description
Splits 'a' into 4 bytes, then performs unsigned addition on each of these bytes with the corresponding byte from 'b', ignoring overflow. Result is stored as unsigned int and returned.
__device__ unsigned int __vaddss2 (unsigned int a, unsigned int b)
Performs per-halfword addition with signed saturation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes, then performs addition with signed saturation on corresponding parts. Result is stored as unsigned int and returned.

__device__ unsigned int __vaddss4 (unsigned int a, unsigned int b)
Performs per-byte addition with signed saturation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte, then performs addition with signed saturation on corresponding parts. Result is stored as unsigned int and returned.

__device__ unsigned int __vaddus2 (unsigned int a, unsigned int b)
Performs per-halfword addition with unsigned saturation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes, then performs addition with unsigned saturation on corresponding parts.
__device__ unsigned int __vaddus4 (unsigned int a, unsigned int b)
 Performs per-byte addition with unsigned saturation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte, then performs addition with unsigned saturation on corresponding parts.

__device__ unsigned int __vavgs2 (unsigned int a, unsigned int b)
Performs per-halfword signed rounded average computation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. then computes signed rounded average of corresponding parts. Result is stored as unsigned int and returned.

__device__ unsigned int __vavgs4 (unsigned int a, unsigned int b)
Computes per-byte signed rounder average.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. then computes signed rounded average of corresponding parts. Result is stored as unsigned int and returned.
__device__ unsigned int __vavgu2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned rounded average computation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. Then computes unsigned rounded average of corresponding parts. Result is stored as unsigned int and returned.

__device__ unsigned int __vavgu4 (unsigned int a, unsigned int b)
Performs per-byte unsigned rounded average.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. Then computes unsigned rounded average of corresponding parts. Result is stored as unsigned int and returned.

__device__ unsigned int __vcmpeq2 (unsigned int a, unsigned int b)
Performs per-halfword (un)signed comparison.

Returns
Returns 0xffff computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts result is ffff if they are equal, and 0000 otherwise. For example __vcmpeq2(0x1234aba5, 0x1234aba6) returns 0xffff0000.
__device__ unsigned int __vcmpeq4 (unsigned int a, unsigned int b)
Performs per-byte (un)signed comparison.

Returns
Returns 0xff if a = b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts result is ff if they are equal, and 00 otherwise. For example __vcmpeq4(0x1234aba5, 0x1234aba6) returns 0xffffffff.

__device__ unsigned int __vcmpges2 (unsigned int a, unsigned int b)
Performs per-halfword signed comparison: a >= b ? 0xffff : 0.

Returns
Returns 0xffff if a >= b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts result is ffff if 'a' part >= 'b' part, and 0000 otherwise. For example __vcmpges2(0x1234aba5, 0x1234aba6) returns 0xffffffff.

__device__ unsigned int __vcmpges4 (unsigned int a, unsigned int b)
Performs per-byte signed comparison.

Returns
Returns 0xff if a >= b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts result is ff if 'a' part >= 'b' part, and 00 otherwise. For example __vcmpges4(0x1234aba5, 0x1234aba6) returns 0xffffffff.
__device__ unsigned int __vcmpgeu2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned comparison: \(a \geq b \, ? \, 0xffffffff : 0\).

**Returns**
Returns 0xffffffff if \(a \geq b\), else returns 0.

**Description**
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts result is 0xffffffff if 'a' part \(\geq\) 'b' part, and 0000 otherwise. For example __vcmpgeu2(0x1234aba5, 0x1234aba6) returns 0xffffffff0000.

__device__ unsigned int __vcmpgeu4 (unsigned int a, unsigned int b)
Performs per-byte unsigned comparison.

**Returns**
Returns 0xff if \(a = b\), else returns 0.

**Description**
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts result is ff if 'a' part \(\geq\) 'b' part, and 00 otherwise. For example __vcmpgeu4(0x1234aba5, 0x1234aba6) returns 0xffffff00.

__device__ unsigned int __vcmpgts2 (unsigned int a, unsigned int b)
Performs per-halfword signed comparison: \(a > b \, ? \, 0xffffffff : 0\).

**Returns**
Returns 0xffffffff if \(a > b\), else returns 0.

**Description**
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts result is 0xffffffff if 'a' part > 'b' part, and 0000 otherwise. For example __vcmpgts2(0x1234aba5, 0x1234aba6) returns 0x00000000.
__device__ unsigned int __vcmpgts4 (unsigned int a, unsigned int b)
Performs per-byte signed comparison.

Returns
Returns 0xff if a > b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts result is ff if 'a' part > 'b' part, and 00 otherwise. For example __vcmpgts4(0x1234aba5, 0x1234aba6) returns 0x00000000.

__device__ unsigned int __vcmpgtu2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned comparison: a > b ? 0xffff : 0.

Returns
Returns 0xffff if a > b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts result is ffff if 'a' part > 'b' part, and 0000 otherwise. For example __vcmpgtu2(0x1234aba5, 0x1234aba6) returns 0x00000000.

__device__ unsigned int __vcmpgtu4 (unsigned int a, unsigned int b)
Performs per-byte unsigned comparison.

Returns
Returns 0xff if a > b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts result is ff if 'a' part > 'b' part, and 00 otherwise. For example __vcmpgtu4(0x1234aba5, 0x1234aba6) returns 0x00000000.
__device__ unsigned int __vcmples2 (unsigned int a, unsigned int b)
Performs per-halfword signed comparison: a <= b ? 0xffff : 0.

Returns
Returns 0xffff if a <= b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts result is ffff if 'a' part <= 'b' part, and 0000 otherwise. For example __vcmples2(0x1234aba5, 0x1234aba6) returns 0xffffffff.

__device__ unsigned int __vcmples4 (unsigned int a, unsigned int b)
Performs per-byte signed comparison.

Returns
Returns 0xff if a <= b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts result is ff if 'a' part <= 'b' part, and 00 otherwise. For example __vcmples4(0x1234aba5, 0x1234aba6) returns 0xffffffff.

__device__ unsigned int __vcmpleu2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned comparison: a <= b ? 0xffff : 0.

Returns
Returns 0xffff if a <= b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts result is ffff if 'a' part <= 'b' part, and 0000 otherwise. For example __vcmpleu2(0x1234aba5, 0x1234aba6) returns 0xffffffff.
__device__ unsigned int __vcumpleu4 (unsigned int a, unsigned int b)
Performs per-byte unsigned comparison.

Returns
Returns 0xff if a <= b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts result is ff if 'a' part <= 'b' part, and 00 otherwise. For example __vcumpleu4(0x1234aba5, 0x1234aba6) returns 0xffffffff.

__device__ unsigned int __vcmpults2 (unsigned int a, unsigned int b)
Performs per-halfword signed comparison: a < b ? 0xffff : 0.

Returns
Returns 0xffff if a < b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts result is ffff if 'a' part < 'b' part, and 0000 otherwise. For example __vcmpults2(0x1234aba5, 0x1234aba6) returns 0x0000ffff.

__device__ unsigned int __vcmpults4 (unsigned int a, unsigned int b)
Performs per-byte signed comparison.

Returns
Returns 0xff if a < b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts result is ff if 'a' part < 'b' part, and 00 otherwise. For example __vcmpults4(0x1234aba5, 0x1234aba6) returns 0x000000ff.
__device__ unsigned int __vcmpltu2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned comparison: a < b ? 0xffff : 0.

Returns
Returns 0xffff if a < b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts result is ffff if 'a' part < 'b' part, and 0000 otherwise. For example __vcmpltu2(0x1234aba5, 0x1234aba6) returns 0x0000ffff.

__device__ unsigned int __vcmpltu4 (unsigned int a, unsigned int b)
Performs per-byte unsigned comparison.

Returns
Returns 0xff if a < b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts result is ff if 'a' part < 'b' part, and 00 otherwise. For example __vcmpltu4(0x1234aba5, 0x1234aba6) returns 0x000000ff.

__device__ unsigned int __vcmpne2 (unsigned int a, unsigned int b)
Performs per-halfword (un)signed comparison: a != b ? 0xffff : 0.

Returns
Returns 0xffff if a != b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts result is ffff if 'a' part != 'b' part, and 0000 otherwise. For example __vcmpne2(0x1234aba5, 0x1234aba6) returns 0x0000ffff.
__device__ unsigned int __vcmpne4 (unsigned int a, unsigned int b)
Performs per-byte (un)signed comparison.

Returns
Returns 0xff if a != b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts result is ff if 'a' part != 'b' part, and 00 otherwise. For example __vcmplts4(0x1234aba5, 0x1234aba6) returns 0x000000ff.

__device__ unsigned int __vhaddu2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned average computation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. then computes unsigned average of corresponding parts. Result is stored as unsigned int and returned.

__device__ unsigned int __vhaddu4 (unsigned int a, unsigned int b)
Computes per-byte unsigned average.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. then computes unsigned average of corresponding parts. Result is stored as unsigned int and returned.
__device__ unsigned int __vmaxs2 (unsigned int a, unsigned int b)
Performs per-halfword signed maximum computation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function computes signed maximum. Result is stored as unsigned int and returned.

__device__ unsigned int __vmaxs4 (unsigned int a, unsigned int b)
Computes per-byte signed maximum.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function computes signed maximum. Result is stored as unsigned int and returned.

__device__ unsigned int __vmaxu2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned maximum computation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function computes unsigned maximum. Result is stored as unsigned int and returned.
__device__ unsigned int __vmaxu4 (unsigned int a, unsigned int b)
Computes per-byte unsigned maximum.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function computes unsigned maximum. Result is stored as unsigned int and returned.

__device__ unsigned int __vmins2 (unsigned int a, unsigned int b)
Performs per-halfword signed minimum computation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function computes signed minimum. Result is stored as unsigned int and returned.

__device__ unsigned int __vmins4 (unsigned int a, unsigned int b)
Computes per-byte signed minimum.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function computes signed minimum. Result is stored as unsigned int and returned.
__device__ unsigned int __vminu2 (unsigned int a, unsigned int b)
Perform per-halfword unsigned minimum computation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function computes unsigned minimum. Result is stored as unsigned int and returned.

__device__ unsigned int __vminu4 (unsigned int a, unsigned int b)
Computes per-byte unsigned minimum.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function computes unsigned minimum. Result is stored as unsigned int and returned.

__device__ unsigned int __vneg2 (unsigned int a)
Computes per-halfword negation.

Returns
Returns computed value.

Description
Splits 4 bytes of argument into 2 parts, each consisting of 2 bytes. For each part function computes negation. Result is stored as unsigned int and returned.
__device__ unsigned int __vneg4 (unsigned int a)
Performs per-byte negation.

Returns
Returns computed value.

Description
Splits 4 bytes of argument into 4 parts, each consisting of 1 byte. For each part function computes negation. Result is stored as unsigned int and returned.

__device__ unsigned int __vnegss2 (unsigned int a)
Computes per-halfword negation with signed saturation.

Returns
Returns computed value.

Description
Splits 4 bytes of argument into 2 parts, each consisting of 2 bytes. For each part function computes negation. Result is stored as unsigned int and returned.

__device__ unsigned int __vnegss4 (unsigned int a)
Performs per-byte negation with signed saturation.

Returns
Returns computed value.

Description
Splits 4 bytes of argument into 4 parts, each consisting of 1 byte. For each part function computes negation. Result is stored as unsigned int and returned.

__device__ unsigned int __vsads2 (unsigned int a, unsigned int b)
Performs per-halfword sum of absolute difference of signed.

Returns
Returns computed value.
**Description**
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts functions computes absolute difference and sum it up. Result is stored as unsigned int and returned.

```c
__device__ unsigned int __vsads4 (unsigned int a, unsigned int b)
```
Computes per-byte sum of abs difference of signed.

**Returns**
Returns computed value.

**Description**
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts functions computes absolute difference and sum it up. Result is stored as unsigned int and returned.

```c
__device__ unsigned int __vsadu2 (unsigned int a, unsigned int b)
```
Computes per-halfword sum of abs diff of unsigned.

**Returns**
Returns computed value.

**Description**
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function computes absolute differences, and returns sum of those differences.

```c
__device__ unsigned int __vsadu4 (unsigned int a, unsigned int b)
```
Computes per-byte sum of abs difference of unsigned.

**Returns**
Returns computed value.
Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function computes absolute differences, and returns sum of those differences.

__device__ unsigned int __vseteq2 (unsigned int a, unsigned int b)
Performs per-halfword (un)signed comparison.

Returns
Returns 1 if a = b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function performs comparison 'a' part == 'b' part. If both equalities are satisfied, function returns 1.

__device__ unsigned int __vseteq4 (unsigned int a, unsigned int b)
Performs per-byte (un)signed comparison.

Returns
Returns 1 if a = b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function performs comparison 'a' part == 'b' part. If both equalities are satisfied, function returns 1.

__device__ unsigned int __vsetges2 (unsigned int a, unsigned int b)
Performs per-halfword signed comparison.

Returns
Returns 1 if a >= b, else returns 0.
Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function performs comparison 'a' part >= 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetges4 (unsigned int a, unsigned int b)
Performs per-byte signed comparison.

Returns
Returns 1 if a >= b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function performs comparison 'a' part >= 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetgeu2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned minimum unsigned comparison.

Returns
Returns 1 if a >= b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function performs comparison 'a' part >= 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetgeu4 (unsigned int a, unsigned int b)
Performs per-byte unsigned comparison.

Returns
Returns 1 if a >= b, else returns 0.
Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function performs comparison 'a' part >= 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetgts2 (unsigned int a, unsigned int b)
Performs per-halfword signed comparison.

Returns
Returns 1 if a > b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function performs comparison 'a' part > 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetgts4 (unsigned int a, unsigned int b)
Performs per-byte signed comparison.

Returns
Returns 1 if a > b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function performs comparison 'a' part > 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetgtu2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned comparison.

Returns
Returns 1 if a > b, else returns 0.
Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function performs comparison 'a' part > 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetgtu4 (unsigned int a, unsigned int b)
Performs per-byte unsigned comparison.

Returns
Returns 1 if a > b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function performs comparison 'a' part > 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetles2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned minimum computation.

Returns
Returns 1 if a <= b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function performs comparison 'a' part <= 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetles4 (unsigned int a, unsigned int b)
Performs per-byte signed comparison.

Returns
Returns 1 if a <= b, else returns 0.
Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding
parts function performs comparison 'a' part <= 'b' part. If both inequalities are satisfied,
function returns 1.

__device__ unsigned int __vsetleu2 (unsigned int a,
unsigned int b)
Performs per-halfword signed comparison.

Returns
Returns 1 if a <= b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For
corresponding parts function performs comparison 'a' part <= 'b' part. If both inequalities
are satisfied, function returns 1.

__device__ unsigned int __vsetleu4 (unsigned int a,
unsigned int b)
Performs per-byte unsigned comparison.

Returns
Returns 1 if a <= b, else returns 0.

Description
Splits 4 bytes of each argument into 4 part, each consisting of 1 byte. For corresponding
parts function performs comparison 'a' part <= 'b' part. If both inequalities are satisfied,
function returns 1.

__device__ unsigned int __vsetlts2 (unsigned int a,
unsigned int b)
Performs per-halfword signed comparison.

Returns
Returns 1 if a < b, else returns 0.
Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function performs comparison 'a' part <= 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetlt4 (unsigned int a, unsigned int b)
Performs per-byte signed comparison.

Returns
Returns 1 if a < b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function performs comparison 'a' part <= 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetltu2 (unsigned int a, unsigned int b)
Performs per-halfword unsigned comparison.

Returns
Returns 1 if a < b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function performs comparison 'a' part <= 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetltu4 (unsigned int a, unsigned int b)
Performs per-byte unsigned comparison.

Returns
Returns 1 if a < b, else returns 0.
Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function performs comparison 'a' part <= 'b' part. If both inequalities are satisfied, function returns 1.

__device__ unsigned int __vsetne2 (unsigned int a, unsigned int b)
Performs per-halfword (un)signed comparison.

Returns
Returns 1 if a != b, else returns 0.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts function performs comparison 'a' part != 'b' part. If both conditions are satisfied, function returns 1.

__device__ unsigned int __vsetne4 (unsigned int a, unsigned int b)
Performs per-byte (un)signed comparison.

Returns
Returns 1 if a != b, else returns 0.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts function performs comparison 'a' part != 'b' part. If both conditions are satisfied, function returns 1.

__device__ unsigned int __vsub2 (unsigned int a, unsigned int b)
Performs per-halfword (un)signed substraction, with wrap-around.

Returns
Returns computed value.
**Description**
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts functions performs substraction. Result is stored as unsigned int and returned.

```
__device__ unsigned int __vsub4 (unsigned int a, unsigned int b)
```
Performs per-byte substraction.

**Returns**
Returns computed value.

**Description**
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts functions performs substraction. Result is stored as unsigned int and returned.

```
__device__ unsigned int __vsubss2 (unsigned int a, unsigned int b)
```
Performs per-halfword (un)signed substraction, with signed saturation.

**Returns**
Returns computed value.

**Description**
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts functions performs substraction with signed saturation. Result is stored as unsigned int and returned.

```
__device__ unsigned int __vsubss4 (unsigned int a, unsigned int b)
```
Performs per-byte substraction with signed saturation.

**Returns**
Returns computed value.
Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts functions performs substraction with signed saturation. Result is stored as unsigned int and returned.

__device__ unsigned int __vsubus2 (unsigned int a, unsigned int b)
Performs per-halfword substraction with unsigned saturation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 2 parts, each consisting of 2 bytes. For corresponding parts functions performs substraction with unsigned saturation. Result is stored as unsigned int and returned.

__device__ unsigned int __vsubus4 (unsigned int a, unsigned int b)
Performs per-byte substraction with unsigned saturation.

Returns
Returns computed value.

Description
Splits 4 bytes of each argument into 4 parts, each consisting of 1 byte. For corresponding parts functions performs substraction with unsigned saturation. Result is stored as unsigned int and returned.
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