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This document describes CUFFT, the NVIDIA® CUDA™ Fast Fourier Transform (FFT) library. The FFT is a divide-and-conquer algorithm for efficiently computing discrete Fourier transforms of complex or real-valued data sets, and it is one of the most important and widely used numerical algorithms, with applications that include computational physics and general signal processing. The CUFFT library provides a simple interface for computing parallel FFTs on an NVIDIA GPU, which allows users to leverage the floating-point power and parallelism of the GPU without having to develop a custom, GPU-based FFT implementation.

FFT libraries typically vary in terms of supported transform sizes and data types. For example, some libraries only implement Radix-2 FFTs, restricting the transform size to a power of two, while other implementations support arbitrary transform sizes. This version of the CUFFT library supports the following features:

- 1D, 2D, and 3D transforms of complex and real-valued data
- Batch execution for doing multiple transforms of any dimension in parallel
- 2D and 3D transform sizes in the range $[2, 16384]$ in any dimension
- 1D transform sizes up to 8 million elements
- In-place and out-of-place transforms for real and complex data
- Double-precision transforms on compatible hardware (GT200 and later GPUs)
- Support for streamed execution, enabling simultaneous computation together with data movement
CUFFT Types and Definitions

The next sections describe the CUFFT types and transform directions:

- “Type cufftHandle” on page 2
- “Type cufftResult” on page 2
- “Type cufftReal” on page 3
- “Type cufftDoubleReal” on page 3
- “Type cufftComplex” on page 3
- “Type cufftDoubleComplex” on page 3
- “Type cufftCompatibility” on page 3
- “CUFFT Transform Types” on page 4
- “CUFFT Transform Directions” on page 5

Type cufftHandle

typedef unsigned int cufftHandle;

is a handle type used to store and access CUFFT plans (see “CUFFT API Functions” on page 7 for more information about plans). For example, the user receives a handle after creating a CUFFT plan and uses this handle to execute the plan.

Type cufftResult

typedef enum cufftResult_t cufftResult;

is an enumeration of values used exclusively as API function return values. The possible return values are defined as follows:

Return Values

<table>
<thead>
<tr>
<th>Return Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUFFT_SUCCESS</td>
<td>Any CUFFT operation is successful.</td>
</tr>
<tr>
<td>CUFFT_INVALID_PLAN</td>
<td>CUFFT is passed an invalid plan handle.</td>
</tr>
<tr>
<td>CUFFT_ALLOC_FAILED</td>
<td>CUFFT failed to allocate GPU memory.</td>
</tr>
<tr>
<td>CUFFT_INVALID_TYPE</td>
<td>The user requests an unsupported type.</td>
</tr>
<tr>
<td>CUFFT_INVALID_VALUE</td>
<td>The user specifies a bad memory pointer.</td>
</tr>
<tr>
<td>CUFFT_INTERNAL_ERROR</td>
<td>Used for all internal driver errors.</td>
</tr>
<tr>
<td>CUFFT_EXEC_FAILED</td>
<td>CUFFT failed to execute an FFT on the GPU.</td>
</tr>
</tbody>
</table>
Return Values (continued)

<table>
<thead>
<tr>
<th>Enum Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUFFT_SETUP_FAILED</td>
<td>The CUFFT library failed to initialize.</td>
</tr>
<tr>
<td>CUFFT_SHUTDOWN_FAILED</td>
<td>The CUFFT library failed to shut down.</td>
</tr>
<tr>
<td>CUFFT_INVALID_SIZE</td>
<td>The user specifies an unsupported FFT size.</td>
</tr>
</tbody>
</table>

Type cufftReal

typedef float cufftReal;

is a single-precision, floating-point real data type.

Type cufftDoubleReal

typedef double cufftDoubleReal;

is a double-precision, floating-point real data type.

Type cufftComplex

typedef cuComplex cufftComplex;

is a single-precision, floating-point complex data type that consists of interleaved real and imaginary components.

Type cufftDoubleComplex

typedef cuDoubleComplex cufftDoubleComplex;

is a double-precision, floating-point complex data type that consists of interleaved real and imaginary components.

Type cufftCompatibility

typedef enum cufftCompatibility_t cufftCompatibility;

is an enumeration of values used to control FFTW data compatibility. See “FFTW Compatibility Mode” on page 6 for details.
CUFFT Transform Types

The CUFFT library supports complex- and real-data transforms. The `cufftType` data type is an enumeration of the types of transform data supported by CUFFT:

```c
typedef enum cufftType_t {
    CUFFT_R2C = 0x2a,  // Real to complex (interleaved)
    CUFFT_C2R = 0x2c,  // Complex (interleaved) to real
    CUFFT_C2C = 0x29,  // Complex to complex, interleaved
    CUFFT_D2Z = 0x6a,  // Double to double-complex
    CUFFT_Z2D = 0x6c,  // Double-complex to double
    CUFFT_Z2Z = 0x69   // Double-complex to double-complex
} cufftType;
```

For complex FFTs, the input and output arrays must interleave the real and imaginary parts (the `cufftComplex` type). The transform size in each dimension is the number of `cufftComplex` elements. The `CUFFT_C2C` constant can be passed to any plan creation function to configure a single-precision complex-to-complex FFT. Pass the `CUFFT_Z2Z` constant to configure a double-precision complex-to-complex FFT.

For real-to-complex FFTs, the output array holds only the non-redundant complex coefficients. So for an N-element transform, the output array holds \( N/2+1 \) `cufftComplex` terms. For higher-dimensional real transforms of the form \( N_0 \times N_1 \times \ldots \times N_n \), the last dimension is cut in half such that the output data is \( N_0 \times N_1 \times \ldots \times (N_n/2+1) \) complex elements. Therefore, in order to perform an in-place FFT, the user has to pad the input array in the last dimension to \( (N_n/2+1) \) complex elements or \( 2 \times (N/2+1) \) real elements. Note that the real-to-complex transform is implicitly forward. Passing the `CUFFT_R2C` constant to any plan creation function configures a single-precision real-to-complex FFT. Passing the `CUFFT_D2Z` constant configures a double-precision real-to-complex FFT.

The requirements for complex-to-real FFTs are similar to those for real-to-complex. In this case, the input array holds only the non-redundant, \( N/2+1 \) complex coefficients from a real-to-complex transform. The output is simply \( N \) elements of type `cufftReal`. However, for an in-place transform, the input size must be padded to \( 2 \times (N/2+1) \) real
elements. The complex-to-real transform is implicitly inverse. Passing the CUFFT_C2R constant to any plan creation function configures a single-precision complex-to-real FFT. Passing CUFFT_Z2D constant configures a double-precision complex-to-real FFT.

For 1D complex-to-complex transforms, the stride between signals in a batch is assumed to be the number of cufftComplex elements in the logical transform size. However, for real-data FFTs, the distance between signals in a batch depends on whether the transform is in-place or out-of-place. For in-place FFTs, the input stride is assumed to be \(2 \times (N/2+1)\) cufftReal elements or \(N/2+1\) cufftComplex elements. For out-of-place transforms, input and output strides match the logical transform size \(N\) and the non-redundant size \((N/2+1)\), respectively.

Starting with CUFFT version 3.0, batched transforms are supported through the cufftPlanMany() function. Although this function takes input parameters that specify input- and output-data strides, in version 3.0 data for each signal within the batch is assumed to immediately follow that of the previous one (a stride of 1).

### CUFFT Transform Directions

The CUFFT library defines forward and inverse Fast Fourier Transforms according to the sign of the complex exponential term:

```c
#define CUFFT_FORWARD -1
#define CUFFT_INVERSE  1
```

For higher-dimensional transforms (2D and 3D), CUFFT performs FFTs in row-major or C order. For example, if the user requests a 3D transform plan for sizes X, Y, and Z, CUFFT transforms along Z, Y, and then X. The user can configure column-major FFTs by simply changing the order of the size parameters to the plan creation API functions.

CUFFT performs un-normalized FFTs; that is, performing a forward FFT on an input data set followed by an inverse FFT on the resulting set yields data that is equal to the input scaled by the number of elements. Scaling either transform by the reciprocal of the size of the data set is left for the user to perform as seen fit.
Streamed CUFFT Transforms

Execution of a transform of a particular size and type may take several stages of processing. A plan for the transform is generated, in which CUFFT specifies the internal steps that need to be taken. These steps may include multiple kernel launches, memory copies, and so on.

Every CUFFT plan may be associated with a CUDA stream. Once so associated, all launches of the internal stages of that plan take place through the specified stream. Streaming of launches allows for potential overlap between transforms and memory copies—see the NVIDIA CUDA Programming Guide for more information on streams. If no stream is associated with a plan, launches take place in stream 0 (the default CUDA stream).

FFTW Compatibility Mode

For some transform sizes, FFTW requires additional padding bytes between rows and planes of Real2Complex (R2C) and Complex2Real (C2R) transforms of rank greater than 1. (For details, please refer to the FFTW online documentation at http://www.fftw.org.)

To speed up R2C and C2R transforms for power-of-2 sizes similar to their Complex2Complex (C2C) equivalent, one can disable FFTW-compatible layout using cufftSetCompatibilityMode(), introduced in release 3.1 and described on page 17. When native mode is selected for this function, power-of-2 transform sizes will be compact and CUFFT will not use padding. Non-power-of-2 sizes will continue to use the same padding layout as FFTW.

The FFTW compatibility modes are as follows:

\begin{verbatim}
CUFFT_COMPATIBILITY_NATIVE
CUFFT_COMPATIBILITY_FFTW_PADDING
CUFFT_COMPATIBILITY_FFTWASYMMETRIC
CUFFT_COMPATIBILITY_FFTW_ALL
\end{verbatim}

CUFFT_COMPATIBILITY_NATIVE mode disables FFTW compatibility, but achieves the highest performance.

CUFFT_COMPATIBILITY_FFTW_PADDING supports FFTW data padding by inserting extra padding between packed in-place transforms for batched transforms with power-of-2 size.
CUFFT_COMPATIBILITY_FFTW_ASYMMETRIC waives the C2R symmetry requirement. Once set, it guarantees FFTW-compatible output for non-symmetric complex inputs for transforms with power-of-2 size. This is only useful for artificial (that is, random) data sets as actual data will always be symmetric if it has come from the real plane. Enabling this mode can significantly impact performance.

CUFFT_COMPATIBILITY_FFTW_ALL enables full FFTW compatibility. Refer to the FFTW documentation (http://www.fftw.org) for FFTW data layout specifications.

**CUFFT API Functions**

The CUFFT API is modeled after FFTW, which is one of the most popular and efficient CPU-based FFT libraries. FFTW provides a simple configuration mechanism called a plan that completely specifies the optimal—that is, the minimum floating-point operation (flop)—plan of execution for a particular FFT size and data type. The advantage of this approach is that once the user creates a plan, the library stores whatever state is needed to execute the plan multiple times without recalculation of the configuration. The FFTW model works well for CUFFT because different kinds of FFTs require different thread configurations and GPU resources, and plans are a simple way to store and reuse configurations.

The CUFFT library initializes internal data upon the first invocation of an API function. Therefore, all API functions could return the CUFFT_SETUP_FAILED error code if the library fails to initialize. CUFFT shuts down automatically when all user-created FFT plans are destroyed. The CUFFT functions are as follows:

- “Function cufftPlan1d()” on page 8
- “Function cufftPlan2d()” on page 9
- “Function cufftPlan3d()” on page 9
- “Function cufftPlanMany()” on page 10
- “Function cufftDestroy()” on page 11
- “Function cufftExecC2C()” on page 12
- “Function cufftExecR2C()” on page 12
Function cufftPlan1d()

cufftResult

cufftPlan1d( cufftHandle *plan, int nx, cufftType type,
               int batch );

creates a 1D FFT plan configuration for a specified signal size and data type. The batch input parameter tells CUFFT how many 1D transforms to configure.

Input

| plan    | Pointer to a cufftHandle object |
| nx      | The transform size (e.g., 256 for a 256-point FFT) |
| type    | The transform data type (e.g., CUFFT_C2C for complex to complex) |
| batch   | Number of transforms of size nx |

Output

| plan    | Contains a CUFFT 1D plan handle value |

Return Values

| CUFFT_SETUP_FAILED | CUFFT library failed to initialize. |
| CUFFT_INVALID_SIZE | The nx parameter is not a supported size. |
| CUFFT_INVALID_TYPE | The type parameter is not supported. |
| CUFFT_ALLOC_FAILED | Allocation of GPU resources for the plan failed. |
| CUFFT_SUCCESS     | CUFFT successfully created the FFT plan. |
Function cufftPlan2d()

cufftResult
cufftPlan2d( cufftHandle *plan, int nx, int ny,
cufftType type );

creates a 2D FFT plan configuration according to specified signal sizes and data type. This function is the same as cufftPlan1d() except that it takes a second size parameter, ny, and does not support batching.

Input

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>plan</td>
<td>Pointer to a cufftHandle object</td>
</tr>
<tr>
<td>nx</td>
<td>The transform size in the X dimension (number of rows)</td>
</tr>
<tr>
<td>ny</td>
<td>The transform size in the Y dimension (number of columns)</td>
</tr>
<tr>
<td>type</td>
<td>The transform data type (e.g., CUFFT_C2R for complex to real)</td>
</tr>
</tbody>
</table>

Output

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>plan</td>
<td>Contains a CUFFT 2D plan handle value</td>
</tr>
</tbody>
</table>

Return Values

- **CUFFT_SETUP_FAILED**: CUFFT library failed to initialize.
- **CUFFT_INVALID_SIZE**: The nx or ny parameter is not a supported size.
- **CUFFT_INVALID_TYPE**: The type parameter is not supported.
- **CUFFT_ALLOC_FAILED**: Allocation of GPU resources for the plan failed.
- **CUFFT_SUCCESS**: CUFFT successfully created the FFT plan.

Function cufftPlan3d()

cufftResult
cufftPlan3d( cufftHandle *plan, int nx, int ny, int nz,
cufftType type );

creates a 3D FFT plan configuration according to specified signal sizes and data type. This function is the same as cufftPlan2d() except that it takes a third size parameter nz.

Input

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>plan</td>
<td>Pointer to a cufftHandle object</td>
</tr>
<tr>
<td>nx</td>
<td>The transform size in the X dimension</td>
</tr>
<tr>
<td>ny</td>
<td>The transform size in the Y dimension</td>
</tr>
<tr>
<td>nz</td>
<td>The transform size in the Z dimension</td>
</tr>
</tbody>
</table>
Function cufftPlanMany()

cufftResult

cufftPlanMany( cufftHandle *plan, int rank, int *n,
    int *inembed, int istride, int idist,
    int *onembed, int ostride, int odist,
    cufftType type, int batch );

creates a FFT plan configuration of dimension rank, with sizes specified in the array n. The batch input parameter tells CUFFT how many transforms to configure in parallel. With this function, batched plans of any dimension may be created.

Input parameters inembed, istride, and idist and output parameters onembed, ostride, and odist will allow setup of non-contiguous input data in a future version. Note that for CUFFT 3.0, these parameters are ignored and the layout of batched data must be side-by-side and not interleaved.

Input

plan Pointer to a cufftHandle object
rank Dimensionality of the transform (1, 2, or 3)
n An array of size rank, describing the size of each dimension
inembed Unused: pass NULL
istride Unused: pass 1
Function `cufftDestroy()`

```c
result = cufftDestroy( cufftHandle plan );
```

frees all GPU resources associated with a CUFFT plan and destroys the internal plan data structure. This function should be called once a plan is no longer needed to avoid wasting GPU memory.

**Input**
- `plan`  
  The `cufftHandle` object of the plan to be destroyed.

**Return Values**
- `CUFFT_SUCCESS`: CUFFT successfully destroyed the FFT plan.
- `CUFFT_SETUP_FAILED`: CUFFT library failed to initialize.
- `CUFFT_SHUTDOWN_FAILED`: CUFFT library failed to shut down.
- `CUFFT_INVALID_PLAN`: The `plan` parameter is not a valid handle.
Function cufftExecC2C()

cufftResult
cufftExecC2C( cufftHandle plan, cufftComplex *idata,
cuftComplex *odata, int direction );

executes a CUFFT single-precision complex-to-complex transform plan as specified by direction. CUFFT uses as input data the GPU memory pointed to by the idata parameter. This function stores the Fourier coefficients in the odata array. If idata and odata are the same, this method does an in-place transform.

Input

| plan | The cufftHandle object for the plan to update |
| idata | Pointer to the single-precision complex input data (in GPU memory) to transform |
| odata | Pointer to the single-precision complex output data (in GPU memory) |
| direction | The transform direction: CUFFT_FORWARD or CUFFT_INVERSE |

Output

| odata | Contains the complex Fourier coefficients |

Return Values

| CUFFT_SETUP_FAILED | CUFFT library failed to initialize. |
| CUFFT_INVALID_PLAN | The plan parameter is not a valid handle. |
| CUFFT_INVALID_VALUE | The idata, odata, and/or direction parameter is not valid. |
| CUFFT_EXEC_FAILED | CUFFT failed to execute the transform on GPU. |
| CUFFT_SUCCESS | CUFFT successfully executed the FFT plan. |

Function cufftExecR2C()

cufftResult
cufftExecR2C( cufftHandle plan, cufftReal *idata,
cuftComplex *odata );

executes a CUFFT single-precision real-to-complex (implicitly forward) transform plan. CUFFT uses as input data the GPU memory pointed to by the idata parameter. This function stores the non-redundant Fourier coefficients in the odata array. If idata and odata
are the same, this method does an in-place transform (See “CUFFT Transform Types” on page 4 for details on real data FFTs.)

Input

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>plan</td>
<td>The cufftHandle object for the plan to update</td>
</tr>
<tr>
<td>idata</td>
<td>Pointer to the single-precision real input data (in GPU memory) to transform</td>
</tr>
<tr>
<td>odata</td>
<td>Pointer to the single-precision complex output data (in GPU memory)</td>
</tr>
</tbody>
</table>

Output

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>odata</td>
<td>Contains the complex Fourier coefficients</td>
</tr>
</tbody>
</table>

Return Values

- **CUFFT_SETUP_FAILED**: CUFFT library failed to initialize.
- **CUFFT_INVALID_PLAN**: The plan parameter is not a valid handle.
- **CUFFT_INVALID_VALUE**: The idata and/or odata parameter is not valid.
- **CUFFT_EXEC_FAILED**: CUFFT failed to execute the transform on GPU.
- **CUFFT_SUCCESS**: CUFFT successfully executed the FFT plan.

Function `cufftExecC2R()`

```c
    cufftResult
    cufftExecC2R( cufftHandle plan, cufftComplex *idata,
                   cufftReal *odata );
```

executes a CUFFT single-precision complex-to-real (implicitly inverse) transform plan. CUFFT uses as input data the GPU memory pointed to by the idata parameter. The input array holds only the non-redundant complex Fourier coefficients. This function stores the real output values in the odata array. If idata and odata are the same, this method does an in-place transform. (See “CUFFT Transform Types” on page 4 for details on real data FFTs.)

Input

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>plan</td>
<td>The cufftHandle object for the plan to update</td>
</tr>
<tr>
<td>idata</td>
<td>Pointer to the single-precision complex input data (in GPU memory) to transform</td>
</tr>
<tr>
<td>odata</td>
<td>Pointer to the single-precision real output data (in GPU memory)</td>
</tr>
</tbody>
</table>
Function `cufftExecZ2Z()`

```
cuftResult cufftExecZ2Z( cufftHandle plan, 
    cufftDoubleComplex *idata, 
    cufftDoubleComplex *odata, int direction );
```

executes a CUFFT double-precision complex-to-complex transform plan as specified by direction. CUFFT uses as input data the GPU memory pointed to by the idata parameter. This function stores the Fourier coefficients in the odata array. If idata and odata are the same, this method does an in-place transform.

**Input**
- **plan** The cufftHandle object for the plan to update
- **idata** Pointer to the double-precision complex input data (in GPU memory) to transform
- **odata** Pointer to the double-precision complex output data (in GPU memory)
- **direction** The transform direction: `CUFFT_FORWARD` or `CUFFT_INVERSE`

**Output**
- **odata** Contains the complex Fourier coefficients

**Return Values**
- **CUFFT_SETUP_FAILED** CUFFT library failed to initialize.
- **CUFFT_INVALID_PLAN** The plan parameter is not a valid handle.
- **CUFFT_INVALID_VALUE** The idata and/or odata parameter is not valid.
- **CUFFT_EXEC_FAILED** CUFFT failed to execute the transform on GPU.
- **CUFFT_SUCCESS** CUFFT successfully executed the FFT plan.
Function cufftExecD2Z()

cufftResult cufftExecD2Z( cufftHandle plan, cufftDoubleReal *idata, cufftDoubleComplex *odata );

executes a CUFFT double-precision real-to-complex (implicitly forward) transform plan. CUFFT uses as input data the GPU memory pointed to by the idata parameter. This function stores the non-redundant Fourier coefficients in the odata array. If idata and odata are the same, this method does an in-place transform (See “CUFFT Transform Types” on page 4 for details on real data FFTs.)

Input

<table>
<thead>
<tr>
<th>plan</th>
<th>The cufftHandle object for the plan to update</th>
</tr>
</thead>
<tbody>
<tr>
<td>idata</td>
<td>Pointer to the double-precision real input data (in GPU memory) to transform</td>
</tr>
<tr>
<td>odata</td>
<td>Pointer to the double-precision complex output data (in GPU memory)</td>
</tr>
</tbody>
</table>

Output

| odata | Contains the complex Fourier coefficients |

Return Values (continued)

| cufftSetupFailed | CUFFT library failed to initialize. |
| cufftInvalidPlan | The plan parameter is not a valid handle. |
| cufftInvalidValue | The idata and/or odata parameter is not valid. |
| cufftExecFailed  | CUFFT failed to execute the transform on GPU. |
| cufftSuccess     | CUFFT successfully executed the FFT plan. |
Function cufftExecZ2D()

cufftResult

cufftExecZ2D( cufftHandle plan,
             cufftDoubleComplex *idata,
             cufftDoubleReal *odata );

executes a CUFFT double-precision complex-to-real (implicitly inverse) transform plan. CUFFT uses as input data the GPU memory pointed to by the idata parameter. The input array holds only the non-redundant complex Fourier coefficients. This function stores the real output values in the odata array. If idata and odata are the same, this method does an in-place transform. (See “CUFFT Transform Types” on page 4 for details on real data FFTs.)

Input

| plan   | The cufftHandle object for the plan to update |
| idata  | Pointer to the double-precision complex input data (in GPU memory) to transform |
| odata  | Pointer to the double-precision real output data (in GPU memory) |

Output

| odata | Contains the real-valued output data |

Return Values

| CUFFT_SETUP_FAILED       | CUFFT library failed to initialize. |
| CUFFT_INVALID_PLAN       | The plan parameter is not a valid handle. |
| CUFFT_INVALID_VALUE      | The idata and/or odata parameter is not valid. |
| CUFFT_EXEC_FAILED        | CUFFT failed to execute the transform on GPU. |
| CUFFT_SUCCESS            | CUFFT successfully executed the FFT plan. |

Function cufftSetStream()

cufftResult

cufftSetStream( cufftHandle plan, cudaStream_t stream );

associates a CUDA stream with a CUFFT plan. All kernel launches made during plan execution are now done through the associated stream, enabling overlap with activity in other streams (for example,
data copying). The association remains until the plan is destroyed or
the stream is changed with another call to cufftSetStream().

Input

| plan      | The cufftHandle object to associate with the stream |
| stream    | A valid CUDA stream created with cudaStreamCreate() (or 0 for the default stream) |

Output

| odata     | Contains the real-valued output data |

Return Values

| CUFFT_INVALID_PLAN | The plan parameter is not a valid handle. |
| CUFFT_SUCCESS      | The stream was associated with the plan. |

Function cufftSetCompatibilityMode()

cufttResult

cufttSetCompatibilityMode( cufftHandle plan,
                           cufftCompatibility mode );

configures the layout of CUFFT output in FFTW-compatible modes. When FFTW compatibility is desired, it can be configured for padding only, for asymmetric complex inputs only, or to be fully compatible.

Input

| plan      | The cufftHandle object to associate with the stream |
| mode      | The cufftCompatibility option to be used: |

CUFFT_COMPATIBILITY_NATIVE: Disable any FFTW compatibility mode.
CUFFT_COMPATIBILITY_FFTW_PADDING: Support FFTW data padding (Default)
CUFFT_COMPATIBILITY_FFTWASYMMETRIC: Waive the C2R symmetry requirement.
Should be used with asymmetric input.
CUFFT_COMPATIBILITY_FFTW_ALL: Enable full FFTW compatibility.

Return Values

| CUFFT_SETUP_FAILED | CUFFT library failed to initialize. |
| CUFFT_INVALID_PLAN | The plan parameter is not a valid handle. |
| CUFFT_SUCCESS      | CUFFT successfully executed the FFT plan. |
Accuracy and Performance

The CUFFT library implements several FFT algorithms, each having different performance and accuracy. The best performance paths correspond to transform sizes that meet two criteria:

- Fit in CUDA’s shared memory
- Are powers of a single factor (for example, powers of two)

These transforms are also the most accurate due to the numeric stability of the chosen FFT algorithm. For transform sizes that meet the first criterion but not second, CUFFT uses a more general mixed-radix FFT algorithm that is usually slower and less numerically accurate. Therefore, if possible it is best to use sizes that are powers of two or four, or powers of other small primes (such as, three, five, or seven). In addition, the power-of-two FFT algorithm in CUFFT makes maximum use of shared memory by blocking sub-transforms for signals that do not meet the first criterion.

For transform sizes that do not meet either criteria above, CUFFT uses an out-of-place, mixed-radix algorithm that stores all intermediate results in CUDA’s global GPU memory. Although this algorithm uses optimized transform modules for many factors, it has generally lower performance because global memory has less bandwidth than shared memory. The one exception is large 1D transforms, where CUFFT uses a distributed algorithm that performs a 1D FFT using a 2D FFT, where the dimensions of the 2D transform are factors of the 1D size. This path attempts to utilize the faster transforms mentioned above even if the signal size is too large to fit in CUDA’s shared memory.

Many FFT algorithms for real data exploit the conjugate symmetry property to reduce computation and memory cost by roughly half. However, CUFFT does not implement any specialized algorithms for real data, and so there is no direct performance benefit to using real-to-complex (or complex-to-real) plans instead of complex-to-complex. For this release, the real data API exists primarily for convenience, so that users do not have to build interleaved complex data from a real data source before using the library. For 1D transforms, the performance for real data will either match or be less than the complex equivalent (due to an extra copy in some cases). However, there is
usually a performance benefit to using real data for 2D and 3D FFTs, since all transforms but the last dimension operate on roughly half the logical signal size.

## CUFFT Code Examples

This section provides six simple examples of 1D, 2D, and 3D complex and real data transforms that use the CUFFT to perform forward and inverse FFTs.

### 1D Complex-to-Complex Transforms

```c
#define NX 256
#define BATCH 10

cufftHandle plan;
cufftComplex *data;
cudaMalloc((void**)&data, sizeof(cufftComplex)*NX*BATCH);

/* Create a 1D FFT plan. */
cufftPlan1d(&plan, NX, CUFFT_C2C, BATCH);

/* Use the CUFFT plan to transform the signal in place. */
cufftExecC2C(plan, data, data, CUFFT_FORWARD);

/* Inverse transform the signal in place. */
cufftExecC2C(plan, data, data, CUFFT_INVERSE);

/* Note:
(1) Divide by number of elements in data set to get back original data
(2) Identical pointers to input and output arrays implies in-place transformation
*/

/* Destroy the CUFFT plan. */
cufftDestroy(plan);
cudaFree(data);
```
1D Real-to-Complex Transforms

#define NX 256
#define BATCH 10

cufftHandle plan;
cufftComplex *data;
cudaMalloc((void**)&data, sizeof(cufftComplex)*(NX/2+1)*BATCH);

/* Create a 1D FFT plan. */
cufftPlan1d(&plan, NX, CUFFT_R2C, BATCH);

/* Use the CUFFT plan to transform the signal in place. */
cufftExecR2C(plan, (cufftReal*)data, data);

/* Destroy the CUFFT plan. */
cufftDestroy(plan);
cudaFree(data);
2D Complex-to-Complex Transforms

#define NX 256
#define NY 128

cufftHandle plan;
cufftComplex *idata, *odata;
cudaMalloc((void**)&idata, sizeof(cufftComplex)*NX*NY);
cudaMalloc((void**)&odata, sizeof(cufftComplex)*NX*NY);

/* Create a 2D FFT plan. */
cufftPlan2d(&plan, NX, NY, CUFFT_C2C);

/* Use the CUFFT plan to transform the signal out of place. */
cufftExecC2C(plan, idata, odata, CUFFT_FORWARD);

/* Note: idata != odata indicates an out-of-place transformation
   to CUFFT at execution time. */
/* Inverse transform the signal in place */
cufftExecC2C(plan, odata, odata, CUFFT_INVERSE);

/* Destroy the CUFFT plan. */
cufftDestroy(plan);
cudaFree(idata); cudaFree(odata);
Batched 2D Complex-to-Complex Transforms

```
#define NX 128
#define NY 256
#define BATCHSIZE 1000

int datalen;
cufftHandle plan;
cufftComplex *indata, *outdata;

datalen = NX * NY * BATCHSIZE;
cudaMalloc((void **)&indata, sizeof(cufftComplex)*datalen);
cudaMalloc((void **)&outdata, sizeof(cufftComplex)*datalen);

/* Create a batched 2D plan */
cufftPlanMany(plan, {NX, NY}, NULL, 1, 0, NULL, 1, 0, CUFFT_C2C, BATCHSIZE);

/* Execute the transform out-of-place */
cufftExecC2C(plan, indata, outdata, CUFFT_FORWARD);

/* Destroy the CUFFT plan */
cufftDestroy(plan);
cudaFree(indata);
cudaFree(outdata);
```
2D Complex-to-Real Transforms

#define NX 256
#define NY 128

cufftHandle plan;
cufftComplex *idata;
cufftReal *odata;
cudaMalloc((void**)&idata, sizeof(cufftComplex)*NX*NY);
cudaMalloc((void**)&odata, sizeof(cufftReal)*NX*NY);

  /* Create a 2D FFT plan. */  
cufftPlan2d(&plan, NX, NY, CUFFT_C2R);

  /* Use the CUFFT plan to transform the signal out of place. */  
cufftExecC2R(plan, idata, odata);

  /* Destroy the CUFFT plan. */  
cufftDestroy(plan);
  cudaFree(idata); cudaFree(odata);
3D Complex-to-Complex Transforms

#define NX 64
#define NY 64
#define NZ 128

cufftHandle plan;
cufftComplex *data1, *data2;
cudaMalloc((void**)&data1, sizeof(cufftComplex)*NX*NY*NZ);
cudaMalloc((void**)&data2, sizeof(cufftComplex)*NX*NY*NZ);

/* Create a 3D FFT plan. */
cufftPlan3d(&plan, NX, NY, NZ, CUFFT_C2C);

/* Transform the first signal in place. */
cufftExecC2C(plan, data1, data1, CUFFT_FORWARD);

/* Transform the second signal using the same plan. */
cufftExecC2C(plan, data2, data2, CUFFT_FORWARD);

/* Destroy the CUFFT plan. */
cufftDestroy(plan);
cudaFree(data1); cudaFree(data2);