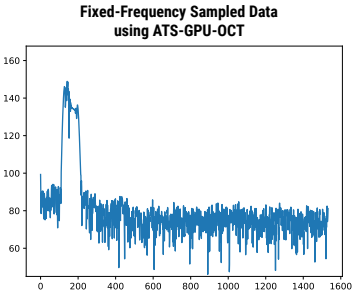
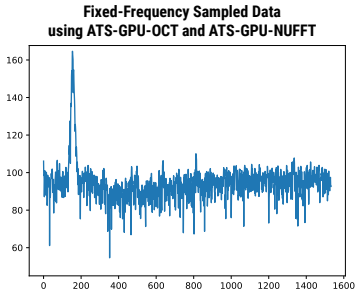
ATS-GPU-NUFFT

OCT Signal Processing Library Extension for Fixed-Frequency Sampled Data

- Very high-speed floating-point FFT on data that is uniformly sampled in time
- Dispersion compensation and windowing functions
- Requires ATS-GPU-BASE and ATS-GPU-OCT
- Transfer A/D data to GPU at high speed
- Up to 22 GB/s transfer rate for PCIe Gen 4 digitizer boards
- Supports CUDA®-enabled GPUs with compute capability 3.0 to 8.9‡
- Designed to work with AlazarTech® PCI Express waveform digitizers
- Compatible with Windows® & Linux®





Product	GPU Compatibility	Operating System	Throughput to GPU	FFT Length	Max. FFTs Per Second
ATS-GPU-NUFFT version 4.2	CUDA compute capability 3.0 to 8.9‡	64-bit Windows & 64-bit Linux	Up to 22 GB/s	Up to 8 M Points	1,200,000 (2048-pt FFTs, see benchmark table below for more details)

Overview

AlazarTech's ATS-GPU-NUFFT is an extension for the ATS-GPU-OCT Signal Processing Library that provides very high-speed floating-point FFT capability for fixed-frequency sampling of data acquired by AlazarTech's PCI Express waveform digitizers. ATS-GPU-NUFFT‡ must be used with ATS-GPU-BASE and ATS-GPU-OCT.

Interfacing waveform digitizers to Graphical Processing Units (GPUs) involves creating a software mechanism to move data from one to the other and back to user buffers. The standard techniques used most often can get the job done, but feature very low data throughput due to software overheads.

AlazarTech designed ATS-GPU-BASE so this software bottleneck is eliminated and data can be moved from AlazarTech PCIe digitizers to CUDA-enabled GPUs and from GPUs to user buffers at full PCIe bus speeds.

Once the data is available in GPU memory, many types of digital signal processing (DSP) can be done on this data at near-hardware speeds.

ATS-GPU-OCT contains floating-point FFT routines that have been optimized to provide the maximum number of FFTs per second. Kernel code running on the GPU can apply a windowing function, do a floating-point FFT, calculate the amplitude and convert the result to a log scale. It is also possible to output phase information.

ATS-GPU-NUFFT is an extension of ATS-GPU-OCT that allows non-uniform FFTs to be performed on data acquired uniformly in time domain using a fixed sampling rate. For SS-OCTs where the wavelength does not vary linearly in time, a fixed sampling rate results in data that is non-uniformly distributed in frequency domain. ATS-GPU-NUFFT allows linearized FFTs to be performed on such data. The non-uniform FFT requires a linearization function that describes how the wavelength of the SS-laser evolves during a sweep of the spectrum. Linearization function can either be user defined or measured directly from a k-clock signal.

Latency

ATS-GPU-BASE uses multiple CUDA streams to move data between the digitizer and GPU. This means there is a latency between data being acquired by the digitizer board and GPU receiving this data. The exact latency is determined by the buffer size used as well as the transfer rate of the PCIe link, but typical values are in the range of several milliseconds.

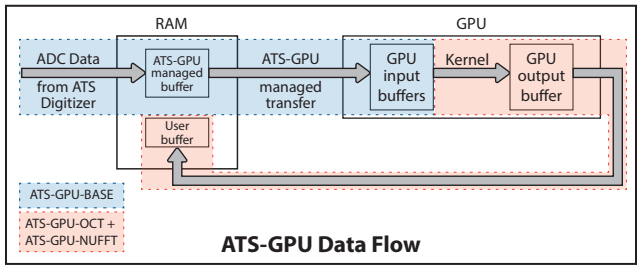
Benchmarks

An AlazarTech ATS®9373 in an Intel i9-7900X 10-Core @ 3.3 GHz system with an ASUS® x299 motherboard, 32 GB DDR4, and NVIDIA® GeForce® RTX 2080 Ti GPU had the following benchmarks for GPU buffer size of 8 MB:

Linearization	FFT Length	FFTs per second
Preset linearization	2048	1,200,000
	4096	600,000
	8192	245,000
	16384	125,000
k-clock linearization	2048	830,000
	4096	410,000
	8192	170,000
	16384	74,000

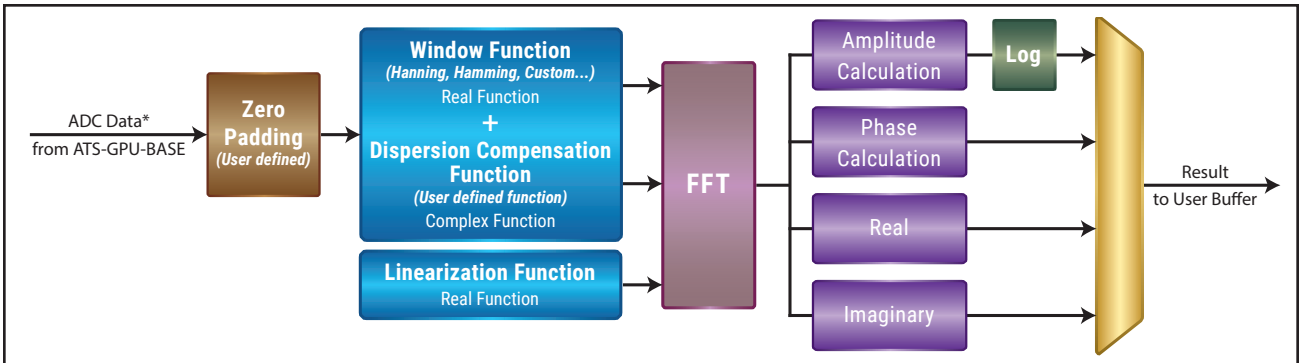
Tests in an Intel i7 5930k 6-core @ 3.5 GHz system with an ASUS x99 Deluxe motherboard, 64 GB DDR4, and the same NVIDIA GeForce RTX 2080 Ti GPU produced very similar results. Tests using different GPU buffer sizes also yielded very similar results.

ATS-GPU Data Flow



ATS-GPU-NUFFT

OCT Signal Processing Library Extension for Fixed-Frequency Sampled Data



ATS-GPU-NUFFT OCT Signal Processing Block Diagram

*Data can come from multiple channels

ATS-GPU-BASE is supplied with an example user application in source code. The application includes GPU kernels that use ATS-GPU-BASE to receive data, do very simple signal processing (data inversion), and copy the processed (inverted) data back to a user buffer. All this is done at the highest possible data transfer rate.

ATS-GPU-NUFFT is supplied with example programs in C/C++, Python, LabVIEW, and MATLAB that allows users to set-up the waveform digitizer parameters, set-up FFT parameters in the GPU, do the acquisition, and receive the FFT result buffer.

Modular API

ATS-GPU-NUFFT has a unique, modular API that allows users to easily customize their signal processing algorithms. The modularity provides many hooks into the GPU data path, where customers can add their own signal processing code.

ATS-GPU and CUDA Runtime Library

ATS-GPU is shipped with a specific version of CUDA runtime library and links statically to it.

Programmers are allowed to use a different version of CUDA runtime library for their custom kernel code. NVIDIA guarantees that the two versions of CUDA runtime libraries will be interoperable.

Note: ATS-GPU only supports Windows versions and Linux distributions that are supported by NVIDIA's CUDA Toolkit. 32-bit operating system support is also similarly limited by NVIDIA. In particular, the ATS-GPU-NUFFT cannot be built as a 32-bit library. We currently use CUDA toolkit 10.2, older versions are untested.

Programming with ATS-GPU-NUFFT

C/C++ example programs are provided with CMake build files. Python code is tested under Python 2.7 and 3.6. 64-bit LabVIEW 2017 or newer is necessary to use LabVIEW example code (LabVIEW NXG is not supported). MATLAB code is developed under MATLAB 2017A, but is expected to work with most 64-bit MATLAB versions.

Waveform digitizer data is transferred to the GPU in a buffer that will contain many records. This number, RecordsPerBuffer, is specified by the user.

CH A †Raw Data (U16)					CH B †Raw Data (U16)					CH B Resampled Data (Float)					‡FFT Output 1 (Float)					...	‡FFT Output n-1 (Float)				
R0	R1	R2	...	Rn-1	R0	R1	R2	...	Rn-1	R0	R1	R2	...	Rn-1	R0	R1	R2	...	Rn-1	...	R0	R1	R2	...	Rn-1

Rn represents n[th] record in the buffer
† Raw data is always provided as unsigned 16-bit integer
‡ FFT output types are dependent upon the parameters passed to ATS_GPU_NUFFT_Setup
Raw data and resample outputs are optional (set by parameter)

Users should make sure that they choose this number such that the buffer size is in the order of 1 to 16 Megabytes. Smaller buffers can reduce overall data throughput.

ATS-GPU-NUFFT can be used to perform zero-padding, if required, and it will apply a complex windowing function to each record. Given a linearization function, it will then do a single-precision floating-point non-uniform FFT, calculate the amplitude and phase, and convert the amplitude to logarithmic values.

Zero Padding

If the number of samples per record (A-scan) is not a power of 2, the user should perform zero-padding before doing further signal processing. Although users can zero pad A-scans to any given length, for performance reasons, we recommend zero-padding A-lines to the next power of two. Code samples to do this zero padding is provided.

Dispersion Compensation Function

Dispersion compensation is an essential part of any OCT signal processing system. The ATS-GPU-NUFFT library extension allows users to multiply the zero-padded data with a user-specified Dispersion Compensation Function (DCF). The DCF is a complex function.

Windowing Function

The windowing function in the ATS-GPU-NUFFT library extension is used to ensure that there are no discontinuities in the FFT. Note that the length of the window function should be the same as the length of the A-Scan, e.g. if the A-scan is 1536 points long, the window function should also be 1536 points long, even though the FFT length will be 2048.

Linearization Function

To perform non-uniform FFT, the ATS-GPU-NUFFT library extension requires a linearization function that describes how the wavelength of the laser changes during a sweep of the laser. Users can choose to determine the linearization function in real-time from a valid k-clock signal. In this case, a linearization function will be measured for every acquired record. On the other hand, users can preset a linearization function before the start of an acquisition. In this case, the same linearization function will be used for all incoming records.

Amplitude and Phase Output

The FFT algorithm implemented in the ATS-GPU-NUFFT library extension is capable of calculating both amplitude and phase outputs. All outputs are provided as single-precision floating-point data (32 bits per data point).

Compatible Waveform Digitizers

All AlazarTech PCI Express and Thunderbolt 3 waveform digitizers are compatible with ATS-GPU. Only single-board configurations are supported at this time.

AlazarTech's PCI bus waveform digitizers are not supported, as the host CPU is more than capable of handling data rates generated by PCI bus boards.

ATS-GPU cannot directly be interfaced with non-AlazarTech waveform digitizers.

User-Supplied Data

For validation purposes, user-supplied data can be used when an AlazarTech PCIe digitizer is installed in the system. This data path has significant performance penalties and should only be used for validation purposes.

Data Throughput to GPU

The data transfer rate to GPU is dependent on the generation of PCI Express digitizer board used or Thunderbolt 3 system configuration:

PCIe Link Speed		Transfer Rate
Gen 4 x16:	ATS9376, ATS9470, ATS9473	Up to 22 GB/s
Gen 3 x8:	ATS9373, ATS9371, ATS9637, ATS9437	Up to 6.9 GB/s
Gen 2 x8:	ATS9360, ATS9416	Up to 3.5 GB/s
Gen 3 x4:	ATS9364, ATS9362	Up to 3 GB/s
Thunderbolt 3:	ATST364	Up to 2.6 GB/s
Gen 2 x4: Gen 1 x8: Thunderbolt 3:	ATS9872, ATS9352, ATS9353, ATS9628, ATS9428 ATS9870, ATS9350, ATS9351, ATS9625, ATS9626, ATS9440 ATST352, ATST872	Up to 1.6 GB/s
Gen 1 x4:	ATS9462	Up to 720 MB/s
Gen 1 x1: Thunderbolt 3:	ATS9146, ATS9182, ATS9130, ATS9120 ATST146	Up to 200 MB/s

Electronic Delivery

As of June 2020, AlazarTech software products are only available as a digital download. Customers who purchase ATS-GPU-NUFFT must provide a valid email address to receive their serial number, download link, and required license key.

Software Licensing Policy

Users are allowed to freely distribute the ATS-GPU-NUFFT library extension as long as there is an AlazarTech PCI Express waveform digitizer present in the same computer.

Users must purchase a separate license for each computer on which ATS-GPU-NUFFT is installed.

In no case is the user sallowed to distribute or share the source code of ATS-GPU-NUFFT with other users.

Annual Subscriptions

The purchase of an ATS-GPU-NUFFT license includes a subscription that allows users to download ATS-GPU-NUFFT updates from the AlazarTech website for a period of 12 months from the date of purchase.

Customers who want to download new releases beyond this 12 month period must purchase extended maintenance.

Extended Maintenance

Customers can extend their ATS-GPU-NUFFT subscription by ordering the 1 year extended maintenance for ATS-GPU-NUFFT (order number ATSGPU-202).

This must be purchased before expiration of the standard subscription (or before expiration of an extended subscription).

If the subscription lapses, renewal at a later date will be subject to a reinstatement fee to cover the administrative costs of reinstatement. Furthermore, subscription extensions must be purchased to cover the lapsed period.

Get your subscription end date by registering your product at: www.alazartech.com/en/my-account/my-products/. You will need the product serial number, which can be found in the email you received with your download link and password.

Subscription extensions will not be offered for discontinued products.

Technical Support

AlazarTech is known for its world-class technical support. Customers receive free technical support on hardware products that are under warranty.

AlazarTech digitizers come with a standard one (1) year parts and labor warranty. This warranty can be extended for a fee (more information can be found in the Extended Warranty section of each digitizer datasheet).

If your waveform digitizer is out of warranty, you will not be eligible for free technical support on AlazarTech hardware or software products and you will need to purchase technical support hours (order number SUPPORT-HR5) to obtain assistance.

In addition, any necessary repairs to your out-of-warranty hardware products will carry a minimum bench charge.

Note that support is provided for product bugs, and not for writing custom GPU kernels or for learning GPU programming.

Use with Out-of-Warranty Waveform Digitizers

In order to avoid possible disappointment in product functionality, customers purchasing ATS-GPU-NUFFT for use with an out-of-warranty waveform digitizer must first confirm that the digitizer is in working order by running a series of tests provided by AlazarTech: https://www.alazartech.com/en/support/faq/?faq=[1067].

AlazarTech reserves the right to refuse orders of ATS-GPU for use with an inadequately functioning digitizer.

‡ Version 4.1+ of ATS-GPU-BASE and ATS-GPU-OCT are required for for the use of ATS-GPU-NUFFT and for the support of GPUs with CUDA-compute capability 3.0 to 8.9.

ATS-GPU-NUFFT main API functions

```
ATS_GPU_NUFFT_AbortCapture
ATS_GPU_NUFFT_AllocBuffer
ATS_GPU_NUFFT_EnableVerificationMode
ATS_GPU_NUFFT_FreeBuffer
ATS_GPU_NUFFT_GenerateWindowFunction
ATS_GPU_NUFFT_GetBuffer
ATS_GPU_NUFFT_PostBuffer
ATS_GPU_NUFFT_SetBuffer
ATS_GPU_NUFFT_Setup
ATS_GPU_NUFFT_SetWindowFunction
ATS_GPU_NUFFT_SetWavenumberFunction
ATS_GPU_NUFFT_StartCapture
```

ORDERING INFORMATION

ATS-GPU-BASE: GPU Streaming Library License + 1 Year Subscription	ATSGPU-001
ATS-GPU-BASE-1YR: 1 year extended maintenance for ATS-GPU-BASE	ATSGPU-002
ATS-GPU-OCT: Signal Processing Library License + 1 Year Subscription (requires ATSGPU-001; also requires ATS-SDK for use with Python, MATLAB, & LabVIEW)	ATSGPU-101
ATS-GPU-OCT-1YR: 1 year extended maintenance for ATS-GPU-OCT	ATSGPU-102
ATS-GPU-NUFFT: ATS-GPU-OCT Extension for fixed-frequency sampled data License + 1 Year Subscription (requires ATSGPU-001 and ATSGPU-101)	ATSGPU-201
ATS-GPU-NUFFT-1YR: 1 year extended maintenance for ATS-GPU-NUFFT	ATSGPU-202
ATS-SDK purchased with a digitizer board or ATS-GPU: License + 1 Year Subscription (Supports C/C++, Python, MATLAB, and LabVIEW)	ATS-SDK
ATS-SDK purchased separately: License + 1 Year Subscription + 5 hours of technical support (Supports C/C++, Python, MATLAB, and LabVIEW)	ATS-SDK-WOD
5 Hours of technical support	SUPPORT-HR5

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DATASHEET REVISION HISTORY

Changes from version 25.1 (Sept 2025) to version 25.1a	Section, Page
Updated LabVIEW version compatibility to LabVIEW 2017	Programming with ATS-GPU-NUFFT, pg. 2

Changes from version 24.2 (Dec 2024) to version 25.1	Section, Page
Updated CUDA Compute Capability: ATS-GPU-BASE now supports compute capability 3.0 to 8.9	Global change
Reformatted table and added ATS9362, and ATST872	Data Throughput to GPU, pg. 3

Changes from version 23.1 (Dec 2023) to version 24.2	Section, Page
Updated maximum data throughput to 22 GB/s (with PCIe Gen 4 x16)	Global change
Added Gen 4 x16	Data Throughput to GPU, pg. 3
Modified reinstatement fee details	Extended Maintenance, pg. 3

Changes from version 4.2.2 (Nov 2022) to version 23.1	Section, Page
Added ATS-GPU-NUFFT data diagram	Programming with ATS-GPU-NUFFT, pg. 2
Added new products to table	Data Throughput to GPU, pg. 3
Replaced password with license key	Electronic Delivery, pg. 3
Modified to include new subscription reinstatement policy	Extended Maintenance, pg. 3

Changes from version 4.2 (Aug 2022) to version 4.2.2	Section, Page
Updated CUDA Compute Capability: ATS-GPU-BASE now supports compute capability 3.0 to 8.6	Global change
Added ATS9364, ATS9182, and ATST364	Data Throughput to GPU, pg. 3
Updated ATS-GPU licensing policy: a separate license is required for each computer	Software Licensing Policy, pg. 3

Changes from version 4.1b (Nov 2021) to version 4.2	Section, Page
Added ATS-GPU-NUFFT version number	Feature Table, pg. 1
Added Thunderbolt 3 digitizers	Compatible Waveform Digitizers, pg. 2
Moved text about user-supplied data from Overview to its own new section	User-Supplied Data, pg. 3
Added ATS9872, ATS9353, and Thunderbolt 3 digitizers	Data Throughput to GPU, pg. 3
Updated section to remove technical support from list of subscription benefits	Annual Subscriptions, pg. 3
Updated section to remove technical support from maintenance extension	Extended Maintenance, pg. 3
Added new section to specify how AlazarTech handles technical support: Customers receive free technical support on hardware products that are under warranty. Out-of-warranty support requires the purchase of support hours.	Technical Support, pg. 3
Added new section to specify that customers who wish to use ATS-GPU-OCT with an out-of-warranty digitizer card are required to complete a series of tests to validate that the dgitizer is in working order prior to purchase.	Use with Out-of-Warranty, pg. 3 Waveform Digitizers
Updated name for product *Software Development Kit* Now called: *ATS-SDK purchased with a digitizer board or ATS-GPU*	Ordering Information, pg. 4
Updated descriptions for maintenance items *ATSGPU-002, ATSGPU-102 & ATSGPU-202:* Removed technical support from maintenance extension	Ordering Information, pg. 4
Added products ATS-SDK-WOD and SUPPORT-HR5	Ordering Information, pg. 4

Changes from version 4.1 (June 2020) to version 4.1a	Section, Page
Updated product registration URL Removed sentence about serial number on CD envelope; this product was never sold on CD.	Extended Support & Maintenance, pg. 3