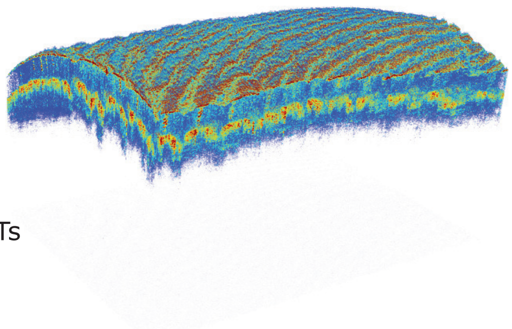
AlazarTech

ATS-GPU-OCT
OCT Signal Processing Library

- Very high-speed floating-point FFT for k-clocked data
- Dispersion compensation and windowing functions
- Requires ATS-GPU-BASE
- Transfer A/D data to GPU at high speed
- Up to 6.9 GB/s transfer rate for PCIe Gen 3 digitizer boards
- Optional ATS-GPU-NUFFT extension for non-uniform FFTs
- Supports CUDA®-enabled GPUs with compute capability 3.0 and higher‡
- Designed to work with AlazarTech® PCI Express waveform digitizers
- Compatible with Windows® & Linux®



! You will need ATS-SDK (sold separately) to use ATS-GPU-OCT.

Product	GPU Compatibility	Operating System	Throughput to GPU	FFT Length	Max. FFTs Per Second
ATS-GPU-OCT version 4.1	CUDA compute capability 3.0+‡	64-bit Windows & 64-bit Linux	Up to 6.9 GB/s	Up to 8 M Points	1,900,000 (2048-pt FFTs, see benchmark table below for more details)

Overview

ATS-GPU-OCT is an OCT Signal Processing Library developed by AlazarTech that provides very high-speed floating-point FFT capability for data acquired by AlazarTech's PCI Express waveform digitizers. User-supplied data can also be used when an AlazarTech PCIe digitizer is installed in the system. ATS-GPU-OCT must be used with ATS-GPU-BASE.

ATS-GPU-BASE allows users to do real-time data transfer from AlazarTech PCI Express waveform digitizers to a CUDA-enabled Graphical Processing Unit (GPU) at rates up to 6.9 GB/s.

Interfacing waveform digitizers to 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 bottle-neck is eliminated and data can be moved from AlazarTech digitizers to 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-OCT is intended to be used with data that is non-uniformly sampled in time domain, i.e. data that is sampled using a k-clock. Using a k-clock allows data to be sampled uniformly in k-space, which is required for ATS-GPU-OCT. If OCT data is acquired using a fixed sampling rate, this will result in data non-uniformly sampled in k-space. If this is the case, the ATS-GPU-NUFFT library extension is also required.

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 in the range of several milliseconds.

Benchmarks

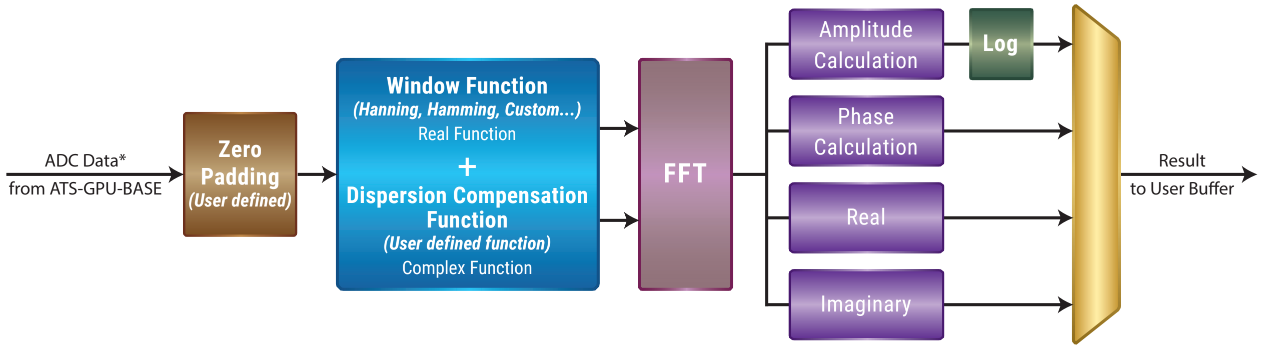
An AlazarTech ATS®9373 in an Intel i9-7900X 10-Core @ 3.3 GHz system with an ASUS® x299 motherboard, 32 GB DDR4, and NVIDIA® Quadro® P5000 GPU had the following benchmarks:

GPU Buffer Size (MB)	FFT Length	FFTs per second
1	2048	1,900,000
	4096	950,000
	8192	485,000
	65536	45,000
4	2048	1,900,000
	4096	950,000
	8192	485,000
	65536	50,000
	1048576	2,500
16	2048	1,900,000
	4096	950,000
	8192	485,000
	65536	55,000
	1048576	2,600

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 Quadro P5000 GPU produced very similar results.

Modular API

ATS-GPU-OCT 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.



OCT Signal Processing Block Diagram

*Data can come from multiple channels

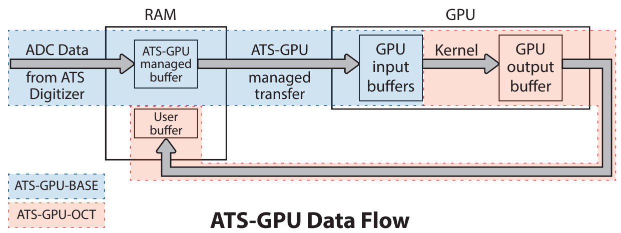
ATS-GPU and CUDA Runtime Library

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-OCT cannot be built as a 32-bit library. We currently use CUDA toolkit 10.2, older versions are untested.

ATS-GPU Data Flow



ATS-GPU Data Flow

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-OCT 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.

Programming with ATS-GPU-OCT

Please note: You will need ATS-SDK (sold separately) to use ATS-GPU-OCT.

C/C++ example programs are provided with Visual Studio projects and CMake build files.

Python code is tested under Python 2.7 and 3.6. 64-bit LabVIEW 2016 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 may contain many records. This number, RecordsPerBuffer, is specified by the user. 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-OCT supports zero-padding, if required, and it will apply a complex windowing function to each record. It will then do a single-precision floating-point FFT, calculate the amplitude and phase, and convert the amplitude to logarithmic values.

Very Long FFTs

For some applications, it is necessary to perform very long FFTs (e.g. one million points).

Even if a waveform digitizer has an on-board FPGA, such very long FFTs do not fit inside an FPGA due to resource limitations of the FPGA.

With the ATS-GPU-OCT Signal Processing Library, ATS-GPU is fully capable of calculating such very long FFTs. Our benchmarks using an Intel i9-7900X 10-Core @ 3.3 GHz system with an ASUS x299 motherboard, and NVIDIA Quadro P5000 GPU have shown that ATS-GPU is capable of doing 2600 one-million-point FFTs per second in single channel mode (keep up with sample rate of up to 2600 MS/s).

Even longer FFTs are possible. We have measured 8-million-point (2^{23}) FFTs but we have not fully tested the limits of FFT length with ATS-GPU.

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. ATS-GPU-OCT Signal Processing Library 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-OCT Signal Processing Library 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.

Amplitude and Phase Output

The FFT algorithm implemented in the OCT Signal Processing Library is capable of calculating both amplitude and phase outputs. All outputs are provided as single-precision floating-point data (32 bits per data point).

Data Throughput to GPU

The data transfer rate to GPU is dependent on the generation of PCI Express digitizer board used:

PCIe Link Speed	Transfer Rate
Gen 3x8: ATS9373, ATS9371	Up to 6.9 GB/s
Gen 2x8: ATS9360, ATS9416	Up to 3.5 GB/s
Gen 2x4: ATS9352 Gen 1x8: ATS9870, ATS9350, ATS9351, ATS9625, ATS9626, ATS9440	Up to 1.6 GB/s
Gen 1x4: ATS9462	Up to 720 MB/s
Gen 1x1: ATS9146, ATS9130, ATS9120	Up to 200 MB/s

Compatible Waveform Digitizers

All AlazarTech PCI Express 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.

Electronic Delivery

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

Software Licensing Policy

Users are allowed to freely distribute the ATS-GPU-OCT library as long as there is an AlazarTech PCI Express waveform digitizer present in the same computer. If an AlazarTech PCI Express waveform digitizer is not present in the computer, users must purchase a separate license for each computer on which ATS-GPU-OCT is installed.

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

Annual Subscriptions

The purchase of an ATS-GPU-OCT license includes a subscription that provides customers with the following benefits for a period of 1 year on ATS-GPU-OCT:

- Download updates from the AlazarTech website;
- Receive new example programs as they become available;
- Receive technical support on ATS-GPU-OCT.

Customers who want to receive technical support and download new releases beyond this 12-month period must purchase extended support and maintenance.

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

Extended Support & Maintenance

Customers can extend their ATS-GPU-OCT subscription by ordering the 1 year extended support & maintenance for ATS-GPU-OCT (order number ATSGPU-102).

This must be purchased before expiration of the standard subscription (or before expiration of an extended subscription). Extended Support & Maintenance can only be purchased while there is a valid subscription in place.

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. In the case of older purchases, the serial number can be found on the CD envelope.

Subscription extensions will not be offered for discontinued products.

ATS-GPU-OCT main API functions

```
ATS_GPU_OCT_AbortCapture
ATS_GPU_OCT_AllocBuffer
ATS_GPU_OCT_EnableVerificationMode
ATS_GPU_OCT_FreeBuffer
ATS_GPU_OCT_GenerateWindowFunction
ATS_GPU_OCT_GetBuffer
ATS_GPU_OCT_PostBuffer
ATS_GPU_OCT_SetBuffer
ATS_GPU_OCT_Setup
ATS_GPU_OCT_SetWindowFunction
ATS_GPU_OCT_StartCapture
```

[‡] Version 4.1 of ATS-GPU-BASE and ATS-GPU-OCT are required for support of GPUs with CUDA-compute capability 3.0 and higher.

Version 4.0.1 provides support for compute capability 3.0 to 7.5.

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ORDERING INFORMATION

ATS-GPU-BASE: GPU Streaming Library License + 1 Year Subscription	ATSGPU-001
ATS-GPU-BASE-1YR: 1 year extended support & 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 support & 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 support & maintenance for ATS-GPU-NUFFT	ATSGPU-202
Software Development Kit License + 1 Year Subscription (Supports C/C++, Python, MATLAB, and LabVIEW)	ATS-SDK

Manufactured By:

Alazar Technologies, Inc.

6600 TRANS-CANADA HIGHWAY, SUITE 310
POINTE-CLAIRE, QC, CANADA H9R 4S2

TOLL FREE: 1-877-7-ALAZAR OR 1-877-725-2927
TEL: (514) 426-4899 FAX: (514) 426-2723

E-MAIL: sales@alazartech.com

DATASHEET REVISION HISTORY

Changes from version 4.1a (Aug 2020) to version 4.1b	Section, Page
Modified note: ATS-SDK (sold separately) is required for using ATS-GPU-OCT	pg. 1
Modified note: ATS-SDK (sold separately) is required for using ATS-GPU-OCT	Programming with ATS-GPU-OCT pg. 2
Updated product registration URL	Extended Support & Maintenance, pg. 3

Changes from version 4.1 (June 2020) to version 4.1a	Section, Page
Added note that ATS-SDK (sold separately) is required for using ATS-GPU-OCT with Python, MATLAB, and LabVIEW.	pg. 1
Added note that ATS-SDK (sold separately) is required for using ATS-GPU-OCT with Python, MATLAB, and LabVIEW.	Programming with ATS-GPU-OCT pg. 2
Added ATS-SDK to order information	Ordering Information, pg. 4

Changes from version 4.0c (Jan 2020) to version 4.1	Section, Page
Updated CUDA Compute Capability: ATS-GPU-BASE 4.1 supports compute capability 3.0 or higher	Global change
Added detail for high-speed floating-point FFT: for k-clocked data Added new optional ATS-GPU-NUFFT extention for non-uniform FFTs	Feature list, pg. 1
Added ATS-GPU-OCT version number	Feature table, pg. 1
Specified that AlazarTech PCIe digitizer must be installed for using user-supplied data Updated introductory text Removed zero-padding from list of signal processing done by kernel code Added paragraph about ATS-GPU-OCT use for data that is non-uniformly sampled in time domain and the new ATS-GPU-NUFFT for data non-uniformly sampled in frequency domain.	Overview, pg. 1
Added section on Latency	Latency, pg. 1
Updated CUDA toolkit in use to version 10.2	ATS-GPU and CUDA Runtime Library, pg. 2
Removed repeated paragraph about provided sample programs. Updated LabVIEW compatibility: 64-bit LabVIEW 2016 or newer is required, Added note that LabVIEW NXG is not supported, Specified 64-bit MATLAB, Updated buffer size for RecordsPerBuffer to 1 to 16 Megabytes, Updated description to reflect that zero-padding is the responsibility of the user.	Programming with ATS-GPU-OCT, pg. 2
Updated to reflect that zero-padding is the responsibility of the user	Zero Padding, pg. 2
Added section Electronic Delivery	Electronic Delivery, pg. 3
Added ATS-GPU-NUFFT library extension order information	Ordering Information, pg. 4

Changes from version 4.0b (May 2019) to version 4.0c	Section, Page
Updated CUDA Compute Capability: ATS-GPU-BASE now supports compute capability 3.0 to 7.5	Global change
Added new products (ATS9352, ATS9146) to data transfer rate table	Data Throughput to GPU, pg. 2

Changes from version 4.0a (Feb 2019) to version 4.0b	Section, Page
Added paragraph about support and updates beyond the included 12 months	Annual Subscriptions, pg. 3
Added section: *Extended Support & Maintenance*	Extended Support & Maintenance, pg. 3

Changes from version 4.0 (Jan 2019) to version 4.0a	Section, Page
Corrected operating systems support: removed 32-bit Windows	Feature table, pg. 1